SumoRoll: An Interactive and Intuitive Motion Controlled Spherical Robot

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***Abstract*—Our project aims to create an interactive experience for our players using motion technology. We give players the ability to use their hands as a remote for a Gyrosphere. SumoRoll is controlled using a Leap Motion Controller. The motions a player's hand makes above the controller are translated on a laptop and are then sent to the microcontroller which is then transmitted to the Gyrosphere. SumoRoll will move along with the motions of the players hand exactly, which will create an accurate and user-friendly experience.**

I. Introduction

THE WORLD OF GESTURING technology has been increasingly advancing over the years as it becomes more prevalent in Electronics and the realm of Virtual Reality. Gesture recognition technology can be seen as a way for computers to start to understand human body language, thus building a more important bridge between machines and humans, in comparison to older text user interfaces and graphical user interfaces (GUIs). There are several examples today of where this technology has been implemented. One example is in a technology called RealSense by Intel [2]. The technology in its earliest stages was able to perform simple cursory functions on a computer, like moving the cursor and opening apps using the user's hand motions. RealSense products have since improved significantly to perform depth-sensing in multiple formats and a computer equipped with it is able to sense the environment around them using true stereoscopic 1080p video. Gesturing technology is also prevalent in the gaming universe, the most recognized system being the Kinect Sensor that pairs with Xbox consoles. The technology here differs from others because it reads the motions of the player's entire body and translates to the video game accordingly. Lastly, in the world of Virtual Reality there has been an addition of hand tracking to many operations; whether gaming, educational, or other entertainment in order to make the experience more realistic for the user.

Doing research in all these technologies made us realize there was one particular similarity; more often than not, the gesture recognition technology was being used to control a digital output, whether that be in a game on a screen, an app in virtual reality or controlling a computer screens with gestures. Of course, all of these uses of the technology are vital in their own merit and they have significantly impacted the space of gesture recognition and its uses, but we want to use gesture recognition a little differently. We want to create a product that is able to use motioning technology to control a physical, mechanical object. The concept isn't unheard of, but we want to implement it in an entertainment scope. We believe using the intuitive nature of gesture/motion technology we can make a small spherical robot that can be controlled by the motions of a user's hands in the environment of a two player game. The hopes and aims of our project is to use gesturing technology (which has proven itself to be more versatile than remote controls) to create an interactive experience for our users. An experience that will hopefully open the doors to more mechanical, gesture driven technology; whether it be for entertainment or for more practical everyday purposes.

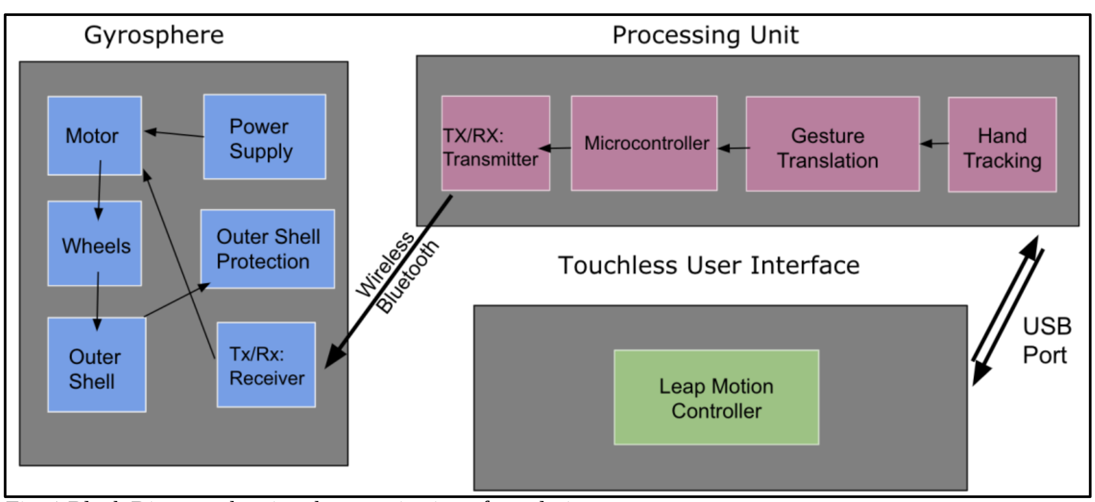

Fig. 1 Block Diagram showing the organization of our design

II. DESIGN

A. Overview

Our design project, named SumoRoll, compromises of two motion controlled robotic gyrospheres. Each gyrosphere is controlled by a single player using a leap motion controller and the object of the game is to control your spherical robot to attack the opposing player's, the first to knock their rivals out of the arena, wins. The idea is simple, but strategy is involved when considering how to most quickly and easily defeat the other player. The key to winning is to build up the speed of your gyrosphere and come in from the correct angle to have the most impact.

