Iron Man's Gauntlet: An Accelerometer Based Lighting Control Device

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Abstract
We have implemented a gesture controlled lighting system. The gestures are read with the help of a wearable device which we are calling as the "Iron Man's Gauntlet" [1]. Our project consists of operating a light system consisting of strips of programmable RGB LED lights. The gesture vocabulary consists of waves and motions made with the palm. These gestures are recognized with the help of an accelerometer and the associated circuitry inside the Iron Man's Gauntlet. The "Laser Repulsor"[2] in the palms is used to convey feedback to the user. With the help of the gestures, we can turn the lights on and off, and control the brightness of the LED strip

Author Keywords
Gestures; Accelerometer; Photon; Hidden Markov Model; Gauntlet;

ACM Classification Keywords
H.5.m. Information interfaces and: Miscellaneous;
H.1.2 User and Machine Systems: Human Factors.

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[1] http://img11.deviantart.net/92c7/i/2013/250/c/8/iron_man_gauntlet_by_missnatsume-d6les3n.jpg
[2] http://www.filmfad.com/wp-content/uploads/2014/09/iron_man_3-e1410372056161.jpg

Introduction

The past and current trends in the industry with respect to indoor lighting have always been focused on motion detection. Such a lighting was also imagined under the purview of security requirements [4]. Of-late, with advancements in lighting mechanisms, these systems have also incorporated the idea of presence detection [5]. Though the idea is convenient, energy-efficient, and reduces effort, it does not provide the user with more control. The system's affordance is pretty straight-forward and unidirectional. With the advent of smart-phones and since the time 'Internet of Things' became implementable, the industry saw a huge number of Wi-Fi enabled, programmable bulbs or "Smart lights" mushrooming. These smart bulbs provided the user with a multitude of functionalities. Some of the features included changing the color of the light, setting the brightness, automating the color according to the time of the day, selecting only the bulbs we want to glow out of the full array, to name a few. Some of the examples of these smart lights include Lutron[1], Philips Hue[3], LIFX[2], Ilumi. The interaction designs of these smart bulbs are pretty simple. These systems have in-built Wi-Fi module and could be controlled using an interface. Some systems like the Philips Hue also have a specific remote control apparatus which can be used to control the bulbs. The bulbs are almost entirely operated with the app. This excessive dependence on an app, or a remote brings us to our problem statement. We feel that the interaction designs of these smart bulbs are in conflict with ubiquitous computing design principles [7]. Because we are using some sort of an interface to communicate at every step, the presence of the intermediary computer is glaring and very pronounced. In an event of anything happening to the phone or the remote, the lighting mechanism would be rendered inoperable. Our project was poised towards realizing the ideals of ubiquitous computing, which dictates that all the communication between the system and the user should take place using seamless, fluid interactions alone; and the system should obscure the presence of a computer in the middle. It also preaches the usage of a minimalistic interface. This is why, we envision a system where with acclimatized usage, the system's behavior could be so deeply ingrained in the user's mental model that the user would forget the presence of the computers in between. A simple function of turning on the light switch could be seen as a function of the limbs, and would not be perceived as a conscious external interaction.

Related Work

In the domain of Human-computer Interaction, there are several existing techniques to interpret gesture recognition. These techniques can be broadly classified into 3 main categories: Vision and environment-based, movement-based, and EMG-based (electromyogram) [8]. Some commercial applications of the vision-based techniques include the Nintendo Wii, which involves holding a controller which can be read. Further advances in vision-based techniques resulted in development of the Kinect by Microsoft. However, there are multitudes of problems while utilizing vision-based techniques [8]. Moreover, there is also a question of adequate lighting. The camera-based systems require a minimum threshold value of lighting to be able to detect and register any presence. Since we are building a light-switch, it would defeat the purpose! Accelerometer based gesture recognition technique has been found to be the most accurate, has lower complexity and cost as compared to other camera based techniques [9] [10]. The product that has come closest to this idea of gesture based lighting mechanism using movement-based technique is "The Desklamp" [6]. The lamp has proximity and an IR sensor in front. By moving the hand across the face of the light, we can change the colors. Likewise moving the hand closer or away from the lights changes the brightness of the lights. Although this design looks very useful and seems to address all the problems that we have pointed out, there are still a couple of important functionalities that this system still does not address completely. Turning on and turning off this system is still by a manual switch which has to be flicked up and down. Moreover, the device is localized, providing lighting in a limited space. Thus, to interact with the device, we have to be physically near it. Our initial idea was to build a lighting system which would span an entire room. Consequently, we didn't want the user to be walking up to the lights to wave and signal right at it. We wanted the interaction to be at user's leisure and comfort and from his space.

