Research Directions in the KES Centre

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Abstract. The ongoing success of the Knowledge-Based Intelligent Information and Engineering Systems (KES) Centre has been stimulated via collaborated with industry and academia for many years. This Centre currently has adjunct personnel and advisors that mentor or collaborate with its students and staff from Defence Science and Technology Organisation (DSTO), BAE Systems (BAE), Boeing Australia Limited (BAL), Ratheon, Tenix, the University of Brighton, University of the West of Scotland, Loyola College in Maryland, University of Milano, Oxford University, Old Dominion University and University of Science Malaysia. Much of our research remains unpublished in the public domain due to these links and intellectual property rights. The list provided is non-exclusive and due to the diverse selection of research activities, only those relating to Intelligent Agent developments are presented.

Keywords: Computational Intelligence, Intelligent Agents, Multi-Agent Systems.

1 Introduction

The KES Centre held its first conference in 1997. This marked a new beginning in Knowledge-Based Engineering Systems, as this conference brought together researchers from around the world to discuss topics relating to this new and emerging area of engineering. Due to its great success the KES conference has now attained full international status. A full history of the KES International Conferences can be found on our web site[1]. The research directions of the KES are focused on modelling, analysis and design in the areas of Intelligent Information Systems, Physiological Sciences Systems, Electronic commerce and Service Engineering. The KES Centre aims to provide applied research support to the Information, Defence and Health Industries. The overall goal will be to synergies contributions from researchers in the diverse disciplines of Engineering, Information Technology, Science, Health, Commerce and Security Engineering. The research projects undertaken in the Centre include adaptive mobile robots, aircraft landing support, learning paradigms and teaming in Multi-Agent System (MAS).

Compare this with the 1^{st} recorded conference relating to the science of Intelligent Agent (IA) itself, which dates back to Dartmouth in 1958. This is 39 years prior to

[1] http://www.unisa.edu.au/kes/International_conference/default.asp

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KES, although microcomputers only started to appear on desktops in the mid-eighties which is when KES was founded. Most of this research involved the progressive use of technology in science to collect and interpret data, prior to representing this as knowledge using “folk law” or “symbology”. The wealth of data became unwieldy, forcing researchers to explore data-mining, warehousing and Knowledge Based System (KBS), however the key research domains remained focused on problem solving using formal/structured or reasoning systems [1]. This era was accompanied with an expansion in research into a variety of intelligent decision support systems that where created to derive greater confidence in the decision being generated [2]. The growing density of data had an overall effect on the efficiency of these systems. Conversely a series of measures where created to report on the performance of Decision Support System (DSS). Factors such as; accuracy, response time and explain-ability were raised as constraints to be considered before specifying courses of action [3]. Since the eighties Artificial Intelligence (AI) applications have concentrated on problem solving, machine vision, speech, natural language processing/translation, common-sense reasoning and robot control [4]. In the nineties there was a flurry of activity using “firmware” solutions to overcome speed and compiler complexities, however around the turn of the century, a return to distributed computing techniques has prevailed. Given his time over, John McCarthy would have labelled AI as “Computational Intelligence” [5]. Today the Windows/Mouse interface currently still dominates as the predominant Human Computer Interface (HCI), although it is acknowledged as being impractical for use with many mainstream AI applications.

2 Research Projects

Several of the projects undertaken by the KES Centre involved the use of intelligent paradigms as below:

– Coordination and Cooperation of Unmanned Air Vehicle Swarms in Hostile Environment,
– Communication and Learning in Multi-Agent Systems,
– Simulation of Pulsed Signals above 100 MHz in a Knowledge-Based Environment,
– Using Artificial Intelligence and Fusion Techniques in Target Detection,
– Intelligent decision support feedback using MAS in a Defence maintenance environment, and
– Improving Agent Communication in a Distributed Application Environment.

