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SURE (Science User Resource Expert): A Science Planning and Scheduling Assistant for a Resource Based Environment

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Abstract

SURE (Science User Resource Expert) is one of three components that compose the SURPASS (Science User Resource Planning and Scheduling System). This system is a planning and scheduling tool which supports distributed planning and scheduling, based on resource allocation and optimization. The SURPASS written in Ada, uses a DEC windows user interface (X based), the INGRES database management system and the SURE system. The SURE system uses the CLIPS/Ada expert system production shell. SURPASS is designed to support a wide range of science applications and can be easily tailored via database modifications, DEC window updates and rule specifications for the SURE system.

Currently SURE is being used within the SURPASS by the UARS (Upper Atmospheric Research Satellite) SOLSTICE instrument to build a daily science plan and activity schedule and in a prototyping effort with NASA GSFC to demonstrate distributed planning and scheduling for the SOLSTICE II instrument on the Eos platform.

For the SOLSTICE application the SURE utilizes a rule-based system. Development of a rule-based program using Ada CLIPS as opposed to using conventional programing, allows for capture of the science planning and scheduling heuristics in rules and provides flexibility in inserting or removing rules as the scientific objectives and mission constraints change. An additional advantage of rule-based programming is that it facilitates the representation of the relationship between instrument operations and resources. SURE uses these rule sets to implicitly assist the science user in planning within the context of the science goals while optimizing instrument operations using the available resources.

This paper describes the SURE system's role as a component in the SURPASS, the purpose of the SURE planning and scheduling tool, the SURE knowledge base, and the software architecture of the SURE component.

This is a synopsis of the paper which was unavailable at the time of publishing

Introduction

The Science Users Resource Expert, SURE is a resource-oriented, knowledge-based, planning and scheduling tool component designed for use by the science planner and instrument scheduler. The SURE system separates the Science Planning Context from the Resource Scheduling Context by allowing the user to plan and schedule instrument activities with respect to scientific goals while maximizing instrument activity with respect to available resources.

The SURE system is currently being developed by the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado in Boulder. The SURE system is used within the SURPASS(Science User Resource Planning and Scheduling System) by the SOLSTICE instrument to plan and schedule science experiments and instrument activities. The SOLSTICE will fly on the UARS(Upper Atmospheric Research Satellite) in 1991 and Eos (Earth Observing System) in 1997. SURPASS is being developed jointly under the SCAN (Scheduling Concepts Architectures and Networks) study sponsored by GSFC code 522 and the UARS SOLSTICE project. The SURE component is being developed under the SCAN testbed study.

The SURPASS system, as illustrated in Figure 1, is composed of three Ada language-based software components, one component being the SURE system, and the other two components, the User Interface(UI) and the Planning and Scheduling System(PASS) Manager. The User Interface is written using the X-based DEC windows package and contains timeline and application specific displays that display the planning and scheduling information within the science context. The PASS Manager component is responsible for data handling, communication, and transactions between the three SURPASS components. The SURE component is written using the CLIPS/Ada expert system production shell. The SURE system incorporates a rule base captured from the knowledge of the planning expert, the instrument engineers and the scientist. The rule base is intended to optimize resource utilization based on the desired science objectives.

CLIPS/Ada is a forward chaining rule language based on the Rete algorithm and is written in Ada and developed by the NASA Johnson Space Center. Using the CLIPS/Ada expert system production shell has allowed

