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Intelligent and assisted medicine dispensing machine for elderly visual impaired people with deep neural network fingerprint authentication system

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A R T I C L E I N F O

Keywords:
Elderly and visually impaired people (EVIP)
Medicine dispensing machine (MDM)
Timely Assistance Messaging (TAM)
Medication
Biometric
Medicine dispenser monitoring and controlling system (MDMC)

A B S T R A C T

Offering a medication to Elderly and Visually Impaired People (EVIP) in rural areas without staff assistance is a difficult task in the field of health care. The current pill dispenser has limitations when it comes to administering medication before and after food, doesn't take into account over- and under-dosing situations, and doesn't send notifications to the relevant medical entities when the weight of the pills falls below the threshold. Despite the availability of numerous techniques and methods for automating the delivery of pills, there is no assistive method for the timely and secure delivery of medication. The suggested architecture provides EVIP with five crucial capabilities that aren't present in any of the current pill dispensers in an integrated way. In this paper, we present a biometric sensor-based secure access method for medication kits. The right person is only allowed access to the kit based on the finger print scanner. Second, the suggested architecture provides a self-managed and patient-centric service through assisted and automatic medication delivery. The third feature of this paper is the design method for the efficient delivery of pills before and after meals. A method of alerting the medical entities whenever a medication is over or under dosed is a fourth feature of the system. As a fifth feature, the implementation also automatically notifies the pharmacist and doctor when the weight of the pill strips in the chamber falls below the threshold value. Through the use of an integrated Timely Assistance Messaging (TAM) algorithm, all five features are implemented in the suggested architecture. A finger print recognition system is included with VGG-16 deep neural network with image enhancement. The EVIP can use this proposed system in residences, medical facilities, and retirement communities.

1. Introduction

The majority of people [1] in the real world reside in urban areas. 54% of the world's population was urban in 2014. Since 1960, there has been a 20% increase in the urban population. In the years from 2015 to 2020, 2020 to 2025, and 2025 to 2030, respectively, the urban region's population growth rate is predicted to be 1.84%, 1.63%, and 1.44%. A survey on the elderly people in 20 states of

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India was conducted in July 2018 by the New Delhi-based Agewell Foundation [2]. According to the report, 23.44% of the elderly respondents in India or roughly one-fourth of all elderly Indians lived alone.

The elderly people [3] of age above 60 years will have diversity in health condition [4] than younger people. Most of the elderly people's need a medical treatment for their disease [5] and illness. Unattended various medical treatment at regular timing may lead to various consequences, which may lead to prolonging recovery time. Therefore, a proper constancy is needed in order to remember the time and dosage of the treatment. Especially elderly and visually impaired people, forget in taking the medicine at the proper time. Poor adherence in the medication may lead to major illness. Recovering to normal life may come with a penalty in terms of time, pain and economy due to lack of proper adherence.

This implementation makes use of the TAM algorithm. Based on the EVIP's activity during the administration of their medication, it sends timely assistance [6] messages. The Medicine Dispensing Machine (MDM) has seven chambers, each containing a different set of tablet strips. To authenticate [7] the EVIP in accessing the medical dispensing machine a deep learning network VGG-16 with image enhancement is employed. In accordance with the Medicine Schedule (MS) table, each chamber will open one at a time. In this work, five tables were used. In each chamber, two Ultrasonic Sensors (US) [8] are utilised. A US standing outside the chamber directs the EVIP's hand motion to the correct chamber. To control how the hand enters and exits the chamber to take the medicine, another US inside the chamber is used. The chamber door is opened and closed using a stepper motor (SM) [9]. The weight of the strips is measured using a load cell (LC) both before and after the chamber door is opened.

The contribution of this paper goes with five folds.

a) Authentication is included for the right person to access the medication box. A deep neural network VGG-16 with image enhancement is employed for this purpose.
b) There is no requirement for medical staff participation in the delivery of the medication.
c) Different timely alerting messages are sent to the EVIP, carer, medical professional, and pharmacist depending on the time of day and the EVIP's activity.
d) When the EVIP does not take the prescribed amount of pills, a warning message is sent to indicate either an underdose or an overdose.
e) When the weight of the strips falls below the threshold value in a chamber, a message about refilling the strips is sent to the doctor and pharmacist.

The literature review of various pill dispensers used by elderly people is covered in Section 2. The various pill dispensers are examined in-depth in terms of technology, methods, components, use, and applications. The proposed architecture for the MDM is covered in Section 3. The components used in architecture construction, the authentication procedure, and typical operation during medication are all covered in this discussion. The implementation of databases and algorithms is explained in detail in Section 4. In Section 5, the experimental design and findings are discussed. In Sections 6 and 7, respectively, the conclusion and future improvement are covered.

2. Related work

The MedTracker pill box was created by T. Hayes et al. [10]. This useful pillbox offers 7 days of storage and offers automatic data collection for medication errors and non-adherence. It is a pillbox with multiple compartments that cannot be programmed. This device provides medication information for review on demand, is portable with the elderly person, and doesn't require a user interface.

A medical dispenser created by S. Mukund [11] allows the user to schedule when to dispense various doses of medication. Two different alerting methods are available for patients: one uses an LED display and the other a beeping sound. The alarm makes the first round of pill-taking. Second, a different alarm signals that the pills are available. This device [12] has the ability to be programmed for 31 days to provide the elderly person with 21 different medications.

A system called RMAIS was suggested by C. McCall et al. [13] for the automatic self-management and monitoring of medication. A built-in scale for dosage measurement and a motor to rotate the plate to deliver the proper dosage are features of this RFID-based adherence system. Additionally, it contains a variety of medication messages, such as reminders to patients and alerts to carers about non-compliance.

To increase medication adherence, B. Abbey et al. [14] introduced a pill box that can be remotely programmed. A web application was developed so that carers and medical professionals could programme and monitor the pill box from a distance [15]. Every column in the pill box has wireless connectivity, which automatically communicates with the mobile phone. To make the chamber number easier for people with limited vision to read, Braille numbers have been added. They also used photographic and video evidence to imply the manufacture of a drug.

A design known as MedAssist is said to have been proposed by K. Gupta et al. [16]. There are two parts to this: a user tag and a MedAssist box. An electronic device called a MedAssist box holds the medication that will be given to the elderly person. The carer can programme it using a panel based on the need for medication. The MedAssist user tag is a tiny electronic device with a transceiver for receiving and sending messages. It saves people from having to memorise their medication schedule and enables timely medication administration. Additionally, it makes it possible for rural residents who are unable to read medicine names to take the medication.

A pill box with a consumption and reminder function for tracking a person's activity while taking pills has been introduced by H. K. Wu et al. [17]. Each medicine bag has a printed matrix bar code. Before and after taking the medication, the elderly person must use a camera to scan the bar code. The pill box has a user interface that shows information about the pills on the screen. Even without internet service, the entire setup functions properly [18]. It lowers the overall cost of implementation.

A device created by M. Hatagundi et al. [19] aids patients in taking their medications on time. It avoids unexpected hospital or doctor visits in the elderly. This device [20] disperses the medication in accordance with the schedule. The motion of the compartment is mediated by a stepper motor. The gadget has an alarm system with a buzzer and an LED light. The time of medication will be indicated by a buzzer and LED based on time.

A. Mondragon et al. [21] provided a medikit that consists of a fixed pill dispenser and a portable device that provides information on medical treatments. The mechatronics design of the pill dispenser reduces the time needed to take the pills. The design of the system [22] is very straightforward, making it usable by patients, family members, nurses, carers, etc. Once the device is loaded with pills and the timing parameters are set, it can work automatically and independently to deliver the pills with ease.

The author [23] has provided a dispenser and pill rest for elderly patients to use when taking medication. This was created with low-cost automated equipment and is simple for people to use. In addition to a standard Adruino microcontroller, the dispenser also includes an IR sensor, GSM module, real-time clock, and LCD display. The details of the pill and the timing of administration are displayed on the LCD. The family doctor or carer receives the message about the medication from the GSM module. The lid of the pill box is opened when it is detected by the IR sensor. The various functions of the medication are coordinated using the real-time clock.

A teleconference-based medication dispenser was recommended by J. Jennifer et al. [24] for patients in rural areas. In their medical device, they used an ultrasonic sensor, temperature sensor, heartbeat sensor, camera, load cell, and headphone. Based on the dialogue between the doctor and the patient, the machine distributes tablets. The server has been upgraded throughout. Patients receive message notifications on their Android phones. ATM Medical Machine is the name of the device (AMM). Patients receive their medications right away.