2.1 Coordination and Cooperation of Unmanned Air Vehicle Swarms in Hostile Environment

The aim of this research is to integrate coordination abilities into agent technology using the concepts of cooperation, collaboration and communication [6]. An example could include the coordination of a swarm of Unmanned Air Vehicles (UAVs) in a hostile environment. There has been substantial research conducted in this area, however the coordination aspect that have been implemented are either specific to an application or difficult to implement. As a result, a rigid and complex architecture is required. Implementing the concepts of cooperation, collaboration and communication in coordination may enhance performance; reduce complexity, and assist in applying coordination in a simple manner. The link between agent coordination and cooperation has been established and two principles have been developed from this link: Coordinative Cooperation and Cooperative Coordination. An architecture, known as the Agent Coordination and Cooperation Cognitive Model (AC^3M), is being developed which incorporates these principles into a MAS. It uses the concepts of Coordinative and Cooperative "events" to allow for each to be realized as a cognitive loop. The next approach is to incorporate the Beliefs, Desires, Intentions (BDI) at a physical level for control and link this to the Observe Orient Decide and Act (OODA) loop at a cognitive level for situation awareness and cooperation [7, 8].

2.2 Communication and Learning in Multi-agent Systems

This research involves encompassing communication and learning in multi-agent systems [9]. Firstly, we develop a hybrid agent teaming framework and analyze how to adapt the simulation system for investigating agent team architecture, learning abilities, and other specific behaviors. Secondly, we adopt the reinforcement learning algorithms to verify goal-oriented agents' competitive and cooperative learning abilities for decision-making. In doing so, a simulation test-bed is applied to test the learning algorithms in the specified scenarios. In addition, the function approximation technique, known as Tile Coding (TC), is used to generate value functions, which can avoid the value function growing exponentially with the number of the state values. Thirdly, Bayesian parameter learning algorithms in conjunction with reinforcement learning techniques are proposed for inferencing and reasoning in the cooperative learning. Finally, we will integrate the learning techniques with an agent teaming architecture with the abilities of coordination, cooperation, and dynamic role assignment. The ultimate goal of our research is to investigate the convergence and efficiency of the learning algorithms and then develop a hybrid agent teaming architecture.

2.3 Multiple UAV Communication in an Intelligent Environment

This research concentrates on using coordination and collaboration within UAV teams to accomplish better communication amongst UAV entities [10]. As the UAVs have limited sensor capabilities, cooperative control relies heavily on communication with appropriate neighbors. The advantages of coordinating and collaborating UAV teams include accomplishing the missions in a shorter period and successfully completing many goals simultaneously. This problem is of interest in UAV applications, as communication is often required between nodes that would not otherwise be able to communicate for instance because of range constraints or line-of-site obstructions. Efficient, reliable, low latency communication is required to fully realize and utilize the benefits of multi-vehicle teams. Achieving the leashing goal for instance in a more optimal way by knowledge sharing is one of the research goals. The design and development of an intelligent communication routing protocol for UAV applications that use heterogeneous networks is another goal of this research. The medium access layer will be modified for accessing the medium and for sensor scheduling. The intelligent routing protocol will be modified to accommodate the network layer. Reinforcement learning will be applied in order to add intelligence to the electronic leashing.

2.4 Simulation of Pulsed Signals Above 100 MHz in a Knowledge-Based Environment

The determination of the nature and identity of a pulsed electromagnetic radiation source has been a evolving for some decades [11]. To date the use of Knowledge Based techniques has not been examined to the same extent as in some other aspects. This research topic, considers the feasibility of the use of Artificial Intelligence techniques as support to the traditional techniques for extraction of data. To achieve this, analysis is performed of the nature of pulsed radiation sources and receiving system characteristics. The model used for traditional simulation is examined and used to generate selected key performance indicators. A more precise, temporal based model, which is considered more applicable to AI techniques evaluation, is generated and the same performance indicators are generated and subsequently compared with the traditional model, thus enabling conclusions to be drawn as to their respective merits. Finally, changes to the respective models, if appropriate, are examined and evaluated. Once a model has been developed, AI techniques will be used to assess the suitability of the model in the future evaluation of AI algorithms as a supplement, and as an alternative, to the traditional DSP methods. Techniques currently considered as suitable for this assessment include Fuzzy Logic, Neural Networks, Expert Systems and Evolutionary Computing.

