

Smart health monitoring system using IoT based smart fitness mirror

Amgad Muneer¹, Suliman Mohamed Fati², Saddam Fuddah³

^{1,3}School of Mechatronics Engineering, Asia Pacific University of Technology & Innovation, Malaysia

²College of Computer and Information Sciences, Prince Sultan University, Saudi Arabia

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ABSTRACT

The smart fitness mirror proposed in this research aims to provide the users with a platform to monitor their health and fitness status on a daily basis. The system employs a number of sensors to monitor the body mass index (BMI) and amount of body fat present in the user's body. A weight scale consisting of four load sensors has been implemented to obtain the weight of the user whereas an ultrasonic sensor has been used to measure the height of the user. In addition, four electrode plates have been implemented on the foot weight scale to infuse a small amount of electric current (1mA) for BIA (bioelectrical impedance analysis) to estimate the amount of body fat percentage, lean body mass and total body water. An IR temperature sensor has been implemented in the research to measure the temperature of the user's body from the forehead. Tests conducted on the system illustrate that it is able to accurately compute the body mass index and perform a bioelectrical impedance analysis on the user. The system is able to achieve a 92.5 % and 93.7 % accuracy in determining the body mass index and body fat percentage respectively. An accuracy of 95.3 % was observed in the determination of the body temperature.

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Corresponding Author:

Suliman Mohamed Fati,
College of Computer and Information Sciences,
Prince Sultan University,
11586, Riyadh, Saudi Arabia.
Email: smfati@yahoo.com

1. INTRODUCTION

With the massive advancement in IT field such as Internet of things, cloud computing, and data analytics, self health care (SHC) is getting popular a day after day. Self health care (SHC) refers to all the activities carried out by the individuals to monitor their health without professional assistance relying on advices and past experiences [1]. Nowadays, self health care (SHC) became recently a growing industry all over the world [2] particularly, with the massive availability of smart and wearable devices. SHC gains its importance from the considerable reduction in costs that may be incurred for patients and also for caregivers' companies [3, 4]. No extra charges related to hospitalization, transportation, and facilities. The hospital providing HHC services will reshape the regular consultant with high quality of satisfaction care for patients. In [5] authors conclude that SHC services are less expensive compared with the hospital services.

Providing medical service at home and away from traditional healthcare facilities was enabled by several enablers mainly information technology (IT) [6, 7]. IT technologies disrupting healthcare fields include internet of things (IoT) [8-12] named also internet of health things, body area network [13], cloud

platforms [1, 14], big data [14, 15] and service robotics and drones [16, 17]. A variety of IT enabled HHC solutions were proposed such e-health [5], smart health care and smart environments like SPHERE and PLAIMOS, we-care, careNet and BESI [8, 9, 12, 16-19], m-health [10] and tele-health [14].

Millennials in today's society are constantly distracted with various issues in the developing society that little or no attention is directed towards maintaining a healthy lifestyle. Poor lifestyles characterized with poor eating habits, fitness routines and rest have made most people in the current centuries prone to health risks and issues. Besides, the wrong habits may cause a significant increase in chronic diseases. Thus, health issues related to poor fitness have become a raging problem in the current world whereby a variety of life-threatening ailments and diseases are being detected each day. Most of the health issues experienced daily originate mainly from poor eating habits, lack of exposure to health and fitness exercises [20]. In the past a lot of efforts have been made to ensure that these diseases are controlled and treated with ease such as conducting frequent visits to the doctor and ensuring that proper feeding habits such as strict diets are followed. But in order to achieve this early detection of the diseases is required through efficient periodic monitoring and collection of health/fitness data. Acquisition of periodic real time fitness and health data is a complex task that is significant in order to identify health issues affecting the user. One way of ensuring that health/fitness data of the user is accessed is by integrating an IoT based smart mirror technology and wireless sensors in monitoring the real time health/fitness state of the user as proposed in this study.

This study highlights the development of a smart mirror that is connected to smart devices for the purposes of offering advanced functionality such as monitoring the health of its users. The proposed smart mirror will help in providing an innovative unique platform for users to monitor their health fitness status with self-adapting features by employing wireless smart sensors and computer vision. A number of literatures has been reviewed based on the development and application of smart mirrors. Various researchers have utilized several approaches to develop smart mirrors based on IoT using Raspberry pi. The studies proposed in the literature reviewed have included some features such as time, date, news, weather updates and calendar. Little or no effort has been made on development of fitness and health based smart mirror except for two studies which monitor the user weight only. Therefore, this study will focus on the implementation of fitness features and health monitoring as well as face recognition to allow the system to continuously monitor the health of a particular user over time. Thus, some of the research questions that will be considered in the development of the proposed fitness monitoring system include:

- What traits will be used to monitor the health/fitness of the user?
- What sensors will be used to collect real time health/fitness data?
- What type and size of mirror will be used?
- What IoT technology will be used to send and receive health/fitness data?
- What techniques will be used to identify a particular user?
- What type of embedded hardware system will be used to analyze the health/fitness data?

2. RELATED WORKS

2.1. Self health care systems

In this section we discuss the way to construct a self-diagnostic system. Mime [10] is a home tablet-based movies system added to augmented reality subsystem. The author reported the user experience with such setup in both assisted and un-assisted using "blood testing" experiments. He described the user experiences in using the movies to guide the patients.

Atallah et al [11] proposed a home assistant system to adapt to needy older patients to improve their autonomy at home, and lessen their dependence on other people. The solution is proactive home monitoring system that adapts to user habits. They used classification and clustering algorithms for activity recognition. Authors in [12] described a cloud-based smart home environment for home healthcare. They used IoT devices to collect data through home wearable sensors and medical contextual data. A smart home gateway was then used to send these data to a private cloud. This cloud was made available to remote healthcare providers. In [13] Hossain et al proposed a smart home health care system for elderly people. The system uses multimodal speech, and video along with other IoT's sensors to continuously capture these data stream to a private cloud. Classification scores are computed in the cloud on the patient condition and conveyed to the caregivers. Another system based on cloud technology was discussed in [15]. Cloud assisted body area network for smart home healthcare used by home patients. It stores, process, and analyse data streams from the wireless smart home IoT devices. They presented a cloud resource allocation strategy based on agent-based modeling and ontology to support diverse CABAN applications. Moreover, an emotion-aware connected healthcare system [18] used different IoT devices to collect streams of data from patient in a smart home healthcare facility. This was fed into an emotion detection algorithm. Both speech and image data were used. They then fused to produce final scores of the emotion.

Verissimo et al [14] presented a ubiquitous healthcare and activity monitoring system through recognizing patient's real-time activities. The proposed system is based on spatiotemporal mining technique to build an activity prediction model. A micro-aggregation approach was used to enhance the privacy of the collected approach human sensed data. A smart in home monitoring system [21] was implemented to help elderly and track their actions. It is an IoT sensory system run by a fuzzy controller. The set of fuzzy rules are written by specialized medical staff. The rules specify a fusion based architecture. A similar system was presented in [22] using a convolutional neural network model for patient consultation. It has high disease diagnosis performance. It enables self-checking of the user's health condition and flow up with him on a regular basis. Certain main symptoms, possible diseases can be pre-diagnosed.

O'Connor, & Andrews [16] presented a framework to assess the quality of online health portals in Asian countries against HON standard. Their study considered Japanese, Korean, Chinese, and Malay. The result showed that only the Japanese websites have highly met HON standards. Authors in [17] presented an encyclopaedia of symptoms/diagnosis in Chinese by fusing medical data extracted from mainstream Chinese healthcare websites. Sadid Hasan et al [18] has proposed a knowledge graph clinical diagnosis algorithm that fused medical knowledge collected from various sources. The system was proven effective when compared to the state-of-the-art deep learning clinical diagnosis systems.

