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RTO MEETING PROCEEDINGS MP-105 **IST-036**

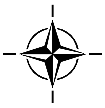
Massive Military Data Fusion and Visualisation: Users Talk with Developers

(La fusion et la visualisation d'ensembles de données massifs militaires : Les utilisateurs parlent aux développeurs)

Papers presented at the RTO Information Systems Technology Panel (IST)
Workshop held at the Norwegian Defence Logistics and Management College,
Halden, Norway on 10-13 September 2002.

Published April 2004

Distribution and Availability on Back Cover



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The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

AVT	Applied Vehicle Technology Panel
HFM	Human Factors and Medicine Panel
IST	Information Systems Technology Panel
NMSG	NATO Modelling and Simulation Group
SAS	Studies, Analysis and Simulation Panel
SCI	Systems Concepts and Integration Panel
SET	Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Published April 2004

ISBN 92-837-1109-2

Massive Military Data Fusion and Visualisation: Users Talk with Developers

(RTO MP-105 / IST-036)

Executive Summary

In World War II, the introduction of the Plan Position Indicator (PPI) Radar display greatly enhanced the users' ability to understand the evolving air-situation. Modern military systems acquire and present far more data, but often present the information in ways not readily assimilated for the various uses such as C2, situation awareness, planning, decision support, intelligence, or information management. An enduring hope for relief lies in visualisation. We now know, however, that this topic is very complex, requiring the synthesis of ideas from a number of disciplines. The NATO workshop IST-036/RWS-005, held in Halden, Norway 10-13 September 2002, brought together people from relevant disciplines. Of the 40 participants, approximately 17 were active or recently retired military officers.

The initiating NATO research group IST-021/RTG-007 ("Multimedia Visualisation of Massive Military Data Sets") argues that visualisation is a lot more than the display of graphics on computer screens. Visualisation happens in the head of the user, and effective visualisation displays might be textual or pictorial, and might involve other modalities in addition to the visual. In its thinking about visualisation, IST-021/RTG-007 uses a reference model based on a three-level feedback process (see www.vistg.net).

The participants at ITS-036/RWS-005 – military users, system developers, and human factor scientists – addressed the main issue of human "information overload", but by disparate approaches. Data fusion uses algorithmic data reduction, whereas visualisation deals with displaying the data in comprehensible form. Presentations by experts in data fusion indicated that visualisation might have a much broader influence than just better presenting the outputs of data fusion algorithms; one example is to improve the human ability to direct sensor- and computer-resources.

One plenary question and answer session was reserved for each of the two keynote speakers, both senior military officers both of whom had extensive active service in operational command and intelligence. Their rich, updated, and complementary viewpoints, together with the views from the other military representatives, justified the workshop subtitle "Users Talk with Developers". One of the keynote speakers stated: "I just want to see the world as it would be if I was looking at it". He had put together a high resolution "team decision table" for real users, having experienced that "visualisation improves discussion".

The workshop consisted of eight sessions over four days, in which 23 presenters gave 21 formal presentations, and each of five syndicates made a written report and a live presentation of their results. The presentations, discussions, and syndicate reports illuminated many approaches toward improving visualisation in future military systems. For example, one presenter used information theory to adapt symbology in maps at sliding scales, suggesting that this old theory may soon be used more in the development of visualisation technology.

La fusion et la visualisation d'ensembles de données massifs militaires : Les utilisateurs parlent aux développeurs

(RTO MP-105 / IST-036)

Synthèse

La mise en service, pendant la deuxième guerre mondiale, de l’indicateur panoramique (PPI) a considérablement facilité l’analyse de la situation aérienne en temps réel. Les systèmes militaires modernes sont capables d’acquérir et d’afficher beaucoup plus de données, mais les informations obtenues ne sont pas toujours présentées d’une façon facilement assimilables en vue de leur exploitation pour le C2, la connaissance de la situation, la planification, les aides à la prise de décisions, le renseignement, et la gestion de l’information. La visualisation représente une solution possible, et ce depuis un certain temps. Cependant, elle est considérée aujourd’hui comme un sujet très complexe, nécessitant la synthèse de concepts issus de nombreuses disciplines. L’atelier OTAN IST-036/RWS-005, organisé à Halden, en Norvège du 10 au 31 septembre 2002 a réuni un certain nombre de personnes travaillant dans le domaine. Dix sept des quarante participants étaient des officiers militaires, soit en activité, soit récemment partis à la retraite.

Le groupe de recherche d’origine, IST-021/RTG-007 sur « La visualisation multimédia d’ensembles massifs de données militaires » a confirmé que la visualisation comporte beaucoup plus que le simple affichage de données graphiques sur un écran d’ordinateur. La visualisation est un processus mental. Il s’ensuit que les éléments affichés peuvent être textuels ou graphiques, associés ou non avec des modalités non-visuelles. Le modèle de référence choisi par IST-021/RTG-007 est basé sur des retours d’information à trois niveaux (voir www.vistg.net).

Les participants à IST-036/RWS-005, à savoir des utilisateurs militaires, des concepteurs de systèmes, et des spécialistes en facteurs humains, ont examiné la question principale de « surcharge d’informations » pour l’opérateur, en adoptant des approches disparates. La fusion de données fait appel à la réduction algorithmique des données, tandis que la visualisation concerne l’affichage de données sous une forme compréhensible. Il est apparu des communications présentées par des spécialistes en fusion de données, que la visualisation pourrait avoir des applications qui dépasseraient la simple présentation des résultats des algorithmes de fusion de données. Elle pourrait, par exemple, être utilisée pour améliorer la capacité de l’opérateur à commander des moyens de calcul et de détection.

Les conférenciers d’honneur, des officiers militaires de haut rang ayant une grande expérience du commandement et du renseignement opérationnels, ont bien voulu animer deux séances de questions et réponses. Leurs points de vue complémentaires, d’actualité et riches d’enseignements, associés aux avis des autres représentants militaires, justifient largement le sous-titre de l’atelier : « Conversations entre utilisateurs et concepteurs ». L’un des conférenciers d’honneur a affirmé : « Je veux simplement voir le monde comme il serait si moi je le regardais ». Il avait élaboré un « tableau de prise de décisions en équipe » à haute résolution pour des utilisateurs réels, puisque selon lui « la visualisation permet d’améliorer la qualité des discussions ».

L’atelier était organisé en huit sessions sur une période de quatre jours, au cours desquels 23 conférenciers ont pu présenter 21 communications, et 5 syndicats ont soumis des rapports écrits, ainsi que des présentations de leurs résultats. Les présentations, discussions et rapports de syndicats ont témoigné de la diversité des approches adoptées en vue d'améliorer la fonction visualisation des futurs systèmes militaires. Par exemple, l’un des conférenciers a fait appel à la théorie de l’information pour adapter la symbologie des cartes géographiques à échelle mobile, en évoquant la mise en œuvre possible de cette vieille théorie dans le développement des technologies de visualisation.

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Preface

This workshop was intended to bring together those who use military visualisation systems, those who develop them, and those whose research enables the developers to build effective systems. The core objective was to have users *talk with* developers and researchers – that is, the workshop was to be a forum for commanders, intelligence officers, logistic officers, network security officers, and others to discuss with developers and researchers their problems and successes with current visualisation systems, which should help to identify particular areas to guide and direct future military visualisation research and development. The aim was to be multidisciplinary since both technological and human factors innovations collaborate in improving visualisation systems. The workshop was to identify problems to which there are as yet no solutions, but where solutions seem possible.

The workshop was planned as an *interactive* workshop, not a forum for presenting papers. The main work was done in thematic discussion periods, both in plenary sessions and in focus groups ("syndicates"). Each plenary discussion period was preceded by a small number of formal presentations (called "provocations") on the particular theme, intended to provoke thoughts from the participants that were further developed in the working discussions.

Acknowledgements

The committee thanks the Norwegian Defence Logistics and Management College (NODLMC) for hosting the workshop at their facilities. We thank our two outstanding keynote speakers, Col. Tom Johansen (Norway) and Col. (Ret.) Randy Alward (Canada), both of whom also volunteered to discuss detailed issues in open fora with all workshop participants. Thanks are due to CDR Robert Barton, USNR, Naval Sea Systems Command (USA) for special contributions to the Plenary Sessions and to the workshop proceedings. We also thank Else Kurland, Norwegian Defence Research Establishment who worked long hours, both before and during the workshop, to make life easy for all the participants. Finally, thanks go to Sarah Rosser (Canada) for invaluable administrative assistance from the beginning of the workshop to the publication of proceedings.

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ACKNOWLEDGEMENTS/REMERCIEMENTS

The Panel wishes to express its thanks to the Norwegian members to RTA for the invitation to hold this Workshop in Halden and for the facilities and personnel which made the Workshop possible.

Le Panel tient à remercier les membres du RTB de la Norvège auprès de la RTA de leur invitation à tenir cette réunion à Halden, ainsi que pour les installations et le personnel mis à sa disposition.

Future Decision Centre (FDC)

Col. Tom Johansen
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1.0 PROBLEM/PURPOSE

The Future Decision Centre (FDC) enables Display of Several Databases (fused together) in a 3-D Map System, in such a way that the information is intuitively understandable for Decision markers from both Military Commands & Civilian Crisis Management Institutions/Organisations.

Today there is a Challenge for Decision Makers on Strategic & Operational Levels to get a sufficient grasp of the situation (awareness) at the Level. At the same time the Strategic and/or Operational Level sometimes has a need to engage (or to be kept Updated) directly on Tactical Scenarios/Operations. The FDC enables this kind of "Scenarios Diving", without loosing Track of the overall picture.

The overwhelming amount of Information on all Levels creates a Demand of Fuse Databases into one Recognized picture, which at all times is directly relevant to the Scenario the audience is observing. The FDC aims at creating such a Picture, and is able to present it on a "FDC Table". Also there is a Challenge to improve the Land Picture, and it is clearly unbalanced when it is compared to Sea/Air Picture. The FDC does not directly improve this unbalance, but indirectly contribute to improve this Picture, as it intends to fuse different scenarios into one COP.

2.0 TECHNOLOGY

The FDC Prototype(s), as it is currently built at NOBLE, has Verified Integrated (fused) Display of UAV Live Scenarios, Recognized Air Picture (RAP) from Multi AEGIS Site Emulator (MASE), Sea Picture & Meteorological Information Layered on a 3-D Map Display System. The Frameless Display Table consists of Highly Modified LCD Panels, designed for use in Multi Screen Solutions. For the 25 Segment Table currently used the Resolution is extremely High, typically 40 – 50 million Pixels.

The FDC Software is able to Fuse Information from Several Databases, and Display it layered onto a sophisticated 3-D Map. There are still challenges in the field of Sensor Fusion and integration of Sensors, either Directly from Live Sensor, or Indirectly from other Databases. The FDC has immense potential for Development in order to tailor the Display exactly to the use of the relevant Decision makers.

3.0 SUPPORT OF JOINT/COMBINED OPERATIONS

The FDC is directly Relevant as a Decision Centre for Joint and/or Combined Operations. The information from Different Platforms or Databases can be tailored to fit the specific Scenarios or Operations carried out. It will also be possible, due to the integrated nature of the FDC Database, to quickly change the Display from Air to Sea to Land Pictures, and decide what kind of installations or objects (ex Oil Platforms, Building, Pipelines, SAM Sites etc.) you would like to be present at the picture you are looking at.

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

The FDC will be able to Display pictures (Strategic, Operational and Tactical) to for example Joint Operation Commanders & Crisis Management Leaders.

4.0 FUTURE/PAST DEMONSTRATIONS

The Prototype(s) FDC has already been tested at different Operations & Scenarios, and the outcome has been very positive. The Testing has (and will) generated/uncovered need for different kind of information and other types of use – it is in constant development.

The following exercises can be mentioned:

- Pre – TACEVAL at Rygge Main Air Station (MAS), Norway. Mainly the FDC Table was used to Display Key Personnel (GPS Indicated) and Unexploded Objects (UXO) inside the Air Station Field.
- Joint – Winter (NATO) Exercise in CAOC-3 at Reitan, Norway. A Single-Screen Display was demonstrated in order to Display Live UAV Sensor Information, for the purpose of Tasking Air Strikes in a Time Critical Targeting Scenario.
- Currently the FDC Table is utilized at F-16 Squadron Level in Manas, Kyrgyzstan, in order to Pre- and De-Brief Pilots on the Portable Flight Planning System (PFPS). The FDC has been loaded with relevant (1:50.000 Russian Maps) Map Information from the Operational Area.

Other Scenarios and Exercises are awaiting use of the present Prototype, and this will constantly generate a basis for future experimenting and development towards our vision.

5.0 COST & TIME SCHEDULE

Currently Norway has invested about 1.2 Million USD in the Development of the Prototype(s). The FDC Table Display Technology is now mature, verified and able to perform the necessary workload. Further investment will mainly be concentrated on the Sensor Fusion & Database development of the FDC.

The funding has been provided to NOBLE through the CHOD Norway Joint Staff. The Procurement of Display Tables itself will mainly be funded directly by the User in each case, but development umbrella, will probably mainly be funded through NOBLE.

6.0 RISK ASSESSMENT

The Risk related to the Display Technology is now Low – Medium. This Technology has been verified, and Prototypes exists at several sites. The challenge is development and integration of sufficient Database Capacity & Processor Power in order to perform the necessary layering of relevant information onto the 3-D Display. The Risk related to this Sensor Fusion part is mainly to get hold of sufficient Personnel/Expert Resources, and probably not highly connected to the Technology itself. Our present contractor has outlined a “Way Ahead” that seems feasible, but is currently not able to keep the Required Tempo due scarce Resources.

7.0 LEAD SERVICE/SPONSOR

Currently Norway is utilizing the FDC Table for different purpose at the Squadron Level in the Air Force, and at the Air Force Base Level.

We foresee a Great potential for Joint Operations and a very interesting use for Homeland Defence/ Management or Crisis Management of Military/Civilian Mix Scenarios, and even at the Political Level.

The FDC will probably best be utilized on Strategic & Operational Levels, in Joint or Complicated Scenarios, but will also be able to Display Tactical Information to the Strategic Level if Requested. A PC Linked Version (which has also been tested) can provide relevant information to Tactical Groups/Teams (Special Ops etc.).

8.0 POINT OF CONTACTS (POC)

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SYMPOSIA DISCUSSION – KEYNOTE ADDRESS 1

Author's Name: Col. Tom Johansen, NOBLE, Norway

Question:
What testing methods are used in the rapid prototyping projects before sending a tool, like the table demonstrated, to the field?

Answer:
The testing process in this development cycle is informal. In this situation, there is immediate need for the tools being developed, and it is preferable to have the additional information from the very new display rather than trying to make decisions with just paper maps. It is not a weapon, just a tool, so the risk is relatively low.

Question:
Because of the technology available, a politician or general can see what is going on at the tactical level. How does this affect operations?

Answer:
Speaking from experience, there are instances where a person who was higher up in the chain of command saw pictures that he wanted acted on immediately. All decision makers should have the ability to see what is going on in real time, and each should know his/her role and when it is appropriate to insert themselves into the decision making process.

A Military C2 Professional's Thoughts on Visualization

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1.0 INTRODUCTION

A commander's ability to visualize his battle space is a necessary condition to winning.

I recently retired from the Canada Forces after 35 years as a command and control specialist. I have served on Communications and Information System staffs (J6) at tactical, operational and strategic level headquarters and commanded at the tactical, operational and strategic levels. I believe I understand the role of and the need for visualization in military operations well. I would like to stimulate discussion by sharing some of my experiences that are relevant to the subject.

2.0 DISCUSSION

I will relate several experiences that will demonstrate a need for better visualization and/or illustrate an aspect relevant to the 'visualization' researcher.

An Electronic Warfare (EW) Example. Today's battlefield presents a dense and hostile electronic environment. One should expect to find our Electronic Warfare sensors operating in unexpected ways, such as indicating a threat that is not present. We need to be able to quickly identify the source of ambiguity and correct it, if possible. For example, programming a 'Radar Warning Receiver' (RWR) requires that you use a set of unique parametrics for each threat radar. The RWR programmer was required to search through lengthy tabular listings of parametrics to find the conflict; a tedious and time consuming exercise. The Canadian Forces Electronic Warfare Center, through Defence Research and Development Canada, Ottawa developed a commercial of the shelf visualization product into a tool called the Visual Interface for Electronic Warfare system (VIEWS), a simple but effective tool that displays EW parametrics in three-dimensional space. It displays a threat as one or more cubes. Overlapping cubes identified ambiguities. This simple visualization tool enabled RWR programmer to easily see and optimally adjust parametrics to eliminate or at least minimize threat ambiguities. I will illustrate the VIEWS tool.

An Air Traffic Control (ATC) Example. I have found that a 'user' is never satisfied, **nor should he be**. The moment you install a system, he will learn the new functionality and begin thinking about how to improve on it. One should plan for system evolution as the user develops his understanding of the system's capabilities and limitations. Where possible one should establish a 'lead user' group to promote development of new concepts and trial them. I will provide a personal example of procuring an ATC display system. I will also comment on the need to evaluate human factors aspects such as facility layout, and display symbology and colour.

A Command and Control (C2) Example. I was NATO/ Central Army Group's Chief of Information Systems between 1990 and 1992. The Allied Central Europe Command and Control Information System was anything but 'the right information, at the right time and in the right form', today's information

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

mantra. I will discuss the Commander's need (and that of his staffs') for multimedia visualization. We were able to modify the existing C2 capability with leading-edge COTS to offer the battle staff an order-of-magnitude improvement.

An Intelligence Example. As we enter the Information Age, we find we are 'drowning' in information. We need better search engines; ones based on concepts rather than words; and we need a means of visualizing the concepts. I will talk about research in these areas and the need for further research. I will briefly mention Canada's work in Cognitive Modality and a colleague, Dr. Zack Jacobson, will illustrate a work in progress called Visual Interface for Textual Analysis (VITA) in a separate presentation. Both areas need further research and development.

An Information Security Example. If you have seen an Intrusion Detection System (IDS) display, you will appreciate the need for improved visualization. The same applies to Information System logs. They produce large volumes of data that require both skill and time to analyse. In the meantime your network may be under attack. 'Ironman' is a Canadian initiative in this area. It serves as an information security command and control center that lets you visualize network activity, including IDS output, and facilitates network analysis. I will illustrate the visualization aspects of the tool.

Information Operations. IO is the warfare strategy of the Information Age. I will present an IO paradigm and show where visualization is situated within the paradigm. It will serve to focus the above examples within the concept of IO. Clearly, IST R&D is critical to advancing our ability to execute an IO strategy.

3.0 CONCLUSION

There are many facets to Visualization. The above vignettes are meant to stimulate discussion. Visualization is about enabling the mind of the decision maker, his staffs and knowledge workers in general. Information Technology Systems, indeed the 'network' are but extensions of the mind. Your task is to understand it through observation and experiment, to train it through exercise and simulation, and to provide tools to empower it to visualize. Your work is a critical and necessary enabler of the information age.

SYMPOSIA DISCUSSION – KEYNOTE ADDRESS 2

Author's Name: Col. (Ret.) Randy G. Alward, former commander, Canadian Forces Information Operations Group

Comment:
The culture of the military must be considered when introducing new technologies into NATO operations. For example, generals being able to talk over videoconference without any other filter or influence.

Comment:
Knowing what question to ask or what question can be asked is important. There are many different dimensions, and the user has to know what kind of information is available and accessible to aid in the decision making process.

Comment:
User input is essential to the development cycle. If the users are consulted in the development process, they will be more satisfied with the results. However this does not mean that they will not want more. As they learn from the new technology and system, they will know what to ask for in the next stage of development.

A Showcase of Visualization Approaches for Military Decision Makers

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ABSTRACT

Military command and control systems use a wealth of visualization techniques that are applied to a variety of application domains, including Command and Control, Intelligence, Logistics and Information Operations. Recognizing this variety, the TTCP C3I Action Group on Information Visualization has conducted a survey of visualization techniques and approaches used in allied command and control systems or being examined as applied R&D activities. A knowledge-based of these techniques – C3I-Vis – has been developed. A presentation of some of the showcased examples contained in C3I-Vis is proposed as a way of stimulating discussion for the workshop. The presentation will highlight good examples of current practices and state of the art approaches, including visual approaches, information representations, user interaction and customization.

1.0 INTRODUCTION

The Revolution in Military Affairs has moved to centre stage the requirement for information dominance in the joint battlespace. It is predicted that the greatest change in the conduct of future military operations will be the result of the application of information technology to military command and control. With this increased complexity, the need for good Situation Awareness is paramount.

When considering the Cognitive Hierarchy of Information, where data evolves into information, knowledge and understanding, future command and control systems should provide the user with an increased degree of situation awareness so that decision-making is eased. The ultimate aim is to provide Battlefield Visualization, whereby the Commanders develop a clear understanding of their current state with relation to the adversary and the environment, envision a desired end state and then subsequently visualize the sequence of activity that will move their assets from the current state to the end state.

Military command and control systems use a wealth of visualization techniques that are applied to a variety of application domains, including Command and Control, Intelligence, Logistics and Information Operations. Recognizing this variety, the TTCP C3I Action Group on Information Visualization (AG-3) has conducted a survey of visualization techniques and approaches used in allied command and control systems or being examined as applied R&D activities [AG-3, 2002]. A knowledge base of these techniques – C3I-Vis – has

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

been developed. It contains in excess of 110 C3I Visualization approaches and over 240 showcase examples (screen shots, video clips), each characterized in terms of the domain contexts, the descriptive aspects and the visualization approaches.

A presentation of some of the showcased examples contained in C3I-Vis is proposed as a way of stimulating discussion for the workshop. The presentation will highlight good examples of current practices and state of the art approaches, including visual approaches, information representations and user interaction.

The presentation first summarizes the Reference Model developed by AG-3, then present and discusses visualization approaches with multiple examples. Finally a summary of significant visualization concepts is provided.

2.0 RM-Vis

A wide range of visualization tools and approaches are already used in the C3I domain. However, there remains vast potential for new and improved applications of information visualization to enhance C3I functions. Such applications should capitalize on the many new approaches and tools being developed by various Defence projects, research organizations, and industry. AG-3 was formed to develop a program of work which would result in a better understanding of how computer-based visualization is and could be applied in C3I.

A Reference Model framework for the application of Visualization approaches (RM-Vis) was defined to support the characterization, identification and showcasing of visualization approaches in the C3I domain. This framework has been used to characterize visualization solutions in terms of their context of use, the representation and presentation techniques used, and key features of tool support provided such as types of user interactions and deployment support.

As shown in Figure 1, RM-Vis has three key dimensions:

- The **Domain Context** is a model that defines the focus for the application of visualization approaches i.e. ***where*** visualization approaches will be applied, ***who*** will be supported, and ***why*** it is needed.
- **Descriptive Aspects** (DA) define what needs to be described for particular domain contexts. For example, DAs could be defined in terms of the various elements (or things) that are of importance, the relationships between those elements and particular attributes that describe the elements and relationships.
- The **Visualization Approach** dimension defines how the required information can be provided through computer-based visualization. Approaches are characterized in terms of the visual representations used (e.g. graphs, charts, maps), visual enhancements (e.g. use of overlays, distortion, animation), interaction (direct manipulation, drag and drop, haptic techniques etc), and deployment which includes the computing environment (display devices, COTS software) and advanced deployment techniques such as intelligent user support and enterprise integration.

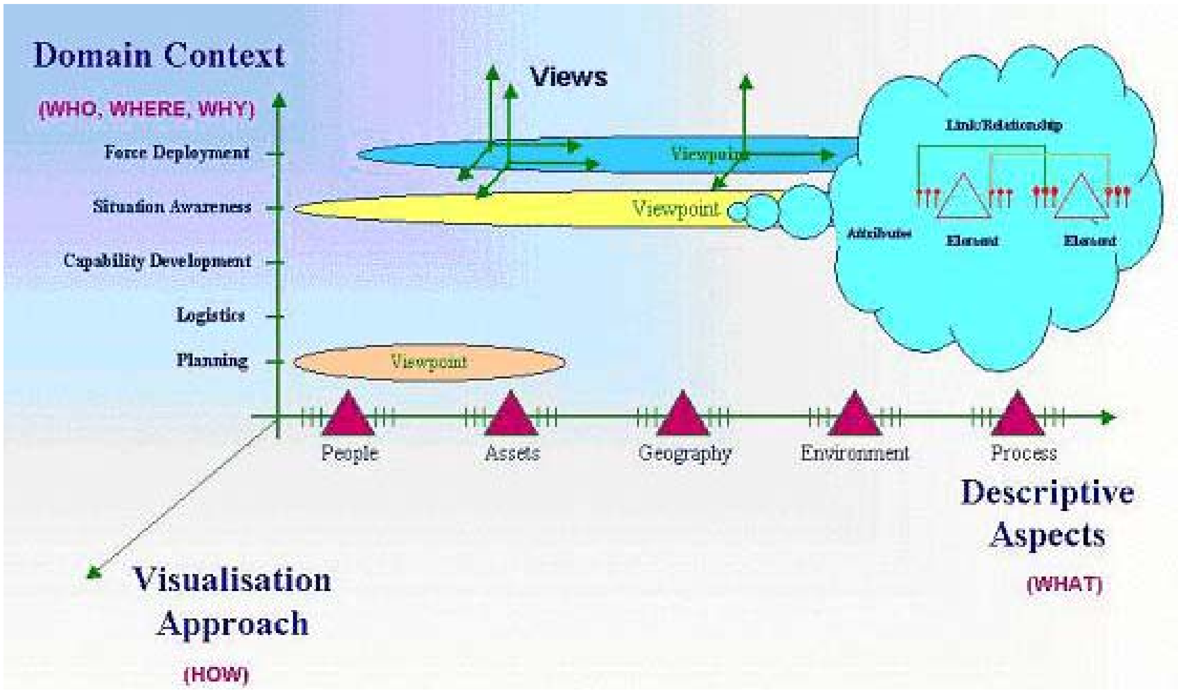


Figure 1: RM-Vis Framework.

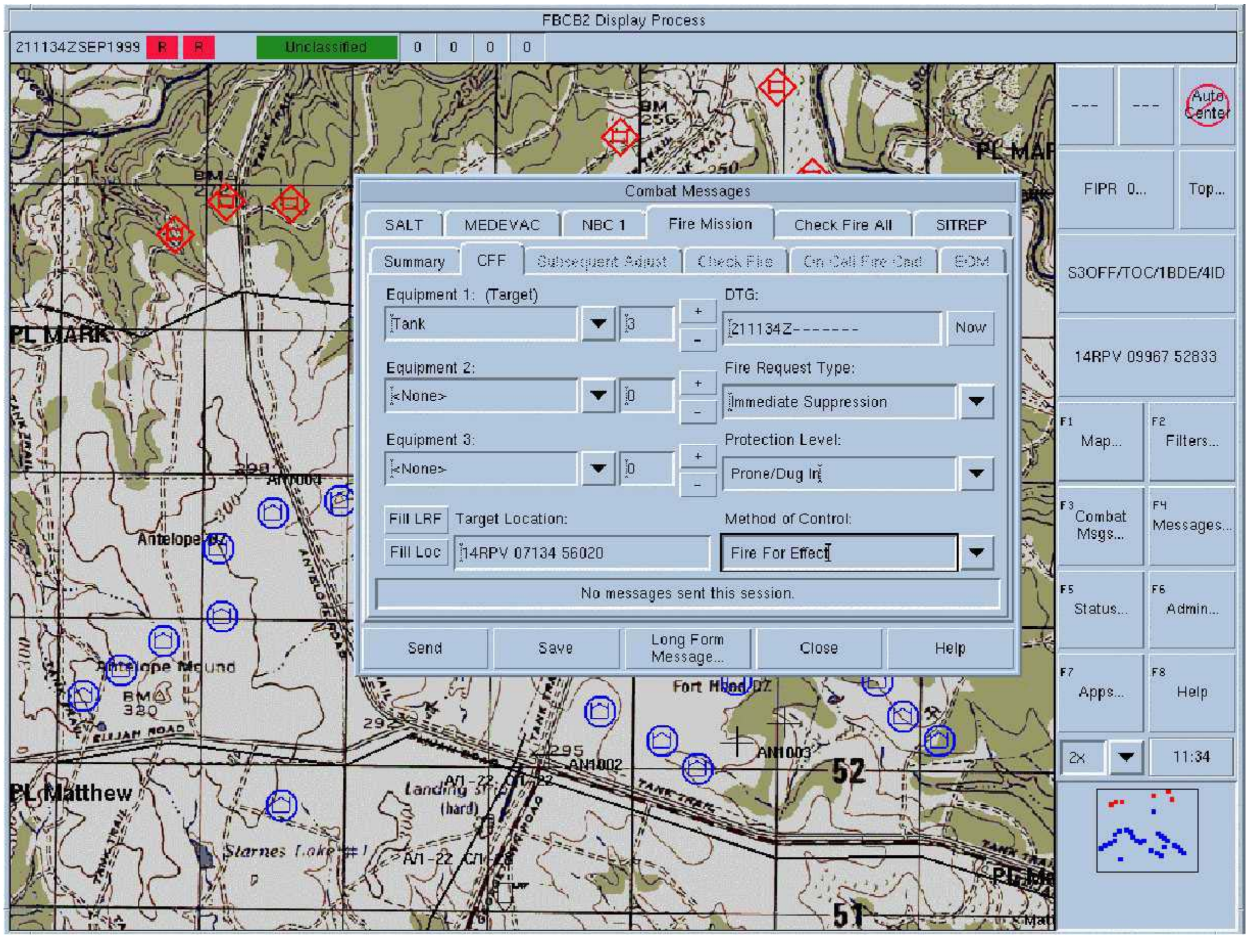
A toolkit implementing the key elements the RM-Vis framework was developed to support the characterization, showcasing and querying of visualization approaches within domain usage contexts. Flexible querying mechanisms were implemented to support analysis activities. Two RM-Vis databases were developed using the toolkit: C3I-Vis which characterizes and showcases visualization approaches in C3I domains based on a survey of national programs and G-Vis which characterizes and showcases general approaches in a range of complementary domains such as transport, finance, medicine, entertainment, and engineering.

3.0 VISUALIZATION EXAMPLES

This Section provides significant visualization examples supporting military decision-making.

3.1 Tactical to Strategic Levels of Command

Command and control at the tactical level brings physical constraints that do not apply at the Strategic level of command. These include space limitation, light conditions and operation on the move. An interesting example of a tactical system in terms of visualization is the DoD Force XXI Battle Command, Brigade and Below (FBCB2) System [TRADOC, 2002]. It provides on-the-move, real time and near-real-time battle command information to tactical combat arms, combat support and soldiers, and is integrated in various Army platforms. As shown in Figure 2, the display is customized for use in a vehicle: maximized use of the screen for showing the map, status bar for showing the message queue, alerts and warnings, large function buttons finger or function key activated, forms subdivided in a number of folders and providing menu lists.



211134ZSEP1999 R R Unclassified 0 0 0 0

Equipment 1: (Target) Tank 3

Equipment 2: <None> 0

Equipment 3: <None> 0

DTG: 211134Z-------

Fire Request Type: Immediate Suppression

Protection Level: Prone/Dug In

Target Location: 14RPV 07134 56020

Method of Control: Fire For Effect

No messages sent this session.

S3OFF/TOC/1BDE/4ID

14RPV 09967 52833

11:34

Figure 2: FBCB2 Tactical Display.

At the Strategic level, where there are less physical constraints, one trend is to exploit ‘data wall’ technology. The U.S. Navy at the SPAWAR System Centre is in the process of developing knowledge wall concepts to replace the traditional situation maps that are ubiquitous in modern operations centres (Figure 3). The purpose of the knowledge wall is to foster shared situation awareness, permit continuous updating of the military situation and enhance the senior staff’s ability to interact with supporting information systems.

Figure 3: SPAWAR Knowledge Wall Concepts.

Based on extensive interviews with 30 senior Naval staff officers, the following characteristics were identified as important criteria for developing the knowledge wall [Oonk et al., 2001]:

- Shared situation awareness among its users
- The integration of relevant mission status information
- An intuitive graphical interface
- Consistently formatted information
- The display of mission goals and Commander's Critical Information Requirements
- The display of summary information provided by "anchor desk" or support staff
- The ability to connect and coordinate or collaborate with others at diverse locations
- A flexible configuration that can easily be changed by users
- The ability to drill-down through displayed information for more detail
- Display of information age and reliability

3.2 Visualization Examples from the Command and Control Domain

Typical command and control visualizations have consisted of static, standardized symbols overlaid on terrain, frequently referred to as 'dots on maps'. The following are some examples of where this concept has been advanced. Figure 4 shows an early visualization developed for the CPOF program, called 'Circular Blobs' [Wright & Kapler, 2002]. This has pseudo 3-dimensional terrain with blobs showing force deployment. In this visualization, the thickness of the line represents strength of force and diameter of blobs shows range of weapons.

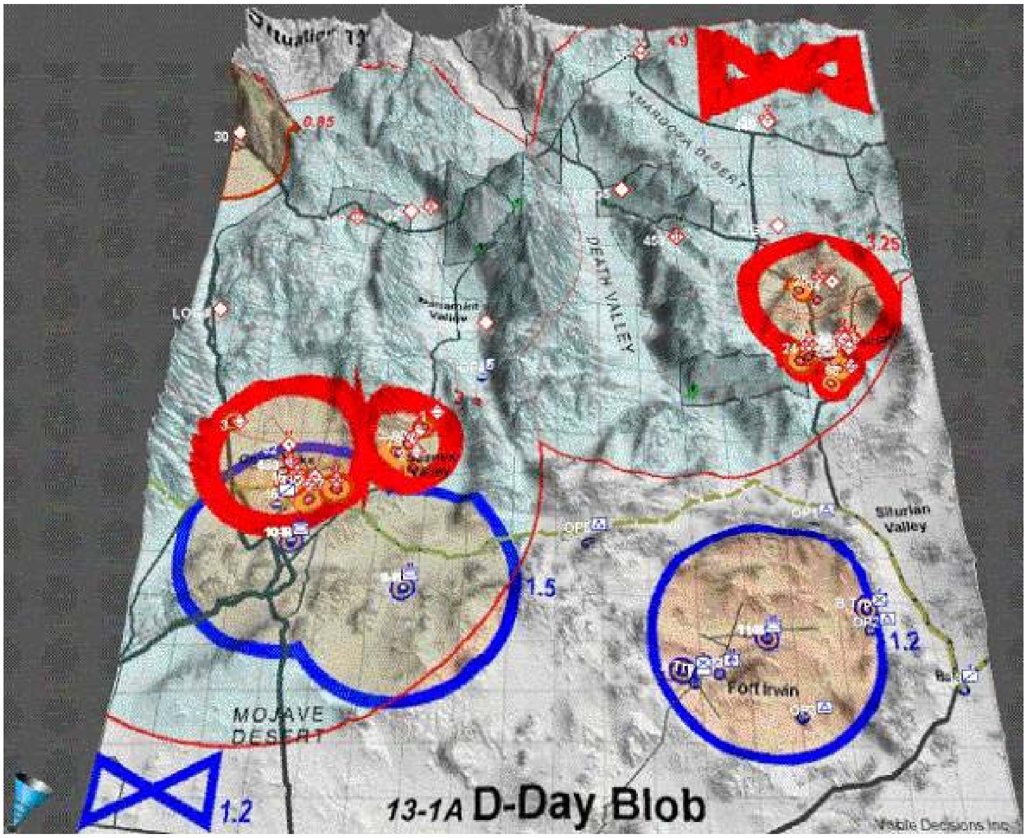


Figure 4: Multi-Dimensional Data Representation Overlaid on Terrain.

The CPOF program has also experimented with shared visualizations to support distributed, collaborative command. The CollabEx system [CollabEx, 2002] was developed to support cross-functional teams – command, intel, fires, manoeuvre – performing tactical planning and execution tasks. The workspace in Figure 5 shows the commander's viewpoint on the left, and the shared view of another team member on the right. Using freehand sketches, and icons (for planned tasks and enemy forces), each team member creates a view that broadcasts his understanding and approach to the problem. By cycling through these views, it is possible for the commander, and every team member, to maintain topsight over what the entire team thinks. These views also support efficient communication. For example, just as a commander gestures on a subordinate's paper map, he can use the system's collaborative pointing and inking tools on any view to convey his intent.

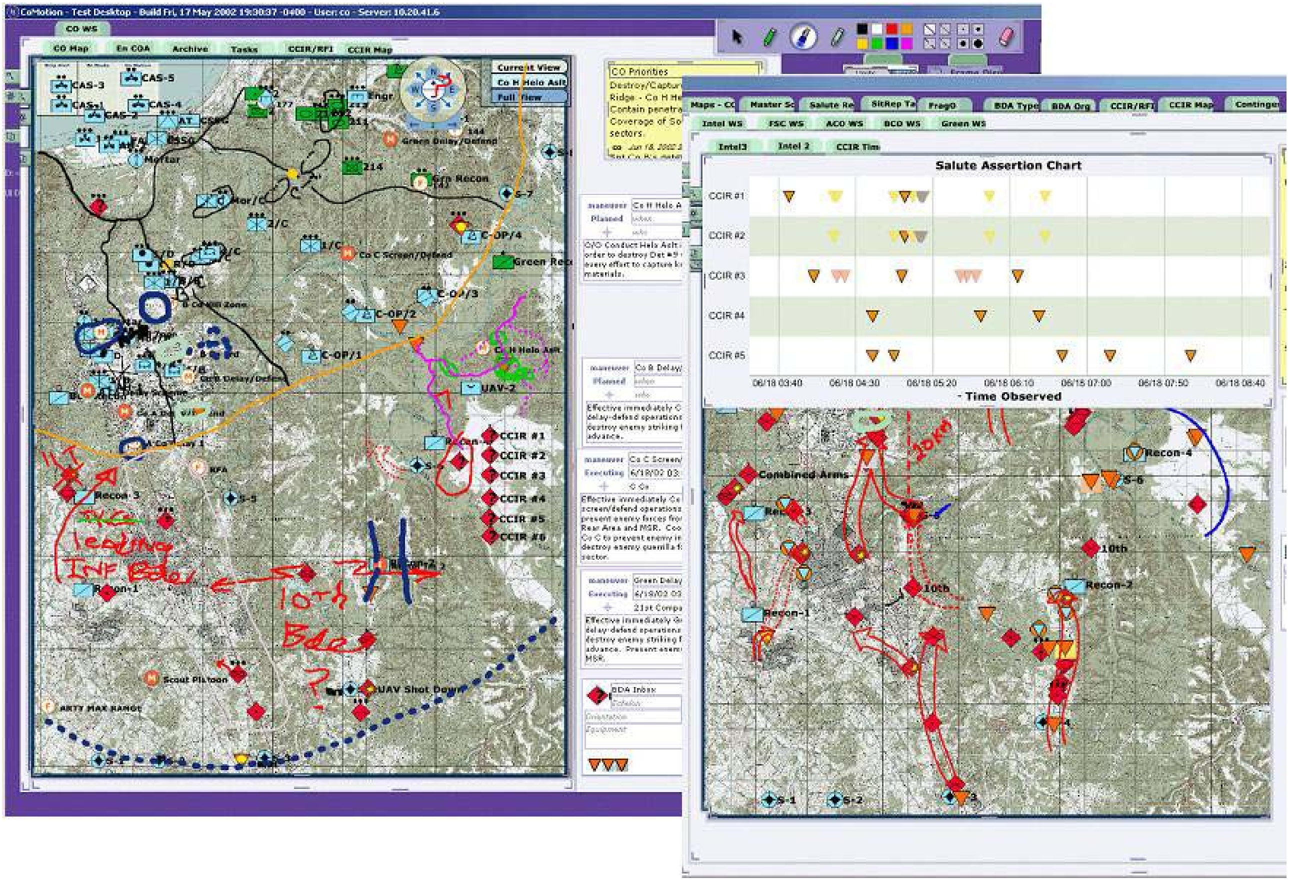
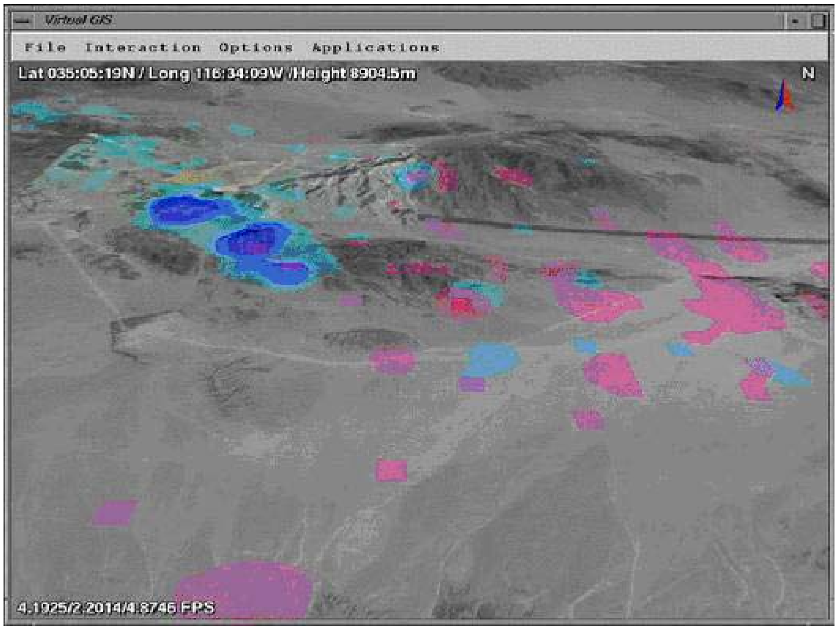


Figure 5: View Coordination and Linking for Collaborative Command Activities.

Other approaches have used flow animations to represent force movements and degrees of uncertainty. Figure 6 shows intuitive battlefield visualization using animated blobs (grouping of entities based on behaviour and status: aggregation and temporal compression involved). This view was created using Virtual GIS at the Army Research Laboratories (USA).



Lat 035:05:19N / Long 116:34:09W /Height 8904.5m

4.1925/2.2014/4.8746 FPS

Figure 6: Blobology View of Battlefield.

Virtual Reality concepts for battlespace visualization are being researched at the Naval Research Laboratories (USA). Figure 7 shows an example from the Virtual Reality Responsive Workbench and shows how immersive Virtual Reality could be used to provide visualization and interaction with battlefield information. The visualization shows: Terrain at field resolution, real-time data feeds, icons and overlays of dynamic models on terrain, 3D and 3D stereo approaches.

LOCAL TIME: Wed Jan 8 15:41:54 1997
GM TIME: Wed Jan 8 20:41:54 1997

LAST INTERSECTED UNIT
Truck (enemy)
Unit Number = 14120
POSITION
Elevation = 11768 feet
Lat = 34:24:19N
Lon = 116:11:14W
UNIT STATUS
Last Update (local time):
Wed Jan 8 15:16:32 1997
Line 1.
Line 2.
Line 3.
Line 4.
Line 5.
Line 6.

GROUND COORDINATES
Lat = 34:24:39N
Lon = 116:12:03W
Elevation:
Sea Level = 15888 feet

From Last Point:
Distance = 4026 meters
Elev. Change = 1853 feet

Cumulative:
Distance = 9222 meters
Elev. Change = 1611 feet

Number of points: 3
Reset: right button.

Figure 7: Planning with the VR Responsive Workbench.

Over the last two years, Enterprise Portal technology and Distributed Collaboration services have become a significant trend in Command and Control Systems. In the coalition context, CINC 21 portal technologies and services are being developed to enable coalition partners to achieve better cross-coalition situational awareness by allowing access to each other's web-based displays and services. For JWID 02, a C2 portal was successfully deployed to support C-CINC 21 experimentation and to demonstrate to the wider JWID audience the value of emerging portal technologies and services (see Figure 8).

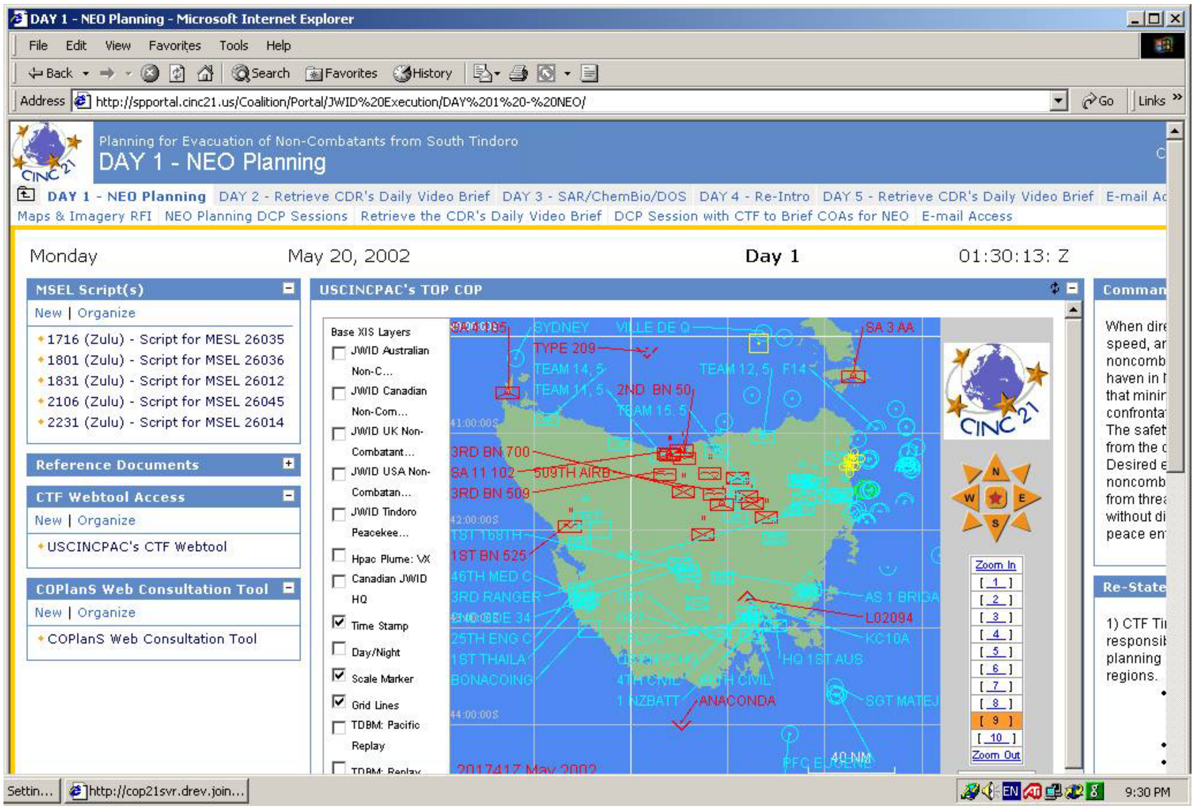


Figure 8: CINC 21 C2 Portal.

As military operations are increasingly performed in urban environments, 3D modeling and visualization capabilities will be required to support commanders in terms of situation awareness and the warfighters in mission rehearsal [Létourneau, 2002]. The production of the models must support an incremental development in terms of granularity and realism, and this granularity must correspond to the tasks to be performed. Figure 9 shows a model of Quebec City that was produced in the context of the American Summit in April 2001.

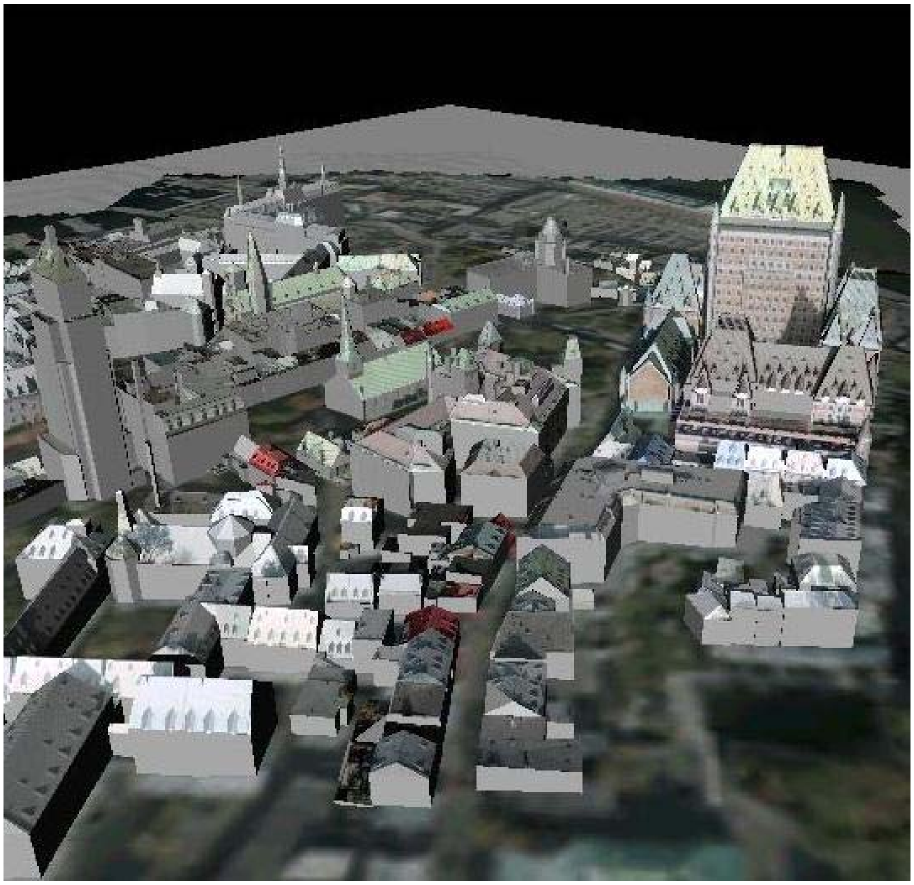


Figure 9: 3D Urban Model of Quebec City.

3.3 Visualization Examples from the Intelligence Domain

The intelligence domain has used similar approaches to the command and control domain but with more emphasis on the visualization of abstract information (from multiple sources) and relationships overlayed on geomatic representations and the ability to have linked and coordinated views on the display real estate. For example, the All Source Intelligence Prototype (ASIP) from Canada shows the use of geomatic representations with overlayed information. The ASIP is a Canadian command and control prototype system aimed at exploring and demonstrating functions for the Intelligence cell. One of its component is the Situation Map application that provides a digital map-based interface, point-and-click and drag and drop user interface, multiple overlays, military map symbology (NATO military symbology standard APP-6(A) and MIL-STD 2525B), map symbol editor, graphical reasoning (tracking, merging, aggregating, link analysis), map symbol palette, annotation, briefing handling. A major contribution of ASIP is in the management of overlays and sharing of views through live channels. Figure 10 shows an interesting feature of ASIP with coalition symbology, where an optional representation of MIL-STD 2525B allows showing the different factions in a Coalition Operation with a different colour, for friendly, enemy and neutral forces.

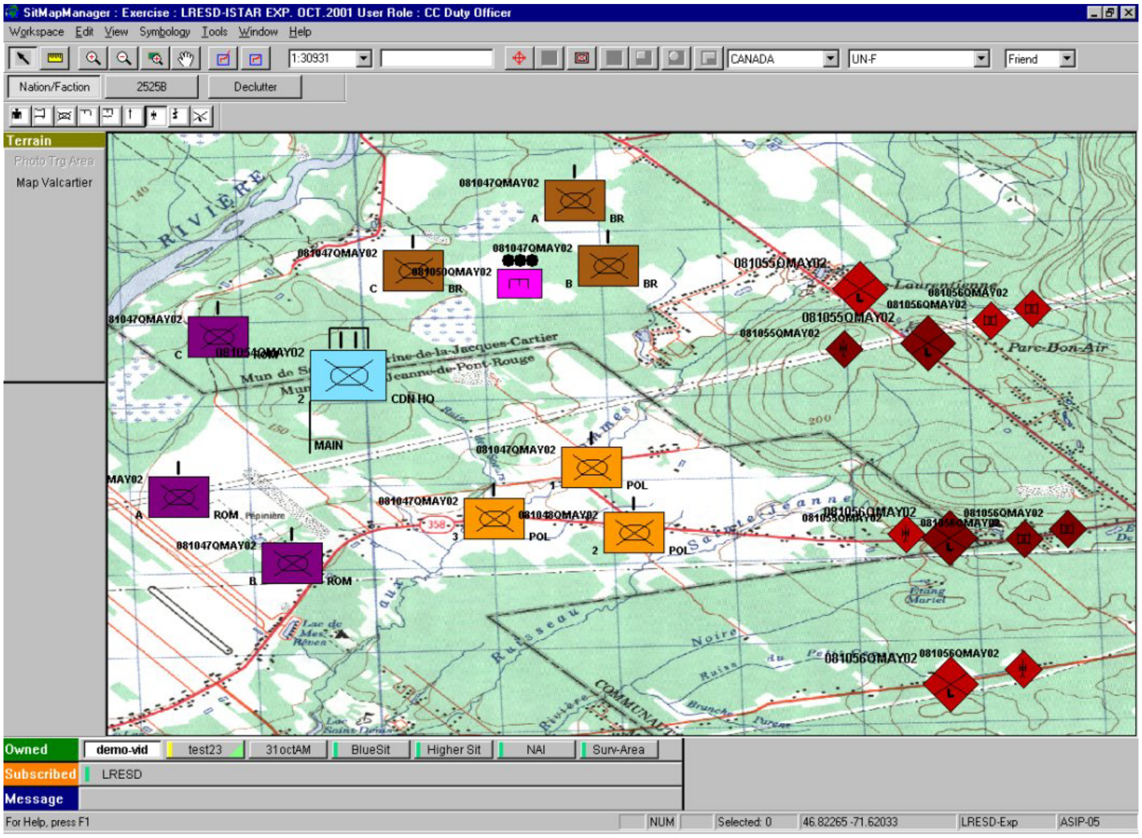


Figure 10: Intelligence View from ASIP.

Sophisticated 3D animated representations have been used in the Intelligence Surveillance and Reconnaissance (ISR) area to represent red and blue asset coverage. Figure 11 shows a view from BattleScape where geometric shapes (conical, spherical, etc) have been used to represent ISR asset coverage. This view also shows the concept of integrating imagery with geographic information. BattleScape is a commercial tool from the USA. It enables recognition of risks and opportunities to assist command of forces. It continuously displays near real time information reported by surveillance and reconnaissance sensors in 2D and 3D with maps, imagery, and terrain. BattleScape interfaces with existing C4ISR processors to create 2D and 3D continuous views of the battlespace, all referenced to digital maps, imagery, and elevation data sets chosen by the Warfighter.

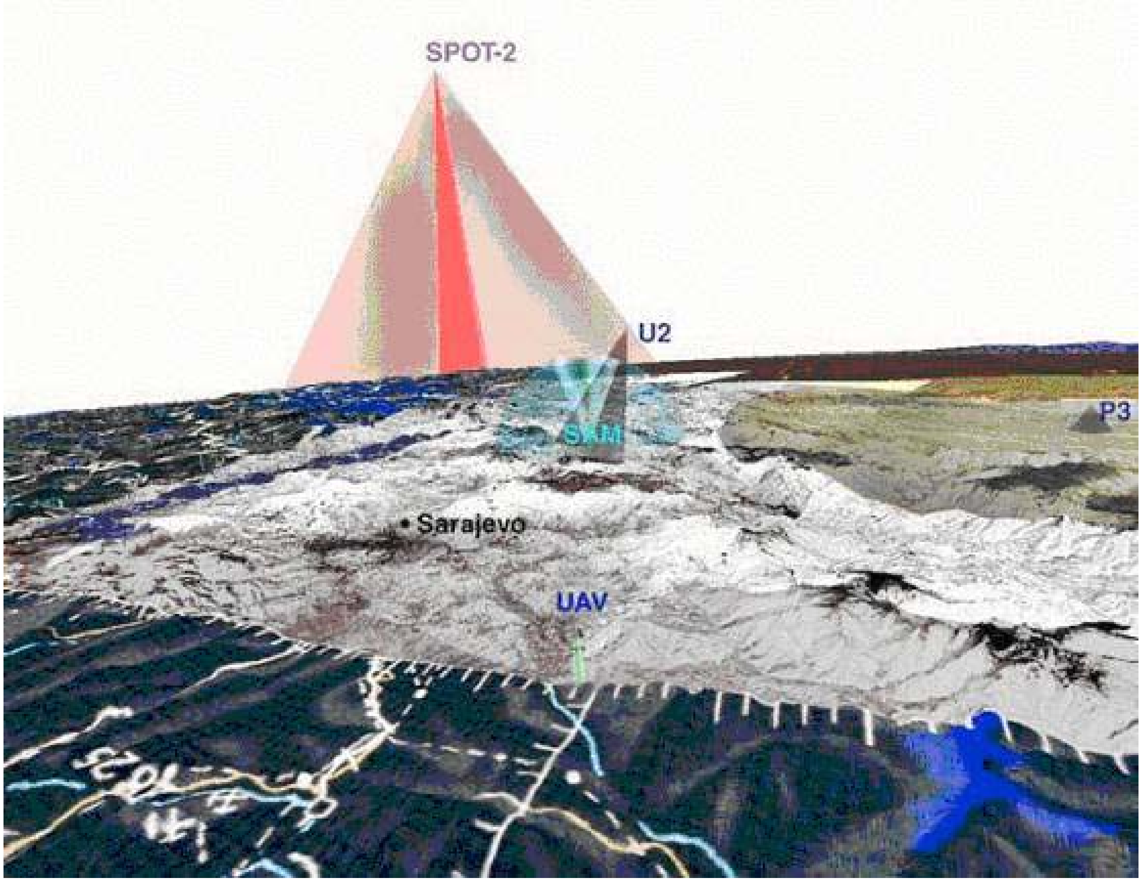
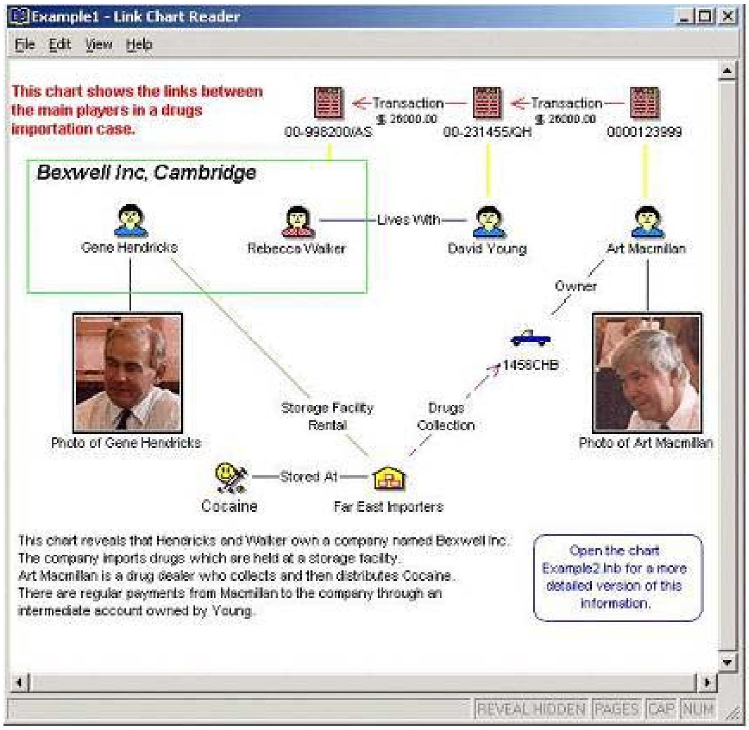


Figure 11: A 3D Intelligence View from Battlescape.

