Computer Modelling of Human Populations in Support of Military and Civil Command and Control (C2) Exercises

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ABSTRACT

This paper discusses the design of a computer modelling framework for a UK military training and education requirement, lessons learned during its construction and implications for representing the complex and contested future operating environment.

The "Influence and Infrastructure Combat Model" (IICM) is a computer simulation that models the flow of information and resources through a Human Terrain and the supporting critical national infrastructure networks (CNI). This project began as a study on methods of modelling the effects of Cyber activities on a local population and was extended to include wider military actions including Hybrid, Military Operations in Urban Areas (MOUT) and Informational Manoeuvre activities.

IICM treats the population as an unstable equilibrium destabilised by external actors. Drawing upon group dynamics theory and epidemiological compartment modelling techniques, information is modelled as mimetic packets which are passed between software agents representing population groups, changing the level of support for different factions. These act as a quantifiable 'target' for influence operations within an exercise.

Drawing on our experience in military exercising, IICM is designed to operate as an independent model or federated with a kinetic warfare simulation. It presents effects as seen by the military decision maker, rather than the low-level analyst or system operator.

1.0 COMMAND AND CONTROL EXERCISES

The Contemporary Operating Environment (COE) is characterised by complex terrain, pockets of high population density and adversaries that seek to engage our forces over multiple domains, physical and virtual. Critical decisions may need to be taken on limited and incomplete information.

Command and Control (C2) exercises test the ability of a command group to assimilate information, make decisions, implement a resultant course of action and observe a potential outcome. These exercises often substitute computer generated forces operating in a synthetic environment for live forces, saving time and material.

The current generation of Modelling and Simulation (M&S) tools struggle to simulate the COE at the level perceived by a unit commander and his support staff. To be effective, a COE model must understand both the current range of effectors (kinetic attack, influence activities and cyber warfare) and the potential targets of action (regular and irregular military forces, and the civil population). A significant part of this requirement is the mood (sentiment) of a local population and its reaction to military forces and information operations

1.1 Current Training Solutions

Current solutions use two different classes of model to represent the battlespace.

- Kinetic warfare models represent the physical world along with the principle military combat units. Time, distance and firepower are key concepts. Human factors are often downplayed to allow the training audience to concentrate on the coordination of physical activity between different units.
- Sociological and Human Terrain models perceive the world in terms of human activity and social linkages. Concepts like geography and time are often highly approximated, allowing a greater focus on information flows through a population. Most models require complex (and expensive) start data and exhibit a wide range of outcomes to small changes in the input orders.

Since they are based on different underlying concepts, integrating the results between Kinetic and Sociological models requires manual processes, often impractical in the timescales and budgets available on training events. Furthermore, these processes are susceptible to unconscious human bias on the part of exercise control and the training audience, reducing confidence in the outcomes and leading to disengagement of the training audience.

2.0 HUMAN TERRAIN REQUIREMENT

In 2017, NSC led a UK project investigating Defensive Cyber Concepts by researching methods of modelling the effects of Cyber Warfare on human and infrastructure networks. This resulted in a report "Dynamic modelling of infrastructure and human networks" (Athena DSTL Project Number 707354).

This report concluded that current population modelling techniques are too expensive to support training events, especially those that include Influence Operations. A requirement was identified for a specialised Human Terrain model designed to support the needs of military exercises and educational tasks.

The report observed that the Human Terrain is a contested domain whose background equilibrium can be disturbed by routine day-to-day military activity in a region, as well as overt Informational Manoeuvre operations. Operations by military and civil forces (including Cyber Warfare) can lead to unintended collateral effects that destabilise components of the Critical National Infrastructure, which in turn affect the ability of the local population to go about their daily activity, and so upset a local balance of power amongst that population.

Several key factors need to be addressed in a potential model:

- The model must work with both real world and fictional scenarios. Since pre-existing fictional scenarios have little or no supporting Social Media data (a common source dataset for existing Human Terrain models), the models will need to use an alternative data source.
- The model output must be comprehensible by a non-specialist training audience as well as an analyst. To further audience understanding, chaotic population behaviour must be constrained, even when this is present in real world scenarios.
- To allow the complete range of HQ functions to be exercised on the same event, the model must link to existing Kinetic Warfare models.

Rather than a designing a predictive model that attempts to emulate real world events, the study highlighted the need for a low-cost informative model that can improve the understanding of Influence Operations amongst practitioners and their commanders.

3.0 SOLUTION

The "Influence and Infrastructure Combat Model" (IICM) is an agent based Human Terrain model intended to support military training and education requirements. Fundamentally, IICM is a novel wargames engine that allows the passage of sentiment to be modelled throughout a target population, both civil and military. Techniques have been adapted from existing social models by decreasing sensitivity to input data and adjusting the measurement of time to match the pace of kinetic events in a training scenario.