3. Proposed architecture

Fig. 1 shows the proposed architecture. MDM is an entirely automated Internet of Things (IoT) [25,26] based system that will promptly deliver pills to the EVIP. The medicine for a heart and diabetic elderly patient [28] is contained in the pills included in the architecture [27], and it is shown in the Medicine DEtail (MDE) Table 1. Through an Android-based mobile phone, this system can provide the EVIP [29] of time-based information. The EVIP keeps their phone with them as they go about their daily business. Through EVIP's mobile phone, the medication-related information is communicated. The success of the system depends on the person having a phone with them.

Through the dongle, Raspberry Pi [30] sends the command to the smartphone. The Android phone processes the command and converts it to a voice command. The EVIP [31] must move in the direction of the medicine kit in response to the announcement. The EVIP will be instructed to use fingerprint authentication [32] in order to gain access to the medicine kit. The right side of the medicine kit contains the biometric device [33].

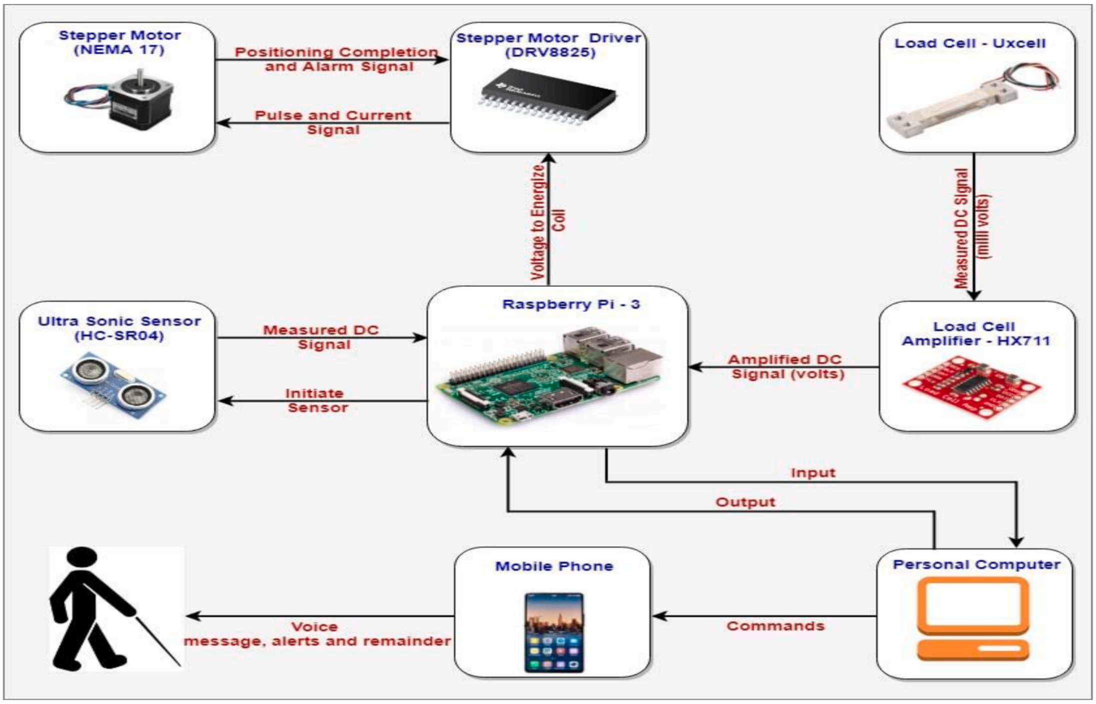

Fig. 1. Proposed architecture medicine dispensing machine.

3.1. Dispensing machine

3.1.1. Construction of dispensing machine

The MDM is made up of wooden box. There are 7 chambers in the medication kit. Each two chamber is controlled by a Raspberry pi. The medication kit requires three Raspberry pi for the complete control of the system. A chamber contains three sub chambers. The Figs. 2 and 3 shows the front view and top view of a chamber. A chamber consists of a Load Cell(LC), Stepper Motor(SM) and Ultrasonic Sensor(US) arranged from right to left as a separate sub chambers. The LC sub chamber consists of a plate for holding the tablet or pills, a load cell to weight the tablet, the load cell amplifier to convert the physical force into a digital signal and a ultrasonic sensor to monitor the hand movement in and out of the chamber for taking the pills. The SM sub chamber consists of a stepper motor to rotate the disk; a stainless steel lead attached with the door opens the chamber and a controller to check the rotation activities of the motor. The US sub chamber consists of a sensor to find the moving hands of the EVIPs across the medication kit. The entire three Raspberry pi are controlled by a Personal Computer (PC) called as Medicine Dispenser Monitoring and Control (MDMC) system. The chamber number is crafted on the top of the each chamber door. This number is used by the EVIP to locate their respective opened chamber using Braille method of reading.

The MDM is made up of a wooden box. There are 7 chambers in the medication kit. Each two chamber is monitored by a Raspberry pi. The medication kit requires three Raspberry pi for the complete control of the system. A chamber contains three sub chambers. The Figs. 2 and 3 shows the front view and top view of a chamber. A chamber consists of a Load Cell (LC), Stepper Motor(SM) and Ultrasonic Sensor(US) [34] arranged from right to left as a separate sub chamber. The LC sub chamber consists of a plate for holding the tablet or pills, a load cell to weight the tablet, the load cell amplifier to convert the physical force into a digital signal and a ultrasonic sensor to monitor the hand movement in and out of the chamber for taking the pills. The SM sub chamber consists of a stepper motor to rotate the disk; a stainless steel lid attached to the door opens the chamber and a controller to check the rotation activities of the motor. The US sub chamber consists of a sensor to find the moving hands of the EVIPs [35] across the medication kit. All the three Raspberry pi are supervised by a Personal Computer [36] (PC) called as Medicine Dispenser Monitoring and Control MDMC system. The chamber number is crafted on the top of the each chamber door. This number is used by the EVIP [37] to locate their respective opened chamber using Braille method of reading.

3.2. Authentication process

Authentication is provided for the safest delivery of the medicine to the EVIP. Unsafe delivery of the pills may lead to the incorrect pills to the EVIPs. Dispatching of incorrect pills to EVIP may lead to overdosage or health [38] related side effects. The Fig. 4 shows the entire authentication process [39] of EVIP. The finger print scanner captures the biometric payload and passes on the payload to

Table 1
Shows the Medicine DEtail table (MDE).

Sl. No.	Tablet Name	Tablet Weight (W_T)	Tablet Description	Tablet Manufacturer	No. of Tablets (N_{TS})	Purpose of the tablet
1	Imdur 30	30mg	Prolonged Release Isosorbide-5-mononitrate Tablets B.P.	Astra Zeneca, Pharma India Limited, 12th Mile, Bellary Road, Bangalore-560083	30	It prevents angina or chest pain in patients with a certain heart condition. (coronary artery disease)
2	Clopilet	75mg	Clopidogrel Tablets I.P.	Sun Pharma laboratories Ltd., Vill : Kokjhar, Mirza Palashbari Road, P. O. Palashbari, Dist : Kamrup, Assam : 781128	15	It avoids blood clots after little procedure and keep opens blood vessels.
3	Cardivas 6.25	6.25mg	Carvedilal Tablets I. P.	Sun Pharma laboratories Ltd., Vill : Kokjhar, Mirza Palashbari Road, P. O. Palashbari, Dist : Kamrup, Assam : 781128	10	It is used to overcome heart failure and high blood pressure during heart attack.
4	Telma 40	40mg	Telmisartan Tablets I.P.	Glenmark Pharmaceuticals Ltd., Village : Kishanpura, Baddi-Nalagarh Road, Tensil Baddi Distt, Solan, (H.P.) - 173205	30	It is used to prevent stroke, treats high blood pressure and other heart diseases.
5	Crosspan-DSR	40mg	Pantoprozole Sodium with Domperidone (Sustained release) capsules	Reltsen Health Care, Spl. Plot. No: 9–11, PIPDIC Electronic Park, Thirubuvanai, Puducherry-605107	10	Stomach ulcers, Intestinal ulcers, Gastro-intestinal reflux, Treatment for symptoms associated with diabetic gastroparesis or idiopathic.
6	Rosuvas 10	10mg	Rosuvastatin Tablets I.P.	Sun Pharma Laboratories Ltd., Plot. No:107–108, Namli Block, P. O. Ranipool, East Sikkim-737135	15	It is used in long term treatment of stroke and heart disease by reducing the bad cholesterol in the body.
7	Nexovas 10	10mg	Cilnidipine Tablets I.P.	Macleods Pharmaceuticals Ltd, Khasra No: 21, 22, 66, 67, 68, Aho Yangtam, Nanchepung, P. O. Ranipool, Sikkim-737135	10	It is used for the management of high blood pressure by relaxing the blood vessels.

