# Smart Shoe in Internet of Things (IoT) based Healthcare Environment

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***Abstract***

*The evolution of Internet of Things (IoT) technology has become more prominent and obtrusive in human life. With an addition of Internet of Things (IoT), smart shoe invention has been innovated and explored in order to develop a new vast technology. This paper discusses and focuses on the elements and components of smart shoe in IoT environment. Furthermore, the technical challenges and open issues are being explored, analyzed and discussed. Hence, the solutions can be made in improvising the smart shoe technology for future interventions.*

***Keywords:*** *Internet of Things, IoT, smart shoe measurement system, smart shoe, healthcare*

## 1. Introduction

Internet of Things (IoT) refers to a network of gadgets that connect to each other's to collect, capture and share the information through the secure service layer (SSL) in the area of wireless communication [1-3]. This paradigm enables people realizing smart environments such as: smart cities (e.g.: smart transportation system) and smart energy (e.g.: smart grid and smart lighting) [1,4]. This proved that IoT plays an important role in broad range of applications including healthcare industry [1]. There are some examples of how IoT take an action towards health services including delivering care to people in remote locations as well as monitoring systems that provide a continuous stream of accurate data for better care decisions. In clinical care, the hospitalized patient who needs close attention can be constantly monitored by non-invasive monitoring as it will regularly check on patient's vital sign and update into the system [1].

Embedded technologies used throughout IoT based healthcare including: sensors that collect patient data; microcontrollers that

process, analyze and wirelessly communicate the data; microprocessors that enable rich graphical user interfaces; Healthcare specific gateways through which sensor data is further analyzed and sent to the cloud [1].

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The evolution of IoT happens due to two reasons: advances in sensor and connectivity technology are allowing devices to collect, record and analyze data that was not accessible before and the ability of devices to gather data automatically on their own [1].

Smart shoe is one of the wearable devices that act as a primary source of data where it contains several types of sensors located in insole or stacked on the shoe cover to capture and measure the useful information. There is various prior research work on wearable devices including smart shoes for healthcare purposes in the past. Kong et al. [5] proposed a gait monitoring system using air pressure and air bladder sensors. Next, W. Donkrajang et al [6] presented smart-shoe system for monitoring human locomotion with Force Sensing Resistors (FSRs) and Accelerometer. Furthermore, Seesaard et al. [7] had developed a smart sniffing shoe for capturing and measuring the foot odor. All of these works are helpful to understand the various uses of smart shoes in healthcare industry.

Smart shoes have paved the way better efficiency, flexibility, mobility and reduced cost measurement systems [8]. Wireless smart shoe measurement system has potential to transfer the data via wireless communication system and the information derived from such measures is important in research for diagnosing lower limb problems, footwear design, sport biomechanics, injury prevention and other applications [8].

In this paper, first we will discuss briefly the architecture of IoT. Next, the elements and components of smart shoes technologies will be extracted and discussed and followed by the challenges faced as well as the future opportunities.

## 2. Architecture of Internet of Things (IOT)

The infrastructure or architecture of IoT is divided into three main layers which are Perception or physical layer, Network or transportation layer as well as Application layer that have been proposed in [9-11]. These layers will be explained in detail below.

a. Perception or physical layer: Perception or physical layer is a first layer which is a part of the overall perception of the main base in IoT. It composed of numerous types of data collector and controller devices or modules including cameras, RFID readers, any type of sensors and etc. [10] as shown in Fig 1. These devices or modules are mainly focused on perceiving, observing, identifying and gathering information [9,10].

b. Network or transportation layer: Its main function is to transmit data through the reliable transmission such as Internet and mobile telecommunication network via wired or wireless network [9,10]. Furthermore, it is also responsible for data processing, classification, allocation, as well as analysis [9]. This layer needs uncountable data processing and management ability as this layer may collect abundant of data in the realworld applications [10]. According to Fig 1, this layer comprised of various types of mobile telecommunication networks including 2G (GSM), 3G (CDMA), 4G (LTE) and Wi-Fi technologies.

c. Application layer: This layer will provide direct deals with the end-users [9]. Besides, it will also provide services to the other various applications [9]. This layer primarily focused on processing data intelligently so this processed data can be used by the end- users [10]. Figure 1 illustrates that application layer composed of systems including smart e-health, smart city, as well as smart energy which have a connection to the end-users.

