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Digital Companion for Elders in Tracking Health and Intelligent Recommendation Support using Deep Learning

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Abstract— Ambient assisted living (AAL) facilitates the daily routines of elderly people, particularly those who have clinical difficulties or physical limitations. The latest technologies like distributed compuring,internet of things (IoT) and machine learning pave the ground for the creation of an effective automated tracker which aids elder citizens to live independently. The suggested system is attempted to design a wearable that monitors the blood glucose level through sweat. To achieve high accuracy, the proposed system uses ambient sensing and deep learning based techniques. It places a strong emphasis on calculating the health index by taking into account numerous disease-related characteristics or vitals such as heart rate, blood pressure, SpO2, blood glucose level, respiration rate, sweat rate, uric acid, and temperature. From the wearable device designed the vital signs are gathered, further environmental sensors and camera fixed around the person continually monitors the behavioral pattern along with physiological signals. This ensures the improved accuracy of health state prediction from its conventional models in place. The key advantage of this device is that it may be held and operated anyplace without interrupting their day-to-day tasks because the device is to be cheap, reliable and speedy.

Keywords- ambient assisted living (AAL); context awareness; deep learning; internet of things (IoT); regulatory monitoring; wearable sensors

I. INTRODUCTION

According to an article in the Economic Times News, India is the fourth most populous country in the world, and the Indian government is expected to have more than 34 crore people aged 60 and more by 2050. Aging has an impact on a person's health as well as their daily activities. Alzheimer's disease, arthritis, cardiovascular disease, hearing loss, hypertension, and other disorders associated with ageing are among the most frequent. As a result, the elders' caregivers provide full support.

It is believed that a loss in amount of physical activity is strictly coupled with ageing and is linked to sadness, poor social function, and cognitive impairment. In order to encourage active and healthy ageing and to enable individuals to maintain their independence for a longer period of time, a focus upon cognitive, physical and social activity is required. Technologies for AAL can step in to assist older persons at various phases of ageing. In fact, the goal of AAL is to foster innovation so that individuals can maintain relationships, good health, and active lifestyles well into old age. It focuses on creating goods and services that actually improve people's lives for those dealing with the difficulties of ageing including those who provide care for elderly persons in need. The need for AAL, technologies for it and applications are deeply investigated [1, 2].

The creation of AAL system applications has drawn significant interest from the research community in recent years for a number of reasons, including their potential to lower the costs associated with offering elderly people with daily living assistance, to monitor the physical and mental health of people who live alone, and to identify changes in behavior that might be an early sign of neuro-degenerative diseases. The applications for AAL and readiness of the user acceptance is captured [3]. The significant challenges to be dealt in facilitating AAL systems are well summarized [4].

This work attempts to derive a complete vital monitor for elderly person with flexible sweat sensor to calculate blood glucose level. Along with biosensors, activity and environmental sensors are adapted to bring effective AAL device in place. The workflow of the proposed system initiated with sensor readings, then it transmits to cloud layer for data processing from context modeling, pre-processing stage and finally to classification phase. Machine learning algorithms are to be applied in order to attain best possible prediction of elder activity and also ascertaining any abnormality in advance.

The remainder of the article is structured as follows: The section 2 analyzed the related work carried out in this domain. Also the real world applications and research gap existed are captured. In section 3 details the design of sweat sensor. It concludes the prototype for complete physiological monitor for AAL. Further the deep learning classifier is elaborated. In section 4 the performance of the classifier is discussed and finally section 5 concludes the work.

II. LITERATURE REVIEW

In this section, noteworthy contributions made by various researchers in obtaining an effective AAL system in real are addressed. Moreover the interesting applications realized in modern world in assisting AAL are also enlisted below. Also the desirable qualities of proposed AAL system are detailed.

A. Related Work

Gowda et al. [5] investigated the scope for AAL and the variety of technologies in implementing the same along with possible hurdles to face with. The different problem phenomenons of elders were analyzed in this system. The system had a high focus in devising AAL which assists the older adults with physical and cognitive impairments. Francesco Piccialli et al. [6] investigated the effective role of modern technologies like cloud models, IoT and deep learning improves the performance of medical devices associated with AAL in their article exhaustively.

