C.A.T.
Crawling Autonomous Terrabot

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Abstract

In viewing the tasks of the Robotics Challenge, we determined that our robot’s primary objective would be to successfully roam through the formidable terrain while functioning autonomously. After analyzing previous designs and results from prior Robotics Challenges, we decided to start from scratch, while also taking some of the sound ideas from before and making them our own and specific to our design. We knew this would be a rigorous project considering that our team consists fully of students that are inexperienced to such tasks. In creating a new design, the first obstacle we had to overcome was creating a drive mechanism that would be able to efficiently traverse through soft sand. We decided to use a tank-like tread design for the propulsion as opposed to some sort of wheel.

Having obstacles of various sizes throughout the designated courses we also wanted our autonomous robot to not only avoid the larger objects but also climb over the smaller ones. To achieve this goal, we designed the shape of the treads to be angled up in the front so we could gradually begin to climb while keeping most of the robot’s weight on the ground to sustain traction and balance. To accommodate the larger objects, we created a bump sensor design. The design we are using this year came from the basic idea of the whiskers used on previous robots. However in previous designs, all of the copper contacts were exposed, rubber bands were used to provide tension and solder joints were weak.

We considered this to be a flimsy setup. In our robot, we reduced the amount of exposure by using small microswitches that we crafted into a bumper-like design that would protrude off the front of our robot simulating the sleek look and sturdy design of a car bumper.

Overall, after the successes previous teams have had, we hope that our team and new design can raise the bar at the Robotics Challenge this Spring and perform better than we ever have at Trinidad State Junior College.

Introduction

In designing C.A.T., many obstacles stood in the way of a successful product. The first problem was the incorporation of using a tank-like tread system. An operational propulsion system is very important for success in the Robotics Challenge. An effective design would give us the ability to traverse through sand and climb small objects with great dexterity.

While using a tread design we ran into unexpected problems. Not only was it hard to keep sand out of the treads and support the large tread frames, we discovered that going from wheels to treads required a lot of variation in our programming in order to achieve success. Changing various routines of the program gave C.A.T. the edge we were looking for.
At the start, we were unsure of which programming language to use for the final product. With the extra weight needed to support the frames, it swayed our decision towards using the Propeller C language, which is just being developed by Parallax Inc. We had a short period of time to learn Propeller C, but by using this language it gave us the opportunity to reduce weight by using only a single board for the whole program.

Another challenge in the design process was to create a sensor system for our robot. We decided to use a whisker-based design knowing that there is too much interference at the dunes to use more complex sensors. The goal of our design was to avoid exposing wires while maintaining a sturdy design.

After balancing our options, we found that using microswitches would be our most effective choice. The microswitches have the important connections on the inside ensuring that the copper will go undisturbed by outside forces-keeping the sensors functional and safe. To stabilize these switches we attached them to a sturdy platform that hangs off the front of our robot, similar to the way a car bumper is designed.

**Design Process**

Our first objective in designing C.A.T. was to ensure that tank-like treads could successfully maneuver our robot through the rugged conditions of the courses at the Great Sand Dunes.

When designing our treads, the biggest problem we saw was that we would have little traction and there would be a high risk of getting sand into our gears and axle setup. Taking this into account, we designed a tread that consisted of small links. Putting space in between the links would reduce the area for sand to accumulate. Being able to adjust the number of links in the chain gave us the ability to easily manipulate the shape and size of the desired treads. Also, instead of the treads laying flush to the ground, we attached small rubber fins to the links providing grip and enabling these treads to dig into the soft sand giving us optimum traction.

In our first attempt to create a prototype, we stripped down an RC truck and attached our initial four tread setup to the body of the vehicle.

![Figure 1. Start of the first prototype](image1)

The four tread setup was problematic on this body; we quickly found that using a single tread on each side would make it simpler to construct and manipulate.

![Figure 2. Completed version of first prototype with modified treads](image2)

After the double treads were replaced with the modified singles, we successfully traversed forward and backward in our sand pit and were able to confirm that only one tread on each side would be used. We found the rubber inserts allowed the treads to slightly dig into the sand for power while also having enough grip to embrace small objects for an easy climb. Due to
the lack of compatibility between the RC truck and the treads we created, this prototype gave us no further suggestions of how to improve our tread design.

Once we extracted all the information we could from the first prototype, it was back to the drawing board. The biggest issue with the first prototype was that it was too small to get accurate readings of how the system would work. We also wanted to see the treads in action while performing tasks similar to ones necessary at the Robotics Challenge, as opposed to the sporadic motions an RC truck makes. Thus, we decided to upscale and use Trinidad State Junior College’s old robot CASPER for the foundation of our second prototype.

![Figure 3. CASPER’s body with aluminum frames attached and the wheels replaced with gears to form treads for the second prototype](image)

To begin our second prototype, we disassembled the wheel setup on CASPER and built two simple aluminum frames to be mounted on each side. The frames were mediocre and needed work, but were stable enough to withstand many test trials. For the first few trial runs we used power switches hooked up straight to the motors. In these trials we saw that the treads were successful in driving CASPER in basic directions. It also showed C.A.T.’s capability of effortlessly climbing small objects.

After the initial trials, we went a step further and connected the motors back into the brains of CASPER enabling us to run simple programs. While running a program to avoid obstacles we discovered a major problem. Every time C.A.T. was backing away from an object, vast amounts of sand would build up in the treads. When too much sand accumulated it caused the treads to pop off of the tracks; this happened multiple times. We saw this to be a minor flaw and figured that a sturdier frame alone or more tension in the tread would account for the problem. We later found this not to be the case.