The project will run over 3 phases, each escalating the models Technology Readiness Level (TRL): -

- Phase 1 - Prototyping the Human Terrain model to prove its underlying concepts and to test its behaviour with reference to computational and source data requirements. (TRL 3/4). This phase concluded summer 2019.
- Phase 2 - Refinement of IICM to handle a contemporary, complex military scenario by linking the Human Terrain model into an existing Kinetic Warfare model. (TRL 4/5). This phase is due to begin late 2019.
- Phase 3 - Integration of IICM into a comprehensive Simulation and Modelling framework such as the UK proposed Synthetic Operating Environment. (TRL 6/7). This phase is expected in 2020-2021.

4.0 PROJECT METHODOLOGY

Phase 1 began by reviewing how other teams have addressed these topics. Notable research sources included: -

- Recent work by David Kilcullen (Out of the Mountains. ISBN-978-1849045117) and Stathis Kalyvas (The Logic of Violence. ISBN-978-0521670043) explored how social groups interact and compete, and how this links to contemporary Counter Insurgency doctrine. This topic was supported by concepts like Narrative Dominance, explored by other NATO working groups.
- Contemporary manual commercial wargames (notably GMT Games COIN series of wargames) demonstrated that a highly aggregated terrain coupled with an area control mechanism can provide enough complexity to model complex political topics, and to challenge a prospective training audience.
- Urban characterisation studies provided a mechanism for modelling populated areas. This saw notable input from Allan W. Shearers work on the Archaria scenario and related PEMSII characterisation work for NATO ACT.
- Infectious Disease modelling techniques explored the use of computational methods of simulating human interactions. These studies highlighted the importance of age in determining the frequency and scope of social interactions. They also introduced the concept of Compartment Models, a process by which the population is divided into compartments, with the assumption that every individual in the same compartment has the same characteristics.

This was followed by an investigation into potential datasets that could support the model. Since data acquisition costs are a major factor in training exercises, Open Source data was prioritised in this investigation. A promising source of social behaviour data was found in medical datasets which described social contacts between different age and cultural groups (for instance; Mossong J, Hens N, Jit M, Beutels P,

Auranen K, Mikolajczyk R, et al. (2008) Social Contacts and Mixing Patterns Relevant to the Spread of Infectious Diseases. PLoS Med 5(3): e74. https://doi.org/10.1371/journal.pmed.0050074 .)

Following the review, a designed a systems architecture was designed which split the solution into four main building blocks based upon the critical capabilities we wanted to demonstrate.

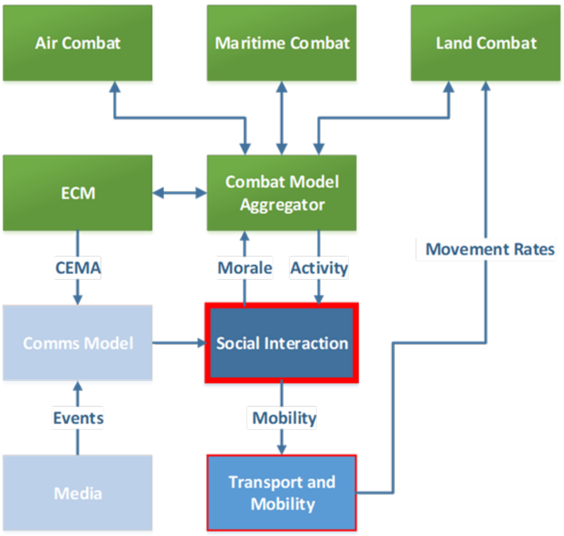

Figure 1: IICM Model Elements.

- Military activity affects the population. The "*Combat Model Aggregator*" acts a bridge into legacy kinetic models.
- Cyber and CNI disruption change electronic communications. A "*Capacity based Comms model*" models electronic information flow.
- People move over a daily cycle between different geographic areas. An Arc-Node based "*Transport and Mobility model*" allows population transport flows to be modelled and disrupted by external events.
- Information flows through a population. An "*Agent based Social Interaction model*" models the transmission of influence between people.

Elements of this design were prototyped to demonstrate the technical viability of the solution and to ensure that it was practical for use on a training event. The 'Agent based Social Interaction Model' and its associated 'Transport and Mobility Model' were prioritised for further investigation.

5.0 MODEL DESIGN

IICM models the Human Terrain through five different, interlinked concepts.

5.1 Geography

Geographically the exercise area is split into a small number of regions. Regions are selected to highlight major population features and include constraints on population mobility. Investigation showed that the administrative regions used for census data often reflect underlying characteristics of the population behaviour.

Where practical, rural and urban areas are separated into different regions, highlighting the different patterns of behaviour exhibited by the population at a local level. Key infrastructure features such as communications hubs, transport nodes and major utilities have physical locations within these regions and act to transport resources between regions. A typical C2 training exercise requires 6 – 12 regions whilst analytical scenarios may use up to 20 regions.