Chandreyee Chowdhury et al. [7] conducted an exhaustive survey on AAL in order to address the growing rate of aging population and their requirements realized around the world. It presented the previous efforts put forth in terms of frameworks devised for AAL, platforms for implementation, technologies deployed and user acceptance rate. Further it reveals the significant role of machine and deep learning practices in delivering effective health informatics for AAL. Liyakathunisa Syed et al. [8] designed a smart framework for AAL by using big data analytics, internet of medical things (IoMT) and machine learning. The system inherently analyzed the different types of machine algorithms. It executed the multinomial naïve bayes classifier to decide upon the elder state over the cloud layer. Further to optimize the functionality of cloud, Hadoop map reduce algorithm also exercised.

Srinivasan et al. [9] designed an IoT based intelligent device for AAL which is a relatively new communication technology that creates a smart item in the environment to assist older people in living independently. The number of older persons living alone is on the rise these days. As a result, it has a significant impact on our society. Using the Internet of Things (IoT) and the Support Vector Machine (SVM) algorithm, the suggested system conducts three operations: monitoring elderly individuals, activity recognition, and health status prediction. The SVM algorithm predicts health status with an accuracy rating of 89 percent for one week data and 84 percent for one month data. Similarly, the K - SVM algorithm has a 91 percent accuracy rate for 1 week data and an 88 percent accuracy rate for 1 month data. The K-SVM algorithm is used in the proposed system to offer.

As people become older, type 2 diabetes and prediabetes are more common. Similar to younger individuals, senior patients receive the same initial therapy for type 2 diabetes, which includes advice on diet, exercise, improving blood glucose control, and causing unnecessary. The adaptation of sweat sensing paves the way to build painless glucometer which records continuous real time recording as possible. The complete survey in facilitating an efficient sweat sensor to monitor blood glucose level is carried out [10]. J.M.J. Den Toonder et al. [11] and Zhang et al. [12] discussed the function of sweat gland and technologies obtaining sweat rate and its usage in glucose calculation for long term in detail. Michael Chung et al. [13] spotlighted the tremendous effort experienced in designing a sweat sensor which helps in analyzing the alcohol consumption rate, blood glucose level and pH value through sweat. The possible design approaches in handling the same was elaborated in this system. Ning Xue et al. [14] best captured the various efforts done in attaining wearable sweat sensor by incorporating electrochemical sensors which operates flexible. The advancement in electrochemical sensor in bringing flexible sweat sensor is discussed [15]. Lan Xu et al. [16] enlisted the three predominant methodologies in designing wearable sweat sensor and compared all of its merits and demerits.

Xueyi Wang et al. [17] reviewed the past attempts in area of fall detection systems for elders. The article revealed the different categories of falls, and practical limitations of single sensor or wearable based solutions. The scope for sensor fusion

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in achieving higher accuracy was discussed in a deeper sense. Anita Ramachandran et al. [18] proposed a wearable design that helps in detecting accidental fall detection of elders in great interest. With detailed survey over fall detection system, the article explored the design requirements and the limitations in obtaining as a core product. The usage of machine learning to attain high accuracy rate is also deeply discussed. Turkane et al. [19] designed a fall detection system for aged persons employing 3 axis accelerator and video camera as its significant components. The system used support vector machine (SVM) which is an artificial intelligence technique in its implementation to derive precise prediction.

Hubert Kenfack Ngankam et al. [20] proposed architecture for AAL incorporating context awareness in it. The system is designed to track wandering nature of dementia person as well day-to-day activities. The system facilitated a remarkable assistance in obtaining a recuperative sleep over wandering. The adaptation of context aware computing into the AAL is elaborated with greater interest. Young-Kuk Kim et al. [21] developed an efficient context-aware recommender system which works well on even sparse dataset with good performance. The system is employed with neural network based auto encoder mechanism over diverse datasets in predicting the right content of interest as recommendation. Context aware modeling of vital sign monitor is well elaborated in [22].Moreover the significant role of fog nodes in achieving quicker analysis out of device is also well detailed.