A growing visualization technique for the Intelligence Domain is Link Analysis. This technique is very useful to show relationships between people, organizations, events, incidents, behaviours and locations as shown on Figure 12a taken from the US IntelCenter. The focus of the IntelCenter is on studying terrorist groups and other threat actors and disseminating that information in a timely manner to those who can take action on it. Its primary client base is comprised of military, law enforcement and intelligence agencies in the US and other allied countries around the world [IntelCenter, 2002]. Figure 12b is a subset of *Mapping al-Qaeda v1.0*, a product utilizing link analysis technology to provide visual maps of terrorist networks around the world and to help foster a better understanding of al-Qaeda's operational characteristics and organizational structure.



This chart shows the links between the main players in a drugs importation case.

This chart reveals that Hendricks and Walker own a company named Bexwell Inc.
The company imports drugs which are held at a storage facility.
Art Macmillan is a drug dealer who collects and then distributes Cocaine.
There are regular payments from Macmillan to the company through an intermediate account owned by Young.

Open the chart Example2.lnb for a more detailed version of this information.

Figure 12a: Link Analysis for Drug Interdiction.

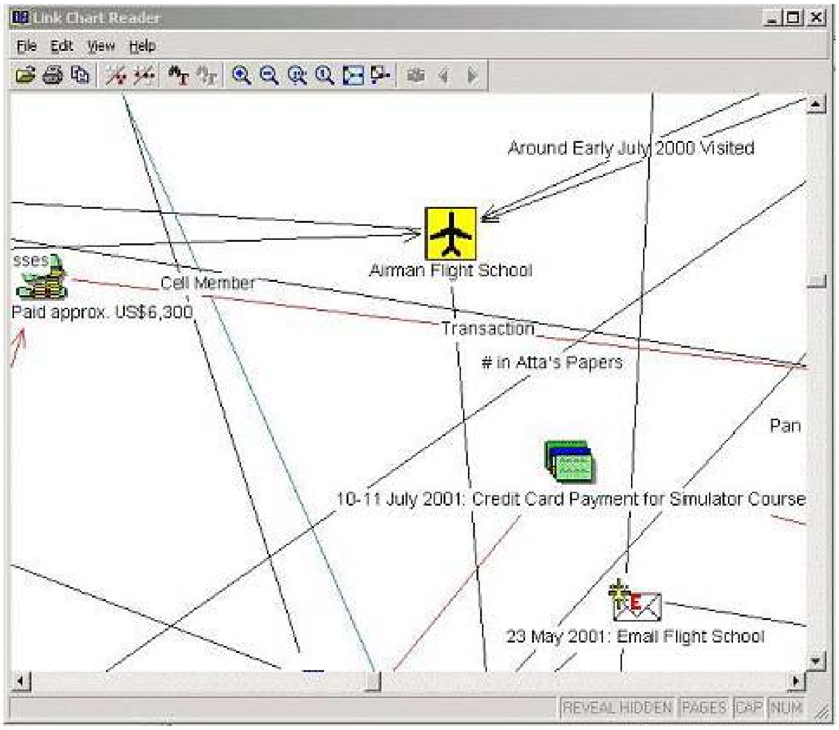


Figure 12b: Link Analysis Applied to the al-Qaeda Network.

3.4 Visualization Examples from the Logistics Domain

In the Logistics domain, resources, assets, inventory, geography, and more importantly, time, process, sequence, status, health and coordination are critical attributes that require integrated visual representations to support logistics activities in dynamic (national and coalition) environments.

The Joint Logistics Advanced Capability Technology Demonstrator (JL ACTD) – Visage represents an approach for coordinating visualizations and analytical tools in data-intensive domains [Roth et al., 1996, Maya, 1997]. It provides techniques for locating, selecting, visualizing, manipulating, and analyzing information. It also provides a user interface for sharing information among other data analysis and presentation tools. Figure 13 shows a screen shot of Visage in action where three linked visual representations (table, map and chart views) are displayed with colour mapping. The example illustrates how an Army analyst, who needs to explore the supply needs of a particular group in an Army organization, uses an outliner table that shows information hierarchically. The analyst starts from a single point in a data network and can drill down or across the hierarchy. Here, he drags a selected set of units from the outliner to a frame that displays its data objects in the form of a bar graph showing the units' supply weight. He can then drag copies of the elements representing these units to yet another frame, this one displaying the data superimposed upon a map. All three displays are coordinated. Users can also drag or copy their analysis displays directly into a briefing slide.

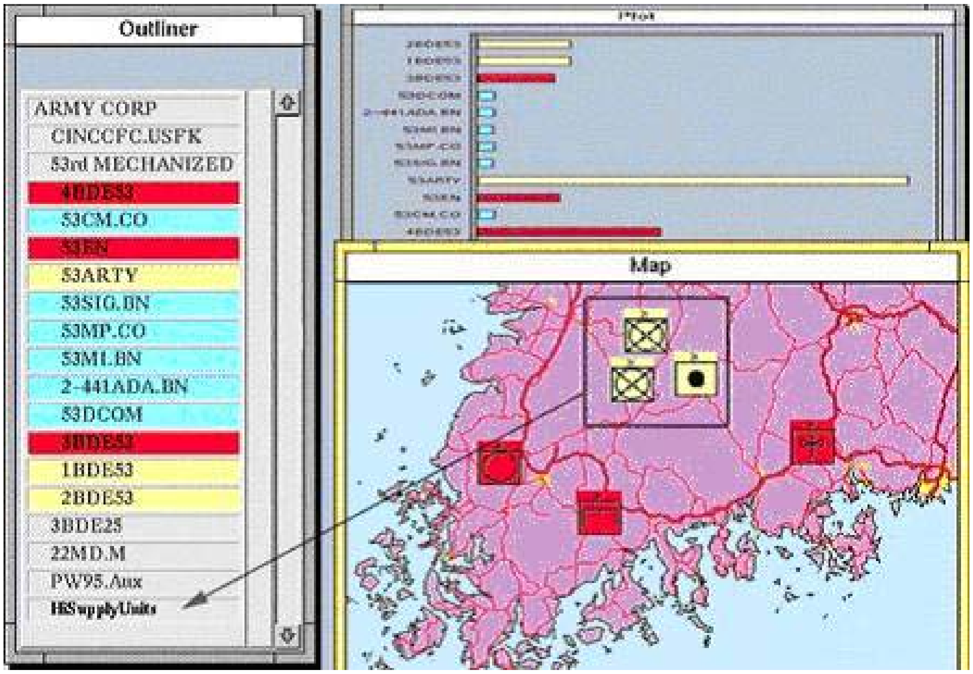
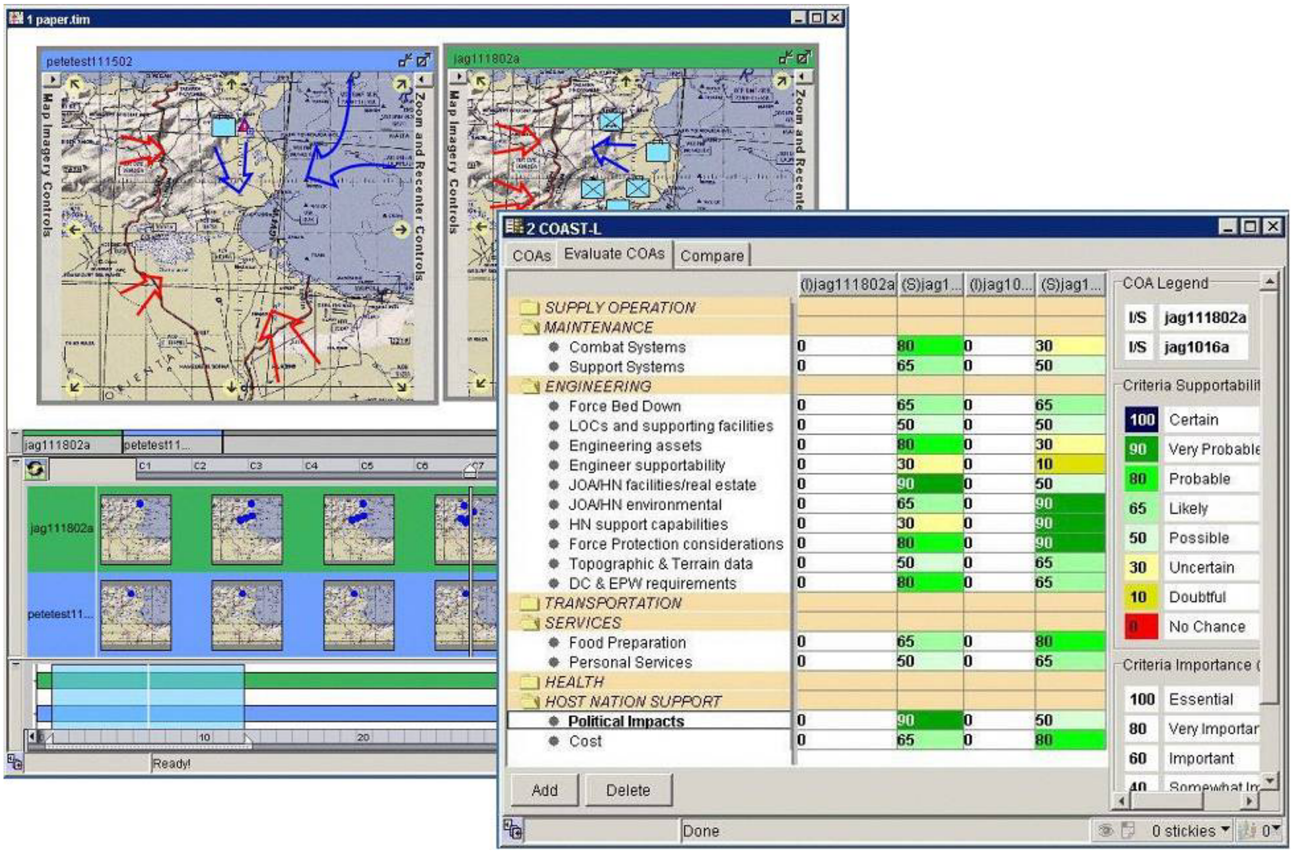


Figure 13: Army Logistics View with JL ACTD Visage.

Another logistics domain tool is the Watchboard tool from the Joint Theatre Logistics (JTL) ACTD [JTL, 2002] shown in Figure 14. One tool allows the comparison of planned vs. actual COAs along abstract dimensions of supportability. Another supports comparison of planned and actual COAs on a coordinated time and geographic visualization called the TimeMap. The TimeMap allows direct re-planning if required changes to the support plan are discovered. JTL's Watchboard tool also monitors critical logistics events, items and personnel with integrated and linked graphical charts, maps, tables and graphs. This is accomplished, to some extent, through the use of agent technology that periodically queries data sources. All the tools in JTL are built using a data visualization framework which allows interfaces to link directly to an underlying data source. As other JTL tools are used which impact the COA data that is visualized in the Watchboard, the Watchboard's display is updated automatically.



	(I)jag111802a	(S)jag1...	(I)jag10...	(S)jag1...
SUPPLY OPERATION				
MAINTENANCE				
● Combat Systems	0	80	0	30
● Support Systems	0	65	0	50
ENGINEERING				
● Force Bed Down	0	65	0	65
● LOCs and supporting facilities	0	50	0	50
● Engineering assets	0	80	0	30
● Engineer supportability	0	30	0	10
● JOA/HN facilities/real estate	0	90	0	50
● JOA/HN environmental	0	65	0	90
● HN support capabilities	0	30	0	90
● Force Protection considerations	0	80	0	90
● Topographic & Terrain data	0	50	0	65
● DC & EPW requirements	0	80	0	65
TRANSPORTATION				
SERVICES				
● Food Preparation	0	65	0	80
● Personal Services	0	50	0	65
HEALTH				
HOST NATION SUPPORT				
● **Political Impacts**	0	90	0	50
● Cost	0	65	0	80

COA Legend

I/S	jag111802a
I/S	jag1016a

Criteria Supportabilit

100	Certain
90	Very Probable
80	Probable
65	Likely
50	Possible
30	Uncertain
10	Doubtful
0	No Chance

Criteria Importance (

100	Essential
80	Very Importar
60	Important
40	Somewhat Im

Figure 14: Logistics Views from JTL ACTD Watchboard.

Figure 15 shows an example from Planimate-Belisi that provides animation, drill down into the details of each unit, sub-unit and function as required, drag and drop of icons, map, and the use of distortion to provide a detail view of an area of interest whilst maintaining the context of the overall picture. Planimate – is software designed for constructing dynamic system models and Animated Management Tools, for use in Animated Planning Platforms. Planimate-Belisi is an instance application developed by the Defence Science and Technology Organisation (DSTO) in Australia to address dynamic logistics planning.

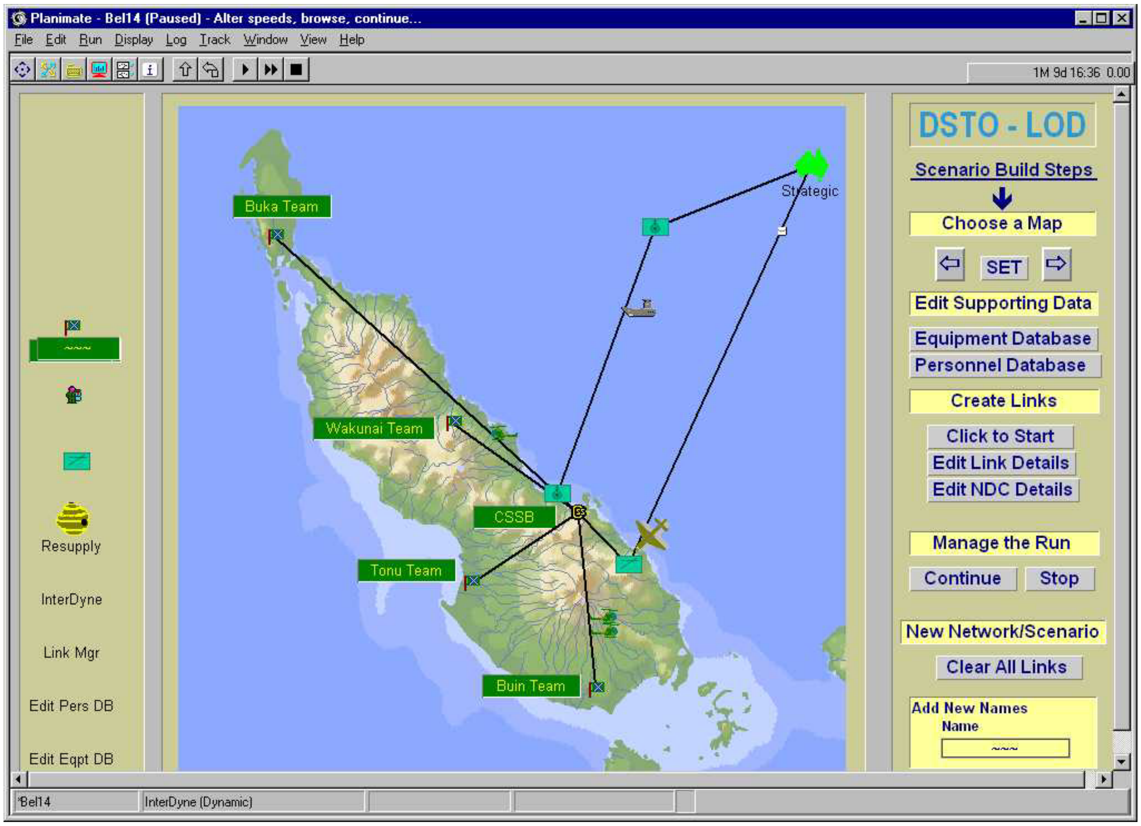


Figure 15: Distorted Logistics View from Planimate Belisi.

Demonstrated during JWID 02, the Canadian COPlanS is an integrated flexible suite of planning, decision-aid and workflow management tools specially designed to support different Military Operations Planning Processes. In particular, it supports the development, analysis and comparison of Courses of Action (COA) using distributed collaboration services, multi-criteria analysis and a number of visual charts (Figure 16). The user is able to assess the various COAs using a number of evaluation criteria. Charts are used to display the evaluation by criterion or globally. Weighting factors can be readjusted graphically.

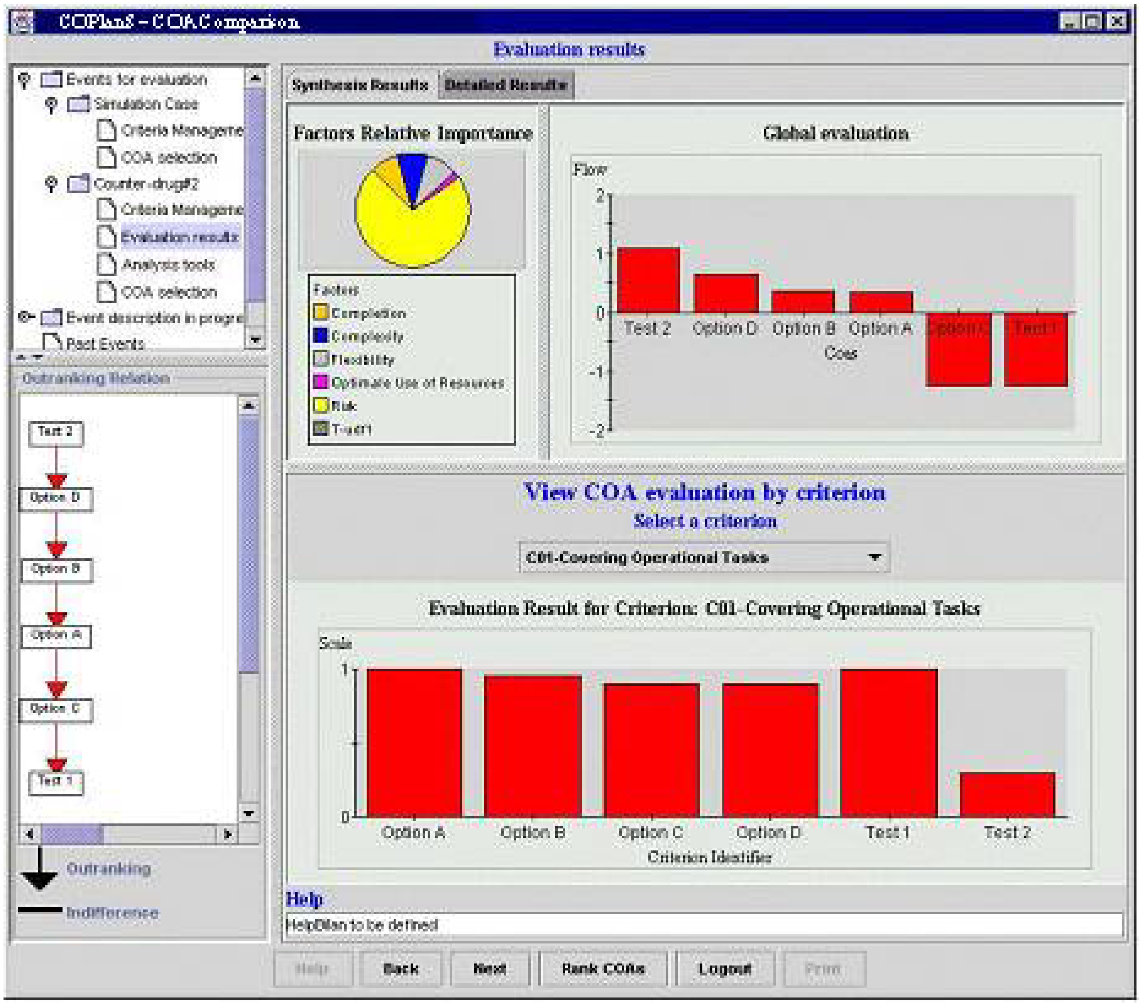
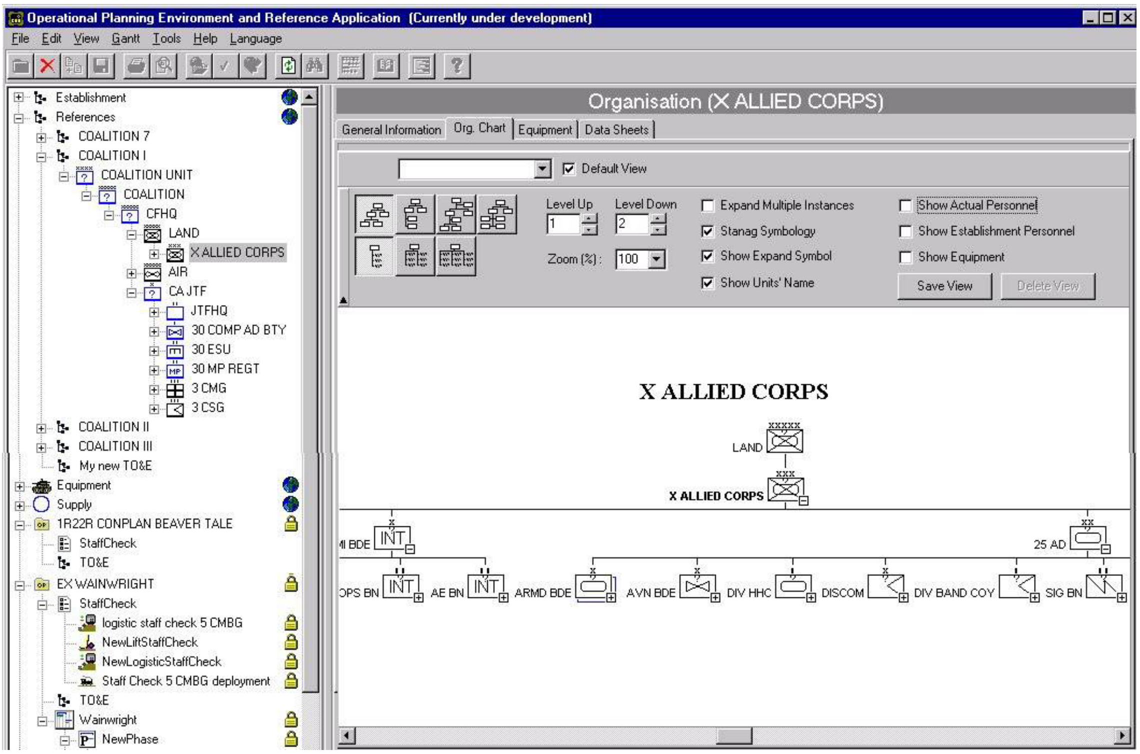


Figure 16: COPlanS Course of Action Comparison.

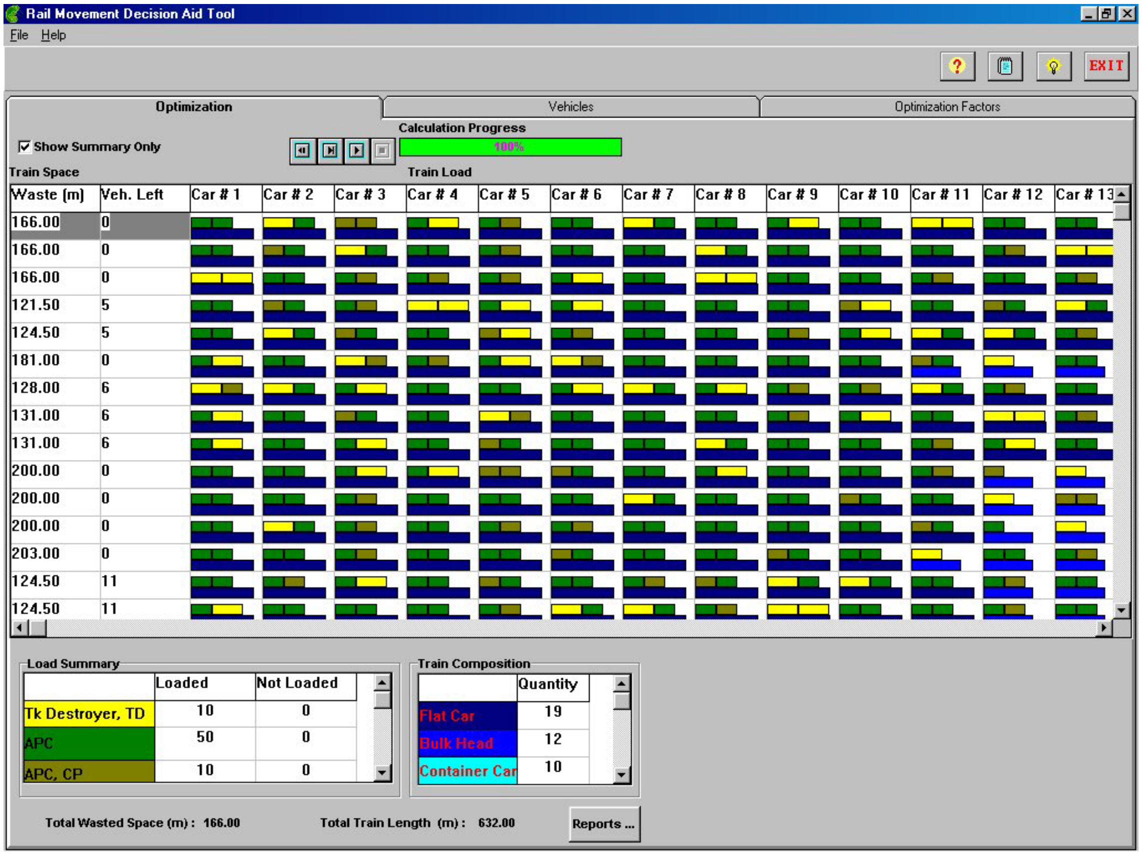
Canada's Operational Planning Environment and Reference Application (OPERA) is a suite of interrelated tools that provide advanced planning and calculation capabilities. The OPERA folder provides a hierarchical display of OPERA elements and subsequent access to corresponding detailed information. These elements include plans, organizations, equipment and reference documents. Depending on the selected element, the appropriate visualization technique is selected. Hence, as shown on Figure 17, the ORBAT (Order of Battle) Browser allows the display and edition of military organizations through either a tree view or organisation chart view, with full control over the displayed information and the display of associated resources.



☑ Default View
Level Up 1
Level Down 2
Zoom (%) : 100
☐ Expand Multiple Instances
☑ Stanag Symbology
☑ Show Expand Symbol
☑ Show Units' Name
☐ Show Actual Personnel
☐ Show Establishment Personnel
☐ Show Equipment

Figure 17: The Operational Planning Environment and Reference Application (OPERA) Orbat Browser.

Chameleon is an approach for developing, capturing and demonstrating command and control concepts using an interactive mock-up. The mock-up is developed in a breadth-first manner using rapid application development tools (i.e. Borland Delphi). It has been used to develop C&C concepts for the Canadian Armed Forces [Gouin, 1997]. Chameleon in Figure 18 illustrates the use of an iconic spreadsheet and colour mapping to help rail embarkation planning. Chameleon has taken the spreadsheet concept further by allowing icons within cells and the characteristics of the icons (i.e., size, shape, colour, etc) to map onto underlying information attributes, the result being a more visually informative spreadsheet.



☑ Show Summary Only

Train Space

Waste (m)	Veh. Left
166.00	0
166.00	0
166.00	0
121.50	5
124.50	5
181.00	0
128.00	6
131.00	6
131.00	6
200.00	0
200.00	0
200.00	0
203.00	0
124.50	11
124.50	11

Load Summary

	Loaded	Not Loaded
Tk Destroyer, TD	10	0
APC	50	0
APC, CP	10	0

Train Composition

	Quantity
Flat Car	19
Bulk Head	12
Container Car	10

Total Wasted Space (m) : 166.00

Total Train Length (m) : 632.00

Figure 18: Rail Movement Planner Logistics View from Chameleon.

3.5 Visualization Examples from the Information Operations Domain

The nature of the information operations domain lends itself to the use of abstract information visualization approaches and novel user-to-computer interactions to aid in the exploration and understanding of very large amounts of data/information. The Information Operations domain primarily has focused on information exploration, data/information relationships and trends.

Ironman (a tool from Canada) is a system, which is being developed and used to integrate academic and commercial tools providing network discovery/scanning, intrusion detection and management capabilities [Kuchta, 2000]. Added to these tools are a data visualization environment, modelling, analysis and reasoning tools, and a policy management framework. Ironman is a prototype environment designed to provide interactive management of networks and network components and services. Interaction is provided through a VRML 2.0 3D virtual environment and through additional extended controls such as forms and dialog boxes. Figure 19 presents a view from Ironman, which shows an automated generation of a mapping from five network components (hosts on a LAN) to one of 313 vulnerabilities, which are scanned for by Ballista (a network vulnerability assessment tool). The links between the network components (light blue boxes) and the red, green and yellow boxes represent associations between a specific vulnerability and network component. In this case, the red boxes represent high-risk vulnerabilities, the yellow boxes represent medium risk vulnerabilities and the green boxes represent low risk vulnerabilities.

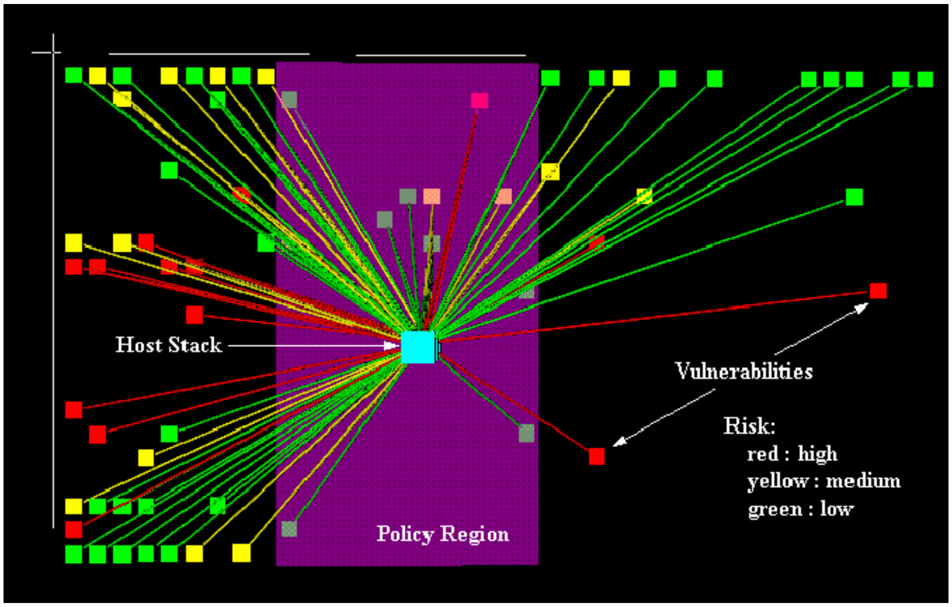
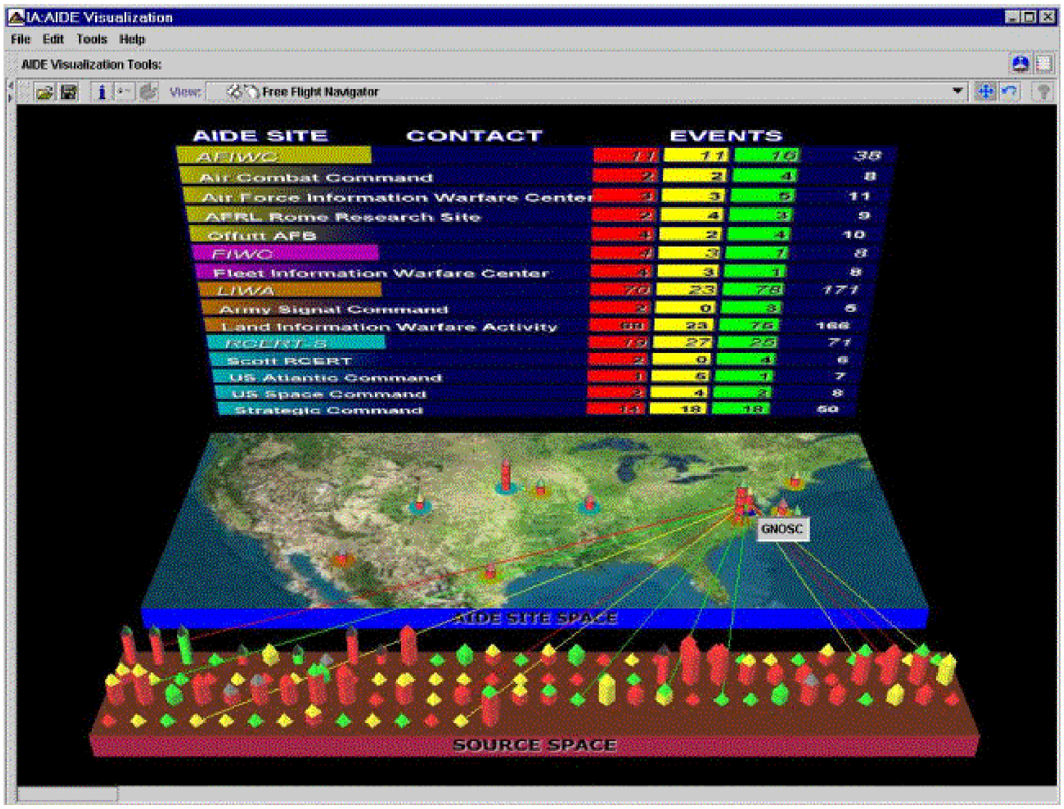


Figure 19: Network Vulnerability View from Ironman.

Shapes Vector is an Australian Defence prototype tool used for the monitoring of very large defence networks. Shapes Vector combines three dimensional visualization techniques with innovative artificial intelligent software agents to patrol and report on wide area network anomalies. Figure 20 provides an example from Shapes Vector, which shows a 3D stereoscopic view of very large networks. Operators interact with the system to determine the nature of anomalies and take action to maintain network security.

Figure 20: Large Network View from Shapes Vector.

The Information Assurance: Automated Intrusion Detection Environment (IA:AIDE) ACTD is a tool from the US Air Force to provide high confidence warning of an Information Warfare (IW) attack [Temin, 1999]. Figure 21 presents an example from IA-AIDE, which shows a composite view that integrates the geographic location of military network sites with information on various classes of intrusion events. Direct manipulation approaches are used to provide specific information on information sources at particular locations.



AIDE SITE	CONTACT	EVENTS			
AFIWC		11	11	16	38
	Air Combat Command	2	2	4	8
	Air Force Information Warfare Center	3	3	5	11
	AFRL Rome Research Site	2	4	3	9
	Offutt AFB	4	2	4	10
FIWC		4	3	1	8
	Fleet Information Warfare Center	4	3	1	8
LIWA		70	23	78	171
	Army Signal Command	3	0	3	6
	Land Information Warfare Activity	68	23	75	166
RCERT-S		19	27	25	71
	Scott RCERT	2	0	4	6
	US Atlantic Command	1	5	1	7
	US Space Command	2	4	2	8
	Strategic Command	14	18	18	50

Figure 21: Composite View from IA-AIDE.

4.0 DISCUSSION

This paper has illustrated a number of interesting military visualization examples. Some of them refer to deployed command and control systems while others represent proof of concept prototypes. Although no comprehensive experimentation has been conducted with these systems as part of the AG-3 work, a number of findings can be derived.

Map-based representation is a privileged form of visual representation for C3I applications. Still, the examples contained in the C3I knowledge base show a wide variety of interface design, support for user interaction, symbology. Some of the positive features are:

- Use of 2D or 3D map representations depending on the task and possibility to transition from one mode to another.
- Information content and map scale that is tailored to the user role / task.

- Use of a meaningful symbology (shapes, colours) including Coalition symbology (different colour for each faction).
- Capability to dim the map background to highlight overlayed information.
- Display of temporal information using traces, playback, blobology.

In terms of non-map-based representations, there is a wide use of Organization Charts, 3D Charts, Gantt charts and an increasing use of dashboards, in particular for Logistics and Planning applications.

The showcased examples used in this paper highlight the adherence to a number of human computer interface principles that provide an intuitive and efficient graphical user interface:

- Interface Design. Careful design of the screen real estate and interface widgets to ensure an efficient interface.
- Outline/Tree Views to present information using a hierarchical representation, with the ability to expand or collapse certain hierarchies selectively.
- Object Explorer widget also to present a hierarchical view of objects, but selecting an object leads to a different visual representation.
- Information Categories. Subdivision of the information into meaningful categories, using sub-areas and tab folders.
- Multimedia information. Use of multimedia (video, imagery, alarms) such as TV feeds, reconnaissance video and collateral imagery to enhance situation awareness.
- Hyperlinks. Use of hyperlinks to provide association between information elements and a capability to drill down into the information.
- Multiple views. Information must be presentable in multiple views.
- Drag and Drop. The user can pass information easily between two applications or tools using drag-and-drop operations.
- Animation. Use of animation to display temporal information, for example to can playback the current situation or to “animate” a plan.

The examples also illustrate significant trends that are occurring in terms of information visualization:

- Collaboration. Users realize the benefits of collaboration tools / services to support collaborative work and the sharing of information.
- Portal Technology. Use of Enterprise Portal technology is a significant trend in providing a common access to information.
- Synchronized views. The use of synchronized views has been shown in a number of research programs.
- Immersive displays. Use of Immersive environments, virtual and augmented reality, and multi-modal interaction are increasingly exploited to provide an enhanced interaction with information.
- Display Devices. A wide variety of display devices such as large screen displays, data / knowledge walls, two/tri panel displays and head mounted-displays are increasingly used.

- Abstract Representation. Significant R&D is being conducted in abstract representations and provides solutions to key threats (e.g. network intrusions, terrorist networks).
- 3D Urban Models. As more and more military operations are taking place in Urban Environments, the use of 3D urban models will improve situation awareness and help in mission rehearsal.
- Coalition operations. The large number of coalition operations impose a need to work towards visualization solutions that provide a coalition shared situation awareness.

5.0 CONCLUSION

This paper illustrates a number of interesting visualization examples extracted from the C3I knowledge based put together by the TTCP C3I Action Group on Information Visualization. These examples highlight a number of novel / efficient visualization concepts addressing the various dimensions of the Visualization Reference Model (RM-Vis): the Domain Context (context of use); the Descriptive Aspects (elements of information) and the Visualization Approach, including the visual representation, visual enhancements and interaction.

Although more experimentation must be conducted for the assessment of visualization solutions in military command and control systems, the C3I visualization database provide a good foundation to share and grow knowledge on visualization.

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SYMPOSIA DISCUSSION – PAPER NO: 1

Author Name: Mr. Denis Gouin, Defence R&D Canada, Canada

Question:
How can we make use of the database of examples?

Author Response:
There is some difficulty in distribution because is it foundation work. They are in a database, but it is not yet known how broadly they can be distributed.

Question:
Where do these examples fit?

Author Response:
More testing is required.

Multi-Sensory, Multi-Modal Concepts for Information Understanding

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ABSTRACT

In recent years, extensive research has focused on the development of techniques for multi-sensor data fusion systems. These fusion systems process data from multiple sensors to develop improved estimates of the position, velocity, attributes, and identity of entities such as targets or entities of interest. Typically, the fused data are displayed on a geographical information display (e.g., data are overlaid on a map with terrain features, political information, and the data are shown as icons representing the observed entities). Analysts interpret the data to develop an assessment of an evolving situation or threat. Despite significant improvements in computer displays, haptic interface devices, and new three-dimensional full-immersion display capabilities, the data fusion displays have seen little changes to take advantage of a human's ability to access data. This paper describes two concepts for improved understanding of data; (1) the utilization of multiple human senses to interact with and interpret data, and (2) the dual use of language and vision to improve information understanding.

INTRODUCTION

Historically, information displays for display and understanding of data fusion products have focused on the use of vision. These displays typically involve geographical information displays involving a map and map overlays. The evolution of such displays has focused on increasing resolution, multi-layer information displays, utilization of icons, and interaction mechanisms using pull-down windows and related techniques. We argue that, while vision is a powerful human sense, such interfaces ignore the other human senses of hearing, touch, smell and taste. True virtual reality would exploit all of these senses to make displayed data seem more "real", and to take advantages of individual preferences for information access and improved understanding via multi-mode interaction. Research conducted by our group at Penn State University has utilized multiple human senses (including vision, sound and touch) to improve the analysis and understanding of data. New techniques have been developed including; (1) use of sound sonification to interpret data uncertainty, (2) use of novel 3D visual devices paradigms, such as height to represent temporal phenomena, (3) use of transparency to represent uncertainty, and (4) haptic devices to interpret data. The utilization of such methods provides the opportunity for improved understanding of complex data such as multi-spectral, multi-sensor environmental data.

The second area of exploration has involved the combined utilization of human visual intelligence and language intelligence to understand data. Humans exhibit intelligence in two broad arenas; vision and language skills. Standard data fusion displays rely only on human visual intelligence to interpret data. Examples of visual intelligence include pattern recognition, understanding of proximity and motion, and utilization of our knowledge of the physical world. Humans have the ability to apply a visual intelligence

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

to interpret information. While this is a powerful cognitive skill, there are cognitive biases based on vision. Examples include our lack of ability to “un-see” a pattern once it has been recognized, identification of patterns in random data (recognition of patterns even when patterns are not meaningful), and an implicit assumption that proximity is related to causal relationships. We have developed some concepts to explicitly use both vision and language capability for improved information understanding. These concepts leverage some newly developed methods for transforming image information into text (viz., descriptions about the image content). Use of such transformations allows a user to access and use both visual intelligence and natural language reasoning ability.

AN EXPERIMENT WITH NASA DATA

Some of the concepts described above were explored under a grant from the National Aeronautics and Space Administration (NASA [1]). The objective of the NASA funded research into information fusion was to combine remote sensor data with other information sources for improved data interpretation and understanding. We focused on automated contextual interpretation of multi-source information integration and fusion supporting human analysis [2].

For this project, information fusion techniques include the correlation and conditioning of data products, both geo-spatially and temporally, and fusion and interpretation of data using a hybrid reasoning approach. The following topics were pursued:

1) Fusion of non-commensurate multi-source sensor data and information, including images and textual reports.
2) Performing automated contextual interpretation of earth science data to assist human analysis by modeling multi-expert knowledge via fuzzy-logic rules, incorporating collected sensor data via neural networks, and combining domain knowledge and observed information via a novel hybrid reasoning approach.

The objective of this research into data visualization techniques was to model, represent, and display complex multi-dimensional terrestrial and atmospheric data and processes. Deception and confusion have been long-standing concerns in the discussion of computer-generated graphics I [3]. Our objective was to create a presentation in which the form and style was consistent with the nature of the data. This environment allows multiple collaborative users to be fully immersed within a digital representation of integrated information. It has been seen that the user interaction components of immersive environment technologies are often poorly designed. As a result, many visually compelling environments are difficult to use and thus unproductive [4]. Our objective was to design and implement an environment that enables the user to easily interact with the earth science data, to facilitate the user’s innate human abilities to work collaboratively and assimilate multi-sensory information.

The following topics have been pursued:

1) Application of multi-dimensional, immersive visualization and interaction techniques to integrating earth science data products and the results of automated reasoning for improved interpretation and data discovery.
2) Development of visualization techniques to augment the presentation of ES geo-spatial, parametric, and temporal attributes within an immersive visualization environment.

Figure 1 presents the project concept of multi-source information integration and fusion for attaining improved contextual interpretation and understanding.

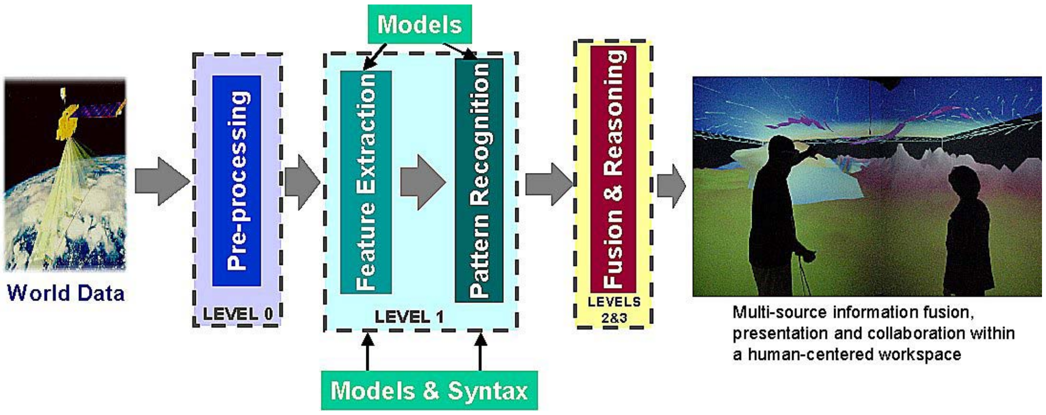

Figure 1: Multi-Source Earth Science Fusion and Visualization Objectives.

SUMMARY OF RESULTS

The research performed on this project demonstrated the potential for the successful application of hybrid reasoning approaches to the problems of earth science information processing, analysis and understanding. Applying hybrid reasoning techniques to the problem of predicting fire danger showed the capability to fuse non-commensurate information and domain knowledge to model, represent, and display complex multi-dimensional terrestrial and atmospheric data. While this effort was not uniquely focused as a solution to the problem of predicting fire danger, it presents the framework of a methodology that could be used for the solution of this and other earth science issues.

The immersive visualization provided an effective environment for users to experience the earth science information and data fusion results, interacting with the environment by means of well-practiced techniques and perceptual skills. By presenting the multi-source data in a geo-spatial, geo-temporal context in which the users could interactively navigate and manipulate the data, this environment showed potential for a variety of earth science analysis tasks. Although there are some limitations due to the current state of the technology, this demonstration showed that usable complex environments are possible. As data collection quantity and resolution continue to increase, the data volume will always exceed the technical capabilities so the community must continue to develop innovative and effective multi-sensory analysis techniques.

We believe that automated fusion methods supporting human analysis, such as those demonstrated by this project, will provide aids to reduce cognitive biases, improve the understanding of heterogeneous, multi-source data, and provide increased opportunities for data discovery.

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SYMPOSIA DISCUSSION – PAPER NO: 2

Author Name: Dr. David L. Hall, Pennsylvania State Univ., USA

Question:
How do you validate a hybrid approach? How do you know when you converge on a solution?

Author Response:
Develop the best set of rules possible, and then train a neural network to faithfully represent those rules. Then it is a matter of allowing the neural network to evolve with more data sets.

Question:
It is often difficult to extract a good percentage of the expert's knowledge, what are some ways of representing human intuition?

Author Response:
It is an iterative process. When you first apply the rules developed with an expert to data and get results, it might point to changes to the rules. The results of the evolved rules are taken back to the expert to confirm. Sometimes the expert did not think to include specific criteria, for example, or doesn't realize they were using a rule until it is pointed out.

Question:
The virtual reality cave method is very nice to look at, but appears awkward to do work in. You can't carry it around, where do you do your analysis, where is your workspace?

Author Response:
Different instantiations of the technology are suited to different users and applications. Oil exploration and automobile design are two of the industries utilizing this technology right now. It gives them the opportunity to bring people, possibly from different areas of expertise into the same environment and understanding. The choice of the display or instantiation of the technology utilized for a specific application should be one of the last things you do, after the requirements and application have been clearly defined.

Examples of uses sited:

- Mineral exploration where you can follow the path of the mine
- Medical applications such as the ability to remotely operate

The IST-05 Reference Model in Evaluation and Design

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INTRODUCTION

A “visualisation system” is a system for presenting, probably interactively, some part of a dataspace, in such a way that a user with some purpose in mind can visualise the import of the data for that purpose. Visualisation is something that happens in the head of a human, and may be evoked not only by graphical presentations, but also by text, or even by non-visual presentations such as touch and sound.

Visualisation is taken to be one of two parallel routes to understanding, the other being analysis. Analysis works primarily by applying reasoning in the form of logic or mathematics to identifiable discrete entities, whereas visualisation often involves the perception of patterns involving the relationships among many items that may not even be individually identifiable. In many situations understanding is best achieved by the mutual support of visualisation and analysis, visualisation providing a context within which analysis provides precision.

The IST-05 Reference model describes visualisation systems in a way that is both general and precise. Because of its generality, it can describe and guide the evaluation of any visualisation system, and as a consequence of its precision, it can be used to guide the system’s design and evolutionary improvement.

The Model is based around a hierarchy of feedback loops. In an outer loop, the human interacts with the dataspace, selecting and manipulating the data and the way the data is viewed, until its import for the human’s purpose can be effectively understood. Of course, the human cannot do this by direct observation if the dataspace is bits and bytes in a computer memory.

To avoid the need for telepathy in manipulating and understanding the data, the IST-05 Reference Model incorporates a processing loop inside the main outer loop. In this inner loop, the human’s visualising processes interact with “Engines” in the computer. Engines are defined as processes that select and organize the data, under the control of the human user. Engines also prepare the data for display by the physical output devices. Engines are therefore tools that convert the human’s physical manipulation of the input devices into operations on the data in the dataspace, and convert segments of the data into forms that the output devices can present to the human. These input and output devices connect to form an innermost major loop that is concerned only with the human’s physical interactions with the display systems.

In the IST-05 Reference Model, then, the outer loop links human understanding with the dataspace, a middle loop links human visualisation with the Engines in the computer, and at the innermost level, the I/O devices allow these loops to take physical form.

EVALUATION

The reference model describes only one inner and one outer loop, but each of these can be analyzed further, both as a skein of parallel loops and as a structure of hierarchic support loops. An individual

Paper presented at the RTO IST Workshop on “Massive Military Data Fusion and Visualisation: Users Talk with Developers”, held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

elementary loop is defined by a purpose that relates to a perception of some aspect of the dataspace. If the current perception satisfies the purpose, then nothing needs to be done, but ordinarily this is not the case, and the human needs to act in some way to alter what is perceived. This defines a simple control loop, which is at the core of the evaluation procedure.

A complete evaluation would consist of identifying every purpose the user might have, from the high-level purpose of understanding, say, the intentions of a battle adversary to the low-level purpose of striking the "k" key on a keyboard. Of course, few, if any, evaluations would be so complete. But the evaluation of each loop defined by a purpose contributes to the evaluation of the system as a whole.

A loop is defined by a purpose, so the first stage in evaluating a loop is to determine its purpose. The second question is to determine what information needs to be available to inform the human's perception, if that purpose is to be achieved. For example, if the purpose is to determine whether a computer network is under distributed attack, the purpose cannot be achieved unless the user can see that certain message packets are coming from different hosts. A display system that provided information about the packets only as a homogenous stream would not serve that purpose.

This second question also has a bearing on user training. A naïve user may need to get information from the system that an expert user would already have available in memory. In evaluating a system, the evaluator must be aware of the possible partitioning of the necessary information into that which is obtained or obtainable from the displays and that which must already be known to the user.

The third question to be asked in an evaluation is what the human needs to do if the current purpose is not served by the currently available information from which the perception is derived. Can the user influence the dataspace so as to get the desired information from it? To continue the previous example, could the user act so that the source hosts of message packets became available to the display? Training also must be considered here, as a naive user may not be aware of means of action that are actually available.

Two more questions complete the evaluation of a single loop. They are what impediments might there be to observing what needs to be observed, and what impediments might there be to acting effectively to generate the desired observations. Impediments can be both internal and external.

An internal impediment to observation might be inadequate display resolution or, at a higher level, lack of an Engine that appropriately interprets the data about packet sources even though those data might exist in the dataspace. In other words, an internal impediment to observation is something on the information pathway between the dataspace and the human, whereas an external impediment to observation might be glare on the screen, or at a higher level, interference from other information being simultaneously displayed and demanding attention – in other words, interference due to attention-splitting. One may consider an internal impediment to be analogous to a restriction of channel bandwidth, and an external impediment to be analogous to an noise added into the channel.

An internal impediment to action might be the lack of an input device with enough degrees of freedom to effect the desired control, or at a higher level, the lack of an engine with appropriate algorithms for selecting data that would be required to create the information needed for the desired observation. An external impediment to action might be the joggling of the command vehicle in which a system was installed, or at a higher level, the sharing of processor resources among compute-intensive engines, such that acting to generate one observation inhibited the possibility of acting to generate another.

Finally, there is a sixth question that relates not to the operations of the single loop being examined, but to the fact that one simple control loop of the model is actually a skein of parallel loops. This sixth question asks if there is some way that the user can be alerted to conditions in which a purpose not currently being actively pursued might be worth pursuing immediately. Maybe important new data has come in that must be dealt with, or, in a more passive environment, maybe an engine has identified some pattern in the data that corresponds to something the user has indicated might be "interesting."

The six questions for any loop can be summarized as follows:

1) What is the user trying to achieve at this point?
2) Can the user perceive whether there is progress toward the goal?
3) Is the user able to influence progress toward the goal?
4) What internal or external impediments might there be to perceiving what is necessary?
5) What internal or external impediments might affect the user's ability to act appropriately?
6) What provision is there to alert the user that something else needs attention?

DESIGN

Design is very much the complement of evaluation. The same six questions for each loop can guide a design. First one asks what the probable user will be wanting to achieve by using the system under design, and that defines the required information flows in the outer loop (presuming the designer knows the characteristics of the dataspace). Each possible action provides a purpose at the next level, which defines another loop, and so forth untill all the potential observations and actions have been incorporated into interactive loops (interaction may be num,m if the display is to be passive, but usually interactive displays are more informative than passive ones).

Not can design *ab initio* be guided by the IST-05 Reference Model, but also evolutionary improvement can be guided by the specific deficiencies identified in an evaluation. If a purpose defined in question 1 is not well satisfied by the answers to questions 2-5, the nature of the problem should be immediately apparent, and a solution, if not obvious, should at least be conceivable.

An example of an imaginary Marine tasking system based on a 3600-year old fresco was used to illustrate the power of the principles and practices embodied in the apparently simple IST-05 Reference Model. The PowerPoint presentation describes the method and the example.

SYMPOSIA DISCUSSION – PAPER NO: 3

Author Name: Dr. Martin M. Taylor, Taylor Consulting, Canada

Discussion deferred to plenary discussion session.

SESSION 2 – PLENARY DISCUSSION

- What is visualisation? In this context, it is an element of communication.
- Should we be thinking of visualisation in the totality of our senses, the breadth of multi-modality in human function?
- Visualisation as a delivery process:
  - How to give information to the user
  - How to present the information
  - How is the information obtained, and how does the user obtain that information
- What is visualisation for? There are initially specified aspects of required information in many circumstances.
- Actionable information is a goal, allowing the user to understand something that contributes to achieving something.
- During one of the briefs audio stimulates were mentioned. Is this a contribution to visualisation?
  - It depends on the context and the purposes of the user. If the audio stimulate helps you get a picture in your mind it is. If it is “noise” it could impede the visualisation.
  - Visualisation is more than graphics and information presented on the screen. Sound and the temperature of the room are two examples of things that could influence visualisation.
- State of mind and environmental factors can impact situational awareness and influence the decision maker. For example, the table demonstrated can influence the dynamics of the group and the feelings of the decision maker.
- Intuition is a major aspect of visualisation and basis for decision-making. The intuitive officer sees the facts and visualizes what is actually going on. It is as though the officer can look through a little crack in the wall and from that understand and see the entire picture.
- The facts of the current situation can be presented, but the intuition is coming from a database that has been built up in that person from experience.
- We need to work on the development of systems that can aid the intuition, or act as intuition amplifiers.
- The IST-021 tries to deal with the intuitive, which is based on the larger context of the data flood. The data flood can be good for intuition, whereas it may not be good for logical analysis. IST-021 explicitly ignores the logical analysis and deals mainly in displays for intuitive visualisation.
- In addition to intuitive decisions, one can also go linearly through all the information to arrive at a logical decision.
- The linear and parallel may not be separate. The ability to intuit may develop as a result of experience and having gone through the linear, logical process.
- Is mental model a better term than visualisation? Is the purpose to construct a detailed picture or to feed into the mental model?

