Design and Control System of Rickshaw Robot

A Preprint

Helene Levy
Department of Mechanical Engineering
University of California Santa Barbara
hjlevy@ucsb.edu

Nobuyuki Iwatsuki
Department of Mechanical Engineering
Tokyo Institute of Technology
nob@mep.titech.ac.jp

October 21, 2019

Abstract

A pulled rickshaw is a human drawn carriage that seats one or two people. In this study, a biped robot was designed in place of the human to draw a cart with two passive wheels. The goal of this study was to create a natural gait and steering system using robot power. For the legs, two four-bar linkage systems were used a half cycle out of phase from each other. A parallelogram steering linkage was introduced on the cart to turn the rickshaw. A prototype of the design was tested for balance under conditions of straight walking and turning at a 40° wheel offset in both directions. Through this experimentation, the stability and feasibility of the robot rickshaw was analyzed.

***K*eywords** rickshaw robot · gait analysis · stability

1 Introduction

Humanoid robotics is a field that has been well researched for many years. The mechanics and control of bipedal walking systems is a feat undertaken by many in order to naturalize human-like tasks such as walking, running, and jumping. The benefit of biped legged robots is their enhanced ability to traverse over a variety of terrains compared to wheeled systems. Optimizing bipedal robots towards human-like motion is complex due to factors of balance, speed, and rigid joints. In order to prevent a fall, the sum of forces and moments must be carefully considered as well as the position in which the "feet" of the robot land during it's gait. True biped robots are thereby difficult to control. Therefore, in this study a cart with two passive wheels was attached to a biped robot (in a rickshaw fashion) for stability and to simplify the controls system.

In order to ensure stability of the robot, the end effector path of the linkage system used for the "legs" was carefully planned. The foot trajectory was optimized by adjusting sizes of links in the linkage system to fulfill requirements detailed in Section 3 while running the motor continuously in one direction. The motor controlling the legs therefore required velocity control while the motor controlling steering required position control to turn the wheels to a certain angle. In addition to adjusting the link system, the zero point moment was analyzed to prevent tipping and determine motor placement.

2 Design

The design of the rickshaw consisted of two main bodies: the biped walking system and the cart. The biped walking system was attached rigidly to the cart. The steering system was integrated in the cart design by turning two passive wheels with a parallelogram linkage. The prototype design can be seen in Figure 1.

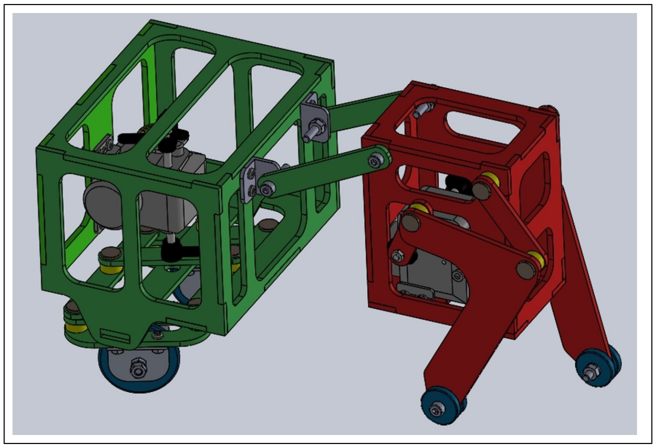


Figure 1: Robot Design

3 Linkage System

The rickshaw robot utilized two different linkage systems to minimize the driving motors in the system. Using the least amount of driving motors was important in the design process in order to have a light and efficient robot. A four-bar linkage system was used for the legs and a parallelogram steering linkage was used to angle the wheels attached to the cart.

3.1 Biped Linkage System

The design specifications of the four-bar linkage system for the legs was important in developing a stable robot. The first design requirement was to have a long gait span in the x direction. The second design requirement was to have a short gait span in the y direction in order to minimize the time spent balancing on one foot. The points of gait trajectory in contact with the ground were desired to be near parallel to the walking surface to again limit the time spent balancing on one foot. The desired path of the end effector or "foot" can be visualized in Figure 2.

