TriBoingus: Towards a Robust Mobile Robot Platform

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Abstract

This paper presents the triBoingus, a three wheeled mobile robot built to encourage robotics exploration. Built over the course of one semester, the first version of the triBoingus explores problems with three wheeled constrained motion control and planning. The construction of the triBoingus is described, and a design and three possible applications for the next-generation triBoingus, v2, are discussed.

Keywords

Mobile robotics, three wheel drive, holonomic motion, sensors, robot suspension, hopping robots.

Figure 1: An early design idea

Introduction

Mobile robots have been built in a variety of configurations, from balancing robots with one wheel to eight-legged monstrosities. Many academic and prototype robots are built on pre-manufactured mobile bases, and the vast majority of these are either four-wheeled car-like devices, or three-wheeled tricycles. While these robot bases meet the needs of many applications, they are directional, which constrains their range of motion. Additionally, they tend to be very delicate, often becoming completely disabled by small malfunctions.

Another major obstacle in robotics development is the difference between laboratory settings and real environments. Often, robots that appear to function well in a controlled setting fail miserably when brought outdoors, or even onto a carpeted surface. This effect tends to block robotics developers from actually solving real problems, as the leap from laboratory "proof-of-concept" to robust product is a great one.

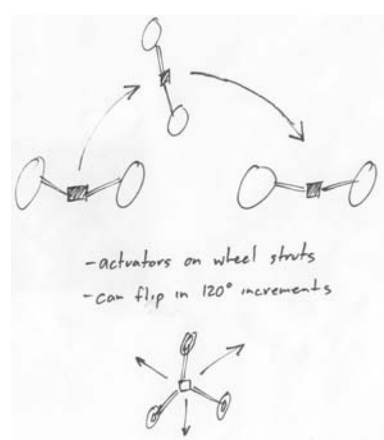

Figure 2: The "boingus"

The triBoingus attempts to address both the robustness and directionality problems inherent in many mobile robots. By using durable off-road tires, suspension and overbuilt construction, the triBoingus can survive outdoor use. With an omnidirectional three wheeled design, the triBoingus can achieve full holonomic motion and avoid the velocity singularities which plague tricycles and robots with Ackerman steering. An additional benefit realized in pursuit of the first two design goals is redundancy. As built, the triBoingus can continue moving if a wheel or drive motor is damaged, and in fact, can pull itself along even after losing two of its three wheels. Unlike "car" or "trike" robots, which can't suffer any major damage, the redundant design of the triBoingus may be suitable for remote exploration in hazardous environments.

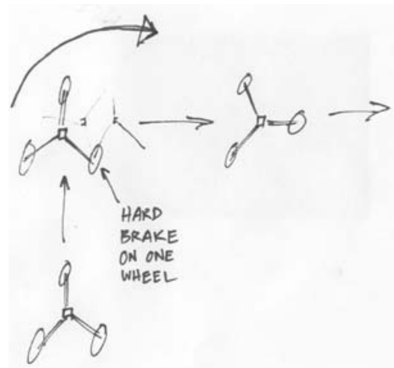

Figure 3: A level 2 action

Construction of the triBoingus also explored the idea of "thinking with built objects". With a Fused Deposition Modeling (FDM) device available, several of the triBoingus' components were repeatedly prototyped and changed, encouraging rapid development and testing of different features and configurations.

Design Details

The design of triBoingus v2 is in process, so as we describe the technical development of triBoingus v1 in detail, we will attempt to suggest the improvements that are being addressed with v2. triBoingus v2 will be smaller, approximately 20cm in diameter, and will forego active suspension, relying on the suspension properties of the oversized tires. An important design goal for v2 is the ability to operate when flipped over, so the body will feature a much lower profile.