The issues of security, privacy of medical healthcare records were addressed in [16-19] particularly in wireless setups. Maria et al [23] used k-medians clustering technique with subsample validation to flatten medical records into the patient level. Authors in [17] presented a classification method to classify medical text data found in medical records. They used neural network algorithms for named entity recognition in Chinese electronic medical records. In [19] authors have identifies clinical concepts automatically from medical records using OCR and applied quantitative analysis. Data were collected from medical notes, lab test, and other outside medical records for verification and validation purposes.

2.2. Internet of healthcare things

The Body area network in [24] is the front end of mobile healthcare in the new personalized healthcare trend. Variety of body sensors are used to acquire signals from the patient and transfer them to his/her mobile phone for collective processing of data. Several mobile medical apps were test and verified. The work in [24] examines a number of FDA-Approved mHealth products in the market classified into seven areas (see the chart above). USA, China, Taiwan, Australia, Canada, New Zealand, and Netherlands are among the largest producers to such products.

2.3. Mobile healthcare/medical apps

Medical Health programs suffers with accuracy of their alarms, Ben Amor and Lahyani tried to reduced false alarms signals generated by medical health programs and apps with using statistical methods to decrease the dimensions of alarm generating factors while simultaneously preserving the relevance of medical health program itself. They incorporated incremental principal component analysis to reduce the dimensions along with multivariate anomaly detection based up on squared prediction errors and anomalous vital sign isolation for contribution graph [25].

Sarwar et. al. discovered a strong correlation between use of smart phone/devices and data transferred to health care providers through these devices. MHealth apps are dramatically changing the scenarios of clinical care. This new setup is much lower in cost and ease of use than existing setups [26]. Sodhro, Luo and Sangaiah investigated ways to optimize medical data communication techniques over 5G networks. This is needed for medical data visualization, high sensing levels, and better quality of service. Window based rate control algorithm is suggested to optimize such techniques. This is sometimes called edge computing based health care. In such setup, network parameters used were 'peak-to-mean', standard deviation, delay, and jitter [27]. Onodera and Sengoku, studied market scope of mobile health (mHealth) programs, their study reveals Europe is currently leading in mHealth initiatives and market partially because of heavy investment and initiatives by various government agencies, however market trend predict strong growth signals from Asia Pacific region and Latin America as well during upcoming years [28].

A business intelligence assessment published by BIS research viz. "Global mobile medical apps market - analysis and forecast, 2017-2025" world mobile medical app market is steadily growing for last few years and is estimated to grow further with persistent, current socio-economic factors in near future. Estimated value of global mobile medical apps was 1.40 \$ billion during year 2016 and is projected to swung by 11.22 \$ by years 2025. Driven by rapidly increasing smartphone market and exponential penetration of mobile phones in individual lives, reliable and cheap network connectivity with advance 4/5G connections, investment by governments, mHealth initiatives will certainly improve the QoS into mobile health care segment [29].

2.4. Smart mirror in SHC applications

Nowadays technology has been enhanced to make human's life better and easy. There are many technologies utilized in smart mirror such as deep learning, artificial intelligence, IoT and cloud. The researchers in [30] have proposed a smart mirror for physically challenged people based on IoT. The proposed system can manage their time and routines effectively and daily. The main idea of the work was to design smart mirror system based Raspberry Pi along with a voice recognition system that can facilitate the carrying out of smart mirror. Lastly, the proposed system implemented all kinds of real technologies that can help the users to manage their time.

Yusri et al, [31] proposed a smart mirror for smart life researcher comes with a proposed system called smart mirror. The idea behind the proposed it is based on IoT and the system allows users to access information as well as control the house lights. The implemented method in the system is evolutionary prototyping which collects all requirements and designs the system in a fast way. The testing has been evaluated with the term of "fail" and "success" in order to know whether "the field has performed well or resorted into failure. Lastly, there are some limitation in [31] such as the system needs improvement in order to implement a new technology on smart mirror and implemented other functionality that has been proposed in [30]. Another work was proposed by [32] which has discussed the fit mirror, a smart mirror for healthcare living. The idea behind this fit mirror is to affect the feelings of the user in a positive way by a rise of his or her, mood motivation and feeling of fitness. According to the experimental results stated that fit mirror can help people to get awake in the morning, and raise their motivation to do sports. Besides, the investigation results stated that among 43 users 839 valid sets of workout data were retrieved. Nevertheless, due to technical problems the data from two participants could not be used for all hypotheses. Moreover, the participants were divided into three unlike types of athlete, which are 11 participants (26.83%) had high, 24 middle (58.54%) and 6 low degrees (14.63%) of sports motivation. Researchers in [33] has presented a "wise" mirror, "a platform for the estimation of cardio-metabolic risk from sensed facial data and the delivery of personalized user guidance towards lifestyle change". The proposed "wise" mirror has an advanced sensing features agenda for unremarkable purchase of videos, images, and 3D scans of individuals standing in front of the mirror. The "wise" mirror involve a multispectral, a visible camera, imaging system, a breath analysis standard devices and 3D optical sensors. Thus, the multispectral imaging system helps to analyze the microcirculation and skin tissue. For emotional analysis visible cameras has been utilized, in order to dedicate the anxiety, stress and fatigue from capturing video sequences. A 3D scan implemented to scan the face change. Thus, there were many limitations such as the accuracy of the proposed system was low.

Maheshwari, Kaur & Anand [34] proposed a reflective interface to maximize productivity, smart mirror. The proposed study presented a new design and development of a smart mirror that signifies an elegant interface for slanting information for multiple people in a home environment. A face recognition approach was utilized in the proposed smart mirror. The system delivers a webpage services in order to access information feeds to the mirror. The system developed included a Raspberry pi 3, computer and a webcam for face detection was utilized as well as LCD panel in order to show the interface. Therefore, the main key features and the working principle of the proposed system as follow, a webcam used behind the mirror facial recognition to recognize the person who is standing in front of the smart mirror. The open CV platform used for machine vision programing. Lastly, the main limitation of the proposed system sometimes the mirror cannot recognize the user face or other user can access the sensitive data for other users. This study needs to enhanced the facial recognition by add a high security. Another research done by [35] has presented an interactive smart mirror based on IoT platform and Raspberry pi 3. The proposed smart mirror was designed to bring technology seamlessly into people's lives to manage their time and daily routines. This system used for user productivity and effective time management. This mirror work on voice recognition to be easy used and it accept natural language. Based on the concept of IoT that has been implemented in the proposed system, the user could communicate with the environment of the living-room around him easily. Moreover, in the developed GUI it has been design some icons such as holidays, time date, weather and news. However, there were some limitations in the proposed system, for example when the user asks the smart mirror about the data needed the system take few minutes to response. Also the system required a good internet connection.

Moreover, the authors in [35] proposed an interactive smart mirror with various features to make sure that every minute of the user is utilized properly. The proposed smart mirror allows users to use a home object as an interactive interface providing customizable services. The main advantage of this mirror is to track the health of the user which results in a healthy life. The developed mirror able to display the real time information like the weather, the particular location and day today schedule as well as the news happening around the world. Besides, the most important feature in the proposed mirror is the weight tracker that can tracked the user weight and make sure that the user is fit and display weight of the user in the daily basis.

Furthermore, the system can also be utilized the window blinds and control lighting in the room based on a control of single point. Another advantage of this system that the weight and other health conditions can be checked live at whatever point the user remains on a heap cell incorporated stool. This will have the capacity to propose and propel the user to decrease weight if needed.

Siripala et al. [36] proposed a magic smart mirror to monitor children while their parents at work. The smart mirror developed based on IoT and it implemented Raspberry pi. This mirror also implemented a smart technology which has the ability to show the details to the user using a smart phone with android application. The researchers stated that the proposed smart mirror is very different from the other mirror that has been developed previously with few features such as time, date, news and weather or even the weight and other health conditions. The Raspberry magic mirror is more advanced and interactive which allows the parents to keep tracking their children even though they are in the work, they can get notification to their smart phone using IoT approach that has been implemented in this study.

