SphereWalker

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ABSTRACT

This article describes the design and the development of a novel six legged robotic walking machine named SphereWalker. The six legs are arranged into pairs and each pair of legs is supported and actuated by a single spherical four-bar mechanism. Two of the four-bar mechanisms are operated in a synchronous fashion while the middle one is operated at 180 degrees out of phase with respect to the other two. A prototype has been built and work is building a motion control system. Once fully operational a variety of gaits will be studied to optimize the performance of SphereWalker for a variety of tasks.

Keywords: Hexapods, Walking Machines, Spherical Mechanisms

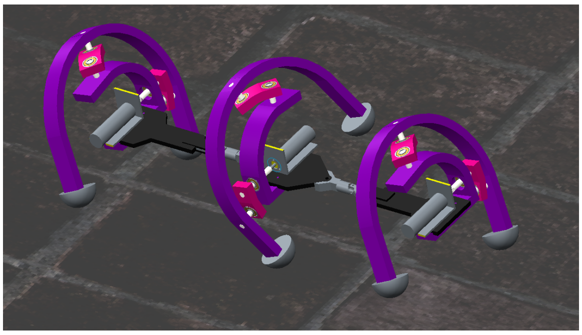

Figure 1. SphereWalker

1. Introduction

1.1 Project Overview & Goals

The goal of the SphereWalker project is to design, simulate, manufacture, and test a hexapod walking machine whose leg pairs are actuated by spherical four-bar mechanisms. The idea was to design a single one degree of freedom crank-rocker spherical four-bar mechanism whose coupler link can be extended such that each end of the link supports one of the hexapod's feet. Then, three identical mechanisms would be used in the device; each driving a pair of legs of the hexapod. Traditionally each leg of a hexapod is driven by at least one actuator [1, 17, 7, 14, 4, 21]. By using a single mechanism to drive a pair of legs only three actuators are needed to drive all six legs. Thereby reducing cost, weight, and complexity. Our hope is that the resulting hexapod will prove to be effective when navigating rough terrain, both indoors and out, and in applications where energy efficiency is paramount.

1.2 Related Works & Paper Outline

Related hexapod walking machine works include the University of California Irvine Spider designed by Soh and McCarthy [21]. In [1, 19] a biologically inspired hexapod with compliant legs named RHex is presented and in [16] an open loop controller is presented that enables RHex to climb stairs. Wait and Goldfarb [22] present a biologically inspired method for the control of the location of a robot hexapod. They build upon the WalkNet control structure to yield stable gaits. In [5] an adaptation strategy for adjusting, in real-time, the stride in a running hexapod's gait is presented. In [6] the robustness of a neural network based locomotion controller for a hexapod is studied. Finally, the computer-aided design tools that were used to create SphereWalker were reported in [12] and [20]. Additional works related to the design, actuation, gait, and control of hexapods include the following [18, 17, 7, 14, 13, 15, 4, 11, 2, 9, 10, 3, 8].

The following sections provide an overview of the SphereWalker mechanism, the motion control system of SphereWalker, simulation and dynamics analysis of SphereWalker, future work, and acknowledgements.

2. Mechanism Overview

The SphereWalker, see Figures 1 and 2, is composed of three spherical four-bar linkages each connected to aluminum base plates, which are in turn connected by two revolute joints. Each linkage is made of identical components, although the central four-bar is rotated 180 degrees about the vertical and the mechanism is assembled in the other circuit.

The legs that propel the SphereWalker are integral extensions of the coupler link, see Figure 3. Having each linkage operate a pair of legs, as opposed to a single leg, allows for the SphereWalker to always have three points of contact

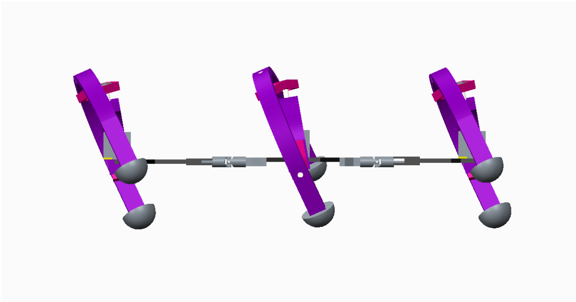

Figure 2. Side-view of SphereWalker

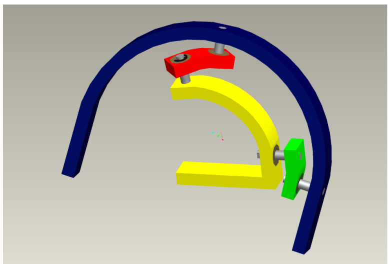

Figure 3. SphereWalker Spherical Four-Bar Mechanism

with the ground at any given time while only requiring three mechanisms instead of six, thus reducing complexity.

3. Motion Control System

As the special mechanism was built, a featured control system must be designed for the SphereWalker. In order to operated SphereWalker and make it to work as desired, a motion control system was designed, see Figure 4, with one Arduino Mega 2560 as mother board, three custom motor controllers (Figure 5) designed using Arduino Duemilanove board and three JYQD_V6.42 BLDC motor drivers, three 24V BLDC servo motors with absolute encoder, one 24V Li-ion battery and other component such as bluetooth, distance sensors and GPS module.

