Colorado State University Robotics Club

***Left to Right: Conor Lansford, Pasha Volchak, Manny Watts, Bradley Richards, Kat Near, Scott Williams, Isaak Malers, Ed Okvath, Dan Sullivan**
Picture by Conor Lansford

2014 NASA Robotics Challenge
Great Sand Dune Nation Park - Alamosa, CO

Report By: Daniel Sullivan

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Introduction and Overview

The Colorado State University Robotics Club (CSURC) entered a robot into the 2014 Robotics Challenge put on by the NASA Colorado Space Grant Consortium. In doing so a great deal was learned by the members of the team in the evolution of the design and engineering process, leadership, and robotics.

The concept behind the final robot was originally to design a robot from lightweight materials that would allow for greater size. This greater size was then to be used as a method to overcome obstacles by allowing the robot to straddle or simply ignore obstacles altogether. A breach of challenge rules led to the robot being re-sized from the initial 46-inch by 46-inch ground coverage to 30 inch by 30 inches, causing the design to be less concerned with weight and allowing use of other materials. The robot was then re-designed with steel brackets from a VEX robotics set. The wheels had a 14-inch diameter and were constructed out a chicken wire like mesh that allows the robot to have higher ground clearance, minimizing obstacles that would otherwise be impassable. The robot was powered by two 7.2 volt batteries and the sensors used are one 433 MHz beacon, one accelerometer, one compass, and three Ultrasonic. The sensors were controlled by three Arduino Uno microcontroller boards.

Team

The team for the CSURC was originally comprised of 5 individuals that later grew to accommodate the general club needs to keep club members active in projects. Adding team members later in the project was found to be a less than desirable choice and is explained in the lessons learned, however, each team member was valuable to the project and brought unique perspectives to the design process. The team members were as follows:

Dan Sullivan (Team Leader/Systems) – Dan was made the team leader by the robotics club president after recruiting the original five members of the team. He is a Computer Science Major with an expected graduation date of May 2015. Throughout the challenge Dan initially took on an active role in early design concepts on the software side of the project and facilitated progress of the overall project. Towards the end of the project Dan was mostly doing labor for hardware and coordinating the project, travel and various tasks.

Bradley Richards (Software Lead) – Bradley was made the software lead by Dan Sullivan due to his more advanced knowledge of programming and software development methods. Brad is a Computer Science Major with an expected graduation date of May 2014. In times of Dan's absence due to splitting up the team to maximize time usage as well as the occasional absence due to personal matters Bradley also filled in as the overall team leader. During the project Bradley developed the overall software design.

Isaak Malers (Hardware Lead) – Isaak Malers was made the hardware lead by Dan Sullivan due to his experience in working with Arduino and his original degree pursuit of Mechanical Engineering. Isaak has since switched his degree pursuit to Computer Science and his expected Graduation date is December 2017. During the project Isaak completed hardware tasks and directed the hardware personnel as required. The original wheel design of using chicken wire as a lightweight material to give ground clearance was developed by Isaak.

Scott Williams (Software) – Scott was instrumental in programming the robot orientation code. At times he took on a systems role by coordinating pin-outs on the Arduino. He also developed the basic drive classes of the robot. After developing those parts of the project he went on to develop libraries and header files for the various classes of the code. Scott is a Computer Science Major with an expected graduation date of May 2015.

Ed Okvath (Hardware) – Ed helped to develop and implement necessary circuits and any hardware used in the project. Ed is a Computer Engineer major with an expected graduation date of December 2015.

Kat Near (Software) – Kat was a late addition over the winter break. She brought some experience in Arduino programming to the team and aided Scott in developing the drive classes. In large part she took lead on getting sensors to send and receive data for the compass, accelerometer, ultrasonics and beacon in conjunction with Pasha and Conor. Kat is a Computer Science major with an expected graduation date of May 2016.

Pasha Volchak (General) – Pasha was a late addition in February. Pasha largely performed research on various components and parts as required by the team and aided Kat and Conor in development of code for the sensors. Pasha also filled in as a jack of all trades and aided team members in whatever tasks came up. Pasha is a Computer Science major with an expected graduation of May 2015.