Therefore, researchers in [37] describes a new design of interactive mirror. The developed smart mirror identifies the user according to the image processing approach and provides a health progress representation. Besides, the health parameter measurement and analysis help the user in leading a healthier life. Furthermore, there several features have been extracted in this system such as emotion recognition, mouth feature extraction, and health progress representation and mirror usage time. It has been tasted each part in order to analyses the performance of the proposed system. However, the system has been trained with 42 images for 9 different people and the result of the system was vary from one to another which means the system cannot recognize some user and display a satisfactory result. Besides that, the system can be enhanced by add some advanced functionality such as speech processing. Lastly, the accuracy of the emotion recognition approach need be improved by extracting additional feature like eye feature.

In summary, smart mirrors commonly allow users some customization in order to bring a personalized service, a smart mirror needs to identify the user who is standing in front of it. Thus, it could access and display the user's personal information like his or her schedule in order to do appointments. Automatic approaches for identifying users include face recognition [38, 39], tag-based identification, biometric data, and personal belongings such as toothbrush [40].

A different work [41] proposed the implementation of anthropometry and bioelectrical impedance analysis as interchangeable techniques for assessing body health of sports persons. In the anthropometry analysis various instruments and equipment were used to compute body density, weight and height which were used to compute body fat percentage. in order to compute bia, a foot scale was used consisting of two electrodes placed parallel to each other, to allow the users feet to be exposed to the low induction current for impedance analysis. Testing was conducted on 83 sports athletes whereby the percentage of body fat was estimated using BIA and anthropometry analysis. The internal consistency of the BF data was measured using Pearson's correlation. Results from the tests conducted illustrate that a better correlation coefficient was achieved using bioelectrical impedance analysis i.e. 14.78 ± 9.29 whereas the anthropometry analysis produced a correlation coefficient of 13.08 ± 5 .

The design and analysis of adjustable constant current source with multi frequency for measurement of bioelectrical impedance has been proposed by [42]. In this research a hand and foot scale analyzer were used for bioelectrical impedance analysis whereby electrodes used for measurement were placed as the front and rear soles of the leg whereas the palm and thumb were used as electrode contacts for the hands. A similar work to [41] proposed by [43] in order to use of bioelectrical impedance analysis to study the reference values of a given population based on their phase angle, age and sex. BIA was used in this study to compute reactance and resistance which was then used as a phase angle indicator. The fat mass was then estimated from a series of parameters consisting of total body water, weight and hydro densitometry which were then implemented in the Siri equation. The phase angles obtained from the equation were then compared over different ages, sexes, body mass index (BMI). Findings from the research conducted by [41] showed that arm posture played a significant role in computing BIA values. Bent arm posture affected the flow of the current whereas stretched out arms produced better results with an accuracy of 92.4% and mean difference of $\pm 0.87\%$. In addition, the system was able to work efficiently between frequencies of 50 and 100 kHz, with the best results obtained at a frequency of 85 kHz. The researchers however recommended that further research should be conducted to study the impact of electrolyte wipes on the effectiveness of bioelectrical impedance analysis.

In [44] a comparison of different techniques used to measure body composition was conducted. In this research, two techniques were used as case studies i.e. bioelectrical impedance analysis (BIA) and air displacement plethysmography (ADP). Testing was conducted on 41 participants on two different occasions after an overnight fasting period with no water and food. Measurement of the height, weight and percentage of body fat was then carried out using the two approaches i.e. BIA and ADP. The skinfold in (1), (2) and (3)

were then used to calculate the percentage of BF (body fat) based on the values derived from the two approaches i.e. FFM (fat free mass (Kg), H (height (cm), BW (body weight (Kg), R (resistance (Ω)).

$$FFM = -10.68 + \left(\frac{0.65H^2}{R}\right) + 0.26W + 0.02R \quad (1)$$

$$FM = BW - FFM \quad (2)$$

$$\% BF = \frac{FM}{BW} \times 100\% \quad (3)$$

The results obtained from the tests illustrate that both systems have a high correlation between them whereby the mean difference observed from BIA and ADP was 3.1% and 4.1% respectively whereas the accuracy was 83.2% and 78.4% for BIA and ADP respectively. The test data from this research indicated that the bioelectrical impedance analysis (BIA) approach was better than the air displacement plethysmography (ADP). In [45] a bioelectrical impedance analysis system has been proposed to evaluate the health of poultry and eggs. BIA was selected by the researchers since it presents a painless and more accurate and non-invasive approach of measuring poultry health at different stages of their life cycle. During testing four values were measured using the bio-impedance apparatus i.e. resistance, reactance, egg weight and phase angle. The phase angle and impedance values obtained from the bioelectrical impedance analysis were also used to differentiate the sex of the poultry in eggs. Results obtained from the study illustrate that the BIA approach is able to accurately predict the sex and health of the eggs and poultry with a correlation value of 0.739 at $p \leq 0.05$.

To conclude, a number of literatures has been reviewed based on the development and application of smart mirrors. Various researchers have utilized several approaches to develop smart mirrors based on IoT using Raspberry pi. The studies proposed in the literature reviewed have included some features such as time, date, news, weather updates and calendar. Little or no effort has been made on development of a fitness and health based smart mirror except for two studies which monitor the user weight only. Therefore, this study will focus on the implementation of fitness features and health monitoring as well as face recognition to allow the system to continuously monitor the health of a particular user over time.

3. PROPOSED SHC SYSTEMS

The proposed smart health/fitness mirror system uses the facial recognition technique to access the historical health data base of the user whereas a network of sensor is used to obtain real time health and fitness data from the user as shown in the block diagram in Figure 1. A health monitoring is then performed based on the user's previous health history whereby the diagnosis and the sensor data are displayed on the smart mirror.

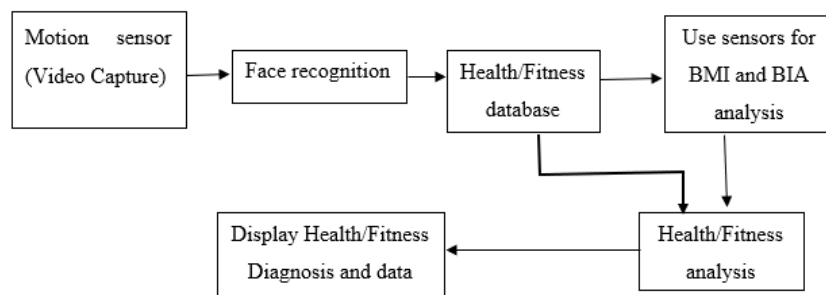


Figure 1. Health/fitness monitoring system block diagram

3.1. Face recognition

According to Zhang et al. [46] face recognition refers to the process of mapping the face of a given individual to their identity. The facial recognition system implemented in this study was used for purposes of identifying the user. Identification of the user enables the system to compare the current health status of the user with previously obtained historical data. A USB web cam was used for the purpose of image acquisition whereas a Raspberry pi 3 fitted with OpenCV was used to develop the face recognition algorithm.

After the process of acquiring the user's image is complete, feature extraction is carried out to isolate keen areas of interest based on his/her facial features. Conversion of the acquired image from RGB to gray scale was then carried out in order to allow the edges of the retrieved image to be found through the process of edge segmentation as shown in Figure 2. Eigenvectors were then employed for reconstructing facial features from the edge map before face localization was done. Face localization was done in three steps as explained below:

- Haar-feature selection stage, whereby the digital features extracted from the face such as eyes, nose and mouth are set apart from the facial image.
- Face vector normalization, whereby the face vector average from each Eigen value are manipulated to lower dimension vectors with the aim of calculating the overall dimensions of the digitized facial features obtained during the previous stage i.e. Haar-feature selection stage.
- Face identification stage, whereby the extracted facial dimensions from the previous stage and the Eigen values are used for purposes of comparing with other facial images hosted in a database. In this stage, cascading classifiers are employed for the process of classifying the images selected.

