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 ongoing to design a feedback 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

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 process of manufacturing and assembling the components of the SphereWalker, actuation and testing of the assembled components, 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 with the ground at any given time while only requiring three mechanisms instead of six, thus reducing complexity.

3. MANUFACTURE

The main components of the SphereWalker- coupler, fixed link, driven link and driving link, were manufactured using a CNC machine that runs on Mastercam software. The first version of the Mastercam software was created by CNC Software, Inc. over 25 years ago and today it is the most widely used CAD/CAM software in the world. A specific layout was drawn using Mastercam in order to fit all of the components onto a piece of one inch thick aluminum plate, see Figure 4. It is easy to be efficient with material use when laying these components out but because our piece of aluminum was previously used and had many holes creating this layout to arrange three sets of afore mentioned components was challenging. After finalizing the layout we selected the path in which the components were to be milled and an appropriate sized flat end mill. We used a $\frac{3}{8}(in)$ diameter cutting tool with an interlink offset space

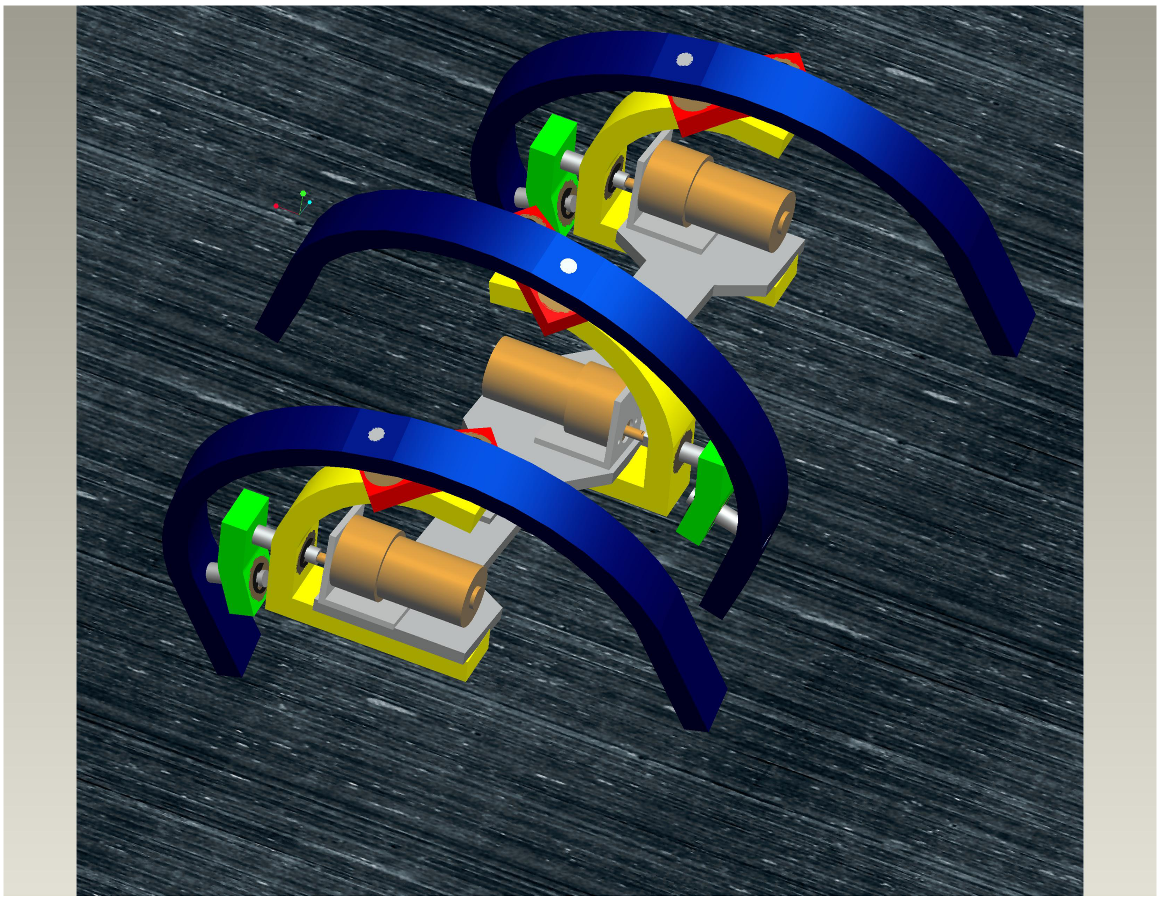

Figure 1: SphereWalker.