The Leap Motion Controller and gyrosphere, connected by wireless Bluetooth connection, make up the main components of our system. The gyrosphere contains two motors, two wheels, a battery power supply, a printed circuit board with Bluetooth receiver, an outer shell, and a rubber shell coating to protect and buffer the gyrosphere against collision. The motor will be given enough power to achieve the specified speed for gyrosphere, roughly 3 mph. The overall structure of the gyrosphere, excluding the electronic components, will be designed for 3D printing. Through elaborate design and careful selection of components and 3D printing materials, the gyrosphere should weigh less than 2 lb and be around the size of a tennis ball. The Leap Motion Controller is less than 1 lb, and is smaller than a typical cell phone. Portability is achieved through these specifications.

The Leap Motion Controller, connected to and powered by a laptop via USB 3.0 port, detects the hand motion of players by using three infrared LEDs and two cameras. The controller is able to capture motion within the range of a 2 ft radius obtuse half-sphere above the device, which satisfied the range specification. The image data is streamed to a computer and is processed by a motion processing software called Leap Motion Service. The image data is matched with programmed gesture information. The result is sent to a microcontroller which sends the command corresponding to the detected gesture to the Bluetooth receiver in the gyrosphere.

Upon receiving data via Bluetooth, the data is processed by the pcb which sends signals to the motors which allows the motors to work in the desired direction, which depends on what command the gesture corresponds with. This chain of events can be seen illustrated in our block diagram (Figure 1).

One design alternative is to use a camera to detect hand motions instead of using Leap Motion Controller. By using different colored tags on each fingers, different command can be programmed by using the combination of colored tags. The use of camera for image processing is utilized in the Sixth Sense, a wearable system developed by MIT Media Lab. The Sixth Sense uses a pocket projector to project images to a surface in front of the user, then allows the user to give command or interact with projected image by using a small camera to capture gestures. We chose the Leap Motion Controller over camera with the consideration of delay and accuracy. Also, using the camera would make our system more complex and we would need to write more code compared to using a Leap Motion Controller.

TABLE I
List of System Requirements and Specifications

System Requirements	**System Specifications**
Portable System	Should be lightweight, full system weighing ~3 lbs
Forwards, Reverse, and Rotational Movement	Two motors on either side of gyrosphere to ensure full movement
System Latency	Command response of ~250ms from User to gyrosphere
System Speed	Gyrosphere should move at around pedestrian speed, which is about 3 mph
System Functionality	Full System should run for at least 30 minutes to ensure quality gameplay Gyrosphere should stop 1 second after stop button is pressed
System Protection	Outer Rubber coating on gyrosphere

B. Touchless User Interface

A major subsystem of the project is concerned with receiving user inputs and processing according to it, so the device chosen should be able to track user's hand motions during system operations. This is why we chose the Leap Motion Controller. The Leap Motion Controller sensor will be placed in terms of user's perspective (facing forward of the user) to ensure easy control and avoid incorrect input commands. The touchless user interface includes both software and hardware components. For the hardware components, we require two Leap Motion Controllers for playing the fighting game simulation. Each Leap Motion controller is a 3 x 1.2 x 0.5 inches in dimension and feels no heavier than a standard USB drive . The major component of the device consists of two cameras and three Infrared LEDs. The LEDs generate pattern-less IR light and the cameras generate almost 200 frames per second of reflected data . They work to track infrared light with a wavelength of 850 nm. The sensor has a wide-angle lens which allows the device to have a great interaction area, which is 2 feet in radius obtuse hemispherical in front of the sensor . To setup the device, it is connected to a laptop via USB cable 3.0. It is compatible with any Mac or Windows with at least 2GB of RAM and an AMD Phenom II or Intel core i3, i5, i7 processor. It is powered by the laptop during operation. We will consider making the device portable in the future by connecting it to a power source and smaller processing unit. After the device is configured and setup with the laptop, we can move on to the software component of the system. With Orion software and SDK downloaded and install from the official website, we can now install applications and do testing with the leap motion sensors.

