Payload Stabilization System

John Bryant
Electrical Engineering
FAMU-FSU College of Engineering
2525 Pottsdamer St.,
Tallahassee, FL 32310
Email: jzb17@my.fsu.edu

Tristan Kirby
Mechanical Engineering
FAMU-FSU College of Engineering
2525 Pottsdamer St.,
Tallahassee, FL 32310
Email: tak14b@my.fsu.edu

Ariel Mathias
Mechanical Engineering
FAMU-FSU College of Engineering
2525 Pottsdamer St.,
Tallahassee, FL 32310
Email: aam14h@my.fsu.edu

Junyi Wang
Mechanical Engineering
FAMU-FSU College of Engineering
2525 Pottsdamer St.,
Tallahassee, FL 32310
Email: jw18cy@my.fsu.edu

Anthony Wyrick
Electrical Engineering
FAMU-FSU College of Engineering
2525 Pottsdamer St.,
Tallahassee, FL 32310
Email: adw17@my.fsu.edu

Around the world, researchers working with legged robots depend on sensors, such as cameras, attached to robots so they can collect data. When these robots are used to collect data, the motion of the robot causes the data to have noise. When data has noise, or outside disruption that affects the data quality, it is hard to interpret and not ideal. This project focuses on designing and employing a stabilization system that reduces the movement of the sensors on robots. With this project, the data returned is more usable and helpful. This is because of motion reduction where the sensors are placed. The baseline of data for this project is the Minitaur robot. The Minitaur is used by Dr. Ordonez and David Balbuena in the Aero-Propulsion, Mechatronics, and Energy Building (AME). Data from the Minitaur has been collected and studied to judge how much motion is affecting the sensors. However, the design of this project involves a mechanical system that can attach to different platforms as well. The design is a system that attaches to the robot and uses four servo motors to counteract the motion. The system also uses software, in combination with hardware, to actively respond to the robot the system is attached to. The motors move the system to balance the motion of the sensors. 3D printing is used to create the frame for the project system. This results in a lightweight product that produces meaningful improvements to data clarity without compromising the operation or effectiveness of the robot. The project uses a camera as the main sensor, so video from the camera shows how the project improves data. Overall, the project can be applied to different platforms and improves sensor feedback.

1 Introduction

Legged robots often draw inspiration from biology, with many robotics drawing from animals such as humans, cheetahs, and dogs. The robots imitate biology and utilize biological characteristics to formulate locomotion. These robots can have many applications from environmental monitoring to substituting human tasks [1,2].

The Aero-propulsions, Mechatronics, and Energy Center at FAMU-FSU College of Engineering has developed a legged robot called the Minitaur. This robot moves using four legs which causes a degree of bounce in the robots motion. This bounces makes any data collected from the robot reflect the displacement of the robots motion. The focus of this project is to create a system aimed at stabilizing the payload of a legged robot. This Minitaur is used as the legged robot to center stabilization efforts around, with the intention of the stabilization system to be effective on other platforms, in addition to the Minitaur.

Two approaches to stabilization are active and passive stabilization. Active stabilization makes use of sensors and microcontrollers to interpret signals and direct corrections to the system. It includes feedback control and mechatronics to ensure recovery of a system even with continuous and, or varying disruption. Passive stabilization has no control power but instead uses tools such as springs or dampers to absorb and dissipate a systems energy. Passive stabilization requires no software or controller and does not include feedback [3,4]. For the stabilization system developed here, both passive and active stabilization techniques were utilized.

2 Design

The design of our system is formulated around the use of four servo motor. Each of three servo motor controls the x, y, and z axis, with a fourth correcting the changing angle. The motors are then connected, either directly or via linkages, allowing them to work together to stabilize the overall system. The motors were selected with consideration of the weight of a camera, the weight of the motors, and the lengths of the linkages. These parameters are all factors in calculating the torque necessary for the motors to produce in order to sufficiently stabilize the system. The summary of design parameters can be found in table 1. The necessary torque is calculated using equation 1.