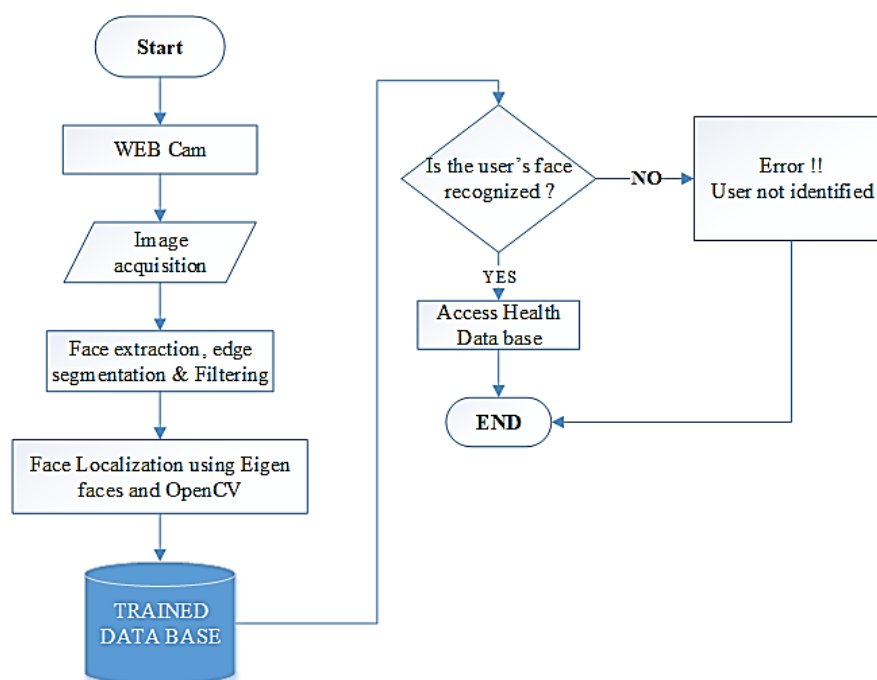


Figure 2. Image processing flowchart

3.2. Health/fitness monitoring

The health fitness system implemented for the smart fitness mirror relies on information obtained from a network of wireless sensors as shown in Figure 3. The IR temperature sensor was used to obtain the temperature of the identified user, whereas the weighing scale was used for BIA (bioelectrical impedance analysis) and BMI analysis. Once the user steps onto the weigh scale, a camera takes a photo of the user to be processed for identification purposes. Once the user is identified, his/her health data is accessed from the data base for comparison with the computed BIA, BMI and body temperature information. If the results obtained are suitable, they are displayed on the smart mirror. However, if the results are considered not to be in the range set, then the results are displayed with recommendations to allow the user to adjust his health/fitness. The body mass index of the user was calculated using (4) as proposed by Kim et al. [47] and Frank [48].

$$BMI = \frac{\text{Weight in Kilograms}}{(\text{Height in meters})^2} \quad (4)$$

BIA (bioelectrical impedance analysis) was used to estimate other health properties of the user such as body fat percentage, lean body mass and total body water as shown in Figure 4. According to Maria et al. [43], BIA measures the amount of opposition (impedance) offered by body tissues to the flow of

a small amount of Ac current i.e. less than 1 mA. The amount of impedance measured varies with the frequency of the current applied i.e. 50 kHz for each frequency. Two bio-electric electrodes were installed at the base of the weighing scale for purposes of performing BIA (bioelectrical impedance analysis) as shown in Figure 3. According to InBody [49], to perform BIA, the body was divided into 3 main sections i.e. trunk, right leg and left leg as shown in Figure 4, whereby the impedance (Z) of each section was computed as shown in Table 1,

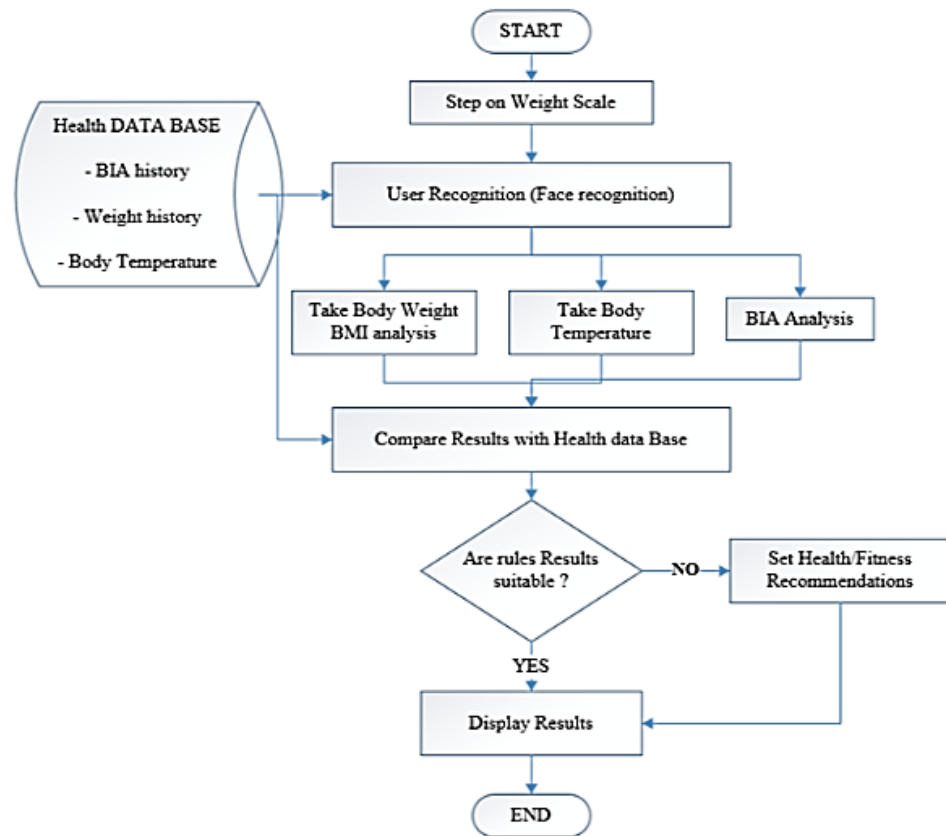


Figure 3. Health monitoring

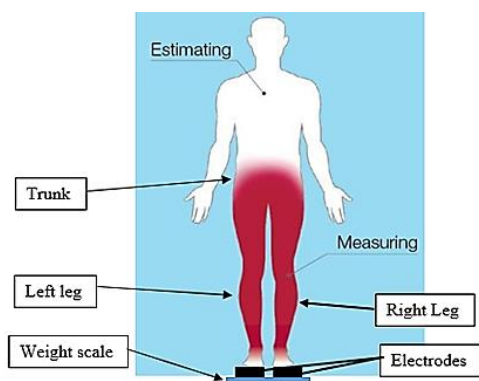


Figure 4. Bioelectrical impedance analysis

Table 1. Impedance of various body parts

Z (Ω)	(Trunk)	(Right Leg)	(Left Leg)
1 kHz	26.8	306.8	316.1
5 kHz	25.7	303.0	314.1
50 kHz	23.0	282.3	289.8
250 kHz	20.4	263.3	272.7
500 kHz	19.1	258.1	267.8
1000 kHz	17.0	254.5	264.0

3.3. Fat free mass (FFM), free mass (FM) and body fat (BF) calculation

In (5), (6) and (7) as proposed by Kim et al. [47] and Frank [48] and InBody [49] were used to calculate the fat free mass (FFM), free mass (FM) and body fat (BF) for the users respectively.

$$FFM = -10.68 + \left(\frac{0.65H^2}{R}\right) + 0.26W + 0.02R \quad (5)$$

$$FM = BW - FFM \quad (6)$$

$$\% BF = \frac{FM}{BW} \times 100\% \quad (7)$$

FFM – fat free mass (Kg), H – height (cm), BW – body weight (Kg), R – resistance (Ω) & BF – body fat

3.4. Electrical construction

The electronic components used for the development of the system are as shown in the electrical schematic in Figure 5. The smart mirror developed relies on a WIFI connection and therefore a Raspberry pi 3 on-board computer was used to provide internet connection and act as the sole microcontroller used to retrieve and transmit data from the sensors and weight scale. The HX711 module was implemented in the system to amplify the signal of the load cell used to measure the overall weight of the user. The analog signal produced by the load cell was weak and therefore the HX711 module was implemented to convert the weak signal into bits and bytes for easy interpretation by the Raspberry pi microcontroller. An LCD TV monitor display with HDMI connection was used to display user's personal information such as emails, weather forecast, Quran quotes, upcoming events, news feed and health data processed from the health monitoring system. The double-sided mirror proposed in the beginning was deemed quite expensive after further research and analysis, therefore a tint film normally used for car and building privacy was used to provide a two-way reflection of the user and relevant fitness information from the LCD screen.

