The Design of an Omnidirectional All-Terrain Rover Chassis

Abstract Submission

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Scope

The objective of this project was to develop a proof -of -concept prototype to demonstrate a new omnidirectional drive system for a small outdoor rover. The unique mechanical chassis design provides holonomic motion on a wide range of terrains, materials and situations.

Background and Context

Small, unmanned ground vehicles are being researched and used for an increasing number and breadth of applications ranging from robotic soccer to rovers that can accompany and aid soldiers on the battlefield. While significant progress has been made in the development of sensor and control technology, one of the major challenges is that of mobility—that is, physically traversing obstacles, soft and rocky soil, and other hazards in complex, unstructured and high-risk environments. This particularly true for smaller, portable rovers (50 Kg or less) with which one is trying to do more with less. Note the term rover is used here to mean a mobile robot or a remotely operated vehicle (ROV).

Most current rover design solutions are improvements over the basic four-wheel or tracked vehicle designs, but these still can be easily foiled in the rover mission. On obstacles, rocky terrains, and soft soils current rover designs can become stuck. In addition, and as part of this problem, current rover designs have limited maneuverability. Current omnidirectional, holonomic drives offer more maneuverability and perform well only on level surfaces, but have not proven practical for rough, outdoor terrain. They are unduly complex both mechanically and electronically--with corresponding expense, weight and bulk—and have problems with either high turning friction or low traction.

A Solution

The innovative chassis omnidirectional design described in this paper provides an alternative to either steered and powered casters or use of universal wheels. With this drive system the rover is driven by three ground-contacting “screws”. On the prototype and in the Figures 1-4 below these are in the form of helical coils, but variations in the form and shape are possible. Unlike the use of augers in past screw-driven vehicles, the outer edge of each helix is rounded with an outer, low friction helical edge profile. Where the screw contacts the ground it produces—like a universal wheel—low friction in one direction tangent to the helix and higher friction (a sort of macro-friction) in the perpendicular direction due to either sinking into the ground material or catching on surface irregularities (See Figure 3). This friction differential allows true holonomic, three-degree-or-freedom motion on rough terrain and surfaces.

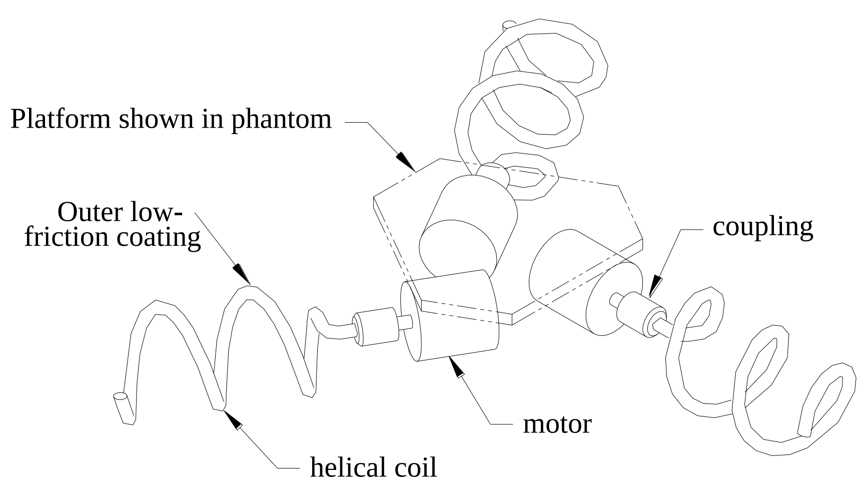

Figure 1.--Isometric view of rover basic drive elements

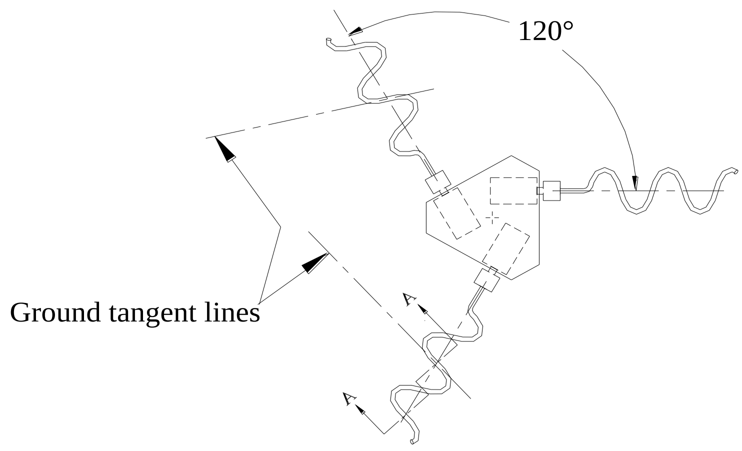

Figure 2.-- Top view of rover drive system, showing ground tangent lines and their relationship.

