PROJECT AMBULARE

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1. Introduction

1.1 Objective

Virtual Reality (VR) has become increasingly popular recently thanks to its ability to immerse users in an experience. Within VR technology, the term *room scale* refers to the size of the play area that the user can move in and still have their movement conveyed in the VR world. Reasonably there's a limit to how big a play area can be, often meaning that the user moves around in the world with the use of a controller. To address this, various treadmill solutions have been proposed [1], but these systems still take up too much space in our opinion and are too costly for the public.

What we are proposing is an affordable device that both recreates the ability to "walk" in a VR world without needing a spacious play area, and can be quickly setup, torn-down, and stored. When wearing this device, the user can walk in place and their “movements” will be translated into relative movement in the VR world. The device in question will be a soft elastic band worn around the knee equipped with an EMG and IR emitters to measure muscle activity, relative location, and direction. Lightweight software will run on the user’s computer and translate this sensor data into movement of variable speed, rotation, and direction (forwards/backwards).

The avatar's body should turn according to the user's leg position and not be dependent on their head movement, though this capability needs to be supported by the VR application. As of now we are planning to use a camera to track IR emitters on the knee band. Another option would be to have a "slide in" slot for the user's cellphone, as we believe for leg tracking we don't need true 6 DOF; the leg will only rotate in place with 360 degrees and not necessarily "tilt" in space. Furthermore, we do not know of common leg animations that use 6 DOF.

Since our device would need to be portable and comfortable, it will be powered by AA batteries with variable resistors for different parts of the circuit. Optional add-ons to improve the walking experience can be a temperature variable mat for the user to walk on depending on the world they are in, and a fan/heater system to blow cool/hot air to the user's feet from the correspond direction. These are not crucial to what we are trying to make, but they would enhance the experience overall.

1.2 Background

Various attempts from the industry to address walking problems in VR have been made through a treadmill approach, and most of them are not yet available for purchase by the public. A few notable mentions are Virtuix Omi, Vue VR Treadmill, and Kat Walk. Although these products promise realistic walking experience utilizing the treadmills, they all share the same problems of size and pricing. Not only do they take up a lot of space to set up and store, they also cost at least as much as a new VR headset (roughly $700) [2][3].

Our product aims to create a realistic-feeling experience while taking cost into highest consideration. We want to provide VR users with this device as an optional add-on as the requirement for VR is already an investment. Though we are confident our product will take VR to the next level. If our product does what we set out to do – sufficiently complementing while not taking away from the experience – then we have succeeded.

1.3 High-level requirements list:

- The device must be easy to wear and take off while providing comfort for the users. This requirement also needs to address power delivery as it directly relates to the weight of the device.
- The device should operate within a margin of error to reproduce walking forwards and backwards in 360 degrees and at a few different speeds at an acceptable lag.
- The device should be affordable to most users, possibly within the $99 range.

2. Design

Ambulare requires a power supply, a WiFi module, and a sensor system to operate. The power supply provides power to different part of the systems, namely the sensors and WiFi module. The WiFi module sends the muscle activity measurements to the computer via standard IEEE 802.11b/g/n/ac network. The sensor system consists of various electrodes as part of an EMG that will measure the electricity between neuron transmission which can be translated into relative speed on the computer. All of these modules should be portable and be housed on an elastic knee band.

