Clear Autonomous Sensory Perceiving -Environment Robot
(CASPER)

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March 23, 2011

Abstract

When evaluating the missions of the Mars Rover, we see that some of the main obstacles are autonomous decision-making, rocks, and arduous terrain. In an attempt to build an autonomous robot that can decipher direction West, and then move in that direction while simultaneously avoiding obstacles by continuous decision making; we will take an in-depth look on what types of wheels can hold up and traverse through the terrain of sand. We hope to design wheels that can propel through sand with ease. The softness of the terrain allows for most objects to sink into the ground when they are trying to move through it. Therefore, we want to create wheels that can keep sand out of the axles, gears, and motors while still being able to move above the surface. Our basic idea is to combine the likes of an old steamboat propeller with land-vehicle wheels to hopefully meet the requirements to overcome any terrain, especially sand-filled environments. We also want to develop wheels that can climb over different sizes and types of obstacles. A successful design will be able to avoid or drive over all obstacles.

1. Introduction

The design included three approaches. The first was to interpret and manipulate the design developed by Georgia tech and their "Sand Bot." Figure IM-1shows the unique design of the legs used by Georgia Tech students.
The Sand Bot design worked very well against many different types of terrain. The curved legs were able to push through sand with ease while simultaneously forcing the robot to stay above the sand. The design also was capable of going up and down flights of stairs with ease. The idea to follow their design was the first step for us in our research for wheels that can traverse over harsh terrain.

The second approach used the design of a steamboat propeller. The fact that these propellers could push a massive boat through water and waves made us believe that it might have the potential to do the same against other terrains such as sand, dirt, or even mud. For a visual, we wanted to incorporate the propeller shown below in Figure IM-2.

Figure IM-1: SandBot (Li, Umbanhowar, Komsuoglu, Goldman, J.Exp. Mechanics, 2010)

Figure IM-2: Steamboat Propeller (Photos.com-Getty Images C:2011)

The third concept we based our wheel design on was that of a children's toy known as a "HexBug." As shown in Figure IM-3, the shape and ability of the miniature robot was incredibly versatile. With speed and agility guiding this trendy toy, we found it to be very valuable to our initial design. Also, the whiskers on the front and back were encouragement to add to our design in our efforts to maneuver around rocks. The fan-like wheels helped us, not only derive a set of our own, but also helped with incorporating our earlier idea of the steamboat propeller. Of course, the main flaw in the design of the Hexbug was having the sprockets on the outside of its assembly. The sprocket became jammed when tested in sand. However, this design flaw provided insight for us to encase our robot's motors and sprockets.

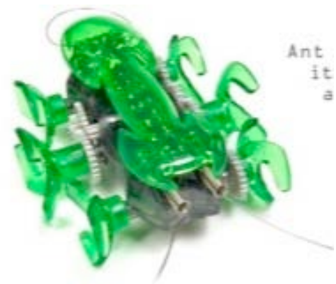


Figure IM-3: Hex-Bug (Innovation First Labs, Inc. ©Copyright 2010)

2. Prototype #1

The first step to building our design was to create a 3D Model. This would provide a prototype to access when deciding what to add or remove. With this initial design, shown in Figures IM-4 and IM-5, we used our basic concepts to create a model that incorporated all three approaches. The wheels were crafted to recreate the wheels of the HexBug, while that of the steamboat propellers replaced the fan-like design. The big loop in the center was an attempt to recreate the legs of the Sand Bot on a larger scale for use when the bot might be stuck on an object or flipped on its back. The loop wheels were designed to be driven by separate motors for emergency situations only. Our first prototype was a practical continuance of our brainstorming day, so most of our ideas transformed dramatically in the following week. We decided that the distance between the flaps on the wheels was too great, and would cause problems when trying to climb over objects such as rocks and plants. Also, the axle required to support the loop wheels would need to be 6 inches from the platform to ensure the functionality of the loop wheel. The problem with having an axle protruding 6 inches is that the whiskers would have to extend the same width off the front. Extending the whiskers would be an unneeded accessory for our robot when we could remove the loops and minimize the whisker size considerably. Since simplicity is always the best way to accomplish some tasks, we chose not to wrestle with 3 more inches of whisker wire hanging off both sides of the front of the robot; also eliminating the need for motors and another motor board to work them. After discussing the advantages and disadvantages of the loops, we removed them from the robot because the inconvenience outweighed the benefits.