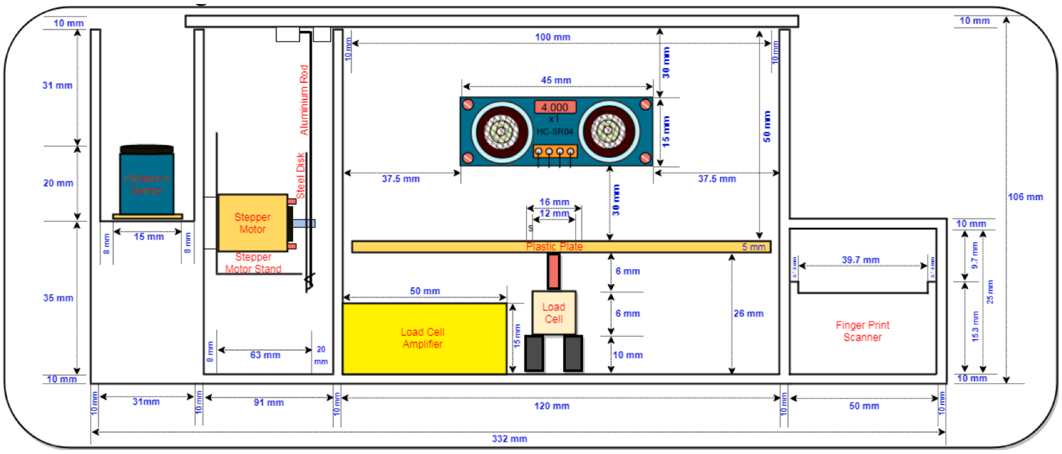

Fig. 2. Shows the arrangement of all components in a single chamber of the medication kit (front view).

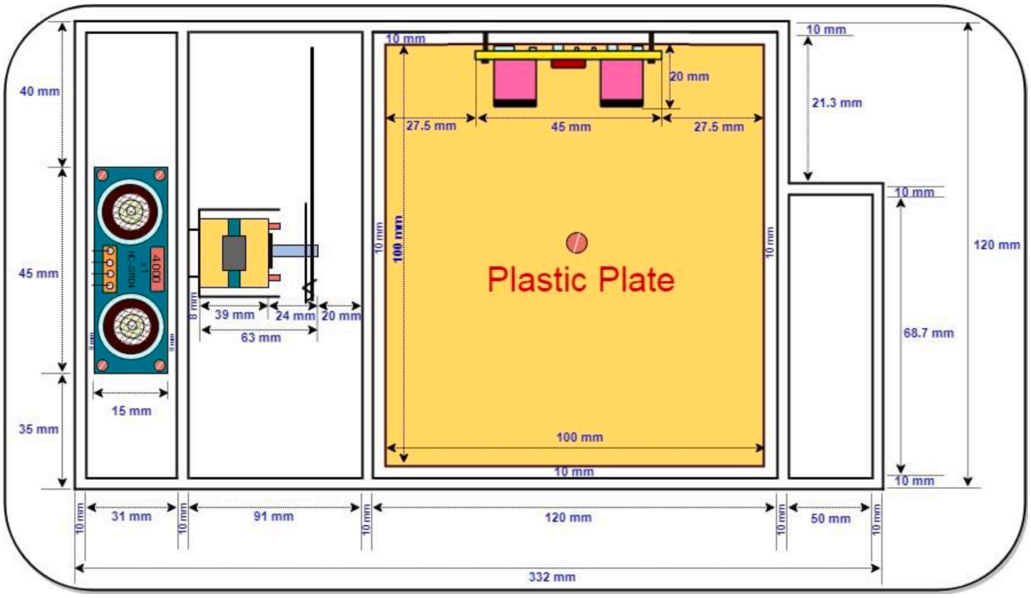

Fig. 3. Shows the arrangement of all components in a single chamber of the medication kit (top view).

MDMC through Raspberry pi. The finger print of EVIP will be verified with the already stored images of the EVIP in the MDMC. If there is an exact match of the payload, the EVIP will be informed about the successful authentication [40]. If it doesn't matches with the stored information, the system will allow maximum of three tries. After the third authentication failure, the MDMC will lock the opening of the medication kit. The normal operation of the system can be taken up by the caretaker.

3.2.1. Recovery of the system

When the authentication fails, the recovery of the system will be done by the caretaker of the EVIP. It is implemented in software using the password lock through the android phone [41]. App will be installed in the mobile phone of the caretaker. During the unsuccessful authentication, the caretaker will be asked to unlock the system for its normal operation. The caretaker will make a phone call to the EVIP, to know what happening during the authentication process. If the caretaker is convinced, he/she will authorise access of the EVIP to the medication kit by providing the password. The MDMC will check the password and unlock the system. The system will return back to the normal operation, where the pills will be dispensed in the customary way. An announced will be made to the EVIP to take medicine in terms of name, dosage and chamber no. based on the Medicine DOsage Table 2 (MDO).

3.3. Normal operation

After authentication, pi refers the Medicine Scheduling Table 3 (MS) for opening of the chambers. Built on the day and time, the list

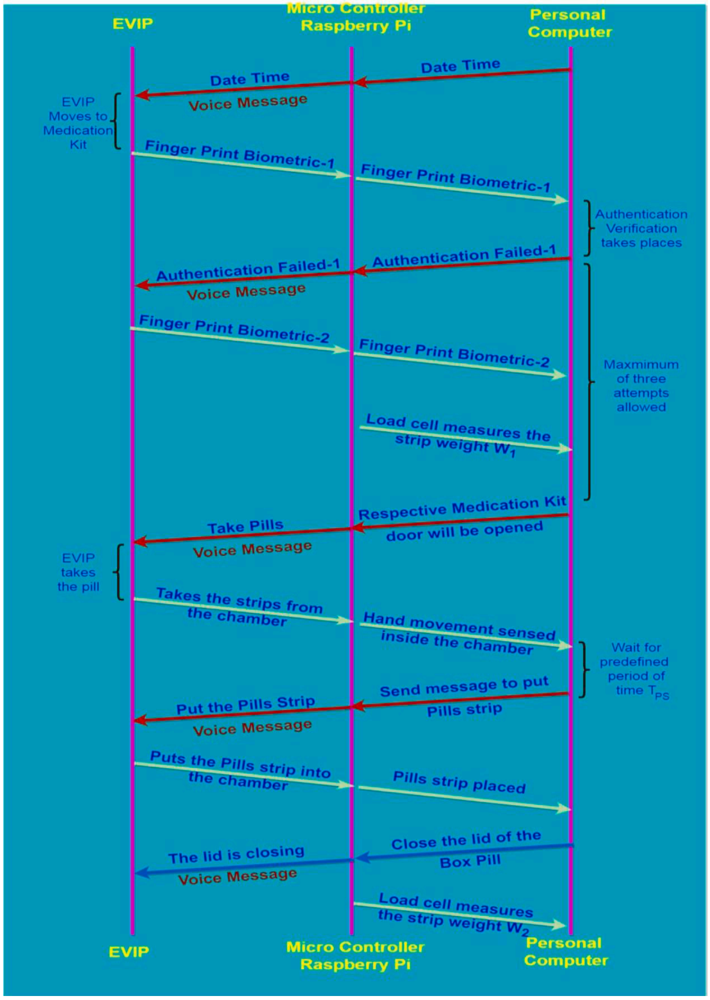

Fig. 4. Shows the sequence of steps involved during the authentication process in the opening the medication kit.

of chambers to be opened is chosen from the schedule table. Medicine chambers which are located on the rightmost side of the biometric [42] sub chamber will have high priority for opening. Each chamber will be opened only after the previous opened chamber is closed. A chamber will be closed completely only after the pill strips are kept in the plate.

3.3.1. Sequence of operation for a chamber

Based on time, the MDMC will initiate the respective Pi for the opening of the chamber door. The S.M. will rotate from 192.5° to 12.5° in clock-wise direction for the opening of the chamber. The opening and closing of the chamber are shown in the Fig. 5. The Stepper motor will rotate for half of the clockwise direction. Pi will initiate the controller to give the required current pulse to the S.M. Once the door is opened, a voice message will be given to the EVIP. Based on the chamber number on the top of the door and with the

Table 2
Shows the Medicine DOsage table (MDO).

Sl.No.	Chamber ID	Tablet Name	Tablet Dosage (D_{PD})	Tablet Session	Tablet Time
1	C001	Imdur 30	1.0	M, N	AF
2	C002	Clopilet	1.0	A	AF
3	C003	Cardivas 6.25	0.5	M, N	AF
4	C004	Telma 40	1.0	N	BE
5	C005	Crosspan-DSR	0.5	M, N	AF
6	C006	Rosuvas 10	1.0	M, N	BE
7	C007	Nexovas 10	1.0	A	AF

M-Morning, A-Afternoon, N—Night.
BE-Before Food, AF-After Food.