- Are the visualisation technical people trying to understand the user, the way they construct the view or visualisation, or is it backed away looking at the task requirements and needs? The work and requirements need to be clearly understood before a system can be developed.

- A system cannot be developed for a specific individual. The developer must understand the purpose of the presentation as well as whom the user group is, and hope to be able to account for personal preferences.

- We know that experts make decisions in very different ways than novices do, for example, with the use of pattern recognition. Experts and novices will use the same information presentations in different ways. It is important to understand the information requirements at different levels of expertise.

- What does the user have to bring to what is provided in order to achieve his purpose. A novice cannot effectively use something designed for an expert. What the expert brings is the understanding of why.

- The difference between the novice and expert in inherent in the VisTG reference model. An impediment to perception is lack of background information.

- One problem of providing detailed information to anyone is that even though each level of authority can restrict his use of information to the needs of that level, the use of information can affect trust. Power is based on information, and it is important to remember the impacts of culture and hierarchy.

- Culture, authority, and societal effects influence the total design.

- Visual context is important in interpreting the focal information.

- An effective presentation can be a director of intuition.

- Intuition is a result of years of hard work. A good commander will be able to select and refine the dataset to be considered, and needs tools that allow him to compress the information in the way he wants.

- Framing problems can arise, as contrary or late information tends to be ignored. A presentation should include information that may appear inconsistent and offer alternatives to the “obvious” solution.

- While intuition is a very powerful tool, it is dangerous to rely on a single person’s intuition – perhaps that is a design issue.

- While a good presentation can be a director of intuition, the commander must be able to be the director of the decision.

- How much influence can efficient, effective, deliveries of fused products have on the decision maker? It is not important to have the 100% solution, but it is important to ensure that the data fusion and information that is there is at the correct quality required.

- Trust in the machine is easily lost.

- An example was sited of an expensive prototype that was developed and installed on a ship. Visiting the ship they found that the instrument turned off. The officer said that it had given them bad data the day before, so they didn’t trust it anymore. Confidence in the data in the presentation is imperative.

- Displaying the level of certainty allows the decision maker to know when to trust the information the system is providing. Providing the uncertainty of the information presented helps preserve the trust of the user. It takes a long time to rebuild trust that is lost, and the level of trust in a system will never be as high as it initially was.

- Users need timely and useable information. If you do not trust the information, it is not usable.

- The idea of uncertainty can be used in information warfare. How can information be injected that induces distrust? That puts the commander in manual modes, as a decision making tool is not going to be utilized if it is not trusted.

- What will the user ask for? The developers need to design flexible systems.

- Distributed fusion is a very new topic. To do something distributed, you have to rely on communication infrastructure that you do not control. With multiple inputs, you have to create a community that will use consensus or authority.

- Visualisation is an interaction between the information and the decision maker. As each person is different, the assembly of the info needs to be dynamic to allow users to obtain the info that they need.

- Need a dynamic development cycle. User should be more involved.

- Is there anything that is specific about a visualisation system that is unique to a NATO operation that we could talk about while we are all here?

- The first things you will see when you go into a NATO headquarters are numerous national intelligence centers. It is not unusual to have one country with more technology. One of the main problems is that each nation will want to screen or filter their data before sending it to one central point, which takes time. Consistency of information is another problem.

Real-Time 3D Nautical Navigational Visualisation

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ABSTRACT

This paper presents a research project suggesting the use of real-time 3D techniques normally used in simulation environments as a navigation aid onboard ships. Based on a three-dimensional geographical database the surrounding world is presented in a "bridge-eye perspective" with navigational information such as own track, other ships in the vicinity and their tracks, water depth and radar echoes integrated in a single display. The integrated display suggested, acts as a complement to traditional electronic charts. The main objective is to lessen the cognitive load of the bridge personal and particularly the helms man in hand steering situations in high-speeds. (See fig. 1.)

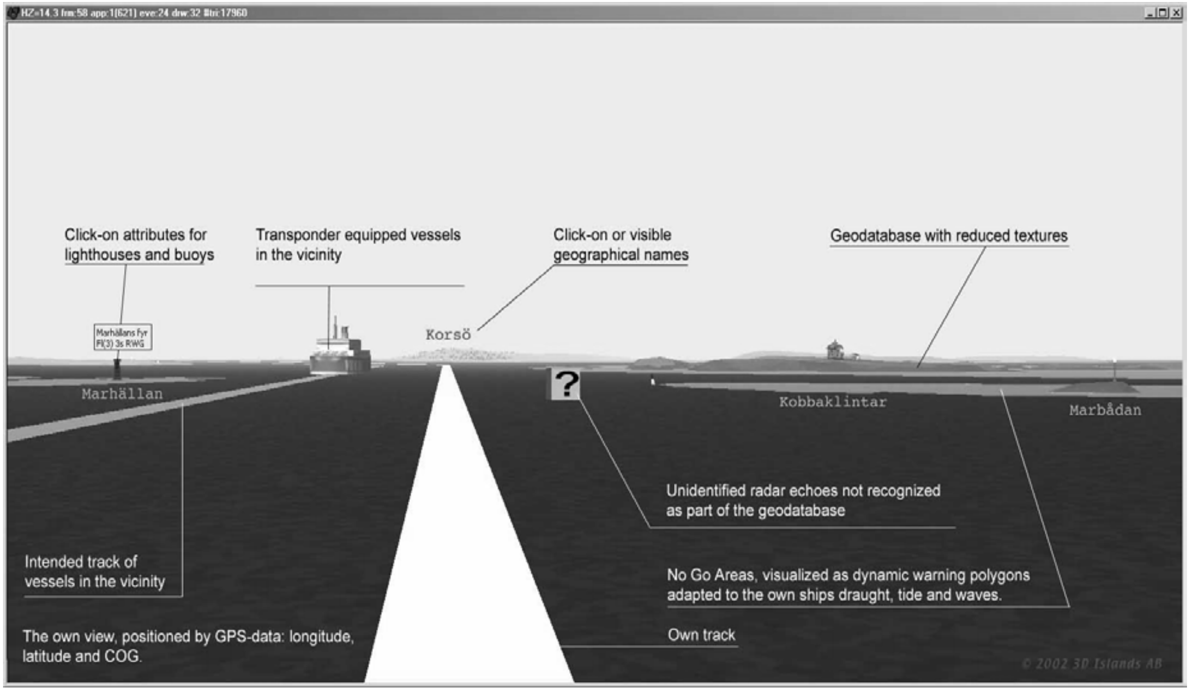

Figure 1: Navigational Information Presented from a Bridge Perspective. The screen dump shows the entrance to Mariehamn in the Åland Archipelago in the Baltic Sea, on the ferry lane between Finland and Sweden.

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

1.0 INTRODUCTION

On many vessels the everyday navigational duties of an Officer of the Watch (OOW) can be peacefully undertaken with a jug of coffee in hand. But the introduction of high-speed crafts and more and more advanced navigation equipment augments rapidly the cognitive load of the OOW and shorten the time of decision-making. There is a need for systems that balance the amount of information and present the right information at the right moment in an easy to understand way.

This paper first touches on the basic cognitive and infological problem of information visualisation. It implies the need for a new theory to understand the cognition and use of new "maps" that are digitally stored, dynamic and adjusted to the user situation, displayed in 3D and merging information from several sources. The bird's-eye and bridge-eye map perspective are discussed. A general overview of the geographical database is presented and, more detailed, the procedure of representing deep-water corridors and No GO Areas.

Concluding the paper is some items of future research.

The aim of this research project is to find ways to lessen the cognitive load of the navigator by presenting all crucial navigational information in one integrated display. The integrated view shall in a glance answer questions like: Am I on the right track? What is the intention of the approaching ship? In case of an evasive manoeuvre, where is there enough water under the keel for my vessel?

To prevent mistakes in stressed situation we are suggesting the use of a coning display using a bridge-eye perspective from a three-dimensional chart instead of the normal cartographic bird's-eye perspective.

2.0 THEORETICAL BACKGROUND

Two different concepts form the theoretical basis of this project: In regards to cognition there is the notion of Spatial Mental Models, and in regards to infological and datalogical questions regarding information systems there is the Infomatic Equation. But before we reach to that we need to do a definition.

2.1 Visualisation/Visualization

The word visualization in the title of this paper may need some further clarification. The word is often in British and Australian English spelled with an "s": visualisation. In Oxford English Dictionary defines the word as "the power or process of forming a mental picture or vision of something not actually present to the sight; a picture thus formed." But the Free On-Line Dictionary of Computing has a different definition: "Making a visible presentation of numerical data, particularly a graphical one. This might include anything from a simple X-Y graph of one dependent variable against one independent variable to a virtual reality which allows you to fly around the data."

What we see here is the confusion between a general use of the word, as something going on inside the human mind, and the computer graphics-people's use of the word, as something going on in a computer and on its display.

Chipman [2] cites a definition of visualization as "…transformations that convert data into a format amenable to understanding by the human perceptual system, while maintaining data integrity," [7].

In the field of Visualization in Scientific Computing (ViSC) Visvalingam 1994 [16] tried to make a distinction based on the spelling of the word: Visualisation, with an "s" he defined as the mental process and product and visualization with a "z" as the computational process resulting in a visual mage on a computer screen.

This distinction has not had much success; We will however use it in this paper. Often in literature the words visualisation/visualization is used without this distinction and one has to be observant on what exactly is meant.

2.2 Spatial Mental Models

There is a notion that people's mental representations of environments are embodied in so-called *cognitive maps*, cognitive mental constructs that, like real maps, can be mentally inspected. As maps they are presumed to be coherent wholes that reflect spatial as well as metric relations among elements.

Stanford cognitive psychologist Barbara Tversky [15] questions the *map* expression, pointing out the many systematic and other errors in people's memory for environments. Instead, she says, people acquirer disparate pieces of knowledge about environments. Pieces like recollections of journeys, memories of maps, recall of verbal directions and facts, and more. Instead of *maps* she wants to call these internal representations *cognitive collages*. "[Cognitive] collages are thematic overlays of multimedia from different points of view. They lack the coherence of maps, but do contain figures, partial information, and differing perspectives," she says. But she also states:

> In other situations, especially where environments are simple or well-learned, people seem to have quite accurate mental representations of spatial layouts. On close examination, these representations capture the categorical spatial relations among elements coherently, allowing perspective-taking, reorientation, and spatial inferences.

Tversky terms these mental representations Spatial Mental Models, and remarks that although they do not preserve metric information, they do preserve coarse spatial relations coherently.

As to the structure, Tversky finds that:

> these spatial mental models are akin to an architect's model or a structural description of an object. They have no prescribed perspective, but permit many perspectives to be taken on them. Thus, spatial mental models are more abstract than images, which are restricted to a specific point of view.

In a series of studies Tversky finds that subjects making descriptions of their spatial mental models take two different, but very specific, perspectives. Tversky calls them route and survey perspective. The essence of the route perspective is the coherent moving viewpoint changing location and orientation in relation to the frame of reference, while the essence of the survey perspective is the fixed perspective allowing for the description of the location of a landmark relative to the location of another landmark. She notes that: "descriptions used either route or survey perspectives or a combination of both. No other style of description emerged."

Could this concept be useful for constructing a navigational aid simulating the spatial mental model, and would such an instrument benefit the voyager in a better way than the prevailing aids?

Perhaps. If we can construct a navigational aid that can simulate our inner spatial mental model, allowing us to freely change perspective, from route to survey and back, to examine ahead on our intended track, in the same way as we can mentally, it will give us a chance to update, and correct the mental model, and prevent errors in the mental model to lead to accidents.

2.3 The Infologic Equation

The first Swedish professor in systems development Borje Langefors already in the end of the 1950's began forming theories for the coming era of information systems. He used the word *infology* to complement *datology* thus putting the focus on information systems rather than data processing systems.[*] Data became information first through an interpretation process. One has to design information systems in close collaboration with the future users of the system in order to make sure that data really will provide the information wanted. [9]

The Langefors *Infologic Equation,* further developed by Backlund [1], is a basic model to calculate/evaluate the nature and complexity of data presented by different users during different situations of stress related to both information load and the present task.

The Infologic Equation is based on a distinction between information and data; between infological and datalogical work areas. The infological problem is how to define the information to be provided by the system in order to satisfy user needs while the datalogical problem is how to organize the set of data and the hardware in order to implement the information system. Four method areas in information systems development can be distinguished, where as the first two are infological and the last two datalogical areas. [10]

- Object system analysis and design
- Information analysis
- Data system architecture, and construction
- Realization, implementation, and operation

The equation defines the information, I, to be dependent on the data, D, and the recipient's prior knowledge, S, sometimes also called the covering structure, by the interpretation process, i, during the time, t:

$$I = i(D, S, t)$$

The recipient's prior knowledge is generally the result of the life experience of the individual, which, in turn, makes that not every individual will receive the intended information even from simple data.

The equation puts the focus on some important points in our intended visualization system: the factors going into the system and the one coming out. Langefors stresses the difference between data and information; information being what the user gets out of data. This is very similar to Visvalingam's distinction: visualisation being what the user gets from the visualization process. We might even try to rewrite the equation

Visualisation=visualization(data, pre-knowledge, time)

To be able to navigate a ship in a safe manner the level of visualisation will need to be constant, meaning a clear understanding of the ships situation in relation to other vessels and the world. With faster vessels the time factor is diminishing. To keep visualisation the same we either need to raise the skill, pre-knowledge, of the navigator, the quality of the data or the effectiveness of the visualization process.

The pre-knowledge of the navigator is of great importance. In other fields studies have shown big individual differences in what can be remembered from a circuit diagram as a function of knowledge of electronics. [2]

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[*] However, Pettersson [12] used the word infology with another meaning than Langefors. Pettersson wrote: "Infology is the science of verbo-visual presentation of information. On the basis of Man's prerequisites, infology encompasses studies of the way a verbo-visual representation should be designed in order to achieve optimum communications between sender and receiver. Some studies concentrate on the sender, others on the receiver, representation or communications process as such."

In studying visualisation we are interested in determining how what is “seen” in the display depends upon the experience and formal training of the individual viewing it. By contrasting what is seen by persons with varying degrees of knowledge, one can separate the influence of general human perceptual capacities from the influence of special knowledge. [2]

But we must also remember the effect of attention narrowing (tunnelling) that affects human beings in situations of stress. [18] Our aim should therefore not rely on increased pre-knowledge, but instead try to allow for less pre-knowledge by being as independent of prior training and as intuitive as possible.

It then remains for us to focus our attention to better data quality and a more efficient visualization process.

The map as a mediator of information serves several functions. Downs & Stea (1977) introduces a four level model 1) orientation, 2) the choice of route, 3) keeping in the right track and 4) discovery of the objective. The map could according Sivertun [13] be regarded as a special form of representation – different from the spoken language and mathematics by its non sequential structure that allows the user to integrate information from different sources and partly with different ontological background into a meaningful context. Fauconnier [6] introduces the Composition – Completion – and Elaboration chain to explain how a user mixes information from several maps. Ljungberg [11] further develops the questions about map semiotics and communication. These factors addresses parts but not all of the cognitive tasks a OOW have on the bridge. Suggestions how to integrate and visualize multidimensional data in 2D maps is also discussed in Sivertun [13]. To facilitate navigation in dynamic 3d environment is, however a much more complex task!

3.0 THE BIRD’S-EYE VIEW (SURVEY PERSPECTIVE)

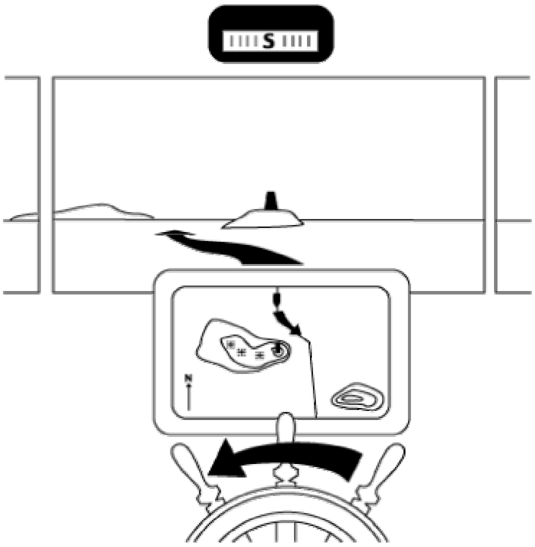
On the bridge of a ship the surrounding world is watched not only by eye and senses, but also with the different kinds of instruments. More important than the out-of- window view is the radar. The radar offers a simple and reliable way to measure distances to objects and landmarks in the vicinity of the ship, both in fog and dark as well as in daylight. The chart, in paper or electronic format, is the other important mean of navigation. A navigational chart is a complicated information system allowing for computations and conversions between compass bearings and geographic locations, time and distance. “A navigation chart represents the accumulation of more observations that any one person could make in a lifetime. It is an artefact that embodies generations of experience and measurements.” [8]

Both these systems are built on the principle that the world is looked upon from above. We call it a “bird’s-eye” perspective but it is actually an artificial, orthogonal, perspective presuming the observer to be directly above all places at the same time. This so called bird’s-eye perspective, or *survey* perspective, as Tversky calls it, is good at showing us an overview, and enabling us to conveniently measure directions and distances. But it has difficulties with representing areas with high resolution without losing the overview. The traditional chart also tells us little of the topography of the coast. For that kind of information we normally have to go to drawn or photographed coastal profiles in the pilot handbooks.

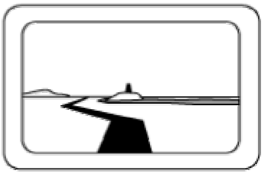
It takes a great deal of experience to map the chart picture to the real world outside the bridge window. The progress of the own ship’s symbol on the radar and chart screen is usually represented in one of two different ways: Eider the own ship is still at the centre, or elsewhere, with the bow facing straight up and the world moving and turning around her (a so called “Head-up” display), or the world is still, normally with north facing up, and the symbol of the ship moving over the screen, with the world jumping into position when the symbol approaches the end of the screen (North-up and True Motion display).

Expert navigators often prefer the North-up display, and also using traditional paper charts oriented north-up. This gives them a common frame of reference when communicating with other ships or other persons.

[17] The problem with the North-up display is that when the vessel is heading south, a starboard turn results in a movement of the own ships symbol on the screen in the opposite direction. [See fig. 2.] This can be confusing for many inexperienced persons and one of the authors of this paper can reveal that this can be the case even for experienced officers, having witnessed a 20.000 ton tanker turning around night time in the German Elbe River in dense traffic. Research confirms that fewer mistakes are made when using the Head-up map. [5]



Charts and radar displays are normaly used in a North-up mode. On this south bound vessel, a desired action to go on the east side of the beacon (on the right side on the chart display) leads to a turn on the weel in the other direction (port/left). This can be confusing.



A conning display with a 3D-chart showing a reduced amout of information from a bridge-eye perspective would simplifie the decision making in this situation.

Figure 2: World Representations in “Bird’s-Eye” and Bridge-Eye Perspective.

With the Head-up display the relative directions are easy to judge, but instead the moving and turning representation of the world, introduces a problem of orientation. The well-known shoreline of an island will not as easily be recognized when turned upside down.

The tradition of visualizing the world through representations from a bird’s eye view goes back to the dawn of mapmaking. This said it must be recognized that understanding and using a map is not a natural skill for mankind but one that has to be trained.

4.0 THE BRIDGE (ROUTE) PERSPECTIVE

There is however another tradition of way finding at sea dating back to the old Greeks: That of the sailing direction (Greek *periplus*). Descriptive sailing directions were the principal navigation aids up until the end of the seventeenth century. [3] A sailing direction is a written document, consisting of consecutive notes of courses to sail, notes of passage time and even drawings of landmarks from the perspective of the sailor. So while the map is an orthogonal, static representation of the world from a fixed position above, a sailing description is a temporal and dynamic representation from the point of view of the ship. [8]

Dana Tolins, [14] suggest this, the “snakes eyes perspective”, in analysing geographical space. To be able to support the navigator with analytical tools, the navigation system should be able to handle data with both global and local perspectives.

Real-time 3D simulation techniques offer a mean to visualize the surroundings of a ship from the point of view of the ship. Based on a geographical database containing the topography both below and over the surface, and an “eye” positioned by GPS-data, a 3D-display from a bridge perspective is suggested as a complement to the traditional electronic chart.

Into such a system crucial navigation data can be fused, such as:

- the current tidal level
- the ships track, represented by a “road” on the surface
- dynamic depth information reduced to navigational (*go*) or not navigational (*no go*) areas for my own ship
- models representing near by vessels positioned by transponder data
- tracks representing planned routs of near by vessels, by transponder data
- geometric representations of unidentified radar echoes.

The geographical dataset mimics the real world and makes it possible to conduct daylight voyaging in dark and fog. The representation of surrounding traffic, own track, Yes and No Go Areas, simplifies navigation in high speeds and reduced visibility. Less professional navigation could be simplified to “car-driving” along a track-”road”. In a cluttered archipelago and in crowded traffic situations the suggestion is, that the bridge-eye perspective offers a second chance to make a right, intuitive, decision when trained skills fail in a crisis situation. This still remains to be scientifically proven.

5.0 THE GEOGRAPHICAL DATA BASE

The system consists of a three-dimensional geographic database containing topographical information as well as attribute data. 3D-geo data bases are well established in the simulations community. Flight and driving simulators use them with different demands for resolution.

The purpose is to provide a terrain model with enough realism to make a direct comparison with the real world possible. Thus in daytime provide a frame for navigational information and in night time and in restricted visibility provide a direct mean of visual navigation.

This is not the place to go into great detail about the geo database, but we will just mention some problems that we are working with:

Above water: We have found traditional digital elevation data with a grid of 25 – 50 meter is insufficient for modelling purposes in the costal zone or in the archipelago where many dangerous rocks risk disappearing. A denser grid of maybe 2 m or less is preferable.

Above water the topographical information is collected by air photos, which are draped over the terrain model in order to provide texture.

Traditional photo grammatical methods returning the bare earth elevation is sufficient in the naked outer archipelagos of Sweden, but on the inner archipelago, the forested islands are not recognizable, lacking the trees necessary for a correct silhouette.

We are currently looking on elevation data from laser radar. This technique returns an elevation model with a grid spacing of less than a meter and accuracy better then 15 centimetres. As the light ray traverses the foliage of a tree it returns several reflections. Collecting the first, tree height, return will hopefully make it possible to correctly model the silhouette of forested islands.

Under water: In Sweden the National Hydrographical Office administers underwater data. The depth databases are classified but chart data is available. Chart data are generalized data from the depth database. The data sets are of different quality. In the commercial tracks the reliability is very high, but along the long Swedish coast there are large areas with old soundings of varying quality. For the pleasure crafts it is a particular problem that very little effort is put into soundings on shallow waters (depths less than 3 meters). Helicopter carried laser bathymetry, which with two colour lasers that can measure the shallow areas of the archipelago will maybe be a solution but is still somewhat in the future.

6.0 NO GO AREA VISUALIZATION

How do we display depth information in a 3D-modell? One of the problems with traditional charts, particularly as the time allowed to read them is shortening as the speed is increasing, is the cognitive effort to calculate if there is enough water for the vessel. This calculation involves the own ship's draught, the tidal level and the depth on different places during the track as well as a consciousness of the chart datum.

The International Hydrographic Organization's (IHO) standard for electronic charts (ECDIS) allows for provisions making it possible to enhance a certain depth curve (of the one present in the chart, i.e. 3, 6, 10, 15 meters etc.) to make it possible to more rapidly recognise no go areas.

The obvious solution in a 3D-modell would be to once and for all solve the problem with the opacity of the sea, which hides the dangerous rocks from human sight.

Tests showed that this only created another unfamiliar environment. "Flying" over the underwater terrain made it difficult to judge the vertical position in the de facto two-dimensional environment of the display. Keeping the water surface in the 3D-modell not only constrained the vertical position of the camera, when in ship-position, but was also fundamental for the recognition and comparison of the model with the real world.

Instead we used the underwater mesh to generate No Go Area warning polygons, which are placed on the surface of the water and displaying waters to shallow for the vessel thus relieving the OOW from the clutter of depth curves and sounding numbers on a traditional chart, while still retaining the familiar view of the archipelago and the water surface. (See fig. 1.)

These No Go Areas are dynamically updated based on the current tidal level, the current draught of the ship, the amplitude of the waves and the elevation of the terrain under the surface.

The warning areas are derived from the intersection of a cutting plane with the underwater terrain. The cutting plane is placed at distance d from the 0-plane (chart datum), so that

$$d = TL - DR - 0.5WA - SM,$$

where TL is the current tidal level, either computed locally based on tidal tables, or, better, received on-line from weather service corrected with deviations due to air pressure, wind and local geographic conditions. *DR* is the current draught of the ship, data brought in from sensors on board in real time and thus taking into account not only the cargo weight but also the changing status of fuel and changes in draught due to the water density. *WA* is the wave amplitude, or actually the heave amplitude, a mean value collected from a sensor onboard. *SM* is a security margin that can be individually set and can depend on different factors as for example the quality of the soundings in the area. (See fig. 3.)

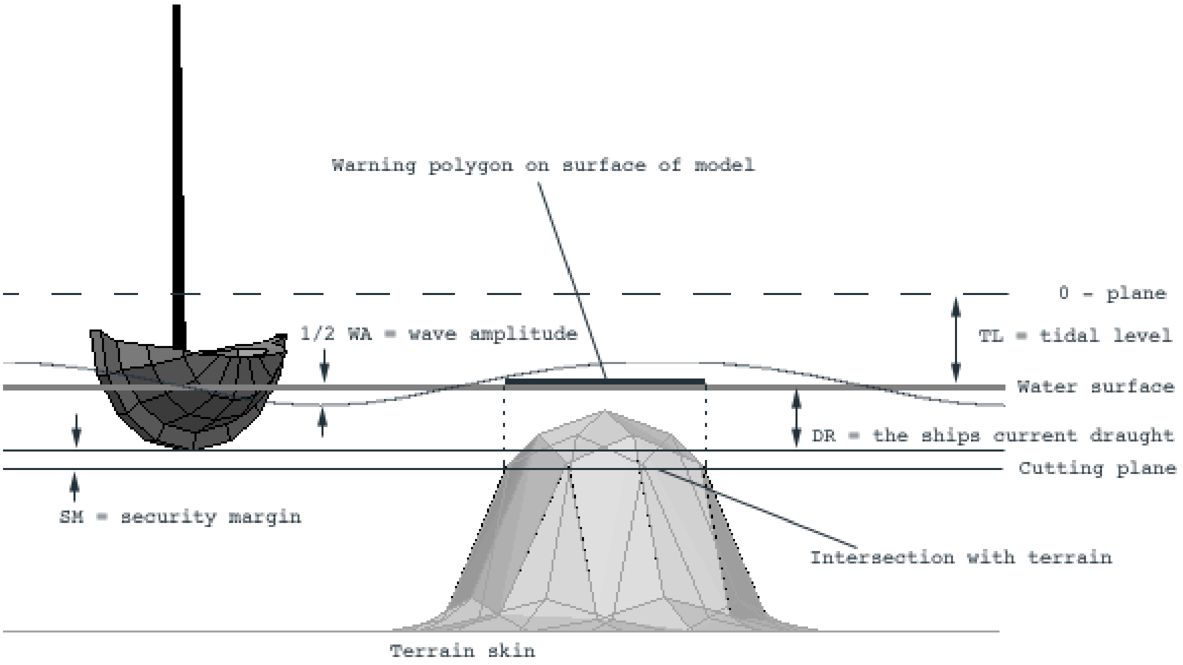


Figure 3: A Schematic Model Showing the Construction of the No Go Area Warning Polygons.

7.0 CONCLUSION AND FUTURE RESEARCH

The main focus of this research project is information design: how to display crucial navigational information to the OOW in an intuitive and reliable way. There is a lot of testing ahead to verify our suggestions.

Further items that remain to be dealt with, is the representation of radar echoes. Briefly put, the radar echo is used to check the positioning of the system and an echo not accounted for in the database is displayed as an unidentified object, represented by some geometric mean.

Vessels equipped with the Automatic Identification System (AIS) transponders send information to surrounding vessels containing the ships name, length, width, destination, cargo, course, speed and position, etc. This information can be used to tag radar echoes, or to place a tagged symbol in the electronic chart. In the proposed system a 3D-model of ships equipped with AIS-transponders in the vicinity can be inserted at the correct position. An amendment to the IHO standard of AIS, compelling ships to send a number of waypoints ahead on their track along with the transponder information, could make it possible to visualize an approaching ships intended track (and not only an extrapolation of the present course and speed, as is a normal function in electronic charts), as well as launch collision warnings in appropriate cases.

Bridge-eye perspective of 3D-terrain has been used in maritime academy simulators for years. The novelty of the suggested system is in the use of the simulation environment to present navigational information onboard the ship.

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SYMPOSIA DISCUSSION – PAPER NO: 4

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Question:
As the high-speed ferry becomes more like a cockpit, can we apply what has been learned in cockpits to nautical navigation visualisation systems?

Author Response:
Traditionally the bridge of a ship is pretty easy going. There is a need to change the culture and perception of the captains and the training of the "pilots", so that much of what has been learned in the cockpits can be applied to high-speed ferry bridges.

Experience from the NATO Exercise STRONG RESOLVE 2002

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MARITIME COMPONENT

by Richard Olsen

For the NATO exercise STRONG RESOLVE 2002, FFI established a Rapid Environmental Assessment Support Centre (REA-SC) in collaboration with the Norwegian Meteorological Institute (met.no), primarily to provide detailed ocean analyses and forecasts to the meteorology/oceanography cell at NATO's Joint Headquarters North in Stavanger, Norway. Forecast and analysis products were based on outputs from ocean circulation models, ocean spectral wave models and from satellite images, and were primarily aimed at supporting the anti-submarine warfare component of the exercise. Products included profiles and sections of sound speed, as well as detailed maps of ocean circulation features indicating the presence of fronts and eddies that can be expected to influence acoustic propagation in the ocean. Some of the key issues facing the oceanographer/analyst are:

- Models provide a wealth of parameters describing the state of the sea and atmosphere in four dimensions (space and time), although not usually at a resolution required for littoral operations.
- At high latitudes and in winter conditions, cloud cover and light conditions – as a general rule – are not amenable to surface observation with optical or IR instruments, so we have emphasized the use of imaging radar. Imaging radar provides very detailed views of the ocean surface, but oceanographic structures are visualized through highly non-linear mechanisms, which sometimes poses difficult challenges for the analyst, and other supporting data becomes very useful.
- Analyses often need to be prepared within short time frames in preparation for handover briefs, as these are never timed to fit with synoptic schedule that the meteorological community works to or to satellite overpass times.
- Making sense of large, multi-parameter, data sets for battlefield environmental assessment therefore becomes a time critical problem, and effective means of analysis, visualization and production are a necessity. The complexity of oceanographic and meteorological processes generally require a great deal of operator analysis to arrive at a product that can be utilized by the warfighter.

Some specialized tools are under development that aim to support rapid METOC analyses for the Royal Norwegian Navy (RNoN). Early versions were used to support operations at the REA-SC during the exercise. They include software for quick analyses of SAR images of ocean features, and combining these with subsets of 4D oceanographic fields for analysis and display in two dimensions. Ocean feature maps are easily drawn and overlaid satellite images and model fields. Outputs include profiles and sections of ocean parameters that can be ingested directly into tools such as the Norwegian sonar performance prediction tool LYBIN, and the Allied Environmental Support System (AESS). The DIANA (Digital ANAlysis) tool developed at met.no, is designed to easily overlay different spatial datasets (primarily

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

model fields and weather satellite imagery) that come at different resolutions and in different map projections, and to easily toggle on/off different layers of meteorological and oceanographic information. An object-oriented representation of major features on a weather or ocean feature map supports easy subjective analyses of the environmental conditions, allowing the analyst to modify e.g. locations and shapes of major circulation features. Throughout the system, priority has been given to ease of operation and customization to minimize the required number of menu selections and mouse clicks, as well as rapid screen response to, among other things, screen panning and zooming.

The presentation shows some examples of screen shots and output products provided during the exercise.

THE LAND COMPONENT

by Pål Bjerke

At FFI there have been projects on satellite imagery for nearly 15 years. The aim of the projects has been to investigate the kind of information it is possible to extract from the images, and how it can be used for military purposes. Through the years, the commercial satellite images have increased their resolution, both because of improved technology, and also through the authorities willingness to reduce security restrictions. The increased resolution has opened up for new uses of the images. For areas where access on both land and airspace are restricted, satellite images are about the only way to get a view of the area. For "friendly" areas, however, aerial photos will be preferred because of resolution and price.

FFI was invited to participate during the NATO exercise, "Strong Resolve 2002", held in central Norway in March this year. Aerial photos were acquired and prepared for the exercise, while satellite images were ordered to be taken during the exercise. The aerial photos had different resolutions, all better than what are available from commercial satellite images today.

The aerial photos were all geometrically corrected by FFI. This is necessary if they are to be used for direct measurements, or if they are to be "fused" with other data. The quality of the correction is related to the precision of the reference and the skill of the operator.

Along with the aerial photos, an elevation model for the area of interest was available. Using software which could handle 3D, the aerial photos were overlaid the elevation model. This gave a 3D view of the terrain. To go further, some of the buildings in the area were modelled in 3D, and some features were coloured for clarity. Military planners concluded those 3D-views gave a better impression of the area, not available from the 2D-images or the maps. Measurements in 3D, like line-of-sight and cover-calculations were also appreciated.

After the exercise, 2 satellite images were received. One was taken from IKONOS with 1 meter resolution and the other from QUICKBIRD with 0.7 meter resolution. Although there had been snow and cloudy weather in the region during the exercise, both images were almost free of clouds and other weather-related effects.

The positions of the different military units at the approximate time the satellite images were taken, came from JHQ North at Jåtta in Stavanger. Looking at the images, a lot of tracks from belt-driven vehicles like tanks, were clearly seen going from the roads out in the terrain and back. Most of the tracks were old, but for some of the new tracks, it was possible to see the vehicle at the end of the track. The command posts were more difficult to spot. The tents could be mistaken for huts. With a little help from officers who had operated in the area, most military units were detected in the satellite images.

As a reference for the satellite images, we used the aerial photos and photos taken from a car every 20 meters along the main roads. The aerial photos were rather new, and were used to see what was supposed to be on the ground, and what could be objects from the exercise. The road photos gave an impression of how things looked in a horizontal view.

The low sun angle combined with the snow, made even small objects detectable because of the contrast of the shadow against the snow. When objects were in groups, the shadows made the individual objects difficult to separate from each other. The increased resolution in satellite images from 1 meter to 0.7 meter was visible but did not add significant information.

The most effective way to handle images is to convert them into an elctronic format, for loading on a computer. With the proper software, the manipulation and measurements of the images can be performed in an easy and effective way, and even include 3D-processing not available in any other way. The necessary hardware and software have been available on the market for some years now, but even so it can be very difficult to introduce such methods into the military services. There can be several reasons for that:

- Price
- Complexity
- Reluctance towards new ideas
- Not effective

It is commonly agreed that headquarters and command posts should be connected with computer terminals, but is it effective for soldiers in the field to use computers with keyboards and menus?

A tank commander showed me his “CCI-system” after the exercise SR2002. It turned out to be 4 sheets of 1:50.000 maps nicely taped together, and folded over to fit into a pocket in his uniform. Using an ink pen, all his movements through the exercise were drawn on the map.

Do You Have to See Everything – All the Time? Or is it at All Possible?

Handling Complex Graphics Using Multiple Levels of Detail Examples from Geographical Applications

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ABSTRACT

This presentation motivates the use of View Dependent Level-of-detail (LOD) in complex graphical displays, both for reducing computer workload and improving visual quality. In addition, some challenges are discussed.

When generating perspective views of geographical data the resulting image can be seen as a map with a very flexible "scale". Areas near the viewer require a high data density, while areas in the background can be shown with very simplified graphics. Using data with only one single detail level gives the view some "myopia" and restricts the possibilities for giving overview presentations. LOD methods on the other hand support several "scales" in the same data model.

LOD MODELS

In general a LOD model is based on storing the model as a coarse base model and a set of refinement operations. The refinement operations transform the model from a coarser to a more detailed state. Each refinement may be dependent on the model being in a given state, that some of the other refinements are applied before. This introduces dependencies between the refinement operations.

The base model with the refinement operations gives a set of possible refined models. If each refinement operation is dependent on only one direct precedent (and all ancestors, by transitive closure) the set of refined models are organized in a strict hierarchy, a tree. If, on the other hand, the refinement operations can be directly dependent on more than one previous refinement the set is organized into a directed acyclic graph.

The refinement operations are reversible, so that a given valid refined model can be simplified to a less detailed model by applying the reverse refinement operations. The complete LOD model (base model and refinement operations) is usually constructed in a "bottom-up" fashion starting with a detailed model, and finding a refinement operation that generates the detailed model from a less detailed model. The less detailed model is again used in a new iteration finding a refinement operation and an even less detailed model.

Associated with the model is a quality measure quantifying the benefit of applying a refinement operation. During construction of the LOD model this is computed and stored together with the refinement operation.

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

The quality measure is also used to guide the construction process, for finding the reverse refinement operations that gives least reduction in quality. In a view-dependent LOD system the quality measures are transformed into the screen space, and are compared with the resolution of the viewing system for evaluating the adjoining refinement operation.

LOD models have a higher level of complexity than traditional single level of detail models, but they also have some built-in advantages:

- Hierarchical search system – the hierarchy of refinements can be used for searching.
- Clustering of data – data about physically near objects have a large probability of being in the same branch of the refinement hierarchy.
- Compression – in many cases the refinement operations only need to store information about local changes, which might compress better than full resolution data.

GEOGRAPHICAL DATA

The challenges are illustrated with examples for some important geographical data types.

Preparing data for LOD viewing has some resemblance to traditional cartographic generalization, but there are several problems that have to be addressed:

- Speed – the models must support interactive tours.
- Range of scales – from street to global view.
- Continuity of model – no visible break between detail levels.
- Data volume – data may be transferred over a network.
- Incremental loading – avoid retransmitting data.
- Heterogeneity – different data types are handled with very different methods. Some of the data integration may be postponed until the final visualization process.

Terrain Elevation Model

There has been developed several methods for LOD surface models. Surface models have a strong continuity, and the refinement operators have a dense network of dependencies to neighboring areas. Several of the LOD surface models can be used for large terrain models.

Terrain Texture Coverages

In its simplest form this can be implemented by an image quad tree. Each detail layer is handled by a new set of images, with doubled resolution for each successive layer. In a more advanced version the image pyramid can be implemented by using a wavelet hierarchy that would only store local refinement operations. Several methods exist, both open standards and proprietary solutions, like JPEG2000, MrSID and ECW.

Discrete Objects

LOD models for discrete objects are well known in current graphic libraries. The traditional LOD approach has been to store separate models for each detail level. To conserve storage space and network capacity it would have been advantageous to use compact update operations instead. Currently there is a large research effort on automated methods for establishing simplification and aggregation hierarchies for buildings and other man-made objects.

Transport Networks

There is currently no widely adapted method for handling transport networks in LOD structures. Using classification hierarchies (Main road – regional road – local road) gives some simple way of structuring roads, but it gives no guarantee of maintaining network continuity or avoidance of cartographic conflicts. There are still many challenges for future research.

FINALLY…

To answer the initial question: No, we can't see everything, all the time. Neither do we want to! However, we can use LOD models for developing a system where we can move fast between a global and a local view. Several suitable methods are known and described in the literature, but for some very common data types more research is needed.

SESSION 3 – PLENARY DISCUSSION

Questions to Col. Johansen

- Col. Johansen was asked to be in a position to answer questions in the context of his experience in conducting command and control tasks and decision processes in recent NATO operations.

- In a decision-making process what are the issues and challenges – availability of data, interpretation of data, locating data, or others?

- Being well prepared is essential. There is usually a small group making difficult, time pressed decisions, but there are several more people and systems that aid in that decision making process by being prepared. If things are running as planned, the constant stream of incoming information may appear as noise to the commander, because he already has a clear picture of what is happening. It is when an unexpected event happens that display and visualisation tools become important. For example, a commander may need a detailed local picture in a very timely manner.

- The talk on high-speed ferries brought up what was needed and required on the bridge. The captains expressed a desire for as few instruments as possible. Does this suggest that in a high-pressure environment it would be more efficient if there were fewer instruments or a single system that can provide all the information?

- The command center needs the displays more than the commander does; the commander only occasionally wants it. In the case of the high-speed ferries, the shift from the traditional bridge to a more cockpit-like environment happened quickly without much re-training of the captains. The captains may need education and preparation to use the displays.

- Comments about selection vs. training of pilots.

- It is important to practice with any new tool. If you give a general a new decision making tool, it is a change in their process, and needs to be practiced. Keep a tool simple. Know your audience and their ability to learn new skills.

- What are the effects of stress?

- In a crisis situation, the visual aids need to be ahead. The people involved should be briefed on the missions ahead of time so that the visual aids can be prepared for a ranged of possibilities before they happen. Prepare what if scenarios before the mission has started. This allows for quick access to crisis-relevant information in the case of an unexpected event. The best way to deal with stress is to be prepared. The tools should be simple and pre-programmable.

- Flexibility is important, as people understand and perceive things differently, it is important to allow for preferences.

- Simple does not mean a low-information visual field or a lack of content. It means not overloading the user with information.

- It is important to be able to move in and out of the level of detail. The commander needs to be able to step back to see the big picture or drill down to the details when required.

- The range of data included in the display may come from different sources that may have different levels of uncertainty. When you are looking at these displays, are you factoring uncertainty in your mind or are you relying on that system and your instincts to be pretty close to the truth?

- It depends on whether the information is from air, water, or land as there is an unbalance in the situational awareness picture. A commander can be confident in where the planes are, pretty sure where the ships are, but not sure of the land picture. The most uncertainty surrounds the land picture due to the fog of war, lack of reliable sensors, a large number of people (often young and inexperienced). Land is the picture that is the most uncertain, and needs the most focus.

- There is a difference in culture between air, navy and army, therefore they may want and need different types of things.

- There is need for support for the entire decision cycle process, from routine daily activities through to crisis. How do we improve the decision making cycle?

- The corner stones of the decision cycle are sensor, shooter, decision maker. Awareness of what kind of sensors that NATO operations are relying on today and in the future to give us a picture is needed. Understanding what these sensors are, what kind of signals they produce, the confidence in the signals, and how to interpret the information. Once it is clear what information is available, then try to decide how to present this information and design displays.

- Are there issues in NATO concerning languages and rules of engagement that affect the command and the display requirements?

- Access to info, different languages and cultures are all challenges in multi-country forces. It is important to keep displays simple and minimize the use of a single language. Try to use symbols or other methods of communication other than language. Why use cryptic symbols when a real picture of a plane, for example, could be used.

- There may be some resistance to non-standard symbols, particularly from middle level people.

- Another problem with using a picture of the plane as an icon means that the symbol has to be pretty big to be able to differentiate types of planes.

- It could be possible to click on an icon to get more information.

- It was mentioned that in the fog of war at a time of crisis you stop talking, and start thinking, trying to understand the new situation. Is that the time visualisation aids would be most useful?

- If something goes not according to plan, there are a handful of people in the command center whose jobs are now very important. These people can better grasp the situation through prepared displays.

- Would it be useful if the few people who need to tell you something could display it on a screen for you?

- The face-to-face is important, but perhaps it can be done around a display where the expert can work with the commander. Visualisation seems to facilitate discussion. When crisis comes, it’s important that the rank of the people is not important. You need the people to be equal so a lower ranking member of the team can talk freely with the commander. The table seems to facilitate this.

- Would you like to use voice recognition technologies?

- No, the technology does not seem to be there yet to have confidence in speech commands to an application. Would rather talk to a person who deals with the machine.

- It sounds as if the common commander-shooter picture is wanted so that the shooter can see the context of an order so as to properly interpret the commander’s intent.

- It is important that the shooter has a good picture of the commander's intent. If the commander has to go straight to the shooter, they should have the same situational awareness. If the commander can see the shooters target, he knows for sure. But it the exchange of information has to be fast, as targets move and so forth.

- Would a head-mounted display be desirable, with a drop down display in front of the eye of the soldier?

- A head mounted display may be a good option for the soldier, but the command room is a social environment. Human beings make the top-level decisions; we do not want to overwhelm them with technology.

- Users could assign value to information. Could a designer sit down with a commander and go through use cases and identify which information is more important in which situations?

- It would be important to speak to the right person for each job. You need to be able talk directly to the people that you are developing for. You need to talk to the different areas – army, navy, and air force – to gain the information on preferences of the different cultures.

- There is an issue of ships not wanting share their location, would this be even more dangerous for the soldiers on land?

- The danger of transmitting the exact position of an individual is that that information could be intercepted. This would be more critical for the Special Forces than for battalions.

- If you were able to chance something in your f16 simulator display, what would it be?

- Why not have satellite pictures and a realistic picture to allow them to actually see what it would be like to fly.

- A picture can be formed of what Red thinks about Blue. Would that be a useful picture if it could become available?

- The danger is that you do not really know what they are thinking. You do not want to confuse the real situation with the assessment. Notional and real should not be on the same representation.

- How do you display the less than perfect data? With confidence threshold that is too high much useful but speculative information is never passed on. What do you know – we know a lot; what do you know for certain – nothing.

- Let the Intel room have their own display for that purpose. Military officers are not really ready or eager to take risk. When risk is necessary, information that is less certain may be useful.

- What was the thinking process, the engineering approach to the table?

- After participation in conflicts there was a feeling that something was missing, which led to the opportunity to create and develop the battle lab. The idea of the table came from the workflow mode, the desire to have a place to gather and discuss with specialists while seeing a central picture.

- There is an argument as to whether the display space should be Euclidean or hyperbolic. Some just want to see the world, as it would be if they were looking at it.

Visualizing Non-Physical, Logical Constructs for Command Decision Support

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MOTIVATION

The motivation for this Provocation Topic presentation is directly related to existing critical issues and challenges in both the Data Fusion and Visualization communities. Both of these communities are wrestling with the meanings (ontologies) of, and means for visualization of what we are calling "logical constructs", or constructs that have relevant semantic meaning in an application context but do not correspond to an observable, measurable reality in the real world. Such constructs correspond to what the Data Fusion community calls "Level 2" and "Level 3" processing, processes that produce results which are called "situations", "threats", "intentions", "operational readiness" and the like. Limited research in the Data Fusion community at these Levels has resulted in a generally poor and unstructured understanding of what these constructs really are and how they might be ontologically structured and related to one another. Even if such definitions and categorizations were known, there is the subsequent question of how to communicate these mental constructs to a human such that they can be "seen in the mind", as described in the Call for Participation.

The reason these issues are important is that these "logical constructs" are the informational states around which higher-level command decision-making occurs; e.g., force-level maneuver decisions will depend on fused estimates of a hostile "threat" state, whereas lower-echelon decisions such as to shoot at a specific target depend instead on fused estimates of a physical target's location in space, corresponding to a physical reality. Without formalized definitions of the set of logical constructs, Data Fusion and Visualization systems will be developed in inconsistent ways and will have irregular payoff and benefit to the upper command levels of the operational military. We propose that the Workshop address the various and complex issues dealing with the topic of "logical constructs", and the means by which the NATO community can develop methodologies and architectures for visualizing these "non-physical, non-geospatial/temporal" constructs.

OBJECTIVES

In recent years research in Data Fusion and Visualization science has focused on understanding physical environments and data types. Advanced visualization techniques including VR and other related technologies have succeeded in providing meaningful outputs. However many abstract concepts are beyond traditional modes of display and hence require new paradigms in visualization.

Our objective is to present an organized, provocative introductory presentation regarding the definitions and ontological structure of such non-physical concepts as well as possible means for visualizing/ communicating their states as a framework to encourage lively discussions among military staff and

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research scientists on approaches for both computing the estimated value of and for efficiently communicating/visualizing the results of fusion-based estimates of these conceptual states. Through such discussion, it is hoped that a NATO consensus can be established on the issues surrounding this important topic, and also that agreement can be established on additional research needed to both better understand this topical area and to develop effective visualization/communication methods.

TECHNICAL APPROACH

We are proposing to come to the Workshop with a presentation that elaborates on these issues. The first point is to define further what is meant by "non-physical entities"; in this case we plan to elaborate on the example of "Operational Readiness", and to discuss what is the modern interpretation of this term and the associated concepts. This will lead into a sampling of a draft ontological construct for this term, showing that, as for many such constructs, it is composed of both entities that do have a physical reality but also notional terms that result from abstract and fuzzy constructs. Given this, the challenge of visualization is elaborated on, to show that there are at least two major challenges to visualization: the dimensionality of these constructs, and the non-geospatial, non-temporal elements of them. It is also argued that the need for an ontological-level, formally-constructed characterization of these constructs is central to a consistent systems-level approach to the design of the overall information fusion process. Further, it is shown by example that such ontologically-based design methodologies are not precedent-setting for defense-type applications. Another factor discussed is the distinction between the user's mental model and the visualization-construct, i.e. the "display". Mental models are usually defined as "deep" constructs, reflecting the comprehensive understanding that a human has about a given process or object; the computed and visualized product can be thought of as an instance of that model, but as a result the delivered visualization should draw on the mental model that a user has. But even if that visualization is consistent in this way, there is still the question of how the user visualizes his mental model in his mind – one challenge or hypothesis to explore is whether the "optimal" visualization is a construct that mirrors the user's mental "image" of his model, or whether these two entities are separate and reside in their own separate contexts (i.e. computer-screen and human mind). A nagging question is also: what is "the" authoritative taxonomical structure from which we should build the relevant ontology? By this is meant that, if the US defense community is typical, there are many lists of vocabulary and terminologies that abound in the defense community – if it is agreed that in fact an ontological framework for the terms of interests is needed, which list is the starting point? In this regard, some examples of the US community's "Essential Elements of Information" or "EEI's" are described along with some limited ontological-structuring of these terms that has been carried out. Finally, we give two major examples of visualization techniques that have been used in defense-type applications as exemplars of some modern-day display constructs: these are the "Event Wall" and the "Starlight" systems. These systems have been designed with the idea of showing information of high-dimension and information having complex interrelationships.

Haptic Rendering Techniques for Non-Physical, Command Decision Support

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MOTIVATION

The purpose of this paper is to explore non-traditional visualization techniques to assess threat and other variables in command center settings. Not all entities that a commander interacts in real life can be converted to visual medium, which is but just one of the five senses that we have. As an example, sense of threat during a critical situation during a mission cannot be easily communicated with color. Many special skills such as a surgeon using a sharp scalpel or a Pilot negotiating a sharp curve cannot be easily represented in videos or even real time Virtual Environments. We call such systems – non-physical visualization. While elsewhere in this conference we speak about Ontological representation of such events, here some techniques currently underdevelopment to 'visualize' such parameters are presented – including tactile and haptic rendering techniques.

BACKGROUND

Usually visualizing battlefield implies maps, computer screens filled with information and perhaps 3-D displays that represent a wide range of data ranging from intel, logistics and threat information. Decision of a commander is often based on understanding a threat level and calculating a probability of success given all the various sets of information. Some problems related to decision making process are:

- Too much data, too little knowledge
- Complex reasoning that cannot be represented graphically
- Problems in drawing attention to some elements due to information overload
- Trust and confidence in the visual data presented

How adding larger, more complex visualization system can solve much of this is a matter of debate. Is there a more sophisticated way to address some of the problems? In the recent years many interesting new concepts have been developed in the area Physically based modeling which could be used to tackle some of the problems. One such idea is to use haptics rendering and modeling to represent information in a new dimension.

Haptics, from the Greek word *Haptikos* is essentially the sense of touch. More broadly in our context it can be referred to as a resistive or feedback force. With the advent of haptics and the ability to add the sense of touch to a virtual environment, it is now possible to develop completely new set of interfaces for decision support. Information, such as threat, risk, confidence levels can be converted to variety of

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physical sensations that have no equivalent representation in the graphics or visual environments. There are many forms of such force rendering such as; vibration, resistance, viscosity etc.

NEW VISUALIZATION INTERFACE

A new command support interface is proposed here that combine sense of touch with a 3-D interface as shown in the figure 1. A 3-D interface is created with one virtual wall representing a map or terrain of the battlespace or the field where military is involved. On a perpendicular virtual wall a haptic rendering of the space is created. When a certain region is clicked on the map, a blown up representation is presented in haptic wall shown as color grids in the figure. In the haptic wall information such as threat is represented mathematically and converted into vibration or viscosity.

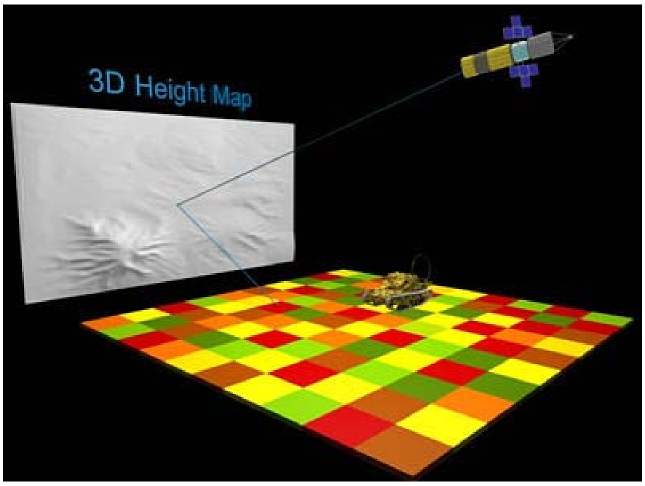

Figure 1: Interface for Haptics in a Control Room.

MODES OF INTERACTION

One example of such a rendering is the probability of the existence of a mine or a cave, which is not obvious from the map or intelligence data. During a decision support activity, the commander uses a Phantom™ type interaction device (figure 2) instead of a mouse to navigate around the battlefield.

Figure 2: Phantom™ – A Commercially Available Haptics Device from Sensable Technologies.

The haptic rendering automatically controls and keeps track of the commander's actions in the given space and dynamically reduces or increases viscosity. Thus when visual map calls for a move in certain direction, existence of high risk will increase the resistance of the navigation task thus reminding the commander about the danger involved in the present decision. By using this system, visual dimension can be freed up to represent other important information.

Results of early research have shown that haptically represented probability of threat while moving towards the goal is a viable control strategy. In a preliminary human subject test it was noticed that users trust and adapt to haptics as to visual feedback system easily.

DISCUSSION

New non-traditional visual interface obviously opens up a number of open-ended questions. We are posing a few here for discussion:

- Will commanders trust haptics or a combination of visual and haptics system?
- What information is suitable for non-traditional visuals?
- What is the range of such devices?
- What is the optimum combination of 3-D VR technology and Haptics?

SYMPOSIA DISCUSSION – PAPER NO: 8

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Comment:
There is the issue of having to know what questions to ask to drill down to more info. There is the trade off between providing enough information to the user without clutter.

Comment:
Response from users is positive, but there is a need to train people to use the techniques.

Support Concept for the Creation and Use of Doctrines – How to Present Planning Items in a Combat Direction System

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Marine operators need modern command, control and weapon systems in order to fulfil their tasks in identification, classification and combat. Configuration adjustments at the technical board systems as well as at the control software have to be performed continuously dependent on the actual operational and tactical situation. These system adaptations depend on variations of parameter adjustments and can be optimised using computer supported configuration aids.

Doctrines allow the early time and situation dependent automated configuration of ships in order to function optimally in time critical situations. The aim is the optimised adjustment of corresponding algorithms and systems. This requires an as complete as possible planning.

Doctrines are special decision rules that describe the dependencies of required actions on occurring events. They refer to task sequences that define the timely configuration of weapon systems and the required parameter adjustments when situation data change that relate to the tactical and technical mission environment. Working with doctrines implies characteristically the handling of a variety and multitude of parameters and situation data and the definition and implementation of their dependencies.

Given this variety a doctrine control without potential interaction of the operator is not conceivable. The operator should be informed about the actual parameter adjustments, the system state, the state of the doctrine control and the chances to intervene manually if required. This can only be ensured, if the support system (in form of a doctrine control) has a task- and user-oriented as well as an ergonomically designed human-machine interface.

In creation of doctrines the main problem is the immense number of parameters to be taken into account as well as adjusted. Regarding that difficulty a support concept has been developed with the main focus on a user deserved conception in consideration of economic, navy-specific requirements. Although dealing here with a naval application the concept can easily be conferred to any other domain like other military forces or even civilian applications.