2.5 Using Artificial Intelligence and Fusion Techniques in Target Detection

Automatic Target Recognition (ATR) is a problem which involves extraction of critical information from complex and uncertain data for which the traditional approaches of signal processing, pattern recognition, and rule based artificial intelligence (AI) techniques have been unable to provide adequate solutions. Target recognition of fixed signatures in stationary backgrounds is a straightforward task for which numerous effective techniques have been developed [12, 13]. If the target signatures and the background are variable in either a limited or known manner, more complex techniques such as using rule-based AI (i.e., expert systems) methods can be effective.

However, rule based AI systems exhibit brittle than robust behavior (i.e., there is great sensitivity to the specific assumptions and environments). When the target signatures or backgrounds vary in an unlimited or unknown manner, the traditional approaches have not been able to furnish appropriate solutions.

The aim of this project is to employ multiple sensors concurrently for detection and recognition using a suitable neural network paradigms. The data is fused in this processing scheme to exploit the spectral and geometric differences and arrive at a more reliable decision. However, there are any instances for multi-sensor fusion such as method for correlating non-simultaneous data from multiple, independent sensors and determination of correct classification of targets when there are conflicting reports. Fusion techniques are be used to improve the detection of man-made/artificial targets in multi-spectral or SAR images (taken on two different platforms with different view

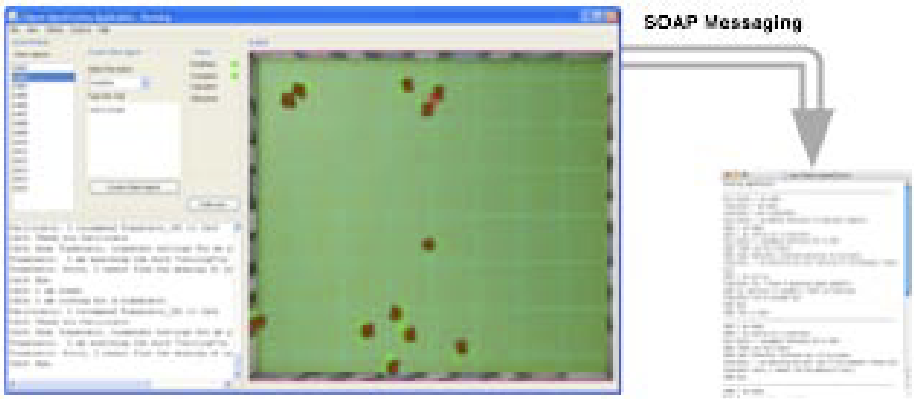

Fig. 1. Example of Agent Communications Demonstrator

angles), using spectral signature, shape/texture, a priori information, and surrounding geography.

2.6 Agent Communication in a Distributed Application Environment

As technology advances, humans are increasingly introducing delays and errors by the lack of response within system time limits. Human intervention must be minimized to avoid system conflicts while enabling the operators avoid repetitive, dull or dangerous tasks. Automation has become necessary in various applications. Since agents are not generally intelligent, they need to posses a capability to interoperate. They also need to interact, communicate, and share knowledge in order to successfully achieve their goal(s). We have found the dynamic nature of the Interface Description Language (IDL), invoked by Simple Object Access Protocol (SOAP) at run time, enables the application to adaptively configure its functionality in real time making the development of intelligent agent applications easier [14, 15]. This research aims to develop improved communication between distributed systems as shown in Figure 1.

