The Montana ALE
(Autonomous Lunar Excavator)

Community Outreach Report

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Introduction

A student team from Montana State University will participate in NASA’s third annual Lunabotics Mining Competition in May 2012. In addition to designing and constructing an excavation robot to compete in the mining challenge, the team was required to participate in public outreach projects. Outreach presentations involving the Lunabot itself are a natural extension of the design project, since the “wow factor” associated with the Lunabot provides a convenient hook for educating and inspiring others about engineering, science, and space exploration. However, in addition to simply displaying the robot, the team wished to provide engaging hands-on activities that would be suitable for students in the elementary grades. To fulfill that end, the “Mini Lunabotics Mining Competition” was conceived. This activity allows participants to direct a small robot through the operations of driving to a mining area, digging, and dumping collected material, much as a team in the actual competition would. Thus, it both promotes the Lunabotics Mining Competition and gives the participants hands-on interaction with a robot, without the risk that would attend giving control of the full-size MSU Lunabot to young children. The full-size Lunabot and/or the Mini Lunabotics Mining Competition were used in a total of seven outreach events over the course of the project. Four of these were primarily targeted at K-12 students; the remainder were targeted at older audiences, mostly college level and up.

Outreach Activity Design

In years past, MSU Lunabotics outreach efforts have consisted of passive presentations and demonstrations to audiences about the NASA Lunabotics Competition and the MSU robot design. This approach was very successful in reaching large numbers of people, but had two major drawbacks. First, it did not provide participants with an interactive, hands-on experience. Second, in order for the presentations to be effective, the excavation robot had to be present and operational. This created a practical limitation on the number of outreach events that could be conducted, due to the lack of a complete robot early in the project timeline and the difficulty of transporting the relatively large, heavy device. Although the team continued to perform formal presentations and demonstrations this year, an additional component, the Mini Lunabotics Mining Competition, was added to the outreach program to address these issues.

![Figure 1. The mini lunabot built from LEGO Mindstorms pieces (left) and a CAD model of the full-size Lunabot design (right).](image)
The centerpiece of the Mini Lunabotics Mining Competition is a small LEGO Mindstorms NXT robot, built to superficially resemble the full-size MSU Lunabot. Featuring durable, snap-together plastic pieces and a simple graphical programming interface, Mindstorms robots are quite popular among elementary robotics educators. There are no safety issues associated with the Mindstorms kit for K-12 students, and the level of hands-on involvement with the robot can be tailored to the maturity of the group and the requirements of the outreach event. For example, participants might simply observe the miniature robot mining and transporting a pile of material, guide it through the mining process with a handheld control, write new programs to enable autonomous operation, construct and program a copy of the robot using additional kits, or even attempt to design their own robots.

Like the full-size design, the Mindstorms robot features a four-wheel skid-steering system and a hollow, rotating drum for excavation and deposition. Since it was essentially impossible to build an excavation drum from existing LEGO Mindstorms pieces, the drum was fabricated from a potato chip can. Several variations of the drum were produced to allow for experimentation with different designs. A drum featuring a single wide scoop proved to work the best, and was therefore most frequently used. (The cardboard drums lack the spiraling internal structure of the full-size Lunabot’s drum, so it is more difficult to retain excavated material in drums that have multiple scoops.) The Mindstorms robot can be controlled with a wireless Xbox controller, much like the MSU Lunabot (although the Mindstorms robot connect to its controlling computer with Bluetooth, instead of the 802.11 protocol employed by the full-size Lunabot). The Microsoft Robotics Studio (MSRS) was used to create the program that enables this control. LEGO also provides a customized CAD program called LEGO Digital Designer, which facilitates quick digital representation of LEGO models and generates detailed build instructions. The miniature Lunabot was modeled in this software so that it could be reconstructed more easily in the future.

![Figure 2. The complete Mini Lunabotics Mining Competition setup, including a laptop computer for remote monitoring of the arena. At right, beans deposited in the collection tray are weighed to determine the robot driver’s score.](image)

In order to promote awareness of the Lunabotics competition among the students participating in the activity, we constructed a miniature “LunArena” tent that emulates the full-scale version. Lights and a web camera were mounted inside the top of the tent, so that participants could drive the robot remotely, while viewing the video feed on a computer screen,
if desired. However, we did not attempt to fill the arena base with anything resembling actual dirt or regolith, instead choosing the cleaner option of dry red beans. These were piled in a “mining area” at one end of the arena base. On the other end, a shallow tray was provided as a place to deposit the beans after they have been “mined.” The tray can be removed from the mini LunArena and placed on a scale in order to weigh the collected beans. The miniature LunArena and the Mindstorms robot are significantly more portable than the full-size Lunabot, and they are suitable for science fairs and trade shows which require one’s exhibit to be confined to a tabletop.

