Human-Robot Interactions to Promote Play and Learning

Byron Lahey, Natalie Freed, Patrick Lu, Camilla Nørgaard Jensen, Kasia Muldner, Winslow Burleson
Arts, Media and Engineering / School of Computing and Informatics
Arizona State University, Tempe, Arizona, USA
{byron.lahey, natalie.freed, yen-ting.lu, camilla.jensen, katarzyna.muldner, winslow.burleson}@asu.edu

ABSTRACT

Research shows that children construct much of their knowledge through active manipulation of the environment, which allows them to connect abstract concepts to observable outcomes. Despite these findings, although the integration of novel pedagogical technologies into classroom settings has begun, the technologies predominantly have focused on instruction in *virtual* contexts. To date, however, little is known about novel technologies that step outside of the virtual realm into the physical classroom, thereby leveraging findings on embodied mathematical cognition to influence educational practices. As a first step in filling this gap, we present the Active Learning Environment with Robotics Tangibles (ALERT) framework. Our system relies on human-robot interaction and tangible instruction to motivate and trigger learning in students through a variety of activities that integrate play and instruction in mixed reality environments. Here we describe some of the activities supported by ALERT, and discuss plans for evaluating the pedagogical utility of the system.

Categories and Subject Descriptors

H.1.2 [**User/Machine Systems]**: *Human Factors;* H.5.2 [**User Interfaces**]: *Interaction styles*; I.5.5 [**Implementation**]: *Interactive systems*; J [**Computer Applications**]: *Education*.

General Terms

Design, Human Factors.

Keywords

Human-Robot Interaction, Learning, Affect

1. INTRODUCTION

The recent decade has seen great advances in robotics in terms of accessibility, cost and functionality, enabling, for instance, the rapid deployment of millions of iRobot Roomba home robots and the popularity of robotic play systems, such as LEGO Mindstorms and NXT. These advances present new opportunities to extend the realm of play even further, into physical environments, through the direct integration of human-robot interaction (HRI) techniques. One such opportunity involves leveraging the engaging nature of robot-based play activities with instruction, i.e., bringing robots into the classroom to foster learning. Instruction incorporating HRI has the potential to facilitate better learning, by engaging students in tangible activities in their environment (i.e., learning by doing) and promote motivation in this process. To date, however, how robotics can enhance education, or how these interactions impact the educational process is not yet fully understood.

Here, we present the Active Learning Environments with Robotic Tangibles (ALERT) framework. ALERT relies on HRI to motivate and trigger learning in students through a variety of activities that integrate play and instruction. We describe a subset of activities supported by this framework and discuss evaluations we plan to conduct to assess the pedagogical utility of our system.

When designing the ALERT framework, our goals were to produce a low-cost, user-friendly platform that is easily accessible to schools, museums and other educational settings. We also aimed to minimize the robot development time so that we could focus on creating engaging human-robot interactions. Consequently, as the core of our framework, we chose the iRobot *Create* , a low cost and easily extensible robot platform. To make the robot appealing to a wide range of children, as well as to help foster story telling and social relationships with the robot, we designed costumes to make the robots appear animal-like (e.g., frog, stork, see Fig. 1).

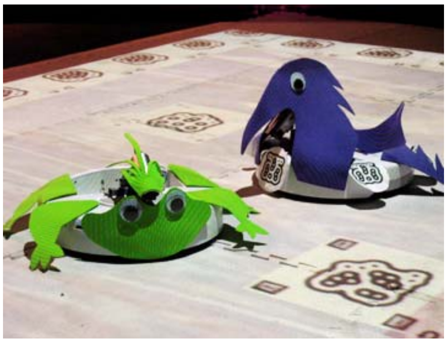

Figure 1: ALERT Robots with projected fiducials

To enable iRobot to recognize objects in its environment, we equipped it with a video camera, supplemented with the reacTIVision computer vision software. The framework also includes a set of fiducials [Fig. 1], "meaningful markers", like product bar codes, that students use to provide just-in-time instructions to the robots. An external computer running Java and Max-MSP software processes the instructions. When the robot "sees" a fiducial marker, the corresponding command is executed, including a sound that is played through a set of speakers. The simplest commands are basic driving functions (drive forward,

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turn, stop, etc.), but these commands can be more complex and specialized (repeat last command, store a “key” which will open a “lock”, send an email with a status report, etc.).