Structure: The body and structural supports of the triBoingus were built out of both ABS plastic and aluminum angle. ABS was chosen for several key joints and connectors because of it's high strength-to-weight ratio and for the ease in which it was designed and printed on the FDM printer in our lab. Through further analysis, the volume of ABS used could be reduced, but it proved to be valuable as a material for custom parts which wouldn't have been feasible to make with other materials. The aluminum angle was chosen for it's low cost and high linear rigidity, and was easily connected to the ABS parts by installation into tight tolerance friction fit slots. Stainless steel allen-head set screws were used to secure aluminum-ABS joints.

Drivetrain: The triBoingus uses six motors, both a dedicated drive and steering motor for each of its three wheels. Standard analog hobby servos were chosen as the steering motors for their low cost and integrated feedback, while small geared DC motors were used to drive the robot. Both motor types worked reasonably well, although v2 may use servo motors exclusively due to their greater torque and reliability.

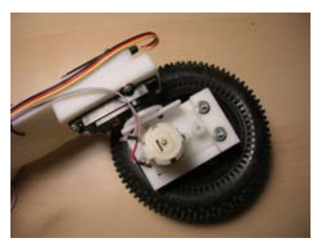

Figure 4: Drive/steering motors

A small physical modification to a servo motor enables continuous rotation, so they could serve both drive and steering purposes well. triBoingus v2 may take advantage of digital servo motors which, although more expensive, offer greater power in a smaller form factor.

Suspension: Oil-filled shock absorbers were used to provide active suspension for the triBoingus. Originally intended for use in radio controlled trucks, the shock absorbers were chosen for their adjustability and pleasing appearance. While flaws in the structural design of v1 preclude extensive outdoor testing, the suspension design was certainly capable. v2, with a smaller overall size, will not need active suspension, taking advantage of the substantial damping inherent in the tire design to cushion its delicate electronics.

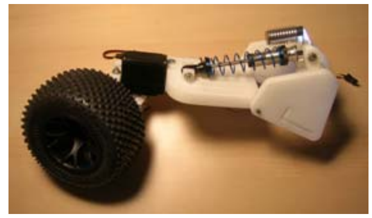

Figure 5: Suspension arm

Controller: The triBoingus is controlled by a Handyboard fitted with an expansion board to power its servo motors. The Handyboard was chosen because it was available, and proved to be adequate for the simple controls necessary to drive v1 using keyboard control. v2 will feature a large upgrade in controller capability with the move to a Gumstix Connex 200, a tiny computer running the Linux operating system. Instead of being constrained to programming in C, this substitution will allow the triBoingus to be programmed in an interpreted language like Python, and will support a larger choice of sensors. Wi-fi support using the Gumstix CFStix expansion board will allow the triBoingus to operate without a tether, greatly increasing its capabilities. For v2, the Player/Stage robotics server will be used to communicate with host computers and other robots.

Sensors: While triBoingus v1 has no sensors and is solely tele-operated, the improved electronics in v2 will encourage the fitment of several different sensor types for environmental interaction. A CMUcam2+ will be installed to offer object tracking and vision capabilities. Sonar and IR sensors will be installed to detect distance to obstacles, and application specific sensors like those for light, heat, sound, metal detection and radiation could be installed easily.

Applications

The triBoingus v2 should be able to serve a variety of purposes in academia, industry, and government applications.

One possible broad application is that of a mobile robot base for experimentation. Often, students and inventors are forced to start from scratch when working on a robotics project, spending time building drivetrains and bases which have been built previously. The triBoingus could be used as a pre-built base, allowing experimenters to mount various sensors and run control programs without "reinventing the wheel."