Conor Lansford (Software) – Conor was the final late addition along with Pasha in February. Conor worked with Kat to develop sensor code and conducted research as necessary. Conor is an Applied Computing Technology major with an expected graduation date of May 2014.

Evolution of Design

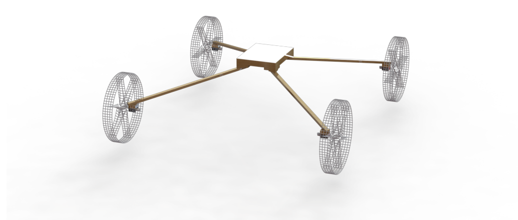
The evolution of design could not be more diverse. There were four major redesigns done during the project before arriving at the final product. In retrospect many lessons were learned about the design process where as a team of developers, gadgets and cool ideas were more of a burden to the design than the terrain of the challenge. Simplicity should have many times won out over cool ideas, and though covered in the "Lessons Learned" section, the failures of design ended up being the most important result and teaching point of the challenge.

Design 1

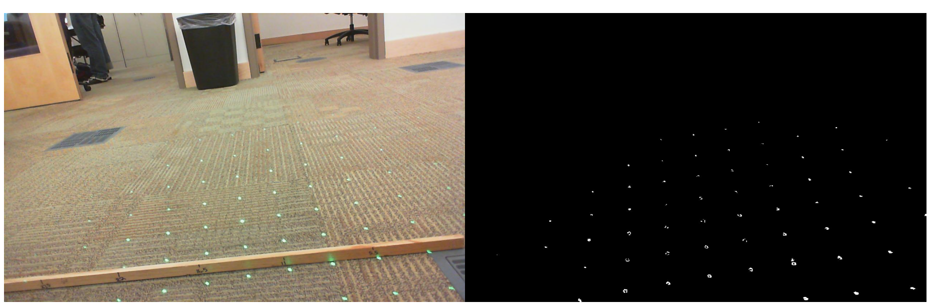
The first design concept in retrospect should have been the one to follow from the beginning. Sadly the design, though largely supported by the team, gave way to imagination and seeking to make a robot that was cool, and never made it off of the whiteboard. The first design was simply to build a robot that had two tracks and rounded sides. The body of the robot would be eclipsed in size by the tracks and would rely on an ultrasonic, a beacon and an accelerometer. The concept was simply to have the robot look forward to ensure it was not going to hit an obstacle bigger than itself and roll towards the beacon. If an obstacle was detected an avoidance algorithm would be implemented. The overall design with the rounded sides otherwise was to have the robot advance towards the beacon and if the terrain flipped the robot the acceleromter would detect a change in the orientation and just change the sensor data 180 degrees to account for the robot rollover.

Design 2

The second design was pursued for a majority of the time of this project time-line. Design 2 was very advanced compared to anything that was seen at the actual challenge on April 5th. Design 2 was to be implemented on four large wheels made of chicken wire and would try to actively avoid all obstacles and find the easiest path. Though the chicken wire wheels stayed in the final project most of design 2 did not make it to the challenge date. Design 2 relied on lightweight materials and size to overcome the terrain with 14-inch diameter wheels and a 46 in x 46 in wheel base. The design was also to use a laser pointer with kaleidoscope that presented a grid of points. A camera was to be used to retrieve the pattern of those lasers and find a clear path of travel for the robot. The software for this design was developed by Bradley Richards to pick up the lasers from a camera. An algorithm to analyze the picture developed from the lasers was being developed by other team members. Additionally a Raspberry PI processor, accelerometer, beacon, compass and ultrasonics were to be used in the design as well.



*Designs 2 and 3 Chassis and Wheels – Render by Isaak Malers



*Laser Grid and Camera Combo – Image data before and after filtered to isolate lasers – Code and pictures by Bradley Richards

The concept of the algorithm using the laser grid was to use the ultrasonics and beacon to find an unobstructed path to the beacon, but in the case that their was no clear path, the laser grid would be analyzed to find a meticulous path.