This control system is composed of a high-level control system and low-level control systems. The SPI comunication is buit between high-level and low-level, see Figure 4, for controlling those motors by Arduino Mega so that the SphereWalker can run as desired. One I2C comunication is set between front and back motor controllers, which is for insuring these two motors running fully sunchronously. One close loop control system is built for motion control of sevo motors, see Figure 5; the Duemilanove can read the SSI from the absolute encoder and get the position and speed of the motor and send a required signal to motor driver to drive the motor. Once the Duemilanove recieved a motion command from Mega, this close loop will work and the motor do a correct motion.

4. Simulation

In order to develop an efficient motion control system, the dynamics analysis and simulation of SphereWalker is being studied. The simulation was performed using PTC Creo 2.0, and a model was built as putting SphereWalker on

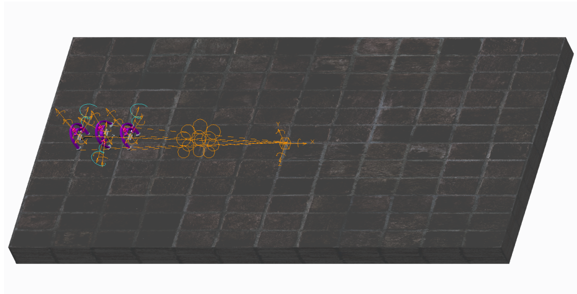

Figure 6. Default-view of SphereWalker on Ground

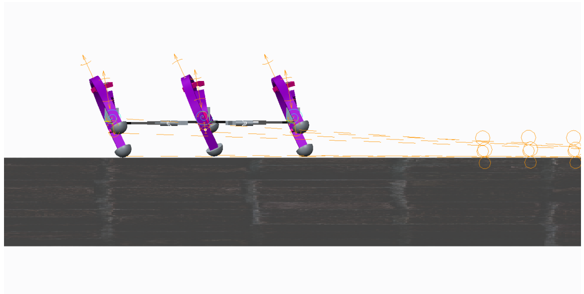

Figure 7. Side-view of SphereWalker on Ground

ground, see Figures 6 and 7. For understanding how will the offset angle of middle mechanism impact on the motion of SphereWalker, several simulations is running with different initial offset angle such as 180 degrees, 30 degrees.

For 180 degrees offset, see Figures 8 and 9, it shows the center point on the plate of the SphereWalker goes straight along X coordinate direction with a little shake on direction Z, while the plate sways up and down on direction Y since the special mechanism.

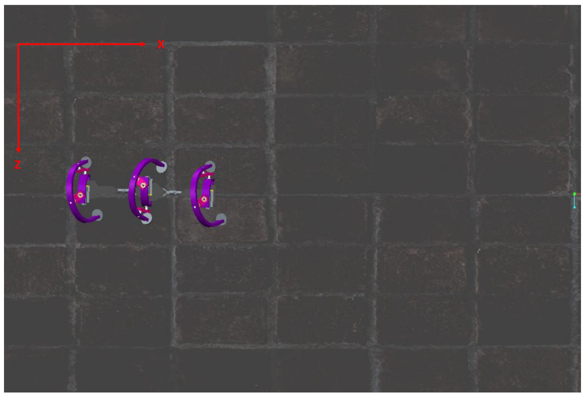

Figure 8. Simulation of SphereWalker

However, for 30 degrees offset, see Figures 8 and 9, the SphereWalker turns to Z direction a little bit.

More different offset angles simulation is working and further analysis include speed and acceleration of SphereWalker as well as the torque of those three motors will be studied.