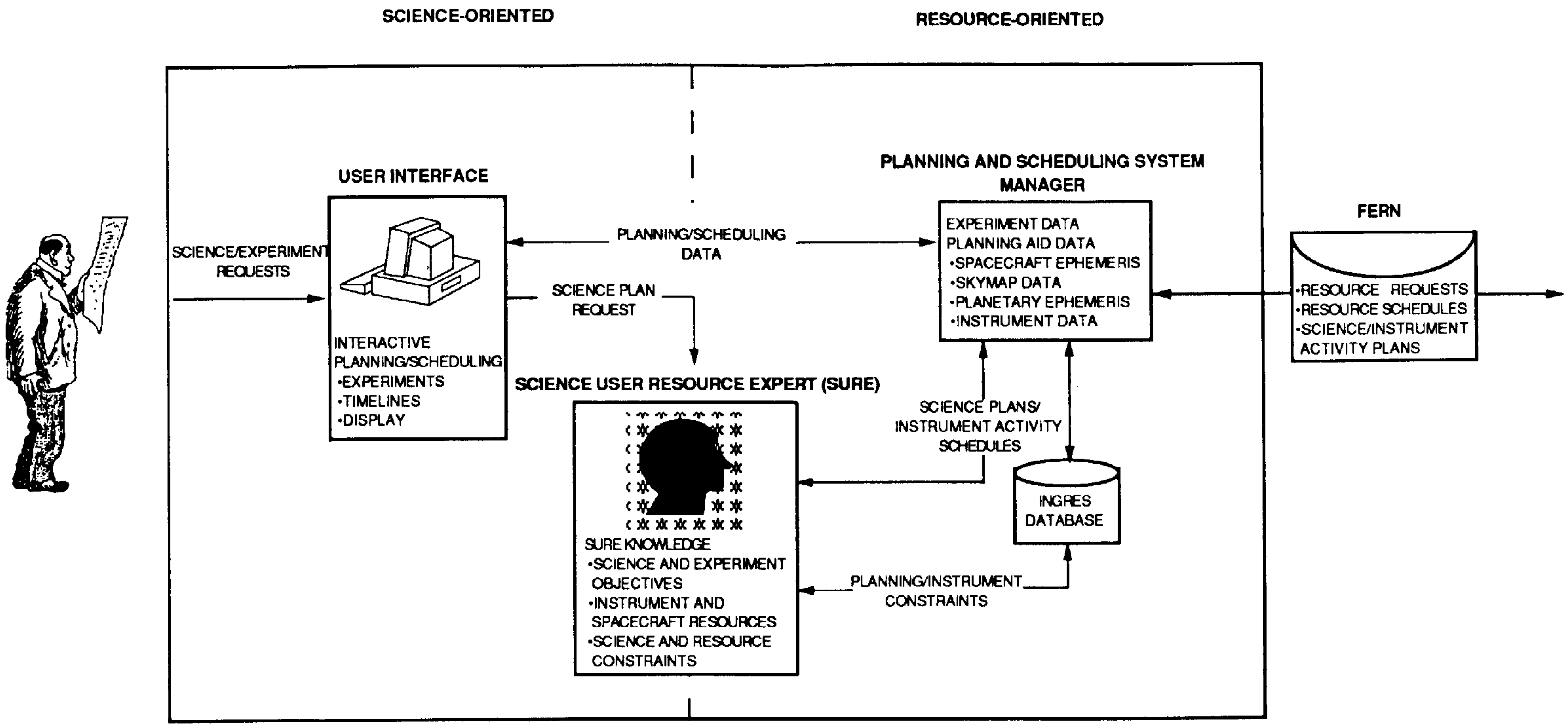

Figure 1 SCIENCE USER RESOURCE PLANNING AND SCHEDULING SYSTEM

rapid prototyping of an instrument planning and scheduling knowledge base. Since the User Interface and PASS Manager components are also written in Ada, this has allowed for easy interfacing and integration of the SURPASS components.

The SURE system's goal is to produce a schedule of science activities and observations within a dynamic resource environment. These observations and activities are scheduled in a way that maximizes instrument activity and hence, the scientific results within the available resource envelopes. Using an expert system has allowed the user to plan science experiments which satisfy science observing objectives and still remain within the given resource constraints without having to schedule these activities based solely on resource availability. The SURE system also reschedules instrument activities based on changing or updated resource availability while maintaining the overall scientific objectives.

Additional features of the SURE system include its ability to constraint check manually generated science plans. SURE will calculate resource requirements, check resource availability constraints, and attempts to reschedule an activity or request additional resources if needed. SURE notifies the user if the activity cannot be inserted into the schedule due to resource or constraint conflicts and may suggest alternate activities or actions.

