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Data Provider Agents in the Polar Radar for Ice Sheet Measurements (PRISM) Project

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Abstract:

The goal of this project is to work with the PRISM Intelligent System codebase, to gain an understanding of the issues involved in the design and implementation of multi-agent systems. Using the PRISM codebase we were able to enhance understanding of multi-agent systems and contribute to the PRISM project by creating UML models of key parts of the multi-agent architecture and its underlying RMI system that allows agents to communicate with other agents over networks. Also we were able to develop sequence diagrams of an agent getting data from a sensor. These diagrams will be used to plan modifications and additions to the multi-agent system and will help plan for additional functionality for future field test.

Introduction

For years NASA has conducted expeditions to collect ice data. The space center has used satellites with visible and infrared sensors to collect vital ice sheet information. Although valuable information was collected, it was often difficult for the satellites to obtain information through the clouds and polar darkness of the arctic environment. NASA has also used microwave radiation to collect information on the ice sheet patterns in the Arctic and Antarctic. Images from the Landsat satellites have been used to measure ice flow rates and also to design photo maps of ice sheets in Greenland and Antarctica.

Theory

The sea level has been rising over the last century and scientists have speculated that global climate change is one factor that is contributing to the rise. Global warming refers to an average increase in the Earth's temperature, which in turn causes changes in climate. A warmer Earth may lead to changes in rainfall patterns, a rise in sea level, and a wide range of impacts on plants, wildlife, and humans. When scientists talk about the issue of climate change, their concern is about global warming caused by human activities. Scientist hypothesize that Earth has warmed by about 1ºF over the past 100 years. The Earth’s temperature rise could be based solely on natural occurrences, but many of the world's leading climate scientists think that pollution and other harmful human acts are helping to make the Earth warmer. Although the immediate impact of sea level rise may be less severe than other effects of global climate change, the long-term consequences can be much more devastating since nearly sixty percent of the world population lives in coastal regions. Scientists theorize that due to long-term global climate change a surplus of water is being released from polar ice sheets. Although there is much speculation, there is insufficient data to prove this theory. This uncertainty has prompted scientists to explore the interactions between ice sheets, oceans, and atmosphere in an attempt to quantify the role of ice sheets in sea level rise. Scientists and engineers at the University of Kansas are applying their expertise to develop and utilize innovative radar and robotic rovers to measure ice thickness and determine bedrock conditions below the ice sheets in Greenland and Antarctica. This combination of data will help Earth scientists determine how quickly the polar ice sheets are melting and to make more accurate predictions of the effects of this melting on sea level rise.

PRISM

The Polar Radar for Ice Sheet Measurements (PRISM) project aims to design and develop an autonomous mobile radar system to measure polar ice sheets. PRISM is a five year 8.7 million dollar research effort funded by a grant from the National Science Foundation and NASA. The research project is currently in its third year and includes a team of over 40 faculty, staff and students working at the University of Kansas’s Information and Telecommunications Technology Center as well as at institutions around the globe**.** The primary faculty investigators on this project include: principle investigator Sivaprasad Gogineni and co-investigators David Braaten, Gleen Prescott, Arvin Agah, Christopher Allen, Victor Frost, and Costas Tsatsoulis.

Teams

The staff and students are divided into several teams to complete this project. PRISM is divided into four primary areas: Communication, Robotics, Intelligent Systems, and Radar. Each area plays a significant role in creating the robotic rover, ensuring that it can function autonomously and survive in harsh conditions, developing communication between the rover and the field and also strengthening the accuracy of ice sheet measurements. Each team is working yearly to improve their area. The teams are increasing the precision of measurements and also decreasing the sizes of some equipment to make it more manageable when traveling.

The Communication team has created a wireless communication system that will enable communication between the equipment and allows data to be transmitted to researchers in other locations. KU engineers are using networking skills to enable this communication; and are constructing antennas for usage in the project. They are also forming technologies that will support planned education and public outreach activities by creating connection between the field and KU so that real-time transfer video, images and other data can be exchanged. The Communication team has also designed a network for the field experiment in Greenland with web access.