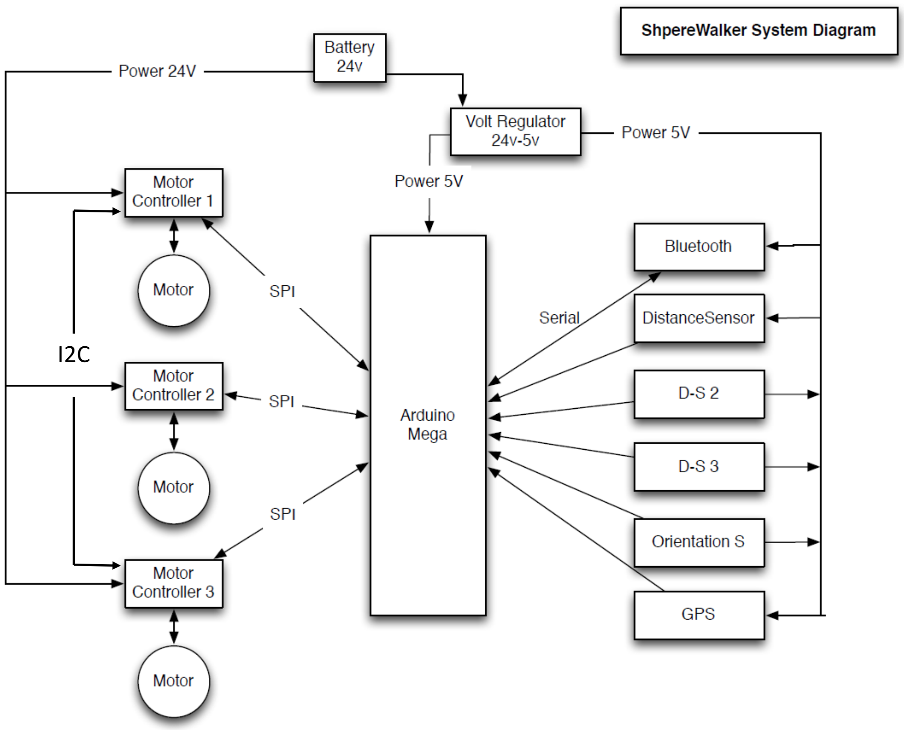

Figure 4. SphereWalker System Diagram

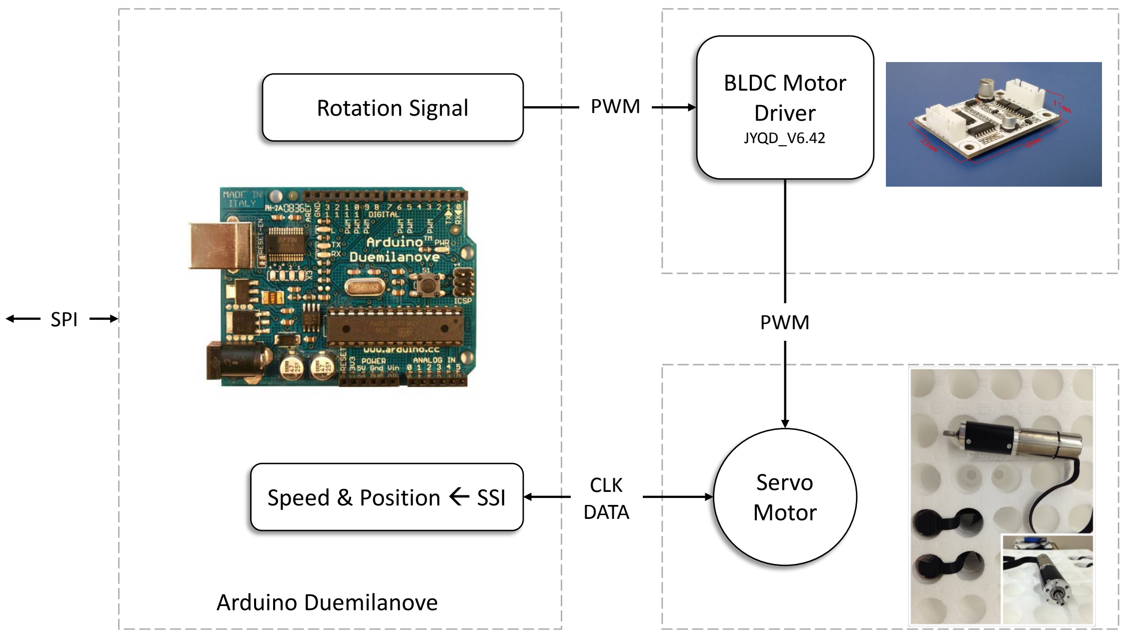

Figure 5. MotorController Block Diagram

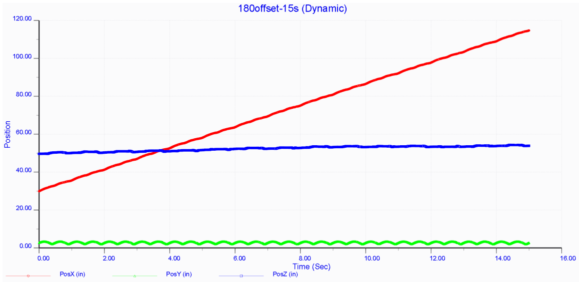

Figure 9. Position vs Time Graph of 180 Degrees Offset

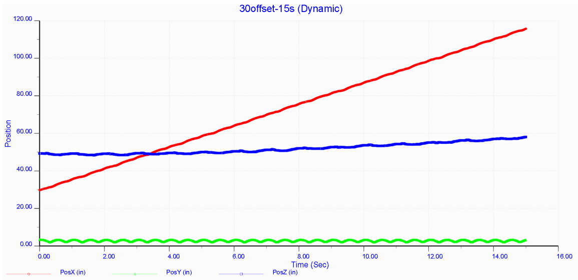

Figure 10. Position vs Time Graph of 180 Degrees Offset

5. Future Work

As the whole control system has been designed and the simulation and dynamics analysis are studing, the next step is to program all microcontrollers. Once all analysis and code programing finished, the control system will be build up into the SphereWalker and several experiments and varieties of tasks will be study.

6. Conclusions

This paper described the design and the development of a novel six legged robotic walking machine named SphereWalker. The SphereWalker has six legs that are arranged into pairs with each pair being supported and actuated by a single spherical four-bar mechanism. The design, and prototyping of the SphereWalker was summarized. A prototype has been built and work is building a motion control system. Once fully operational a variety of gaits will be studied to optimize the performance of SphereWalker for a variety of tasks.

7. Acknowledgments

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