

Commentary on Research trends in Autonomous Space-based Planning & Scheduling by Moylan and Atkins

Commentary by:
Steve Chien
Jet Propulsion Laboratory
California Institute of Technology

The authors Moylan and Atkins have chosen a challenging and useful task – to summarize a wide-ranging not well documented line of work. While the vast majority of their points I agree with, in the following I point out several points of clarification or even outright disagreement.

Challenges to Space Automation

The authors list challenges to deploying automation for space missions. Not surprisingly there is considerable overlap between this list and the list we presented in the Agents 2004 paper on ASE [Chien et al. 2004] cited by the authors.

Prior work in coordinating multiple assets

Regarding prior work on coordinating multiple assets (rovers, spacecraft) autonomously, I would also point the authors to a range of earlier work [Bummet 1998, Barrett 1999, Estlin 1999, Barrett 2000, Chien 2000, Globus 2002]

Drawbacks to ASE Architecture

There is no evidence to support the statement (p.2 middle of column 2) that the ASE architecture is the cause of the expensive build-release process or the reduced observational flexibility. The

expensive build, release, testing process was caused by the high reliability standards imposed on the software [Cichy et al. 2004].. The second is caused by the limited onboard computing resources [Tran et al, 2004], indeed ground automation (using the same planner) is able to use the increased computing resources to examine more scheduling flexibility [Tran et al. 2006].

Clarity and 2 layers versus 3

P.3 Column 2. Clarity does not compel any tighter integration of planning and execution. Clarity instead breaks up the layers into two general areas, decision, and functional. Within the decision layer many of the same components reside, with items such as TDL, Universal Exec, and CASPER all existing with identical closeness (or lack thereof) in their integration.

ASE planning and execution

Table 1 – ASE does plan repair during execution, all of the planning and execution are fully concurrent, as with any true embedded system.

Autonomy Trends and Limitations

I disagree strongly with the point that standardized system validation at all levels is prohibitive. This is indeed one of the primary roles of the planner, as they overall arbiter of interactions between subsystems. I do agree that standardized formal validation is made much more difficult by the heterogeneity of the subsystems. But indeed validation via informal methods (standardized) as in ASE is going to be the pathway to flight for the near future.

Regarding the more expressive representations required by space systems, those focusing on space applications have not generally used the more limited representations pointed out by Fox & Long. Indeed, more expressive temporal representations go back all the way to Vere/Deviser [Vere 1983].

Common recommendations

This section contains a great number of suggestions for how future autonomous systems and deployments of autonomous systems can be more successful. The challenge of course, is the prioritization of these areas. No actual project will have the resources to truly excel (or even be adequate) at all of these areas. Additionally, while high level guidance such as is given is useful, actual application of the general principles is often a challenging task in practice.

Architecture

Incorporate flexible time execution – there are many difficulties with adopting this including: lack accurate information on true flexibility (see [Chien 1998] for a discussion of this). Additionally, the most commonly adopted flexible time framework “Simple Temporal Network”

is applied incorrectly in its semantics. An STN semantics implies that controllability of durations but it is usually applied to situations where durations are not controllable.

Validation

Formally validate...

--- Not practical for the near future. Current formal validation techniques cannot model the expressiveness of current systems and cannot scale to the complexity of current models.

Summary

The authors are to be lauded for taking on the truly daunting task of not only trying to summarize an incredible range of work, but they also provide guidance to future work in the area. Because in this commentary I have focused on the areas in which I disagree with the text, it would be easy to infer that I disagreed with the majority of the points of the paper. That is definitely not the case, I agreed with the vast majority of the points made by the authors.

References

S. Chien et al, The EO-1 Autonomous Science Agent, Conference on Autonomous Agents and Multi-Agent Systems (AAMAS 2004). New York City, USA. July 2004

A. Barrett , Autonomy Architectures for a Constellation of Spacecraft , International Symposium on Artificial Intelligence Robotics and Automation in Space (ISAIRAS 1999). Noordwijk, The Netherlands. June 1999.

Bummit, B., and Stentz, A. 1988. GRAMMPS: A generalized mission planner for multiple mobile robots in unstructured environments. In Proceedings of the IEEE Conference on Robots and Automation.

T. Estlin, T. Mann, A. Gray, G. Rabideau, R. Castano, S. Chien, E. Mjolsness, An Integrated System for Multi-Rover Scientific Exploration, National Conference of Artificial Intelligence (AAAI 1999). Orlando, FL. July 1999

T. Estlin, S. Hayati, A. Jain, J. Yen, G. Rabideau, R. Castano, R. Petras, S. Peters, D. Decoste, E. Tunstel, S. Chien, E. Mjolsness, R. Steele, D. Mutz, A. Gray, T. Mann, An Integrated Architecture for Cooperating Rovers, International Symposium on Artificial Intelligence Robotics and Automation in Space (ISAIRAS 1999). Noordwijk, The Netherlands. June 1999

A. Barrett, From Rovers to Orbiters: Continuous Task Distribution Based Coordination, International NASA Workshop on Planning and Scheduling for Space. San Francisco, CA. 2000.

S. Chien, A. Barrett, T. Estlin, G. Rabideau, A Comparison of Coordinated Planning Methods for Cooperating Rovers, International Conference on Autonomous Agents (Agents 2000). Barcelona, Spain. June 2000.

Globus, Crawford, Lohn, Morris, Scheduling Earth Observing Fleets Using Evolutionary Algorithms: Problem Description and Approach, Intl Workshop on Planning & Scheduling for Space 2002.

B. Cichy, S. Chien, S. Schaffer, D. Tran, G. Rabideau, R. Sherwood, Validating the Autonomous EO-1 Science Agent, International Workshop on Planning and Scheduling for Space (IW PSS 2004). Darmstadt, Germany. June 2004.

D. Tran, S. Chien, G. Rabideau, B. Cichy, Flight Software Issues in Onboard Automated Planning: Lessons Learned on EO-1, International Workshop on Planning and Scheduling for Space (IW PSS 2004). Darmstadt, Germany. June 2004

Automation and Autonomy of the EO-1 Mission Operations System, D. Tran, G. Rabideau, S. Chien, B. Cichy, R. Sherwood, D. Mandl, S. Frye, S. Shulman, J. Szwaczkowski, D. Boyer, J. Van Gaasbeek, Space Mission challenged for Information technology July 2006, Pasadena, CA.

Steven A. Vere. Planning in time: Windows and duration for activities and goals. IEEE Transactions on Pattern Analysis and Machine Intelligence, 5(3):246--267, 1983.

Automated Planning and Scheduling for Goal-based Autonomous Spacecraft S. Chien, N. Muscettola, K. Rajan, B. Smith, G. Rabideau, IEEE Intelligent Systems . September/October 1998 .