Integration of Mixed−Integer Linear Programming into the Reactive Model−Based Programming Language

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There are many environments which pose significant barriers to human exploration. For example, sending a human to the depths of the ocean or the surface of Mars requires incredible biological support technology at incredible expense. As an alternative to this costly approach, robots are being used instead of humans. Robots can be sent to hazardous locations without concern for their safe return and for less money than it would cost to send a human.

There are, however, disadvantages to using robots. Robots tend to act without intelligence, mindlessly following orders. This not only requires extensive human supervision, but also poses the threat of failure when the mindless robot blindly follows every command, regardless of its consequences. For example, some NASA Mars robots have been destroyed when they mindlessly obeyed erroneous commands.

To remedy this problem, the Model–Based Embedded and Robotic Systems group is striving to develop a new paradigm for rapidly creating collections of long–lived, robotic explorers that reason quickly, extensively and accurately about their world. Our goal is to create robots that will be controlled via high–level, abstract instructions from their human supervisors. They will be able to autonomously create a plan which they execute while avoiding hazards which would result in the failure of the mission or loss of the robot.

The Model–Based Embedded and Robotic Systems group has developed technology that allows robots to create their own plans called the Reactive Model–Based Programming Language, or RMPL. RMPL is centered around temporal planning networks, or TPNs, which encode a set of objectives along with time constraints specifying when the objectives must be accomplished. The group has also developed software that processes RMPL code, called Kirk. The Kirk engine is being used extensively to refine the RMPL and TPN framework.

As of now, Kirk is effective at producing high–level plans using RMPL to coordinate the robots' behavior. However, there is another technology, called Mixed–Integer Linear Programming, or MILP, which could be very useful in the low–level planning required by a robot. To clarify briefly, high–level planning is the determination of actions which are to be performed to accomplish an objective. Low–level planning pertains to deciding how to accomplish an individual action. For example, a high–level planner may determine that a robot needs to go through a doorway. The low–level planner would figure out precisely how the robot should move to get through the doorway without running into the wall.

As mentioned before, the low–level planning is going to be performed using Mixed–Integer Linear Programming, or MILP. MILP, a variation of Linear Programming, is a method in which a problem is expressed as a system of linear equations. One of the benefits of using Linear Programming is that it often speeds the solving time immensely. This will be useful, as we hope to be able to do low–level planning in real time.

In Mixed–Integer Linear Programming, variable values are restricted to real or integer constraints, depending on the variable. A cost function is used to evaluate solutions to the equation sets in a MILP problem, and search is used to find the lowest cost solution.

My project will be to study MILP and RMPL, determine a common language to allow the Kirk engine to communicate with the MILP processor and create code that lets Kirk generate MILP equation sets. When this is complete, Kirk will be able to make high–level plans itself as well as call upon the MILP processor to perform the low–level planning. When my research is complete, my group's test rovers will ideally be able to complete an abstract objective autonomously through the use of its on–board Kirk and

MILP engines.

During IAP 2002 I will focus on learning about MILP and the various technologies used by my research group. I do not expect to accomplish tangible goals, but this preparation should prepare me to begin working in the Spring term. This Spring I will take one or two classes, spending the rest of my time focussing on getting started with my research. Rather than plan a single−pass, linear research schedule, my advisor and I agreed that it would be helpful to start early and get a simple working model working as soon as possible. Then, I will be able to improve upon my initial work before the end of my M.Eng project. To this end, I hope to make significant progress in the Spring 2002 towards having an initial RMPL/MILP engine functioning.

I will remain at MIT for the summer 2002, while I continue my work, ideally finishing in Fall 2002. During the academic year 2002−2003, I will take my required graduate level courses and then in Spring 2003, I will finish my thesis paper.

My project is being funded by Brian Williams and the Model−Based Embedded and Robotic Systems group and the group will be granting me financial support. For my work, I will be utilizing the Kirk and RMPL software, various aircraft simulation programs and a small armada of RWI ATRV2 rovers. All of this equipment has been purchased already, so I do not expect funding to be an issue regarding these tools. It is possible that RMPL and MILP will prove to be more incompatible than we currently believe, in which case the robot demonstration may not work properly. In this event, I may have to explore other algorithms to accomplish my goal. I am slightly ahead of the typical M.Eng timeline, so I will have a slight buffer should I encounter problems during my M.Eng project.

Through the research of groups like the Model−Based Embedded and Robotic Systems group, robots may one day be intelligent enough to explore remote planets and harsh Earth environments without failing or requiring intense human supervision. I hope my M.Eng project will contribute to bringing us closer to that goal.