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

Balaji Iyengar
Rochester Institute of Technology
Rochester, NY 14623, USA
tr1682@rit.edu

Sabarinathan Masilamani
Rochester Institute of Technology
Rochester, NY 14623, USA
sm2550@rit.edu

Abstract
We are planning to implement a gesture controlled lighting mechanism. We are envisioning this system for indoor lighting purposes only. The gesture vocabulary would consist of waves and motions made with the palm. These gestures would be read with the help of the IronMan's Gauntlet[1]. The "Laser Repulsor"[2] in the palms would read the gestures and convey it to the system to trigger the appropriate, consequent change. The lighting mechanism on itself would consist of a length strip of RGB LED lights. With the help of the gestures, we would be able to turn the lights on and off, control the brightness, increase or decrease the length of the strip that gets illuminated.

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.

[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 alighting was also imagined under the purview of security requirements [4]. Of-late, with evolution, 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 smartphones and Internet of Things, the industry saw a huge number of smart bulbs with associated apps 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 bulbs 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 the app. 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. The dependence on apps while using the smart bulbs is so high that we can summarize it with this joke:
Q: How many engineers does it take to change a light bulb?
A: 1 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 Ubicomp's design principles [7]. Because we are using the app 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. 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 an extension of the human limbic movement, 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-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]. 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 '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. We are looking at a lighting system which spans an entire room. Consequently, we don't want the user to be walking up to the lights to wave and signal right at it. We want 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].

Proposed Solution

The Iron Man's Gauntlet: The glove which can interpret hand gestures and convey the signals to the system. The system in turn has to be intelligent enough to make sense of the signals and provide the appropriate output. For gestures, this is what we have thought of implementing:

1. Turning the palm up and down along the z-axis: To turn on and off the LED Strip.
2. A slow wave of the palm from left to right along the x-axis: Controlling the length of the strip which gets illuminated.
3. A slow wave of the palm from left to right along y-axis: Controlling the brightness of the lights.

Future Implementation:
Turning the palm by an angle: To control the color.

Implementation steps

The accelerometer and Arduino Uno: The accelerometer is a device which is capable of sensing movements in all the 3 planes: viz, the X, Y, and Z axes. Our idea is to embed this accelerometer in the gauntlet. Whatever signals that the accelerometer reads, it will pass it on to the Arduino Uno. The Arduino then relays this signal via Wi-Fi to the cloud. We will have a Particle-Photon listening for signals from the Arduino Uno. This Particle-Photon will be connected to the LED Strip. Depending on the signals that it receives, it'll modify the LED strip. The logic processing and intelligence will have to be implemented at the Arduino's end.

A tiny led circlet resembling “The LaserRepulsor”: This circlet would be around the accelerometer in the center of the gauntlet. The main purpose of this circlet is to provide feedback about the status of the accelerometer. If the device is up and running, it would glow with a soft pulsing light. In case of connectivity and Wi-Fi problems, it would glow red.

Challenges

There are many challenges in implementing the accelerometer based gesture mechanism. The most important challenge being, differentiating between intentional and unintentional gestures [11]. Some of the other challenges include providing appropriate feedback to the user to signal that the gestures are actually being read, and to not keep the user in the dark blindly waving his hands without knowing the system status [11]. We also have to train the user’s mental model by providing the full set of available gestures to the user and train them to use it appropriately [11].

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. The idea is also to minimize the complexity, to keep the learning curve as steep as possible and intuitive. Based on our background research about gesture recognition using accelerometers, we have narrowed down on Adafruit LIS3DH Triple-Axis Accelerometer. It uses the concepts of Discrete Hidden Markov’s Model [12] and Dynamic Time Warping [10] to produce the exact motion vectors, with rotational and tilt-based values along the 3 planes. There is little or almost no math involved. So based on the values received from this device, we might have to explore all the possible affordances, and how to direct user’s actions.

References

1. Hanna, Robert S., et al. "Lighting control device." U.S. Patent No. 5,248,919. 28 Sep. 1993 *http://www.lutron.com/en-US/Products/Pages/Components/ConnectedBulbRemoteControl/Overview.aspx*
2. Bosua, P. "LIFX: The light bulb reinvented." *2010-10-01]. http://www, kickstarter, com/projects/limemouse/lifx the light-bulb-reinvented* (2012).
3. Hue, P. "Philips hue." (2012). *http://www2.meethue.com/en-us/*
4. Hoberman, Kenneth, Kim Kirwan, and Gary Gordon. "Security light controlled by motion detector." U.S. Patent No. 5,015,994. 14 May 1991.
5. Roisin, Benoit, et al. "Lighting energy savings in offices using different control systems and their real consumption." *Energy and Buildings* 40.4 (2008): 514-523.
6. Spaulding, Jeremy, Jeffrey Holt, and Karlin Jessen. "Light control method and lighting device using the same." U.S. Patent Application 13/294,614. *http://www.ledlightforyou.com/Partners/Highlights/en-Desklamp.php*
7. Weiser, Mark. "Ubiquitous computing." Ubiquitous Computing Homepage. March 17.1996 (2006): 12.
8. Zhang, X., Chen, X., Wang, W. H., Yang, J. H., Lantz, V., & Wang, K. Q. (2009, February). Hand gesture recognition and virtual game control based on 3D accelerometer and EMG sensors. In *Proceedings of the 14th international conference on Intelligent user interfaces* (pp. 401-406). ACM.

9. Mäntyjärvi, J., Kela, J., Korpipää, P., & Kallio, S. (2004, October). Enabling fast and effortless customisation in accelerometer based gesture interaction. In *Proceedings of the 3rd international conference on Mobile and ubiquitous multimedia* (pp. 25-31). ACM.

10. Mace, D., Gao, W., & Coskun, A. (2013, March). Accelerometer-based hand gesture recognition using feature weighted naïve bayesian classifiers and dynamic time warping. In *Proceedings of the companion publication of the 2013 international conference on Intelligent user interfaces companion* (pp. 83-84). ACM.

11. Kallio, S., Kela, J., Mäntyjärvi, J., & Plomp, J. (2006, May). Visualization of hand gestures for pervasive computing environments. In *Proceedings of the working conference on Advanced visual interfaces* (pp. 480-483). ACM.

12. Mantyla, V. M. (2001). Discrete hidden Markov models with application to isolated user-dependent hand gesture recognition. *VTT publications*, *4*(4), 9.

13. Lu, Z., Chen, X., Zhao, Z., & Wang, K. (2011, August). A prototype of gesture-based interface. In *Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services* (pp. 33-36). ACM.