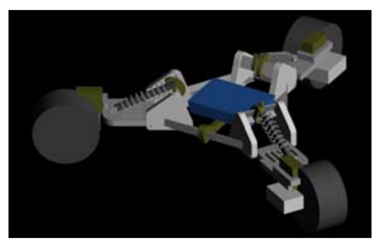

Figure 6: An early rendering

The United Nations estimates the number of current unexploded land mines to be in the "several million" range [United Nations 2005]. The knowledge that accidents happening every day in Southeast Asia and Eastern Europe could be prevented is a powerful drive to develop better robots for humanitarian landmine detection and removal. Current efforts are effective only on very small areas, happen slowly, and require an enormous amount of money and effort. It is our vision that large fleets of inexpensive mobile robots based on the triBoingus platform could be deployed in remote areas, communicating with each other and using coverage algorithms to detect land mines which would have otherwise remained buried. We are currently exploring the possibility of integrating the triBoingus with existing land mine detection technology and coverage software.

A similar, but substantially less critical problem is the abundance of trash left in natural areas. In the Sonoran desert, for instance, litter abounds, and the cost and effectiveness of hiring human laborers to collect it is prohibitive. One scenario might feature a truckload of hundred of triBoinguses (triBoingi?) delivered to a remote site which then fan out and collect trash, operating as a large distributed system. They would operated autonomously, using map-coverage algorithms, and communicating with each other to optimize path planning. They would return to the base truck individually to dump their loads and restart where they left off. Ideally, this could be monitored by one human operator who performs maintenance and monitors the fleet.

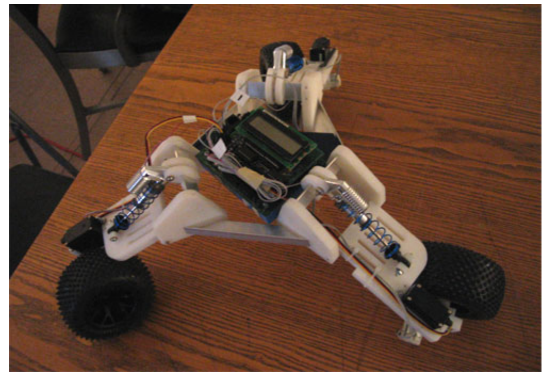

Figure 7: triBoingus v1

Related Work

There are probably more three wheeled robots than any other configuration, but they tend to be built as tricycles, with only one or two drive wheels and a passive caster. Although the field of three wheel drive robots is small, the triBoingus has features in common with several current projects.

At Carnegie Mellon, the PPRK [Reshko 2002] is a simple omnidirectional robot which has been packaged into a retail kit for hobbyists. The PPRK is controlled by a Palm Pilot, and uses only three motors and omniwheels for locomotion. Omniwheels, like the bi-directional rollers found on airline loading devices, allow the robot to turn by varying power to the drive motors, while keeping the wheels in a fixed configuration. The crevices inherent in the omniwheel design make the PPRK suitable only for indoor use, and its lack of resistance to lateral forces make it unable to travel on any surface other than flat ground.

The “Scooter” Cobot project at Northwestern University [Moore 1999] is a passive mobile base, designed to provide support and guiding for a human operator. It features a three wheeled design and some interesting control methods, but only one degree of freedom and indoor-specific components.

The ROLLMOBS drive concept from the Université Catholique de Louvain [Ferriere 2001] explores a creative solution to the problem of three wheel drive by turning spherical drive wheels with fixed omniwheels. Although several engineering challenges still exist, this drive system may evolve into a viable solution for a robot like the triBoingus, which seeks to retain mobility even when flipped on its back.

Also at Carnegie Mellon, Brown and Zeglin’s Bow Leg Hopping Robot [Brown 1998] uses a fiberglass leaf spring to increase jumping performance. Although it is a tethered monopod, the hopping mechanisms and control strategies will be useful for a fully actuated version of the triBoingus.

Conclusion

The triBoingus, for all of its shortcomings, allows us to effectively experiment with three-wheeled robot control and manipulation. While version one is limited to careful use and software experimentation, v2 may prove to be a capable mobile robot for deployment. It has been shown that an omnidirectional three wheel drive robot is feasible and controllable, and that FDM devices offer many benefits to the design of mobile robots.

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