Solenodon: Unstable Hexapod Walking

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ABSTRACT

The Solenodon research robot is a six legged mechanical walking platform designed at Ryerson Polytechnic University's School of Computer Science. It was our goal to develop a platform that would facilitate the examination of issues involving stability in walking robots. The vehicle is available in several configurations ranging from fully teleoperated to low level autonomous operation.

Keywords: Robotics, Control, Stability, Hexapod walking.

1. INTRODUCTION

Over time, numerous mechanical walking, and near-walking [1], devices have been created with varying numbers of legs and different control strategies [2][3]. The common goal shared among these systems is achieving stable walking.

Hexapod walking has been examined in great detail by a number of investigators including [4] and [5], who have selected it because of several inherently stable gaits applicable to six 3 pairs of opposed legs. Our motivation was radically different. Our intent was to create a vehicle that would walk but was inherently difficult to control. Our reasoning for doing this was that we wished to be able to compare stabilization mechanisms on an "apples for apples" basis. We did not wish the walking stabilization to be in any way tied to the learning of the human controller--we have created a walking vehicle with six legs but without any form of recognizable stabilizing gait.

The Solenodon robot takes its inspiration and name from the Haitian Solenodon. This rodent inhabits certain nut trees on the Caribbean Island of Haiti. While quite adept at climbing, the animal must descend to the ground to pick up the ripe nuts, which have fallen from trees and make up its primary food source. While the Solenodon is well adapted to tree life, its long and curved claws give it an ungainly waddle, which causes the creature to constantly compensate for its instability [6].

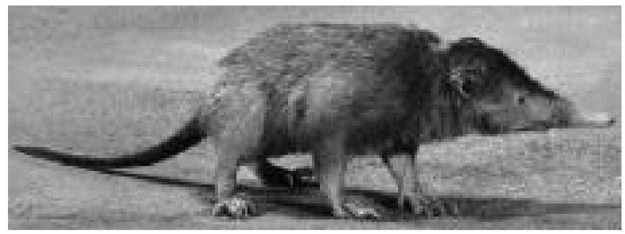

Figure 1 Haitian Solenodon.

2. DELIBERATE INSTABILITY

The essential characteristic of the Solenodon robot is that it is sufficiently stable to provide hexapod walking but has no inherent mechanism to provide additional stabilization. For example, while a stable hexapod walker might employ the familiar "alternating tripod" gait [1], the Solenodon provides no support for this gait or any other deliberate gait.

The walking that is generated is through the mechanical interaction of the vehicle's leg components. In addition, the motion of the left legs is not coordinated with those of the right. This causes very unpredictable motion and is very difficult to anticipate or control for even experienced operators.

As a result of this deliberate instability, any improvement in stabilization can be attributed to stabilization subsystems rather than a spurious improvement resulting from the controller simply learning how to control the vehicle better.

While, in a vast majority of robotic applications, instability is viewed as a significant disadvantage we have used the Solenodon platform to examine various techniques for providing improved stabilization performance.

A situation is cited in [7] discussing the difficulties novice sailors have in learning to steer a compass course using the tiller of a boat. He proposed that "even a task that has but a single mechanism to control a single variable can be difficult to understand, to learn, and to do." It was our intent to create such a device.

The remainder of this paper presents how we designed and constructed the Solenodon series of robots and presents experimental evidence that support our claim that the Solenodon series of robots help to eliminate spurious stabilization control performance. In addition, we suggest a “track” which can be easily constructed to test the performance of various stabilization strategies.

3. THE VEHICLE

A relatively simple functional and robust six-legged walking vehicle was constructed from readily available material. The Solenodon is made almost entirely of off-the-shelf items consisting primarily of Meccano [8] members with some additional Lego components suggested in [9].

The design of the Solenodon series has gone through a series of incremental improvements beginning with the Solenodon I concept vehicle depicted in figure below. Our original goal--that continues to influence the design of the Solenodon series—was to rely on the natural connective ratios of the building members of Meccano to provide easily reproducible walking motion.

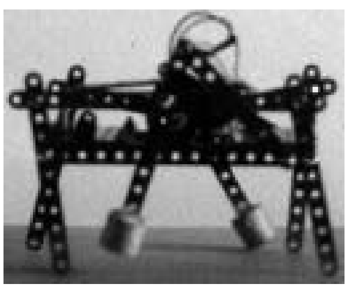

Figure 2 the Solenodon I

With each iteration in our design process we improved the reliability of walking achievable through our vehicles without compromising their essential instability. We wished to encourage the reproduction of the Solenodon with relative ease and limited expense. A schematic diagram the most recent iteration vehicle--the Solenodon IV--is presented below.