The generic ergonomic support concept describes the support requirements for the different users of the complete planning process. It starts with the creation of basic building blocks (components like situation data, system states, parameter adjustments, actions, etc.), continues with the creation and evaluation of mission specific planning items and ends with the use onboard (or "in the field" considering a different application domain). The tasks in creation and use of doctrines are conceptually comparable for the *basic data manager*, the *mission planer* and the *navy operator* onboard but differ in their objective targets.

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One part of this generic concept has been realised prototypically, i.e. the support of the mission planer in creating and using doctrines. For the creation a doctrine editor with doctrine database has been developed. For the use, i.e. evaluation of the "mission database" by the mission planer, an interactive simulation component has been created and implemented. In order to demonstrate the feasibility a prototype has been developed with the following components (picture 1):

1) the *doctrine database* with the *doctrine editor* as user interface
2) the *situation database* for inputting, managing and processing scenario, own ship and mission data with a visualisation component for the situation data
3) a central *simulation component* with inference engine, database and time management
4) an *output component* for presenting system parameters and "operator notifications"

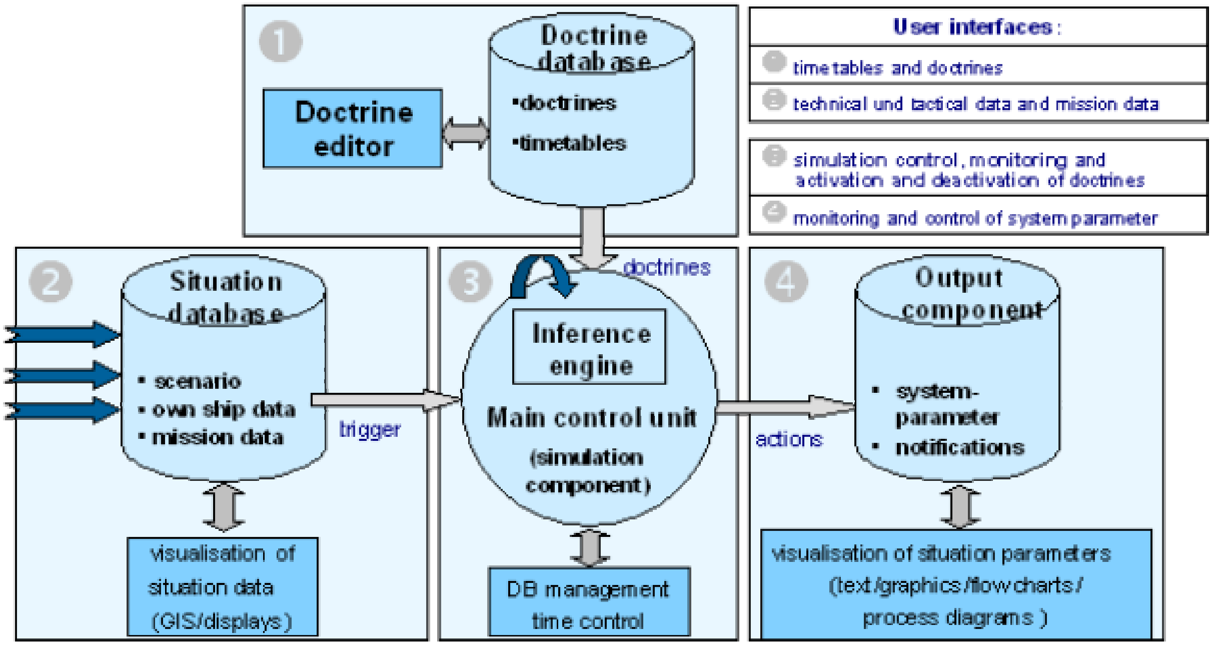

Figure 1: Architecture of the Prototype.

The prototype provides in its functionality the doctrine creation as well as dynamic simulations. This allows the test of the interrelations of doctrine creation and use and the optimisation of the "mission database" by evaluation before it is used as a "Ready4ActionDatabase" onboard. In order to present the feasibility the simulation runs with the "mission database", the system data, a representative scenario and situation data as events.

A scenario describing a two-day mission/exercise has been defined in cooperation with navy personnel. It was used to demonstrate the support of the mission planer in creating a mission database using the ergonomical designed doctrine editor. The layout/structure of the database reflects the actual planning state at any time. The simulation environment represents the mission process, the state of the doctrine control as well as the intervention possibilities.

Future work will deal with the complete planning process. In the area of the mission planning solutions have to be found for the evaluation of the "mission database" in manual or automated form. Prerequisites are the determination of evaluation criteria for the quality of the "mission database" (by the Navy). Typical scenarios and missions have to be identified and formulated for verification of the doctrines.

From the ergonomic point of view the visualisation of the numerous planning items, like “Operational Parameter”, “Situation Data”, “System Data” as well as doctrines, time tables etc., is an important, user friendly aspect that refers to the complete handling with doctrines. A visualisation concept dependent on the requirements for the system users has to be developed.

Problems arise while facing the variety and the magnitude of data involved in the planning and execution of (naval) missions. A user interface for system conditioning has to be developed that allows the operator to visualize the system state in regard to the qualitative effect of parameter values (reading access). Optimised tools should enable a safe and situation related direct control of parameter adjustments (writing access).

The following aspects related to visualisation have to be considered:

- Representation of adjustments of operational parameters; development of “orientation guides” and procedures that consider the diversity of parameter values and their logical groupings.
- Representation procedures for clarifying the coaction of various parameters (e.g. parameters in “function chains”, mission- and user-conditional dependencies).
- Representation of the actual system state and an anticipated system state (projection) after parameter changes.
- Change of single parameter values either manually on the basis of the presented system state or automatically by the use of doctrines. Representation of critical effects in the overall context of parameter settings.
- Representation of conflict cases, e.g. detection of doctrines that are inconsistent with manually modified parameter values or that are inconsistent with automatically crated doctrines.

This presentation will demonstrate how Navy officers/operators may be supported in the creation, handling and use of doctrines in a Combat Direction System. Ergonomically designed user interfaces for a doctrine editor as well as a doctrine database will be shown. A possible interface for the use of doctrines for testing and evaluating a mission database is demonstrated. Presentation issues for the various numerous planning items and system variables as well as their coactions that are important for visualisation by the user in order to fulfil his task/mission will be subject for discussion.

SESSION 4 – PLENARY DISCUSSION

- There seems to be conflicting directions and requirements about visualisation. On one hand we want the displays to be very simple to avoid distraction in crisis, but on the other hand we want sophisticated systems that allow you to explore different alternatives.

- Different systems are required for different applications and users. For example, at the command level, a simple interface to obtain just want is needed when it is needed is desired, while the shooter might have a head mounted display that allows the commander to show the shooter what he wants him to see.

- The commander may require a simple and quick system, but the staff officers preparing for the mission could use a more complex system that takes more time. The extra environmental input, such as audio, may be useful to the staff officers if not to the commander.

- A bottling factory simulation was discussed. In one case they were allowed to hear auditory cues. In this case they noticed failures faster than when they just had visual alarms.

- Different environments require different interfaces. The decision cycle will vary from environment to environment, for example, the strategic and tactical environments have very different requirements. Interfaces will require a certain level of training. The key is to find the right interface for the right audience.

- The PowerPoint charts used in many presentations do not communicate effectively. Slides often contain the total written product after the presentation with many words that may be specific to the research community. What is on the slides often does not coincide with what the speaker is saying, and in this case it might be better to just have the slides or just the speaker. If there are two sources of information, such as slides and a speaker, it is imperative that the messages are the same. We should be applying our navigation techniques to our presentations.

- What kind of information should be selected is very context dependant; therefore you cannot make a good selection of data to present if you do not have a strong knowledge of the user?

- Differences are very important. It is more important to shout that something has changed than it is to show the constant values.

- When Col. Johansen made a comment about making it simple, he hit on the most difficult thing. How do we select the data to show?

- That is the point of the Navigation Engines in the VisTG model.

- Children today, or Generation I, do not seem to have the same processes as we have. Perhaps the haptic research will be more applicable in the future. Design systems for people now, but take into consideration the next generation of users.

- The generation coming up now has had much more exposure to interacting with systems and technology and is a more flexible and adaptable user. Do not underestimate the generational change.

- There are some things with visualisation that are independent of age and culture, for example a bigger box represents a bigger value.

- Does ability to play video games imply a later ability to make good decisions?

- There appear to be different styles of analysis with age.
- You may not be able to give the commander something in those exact 8 seconds of crisis, but you hopefully have helped him develop that experience that allows him to make that decision.
- Keep in mind the sensor – shooter – decision maker cycle. How do you deal with the common operation picture?
- We have all experienced being distracted from a task by looking at the computer screen. The problem with presenting too much info is that it is distracting.
- Visualisation spans many industries and applications. Resolution is important in the solution. A cave environment may not have the appropriate resolution for all applications.
- UAVs allow you to see video right from the battlefield. It is great to see everything, but you can get in an issue where you are just watching what is going on. The decision maker may be distracted by the high resolution.
- When designing tools to be used in social decision-making it seems that there is a need to be able to point and touch, to talk and see each other, and to indicate what you are talking about.
- A commander wants to assess the situation, and then be able to talk to his support staff to provide the background or details. There is a need to display the main information and supporting evidence, and also be able to fulfill potentially unexpected additional information requirements.
- Sometimes we are starting with the technology then trying to see where it can be utilized, instead of understanding the users' task first and then defining what technology will best fit their application.
- There is a standard tension between operational people who do not know what is possible and developers who do not know what is needed.
- The J6 is the person who can be your interface to the commander.
- This workshop is about bringing those groups together.

Click here to view PowerPoint presentation; Press Esc to exit

Ontology Driven Sensor Independence in a Query Supported C_2-System

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ABSTRACT

Information systems requiring sensor data input must generally include means for sensor data fusion as well as powerful mechanisms for user interaction and result visualization. From a user perspective the use of sensor data requires knowledge about the attached sensors and the data they generate. However, most end-user do not possess this kind of knowledge and for this reason techniques for sensor data independence must be developed to ensure that the users easily can apply their queries and interpret the result without too much trouble. In this work, an information system including a query language that can be applied to multiple sensor data is described. The query language allows data fusion when ever necessary. To facilitate query composition the query language has been furnished with a visual user interface that allows the end-users to apply their queries in a simple way. Furthermore, the query language has also been supplied with means for sensor data independence to make it possible for the end-users to apply queries without specific sensor and sensor data domain knowledge. The sensor data independence is made possible by an ontological knowledge base system.

1.0 INTRODUCTION

In current sensor-based information systems detailed knowledge about the sensors is required. Therefore sensor selection has been left to the users who supposedly are sensor experts. However, in real life this is not always the case. A user cannot be an expert on all sensors and sensor data types. Therefore systems with the ability to hide this kind of low-level information from the users need to be developed. Powerful user interfaces also need to be designed to allow the users to formulate queries with ease and request information at a high level of abstraction to accomplish sensor data independence. In the query language designed for multiple sensor data sources described in this work an approach to overcome these problems and to accomplish sensor data independence is proposed through the introduction of some novel concepts; among these are *the sensor dependency tree*, *the query refinement technique, the multi-level view databases*, and *an ontological knowledge base* for determination of the sensor algorithms. The concept of sensor data independence as introduced in this work should be seen from a user perspective where the purpose is to allow the end-users to apply queries concerned with an environment registered by multiple sensors by using well-known notions such as *area of interest*, *time interval of interest* and *requested object type*. Clearly, it is simpler to design user interfaces based on this type of notions instead of more complex types that must deal with the sensor data from specified sensors, which require a higher degree of domain knowledge. In sensor-based information systems [1][2] that include facilities for data fusion no concept similar to sensor data independence has yet been suggested. There are many reasons for this, for instance, users are expected to be sensor domain experts. This is, however, not always the case and since the users

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

are still not sufficiently competent they have not yet been able to specify and request this type of system property. Furthermore, this area is still somewhat immature with respect to the design and development of information systems with sensor databases. An important observation that needs to be pointed out is that while we in this work discuss the concept of sensor independence this also involves sensor data independence. Subsequently, we therefore talk about sensor data independence but this involves for the most part sensor independence as well although the latter concept may not be explicitly mentioned. This is motivated by the fact that these two concepts must go together.

The query language, ΣQL [3][4] can be seen as a tool for handling spatial/temporal information including means for sensor data fusion on data from multiple sensors. A query language of this type will use too complex query structures unless means to ensure simplification of the way the queries are defined can be made available. The query language is based upon a single operator type, i.e. the σ–operator that leads to a query structure with a relatively high degree of simplicity. Another, somewhat less important advantage of the concept is the natural and simple mapping of ΣQL-structures into an SQL-like query language. However, the SQL-like approach is primarily useful just in theoretical investigations, while the σ–query language that is easy to implement also is preferable because it is a step towards a user-friendly visual query language.

The work described in this paper is organized as follows. In section two the underlying concept of ontology driven sensor data independence is discussed. The query language and its general properties are more deeply discussed in section 3. The ontological knowledge base system that plays a fundamental role in the query system is described in section 4 while the user interface is discussed in section 5. Eventually the conclusions of the work are drawn in section 6.

2.0 ONTOLOGY DRIVEN SENSOR DATA INDEPENDENCE

Sensor data independence relates basically to data independence as introduced in database design where data independence was first introduced to allow modifications of the physical databases without affecting the application programs [5]. This was a very powerful innovation in information technology. The main purpose was to simplify the use of the databases from an end-user's perspective while at the same time allow a more flexible administration of the databases themselves [6]. A sensor based information system with properties of sensor data independence similar to the data independence in traditional databases would for similar reasons be an advantage.

A more serious motivation for sensor data independence depends on the extremely large data quantities that will be generated by the multi-sensor data systems. These data sources, i.e. the sensors, generally create heterogeneous data in large quantities. Thus it will in the future become more or less impossible to visualize these data individually with respect to their type, in such a way that the users will be able to extract all relevant information by means of the queries. That is, the users will not be able to identify objects of interest and even less so when multiple sources are available and fusion is the only way to determine a reliable result. This situation becomes even more obvious when considering that in many cases the users need responses to their queries quickly and in a suitable way because otherwise the workload of the users will be extremely high. Despite this, in many cases inexperienced users request raw data from single or multiple sensors without reflecting over whether this is realistic or whether they will be able to analyze these large data volumes in the first place. For these reasons sensor data independence is a necessary property of most future sensor data information systems. A very obvious consequence of the sensor data independence concept is that the user must learn to trust the system and the result presented to the users. Another important advantage with the sensor independence is that new sensor types can be integrated by just updating the ontological knowledge-base and if required include new recognition algorithms into the system. Thus integration of new sensor types can be done without informing the end-user.

Of main concern is how to design a system with the property of sensor data independence, which is one of the main research problems in this work. Similar to the data independence that is at hand in traditional databases sensor data independence must include a conceptual object description similar to a database schema. The conceptual object description must support the choice of sensors and sensor data algorithms and it must also be possible to tell which information that can be registered by a certain sensor. Such a structure can be described in terms of an ontology, e.g. [7]. However, the ontology is by no means sufficient by itself. To carry out the sensor and algorithm selections a mechanism that by means of the *requested objects, the actual weather conditions, the time of the day*, *the available sensor data* and the ontology must be available. For this a rule-based approach has been designed which will be discussed further in section 4.

3.0 ΣQL

The query language, ΣQL can be seen as a tool for the handling spatial/temporal information for sensor-based information fusion, because most sensors are generating spatial information in a temporal sequential manner. A query language of this type must be able to handle large data volumes because most sensors generate large quantities of data in very short periods of time. Another aspect to consider is that user queries may be concerned with data from more than one sensor, which consequently will lead to complex query structures, because the use of data from more than one sensor may require methods for multiple sensor data fusion.

3.1 The Query Language Structure

The strength of the query structure is its simplicity: the query language is based upon a single operator type, i.e. the σ–operator. The σ–query language can be seen as tool applied to the data sources and corresponding to a multidimensional space. This *source, R*, is also called a *universe.* Each query is made up by a sequence of σ-operators that primarily should allow operations on a sensor-data-independent level, i.e. the acquired sensor data should be transformed into a unified information structure at a high abstraction level that is sensor independent. To accomplish this, the queries should be expressed in terms of operator sequences where the operators carry out the transformations stepwise. Basically, the operators reduce the dimensions of the multi-dimensional search space to which each new operator is applied with respect to the dimensions in focus of the query. The reduced search space is subsequently called a *cluster*. Thus, as new operators are applied, the clusters become more and more refined until eventually a final cluster is returned and this cluster corresponds to the answer of the applied query.

An illustration of the query language could, for instance, be a video sequence, i.e. the universe R, from which a limited set of frames can be extracted. Thus if we are interested in three frames at different predetermined times, t_1, t_2, and t_3, along the time axis, this will correspond to the σ-operator σ_t (t_1, t_2, t_3), which means that the three frames should be selected from the time axis of the universe R. However, the main purpose of the operator sequences is to serve as an intermediate representation between the graphical user interface and the query interpreter. Evidently, this cannot be seen as a reasonable query technique for the end-users and thus a more user-adapted approach is needed. This will be discussed subsequently in section 5.

3.2 The Sensor Dependency Tree

In database theory, query optimization is often performed with respect to a query plan where the nodes represent the various database operations to be performed [8]. The query plan can be transformed in various ways to optimize query processing with respect to certain cost functions. In sensor-based query processing, a concept similar to the query plan is proposed. It is called the *sensor dependency tree*, which is a tree in which each node P_i has the following parameters:

object	is the object type to be recognized
source	is the information source
$recog_i$	is the object recognition algorithm to be applied
aoi_i	is the spatial area-of-interest for object recognition
ioi_i	is the temporal interval of interest for object recognition
$time_i$	is the estimated computation time in some unit such as seconds
$range_i$	is the confidence range in applying the recognition algorithm represented by two numbers min and max from the closed interval [0,1]

Query processing is accomplished by repeated computation and updates of the sensor dependency tree. During each iteration, one or more nodes are selected for computation. The selected nodes must *not* be dependent on any other nodes. After the computation, one or more nodes are removed from the sensor dependency tree. The process then iterates and eventually the last node in the tree is reached; the last node of the dependency tree is generally the fusion node, which performs the fusion operation. After the fusion operation is carried out the process terminates. Fusion in ΣQL is based on a voting approach [9]. The motivation for this fusion approach is that it is fast which is necessary requirement in a query language. However, the fusion method is interchangeable. A further aspect is that the fusion method must be well integrated with the query system such that the end-users do not have to bother with how the fusion method behaves. To accomplish this, there must be methods available that will support the end-users in judging the result of a fused query; this is discussed further in connection to the confidence values in section 5.

3.3 Multi-Level View Database

A multi-level view database (MLVD) is needed to support sensor-based query processing. The status information is obtained from the sensors, which includes the object type, the attribute values such as colour or length, status information of type position, orientation, and so on. The positions of the query originator and the sensors may also change. This information is processed and integrated into the multi-level view database. Whenever the query processor needs some information, it asks the view manager which is the subsystem that maintains the view database. The view manager also shields the rest of the system from the details of managing sensor data, thus achieving sensor data independence.

The multiple views may include the following three views in a resolution pyramid like structure: the global view, the local view and the object view. The *global view* describes where the target object is situated in relation to some other objects, e.g. a road from a map. This will enable the sensor analysis program to find the location of the target object with greater accuracy and thus make a better analysis. The *local view* provides the information such as whether the target object is partially hidden. The local view can be described, for example, in terms of Symbolic Projection [10]. Finally, there is also a need for a *symbolic object description,* which describes the target itself in great detail. The three views may include information about the query originator and can be used later on in other tasks such as in situation analysis [10].

The view manager can be regarded as an agent, or as middleware, depending upon the system architecture. The multi-level views are managed by the view manager. The global view is obtained primarily from a geographic information system (GIS). The local view and the object view are more detailed descriptions of local areas and objects. The results of query processing, and the movements of the query originator, may both lead to the updating of all three views.

3.4 Query Refinement

There is another class of queries that require more sophisticated query refinement. We will call this class of queries *evolutionary queries*. An evolutionary query is a query that may change over time and/or in space. For example when an emergency management worker moves around in a disaster area, a predefined query can be executed repeatedly to evaluate the surrounding area to find objects of threat. However, queries and query processing are affected by the spatial/ temporal relations among the query originator, the sensors and the sensed objects.

Given a user query in a high-level language, i.e. either the natural language or a visual language forms the query refinement approach that is outlined below, where *italic words* indicate operations for the second (and subsequent) iteration.

Step 1. Analyze the user query to generate/*update* the sensor dependency tree based upon the ontological knowledge base and the multi-level view database that contains up-to-date contextual information in the object view, the local and the global views.

Step 2. If the sensor dependency tree is empty then terminate otherwise if only the fusion node remains, perform the fusion operation and terminate. Otherwise build/*refine* the σ-query, i.e. the internal query, based upon the user query, the sensor dependency tree and the multi-level view database.

Step 3. Execute the portion of the σ-query that is executable according to the sensor dependency tree.

Step 4. Update the multi-level view database and go back to Step 1.

In query processing/refinement, the spatial/temporal relations must be taken into consideration in the construction/update of the sensor dependency tree, which is controlled by the ontology system. The temporal relations such as “followed by”, “preceded by” should be allowed while the spatial relations should include the common spatial relations, see e.g. [11]. Other special relations such as “occluded by”, and so on must be available as well.

4.0 THE ONTOLOGY SYSTEM

The purpose of the sensor data independence concept introduced above is to simplify the use of the system and to let the system take the responsibility of deciding which sensors and which sensor data analysis algorithms that should be applied under given circumstances in response to a particular query. To support this activity an ontological knowledge base system (OKBS) has been developed. This is a step towards a general technique to generate/refine queries based upon incomplete knowledge about the real world. However, the knowledge stored in the ontology differs from knowledge in other domains in that it includes not just object knowledge but sensor and sensor data control knowledge as well.

The ontology is taxonomically divided into three parts: the *sensor & algorithm part* describing the sensors and recognition algorithms, the *conditions part* describing external conditions such as weather and light conditions and the *thing-to-be-sensed part* describing the objects and the object properties to be sensed. In figure 1 a simplified overview of the ontology is presented. The concepts in the *sensor & algorithm part* are presented to the left of the *ThingToBeSensed* concept. The *conditions part* is to the right of the *ThingToBeSensed* concept and the *ThingToBeSensed* concept itself together with its subconcepts make up the *thing-to-be-sensed part*.

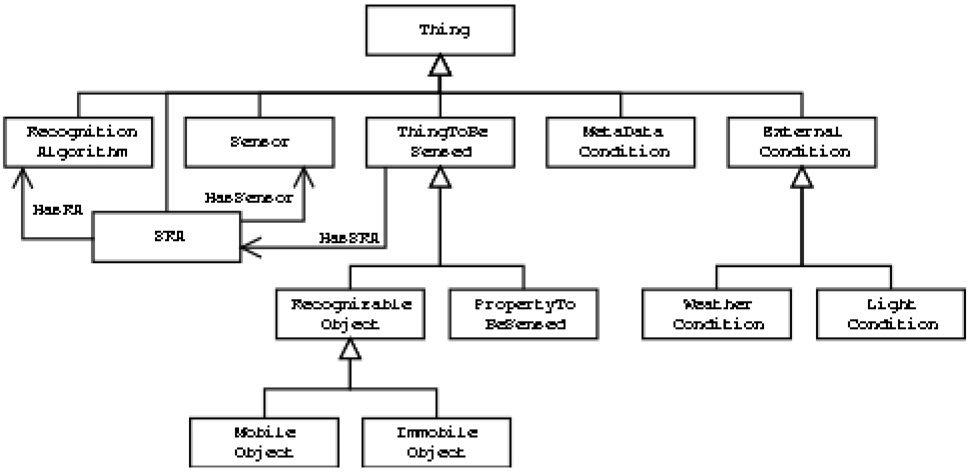

Figure 1: Ontology Overview Describing the General Knowledge Structure.

Using this knowledge in conjunction with information about the objects to be sensed and rules describing under what conditions certain sensors and recognition algorithms are appropriate to use, the OKBS determines which sensors and recognition algorithms to use under the given conditions. For example, IR (infrared) and LR (laser radar) sensors can be used at night, while CCD (digital camera) cannot. Probably, IR can be used in a foggy weather, but LR and CCD cannot, etc.

Most of the concepts in the simplified ontology overview in figure 1 are self-explanatory. The *SRA* concept models a many-to-many relation between sensors and recognition algorithms, meaning that a certain recognition algorithm can be used on data from different kinds of sensors and many different recognition algorithms can be used on data from a certain sensor type. This means that each SRA can be used to determine a combination of a sensor and a recognition algorithm that work well together. The *HasRA* and *HasSensor* relations are used to model this.

MetaData condition is a concept that models meta-data conditions like data quality. *PropertyToBeSensed* models properties that the sensors can sense, e.g. color, temperature, etc. *RecognizableObject* models all objects that the recognition algorithms can recognize.

Relations and concept attributes are inherited down the inheritance chain, meaning that the *HasSRA* relation applies not only to the *ThingToBeSensed* concept. It also applies to all its subconcepts, e.g. *RecognizableObject*, *MobileObject*, etc.

The *HasSRA* relation describes which combinations of sensors and recognition algorithms are the most appropriate to use under ideal external conditions (weather, time of day, etc). When the OKBS generates/refines a query it first uses this relation to find out which sensors and recognition algorithms that are appropriate when trying to recognize the requested object type(s) under ideal conditions.

The next step is to take meta-data conditions such as sensor data quality into account. The sensors and recognition algorithms selected in the first step are re-evaluated with respect to their respective meta-data quality at the time and place indicated in the query.

Finally, the external conditions are taken into account. To perform this step a rule based system has been developed. Given the external conditions at the time and place indicated in the query, this step re-evaluates the selected sensors and recognition algorithms according to the rules that describe how appropriate the selected sensors and recognition algorithms are under certain conditions. Each rule describes the appropriateness of a certain sensor or recognition algorithm given a complete set of external conditions.

The result of the described process is a prioritized list of appropriate combinations of sensors and recognition algorithms to use for the given query under the external conditions at the time and place of the query. This information is used to construct/refine the sensor dependency tree that in turn determines in which order different parts of the query should be processed.

When the number of sensor types and recognition algorithms grow the number of rules will also grow. At present, the rules are updated manually, but as more sensor data becomes available from different test scenarios it will be possible to develop a system that can tune the rules in a semi-automatic manner by means of mathematical statistics and artificial intelligence techniques.

The ontological knowledge base system is described in much more detail in [12] where complete descriptions of all the concepts in the ontology can be found.

5.0 THE USER INTERFACE

In current sensor-based information systems detailed knowledge about the sensors is required. Therefore sensor selection is left to the users who supposedly are also experts on sensors. However, in real life this is not always the case. A user cannot be an expert on all sensors and all sensor data types. Therefore query systems with the ability to hide this kind of low-level information from the users need to be developed. User interfaces also need to be designed to allow the users to formulate queries with ease and request information at a high-level of abstraction to accomplish sensor data independence. An approach to overcome these problems and to accomplish sensor data independence is proposed through the use of the sensor dependency tree, the query refinement technique, the multi-level view databases, and an ontological knowledge base for the sensors and objects to be sensed.

One of the advantages with this system is that the user is not restricted to querying the system about things that one single sensor may answer. He can also make queries that use the combined information from sensors. He can for instance ask for the location of all blue vehicles that have their engines running. This query requires information both from an infrared camera to see if the engine is hot and from a camera in the visual range to see if the vehicle is blue. The user does not have to feel restricted to the information a single sensor might be able to provide, but is free to make the queries that he needs an answer of and the system will find out which sensors that are appropriate to use.

To run a query of general type the user needs an interface where he can select which area he is interested in (AOI), the relevant period in time (IOI) and what kind of objects he is looking for. Other query types are allowed as well and could be made up by combinations of these three concepts including required property conditions. However, the user will not be given a choice of sensors, instead information will be available on which areas and which times are covered by any of the sensors. The user will have the possibility to visually specify attributes of objects and relations between the objects to be able to make more advanced queries.

The ontological knowledge base provides the user interface with all objects and attributes that can be queried i.e. all attributes that at least one sensor can recognize. That way, the user has access to all currently available options without having to know anything about the available sensors and algorithms.

As described in previous sections, some queries such as the evolutionary queries need to be processed repeatedly, with minor changes, during a certain period of time (time interval of interest) and/or within a certain geographical area (area of interest). Since most users of sensor-based information systems are not experts in sensors, we propose to attack the problem in two ways. By constructing an ontological knowledge base, where the low-level detailed information about sensors, objects to be sensed and environmental conditions can be stored. By providing query templates, the commonly encountered queries can be specified by e.g. form-filling. To formulate such queries a template can be used accordingly:

Step 1. The user enters the selected dimensions, the ordering of the projections, the sources, and the join conditions.

Step 2. Dimensions, sources, join conditions can all be based upon selections from pull-down menus.

Step 3. A query template is filled in to generate the query.

Step 4. In the WHERE part, if the type of an object is set to 'aaa', there must be an algorithm to recognize the object 'aaa', or the object 'aaa' is already in the database. This can be determined by checking with the ontological knowledge.

Step 5. The query processor processes the σ-join-query.

To support evolutionary queries, a further refinement of the technique is to let the user specify queries with additional parameters, such as how often to run the query, in what time intervals and geographical areas, and so on. Since evolutionary queries usually change slowly, we will investigate techniques to optimize evolutionary query processing, by maximizing the sharing of information in the processing of consecutive evolutionary queries.

A general and most important aspect of any query system and particularly in sensor data fusion systems, is the confidence in the query result, which must be acknowledged by the user. This is due to the fact that data acquired from sensors are always mapping the reality with some level of uncertainty. The uncertainties are due to, among other things, technical imperfections in the sensors. Generally, these uncertainties can be represented with some kind of confidence value that may be normalized, i.e. within the interval [0,1]. Confidence values should be interpreted as the confidence a user may have in a query result. This way of representing uncertainties in the data becomes even more necessary in the sensor data fusion processes. Consequently, when evaluating the result from a query applied to data from multiple sensors the confidence values corresponding to the uncertainties of the fused result is required. This kind of confidence structure is used in ΣQL to support the user in interpreting the query result.

The result of the query is presented on a map that covers the given AOI. All objects found are presented by using the standardized unit symbols. At the user's request all available information about an object will be displayed, i.e. color, number of antennas and the deduction behind the sensor information fusion. To get an intuitive feeling of how reliable the result is the symbols will be color coded with respect to the confidence values, i.e. strong color – high confidence, weak color – low confidence values.

The map view is a good way to get a spatial overview of the result. It is also similar to what is done in classical C_2-systems. In some cases spatial overview is not the optimal way, so in addition to the map view the user has the option to get the information in a spreadsheet oriented way where the user has the option to sort the data in any way he wants.

6.0 CONCLUSIONS

In this paper, a query language for heterogeneous data sources, generally corresponding to various types of sensors, has been introduced. An important characteristic of this query language is the concept of sensor data independence. In particular, there are three important aspects of sensor data independence which all have a strong influence on the users' working situation. Thus the consequences of this concept are:

- The users do not need to have any knowledge about the sensors that are used to answer a particular query.
- For a query that repeatedly is applied over a fairly long period in time sensors can be engaged/disengaged without the users knowledge depending on e.g. weather or light conditions.

- New sensor types and recognition algorithms can be added/deleted to the system, when ever suitable, without informing the users.

Most of these aspects depend on the ontological knowledge-base system and furthermore, this subsystem also has an influence on the query refinement concept that is supported by the introduction of the global, local and object views.

A further characteristic, that is of vital interest to the users, is that the users by the introduction of the sensor data independence concept are able to use application dependent notions in their queries, e.g. area of interest, object type, relations etc. These notions will make it possible to design a powerful visual user interface or language suitable to the ΣQL query language.

An important aspect that concerns the sensor data fusion part of the system is that fusion is an integrated part of the query language that is of less concern to the end-users. Thus, from the users perspective, of concern is how to handle the confidence values that are given as complementary parts of the query results. A question of concern in relation to these confidence values is how to present this information to the end-users in a way that is simple to interpret. For example, do we believe in the given query result or not.

Future research of concern in this work will heavily be focusing on the design of the visual user interface and further development of the OKBS in order to determine improvements of the concept of sensor data independence.

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SYMPOSIA DISCUSSION – PAPER NO: 10

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Question:
Targets are color coded with respect to confidence values, but there are different types of uncertainty such as where or what type. What is the color referring to in this case?

Author's Response:
In this case, the uncertainty has to do with whether or not there is a target in the location indicated.

Question:
Collection management is currently a manual process that takes a long time to task a series of sensors to obtain data. Have you given any thoughts on a process to automate the process?

Author's Response:
In a real situation, it has to be trained. Also looking at selecting the sensor that has the best value available.

Large Scale Interactive Data Visualization for Undersea Warfare Applications

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ABSTRACT

Today, the US Navy's submarine fleet is equipped with a multitude of advanced, highly capable acoustic sensors and systems that are utilized in many aspects of tactical, navigational, and operational Command and Control (C2). These modern sonar systems collect, process, store, disseminate, and display sensor data. Rapid advances in processing techniques, computing power, and sensor technology present a new challenge – sonar operators require extensive training and experience in order to deal with an enormous amount of acoustic data using 2D display and interaction tools, which have remained nearly unchanged in the past 25 years. Fraunhofer CRCG and the Naval Undersea Warfare Center present a highly interactive Large Scale Visualization Environment (LSVE) for performing the essential tasks of detection and classification of sonar contacts. Our prototype application employs a semi-immersive 3D display system, multiple and mixed modalities of interaction and feedback, and state-of-the-art volumetric visualization techniques. An operator can use the LSVE to rapidly detect a contact in a low signal to noise environment and perform the tasks of detection, tracking, and classification of contacts.

Index Terms – Data Visualization, Sonar, Interactive Data Analysis.

INTRODUCTION

Submarine sonar system technology has benefited in recent years primarily from accelerated developments in digital signal processing, computational power, and advances in sensors. Today's most capable undersea platforms deploy several different acoustic sensor arrays both, hull-mounted and towed. Each sensor suite is specifically designed for a particular mission, creating a massive amount of sensor data to be analyzed by the sonar operators. Even though these sonar arrays and processing systems are state-of-the-art, the presentation of acoustic data to the operator onboard these platforms has not appreciably changed in the last 35 years.

The analysis of relatively low-level sensor data by an operator is unique today to sonar Operators must search and evaluate acoustic energy across many frequency bands, apertures, arrays and directions,

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

and make decisions on the presence or absence of contacts of interest, largely unassisted by automation. The sonar operator is challenged by an enormous data overload problem, coupled with antiquated, non-intuitive display technology with restricted interaction and limited tools to accomplish the vital tasks of detection, tracking, and classification of contacts.

To maximize performance under these conditions, the conduct of undersea warfare requires the highest degree of information extraction and exploitation from a myriad of onboard acoustic sensors and processing systems. A new technology and human systems approach is needed in order to focus high-performance computing, display, and human/machine interaction technologies on the problems and tasks faced by human operators and decision makers.

INTERACTIVE APPLICATIONS FOR SONAR DATA PROCESSING

In collaboration with the Naval Undersea Warfare Center (NUWC) in Newport, Rhode Island, the Fraunhofer Center for Research in Computer Graphics (CRCG), Inc., has taken the approach of developing intuitive, highly interactive analysis tools to increase the performance of the sonar operator.

Interactive Data Exploration

At the most basic level, the challenge from an interaction point of view is to provide access and manipulation tools to find correlations that are hidden in the vast amount of data available to the user.

EZ-Grams – Exploiting Harmonic Relationships

By focusing on perceptual information cues, NUWC and Fraunhofer CRCG have developed interactive, intuitive tools and techniques by which the operator can rapidly extract pertinent information from the raw data within a specific task domain. Collectively, these display tools are represented as a new class of aids called *EZ-grams*, which help an operator transform raw sensor data into useful information [Barton, Rowland et al. 2000]. An *EZ-Gram* embodies a collection of pertinent sensor data that represents the hypothesis that a contact is of interest. *EZ-Grams* allow operators to rapidly test hypotheses, search for corroborating data, and build confidence in the solution.

One such EZ-Gram is the *harmonogram*, which is based upon an hypothesis that energy of interest exists in some or all of the harmonics associated with a given or selected frequency band, or “bin.” The frequency bins of the harmonogram are superimposed to enhance the dynamic representation of Doppler, while reducing non-correlated data in the display. Furthermore, the harmonogram displays time-record data through animation, allowing the user to “replay” local history and view target or contact motion, which can provide valuable insight into signal dynamics. Subtle effects not observed in single image data presentations are potentially quite obvious when animated.

Figure 1 shows a typical time-frequency or “waterfall” representation of acoustic sensor data presented to a sonar operator today, in which data correlations are difficult to discern. In most cases, each gram has time on the vertical axis, and either bearing or frequency along the horizontal. Signal intensity is monochrome and subsampled down to only 8 levels, i.e. 3 bit resolution presentation. These displays are the primary workplace for the sonar operators.

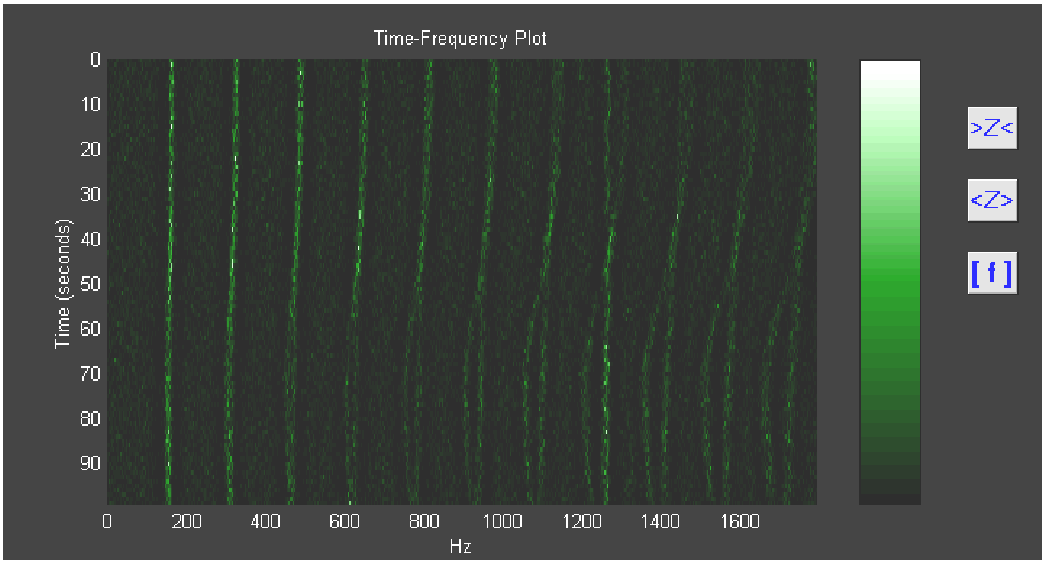

Figure 1: Typical Time-History Spectrogram Sonar Display.

Figure 2 shows a harmonogram in which a selected hypothesis is clearly shown to be valid, because it is displayed as a harmonically related frequency-frequency plot, with time history presented to the user as an animated sequence. Note that only the data already available in the waterfall is portrayed in the harmonogram, but the data is filtered to the hypothesis of interest, and displayed so that the information cues that the operator is seeking are distinctly presented. NUWC is currently developing several examples of EZ-Gram display tools for transition into current and future US Naval submarine sonar display systems.

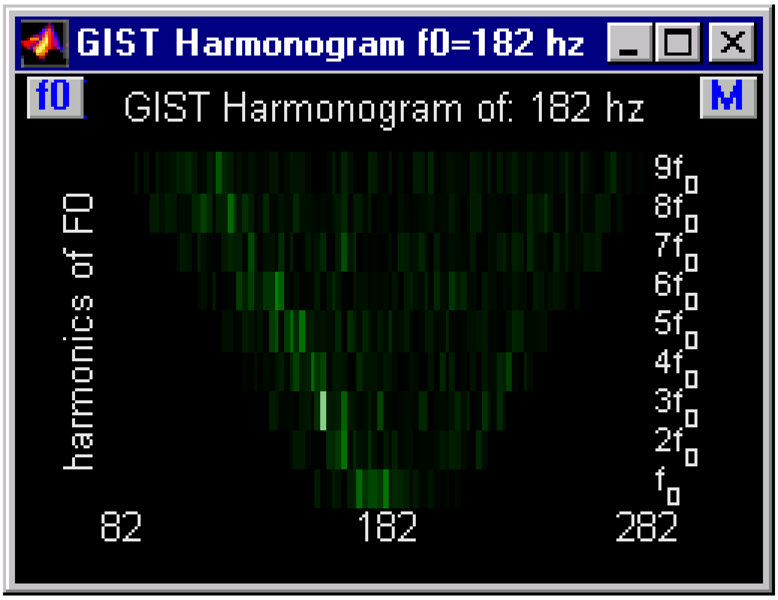

Figure 2: Harmonogram Representation.

Large Scale Visualization Environment

Fraunhofer CRCG and NUWC have used a two-stage approach in the development of an intuitive, highly interactive, Large Scale Visualization Environment (LSVE) that will enable human talents, experience, and intuition to leverage and direct high-performance computing resources [Encarnação, Barton et al. 2000]. The LSVE consists of two main components, "search&detect" and "analyze&classify" which will be discussed below. The LSVE has been implemented on a "virtual table" display device as seen in Figure 3. The rear-projection display surface can be oriented at any angle from horizontal to nearly vertical.

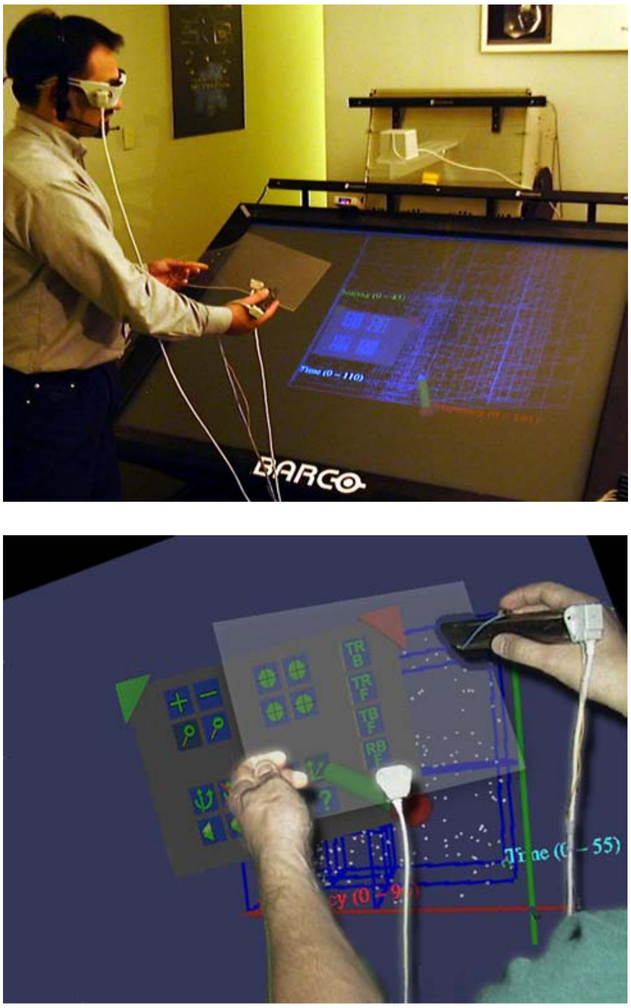

Figure 3: System Setup (above). The Two-Handed Input Device – Pen and Pad – for the Virtual Table (below).

Transparent pen and pad props made of Plexiglas have been created to display stereoscopic 3D graphics that the user perceives as coincident with the physical position of the devices [Schmalstieg, Encarnação et al. 1999]. The transparent non-reflecting surface of the pad virtually disappears when the table graphics are switched on. The user then sees computer-generated images while the physical properties of pen and pad are retained. In particular, pen and pad allow tactile feedback and users intuitively understand and can easily exploit the relative position and orientation of pen, pad, and table surface.

Objects can be aligned with the surface of the pad, and also appear floating above or below the pad. The pad essentially becomes a hand-held palette that may carry all kinds of 2D and 3D user-interface elements (e. g., buttons, sliders, dials) as well as three-dimensional objects [Encarnação, Schmalstieg et al. 2000]. The pen is equipped with a single button that triggers various actions depending on the context in which it is used.

Data Management

The data sets examined in this effort were based on a Spatial Vernier (range focused) simulation of the sonar space. They consisted of one broadband data set and four bands of narrowband data. The broadband dataset is a four-dimensional dataset consisting of the dimensions *time*, *range*, *beam* and *power*. The time dimension consists of 7000 uniformly sampled bins. The beam dimension has 360 bins, each equivalent to an angular degree. The range bins consist of a eight focus distances between 2500.0 and 12000.0 yards. Therefore a signal, if it exists, will be evident in all of these ranges but focused in one. The narrow band datasets were derived from an identical simulation to the broadband data set. The difference is the narrowband data provides information on the frequency of the signal. The narrowband data set is therefore five-dimensional and is broken into four bands of frequency (A-D) between 6.0 and 450.0 Hz, which also use a different number of beams (between 45 and 360). The number of frequency bins in each dataset is 191.

Search & Detect Component

The LSVE first component (“search&detect”) aims at providing advanced visualization and human/machine interface techniques to enable sonar operators to quickly and confidently detect and classify contacts in low signal-to-noise dataspaces. This can be thought of as a problem of searching for subtle contact indicators in a very large and multidimensional dataspace. The goal is to enable the operator to focus computational resources on the volumes of interest, providing rapid initial detection.

The dataspace is represented as a set of 4D volumes, that is, 3D volumes that are dynamically updated during the time course of an operation. Multi-sensory visualization techniques are employed to indicate volumes of interest, which may contain a contact or contacts.

The operator is initially presented with a coarse visualization of potential areas of interest. This visualization employs a low-resolution visual presentation for fast searches over the data space assisting the user with the decision on where to focus attention. The visual presentation of the dataset appears subdivided in regions with a cubic shape or ‘cells’. The smaller a cell is subdivided (more resolution) the more interesting that volume is to be explored, according to the chosen analysis algorithm. Within each cell a cloud of points is displayed representing information about the signal intensity within that region. The number of points as well as the color intensity is proportional with the signal intensity. Dense white clouds represent higher signal above threshold than sparse dull color clouds.

For the exploration of the data set, numerous interaction techniques are supported, based on the transparent interaction props (pen and pad) described earlier. Voice input is also supported.

Analyze & Classify Component

In the second LSVE component (“analyze&classify”), we utilize a highly interactive 3D representation of the tactical environment. Once an area of interest has been designated in the initial search phase, the visualization coverts to a volumetric display of the multidimensional raw data of the corresponding passive narrowband sensor information. Employing visual and auditory cues, the operator can then interact with and interrogate this data cloud. Lastly, we provide aids to display non-spatial qualitative relationships in this data set, in an attempt to capitalize on inherent human pattern recognition capabilities.

At any point in time, an area of interest can be selected and then further investigated. In analyze&classify the visualization switches to the raw data view (Figure 4) of the corresponding passive narrow-band sensor information. The operator can further apply many interaction and manipulation techniques for volume data, most of which have been successfully applied in the past to the area of medical visualization. These include defining oblique and axis-parallel cutting planes to detect tracks, maximum intensity projection to enhance the contrast, and adjusting the intensity lookup table for certain known thresholds.

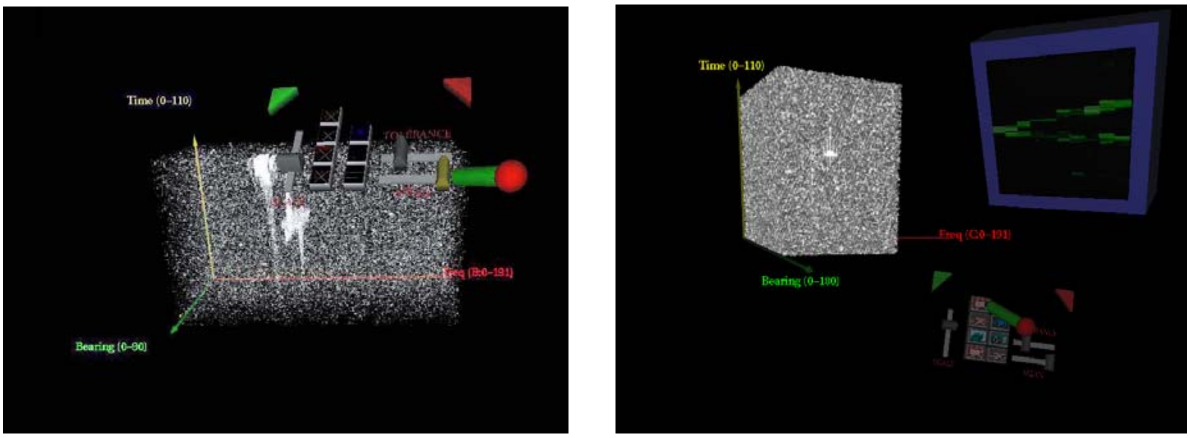

Figure 4: ‘Analyze&Classify’ Visualization: Detection of multiple threats through modification of the volumes lookup table (left) and employing an additional harmonogram (right).

In the real world we analyze objects by grabbing, rotating and bringing them closer to our eyes to get more details about interesting parts. We provide the same abilities in LSVE with our interaction tools.

While no formal evaluations have been conducted, users, including active or retired Naval personnel with USW experience, were impressed by the LSVE.

DECISION-CENTERED VISUALIZATION

Often under high-stress and workload in high-risk situations, the SONAR/Control team must rapidly achieve and maintain situation awareness – they must understand the tactical situation within the sensor performance envelope. In such situations, operators and decision makers do not have the luxury of time either to interactively specify an information presentation, or describe to a human operator what to display and how to display it.

Current work in the visualization community supports highly interactive and often immersive presentations in a variety of applications. While extensive interactive viewing and data selection is supported, current visualization systems, for the most part, only maintain information about *pixels* and *polygons*. They do *not* represent and use meta-knowledge about the data and information that is being displayed, and thus have no capacity for actively *supporting* the user by:

- presenting information known to be critical for task performance,
- alerting the user to missing data, and
- highlighting information crucial to sound decision making.

A new technology and systems approach is needed which will provide the SONAR/Control team with interactive information visualizations that merge decision support with situational awareness. An important approach to this problem is to embed in the visualization system knowledge of the application domain, the key concepts and operations, its missions, tasks, and decisions.

Fraunhofer CRCG has developed a new technology called Decision-Centered Visualization (DCV), which can provide decision makers with interactive information visualizations that merge domain knowledge and decision support with situational awareness presentations. Please see Figure 5. Decision and task models, knowledge of the information environment of the application domain, including concepts, events, and operations, are tightly-coupled with the human/machine interface and the visualization architecture in order to produce timely, decision-centered visualizations. DCV uses knowledge to track the context of an evolving situation, to classify and prioritize incoming operational data, and to automatically tailor and organize presentations in context with the tasks and decisions being worked, enabling a genuine human/machine information symbiosis. The main objectives of DCV are to reduce the information workload of operators and decision makers by providing in-context, to-the-point information presentations, and to reduce decision time by timely presentation of mission-relevant and mission-critical information.

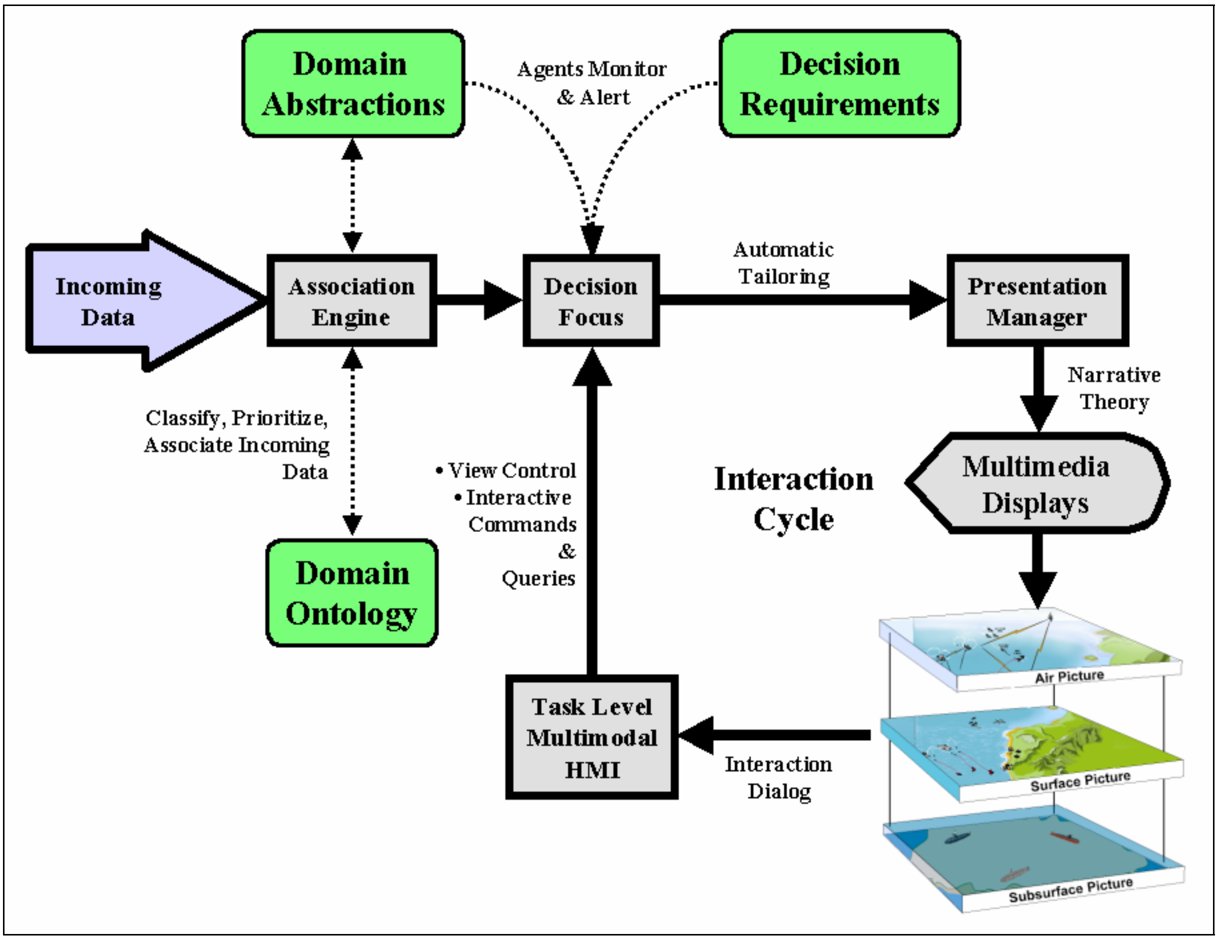

Figure 5: High-level Architecture for Decision-Centered Visualization (DCV). The distinguishing feature of this technology is the incorporation of knowledge modules into the visualization system. These knowledge modules consist of *domain ontology* and domain *abstractions, decision requirements* and *decision focus.*

The DCV architecture is intended to be domain-independent to support visualization in a variety of applications. Application-specific information is localized in well-defined modules – *domain ontology, domain abstractions*, and *decision requirements* – that are addressed early in the design phase when developing a particular application. The DCV *interaction cycle* is intended to be generic and parameterized in order to display and manipulate this application-specific information.

CONCLUSIONS AND FUTURE WORK

We have presented a variety of tools, approaches and paradigms in support of effective interactive data analysis for the underwater sonar space. Furthermore, Fraunhofer CRCG is currently investigating the integration of knowledge engineering and visualization technology, to enable Decision-Centered Visualization

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SYMPOSIA DISCUSSION – PAPER NO: 11

Author's Name(s):

Cdr. Robert J. Barton, NUWC, Newport, USA
Mr. David Zeltzer, Fraunhofer Center for Research in Computer Graphics Inc., USA

Question:
How are the graphics displayed on the tablet?

Author's Response:
There are not any actual graphics on the tablet. The virtual reality environment can sense where the user is looking and can project the graphics to a location on the virtual table to make it seem like graphics are on the tablet.

Comment:
Experience can be incorporated in the development cycle when the rules are being implemented.

Question:
Has historical data been incorporated? Can the user ask for retrospective information?

Author's Response:
As this is a prototype, that has not yet been developed, however it would be important in an implementation of the system.

Pixel-Level Fusion of Active/Passive Data for Real-Time Composite Feature Extraction and Visualization

Alan Steinberg and Robert Pack
Space Dynamics Laboratory/Utah State University

ABSTRACT

System Concept

A system has been developed whereby active LADAR and passive imaging data are registered in hardware at the pixel level. For the sake of discussion, the sensor is herein called a “LADAR/EO pixel-level Fusion Sensor” or LEFS. This sensor produces structural and spectral data embodied in one dataset, permitting composite feature extraction and visualization.