In addition, a DHT11 temperature sensor was used to read and record the environment temperature i.e. temperature of the room, to enable the user to be aware of the room temperature and make necessary adjustments to the HVAC system. However, an IR temperature sensor was used for purposes of obtaining the body temperature of the user. An infra-red temperature sensor was used in comparison to other temperature sensors since it does not require the user to be in contact with-it during operation. In addition, IR temperature sensors are known to be more accurate, precise and wear free since there is no physical contact with the user. The temperature obtained from the body would then be compared with previously collected values in order to obtain a conclusion i.e. if temperature is normal or abnormal. The hardware system developed for the smart fitness mirror consists of a Bluetooth enabled weighing scale and a smart mirror. The weighing scale was made from 3D printed material and measures 30.3 cm by 35.2 cm by 4.8 cm. Four load sensors located at the four corners of the weighing scale were used to measure the weight of the user as shown in Figure 6.

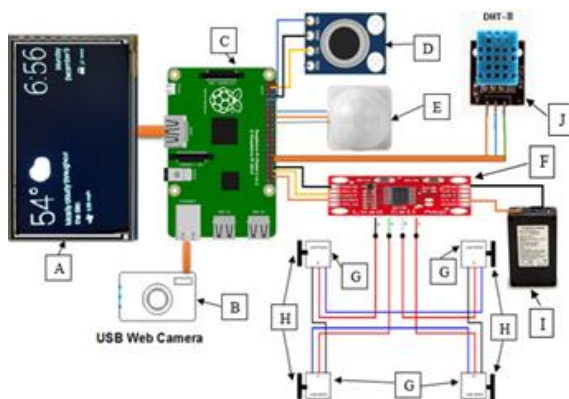


Figure 5. Electrical schematic

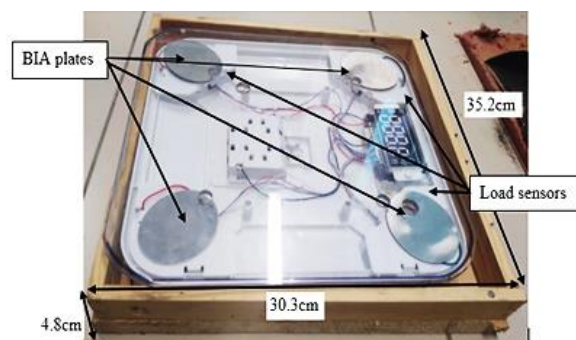


Figure 6. Weight foot scale

Furthermore, four stainless steel electrode plates also located at the four corners of the weight scale above the load sensors were used for BIA (bioelectrical impedance analysis) in order to calculate other health properties of the user such as body fat percentage, lean body mass and total body water. The smart mirror developed measures 45.2 cm by 115 cm by 6.7 cm and consists of an LCD screen mounted onto a wooden frame and covered with a thin film of window tint to produce the effect of a double-sided mirror. The complete system has been reconstructed and tested for the purpose of proving its functionality and

performance. Figures 7, 8 and 9 depict the running system. The android application developed using android studio for body health and fitness tracking is as shown in Figure 10 and Figure 11 where the identification of the user, body weight and fat shown in the developed mobile app. Also, the Raspberry pi GUI for the smart fitness/health monitoring mirror is as shown in Figure 12.

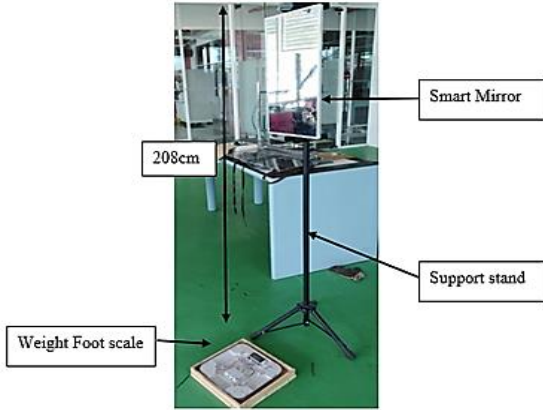


Figure 7. Foot scale and smart mirror

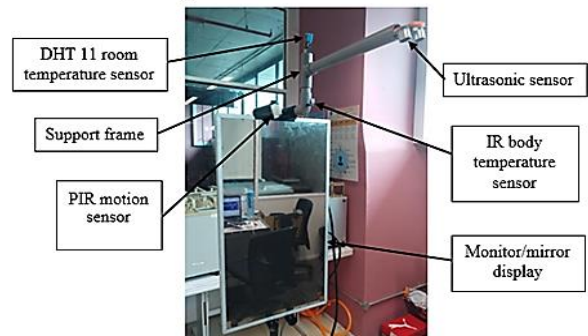


Figure 8. Sensor and mirror construction

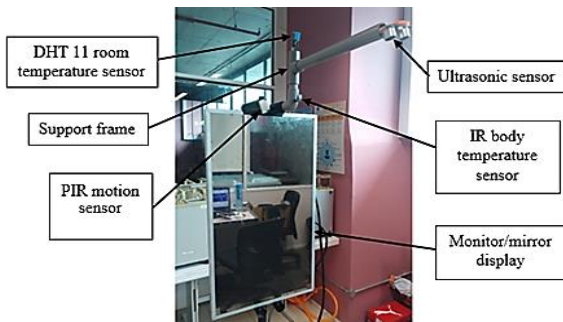


Figure 9. Sensor and mirror construction



Figure 10. Android Application

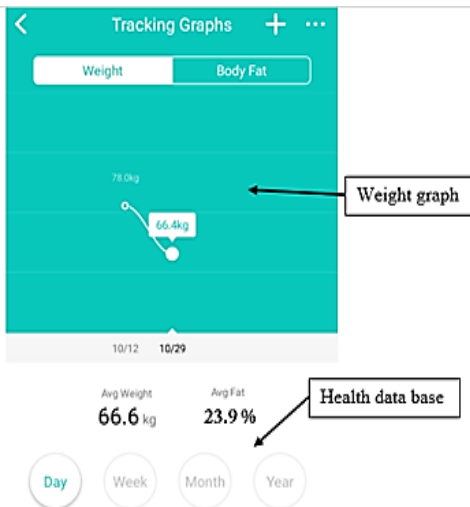


Figure 11. Tracking graph data base

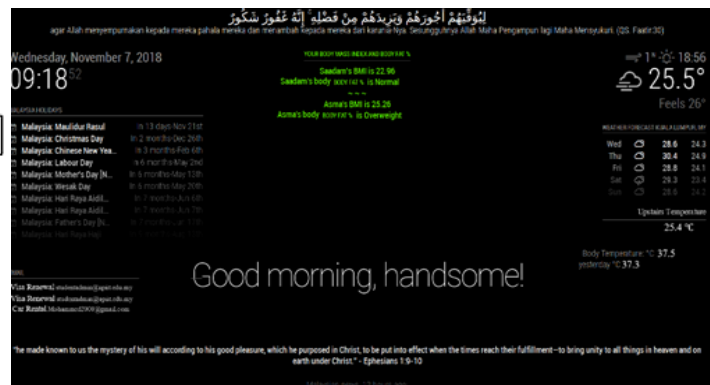


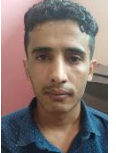

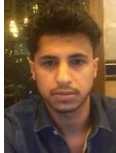






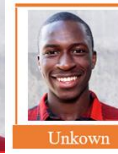


Figure 12. Smart mirror GUI

4. RESULTS AND ANALYSIS

The smart fitness mirror developed was tested and the results obtain that face recognition system was able to correctly identify the user and thereby allow access to the user’s historical health data as shown in Table 2. However, if the user was not recognized, the system would issue an alert message i.e. “user unknown”. Once the user was recognized, the BMI and BIA analysis was conducted using the information obtained from the weigh scale and computation algorithm. The results were displayed on the mirror as shown in Figure 12. Several tests were conducted on different sections that make up the smart fitness mirror system as listed below:

Table 2. Smart fitness mirror user identification

					
	Saddam		Saddam		Amgad
					
	Mariyam		Khalifa		Unkown

4.1. Weight identification test

A weight identification test was carried out to analyze the ability of the system to accurately identify various weights loaded onto the weighing mechanism. Accurate weight identification was important since the weight of the user was used to compute BIA and BMI. The four load sensors were strategically located on the weighing mechanism as shown in Figure 13. A normal weighing scale was used to obtain the theoretical weight of the user for comparison with the value obtained from the implemented system.