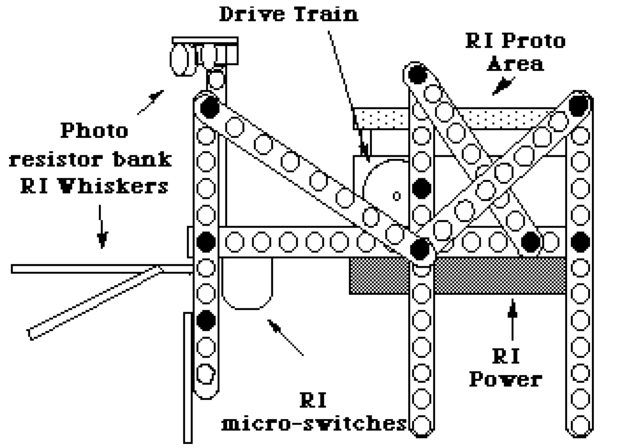

Figure 3 Basic Solenodon - Schematic View.

Each leg is connected to the others on a particular side by a series of flexible Meccano members, which are driven by the motion of the middle leg. Each side of the vehicle is equipped with a single drive train powered by an independent 6V DC motor. While the vehicle is being teleoperated, the speed and direction of each motor is controlled by a joystick. During autonomous operation, an on-board controller can control these motors.

The vehicle is powered through its middle legs. The Oscillation of the middle leg is caused by the interaction of a series of fixed and free pivot points that also causes the other legs to move in a manner which provides the forward and backward motion of the vehicle. The motion of the middle legs is depicted in the figure below.

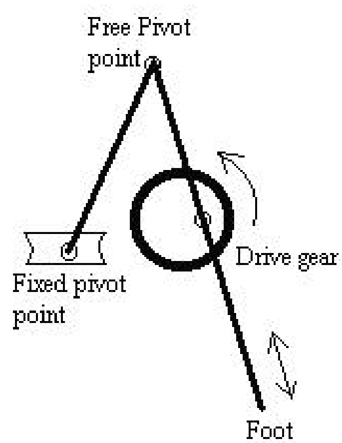

Figure 4 Middle Leg Drive Mechanism.

Differential steering is provided by the alternate acceleration of either side. For example, if the controller intends the vehicle to move to the left the speed of the right side legs must be increased consequently causing the motion in the desired direction.

Various low-level sensors are attached to the vehicle including forward and side whiskers and an array of photo-resistors that can easily be replaced with sonar or similar devices. Meccano provides a large number of mount points that can easily accommodate any number of sensors in various configurations.

A generous prototyping area is provided on the “back” of the vehicle. This consists of a powered protoboard with labeled sensor contact points. Electric power is provided by a battery pack slung from the “belly” of the vehicle with additional space for optional batteries under the prototyping area.

A photograph of a Solenodon IV is shown below. It is equipped for low level autonomous operation with a controller designed to avoid obstacles that are sensed through whisker contacts and to follow light detected via photo-resistors.

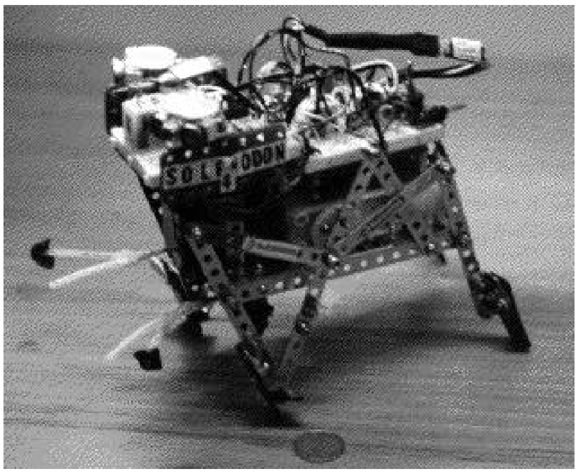

Figure 5 Solenodon IV, 3/4 View.

Another view of the vehicle and optional joystick controller is provided in the figure below.