Fig. 2 Inner Parts of Leap Motion Controller

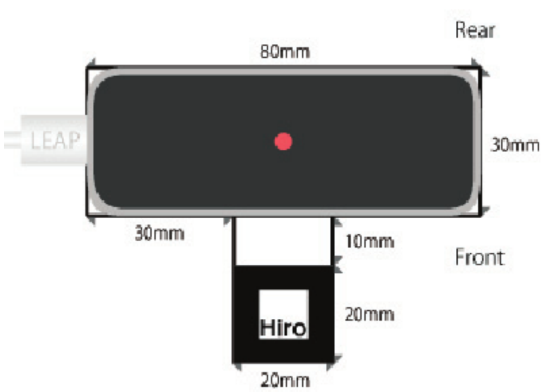

Fig. 3 Dimensions of Leap Motion Controller

Experiments have been conducted for testing the actual interaction area, latency, focus pointer and etc. The device has to be oriented to detect motions in front of the user instead of facing upward on the table due to our game strategy. The device successfully capture user hand motions in Euclidean (xyz) positions with accuracy and minimal delays. A hand model is used by the software to project hand gestures into the software, therefore minor hand characteristics are ignored.

Overall the device is quick, lightweight, and meets our expectations. The are few cases when it becomes difficult to focus the pointer and the Leap Motion can lose tracking for a period of time; however, it should not be enough to disrupt gameplay. Some applications we use for testing included Cat Explorer and Paint. More experiments will be conducted to ensure it meet our specification.

The core mission the this subsystem is the integration of hand gesture and control of the Gyrosphere. A program in java script will be written and used to create a connection between Leap Motion Controller and controlling the Gyrosphere.

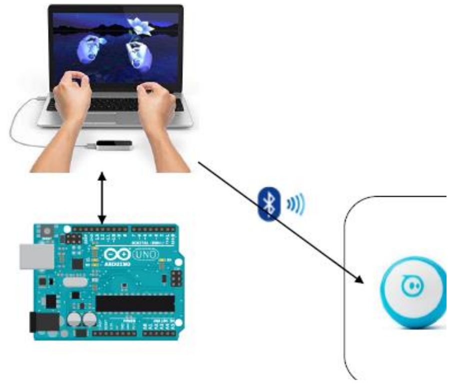

Fig. 4 System topology of SumoRoll

The overall system topology is to translate hand gestures into a series of commands and have it delivered to the Gyrosphere for execution. As the leap motion controller is connected to the laptop which tracks user’s hand gestures, the laptop then connects to the Gyrosphere via Bluetooth. We would like to control the Gyrosphere directly using laptop keyboards, then we will match specific hand gestures to different keys, thus translate the hand gesture into commands that transmit to the Gyrosphere.

Using the product Sphero, a small programmable gyrosphere, we are able to program the gyrosphere and control its movement via Bluetooth and laptop, we aim to transfer the code to the fabricated design after our Gyrosphere is built. We are also working on writing the javascript program for hand gesture translation. The design will based on the open source of using Leap motion controller to control sphero.

C. Bluetooth Data Transmission and Receive

The Tx and Rx block will be the connection between the hand gesture to the gyrosphere. The leap motion controller will collects the data from the hand motion and send this data to the gyrosphere through the bluetooth. Bluetooth is a type of wireless communication used to transmit data at high speed using radio waves. To establish this connection we decided to use the HC-05 bluetooth module as our main component.