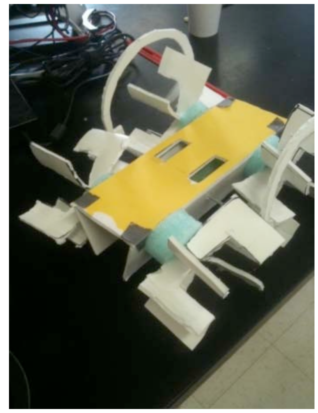


Figure IM-4: 3D Model Top View

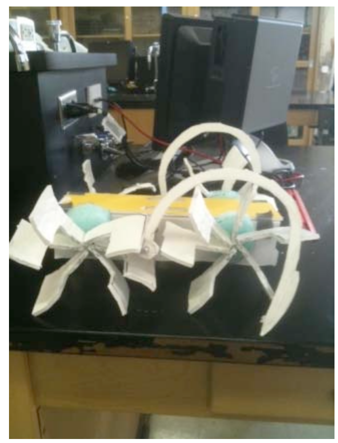


Figure IM-5: 3D Model Side View

3. Prototype #2

The second attempt to create wheels that could withstand harsh environments was much more of a success than the previous attempt because they were constructed of wood instead of foam, and were attached to a Rock Crawler R/C car (Figure I-M 6). The design of the wheels changed dramatically in a couple ways. The first way was the removal of the steamboat propeller idea because the gaps in the flaps allowed too much opportunity for objects to get tangled up inside them. The sizes of the wheels were enlarged from 5 inches in diameter to 7 inches to allow a higher axle joint for higher clearance when attached to a chassis. Also, we added the curve feature, used by the Sand Bot, to the wheels every 60 degrees to get the maximum amount of downward force from each rotation. The curve features on the wheels were named tentacles because of the resemblance to octopus tentacles. The use of the curve allowed the R/C car to keep itself from digging into sand or other surfaces that allow objects to sink in. These wheels also had the advantage of being able to tread through flaky surfaces because the curvature of the wheel tentacles did not grasp the flakes and instead threw off the flakes by the end of the rotation if any did come up on the wheel. A great example of the tentacles throwing sand away is when we tested this design and the only residue of sand found after the test was on the platform rather than stuck to the tentacles of the wheels. Since most of our tests were on very fine sand, we wanted to avoid capturing so much sand that the robot would be slowed or weighed down by it. A design flaw of these wheels was discovered when tested against various obstacles. The first test was over a human hand, which showed that the wheels could go over objects low and flat to the ground. When tested against rocks sticking out of the ground, the wheels tended to slide off the sides and never gave clear evidence that the R/C car could climb over them. One problem we saw after testing different objects in a classroom was that the sturdiness of the tentacles was questionable. We tried to have R/C car pass over a table leg, which is merely 3 inches off the ground. A tentacle broke off the wheel. The slimness of the table's leg slipped into the gap of the tentacles and forced it to snap loose. After reattaching the broken tentacle, the R/C car was then tested once more in the sand; this time in reverse. The results of this experiment forced the team back to the drawing board. When in reverse, the wheels slowed and dug into the sand 2 .5 in 5 seconds then stopped. This might not have been a problem but when avoiding obstacles in the field being able to reverse is required. The results of this test may have been disheartening, but gave valuable data and understanding of this new style of wheel.

Figure I-M 6: Second wheel design attached to R/C car.

4. Final Production

For our final product we wanted to take all the weaknesses of our previous attempts and turn them into strengths for CASPER, our robot. The first weakness we addressed was the weight of the wheels themselves. Lighter wheels would allow the motors to put more power into getting over obstacles rather than turning the wheels. We solved this problem by designing wheels constructed of DELRIN plastic. This material is significantly lighter than wood and is almost indestructible under normal circumstances. Another problem we addressed was the inability to make it over a skinny obstacle such as a table leg. In order to do this, the curves were closed off as shown in Figure IM-7.

Figure IM-7: Wheel with closed-off curves.

By closing off the tentacles, we lowered the chances of catching things in between each leg on the wheel. By adding walls in between each curve, there was added support and flexibility. The walls also gave the wheel a "bounciness" to it that helped it pass over large obstacles because it acted as a spring similar to shocks found in a car. This bounciness helped in several ways; for sand, the wheels would actually propel forward through it while continuously bounding upwards, which kept CASPER from digging in. Bounciness was not the only reason we did not sink into the sand. The main reason was in the design change. We added 1.5 inches to the width of the wheel. This allowed for a greater surface area on the sand, which helped distribute the weight of the robot over a greater distance, which in turn kept us from digging in at a fast rate. By widening the width of the wheel, larger obstacles were easier to drive over because CASPER would not slide off the sides. Since the wheels would not slide off of the obstacles, the motors could finally work to push over and past it. The curve feature on our wheels allowed our robot to tread through the sand. The wheels throw sand away from the body while simultaneously moving through it.

Another tactical advantage of the wheels was the 7-inch diameter. The large diameter of the wheels allowed our chassis to sit 3 inches off the ground. This was an advantage because it added a large clearance for the undercarriage. The more clearance underneath CASPER meant less worry about small obstacles in front of the robot. Another problem we wanted to address was the number of motors and motor boards for the wheels. We attached the left wheels with chain and sprockets to one motor to run both wheels as we did for the right side.