Table 3
Shows the Medicine Scheduling table(MS).

Sl. No.	Tablet Session	Time Slot	Tablet Time	Chamber ID
1	M	BE	09:00	C006
2		AF	09:30	C001, C003,C005
3	A	BE	12:30	
4		AF	01:00	C002, C007
5	N	BE	08:00	C004, C006
6		AF	08:30	C001,C003, C005

M-Morning, A-Afternoon, N-Night.
BE-Before Food, AF-After Food.

help of a voice message, the EVIP can move his hand across the medication kit. While moving the hand, the U.S. in each chamber will serve to move the hand to the correct opened chamber. When the hand moves in wrong direction, it will be sensed by the U.S. in anyone of the chamber. Due to modify in the distance, the U.S. will be informed about the movement of hand to MDMC. In turn, the MDMC will convey the message to EVIP.

Before opening the chamber, the Pi will record the initial weight of the L. C. in milli-volts. The L. C. amplifier will scale the millivolts to volts for further measurement. The measured value will be sent to the MDMC through Pi. This value is called W_1. Once the user has picked the right chamber, he can take the pills strip from the plate. The name of the pill and the dosage quantity along with the purpose of the pill will be informed to the EVIP through phone. After EVIP taking the pill, he/she may keep the pills strip on the plate.

An U. S. is present inside the L.C. sub chamber. It is situated above the plastic plate and attached to the back wall of the sub chamber. It is used to identify the entry and exit of the hand inside the chamber for taking of pills strip. When user has informed to pick the strips from the chamber, U. S. will identify the entry of hand into the chamber. There will be a change in the sound waves from the habitual reading. The hand entered into the chamber deflects the sound wave, which creates the shorter travelling of waves. The time at which the hand enters into the chamber will be recorded by Pi and stored in MDMC.

Likewise, when the EVIP keeps the strip inside the chamber, again the time of entry will be recorded. Now, the MDMC initiates Pi to trigger the S. M. The S. M. will rotate from 12.5° to 192.5° in clockwise direction for closing the chamber. The load cell [43] will read the weight of the strip. The measured weight will be transferred to MDMC. This measured value is called W_2. Already measured weight (W_1) will be subtracted with the presently measured weight (W_2), which will give the difference in weight (ΔW) (1). The ΔW will be compared with the threshold weight (W_T) of the chamber. The threshold weight will be obtained from a Medicine Weight Threshold Table 4 (MWT).

$$\Delta W = W_2 - W_1 \tag{1}$$

If ΔW is greater than the W_T, there is no need for an emergency alert to be generated i.e., normal operation. Otherwise, a message will be attached to a report. At the end of the medication, the emergency report will be delivered to all the phone numbers which is stored in the phone Table 5.

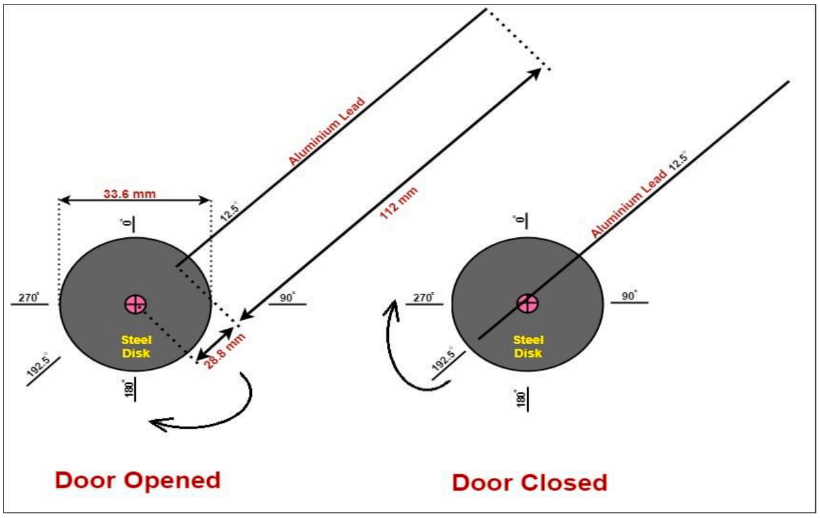

Fig. 5. Shows the position of the disk in opening and closing the door.

Table 4
Shows the Medicine Weight Threshold table (MWT).

Sl. No.	Chamber ID	Tablet Name	No. of Strips (N_{SC})	Total Weight of a single strip (W_S) (mg)	Empty Strip Weight (W_{ESW}) (mg)	Threshold Weight (W_{TWS}) (mg)
1	C001	Imdur 30	2	1050.0	150	270
2	C002	Clopilet	2	1325.0	200	500
3	C003	Cardivas 6.25	2	92.5	30	55
4	C004	Telma 40	1	1325.0	125	285
5	C005	Crosspan-DSR	2	445.0	45	205
6	C006	Rosuvas 10	2	180.0	30	70
7	C007	Nexovas 10	3	125.0	25	65

3.4. *Architecture of fingerprint recognition*

This recognition system shown in Fig. 6 is composed of RGB to GrayScale convertor, Gaussian Blur filter, Adaptive Gaussain Threshold and VGG-16 classifier. All colour information is removed, leaving only various shades of grey, with white being the lightest and black being the darkest in the initial conversion process. The Gaussian blur is a low-pass filtering technique is employed to eliminate Gaussian noise or random noise from the image. The adaptive thresholding uses the differences in pixel intensities of each region to distinguish between desirable foreground image objects and the background. VGG16 is an classification and object detection algorithm that classifies 1000 images into 1000 different categories.

3.4.1. *Gaussian blur*

In two dimensions, it is the product of two such Gaussians (2), one per direction:

$$G_{xy} = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{2}$$

where 'x' is the distance in the horizontal axis from the origin, 'y' is the distance in the vertical axis from the origin, and 'σ' is the standard deviation of the Gaussian distribution. This formula, when used in two dimensions, creates a surface with concentric circles that have a Gaussian distribution away from the centre point. A convolution matrix is created using values from this distribution and then applied to the original image. The new value for each pixel is set to a weighted average of its surrounding area. The value of the original pixel, which has the highest Gaussian value, is given the most weight, and as the distance between pixels grows, so do their weights. As a result, there is a blur that better maintains boundaries and edges.

3.4.2. *Adaptive threshold Gaussian method*

The Simple Thresholding technique compares each image pixel value to a global threshold that has been set. However, for a variety of reasons, the lighting and brightness of the image won't always be uniform throughout the image. Simple thresholding is not very practical for many use cases because it has obvious flaws and demands fairly pristine input. The threshold values for smaller regions of the image are dynamically determined when using the adaptive thresholding technique. As a result, depending on the surroundings of each photo area, different threshold values will apply. The weighted sum of the pixel values in the surrounding area, where the weights are assigned using the gaussian window technique, is used by the Gaussian method to calculate the threshold. The algorithm of adaptive threshold is given below (Algorithm 1).

3.4.3. *VGGNet-16*

The VGGNet-16 can classify images into 1000 different object categories, including keyboard, animals, pencil, mouse, and more. It supports 16 layers. The model also accepts images with a resolution of 224 by 224. Very tiny convolutional filters are used in the construction of the VGG network. Thirteen convolutional layers and three fully connected layers make up the VGG-16. This indicates that the VGG16 network is quite large, with a total of about 138 million parameters. The important blocks present in the architecture included are presented in the Fig. 7.

3.4.3. .1 Input layer. The VGGNet accepts 224×224-pixel images as input. To maintain a consistent input size for the ImageNet

Table 5
List of phone numbers for sending alert message.

Sl. No.	Person	Primary Number	Secondary Number
1	EVIP	98*** ***49	94*** ***78
2	Caretaker	88*** ***19	76*** ***14
3	Doctor	86*** ***56	63*** ***18
4	Pharmacist	97*** ***47	95*** ***26

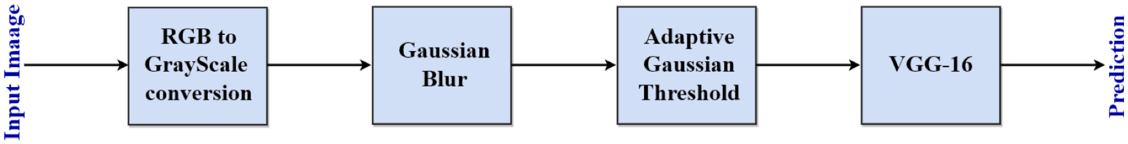

Fig. 6. Steps involved in fingerprint recognition.

Algorithm 1
Adaptive threshold.