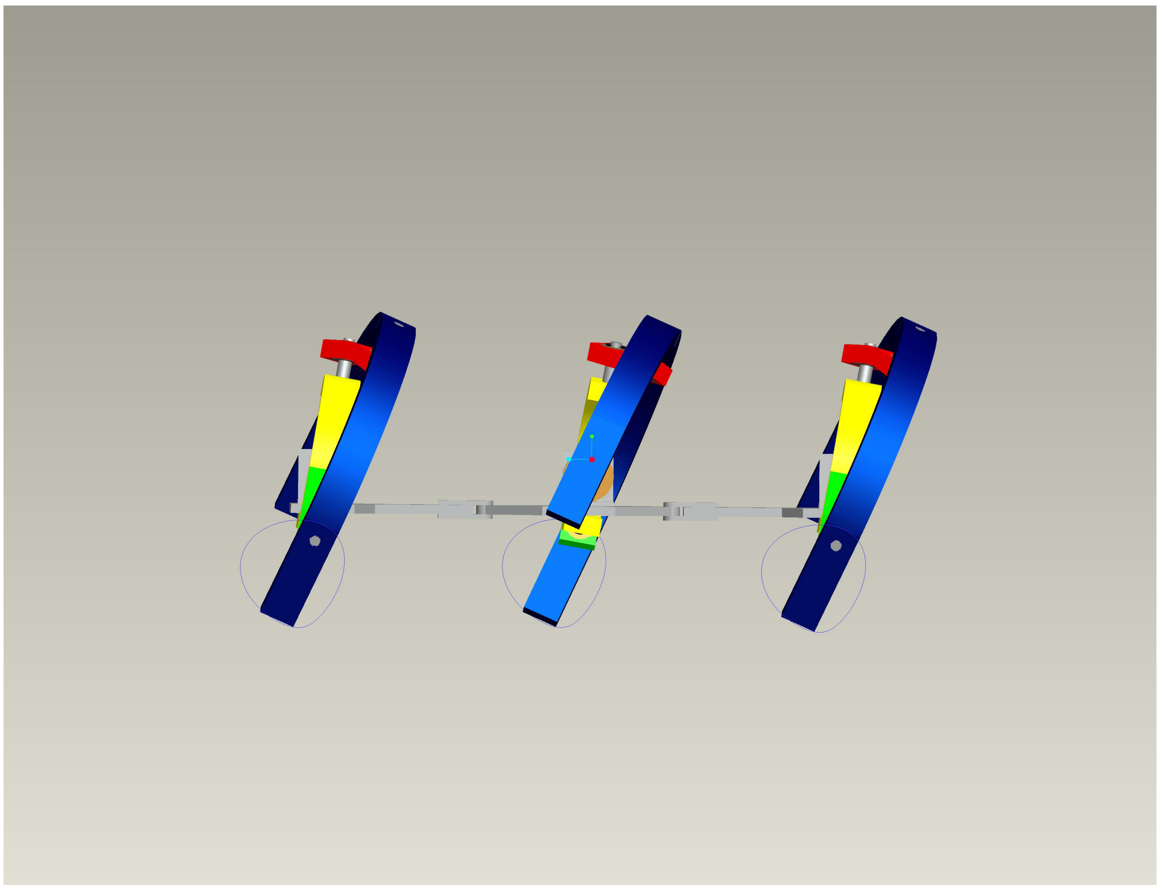

Figure 2: SphereWalker with Coupler Curves.