The Robotics group created a virtual prototype model that has been a guide to the design and operation of the rover, which includes maneuverability limits, speed limits and antenna towering capability. The robotics team examined the mobility, power requirements, endurance, storage capacity for radar equipment, towing capability for radar and antennas and also costs of the robotic rover. The team ensured that the vehicle had very simple controls that are easily accessible, making the task of automation easier and less time consuming, and also eliminating potential mechanical mishaps. The team designed the vehicle so that it can operate on either snow or ice.

The Radar team designed ice-penetrating radar that is used to make scientific measurement of the ice sheets in Greenland and Antarctica. The two main radars used in this project are: synthetic aperture radar (SAR) and dual mode radar. The synthetic aperture radar is used to create 2D maps of ice beds to detect the presence of liquid water. The measurement of basal water is important because it lubricates the ice/bedrock interface and makes it easier for the ice to flow toward the ocean. The SAR will help establish more accurate ice flow models, giving researchers more evidence to help evaluate their theories on the melting polar ice sheets.

The Intelligent Systems team has designed the specifications for an intelligent agency for radar and vehicle control. They have created an intelligent system that will provide data on demand. The system is designed so that agents can communicate with each other and also with sensors on the robotic rover. The team uses multi-agents or collaborative agents to collect, and analyze data collected from the sensors.

With the newly developed technology, PRISM engineers can successfully use radar and robotic rovers to measure ice sheets in Greenland and Antarctica. This will therefore allow scientist to determine the effect of ice sheets on sea level rise. With the development of an intelligent system and advanced radar a robotic rover has been created that can effectively calculate ice sheet measurements. With the help of the communication team the quantitative information can be shared with other KU faculty and affiliates. These robotic rovers can be used to collect essential data for the project.

The Rover

The robotic rover must be able to function autonomously, monitor its own health, sense its environment, and navigate the necessary paths. It must have coordination and interaction and precise positioning and timing. The rover must not only be able to survive in harsh environments but also function properly. The rover has many sensors that contribute to its functionality. To avoid obstacles it uses the laser range finder and the bump sensor. The rover monitors it health using fuel level sensors, tilt sensors and temperature sensors. The GPS sensor and heading sensors are only a few examples of how the robot knows its positioning. Information sources, such as the dual-mode radar, the SAR, and the GPS, are wrapped and appear to the other agents in the environment as simple, data-producing agents. The PRISM Multi-Agent System makes this possible.

PRISM Multi-Agents

The PRISM Intelligent System uses many agents to successfully collect data from various information sources. Some of the various components of the PRISM multi-agent system are the: Bayesian Decision Agents, Data Provider Agents, Data Processing Agents and the Control Agents. Each agent plays a significant role in collecting data. The Bayesian Decision Agents formulate decisions that control the rover and radars. The Data Provider Agents, which includes the wrap sensors, provides sensor data to other agents. The Data Processing Agents perform services for other agents, and the Control Agents set radar parameters and activate rover actuators. This system is what allows agents to communicate with each other and with information sources.

Object Oriented Design

When working with object-oriented technology you must first understand objects. The programming language Java describes an object as a software bundle of variables and related methods. Software objects are often used when depicting objects in the real-world. All real-world objects have state and behavior. For example, a cat's state would be its name or breed, and its behavior could be walking or purring. Software objects express state and behavior through variables and methods. A variable is an item of data named by an identifier; therefore expressing the object's state. A method is a function associated with an object; therefore it expresses a software object's behavior. Methods and variables are the two primary characteristics of software objects.

Java

The PRISM Intelligent System codebase is written in the programming language Java. Java is an object-oriented programming language developed by Sun Microsystems around 1992. It was proposed for use on the tiny computers inside cell phones and similar devices. It was designed to have some similar functions of the C++ language, but it is simpler to use than C++ and also introduces an object-oriented view of programming. Java was created to be platform-independent. This is achieved by the use of "virtual machines." A virtual machine allows Java programs to run on a particular operating system. The programming language was particularly intended for the distributed environment of the Web and can be used to create applications that can run on a single computer or distributed among several computers in a network. One of the common uses of Java is to create Applets that run inside a web page. Applets make it possible for a Web page user to interact with the page.

UML

UML is an acronym for Unified Modeling Language. It is designed for object-oriented programming. UML helps specify, visualize, and document software systems, including their structure and design. It is divided into three primary categories: structural diagrams, behavioral diagrams, and model management diagrams. The structural diagrams include: the class diagram and the object diagram. The behavior diagrams include: case diagrams, sequence diagrams, and activity diagrams. Packages, subsystems, and models are some examples of model management diagrams. We worked with sequence diagrams. Sequence diagrams describe interactions among classes by illustrating messages that are exchanged over time.