B. Convincing Real Applications

The noteworthy wearable's existed as smart watch intended to assist the elders via tracking health cum daily activities, detecting fall rate and alarming messages, voice or video call facilities and built-in alexa recommendations are listed as below:

- Apple 5
- Apple 4
- Fitbit Versa 2
- Samsung Gear 3
- Remote Health
- Freedom Guardian

Caring.com is a web portal offers AAL solutions to elders in the form of suggesting home care products, enabling nursing services, listing the community centers, finding nearest AAL centers with facilities, recommendations and alert services to care givers. Kitescare is a web portal offers care service to elders. Inspired by elders & delivered by passionate professionals, KITES Senior Care is the geriatric care specialist brand setup in 2016 with a vision to be the trusted out of hospital care continuum partner to the elderly & their family.

C. Functionalities of Proposed System

In correlation with exhaustive review conducted over existing systems pertaining ambient assisted living (AAL) to elders, facilitated smart AAL with the help of IoT and few efforts are made in empowering the sensing data with intelligence through machine learning. The maximum work focused on particular health issue or illness like diabetics, fall detection and cardiac problems in delivering the AAL solutions. Further it invokes few set of functionalities like activity or health index monitoring, reporting and notifications.

The proposed system is aimed to design a comprehensive solution incorporating the features as follows:

- Accommodating all the major health issues of aging
- Accounting environmental factors around the scenario
- Proposing a sweat sensor for measuring blood glucose and pH value as possible

The primary motive is to bring an AAL system facilitating all significant functionalities in one application that too in cheap in cost. The functionalities of AAL to be in implementation path are as follows:

- Alarm service in emergency
- Daily activity tracking
- Detecting fall rate
- Exploring emotional connect
- Regular health index calculation
- Regulating self-discipline practices through recommendations
- Reporting to care givers and medical professionals

The novelty of the system lies in achieving effective biosensor for blood glucose monitoring and accumulating the above mentioned functionalities of AAL.

III. COMPREHENSIVE PHYSIOLOGICAL MONITOR FOR AAL: DESIGN AND PROCESS

The implementation of the proposed system is divided into the modules and is discussed below in detail.

A. Designing a Device Layer

Regularly or infrequently, the smart physiological monitor typically monitors health progress of elder person, communicates it to its users, and attempts to predict future problems. Using IoT devices, the user's physiological state is gathered. Data processing as well as analysis is often carried out at the cloud server in order to respond. The following problems must be resolved in modern remote patient monitoring in order to adjust to emerging technologies.

- User data won't stay the same; it will alter based on the surroundings. Human body temperature, for instance, will fluctuate depending on the environment in the room.
- IoT nodes that are scalable and power-constrained

- Cloud platform computation and security costs

This proposed approach to solve the issues places fog nodes between the device and cloud layer. The Figure 1 depicts the proposed model's structural elements and services.

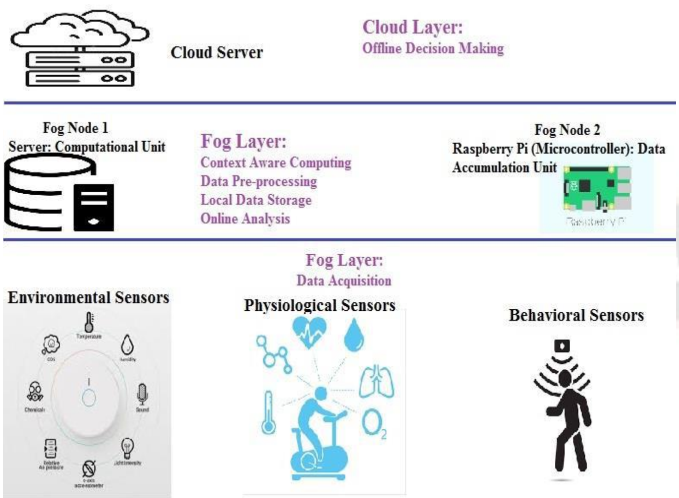

Figure 1. The generic architecture of the proposed AAL. (Source: K. Revathi et al.)

