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# Gesture based IoT Light Control for Smart Clothing

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***Abstract*—In this paper, a smart wireless wristband is proposed. The potential of innovative gesture based interactivity with connected lighting solutions is reviewed. The solution is intended to offer numerous benefits, in terms of ease of use, and enhanced dynamic interactive functionality. A comparative analysis will be carried out between this work and existing solutions. The evolution of lighting and gesture controls will be discussed and an overview of alternative applications will be provided, as part of the critical analysis.**

***Keywords : IoT, Gesture Controls, Smart Lighting, Internet of Things, Web of Things, Wearable Technologies.***

## I. INTRODUCTION

The Internet of Things (IoT) is driving the lighting industry to develop new methods of control and interaction with lights. "*Connected lighting*" is such that it is linked to a network infrastructure, typically wireless communications whereby ubiquitous devices can control lights anytime, anywhere. Gesture based methods of interaction have emerged as a novel way to control devices using non-haptics methods, and wearable systems in the form of smart clothing are set to create exciting, convenient and user friendly human machine interfaces. In this paper we will be discussing the integration of such technologies, to create a holistic platform of simple dynamic interaction, based on Constrained Application Protocol (CoAP). A prototype smart clothing wristband based on our platform has been created and is presented here in terms of early stages in development. The paper is divided into the following sections. Section II reviews and discusses gesture based control methods, Section III takes a look at smart clothing, Section IV discusses IoT protocols, Section V introduces our proposed solution, Section VI presents our current results, and Section VII concludes the paper.

## II. GESTURE BASED CONTROL

Research in the area of gesture based controls has increased over the past couple of years. This has been mainly due to the increased proliferation of IoT devices and interest in home automation. Furthermore, gaming devices such as the Microsoft Kinect have inspired novel methods of gesture interaction. Google is also prevalent in the area, by promoting the use of radar based technology as part of Project Soli [1]. Recently there have been attempts to commercialize hands-free control systems such as Myo [2]. These gesture-based control systems can be further categorized into camera-based or movement sensor-based solutions. Table I and II summarizes the overall features and benefits of non-haptics solutions in general.

### A. *Camera Based Methods*

Camera-based recognition is suitable for stationary applications and usually requires specific camera setup and calibration. For instance, a camera-based control device known as the Gesture Pendant [3] enables its wearer to control elements in the home via palm and figure gestures. The major drawback with this system however is that the information received has to be processed on a reasonably powerful computer before implementation of the action which is a time consuming process, and limits real-time interactivity. The Microsoft Kinect works on a similar principal, and has been implemented in innovative applications such as human - robot arm control [4]. Furthermore, reliance on camera based methods raises additional privacy concerns particularly when adopted in public. Other issues include that of having adequate lighting in order to perform the visual recognition - something that would be prove challenging in darkened environments.

### B. *Sensor Based Methods*

The sensor-based method uses different sensors such as radar, tilt, acceleration, pressure etc. to measure movement. For example [5] created a wrist watch-type gesture recognition device using acceleration sensors to detect basic hand and finger gestures. One drawback was that it required extensive training for four individual sensors, though commendably their system was integrated onto a small everyday device such as a watch. One interesting implementation of acceleration-based gesture recognition, was in the area of musical performance control and conducting systems [6]. Tsukada and Yashmura [7] developed a wearable interface called ubi-finger, using acceleration touch and bend sensors to detect a fixed set of hand gestures that mimicked a haptics style of interaction such as pushing a virtual switch.

