SkateBot: Bipedal Skating Robot Design

Alexander Piedra, Trevor Solorzano, Kishan Kalpoe, Neha Chawla, Sabri Tosunoglu

Department of Mechanical and Materials Engineering
Florida International University
10555 West Flagler Street
Miami, Florida 33174

apied015@fiu.edu, tsolo013@fiu.edu, kkalp001@fiu.edu, nchaw002@fiu.edu, tosun@fiu.edu

ABSTRACT

A bipedal skating robot is designed to maneuver effectively while carrying a light payload. Research on current available technology is performed. Multiple designs are evaluated based on a literature survey. Several parameters are used from an existing design, assisting the construction of a prototype. Experiments including self-balancing and leg control are conducted. Faults with the prototype and improvements for future iterations are discussed.

Keywords

Skate, Balance, Bipedal, Gyro, Servo, Agility, Speed, Logistics.

1. INTRODUCTION

1.1 Problem Definition

Nowadays, many companies are seeking to automate their logistics. The transportation of goods in warehouses is relying more and more on robots rather than humans. Creating an agile robot that can perform a wide assortment of tasks quickly and efficiently, while still maintaining a small footprint, could prove to be very beneficial for many industries including commercial and military applications. Bipedal robots are capable of many tasks, but lack the speed of wheeled systems. Wheeled robots can quickly maneuver environments, but lack the versatility that bipedal robots can provide. Creating an agile, wheeled bipedal robot can improve the productivity of sectors that require robotic technologies.

1.2 Motivation and Benefits

The intent of this project is to create a robot that combines the speed of wheeled robots with the versatility of bipedal robots. Inspiration came from the recently announced “Handle” robot made by Boston Dynamics. Possible uses for this robot include: Handling and transporting loads/objects, assistance in shipping and handling process, application in industrial settings as well as assistance in military settings. The benefits of this robot include: higher energy efficiency, higher mobility, and a smaller footprint compared to traditional legged robots, with a larger range of possible tasks nest to wheeled robotic systems.

1.3 Literature Survey

Multiple ideas and projects were researched and performed on self-balancing robots which include the robots that balance with actual legs and knees and robots that balance using the traditional 2 wheeled system.

A major contributor to the main idea of this report is attributed to the Boston Dynamics Handle robot. Much like the other projects that Boston Dynamics spearheads like the Big Dog, the Atlas, and the Cheetah, Handle is made to do heavy lifting while operating in a lifelike form as a human. Incredibly, the Handle is able to lift 100 lbs. vertically and is able to transport it from one location to the next as long as there are no major obstacles or rough terrain.

Figure 1. Boston Dynamics Handle Robot

We found that there are many commercially available robot kits that can balance on two wheels. These proved to be a major source of information for our research.

Research on the controller of choice led to the necessity of integrating a PID controller to keep the robot upright. PID stands for Proportional, Integral and Derivative, which identifies how the controller reads input via the gyroscopic sensors and how it outputs signal to the servo motors. The Arduino Uno is a capable platform with the ATmega328P microcontroller, which allows for 14 digital input/output pins, 6 of which are capable of PWM output. For the project, this provides us with enough input and output to read all gyroscope and proximity sensors as well as the control of all servos and motors.

The recommended gyroscope is the MPU-6050 six-axis gyro and accelerometer by Motion Tracking Devices. This provides the angular data needed by the microcontroller to balance the robot on two wheels.

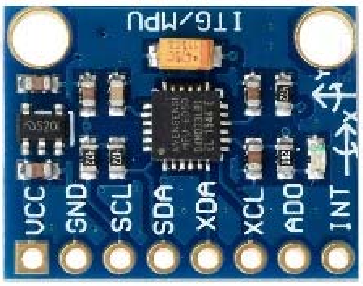

Figure 2. MPU-6050 Six-Axis Gyro+Accelerometer

2. DESIGN

The self-balancing robot (dubbed the “SkateBot”) was designed to balance itself, traverse an environment, and carry a small payload. Ideally the robot will move itself and various payloads from one location to another while being remotely controlled by a user. The inspiration for our robot came from the recently announced “Handle” robot from Boston Dynamics. Our design criteria was loosely based on the Handle’s design. For this project, it was deemed unfeasible to create a fully functional wheeled bipedal robot with functioning arms and a full torso. Because of this, it was chosen to design a wheeled bipedal robot consisting of only two individual legs, wheels as feet, and a small representation of a torso. The design is also simplified with minimal degrees of freedom when compared to the Handle robot as to not overcomplicate the project and to reach completion within our target window.