5.2 Political

Politically, the Human Terrain is split into a relatively small number of competing factions. Factions can be used to represent political affiliations, tribal membership or other grouping which the training audience wish to measure or influence. The population is divided into Factions through Group Dynamics principles, using the concept of a ‘Category’ collection (that is a group that a person self-identified with). Remaining Group Dynamics collections (Primary, Social and Collective groups) are represented by other attributes in the model.

Competing military forces are included as active factions within the system. This allows their physical presence to generate influence on the wider population and permits them to be targeted by hostile influence operations.

Basic scenarios use at least 5 factions, typically including two or more military forces, the local government and at least two civil groups. Advanced scenarios require 10 or more factions, allowing greater fidelity of the civil population behaviour.

5.3 Population

IICM divides a regional population into small collections of people that share characteristics, called Population Groups (PG). Members of a PG share a common faction, age band, home region and work region and are assumed to be in a state of near constant communication amongst themselves. Consequently, IICM can use Group Dynamics principles to aggregate the behaviour of the PG members together to give a common response to external stimuli.

The model treats each PG as a semi-autonomous software agent and tracks them as they move between the different geographic regions and interact with each other. A typical scenario includes 100's to 1000's of these groups, each representing 25 – 1000 individuals.

5.4 Cultural Distance

Differences in cultural behaviour and language act as an impediment to successful communication between groups of people. IICM uses the concept of Cultural Distance (CD) to describe the ability of factions to communicate with, and so influence, each other.

Currently, IICM use a Lewis model to generate a single CD value that determines the chance of successful communication, irrespective of the communication channel. Enhanced versions of IICM will use a Hofstede Cultural Dimensions model to better reflect how each faction is perceived (and trusted) by other factions depending on the form which communication takes place, allowing better representation of mass media and social media.

5.5 Messages

IICM implements a SMCR communications model which describes information flow in terms of a Source, Message (Payload), Channel (Delivery Mechanism) and Receiver. The Source and Receiver are the PG entities communicating with each other. The message encodes a change of support (positive or negative) for a faction modelled in the system and includes information on the authors faction. Since IICM assumes that Face-to-Face communication is the most effective method of conveying complex information, this as the primary information channel.

A message can be described as an infectious agent (or Meme) which is passed between PG entities. Consequently, the behaviour of a message can be modelled using epidemiological Compartment Models. In common with biological systems, messages have the following key behaviours: -

- A message is normally transmitted when two PG's are in the same region and interacting with each other. The chance of interaction depends on age and other cultural factors.
- Some messages are more 'infectious' (believable) than others. The smaller the Cultural Distance between the message author and the recipient, the more chance of it changing the perception of the recipient.
- Messages can be 'misunderstood' as they are passed between PG's and so 'mutate' into a new form. The greater the Cultural Distance, the higher the chance of mutation.
- Some messages are more interesting than others and so have a higher 'virulence'. This allows them to take precedence during communications and so be exchanged faster throughout a population.
- Messages have a lifespan after which the information it encodes becomes 'stale' and no longer newsworthy. Once a message reaches this point it is no longer infectious and becomes dormant.

To represent the effects of social media and other background communications, IICM includes a smoothing model which allows influence scores (but not the underlying messages) to propagate throughout all members of a faction, no matter where they are physically located.

Message transmission and effects are evaluated on an hourly basis and results typically generated every 12 to 24 hours of exercise time to match a formations battle rhythm. Outputs take the form of graphs and bar charts showing the change of influence over time.

6.0 PROGRESS AND CONCLUSIONS

IICM is currently under active development. Key elements of the computer simulation have been designed, constructed and tested. Datasets representing a wide range of real world and fictional scenarios have been built using a combination of open source and synthetic datasets. These have been tested against the requirements of different user communities, including use on real training events.

Access to open source social contact models allowed the construction of viable training scenarios without resorting to Social Media derived datasets. However, this required an understanding of a local transport network and the location of key social gathering points like local markets and schools. The division of a population into age bands as well as political affiliations was essential to replicating real world test cases.

In its current form, IICM is best suited at describing human populations numbering 10,000 – 100,000 people. This covers the intended Battalion to Brigade mission sets and allows up to 10 days of activity to be modelled. The main limitation in exercise complexity is not computer processing power, rather the ability to present the resulting data in a format that can rapidly assimilated.

The next stage of development, Phase 2, will expand the communication model to include broadcast media and other electronic methods of communication. This will allow the flow of influence through a population to be altered by disruption to the communications chain, in turn allowing aspects of Cyber Warfare to be modelled. Refinements to the Combat Model Aggregator will allow the automatic generation of messages (and so influence) in response to activity within the kinetic warfare models. Enhanced methods of data presentation will also be trialled.