More specifically, sensors incorporated into to the kit's design will be used to determine a person's health status. In order to read the state of physiological measurements such heart rate, blood oxygen level, blood glucose level, muscle activity, brain activity, and so on, biosensors are inserted into the human body. In the actual world, ECG sensors, EEG sensors, and pulse oximeters are used to measure SpO2, heart rate, and brain activity, respectively. The motion sensors, gyroscope, and accelerometer can be used in conjunction with biosensors to identify the human body's motion patterns. As they are placed on the human body, activities and biosensors create a wireless body area network (WBAN). Environmental sensors gauge the space's temperature, noise level, and air quality. Biosensors and activity sensors alone were discovered to be used in existing systems to forecast human health with reduced accuracy due to environmental factors. By taking into account environmental factors, such as the effect of room temperature, noise and air quality on human physiological tests, the suggested study increases accuracy. In this system, along with activity sensors, the multimedia device like camera is also utilized to detect the person’s well position according to the behavior.

In bringing the appropriate layout of IoT kit assisting elders, the necessary components have to be identified. The proposed system provides a complete solution to AAL system through integrating wearable sensors with ambient sensors installed around the environment. The significant wearable and ambient sensors to be considered for design are tabulated as 1 and 2 respectively.

TABLE I. LIST OF AMBIENT SENSORS FOR DESIGNING AN AAL

Sensor	Measurement	Date Rate	Communication Method
Pressure	Pressure on mats, chairs, etc.	Very low	I2C/SPI
Passive Infrared (PIR)	Motion	Low	I2C/SPI
Active Infrared	Motion, Identification	Low	I2C, USB
RFID	Location, Object information	High	USB, Ethernet
Smart Tiles	Pressure on the floor, location	Very low	I2C/SPI
Magnetic switches	Door/Window/Cabinet opening closing	Very low	I2C/SPI
Temperature	Room temperature	Very low	Single wire or 12C
Ultrasonic	Motion	Low	I2C
Microphone	Sound, Activity	High	USB
Camera	Video, Activity	Very high	HDMI

TABLE II. WEARABLE SENSORS FOR DESIGNING AN AAL

Sensor	Measurement	Date Rate	Communication Method
Accelerometer	Acceleration	High	Bluetooth
Gyroscope	Orientation	High	Bluetooth
Glucometer	Blood Glucose	High	Bluetooth
Temperature	Body temperature	Very low	Bluetooth
Pressure	Blood pressure	Low	Bluetooth
Pulse Oximeter	Blood oxygen saturation	Low	Bluetooth
ECG	Cardiac activity	High	Bluetooth
EEG	Brain activity	High	Bluetooth
EMG	Muscle activity	Very High	Wired or Wi-Fi

A number of variables, including the outside temperature, physical activity, emotional condition, etc., have an impact on sweat production. Hence, it is possible to determine the physical and mental health of the human body using the relevant biochemical information in sweat. Sweat mostly consists of water and sodium chloride (NaCl), but it may also contain other ions (such as K^+ and Ca^{2+}), metabolites (such as lactic acid, glucose, and alcohol), and other substances, depending on where on the body it is produced. Monitoring sweat components, which flow from the bloodstream to the skin's surface through sweat and convey a wealth of physiological data, is one of the most crucial ways to alter the physiological index in real time. The sweat sensor is to be

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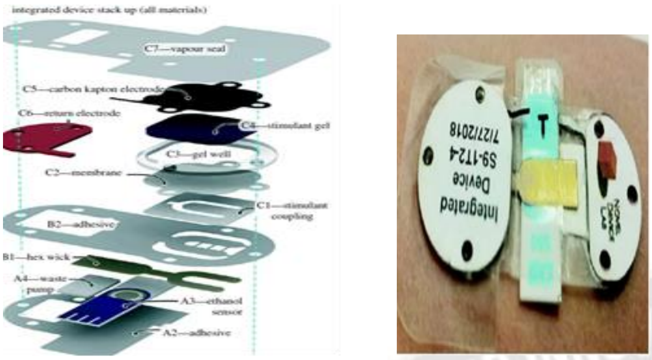
developed to obtain the blood glucose level, alcohol and the pH value of the person and it is captured in Figure 2.