2.1 First Conceptual Design

Our initial conceptual design consisted of a self-balancing wheelbase with a movable arm mounted on top of it. The wheelbase would be the balancing platform, independent of the moving arm. This way, balancing the robot would be less intensive, as it would utilize an existing, proven design. This was primarily based on the findings from our literature survey and not as much on the “Handle”, which we initially wanted to base our project on.

The arm on top of the base would perform its tasks, while the base would work on balancing the robot. This is a less involved process, as the arm and balancing platform work almost independently of each other. Shifting the weight of the arm would cause the balancing platform to move forward or backward. In short, this is a very easy and doable design.

The drawback of this design was that the robot would be less agile. This design does not use two independent legs, but a base platform instead. This means that the robot would not be able to go upstairs, for example.

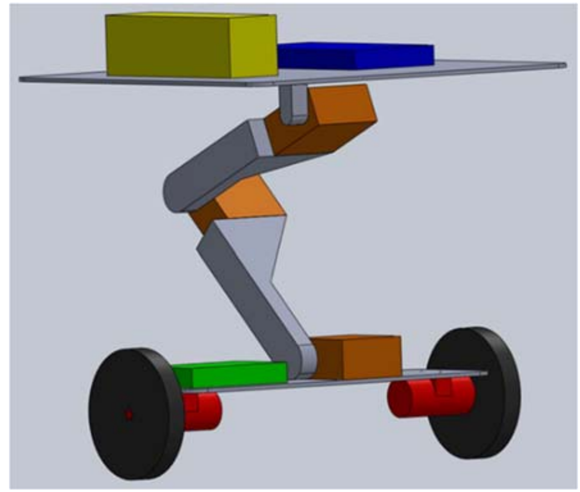

Figure 3. First Concept

2.2 Second Conceptual Design

The alternate conceptual design is more akin to the “Handle” that initially inspired our project. It consists of two independent legs with wheels as feet. A platform is mounted on top of those two legs. It does not have a movable arm. In this design, the movement of the legs and the balancing of the robot itself are not as independent from each other as the initial conceptual design. This concept uses roughly the same components as the previous one with additional servos.

This design offers more maneuverability than the initial design. The independent legs allow the robot to climb stairs for example and give it the ability to lean into corners when at high speeds. To conclude, this design is more complex than the initial concept but offers many advantages by two individual legs. Therefore, it is the design of which our first prototype is based on.

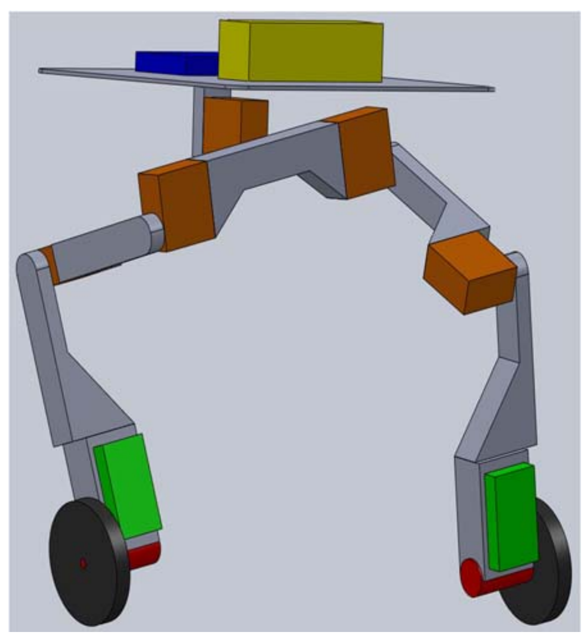

Figure 4. Second Concept with Increased Complexity

3. BASE PLATFORM EXPERIMENT

With our limited experience on many of the aspects required for this project, it was first wanted to familiarize ourselves with the balancing aspect of the drone. To do that, a kit was purchased specifically made to showcase the balancing capabilities of two wheeled robots. This also gave the team the opportunity to get familiar with the components required to complete the project. The base platform consisted of a simple balancing base with two wheels and a hard-mounted platform on top of it.