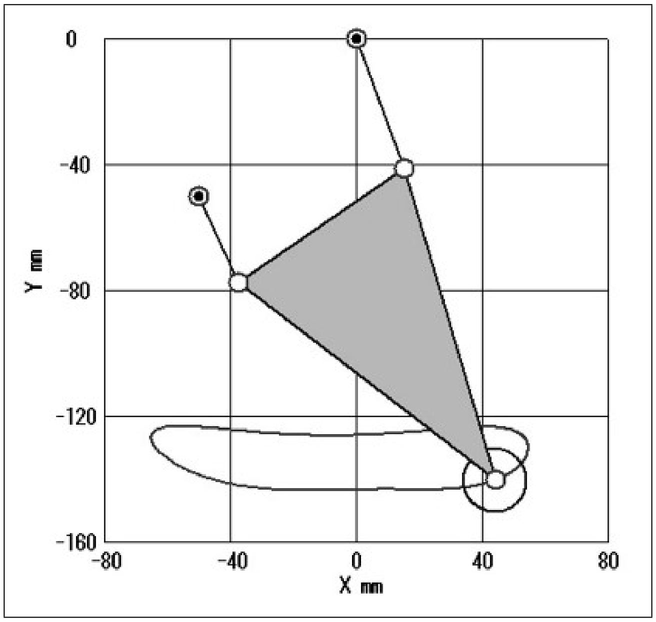


Figure 2: Four Bar Linkage System

3.2 Cart Linkage System

The linkage system of the cart consisted of a parallelogram steering linkage in order to turn both wheels over a range of 80 degrees. With this linkage, both wheels remained parallel to each other at all times and were driven by one motor. A stick diagram of the system can be observed in Figure 3.

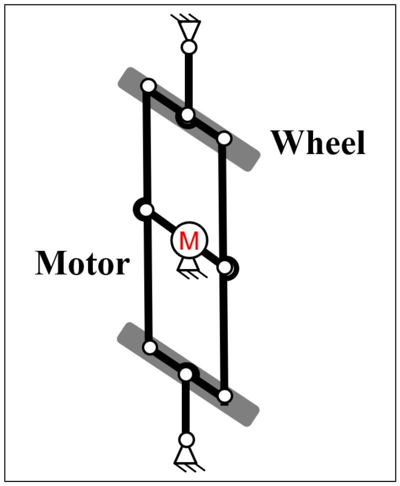


Figure 3: Parallelogram Link Steering System

4 Results

The success of the robot rickshaw was measured by conducting a straight walking test, a fixed angle turning test, and a dynamic turning test on a flat surface. The straight walking test as well as the fixed turning test utilized rubber wheels on the cart. The dynamic turning test utilized acrylic wheels in order to reduce surface friction preventing the steering actuation of the wheels mid-path.

4.1 Straight Walking Experiment

The straight walking test was conducted over one meter on a flat surface. Over two experiments, the average offset angle from initial to final position was 8.95°. Four different positions in time of this experiment were taken in order to yield a best fit line from the horizontal. The displacement of the robot in time can be seen in Figure 4.

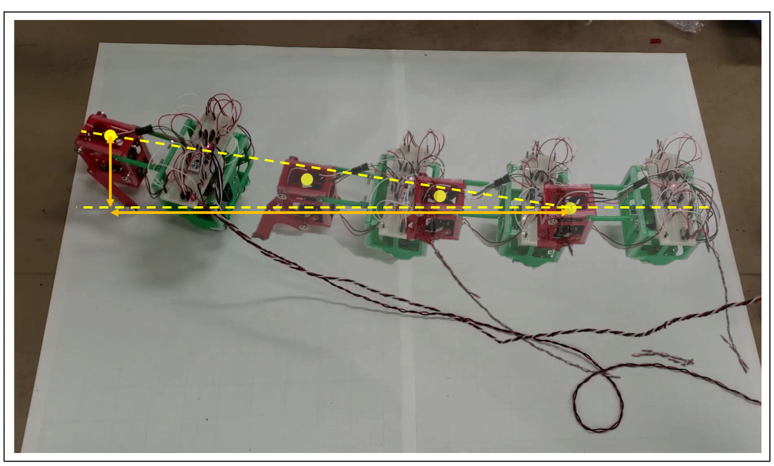
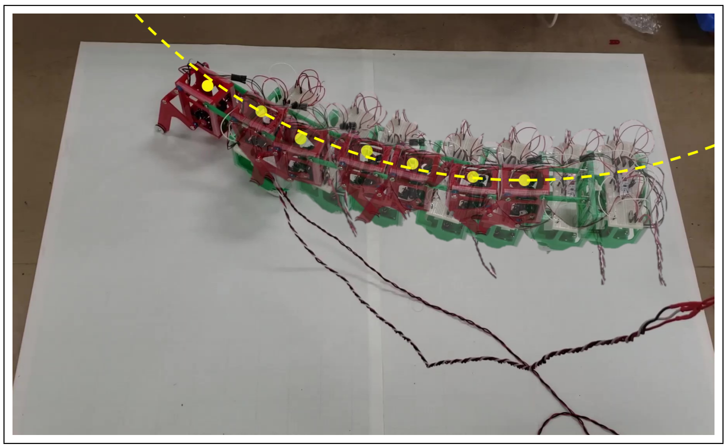