RMI

RMI is an abbreviation for Java Remote Method Invocation. The Java Remote Method Invocation (RMI) system allows an object running in one Java Virtual Machine (VM) to invoke methods on an object running in another Java VM. RMI provides for remote communication between programs written in the Java programming language. RMI is also used in the PRISM Intelligent System codebase.

Temperature Agent talks to the Temperature Sensor on the robot using RMI

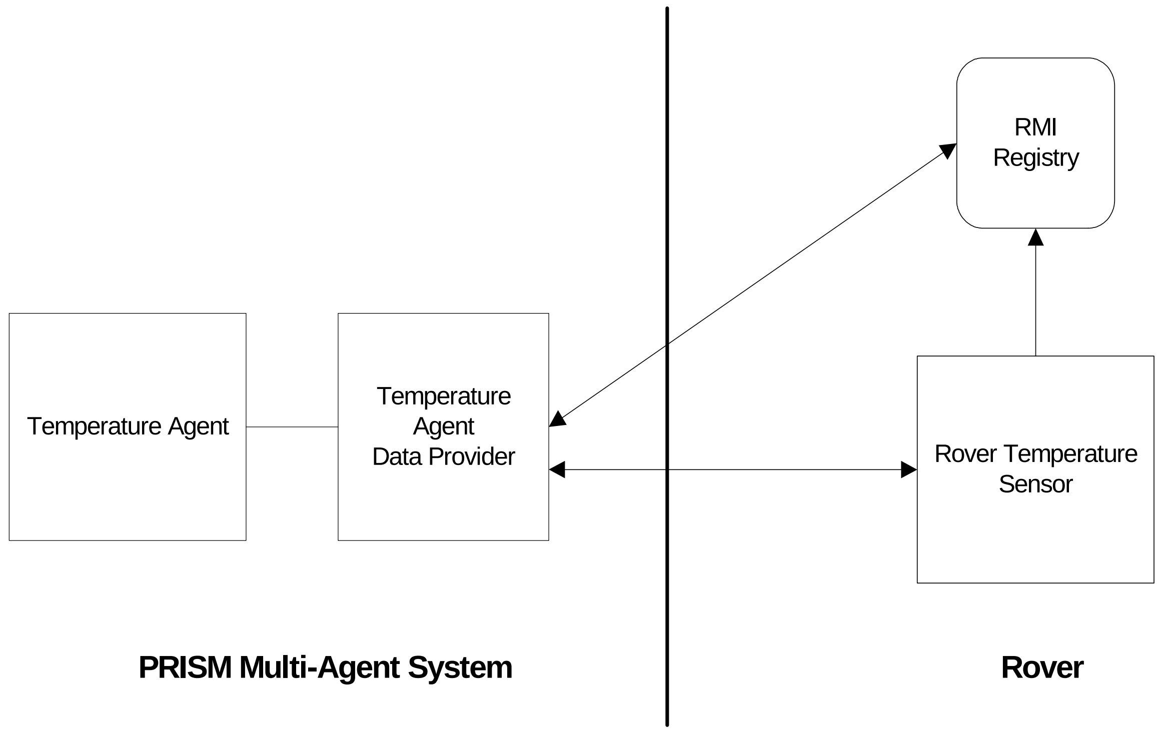

Figure 1: Illustrates how RMI works when the temperature agent is talking to the temperature sensor on the rover

1.) The Rover Temperature Sensor announces itself to the RMI Registry.
2.) Temperature Agent asks the Temperature Agent Data Provider for the temperature.
3.) Temperature Agent Data Provider asks the RMI Registry for an interface so it can talk to the Rover Temperature Sensor.
4.) The RMI Registry gives the Temperature Agent Data Provider an interface and it talks to the Rover Temperature Sensor through remote communication.
5.) Rover Temperature Sensor provides the Temperature Agent Data Provider with a numerical temperature.
6.) The Temperature Agent Data Provider gives the temperature to the Temperature Agent.