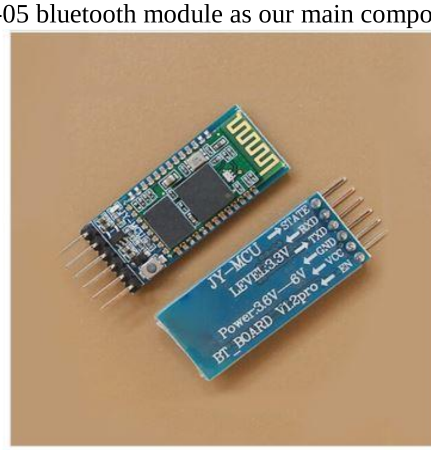

Fig 5. HC-05 Bluetooth Module

The Bluetooth module has a range of around 100 meters at a transmit power of 1 m watt and data transfer rate of 3 Mbps, also it has the ability to establish communications between many different types of devices, including mobile phones, computers and other electronics [1]. The Bluetooth transmits and receives at a frequency band of 2.4 GHz. The Bluetooth device uses a IEEE 802 standards wherein the connections can be point-to-point or point-to-multipoint. The default baud rate is 38400 and other supported baud rates are 9600, 19200, 57600, 115200, 230400 and 460800 [1]. Bluetooth can connect up to 8 devices simultaneously. It uses the spread spectrum technology in which each device uses different frequency band and hence the devices do not transmit at same time. When the two devices come in range with each other, the transmission takes place between them. However, in this project there will only be using one Bluetooth HC-05 module connecting to two different devices. One from a smart device (i.e. laptop or phone) connecting to our bluetooth HC-05 module in our gyrosphere.

There are three types of connections in Bluetooth, single slave, multi slave or scatter net. Multiple Bluetooth devices from a piconet network [1]. A piconet consists of one hub device along with seven client devices, and a piconet network is a wireless personal area network [1]. In order to transmit or receive information with the client it should be in active mode. In a scatter net , the time and frequency of the two piconets are not synchronized [1]. Each of them operates in its own frequency band, multiple piconets can work simultaneously using frequency division multiplexing.

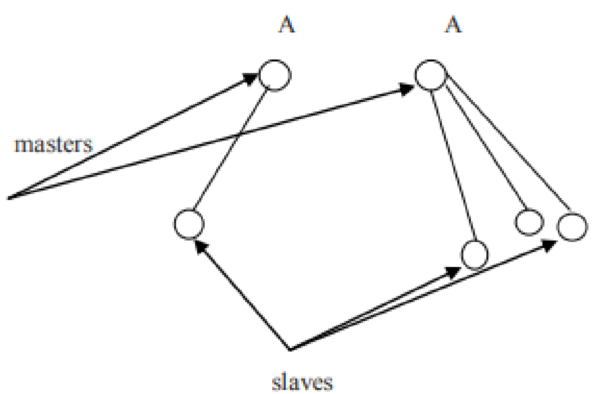

Fig. 6 Bluetooth Network Topology

HC-05 Bluetooth can be easily interfaced with Arduino mega board, which has been demonstrated in our MDR Demonstration of an Android device controlling two motor using Arduino and HC-05 Bluetooth module.

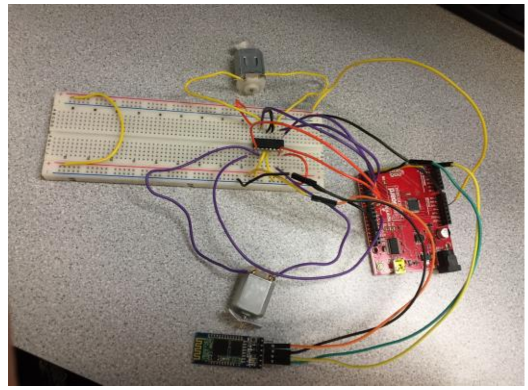

Fig. 7 Controlling two Motors Using HC-05 Bluetooth module

The Arduino was coded to the L293D Motor Driver, which is connected to two motors. The Android mobile device was paired up with the HC-05 Bluetooth module and it sent commands to the Motor Driver via Bluetooth signal. By sending the data from the mobile device to the Android through the Bluetooth module, the motors are successfully controlled. The result showed the connection from mobile device to the motor was successfully made by using the Bluetooth module. Therefore by replacing the data from mobile device with the data from the leap motion controller, then the direction of the gyrosphere will be under our control.

D. Structural Design

We would like to have our own gyrosphere, therefore we need to come up with our own idea of the structure design for the gyrosphere. Before we started the design of our own gyrosphere, we did some research on any similar project that are open sourced. We were able to find several projects that made larger gyrospheres than we had in mind for our design, however, we were able to draw inspiration from these other project to make in our own design.