The combined use of LADAR and passive EO/IR data has well known synergism. Our system fuses these two data types in a novel way such that real-time performance is possible. This significantly enhances the ability to quickly and correctly identify targets.

By fusing the range data from the active sensor with the pixel-registered imagery, registered 3D images are available in real time (Figure 1). Each pixel is coded with full spectral information combined with structural information obtained by the active system (Figure 2). The resulting fully aligned high-dimension feature vector enhances target recognition and permits dense point matching for precise image mosaicking.

A significant benefit is in combining the ability of pencil beam active systems to work at long ranges and to penetrate obscurants with the passive array’s wide instantaneous field of view at increased resolution. One application in which this has had enormous benefit is in observation through partial or intermittent obscuration; e.g. with partial cloud cover or foliage. Reflected radiation associated with features within gaps in the obscuration are sensed passively while at the same time the active pencil beam efficiently maps structure within the revealed region (Figure 3). Pixel-level registration of data permits extended regions to be mapped by combining temporally or spatially diverse collections (Figure 4).

Applications

Military application for which this technology is being developed or assessed include precision tactical targeting, Precision Controlled Reference Image Base (CRIB) production and Automatic Registration of targeting data into the CRIB.

Civil applications include 3D city modeling, real-time airborne mapping, post-disaster reconnaissance, floodplain and coastline mapping, drug interdiction target detection, environmental monitoring, and search and rescue.

Paper presented at the RTO IST Workshop on “Massive Military Data Fusion and Visualisation: Users Talk with Developers”, held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

Visualization Implications

Such detailed three-dimensional multi-spectral data present challenges and opportunities for visualization.

The multispectral character of the data presents the familiar problem of presenting high dimensional data. Adaptive use of false colors is the most obvious approach. In the case of an LEFS system, the false color scene is wrapped into a 3D structure.

The opportunity to recover range-tagged feature data through partial or intermittent obscuration permits partial 3D scene reconstruction. The use of multiple viewpoints enables the filling in of the inevitable residual shadowing associated with a given viewpoint. One potential visualization technique is that of selective layering. Using this technique, the analyst is able to scan or step through layers of the data, either in the range dimension or in a dimension contoured to modeled terrain. In this way, for example, the analyst can explore the scene at or near ground level by suppressing the intervening cloud or foliage obscuration. Alternatively, he can isolate aircraft or other objects from an earth background.

A very high degree of compensation for motion in the sensor platform is achievable because the precise range is obtained from the LADAR at the same time the fully registered precise angle data from the passive optical system is collected. This eliminates the parallax problems encountered by passive systems alone. Thus passive images can be automatically co-registered as proved by a prototype LEFS system at Utah State University. Figure 5 shows an example of an automatic image mosaic reconstructed on-the-fly using the wire-frame surface structure derived from LADAR shown in Figure 6. The vantage point of the viewer of these Figures happens to be above and to the left of the point from which the data was collected. Such virtual positioning is possible only because of the 3D nature of the database. Shadows in the figure are regions that were blocked from the view of the instruments, where no data could be collected. The linear seam on the right side of the lower image indicates the boundary between two adjacent digital camera shots. Brightness was deliberately increased in the image on the right of the seam to help locate the seam. Note how perfectly the two images are knitted together because of the georegistration of the data.

Ultimately a full tomographic capability could be provided. Such may have applications in dense, complex three dimensional scenes as might be encountered in urban environments. For example, it should be possible to construct detailed imagery or video of individual vehicles or people as they move through crowded streets, which intermittent blockage by other vehicles or people, buildings, etc.

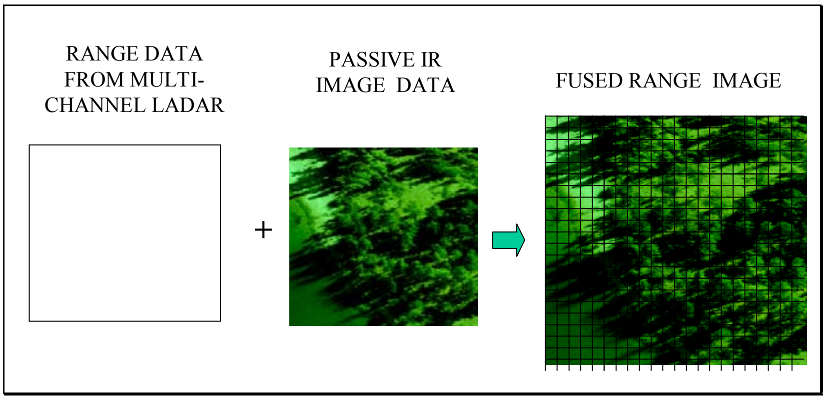


Figure 1. Hybrid 3D Image via Pixel-Level Registration

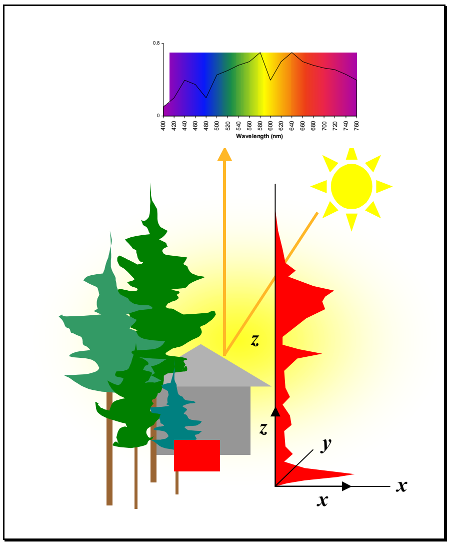


Figure 2. Pixel-Level Spectral and Structural Feature Set

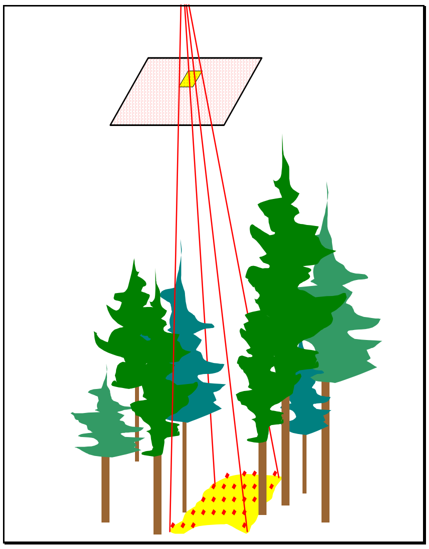
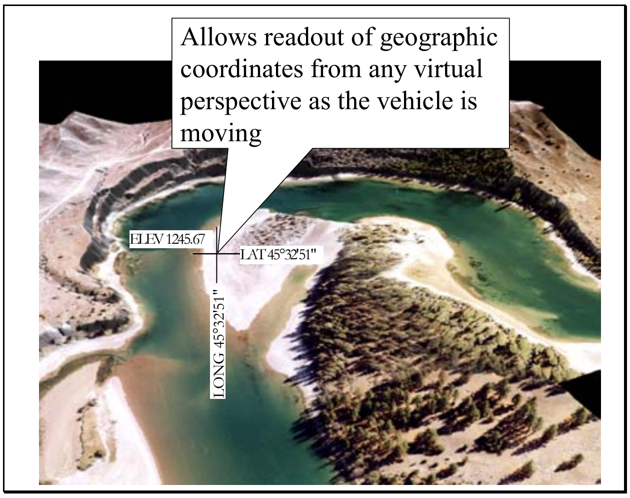


Figure 3. Observation through Partial Obscuration



Allows readout of geographic coordinates from any virtual perspective as the vehicle is moving

Figure 4. Large-scale image fusion

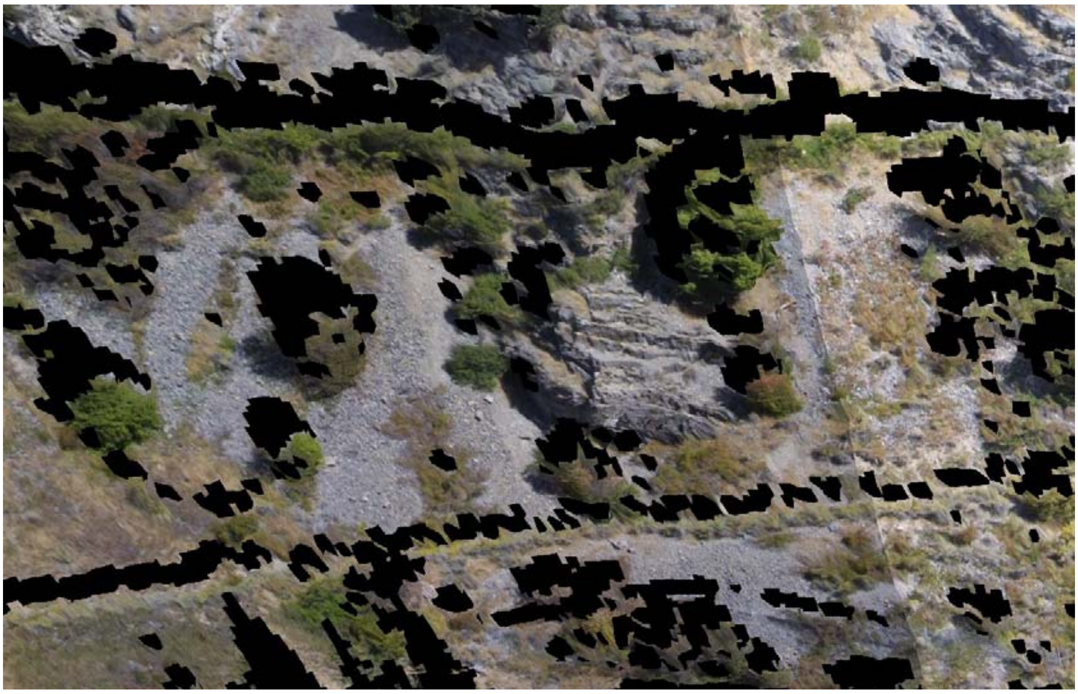


Figure 5. 3D images mosaicked using LADAR data shown in Figure 6. Note the seam defined by two images of differing brightness.

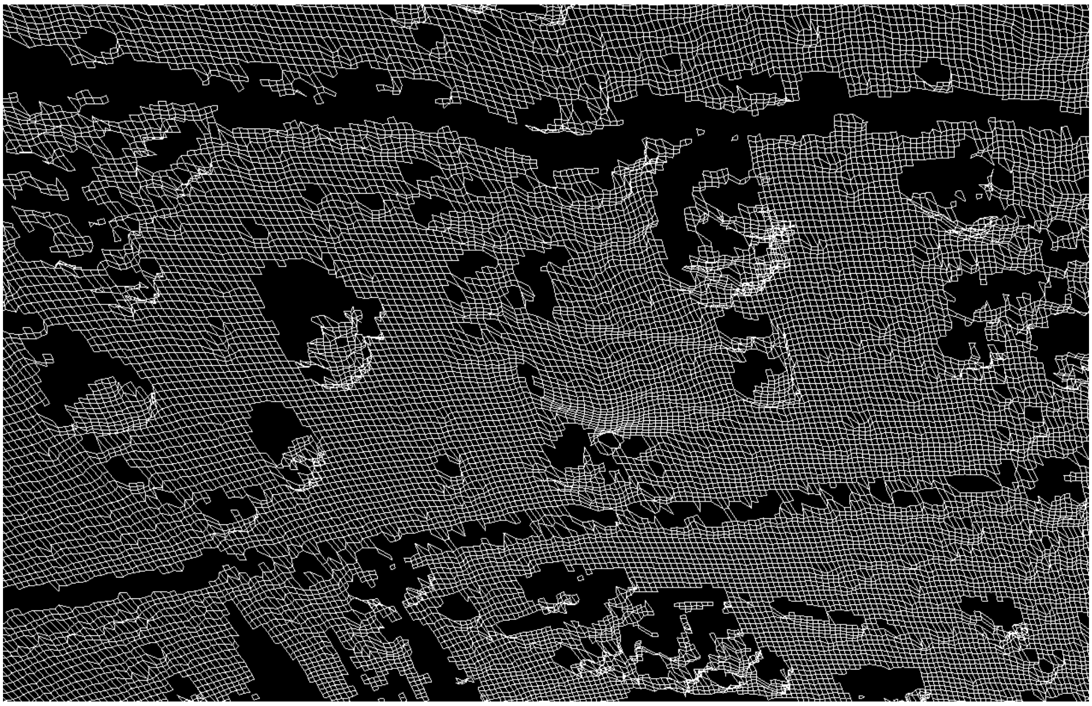


Figure 6. Wire frame constructed from LADAR data

SYMPOSIA DISCUSSION – PAPER NO: 12

Author's Name(s):

Mr. Alan Steinberg, Utah State University, USA
Robert Pack, Space Dynamics Laboratory/Utah State University, USA

Question:
Range data and image data were precisely rectified in this application. How difficult is it to merge data from different platforms?

Author's Response:
The ability to co-register data sets is more straightforward if you have the same sensor types. With different sensors it is difficult to have such a precise correlation.

Comment:
You can see how knowledge evolves over time by observing and understanding the estimate of knowledge over time.

Comment:
By running the contour map of sensor performance back over a period of time you can see your ability to observe or be observed.

NATO Task Group on Information Fusion

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INTRODUCTION

The Task Group on Information Fusion (TgonIF) is a task group affiliated to the NATO Research Technology Organisation (RTO) / Information Systems Technology (IST) Panel. The task group is addressing the importance and difficulty of fusing the always increasing variety and quantity of information produced by the full spectrum of sensors and sources during the ever changing type of military operations.

The first part of this report is a slightly updated version of the official status report made by the chairman of the task group, Gaetan Thibault from DRDC (Valcartier), Canada, and presented at the 9th IST Panel Business meeting taking place 30-31 May 2002 in Estoril Portugal.

The second part is a sample of examples taken from a course in Intelligence for OOTW given by WO1 Dave Steer, Defence Intelligence and Security Centre, Chicksands, UK. All names and references in these examples have been changed for security reasons.

OBJECTIVE

The Objective of the group is to identify, develop, improve and evaluate JDL Data Fusion level 2 (Situational Assessment) and level 3 (Threat Assessment) related information fusion capabilities within the context of an Multinational Intelligence Cell (MIC) in support of a Combined/Joint HQ deployed in operational level Peace Support Operations.

The focus of the task group stays strict to this objective meaning that the dissemination part of the intelligence cycle, including HCI, presentation and visualization issues, is not a part of study of the task group.

MEMBERSHIP

The members of task group is a mixture of developers, scientists and military advisors from the seven member nations: Canada, Denmark, France, Germany, the Netherlands, UK and USA.

The task group has held meetings hosted by the nations regularly twice a year starting October 1999.

ACHIEVEMENTS

The task group will complete its work by the end of 2003 and the results include:

- A Peace Support Operations scenario (Main Event List)

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

- A Multinational Intelligence Cell (MIC) Conceptual Model levels 0, 1 and 2 (Rational Rose)
- A Multinational Intelligence Cell (MIC) Functional Model
- A subset of the MIC internal Functions and Sub-functions which are of most interest to intelligence staff
- A detailed list of prioritized Functions and Sub-functions
- Physical models of few selected Functions and Sub-functions
- Identification of emerging technologies to solve MIC problems
- A shared Web site for the Task Group members containing documentation of all achievements and relevant information.

THE INTELLIGENCE CYCLE

To transform information to intelligence a number of processes are taking place:

- Collation
- Evaluation
- Analysis
- Integration
- Interpretation

Of these processes, Analysis and Integration are identified to be of most interest for the follow on task group, Task Group on Information Fusion Demonstrator. Here functions from the prioritized list mentioned above will be implemented in order to demonstrate their usefulness for the Intelligence Analyst.

EXAMPLES

Information to be handled in OOTW are at the moment mainly of textural form either as structured reports or free text. When handled be the analyst in the collation process different visual tools are used like incident overlays, link analysis diagrams and pattern analysis plots. These are afterwards used in the analysis and integration process.

CONCLUSION

The work of the Task Group on Information Fusion is almost completed and the results will be carried over to the following Task Group on Information Fusion Demonstrator.

SESSION 5 – PLENARY DISCUSSION

Questions to Col. (Ret) Alward

- Col. Alward was asked to provide his perspective and answer questions based on his experiences.

- Different perspective than Col. Johansen, with experience commanding information support, including J6 – information and communications. In general, commanders do not have to make instantaneous decisions. It is a methodical and deliberative process. The commander needs to have a good battle staff. That battle staff needs to have information.

- Most nations use the continental staff system including J1-J6(9): J1– personnel, J2 – intelligence, J3 – operational, J4 – logistics, J5 – plans organization, J6 – communications and information systems. There is a rhythm to the battle group. There are set events that happen around the clock. The commander gives his staff guidance and the staff then tries to articulate that guidance into a plan. They come back with suggestions and alternative plans. They cannot do that without good information. There is a need for information to flow from organizations and nations fluently.

- At an intelligence conference, several commanders who had been in conflicts said their single most critical problem is lack of information. Part of the problem is a lack of sharing information between nations. A way to sanitize the information for transmission in needed.

- Experience in NORAD battle staff in the J6 role, in Boden as the CO of communications unit, in CENTAG was J6 with a large distributed staff. In all cases visualisation was needed to make sense of the information and distribute it around the observe-orient-decide-act loop.

- Command centers do not have the latest in equipment. What is in the lab now is about 2 or three steps from what is in the field.

- Developers must look at the whole command center process from the top down. Where does the application fit into the command process?

- We have heard a lot about automated aids to decision models. What do you think about pre-designed systems? Does the commander want to be bothered with asking for information, or should the information be expected to be flowing?

- In most of today’s command centers it would be the ultimate goal to have systems and process that predicted your needs and had information available for you, as you need it. It would be nice for the commander to not have to ask for it. Often the commander is not the one who wants the information, it is his staff who need it in order to be able to prepare alternatives to present to the commander.

- The procurement process in the military is so slow right now that it takes about 5 years to get new systems into the field.

- NATO was set up to against a defined adversary. Now the understanding of potential antagonists must be less certain. How does this change things?

- Previously within the NATO community, the battle staff knew exactly what was gong to happen. Things have changed, for example, peacekeeping is now peacemaking. The battle staff needs to be creative and flexible to be able to adapt to a changing environment. Equipment is beginning to get out to some of the field, but often they do not have the tools they need and are scrambling to make something work. There is a need to get public affairs people involved as well as to consider the question of human adaptation.

- We had discussions about operations centers and the distinction between available data and available information. Is it a need for more sensors, or more tools to provide information, or better integration?
- Many operations lack both data and information. The data may be lacking because of a political issue where the data might not have been shared even when it was available.
- It was mentioned that there is a blurring between tactical, operational, and strategic levels, as well as the problem of micromanagement.
- There is no longer such a distinct line between tactical, operational, and strategic operations. Much of this is because of the media information flow. Often CNN is showing what is happening at the tactical level, having immediate impact at the strategic level, and may lead politicians to micromanage. It is not the responsibility of the information systems to correct this; rather it should be the discipline of the command hierarchy. The individual should know what they should act on. Intermediate levels of command may fade away as better information and command systems come about.
- There is desire for simple displays and less use of symbols, but NATO requires the use of standard symbols, could that change?
- Although training is necessary to be able to recognize the symbols, there is value in the symbols. They can provide concise information in small space.
- There is resistance to change standard symbols.
- Standards can change. It would be nice to have symbology that was uniform across all platforms and across the services and nations.
- The cycle of technology is much shorter than that of bringing new technology in to the service. Does it make sense to look at deploying civil technology rather than special military builds?
- The procurement cycle is politically slow. The NATO budget cycle can be slowed by one nation if they feel it would benefit their country's businesses to wait. But the process is improving. We would like to think that decisions are made just on what is the best and least expensive alternative, but there are other influences.
- Where can visualisation play the largest role? Where might it be most important but lacking?
- In all the areas of the battle staff: J2 staff needs to see the field, J6 needs to visualize the network space, and J3 needs geography and terrain information. Also, new tools are needed to ensure a common operating picture.
- A good starting point for design of the systems might be workflow management. Are there characterizations of the workflow that are common?
- There are doctrines that say how procedures and processes work. These reference documents can help developers understand the process.
- It is likely that there will be opposition from those in the command center whose roles and functions may be affected.
- How do you inject visualisation technology into the business process of the command post?
- DRDC-Valcartier is doing some of that process analysis.

- At DRDC-Valcartier there are projects looking at the information flow models and 21st century process.

- The final user is NATO, and there is a useful book that details the long-term requirements. It includes information on what will be the long-term requirements, identifies the need and in which areas the requirements are and are not being met. The book is available on the RTA web page.

- If possible, find a way to get out into the command centers. See first hand how they function. Look at more than one, as each person has their own personality and commanders are different.

Approaches to the Evaluation of Intelligence

Massive Military Data Fusion and Visualisation: Users Talk with Developers

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Traditionally, intelligence gathering has involved three areas of technology: sensor and signal processing, database technology and evaluation technology. The current pace of globalisation, the rapid penetration of Internet usage and continuing advances in sensor sophistication mean that vast amounts of information are being gathered, as never before. Traditional intelligence processing methods are feeling the strain.

MEDAV GmbH is a developer of intelligence processing hardware and software. For the past 20 years, we have been engaged in studies and commercial projects for the German Federal Armed Forces and for other German and international government agencies. Our business is to predict and respond rapidly to the needs of the intelligence community. The current trends are clear:

1) An increasing variety of sensors are being distributed over larger and larger areas. The problem is not just the amount of information being collected but the diversity of it. The challenge is to find meaningful ways to integrate diverse information. Humans are not as good at data analysis as computers but they are excellent at pattern recognition. The two should be allowed to complement one another. A visualisation tool should present data in a way that allows humans to recognise the patterns within it – as opposed to presenting only pre-defined patterns. Visualisation software that does not allow users to apply their own pattern recognition intelligence is self-defeating.

2) The Internet explosion means that open source intelligence (OSINT) is becoming as important as the traditional HUMINT and SIGINT. Thus we require language processing and document processing software to complement the signal processing software already available. In particular, tools for the visualisation and summarisation of text are required. Another consequence of internationalisation is the necessity to incorporate Unicode capability into software. However the multitude of *ad hoc* solutions to script encoding already in existence will continue to persist in the future despite the adoption of Unicode.

3) To cope with information overload, it will be necessary to integrate more closely the three domains of information acquisition, storage and processing. In particular, automated evaluation will be required closer to the point of acquisition in order to filter at an early stage the mass inflow of irrelevant information. Likewise, storage must be more closely coupled to evaluation technologies in order to give users easy and intuitive opportunities to interact with their data.

4) In the intelligence environment, information is usually incomplete. For example, the resources necessary to resolve ambiguous or missing words may not be available. And context, which allows information to be interpreted, may also be incomplete. Such *cold start* situations are typical in military intelligence. The conclusion is that information processing algorithms, which are able to process incomplete and fuzzy information, will become the norm.

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

The rapidly changing needs of the intelligence community place severe constraints on the development of software solutions:

1) Hardware and software must be modular, so that parts can be regularly updated without disrupting the whole. Modules must communicate through standard interfaces. Modularity allows a *building blocks* approach to the construction of complex functionality. Because effective visualisation tools tend to have long development times and therefore high costs, modularisation will be essential.
2) It is better to have generic modules that can be configured by the user for varying situations as they arise, rather than specific solutions for specific situations. The user, rather than the factory, should be able to reconfigure a visualisation tool, for example, so that it operates interactively in one situation but automatically in another. Open architectures and the ability to modify software are preferable to proprietary black-box solutions. However, visualisation tools tend to be task specific. The challenge will be to find ways of developing generic visualisation tools.
3) Solutions to intelligence problems involve compromises. In the real world, it is necessary to make do with what one has. Complex algorithms developed in the ideal world of the research laboratory may not be practical in a world of limited resources. It is easy to be blinded by hi-tech solutions when simpler solutions may be more practical.
4) Many of the problems confronted by the intelligence community are also faced by large commercial operations, for example media and finance organisations. It is better to use COTS tools where these are available, rather than “re-invent the wheel”. COTS products make sense if they reduce costs and inventory without compromising quality and security.

Over the past 20 years, MEDAV has developed integrated intelligence processing packages, that acquire, automatically evaluate, archive and interactively evaluate both signals and text documents. The archive is the hub of the architecture. Automatic evaluation serves two purposes - it filters out the mass of irrelevant information but it also serves to enrich the incoming signals or documents with annotations that assist subsequent evaluation.

Different processing and visualisation modules can be incorporated into this general architecture according to need. In studies with the German Federal Armed Forces, we have developed a variety of speech processing, text processing and visualisation tools. While it is true that “a picture tells a thousand words”, we find that users need to have different views over the same data. For example a graphical display of a military command structure can be usefully complemented by a simple tabular display of other information. However, neither display by itself is adequate. As another example, a graphical content summary of a text document may be useful if the document is large but for small documents (or parts of documents), the user may prefer textual summaries.

It is helpful to distinguish three types of display; 1) traditional static predefined displays, 2) augmented reality displays (where interactive iconic and textual information are embedded in realistic terrain images, for example) and 3) virtual reality displays (where the user becomes part of the image). We still have much to learn about how to use all three effectively. The development of effective visualisation tools depends on a keen understanding of the psychology of vision. The conclusion is that the results of fundamental research into human visual processing must be fed into software development projects.

SYMPOSIA DISCUSSION – PAPER NO: 14

Author Name: Dr. Ing. Hans-Joachim Kolb, MEDAV, Germany

Question:
What statistical pattern recognition is being used in regards to email?

Author's Response:
No features concerning content of the messages are being used, just behavior, such as time elapsed from getting an email to answering it, or the size of the message.

Question:
Is there any special storage or computing being used for the high volume?

Author's Response:
No. If you calculate how much space you need, you find you can get a great deal of data on one disk. If you are successful in finding an area of interest in an image it makes sense just to keep the area of interest.

Visualization Techniques for Intrusion Detection

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INTRODUCTION

This paper reports on the experiences of using interactive animated 2D and 3D graphics in an Intrusion Detection (ID) Analysts Workbench prototype. Visualization techniques allow people to see and comprehend large amounts of complex data. Graphics are used to assist with the ID investigation and reporting process by helping the analyst identify significant incidents and reduce false conditions (positives, negatives and alarms). Visualization is then used in reporting incidents to a broader senior level audience. Complex patterns are clearly displayed over time in an easy to understand and compelling manner. Initial evaluations of the prototype have been positive, and a second development stage has been initiated.

ID ISSUES

Large numbers of events are generated by network intrusion detection sensors; however not all these events are malicious in nature, not all malicious events are applicable to a given network environment and, perhaps of even more concern, certain malicious events can be missed.

There are several emerging trends in enterprise networking that are making traditional signature based intrusion detection more challenging. The increase use of very high-speed lines and more prevalent use of encryption technology are a challenge for the intrusion detection community. As the data collected becomes larger in volume, or the increasing dependence on traffic pattern anomaly detection as a workaround for payload encryption becomes more widespread, the amount of data the analyst must cope with increases.

Through the use of various types of detection tools and techniques, including signature based network intrusion detection, anomaly based network intrusion detection, and full packet capture, a better picture can be formed. The analyst is able to fuse this data and gain a more comprehensive insight into what is truly of malicious nature.

The massive amounts of data involved in this type of thorough multi-source analysis make it infeasible for most organizations. The significance of the events contained within the data can often only be determined by scanning the huge amounts of data looking for subtle and sometimes unexpected patterns and correlations.

This investigative process is required in order to place the events around an alarm in context and to assess if further action is required, but the process is labor intensive. Fused logs for a short period can easily contain tens to hundreds of thousands of records. Tools are needed to help accomplish this investigative task in less time.

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

Another issue is that network ID sensors are not always effective for detecting new exploits or for activities that span many weeks and / or multiple network systems. To detect and investigate these types of activities requires the analyst to review extremely large amounts of packet level data.

A related problem is in reporting the attacks and the nature of those attacks to senior managers. This is important in order to raise awareness and provide an understanding of the need for information technology security in industry and government. Without this senior level understanding and support, obtaining security funding can be challenging. The output of most ID processes can be cryptic, and inaccessible to non-experts.

SOLUTIONS

Two graphical consoles have been built to evaluate the usefulness of visualizing intrusion data. Figure 1 shows the Intrusion Detection Analysts Workbench. Up to 2,000,000 event records or more can be displayed and analyzed in multiple concurrent dynamic charts. Each event record includes fields such as source and destination IP, port ID, alarm code, date, time. The charts are scaleable so that, for example, a bar chart showing number of events by destination IPs can easily display ten's of thousands of IP addresses. The charts are also linked. Selecting events in one chart will highlight those events in all the other charts. So for example, selecting events associated with one type of alarm will cross reference those events in the source IP bar chart, and the destination IP bar chart. The analyst workbench is used to investigate, isolate and prioritize events. It was evaluated in a side-by-side test with existing methods and proved to be a significantly faster method. The workbench makes use of the commercial off-the-shelf Advizor product.

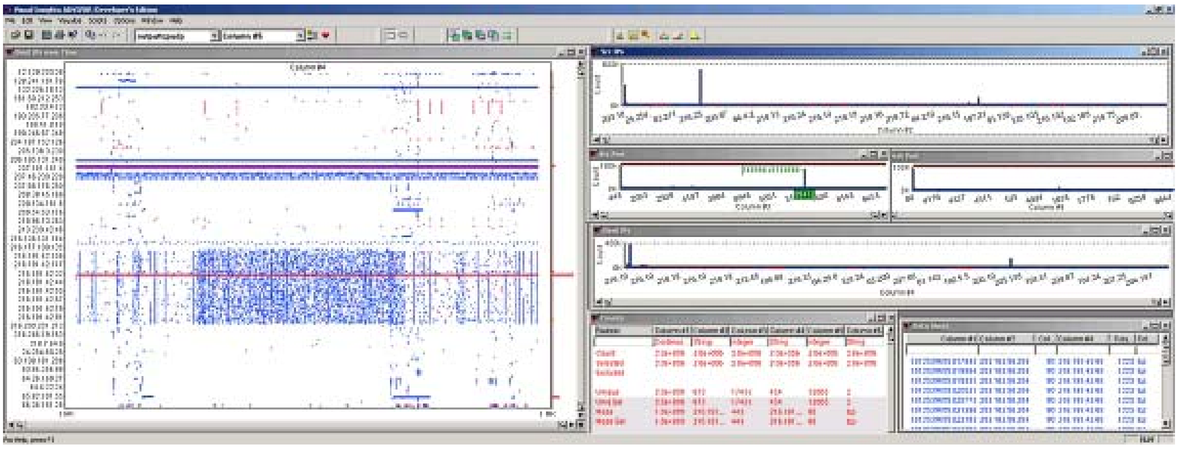

Figure 1: Intrusion Detection Workbench with 2M TCP and UDP Records.

The Analysts Workbench graphical tool can concurrently display the raw packet or alarm data as well as output from analytical tools that, for example, filter events or compute statistical metrics.

Figure 2 shows the Animated Incident Reporting component. It is used to report intrusion activity to senior management, and is designed to show the significance and nature of the events without overwhelming the viewer. The objective is to clearly see who did what to whom and when. A number of interactions are supported including filtering and an adjustable playback speed. This component was evaluated in a series of presentations to senior levels of government and industry.

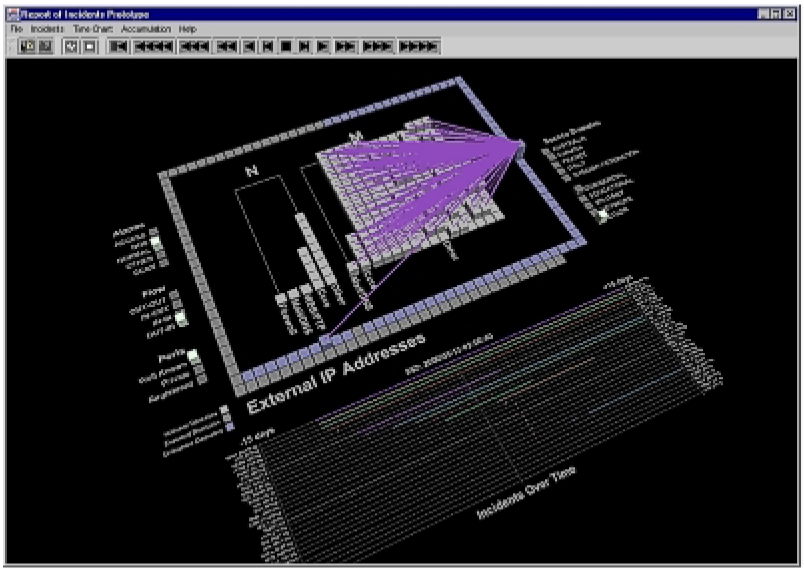

Figure 2: Animated Incident Reporting.

FUTURE DEVELOPMENT

Future work involves two separate but related streams:

The first is the expansion and integration of the two visualization tools to create a seamless intrusion detection visualization workflow environment. Given that intrusion detection analysis is often only part of a systems administration function, time is a consideration. The more effectively the visualization tools can be adapted to fit, and enhance, the human decision making process (orient, observe, decide and act), the more incidents can be effectively assessed and escalated or discarded in a shorter time period.

The second is work on migrating the tools towards an anomaly detection capability through the use of raw network data along with the fused intrusion detection alarms to gain a more comprehensive view into the network.

CONCLUSION

People excel in detecting patterns and identifying relationships when data is presented visually. Extremely large amounts of data can be viewed and compared. This is a useful ability for the ID analyst.

Experience with the visualization methods used in this work has lead to observations and recommendations for developing new methods.

Initial evaluations of the prototype have been positive, and a second development stage has been initiated. The objectives of this second stage will be discussed in the paper.

SYMPOSIA DISCUSSION – PAPER NO: 15

Author's Name:

Mr. William Wright, Oculus Info Inc, Canada
Presented by Ms. Pascale Proulx, Oculus Info Inc, Canada

Question:
What type of methodology was applied in the design of the visualisation?

Author's Response:
User consultations.

Comment:
The system is ten times faster than the previous system that did not use any visual display at all.

Comment:
These display techniques would be useful for all statistical data such as traffic jams.

Question:
Is it possible to transfer the knowledge of the operator into rules for the system to automate the process?

Author's Response:
It may be possible to recognize the patterns, but it is important to investigate more to see what is generating the pattern. For example, a pattern that initially appears dangerous may only be a virus definition update.

Question:
In advance of developing this system, was there consideration of mathematical methods that maybe amenable to clustering and statistical analysis?

Author's Response:
There is a trade off between the math and the visual analysis, as well as between implementation time of the math and algorithms and human interaction. There is research going on in this area right now.

Comment:
Change detection might be important to an analyst.

Question:
There are clustering techniques that could be applied, but require a large amount of training data to make the systems work well. How much data is available for training?

Author's Response:
There currently are not many full data sets. There is a conference in LA that puts hackers against professions, but that produces a data set that is not necessarily typical. Also, networks are dynamic, so constant retraining is required.

VITA in Use: Technology Watch

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INTRODUCTION

The potential wealth to be discovered from mining large data sets or electronic text files for nuggets of knowledge is an alluring prospect. Textual displays, however, do not lend themselves easily to the task as the results still require reading and analysis before the analyst/user can acquire new knowledge from the information therein. Visual displays, on the other hand, attempt to perform some of the preliminary cognitive analysis.

VITA, a "Visual Interface for Text Analysis", is a 3-dimensional paradigm to identify the relations found among meanings or concepts represented in the elements in large text corpora. The paradigm has been realized as a working software application used to direct computer-based document searches. It allows a user, via mouse and keyboard action, to interact with search mechanisms – e.g. search engines on the Internet, such as Google and AltaVista - to present visually the sets and relationships of documents. VITA has control features that allow visual clustering of like documents, thus enabling quick refinement of the search process. The visual features of VITA also support the observation and investigation of the, sometimes unexpected, relationships among documents.

VITA can also be used to help in reducing document search complexity. Originally conceptualized as a response to the problem of comprehending the results of large computer-based document searches, VITA has the potential for broader applications in text mining and knowledge discovery. One such application is Technology Watch.

"Tech Watch" is a methodology used to identify technology trends and make strategic investments in science and technology research and procurement. It looks for strengths, gaps and trends within the national and international technology scenes to incorporate into long-term planning. Defence R&D Canada is investigating various tools for potential use in their Tech Watch project and proposed that VITA demonstrate its applicability for this problem. This paper shows how VITA responded in the practical situation and discusses how it might be adapted to future Tech Watch problems.

FEATURES OF VITA

Built as a "bolt-in" application that accepts a standard search engine and generates an interactive display, VITA parallels the IST-05 Reference model closely [see figure 1].

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

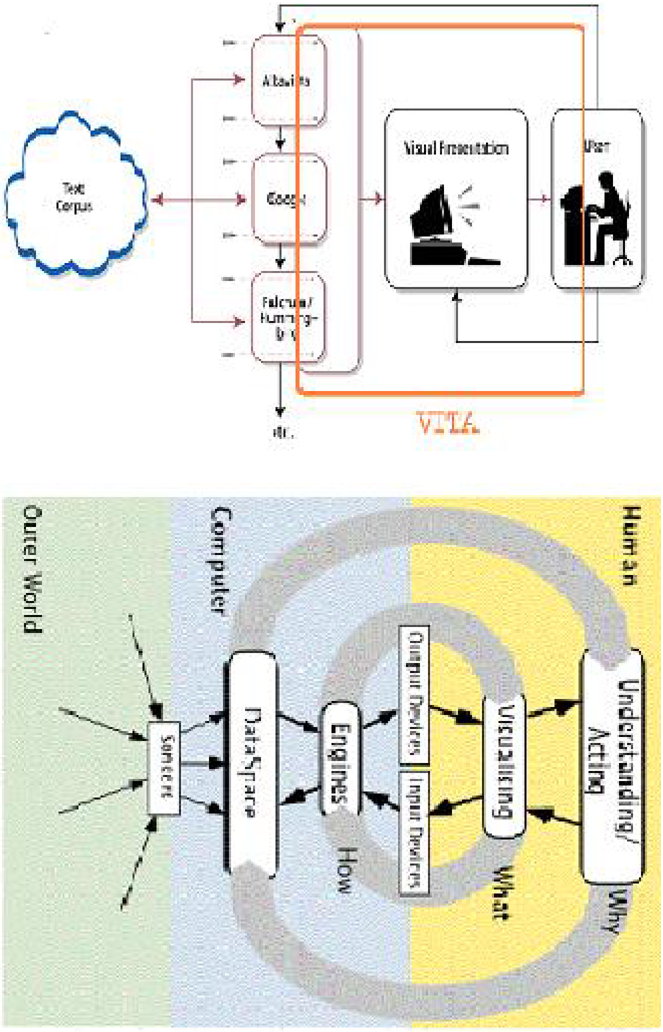

Figure 1: VITA Follows The Standard IST-05 Reference Model.

There are four suggested functions, as per the IST-05 Reference Model, that a visualization system such as VITA could be applied to, controlling or monitoring, searching, exploring (screening) and alerting. The VITA system has shown varying utility based on the function or task that is being performed, with the initial results reflecting the greatest use in the exploring or screening of a data set. Each function is also influenced by other factors such as the specificity and applicability of the query set; the detail and nature of the tagging of the elements of a dataset; and human factors related to subject matter expertise, an understanding of the task, and an understanding of the strengths and limitations of the visualization tool.

VITA allows a user, via mouse and keyboard action, to interact with search mechanisms such as search engines on the Internet, e.g., Google or AltaVista, to present visual displays of documents sets of potential interest. VITA has control features that allow visual clustering of like documents, thus enabling quick refinement of the search process. The visual features of VITA also support the observation and investigation of, sometimes unexpected, relationships among documents.

VITA has been developed as a research testbed to identify better methods of visualizing relevant document clusters and identifying their relationships. As such, there have been various prototypes created as different ideas emerge. VITA presently exists in two versions: VITA-delta and VITA-epsilon. VITA-Delta is written in Visual Basic 6.0 and is a more elaborate, but scale-limited research-oriented

Epsilon is written in C++ and is faster and more robust. As each has its strengths, both were employed in the Tech Watch project.

TESTING VITA FOR TECH WATCH

Two approaches to evaluate VITA as a potential Tech Watch tool were determined. The first was to employ a defence-technologies taxonomy to determine how it would be mapped in an open source context. The Canadian Defence R&D Program taxonomy was mapped to the U.S. Defence Technology Area Plan (DTAP). The entire taxonomy was then searched on a sub-set of Canadian sites. For this test, the VITA – epsilon version was used.

The results of the mapping, shown in figure 2, display the relationships between the two taxonomies. The selected example, missiles, is a component of a number of areas of research. It is easy to see, in this figure, which technologies are well addressed, and perhaps more importantly, which are not well addressed or not addressed at all. In practice, VITA serendipitously shows the “holes” at as easily as the “doughnut”.

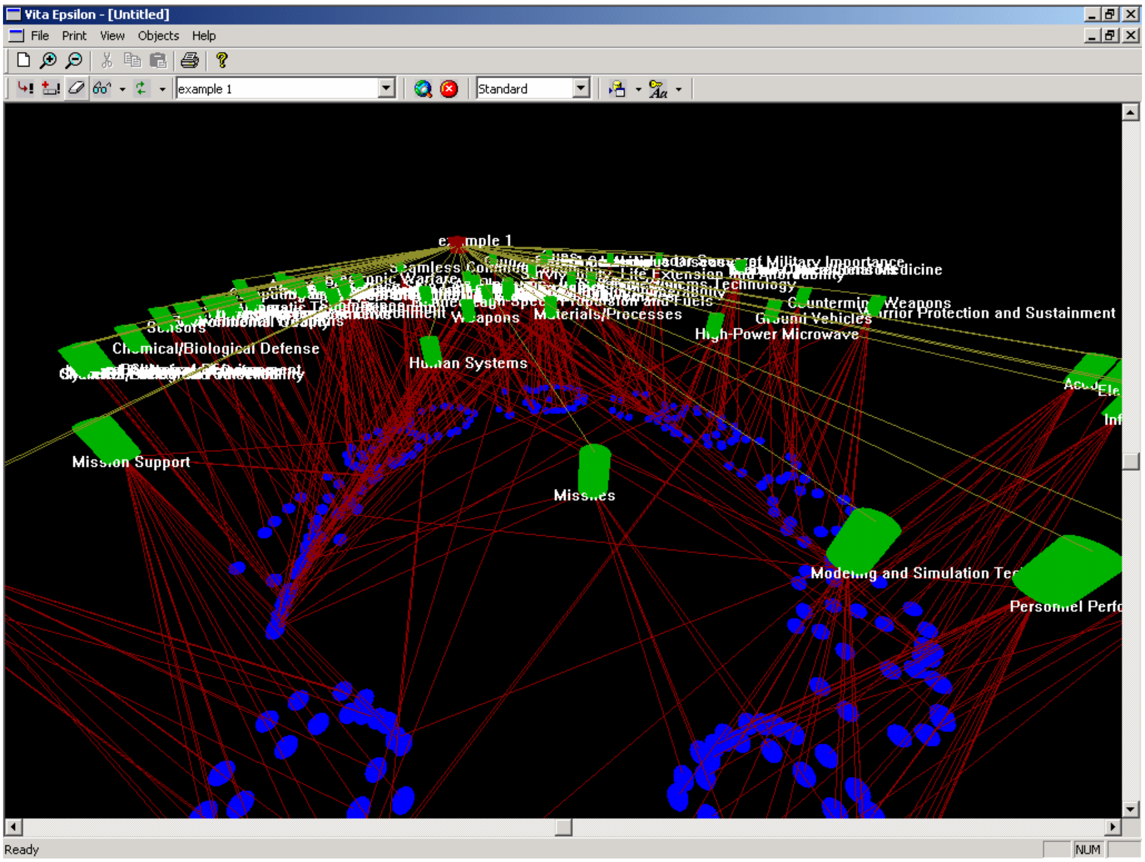

Figure 2: The more robust “production” epsilon version of VITA was used to map the defence taxonomy against all existing Canadian Defence R&D projects. Green cylinders show the technologies and concepts in the taxonomy. Blue spheres show specific R&D projects that relate to those concepts. Linkages are shown as red lines.

The second test used VITA-delta to search for a specific example taken from the taxonomy. Canada’s National Research Council website was queried for documents connecting fuel cells and air weapons systems.

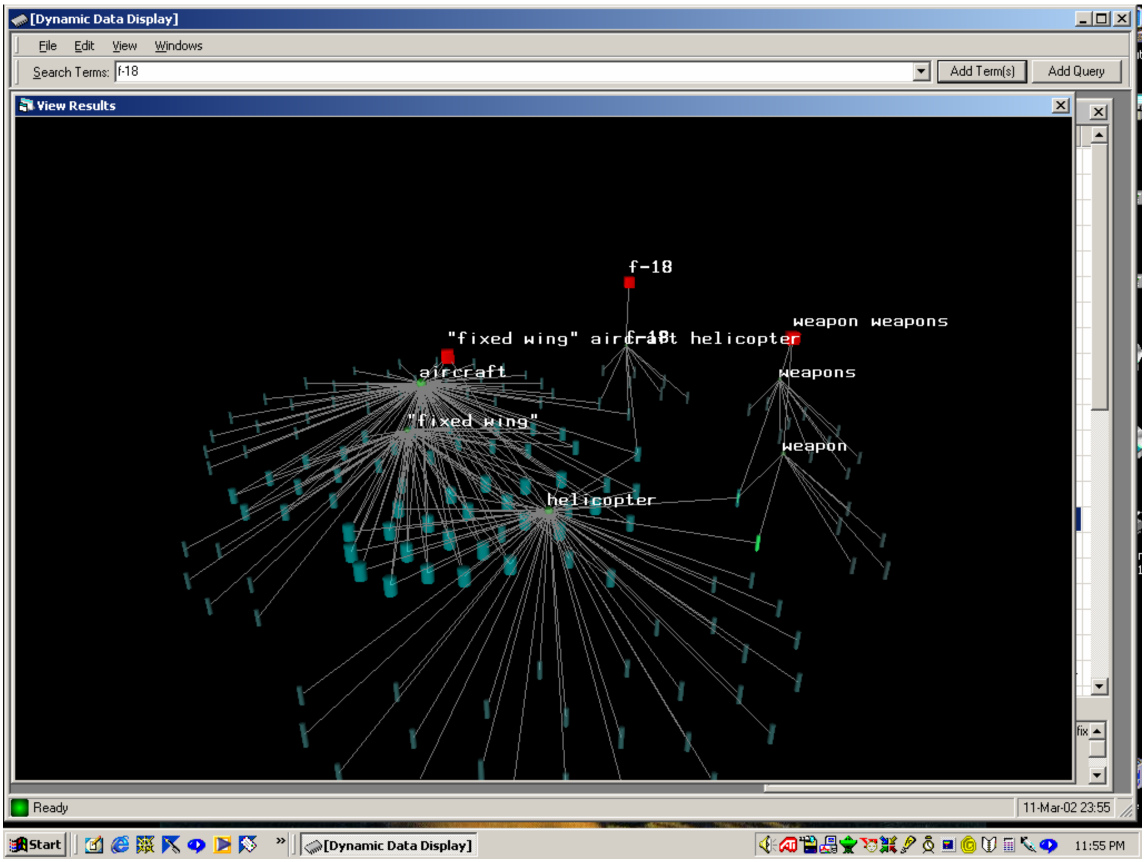
Search Terms: f-18

Figure 3: VITA session showing a series of progressively more refined queries concerning aircraft uses of fuel cells and related work and interest at the National Research Council of Canada.

The taxonomy shows:

Air Platforms (DTAP broad term)

- Air Weapons Systems (CA Thrust 13e)
- Aircraft/Weapon System Compatibility (CA Project 13ec)

Fixed-Wing Vehicles (DTAP narrow term)

Rotary-Wing Vehicles (DTAP NT)

Integrated High-Performance Turbine Engine Technologies (DTAP NT)

Aircraft Power (DTAP NT)

- Advanced Power Sources (CA Project 13gf)
- Advanced Portable Fuel Cells (CA Project 13gj)

High-Speed Propulsion and Fuels (DTAP NT)…

We derived search terms for queries and probes were derived from this segment. The search proceeded as follows:

The first query was
Aircraft, “fixed-wing”, helicopter....
This yielded a filled field of returns. But the query

Weapon weapons system…
showed only a slight intersection with any part of the previous query, and none with ***fixed wing***.

The two intersects with ***helicopter*** only showed superficial connection with the topics in question and it was thus concluded that little or no aircraft weapons work is being done at NRC. As the F-18 is Canada’s primary fighter aircraft, the term was used *as* a probe to confirm the result of the search. Nothing was returned, confirming the earlier inference.

CONCLUSIONS

The preliminary tests seem to indicate that analysts might find VITA useful to research major corpora and to confirm or dis-confirm information concerning the activities described in that corpus and, second, their conceptual inter-relations.

Further experimentation is required to determine the applicability of the VITA as a tool for Tech Watch. This could be accomplished by a targeted search of a structured database using sections of a more detailed taxonomy or thesaurus.

The delta version is now installed in small practical applications, for user testing. Following several months, the development team will select features for inclusion in the C++ [epsilon] version, for production use.

SYMPOSIA DISCUSSION – PAPER NO: 16

Author's Name: Dr. Zack Jacobson, Health Canada, Canada

Question:
In the search process does the user apply ontology?

Author's Response:
No, there are some built in, but the real ontology is the clustering.

Question:
Does the application use one search engine at once?

Author's Response:
In theory the number of search engines used is limited only by processing power.

Question:
Do you see a value in using multiple engines?

Author's Response:
A large difference has not been noticed. Google has been found to produce good results. Hummingbird has also been used with this system, and is a good alternative as it also returns good results and the html is stable.

Comment:
It is interesting to see the 3D connections, which have many similarities to the latest brain research. This system could have many applications where the associations and connections within a dataset is the important information to be brought out.

SESSION 6 – PLENARY DISCUSSION

- The user should determine which information would satisfy their needs in a situation. This will have an impact on how the information is extracted, how information is presented, and how the system is designed.
- Without models of the users' needs, developers lack guidance.
- Be careful whom you call a user. You cannot decouple all the variables, such as the operator, the politics, and the technology.
- Get away from the user as some entity. There are many types of people who use and learn in different ways. The person in front of the system may have difficulty defining their needs, or they may be different from what they will need in the future.
- Trying to define the entire process can take a very long time. Conceptual process modeling is important; the pitfall is that a psychologist will look from that perspective, whereas a technologist will have another. Consider the human element, training, and resources, and use task-oriented design.
- Often users go beyond actually defining their requirements. Users should be able to tell you what they would like to see and how. However, often when asked what they want, they will suggest something they have seen. Users are key in defining the requirements, but then is should be turned over to people who have the expertise in developing the system.
- Everyone has been talking about before the system is in use. You need to have the system developed so that the user can decide what they want at that time and present it in the way they want. Systems need to be flexible. The user's need is not static; a static design will be too rigid even if it has been designed with user input.
- Often a user who is involved with use of a system in place will describe his needs and requirements in the context of the existing system. Sometimes they might not be the ones who can step back and actually look at the desired results, since it may not be the same process or series of tasks that will necessarily provide those results.
- If you are just improving an existing system, users working continuously with developers works very well. When you are going to a new system, changing it from the conceptual view, users should not be the only group that is involved.
- There is a need to consider the inductive reasoning. When a user has been looking at a map he will remember some of it, and for a changed situation maybe only the changes need be highlighted. Can the system have knowledge of what the user really knows?
- It is only recently that systems have been open enough to let the user freely navigate. There are still limitations, i.e. security.
- People and users tend to learn as they go. Change is the only constant in the development process. Your requirements when you need the system, and the requirements of the system are different.
- In the future systems have to adapt with various users. You cannot design a system for each and every person.
- Interfaces could be personalized, for example putting in your smart card and having your preferences there.

- Time to develop – if you deal with someone who says exactly what he wants right now, it is designing for the last war and is not forward looking. What has to be known is what invariants exist in the system. Keep them as standard as possible, and everything else is replaceable. The Internet is an example of such an evolutionary system. What started as the ARPANET has changed completely, the invariants in this case are things such as the routers and protocols.

- There was an "aha" at the beginning of the Internet. The designers asked them what the problem was, and came up with a new way of doing something.

- The user will simply automate what they have today. The militaries today are trying to do three things; sustain current operations, build tomorrow (possibly just automation), and also building the future (exploring new technologies). It is an interactive process that will take years.

- Avoid putting old systems on new computers.

- Users cannot necessarily tell you what info they are using to perform a task. Consider someone navigating a ship into a harbour mainly visually. If you are trying to design a system to automatically guide that ship into the harbour, it is very difficult to identify the cues they are using to do the job.

- In Syndicate 5 it was found it can be asserted that certain objects can be needed for particular tasks.

- If you have a new resource it brings out new ways of doing things. Jobs that people are doing may be changed significantly by new capabilities.

- Put the functional flow together in a matter that is technology and organisationally independent. After a clear understanding is realised, then consider what technology might be the best alternative, and then talk to the users and see what they want.

- Data sources are also considerations in the requirements of the system.

Improving Campaign Assessment and Decision Making in Command and Control Through the Use of Visualisation Techniques

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At present, no adequate visualisation tool exists to support command teams in situation assessment and selection of appropriate courses of action. Research, intending to counter a gap identified between technology and the human operator, is being conducted to understand the psychological processes underlying campaign planning and situation assessment. Through a better understanding of the underlying psychological processes, it may be possible to design the most appropriate visualisation techniques to support the operators' mental models of the scenario.

Humans are very effective at representing large amounts of highly complex and multivariate information visually. Research has shown that memory for previously shown visual material is very accurate and much better than for textual material (Anderson, 1995). If incoming information is organised and linked to existing knowledge, enhanced meaning is attributed to the links. Providing visual information in a framework, as described above, will facilitate processing and comprehension (Macklin, Cook, Angus, Adams, Cook and Cooper, 2002). Visualisation technologies can aid humans in perceiving and processing information. This in turn will enhance their ability to understand, co-ordinate, share and act on information (Sands, 2000).

Visualisations have the potential to guide our perceptions of data by facilitating the identification of interrelationships. Visualisations should enable the user to interact and cope with large amounts of data. The visualisation should allow the human viewer to extract information from a vast source of information, draw conclusions and make predictions related to the command environment. The research being carried out by QinetiQ Centre for Human Sciences, aims to develop visual metaphors to support command and control tasks, with the overall objective of visualising the battlefield more effectively. By enhancing military command and control teams' situation assessment, consequent decision making and selection of appropriate actions can be facilitated.

The approach, that needs to be taken in developing appropriate visualisations for command teams, should begin with understanding how command teams make their situation assessments and how visualisations could be formulated to enhance such processes. User characteristics, decision requirements, user tasks, heuristics and circumstances of use/constraints depicting the command environment need to be considered in the proposed system/display.

In essence, visualisation is presenting information in a format that facilitates the formation of internal representations. The format of these internal frameworks can aid human cognition because they provide a visual structure that allows information and knowledge to be organised. In a complex and dynamic military setting, these can be of particular use, where comprehension of relationships among sets of

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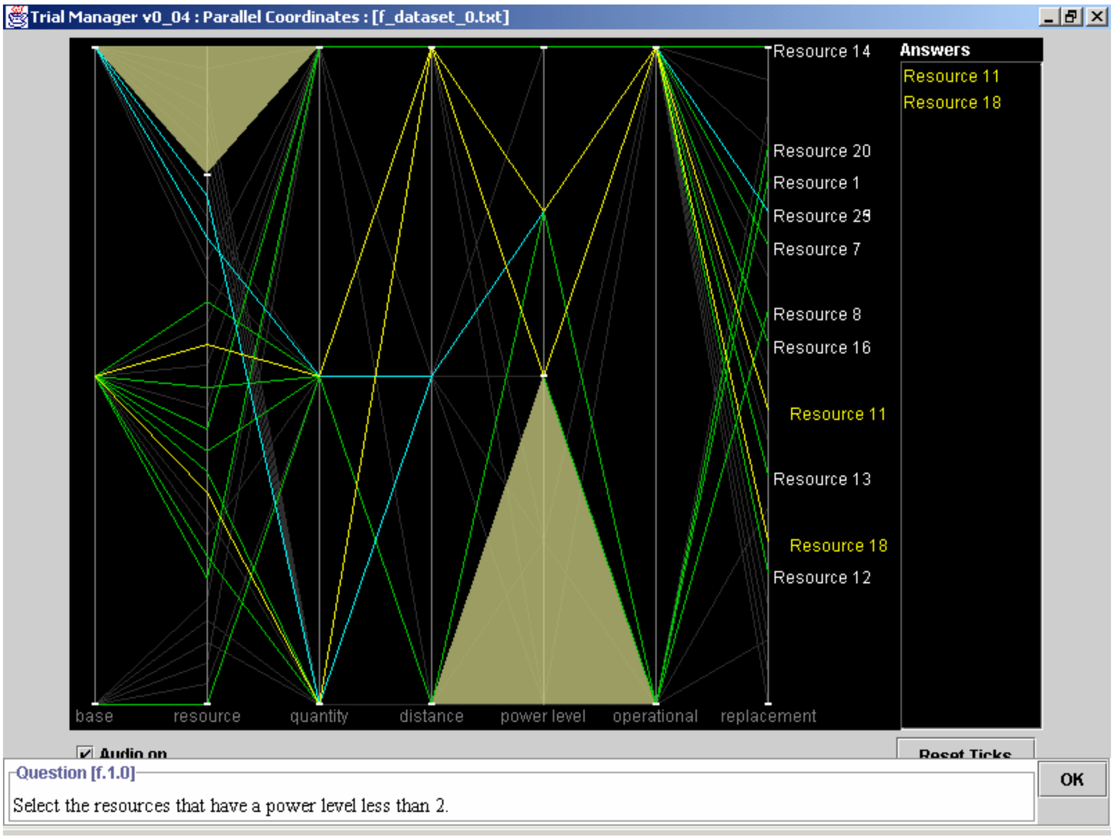
variables is crucial in order to comprehend important domain-relevant information (Goldman and Petrosino, 1999).