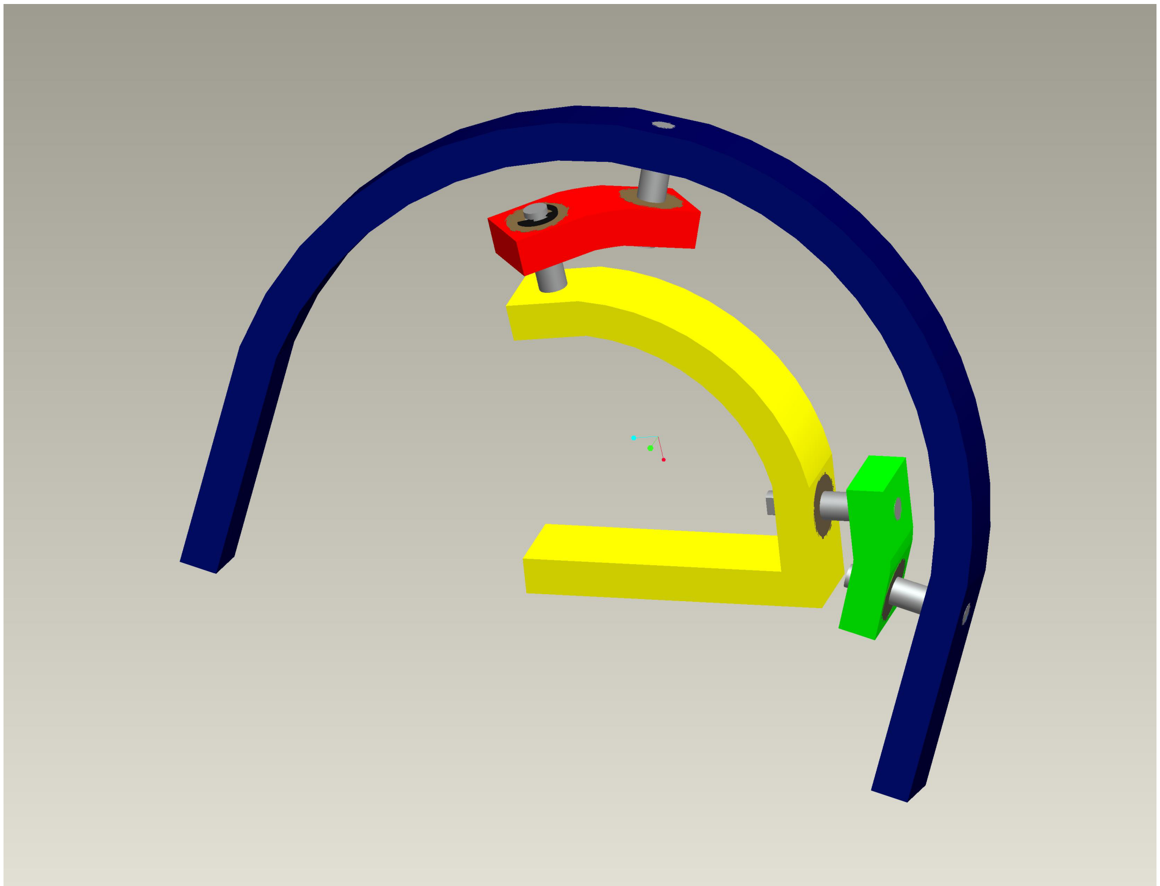

Figure 3: SphereWalker Spherical Four-Bar Mechanism.

