A.R.K. (Applied Random Knowledge) rover

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Abstract

In the development of an autonomous, beacon-seeking robot, capable of traversing a Mars like landscape, an exhaustive design process was implemented. This process consisted of identification and definition of the requirements for the A.R.K. rover, development of the robots functional specifications, and concept generation. The final design decision was heavily influenced by the trade-offs between and rugged capability for overcoming as many obstacles as possible.

The current ARK Rover features an active tread suspension which provides ample ground clearance and a consistent drive force applied to the treads on uneven terrain. The chassis is constructed of plywood which has proven to have an excellent strength to weight ratio. Navigation and obstacle avoidance consists of an array of ultrasonic sensors as well as an accelerometer, a compass, and radio transceiver which are all integrated by an Arduino Mega microprocessor.

Despite the ARK Rover not being the simplest or previously proven design, as well as the ongoing modifications that it has required, the overall concept shows great promise heading into field testing.

1. Introduction

The purpose of NASA's Space Robotics Challenge is to increase robotic exploration capabilities on Mars. In Colorado at Great Sand Dunes National Park, the terrain has been found to be nearly identical to Mars with the similarly shaped dune fields, rocky river beds and precipitous cliffs (these are simulated at the challenge by impassably deep holes). This unforgiving terrain, in combination with Robotics Challenge design constraints, provides a daunting engineering task.

This is a project in which a beacon-seeking and obstacle avoiding robot was created. The main goals for this project were to create a mechanically superior robot in order to traverse over nearly all obstacles in our way and use obstacle avoidance only for very large obstacles and ditches.

The robot had a large ground clearance and utilized two sets of continuous tracks with three independent suspension arms and rollers to enable adequate traction on any surface. For obstacle avoidance and ditch detection, 6 ultrasonic sensors were used to sense obstructions too large for the bot to climb. The entire bot was manufactured from plywood and 3-d printed ABS components due to their quick production rates. Quick adjustments to suspension and track tension were designed in to increase adaptability. Sensors are mounted such that they can be easily adjusted to allow fine tuning of obstacle avoidance.

2. The Design Process

In order to begin the design process for A.R.K., a list of the most important or potentially problematic obstacles was compiled from information taken from previous years Challenges. The main four were thought to be:

- Deep, soft sand.
- Moderate sized, irregularly shaped rocks that could cause the rover to become high centered when attempting to traverse.
- Rings or mostly enclosed spaces of impassable terrain that if the rover were to enter may not be able to navigate out of.
- The simulated cliff (deep trenches/holes) where the robot would essentially be destroyed if not avoided completely.

From this list, we sought to balance the requirements for brute force with agility and rugged construction with the maximum weight limit of 4 kilograms. Overall simplicity in the design, ease of construction, and the 500 dollar budget were important factors in the final concept decision as well. By considering these requirements, we narrowed our consideration of modes of propulsion down to wheels and treads.

Brainstorming and searching for past products were the main two forms of concept generation used. Many different ideas were generated and then evaluated based on our specifications.

Traditional four and six wheeled rock crawler type vehicles are a good choice for many reasons. First of all, this is a proven design that can traverse many types of terrain. Secondly, there are many, readily available R.C. kits that can be copied or simply modified. Going this route would have certainly kept with simplicity and ease of construction, however, this approach seemed to contradict the spirit of this competition.

Treaded vehicles have also proven to be a very successful means of propulsion for many vehicles such as tanks, snow cats, and various other ATVs. The design that ultimately inspired the A.R.K. rover came from iRobots® ASIM (Advanced Suspension for Improved Mobility) program. We chose to model the Packbots® active suspension mainly for its combination of agility and ruggedness but also for the added challenge of reproducing this cutting edge technology.

To achieve the best obstacle avoidance system possible, an array of ultrasonic sensors was chosen.

This was due, in part to numerous warnings about the adverse affects of direct and reflected sunlight on infrared sensors, as well as the need to be able to detect distances accurately (primarily the depth of holes or trenches).

In finalizing the design, engineering analysis was done as follows. Specifications for the DC motors were developed from basic kinetics calculations. The robots final weight was assumed to be eight pounds and without taking the drag in the system into account, a factor of safety of three was implemented to ensure ample power. Specifications for the shocks were developed from the suspension geometry analysis but in the end, shocks were chosen based on availability and cost. Finally CAD drawings of the chassis, suspension components and rollers were produced.

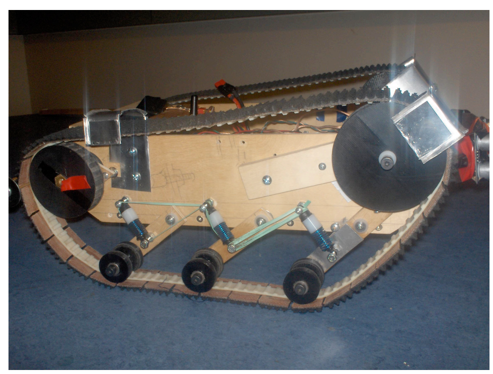

Figure 1

3. Fabrication and assembly

The tread rollers were produced with a 3-D printer and were made of ABS plastic. While this is a rapid prototyping method, operator experience is invaluable in producing a precise part. Due to an initial lack of this experience, as well as various design changes, multiple iterations of all three types of rollers (Drive, Tension, and Idler) had to be produced.