Table 1. Design Parameters

Motor Weight	55 grams
Camera Weight	73 grams
Linkage Length	10 cm

T=weight x radius [Eq. 1]
T=(55g)x(10cm)+(73cm+55cm)x(20cm)
T=3.11 (kg x cm)

The calculation of torque showed that approximately 3 kgxcm was required from the motors, however, the motors selected for this have a stall torque of 12 kgxcm. This allows them to be more than capable of producing the necessary torques for the stabilization of the system, compensating for any oversimplification in system weight. It also allows for the weight of the payload to be increased if desired without stalling the motors.

After motor selection, the mechanical design of the system was detailed. The final mechanical design has a motor vertically aligned and mounted on a baseplate that can be used to attached the system to the Minitaur, or many other robotic systems. Attached to this vertically mounted motor is a second motor, directly connected to the first motor shaft. This connection minimizes the weight of the overall system, without compromising effectiveness of the correction factor. A linkage is then screwed to the second motor and the third motor. From the third motor, the second linkage is connected to the fourth motor. Figure 1. shows the full assembly of the system, along with the camera attached the fourth motor as the system payload.

Figure 1. Stabilization system assembly.

The system uses a gyroscope at the payload location to read the changing position of the payload. This sensor signal is then run through a for loop that directs the motors to correct the rotated motion a proportional amount to the change, stabilizing the payload. There is also a layer of damping material at the base of the robot, which dissipates some of the vibration within the system.

3 Methods

Our system is designed with 3D printing in mind. All major structural components are printed using an extrusion style Davinci Pro 3D printer. The stereolithograph (.stl) files used for printing are created using PTC CREO software.

The active stabilization system relies on four servo motors to counteract the motion of the Minitaur robot. Angular acceleration and force are measured by the system using a gyroscope pair, one at the base of the system and one mounted at the camera. The raw data from the gyroscopes is interpreted by an arduino which controls the servo motors.

Passive stabilization is employed at the base of the system as well as in between the active system and the camera. This helps reduce vibration transmitted by the system.

Due to limited access to the Minitaur robot the prototype stabilization system is tested using a rig that consists of a platform controlled by four servo motor - two bar linkage assemblies. This set up allows us to easily simulate the roll, pitch, yaw, and vertical oscillation generated by the Minitaur's locomotion.

4 Results

Our original design for the the linkages and motor housings had to be changed due to durability and fitment issues. Our current design has solved these issues and is the design that we will use for any future work.

We have succeeded in making our system counteract the angular components of the robot motion. Due to lack of access to the Minitaur and lead times for components of the testing rig we do not know yet to what degree our system is able to compensate.

At this point our system in unable to counteract the oscillatory components of motion.We firmly believe that this is not a fault with our design but rather our code. Countering the oscillations of the robot requires controlling multiple motors simultaneously for each axis. This makes for more complicated coding and lots of calibration as there is some variation between the motors. An additional error in the code as it is currently is that the gyroscope readings have a degree of drift that causes the motors to shift the system slightly even when no motion should be detected. The current fix to the drift in numbers is a hard code removal of the float value reading of the gyroscope.

5 Discussion - Emphasize

The first iteration of 3D printing had a few issues. The initial motor housings were fit too tightly to fit the wiring of the motors and the casings were unnecessarily thick. The rounded ends of the linkages were also not printed accurately enough to properly secure the linkages to the motor housings. Images of the first iteration of 3D printing can be seen in figures 2 and 3.

Figure 2. First iteration of 3D printed linkages.

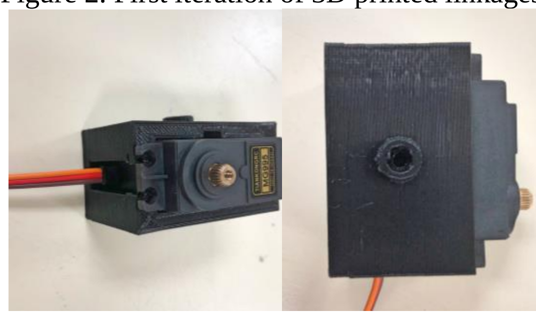

Figure 3. First iteration of 3D printed motor housing.

For the second iteration the thickness of the motor housing walls was reduced and the design was altered to allow space for the motor wiring. Additionally, the linkage ends were redesigned to be square so they would better fit into the pairings on the motor housings. Images of the second iteration of 3D printing can be seen in figure 4.