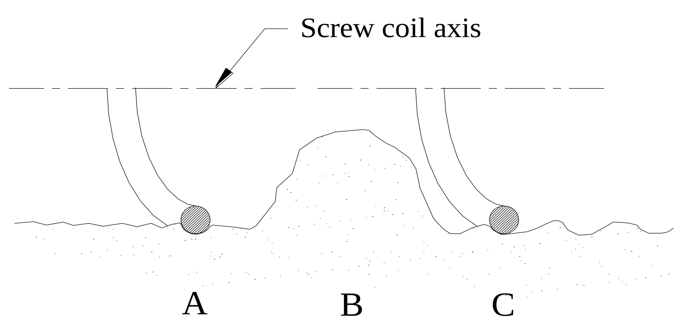

Figure 3.-- View of Section A-A from Figure 1, looking parallel to ground tangent lines. showing three cases of ground contact: A) coil sinking into ground; B) coil straddling obstacle; and C) coil catching on gound roughness.

The radio control aspect of the prototype to this point is appropriate as it affords the best means of experimenting with and demonstrating a new ground drive system on a wide variety of outdoor terrains and materials. This paper covers the design of a mobile robotics chassis, without the development of a robotic control system to make it autonomous or semiautonomous. Future holonomic control would be very similar to that standard for indoor designs using three universal wheels, such as that used in the Palm Pilot Robot Kit (PPRK) developed by Carnegie Mellon

Robotics Institute, in which the three motor speeds are controlled to get the desired direction, speed and rotation.

Significance

This project has passed through a series of prototypes and design revisions resulting in a working prototype all-terrain rover drive system. This has accomplished two main goals:

1. The development work and current prototype have confirmed and demonstrated the unique advantages of the design. These are: a) a durable and robust design; b) the ability to operate omnidirectionally over a wide variety of rough terrains and obstacles, including on materials such as sand, gravel, dirt and rocks; c) the ability to take advantage of the variable orientation to approach difficult obstacles, terrain or materials with an advantageous stance or configuration; d) distributed ground contact and ground contact pattern that varies with orientation; and e) the advantages of the overall design with more mobility options, including options for avoiding getting stuck, or getting un-stuck. This is significant for high risk terrain where it is beneficial to have a simple robust design that gives a range of options for mobility. While there is constant sliding friction against the ground, there is on the other hand no tire or track scrubbing during turning; and it this sliding friction that allows this design its maneuverability and other advantages over other designs. Figure 4 shows a possible body design for the rover.

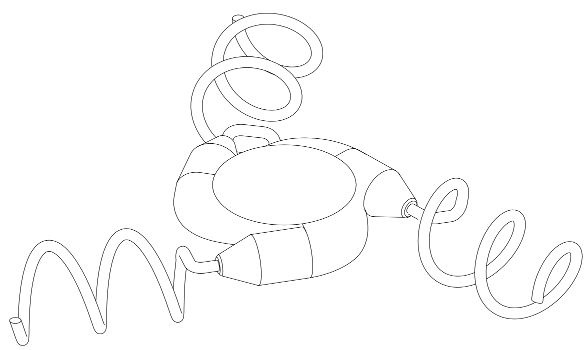

Figure 4.-- View of one rover layout with helical screws and a possible symmetrical body design.

2. The design has been refined to allow for practical testing, with significant progress toward an optimum arrangement for practical use.

a. The design is extremely simple, which has many implications for robustness, durability, reliability, weight and cost. The design has no linkages, no steering mechanism and no suspension. Each of three servo gearmotors is connected via a simple coupling to one end of its drive screw: there are no other moving parts.

b. The design is fairly compact design with a comparatively small body supporting outward facing, cantilevered screws distributing the driving forces over a larger area.

c. The design paradoxically avoids some of the ground clearance and hang-up problems associated with other vehicle designs, while allowing for a very low profile with high resistance to tipping.

d. The design also affords opportunity to take advantage of the variable orientation of the chassis, with possibilities for non-symmetric features, including the possibility that the three drives screws can be different.

Relevance

This paper fits the conference theme of new technologies in robotics and their practical applications, by providing a new drive system for outdoor and rough terrain such as would be useful for mobile robotics used in military, security, search-and-rescue, demining, and exploration applications. It is particularly suited for applications requiring flexibility and high maneuverability. The paper also fits the theme of the 2011 Robotics Innovation Conference & Competition, which will focus on Robot Mobility through Unconventional Means.

End of Abstract