The SURE Knowledge Base

Development of a knowledge-based system as opposed to using a conventional programming methodology, allows for the representation and capture of knowledge by the scientist, the instrument operator and planner, and the instrument engineers into rules. These rules combine to provide the translation of scientific goals, instrument operating modes and resource requirements, and operational constraints into a optimized resource based schedule and instrument sequence. These rules also allow flexibility as instrument operating characteristics and the instrument environment change requiring different resources levels.

For this application, rules have been designed to select specific solar observation times from an initial preallocation of available solar resources and based on scientific goals, determine the solar experiments to be executed during the selected solar observation times. These experiments are selected to fit within available resource envelopes. If an experiment can not be found based on the scientific goals, increased resources may be requested. The next step is to determine the stellar viewing periods and for each period select specific stars to be observed based on star observation statistics.

Star observation statistics which reside in the data volume are the actual, scheduled, and planned experiment data maintained on each star. The observations statistics from the data volume guide the expert system's selection of star experiments. The goal is to equally observe each star and it's corresponding wavelengths, so that the data volume is uniformly dense throughout. The data volume concept is illustrated by Figure 2.

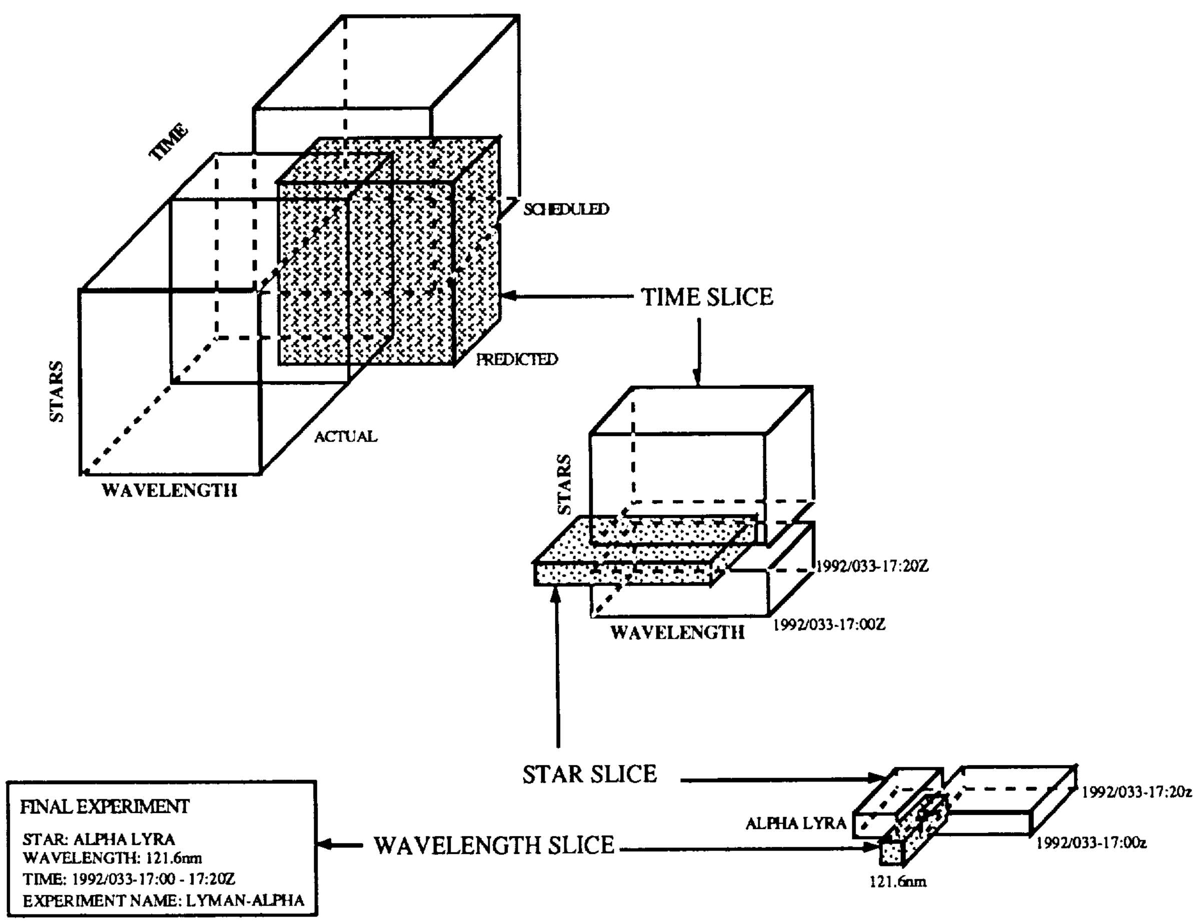

Figure 2 DATA VOLUME CONCEPT

For the selected stars an optimal instrument tracking plan to minimize instrument dead time within operating resource envelopes is then determined. Once the maximum stellar dwell time is determined for each target, experiments are selected based on the scientific goals. If experiments do not fit with the determined time additional resources may be requested to increase the dwell time. The resulting schedule is an initial science plan with a optimal target acquisition sequence which contains scheduled solar and stellar experiments. This schedule is passed to the PASS manager and User Interface for the user to review.

