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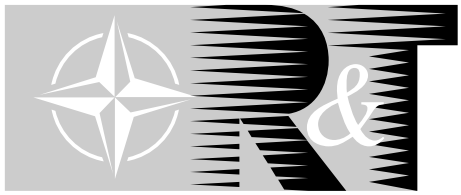

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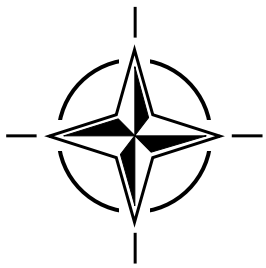
Intelligent Systems for Aeronautics

(Systèmes intelligents pour l'aéronautique)

The material in this publication was assembled to support a RTO/VKI Special Course under the sponsorship of the Applied Vehicle Technology Panel (AVT) and the von Kármán Institute for Fluid Dynamics (VKI) presented on 13-17 May 2002, in Rhode-Saint-Genèse, Belgium.



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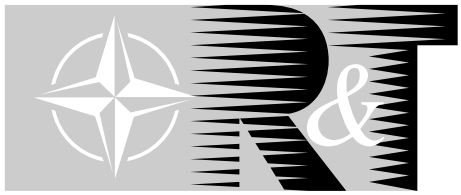

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RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), 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 coordinates RTO's cooperation 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 initial cooperation.

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 cooperation 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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Intelligent Systems for Aeronautics

(RTO EN-022 / AVT-095)

Executive Summary

Intelligent Systems (IS) are nature-inspired problem solving tools and methodologies that have recently become important in information technology applications. Artificially intelligent systems use computers to emulate various faculties of human intelligence, and biological metaphors. They use a combination of symbolic and sub-symbolic systems capable of developing human-like cognitive skills and intelligence, not just systems capable of doing things humans do not do well. Intelligent systems are ideally suited for tasks such as search and optimization, pattern recognition and matching, planning, uncertainty management, control and adaptation.

These lecture notes approach IS from two perspectives: techniques and applications. The emphasis is on aeronautical and space applications of IS, rather than basic research or tool development. The objectives of this NATO Research and Technology Organisation (RTO) sponsored Lecture series is to provide a series of comprehensive lectures by leading experts:

1. to enable the understanding of the concept, history, and benefits of intelligent system technologies;
2. to enable an understanding of the areas of applicability of IS technologies to aeronautics and space;
3. to enable an understanding of the state-of-the-art applications of IS technologies in aeronautics and space.

The lectures were intended to accommodate attendees of both novice and advanced levels of technical expertise.

For this purpose, the following techniques commonly used in IS were reviewed: decision strategy tools based on game theory (Dr. J. Périaux, MDBA, France), neural network techniques for fault identification (Prof. M. Innocenti, U. Pisa, Italy), genetic algorithms (Dr. M. Anderson, Sverdrup Technology, USA; Dr. D. Quagliarella, CIRA, Italy) and multi-agent theory (Dr. I. Degirmenciyan, MDBA, France)

These techniques were illustrated by numerous applications: optimal air combat tactics (Dr. K. Krishnakumar, NASA Ames), control of unmanned air vehicles (Dr. M. Ricard, Draper Lab, USA), air combat simulation (Dr. I. Degirmenciyan, MDBA, France), space exploration (Dr. R. Doyle, JPL, USA), unmanned aircraft navigation and formation control (Prof. M. Innocenti, U. Pisa, Italy), missile design (Dr. M. Anderson, Sverdrup Technology, USA), airfoil design (Dr. D. Quagliarella, CIRA, Italy) and finally analysis of rocket plume data for condition monitoring (Prof. K. Whitaker, U. Alabama, USA). Most of these applications have a clear military aspect, whether at the system design level (missile design, control of unmanned air vehicles) or at operational level (optimal air combat tactics, unmanned aircraft formation control, air combat simulation), hence highlighting the relevance and importance of Intelligent Systems for military issues.

G. Degrez[1] & K. Krishnakumar.[2]
[1]von Kármán Institute, Belgium & [2]NASA Ames, USA
Lecture Series Editors

Systèmes intelligents pour l'aéronautique

(RTO EN-022 / AVT-095)

Synthèse

Les systèmes intelligents (SI) sont des outils et des méthodologies de résolution de problèmes, d'inspiration humaine, qui ont récemment pris de l'importance dans les applications des technologies de l'information. Les systèmes d'intelligence artificielle font appel à des ordinateurs et à des métaphores biologiques pour imiter les différentes facultés de l'intelligence humaine. Ils exploitent en combinaison des systèmes symboliques et sous-symboliques capables de développer des compétences cognitives et de l'intelligence pseudo-humaines et non pas simplement des systèmes capables de réaliser ce que l'être humain ne réalise pas bien. Les systèmes intelligents sont idéalement adaptés à des tâches telles que la recherche et l'optimisation, la reconnaissance des formes, la planification, la gestion de l'incertitude, le contrôle et l'adaptation.