1: Pick a starting estimate for T. (typically the average grey level in the image)
2: Each grey level g(x, y) should be classified using a threshold j that was previously calculated:

$$pixel(x,y) \in \begin{cases} C_{ob:[j]} \text{if} g(x,y) \le \theta_j \\ C_{bg:[j]} \text{if} g(x,y) > \theta_j \end{cases} \quad (3)$$

The object and background regions in the image g at iteration j are designated as $C_{ob:[j]}$ and $C_{bg:[j]}$, respectively.
3: For each class, calculate the mean grey values (4) and (5):

$$\mu_{ob:[j]} = \frac{1}{|C_{ob:[j]}|} \sum_{(x,y) \in C_{ob:[j]}} g(x,y) \quad (4)$$

$$\mu_{bg:[j]} = \frac{1}{|C_{bg:[j]}|} \sum_{(x,y) \in C_{bg:[j]}} g(x,y) \quad (5)$$

where |C| stands for the quantity of pixels in region C.
4: Make a new threshold calculation (6):

$$\theta_{j+1} = \frac{1}{2}(\mu_{ob:[j]} + \mu_{bg:[j]}) \quad (6)$$

5: Repeat steps 2 – 4 until the difference in T in successive iterations is less than a predefined limit T∞

competition, the model's developers cropped out the central 224×224 patch in each image.

3.4.3. 2 Convolutional layers. VGG's convolutional layers use the smallest possible receptive field, or 3×3, to capture left-to-right and up-to-down movement. Additionally, 11 convolution filters are used to transform the input linearly. The next component is a ReLU unit, a significant advancement from AlexNet that shortens training time.

3.4.3. .2 ReLU. The Rectified Linear Unit Activation Function (ReLU) component, which is AlexNet's key innovation for shortening training times, is the next. ReLU is a linear function that outputs zero for negative inputs and a matching output for positive inputs. To maintain spatial resolution after convolution, VGG has a predetermined convolution stride of 1 pixel (the stride value represents how many pixels the filter "moves" to cover the entire space of the image).

3.4.3. .3 Hidden layers. The VGG network's hidden layers all make use of ReLU. Local Response Normalization (LRN) is typically not used with VGG as it increases memory usage and training time. Furthermore, it doesn't increase overall accuracy.

3.4.3. .4 Pooling layers. It aids in lowering the dimension and parameter count of the feature maps produced by each VGG-16 convolution layer. Given the quick increase in the number of available filters from 64 to 128, 256, and finally 512 in the final layers, pooling is essential.

3.4.3. .5 Fully connected layers. The VGGNet has three layers with full connectivity. The first two layers each have 4096 channels, and

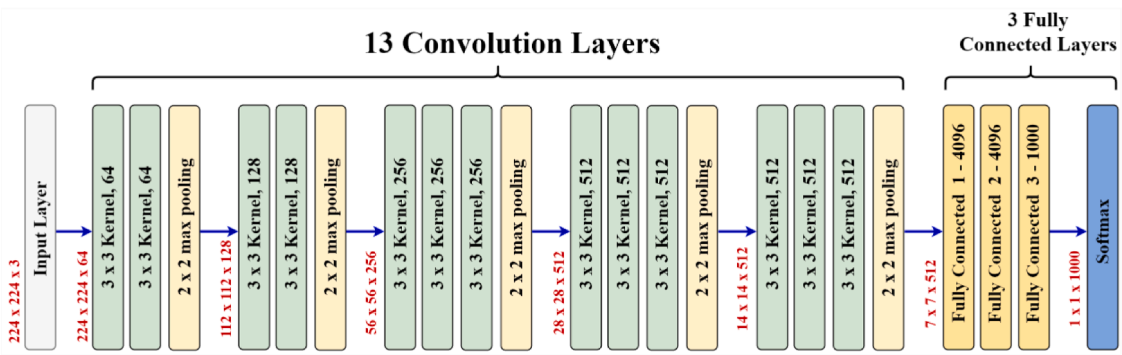

Fig. 7. Various layers of VGG-16.

the third layer has 1000 channels with one channel for each class.

The height and width are decreased by a pooling layer that comes after a few convolution layers. There are roughly 64 filters available, which we can then multiply by two to get about 128 filters, and so on up to 256 filters. We can use 512 filters in the final layers.

4. Implementation

4.1. Database

There are four tables in this implementation. Each table is stored in the form of a database in MySQL. The Table 1 named as MDE table gives the detailed description of the medicine to be taken by EVIP. The Table 2 gives the information about the dosage of medication taken by the EVIP. It is called as MDO table. The scheduling of the medication is given in the Table 3 i.e., MS table. The threshold weight of each tablet in the chamber is maintained at the MWT table. The MDE table has the information about the name of the tablet, weight of a tablet in milligrams, description of the tablet, and manufacturer of the tablet, number of tablets in a strip and purpose of the tablet.

The MDO table holds the detail about the tablet name, chamber number in which the tablet is placed, dosage of the tablet to be taken by the EVIP, session of the medication (Morning, Afternoon and Night) and time slot of the medication (Before/After food). The 'M', 'N' and 'A' in the tablet session column represents the morning, night and afternoon respectively of the tablet medication session. In time slot column, the "AF" and "BF" stands for after food and before food time of taking the medicine. The MS table describes about the tablet session, time slot, tablet time and chamber ids to be opened. For example, in the MS table, the second row represents the morning session and after food, the chambers C001, C003 and C005 will be opened for medication. The MWT table gives the information about chamber ids of the medication box, tablet name inside the chamber, number of strips inside each chamber, empty strip weight and threshold weight of strips.

The empty strip weight (W_{ESW}) (7) is calculated by knowing the weight of a strip (W_S), no. of tablets in the strip (N_{TS}) and weight of a tablet in the strip (W_T).

$$W_{ESW} = W_S - (N_{TS} * W_T) \tag{7}$$

The threshold weight of a strip (W_{TWS}) (8) is calculated by knowing the weight of empty strip (W_{ESW}), weight of a tablet in the strip W_T and number of tablets in the strip is set to four. The four indicates a message to be sent to pharmacists and doctor, once the number of tablets in the chamber goes less than four.

$$W_{TWS} = W_{ESW} + (4 * W_T) \tag{8}$$

Table 6
List of notations used in the algorithm.

Sl.No.	Notation	Description	Algorithm
1	T_A	Time at which the announcement made	Algorithm 2
2	T_{MW}	Maximum distance walking time of EVIP (2 min)	Algorithm 2
3	T_{Buff}	Buffer time to reach the dispenser (5 min)	Algorithm 2
4	T_{EB}	Time at which the EVIP done fingerprint biometric	Algorithm 2 and 3
5	T_{Th}	Maximum allowable time for biometric process	Algorithm 2
6	T_{clk}	Time of Medical Dispenser Monitoring and Controlling system	Algorithm 2
7	T_{med}	Predefined medication table	Algorithm 2
8	D_C	Current dosage of a tablet taken by EVIP	Algorithm 2
9	D_T	Tablet dosage to be taken by the EVIP	Algorithm 2
10	D_{PD}	Predefined dosage of a tablet	Algorithm 2
11	D_{PER}	Dosage percentage of a tablet(20%)	Algorithm 2
12	D_O	Over Dosage percentage of a tablet	Algorithm 2
13	D_U	Under Dosage percentage of a tablet	Algorithm 2
14	W_{CTC}^{Bef}	Current weight of the tablet strips in the chamber before medication	Algorithm 2
15	W_{CTC}^{Aft}	Current weight of the tablet strips in the chamber after medication	Algorithm 2
16	W_{TWS}	Threshold weight of the tablet strips	Algorithm 2
17	T_{BP}	Biometric processing time	Algorithm 3
18	T_{OB}	Overall biometric time	Algorithm 3
19	T_{PB}	Predefined biometric time(3 min)	Algorithm 3
20	T_{PS}	Predefined time to hold the pill strips	Algorithm 4
21	T_{PT}	Time at which the pills strip is taken	Algorithm 4
22	T_{PK}	Time at which the pills strip is kept inside	Algorithm 4
23	T_{TP}	Threshold time for taking pills	Algorithm 4

Algorithm 2 –Timely Assistance Messaging algorithm.
Algorithm 3 –Biometric algorithm.
Algorithm 4 –Individual Chamber Operation algorithm.

4.2. Algorithm

This section explains the algorithm [44] implementation of the system. The various notations used in the algorithms are listed in the Table 6. Three algorithms are implemented in Python for monitoring and reporting the activity of the EVIPs. The monitoring is done in the residence of the EVIPs. Reporting about the EVIP medication is given to the EVIP, caretaker, pharmacist and medical professional mobile number [45] in the form of voice and text message.