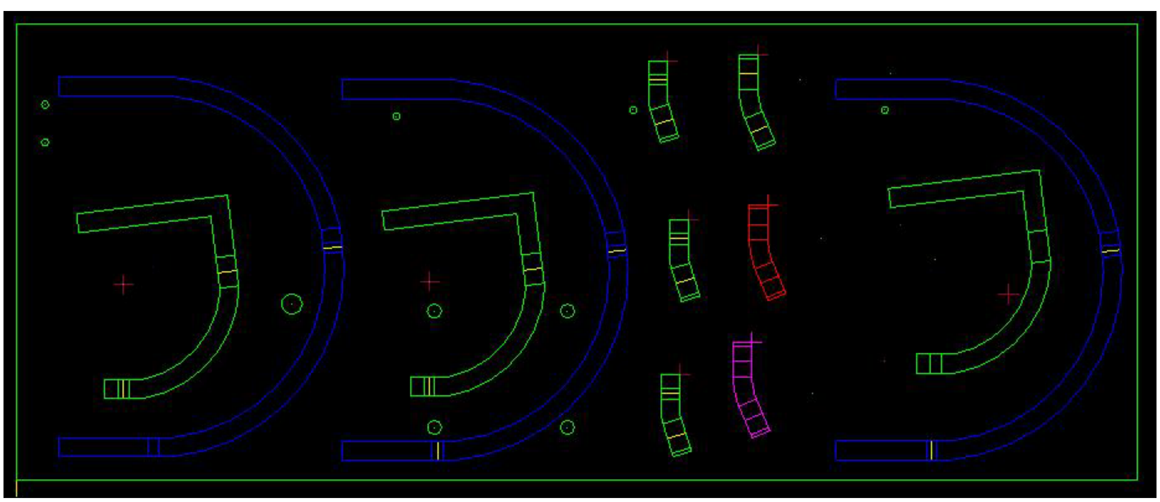

Figure 4: SphereWalker Part Layout.

of $\frac{1}{8}(in)$ which resulted in a $\frac{1}{2}(in)$ spacing between links. The path chosen was to start with the smaller components inside and work outwards to the larger components. When we completed the program we converted it to the G1 code that the CNC machine reads. The aluminum was clamped directly to the CNC, the code was uploaded and we started the program. Some slight complications arose as this piece of aluminum was slightly bowed in the middle due to the way it had to be clamped down. The components weren't greatly affected but some needed minor tweaks in order to be precise. The next part of manufacturing was to drill holes for the bearings and gauge pins. The bearing holes are only on the fixed, driven and driving links. Two different programs were written in Mastercam one for the fixed link and one for both the driving and driven links. The holes were made two thousandths smaller than the bearings so they could be press-fitted in. The next thing to do was to create programs for the gauge pin holes which are only on the coupler, fixed link and driving link. Two different programs were written in Mastercam one for the coupler and one for both the fixed and driving links. These holes were also made two thousandths smaller so the gauge pins could be press-fitted in. This was most complicated part of the manufacturing process because the gauge pin holes on the coupler and fixed link were not positioned in a manner that would be easily accessed. These components, with the coupler being the more difficult of the two, had to be completely barricaded in order to avoid vibrations and the drilling of an imprecise hole. In order to increase the wall thickness around the bearing holes and reduce bearing stresses, new fixed and input links were made from 1.25 (inch) thick plate. To assemble the components, the links may be connected from the center of the sphere outwards. All the bearings are press fitted into the fixed, driving, and driven links. The first components to connect are the fixed and driving links. One end of a gauge pin is placed in the bearing of the fixed link as the other end is placed in the driving link. The second components to connect are the fixed and driven links. One end of the gauge pin is place in the fixed link as the other end is placed in the bearing of the driven link. Now there are two gauge pins, one coming from the driving link and the other from the driven link that are to be connected to the coupler. A support is built in order to press fit these last gauge pins, but only one can be done at a time. We use standard roller skate or skateboard bearings simply because they are strong and relatively inexpensive. The gauge pins we decided to use are oil hardened and therefore very dependable. We decided to use gauge pins because it was easier than turning down rod to hand make pins.

4. ACTUATION & TESTING

In order to actuate the SphereWalker, motive power in the form of permanent magnet 24 (Volt) DC motors was chosen. The system used to currently control them is an open-loop system, chosen for sheer simplicity. The limited control offered by an open-loop system was deemed acceptable for prototyping, as the only information required was whether the spherical mechanisms would work appropriately and cause lateral movement of the SphereWalker.

5. FUTURE WORK

As the inherent inaccuracy of DC motors on an open-loop control system causes them to be inadequate for realizing the full potential of the SphereWalker design, the next step is to augment each of the DC motors with output feedback and use an onboard microprocessor to control them. Most likely, this microprocessor will be a PIC from Microchip Technology, due to their low cost, ease of use, and past experience with them. With a closed-loop system, it will be possible to test various speeds and build in increased functionality for non-level surfaces, and with the use of PIC microcontrollers, the speed and position of each of the three linkages can be varied on-the-fly from either a laptop computer or a dedicated on-board control box.

6. SUMMARY

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, manufacture, and prototyping of the SphereWalker was summarized. A prototype has been built and work is ongoing to design a feedback 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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