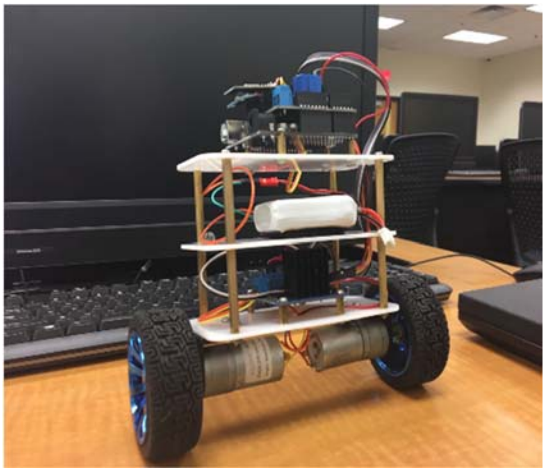

Figure 5. Base Platform

After procurement of the base platform, several tasks were completed towards getting the robot to function as intended and understanding how it works. These tasks include properly connecting the components of the system as well as trouble shooting several of the provided components. By analyzing the provided code, it was possible to understand how the robot functions in terms of balancing.

Once the components, programing, and self-balancing aspects were made familiar with, a greater foresight into the creation of the prototype was achieved.

4. COMPONENTS

The first purchase made for the construction of the prototype was the SainSmart InstaBots, 2-Wheel Self-Balancing Upright Rover Robot Kit. The kit allowed the team to learn about the balance and coding aspects of the conceptual bipedal wheeled robot design that our team built. A quick list of all components included in the set are listed below:

- SainSmart Arudino Uno (x2)
- SainSmart upright rover sensor shield
- ASLONG geared DC motors JGA25-370-12V-400 RPM
- MPU-6050 6 Axis Gyro Accelerometer Module
- SainSmart L298N Dual H Bridge Stepper Motor Driver Controller
- 2.4 GHz controller
- 2 Wheels

All components that were originally a part of the upright rover kit were dismantled and used to create the conceptual bipedal robot. Additional components were bought to make the conceptual design possible. The additional items and components that were purchased to construct the prototype concept robot are listed below:

- Futaba S3004 Servos (x4)
- Turnigy TGY-1501MG High torque servo
- Xbox 360 controller
- SenMod Arduino USB Host Shield
- Microsoft Xbox 360 Wireless Receiver for Windows
- SunFounder PCA9685 16 Ch Servo Driver
- Balsa Wood
- Epoxy Glue mix

Components such as servos had to be purchased to allow for motion in the two legs. An Xbox 360 controller was found to be a good interface for controlling the robot. An interface was required to control the robot using the controller. This necessitated the purchase of the USB host shield. The Servo driver was purchased to power all 5 servos. The balsa wood was used to create the legs and the epoxy glue was used to connect the servo motors and dc motors to the balsa wood pieces.

Table 1. Cost Analysis

Component	Price per Part	Number of Parts	Total Price
Upright Rover Kit	$85.99	1	$85.99
Xbox Controller	$30.00	1	$30.00
Servos (Futaba)	$13.00	4	$52.00
Servo (Turnigy)	$12.00	1	$12.00
SunFounder PCA9685 16 Ch Servo Driver	$11.99	1	$11.99
SenMod Arduino USB HOST Shield	$16.18	1	$16.18
Microsoft Xbox 360 Wireless Receiver for Windows	$17.65	1	$17.65
Balsa Wood	$10	3	$30.00
Epoxy Glue Mix	$9.99	1	$9.99
Total Price			$ 265.80

5. CONTROL

For the first iteration of the SkateBot prototype, a simple but intuitive control scheme was opted to allow the user ease of use and smooth control of the robot. The initial base platform was controlled by an included remote consisting of two analog sticks as well as an LCD screen. The left analog stick was dedicated to controlling forward and backward motion, while the right analog stick would cause an offset between the motors, inducing a right or left turn. Meanwhile, the LCD would output the angle values recorded by the Gyro/Accelerometer as well as the PID values stemming from the potentiometers.