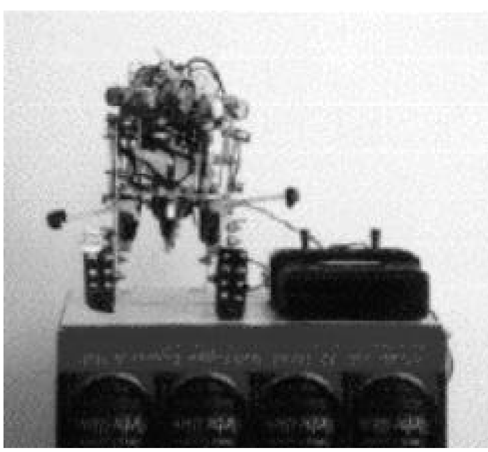

Figure 6 Solenodon with Manual Controller.

4. TESTING THE SOLENODON VEHICLES

The Solenodon vehicles have been controlled by dozens of human controllers and most have made the observation that the vehicles can be driven but are quite difficult to control. In addition, the most experienced drivers of the vehicle have shown only marginally better performance over time. Because the human controllers do not become better at the control task, we are confident that improvement in performance is due to mechanism that we add to the vehicle to help in controlling it. In this way we are capable of making valid comparisons between schemes for improved control of the vehicle.

In our initial trials we selected four as operators of a Solenodon IV vehicle. Each operator was given the opportunity to "drive" the test vehicle for at least 15 minutes prior to the actual trials. The test vehicle had no stabilization mechanism active at that time. During the trials each driver was asked to drive the vehicle three times. Once without stabilization, once with and then again without. The rational for this was that if our assumptions were correct there should be no noticeable difference in the unstabilized runs—implying the drivers did not learn how to control the vehicle better--and improvement with a stabilization strategy.

For the purposes of these trials a stabilization circuit was devised instantiating active reflexes as described in [10]. We have used this circuit in other work [11] and have found it to provide good results in helping to control the Solenodons.

The goal given to each of the human operators was to move the vehicle through the course as quickly as possible while minimizing the number of collisions. For the purposes of these trials a collision was defined as "any non-sensor contact with a vertical surface". An observer was assigned to count the incidents of collisions with either walls or pylons. Essentially, the fewer the contacts the better the stabilization strategy.

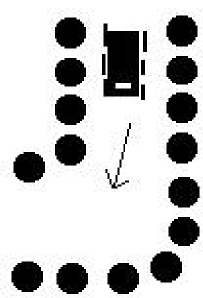

Figure 7 Vehicle and Pylons.

The photo below shows the Solenodon IV vehicle at the start of a trial. The pylons used are simply empty beer bottles.

Figure 8 Solenodon on Track.

The photo below was taken just after the completion of an unstabilized run. The pylons would normally be in straight rows.

Figure 9 Track after Solenodon Traversal.

5. PERFORMANCE

The table below shows the results of the drivers the first time through the course without any vehicle stabilization.

Table 1 Results of First Trial (No Stabilization).

Driver	Collisions	Time (sec.)
1	7	47
2	11	45
3	15	47
4	12	50

In the second run stabilization was provided and the results are shown below.

Table 2 Results of Second Trial (With Stabilization).

Driver	Collisions	Time (sec)
1	2	41
2	2	47
3	3	43
4	2	48

In the final run, stabilization was not provided with the following results.

Table 3 Results of Third Trial (No Stabilization).

Driver	Collisions	Time (sec)
1	8	49
2	12	43
3	19	53
4	14	48

Simply observing the data one can see that no appreciable improvement in driver/vehicle performance occurred in the first and third unstabilized trials and considerable improvement was shown with stabilization in trial two, with both fewer collisions and faster times.

We have run several dozen of such trials with different driver groups with these results being typical. We have received various comments from drivers who complain that the vehicle is rather difficult to control and barely adequate for the task. We have received these as praise.

Figure 10 Frustrated Driver.

6. CONCLUSION

We have created a six-legged walking vehicle that is sufficiently stable to walk on flat surfaces yet is rather difficult to control and whose control cannot be mastered through learning. We have done this in order to test stabilization strategies using a common test-bed. To date we have created four versions of the Solenodon vehicle ranging from fully teleoperated to low level autonomous operation. We have tested the vehicle with several stabilization strategies and found it ideal for this type of comparison. Future plans include minimizing the components required to achieve walking and providing the plans for the construction of such vehicles to interested parties.

9. REFERENCES

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