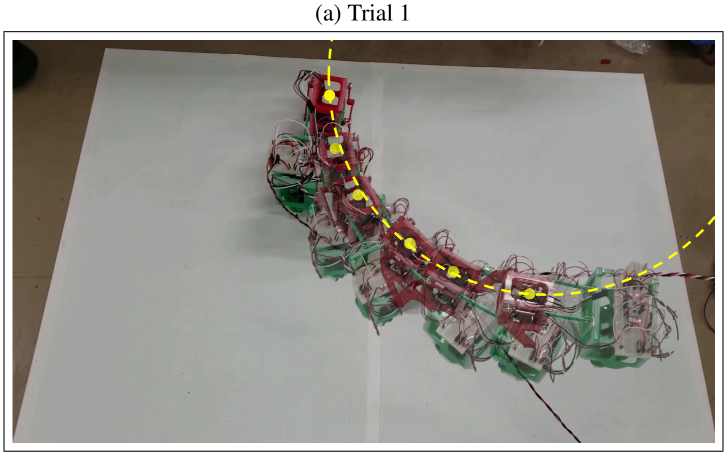
Figure 4: Straight Walking Experiment

4.2 Fixed Angle Turn Experiment

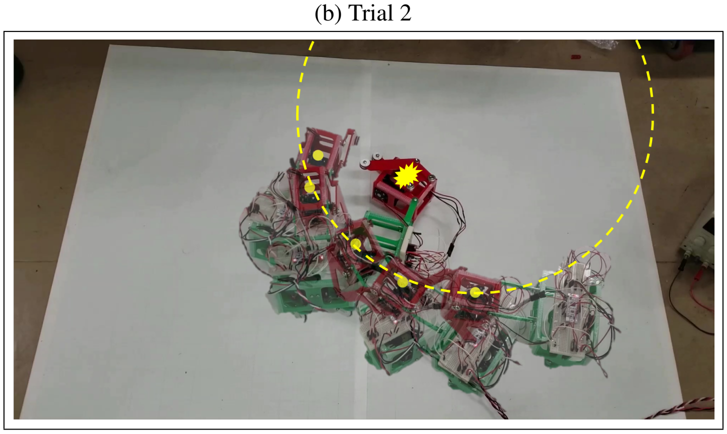
The first turning experiment involved setting the passive wheels to a 40° offset from the basis (pointing straight in line with legs). Three experiments were conducted of which the robot fell once. The turning radius also varied between trials. The experiments can be seen in Figure 5. The turning radii are recorded in Table 1.



(a) Trial 1



(b) Trial 2



(c) Trial 3

Figure 5: Static Turning Experiments

Table 1: Fixed Angle Turning Radius

Trial	Radius (m)
1	1.47
2	0.62
3	0.53

4.3 Dynamic Turn Experiment

The dynamic turning experiment entailed actuating wheels to turn mid-path as opposed to starting the robot with wheels at a fixed turn angle as done in the fixed-angle turn experiment detailed in Section 4.2. This experiment required the use of acrylic wheels. The rubber wheels used in the previous experiments could not overcome friction in the transverse direction and therefore could not actuate the wheels mid-path. The trajectory of the dynamic experiment can be seen in Figure 6.

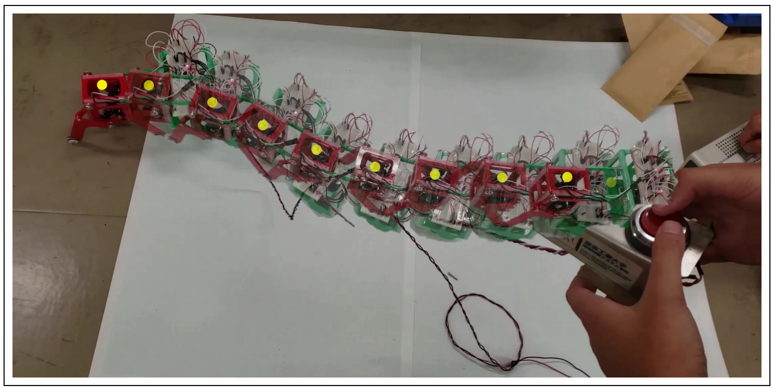


Figure 6: Dynamic Turn Experiment

5 Conclusion

The stability and feasibility of the robot rickshaw prototype was tested using straight and turning tests. The goal was to create a natural robotic gait and to avoid tipping. Based on the experimental results in Section 4, the robot could safely travel for turning radii over 0.53 meters. However for turning radii at 0.53 meters and below the robot would fall over. The robot had a slight offset of 8.75° for the straight walking test that may be due to an uneven weight distribution by the breadboard attached to the cart. The robot was able to perform without failure in the dynamic turning tests with acrylic wheels but not rubber wheels.

For the next prototype, a more careful selection of wheels and weight distribution analysis should be done. Omni wheels could be used in order to allow for free movement in the transverse direction. This would allow the robot to overcome friction in the transverse direction and could prevent tipping by turning. In addition, a smaller printed circuit board could be used in order to minimize the effects of weight distribution on the cart that could have caused tipping.

Future experiments should include testing various amounts of weight in the cart. This would better simulate and understand the mechanics of a human rickshaw. An additional experiment would be driving the robot rickshaw over uneven surfaces to test the feasibility of rickshaw robots in real world environments.