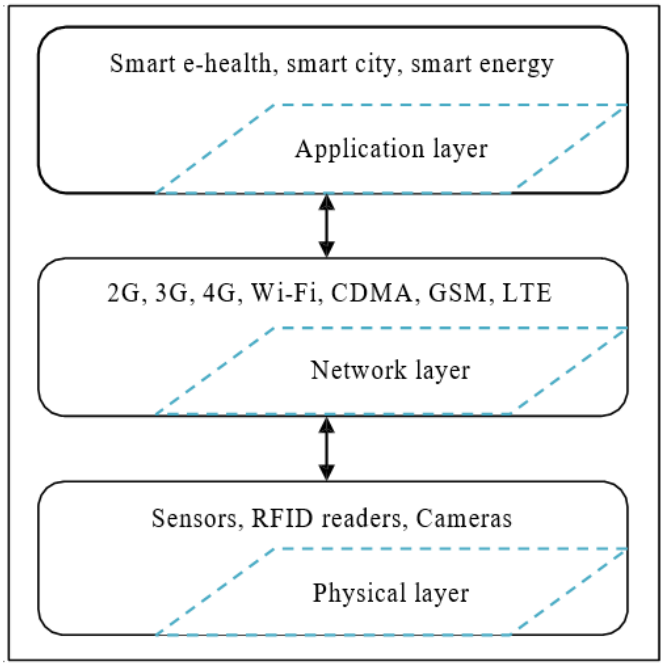


**Figure 1. IoT Architecture (illustrated from [9])**

## 3. Elements of Smart Shoe

The elements and components of smart shoes are categorized into six: Data source, Sensors, Network and Connectivity, Communication platform, Systems and services as well as Things or devices. These elements will be further discussed in the following sections.

### 3.1. Data Source

Data, a set of qualitative or quantitative variables is an essential element for all researches including smart shoes measurement system. The raw data will be collected by the operation sensors via certain network communications, then processed and evaluated into the simplest information understandable by the end-user via specific systems and algorithms.

Various kinds of data will be collected according to purposes and objectives of the studies. The data such as walking behavior (e.g. walking sitting and standing) are handed out at most.

### 3.2. Sensors

Sensors are crucial tools to collect the raw data, process it and then transmit the processed data into the other things (e.g. machine, device). Sensors used in smart shoes technology related healthcare can be divided into several types including

pressure sensors, Inertial Measurement Unit (IMU), ultrasonic transducer, chemical gas sensors as well as temperature and humidity sensors.

Based on Abdul Razak et al [8], there are four common types of pressure sensors available on market recently. They are capacitive sensor, resistive sensor, piezo-electric sensor as well as piezo-resistive sensor. Capacitive sensor composed of two electrically charged plates separated by dielectric elastic layer. The dielectric elastic layer will bend during the application of pressure hence, the distance between the two plates will be shortens resulting in voltage changing proportional to the applied pressure [8].

Resistive sensor is made of conductive foam between two electrodes which changes the resistance into force. This sensor will measure the resistance of conductive foam when the pressure is applied [8]. The suitable example for this sensor is Force-Resistive Sensor (FSR). Based on Srivises et al. [12], and Donkrajang et al. [6], FSR is functioning as analyzer and observer for human gait patterns as well as foot pressure distribution beneath foot of various activities. This sensor has lower cost compared to capacitive and piezo-electric sensor [8]. Furthermore, it is very thin as its size only 0.55 mm so that it is comfortable for users to wear when it is embedded in the insole. Nevertheless, FSR does not adequately reflect the actual foot pressure due to its small area and small sensing range.

Piezo-electric sensor has high impedance hence; it is susceptible to excessive electrical interference. It tends to produce a voltage in response to pressure [8]. Meanwhile piezo-resistive sensor is made up of semiconductor thus, its resistivity works vice versa which means the resistance will increase when the sensor is unload and decrease when the pressure is applied [8].

Inertial Measurement Unit (IMU) comprised of three types of sensors which are accelerometer, gyroscope and magnetometer that sample three spatial dimensions according to their functions respectively. This unit mainly used to measure the detail information of position or posture of the foot including the magnitude of acceleration as well as inclination angle of the foot.

Accelerometer is used to measure the acceleration and information due to motion of various activities as well as gravitational acceleration. This type of sensor is known to provide distinct readings to improve the accuracy of step-analysis. Nevertheless, there are a few drawbacks of accelerometer such as the component of it tends to add up a gradual velocity at each footstep which resulting in accumulating distance error overtime. In addition, the resulting shock happened from foot stepping motion, may exerts a negative impact on the other sensors.

Gyroscope responsible in measuring and collecting the data of angular velocity along sagittal plane with respect to the reference axis fixed on the sensor. This angular velocity information will be integrated to estimate the rotation angle and rate. Magnetometer reports on magnetic field strength, which include angle perpendicular to the gravity's direction. The estimated data measured by magnetometer signals are usually expresses the coordinate relationship body frame (local sensors) and navigation (sensor measurements).

Ultrasonic transducer is comprised with two elements including transmitter and receiver. The optimization of ultrasonic beam coverage scope is adjusted by the

orientation of transducer. Thus, it is able for ground-level obstacles of different heights, pits and holes been detected. Chemical gas sensor array composed of several sensor elements, which is fabricated by different types of polymer-carbon nanotubes composites onto the fabric electrodes usually embroidered on the cloth surface. This design allows easy installment as well as conveniently maintained. According to the name itself, temperature and humidity sensors are responsible to measure and collect all the data related to the environment temperature and humidity. These types of data are essential for certain researches relevant to the situation of the ground surface [13].