It is essential for newly designed techniques to successfully support users in task performance. Fundamentally, appropriately designed visualisations will only support users engaged in situation assessment and command and control that they have been designed for (Macklin and Dudfield, 2001). The design requirements for visualisation need to address the way that the proposed design will influence the social interaction across the command team. A poor or clumsy visualisation could undermine the process it aims to support. Any poorly designed visualisation tool, that robs the decision making process of cognitive resources and social process of time to communicate, will augment the conditions for failure (Macklin, Cook, Angus, Adams, Cook and Cooper, 2002).

To find out what information and cues are needed to support naturalistic decision making in a complex, dynamic environment, it is essential to develop an understanding of how operational staff, actually make decisions. This can be achieved through conducting Critical Decision Method (CDM) interviews with military personnel. Researchers (Cook and Cooper, 2001) used this approach in a cognitive task analysis exercise and responses were coded using a framework adapted from one developed for previous research into socio-cognitive processes in command teams. Responses were coded into statements arranged under four higher order categories of Cognitive Factors; Social, Organisational and Role Related Factors; Contextual Factors; and Time and Resource Management Factors. The results from the qualitative analysis support the view that the visualisation process in command teams, is likely to be a socio-cognitive process along the lines identified by Vertzberger's (1998) model of military decision making.

The issues highlighted from CDM interviews provide a basis for designing a campaign visualisation tool. These in conjunction with a collection of experience-based heuristics, can be embedded into structured templates. These templates can then be used by visualisation designers as part of a formal methodology to develop effective visualisations. Drawing on empirical evidence, sets of alternative visualisations can be designed and prototyped. Each visualisation will support a particular set of tasks. The next stage of research being conducted by QinetiQ will consider how best to present such visualisations. Evaluations have been conducted on the prototypes using cognitive walkthrough techniques involving representative end- users. Observations and comments have been fed into the final stage of prototype design. Exemplar visualisations, at the current stage of development, can be seen below. It is these visualisations that will be trialed to evaluate their effectiveness as a tool for supporting situation assessment. It is anticipated that preliminary findings will be available for presentation/discussion at the Workshop in September.



Answers
Resource 11
Resource 18

Question [f.1.0]
Select the resources that have a power level less than 2.

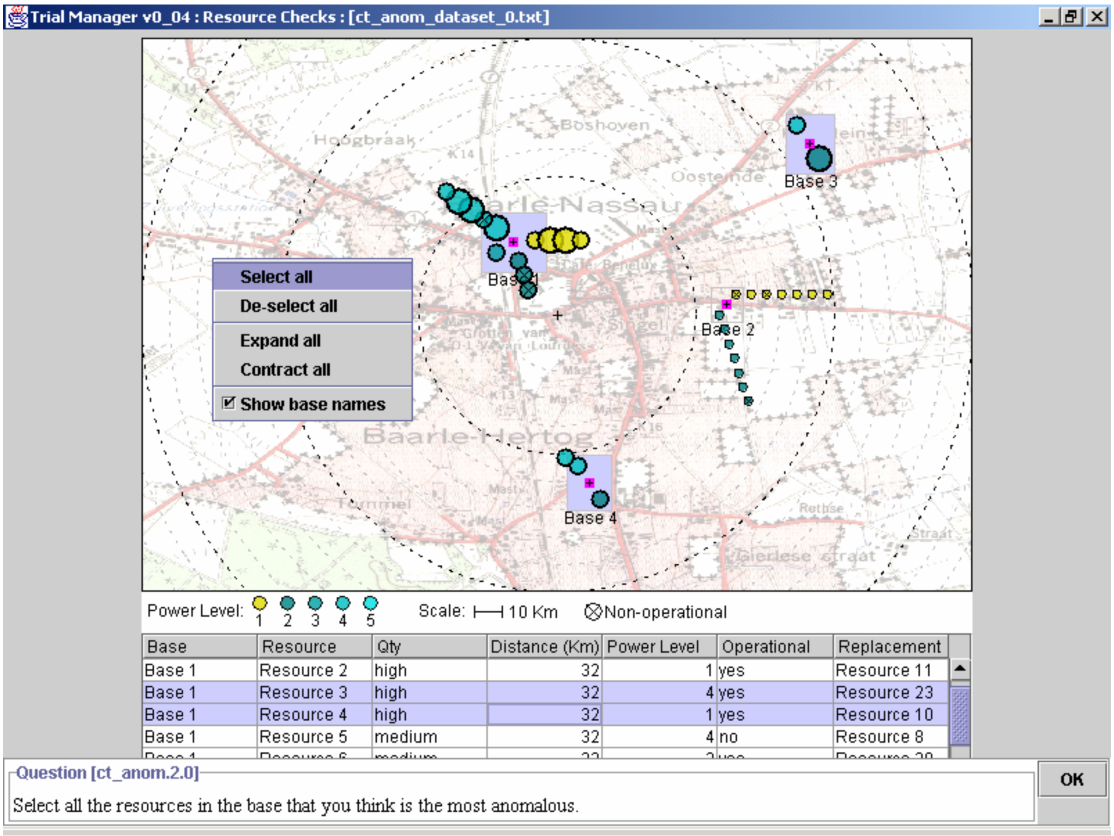
EXEMPLAR VISUALISATIONS

Parallel Co-Ordinates Visualisation

This visualisation presents a filter-based display showing several dimensions relating to the resources. Information concerning resource labels, quantity, distance, power levels, operational status and replacement options, can be displayed.

The main features of the Parallel Co-ordinates visualisation are as follows:

- Resources are shown as lines crossing discrete points on scales for each category (bases, quantity etc.).
- Categories are shown in columns which is labelled at bottom in grey (base, quantity etc.).
- All resources are labelled on right side. Resources depicted in white indicate they are unselected, once selected they become yellow.
- Category indicators can be moved up and down to eliminate/ restore resource information. Once an area has been eliminated, the area becomes shaded by grey.
- Unselected lines (resources) are shown in green. Once these are selected they become yellow in appearance.
- Resources can be highlighted. The highlighted resources are shown by blue lines.
- The visualisation has an audio function that allows a warning bleep to sound when tick marks have been correctly clicked on.



Base	Resource	Qty	Distance (Km)	Power Level	Operational	Replacement
Base 1	Resource 2	high	32	1	yes	Resource 11
Base 1	Resource 3	high	32	4	yes	Resource 23
Base 1	Resource 4	high	32	1	yes	Resource 10
Base 1	Resource 5	medium	32	4	no	Resource 8

Question [ct_anom.2.0]

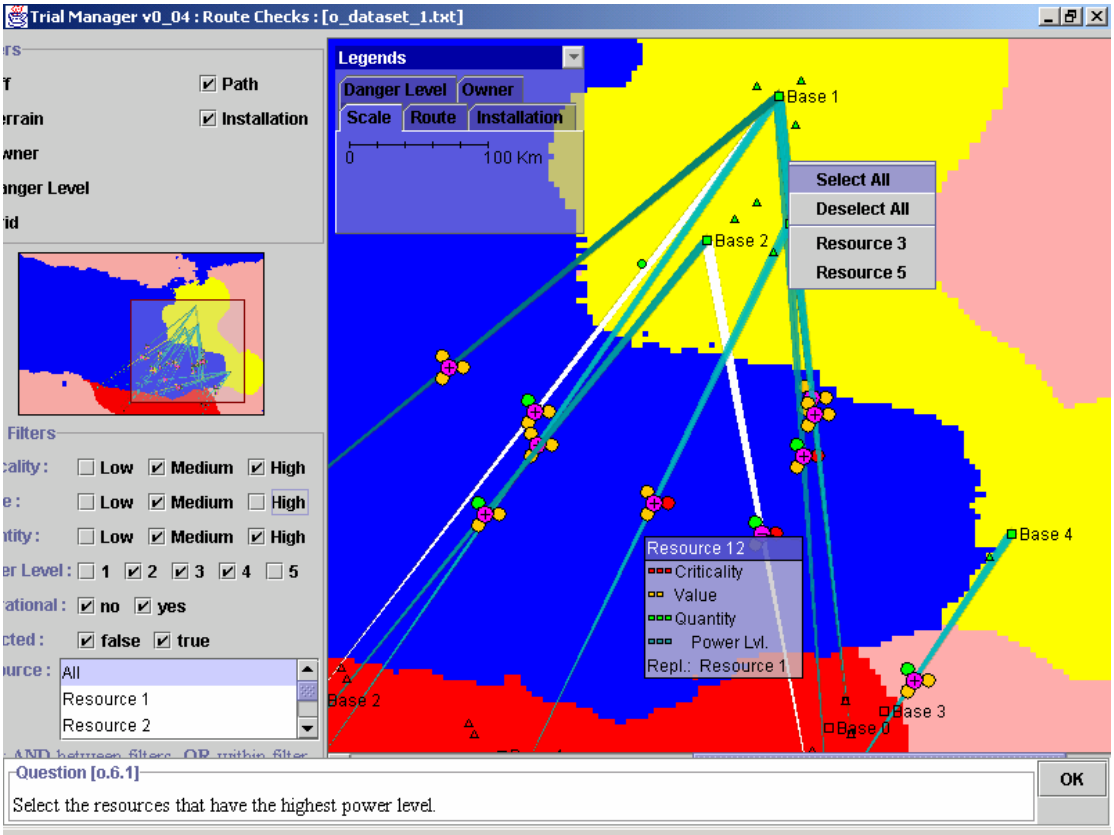
Select all the resources in the base that you think is the most anomalous.

RESOURCE CHECKS VISUALISATION

This visualisation presents a map-based display showing the locations of resources at differing bases. Information is presented regarding the quantity, power level, distance and whether operational of given resources. This visualisation also has the facility of indicating replacement resources.

The main features of the Resource Checks visualisation are as follows:

- Bases are shown as clusters of circles surrounding a pink square.
- The pink square is used for expansion and contraction to show all or a few of the resources.
- Expanded bases are shown as ‘arms’ of circles radiating from the pink square.
- Each circle represents a resource.
- The actual location of base is depicted by the location of the pink square.
- Non-operational resources have a cross in the circle.
- The size of circle represents quantity of the resource.
- Power levels of circles are represented by colour code.
- When resources are selected the information appears in a table below.



Trial Manager v0_04 : Route Checks : [o_dataset_1.txt]

Question [o.6.1]

Select the resources that have the highest power level.

ROUTE CHECKS VISUALISATION

This visualisation presents a map-based display showing the routes that resources take from different types of friendly bases to enemy bases. Information is presented regarding the value, criticality, quantity, power level and whether operational. There is also the option of showing different backgrounds such as terrain, danger level and ownership.

The main features of the Route Checks visualisation are as follows:

- Base numbers are shown on the map.
- A Legends panel, shows five sets of information on Danger Level, Owner, Scale, Route and Installation.
- A Danger level legend is shown by display danger in varying colours. These are as follows: no danger- dark green, low danger- light green, medium danger- yellow, high danger- orange, very high danger- red.
- An Owner legend is displayed to indicate whether base is neutral (territory pink), enemy (red) or friendly (yellow).
- Base types are depicted using different shapes. A SAM Site is shown by a triangle, a power station is represented as a circle.
- A Route legend shows each resource as a tapered line with the colour indicating power level rated 1-5 (yellow to blue). Half way along each line is a circle cluster showing quantity, value and criticality of resource colour coded to indicate low, medium or high. At the centre of the cluster is a pink circle, which can be used to activate the pop up window.

SYMPOSIA DISCUSSION – PAPER NO: 17

Author's Name: Ms. Liz Fricker, QinetiQ, Farnborough, UK

Question:
Visualisation is a very broad multidisciplinary effort. How does this research give us guidance?

Author's Response:
This research is attempting to create guidelines as to what elements should be included in a display and where different elements fit.

Question:
How do the features of the organic displays map to the information?

Author's Response:
The legs map to the locations and the size.

Question:
Have these interfaces been presented to a command and control user group?

Author's Response:
Yes, users from across the services have been consulted. It has been an iterative interaction, with the cognitive walk through being the first stage and the “wow viz” being developed taking their comments into consideration.

Question:
How are data with different degrees of uncertainty due to the fog of war displayed?

Author's Response:
This has not been specifically addressed in this system yet.

Click here to view PowerPoint presentation; Press Esc to exit

Transformation of Geographical Information into Linguistic Sentences: Two Case Studies

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Information can be communicated at three levels, i.e., the syntactic, the semantic and the pragmatic level. Since the pragmatic level is related to the application of the data, transformation of information from the lower level representations to the pragmatic level can reduce the amount of information to be processed by the receiver and speed up the perception of the information. For example, assume a display showing a submarines position relative the terrain surface. Since the distance along six axes must be evaluated, i.e., ahead, backwards, port, starboard, up and down, the presentation of the numerical values along the axes must be carefully designed in order to communicate the information unambiguous to a human operator. The first part of the present paper shows how fuzzy logic can be used to design the kind of instrument considered. The second part of the paper shows how the zone of safety around the submarine, the uncertainties of the terrain model and the submarines position can be modelled as fuzzy regions and how the topological relations between this kind of regions can be described in natural language sentences.

Based on a perception study we found that the perception of "long distance" is related to the frame of the map. The experiment did show that people associate the term "long distance" to two points when the distance between them is 40% of their maximal distance in the display. From this experiment we have designed an instrument to communicate the degree of risk so that a bar gets length 40% of its maximal length when the risk is on the boarder between low and high. From the knowledge of the speed of the submarine and the tactical assessments the degree of risk is modelled as a fuzzy membership function. In that way the distance from the vessel to the terrain surface can be visualized as the degree of risk along the six axes considered. The distance corresponding to the boarder between low and high risk is marked by its numerical value at the 0.4 level of the risk bar.

The second part of the paper describes a method to generate natural language statements about topological relations between fuzzy regions. The methodology, which relies on the fuzzy 4-intersection, is a generalization of the crisp 4-intersection of Egenhofer and co-workers. From the computation of the similarity between the fuzzy- and the crisp 4-intersection the natural language statement, i.e., the linguistic variable, is derived. The linguistic variable contains a semantic part which gives an immediate association to a crisp relation and a quantifier which indicates the strength of the relation. Since the derivation of the linguistic variable depends on the definition of the boundary of the fuzzy regions, a method to compute fuzzy boundaries is presented. A simulation experiment demonstrates the properties of the proposed methodology, and it shows how the linguistic variable relates to an inclusion index. An example illustrates how some level of action can be associated to the linguistic variable, which is applicable in course control of moving crafts, in military applications or in other kinds of operations where the level of warning or action depends on the topological relation between the fuzzy regions.

Since processing spatial information often entails dealing with features which are inexact in some sense, the problem of dealing with non-exact objects or classes is of considerable practical importance in geographical information systems (GIS). Despite that the phenomenon of the real world often are non-

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exact, the crisp model is widely used in GIS. The limitation imposed by the crisp model or the two-valued logic is recognized in geographical information and several other disciplines like soil science and engineering, in areas of application like object-oriented databases, and data mining. In the literature there are several attempts at defining topological relations between non-exact regions, i.e., fuzzy regions. The difficulty in the extension of the crisp topology to the fuzzy case lies in how to pick out the suitable generalization from the large number of approaches. Imagine some kind of field operation. Due to some tactical assessment, for example in a military operation, the area of interest is assumed to be classified according to its accessibility. If we apply the crisp model and classify the different parts of the area as accessible or not, we can imagine the difficulty in drawing the line between the two classes. In some cases there may be regions which clearly not belong to the one or the other group. If we introduce the degree of accessibility, i.e., we apply the fuzzy model, we can make finer distinctions between the different parts of the area. Let us extend the example and assume that we have a moving craft and a security zone around it. The craft and its zone can be modelled as a fuzzy region B with the membership in B decreasing from 1 to 0 as the distance from the craft increases. The membership function can take different parameters as arguments like the speed of the craft, the accuracy of its computed position and the distance from the craft. Let us assume that B is moving towards fuzzy region area A. First we assume that the relation between B and A can be characterized as "B and A are clearly disjoint." As B moves closer to A, the relation gradually changes from disjoint to inside. How the topological relation between B and A changes from "clearly outside" to "clearly inside" is the topic for this paper. A novel idea to model this kind of relations between spatial features is presented. The method applies the bi-combination of the five natural language terms (1) disjoint, (2) touch, (3) overlap, (4) inside, and (5) covers. By the application of qualifiers like clearly, mostly, somewhat and slightly the topological relations between two fuzzy regions can be described as (clearly disjoint), (somewhat disjoint/slightly touch), or (mostly inside/somewhat overlap). The method for the derivation of the linguistic descriptions is founded on a similarity computation to the Egenhofer 4-intersection model.

SYMPOSIA DISCUSSION – PAPER NO: 18

Author's Name: Dr. Jan Terje Bjørke, FFI, Norway

Comment:
Cognitive behavior is specific to an individual, since people interpret displays in different ways. It will be important when developing tools to select the people with the abilities to interpret the displays correctly.

Question:
Were computer games tried out as a measurement and guideline for the design?

Author's Response:
No but it could be useful.

Comment:
Consider adding the dimension of stress and utility. If an analog domain is mapped into discrete symbols the user will recreate the analog situation in their mind. Each user may impose biases on the interpretation of the symbols and will also be influenced by the stress level at the time.

Comment:
It may be beneficial to add a complementary display. Include the safety factor in addition to the risk factor. Indicate the right way to go, not just the wrong way.

Task Switching with 2D and 3D Displays of Geographic Terrain: The Role of Visual Momentum

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ABSTRACT

We were interested in determining if the visual momentum provided by gradual transition between 2D and 3D views of geographic terrain aided task switching. Forty-two participants made judgments about the properties of two points placed on terrain depicted as 2D or 3D displays. Participants performed the tasks in pairs of trials, switching tasks and displays between trials. On half the trials (continuous transition), the display dynamically rotated in depth from one display format to the other. On the other half (discrete transition), a blank screen was shown for the same duration. The results showed that performance improved more for the continuous transition than the discrete transition condition. We argue that this was because the transition provided improved visual momentum between consecutive displays, and recommend the use of dynamic transition when commanders are viewing multiple display windows over time.

INTRODUCTION

A topic that has received little attention with respect to tactical displays is the role of *visual momentum* in user-computer interaction, or the user's ability to extract and integrate data from multiple consecutive display windows (Woods, 1984). Some methods proposed for improving visual momentum include placing perceptual landmarks across displays, overlapping consecutive representations, or spatially representing the relationship among the displays (Woods, 1984). Another method involves gradually transforming one display into another. We were interested in determining if the visual momentum provided by gradual transition helped people when they switched tasks.

For geographic terrain, there is benefit to allowing multiple views of a battlespace, and therefore both 2D and 3D display formats should be made available to the commander. This is because the effectiveness of 2D and 3D displays of geographic terrain depends on the judgment task (for a summary, see Wickens & Hollands, 2000). 2D renderings are generally useful for judging relative position, because the normal viewing angles minimize distortion, while the advantage of 3D views is in shape and layout understanding, because they integrate all three dimensions and allow for features otherwise invisible in 2D view to be depicted (St. John, Cowen, Smallman, & Oonk, 2001; Wickens & Thomas, 2000). This implies that to perform these various types of tasks, the commander will need multiple views.

The commander also needs to switch tasks frequently when monitoring a battlespace. While the display can be changed to match the task at hand, the actual transition from one display to another may still be difficult. Abruptly changing frames of reference (changing views from 2D to 3D and vice versa) can cause disorientation. To alleviate this problem, a gradual transition between 2D and 3D perspectives incorporating animation of viewpoint during task switching may be effective.

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

Objectives and Prediction

Our experiment addressed the issue of whether gradual transition in viewpoint (e.g., from 2D topographic map to 3D terrain viewed from a 45 degree angle) improves task performance relative to discrete transition. To do this, we used two tasks developed by St. John et al. (2001). Tasks required the participant to judge whether one ground location was visible from another (*A-See-B* Task), or which one of two points was of higher altitude (*A-Hi-B* Task). The St. John et al. results showed that the A-See-B task was performed better with a 3D display, whereas the A-Hi-B Task was performed better with a 2D topographic map.

With respect to tasks and displays, our experiment was a replication of the St. John et al. (2001) experiments (in particular, their Experiments 4 and 5). However, in our experiment, we had participants switch tasks across trials to determine whether knowledge of terrain obtained when performing one task in the first trial affected performance on a different task in the subsequent trial. On half the trial pairs, there was a continuous rotation of the space from 2D to 3D views; on the other half, a blank screen was shown. We predicted that the transition would improve performance by providing visual momentum as our participants switched from one task to the other.

METHOD

Participants

We ran 42 participants (22 male and 20 female), aged 19-49 yrs, with normal or corrected-to-normal vision, recruited from DRDC Toronto and the nearby community. Participants were financially compensated for their participation.

Stimuli and Apparatus

Ten different terrain models were created from Digital Terrain Elevation Data (DTED) of regions of Wyoming using Creator/TerrainPro (Multigen-Paradigm, 2001a) modelling tools. Each model represented a 13351 x 11288 m^2 area. Pairs of A and B points were randomly selected for each terrain model, with the following constraints. The points were separated in altitude by 500 m. The distance between points was more than 2000 m. To avoid picking points near the model edge, points were selected from a central 11600 x 10600 m^2 area. For half the A-B pairs, point B could be seen from point A (A-See-B-Yes pairs). For the other half (A-See-B-No pairs) point B could not be seen from point A. For half of the A-See-B-Yes pairs, point A was higher than point B, and for the other half, point B was higher. The same was true for A-See-B-No pairs. Two pairs of points meeting these constraints were chosen, resulting in 8 pairs of A-B points for each terrain model. The terrain models and pair locations were the same for both transition conditions.

In general, 2D and 3D displays were constructed to resemble those used by St. John et al. (2001). The Vega visual simulation system (MultiGen-Paradigm, 2001b) was used to render each terrain model as a 3D display, and an example is shown in Figure 1. MICRODEM (Microcomputer Digital Elevation Models, Guth, 2001) was used to create a 2D display for each of the 10 terrain models with coloured contour lines (see Figure 2 for an example). A 2D and 3D display depicting each of the 8 A-B pairs was constructed for each terrain model, resulting in 16 different displays per terrain model. Each location in a pair was represented by a point superimposed on the map labelled A or B.

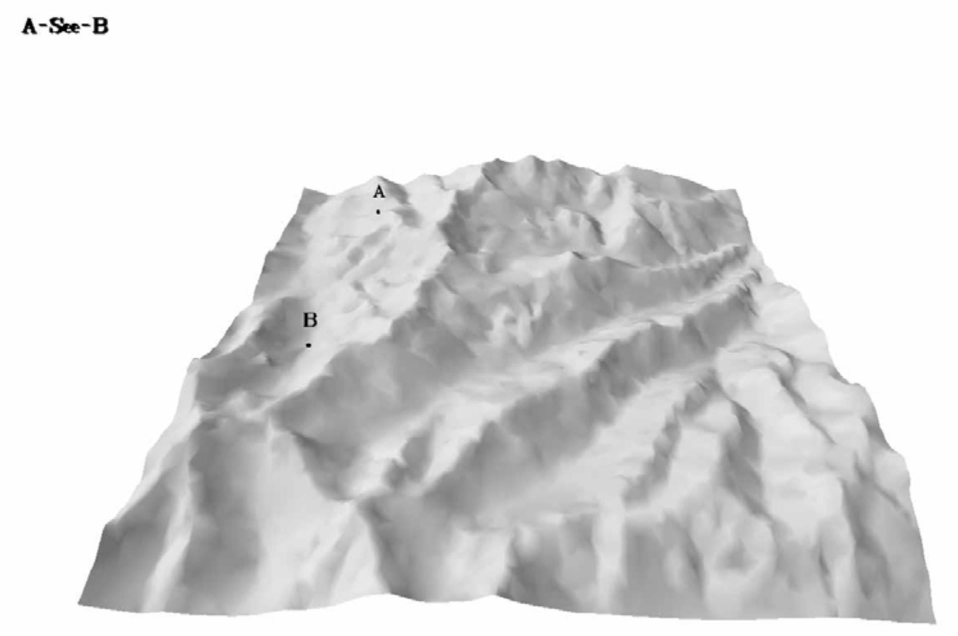

Figure 1: Example of 3D Display Used in Experiment.

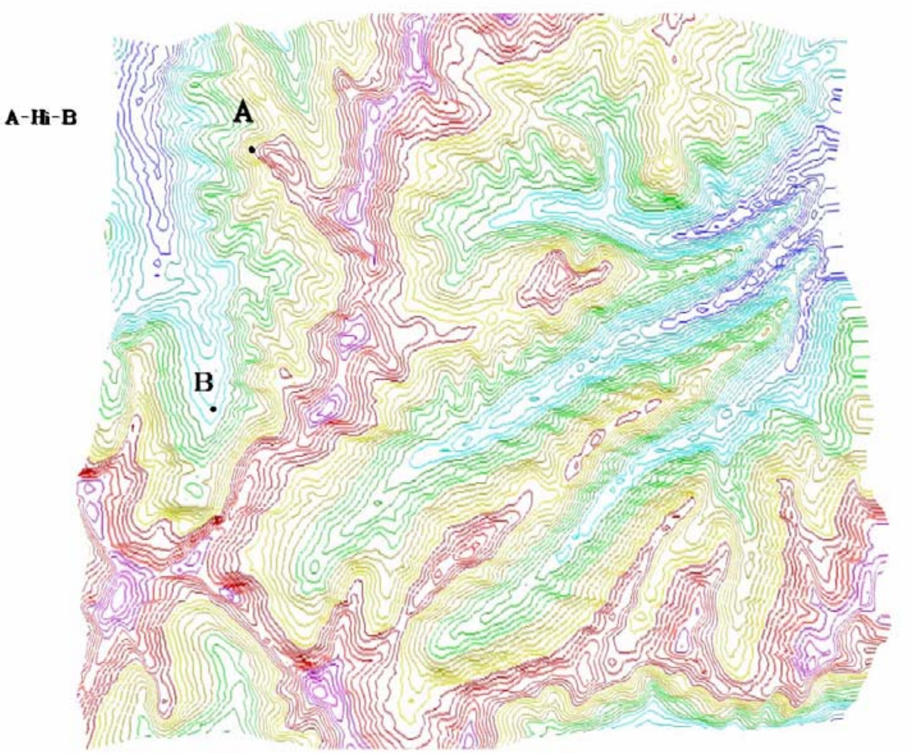

Figure 2: Example of 2D Display Used in Experiment.

The experiment was conducted in a room with dimmed lighting to accentuate visibility and contrast. The stimuli were presented on a 21” (53 cm) Hitachi SuperScan 814 monitor at 1280 x 1024 resolution, and keystrokes and response times were collected by a Windows NT graphics workstation. Participants sat at a comfortable viewing distance.

Design and Procedure

The experiment had a 2 x 2 x 2 x 2 within-subjects design with display (2D vs. 3D), task (A-See-B vs. A-High-B) transition (continuous vs. discrete), and trial (1st vs. 2nd) as independent variables. Dependent measures were response time and accuracy (proportion correct).

Each participant read a brief description of the experiment and signed an informed consent form. General questions about the experimental design were answered. Participants performed two tasks. In the A-Hi-B task, participants indicated which of two points, A or B, was higher. In the A-See-B task, participants indicated whether they could see point B if they were standing at point A. Participants performed each task with both 2D and 3D displays. Participants performed one block of practice trials with a unique terrain model prior to the session for each transition condition.

Participants performed the tasks in pairs of trials. The terrain model and A-B points were the same within each trial pair. For each pair, there was a switch in the display type across trials from 2D to 3D (or vice-versa), and a simultaneous task switch, leading to 4 possible sequences of displays and tasks. As noted above, there were 8 pairs of A-B points for each terrain model, two pairs for each possible response sequence (YY, YN, NY, NN). For each terrain model, we assigned the first A-B pair to trial pairs 1-8 as shown in Table 1, and the second pair to trial pairs 9-16.

Thus, the 16 trial pairs shown in Table 1 were used for each of the 10 terrain models, creating 160 trial pairs. These 160 trial pairs were arranged in 4 blocks (40 trials per block). To create each block, a set of 4 trial pairs was chosen randomly without replacement for each of the 10 terrain models (with the constraint that the 2nd trial of one pair was not identical to the 1st trial of the next pair). The order of the terrain models was randomized within blocks. The ordering of terrain models and trial pairs across blocks was unique for every participant.

Table 1: Trial-Pair Combinations for Each Terrain Model

Trial Pair	Trial 1	Response Type	Trial 2	Response Type
1	2D A-see-B	Y	3D A-hi-B	Y
2	2D A-see-B	Y	3D A-hi-B	N
3	2D A-see-B	N	3D A-hi-B	Y
4	2D A-see-B	N	3D A-hi-B	N
5	3D A-hi-B	Y	2D A-see-B	Y
6	3D A-hi-B	N	2D A-see-B	Y
7	3D A-hi-B	Y	2D A-see-B	N
8	3D A-hi-B	N	2D A-see-B	N
9	2D A-hi-B	Y	3D A-see-B	Y
10	2D A-hi-B	Y	3D A-see-B	N
11	2D A-hi-B	N	3D A-see-B	Y
12	2D A-hi-B	N	3D A-see-B	N
13	3D A-see-B	Y	2D A-hi-B	Y
14	3D A-see-B	N	2D A-hi-B	Y
15	3D A-see-B	Y	2D A-hi-B	N
16	3D A-see-B	N	2D A-hi-B	N

There were 160 trial pairs (identical with respect to order of terrain model and trial pairs) for each transition condition. In the *continuous transition* condition the terrain model gradually rotated in depth from the 2D to the 3D display (or vice versa) from the first trial to the second. The 3D display depicted the terrain model at a viewing angle of 45 degrees with respect to the ground plain. The rotation took approximately 3 seconds. In the *discrete transition* condition, the terrain model was shown sequentially: first using the 2D display, and then the 3D display (or vice versa). A blank screen was shown between the two views for a duration equivalent to the animated rotation in the continuous transition condition. The order of continuous and discrete transition conditions was counterbalanced across participants.

For both transition conditions, each pair of trials was initiated by pressing the space bar. The participant's response on the first trial initiated the transition. For each trial in the pair, the participant responded by pressing a key marked "Y" or "N" (the "1" or "2" key on the numeric keypad), and the participant was asked to respond as quickly and accurately as possible.

The experiment took about 1½ hours to complete, including breaks between blocks of trials. At the conclusion of the experiment, the experimenter thanked and debriefed the participant, and answered the participant's questions.

RESULTS

Response Time

A mean response time for accurate trials was computed for each participant in each condition. (The response time was calculated as the elapsed time from the start of each trial to the participant's key press and did not include the time for the rotation of the terrain model in the continuous transition condition). These data were submitted to a 2 x 2 x 2 x 2 within-subjects analysis of variance (ANOVA) with transition, task, view, and trial serving as independent variables. For brevity we report here only those effects involving transition. Continuous transition produced shorter response times than discrete transition for the second trial in a pair (but not the first), $F(1,41) = 65.17$, $MS_e = 1.08$, $p < .0001$. Mean values are shown in Figure 3. Continuous transition shortened response times more for the A-See-B task (3.58 s for continuous vs. 4.50 s for discrete) than the A-Hi-B task (3.20 s for continuous vs. 3.83 s for discrete), $F(1,41) = 4.34$, $MS_e = 0.79$, $p < .05$.

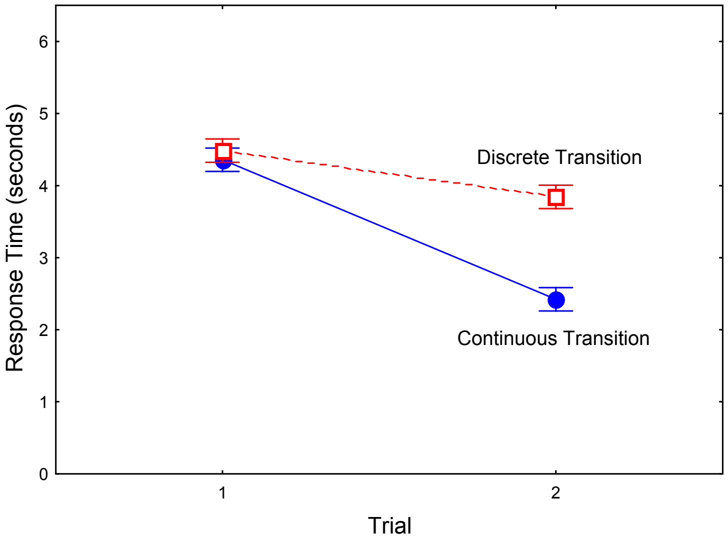

Figure 3: Response time in seconds as a function of transition and trial in pair. Error bars indicate the within-subjects standard error of the mean (Loftus & Masson, 1994).

Accuracy

Each trial was scored as correct or incorrect. The proportion of correct trials was computed for each participant in each condition. These data were submitted to a 2 x 2 x 2 x 2 within-subjects ANOVA with transition, task, view, and trial serving as independent variables. Again we report only those effects involving transition. As shown in Figure 4, continuous transition produced greater accuracy than discrete transition for the second trial in a pair (but not for the first), although the effect just failed to reach conventional significance levels, $F(1,41) = 3.77$, $MS_e = 0.0017$, $p = .059$. Continuous transition increased accuracy for the A-Hi-B task (.94 for continuous vs. .92 for discrete) but not for the A-See-B task (.73 for continuous vs. .74 for discrete), $F(1,41) = 7.02$, $MS_e = 0.0037$, $p < .05$.

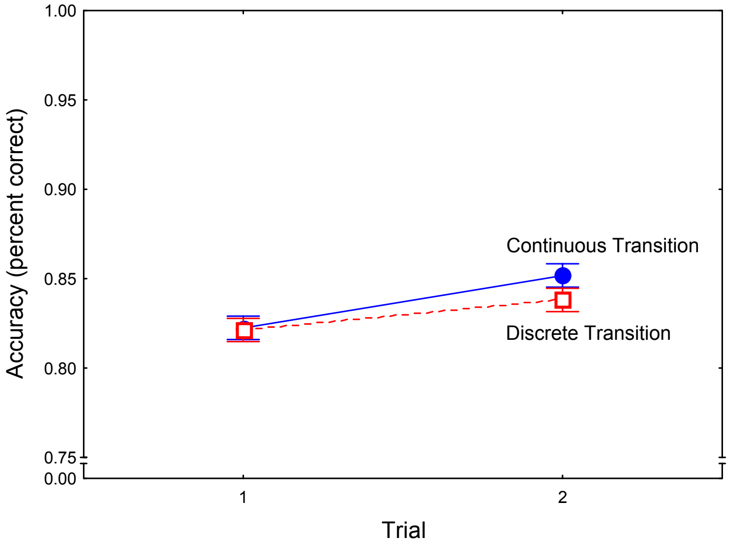

Figure 4: Accuracy (proportion correct) as a function of transition and trial in pair. Error bars indicate the within-subjects standard error of the mean (Loftus & Masson, 1994).

DISCUSSION

In the experiment, participants made a pair of judgments about geographic terrain. For each trial pair, there was a switch in the display type across trials from 2D to 3D (or vice-versa), and a simultaneous task switch, with all four possible combinations of displays and tasks used. In the continuous transition condition, participants viewed a dynamic rotation from a 2D topographic map to a 3D perspective rendering of the same terrain (or vice versa). As predicted, the results showed that a continuous transition between the display types improved performance on the trial after transition relative to the discrete condition. Participants were faster and there was a trend toward greater accuracy on the second trial of the pair with the continuous transition. Presumably, this was because the transition provided improved visual momentum between consecutive displays.

The response time advantage for continuous transition was true regardless of task, although it was greater for the A-See-B task. An accuracy advantage for continuous transition was only observed for the A-Hi-B task. We were surprised that no accuracy advantage of continuous transition was evident for A-See-B, although participants were faster with continuous transition in that task. Continuous transition may help in maintaining the location of the A-B points with respect to the terrain, speeding processing, but not aiding the accuracy of the judgment because that would further depend upon the height of the intervening terrain.

The results indicate that dynamic transition between different views on terrain should assist the commander in a multi-task environment. This may be useful in the design of future command and control and command post systems. The use of dynamic transition is therefore recommended when commanders are viewing multiple display windows over time.

It is possible that because participants viewed the terrain model longer in the dynamic transition condition, the extra viewing time provided an advantage. We doubt that this is the case because participants had unlimited time to view the terrain on each trial. However, as a check we are running an experiment where the time spent viewing the terrain is equalized in continuous and discrete transition conditions. We also plan to investigate whether further rotating the geographic terrain model so that the viewpoint is in alignment with the A-B axis assists in performing the A-See-B task, and whether the dynamic transition provided by visual momentum is still useful in this context.

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SYMPOSIA DISCUSSION – PAPER NO: 19

Author's Name: Dr. Justin Hollands, Defence R&D Canada, Canada

Comment:
Col. Johansen has an intuitive desire for a flexible display. Zooming into a location while leaving the context around the outside of the display was an example of implementing visual momentum in the display.

Question:
What was the reason for not placing the view on the ground at either point A or B?

Author's Response:
This was done in order to try to replicate an earlier experiment so that results could be compared. Future work will look at a greater degree of immersion. It will be interesting to see how close to the actual view point of the position does the user have to be before it is obvious whether one point can be seen from the other, or which is at a higher altitude.

Question:
Could the user be shown both the 2D and 3D views at once and given the ability to choose which view to use for which task?

Author's Response:
There is some advantage to showing both displays, but there is the issue of mapping from one to the other.

Comment:
Visual momentum is about the transformation crutch, it does not have to be dynamic in time.

Comment:
There are individual skills related to understanding a 3D display. The experience and training the user has had will influence the ability to interpret the display. In this experiment, users self reported on their ability to navigate. It was interesting that those people who rated themselves higher in that ability actually rated higher in the continuous rotation.

Personal Decision Support Aids for Special Operations

Report of Syndicate One

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1.0 INTRODUCTION

1.1 Criteria

Syndicate 1 identified three criteria upon which to guide its work; the subject must be useful to NATO, it should have a counter-terrorism focus given recent events and it should produce results within 18 months. In response, a concept was developed to provide powerful improvements in capability for NATO teams of special operations soldiers, applicable to counter-terrorism and a diversity of other operational missions. The goal is to facilitate coordinated action within a small unit and to provide improved situation awareness to the individual soldiers.

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

1.2 Counter Terrorism Cycle

The counter-terrorism cycle is comprised of four elements: protection, detection, reaction and restoration. As an example, security at an airport includes physical *protection* measures – such as fences and locked, compartmented areas – as a key component of its design, intended to reduce the risk of terrorism. *Detection* in airport security includes various aspects of personnel screening from the entrance, to ticketing, to passenger area, to aircraft boarding. *Reaction* follows detection; e.g. in the form of Special Operations personnel, highly trained and specially equipped to counter terrorists. Finally, if a terrorist act is successful, one must plan for *restoration*.

Syndicate 1 has chosen to focus on the reaction cycle and the needs of Special Operations personnel.

1.3 Requirements

We have identified the requirements of Special Ops personnel to include:

- Navigation
- Communications
- Information (incl. Intelligence)
- Sensory enhancement
- Protective equipment
- Training and preparation

2.0 SCENARIOS

Several scenarios can be provided to facilitate the discussion and visualisation of the concept.

2.1 Scenario 1: Sniper Elimination

A simple scenario is one in which a sniper has been detected and a squad-sized special operations force is tasked to eliminate the sniper. We postulate that each member of the special force is equipped with a laser range finder, a helmet mounted CCD camera and a Global Position System (GPS) receiver.

Imagine now that we have a display system as for instance a PDA in which it is possible to present 3D fused image of the data from the range finder and CCD image of all the special operations force members. The orientation and awareness capabilities of the individuals will then be considerably enhanced. As we have the position from the GPS receiver, it may be possible to obtain construction data of the building hiding the sniper from some background database. With this information available to the special operations force members together with a kind of pathfinder/path advisor and Line-of-Sight (LOS) calculations, the effectiveness of the operation can be significantly improved, with reduced risk in approaching the sniper. It may also be possible to use a wearable through-the-wall radar, which will alert the soldier to the presence of personnel and movement inside the building.

The PDA system can also be used for communication purposes, for instance for the operations centre to provide confirmation and for synchronising actions among the force members.

Equipment

- Laser range finder
- CCD image
- GPS (direction)
- Through-the-wall radar

Functions

- 3D fused image
- Construction data
- Pathfinder/advisor
- LOS calculations
- Synchronisation
- Movement detection inside buildings

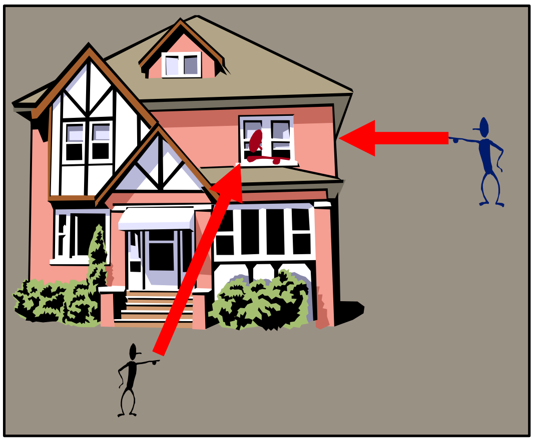

Figure 1: The Sniper Elimination.

2.2 Scenario 2: Hazardous Plant Explosion

The special operations force from the sniper scenario above can handle other tasks quite different from sniper elimination with a modest addition of more equipment.

Consider a case of a situation in which special operations soldiers are tasked to respond to an explosion within a hazardous plant, whether it was just an accidental explosion or the result of a terrorist attack. If NBC sensor equipment is added to the soldiers' equipment, they will be much better capable of assessing the situation and responding in an appropriate and coordinated manner. With the fusion of the data from the imaging, range-finding and NBC sensors, it is will be possible to show the density of the contaminants on a digital map and thus enabling the response team to avoid the most dangerous areas.

Equipment

- Laser range finder
- CCD image
- GPS (direction)
- NBC Sensors

Functions

- 3D fused image
- Construction data
- Pathfinder/advisor
- Synchronisation
- Contaminant location & spread

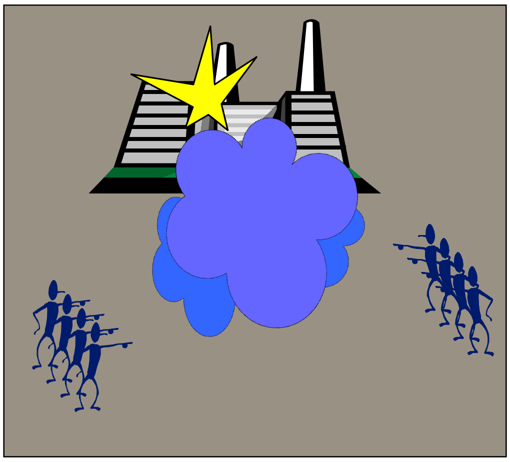

Figure 2: Hazardous Plant Explosion.

2.3 Other Scenarios/Applications

Yet other examples of tasks can be handled by the special operations force with no or only modest additional equipment and functionality: Response to Hijacking or Hostage situations, Minefield crossing, civil disasters or POW interrogations, just to mention few. The last example, POW interrogation, can be easily performed by a member of the special operations force if the functionality of his display system is enhanced with a speech recognition/automatic translation function, whereby the recognition/translation process can be performed at a more powerful computer at headquarter.

3.0 SYSTEM CONCEPT

A concept was developed to provide such powerful improvements in capability for individual special operations soldiers (Figure 3). The goal is to facilitate coordinated action within a small unit and to provide improved situation awareness to the individual soldiers.

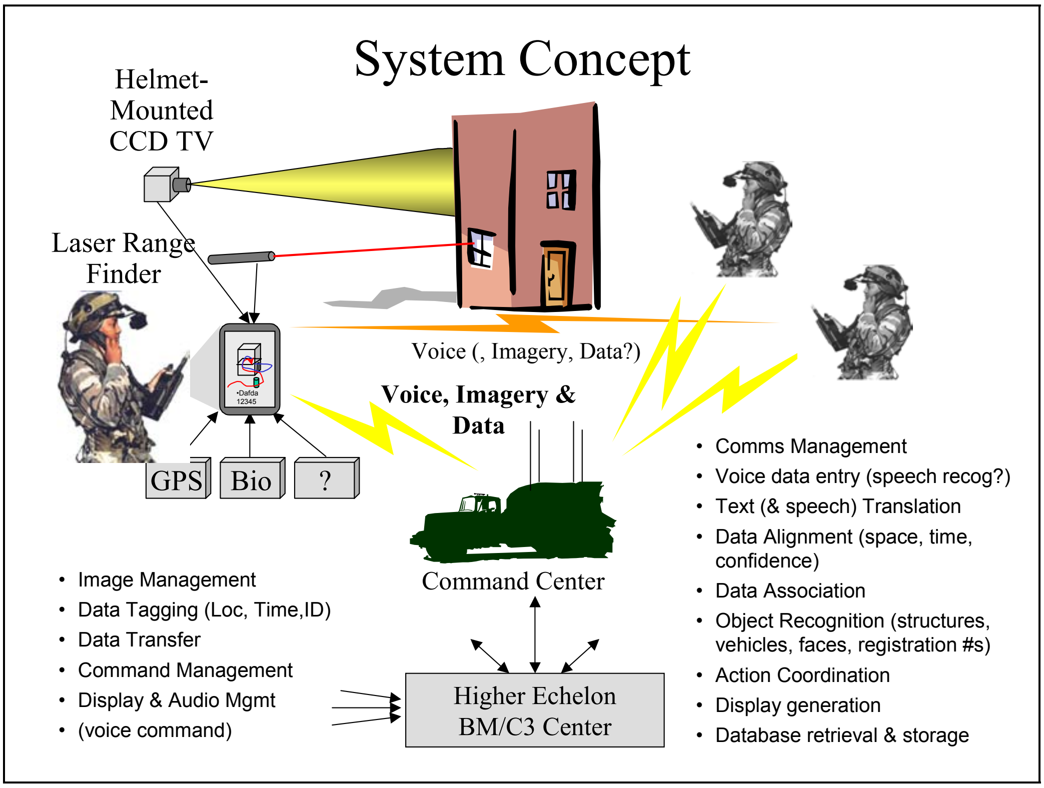

Figure 3: The System Concept.

The premise is that NATO special operations forces typically will be operating in teams, in radio communications with a mobile or deployable command centre. This provides opportunities for sharing information, maintaining a consistent situational awareness and coordination among team member. It also allows much sophisticated information storage and processing to reside at the command centre, reducing the need for the dismounted soldier to carry heavy, power-consuming equipment.

The individual soldier would be equipped with a minimal set of light-weight, portable, rugged sensors. An initial configuration can readily be built from commercially-available, inexpensive components (possibly requiring ruggedization). These can include a CCD television camera integrated with a laser range finder, miniaturized GPS/INS and possibly biometric sensors. Processing, display and voice/data communications can be performed by a standard Personal Data Assistant (PDA), given that the bulk of processing can be performed at the command centre. Enhancements in sensing, navigation and PDA functions can be incorporated as capabilities in these areas become available.

Even the minimal, initial configuration, would provide special operations units a powerful capability improvement. A team of soldiers would be able to share imagery and full three-dimensional views (provided by the pixel-level fusion of 2D TV imagery with laser ranging). Integration of such data among team members and with data from other sensors and databases (terrain, cultural maps, building plans, red/blue force deployment, etc.) would be performed at the command centre and provided to team members by voice or touch-pad request. The PDA display can be used to indicate ingress/egress routes, status of team members and of the tactical situation. Audio can provide alerts and aid in coordinating team action.

The command centre, involving one or more laptop workstations, supports the soldiers in the field with:

- Managing communications with team members and with external entities (other command centres, higher-echelon command and intelligence centres, etc.);
- Voice data entry (possibly to include speech recognition);
- Text (& possibly speech) translation;
- Spatio/temporal data alignment;
- Assigning and maintaining confidence of various information sources and data sets;
- Associating data received from team members, from external sensors, sources and databases;
- Object Recognition within the data from team member (structures, vehicles, faces, registration numbers, etc.);
- Coordinating team action;
- Generating displays for command post analysts and for transmission to team members;
- Database retrieval & storage.

4.0 INPUT/OUTPUT-DEVICES AND SENSORS

Like communications, input and output devices are a serious concern of the system, in that the flexibility and operability of the system depends mostly on these three aspects. On the other hand the plug-and-play input and output devices here enumerated can easily be changed depending on the scenario.

4.1 Input Devices

- **Voice activated control:** To operate the system and initiate communications.
- **Touch sensitive screen:** To operate the system.
- **Pencil shape scanner:** Input for written material.
- **Multi spectral camera:** Visual input device, image enhancer.
- **Laser Range Finder:** Target range assessment; common data registration.
- **Microphone:** Permitting voice communications and alarms in normal mode.
- **Morse Key or SMS (12 key keyboard) (silent mode):** Communications in silent mode.
- **GPS receiver:** Geographical data and common data registration.
- **Storage reading device (e.g. DVD or flash memory):** To maintain consistent real-time databases.

4.2 Output Devices

- **Headphones:** For: team communications, microphone amplification and real-time translation.
- **Intelligent helmet and/or wrist PDA screen:** A visual interface that frees the fighter hands to handle a weapon.
- **Signalling vibrating device:** Signalling system alarms or information arrival.

4.3 Sensors

An initial set of sensors to be integrated with the special operational soldier's equipment can include:

- **CCD camera (still & video, visual band)**
- **Laser Range Finder**
- **Digital compass**
- **Biometric sensors (for status indication, user ID, medical triage)**
- **Optical Character Reader (for document, sign translation via command centre)**
- **GPS Receiver**
- **Accelerometers**

Commercial units of these types are available for immediate proof-of-concept testing. Some have been militarized. Such testing would be followed by an engineering effort to select the appropriate technologies, adapt and package components for battlefield operations.

Enhancements will be determined by the evolving military requirements, CONOPS and technology maturation. Among feasible enhancements in the near-terms are the following:

- **Multi-spectral IR/Visual camera**
- **Range imager**
- **Directional microphone**
- **Advanced navigation aids (integrated GPS/INS)**
- **Radio Frequency Direction Finding (RF/DF)**
- **Integrated Nuclear, Biological and Chemical (NBC) sensor**

Also the system might take advantage of recent developments in light-weight radio frequency sensors, which might be helmet mounted. This can be implemented as a ***Radio Frequency Awareness Sensor (RFAS).*** Functions to be provided may include:

- Passive RF sensor that intercepts comms transmissions in HF, VHF and microwave bands, provides direction finding, triangulation, classification, threat analysis and comms intercept;
- Sensor function utilizing remote transmitters/transmitters of opportunity for close up MTI function and medium range situation awareness (10-200m);
- Sensor function utilizing mm wave integrated transmitter for close-up mapping and target detection (0-100m).

5.0 COMMUNICATIONS AND INFORMATION SYSTEMS

This section briefly describes the specific CIS requirements for coordinating a Special Ops team combating terrorism.

5.1 Information/Data Requirements

With recent improvements in technology, the availability as well as the need for information has increased. Today we are able to supply to the soldier the needed information/data for a safer and quicker operation directly and real-time. The following types of information that will need to be communicated to achieve the proposed concept:

- **Geometric Data:** Needed for better assessment of the operational area's environmental aspects.
- **Architectural Data:** As the previous it gives the soldier knowledge to operate on urban areas or fighting targets placed on buildings.
- **Linguistic / Translation Data:** Needed to get real-time translations of conversations or to understand written documents.
- **Intelligence Data:** To include any other data that can support the mission accomplishment regarding, for example, the characteristics of the enemy or suspicious material.
- **Sensor Referential Data:** This information, like the referred on the next point will supply to the fighter, for example, reference values regarding personal safety and triggering alarms. (e.g. IFF, exposure to NBC agents, etc.)
- **Biometrics Referential Data:** Personal safety issue. Needed for the assessment of personal fighting capacity.
- **Local and remotely updateable data:** As the need, nature and source of information can change during the mission, data requirements can change as well, and regarding this the system has to have the availability to be updated on user request or by the command centre.

5.2 Electronic Warfare Requirements

A personal system like this must address EW issues to ensure the robustness and security of the system and to increase fighting capability. EW provisions of the system must include the following:

The individual soldier's equipment should have integral EPM (Electronic Protection Measures) and possibly could include ESM/Direction finding sensors:

- **EPM:** Minimize the electromagnetic signature of the system, high-speed transmission and low power.
- **ESM:** Medium range electromagnetic source detector.

The Command Centre could provide signal and data processing to support ESM (Electronic Support Measures) and could provide ECM (Electronic Counter Measures) capabilities as well:

- **ESM:** The use of Direction Finding information from multiple personnel equipment will help to build a scenario picture and to detect and locate targets.
- **ECM:** A limited capacity, e.g. to avoid the enemy use of wireless systems, could be provided at the command centre.

5.3 Computational Capacity Requirements

In assessing the data processing and storage requirements, the system is envisioned as operating either as stand alone or integrated in a network. Since portability has its costs regarding weight and power consumption, the system in a stand-alone version would not have all the resources needed (mainly storage capacity), which can be solved when integrated in different level network. Functions to be performed include the following:

Local (Individual Soldier)

It should control the sensors and communications. It needs limited storage capability, low power consumption and to be physically simple and robust.

Mobile Command Centre (Team)

It is the intermediate level of processing. It should process information from several individual systems (data fusion). It should be able of operating remotely an individual system. It can be placed in a vehicle.

Central Capacity (Operational Command)

A backup system located at an operational command and can be as large and powerful as necessary.

5.4 Communication Requirements

Two different needs have been considered in specifying the communication requirements. Voice communications among team members and between the team and command centre tends to be essential for operational coordination. Therefore, team link requirements need to be particularly careful about emitted power.

On the other hand, data links between individual soldiers and the command centre can use new spread spectrum multi-hopping technologies that more efficiently use the spectrum and are more difficult to detect or locate.

As we have considered this system as an evolutionary system, COTS with TETRA standards could be used in early/test versions.

Duplex or half-duplex voice and data link to:

• **Team**	Operational coordination; multimedia information exchange.
• **Command Centre**	Operational coordination; voice / data situation report; receive / acknowledge orders, etc.

Sensor data simplex channel to Command Centre

• **Biometrics**	Reports fighter health vulnerabilities.
• **NBC warfare sensors**	Reports NBC agent’s concentration or threat.
• **Direction Finder**	Transmits information about electromagnetic sources.
• **Multi spectral image**	Transmits operational theatre multimedia visualization.
• **Sound**	(Like previous).
• **Navigational (GPS, INS)**	Reports positional coordinates.
• **System Power alarm**	Reports system autonomy.

6.0 HUMAN FACTORS ASPECTS IN SPECIAL OPERATIONS

6.1 General Aspects

This section briefly introduces the main human factors elements that should be considered in the design of equipment to be used by the Special Ops individuals.

Fundamental to aiding the understanding of the soldier in the field, *information* needs to be presented in a mode that aids perception. Information that can be visualised should be presented in a simplistic and intuitive way. In the environment in which the solider is likely to be operating, influences of environmental factors affecting an operator's performance should be attenuated as far as possible. By use of presentation formats that promote universal comprehension, information should be accessible to all parties involved in NATO operations. It should also be noted that if a universal ease of understanding is captured, training requirements for comprehension of information should be reduced. This will be a valuable time-saving factor in introducing the product to operational forces.

Information provided to special ops personnel needs to be reliable for an operator to place his/hers trust in carrying out the task at hand. This issue should be dealt with at the command centre level and only information deemed dependable should be exported. Compressing the information at the command centre level will also prevent the operator from becoming overloaded with information that is not necessarily pertinent or of value to the mission.

The process for designing the decision aid for Special Ops, needs to be both user- and task-orientated. By ensuring that the development occurs considering user and task attributes, the tool's adaptability and flexibility will be enhanced. The system will meet not only the goals of the individuals, but also the needs relating to the task.

To facilitate the ease of *control* on the system, levels of automation can be compiled prior to the operator entering the environment. If the task environment is likely to involve constraints to the operator's effectiveness, levels of automation could be set to a higher degree than if the environment was perceived as less demanding.

Feedback is an essential process that needs to take place between all parties and all stages of the operation. By ensuring that feedback transpires throughout the *communication* chain, the special ops soldiers and command staff will be kept well informed.