Throughout the design of the framework, we have engaged users via participatory design to ensure usability and user satisfaction. For instance, we developed the set of fiducials through ALERT-based activities with children of various ages; we are constantly expanding and optimizing this set as we conduct new pilots evaluations. In our pilots, we have also experimented with a variety of camera systems in order to maximize accuracy and usability and minimize cost. We initially placed a MacBook laptop computer on the iRobot and the laptop’s built-in camera for vision recognition. Later, desiring a lower cost and more child resistant robot, we attached a wireless camera to the iRobot. This solution proved generally effective and is still being used but we found the wireless transmissions to be less robust than we ultimately desired. Consequently, we are transitioning back to a variation of our original solution, i.e., placing a laptop directly on the iRobot. However, in this iteration, we are using smaller and lower cost Acer miniature laptops, with solid state hard drives, in place of the relatively expensive and fragile MacBook computers. To further increase the robustness and child friendly nature of our systems we use USB cameras, allowing us to run the robots with the laptops closed, protecting the computers from unintended interactions and dangerous contact.

2. INTERACTING WITH ALERT ROBOTS

Once an ALERT robot is turned on, it waits for commands. Students instruct the robot to perform a variety of actions by placing fiducial markers in the path of the robot. Each fiducial expresses a particular command, such as “turn left”, “turn right”, “stop”, “turn 30 degrees clockwise”, etc. Instructing a robot can take a variety of forms. The simplest involves using the fiducials as just-in time instructions to the robot: students place the desired fiducial in front of the robot precisely when they want the robot to execute the corresponding command. An alternative approach, which requires more forethought and planning, involves placing a series of fiducials in a sequence, defining the entire “program for the robot to execute prior to initiating the robot’s movement. If a student wants the robot to have more autonomous behavior, fiducials can be arranged in a space to create a landscape, defining boundaries, rewards, dangers, etc. When encountered, the fiducials instruct the robot to veer away from one fiducial or set of fiducials (obstacles) and toward others. One of the most basic versions of this scenario involves creating a fiducial boundary that “bounces” the robot around within the space. An extension of this approach can create a labyrinth. Placing multiple robots in a common space and attaching fiducial markers to the bodies of the robots adds further complexity in the system

As we illustrated above, the flexibility of the ALERT framework affords a great variety of activities that can be used, for instance, to teach children about geometric concepts in a fun and play-oriented way, such as:

- Children are shown a path on paper and asked to reproduce it by “writing a program”, via fiducials.
- Children play a 'Get the Toys' game that uses fiducials to instruct the robot to get three toys before its battery runs out of energy (the battery life is simulated.) In this game only 90 degree turns are allowed. The goal is for students to learn about turns and to differentiate turn and displacement situations.
- Children are asked to estimate certain turns (e.g., right 40) by drawing them, and then realizing them in the physical environment with the ALERT robots.
- Children instruct the robots to “draw” equilateral triangles. This activity stimulates children to think about finding the turns needed to generate this class of figures

2.1 Robots as Pets

Building on the ALERT framework, we have designed robots that incorporate additional sensors and software to simulate pet-like behaviors. For instance, one such robot engages users in a “retreat-and-advance game”: the robot recognizes and approaches a human until it comes within a certain distance, but if the human approaches too quickly or gets too close, the robot rapidly retreats in a shuffling manner, much as a puppy would do. Our goal with this project is to attract students to STEM topics through entertaining and thought provoking human-robot interactions and to provide a template for their own development of robotic pets.

3. IMPACT OF TANGIBLE INTERACTIONS

As indicated above, one goal of ALERT’s is to foster learning. Traditionally, the value of pedagogical applications has been assessed by analyzing impact on learning gains. While this is an avenue we are interested in pursuing, affect and motivation need also be considered, as they play a key role in the educational process [3]. Novel technologies, such as ALERT, have the potential to motivate and excite students, but their impact on learning, motivation and affect to date is not fully understood.

We have piloted the ALERT robots in a series of evaluations with a range of participants (see [1]). These pilots have shown that students are highly engaged with the robots, and have allowed us to shape the design of the framework. As our next step, we plan to conduct formal *in situ* evaluations in students’ classrooms and related environments (e.g., after-school clubs).

To obtain an understanding of how tangible agents influence the instructional process, we plan to compare the impact of ALERT against more traditional environments designed to teach children geometric concepts through programming (e.g., LOGO-based applications [2]). As our dependent variables, we plan to use both traditional learning measures (e.g., pre to post test differences) as well as motivation and affect variables, obtained through questionnaires and interviews with students. We are especially interested in evaluating how the tangible, physical interactions afforded by ALERT impact these variables of interest, as compared to the traditional programming environments.

4. REFERENCES

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