4.2.1. Timely Assistance Messaging algorithm (TMS)

Timely Assistance Messaging Algorithm 2 controls the overall activity of the system. This algorithm takes a *'slot'* argument, which identifies the time at which the medication has to be taken to i.e.,(before/after food). The *Get_tablet_time( )* takes *'slot'* as an argument and returns the time in which the medication has to be taken from the MS table i.e., T_{Med}. It checks the time of MDMC T_{clk} is equal to T_{Med}. If it is true, it sends an alert to the EVIP by conveying him to move towards the dispenser. Information is conveyed to EVIP through *Alert_EVIP( )* function, which returns a value T_A i.e., the time at which the announcement made. The biometric [46] time T_{EB} is initialise to zero. T_{MW} be the time taken by the EVIP to reach the medication kit by walking i.e., maximum distance (2 min). T_{Buff} be the buffer time to reach the dispenser. I.e., additional time taken to reach the medication kit i.e., 5 min. (due to tiredness, obstacles in the middle, went in the wrong direction or announcement message not reached properly). T_{Th} be the threshold time i.e., maximum allowable time for the biometric process. The threshold time is calculated using the formula (9). T_{MW} and T_{Buff} are fixed values, while

Algorithm 2
Timely_Assistance_Messaging(slot).

T_{med} = Get_tablet_time(slot)
if ($T_{clk} == T_{med}$) ***then***
T_A = Alert_EVIP("Reach the Medicine Dispenser")
$T_{EB} = 0$
repeat
$T_{Th} = T_{MW} + T_{Buff} + T_A$
if ($T_{clk} > T_{Th}$) ***then***
T_A = Alert_EVIP("Reach the Medicine Dispenser")
end if
T_{EB} =Check_biometric( )
until (T_{EB}!=0)
required_medicine = taken_medicine = null
Algorithm Biometric(T_{EB})
ses = Get_session( )
chamber_to_open = Get_medicine_schedule(ses, slot)
chamber_len = Length(chamber_to_open)
for ind = 0 ***to*** chamber_len ***do***
chamber_no = chamber_to_open[ind]
W_{CTC}^{Bef} = Read_load_cell(chamber_no)
Algorithm_Individual_Chamber_Operation(chamber_no)
W_{CTC}^{Aft} = Read_load_cell(chamber_no)
$D_C = W_{CTC}^{Bef} - W_{CTC}^{Aft}$
D_{PD}= Get_predefined_dosage(chamber_no)
$D_T = D_{PD} - W_T$
$D_{PER} = (D_T/100)*20$
$D_O = D_T + D_{PER}$
$D_U = D_T - D_{PER}$
if ($D_C > D_O$) ***then***
Alert_doctor("Over Dosage")
Alert_caretaker("Over Dosage")
end if
if ($D_C < D_U$) ***then***
Alert_doctor("Under Dosage")
Alert_caretaker("Under Dosage")
end if
W_{TWS} = Get_threshold_weight(chamber_no)
if ($W_{CTC}^{Aft} < W_{TWS}$) **then**
Add_message(required_medicine, chamber_no)
Add_message(taken_medicine, chamber_no)
else
Add_message(taken_medicine, chamber_no)
end if
end for
if (required_medicine != null) **then**
Alert_pharmicists(required_medicine)
end if
Alert_doctor(taken_medicine)
end if

T_A will vary in time. Within the threshold time T_{Th}, if the EVIP has not reached, a second announcement will be made.

$$T_{Th} = T_{MW} + T_{Buff} + T_A \tag{9}$$

When the MDMC clock exceeds the value of T_{Th}, second announcement will be sent to the EVIP. If the MDMC clock is within the T_{Th}, then fingerprint scanner will be checked. The *Check_biometric( )* function returns 0 if the biometric is not done by the EVIP. Otherwise it returns the time of biometric done by the EVIP. *Biometric( )* algorithm monitors the entire activity of the finger print scanner and it takes T_{EB} as an argument. Two variables *'required_medicine'* and *'taken_medicine'* are initialized to null. A *Get_session( )* function returns the session of the day in the form of *'M'* for morning, *'A'* for afternoon and *'N'* for night. The *Get_medicine_schedule( )* function is called with *'ses'* and *'slot'* as arguments. This function refers to the medicine schedule table and return the number of chambers to be opened to the variable *'chamber_to_open'*. The *Length( )* function returns the no. of chambers to be opened for medication. A *for* loop is used to open all the chamber one after another in the list *'chamber_to_open'*. The *Read_load_cell ( )* function reads the present weight value of the strips inside the chamber. The *Individual_chamber_operation( )* algorithm opens and closes the specific chamber for medication. Before opening and closing of the chamber, the *Read_load_cell( )* calculates the weights of the strips W_{CTC}^{Bef} and W_{CTC}^{Aft} i.e., as current weight of the tablet strips inside the chamber before and after medication respectively.

The current dosage D_C taken by the EVIP can be calculated using the current weight of the tablet inside the chamber before and after medication is shown in the Eq. (10).

$$D_C = W_{CTC}^{Bef} - W_{CTC}^{Aft} \tag{10}$$

The predefined dosage D_{PD} for a tablet is obtain by *Get_predefined_dosage( )* function by looking the MDO table. The tablet dosage D_T to be taken by the EVIP is calculated by using the formula (11).

$$D_T = D_{PD} * W_T \tag{11}$$

Dosage percentage D_{PER} is calculated for adjustment in errors as 20% of the tablet dosage D_T. The dosage percentage is calculated using the formula (12), it is considered as an error factor due to slight variation in the measurement of the load cell weight.

$$D_{PER} = \frac{D_T}{100} * 20 \tag{12}$$

This D_{PER} is helpful in calculating over dosage (13) and under dosage (14). The D_O over dosage is calculated as a sum of D_T and D_{PER}. The D_U under dosage is calculated as a difference between D_T and D_{PER}.

$$D_O = D_T + D_{PER} \tag{13}$$

$$D_U = D_T - D_{PER} \tag{14}$$

If the current dosage is greater than D_O, an alert message *overdose* is sent to the doctor and the caretaker. If the current dosage is less then D_U, an alert message *underdose* is sent to the doctor and caretaker. The threshold weight W_{TWS} of a tablet strip in a chamber is obtained from the MWT table using the function *Get_threshold_weight( )*. When the measured weight W_{CTC}^{Aft} is less than the W_{TWS}, *'chamber'* is added to the *'required_medicine'* and *'taken_medicine'* list. Otherwise, *'chamber_no'* is added only to the *'taken_medicine'* list. If *'required_medicine'* is not equal to null, an alert message will be send to pharmacists and doctor with the *'required_medicine'* and *'taken_medicine'* list as the message. Otherwise, an alert message will be sent only to the doctor.

4.2.2. Biometric algorithm

The *Biometric( )* Algorithm 3 alerts the successful and unsuccessful operation of biometric process. It gives a maximum of three attempts for EVIP to access the medication kit. Once three attempts are made, the biometric system will be locked. The system can be

Algorithm 3
Biometric(T_{EB}).

```
no_of_attempt = 0
repeat
  verification = Fingerprint_biometric( )
  T_OB = T_EB + T_BP
  if (T_OB > T_PB) then
    no_of_attempt = no_of_attempt + 1
    Alert_EVIP("Again Do Biometric")
  else
    Alert_EVIP("Authentication Successful")
      Exit_Biometric( )
   end if
   T_EB = Check_biometric( )
until ((no_of_attempts <= 3) && (verification != True))
if (no_of_attempts > 3) then
   Alert_EVIP("Authentication Failed")
   Alert_caretaker("Authentication Failed Unlock")
end if
```

Algorithm 4
Individual_Chamber_Operation(chamber_no).

```
Door_open(chamber_no)
Alert_EVIP("Take Pills Strip")
T_PT = Check_inside_US( )
T_PK = 0
T_TP = T_PT + T_PS
repeat
   T_PK = Check_inside_US( )
   if (T_PK > T_TP) then
      Alert_EVIP("Keep the Pills Strip Inside")
      T_TP = T_clk + T_PS
      T_PK = 0
   end if
   if (T_PK <= T_TP) then
      Alert_EVIP ("The Chamber Lid is Closing")
      Exit_Individual_Chamber_Operation( )
   end if
until(T_PK!=0)
```

recovered by the caretaker through unlocking the system by giving a password. The variable *'no_of_attempt'* is initialized to zero and it keeps tracks the total number of attempts made by the EVIP. The *Fingerprint_biometric( )* algorithm is called for the verification of the fingerprint payload. The time taken by the *Fingerprint_biometric( )* for verification is T_{BP}. This functions returns true if the payload matches to the *'verification'* variable. The overall biometric time T_{OB} is calculated by summing the T_{EB} and T_{BP}. The time T_{PB} is predefined time for biometric process. It is kept maximum based on the processing time of the *Fingerprint_biometric( )* function. If T_{OB} is greater than T_{PB}, then the number of attempts is incremented by one and a notification is sent to EVIP informing to do authentication again. Otherwise, the authentication successful alert message is sent to the EVIP and *Biometric( )* algorithm is exited. The biometric process will repeatedly check until *"no_of_attempts"* is less then three and the *'verification'* of biometric is false. If the *no_of_attempts* is greater than three; two alert messages are send, one for informing EVIP about the failure of authentication process [47] and another for informing caretaker about the failure and to unlock the process.