Using two motors instead of four—one for each wheel—lowered the overall weight of CASPER by 0.5 kg. This created another advantage because lowering the weight would make the motors put more work into using the design of the wheels to move through terrain rather than withholding power to turn the wheels of a heavy robot. We also found that the faster the wheels rotated determined the capability to maneuver through or around large obstacles. Since faster rotation of the wheels determined CASPER's capabilities, lowering the overall weight gave us the upper hand on fast mobility.

5. Conclusion

The wheel design turned out to be a great success against different types of terrain. However, some obstacles were too large to drive over and some got underneath the chassis and made it high-center. The realization that the wheels were not the only determining factor of being able to maneuver through rough terrain was the beginning of our research to build CASPER. The robot was built with plexi-glass to ensure a light and durable frame. The fact that CASPER was free-running during its test stages gave incentive to add a navigation system. We added a compass and a beacon transceiver to be able to go in the direction we chose. With the integrated compass, CASPER determines west and travels in this direction. With a switch on our platform, we can change over to a beacon receiver program and that will provide the direction CASPER will follow once it receives a beacon signal. The versatility of having two interchangeable programs helps with traversing to and from different locations with simplicity. To add to CASPER's ability, two front whiskers were attached to warn the robot when obstacles could not be run over were in the way. Since the chassis and the wheels' clearances were different by 2 inches, the whiskers are divided for both chassis and wheel height clearance as shown in Figure IM-8 and IM-9.

We also found evidence that our robot can back up into objects and get stuck that way. To prevent such things from happening again, we added a back whisker to send a message to the main board telling it that there are objects behind it that can be harmful. In some cases, CASPER would not have any objects in the way but would have to drive up and down steep hills. At 65 degrees, CASPER was unable to continue moving in sand. Adding a tilt sensor to the compass board solved this problem. The tilt sensor continuously checks the angle at which CASPER sits and then emits a signal to the main board when it has reached its maximum of 65 degrees. At this point, the robot would back down the hill and turn to find a different route around the mound. After all of our test runs and upgrades to the wheel design and CASPER itself, the final challenge was completed. CASPER is now able to travel in any given direction, follow a beacon signal, traverse through and over harsh terrains, and avoid obstacles that originally would obstruct CASPER'S mission.

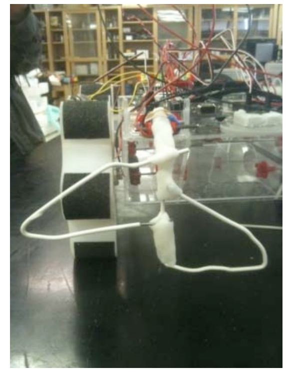


Figure IM-8: CASPER whisker

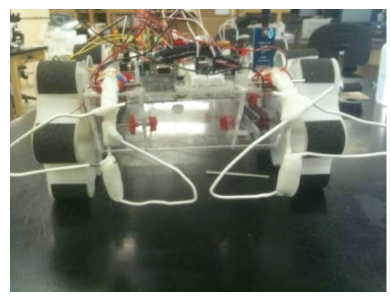


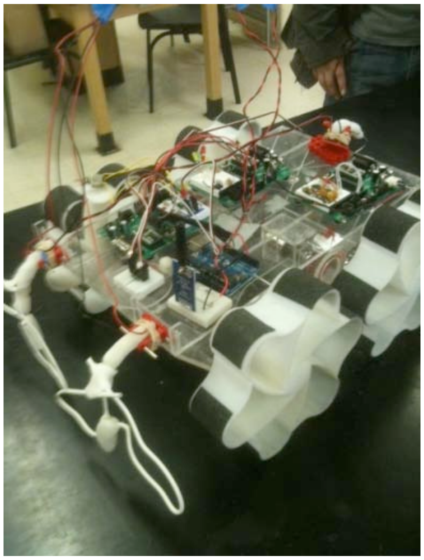
Figure IM-9: Both whiskers

8. References

[1] Anonymous. "92245097", http://www.photos.com/search/royaltyfree/92245097.Getty Images Photos.com, 2011.

[2] C. Li · P.B. Umbanhowar · H. Komsuoglu · D.I. Goldman "The Effect of Limb Kinematics on the Speed of a Legged Robot on Granular Media", Experimental Mechanics, DOI 10.1007/s11340-010-9347-1, 15 March 2010.

[3] HEXBUG® is a registered trademark of Innovation First Labs, Inc. http://www.hexbug.com/ant. ©Copyright 2010.



CASPER

Special thanks to Pueblo Community College for collaboration with Trinidad State Junior College and construction of CASPER wheel design.