Under the gamut of movement-based gesture recognition, there has been a lot of research conducted on wearable technology combining accelerometers and SEMG (Surface based Electromyogram) [13]. The idea is to capture the frequency and acceleration of motion during the time when muscle activity is detected. Based on this effective signal, 3 further steps are required to make sense of the gesture. They are: i) Preprocessing and noise reduction ii) Rotation normalization iii) Post processing using Discrete Hidden Markov Model implemented with Bayesian Classifier and Dynamic Time Warping [10]. This technique has 2 main stages of operation. The "training" phase when all the possible gestures are defined, and the "recognition" phase when the device actually registers a gesture. The bigger the training set, better the recognition [13]. These processes involve a lot of complicated algorithms but provide highly accurate results [10].

Our Finished Prototype

The Iron Man's Gauntlet and Laser Repulsor: The glove which can interpret hand gestures. The gauntlet apparatus that is shown in figure 1 sits on the back of the palm.

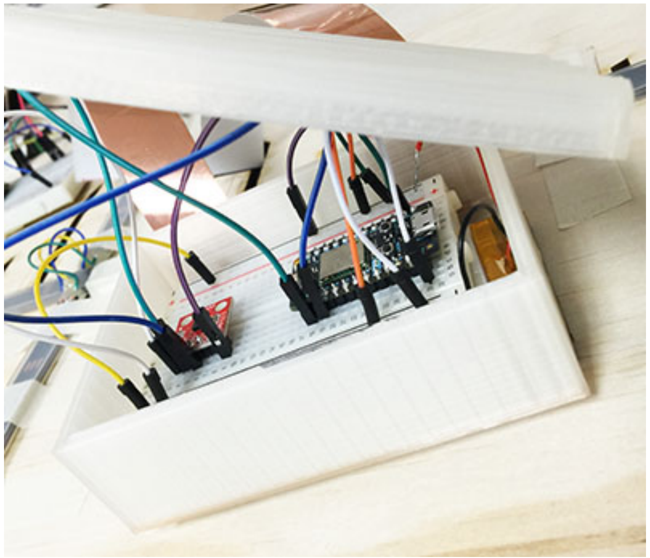

Figure 1. Gauntlet apparatus.

It has a triple-axis accelerometer to measure the hand's movement. Figure 2 - the accelerometer is connected to a photon – let's call it photon A. It reads all the data and publishes the events to the particle cloud. We have another photon – called Photon B connected to the LED light strip, that is shown in figure 3. This photon listens to events sent from photon A.

Depending on data and events received via cloud, photon B triggers appropriate changes in our lighting system.

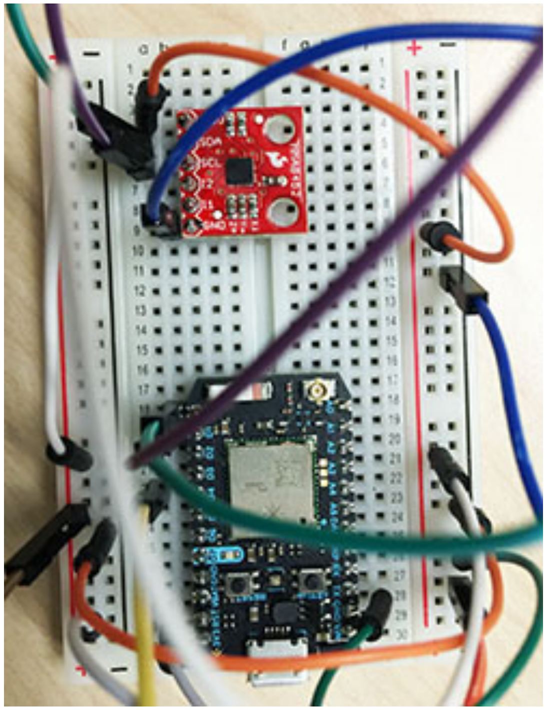

Figure 2. Gauntlet apparatus.