4.2.3. Individual Chamber Operation algorithm (ICO)

The *Individual_Chamber_Operation( )* Algorithm 4 monitors the activity of the chamber door and alerts are sent to EVIP. Each chamber is opened by *Door_open( )* function, which takes the *'chamber_no'* as argument. An alert message is sent to inform EVIP about taking the pills. The *Check_inside_US( )* is a function which checks the hand movement inside and outside of the chamber for taking and placing of the pill strips. This function returns a time value T_{PT}, when the pill strip is taken and again it returns a value T_{PK}, when the pill strips are kept. Initially the T_{PK} is initialized to zero. The time T_{PS} is the holding time of the strips for taking medicine. It is a predefined time of about 3 min. The total time took [48] in processing the pill strip is obtained by summing the T_{PT} and T_{PS}. If T_{PK} is greater than T_{TP}, then an alert message is send to EVIP informing to keep the pills and a new T_{TP} is calculated by summing the current clock time T_{clk} and time to hold the strip T_{PS}. Otherwise, an alert message is sent to the EVIP, saying that chamber is closing and the algorithm exit. The algorithm checks continuously until the EVIP keeps the pill strips inside the chamber by the condition T_{PK} is not equal to zero.

5. Result and discussion

This section discusses the experimental setup used, the fingerprint authentication system, the experiment discussion and the comparison of existing pill dispensers.

5.1. Experimental setup

5.1.1. Medical Dispenser Monitoring and Controlling system (MDMC)

The system is implemented in Intel core i7 7th generation processor. It has a RAM capacity of 8GB and 1 TB of hard disk. It is running on Ubuntu 16.04 operating systems. This PC controls and monitors the Raspberry Pi [49] micro controller through a Python script. The python version employed in the experiments is 3.5. MySQL 7.0 [50] running on the port 3306 is used as a database for storing the medication tables. A Med App is designed using the Android 8.0 Oreo. Web interaction takes place between MDMC and the mobile app through PHP. Web scripts are designed using PHP 7.1, which runs in the Apache 2.3.1 web server in the port 8000. To send a message from MDMC to the mobile phone, *Nexmo* APIs are used. For the verification of the biometric process, we have used VGG-16 with image enhancement method [51].

The Med App receives and reads the message from MDMC. It converts it into a voice reply through *TextToSpeech* [52] API. Python scripts run the PHP web page using the *urllib2* modules. The method *request( ), urlOpen( )* and *read( )* defined in *urllib2* are needed to call the PHP web pages. The experiment comprises of 7 chambers in the medicine dispenser. There are 3 Raspberry pi involved in the medicine dispenser. The Raspberry pi-1 controls fingerprint scanner, chamber 1 and 2. The chamber 3, 4 and 5 are controlled by pi-2. The remaining chambers are controlled by pi-3. Each table in this implementation contains information related to a heart and diabetic elderly patient [53]. The complete experiment is done and monitored at the resident of the patient [54] for duration of three months.

In this section, many formula are used in the calculation of the results like W_{CTC}^{Aft}, D_O, andD_U. Table 7 and 8 are calculated dynamically to measure the above said parameters. The table are consolidated at the end of medication session and it can be send as a report.

Steps involved in calculation of the load cell output in milligrams:

a) Obtain the Rated capacity in milli grams(W_{max}), Excitation voltage in volts (V_E) and Sensitivity in milli volts per volts (μ) from the specification of the load cell.
b) Obtain the reading of the load cell in milli volts (V_L) i.e.,V_{out}.
c) Calculate the divider α using the formula (15).

$$\alpha = \frac{\mu}{V_E} \tag{15}$$

d) Calculate the full scale weight using the formula (16).

$$FSW = V_L * W_{max} \tag{16}$$

e) Current weight of tablets in the chamber can be calculated using the formula (17).

$$W_{CTC} = \frac{FSW}{\alpha} \tag{17}$$

The total no. of tablet in the chamber is given in the Eq. (18) can be calculated by using the current weight of the tablet in the chamber before medication, empty strip weight and weight of the tablet.

$$N_{TTC} = \frac{W_{CTC}^{Bef} - W_{ESW}}{W_T} \tag{18}$$

The number of strips in the chamber can be calculated (19) using the total no. of tablets in the chamber before medication and total no. of tablets in a strip is given in the below equation.

$$N_{SC} = Ceil\left(\frac{N_{TTC}}{N_{TS}}\right) \tag{19}$$

5.1.1.1. Filling of tablet. The Table 7 shows the status of filling and unfilling of tablets after medication taken by the EVIP during a night session. The table contains following columns N_{SC}, N_{TTC}, W_{CTC}^{Bef}, W_{CTC}^{Aft} and W_{TWS}. The weight of the strips W_{CTC}^{Bef} and W_{CTC}^{Aft} medication is calculated using the formula (17). It is a measured weight of the strip from the load cell amplifier. This measured load cell value W_{CTC}^{Aft} is compared with the W_{TWS}. In the 7th table chamber 6, W_{CTC}^{Aft} is less than W_{TWS}, while all other chamber W_{CTC}^{Aft} is greater than W_{TWS}. A compliance message will be send to pharmacists and doctor telling that chamber '6′ is to be filled. Fig. 8 shows the filling of tablets when the weight of strips goes below the threshold weight.

5.1.1.2. Overdose/underdose situation. The Table 8 shows the over dosage and under dosage status after medication taken by the EVIP during a night session. The table contains following columns D_{PD}, W_T, D_{PER}, D_T, D_O, D_U, W_{CTC}^{Bef}, W_{CTC}^{Aft} and D_C. The dosages D_T, D_{PER}, D_O

Table 7
Shows the status of filling and unfilling of tablets after medication taken by the EVIP during a night session.

Sl. No.	Chamber ID	Tablet Time	No. of Strips in the Chamber (N_{SC})	Total no. of tablets in the chamber (Before med) (N_{TTC})	Current Weight of the tablet strips in the chamber (Before medication) (W_{CTC}^{Bef})	Current Weight of the tablet strips in the chamber (After medication) (W_{CTC}^{Aft})	Threshold Weight of the tablet strips (W_{TWS})	Action to be taken
1	001	AF	02	34	1322.31	1293.470	270	No
2	002	NT	01	11	1026.17	1025.280	500	No
3	003	AF	02	13	141.34	138.129	55	No
4	004	BE	01	24	1086.46	1043.640	285	No
5	005	AF	02	17	771.24	729.460	205	No
6	006	BE	01	04	70.53	60.870	70	Filling
7	007	NT	01	08	104.86	106.180	65	No

BE–Before Food, AF–After Food, NT–Not Taken.

Table 8
Shows the over dosage and under dosage status after medication taken by the EVIP during a night session.

Chamber ID	Predefined Dosage (D_{PD})	Tablet Weight (W_T)	Dosage% (D_{PER})	Tablet Dosage (D_T)	Over Dosage (D_O)	Under Dosage (D_U)	Current Weight of the tablet strips in the chamber (Before medication)(W_{CTC}^{Bef})	Current Weight of the tablet strips in the chamber (After medication) (W_{CTC}^{Aft})	Current Dosage (D_C)	Action to be taken
001	1.0	30.00mg	6.000	30.000	36.000	24.00	1322.31	1293.470	28.840	CD
002	1.0	75.00mg	15.000	75.000	90.000	60.00	1026.17	1025.280	0.890	NT
003	0.5	6.25mg	0.625	3.125	3.750	2.50	141.34	138.129	03.210	CD
004	1.0	40.00mg	8.000	40.000	48.000	32.00	1086.46	1043.640	42.820	CD
005	0.5	40.00mg	4.000	20.000	24.000	16.00	771.24	729.460	41.780	OD
006	1.0	10.00mg	2.000	10.000	12.000	8.00	70.53	60.870	09.660	CD
007	1.0	10.00mg	2.000	10.000	12.000	8.00	104.86	106.18	1.320	NT

CD–Correct Dosage, NT–Not Taken, OD–Over Dosage.

