The Knowledge Engineering Review, Vol. 8:3, 1993, 251–254

4th Workshop on Artificial Intelligence and Knowledge Based Systems for Space

JOACHIM FUCHS
ESA/ESTEC-WGS

1 Introduction

The Workshop on Artificial Intelligence and Knowledge-Based Systems for Space is a bi-annual event organized by the European Space Agency (ESA) at its Technology Centre (ESTEC) in Noordwijk, The Netherlands. It reflects the interest of the Agency in advanced technologies, including software. The 4th Workshop was held on May 17th-19th 1993, and was attended by over 100 industrial and research participants.

The Workshop topics focussed on some interests of ESA, in particular: AI techniques in operational or quasi-operational applications; methodology, particularly Verification and Validation of KBSs; and Model-Based Reasoning, Knowledge Reuse and Planning/Scheduling.

The keynote speech defined AI as a means of increasing levels of autonomy in spacecraft systems, both on-board and on the ground. AI based products have moved from laboratory demonstrations to be an integral part of space systems development in a number of areas. These "success stories" justify continued research in the domain, especially in a time of limited budgets.

Paul Braffort, a well-known figure at ESA from its pioneering days and author of the first book on A.I. published in Europe gave a very well presented story of the history of AI, from 300 B.C. to the present, highlighting the main AI technologies and their emergence.

Application and integration of A.I. techniques in space systems was illustrated by several papers, most significantly the paper by B. Glass (NASA) on the research programme for the Space Station Freedom. The programme is designed to bridge between basic AI research and the space programme. AI based developments have not only qualified for large cost savings of running and future programs, but actually demonstrated the savings on past flights. The convincing return on investments has made the programme the only surviving advanced technology for the Space Station.

Also industry has an increasing interest in the reuse of their prototype developments and to prove their usefulness and a return on investments; J.M. Darroy (MATRA MARCONI SPACE), provided an overview of the products and tools that have emerged as a result of the investments in AI. The "OPSWARE" concept was presented, which consists of a set of tools that automates many of the work-intensive activities associated with the definition, preparation and execution of space- craft operations. The investments made by Matra, combined with work performed for ESTEC, CNES (the French Space Agency) and others, has enabled the successful deployment of a number of AI based systems for a large range of spacecraft and launch programmes and created spin-offs to non-space activities.

2. Applications

One of the goals of this workshop was to provide a forum to present applications of AI techniques. Applications appeared in different contexts throughout the workshop, and comprised a very wide range of proposed systems, from systems in development to systems already available. Altogether the workshop showed very promising and encouraging proposals and results.

T. Laffey (Talarian, USA) presented the expert system used to assist operations in the Hubble Space Telescope control system, one of the few really operational systems. It was demonstrated how a simple real-time expert system had significantly reduced the operational costs of the Space Telescope, and even justified itself just after the launch, when the system successfully diagnosed a motor problem, enabling the Operations Centre to report the problem instantaneously to ESA.

Other developments soon to be put into operational use were Previse (A KBS to Support the Preparation and Verification of Crew Procedures, an ESA development) and Quatrain (A Design Support Tool and a Data Processing Sequence Supervisor, developed by FRAMENTEC-COGNITECH, France). They demonstrate that AI, especially KBSs, are already very advanced when it comes to the preparation and verification of complex operations procedures. An example of the more classical application of AI technology, although still in development, was the presentation of an intelligent tutoring system named ATIS (an ESA project) for the specialized training of Astronauts.

Promising concepts for autonomy were demonstrated in several papers: the proposed AI supported "Soft" Real-Time Planning methods for a Mars rover (ChronoLogics, USA) allows the rover to make discoveries and take advantages of them without interaction by ground controllers. C. Lindley (CSIRO, Australia) reported on the work to develop a behavioral system for power distribution and control of a fully autonomous satellite. Currently, the work is in the University research stage, but the design, development and possible launch of a technology research satellite are planned. Another proposed approach to the control problem was second order learning, applied to the adaptive control of the attitude of a spacecraft. However, this method still lacks a validation and verification method.

