Decision Support Tool for Prediction of Critical Data to the Satellite Integrity

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Abstract. *The perspectives of multiple launchings, in the near future, by INPE's satellite program motivated the development of an application using temporal planning techniques based on Artificial Intelligence (AI) concepts. It will be used for automatic generation of flight operation plans to control satellite activities. However, making a critical analysis of these plans before real execution is impossible. We proposed a different approach using a decision support tool combining Bayesian Networking and AI-based data mining techniques for data prediction, aiming to maintain the integrity of the satellite.*

1. Introduction

There is a general interest in automating the satellite control operations concerning with the task of controlling multiple satellites as according to INPE ´s Space Program. In addition, there is an agreement that the automation of control satellite activities represents a way of reducing in-orbit satellite maintenance costs. In INPE, autonomous systems to control satellite operations employing technical planning on Artificial Intelligence based are being developed to automation of ground segment operations.

However, this increased autonomy in satellite control operations can lead to distrust of the control system behavior in opposition to the well known and routine manual control system. In such case, these systems still require an improvement in reliability to become operational.

In order to achieve this breakthrough in reliability, predictability and safety the activities of controlling satellites, a strategy for validation of a flight operations plan automatically generated by a planner IA-based is presented. This is an architecture composed of software components, which results from the combination of verification and validation techniques. As a relevant part of this strategy, a decision support tool is proposed in this article, to assist experts in evaluating the actions of the plan, aiming to guarantee the integrity of the satellite. Consist in a software tool using Artificial Intelligence techniques for data prediction of critical platform subsystem, as the power supply subsystem, directly affected by the actions contained in each flight operation plan.

This paper presents in the following section some concepts about the automation of the control activities of the satellite in orbit. Section 3 describes the strategy for validation of a flight operations plan, an overview of that architecture and general behavior. Section 4 shows some Artificial Intelligence techniques for data prediction, as Bayesian methods make the learning as a form of probabilistic inferences and data mining Section 5 presents the design of the tool for prediction is being developed. Following in Section 6, the paper concludes.

2. Satellite Flight Operation Plan

Flight Operations Plan (*POV*) includes the planning of control operations of space missions and ground segment activities of the planning, execution and control of the satellite in orbit. Each *POV* aims to maintain the satellite in orbit working to achieve the goals of the mission, containing all the necessary information to control the satellite in orbit, such as: procedures for the control of flight, procedures for recovery of contingencies, rules, plans and schedules. All activities included in *POV* have the starting point the passage of the satellite on earth station. The amount of time that a satellite is visible to a given earth station, determine the sets that flight operations should be performed during each pass. Among the activities to control for this period is the sending of commands from ground, called telecommand, and reception of telemetry, which indicates the general state of the satellite.

To meet the growing demand for satellites in orbit and reduce costs significantly, recent studies in AI-based planning are being realized, aiming at the development of tools that automate the tasks of controlling ground operations in INPE. The system called Intelligent Planning of Flight Operation Plans (*PlanIPOV*) [Cardoso et al. 2006], uses temporal planning AI techniques (temporal planner) on the automatic generation of flight operation plans to support the activities of controlling satellites in orbit.

Meantime, the use of *POV* automatically generated leads to many doubts. Part of them is related the new technologies, but the greatest resistance is related to reliability in the execution of these actions, predictability and safety of satellites. This increase in autonomy can lead to suspicion about the behavior, often well known and routine. The set of actions contained in a plan acts directly on data critical to maintenance of the satellite integrity. Furthermore, depending on the demand for satellites in orbit, a careful validation of these plans would become unviable.

3. Strategy for Validation of Flight Operation Plan

The strategy of validation consist in an architecture composed of several software components for validation of a flight operation plan generated automatically to be executed before actual execution (Figure 1). It’s designed as a result of appropriate assurance techniques for space system [Blanquart et al. 2004].

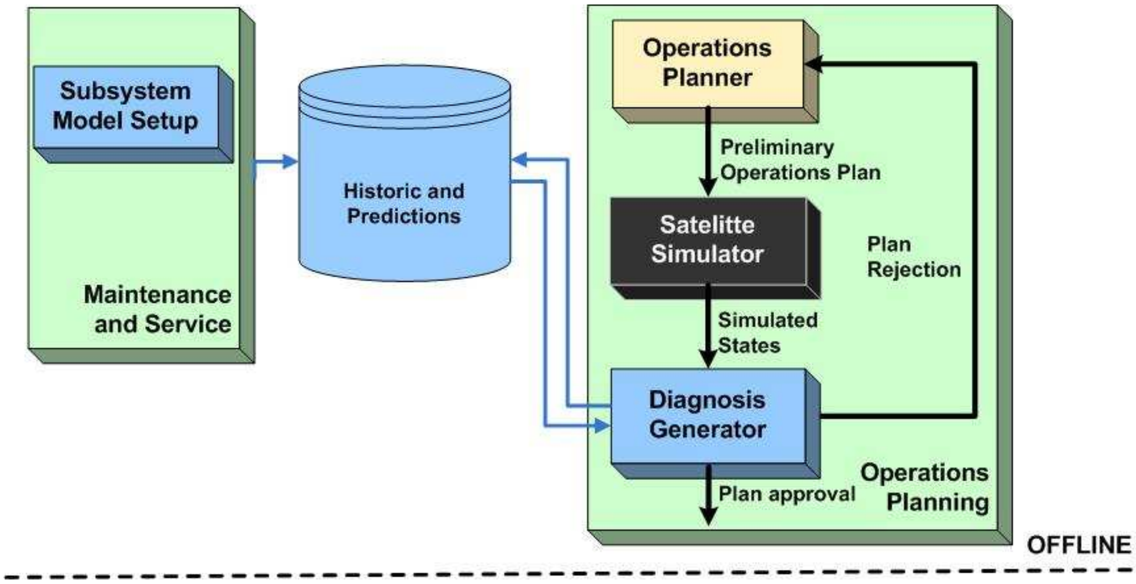

Figure 1. Validation of Flight Operation Plan: architecture and situation.