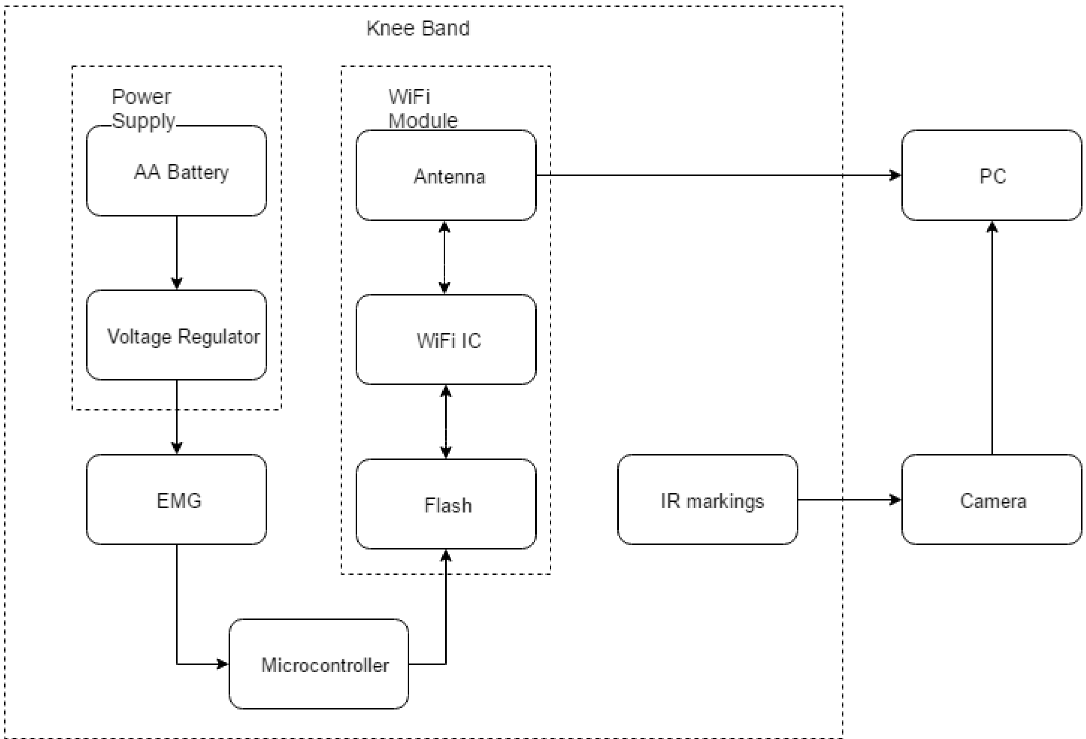

Figure 1. Block Diagram

2.1 Power Supply

The power module will provide power for the WiFi module as well as the sensors for the EMG circuits and the IR LEDs.

2.1.1 AA Battery

AA batteries are chosen because of how common and safe they are. More measurements will be needed to assess the power consumption necessary for our circuit, but based on previous EMG experience, our batteries are expected to last up to at least 6 months.

2.1.2 Voltage Regulator

The voltage regulator will be variable to provide different voltages for different parts of the system. On estimate the EMG sensors will need ~9V while the WiFi module will only consume ~800 µA at idle.

2.2 WiFi Module

Collected measurements from EMG sensors will be sent to the computer via WiFi network.

2.2.1 Antenna

Due to WiFi saturation, perhaps a 5GHz channel antenna is desired as it will help provide a better signal, crucial to minimizing the delay with our EMG signal transmission. Users will have no reason to play far away from their computer with Ambulare, so the shorter range of 5GHz channels is not an issue. since

2.2.2 WiFi IC

We are considering the WL1801MOD module because of its excellent low power consumption and better range than single antenna. It also supports Bluetooth which is something we will have in mind in case we decide to change the communication method. While relatively expensive, we believe the transmission module is crucial to the design overall and should provide little to no delay of measurements.

2.2.3 Flash

The measurements from the EMG sensors reside here, then are sent via WiFi to the computer.

2.3 Knee Band

An enclosing case is needed to house the EMG circuits as well as IR emitters for the camera's tracking. The band should be made out of elastic material and allowed breathing to provide comfort to the users.

2.3.1 EMG

The EMG circuits consist of various sensors to measure muscle activities when the user walks in place and pass it through the microcontroller to send it to the computer. This circuit should be designed while keeping the knee band in mind so that the electrode can be directly attached to it and not require dangling wires.

2.3.2 IR Emitters

IR emitters will be placed on various location on the knee band to provide reference tracking for the camera to read and interpret.

2.4 Microcontroller

We are considering the CC3100 chip because it has low power consumption with plenty of host interfaces and integrated WiFi on chip. We will need to conduct more measurements, but if this chip or another within this family can provide the required specs then we won't need the antenna module and can essentially downsize the knee band's design.

2.5 Camera

The camera is used to track the legs' movement via IR markings. We are currently discussing whether or not to use a separate camera module or implement the function via an open SDK like Oculus. Doing so will cut the cost of the product and allow a more streamlined process.

2.6 Risk Analysis

The WiFi module is one of the crucial parts of this project. It needs to transmit the EMG measurement with a maximum delay of 11.1ms to achieve a smooth 90 frame per second (FPS), according to VR best practices [4]. While it doesn't need an extensive range as the users are likely to use the device near their computers, the signal should not be dropped at any point in time because it will cause motion sickness and nausea due to losing sense of direction. Since we are considering using a system on chip for both the WiFi module and Microcontroller, we need to do further analysis to see which one provides better performance while taking cost into consideration.

Besides minimizing the delay through signal transmission, the motion tracking module is also a critical part to the project as it will directly reflect the user's movement and can cause similar motion sickness. Our current approach considers using IR emitters on the knee band to track the legs' movements via camera. We will also consider other alternatives for tracking such as a capacitive mattress, using the user's phone for its sensors, or computer vision recognition.

3. Safety and Ethics

There are a few safety issues that we must address in our product. The first concern is the power supply. We need to make sure the product is safe for use by thoroughly testing the power supply and the corresponding protection methods we can use.

Another safety concern that we came up with right now is the usage of the EMG sensors. Since we are using the EMG sensors for recording the electrical activity of the muscle, we need to make sure that it won't have any side effects at any point in the user's range of motion.

From the ethic aspects, we will strictly follow the IEEE Code of Ethics. In order to follow rule #1 [5], we need to take good care of the user's knee, and make it our first concern. Since our product might need to track the muscle traction on the knee, we need to reduce the risk of causing any uncomfortable feeling or damage to the knee to reasonable levels.

We can also apply rule #5 [5] during our design process by providing documentation and warning labels regarding the proper use of our wearable product. We are responsible for providing correct and safe correct usage instructions, as well as warning for all possible consequences of using the product.

References

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[4] O. VR, "Introduction to best practices," 2016. [Online]. Available: https://developer3.oculus.com/documentation/intro-vr/latest/concepts/bp_intro/. Accessed: Feb. 9, 2017.

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