Although this original controller functioned well for the base platform, it was desired to have more control and allow the user to control the legs of the skate bot. Multiple control schemes were considered, including one where the user would press a button activating a crouching routine. With this, the user could toggle between a crouched and straight leg position. While this control scheme is very straight forward, it does not allow individual leg control. A two-button configuration was considered with each button toggling its respective leg between a straight and contracted position. While this two-button configuration allows individual control of the legs, it is still rather binary, solely allowing a crouched and un crouched position.

For these reasons, an Xbox controller was ultimately selected as our controller and with a proper configuration will give the user more control of the crouching motion. The action of the Xbox controller's triggers reads a significant number of steps between pressed and depressed. These steps can allow incremental adjustments to the contracting of each leg. Therefore, the legs can be partially contracted when the trigger is only partially pulled. The left trigger will be dedicated to the contracting level of the left leg while the same effect is mirrored with the right trigger and right leg. This should feel natural and be generally intuitive for most users.

Meanwhile, the Xbox controller's analog sticks would function similarly to the initial base platforms analog sticks. Most other gamepad like controllers would have sufficed, but the Xbox controller was already procured. Also, an LCD was chosen not to be used as it was decided it would not significantly improve the users' control experience without a large amount of resources invested into making the screen more worthwhile. To conclude, this control configuration is intuitive, simple and provides an acceptable range of control for the SkateBot.

To continue, several adjustments to the base platforms Arduino code would have to be implemented to adjust to multiple introduced variables. Due to the center of gravity of the system changing while the legs are contracted, the intensity of the compensation required from the motors to keep the system balanced will need to be dynamic. This requires the PID values to adjust proportionally to the height of the system.

The torso section of the robot will also have to adjust and keep the payload and electronic components leveled when the legs are contracting at different levels. Therefore, the servo controlling the torso must adjust to the crouching offset of the two legs. This will be done by obtaining the difference of the contracting levels of the legs while having the torso servo turning accordingly. In addition, other possible control systems where discussed. An example would be having the code contract one leg while turning at higher speeds. This would automatically have the system lean into corners. While this should overall increase the stability of the SkateBot, it was decided to prioritize other features of the robot and simply allow the user to always control the legs of the system.

6. PROTOTYPE

As stated previously, the team decided to use the second conceptual design as our prototype. It was built simply using balsa and plywood. This was done to minimize cost and allow for rapid construction of the prototype, as wood is very easy to work with.

The electronics consisted of two Arduino Uno boards. One was dedicated to balancing the robot, so it used the sensor shield. The other was dedicated to servo control and the Xbox 360 controller remote interface, so that one used the USB host shield. 5 servos are used throughout the prototype.

One is for tilting the platform side to side. The other four are split amongst both legs and allow the legs to contract and expand. The motor driver was used to power the two motors that drive the wheels the robot stands on. Finally, the servo driver was used to control each of the servos.