The theoretical and measured weight of the users was obtained and recorded during the expermint conducted. The weight reordered was measured from both male and female users. Results obtained from the weighing system showed that it was able to identify the weight of the user irrespective of the gender. However, some discrepancies were observed whereby an error of ± 0.2 was observed for some measurements as shown in Figure 14. In addition, as the weight of the user increased, the accuracy of the system reduced slightly; especially for users weighing above 100 Kg. On further research it was observed that the load sensors used for the system have a weight limit beyond which the accuracy and resolution of the sensors is affected. Therefore, the maximum weight threshold set for the developed weighing scale was 110 Kg, beyond which the system will give errors.

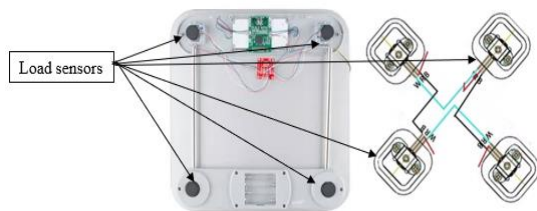


Figure 13. Weight scale with load sensors

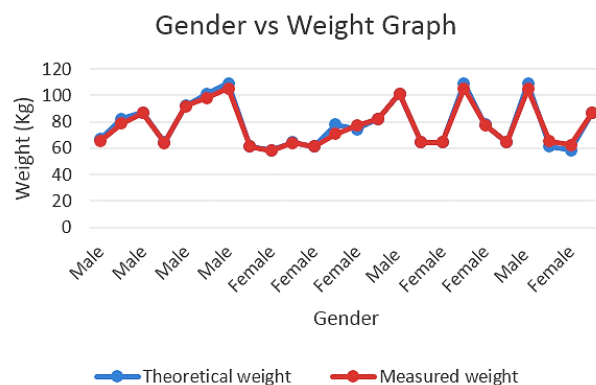


Figure 14. Gender vs weight graph

4.2. Height identification test

According to Gin et al. [50], the height of a person is the distance from the head to the toe of the individual. The height was used to compute the body mass index and the BIA (bioelectrical impedance analysis) of the user. Therefore, accurate height identification was important in order to compute accurate

BMI and BIA. The height of the user was obtained using an ultrasonic sensor placed on top of the weight scale. Different users of different height were used for this test whereby their theoretical and measured height was tabulated as shown in Figure 15. However, a slight deviation was observed between the measured and theoretical height of the users. This deviation was observed due to the uneven head surface which affected the reflection of ultrasonic waves off the surface. In addition, the uneven strands of hair with air gaps enabled the absorption of the ultrasonic waves thereby leading to some minor errors.

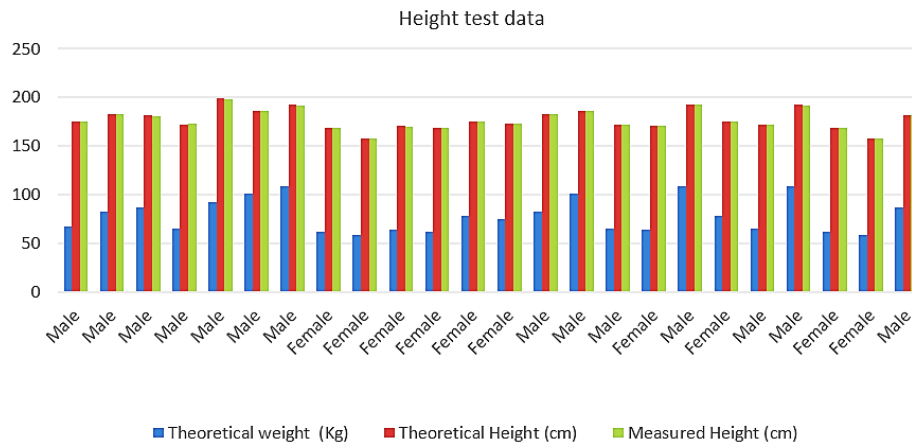


Figure 15. Height test data

4.3. Temperature test

Body temperature has been used a measure of body health over the decades and still remains a vital source of information related to health and body fitness [51]. Abnormal body temperature i.e. above or below 37°C is considered as a sign of illness or abnormal body activity. A non-contact infra-red temperature sensor was used to measure body temperature of the user standing in front of the mirror from the forehead. The theoretical temperature ranges for normal human body temperature are as follows: normal (36.1-37.8), fever (>37.8), and hypothermia (<36). The temperature of different users standing in front of the mirror was obtained based on different genders and distances away from the mirror as shown in Figure 16. The measured temperature of the users was then compared with theoretical temperature values which were obtained by means of a digital thermometer shown in Figure 16.

Temperature data collected from the IR temperature sensor illustrate that the implemented temperature monitoring system is able to read human body temperature from the forehead. In addition, the system is able to categorize the health status of the user based on their temperature. The system was also exposed to manually control low and high temperatures since it was not possible to find a human specimen whose temperature was in these ranges. The system was able to respond in kind to temperatures below and above the set threshold whereby only a minor discrepancy was observed between the measured and theoretical values.

4.4. BMI test

According to Kim et al. [47], BMI is considered as an efficient technique of gauging the amount of fat present in the body since too much body fat can be life threatening. The body mass index (BMI) of a person is obtained as the ratio of body weight (kg) to the height (m). The theoretical ranges as proposed by health digest, [52] as follows: underweight: <18.5, normal: 18.5–22.9, overweight: 23-24.9, pre-obese: 25–29.9, and obese: >30. A number of users with varying height participated in this experiment. The ultrasonic sensor was used to record height of the users whereas a weighing scale was used to compute their respective weights. The BMI was computed and the values obtained were recorded. The data obtained from the BMI test illustrates that the implemented system is able to monitor the body mass index of the users irrespective of their gender. However, a minor discrepancy was observed between the measured and theoretical values. The minor error observed was mainly from the minor deviation between the measured height and the theoretical height. This is because the implemented height measurement system relies on an ultrasonic sensor which operates based on the ultrasonic waves bouncing off the uneven head surface. Therefore, the user needs to be in a still position for at least 5 seconds for the ultrasonic sensor to take accurate readings.

4.5. BIA (bioelectrical impedance analysis)

According to Gin et al. [50] BIA is a broadly and newly applied concept used in many health care assessment products and systems. BIA (bioelectrical impedance analysis) was used to estimate other health properties of the user such as body fat percentage, lean body mass and total body water. According to Maria et al. [43], BIA measures the amount of opposition (impedance) offered by body tissues to the flow of a small amount of Ac current i.e. less than 1mA. The amount of impedance measured varies with the frequency of the current applied i.e. 50 kHz for each frequency. During experimentation, the user stood on the weight scale developed, bare footed with both legs placed parallel on top of the stainless-steel electrodes. Then a small amount of Ac current i.e. less than 1mA was sent from the electrode on the right foot, up the right leg, down the left leg and finally down the electrode on the left foot. The resulting impedance (Ω) was then measured using the scale to be later applied in the calculation of Body Fat percentage. An ultrasonic sensor placed on top of the smart mirror was used to measure the height of the user. The theoretical body fat data used for the implemented system is as introduced in [48].