This concept demonstrator is developed using Java to simulate this scenario and investigate the interaction, communication, and knowledge-sharing activities among agents within MASs. With the introduction of distributed computing, the problem of inter system communicated created a wide range of solution. The relationship between Web-Services Description Language (WSDL) and OWL-Services (OWL-S) is implied. Both languages are NOT covered in the same domain, however the overlap is obvious. The "service descriptions provide a powerful way of assembling information resources in contexts [16]". Threads, Agents and Distributed computing and reconfigurable silicon designs have attracted serious attention, forcing both industry and developers to reflect on existing paradigms in order to rethink the future. SOA makes it easier to product functional designs with limited functionality. The research conducted so far by KES has developed a blackboard design upon which segregated functions can be integrated into an application of aimed at achieving this goal. More research is required to

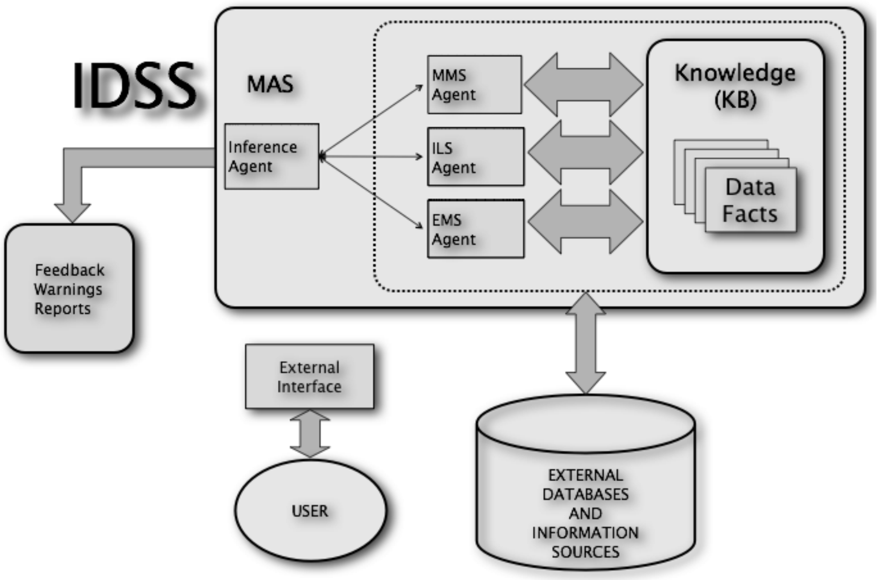

Fig. 2. Example of the Agent Communications Demonstrator

enable agents to communicate and cooperate and self organize in order to maximize the efficiency of any MAS.

2.7 Intelligent Decision Support Feedback Using MAS in a Defence Maintenance Environment

Safety and airworthiness of airborne platforms rest heavily on maintainability and reliability to maximize availability and reduce logistics down time. Maintenance data from test results rely heavily on paper trails and generally fail to provide preventive analysis. An expert system using intelligent agents could be employed to create an expert system in the form of an Information Management Systems (IMS). This concept would develop into an Intelligent Decision Support System (IDSS) that extrapolates forecasts and warnings as shown in Figure 2.

An Intelligent Decision Support System (IDSS) is required to provide adaptive automated responses for provisioning and maintenance of an increasing number of Defence platforms. Many are now emerging to support an increasing number of long-term maintenance contracts from within the private sector. Traditional methods of repair are already being modified to include automated testing although legacy platforms which still rely heavily on manual maintenance techniques. The conceptual development of a multi-agent expert system; referred to above as an IDSS. This system should be able to provide cognitive feedback to support reliability predictions and informed decision making to proactively minimize the issues of logistics down time, obsolescence and any associated risks [17, 18].

3 Future

The KES Centre has entered a new era fuelled by technology that has surpassed a milestone that has enabled renewed vigor into research activities that had previously stalled. It is widely acknowledged that current computer architectures have limited the wide spread implementation of many large scale, commercial quality applications in the artificial intelligence arena. The terms: automation, dynamic reconfiguration, learning, inference and self directed (intelligent) team behavior are all approaching a maturity level upon which large scaled, distributed applications, will become interoperable, spurred on by the technology leap required to surpass the barriers currently being experienced in many of these fields.

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