Commentary on:
“P&S Requirements for *e*Partner-supported Astronaut-Rover Teams during Planetary Surface Operations”

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Introduction

The article (Grant, Neerincx, and Wolff 2011) introduces some considerations taken from the experience of the authors participation in the ESA project called MECA (Mission Execution Crew Assistant). The idea of MECA is to form a network of agents (both human and software), in which each unit, called e-partner, is capable of detecting and influencing the physical, cognitive and affective state of its respective human users. The article describes the three stages along which the project evolves and presents a list of system requirements among which authors highlight those that can be classified under the label of Planning and Scheduling (P&S). In addition to the P&S requirements the most interesting contribution of the paper is probably the concept of e-partners and the description of the cognitive workload model on the base of which authors think to build the e-partner agent.

We subdivide the commentary in different parts. We first offer a slightly different perspective with respect to the role of planning and scheduling, then sketch an architecture for using planning technology in continuous loop with the humans, and then we formulate some questions to corroborate debate at the workshop.

Possible Role for Planning and Scheduling

A possible way to address MECA requirements is to consider developing a software intensive capability that allow deep space mission human crew to keep under control the multiple activities that are carried out during spacecraft operations. A generic Planning and Scheduling Module (PSM) could be one of the components of such software intensive systems and should be continuously accessible through the crew interaction modality.

The general MECA demonstrator environment could be intended as an advanced environment that (a) is up-dated with state of the art technology (b) contains advanced functionalities that push such state of the art ahead consistently with current research development. This is because manned missions are scheduled to happen in a long time horizon so it is realistic to think them as containing the more recent advancements in technology.

Planning and scheduling functionalities are traditionally seen as Ground Segments activities, but in new scenarios set up by deep space missions it is worth inserting a certain amount of these functionalities in the command post of the human crew on the Flight Segment. This is justified: (a) by the inevitable communication delays in the dialogue ground-flight segments, (b) by the importance for human mission personnel to maintain a level of active intervention on the on-flight scenario, hence the need for humans to understand both the context and the current activities also with the support of software decision aids (see for example the concept of adjustable autonomy introduced and explored for manned NASA missions to Mars, e.g., (Musliner and Pell 1999)).

In this perspective we can assume that a master plan is arriving from the ground segment, and is represented in the PSM to be used as a baseline schedule for the on-board mission activities. In designing a PSM for the MECA demonstrator we can focus our attention on a set of realistic expectations:

- The on-board crew should maintain a level of understanding of the activities that are currently under execution (they access the baseline schedule for inspection but also some background knowledge able to offer explanations);
- The representation the crew deals with should be easily comprehensible, and should avoid cognitive overload (as a consequence an abstraction step with respect to low level commands is worth being produced);
- The representation of the PSM is consistent with the one used to produce plans in the ground data segment (this is to allow a dialogue between crew and the ground mission planning experts);
- The PSM should allow the crew to simulate what-if scenarios on activities on the current master plan.

We can consider endowing the PSM of different modalities, of increasing complexity, all acting on the representation of a baseline plan (e.g., we can imagine using the APSI-TRF representation and building on top of it (Cesta and Fratini 2008)).

Execution Inspection: This modality is the more basic. The execution of different activities in the plan is automated with a layer dedicated to task execution. The crew may observe the evolution of such execution on a “active blackboard” in which a number of additional information is also shown. For example they observe a representation of the whole plan and may focus on the activities currently in execution and understand their causal relation with the rest of the plan. They can even receive an active visual feedback to tell if activity execution is nominal or some temporal delay is happening. Additionally they may observe the resource consumption over time receiving feedback if everything is nominal or some value is having exceptional behavior. In broad sense this modality would complement the information that comes from the spacecraft housekeeping giving an additional representation to help crew to be aware of the activities in execution and the context of such execution. The goal is to allow crew to localize in the plan the impact of on-going events, by means of an "additional lens" given to the human supervisor to interpret raw data, by interpreting those data in term of the activities that are under execution at a certain time instant.

Plan Modification: This second modality supports an active role of the users giving him/her a first set of commands to modify locally the master plan while understanding the impact of the modification. Attention should be dedicated to activity insertion on the master plan. An example is the need of some activities for maintenance scheduled at day X that should be anticipated due to some data observation (an additional need). A crew member should be able to define the main characteristics of such activity (its duration, the resources needed) and then connect this new activity with others in the current plan (e.g., the new A300 starts 30 seconds after activity A20 and should end within 2 minutes from its start and in any case before start of activity A70). After any modification the planning software checks for the consistency of all the new constraints introduced in the plan and updates the master plan or gives a result of inconsistency. Further commands for crew members should allow to delay an activity, to change some nominal value in the description of an activity or resource availability. The PSM answers to any of these commands with a constraint checking and an update of the master plan. The motivation for this modality if to allow crew a level of responsible change of the master plan, supported by the plan representation tool. The commands of this layer may be used in "simulation mode" first to allow "what-if" simulation of alternatives, then the crew member that have authority on the master plan may take the decision of updating the master plan according to a current set of studied changes.

Goal-based Plan Synthesis: The third modality evolves from the previous layer and allows for (a) the synthesis of a master plan from scratch; (b) a significant update of an existing master plan to integrate a "mini-plan" for a specific goal non included in the initial scope of the plan. The crew member here is helped by the introduction of a further level of abstraction, the goal specification. He can define of the "active blackboard" a set of goals to be achieved by the master plan, the PSM will rely on a library of "mini-plan" associated to each goal and will synthesize a composition of them in order to satisfy all the goals or a set of them according to their priority. This modality is intended to be used when communication to ground is seriously deteriorated or when some event has happened that is not addressable by the very specific commands allowed by the Plan Modify Modality. The idea of the library of "mini-plan" is a reasonable compromise between moving planning responsibility on board and maintaining the highest standards of security required by this kind of mission. It is worth specifying that the "mini-plans" may be synthesized, validated and certificated on ground and even updated during mission through uplink to reflect changes in the model of the spacecraft after a certain amount of operation (for recent results on plan validation of a TRF-based representation see (Cesta et al. 2011b)).