Through an execution off-line of the generated plan by planner, each action of the plan is executed and a simulation of the behavior of the satellite is performed by a satellite simulator. The simulator is based on a virtual satellite, with simplified models, which is also part of the strategy for validation of the generated plan [Tominaga et al. 2008].

The simulator returns to a tool called Diagnosis Generator, parameters and telemetries (see section 2) containing the simulated state of the satellite, resulting from the execution of the plan's actions. Upon receiving the status of the system, the Diagnosis Generator tool provides results of historic and prediction for these parameters and telemetries, indicating how the general state of the satellite will evolve, suggesting the adoption or rejection of the plan.

4. Techniques for Data Prediction

Prediction computational models are based on the probabilistic reasoning over time, interpreting the present; understand the past and future forecast [Russel and Norvig 2004]. The prediction is one of the basic inference tasks in time models, in which the posterior distribution on the future state is calculated, given all the evidence to date. In short, predictive inference is an interpretation of probability that emphasizes the prediction of future observations based on past observations.

Bayesian methods make the learning as a form of probabilistic inference, using observations to update a distribution on a priori hypothesis. A Bayesian network, belief network or directed acyclic graphical model is probabilistic graphical model that represents a set of random variables and their conditional independencies via a directed acyclic graph (DAG). Formally, Bayesian networks are directed acyclic graphs whose nodes represent variables, and whose missing edges encode conditional independencies between the variables. Nodes represent random variables, but in the Bayesian sense: they may be observable quantities, latent variables, unknown parameters or hypotheses. Efficient algorithms exist that perform inference and learning in Bayesian networks [Niedermayer 1998].

Data mining is other method, which the ultimate goal is prediction and represents a process developed to examine large amounts of data routinely collected. The term also refers to a collection of tools used to perform the process. It's an analytic process designed to explore data (usually large amounts of data) in search of consistent patterns and/or systematic relationships between variables, and then to validate the findings by applying the detected patterns to new subsets of data. The process of data mining consists of three stages: initial exploration, model building or pattern identification with validation/verification, and deployment (i.e., the application of the model to new data in order to generate predictions) [Fayyad et al. 1996]. Predictive data mining is used in most areas where data are collected-marketing, health, science, communications, etc].

5. Diagnosis Generator: A Tool for Data Prediction

As mentioned in the section 3, the Diagnosis Generator tool should be able to provide results of historic and data prediction for a critical subsystem. A set of telemetries, parameters and operational limits of a simplified model of Power Supply Subsystem (PSS) based on a virtual satellite is being used as input data (Table 1).

Table 1. Example of critical telemetry indicating the voltage values of one battery.

TMD014	TMD014	TMD014
BAT1 VOLT	Min. BAT1 VOLT	Max. BAT1 VOLT
VOLT	VOLT	VOLT
45,4	44,6	46
45,9	43,2	49,1
50	49,3	50,5
51,1	50,6	51,6
52,1	51,7	52,6
53,2	52,7	53,8
54,3	53,7	54,8
54,3	53,6	54,9
54,2	53,3	55
54,2	53,8	54,9
54,4	53,7	54,8
50,9	49,6	54,4
48,7	48	49,3
47,2	46,7	47,8
46	45,4	46,5
44,7	43,1	46,9
49,3	48,1	50,1

The idea is apply the two different techniques described in the section 4, on these data (Table 1) to generate predictions about future satellite behavior, evaluating predictive results from each one. For this, we plan to work in the following directions: the initial step is the construction of a prototype for analysis of the techniques applied for prediction. For implementation of techniques employs the Waikato Environment for Knowledge Analysis (WEKA), a suite of machine learning software written in Java [University of Waikato 2006]. WEKA is free software available under the GNU General Public License, aiming to add algorithms from different approaches in sub-area of Artificial Intelligence, dedicated to the study of learning by machines.

6. Conclusion

This paper presented a design of a tool for prediction, that is being developed, which is a relevant part inside of the validation strategy of a flight operation plan generated automatically to control and track satellites. The tool applies Artificial Intelligence techniques for data prediction of critical platform subsystem, directly affected by the actions contained in each satellite flight plan. In addition, the tool assists experts in impact analysis of each plan’s action on the satellite behavior, suggesting the adoption or refusal of the plan.

After concluding this implementation phase, the next step is compare with real data, the results provided by each technique used to prediction. With this prototype at hand, we will implement the Diagnosis Generator to be integrated to simulator, so that support experts effectively, representing a advance in reliability, predictability and safety of the satellite control activities generated automatically, especially considering multiple launchings in the near future, when a careful evaluation of these plans, before real execution would become impossible.

7. References

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