

Bridging the Gap between Space Robotics Research and Robotics Education

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1. Introduction

The focus of Jet Propulsion Laboratory's Office of Communication and Education is to engage the public through the implementation of innovative approaches such as informal and formal education methods, science outreach, and research development efforts [1]. One of the direct outcomes of this emphasis is to create a bridge to provide students access to the research and development activities involved in space exploration, as well as to support and develop a pipeline program to encourage the next generation of engineers and scientists. Of special interest is to transfer robotics research knowledge derived from JPL efforts to the educational arena [2]. The robotics field represents the integration of multiple facets of engineering and science – from mechanical construction to intelligence programming to science data analysis. It is an ideal opportunity to showcase the relationship math and science have on tangible real-world applications. In addition, the robotics field incorporates non-traditional areas of study such as the social aspects of teamwork, system engineering, and hands-on experimentation methods. These represent only a small subset of the elements necessary for developing an integrated, intelligent robotic system for space exploration.

To promote robotics education, there is a concrete process needed for transferring the knowledge derived from space robotics research to platforms capable of teaching individual artificial intelligence topics, providing step-by-step instructions on robotics techniques, or integrating hands-on learning into the curriculum. In this paper, we will discuss the AI Toolkit, a task carried out at NASA's Jet Propulsion Laboratory (JPL) that focuses on bridging the gap between robotics research efforts and the classroom environment. The AI Toolkit enables training on artificial intelligence techniques through step-by-step instruction and hands-on exercises applied to the robotics arena.

2. Relevant Efforts

There is a rich history at JPL of transferring robotic research efforts to the educational arena [3], among these

are Web-Interface for TeleScience (WITS) project [4] and the Athena Student Interns Program (ASIP) [5]. WITS is a software package developed to provide Internet-based control of planetary lander and rover missions. WITS is used for the Mars Polar Lander Mission, FIDO Prototype Mars Rover, and Mars Exploration Rover (MER) mission. The public version of WITS enables students to participate in future planetary missions, and allows them to send real WITS commands to control virtual NASA robot rovers and arms. For the Athena Student Interns Program, teams of students and teachers work one-on-one with scientists and engineers as they perform their assignments for the Mars Exploration Mission. Motivated by the inclusion of student interns during the testing of the Field Integrated Design and Operations (FIDO) rover, this Mars expedition will be the first to include high school students in a current mission.

3. The Artificial Intelligence Toolkit

JPL's Artificial Intelligence Toolkit (AI Toolkit) is a software package designed to train future scientists and engineers on soft-computing methods that are applied to current robotic research efforts. Three artificial intelligence techniques are introduced in the software toolkit, namely fuzzy logic, neural networks, and genetic algorithms. The infusion of these multiple technologies have been used in various aspects of the space robotics research arena – from rover navigation on the rough terrain such as found on Mars [6] to safely landing a robotic spacecraft on a previously unknown planetary surface [7]. To successfully bridge the gap between robotics research and robotics education, three main issues were addressed:

- o What is the process needed to transfer robotic knowledge into a tool that is both educational and informative?
- o How do you join together different AI learning techniques, applied to different NASA projects, into a common repository?
- o How do you ensure the transfer of knowledge is student-friendly, while maintaining widespread cultural appeal?

Transferring Knowledge

When designing a robotic solution for a space exploration task, it is not always feasible to design a generalized solution that addresses all problems. In most cases, the overhead arising from developing a generalized solution is not compatible with the limited computational power and memory allocations available on space-qualified processors. For example, a rover vision system that operates on the surface of Mars does not require the ability to differentiate grass from sand. Thus, a texture analysis algorithm can be created that focuses specifically on real-time rock detection during rover traversal, versus generalized surface or obstacle detection. Based on this concept, space robotics research efforts usually result in the development of tightly coupled learning modules integrated directly into the rover control system. The process to then, later, extract common software elements for transfer to the educational arena becomes a daunting task. Not only must the common software elements for robotics learning be mined, but the elements that could hinder understanding of the robotic learning techniques must also be removed.