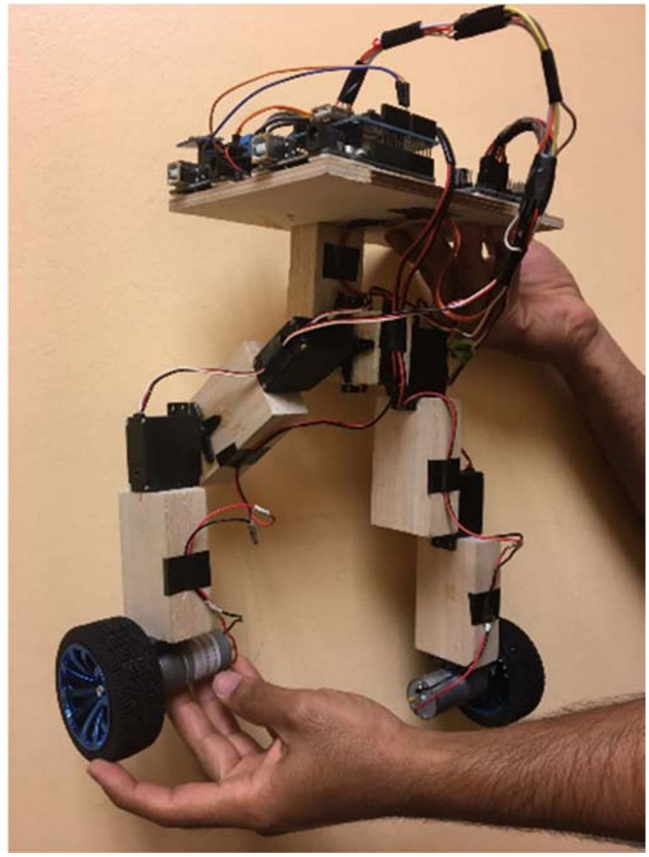

Figure 6: Final Prototype

7. EXPERIMENTS

Once the prototype was constructed, testing commenced. The self-balancing capabilities of the prototype were tested. Since the balancing system was now placed on a new platform, issues could arise. However, no issues were expected, as the balancing system was deemed very capable from the base platform experimentation. The servos were also tested to verify their center positions and maximum deflections. The servos had to move freely without binding on anything or pulling the wires too tightly.

8. RESULTS

The servo driver made it difficult to program the servos. We therefore decided to power the servos through the servo driver, but send the signals to the servos directly from the Arduino, instead of through the driver.

Power issues were encountered when trying to power the entire system using one battery. The motor driver required to be replaced due to damage stemming from this issue. This lead to the use of an 11.1 V lithium polymer battery for powering the DC motors and the two Arduino boards, and another 6 V Nickel Cadmium battery to power the servos.

Additional experiments for remote controlling of the robot, as well as leg control are intended to take place following the addressing of the power issues

9. CONCLUSIONS

A prototype of the lower section of a wheeled bipedal robot was constructed, but after testing, issues with the power delivery system made it unable to function. It is still intended to make this prototype functional. Further testing of the power delivery configuration will be performed once the motor driver has been replaced. Following this, additional developments will be made on controlling of the servos. Factors such as quality, coding, and connectivity of the servos will be researched in the hopes of improving their performance. Advancements with the remote control of the SkateBot are also intended.

For future iterations of the SkateBot, there are multiple adjustments to the electrical components and materials used that can be made. Using solely one micro controller rather than two will reduce the power consumption and redundancy of the electrical components. Using plastic and or 3D printed parts, rather than the wood and glue currently used, will increase the strength and durability of the SkateBot. Additional servos could be added to increase the degrees of freedom as well as the dexterity of the system. Once the SkateBot reaches a commendable level of functionality, additions of a torso as well as arms may be explored.

10. REFERENCES

[1] U. (2016, May 12). 2-Wheel Self Balancing Robot by Using Arduino and MPU6050. Retrieved May 02, 2017, from http://www.instructables.com/id/2-Wheel-Self-Balancing-Robot-by-using-Arduino-and-/, 2016.

[2] SainSmart InstaBots Upright Rover Kit V2.0 Updated 2-Wheel Self-Balancing Robot Kit. (n.d.). Retrieved February 28, 2017, from http://www.sainsmart.com/sainsmart-balancing-robot-kit-v2.html, 2017.

[3] How do I power my Arduino? (2015, September 18). Retrieved April 20, 2017, from http://www.modmypi.com/blog/how-do-i-power-my-arduino, 2017.

[4] Glaser, A. (2017, March 01). Roboticists say Boston Dynamic's new nightmare robot is unlike anything ever seen before. Retrieved March 15, 2017, from https://www.recode.net/2017/3/1/14771330/boston-dynamics-new-nightmare-robot, 2017.