In (5), (6), and (7) was used to calculate the fat free mass (FFM), free mass (FM) and body fat (BF) for the users respectively. The theoretical percentage of Body Fat was obtained using a BIA foot scale. The data collected from the BIA test show that the system is able to compute the percentage of body fat present in the human body based on the impedance measured using the electrodes. However, a small error in the range of ± 0.4 was observed during testing despite the error having minimum impact on the final result. It was also observed that the amount of body fat expressed as a percentage increased with increase in body weight and height. Figure 17 shows the difference between the theoretical BIA value and the measured value.

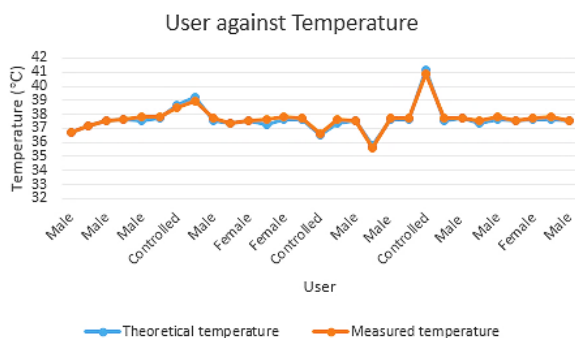


Figure 16. User against temperature

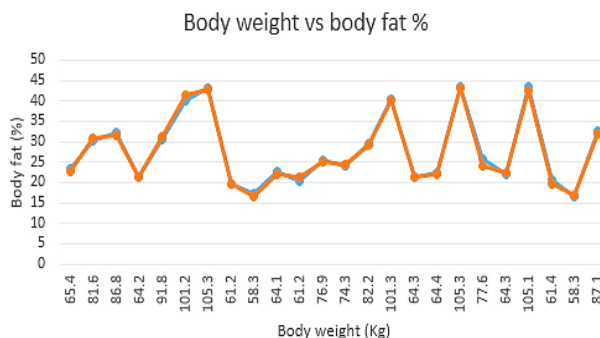


Figure 17. Body weight vs body fat percentage

5. CONCLUSION

To conclude, the system implemented has the ability to monitor the health and fitness of the user using an embedded hardware and software system. The robust system is also able to successfully achieve the aim and objectives proposed for this research. The smart fitness mirror system developed has a few limitations that were observed during implementation. The weight measurement system consisting of the four load cells can only measure a maximum body weight of 110 kg, beyond which, the system would produce errors. In addition, the load sensors cannot measure body mass less than 500 g. This limitation is mainly due to the sensitivity range of the load cell sensors. The bioelectrical impedance analysis carried out by the system relies on the contact of the human skin with the stainless steel electrodes in order to measure impedance. This means that the system can only be used if the user removes their shoes and climbs onto the weight scale. Further research can be conducted to develop a weight scale that can measure larger body masses, beyond the limit set. This would involve the use of more load cells with a wider measurement range as well as better sensitivity. A hand scale can also be embedded into the system for bioelectrical impedance analysis. The incorporation of a hand and foot scale into the health and fitness monitoring system would increase the accuracy of the system and provide a better body fat analysis platform.

REFERENCES

- [1] Karlin Nancy J., Joyce Weil, and Wejdan Felmban, "Aging in Saudi Arabia: an exploratory study of contemporary older persons' views about daily life, health, and the experience of aging," *Gerontology and Geriatric Medicine* 2, vol. 2, pp. 1-9, 2016.
- [2] King R. C., Villeneuve E., White R. J., Sherratt R. S., Holderbaum W., & Harwin W. S., "Application of data fusion techniques and technologies for wearable health monitoring," *Medical engineering & physics*, vol. 42, pp. 1-12, 2017.

- [3] S. S. M. Alqarni, "A review of prevalence of obesity in Saudi Arabia," *J Obes Eat Disord*, vol. 2, no. 2, pp. 1-6, 2016.
- [4] Ministry of Health, "The MOH Initiatives Related to the NTP 2020 and Saudi Vision 2030," [Online] Available: <https://www.moh.gov.sa/en/Ministry/nehs/Pages/vision2030.aspx>, 2020.
- [5] Khaleghi B., Khamis A., Karray F. O., & Razavi S. N., "Multisensor data fusion: A review of the state-of-the-art," *Information fusion*, vol. 14, no. 1, pp. 28-44, 2013.
- [6] Ben Amor L., Lahyani, I., & Jmaiel M., "Data accuracy aware mobile healthcare applications," *Computers in Industry*, vol. 97, pp. 54-66, 2018.
- [7] Sarwar C. M. S., Vaduganathan M., Anker, S. D., Coiro, S., Papadimitriou, L., Saltz, J., Butler, J., "Mobile health applications in cardiovascular research," *International Journal of Cardiology*, vol. 269, pp. 265-271, 2018.
- [8] Sodhro A. H., Luo Z., Sangaiah A. K., & Baik S. W., "Mobile edge computing based QoS optimization in medical healthcare applications," *International Journal of Information Management*, vol. 45, pp. 308-318, Aug 2018.
- [9] Onodera, R., & Sengoku, S., "Innovation process of mHealth: An overview of FDA-approved mobile medical applications," *International Journal of Medical Informatics*, vol. 118, pp. 65-71, 2018.
- [10] By, N. P., & Article, S. T., "Global Mobile Medical Apps Market Reports BIS Research," 2018.
- [11] Atallah N., Khalifa M., El Metwally A., & Househ M., "The prevalence and usage of mobile health applications among mental health patients in Saudi Arabia," *Computer Methods and Programs in Biomedicine*, vol. 156, pp. 163-168, 2018.
- [12] Kelly B. W., "Mobile apps for healthcare professionals: Current and future trends," [Online] Available: <https://mobilebusinessinsights.com/2018/03/mobile-apps-for-healthcare-professionals-current-and-futuretrends/>, 2018.
- [13] Pai R. R., & Alathur S., "Assessing mobile health applications with twitter analytics," *International Journal of Medical Informatics*, vol. 113, pp. 72-84, 2018.
- [14] Veríssimo J. M. C., "Usage intensity of mobile medical apps: A tale of two methods," *Journal of Business Research*, vol. 89, pp. 442-447, 2018.
- [15] Burgdorf A., Güthe I., Jovanovic M., Kutafina E., Kohlschein C., Bitsch J. Á., & Jonas S. M., "The mobile sleep lab app: An open-source framework for mobile sleep assessment based on consumer-grade wearable devices," *Computers in Biology and Medicine*, vol. 133, pp. 8-16, 2018.
- [16] O'Connor S., & Andrews T., "Smartphones and mobile applications (apps) in clinical nursing education: A student perspective," *Nurse Education Today*, vol. 69, pp. 172-178, 2018.
- [17] Yuan S. L. K., & Marques A. P., "Development of ProFibro — a mobile application to promote selfcare in patients with fibromyalgia," *Physiotherapy (United Kingdom)*, vol. 104, no. 3, pp. 311-317, 2018.
- [18] Cannon C., "Telehealth, Mobile Applications, and Wearable Devices are Expanding Cancer Care beyond Walls," *Seminars in Oncology Nursing*, vol. 34, no. 2, pp. 118-125, 2018.
- [19] Kao H. Y., Wei C. W., Yu M. C., Liang T. Y., Wu W. H., & Wu Y. J., "Integrating a mobile health application for self-management to enhance Telecare system," *Telematics and Informatics*, vol. 35, no. 4, pp. 815-825, 2018.
- [20] Vivek V., Rajan H., Vijay R., Surendar S. and Geetha R., "IoT Enabled Smart Mirror for Physically Challenged," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 7, no. 2, pp. 334-338, 2018.
- [21] Pal D., Funilkul S., Charoenkitkarn N., & Kanthamanon P., "Internet-of-things and smart homes for elderly healthcare: An end user perspective," *IEEE Access*, vol. 6, pp. 10483-10496, 2018.
- [22] Charu P., Munna, K., And Saini, J., "Design and Analysis of Adjustable Constant Current Source with Multi Frequency for Measurement of Bioelectrical Impedance," *International Journal of Applied Engineering Research*, vol. 13, no. 1, pp. 262-267, 2018.
- [23] Maria C., Barbosa S., Aluísio J., Barros J., Wang B., Heymsfield R., Pierson J., "Bioelectrical impedance analysis: population reference values for phase angle by age and sex," *The American Journal of Clinical Nutrition*, vol. 82, no. 1, pp. 49-52, 2015.
- [24] Varkey G., Balakrishnan A., & Prajith R., "Presentation of Patient Information on the Doctor's Smart Phone for Acute Care," *Proceedings of the 10th International Conference on Theory and Practice of Electronic Governance- ICEGOV '17*, pp. 321-328, 2017.
- [25] Gravenhorst F., Muaremi A., Bardram J., Grünerbl A., Mayora O., Wurzer G., Tröster G., "Mobile phones as medical devices in mental disorder treatment: an overview," *Personal and Ubiquitous Computing*, vol. 19, no. 2, pp. 335-353, 2015.
- [26] Dantas T., Santos M., Queirós A., & Silva A. G., "Mobile Applications in the Management of Headache," *Procedia Computer Science*, vol. 100, pp. 369-374, 2016.
- [27] Fischer M., & Lam M., "From Books to Bots," *Proceedings of the First Workshop on IoT-Enabled Healthcare and Wellness Technologies and Systems - IoT of Health '16*, pp. 23-28, 2016.
- [28] Ibarra-Yruegas B. E., Camara-Lemarroy C. R., Loredó-Díaz L. E., & Kawas-Valle O., "Social networks in medical practice," *Medicina Universitaria*, vol. 17, no. 67, pp. 108-113, 2015.
- [29] Gravenhorst F., Muaremi A., Bardram J., Grünerbl A., Mayora O., Wurzer G., Tröster G., "Mobile phones as medical devices in mental disorder treatment: an overview," *Personal and Ubiquitous Computing*, vol. 19, pp. 335-353, 2015.
- [30] Vivek V., Rajan H., Vijay R., Surendar S., and Geetha R., "IoT Enabled Smart Mirror for Physically Challenged," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 7, no. 2, pp. 334-338, 2018.