### C. *Alternative non-haptics control mechanisms*

Voice control is another alternative control mechanism, that although being hands-free, has struggled to gain adequate traction, due to issues with recognition from multiple users, and requirements for quiet and private environments. A more recent use of voice control showed the use of an Arduino Uno, Android Phone and Bluetooth Module with Relay modules

TABLE I
CONTRASTING NON-HAPTICS CONTROL METHODS

| CONTROL METHOD | ADVANTAGES | DISADVANTAGES |
|---|---|---|
| Camera-Based Gesture Control | Easy to use<br>Generally available<br>Detailed context information<br>Portable<br>Spatial resolution highly feasible | High cost of accurate optics<br>Issues of confidentiality<br>Large disk storage required<br>Prone to occlusion<br>Resolution issues usually low and temporal |
| Voice Control | Fairly cheap<br>Small size<br>Works in both dark and light rooms<br>Hands-free<br>Users can carry out multiple actions | Does not work in noisy environment<br>Limitations of speech recognition systems<br>Sensitive to local accent |
| Accelerometer-Based Gesture Control | Fairly cheap<br>Energy consumption is low and efficient<br>Confidentiallity is assured<br>Portable<br>Embedded battery<br>Capable of use in complex operations | There could be data loss (wireless)<br>Issue of consistency<br>Life span of battery maybe limited<br>Relative movement capture only |

called Auto home [8]. This project showed how home appliances can be controlled from one point of the home using voice control and Bluetooth. Another examples of this was done using ZigBee wireless communications [9]. Zigbee is low power and covers reasonably long distances for signal transmission. The need for a better communication has brought about the use of WiFi over ZigBee for Voice control/Voice recognition (e.g. Amazon Echo, Google Home), however there still remains issues with clarity, accent and detection of voices in noisy environments. A simpler solution is the clap On/Off light, which is another variation of voice/sound recognition systems and utilizes acoustics to control lights. Kashinath Murmu [10] developed a device that controls lights and fans using claps and whistles - this device comprised of a simple microcontroller, clap and whistle filtering circuits with a microphone which detects the sounds made by the user. The main problem with this device was that it could not distinguish between tapping sounds and claps, so if users would make a sudden sound the device would detect it as a command and initiate an action. To conclude sound based methods of interaction, though intuitive, have numerous technical issues in terms of accurate detection techniques.

## III. SMART CLOTHING

The emergence of wearable technology and conductive threading has introduced innovative applications to clothing technology known as "*Smart Clothing*". Smart clothing is where technology merge with textiles creating fashionable, functional and comfortable solutions to meet everyday needs whether it is in sports and fitness, outdoor and leisure, home and leisure, home care and health care[8]. Smart clothing and textiles can be divided into passive smart, active smart and very smart systems. Passive smart systems are those that can only sense the environment. An active smart system can sense and react to the stimuli from the environment and very smart systems can adapt to the circumstances [11].One of the first early implementations was the Bristol Cyber-Jacket [12] which had sensors such as a GPS receiver, ultrasonic indoor location sensors, an electronic compass and accelerometers. The user interface included, a speech recognition system with audio playback and displays that could be handheld, headmounted or worn on the sleeve. Though at the time a showcase of the potential of wearable technology (in tourist guide applications), nowadays, wearable computers in the form of smart clothing have been gaining popularity in health and fitness applications. Examples include the EnFlux [13] which provides usable feedback of body movements from ten sensors integrated into a fitness suit. These sensors can provide real-time body movement analysis in the form of a 3D avatar which can be further processed to advise on exercise styles. In terms of other novel control applications using clothes, Google has partnered with Levis to create Project Jacquard [14]. This project looks to develop smart clothing based on conductive thread touch panels weaved directly into any fabric.

## IV. INTERNET OF THINGS (IOT) COMMUNICATIONS PROTOCOLS

Internet of things (IoT) has shown tremendous growth over the past years, this growth can be seen in areas such as; Smart living, Assisted living, Smart homes, Smart cars, Smart Clothing, Smart cities, Health monitoring systems and much more.The IoT has different protocols for different purposes

TABLE II
TECHNOLOGY COMPARISON

| Technology | Detection | Cost | Equipment | Issues | Social Acceptance | Influence of Use |
|---|---|---|---|---|---|---|
| Camera-based gesture | High | High | Camera | Light Interference, Processing | High | Medium |
| Voice recognition | Medium | Medium | Microphone, telephone | Accents, Background noise | Low | Medium |
| Accelerometer-based gesture | High-Medium | Low | Sensor | Wrist injury, Accuracy | High | High-Medium |