It was after the late trials of the second prototype that we had acquired enough information to begin the official construction of C.A.T.. To begin the process we had to determine the desired chassis size. We wanted to minimize space for the layout of the board, battery, fuse and switch board, and compass while maintaining a large enough structure to support the treads and motors. Once the optimal size was decided, scaled and dimensioned drawings of the body and parts were drafted.

![Figure 4. Completed scaled and dimensioned birds’ eye view draft](image)

With the model drawings finished it was time to begin the physical construction process. To start we had to build a body. The chassis of C.A.T. was designed to have a hollow trapezoidal prism shape. The body had to be light weight and sturdy so we chose to use polycarbonate for the structure. The polycarbonate worked great because it was easy to work with and it’s transparency allows vision to all parts of the robot, making it easy to troubleshoot possible problems. On the inside of the chassis we attached
two bulkheads across the full body length. The bulkheads are where we have our motors mounted and our chain drive mechanism set up. To protect these parts from sand and other obstructions we designed the bottom of the chassis to have a removable plate. This way we could seal it off but still have the capability to make adjustments if necessary.

On each side of the chassis we attached two long brackets where the CAD designed tread frames could be mounted. We chose to build this setup to have the potential of changing our design in the case that our treads were not successful. The frames of the treads are angled upward in the front facilitating climbing capabilities. To keep the treads tight on the tracks we put a tensioner in the assembly.

With having everything intact we began to construct the bump sensors design. We first constructed and attached a base plate to mount the bumpers on.

![Figure 6. Microswitches mounted into bumper design](image)

We designed the plate to be capable of sliding up and down. Once the desired height was determined we made the attachment permanent. In testing we found that the ninety degree angle formed between the base plate and body was problematic. If we were to come across an obstacle that was low enough to go under the bumpers it had the chance to get stuck on the body. To fix this we simply attached a small rectangular plate that went from the bottom of the body to base plate of the bumpers. This correction to the design allowed those in-between size obstacles to slide completely under the chassis of C.A.T..

After establishing the treads and bumpers worked we assembled the rest of the pieces onto C.A.T. and prepared to run our first program. The first time running a program was a failure. With the new beta language in use, the prop plug had a design flaw in it that required us to pull the prop plug out along with the cord which corrected our first failure. This meant however, that we could not go through with our initial plan of putting the circuit board and chip on the inside of the robot because we needed full access to the board. In retrospect, making a sliding top instead of a sliding bottom plate would have allowed us to put
the electronics inside and still give us access to the motors. In the second attempt of running the program we had moderate success.

As testing continued we still were running into the same problems. Almost every time we would hit our bumper and take a quick back up turn, our tread would pop off. We had already made all the possible physical adjustments for the design. It seemed nothing was going to help until we took a deeper look into the programming. We knew that the program was functional, but for some reason, did not work well for C.A.T.

Finally, we discovered this program worked successfully for wheels but that the tread design required variations in speeds and types of maneuvers. In our bumper part of the program we replaced our sharp quick turns with a sequence of smaller turns. This prevented the excess build-up of sand in the treads. After running our modified program one last time our problem was solved.

The Propeller C language that we were beta testing created problems for us in our final program. The code for SPI communication had not been written yet which forced us into using solely a compass. This being the case was not a major problem, but would require the compass to be adjusted on every course we would attempt to conquer. We later found this to be a more severe problem. With the compass program not yet perfected by Parallax; it did not take the z-axis into account and would seriously skew our compass readings if we were at any slight tilt. To resolve this problem we modified our tilt program to not only react to a high tilt but, to also shut off our compass program while encountering a minor tilt.

The incomplete language created more problems beyond the communications. We had no motor control; our motors could be on or off, stripping us of the ability to vary speeds. This created an obstacle by limiting us to only one speed, and even more, we had to incorporate a voltage regulator in the design. We needed a battery strong enough to last through multiple courses but our motors could not withstand such high power at once. We used our twelve volt battery and with a DC power supply unit found that nine volts was the most effective amount of voltage to power C.A.T. So we used the regulator to reduce the voltage down to that level.

**Final Product**

It was a long and hard fought battle to get C.A.T. working at a satisfactory level. After many adjustments and compromises, the design was complete. While using only the bumpers and compass sensors, C.A.T. reacts extremely well in most environments. Sensory input is very important for the Challenge; our sensor designs are safe from any obstruction and interference at the Great Sand Dunes, ensuring that we will be able to perform substantially well.

On the last day our team met before the Challenge we worked out the rest of the kinks in the program and saddled C.A.T. up for one last test run. We ran our program for no more than a minute; enough time to see that all was working correctly.

![Figure 7. C.A.T.](image)

**Conclusion**

Although a tough journey, all the hard work paid off. C.A.T. performed very well at the Dunes and conquered almost every one of six
courses set up. We had only one issue the whole day which we have not completely figured out yet. For some reason we were losing juice and did not have enough power to propel C.A.T. after a long run and through repeated turns. We skipped one of the courses because it did not pose a threat and completed four others with ease. On the last run of the day we attempted the course that was set to be near impossible. C.A.T. died before it had an honest chance to complete the rigorous obstacles that were set up.

Overall, we were very pleased with the results in our performance at the Robotics Challenge. We had done more than was expected of our inexperienced team and surpassed our own goals of raising the bar at Trinidad State Junior College. Although our final performance was very rewarding, the lessons we have learned along the way are invaluable.