6.2 Further Applicability to Special Ops

Additional special aspects of *information presentation, communication* and *sensory enhancement* must be considered in designing equipment for Special Ops (per Special Ops, Ch. 1.3). Among such factors are the following:

In order to make an information network as robust and survivable as possible, the manner in which information is presented should be limited to presenting only salient information. This compression of information should reduce the risk of a system failing due to overload. Information sources should be compiled to allow for incomplete and partly inconsistent data. If a system is to deal with inferior quality reports it should not cause network damage or break down.

Communication generally occurs on auditory and visual channels. Voice recording and voice exchange play a major role. The above mentioned need for an increase in confidence of the individuals and the reliability of the provided information by feedback, as well as clarification of the source of information, should also take into account scenarios where individuals are absent from their team members and self-responsible. They therefore need particular support while in mission.

In order to facilitate task performance of the individual Special Ops soldiers, unnecessary distraction and task interruption should be prevented as far as possible. Alerts should only be issued if essential to the task in hand.

Navigation support can be carried out in various ways. Besides auditory instructions, visual aids in form of appropriate maps, graphs and textual information/symbology should be displayed on each individuals' PDA. Ergonomic characteristics like readability, consistency, uniformity, adequate colouring, texture, etc. should be taken into account.

When designing the individual soldier's *equipment,* the environmental situation has to be considered. The clothing has to be weather-proofed, be appropriate in regard to anthropo-metrical data, visibility, reachability, movement requirements in general, etc. Physiological data should be transferred to the command centre in order to react in critical situations like illness of, dizziness of and danger for the individuals.

Considering *training* and *preparation* issues for the Special Ops individuals, the importance of the user- and task-oriented design of the equipment must be emphasized. The more the aforementioned human factors elements are taken into account the less training and preparation is necessary. As a matter of course adequate training is inevitable. However, by incorporating ergonomic principles into the design of equipment and tools aids the minimization of effort needed whilst still optimizing task performance.

The individual soldiers and command centre personnel have to be incorporated in the *planning process* for a Special Ops mission. Hierarchical planning, i.e. from rough to detailed has to be supported. Feedback ought to be provided at any single step in the planning process. Database applications and expert systems should be employed to optimize the mission preparation and to support the mission planer as well as the Special Ops individuals. Heuristics might be applied in order to increase familiarity and confidence in the task.

Last but not least, the aspects of understanding/communication in terms of *real-time language translation* have to be considered. Messages back and forth between command centre and individuals should be as universal and as simple as possible. Individual translation facilities might be employed where necessary.

6.3 Applying the VisTG-Reference-Model to Special Operations

The organisers of this workshop, the IST021-RTG007: "Multimedia Visualisation of Massive Military Datasets", have developed a Reference Model for visualisation (*RTO TR-030*). In order to emphasize the importance of visualisation aspects in the Personal Decision Support Aids for Special Operations the various issues for visualisation have been represented in the model.

Figure 4 extracts the core human and computational elements central to the visualisation process. The most important feature of this model is that "Visualising" is something that happens inside the human mind, in support of the human's understanding of a world of data. The data may reside in a machine but they ordinarily represent states and processes in an outer world of interest to the human.

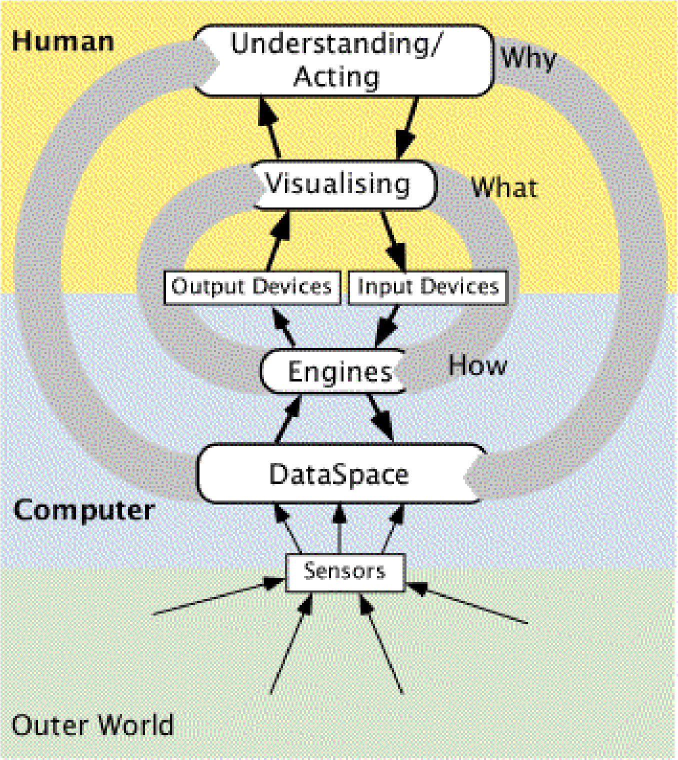

Figure 4: The VisTG-Reference Model.

Visualisation is a human process supported by a corresponding set of processes inside the machines, which are generically called "Engines". Engines communicate with the data in the data space, selecting, manipulation, and perhaps modifying it. The results of the work of the Engines are communicated to Presentation systems, which in turn prepare the data from the Engines for presentation to the user through the physical input/output devices. The Presentation systems also allow the user to communicate with the Engines to determine how they interact with the data space. The machine engine processes and the human visualisation processes communicate through Input and Output (I/O) Devices, which we take to include not only the physical devices, but also all the interaction processes involved with their control and use.

For the Special Ops the model components apply as follows:

- ***Sensors*** are, e.g. camera, Biometrics, NBC, as in Chapter 4 listed.
- The ***Data space*** is comprised by all the information sources stored in the various databases involved in the Special Ops environment.
- The ***Engines*** are Navigators, Explorers, PDA-COTS, etc. that process and provide the information to the users.
- ***Output devices*** are among others displays, headphones and vibrators, whereas ***Input Devices*** are PDA, microphones and touch screens.

All the environmental and operational data have to be represented for ***visualising*** by the human, such as target information, positional and navigational information, site information, orders, sensor alerts and others.

The human who has to ***understand*** and ***act*** according to his mission is the Special Ops individual and certainly the team colleges, team leaders and the commanders.

7.0 RECOMMENDATIONS AND CONCLUSIONS

Syndicate 1 recommends the IST staff this report in the form of a tasking. Specifically:

a) NC3B might develop a concept demonstrator based on the use of COTS with an 18 months delivery date; and

b) A NATO RTB Task Group could be formed to steer development.

In conclusion, the proposed **"Personal Decision Support Aids for Special Operations"** project:

a) Offers a near-term improved capability; and

b) Supports evolutionary development.

8.0 REFERENCES

RTO TR-030: *Visualisation of Massive Military Datasets, Human Factors, Applications and Technologies*, Final Report of IST-013/RTG-002 submitted by the members of IST-013/RTG-002 for the RTO Information Systems Technology Panel (IST), May 2001.

SYMPOSIA DISCUSSION – SYNDICATE 1

Question:
Information security is a concern, what if a node is taken over by the enemy?

Response:
There are electronic protection measures that can be taken to minimize the possibility of happening, such as jamming cell phones. Biomedical sensors could also indicate if equipment was removed.

Comment:
COTS might be a good option for a prototype, but proprietary equipment may be necessary for implementation.

Click here to view PowerPoint presentation; Press Esc to exit

Data Source Discovery in Coalition Operations

Syndicate 2 Final Report

1.0 MEMBERS OF IST-036/RWS-005 SYNDICATE 2

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2.0 EXECUTIVE SUMMARY

The group addressed the issue of information and data source discovery in a real-time NATO or coalition operational environment. The group analyzed a conceptual approach to the design of an interactive visualization system to be used for data resource discovery. Needs and requirements are discussed through a process of answering (in part) six key questions that would guide system design. The group chose a use-case for illustration. The group concludes by recommending that the issue of data resource discovery, understanding, and availability in a NATO operation be further studied.

3.0 INTRODUCTION

3.1 NATO Operational Problem Statement

In a multinational coalition operational environment, the effectiveness of a commander's decision-making can be impaired during critical real-time planning activities by the lack of knowledge of information resources. High-tempo decision makers require an awareness and understanding of the existence, availability, and quality of time-dependent information resources. These resources can include national, coalition, theater, organic, or global sensors, systems and platforms, or other data sources (eg. open press, media, www, … etc.).

From the Operational Commander (User) –

> ***"…NATO nations in an operational context, often do not adequately share national information assets and products in an efficient and effective manner…"***

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

3.2 Question Addressed by IST-036/RWS-005 Syndicate 2

How might a visualization system assist in the understanding of the existence, availability, and quality of information resources in a distributed NATO or coalition operational environment?

3.3 Applicability to Counter-Terrorism Application

Counter-terrorism activities often involve multi-national or coalition efforts. Additionally, non-military resources such as local law enforcement and emergency response personnel may be utilized, each having its own as well as shared information and data resources. Access and understanding of these resources can play a vital role in a commander's operational effectives and situational awareness.

4.0 PROBLEM ANALYSIS

In order to conduct an analysis of this problem, the group chose to follow the VisTG[1] model of visualization system design. This model was chosen in order to use the posed questions as guidance in the analysis process. The group further developed a brief straw-man and operational scenario, in order to illustrate the key features and issues to be addressed.

4.1 Example Use Case

To assist the analysis and understanding of this problem, the group explored the potential situation of a downed pilot during a tactical mission tasking. The tactical operational commander needs to obtain the necessary information in order to plan and execute an extraction operation. Following is a possible chain-of-events as they would occur on a commander's data.

1) Pilot goes down.
2) Transponder on aircraft is activated.
3) Table console (TC) in command and control (C&C) flashes red dot.
4) Commander zooms TC into pilot location to view terrain/image model at fine resolution.
5) J2 and J3 initiate a data availability request for area of interest (AOI) around the pilot.
6) Data list is retrieved from metadatabase that is continuously updated by Allies. Such a list might include:

Source Platform	Available Data	ETA	NIC
UAV	High Resolution IR	5 min	US-12
Platoon	Visual	30 min	NOR-2
Satellite	1 m Multispectral	3 hours	CAN-3
Special Forces	Medical Condition	1 hour	UK-1
F-16	Sighting	-10 min	FRA-4

7) J2 and J3 chose from the above-noted list then initiate AOI data requests to all relevant National Intelligence Centers (NIC's) including commander's own NIC.

---

[1] The VisTG Model identifies a hierarchical, nested processing loop for visualization. The model poses six key questions to assist in the design of a visualization system.

8) Metadatabase indicates probable time of data retrieval. In addition, answers are received from NIC's for non-standard data requests.

9) As data is received or retrieved, update the TC and provide personal reports for J2 and J3 to the Commander. Objects of interest would be displayed as icons that are easily identified at a glance.

10) Have TC report the percentage of data downloaded from each NIC and expected time of receipt of remaining data. These might be displayed on the TC as NIC-specific information bars.

11) Have preset datasets (groups of data types) selectively available at the touch of a button. These could be pushed by the commander or requested from the J2 or J3. The dataset would also be editable to include more or less sets.

12) Display the "probability of detection" or "probability missing data" for any variable the commander specifies.

13) Predict and display the enemy forces' situational awareness of AOI.

14) Enable ability to gain control of, and task, mobile sensors.

4.2 Using the VisTG Reference Model for Design

Several times during the workshop it was mentioned that one of the problems with coalition operations is that nations do not necessarily make pass to the coalition command all the information they have. Some of this information might be made available on request, some might be made available after being sanitized, and some might not be made available outside the national command. Furthermore, the command staff may find for particular situations that unconventional information sources are both available and useful.

Accordingly, an appropriate task for the Syndicate seemed to be to suggest a visuaalisation system that would assist a commander and the command staff to determine what sources might be able to provide what kinds of information relevant to the situation of immediate interest. It was assumed that very many different kinds of data source might be available, both official and unofficial, and that the nature of all of them would be contained in some kind of a dataspace accessible to the user (the command staff). There would be too many possible data sources for any staff officer to be able to remember all of them reliably.

The method chosen for the development was the VisTG Reference Model illustrated in Figure 1. To make the example concrete, a use-case was chosen, in which a plan was to be developed for recovering a downed pilot.

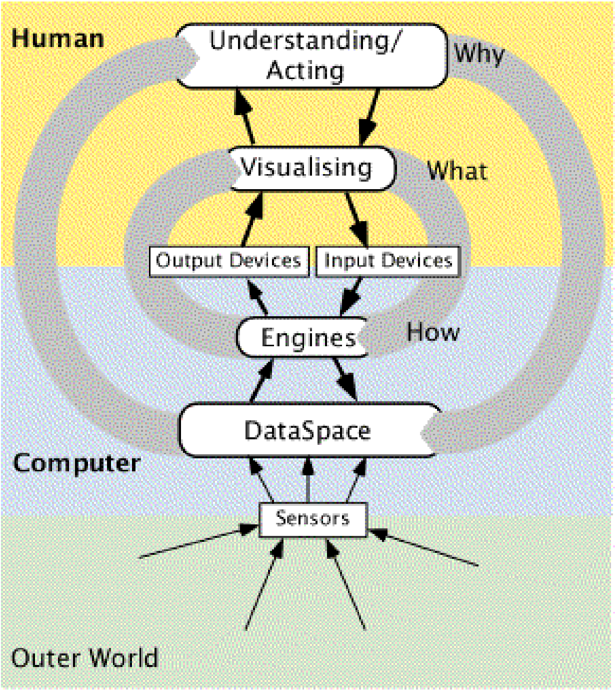

Figure 1

The VisTG Reference model treats visualisation as one of two routes to understanding, the other being analysis. The user wants to understand and to act upon some dataspace that contains information about the world of interest. Visualisation may be considered similar to intuition, which both supports and is supported by analysis.

The Reference Model does not explicitly address the analytic process, which has different presentation requirements than does visualisation. In particular, analysis ordinarily deals in individuated entities and their relationships, whereas visualisation is more concerned with patterns in an extended context.

Analysis is impeded by clutter in the presentation, whereas visualisation may be aided by the same clutter, clutter which is similar to that with which every person is confronted every moment of the day. To put it crudely, visualisation depends heavily on context, whereas analysis depends on individuation and is normally context-free.

4.3 Design of a Data-Source Discovery System

The design process using the VisTG Reference Model proceeds in stages. The model assumes a series of nested loops, each based around the achievement of some purpose, or goal, and the perceptions needed by the user if progress toward achieving that goal is to be assessed. At any one level, there may be several parallel loops, and any one of these may simultaneously serve more than one purpose at a higher (outer) loop level. For each of these many loops, the method identifies six basic questions, which can be summarized:

1) What is the purpose of the loop?
2) What does the user need to perceive if the purpose is to be achieved?
3) What does the user need to be able to do to achieve the desired perception?
4) What impediments might detract from the user's ability to perceive (including lack of user training)?

5) What impediments might reduce the user's ability to act to affect the necessary perception (including lack of user training)?
6) What provisions might be available for alerting the user to portions of the dataspace potentially relevant to the purpose of the loop?

Outer (Level 1) Loop

The first stage of the design process, then, must be to assert the purpose that a given loop is to serve. In the problem at hand, the system to be designed is supposed to help a command staff (including the commander) to be able to understand those data sources that might reasonably be expected to have, and to be willing to provide, data relevant to the situation of immediate interest, including understanding of their probable reliability, relevance, and latency (time to deliver the information).

Translating these requirements to the use-case, relevant data sources include those that could potentially supply information about:

- The location of the downed aircraft and its pilot
- The pilot's state of health
- The character and socio-political environment of the people in the region
- The location, numbers, identity, and movement of nearby blue, red and orange forces
- The local physical environment, such as terrain, weather, trafficability, visibility, and so forth.

The answer to Question 1 for the outer loop (i.e., Q 1.1), *What is the purpose of the system*, then, is that the system is to help the command staff to distinguish from a potentially very large number of official and unofficial data sources those that could potentially supply any of the desired kinds of information, and to prioritize among the potentially relevant ones those that would be most likely to be useful within the time frame available for the operation.

Question 1.2, *What does the user need to perceive*, is about the relationship of the sources to the necessary data. The data requirement information is paramount, the source is a means to acquire it. This means that the user does NOT need to perceive available data as an attribute of the set of potential data sources. Rather, sources that could provide data such as location, politico-social climate, or local weather, should be presented as attributes of the data type, however that presentation is instantiated. The user knows the required data, and needs to be able to use that knowledge as an "index" into the potentially large set of possible data sources. The system must be able to present the data so that the user can see not only which sources can provide which specific kinds of data, but also the likelihood of getting the information, its probable reliability, and the probable delay (latency) before the information is made available.

Question 1.3, *What does the user need in order to be able to act to achieve the desired perception*, is about the user's ability to let the system know what kinds of data are desired, so that the system can search its dataspace to determine what sources might be able to provide them. For example, if the user wants to contact a known friendly person in a town near the downed pilot, a local telephone directory would be a useful data source. A taskable UAV might be available to provide detailed terrain information, and one might actually be near the place in question, though tasked for some other purpose. A satellite image or a meteorological officer might be useful data sources if the required information is the local weather in the next few hours. The same satellite image might be a useful data source for other aspects of the physical environment. SIGINT and HUMINT sources collated by coalition and national intelligence cells might provide information about force movements, but some national cells might divulge only sanitized versions, and then only after appreciable delay.

The user's actions need to be able to give the system enough information that the system is able to present to the user what is necessary to perceive. The user must be able to specify, for example, limits on latency. Under some circumstances, retrieving the downed pilot might require no more than asking the local mayor to put the pilot on a bus, with a promise to refund the ticket price. Under others, a delay of 30 minutes might make the difference between success and failure of the retrieval mission in hostile territory. The use has to be able to let the system know the degree to which latency matters, just as much as to let the system know what kinds of data are required.

Question 1.4 *What impediments might detract from the user's ability to perceive what is necessary* is about both external impediments, such as the uncertain willingness of National Intelligence Cells to release information they may be known to have, and internal impediments such as the user's lack of knowledge that certain kinds of data or sources of data might be accessible or useful. The latter component may be characterized as possible lack of training or experience. The former, however, can be treated directly, and answered, at least in part, by saying that some sources may not identify the kinds of data they are willing to provide on request. Consequently, the appropriate linkages would not occur in the database and could not be presented by the system.

Question 1.5 *What impediments might detract from the user's ability to act to generate the desired perception* is about the user's ability to get out of the database the displays that would show the immediately useful sources, the usefulness of the data they could provide, and the means to acquire the information from the useful sources. It is a question about user control of the content of the presentation displays (sometimes erroneously called the "visualisations"). An example of a potential impediment might be an inability to specify the relevance of a sufficient range of data attributes, either because of restrictions in available control menus or data glossaries, or because of inadequate user training in the use of a complex interface. In the use-case, for example, the system might make it difficult for the command staff to specify that they needed to ascertain how long it would take to acquire imagery from a UAV that might already be in the vicinity or that might have to be tasked to take off on a specific mission related to the retrieval of tha downed pilot. This information might affect the relevance level of other possible sources of similar data.

Question 1.6 *What provision is there for alerting the user to potentially useful regions of the dataspace* concerns autonomous actions performed by the system under general rather than specific control of the user. The user (or system designer) may set up criteria for determining what patterns in the dataspace warrant being labelled "potentially useful", but the system does the labelling independently of immediate user control. Alerting occurs when the system affects the presentation so as to draw the user's attention, however momentarily, to the "potentially useful" aspect of the dataspace. Typically, the labelling will be affected by prebuilt scenarios. For the use-case of a downed pilot, the system might be set up to highlight data sources related to the attributes mentioned above: location, terrain, weather, pilot's health, local socio-political environment, force dispositions, etc. For other scenarios, other constellations of data sources might be highlighted.

Engine (Level 2) Loops

The questions discussed above are all cast in terms of the purpose of the system as a whole, and as a group, they specify the requirements and illustrate some possible pitfalls to be avoided in the design. The design process builds on the answers to the Level 1 questions, using them as partial specifications for questions that define Level 2 loops.

Generically, any visualisation system has four kinds of engine loops at level 2:

- Navigation Engines, which allow the user to move around the dataspace,
- Data Selection Engines, which allow the user to choose subsets of the data for manipulation,

- Algorithm Selection Engines, which allow the user to determine how the selected data subsets are to be manipulated, and
- Algorithm Execution Engines, which do the actual manipulation of the data, including the preparation of presentations such as 2-D and 3-D displays, textual and tabular representations, or auditory or haptic displays.

In a detailed design, each of the six questions should be addressed for each engine in each of the four classes of engines. For the present purposes, it may suffice to illustrate some examples and suggest the implications of the answers for the presentation-level systems (e.g. screen, keyboards, etc.).

Navigation Engines allow the User to examine different parts of the dataspace. They tend to work closely with Data Selection Engines. Indeed, data selection can be an aspect of navigation, in that it can refine whole sections of the dataspace, in effect reducing the volume in which navigation might occur. The user may navigate (alter the viewable part of the dataspace) and then select within the displayed parts of the dataspace, or may first select using definable attributes, and then navigate within the selected subset of the data. In the end, however, the result is a data subset on which selected algorithms may operate, both to change the content of the dataspace and to prepare for the actual user presentation of the computed results. The six wuestions can be applied to each engine within each class. Here, for simplicity, the system will be treated as if there were only one engine in each class.

Navigation engine(s):

Q2.1.nav (Purpose) The user needs to be able to navigate so that relevant data sources are viewable.

Q2.2nav (Perceptual requirement) The user needs to be able to see the relevance of data sources brought into view, to be able to see where to navigate so as to view other data sources, and to be able to see the functions of any control mechanisms provided to change the view.

Q2.3nav (Ability to act) Controls must be available to allow the user to affect the data sources displayed, in such a way that the various attributes of the data sources may be used to affect which ones are actually displayed.

Q2.4nav (Possible impediments to perception) Inability to see the functions of available controls (either because of presentation design or because of lack of training); inability to see where in the dataspace might be a useful region to examine; inability to see the relevance of potential data sources (because of presentation design flaws or lack of training).

Q2.5nav (Possible impediments to action) Failure of design to provide appropriate navigation controls. Complexity of control mechanisms requiring use of controls not simultaneously accessible.

Q2.6nav (Potential Alerting systems) Agents might be developed to indicate useful data sources for a variety of standard scenarios, and thereby to alert the user to possibilities that might not be immediately obvious.

Data Selection Engine(s):

Q2.1DS (Purpose) To allow the user to select those data sources most likely to be immediately useful (and in a broader appreciation of the system in use, thereby to allow the user to begin the process of acquiring the data from the selected sources).

Q2.2DS (Perceptual Requirement) To allow the user to perceive which sources are currently selected, and to perceive how to alter the selected subset by addition or removal (i.e. to perceive the means of controlling the selection).

Q2.3DS (Ability to Act) Means must be provided for the user to add to or exclude from the selection by data attribute, by source identity or attribute (e.g. nationality, latency, or reliability), by location within the display, or by other suitable attribute.

Q2.4DS (Possible impediments to necessary perceptions) Inability to distinguish selected from non-selected data sources (e.g. colour blindness); Inability to perceive data attributes relevant to selection; Failure in the design to make apparent the functions of selection controls.

Q2.5DS (Possible impediments to action) Failure to provide means for selection by potentially useful source or data attributes. Lack of training in the use of selection mechanisms actually provided.

Q2.6DS (Alerting) Ambiguities of selection could be represented and opportunity for disambiguation provided.

There is no need here to analyze the possible loops for Algorithm selection and execution loops. Among the algorithms might be those that enable the user actually to begin the process of acquiring the data from the source, such as by initiating the tasking of a UAV, by looking up a phone book for the locality of the downed pilot, by generating a formal request for data from a national NIC, and so forth. All of these represent operations on the data, and have implications for the actual presentations generated by the system. However, the question at issue is the discovery of the set of most useful data sources for the user's immediate problem, which, in the use-case, is to generate a plan for the recovery of the downed pilot. The actual generation of the plan is outside the scope of the present discussion.

The answers to the Engine-level questions have implications for the physical design of the presentations and the control input devices. For example, the answers to Q2.2nav and Q2.2DS suggest that at least two kinds of display would be useful in the use-case example, one map-based, to allow theuser to limit the range of data sources to those potentially able to provide information relevant to the area of interest, and the other somewhat VITA-like in which data types and sources are cross-linked so that sources with much coordinated relevant data could be given selection priority (see Annex).

Likewise, the answers to the Q2.3 questions indicate the need for clear and clearly labelled controls for exploding aggregated data sources, and for quasi-spatial navigation within a displayed 2-D or 3-D presentation space (especially with map or VITA-like displays). For data selection, controls based on area or volume selection within the presentation space, or on linguistically labelled data or source attributes marking selection boundaries numerically or using sliders, would seem to be necessary.

The detailed design of the presentations forms the third loop level, and as with the other two levels, the purposes of the presentations are determined by the answers to the questions at the level immediately above. Some of the more obvious implications are indicated above, but for a full design, each of the level 2 answers needs to be seen as a generator of purpose for one or more elements of the presentation displays and of the control input mechanisms. Once those purposes have been defined, the actual presentations and the means whereby the user can navigate within them and move among them can be specified using the same pattern of five questions (the sixth being Q 1, about Purpose, which has already been answered).

At each level, when there are parallel loops, the designer must ask about the possibilities for interference among them. If the user is paying attention to one, does that detract from the immediate usefulness of another? Does the provision of multiple perceptual possibilities create confusion or context? Are the required actions mutually incompatible? Is the question of the moment one of precision or of pattern? All such questions must be resolved, whether by design or by default, when a system is finally built.

Annex: The VITA Presentation

The VITA engine suite (Jacobson, McIntyre and Romet, Workshop ppresentation Session 6) was developed in the context of discovering patterns of concepts within Web pages, but is not limited to that area of application. It contains both Data Selection and Algorithm Execution engines, and Algorithm Selection is to some extent also incorporated in the form of prior user control.

In the VITA original design, one or more “Query” instances are submitted to search engines. Each Query contains a set of concepts (keywords, in the initial implementation), and the search engines return for display Web pages that contain at least a threshold number of concepts. In the 3-D VITA display, the Queries are displayed as nodes in one plane, the concepts as nodes in a second plane, and the Web pages that pass the threshold test as nodes in a third plane. Concept nodes are shown as linked to Query nodes on the one side, and to Web page nodes on the other. The placement of concept and Web page nodes within their respective planes is controlled by a self-organizing process that locates similar entities near each other.

In the context of a data source discovery process, a similar display might substitute Standard Scenarios for the Queries, Data Requirements for the Concepts, and Data Sources for the Web pages. The user’s eye would tend to be drawn to those data sources most relevant for the scenario at hand. If more than one scenario applied, the display would be essentially the same, except that the “Query” plane would be more heavily populated, as is the case with “standard” VITA when displaying the combined results of several independent Queries.

The standard VITA display allows for variable representation of concept and page nodes according to their attributes, such as whether the page has been examined. Using a VITA-like display for Data Source discovery, valuable attributes might affect either the placement or the representation of the node, or both. For example, probable latency might affect the transparency or some shape-related iconic value of the data source representation, or might affect its location above or below its “natural” representation plane. Or, if the user were given the ability to indicate to the system the relative importance of attributes such as latency and reliability, the data sources might be represented in colour variations that represent the important attributes. There are many possibilities for enhancing the standard VITA presentation to take advantage of the requirements brought out by the “six-question” analyses generated by using the VisTG Reference Model.

5.0 RESEARCH AND DEVELOPMENT ISSUES

The following are some research issues that should be addressed to achieve the desired capability.

1) Information translation/transformation – how can general information requests/queries be translated into specific requests for data? For example if a user wants to locate, characterize and identify a specific target, what is the relationship between the target type and observable quantities? Need to link:

   target information -> observable quantities -> sensors/sources

   Note the description of the ontology-driven sensor independencies (by E. Jungert) is pertinent here. Special challenges here include:

   - situation in which multiple sources/sensors might work in concert to achieve requisite information (e.g. observing different attributes may lead to identity knowledge)
   - understanding how to relate accuracy requirements to sensor/source performance.

2) Representation/Propagation of Uncertainty – How can we link information requirements (confidence/uncertainty) to requirements for the information sources. For Example, if we need to know the location of a target within one meter, what does this imply about the number of measurements, accuracy of angle and range measurements, etc. A more difficult issue involves the link between confidence in target identity and observable features. How can we show what is observable/knowable and what cannot be observed or known.

3) Visualization of source availability/performance – How can we readily show the user the availability and capability of sources. It is one thing, for example, to show the footprint of an airborne based image sensor (e.g. to show what the sensor could "see"). It is more difficult to understand how to show how multiple sensors could be used within an area to identify a target type (Steinberg & Pack, this workshop).

4) Maintenance of a Metadatabase (data about data) – Data about what sensor data/information is potentially available to NATO forces needs to be stored in a common format. This will enable searches and queries between national intelligence centers. This database will be maintained and updated by all involved forces as new data is made available or existing data is removed. The database can include reference to information such as IR images owned by a country, the phone number to a mayor in a nearby city, or the URL of a site containing European train tables. Each metadata entry would include at least the following information: senor type, data quality, area covered, time of acquisition, time to become available, and how to access the data.

5) How to discover potential data sources – Incorporate a method for discovering data sources that have the potential of delivering relevant data. For example, the fact that a UAV is flying within the vicinity of the AOI needs to be discovered such that it might be rerouted to fly over the AOI.
    - Nature of the location and area of the downed aircraft. What are the physical and environmental factors?
        - Potential data sources – organic video, satellite imagery, weather maps
    - Physiological assessment of the pilot. State of vitals. Mobility.
        - Potential data sources – radio comms, cell phone?
    - Sociological and political environment in the area? Status of civilian crowds. Attitudes towards blue forces. State of local police, emergency personnel activities, etc.
        - Potential data sources – Intelligence packages, video, local media, on-site personnel and forces
    - Status, make-up, threat level, and locations of all friendly, hostile, and other forces in the area.
        - Potential data sources – organic and/or air/space based multi-national sensors, Intelligence packages
    - Current status of extraction team forces.
        - Potential data sources – organic command and control system

For each information and data source, it is also required to know the timeliness of the data, its reliability and relevance into the future for some period of time. Additionally, what is the time required to get information from these data sources?

6.0 CONCLUSIONS

The group recommends that the issue of the knowledge and availability of all relevant and potentially relevant sources of data and information by NATO commanders in a multinational or coalition operation be further studied and analyzed. The group further recommends that the design of an interactive visualization system that would assist the commander in information and data resource and sensor discovery be explored.

SYMPOSIA DISCUSSION – SYNDICATE 2

Comment:
In Step 6 it is J2 and J3 who select the best sensors.

Question:
Is there automation, or is this a manual process?

Response:
Automation would be nice, but would depend on the sophistication of the preset databases. The idea is to get the requests out as soon as possible.

Using Visualization to Address Human Capacity Limitations

Syndicate 3

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ABSTRACT

An intriguing aspect of visualization as a technology is that it offers the potential to improve the functional capacity of the human operator. In this report, we discuss how this can be done in a variety of ways: by recoding information, by using multimodal displays, by training, or by using intelligent interfaces, agents, and ontologies. In doing so, we argue that the capacity of the human-machine system should be defined as ***distributed working memory*** *– at information shared between the human and machine when performing a dynamic task. We also discuss how the system design process can be structured to incorporate human capacity.*

INTRODUCTION

We have known for a long time that the main bottleneck in human information processing is not how much of the environment we can perceive using our various sensory systems, nor in how much knowledge we can accumulate. Rather, the tightest constraint lies in how much information we can process simultaneously. This constraint has two key sources: an attentional bottleneck (e.g., Pashler, 1998), and as a constraint in working memory (Baddeley, 1995) or limited mental resources (e.g., Wickens, 1984). In this paper, we attempt to define capacity by briefly reviewing the literature on attention, limitations on our information processing, chunking, working memory, multiple resource theory, and long-term working memory. In so doing, we examine the effects of combining modalities (vision, audition, haptics, kinesthetics). Then we consider technology as a method for increasing capacity, both in terms of improved interface design and by using intelligent systems. We present a model of task demands on working memory, leading to a model of *distributed working memory*. Finally we discuss how the system design process can be structured to incorporate human capacity.

Attentional Constraints

The notion of attention as a spotlight is a useful metaphor. It highlights some of problems we have with attention; sometimes the spotlight is in the wrong place (problem of selective attention), sometimes the spotlight is set too broadly so that irrelevant information intrudes (problem of focused attention); and sometimes it is difficult to broaden the spotlight sufficiently to process all task-relevant information (problem of divided attention) (Wickens & Hollands, 2000). Because it seems most relevant to the process of visualization, we consider here the situation where a task cannot be performed without particular task-relevant information being displayed to the operator. In this context, there appear to be two fundamental problems related to capacity and visual attention. The first is that attention needs to be allocated to task-relevant source or sources. If this fails, and no task relevant information is identified, the operator will fail. To the extent that the operator can identify task-relevant information in the scene, performance will improve. If spatial attention is allocated to inappropriate data sources (the problem of selective attention)

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

performance will degrade. This may happen because irrelevant data are highly salient, for example. In some cases, the operator may be able to perform the task even if not all task relevant information is identified (by deduction from obtained information, for example). However it will serve to increase the amount of processing that working memory must do later. If attention is guided using specific display techniques (e.g., Muller & Rabbitt, 1989), then detection of task-relevant information may be aided. Even the best sensor data, data fusion algorithms, and display technology will not aid the operator if the data being collected, fused, and displayed is not relevant to the operator's task. Visualization software is most effective when it presents task-relevant information.

If other data are also portrayed with task-relevant information, the operator should still be able to perform the task. However, this leads to the second problem for capacity and visual attention. If there are too many data sources, performance tends to degrade given attentional limitations. The operator must filter the irrelevant data from the relevant data (producing the problem of focused attention described above), or may find it too difficult to broaden the attentional spotlight sufficiently to attend to all task-relevant information sources (producing the problem of divided attention). What is necessary is to detect task-relevant information in the environment and dynamically allocate attention to those sources. The less irrelevant data there are, the better the operator's performance. Visualization software will be maximally effective when it presents task-relevant information only.

Sometimes however, we are not aware of the location of the task-relevant information and need to search for it. In *visual search* (where an observer searches for a particular target symbol among a set of distractor symbols) there is evidence that some targets can be found very quickly with no penalty for an increase in the number of distractors (efficient search, or *pop out*) (Wolfe, 1997). For example, it is easy to find the sole red symbol in a field of blue symbols. In contrast, visual search for other symbols is less efficient, with search time increasing with the number of distractors (e.g., finding an O in a set of Qs). Careful formatting and well-designed symbology can lead to more efficient search on maps and tactical displays. Some information can be processed with little attentional demand, whereas efficient search reflects a preattentive capacity – bypassing the attentional bottleneck altogether (Treisman & Gelade, 1980). In contrast, controlled search taps attentional resources for the duration of the search. Thus, efficient search has the potential to increase our attentional capacity in terms of bandwidth – reducing the time to find what we seek.

In summary, effective visualization is better realized when task relevant information is presented without extraneous data, or when the task-relevant information is made more salient. If search is necessary, it is better to make the target of that search preattentive, by using unique stimulus levels or dimensions.

Some Constraints on our Ability to Process Information

In his classic paper, Miller (1956) summarized the large literature on absolute judgment by showing how our capacity to classify alternatives was relatively constant regardless of stimulus type (shapes, sizes, tastes, odors, etc). The magical number was approximately 7 alternatives (7 ± 2). In the absolute judgment task, an observer is presented with a set of stimuli and asked to classify them by name or number. As the number of alternatives in the set is increased, so does the information that a human observer can transmit, but errors start to occur between 2 and 3 bits (4 or 8 stimulus alternatives), with an asymptote of 2.6 bits (7 alternatives).

Later work combining multiple dimensions (e.g., Egeth & Pachella, 1969) showed that this capacity could be increased by having people classify alternatives varying on multiple stimulus dimensions (e.g., length, width, and color). With this technique, capacity can be increased: for example observers can transmit 5.8 bits (or approximately 100 positions) for the spatial position of a dot in a square (two dimensions of length and width). As the number of dimensions is increased beyond two, the amount of information transmitted asymptotes at about 6.8 bits.

The nature of the different dimensions being combined is also important for capacity. Work on multiple resource theory showed that it is possible to perform multiple tasks simultaneously (good *time-sharing*) if they drew upon different resource pools (Wickens & Hollands, 2000). We can divide attention between eye and ear better than between two auditory or visual channels, for example. We can also perform simultaneously a verbal task and a spatial task better than two verbal tasks or two spatial tasks.

In related work, Baddeley (1986, 1995) proposed that *working memory* (WM) can be subdivided into a number of component systems (*articulatory loop* for verbal/phonological processing; *visuospatial sketchpad* for visuospatial processing, and a *central executive* component). There is also evidence for an additional kinaesthetic component used for maintaining information about body position (Woodin & Heil, 1996). Evidence in support of this separation of WM activity is provided by experiments where participants perform multiple tasks simultaneously. As with the multiple resource experiments, interference is observed when two tasks draw on the same component system, but not when the tasks draw on different systems. In summary, results from multiple resource and WM research indicate that capacity can potentially be increased beyond the 6.8 bits limit if we take advantage of different sensory modalities, or different types of processing codes.

Limits on WM capacity are also affected by stress. In particular, although moderate arousal levels can be beneficial to performance, high stress reduces working memory capacity and tends to produce attentional narrowing or cognitive tunnelling (Wickens & Hollands, 2000). The user tends to focus on specific characteristics of the situation and has difficulty switching the focus of attention (*perseveration*). If irrelevant data are presented in a salient manner, this can heighten to focused attention problem for the operator. Increase in stress levels has been shown to interfere with situation awareness, also (Orasanu, 1997). It appears especially important, therefore, to find display techniques that present all task-relevant information to reduce the need for computation, and present task-relevant information to the exclusion of irrelevant data (to reduce the need for attentional filtering).

It is evident that the background or expertise of the user influences processing capacity. For example, it is well known that when a procedure becomes well learned it becomes *automatized*; that is, it requires fewer processing resources, thereby making it easier to perform that task with another task. Thus, expertise in a task domain offers a method for improving performance by reducing WM demands. A second advantage of expertise is that the contents of WM change. Consider, for example, the chess master who can memorize the position of chess pieces after brief presentation (Chase & Simon, 1973). Experts can group or *chunk* relevant information together based on meaning (e.g., chess pieces into chess positions), allowing the operator to maintain much more information in WM (Miller, 1956). Thus, WM capacity is better indexed by chunks than bits. This offers an alternative solution to increasing WM capacity. Indeed, these two processes work together so that using WM contents to access long-term memory may become automatized with sufficient practice or training, offering a *long-term working memory* (LTWM) with immense capacity (Ericsson & Kintsch, 1995). We speculate that since Generation Y are pre-trained on many basic computer interface techniques the current generation of soldiers can take advantage of a wider variety of innovative interfaces to accomplish a task. If a particular response device (e.g., joystick) is highly automatized for a member of Generation Y, its use will not tap WM resources and will not preclude good performance on concurrent tasks.

FACTORS AFFECTING WORKING MEMORY LOAD

We argue that a variety of factors can serve to reduce demand on working memory resources. These are illustrated in Figure 1, which plots working memory load as a function of a variety of capacity-enhancing strategies. Each vector represents a particular strategy, which we outline below. Because effective visualization designs would probably employ the various strategies in combination, we represent the effect of the strategies on two tasks, A and B, using a hyperplane surface. The effect of each strategy is to decrease working memory load, although different strategies may have differential effects for particular tasks. The figure depicts Task A as generally requiring greater working memory resources than Task B, although the use of capacity-enhancing strategies could allow WM load for Tasks A and B to be equal.

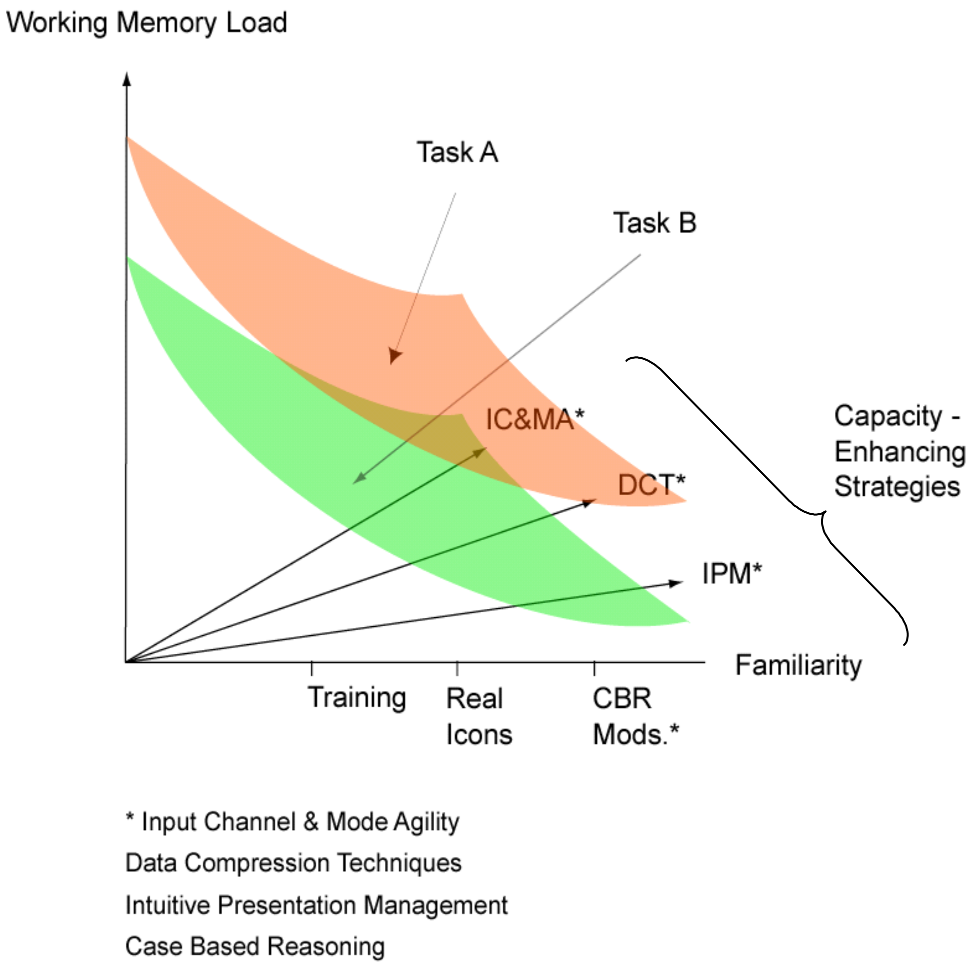


Figure 1: Working Memory Load as a Function of Several Capacity Enhancing Strategies.

Familiarity and case-based reasoning. As discussed earlier, working-memory load is influenced by familiarity. Familiarity on a task has three key benefits: automaticity, chunking, and automatized long-term memory access (LTWM). Automaticity is typically produced from repetitive experience (training) in the work environment, which can be tremendously useful for repetitive tasks but is also highly specific to particular situations (Schneider & Shiffrin, 1977). The use of LTWM allows for *recognition-primed decision-making*, which asserts that decision options are quickly selected on the basis of familiarity; that is, similarity of the current situation (that portrayed on the display) to previously experienced situations (Klein, 1989). The model in Figure 1 was also influenced by Commanders' (Cols Johansen and Alward, 2002 this workshop) remarks regarding the need for familiarity in all display aspects for efficiency and stress reduction. In the figure, we use the term *case-based reasoning* to indicate more directly the change in the nature of mental processing that occurs with expertise. We view this as a greater change along the familiarity magnitude because it is more flexible and of broader utility.

By finding familiar metaphors in visualization, decision making or problem solving can be reduced to "an already encountered problem", and thus dealt with in a known way. A simple example would be to depict abstract non-spatial data using a familiar spatial technique (e.g., depicting intrusion detection data by plotting file transfer activity as a function of time and server location using a 3D surface and allowing the user to fly over the surface looking for the region with the highest mountains).

Response modality also plays a role here. By taking away buttons, handles and sticks, and moving controls into digital displays where the same buttons have different mode-dependent meanings, it puts strain on WM resources and does not allow automaticity to develop.

Input channel and mode agility. Particular input channels may be better suited to particular tasks. For example, there is a well recognized relationship between mode of input (visual vs. auditory) and the nature of the person's output (spatial vs. verbal), part of the concept of *stimulus-response compatibility* (Wickens & Hollands, 2000). Moreover, an implication of the work on multiple resource theory (Wickens 1984) is that capacity can be enhanced (i.e., working memory load can be reduced) when two tasks draw on different resource types. This has implications for how information is displayed to the user. Results from absolute judgment experiments indicate that using multiple stimulus dimensions can increase working memory capacity – whether this advantage is greater when multiple modalities are used has not to our knowledge been well investigated. Particular individuals may be better able to switch between different modalities as they perform tasks, an attribute we call *mode agility*. (We speculate that Generation Y may have particular advantages in this regard, due to gaming experience). The use of different display modalities would presumably be more effective for these individuals. Whether this is trainable is also not well investigated to our knowledge.

The nature of the response method is also important and must be considered in visualization. For example, by allowing users to point to a location of interest on the battlefield using gesture recognition, little demand is placed on WM (consider Colonel Johansen's idea behind "the table", this workshop). In contrast, by designing displays in such a way that users forced to define locations verbally, WM resources are diverted to an unnecessary task.

Data compression techniques. Most sensors collect vast quantities of data and their output needs to summarized and co-ordinated thru various *data fusion* techniques (Waltz & Llinas, 1990). We argue that such techniques can serve to reduce working memory load relative to processing data in rawer form and thereby offer a tremendous benefit to the user. For example, it has been demonstrated that sonar data are best presented to the operator after filtering and other integration techniques have been conducted.

Intuitive presentation management. Here we argue for visualization systems to ensure that task-relevant information is displayed. Information should correspond to the mental processing required to perform task-related activities with respect to a particular work domain. Further, we argue that intuitive displays decrease the amount of mental processing required to perform the task, reducing working memory load. One might argue that the computer can perform the necessary computation using RAM and cached storage so that the user does not use limited working memory resources to that end. For example, by re-orienting the viewpoint location on a three-dimensional (3D) geographic terrain model the user can perceive the correspondence between terrain elements on a PDA display and the forward field of view (FFOV). In contrast, the use of a fixed viewpoint can lead to left-right reversals with respect to terrain elements and could require mental rotation to determine which display object corresponds to objects in the FFOV. Porathe (2002, this workshop) describes a similar design solution for a display on a ferry bridge.

This strategy may also be enhanced through the use of intelligent agents or ontologies. For example, Zeltzer (2002, this workshop) demonstrated software that depicted planned routes through terrain given current conditions and intelligence information. The route was plotted on a 3D terrain model and could be viewed from multiple orientations.

If task-relevant information is not present at point of gaze, the user must search for it, requiring allocation of attention over available display space, and may also require command input to the computer to change the nature of the displayed information to address task requirements. Both activities should increase working memory load, although certain display characteristics can reduce attentional demand, and highly overlearned command sequences can be issued automatically (without controlled processing). In the former case, the search for certain kinds of targets among certain kinds of distractors can lead to highly efficient search in which the number of objects on the display has no effect on search time (Wolfe, 1997). In the latter case, command sequences must be used consistently and repeatedly to produce automatic processing with training. The use of keyboard commands has been shown to be more efficient than long menu searches for this purpose (Raskin, 2000).

DISTRIBUTED WORKING MEMORY

Consider the Turing test (Turing, 1950). If the mechanism for intelligent activity is hidden from the observer, and the observer believes it to be acting intelligently, it does not matter whether the behavior was generated by a human, a machine, or some combination thereof. In a human-computer or human-machine system, we argue that the activity of working memory can be shared between the information displayed by the interface (visual, auditory, haptic, etc) and the human operator. We call this model distributed working memory (DWM). DWM is thus conceived of as task relevant displayed information and the contents of a user's working memory.

The simplest version of the DWM model is depicted in Figure 2. Here, DWM is depicted as a stacked bar whose sum represents the information in the system. At the top of the bar is data stored in the computer or in the world via sensor information. Below that is information portrayed on a display device, including visual displays, auditory displays, or kinaesthetic information from controls such as joysticks, buttons, mice, etc. The line just below this represents the interface. Below that WM contents are represented. At the bottom is a large long-term memory store (LTM).

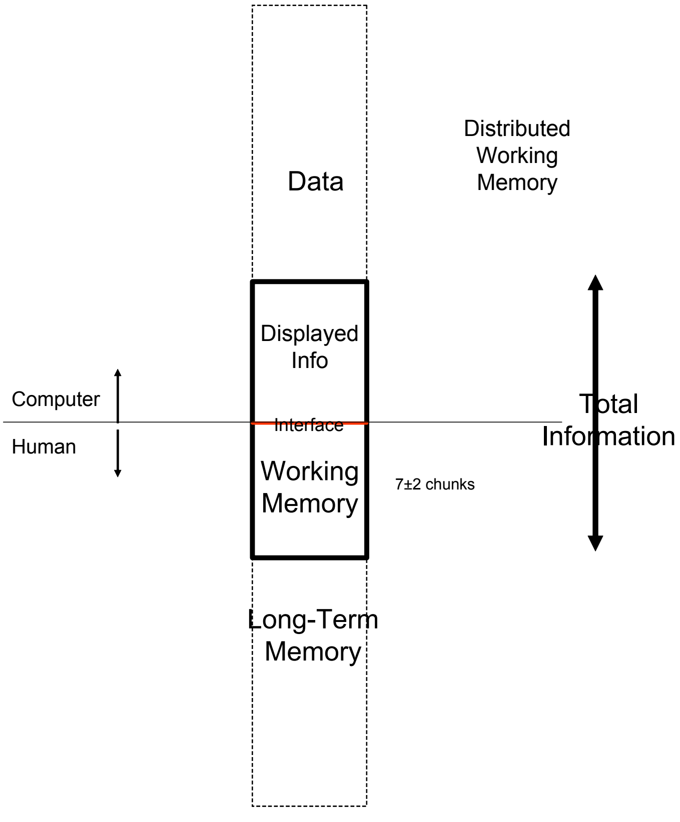


Figure 2: A Model of Distributed Working Memory (DWM).

We focus on two capacity limitations in this system, both on the human side. The first capacity limitation in this system is the attentional bottleneck. Attention is portrayed as the interface of working memory and information on the display(s). If the contents of the display are highly related to the user's current task, as shown in Figure 2, there is little need for attentional selection or broadening. If only some display contents are related to the task, as shown in Figure 3, there is need for attentional selection. If task relevant information is not at the point of gaze, visual search is necessary, which may require attentional resources. If some information is not currently available in the display, working memory resources may be required to issue a series of commands to the computer to change the displayed information to correspond (unless the command sequence is automatized).

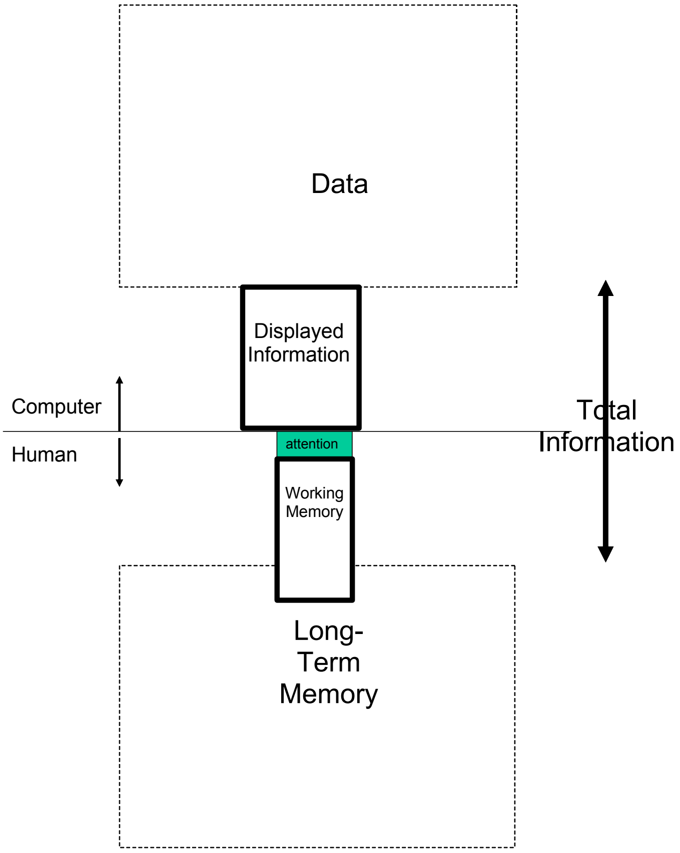


Figure 3: DWM as a Function of Changes in the Allocation of Attention.

The second capacity limitation is WM capacity. Performing a task will typically require WM resources. Units of WM capacity are chunks, to allow for domain expertise due to recoding or training. For example, a commander may be monitoring the altitudes of and distances between multiple aircraft over time using a tactical display. If the commander knows that the formation being flown specifies relatively fixed distances between aircraft, one value can be maintained in working memory rather than multiple values, freeing up WM resources. If the orientation of two tactical displays is inconsistent, forcing the observer to mentally rotate one or the other (or to make L-R reversals) this will require greater WM resources than if the two displays are aligned. If information from a surveillance aircraft indicates that all altitudes were incorrect and need to be doubled, extra computation will be required every time the observer must communicate altitude information to other members of the command team, demanding WM resources.

We assume computer memory capacity is infinite, or at least so large with respect to human WM that increases in displayed information have minimal effect on the processing capacity of the computer.

Intuitive presentation management can be accomplished using dynamic memory allocation – that is, better designed or intelligent interfaces can perform some of the computation that otherwise the human would do, freeing up WM resources. As noted above, intelligent interfaces and ontologies that depict planned routes through terrain given current conditions and intelligence information serve this role. Effective data fusion and compression techniques can similarly be effective. Consider the system developed by Jungert et al. (2002, this workshop). Their design ensures that it is not necessary for the user to specify the precise level of sensor data to formulate a query.

Figure 4 depicts an augmentation to the model to allow for different processing resources as a function of modality. We have discussed the notion of a WM subsystem, identified a distinction between spatial and verbal processing, and noted that a verbal-spatial task combination will be performed better than a verbal-verbal or spatial-spatial. Similarly, we may consider that our mental resources are differentiable by modality (e.g., visual, auditory, tactile) or processing stage (Wickens, 1984). Another way of thinking about the shift from physical buttons handles and sticks to virtual controls described earlier is that we have shifted from taking advantage of a different (output, or late processing stage) to drawing on already overtaxed WM resources.

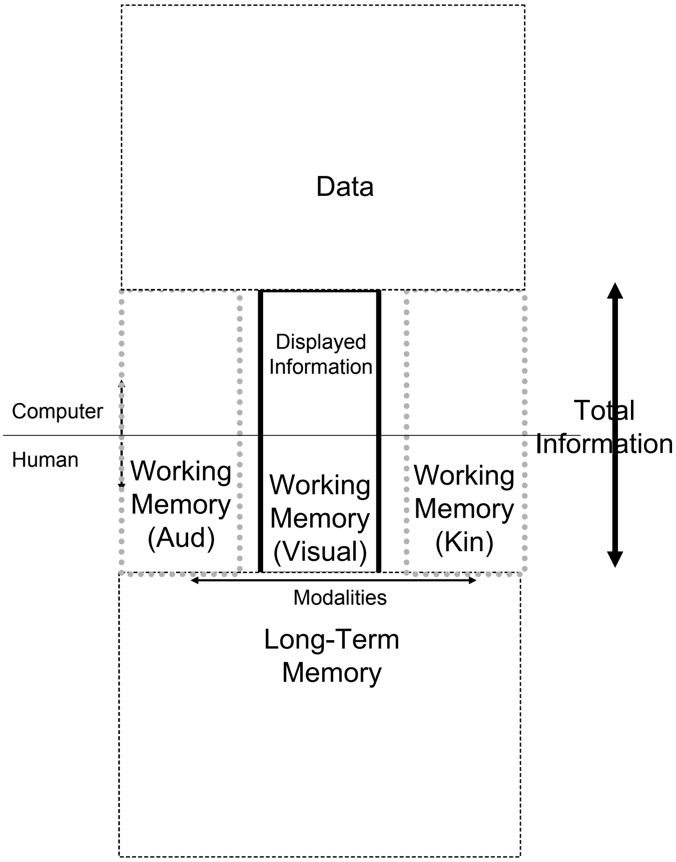
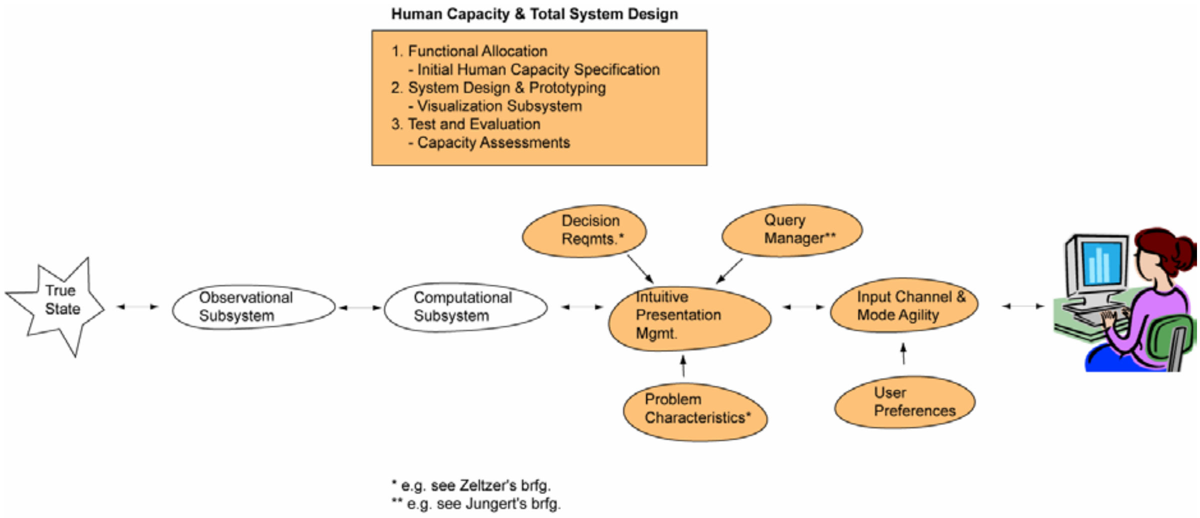


Figure 4: DWM Modified to Incorporate Multiple Sensory Modalities.