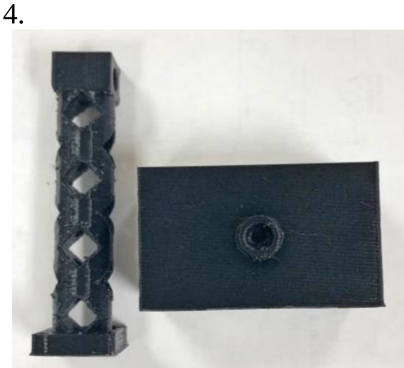

Figure 4. Second iteration of 3D printing.

A third iteration of printing was necessary for the linkages because the diamond shaped cut outs intended to save weight on the linkages caused a weak point where the linkages would fracture during attempted assembly. The orientation of the linkages during printing was also changed to maximize the strength in the direction of force on the linkages. An image of the complete assembly can be seen in figure 5.

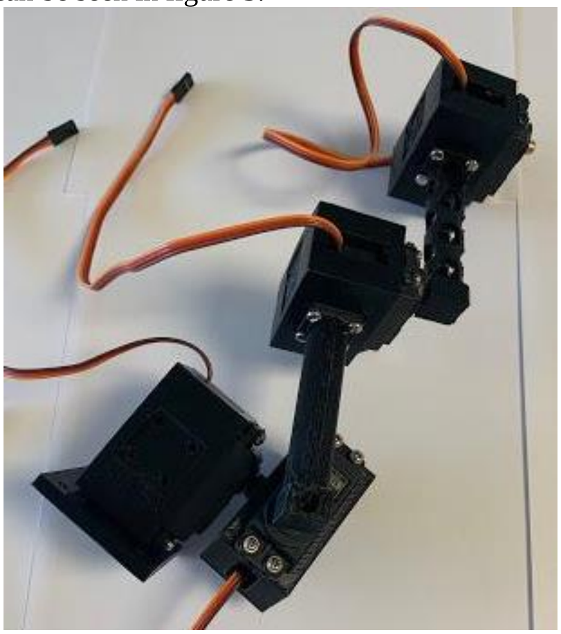

Figure 5. Stabilization system assembly.

A takeaway from this design process was that 3D printing often takes several iterations to produce an accurate and desirable result. It was also determined that shapes with edges (e.g. square vs. circle) generally print better when using extrusion 3D printers. Integration of software and electrical components were also necessary considerations when formulating overall hardware assembly.

6 Conclusion

This paper presents a system that stabilizes the payload of a legged robot. The system is lightweight and effective, stabilizing the payload of a legged robot and reducing the effect of the robots gait on the payload. The stabilization system uses both active and passive damping techniques to control the payloads position and dissipate vibration from the system. Several iterations were required to produce a successful hardware design, and the software utilizes a feedback loop to direct the motors and regulate the motion.

7 Future Work

Future work should involve steps to reduce the weight while improving the durability of the system. Redesign of the structural components could also improve strength and accuracy. The motors could also be reselected to be of necessary torque and speed but of lighter weight. Depending on the desired payload, motors could be significantly optimized. Higher quality damping material could be further introduced to the system to assist in the stabilization. Additional testing should also be conducted. Different legged robot gaits could be tested to evaluate how the system responds under varying motion conditions. Limited access to the Minitaur was granted during the duration of this project and future work could include further testing on the Minitaur.

Acknowledgment

Thank you to our sponsor, Northrop Grumman, for their contributions to the project. We’re grateful for their support of engineering pursuits at FAMU-FSU College of Engineering. Thank you to our advisor, Camilo Ordonez for assisting us through his expertise in robotics.

References

[1] Clapaud Alain.(26 Dec. 2014). Biorobotics: When Robots Imitate Nature. *4ime Revolution*.

[2] Javelosa June.(8 Jan. 2017). More Than Human: Scientist is Building Animal-Like Machines to Save Lives. *Futurism.*

[3] Bonakdarpour B., Kulkarni S.S. (2011) Active Stabilization. In: Défago X., Petit F., Villain V. (eds) Stabilization, Safety, and Security of Distributed Systems. SSS 2011. Lecture Notes in Computer Science, vol 6976.

[4] Collins, S. H., Wisse, M., & Ruina, A. (2001). A Three-Dimensional Passive-Dynamic Walking Robot with Two Legs and Knees. *The International Journal of Robotics Research*, *Volume 20 (*Issue 7), pp. 607-615.