Timing Analysis and Scheduling of the X-38 Space Station Crew Return Vehicle and Other Space Vehicles

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A Mini-Report

Abstract—This project has performed timing analysis and scheduling of the X-38 autonomous spacecraft built by NASA as a prototype of the International Space Station (ISS) Crew Return Vehicle (CRV). The avionics hardware and software design phase for this spacecraft requires tools for representing, analyzing, and verifying the hard real-time timing aspects of the system. To verify the planned performance of the safety-critical system functions, a high-level specification of the X-38 multi-processor system task structure is modeled in Real-Time Logic (RTL) and Presburger Arithmetic representations.

REAL-TIME SYSTEMS OFTEN OPERATE IN AN ENVIRONMENT with stringent safety and response time constraints.[1] These systems include airplane avionics, autonomous vehicles, medical monitoring instruments, smart robots, and spacecrafts.[2-4] The result of missing a deadline imposed on task execution in these systems may be catastrophic. If a given real-time system cannot deliver an adequate performance in bounded time, then it has to be optimized or re-synthesized. Many formal analysis and verification techniques for real-time systems have been developed in the past two decades, but they are seldom practically applied to a large-scale industrial system. Furthermore, commercial scheduling tools based on sound real-time scheduling theory are also becoming more available and need to be evaluated by applying them to the task of scheduling of a large-scale system.

This project has performed an analysis of the timing properties of the X-38, a family of vehicles built as incremental development prototypes for the Crew Return Vehicle (CRV) of the International Space Station (ISS). The CRV, projected for a launch onboard the Space Shuttle, will be attached to the ISS. It will have the capability to automatically and safely bring to earth a crew of seven (7) passengers in the event of an emergency ISS evacuation. The CRV vehicle will be designed to autonomously perform all guidance, navigation, and control functions, the deorbit burn, a parafoil-assisted glide through the atmosphere, and land horizontally at one of several pre-determined landing sites. The X-38 131 model vehicle, shown in Fig. 1, was successfully drop-tested from a B-52 in March 1998 to demonstrate body design and parafoil landing. The X-38 model 132 will incrementally employ increased automatic guidance capability and will undergo several atmospheric drop tests. This project focuses on the X-38 vehicle 201 avionics timing properties analysis.

Results

We have investigated the X-38 201 vehicle avionics system development through its requirements and design phases. Although the system is intentionally designed to reflect deterministic software timing relationships, one or more tools are still required for modeling and analyzing critical system performance throughout the life-cycle. A scheduling tool similar to those evaluated is believed necessary to provide a means of easily analyzing possibly fluctuating workloads, to ensure deadlines are met, and to provide a pictorial representation of the system timeline for communication. Although none of the tools met all evaluation requirements, researchers decided that rather than building a custom tool for this project, it would be best to choose one or more of the commercially available tools and try to extend them for our particular needs. RAPID RMA and TimeWiz were both chosen for further development based upon their current state of development as well as maintenance support.

In addition to a scheduling tool, the RTL representation seems to be a promising mechanism to satisfy similar timing analysis and verification tool requirements. The RTL representation presented here represents one aspect, task loop timing, of a complex avionic system. The specification language itself seems well-suited for representing this as well as possibly a broader range of areas of the system specification. For example, only one of the four FCC's high-level task structure is modeled. It may be possible to model redundancy aspects of the system as well as actual hardware devices in order to verify system fault tolerance. The RTL representation combined with the graphical constraint analysis mechanism seems to be a powerful enough tool to represent many aspects of the system which may aid in timing, schedulability, fault, and safety analysis as well as verification. This methodology can be readily applied to verify the timing properties of other space vehicles.

References

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