(a) (b)

Figure 2. The proposed sweat sensor representing a) cross cut view and b) top view. (Source: M. Chung et al.)

Integration of the all the necessary sensors chosen for proposed system into the IoT development board brings the prototype of IoT kit devised for AAL. Along with this the environmental data observed from the ambient sensors have to incorporated in empowering IoT device for AAL with context aware computing.

B. *Proposing a Processing Layer*

The acquired data from sensor needs to be processed to attain the optimal result in deciding state and health index of the aged cares. In order to promote faster computation, fog nodes are introduced in this system. It facilitates data pre-processing, context modeling and presents real-time monitoring data. The cloud server executes machine learning algorithms in order to predict the health condition of the person early. The machine learning techniques are exercised here to reduce the error rate in classification. The deep learning algorithms like convolutional neural network (ConvNets / CNN) gained attention recently because of its efficiency in mapping voluminous image mapping within a minimal execution time period. The CNN based architecture of the proposed model for predicting health state of elder is depicted as Figure 3.

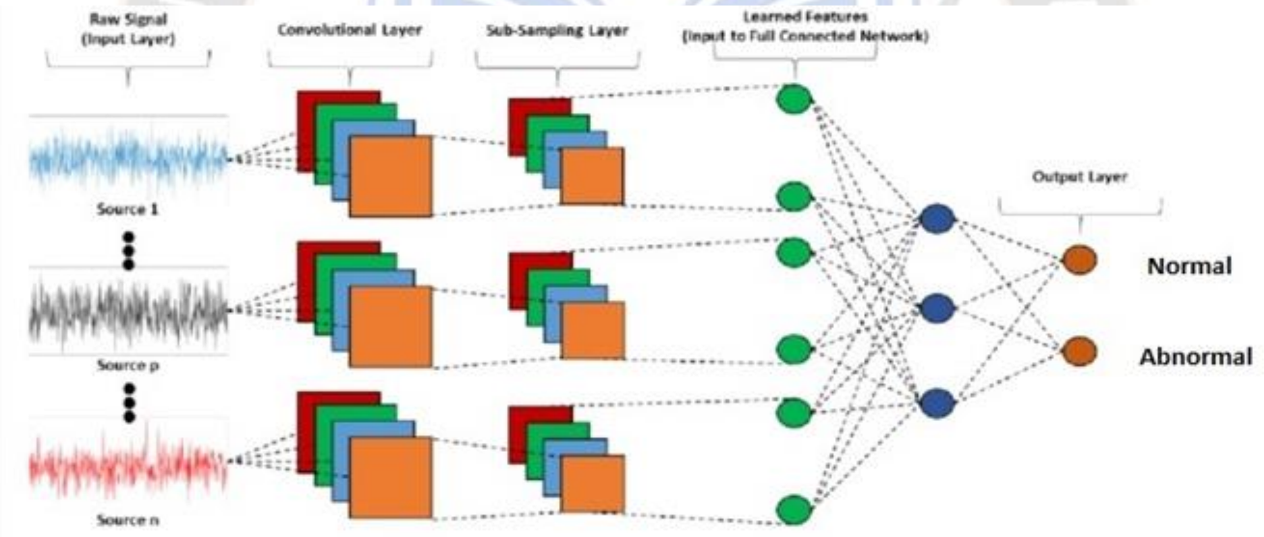


Figure 3. CNN based Framework for Predicting Health State of a Person.

Further the result set can be optimized in enhancing the accuracy of prediction, a particle swarm optimization (PSO) is to be employed here and the same illustrated in Table 3.