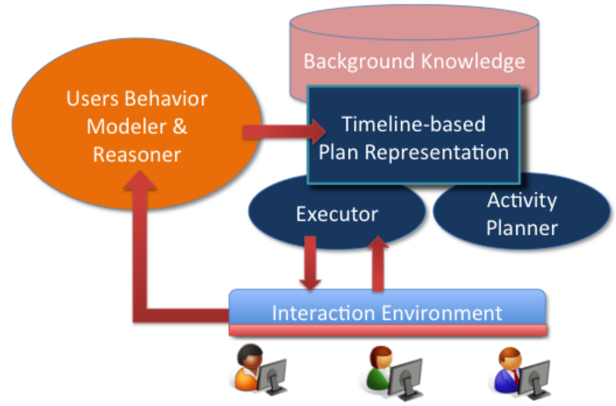

Figure 1: *A sketchy cognitive & planning agent*

A Cognitive System that Plans

As said in the introduction the paper authors use a broader perspective, with respect to pure P&S, and underscore the relevance of the human factors in designing artifacts in continuous loop with humans. This is a decision to share. In other terms we agree that "Planning is not enough!" but ... "what else is needed?". It seems to us that there is the need to build a sort of intelligent assistant, a cognitive agent, that continuously look over the shoulders of our astronauts to help them in daily tasks on a continuous basis. Indeed the competence of such an agent should not be just technical but because of the continuous contact with humans the possibility for a level of personalization and adaptiveness is is not only open but really necessary.

In figure 1 we have sketched a sort of minimal architecture for such an agent [1]. We can recognize the three blocks from planning technology: (a) the plan data-base (here represented as set of timelines), (b) the planner, and (c) the executor. These three blocks together can offer the three modalities previously defined by using state of the art technology. The figure underscores also three additional blocks that are needed to create capabilities larger of those strictly associated to P&S: (d) a knowledge-base that working in background allows more sophisticated forms of help to be produced; (e) an interaction environment that is in continuous contact with the human and guarantee a sort of sensor and actuator of the agent actions toward/from the assisted human; (f) a user model that dynamically updates and refines its internal representation of the assisted person and can influence the way the plan under execution is updated as

[1] The drawing is mildly inspired to work we are currently doing in the PANDORA project where we use planning for training people (see (Cesta et al. 2011a)).

soon as new user conditions are detected [2]. Such technology is currently available and can be taken into account as an on-line possibility during a long term human mission in space as a complement to sophisticated data analysis performed on-ground. The possibility offered by a continuous loop over user psychological and physiological data can be used for example to modulate to amount of cognitive and physical activity required to an astronaut hence on-line monitoring him/her under extreme conditions.

Some Questions for the Authors

In order to foster the discussion during the workshop we encourage authors to further elaborate some aspects that still are not particularly evident in the paper. Specifically the issue around which authors could better elaborate are related to the two main areas they touch upon: (a) user modeling and affective computing (b) P&S requirements.

User modeling and affective computing. In the paper some factors are mentioned that seem relevant in the human-system interaction of a manned space mission. Among these, authors mention personality, experience, heart rate activity etc.

- Is this selection based on some preliminary study authors performed by for example examining past missions? Did authors obtained feedback from possible users of the system? Overall, which is the rationale behind this selection and can we consider these factors to be representative of the key human factors to consider when modeling these types of users?
- Is there already a model for these features? How are they modeled and incorporated within the MECA architecture? It seems that current P&S technology is already ready to represent these features but is it also clear how to use them to compute more efficient and intelligent activity plans for users?
- How did you use or how do you plan to use this "user knowledge" within the MECA system? How could you for instance use it to modulate the systems autonomy? How do you exploit a user model to modulate the behavior of the system depending on the particular user's emotional, physical and affective state?
- How do you use the PAD model for the representation of the user's emotional states? In particular, which is the role of the two dimensions of "arousal" and "valence" in relation to the planning and scheduling engine?

Planning and Scheduling Requirements. The list of the Planning & scheduling requirements is presented (a bit too much) in terms of functionality the system should be guaranteed. Could you elaborate on these requirements and formulate them so as to highlight for instance the challenges for P&S?

- Can you classify them according for instance to the relative difficulty/simplicity for the P&S research progression to achieve them? (see for example (Chien et al. 2010) as an attempt to evaluate the desired features of a P&S system in terms of their current technological difficulty).
- Among the requirements one particularly interesting states that the information on the status of the user could be used to optimize the plans? How exactly this can be done? How far are we from the use of these models in Planning & Scheduling systems?

Conclusions

Overall we think that the current trend to build systems more intelligent and able to adapt to the users emotional states and needs is particularly interesting and original. It would be interesting to the Planning & Scheduling community to further dwell on what will be the benefits, difficulties, critical points of an integration of models and solutions from affective computing / user modeling into P&S systems.

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[2] In (Cortellessa et al. 2011) we present an example of integrated user model in continuous loop with a plan data-base by reasoning continuously of psychological conditions of a person under training (e.g., dynamically intermixing to normal activities some questions to the users to fetch their personal status), and physiological state (e.g., dynamically interpreting the "personal telemetry" of the human to check his/her level of stress).