**IoT Vision**

**Version 1.0**

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**Introduction**

Biology has inspired engineers to create many engineered systems such as jellyfish inspired water robots, burdock burr inspired Velcro, and water filters inspired by membrane proteins. Human anatomy also inspires many inventions such as neural networks, robotic arms, and acoustic systems. One part of human anatomy that allows them to do so much in the world is their ability to see it. Humans are able to see and perceive their world almost exclusively using input from their eyes. It allows them to catch objects such as a baseball, avoid collisions from incoming objects such as cars, and judge the distance to objects. Many robots existing today are able to take in inputs such as infrared and some video and process them into outputs. Algorithms exist to calculate many features that our eyes are able to calculate. So far, very little research has been done on applying those techniques to existing robots. That is where this project comes in.

The goal of this project is design a system which will give a robot the ability to perceive its environment in a three dimensional world and use that data to make decisions. The only data the system will have available to process will be image/video feed(s). Image processing algorithms will be used to recreate the environment in three dimensions. Once the three dimensional world has been created, a physics engine will be used to help the robot make decisions. The robot will internally simulate an appropriate amount of decisions and use that data to make the best decision. The decision that will be tested in this project is moving cue balls to their appropriate place on a pool table after a computer simulation. Pre-determined physics using known values will be used for the cue ball, and dimensions of the pool table. If time allows, additional work will be done to use additional sensors to allow the robot to perceive that data itself without already knowing those values. Additionally the system will use Wi-Fi communication to transmit data between the robot and image processing system.

**Acronyms Used in this Document**

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| Acronym | Expanded | Definition |
| CV | Computer Vision | Methods for acquiring, processing, analyzing, and understanding images and, in general, high-dimensional data from the real world in order to produce numerical or symbolic information |
| GUI | Graphical User Interface | A human computer interface which uses windows, icons, buttons, etc. to allow the user to interact with a computer. |
| IoT | Internet of Things | A network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment. |
| GPIO | General Purpose Input/Output | Pins used by an embedded system whose status can be controlled with code. |
| USB | Universal Serial Bus | An industry standard developed in the mid-1990s that defines the cables, connectors and communications protocols used in a bus for connection, communication, and power supply between computers and electronic devices. |
| FPS | Frames Per Second | The number of images a video capture system is able to capture in one second. |
| MP | Mega Pixels | A unit of graphic resolution equivalent to one million or (strictly) 1,048,576 (220) pixels. |
| Wi-Fi | Wireless Fidelity | A facility allowing computers, smartphones, or other devices to connect to the Internet or communicate with one another wirelessly within a particular area. |
| HDMI | High Definition Multimedia Interface | A standard for connecting high-definition video devices. |

**Design Requirements**

**System Design**

1. The system must consist of at least one robot, a cue ball, at least one camera, and a device capable of running a Unity application and scripts.
2. The system must be able to send the robot coordinates
3. The robot must be able to receive those coordinates and move a cue ball to a specified location.
4. The system must be able to simulate possible actions for the robot to take using a physics engine.
5. The robot must be able to complete the task without outside assistance of any kind.

**Hardware Design**

1. Robot
   1. The robot for the project will be using a Raspberry Pi as the platform.
      1. The robot will be able to run using the Raspberry Pi 2
      2. The robot will be able to run using the Raspberry Pi B+
   2. The robot will use two DC gear motors to provide transportation for the robot.
      1. The DC gear motors will be able to move a cue ball which has an average weight of 156-170 grams.
   3. The robot will use a battery pack lasting at least 1 hour for power.
      1. Additional weight requirements or the battery pack will be added as needed.
   4. The robot will use a custom 3d printed body with features that are distinguishable by a camera.
      1. The body will take into consideration the inputs and outputs of the Raspberry Pi to allow them to be used.
      2. The body will have proper ventilation to prevent overheating.
      3. The body will have properly marked features to allow camera to process direction.
   5. The robot will have Wi-Fi capabilities allowing it to send and receive data over wifi.
      1. The Wi-Fi being used will be a USB dongle the plugs into one of the USB ports on the Raspberry Pi.
2. Camera/Image Processing
   1. The Camera will be a USB web camera capable of taking 5MP images and 720p 30fps video.
   2. The camera will be mounted above the test area and able to capture entire area.
   3. The camera will be set to a pre-calculated height and angle above the project area.