**Outreach Events**

An early version of the miniature Lunabot was featured on Science Fun Night at the local Museum of the Rockies in Bozeman, MT, on November 17, 2011. The event was open to the public, but was primarily intended for the over five hundred middle and high school students who had traveled to Bozeman to participate in the statewide science Olympiad. These students came from schools all across Montana, and were brought to the Museum in groups to tour the various exhibits. The early variation of the Lunabot displayed at this event used a shovel for digging, rather than a rotating drum, and was programmed to autonomously collect and deposit beans. One member of the MSU Lunabotics team demonstrated this robot for the passing crowds and answered their questions. The official time lapse video from the 2010 Lunabotics Mining Competition was also shown looping on a nearby screen. The event lasted four hours and was an overwhelming success in terms of attendance. Numerous students engaged with the robotics exhibit; questions asked ranged from how the robot was programmed, to how the design was constructed, to what robotics opportunities existed in electrical engineering.

![Figure 3. Science Fun Night outreach exhibit. At left, Jennifer Hane prepares to demonstrate an early version of the Mini Lunabot. At right, students and their parents watch as the robot autonomously moves beans.](image)

For the second outreach event, the team collaborated with MSU Computer Science professor Hunter Lloyd (one of the project advisors), who regularly works with local elementary classes. The main focus of Hunter Lloyd's events is the assembly and programming of a LEGO Mindstorms robot (somewhat simpler than the mini Lunabot). Members of the Lunabotics team were on hand at Prof. Lloyd's January 25 outreach session, providing help and support to the students as they put together and programmed their robots. The Mini Lunabotics Mining
Competition was also present for the event. The Lunabotics team explained the Competition to the students and allowed them to drive the mini Lunabot, timing them while they “mined” in the heap of dry beans. All of the students participating in this event were members of Irving Elementary School's 4th grade class.

![Figure 4. Irving Elementary 4th graders drive the mini Lunabot and compete for the largest number of beans deposited.](image)

The Miniature Lunabotics Mining Competition was also present for the Billings Clinic Research Center Science Expo, a four-hour event held on the MSU Billings campus on March 24. The Expo is a science fair in which K-12 students from twenty-four counties in southeastern Montana may participate. It includes both a competition session, in which the students present their own projects, and an educational outreach day which features exhibits for the students' benefit. The theme of this year's Expo was “Space: Infinite Possibilities,” making the Miniature Lunabotics Mining Competition an ideal exhibit to include. The Lunarena was set up on a tabletop, accompanied by some display materials, and passing students were allowed to drive the Lunabot with the wireless controller and attempt to mine some beans. They were obviously drawn to the robot, and it seldom sat idle. Most students drove it for several minutes before moving on, unless they were asked to give up the controller to someone else in line, and some returned later for a repeat session. Several expressed curiosity about how the robot was programmed or how it communicated with the controller.

![Figure 5. Attendees at the Billings Clinic Research Center Science Expo enjoyed using the mini Lunabot to collect and deposit beans.](image)
Finally, both the Miniature Lunabotics Mining Competition and the full-size robot were present as exhibits at Astronomy Days on April 21. This event was also held at the Museum of the Rockies in Bozeman, and lasted three hours. It was open to the general public, and the K-12 age group was well-represented among the attendees. The exhibit format was much the same as the one used for the science expo; young people passing the exhibit were shown how to drive the mini robot and given a chance to mine beans in the arena. The competition robot sat nearby as a stationary display, with several team members present to explain its purpose and answer questions. The Lunabotics exhibit proved very popular and received a nearly constant stream of visitors until crowds thinned toward the end of the Astronomy Days event.

![Figure 6. The MSU Lunabotics exhibit at Astronomy Days. At left, the mini Lunabot engages young attendees. At right, the team is excited to show off the full-size Lunabot.](image)

Although hands-on outreach using the mini Lunabot has been the focus of the team's efforts this year, traditional presentations were not neglected. On March 5, the team demonstrated the partially completed full-size Lunabot at a meeting of the MSU College of Engineering's External Advisory Board. The team also attended the 2012 MSU Student Research Celebration on April 19 with their robot and an informative poster, and expect to bring the same to the MSU Engineering Design Fair on April 26. Both of these latter events provide opportunities for the team to present the completed robot to MSU faculty, their peers, and the general public.

![Figure 7. Presentations and demonstrations. At left, Daniel Benson drives the robot's chassis while members of the COE Advisory Board look on. At right, Logan Warberg mans the poster board at the Student Research Celebration.](image)