We have designed the lighting system as a replica of the Golden Gate Bridge. It has been etched and laser cut on a wooden board which is shown in figure 4. It has a horizontal row of blue lights, and 2 vertical rows for the 2 pillars; one glows red and the other glows green.
The laser repulsor that is shown in figure 5 lights up when activated. It can be activated by a simple shake of the glove. Likewise, it can be deactivated by shaking again.

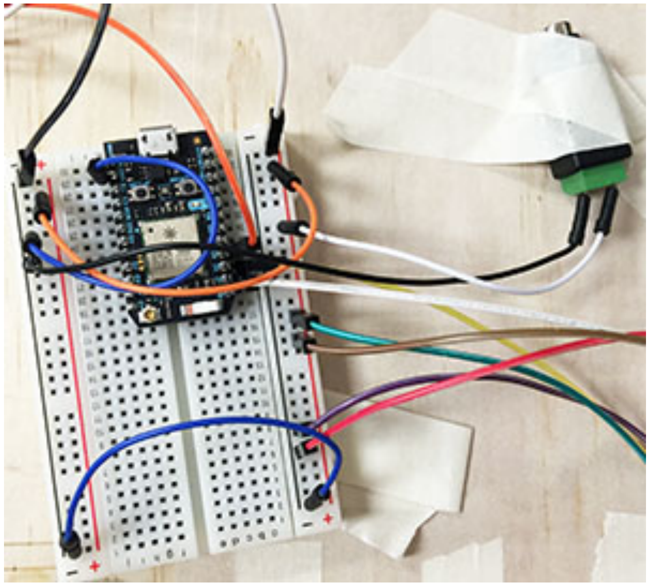

Figure 3. Gauntlet apparatus.

Figure 4. Lighting Display.

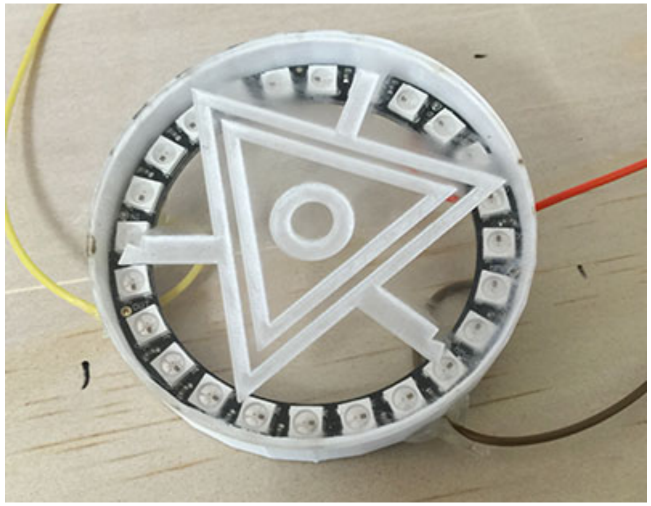

Figure 5. Laser Repulsor.

The glove will read accelerometer data, only when the laser repulsor indicates that it is active. When the laser repulsor is inactive, any actions performed while wearing the glove will not be registered. We introduced this check on purpose since we wanted to eliminate the false positive and errors arising out of unintentional gesture that the user may perform while wearing the glove. Thus, effectively, if you want to perform an action, you'll have to wake up the glove by shaking it, make sure that the repulsor is glowing, and perform the action. Likewise, when you have finished your gesture, shake your glove once to put it to sleep and you can continue with doing your chores.

We have defined and programmed for 2 gestures:

i) Turning the palm up and down about the wrist held in-line with the forearm: Turning on the red and blue vertical strips along the pillars of the Golden Gate bridge

ii) Rotating the glove in a swivel motion: Controlling the brightness of the blue horizontal strip

One of our initial plans was to control the length of the blue strip which gets illuminated. But we ran into problems which we'll discuss later.