TABLE III
CONTRASTING IOT PROTOCOLS

| PROTOCOL | TRANSPORT | INTERACTION MODEL | DISCOVERY |
|---|---|---|---|
| CoAP | UDP | Request/Reply | Yes |
| MQTT | TCP/IP | Publish/Subscribe | No |
| XMPP | TCP/IP | Point-to-Point Message Exchange | No |

and scenarios, each with its own purpose. The internet breaks the protocols into layers based on functionality (Table III); the following sections will discuss these protocols.

### A. Constrained Application Protocol (CoAP)

CoAP is an application layer protocol developed for smart devices to connect to the Internet. There are many components that are constrained with resources, hence variation in computing power and communication bandwidth require to be accommodated for a wide range of devices. CoAP is optimized to be light and reliable for M2M/IoT applications. CoAP utilizes UDP (or a UDP-like) protocol, rather than TCP/IP. CoAP can be viewed as a compressed version of HTTP for constrained devices. Constrained devices can be large in numbers but are often related to each other in function or by location, and thus can make use of IP multicast techniques [15]. An example of this, would be sets of lights in a home, grouped according to rooms. Group communication mechanisms can improve efficiency and latency of communication and reduce bandwidth requirements for any given application, which will be essential for smart clothing scenarios and control of large sets of building service equipment related to comfort setting (e.g. HVAC, Lights) on IP networks. CoAP uses basic methods such as GET,POST,PUT and DELETE.

### B. Message Queue Telemetry Transport (MQTT)

MQTT is a light weight event and message oriented protocol allowing devices to asynchronously communicate efficiently across constrained networks to remote systems [16].Although MQTT and CoAP have similar functions, their characteristics are different. MQTT's transport layer is TCP, whilst CoAP is UDP, and it uses TLS as security, while CoAP uses DTLS. MQTT's model is Publish/Subscribe, whilst for CoAP it is Request/Reply (REST). MQTT also does not provide resource discovery, whilst CoAP does make for this provision.MQTT uses basic methods such as Publish,Subscribe and Unsubscribe.

### C. Extensible Messaging and Presence Protocol (XMPP)

The Extensible Messaging and Presence Protocol (XMPP) is an open technology for real time communication, using the Extensible Markup Language (XML) as the base format for exchanging information. In essence, XMPP provides a way to send small pieces of XML from one entity to another in close to real time[17].

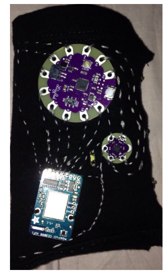

Fig. 1. Lilypad, ADXL Accelerometer and WiFi Module wired together using conductive thread to create smart wristband

TABLE IV
CONTROL AND FUNCTIONS

| CONTROL | FUNCTION |
|---|---|
| Move Up | Switch On |
| Move Down | Switch Off |
| Move Left | Increase Brightness |
| Move Right | Decrease Brightness |
| Move Forward | Activate Control |
| Move Backward | Deactivate Control |

## V. PROPOSED SOLUTION

The proposed system consists of an element of smart clothing communicating directly with groups of smart WiFi enabled lightbulbs using CoAP which has support for discovery compared to other IoT protocols. An early stage prototype has been developed as a cloth wristband, which could be integrated into a larger piece of clothing such as a long sleeved sweatshirt. Our approach involves the integration of existing sensors and microcontrollers such as the Arduino Lilypad series, which has been designed specifically for wearable computing. Our solution is a work-in-progress as we investigate the method of gesture processing to control lights over a wireless IoT network. The intention is to create a natural method of control, that is fast, simple to operate and intuitive. Furthermore, our solution is low cost compared to other complex hand gesture devices such as the Myo gesture armband. Our proposed system is made up of three components, a 3-axis accelerometer (ADXL335), Lilypad arduino based microcontroller and a WiFi module (CC3000), which the user will wear on his/her wrist as a smart wristband as the first iteration. Figure 1 shows the wiring of the devices using conductive threading, and Figure 2 shows the proposed architecture. It is proposed that the system be powered with a 3.7V (6600mAh) Lithium ion battery, for prototyping purposes.