### 3.3. Network and Connectivity

The network and connectivity for smart shoes technology can be classified into two categories which are: wired system application and wireless system application. Wireless system application can be further categorized into Wireless Sensor Network (WSN); Bluetooth; ZigBee; and Wi-Fi.

**3.3.1. Wired system application:** Wired communication refers to the transmission of data over a wired-based communication technology. In this application, data was transferred from the sensors to a data acquisition card on a computer or any connected hand-held devices. It is reported that the wired this type of system is more accurate than wireless-based communication.

**3.3.2. Wireless system application:** Wireless networks and technologies allow devices to transmit data to each other and to the web without cables. Transmission of data occurs via radio waves. Issues facing by wired system such as mobility and freedom can be overcome by this application. There is less clutter and fewer wires to worry about. Yet, issues including security and speed usually concerned.

a. Wireless Sensor Network (WSN)

WSN is a group of specialized sensors known as nodes involved with real time and virtual communication in monitoring and sharing at diverse locations using dynamic network. It draws some attentions over the past several years as it provides many advantages such as it has no difficult installation, no ore expenditure and has a lot of way to save money band time. Initially, WSN is used for monitoring the physical conditions, regularity of temperature, odors, pressure, vibrations as well as sound.

Generally, WSN comprised of sensor nodes which are specifically designed in such way that they have a microcontroller which controls the monitoring, radio transceiver for generating radio waves, different type of wireless communicating devices as well as energy source like battery.

b. Bluetooth

Bluetooth is a wireless technology used to transfer data over short distances. This technology frequently used in small devices that connect to user's phones and tablets. It communicates through small radio transceivers called radio modules. UHF radio wave is used to transfer the data. Special software named link manager is used to identify other Bluetooth devices and

then, links will be created with them. This happened normally in Personal Area Network (PAN).

c. Zigbee

ZigBee is an open global standard that specify for a suite of high-level communication protocols based on IEEE 802 standard for PAN. This technology is inexpensive to run and, in the meantime, it is also does not require a lot of power consumption, low latency, low duty cycle, making it ideal solution for many industrial applications. This technology allows nodes to be connected together through multiple pathways together simultaneously hence, makes it ideal for smart shoes technology.

d. Wi-Fi

Wi-Fi or Wireless hotspots is a high-speed wireless network involving hybridization of wireless and wired part of the network system. Its architecture enables the computing devices to be wirelessly connected to the associated access point to gain access to the internet. It uses radio waves to communicate with one another.

### 3.4. Communication Platform

A computing platform is combination of hardware architecture and software framework which allows software to run. It comprised of computers architecture, operating system, programing languages as well as user interfaces. Based on the reviewed articles, there are three common communication platforms constructed during researches. They are Microsoft Windows mostly developed via computer or PC, meanwhile Android and IOS designed over mobile or related hand-held devices.

### 3.5. Systems and Services

Systems and services act as a data processors and analyzer where they process a big data and turn it into valuable information, or build and run innovative applications with advance algorithms to have desired results and provide storage and databases for the raw as well as processed data collected.

### 3.6. Things

Things are physical devices (e.g. shoes, computer, mobile) which also one of the significant components in smart shoe measurement system. They act as a basic medium in which other components run their responsibilities.

## 4. Challenges of Smart Shoe Technology in IoT Environment

Although smart shoes technology has been globally invented, there are still a lot of limitations and there is a need to improve it. These limitations are including:

a. Hardware challenges – High power consumption; the size of sensors which highly related with the mobility of smart shoes technology.

b. Software challenges – synchronization; accurate detection by the sensors; data processing challenges.

c. Security and privacy issues – information hacking

d. Advanced technology – the advancements of the other technologies that meets the technical requirements which has been a problem to smart shoes technology.

## 5. Challenges of Smart Shoe Technology in IoT Environment

Some criteria that were expected to be implemented in smart shoes technology are:

a. Allows further development – the researches are still working on demand to explore the new implementation of smart shoes technology that will enhance the processes, business values and the information exchanges.

b. Ease of use – Making the whole system more user-friendly-zone regardless of the ages.

c. Time saving – The system can work faster with light transmission data rate and accurate data reading.

d. Very mobile – The hardware used is light and small in size as it is embedded in insole or surrounding the shoes' surface.

e. Limited cabling – Limited or wireless cabling to ensure comfortable, and safety of the users.

f. Financial benefits – Affordable for people to benefit from inexpensive.

## 6. Conclusion

In this paper, the elements and components of smart shoe in IoT environment have been reviewed, analyzed and discussed. Besides, the technical challenges and open issues are being explored and the solutions can be made in improvising the smart shoe technology for future interventions.

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