Fig. 8 Inside structure of a BB 8 sphero toy

This is the inside structure of a small BB 8 Sphero Toy. It has magnet and two roller on top, two wheels and center of mass at the bottom. This toy is very close to what we have in our mind, so we begin our design with inspiration of this structure.

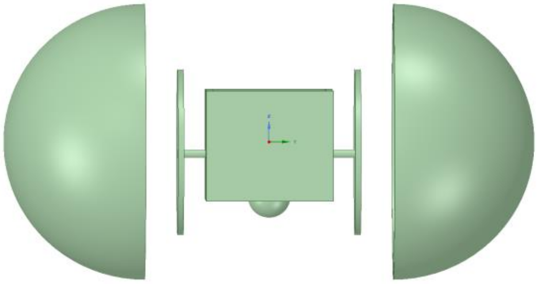

Fig. 9 Overall view of the structure design

Instead of having a circular structure inside, we would like it to be a cube. This cube is 4in*4in*4in, it will have two shafts coming out on either side of the cube that are connecting the wheels and motor. The outer sphere has a radius of 4in. There will be a solid roller on the bottom of inner cube to serve as the center of mass. The center of mass will help to prevent the cube structure from rolling, and the structure will have no contact to the outer sphere. The outer sphere will be covered with a rubber coating to ensure protection of the sphere during collision and also help there to be a rebound effect.

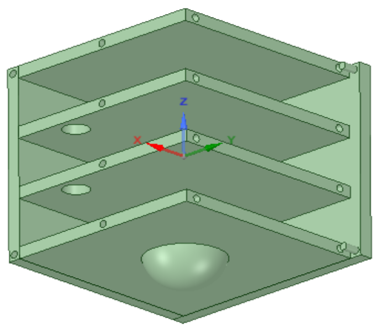

Fig. 10 Inside structure design of the cube

This is the inside view of the cube structure, each plane and wall will be 4in by 4in with a thickness of 0.25in. There will be three level of the structure, and each level will be in different use. The highest level will be the control center, where the arduino or PCB will be, also there is a hole on the plane to provide any wire connection. The second level is where the driving system will be placed, it will have motors and any gearboxes mounted and connected to a shaft to the wheel. The lowest level is for the power supplies, it will provide some weight to the structure and serve as additional support for the center of mass.

The structural design is completed, now all we need to do is to 3D print and assemble the structure in order to test it. We will make any necessary structural change before CDR to make the final Gyrosphere structure stable.

E. Motor Driver

The Motor Driver chip we used in our MDR Demonstration of our Project was L293D. The motor driver acted as an interface between our motors and microcontroller. For our project we used the Arduino SparkFun RedBoard to program the L293D to control our two motors simultaneously as we see fit.

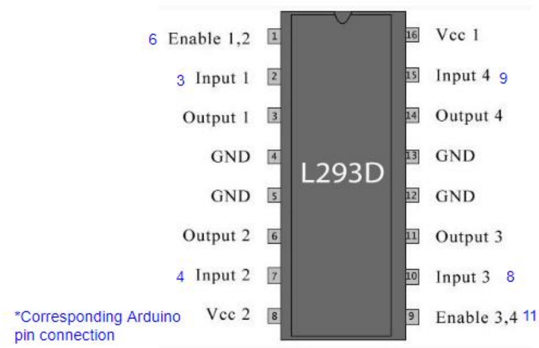

Fig. 11 Pin Connections

The Enable pins on each side of the motor driver work to turn on the corresponding side of the chip. This means when one enable is on HIGH than the corresponding motor on that side will be able to receive given commands. The Input pins are used to make current flow through the output, when it is in HIGH