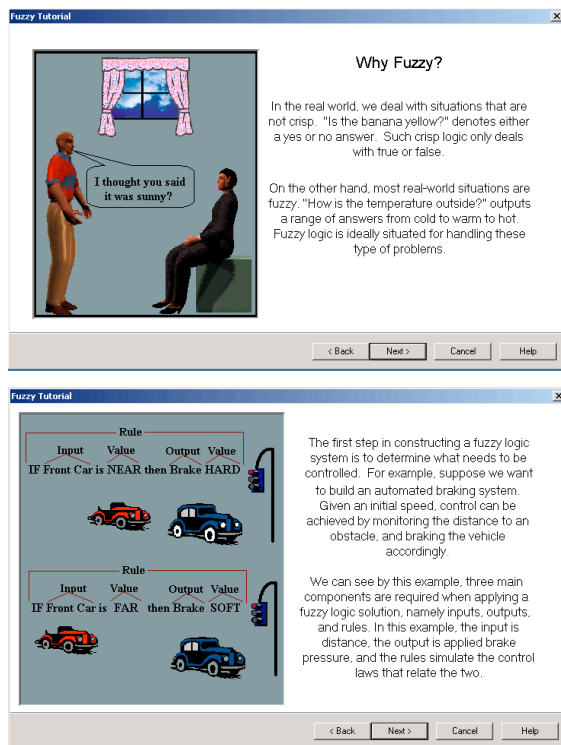


Figure 1. Storyboard sequence

The first step used for modeling technical knowledge for use in the education arena is the concept of storyboarding. Storyboarding [8] is a classical approach used in the entertainment world to visualize a story sequence before production. In documented studies, it has been shown that edutainment allows students to learn with pedagogical

techniques that combine education and entertainment [9]. We therefore reproduce factions of the edutainment practices and use the concept of storyboarding to model the flow of robotic learning techniques for inclusion in the AI toolkit. This process involves documenting the steps required to develop the artificial intelligence solution, which is similar to creating an instruction set or user manual for each AI technique discussed. The storyboard sequence should allow a non-developer of the application to recreate an AI solution from scratch, should transform technical jargon, acronyms, and assumption into descriptive sentences, and should use readability practices to ensure ease of understanding [10]. Using this storyboarding technique, Figure 1 shows examples of the fuzzy logic instructions embedded in the AI toolkit.

Knowledge Integration

The outcome of the storyboarding effort is a learning sequence documenting, step-by-step, the various techniques used in various, diverse, NASA robotic applications. The next step of knowledge integration involves extracting the software elements associated with each storyboard sequence. In some cases, this requires removing unnecessary elements from the software developed for the robotic task, or even modifying the software to ensure compatibility with the storyboard sequence. As true for most engineering applications, the integration effort represents the most time-consuming element of bridging the gap since the robotic software must be transformed into a simulated representation of the real-world application. In addition, associated with each storyboard sequence, i.e. individual artificial intelligence technique, an example hands-on exercise must be created that models the relevant elements of the robotic application. The exercises associated with each technique should be complementary, and should address different aspects of the robotic problem. As an example, Figure 2 displays the genetic algorithm while Figure 3 displays the fuzzy logic hands-on exercise that is modeled in the AI toolkit.



Figure 2. Integration of knowledge into a genetic algorithm application for spacecraft planning

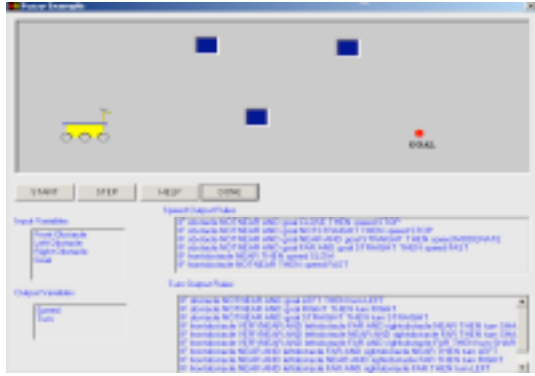


Figure 3. Integration of knowledge into a fuzzy logic application for rover navigation

Knowledge Presentation

The software to support the storyboard sequence has been gathered. The hands-on exercises used to reinforce the techniques learned from the storyboard sequence have been designed. These elements must now be assembled into a student-friendly educational package, while ensuring that the tool maintains widespread appeal. The use of images has been shown to assist memory and increase a student's ability to transfer new ideas and apply new knowledge [11]. Thus, a graphical-based interface employing the theories of relevance, clarity, and appeal is developed to showcase the storyboard sequence and hands-on exercises. Studies have also shown that the cultural identity of a computer agent influences how a user interacts with the computer, through belief, trustworthiness, and attractiveness of the agent for the user [12]. These findings show the need for culture, and gender, specific influences in human-computer interaction scenarios. Based on the U.S. Census Bureau statistics collected in 2000, 51% of the American population are women and 24.9% belong to a minority class. Thus, to ensure widespread appeal, interfaces in the AI toolkit are strategically designed to incorporate the diversity present in U.S. culture.

4. Conclusions

Through the process of knowledge transfer, integration, and presentation, the AI Toolkit represents a method for bridging the gap between robotics research and education. This process allows the inclusion of informal education methods to permeate throughout the classroom environment. Robotics represents a way "to inspire the next generation of explorers" [13] to develop the skills necessary to become future engineers and scientists. Robotics represents an exciting hands-on opportunity to apply theoretical math and science to real-world problems. The AI Toolkit [14] is just one effort to assist in this learning process.

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