The schedule produced by the SURE system is based on broad scientific goals and may not reflect detailed short term changes to scientific objectives. The user may interact with the initial schedule generated by the SURE system through the User Interface to include enhanced science objectives. SURE aids the user interaction by constraint checking user inputs with respect to available resources.

SURE Software Architecture

The SURE software architecture, as illustrated in Figure 3, consists of a SURE task, several Ada packages, and the CLIPS/Ada expert system production shell. The SURE task is an Ada task containing a rendezvous for starting up the expert system. For the UARS SOLSTICE application this rendezvous is with the PASS Manager component of SURPASS. The SURE_INTERFACE_PKG contains procedures which are responsible for obtaining resource availability data and resource constraints from the STAR_INTERVALS_PKG. The SURE_INTERFACE_PKG procedures take the resource availability and constraint data and build facts for the expert system, load the SURE rule set into the CLIPS/Ada inference engine and start the execution of the expert system. Internally, the inference engine uses facts, available resources and star observation statistics, and tries to match these facts with rules from the knowledge base (see Figure 4). In the UARS SOLSTICE case, the expert system appropriately generates either scheduled solar and stellar experiments, scheduled slew times, or resource constraint error messages. These are transmitted from the SURE task via Ada rendezvous with the PASS Manager. These scheduled experiments are made available in working memory to the User Interface which displays the experiments on a timeline or in application specific windows.

The SURE system uses the CLIPS/Ada production shell which contains a forward-chaining inference engine and the SURE rule set has been written using the CLIPS/Ada rule-based language. The SURE rule set