- [31] Yusri M., Kasim S., Hassan R., Abdullah Z., Ruslai H., Jahidin K., and Arshad M., "Smart Mirror for Smart Life," *2017 6th ICT International Student Project Conference (ICT-ISPC)*, Skudai, pp. 1-5, 2017.
- [32] Gambhir S. S., Ge T. J., Vermesh O., & Spittler R., "Toward achieving precision health," *Science translational medicine*, vol. 10, no. 430, pp. 1-9, 2018.
- [33] Colantonio S., Coppini G., Germanese D., Giorgi D., Magrini M., Marraccini P., Martinelli M., Morales M.A., Pascali M.A., Raccichini G., and Righi M., "A smart mirror to promote a healthy lifestyle," *Bio systems Engineering*, vol. 138, pp. 33-43, 2015.
- [34] Maheshwari P., Kaur M. J., and Anand S., "Smart Mirror: A Reflective Interface to Maximize Productivity," *International Journal of Computer Applications*, vol. 166, no. 9, pp. 30-35, 2017.
- [35] Sarnin S. S., Akbar A., Mohamad W. N. W., Idris A., fadzlina Naim N., & Ya'acob N., "Maleficent Mirror with ALEXA Voice Services as an Internet of Things Implement Using Raspberry Pi 3 Model B," in *TENCON 2018-2018 IEEE Region 10 Conference*, pp. 1202-1207, 2018.
- [36] Siripala M., Nirosha P., Jayaweera N., Dananjaya M., Fernando S., "Raspbian Magic Mirror-A Smart Mirror to Monitor Children by Using Raspberry Pi Technology," *International Journal of Scientific and Research Publications*, vol. 7, no. 12, pp. 281-295, 2017.
- [37] Sethukkarasi C., Hari Krishnan V., and Pitchiah R., "Design and development of interactive mirror for aware home," in *Proceedings of the First International Conference on Smart Systems, Devices and Technologies*, pp. 1-8, 2012.
- [38] Fujinami F., Kawsar K., and Nakajima T., "Aware Mirror: A personalized display using a mirror," in *Proceedings of the Third International Conference on Pervasive Computing*, pp. 315-332, 2005.
- [39] Hossain P., Atrey K., and Saddik A., "Smart mirror for ambient home environment," in *Proceedings of the Third IET International Conference on Intelligent Environments*, pp. 589-596, 2007.
- [40] Sethukkarasi C., Hari Krishnan V., and Pitchiah R., "Design and development of interactive mirror for aware home," in *Proceedings of the First International Conference on Smart Systems, Devices and Technologies*, pp. 1-8, 2013.
- [41] Alisha K., Jyotsna A., and Meenu, D., "Application of bioelectrical impedance analysis and anthropometry as interchangeable methods to assess body composition of sportspersons," *International Journal of Biomedical and Advance Research*, vol. 8, no. 11, pp. 400-406, 2017.
- [42] Charu P., Munna K., and Saini J., "Design and Analysis of Adjustable Constant Current Source with Multi Frequency for Measurement of Bioelectrical Impedance," *International Journal of Applied Engineering Research*, vol. 13, no. 1, pp. 262-267, 2018.
- [43] Maria C., Barbosa S., Aluísio J., Barros J., Wang B., Heymsfield R., Pierson J., "Bioelectrical impedance analysis: population reference values for phase angle by age and sex," *The American Journal of Clinical Nutrition*, vol. 82, no. 1, pp. 49-52, 2015.
- [44] Hillier, S. E., Beck, L., Petropoulou, A., & Clegg, M. E. (2014). A comparison of body composition measurement techniques. *Journal of human nutrition and dietetics*, 27(6), 626-631. DOI: 10.1111/jhn.12197.
- [45] Pal D., Funilkul S., Charoenkitkam N., & Kanthamanon P., "Internet-of-things and smart homes for elderly healthcare: An end user perspective," *IEEE Access*, vol. 6, pp. 10483-10496, 2018.
- [46] Zhang M., Xin H., Thomas G., Jafar S., "A Comprehensive Review of Significant Researches on Face Recognition Based on Various Conditions," *International Journal of Computer Theory and Engineering*, vol. 6, pp. 7-15, 2017.
- [47] Kim, N. H., Lee, J., Kim, T. J., Kim, N. H., Choi, K. M., Baik, S. H., ... & Kim, S. G. (2015). Body mass index and mortality in the general population and in subjects with chronic disease in Korea: a nationwide cohort study (2002-2010). *PLoS One*, 10(10), e0139924. DOI: <https://doi.org/10.1371/journal.pone.0139924>
- [48] Frank, L. D., Schmid, T. L., Sallis, J. F., Chapman, J., & Saelens, B. E. (2005). Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. *American journal of preventive medicine*, 28(2), 117-125. DOI: <https://doi.org/10.1016/j.amepre.2004.04.011>.
- [49] INBODY, "Bio Impedance Analysis technology and applications," [Online] Available: <https://inbodyusa.com/blogs/inbodyblog/bia-technology/39971073-bia-once-flawed-not-anymore/>, 2018.
- [50] Gin, R. Wang, J. Lin, M. Ho, M., "Different Measuring Techniques for Body Fat Analysis," *International Journal of Computer Science & Information Technology (IJCSIT)*, vol. 118, pp. 102-105, 2018. <http://oaji.net/articles/2015/731-1436091517.pdf>
- [51] Morrison, S., "Regulation of body temperature," in Boron WF, Boulais EL, eds., "Medical Physiology," 3rd ed. Philadelphia, PA: Elsevier, 2017.
- [52] Health Digest, "The risks of Poor Fitness," [Online] Available: <https://www.rd.com/health-digest/>, 2016.