TABLE III. PROCESS FLOW OF PARTICLE SWARM OPTIMIZATION

1. Initialize X_i and V_i such that $x_i \in rand(X^{min}, X^{max})$ and $V_i = 0$ where $rand(X^{min}, X^{max})$ is the uniform random number between X^{min} and X^{max} $(\forall_i = 1,2,\dots,n)$
2. $\hat{X}_i \leftarrow X_i \; and \; \hat{g} \leftarrow \arg\min x_i \, f(x_i)$
3. While not converged:
   - For each particle:
     - Generate uniform random numbers
     - Update the velocities of each particle:

       $$V_i^{k+1} \leftarrow \omega v_i^k + c_1 r_1 \left(\hat{x}_i - x_i^k\right) + c_2 r_2 \left(\hat{g} - x_i^k\right)$$
   - Update the positions of each particle: $x_i^{k+1} \leftarrow x_i^k + v_i^{k+1}$
   - Calculate $f(x_i)$
   - Update the local bests: $\hat{x}_i \leftarrow x_i \; if \; f(x_i) < f(\hat{x}_i)$
   - Update the global best: $\hat{g} \leftarrow x_i \; if \; f(x_i) < f(\hat{g})$

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Swarm Intelligence (SI), a significant subset of artificial intelligence, is based in part on the naturally occurring social swarms' intelligent collective activity. The PSO algorithm is one of the most well-liked SI paradigms. PSO has been used in a variety of applications during the last few years, and researchers' interest in it has grown [23]. We start with a number of random locations on the plane (call them particles) and let them search for the minimum point in a variety of directions, much like a flock of birds searching for food. Every particle should look around the lowest position it has ever found as well as the lowest point the entire swarm of particles has ever found at each step. We believe that after a given number of iterations, the smallest point of the function represents the lowest position that this swarm of particles has ever investigated. The terms "cognitive coefficient" and "social coefficient" refer to the parameters c_1 and c_2, respectively. They decide how much importance should be placed on both recognizing the search result of the swarm and fine-tuning the search result of the particle itself. These factors can be thought of as influencing the trade-off between exploration and exploitation [24]. This technique has an intriguing characteristic that sets it apart from other optimization algorithms: it is independent of the gradient of the objective function. The ease with which PSO can be parallelized is another feature.

IV. RESULTS AND DIXCUSSION

The execution setting, performance metrics of significance to show the effectiveness of the suggested deep learning model, and the assessment findings are all covered in detail in this part.

A. *Execution Platform*

The suggested deep learning model's performance is evaluated using the TensorFlow 2.0 execution environment. It was created by Google as an open source. It has been a preferred option among developers and is simply accessible to everyone. Table 4 summarizes the system requirements to carry out deep learning experiments in the TensorFlow environment.

TABLE IV. SYSTEM REQUIREMENTS

Software Requirements	Hardware Requirements
Microsoft Visual C++ Redistributable pip 19.0 Python 3.5 Raspbian 19.0 Windows 10	Central Processing Unit (CPU) : Intel Core i7-2.9Ghz Graphics Processing Unit (GPU) : NVIDIA GTX 1050 Ti with 4 GB RAM

B. *Performance Measures and Evaluation Results*

The following measures of interest are used to evaluate the effectiveness of the vital monitoring for AAL model, and they are predicted as Table 5 below.

TABLE V. PERFORMANCE INDICATORS

Performance Measure	*Formula*
Accuracy	$A = \frac{TP + TN}{TP + TN + FP + FN}$
Precision	$P = \frac{TP}{TP + FP}$
Recall	$R = \frac{TP}{TP + FN}$
F-Score	$F = 2 * \frac{P * R}{P + R}$