**Software Design**

1. Application
   1. The application will be able to take in a text file input of three dimensional coordinates.
   2. The application will have three dimensional modeling capabilities.
   3. The application will have a physics engine built in.
      1. The physics engine will be able to calculate weights and distances of objects as well as gravity and friction.
   4. The application will be able to display created environment to user.
      1. The environment will be displayed through an HDMI monitor.
   5. The application will have a GUI which allows the user to customize settings.
2. Camera/Image Processing

2.1 The image processing will be done using a pre created image processing library.

2.2 The image processing will be done using Python.

2.3 Image processing will be done using a combination of existing and new image processing libraries in Python.

3. Robot

3.1 The robot will use the Raspbian Linux platform.

3.1.1 The newest image of the platform will be used and supported up until the projects end.

3.2 The robot will use python to control its GPIO.

3.3 The robot will have the ability to send and receive data through Wi-Fi.

3.3.1 The robot will use a USB dongle to achieve Wi-Fi connectivity.

**Testing Requirements**

**Hardware Testing**

1. Robot
   1. The amount of weight that the robot can push forward will be tested.
   2. The maximum speed of the robot will be tested.
   3. The robot’s rotation angle will be tested to meet 90 degrees +- 1 degree.
   4. The battery life will be tested to last over 1 hour.
2. Camera/Image Processing

2.1 The height of the camera will be tested.

2.2 The angle of the camera will be tested.

2.3 The field of view of the camera at the height and angle will be tested.

2.4 The resolution of the camera will be tested.

**Software Testing**

1. Application
   1. The application will be tested to display the coordinates received in a text file.
   2. The physics of the application will be tested.
   3. All GUI elements will be tested to ensure correct functionality.
2. Camera/Image Processing

2.1 The connection of the camera will be tested.

2.2 The time delay of the video feed will be tested.

2.3 The accuracy of the text file coordinates will be tested.

2.4 The Wi-Fi connection and speed will be tested.

1. Robot

3.3 The response time of the robot will be tested.

3.4 Each of the commands the robot can use will be tested.

3.5 A test will be developed to test the coordinates being received by the robot.

3.4 The Wi-Fi connection and speed will be tested.

**Summary**

The requirements set out in this document will allow us to build a system which allows a robot to make decisions using computer vision. Many of the requirements are loose to allow us the freedom of picking the best option to our desired outcome. As our project evolves, we will update the requirements to meet our needs. We will take great care to update the requirements without compromising the integrity of our project.

Successful completion of this project will prove that a three dimensional environment can be mapped using only image/video input. This has many applications in robotics. Anything from aviation to medical robots would be able to use this system to map their environments, and perform useful decisions based upon it. Many improvements will need to be made to our system to maximize its effectiveness.

Many technological improvements can be made to our design to improve its effectiveness. These improvements include using neural networks to learn how to collect data and make decisions faster, faster processors to make more accurate decisions, and additional sensor to improve decision making. Neural networks are systems that follow a similar model to human neurons. They can be used to create systems which make a trained educated guess to an output given a set of inputs. Neural networks are able to learn how to react to inputs by continuously updating their algorithms. This also helps them make faster decision because they already have a good idea of what the expected output should be. Faster processors will decrease latency between data transferring. This means that the robot will be able to make more simulations of decisions faster, increasing its effectiveness. Additional sensors such as infrared and GPS sensors can help the robot collect more data allowing it to make more accurate decisions. For example, a force sensor can tell the robot exactly how heavy an object is. That would allow it to make decisions on if it could move the object, the best way to move the object, etc.

**This document describes all project requirements set forth by the advisor and/or client. Grading will be performed at the end of the semester according to the level at which these requirements are met.**

***Advisor Signatures***

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