DESIGN RECOMMENDATIONS

Figure 5 asserts that the capacity-enhancing aspects of any visualization design is a "system" problem. The box at the top of the figure describes components of system design that must be considered with respect to the human user, the work domain, and the task. The design problem starts with the assessment of the human role in any computer-aided system, and that is at the "Functional Allocation" step in which the human-machine roles are defined and characterized. The second stage is to prototype the system incorporating information gained from cognitive task analysis and cognitive work analysis approaches, which allow better understanding of the user's task and work domain, respectively. The achievement of intuitive presentation management (central oval in the figure) depends on consideration of the many design-influencing factors surrounding that oval. If these components are incorporated into the design process, the result should be a system that allows the user to visualize task-relevant information in a quick, efficient way.



* e.g. see Zeltzer's brfg.
** e.g. see Jungert's brfg.

Figure 5: Capacity-Enhancing Strategies Incorporated into Design.

RESEARCH RECOMMENDATIONS

We make the following recommendations for research topics:

1) Examine/explore whether capacity can be increased by using coding dimensions from different modalities
2) Determine how can we design systems that adapt to:
    a) Limitations of the human--Increasing "capacity" by design: navigation engines etc.
    b) Flow of information to correspond to situational demands
3) Examine whether Generation Y has increased mental capacity given their early exploration of computers.

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SYMPOSIA DISCUSSION – SYNDICATE 3

Comment:
With expertise and learning, people can develop long-term memory that can function as working memory.

Comment:
It would be interesting to integrate the findings of vast numbers of small experiments that have been done to compile the evidence that exists in areas such as human cognitive architecture, as well as parallel and motor human possessors.

Question:
Research that suggests that different people think in different ways, should the same modalities be presented to every user, or can you exploit the capabilities of the individual?

Response:
Research into the system learning about the capabilities of the user and knowledge the user's preferences and abilities and provide info accordingly.

Information Visualisation, Counterterror Intelligence

Syndicate 4

INTRODUCTION

The participants in Syndicate 4 were Denis Gouin, Zachary Jacobson, “Kesh” Kesavadas, Hans Joachim Kolb, Vincent Taylor, Johan Carsten Thiis and David Zeltzer. Portions of this report were authored by Michael Towsey.

By consensus, the members of the Syndicate selected the broad area of *information visualisation* as the topic of interest. In general, it is agreed that information visualisation refers to the presentation of “non-physical” data with no obvious 3D referents, as typified, for example, by multidimensional sonar or financial data; concepts embodied in documents and the relationships among them, or the morale and readiness of military units [Card, Mackinlay et al. 1999].

It was felt that the mission of the Syndicate was to:

- identify information visualisation issues in application domains of importance to NATO,
- identify and characterize the required capabilities and available technologies that address those domains, and
- recommend research and development priorities with respect to the technologies involved.

A number of application domains were considered, but due to the short time available to the Syndicate, this list was reduced to four, and ultimately only one application domain – counterterror intelligence – was addressed. This area is clearly of high priority to NATO, and at the same time, it is largely characterized by non-physical types of data that are problematic to present, and so counterterror intelligence is well-suited to consideration by Syndicate 4.

VISUALISATION REFERENCE MODEL

Once the topic of interest *information visualisation* and the application domain *counterterror intelligence* were selected, the next steps were to identify and characterize component technologies necessary for visualisation of counterterror intelligence data, and to estimate the level of maturity of these technologies.

It was thought that a *visualisation reference model* would be helpful in order to ensure that the Syndicate agree on the visualisation process under consideration, and to consider the technologies that comprise counterterror intelligence visualisation.

The model chosen is close to the VisTG model developed by Martin Taylor, but focuses primarily on the computational engines involved in data analysis and presentation (cf. *The VisTG Model for Visualisation*, these proceedings).

Paper presented at the RTO IST Workshop on “Massive Military Data Fusion and Visualisation: Users Talk with Developers”, held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.

Figure 1 illustrates this visualisation model. The Syndicate specifically assumed that consideration of sensor technologies for gathering data was outside the scope of its analysis. It was also assumed that, in general, visualisation is a multimedia and multimodal activity. That is, data must be presented to analysts and decision makers visually, aurally and perhaps, haptically, as appropriate for the application in question. Likewise, they should be able to intuitively interact with presentations naturally with voice and gestures, again, according to the requirements of the application. Furthermore, a "task level" human-machine interface (HMI) enables decision makers to interact with a computer-mediated activity in terms of interest to the human, not the machine. Humans should not be burdened with extraneous cognitive tasks required to operate a computer system – a well-designed HMI should make the computer "invisible" to its users, in the words of Donald Norman [Norman 1998].

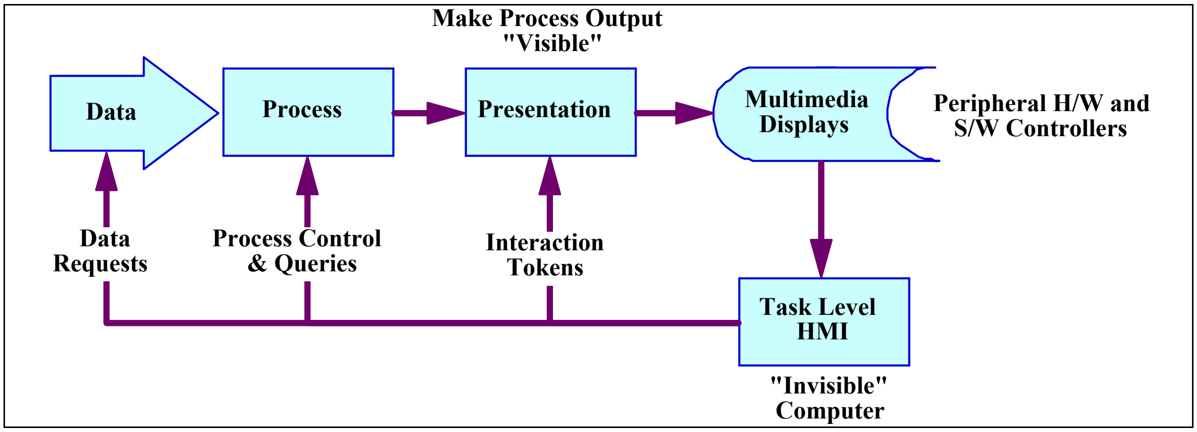


Figure 1: A Schematic View of the Computational Processes Involved in the Presentation of Data to be Visualised. The syndicate focused on characterizing the functionalities contained in the "Process" and "Presentation" modules, and identifying and rating the maturity of the technologies that address those functionalities.

COUNTERTERROR INTEL REQUIREMENTS

The Syndicate considered three main requirements areas in this application domain. Data must be

- gathered from a variety of sources,
- analyzed with a range of tools, some automated and some human-in-the-loop, and the
- analyzed data would be presented to decision makers.

Data Sources

While this is not an exhaustive listing, the Syndicate identified four primary sources of data that would be of interest to the intelligence community:

- communications, such as
  - email, phone, FAX, radio, video, . . .;
- open sources, such as
  - newspapers, WWW, newsgroups, TV, . . .;

- commercial transactions; and
- behaviour of people and organizations.

For each of these data sources, functionalities and technologies required to analyze the data were characterized, and rated as to the respective technology maturity level – *high, medium, or low*.

In addition, several main processing steps were identified. First, since it is practically impossible to attend to unfiltered streams of data of the magnitude represented by counterterror intelligence, the first step would be to rapidly analyze the incoming data streams for features of interest, which would be used to distinguish data to be analyzed further. Therefore, for each data source identified by the Syndicate, a first step would be to estimate the maturity of technologies available to recognize features in the various data streams. Once features can be identified, categorized and prioritized, the filtering of the data becomes straightforward.

Processing Engines

Filtered data becomes the input stream for further analysis. The Syndicate roughly characterized three further stages of data analysis:

- link analysis,
- data mining, and
- behaviour analysis.

In the view of Syndicate 4, each of these processes may be implemented by processing engines consisting of arbitrarily complex algorithms and software systems, some of which might be completely automated, while others may be "human-in-the-loop". Especially for human-in-the-loop processes, each of these analysis activities will require its own visualisation and HMI components.

In the final stages, the data output of the processing algorithms must be presented to decision makers for action. Visualisation and HMI issues were identified in each of the three analysis areas.

DATA SOURCES

Feature Recognition and Communications

Email, phone, FAX, radio, video

In point-to-point communications content is arbitrary and unconstrained. This means that a robust natural language understanding (NL) capability is required to fully comprehend the content and intent of such messages, which is largely beyond current capabilities. Nonetheless, textual analysis technologies do exist to identify content features of such communication, so even though technology for understanding arbitrary NL content is not yet available, communications can still be categorized and related based on identified concepts contained therein.

In addition, many easily recognized parameters of communications can be derived, including

- Source,
- destination(s),

- length,
- encrypted(?),
- language,
- subject field,
- attachments,
- routing,
- etc.

Content analysis

Textual concept recognition	
in some languages	High
for multilingual	Low
OCR	High
Speech recognition	High
Image and video feature recognition	Low
Intent recognition	Low

Feature Recognition and Open Sources

Newspapers, WWW, newsgroups, radio, TV, . . .

These are largely broadcast media, in which the domain of discourse is largely constrained by context. In such cases, for example, newspaper articles, NL technologies have been available for some time that can interpret such media and provide reliable paraphrased interpretations.

Content analysis

Textual concept recognition	
in some languages	High
for multilingual	Low
OCR	High
Speech recognition	High
Image and video feature recognition	Low
Intent recognition technologies	Medium (NL paraphrasing technologies exist)

Feature Recognition and Commercial Transactions

Transaction signatures

Customer ID

Credit card #

- Product(s) purchased
- Amount of product purchased
- Purchasing frequency and history
- . . .

All such signature parameters are typically maintained by merchants and are subject to data mining.

Feature Recognition and Behaviours

Especially in democratic societies, for a host of reasons, it is simply not possible or desirable to monitor the behavior of all citizens. On the other hand, law enforcement and intelligence agencies have ample surveillance tools to monitor individuals and groups that have come to their attention.

Scope
- Suspect entities

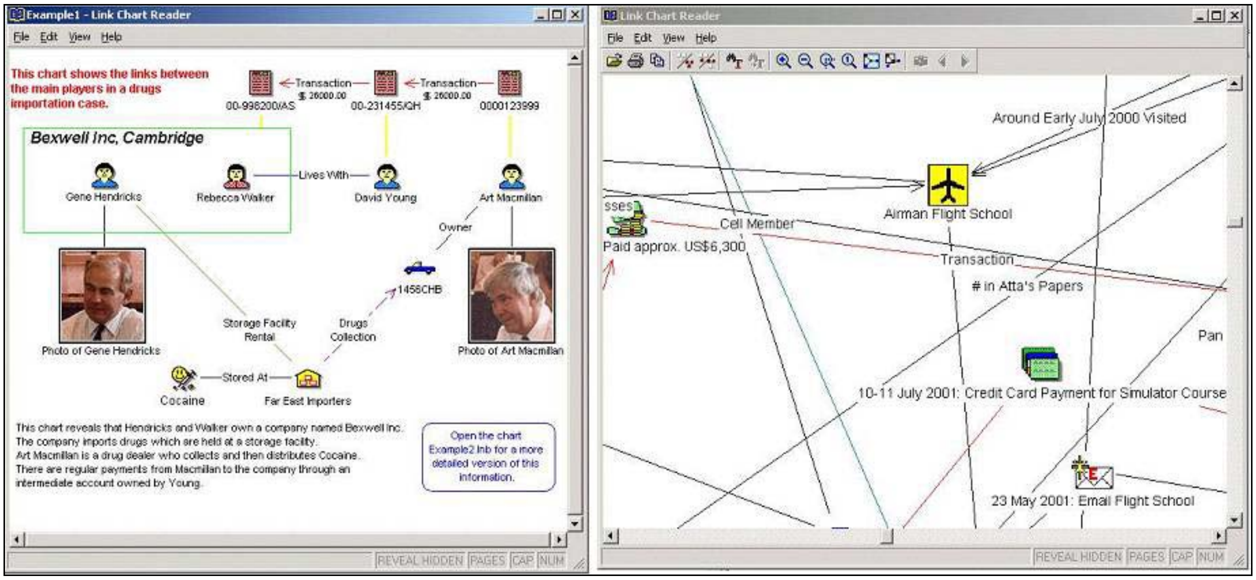
Behaviour signatures
- Phone calls
- Recipient and locations
- Travel
- Residence
- Biographical data
- Gait, action and mannerisms
- . . .

Data sources
- Current law enforcement surveillance methodologies collect behavior signatures.

PROCESSING ENGINES

Link Analysis

Link Analysis is a technique very useful to show relationships among people, organizations, events, incidents, behaviours and locations as shown on the left side of Figure 2 taken, from the U.S. company IntelCenter. Shown on the right side of Figure 2 is a subset of Mapping al-Qaeda v1.0, a product utilizing link analysis technology to provide visual maps of terrorist networks around the world and to help foster a better understanding of al-Qaeda’s operational characteristics and organizational structure.



This chart shows the links between the main players in a drugs importation case.

This chart reveals that Hendricks and Walker own a company named Bexwell Inc.
The company imports drugs which are held at a storage facility.
Art Macmillan is a drug dealer who collects and then distributes Cocaine.
There are regular payments from Macmillan to the company through an intermediate account owned by Young.

Open the chart Example2.lnb for a more detailed version of this information.

Figure 2: Examples of Link Analysis.

Mapping al-Qaeda v1.0 was produced by the private company, IntelCenter. The focus of IntelCenter is on studying terrorist groups and other threat actors and disseminating that information in a timely manner to those who can take action on it. Its primary client base is comprised of military, law enforcement and intelligence agencies in the US and other allied countries around the world (http://www.intelcenter.com/linkanalysis.html).

Medium technology maturity

Data Mining

Data mining has been a technology applied to marketing data bases for some time. The Syndicate felt that a number of off-the-shelf products are available to perform data mining of information contained in commercially-available data base systems. Such information was considered to be *structured data* stored in categories and formats defined *a priori*. It was felt that, on the whole, such tools have suboptimal HMIs and visualization components, and therefore, require further development for use in the counterterror domain. Finally, data mining of new types of data, which would be largely *unstructured*, remains a technological challenge.

Mining *structured* data

E.g., commercial transaction data

Off-the-shelf technologies available but difficult to use

High maturity but visualisation and HMI development required

Mining *unstructured* data

Low maturity

Data representation and association, automation tools, HMI and visualisation require major R&D

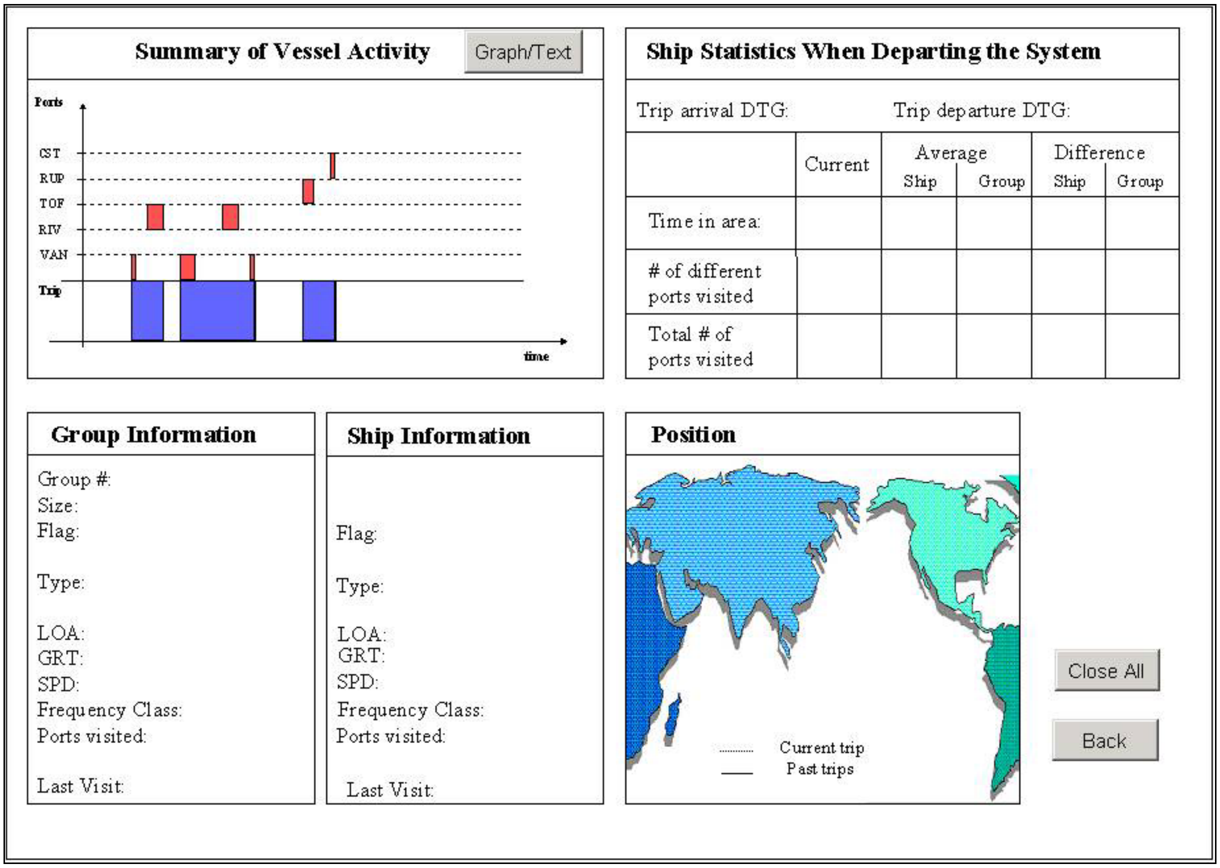
Behaviour Analysis

Behaviour analysis is an emerging technique that allows investigators to identify suspect behaviours by comparing events with ‘normal’ information stored in a knowledge base. An example that could be drawn from a drug interdiction scenario is shown in Figure 3. In this case, the behaviour of a ship in terms of the itinerary, ports visited, time spent in each port is compared with information describing normal activities of the same category of vessel / ship Kluchert 1998].

Scope

Suspect entities

Technology maturity <u>Low</u>



	Current	Average		Difference	
		Ship	Group	Ship	Group
Time in area:					
# of different ports visited					
Total # of ports visited					

Figure 3: Examples of Behavior Analysis.

In order to exploit behavior signature collection, it is necessary to find patterns in recognized features. Some tools are available, some are automated systems, and some depend on human-in-the-loop processing. The latter have, of course, human/machine interaction and visualisation requirements. Since the scope and scale of behavior signature collection is so large, and because information visualization is so strongly application dependent, further R&D will be required to define and develop interaction techniques and metaphors, as well as visualization solutions.

Many components of behavior analysis technology are currently available but major integration engineering is required to develop a complete behavior analysis toolset. Emerging technologies typically suffer from prohibitively high false alarm rates. Human-in-the-loop signal detection requires visualisation and HMI R&D. Figure 4 illustrates a schematic view of the purported components of a distributed, behavioral analysis toolset, with regional, local, and on-site components.

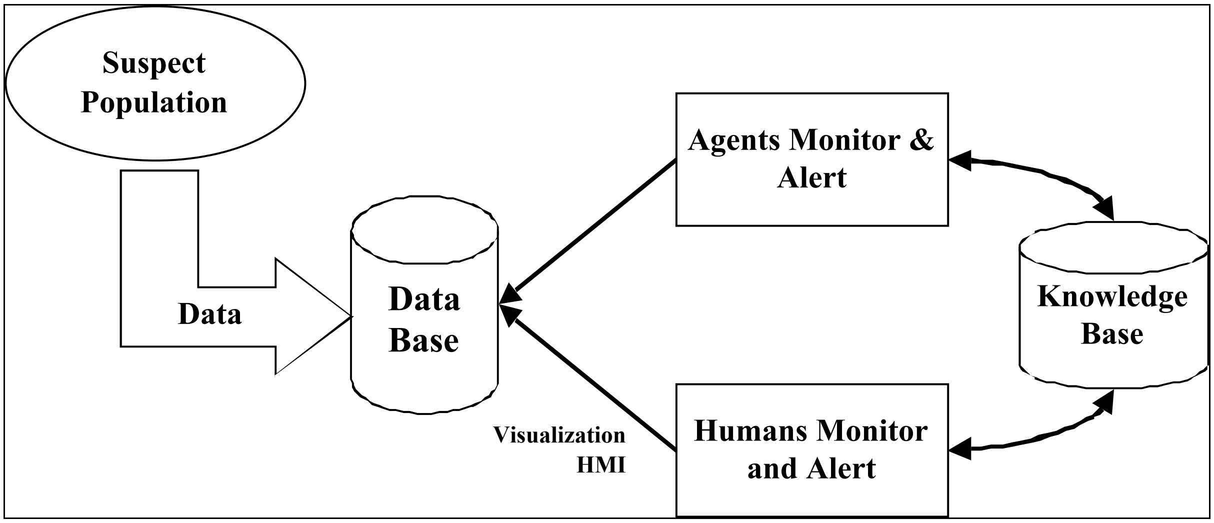


Figure 4: A Schematic View of a Technology for Monitoring a Suspect Population.

SOME ISSUES IN INFORMATION VISUALISATION

It is clear from the above examples that different kinds of data require different kinds of visualisation algorithm and different kinds of human interaction. Human intervention can take place at three levels: first to decide on the appropriate visualisation algorithm, second to set the algorithm parameters and finally real-time interaction with the displayed information.

In the case of mining structured information, typically each datum can be represented as a point in an n-dimensional feature space. It is possible to visualise large amounts of information by projecting a high-dimensional space onto a 2 or 3 dimensional space. As an example, Figure 5 displays a large number of communications between multiple senders and receivers over time. Despite the high volume of data, the representational framework is a simple cube, which can be easily manipulated to offer different views.

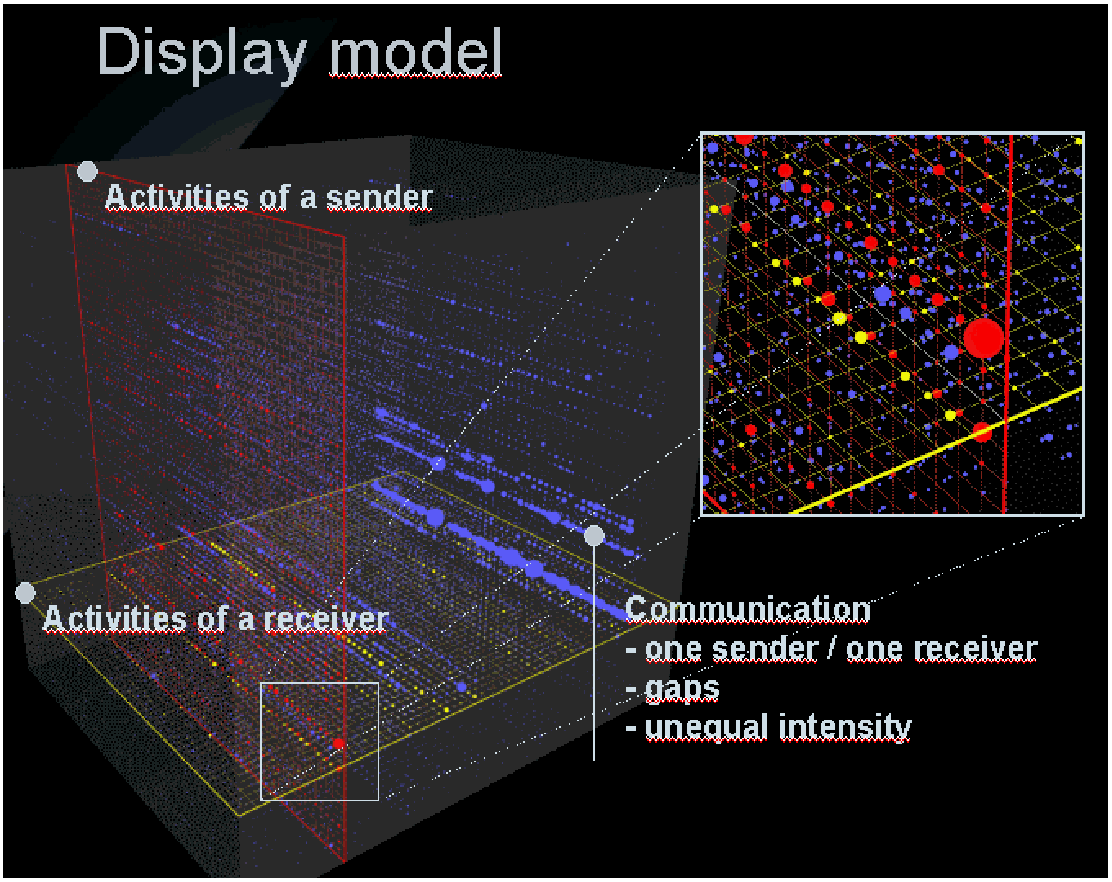
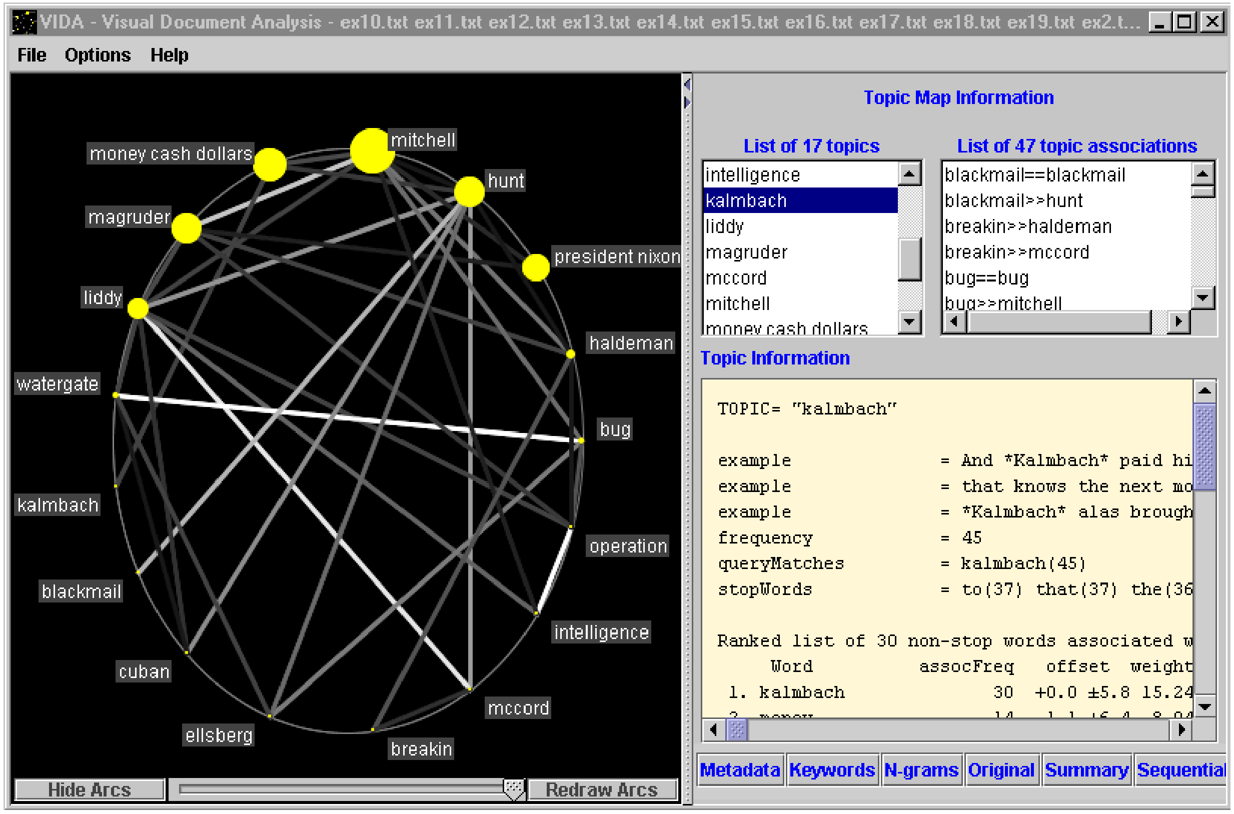


Figure 5: Visualisation of Communication Channels Over Time.

By contrast, the visual representation of textual or behavioural data is difficult because each of the data items sits in a different 'space'. The appropriate data model is a directed graph but the effective visualisation of graphs remains an area of active research. Even a small graph as in Figure 2 can be difficult to display in a way that clarifies rather than obfuscates the data. One computational difficulty is to position the nodes so as to preserve spatial proximity between closely related objects and yet to prevent a confusion of crossing arcs. An example of a fully automated visualisation of a complex text is illustrated in the left side of Figure 6. The text is the 130,000 word Nixon-Watergate transcripts. The nodes represent important terms or concepts in the transcripts. The arcs show the strength of the associations between the concepts. An important feature of the software is that it offers multiple (visual and textual) views into the one text and it allows the user to manipulate the representation if desired.



```
TOPIC= "kalmbach"

example                   = And *Kalmbach* paid hi
example                   = that knows the next mo
example                   = *Kalmbach* alas brough
frequency                 = 45
queryMatches              = kalmbach(45)
stopWords                 = to(37) that(37) the(36

Ranked list of 30 non-stop words associated w
     Word              assocFreq   offset  weight
 1. kalmbach                  30  +0.0 ±5.8 15.24
```

Figure 6: A Visualisation of Topics in the Nixon-Watergate Transcripts.

Another strategy used to visualise and navigate large amounts of information is *zoom and focus*. The total data space is first represented on the screen in low resolution. The user selects one part of the space which is then enlarged and displayed in higher resolution. This approach is particularly meaningful if the data structure is a tree. However a difficulty with *zoom and focus* is that information tends to loose its meaning when taken out of context. This is true regardless of whether the information items are textual or visual. Current research is attempting to get around this problem by using a variety of *fish-eye views* on data. That is, user-selected data is enlarged in the centre of view, while connected information is shown less prominently on the edges.

The issues in information representation are not only algorithmic. Physiological and psychological considerations are also important. The *grok box* project (http://vader.mindtel.com/concepts.html) is exploring ways of conveying information through sensory modalities other than vision. Just as the geometry, color, texture and dynamics of a visual icon are all meaningful features which can be encoded with information, so too, an auditory or 'sonified' icon can convey information through its tone, pitch, timbre, duration and location. And tactile stimuli which impinge on hands, fingers, arms, or skin and muscle sensations of the body can convey information through touch, felt position, motion, and force. The principle is to push all the sensory modalities to their 'margin' in order to interpret large volumes of information. But an important question is how much information can be and should be loaded into icons representing abstract entities? Iconography is itself a language which must be learned and if the language is not intuitive, the effort to learn it may become an obstacle. Figures 6, 7 and 8 illustrate examples from the spectrum of possibilities.

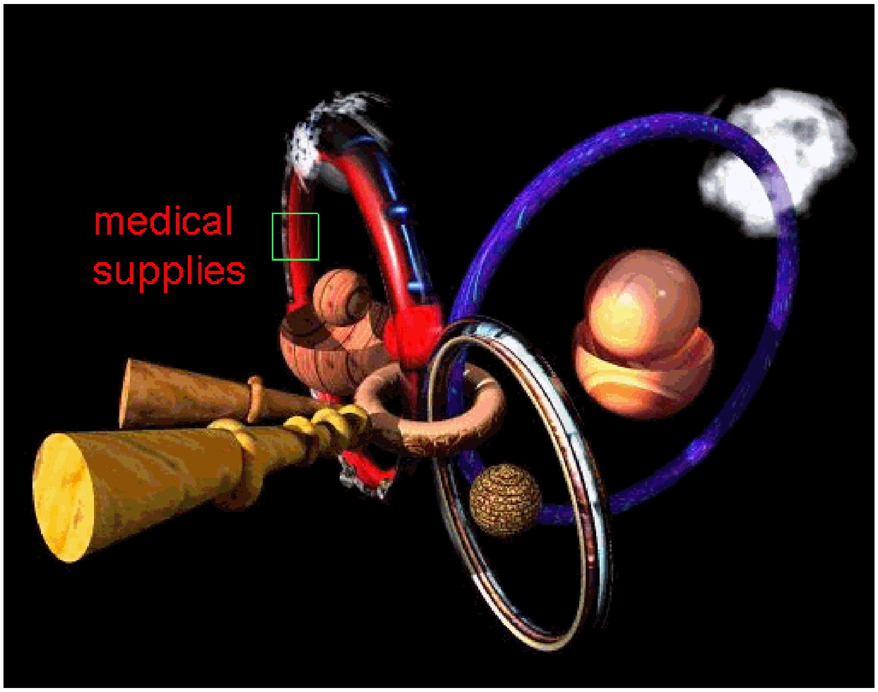


Figure 7: Visual Representation of a Refugee Camp in Africa.
Accessed through http://vader.mindtel.com/concepts.html (click on applications)

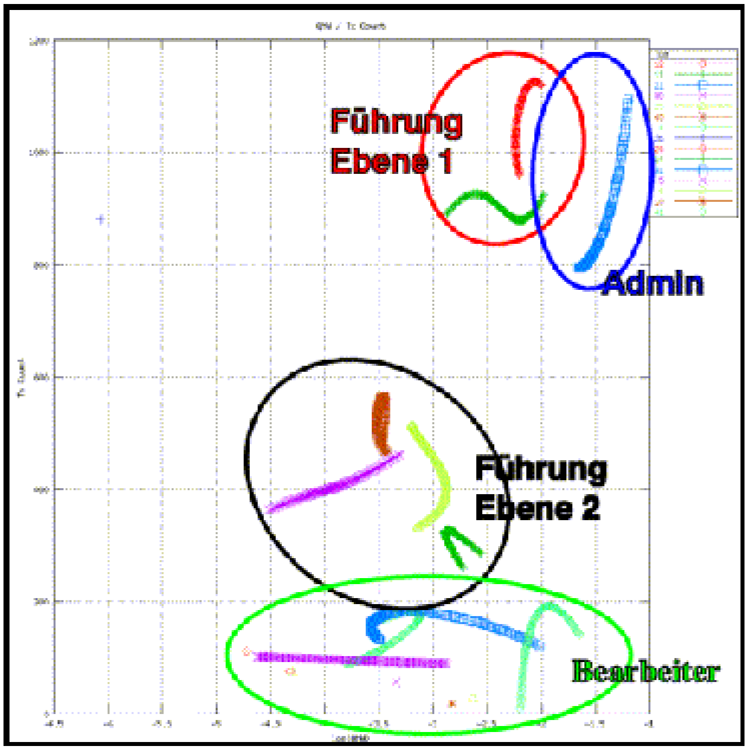


Figure 8: Visualisation of Topics in the Nixon-Watergate Transcripts.

Figure 7 is an abstract representation of a refugee camp in Africa. The iconography is complex because all the features of each icon are encoded with information. The wooden ring in the centre represents the camp itself and the other icons are influences acting on or interacting with the camp. The red ring represents medical supplies but it has several attached features which must also be interpreted. The language of the icons in Figure 7 is complex and would take some time to learn.

In Figure 6, by contrast, the iconography remains limited but intuitive and therefore immediately comprehensible. The size of a node represents the frequency of a term in the text and the intensity of the arc represents the strength of the association. Figure 8 illustrates an intermediate example of iconic complexity. It is a representation of a command structure obtained by cluster analysis of communications. The command hierarchy is illustrated in the vertical dimension while the colours and shapes are easily interpreted by reference to the index at top-right.

SUMMARY

It is said that “a picture tells a thousand words” but this wisdom does not automatically extend to the representation of *non-physical* data having no obvious 3D referents. Future progress in information visualisation will depend both on algorithmic developments and on a population of users gradually learning an iconic language, much in the same way that PC users have learnt Windows iconography over the past 20 years. Much depends on the application. In mission-critical applications, one might expect iconography to remain conservative. Non-critical applications will allow increasing exploration of iconography in its broadest sense.

Currently, link analysis and data mining are the “low hanging fruit.” These technologies are “almost there” and potentially may be most productive in the short term for generating useful intelligence. However, in current systems, visualisation capabilities, and the human/machine interface are poor. The most difficult challenge, moreover, is scaling the algorithms to handle the vast quantity of data that must be processed.

Behaviour analysis is a promising application and it is based on existing information technologies. Matching behavior to known parameters based on biometrics can also be a potential area of great promise. Proof-of-concept prototypes, however, need to be developed and evaluated.

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Information Taxonomy for Presentation, Selection and Design

Syndicate 5

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Tore Smestad

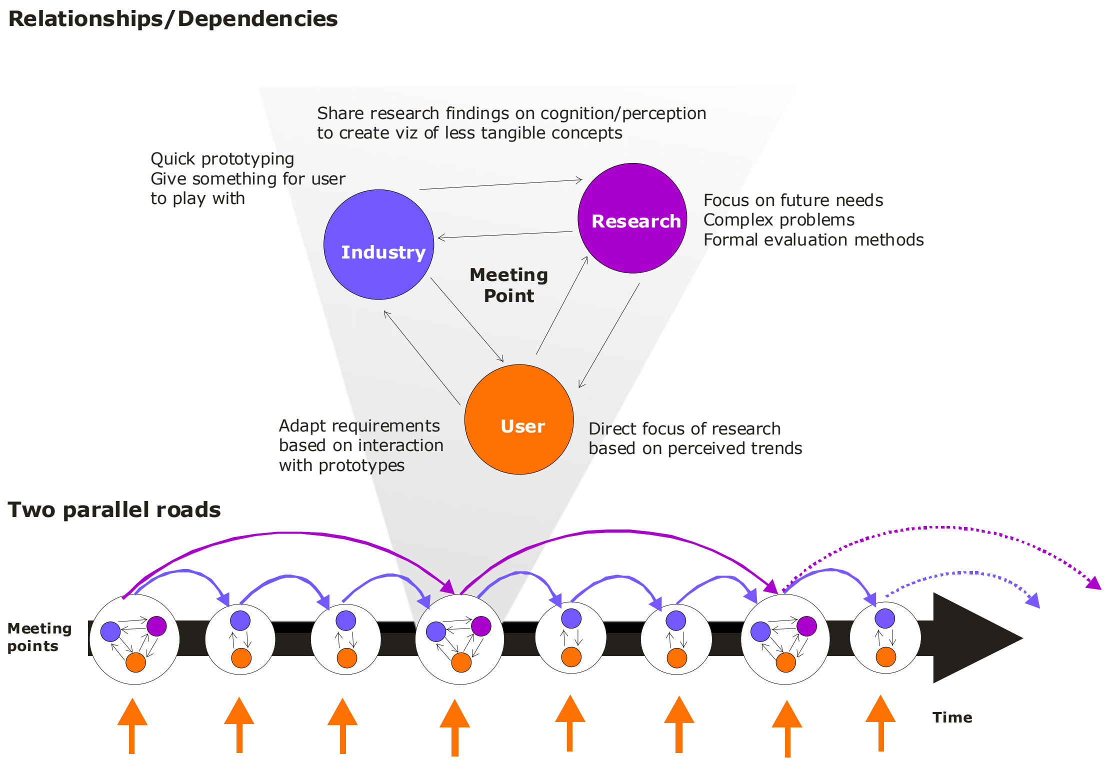
ABSTRACT

This report contains the ideas shared during our syndicate sessions. We tried to use these few hours of brainstorming to come up with guidelines about how to improve future visualization techniques to address military issues. The results of our discussions consist of a) advice on how the industry, the research community and user representatives should work together to best serve the military needs, b) a preliminary look at how sensors and weapons capabilities, performance and constraints could be presented, c) additional areas of research that were identified while considering military issues, and d) some guidelines about how to evaluate a visualization tool.

1.0 ADVICE ON WORK PROCESS

Considering the urgency and the complexity of the military needs for visualization tools, we concluded that both trial-and-error quick prototypes and longer term research to solve hard problems are equally important. Rigorous research is obviously necessary to tackle the many hard problems in presenting just what the users need to perform theirs task. However, systems should be put in the users' hands as quickly as possible. Fast-prototyping and trial and error are appropriate methods for this task since the users' needs will change as they get to interact with the tools. Users are crucial in the development loop since someone has to be very knowledgeable about the domain to know what elements of information need to be presented. A related fact mentioned was that a lack of representative data often ends up being a serious bottleneck in the development process of visualization tools. Hence, regular exchange points need to be scheduled between industry, research community and military personnel in order to exchange needs, views and results. This would also help to get the different parties to talk the same language and work in a way that would minimize redundancy and facilitate integration.

Paper presented at the RTO IST Workshop on "Massive Military Data Fusion and Visualisation: Users Talk with Developers", held in Halden, Norway, 10-13 September 2002, and published in RTO-MP-105.



2.0 PROCESS ILLUSTRATION (How We Came to Choose Our Topic)

The keynotes speakers strongly communicated their need for a better common operational picture (COP). The first step for our syndicate was then to define which elements of information should be presented to satisfy this need.

Our user representative produced a list of elements of interest. An attempt at mapping visualization approaches to the different elements of information in the domain context brought to the foreground the challenge of not only dealing with huge amount of physical information, but also the need to extract much **less tangible information**, such as ‘intentions’, ‘uncertainties’, ‘threats’, ‘operational readiness’, etc.

Another point that was emphasized by the user representatives during this workshop is the fact that in the new higher tempo kind of warfare, higher-level decision-makers are more likely to be faced with very little time to make very difficult decisions. It follows that to be useful in that kind of critical situation, the COP needs to provide more than situation awareness: it needs to become more of a decision aid.

The challenge consists in reducing latency in the decision cycle by creating visualizations that emphasize ‘actionable’ information.

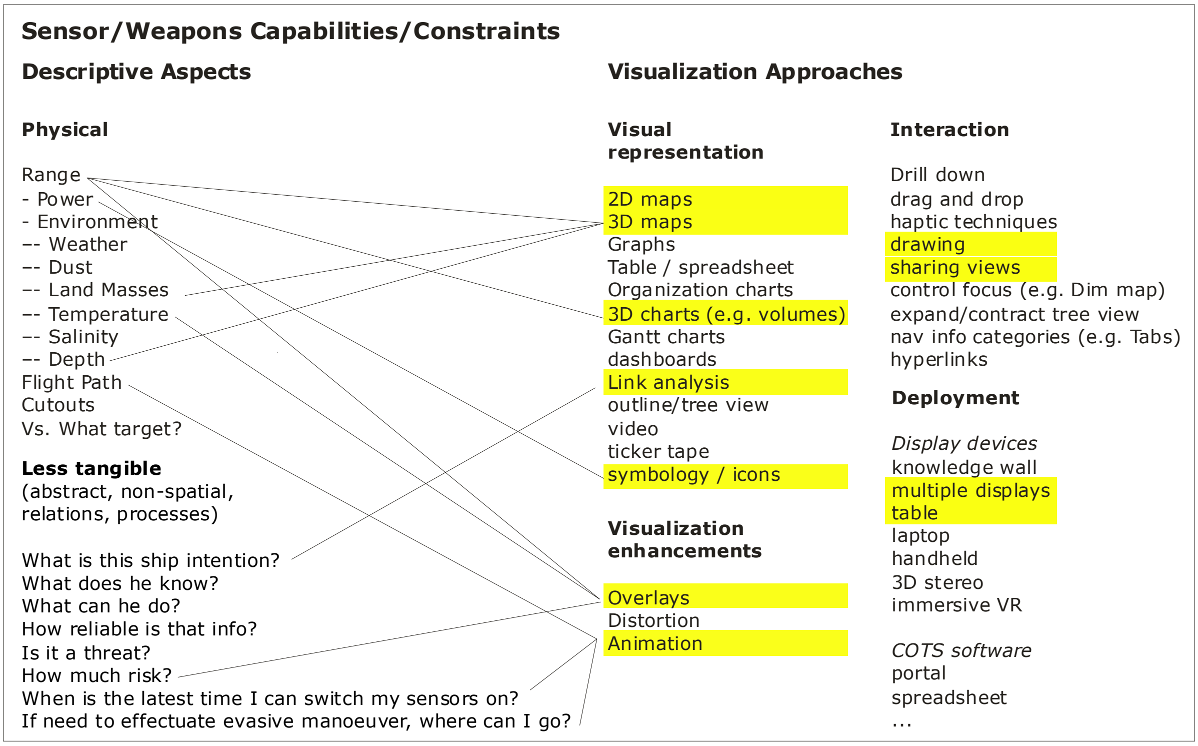
Based on our user representative area of expertise and knowledge of what is currently poorly done, we narrowed our focus to look at possible ways to visualize sensor and weapon capabilities and constraints. Furthermore, we decided to look at how decision points and timelines could be extracted from these visualizations based on movement and dynamics of the situation.

3.0 DOMAIN CONTEXT FOR PRESENTATION TECHNIQUES NEEDS

The issue of choosing the right visualization approach to present particular elements of information caught the interest of this syndicate.

The work of the TTCP C3I Action Group on Information Visualization (AG-3) presented by Denis Gouin during this workshop is a good start at tackling this issue. Part of that effort was the creation of a toolkit which queries databases to find the visualization tools supporting a specific analysis task. It would be beneficial for the visualization community to produce or gain access to such databases in order to facilitate the creation of an infrastructure/framework for the domain.

Our initial attempt (far from complete) to map visualization techniques to the elements of information needed for our selected topic is shown in the figure below. The visualization approaches listed in the diagram were taken from the paper Denis Gouin wrote for this workshop.



4.0 SELECTED TOPIC – SENSORS AND WEAPONS CAPABILITIES / PERFORMANCE / CONSTRAINTS

4.1 Present sensors and weapons (and communications) performance constraints showing 3D contours based on varying parameters values such as:

- **Environment (weather, terrain, salinity)**
- **Emission levels**
- **Probability of kill**
- **Countermeasures**
- **Time**

By showing the sensors and weapons volume coverage or range, what is not covered is also highlighted, which might be even more crucial in certain situations. Discontinuation of target tracking can then be predicted. Likewise, in a sensor network, the likely start of track reporting by own (firing quality) sensors can be predicted.

4.2 Showing target objects in relation to volume presentation – and volumes in relation to other volumes

As Battlespace volumes (performance constraints) of opposing platforms or forces approach each other, timelines and decision points can be extracted from presentation.

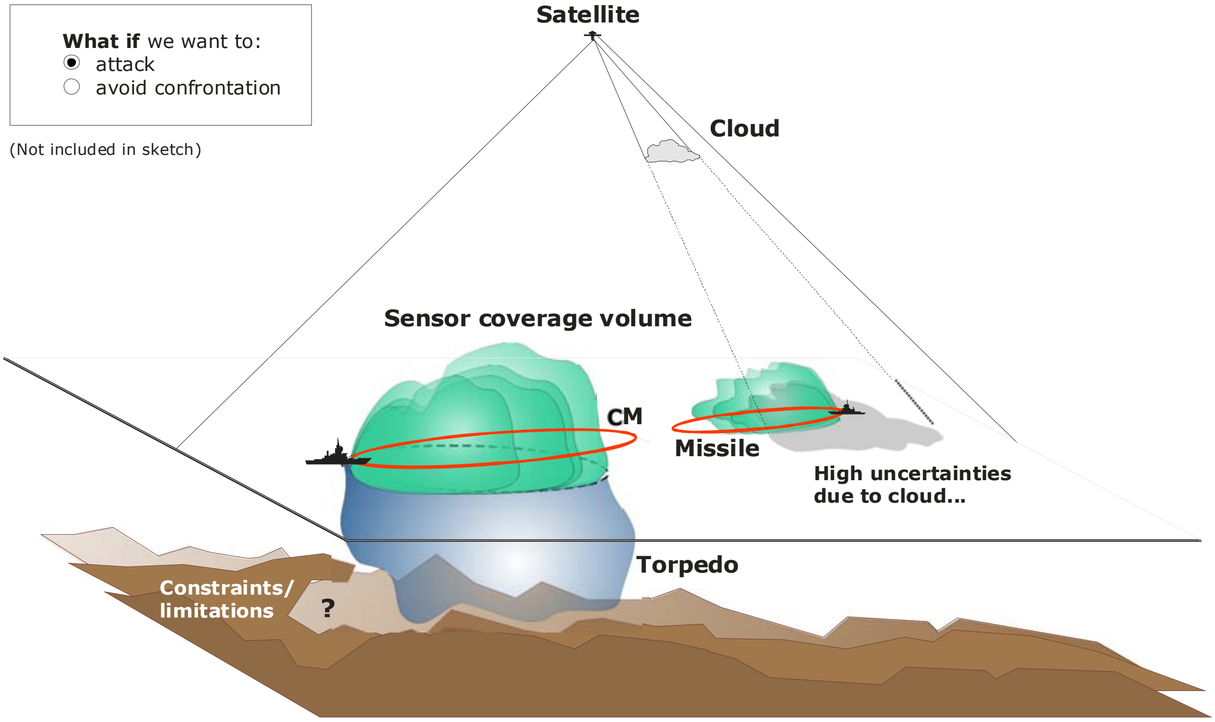
The view should allow users to answer questions at a glance like:

- What are the margins for detection of own platform/force based on the uncertainty regarding the constraints of **enemy sensors**?
- What are the margins for detection of enemy platforms/forces based on the uncertainty regarding the constraints of **own sensors**?
- When is the likely moment of first enemy hostile act?
- How reliable is the info about the other ship's location with respect to the constraints of my sensors?
- When is the latest time I can switch my sensors on in order to avoid early detection and to employ own weapons at their maximum capability?

The box at the top left of the sketch below illustrate the idea of listing possible decisions that could be analysed visually by selecting it. For example, choosing attack could overlay on the picture time, risk, etc. involved in that action.

4.3 Optimizing Volume Presentations

Volumetric presentations would convey the capabilities/constraints well, but experimentation is needed to be able to show complex intersecting volumes in a clear simple way as well as targets appearing in front of, inside of or behind volumes.



5.0 OTHER INTERESTING AREAS OF RESEARCH

5.1 Displaying Levels of Abstraction for Various Users

Different users at different levels of the military organization need different perspectives or level of details to accomplish their respective tasks. Furthermore, commanders might find it useful at times to look at what his or her subordinates see. Ideally, one tool would allow for continuous levels of abstraction.

The challenge is to create a set of rules that define how the elements of information can be aggregated when a simplified picture is needed.

5.2 Provide Alternate Modalities

One noticeable after effect of September 11 attacks is that the amount of information to be processed has increased dramatically. The information comes from multiple sources and in different forms (voice, chat, email, message, etc). Fusion needs to be applied to eliminate excess and redundancy, but without slowing the traffic too much since a lot of that information might be time sensitive.

It would be useful to find ways to level out the modalities used to process the information. The simple example brought up to explain the idea was your colleague writing ‘Lunch time!’ on a piece of paper and showing it to you while you are talking on the phone.

5.3 How “Real” is Necessary?

Comments from the user representatives such as “I want to see a helicopter, not a dot.”, or “Resolution is never good enough.” highlighted the question “How ‘Real’ is necessary?”.

Obviously, it depends on the task. Realistic looking 3D models of airplanes might be attractive, but if, in order to recognize the type of aircraft, the models need to be so big that it becomes very hard to determine their altitude or relative distance, then it fails.

In this case, the challenge is to create simple icons that emphasize the crucial differences between the aircrafts that are used to tell them apart.

On the other hand, it was raised that the traditional military symbols need to be replaced because in the context of coalitions, language and cultural differences pose a serious problem.

SPAWAR developed the so-called ‘Symbicons’ to deal with that issue. At the time presented, they were rejected, but Col. Johansen suggested that they should try again, now that the need is more obvious.

Generally speaking, it would be useful to come up with guidelines defining when symbols/graphs work better than realistic representations.

5.4 Automatic Stress/Workload Detection

This provocative topic deals with the fact that under stress, humans have a tendency to narrow their focus and lose important context or big picture. The effect is called tunneling. It might be interesting to investigate if a system could automatically detect the level of stress and the cognitive load of the user and when those passes certain thresholds, the system would adaptively change the level of information being presented, forcing the user to pull back and look at the big picture again.

5.5 Automatic Display of Threats

This is another provocative suggestion that is partly based on Col. Johansen comment about the annoyance caused by the time it takes to put on the screen the particular view that is needed at a particular moment. He mentioned that when things are planned and most likely outcomes are known, the staff will setup the views that might be needed in advance. Maybe a system of bookmarks could be implemented to facilitate that solution.

With the assumptions that a system could automatically detect threats and know which views are needed to deal with them, then an alert could appear. Selecting it would display the right view to look at the threat. Unless the threat is much more crucial than the task at hand, it would probably be better to let the operator decide when to change what is shown on display.

6.0 EVALUATION/ASSESSMENT ISSUES

Finally, our syndicate also discussed the issue of assessing visualization systems. There is a need for metrics to assess its value. As mentioned above, the fact that ‘the user likes it’ might not necessarily be productive. Therefore here are a few guidelines that should be considered:

Go beyond the HAT report model –

This is needed because “cognitive walkthroughs” and comparable methods are NOT good predictors of usability in practice.

Elaborate on what the system is used for. Develop a representative sample of tasks.

Develop/agree upon measures of task performance, process as well as ultimate outcome.

If the system exists – Conduct experimental studies of users performing the sample tasks.

A reasonable number of users should be greater than ten.

The users involved in the experiment should get appropriate prior training before performance measurements.

If the system does not yet exist, but there is a design – Apply cognitive modelling to the sample of tasks (Card, Moran & Newell, Kieras & John).

This step may reveal that the task requirements cannot be met.

It also allows comparisons of alternative designs.

However, the scope of what can be modelled today is somewhat limited.

7.0 CONCLUSIONS

The sole fact that some results could be presented in this report should highlight the success of the syndicate concept with respect to having members of the different communities exchange data and views. This is a step in the right direction, but much more efforts need to be devoted to the creation of a solid infrastructure to support the creation of innovative visualization techniques that would effectively address the issues the military is faced with now and will be facing in the future.

SYMPOSIA DISCUSSION – SYNDICATE 5

Comment:
Recommend that there is effort and resources put into a decision tool that looks at resource distribution.

Comment:
In the NATO context, the political context is important to the common operational picture.

Question:
What impact can the three different domains - physical, information, cognitive domain (including moral, ethical, and political) – have on development of decision support tools?

Response:
Decision support tools can be applied in all domains, but analysis of the domains and requirements is need. Research is just in the beginning of defining those requirements. Focus right now is on the physical domain.

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's References	3. Further Reference	4. Security Classification of Document
	RTO-MP-105 AC/323(IST-036)TP/20	ISBN 92-837-1109-2	UNCLASSIFIED/ UNLIMITED

5. Originator

Research and Technology Organisation
North Atlantic Treaty Organisation
BP 25, F-92201 Neuilly-sur-Seine Cedex, France

6. Title

Massive Military Data Fusion and Visualisation: Users Talk with Developers

7. Presented at/Sponsored by

The RTO Information Systems Technology Panel (IST) Workshop held at the Norwegian Defence Logistics and Management College, Halden, Norway on 10-13 September 2002.

8. Author(s)/Editor(s)	9. Date
Multiple	April 2004

10. Author's/Editor's Address	11. Pages
Multiple	226 (text) 648 (slides)

12. Distribution Statement

There are no restrictions on the distribution of this document. Information about the availability of this and other RTO unclassified publications is given on the back cover.

13. Keywords/Descriptors

Concept display
Human computer interaction
Military requirements
Visualisation
Visualization
Computer programs
Data acquisition
Data fusion
Data management
Human factors engineering
Information systems
Man computer interface
Models
Multimedia
Software development
Software engineering

14. Abstract

The work of this interactive workshop was done in thematic discussion periods both in plenary sessions and in focus groups ("syndicates"). Each plenary discussion period was preceded by a small number of formal presentations on the particular theme, intended to provoke thoughts from the participants that were further developed in the working discussions. The publication is divided in 8 sessions. Sessions 1 to 7 end with Questions and Answers. Session 8 presents the conclusions of the focus groups in 5 separate "syndicates".

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