The initial chassis and suspension arms were made of quarter inch plywood. This material is very easy to machine, readily available and posses a good strength (mainly in shear) to weight ratio.

Treads were custom made by gluing a Urethane/Kevlar timing belt to the inside of SBR rubber conveyor belt material. The SBR rubber was chosen for its ease of machining, grip, and tread pattern. The timing belt was oriented tooth side in to mesh with the drive roller that was printed with the same tooth pattern. Flexibility of the SBR rubber was too low as a continuous belt and had to be cut and applied to the timing belt as segments with eighth inch gaps in between.

A wide variety of fasteners, bushings, spacers, and washers were used in the assembly of this robot. Coming to the final assembly for the moving parts, such as the pivot point of the suspension arms was achieved by trial and error with many trips made to the hardware store.

4. Electronics and programming

The final microprocessor used to integrate the variety of sensors was the Arduino Mega. Initially the Arduino Due was used but issues with I^2C components necessitated the switch. The on board sensors and their intended use are as follows.

Primary obstacle detection was done by the six ultrasonic sensors. On the front of the robot there was a left, middle, and right sensor mounted at a height so that they would not detect obstacles that the robot could climb. Also in the front there was a forward and downward facing sensor in order to detect deep drops in terrain level. The last two ultrasonic sensors were mounted in the rear, one in the middle above small obstacle height and the other downward facing to prevent backing into a trench or hole. These sensors provided a smooth input when the signal was filtered.

A radio transceiver was necessary for locating the beacon. At the challenge, many of the other teams reported a problem detecting the beacon.

A compass was used to navigate in conjunction with the transceiver and was very useful in testing when there was no beacon to locate.

The final sensor used was a gyroscope/accelerometer with the idea being that the robot could detect whether or not it was moving according to how it thought it should be moving or if it had become stuck.

The programming language used was Arduino which is very similar to **C++. JAVA** Custom built libraries were implemented to handle the inputs and outputs so that the main documents only contained behavioral information.

The behavior of A.R.K. was broken down into four different states.

- First was normal mode where the beacon was located and no impassable objects were detected, full speed ahead.
- Secondly there was cautious mode in which potentially hazardous conditions had been detected and speed was reduced by half. In cautious mode the idea was to avoid the impassable obstacle by turning to the left. The obstacle would then be monitored by the right facing ultrasonic sensor and once no longer detected the robot would again head toward the beacon.
- Backup mode was designed specifically for the U-shaped or semi-enclosed obstacle areas. This mode prevented the robot from getting wedged into a tight corner or simply turning in circles believing that it was completely surrounded by hazards.
- The final state was courageous or more commonly referred to as Y.O.L.O. (You Only Live Once) mode. This was intended to be a last ditch effort to reach the beacon after the robot believed it was either stuck or trapped. In YOLO, the robot turned towards the beacon and went full speed.
- Additionally, a “ramp up” cycle was programmed for the motors in all modes. This means the motors were powered up gradually instead of instant full power. The intent was to ease the wear on the controller and motors as well as decrease wobbling of the chassis.

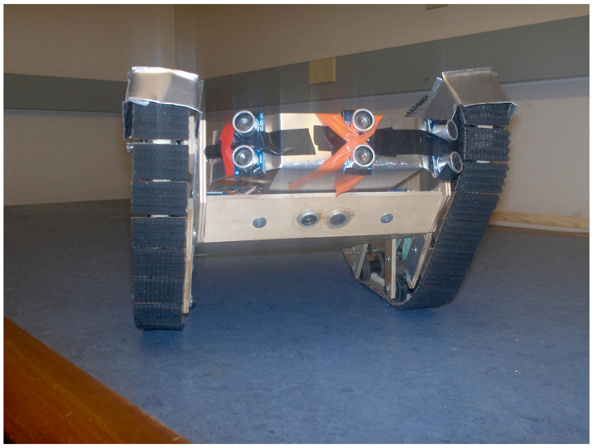

Figure 2

5. Conclusion

Regardless of its level of achievement at the 2014 Space robotics challenge, the A.R.K. rover should be considered a successful product. Having achieved the teams primary goal of arriving with and returning home from the challenge with an operational autonomous robot along with gaining the invaluable experience that only comes from participation in such a project.

To summarize the more notable improvements that would have been done, time allowing:

- While plywood was not intended to be the final construction material, as time and money dwindled, it was accepted as a suitable substitute for other high strength plastic sheet goods or 3-D printed parts that would exhibit better flexural strength and hardness. The major drawback was evident primarily in the suspension arms, due to the lack of lateral rigidity and the tendency of the plywood to loosen around the pivot and axel connection points which exaggerated the lateral instability.
- The interface between the drive roller and the tread would be greatly improved of the teeth on the roller had a more positive interlocking with the tread itself. This interlocking action would likely solve the issues of the drive roller slipping as well as the tread alignment where the tread tended to “walk” off of any one of the rollers at any time.
- Gaining a better understanding of the requirements of the motor driver/shield and how it is affected by motor and battery type.
- Make testing a priority. So many problems, small and large become clear once sufficient testing takes place. If testing is not conducted early enough in the process, it is likely that many problems that emerge will not be able to be solved completely due to lack of time and resources.

The task of sending an autonomous robot to explore the surface of another planet holds numerous challenges. The space robotics challenge approaches this problem in a most engaging way that allows everyone who participates to benefit from the experience.