The application of AI methods for the improvement and automation of scientific data analysis is being investigated by the Space Plasma Physicists at Imperial College (UK). They study the detection, recognition and prediction of Plasma Events, aiming at an increase of resolution in telemetry data or improved analysis and archiving of scientific data.

3. Model-Based Reasoning

Due to the increasing interest of the agency in autonomous aerospace systems and intelligent diagnostic techniques, one round table of this Workshop was dedicated to Model-Based Reasoning (MBR) and Model-Based Diagnosis (MBD).

The presentations addressed both applications and theoretical issues. Applications concentrated on ground systems, like FORMENTOR (Aerospatiale, France) for Real-Time Assistance in Operation, Risk Prevention and Crisis Management, or SE-TC2: Expert System Telecom 2 (CNES, France) and DESCO (LABEN, Italy) which aims at diagnosis of satellite (sub-)systems on the ground. Two presentations advocated the reuse of existing engineering information to construct a model. In one case CAD attempts faster development of a structural model of the system (University of Twente, NL), whereas SADT (functional) analysis models and their use for system level diagnostic purposes was addressed in a presentation by ESA. A technical paper on the Use of Constraint Logic Programming in Model-Based Reasoning concluded the presentations.

A discussion about important issues and open problems in the field followed the presentations. It was not the main purpose of this round table to suggest solutions, but rather to identify the critical areas in order to better tackle the problems. One problem identified was why, despite the agreed advantages of MBR, there are still only few operational applications. The following reasons were suggested:

- The return on investment is sometimes difficult to demonstrate.
- There are still open technical problems, like the one to find an appropriate system model or the problem of Verification & Validation of MBR systems.
- It is difficult to sell MBR products in some domains; e.g. diagnosis systems for satellite applications, because only few failures occur although they are difficult to diagnose.

It was generally agreed that several questions have to be tackled before a general guideline about the potential application domains of MBR can be established. One of the identified difficulties is the assessment of the necessary granularity of models, or the open question whether there is a generally usable reference model for multiple tasks or not, i.e. if model use across different tasks is possible. It was stated that MBD is no cure-all, but its applicability has to be carefully considered for every application problem. MBR can as well be applied for tutoring/training or for planning.

In the context of space applications it was admitted that it does not make sense to introduce MBR techniques for existing and operational spacecraft projects, but that it should rather be proposed for new projects, modelling being an activity right from the beginning of a design.

4. Knowledge Reuse

The Knowledge Reuse round table was the most advanced concerning techniques and methods. More questions have been raised than answered, and it was recognized that more theoretical work remains to be done. The dimensions of Knowledge Reuse are manifold, but the main stress lies in the capture and the reuse of corporate knowledge. The problem context is one of rapidly changing project teams and the loss of a long experience when experts leave a company. A possible pragmatic approach starts with integration of Databases and Knowledgebases which are already used in an organization, followed by the interoperability between different applications. This could be a first step towards a more universal knowledge repository which would allow the reuse of corporate knowledge.

However, this approach needs interchange formats and common knowledge representations and ontologies to be defined, although there are different initiatives under way. Two were proposed in the session, the EuroKnowledge initiative (European Initiative for Knowledge Presentation Standardization) and the Advanced Technology Operations System, designed for ESA, where the problem of common ontologies are tackled for the particular domain of spacecraft operations.

The problem of different views of the same knowledge by different people is being tackled for the design process. SCRIPT (Dassault Aviation, France) is in use in the design of airplanes, and CNES have developed a way of accommodating multiple views in the design of complex space systems.

5. Planning and Scheduling

For several years the Agency and industry have shown a large interest in planning and scheduling, which was the subject of a further round-table.