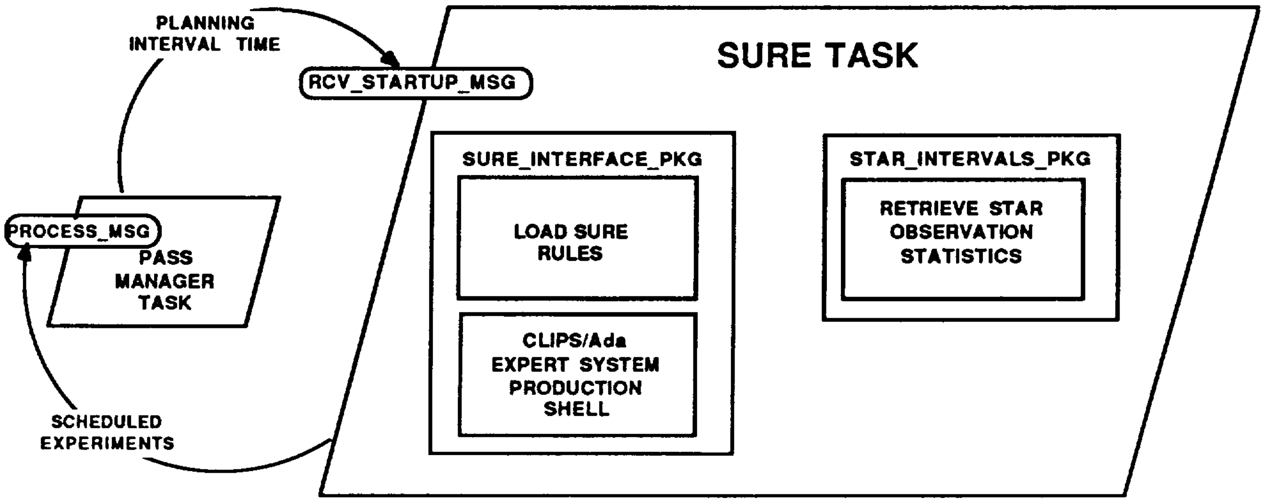

Figure 3 SCIENCE USERS RESOURCE EXPERT SOFTWARE ARCHITECTURE

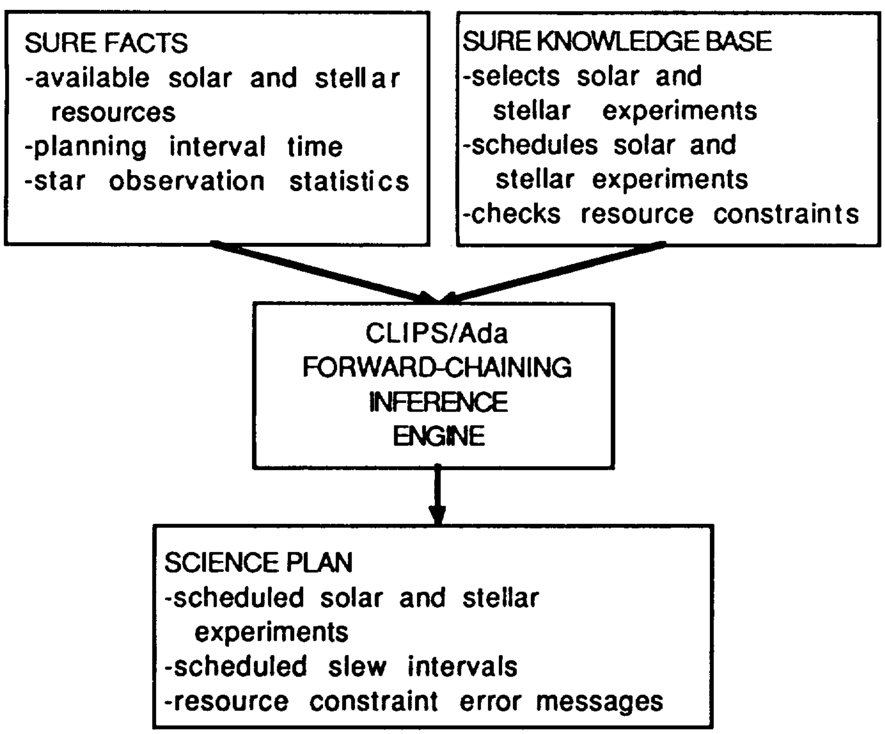

Figure 4 SOLSTICE EXPERT SYSTEM

is designed to select available resources needed for experiments and schedule resources in a manner which maximizes their usage. The SURE rule set or knowledge base can be modified and tailored for other applications by the development of a different rule base.

As a planning/scheduling tool the expert system allows the user to spend more time concentrating on scientific goals and less time scheduling experimental activities and available resources. For the UARS SOLSTICE application, the human planner/scheduler takes approximately 6 hours to produce a 24 hour science plan. The SURE system using rules reduces the time to schedule a 24 hour day to only 30 minutes. This is a significant reduction in scheduling time.

Conclusions

Using an expert system such as the SURE knowledge-based application frees the user from becoming a planning or scheduling expert and allows the science user to plan and schedule instrument activities with respect to the project's scientific goals. The SURE expert planner/scheduler builds an experiment plan that is based upon scientific goals and takes care of the details of instrument operations and resources. The SURE expert system is an application independent scheduler and can be tailored and adapted for use with other instrument control systems.

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