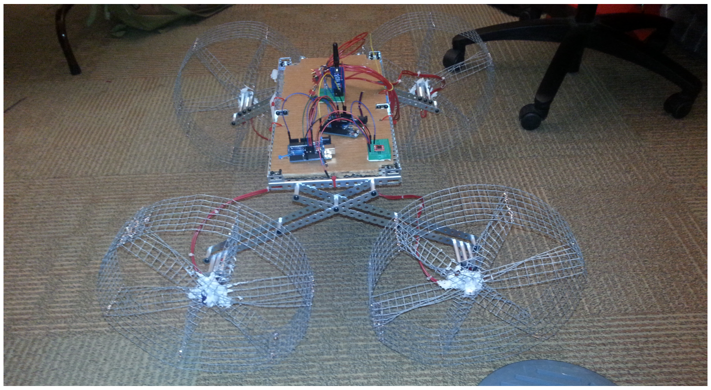
Design 2 failed to make it to prototype because of the inadequacies of the lasers available. When the laser was a single pointer it was visible in all sunlight when projected on the ground. When the kaleidoscope was attached to the laser, however, the laser lost power and was barely visible to the naked eye much less a modified web camera in sunny outdoor conditions. When a part was ordered to increase laser power, the wrong part was shipped to the team. There was not enough time to fix the shipping error and design 2 failed to go any further.

Design 3

Design 3 was the same hardware as Design 2 minus the Raspberry Pi and Laser Camera combo. With the laser and camera out there was little need for the advanced processing power of the Raspberry PI. As a result the robot was taken to a design of an array of ultrasonic sensors, beacon, compass, accelerometer and IR sensors all utilized from Arduino micro-controllers. It was found out during a teleconference call with Brian Sanders who was directing the challenge, the size of the robot was too large and needed to be brought down to at most a wheel base of 30 in x 30 in.

Final Design

The final design that was taken to the challenge was in response to the “size of a cat” rule of the challenge that was previously overseen. The team still contends that “house cat” was not specified and a “mountain lion” is still a cat, but we appeared to be alone in this thought and had to resize the robot. The wheels from the previous design remained in place but the chassis needed to be replaced by a design that would keep the ground coverage under 30 in x 30 in. This was accomplished relatively quickly with parts from a Vex kit owned by the CSURC since weight was then less of an issue with the smaller size. The design went from the render previously shown to the final product.



*Final design chassis and wheels – Picture by Dan Sullivan

With the final design of the chassis and completed, the remaining hardware, sensors, beacon, and algorithm needed to be implemented. The power was still applied by the same two Vex 7.2 volt batteries. The design initially required two Arduino Uno microcontroller boards. One Arduino was to be dedicated for the beacon to actively listen at all times for a signal as recommended by the challenge and Brian Sanders. This Arudino/beacon combo remained in tact through the remainder of the project.

The second Arduino Uno was meant to control the sensors and motors. As testing was being conducted the motor controllers used were continually burning out. As a result of burning out the original motor controllers were replaced by a Seeedstudio Arduino motor shield. Due to short time and technical errors a third Arduino Uno was implemented to control the motor controllers individually.

The motors initially used were 4 Fingertech 600:1 motors. It is believed the size of the wheels on relatively small motors burned out and broke several gear boxes due to the torque required. As a result of this error and lack of time to order new motors, Isaak Malers went home and stole the motors from his little sister's Power Wheel. As a matter of morality the team was repulsed by such callousness but then a general consensus was reached that his little sister needed to learn the world is a hard place. Afterwards it was generally regarded as a good idea. The problem resulting from such motors, though, was that to use them at full power drained the batteries in 3 minutes or less. The power was then regulated through the code and the motor shields to prevent such accelerated battery depletion, however in doing so climbing power of the robot was minimized.

The sensors used were three ultrasonic sensors in a forward pointing array on the robot, two IR sensors placed in front of the wheels pointing downward, a compass sensor, a 433 MHz beacon transceiver, and an accelerometer. The intent of the sensors was to implement a simple avoidance algorithm. The algorithm consisted of the following steps:

- Check accelerometer sensor data, ensure robot is not about to tip – if so, go to avoidance
- Check IR sensor data, ensure robot is not about to roll into pit – if so, go to avoidance
- Pull beacon direction
- Check forward ultrasonic
    - If clear move forward toward beacon
    - If obstructed check left and right beacon – move toward furthest away obstacle – reorient to beacon
- Repeat steps

If avoidance was triggered:

- Back up from position
- Conduct above steps deliberately ignoring beacon and choosing a different move based on ultrasonic data
- reorient to beacon when complete
- continue on with regular algorithm until avoidance again triggered.