UML Sequence Diagram

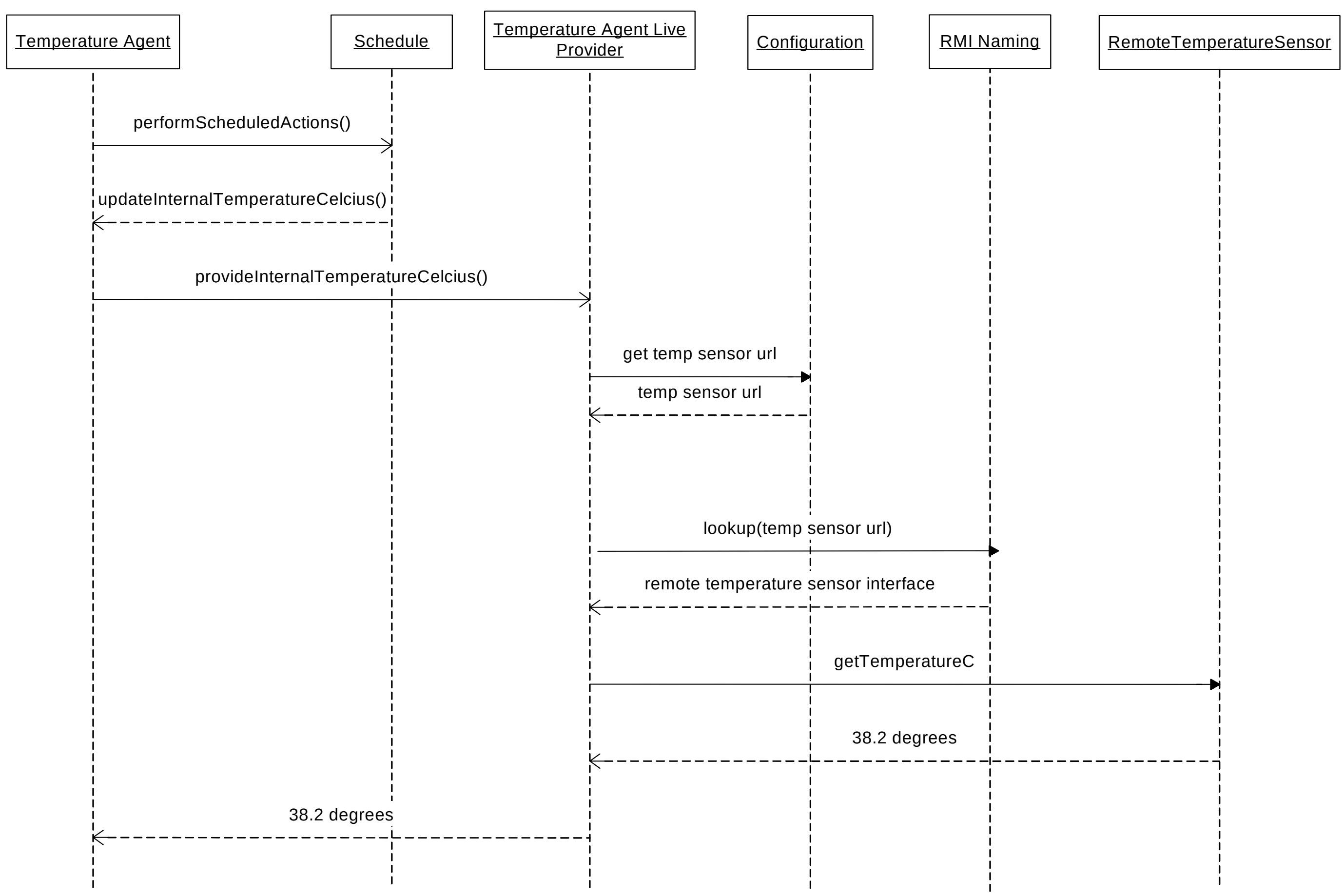

Figure 2: This is a sequence diagram that illustrates how a temperature agent gets the temperature from a remote temperature sensor on the rover.

Inside the boxes are the objects in the system. The lines in between the boxes show interaction between the objects and are also know as method calls. The dashed lines show a message being returned. These diagrams will be used to plan modifications and additions to the multi-agent system and will help plan for additional functionality for next years field test. With these models the Prism Intelligent Systems Team can easily identify problems and areas that can be improved.

References

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