Ce support de cours aborde les systèmes intelligents sous deux angles différents : techniques et applications. L'accent est mis sur les applications aéronautiques et spatiales des SI plutôt que la recherche de base ou le développement d'outils. Ce cycle de conférences organisé par l'Organisation OTAN pour la recherche et la technologie (RTO) a pour objectif de proposer une série de conférences complètes présentées par d'éminents spécialistes du domaine afin de permettre de mieux comprendre :

1. le concept, l'historique, et les avantages des technologies des systèmes intelligents;
2. les domaines d'application des technologies des SI pour l'aéronautique et l'espace;
3. les applications de pointe des technologies des SI pour l'aéronautique et l'espace.

Les conférences sont destinées à des participants de tous niveaux de compétence technique, du novice jusqu'au spécialiste.

Dans cette optique, les techniques suivantes, couramment employées en IS, ont été examinées : des outils de prise de décisions stratégiques basés sur la théorie des jeux (Dr. J. Périaux, MDBA, France), des techniques de réseaux neuronaux pour l'identification des défaillances (Prof. M. Innocenti, U. Pisa, Italie), des algorithmes génétiques (Dr. M. Anderson, Sverdrup Technology, USA; Dr. D Quagliarella, CIRA, Italie), et des théories multi-agents (Dr. I. Degirmenciyan, MDBA, France)

Ces techniques ont été illustrées par de nombreuses applications : les tactiques optimales de combat aérien (Dr. K Krishnakumar, NASA, Ames), le pilotage des véhicules aériens sans pilote (Dr. M. Ricard, Draper Lab, USA), la simulation du combat aérien (Dr. I. Degirmenciyan, MDBA, France), l'exploration de l'espace (Dr. R. Doyle, JPL, USA), la navigation et le contrôle de formation des véhicules sans pilote (Prof. M. Innocenti, U. Pisa, Italie), la conception des missiles (Dr. M. Anderson, Svedrup Technology, USA), la conception des profils aérodynamiques (Dr. D. Quagliarella, CIRA, Italie), et finalement l'analyse des données de panache des moteurs fusées pour le contrôle de l'état du moteur (Prof. K. Whitaker, U. Alabama, USA). La plupart de ces applications ont des implications militaires évidentes, soit au niveau de la conception du système (conception des missiles, pilotage des véhicules aériens sans pilote) soit au niveau opérationnel (les tactiques optimales de combat, le contrôle d'aéronefs sans pilote en formation, la simulation du combat aérien), ce qui fait ressortir l'intérêt et l'importance de systèmes intelligents pour applications militaires.

G. Degrez[1] & K. Krishnakumar.[2]
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Lecture Series Editors

Contents

† Paper not provided in time for publication.

Preface

Intelligent Systems (IS) embody varying degrees of representation of biological and cognitive systems for efficient solution of complex problems. In our society today, intelligent systems have become extremely fascinating tools for significantly improving the trends in information technology applications. Intelligent systems are ideally suited for tasks such as search and optimization, pattern recognition and matching, planning, uncertainty management, control and adaptation. This lecture notes will approach IS from two ends: techniques and applications. The emphasis is on aeronautical and space applications of IS, rather than basic research or tool development.

The objectives of this NATO Research and Technology Office (RTO) sponsored Lecture series is to provide a series of comprehensive lectures by leading experts.

1. To enable the understanding of the concept, history, and benefits of intelligent system technologies;
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3. To enable an understanding of the state-of-the-art applications of IS technologies in aeronautics and space. The lectures are intended to accommodate attendees of both novice and advanced levels of technical expertise.

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Multi-agent theory
Neural networks
Optimization
Pattern recognition
Planning
Problem solving
Rocket plume data for condition monitoring
Search theory
Space exploration
Sub-symbolic systems
Symbolic
Uncertainty management

14. Abstract

Intelligent systems are suited as search and optimization, pattern recognition and matching, planning, uncertainty management control and adaptation.

These lecture notes cover techniques and application with emphasis on aeronautical and space applications.

Techniques reviewed: decision strategy tools based on game theory, neural network techniques for fault identification, genetic algorithms and multi-agent theory.

Application reviewed: air combat tactics, control of unmanned air vehicles, air combat simulation, space exploration, missile design, airfoil design, analysis of rocket plume data for condition monitoring. These applications highlight the relevance and importance of Intelligent Systems for military issues.

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