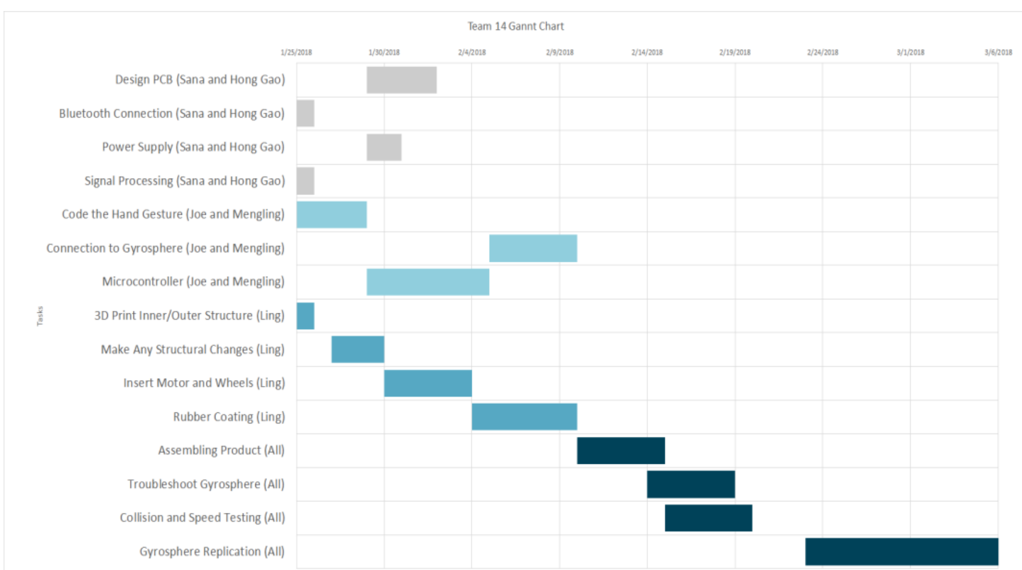

Fig. 12 GANNT Chart

state on Arduino. The two output pins are connected to either ends of the motor and depending on which Input pin (1/2 , 3/4) is set HIGH it will send current in a one output or another, dictating the direction of the wheel. When both Input 1 and 4 are HIGH the motors spin forward. When the Input pins 2 and 3 are high the motors spin in reverse. Pin 8 or VCC 2 is the voltage supplied to the motors and Pin 16 or VCC 1 is the power source to the IC, which is set to be 5V. We also supplied our motors with 5V.

III. Project Management

TABLE II
PROPOSED MDR DELIVERABLES

MDR Goal	**Status**
We want to be able to have gesture recognition coded using one leap motion controller that we have purchased and have it connect to a mechanical output (not necessarily the gyrosphere, perhaps a RC car). We plan to use open-source code to start developing our gesture recognition code.	Almost there
Will test signal transmission and motors using Arduino and be able to send Signals via bluetooth to control the set of motors. We plan to use existing motors from M5, as well as Arduinos from M5 to do our testing	Done
Design Outer and Inner structure of gyrosphere, to be 3D printed	Done

Our Gannt Chart (Figure 12), shows the future plans of our design project and where each team member will focus their time. It is apparent that we have taken into consideration of the majors of each our members and assigned them tasks according to their level of expertise in the matter; however, there are also tasks that we will all take part in in an effort to understand all aspects of our design project.

IV. Conclusion

We made good progress on three main parts of our system: the setup and programming with Leap Motion Controller, the overall design of the gyrosphere, and the wireless Bluetooth module involving a microcontroller, two motors, and a Bluetooth device that sends direction commands to the microcontroller which make motors to turn in the desired direction. These accomplishments allows us to make a step closer to the full prototype of our designed system.

Going forward, we would like to focus on establishing stable connection between the three parts that we have been working on. The Bluetooth module will be integrated into the gyrosphere structure, allowing connection between the gyrosphere and the Leap Motion Controller.

We expect the most difficulties in integrating the completed parts because if the system is not working, it is hard to determine which part of the design is flawed. Our solution to this problem is to test individual parts before integration to make sure their functionalities are met with our expectations.

Once we have successfully built a functioning gyrosphere that responds to gesture commands by the time of CDR, we can move forward to building the second gyrosphere and aim to improve on the functionalities on that gyrosphere.

Acknowledgment

We would like to thank our advisor, Professor Janaswamy, for his insight and advice throughout the semester on our project. He helped us to think critically about the decisions we made and kept us moving forward with our design. We would also like to thank our faculty evaluators, Professor Hollot and Professor Leonard, for advising us on our design and management of our project. Also, we want to thank the staff at M5 for providing us with supplies for our project. We truly appreciate the time and support of all these people.

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[2] https://www.intel.com/content/www/us/en/architecture-and-technology/realsense-overview.html