Implementation

The accelerometer and photon: The accelerometer is a device capable of reading acceleration in 3 planes, i.e., along the X, Y, and the Z axes. We had to account of stray data, variations in data due to the design of the gauntlet, human ergonomic factors, and imperfections due to imprecise alignment of the hand. Hence, we had to be very precise with regards to when to publish and trigger an event. We set threshold values for the data received from the accelerometer. Once the input crossed a threshold value, we could be ensured that the value is not a noise and is a genuine input. For the motion along the Y axis, the accelerometer provided values ranging from -1000 to 0 for moving the palm down, and 0 to +1000 for moving the palm up. Since we were working only with the acceleration values and not the inertial measurements, in order to publish an event, we had to generate and register acceleration along one of the axes. After repeated trial and errors, we were able to set an arbitrary threshold value for Y axes. So, a bulb "On" event is triggered when the Y axis input exceeds +650. Likewise, an "Off" event is published when accelerometer provides a Y value less than -650. We ran into a couple of problems while trying to decipher the X and Z axes values. We have spoken more about this later. We could effectively use only 1 value. Since the Z value was rounded, we decided to define the 2nd gesture of the glove based on this X value. It varied from -1000 to 0 for counter-clockwise motion, and 0 to 1000 for clockwise motion. We split this range of 2000 into discrete chunks. For every 500 change in the input of X, we trigger a change of 50 in the brightness of the LED bulbs. The bulbs themselves operate on a brightness scale which goes from 0-255.

Challenges

There are many challenges in implementing the accelerometer based gesture mechanism. The biggest hurdle we faced was provisioning the photons. The photons sometimes would not work properly and we would have a hard time determining the root cause. We also had a lot of connectivity and internet problems. There were many instances when we would be gesturing with the glove but nothing would happen. It would confound us for a long time. The actual reason would turn out to be bad internet. One or both of the photons would still be searching for internet (pulsing green).

Also, the accelerometer has been fixed pretty firmly on the supporting bread-board underneath. So, the action of shaking it to activate has to be done with a good force. We would often have to shaken the glove multiple times to activate or deactivate it. Also, sometimes there is a considerable delay between the glove's gesture and the light's outcome (of about 4-5 seconds). There have been times when moving the palm too quickly would not result in any noticeable change.

The second biggest challenge which we faced was in extracting a second intelligible output from the accelerometer data. We tried all the possible movements and rotations using the accelerometer. The Y axis value changed perfectly. The X and Z values were often inverse values of each other. They would change when the accelerometer would be rotated along its plane. Earlier when we studied and had thought of using the Adafruit LIS3DH Triple-Axis IMU, we had reserved the gesture of moving the accelerometer on the horizontal plane for controlling the length of the blue strip. But when we used Sparkfun's accelerometer, movement on a horizontal plane produced no observable change in any value. Hence, we could not get any effective data and thus, we were not able to trigger/control this event. So, after repeated efforts, we realized that we can utilize only 2 values from the accelerometer's output:

i) Y- Value
ii) Either X or Z value

Workflow

Since the accelerometer-photon apparatus relies on Wi-Fi, there wouldn't be a need to be physically present near the LED lights. Moreover, since we are eliminating any kind of interfaces, there would be no hard interactions like clicking a button or flicking a switch. We are using a 24 bulb Adafruit NeoPixel ring for the laser repulsor, which is shown in figure 6.

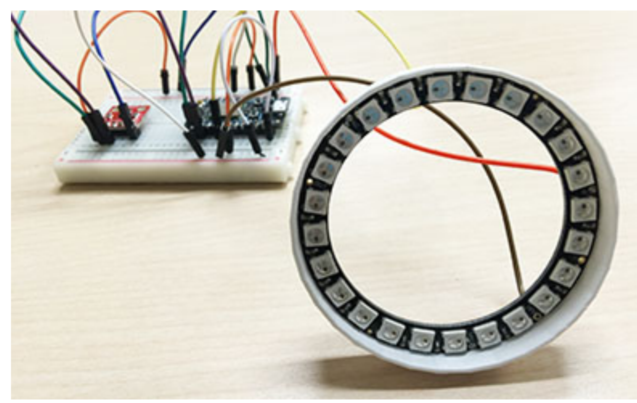

Figure 6. Adafruit Neopixel Ring.

The data-input for the ring is provided by photon-A depending on inputs from the accelerometer. We are using the SparkFun Triple Axis Accelerometer Breakout - MMA8452. Since it is not an inertial measurement device, it measures acceleration only and hence range of our gestures became limited. The gauntlet has been 3D printed and the pattern of the laser repulsor is etched used a laser cutter. Likewise, the Golden Gate Bridge also has been etched and laser cut. We had to make precise measurements to determine the length of the RGB LED strips which we would need. The LEDs are powered by a 5V DC input and are connected to separate data-inputs of photon B.