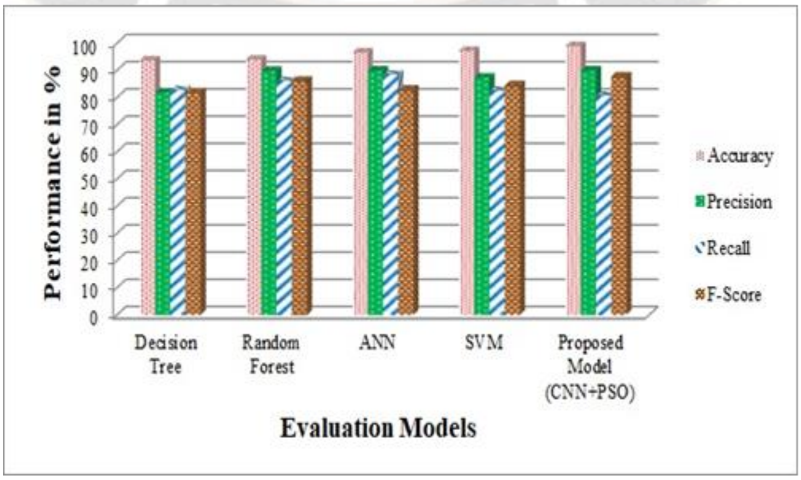

Figure 4. Preferable design of screenshots pertaining to proposed work.

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The suggested model is put to the test against significant AAL initiatives like ANN, decision trees, random forests, and SVM. The Figure 4 best depicts the graphic depiction of several methods used to estimate the classifier for AAL system. The proposed model is obviously intended to produce superior outcomes to other approaches used for comparison analysis. Since the F-Score is a harmonic mean of precision and recall, it projects the robustness and precision of the classifier or model. It denotes the total test accuracy. The greater accuracy is guaranteed by a higher F-Score. The proposed model's F-Score value is 87.7%, which is higher than alternative evaluation methods.

C. Visualization in Application Layer

Apart from the high technological content in the application, the well design of user interface only attracts the customer. The usability of application lies in the design of the interface and it has to be simple in design, easy-to-use, facilitate necessary content in more appealing manner, reliable and error free. Here Android is used to achieve the required mobile application of tracking and recommender design to support AAL. The preferable design for proposed AAL is captured in Figure 5 as below.

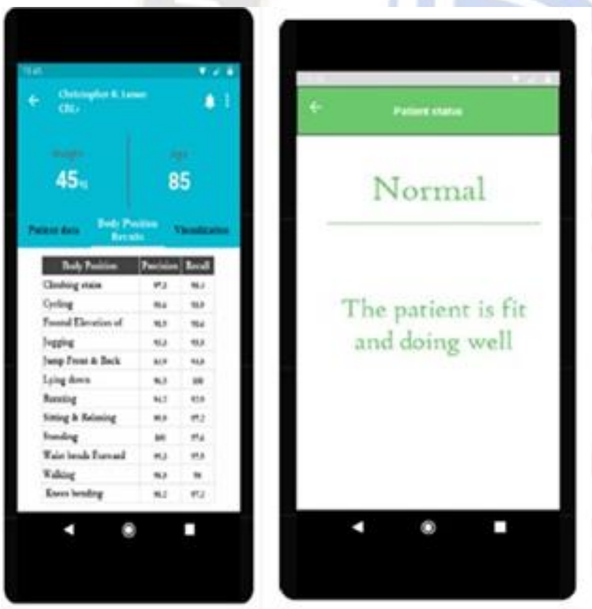

Figure 5. Preferable design of screenshots pertaining to proposed work.

V. CONCLUSION

Acute sensors for monitoring old persons are thoroughly explored in this work. Moreover, a versatile sweat sensor design and a successful IoT-based AAL design are also addressed. Also, a novel classifier CNN optimized with PSO is developed, and its performance is compared to well-known classifiers including ANN, decision tree, random forest, and SVM. The trial findings showed that the suggested DFF enabled encouraging accuracy of 98.9%. The work is heavily concentrated on developing the best classifier for predicting elders' health status. Also, a comprehensive AAL mobile application design is shown.

In future biochemical sensor use in determining a person's full state of health can be taken into account and implemented, ensuring high accuracy.

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AUTHORS CONTRIBUTION

Author 1 specified the concept and it was implemented by authors 2 & 3. Author 4 drafted the entire article upon the suggestion given by author 1.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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