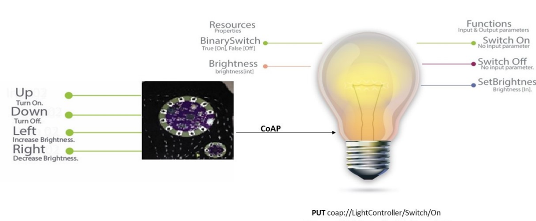


Fig. 2. CoAP Architecture

The current solution involves an intermediate processing PC, which limits real-time interactivity,and even if the solution was made on-line, delays would be encountered in the gesture detection algorithms, currently configured in Matlab. As part of the next phase of implementation we will be using an Arduino based microcontoller to actuate relays that will turn on and off a lightbulb using CoAP. Essentially the lightbulb will take on the role of a server, requiring a smart wristband to connect as a CoAP client.

## VI. Preliminary Results

Our current implementation comprises of data communication between the wristband and the server over Wi-Fi as the user performs gestures. In order to detect gestures, the data collected from the accelerometer are smoothed using the Savitzky-Golay filter. The filter is used for smoothing sets of digital data points, in order to increase the signal-to-noise ratio while preserving the signal. This process is achieved during the convolution, by fitting numerous subsets of data points to a low-degree polynomial by using a linear least square.The estimation of the smoothed signal can be found in the form of convolution coefficient which is then applied to all data subsets [18].

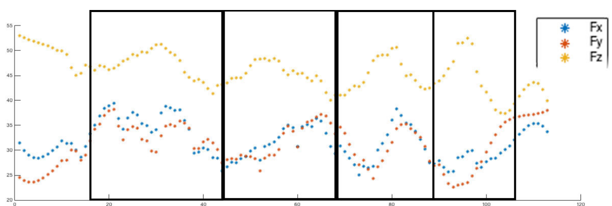


Fig. 3. Left and Right

Figure 3 shows the detection of four left and four right hand gestures, highlighted in the black squares. The movements are primarily detected through the $Z$ axis.

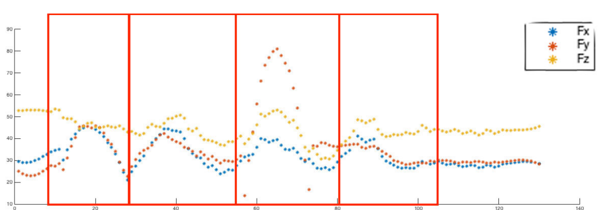


Fig. 4. Up and Down

Figure 4 shows the detection of up and down movement. The acceleration data provided by the accelerometer reflects the movement on the $X$, however, by using the Savitzky-Golay it is possible to detect higher peaks on the $Y$ axis as shown. This phenomenon is due to the arm of the subject to move from forward and backward as well as to noise when collecting the data. As shown in both Figure 3 and Figure 4 numerous movements are able to be detected by our algorithm through the data provided by the wristband and mapped to the numerous control functions provided.

## VII. Conclusion

This paper proposes an innovative way of controlling a light bulb based on CoAP as an application of smart clothing. As an advancement in technology, gesture based interaction has proven to have a future of interaction between users and electrical appliances or devices. The proposed device gives users a new experience which traditional lighting control cannot make and our solution will make the interaction between the user and lights more natural. In the future our research will focus on seamless integration within smart homes and intelligent buildings, as well as provide the user with a enhanced lighting experience by integrating the gesture detection processes on-board the smart clothing gesture control platform.

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