Learnings

Our initial proposed plan of implementation was very different from what we actually ended up with. This was partly due to the fact that we faced many hurdles and insurmountable challenges, time-constraints, and even hardware limitations. But it was a rich learning experience for us. Some of the major takeaways for us are:

1) We had planned to use the Adafruit Gemma to operate the NeoPixel Ring. Earlier, we had imagined the Laser Repulsor to be an independent apparatus that is shown figure 7. We quickly realized that the Gemma can be programmed only once and cannot be dynamically provided with input. Meaning, once it starts glowing, we would have to manually flash a new code to make any changes to it. So, we had to improvise and make the Laser Repulsor connected to the gauntlet circuitry. This meant, we could get rid of Gemma entirely.

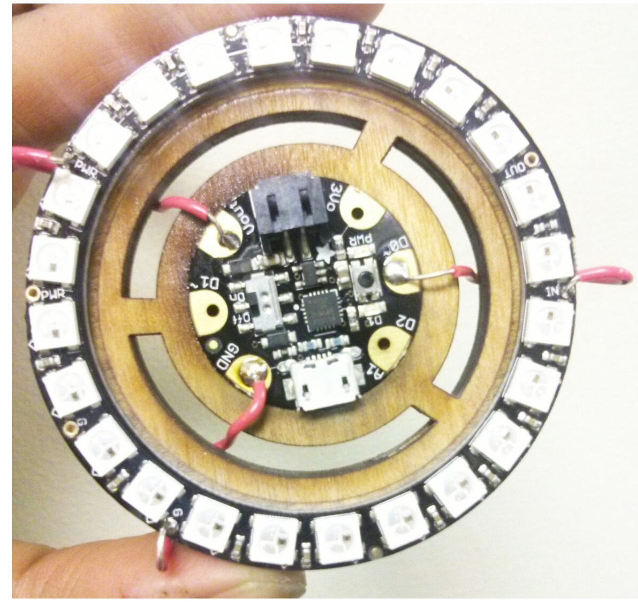

Figure 7. Initial Prototype of Ring with Gemma.

2) We had planned to use Adafruit LIS3DH Triple-Axis IMU Accelerometer. This was to be connected to the Arduino Uno and the data was to be read via serial. It was only after programming the code and seeing the serial output that we realized that the Arduino Uno does not come with a Wi-Fi module. Hence publishing an event would be cumbersome. It was at this point that we realized that we'd be needing an Arduino Wi-Fi Shield. It was already too late. As a work around, we could have connected the Arduino via serial to a computer and hosted the data to cloud via node.js. But that would mean having the gauntlet plugged to a computer at all times. That would

defeat our goal of achieving the ideal of ubiquitous computing. So, as a work-around, we had to settle to using Sparkfun's accelerometer and connect it a Particle Photon. But since this accelerometer was not an IMU, we were not able to get a clean, precise data like the way the Adafruit IMU provided.

Though we had our share of failures, we also had some unprecedented successes along the way:

1) We had planned to connect a separate 5V DC input to the gauntlet since it was powering the NeoPixel ring, and the description page for the ring mentioned that it needed a 5V input. But to our surprise, the NeoPixel ring powered up and started glowing even with a 3v DV output drawn from the photon when connected via the USB. This helped us to test our code and implementation with greater freedom. This also gave us the idea of using a rechargeable 3.7V Li-ion Poly Rechargeable battery to power the gauntlet.
2) Using Particle Photon proved to be a blessing in disguise for us. The photon has an excellent mechanism in place for publishing events to cloud, since particle provides its own cloud. Hence, it was very easy for us to publish events and establish a communication between the photons over the particle cloud.

Conclusion and Future Work

If we could use a Triple-Axis IMU in the gauntlet, we can get highly precise movement data. There won't be any need to depend on accelerated gestures. This would open up whole lot of avenues for us to define the gesture vocabulary. We don't have an efficient mechanism to portray the status of the Wi-Fi on the photons. We have to open the gauntlet to check in case of Photon-A, and we have open the back case of the lights to check in case of Photon-B. We need to convey the status of the photon in some way at both ends. Likewise, since we are using the fatter bread board, the gauntlet is bulky and is not ergonomic in design. Using the thinner board with shorter wires will help us in making the gauntlet sleeker.

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