The distinction between planning and scheduling in the space context is as follows. Planning concerns the definition of a set of tasks, resources and activities to achieve (mission goals), whereas scheduling is the conflict free placement of activities, given temporal, spatial, resource and other constraints to obtain an executable timeline (schedule). The presentations dealt mainly with scheduling problems in the sense of time and resource allocation, solving constraint problems. It became clear that constraint handling does not pose any major problem today, but preferences ("soft" constraints) are more challenging since the require definition of the "quality" of a plan or schedule.

Experience has shown that rescheduling still requires an operator. The reason is that a complete diagnosis is often necessary to understand the reasons for a failure, and then according to the problem replanning and rescheduling might be necessary to redefine the plan, with the constraint that it still respects the goals of the previous plan. This motivates a strong request for explanations and other interactions between the scheduler and the users during rescheduling activities. Automatic rescheduling is very difficult as acquiring sufficient knowledge to correct/react to any problem during the execution of the plan is a very demanding task. An additional constraint for rescheduling is the desire that it does not start from scratch, but finds a solution which is not so far from the previous one. Generic tools for planning, scheduling, conflict resolution etc. are still a long term objective in the field of planning and scheduling.

A classification of applications was proposed along the following lines:

- Request Driven Applications, where he activities are logically independent. (ex. Earth Observation satellites). This is a pure scheduling problem.

- Goal Driven Applications, where the activities are logically combined to reach a goal (ex. project management, logistic planning, telescience missions). This is a planning and scheduling problem.

It was agreed that scheduling tools seem mature enough to be used in operational environments, but efforts are still needed on plan revision, user interaction (explanations) and modelling of preferences. Goal driven planning still seems to be a human activity at the moment.

6. Methodology

A last (but not least) topic of the workshop was dedicated to methodology. The aspect of Verification &Validation (V&V) of knowledge-based systems had a prominent place in this area, since the application of AI methods and techniques to space projects requires very high quality assurance. Only with sound methods for this problem do the chances rise for the operational use of the proposed techniques.

Two activities on the European level, especially supported by the European Community with its ESPRIT programme, were presented. The two approaches were VALID and ViVa, both tackling the problem by proposing methods for the V&V process and develop associated tools with it. These methods involve an additional overhead on the development life-cycle of a knowledge-based system, but it should result in higher software quality at the end of the development process. A formal approach to V&V of Knowledge-based systems (a Knowledge Specification Language) has been proposed by ONERA/CERT.

Problems of the knowledge engineering process (knowledge acquisition, formalizing and maintenance) was addressed in presentations about another ESPRIT sponsored activity, VITAL, which built tools to support the KADS methodology. The university of Gent presented an application where knowledge maintenance has been implemented using annotations by the end-user. Aspects of coherence were addressed by proposed knowledge metrics for cognitive risk analysis (CISI, France).

Through many presentations it became clear that the general trend in AI applications is the integration of different methods and techniques, in order to profit from the benefits from the different techniques and avoiding certain weaknesses at the same time. Two papers explicitly addressed this point: Case-Based Reasoning techniques were used together with expert systems in two applications of ARAMIIHS-MATRA (France), and a common framework for reasoning with uncertainty on both symbolic and numerical levels has been presented by CERT- ONERA.

7. Conclusion

The workshop showed that work remains to be done for the verification and validation process of critical applications, as well as for long term activities like knowledge repositories, where three is still some fundamental work to be done. However, it was clearly demonstrated that AI techniques are ready to be applied in an operational context in large domains, like planning and scheduling, and model-based reasoning. No major fundamental problems remain open in these areas.

At the opening of the Workshop, a call was made to industry to include mature AI techniques in their proposals to the Agency projects. The discussions held during the Workshop have shown that this call was successful. They have also shown that, despite the very conservative attitude of Space Projects towards "advanced informatics" techniques (such as Artificial Intelligence), the most dynamic industries are investing in those techniques, outside and on top of ESA funding, in order to create an industrial infrastructure and expertise which enhances their competitiveness. Those industries have articulated back to the Agency a request to pursue efforts in the directions which were discussed during the Workshop.