Challenge Results and Lessons Learned

The CSURC results of the challenge were lackluster due to transportation problems. While in transit the wheels of the robot became unstable at the point of attachment to the motor. As a result, the robot at the challenge was literally ran until the wheels fell off. Also in transit and storage one of the Arduinos became damaged.

A minor victory coming from the challenge was the lightweight size design. Though almost every problem imaginable occurred during transportation, when the robot was up and running the chicken wire wheels size eclipsed almost every obstacle on the course. Also the design of the wheels being constructed from such flexible materials absorbed the shock of the terrain and kept the chassis relatively stable throughout any run it made.

The major victory and reward for the CSURC team came in the form of lessons learned. Though this sounds like trying to put a positive spin on an otherwise bad showing, it was in fact an invaluable experience for just the reason of learning. The CSURC is a club in its infancy or rebirth depending on how one chooses to define the club. This year's team was completely comprised of first time robot club members. Due to the club's location in the CSU Computer Science building, the club is almost entirely comprised of computer science students. While this is great for software development, it left much to be desired on the hardware and chassis design. One lesson learned was a major effort to recruit engineering students needs to be conducted.

Another lesson learned and probably the biggest lesson was that simplicity is key. Seeing some of the other more successful designs at the challenge, simplicity appeared to outperform *cool* and *sexy* designs in most cases. As mentioned in the *Evolution of Design* section, the very first design the CSURC team came up with in retrospect would have most likely been more effective as it's simplicity would have allowed more time for testing and refinement. Also the algorithm required for the first design was less complex and would have left less chance for software errors.

Time management and deadline management were also a major issue and lesson learned. In large part this management commonly fell apart due to trying to implement a more complex design and algorithm. With that said, leadership during this challenge was the largest error on this issue. The team leader (Dan Sullivan) in part was trying to avoid micro-managing. He sees that as a trait that repulses persons in the workplace and would do even worse in a voluntary club where people can walk away at any time. The major lesson that deadlines, when set firm, need to be held regardless of any issues that come up. If a deadline is missed other team members need to be reassigned to bring that portion up to speed, or otherwise some action needs to be taken. Though as previously mentioned a lack of engineers and a more advanced design greatly added to these missed deadlines, the management of such errors only added to the poor performance at the challenge.

The last notable lesson learned came in the form of team size and personnel management. By virtue of the CSURC being in it's infancy and a small club size, attempts to recruit after the NASA challenge team was already working meant that additional members were added throughout the project. This was in an attempt to keep new members to the club active in projects when the bigger club ran out of projects for new persons. As a result 3 new members were added as late as mid-February of 2014. While each person had strong skill sets that added to the dynamic of the team, eventually there came a time when there were too many people trying to do too many things at once. With too much going on at any given time, communications between team members occasionally broke down, especially when members came into the project halfway and were not knowledgeable of previous work. Additionally having many opinions can be a good thing, but too many can become cumbersome. An example of this is when trying to decide on how to implement an ultrasonic array. Eight different people throwing out eight different ideas made a consensus nearly impossible to come to. Everyone had good ideas, but no idea was ever endorsed by the majority so the project and progress suffered in that time.

Other lessons were learned such as materials and programming knowledge as would be expected with any robotics project, but none that were particularly noteworthy to bring forward. As a bi-product of some of the ideas pursued in this challenge some club designs are going to be implemented using the laser grid and camera combo that were developed through the earlier and mid stages of this project.

Conclusion

The CSU Robotics Club participation in the 2014 NASA challenge at the Great Sand Dunes National Park was an extremely valuable experience. Though the final showing left much to be desired, the lessons learned along the way have been collected within the club and will be used to improve in next years challenge. With only two of the team's eight members graduating this year, a much more experienced team will move into next year's challenge with some engineers and bring forward a stronger showing for CSU. This challenge has already been successful in attracting more attention for the CSU Robotics Club and recruiting will add more vigor and hopefully competition to next year's challenge.