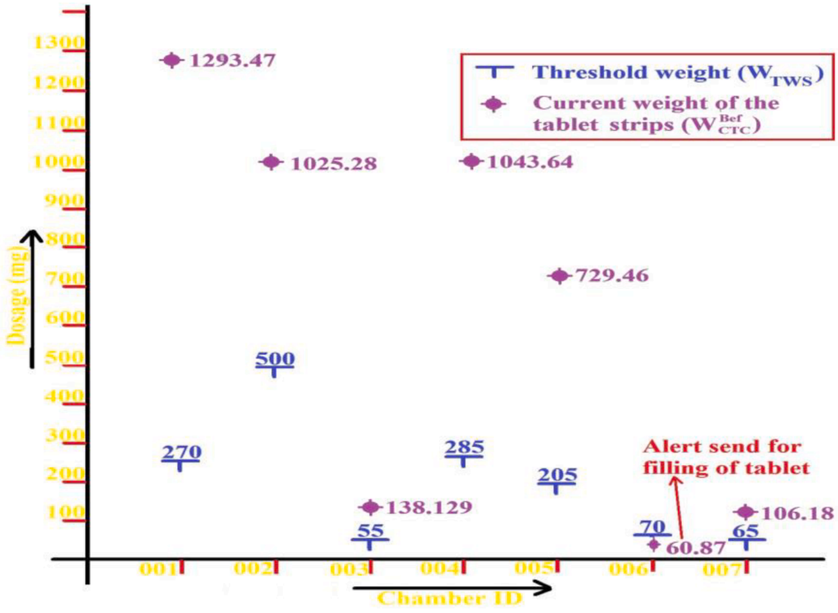

Fig. 8. Filling of tablets when the weight of strips goes below the threshold weight.

and D_U are calculated using the formulas 11, 12, 13 and 14 respectively. The current dosage taken by EVIP D_C is calculated by the Eq. (10). In the 8th table chamber 5, D_C is greater than D_O limit, then an over dosage compliance message will be send to the doctor and caretaker. For all other chambers, D_C is within the limit of D_O and D_U. Fig. 9 shows the situation of over dosage and under dosage of a tablet during medication.

5.1.2. *Fingerprint recognition system*

5.1.2.1. Dataset description. The SOCOFing dataset is constructed from 600 African subjects with a collection of 6000 fingerprints. Each subject has 10 fingerprints, and they are all at least 18 years old. SOCOFing includes distinctive characteristics like labels for gender, hand, and finger names. A brand-new framework called STRANGE allows you to create realistic synthetic alterations to fingerprint images. Additionally, using the STRANGE toolbox, synthetically altered versions of these fingerprints are offered with three distinct levels of alteration for obliteration, central rotation, and z-cut.

Changes were made using the STRANGE toolbox over 500dbi resolution images with the easy, medium, and hard parameter

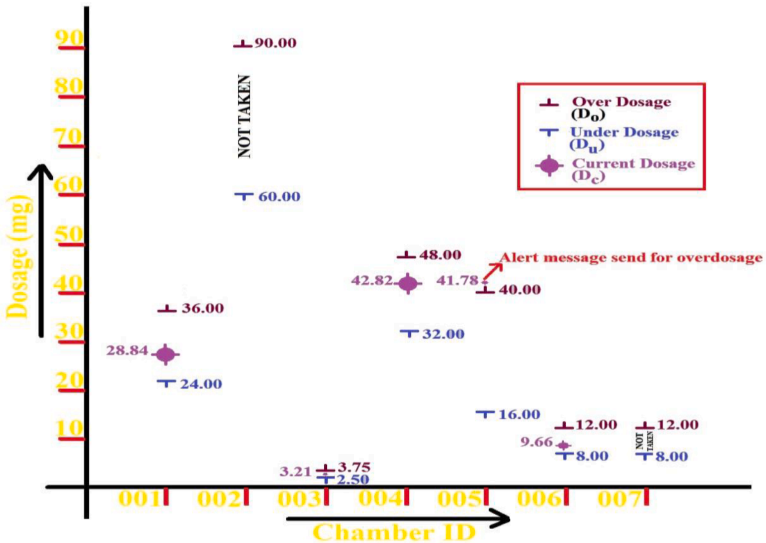

Fig. 9. Situation of over dosage and under dosage of a tablet during medication.

settings. For instance, 5977 real images resulted in 5977 central rotation, 5977 Z-cut alteration, and 5977 fingerprints that were completely erased. As a result, there will be 17,931 altered fingerprints presented as fake in the easy category for every 5977 real fingerprints. Similarly, 17,067 fingerprints total are presented as altered in the medium category, and 14,274 fingerprints total are presented as altered in the hard category.

5.1.2.2. Preprocessing. Before applying the model, the dataset is preprocessed to look for noisy data, and other inconsistencies. One of the primary applications for Gaussian smoothing is noise reduction. The principal behind the Gaussian smoothing is width of the filter can be changed to affect how well the low-pass feature works. Noise reduced images are passed through the different threshold method to find optimum image enhancement method. In global threshold method, a single pixel intensity threshold value is applied to all of the image's pixels. An issue with global thresholding is that it may result in some areas of the scene being brighter and other areas being darker for reasons unrelated to the objects in the image.

To overcome the above issues, adaptive thresholding is more popular which calculates the threshold values based on neighbourhood of pixels. The threshold value in adaptive Gaussian thresholding is the weighted sum of the neighbourhood values, with the weights being a gaussian window. It is better than the mean threshold method in calculating the threshold at each pixel and it is shown in the Fig. 10. After applying Gaussian Blur and Adapative Gaussian Thresholding in the preprocessing steps, the image enhanced vector is passed on to the VGG-16 deep neural network for classification.

5.1.2.3. Evaluation metrics. The metrics are the performance indicator of the models. It is a good indicator of correctness of the model in predicting the results. We have used Accuracy, Weighted Average Precision, Weighted Average Recall and Weighted Average F1 score to evaluate the models. Accuracy is the percentage of correct prediction done by our Fingerprint Recognition System and it is given in Eq. (20).

$$Accuracy = \frac{TP+\mathrm{FP}}{TP+\mathrm{TN}+\mathrm{FP}+\mathrm{FN}} \tag{20}$$

Where,

TP – true positive represents an instance for which both predicted and actual values are positive,
TN – true negative represents an instance for which both predicted and actual values are negative,
FP – false positive represents an instance for which predicted value is positive but actual value is negative and
FN – false negative represents an instance for which predicted value is negative but actual value is positive.

Based on the distribution of instance in the different classes it is necessary to compute the per class values of Precision, Recall and F_1 score. In multi-class classification problem it is important to calculate the Precision, Recall and F_1 score for each class in a One-vs-Rest approach instead of overall single calculation for each metric. To obtain the overall performance of the model for the unbalanced dataset, it is better to calculate average value instead of single value of a metric.

In weighted average method the output average is calculated as contribution of each class weight with the number of instances in the class. The Weighted Average Precision (21) is computed by considering the average of all per-class Precision while taking each class support. The support is a ratio between no. of instances in the particular class by total no. of instances in the dataset.

Fig. 10. Preprocessing of finger print recognition.

$$Wt.\text{Avg.Precision} = \frac{\sum_{i=1}^{n} y_i \frac{TP_i}{TP_i + FP_i}}{Y} = \frac{\sum_{i=1}^{n} y_i \text{P}_i}{Y} \tag{21}$$

Where, y_i represents the no. of instances in 'i'th class,

TP_i represents True Positive of 'i'th class,
FP_i represents False Positive of 'i'th class and
Y represents total no. of instances in the dataset.

Similarly, Weighted Average Recall and Weighted Average F1 score can be calculated as shown in Eqs. (22) and (23).

$$Wt.\text{Avg.Recall} = \frac{\sum_{i=1}^{n} y_i \frac{TP_i}{TP_i + FN_i}}{Y} = \frac{\sum_{i=1}^{n} y_i \text{R}_i}{Y} \tag{22}$$

$$Wt.\text{Avg.F1} = \frac{\sum_{i=1}^{n} y_i \text{F1}_i}{Y} \tag{23}$$

5.1.2.4. Experiments. In order to achieve performance gain of finger print recognition, input images are preprocessed to improve the quality of the image for classification. To differentiate the performance gain two experiments are conducted namely (i) VGG-16 without image enhancement (Experiment-1) and (ii) VGG-16 with image enhancement (Experiment-2). The dataset used in the experiment is Sokoto Coventry Fingerprint Dataset. We have chosen training set as a combination of 17,934, 17,067 and 14,272 of altered images from easy, medium and hard settings respectively. So, total there are 49,273 images in the training set. Remaining 6000 images from the original dataset is chosen as test set. This test set consists of 1200 images from each category of fingers namely small, ring, middle, index and thumb. It is a multi-class recognition system in which the dataset is divided into class 0, class 1, class 2, class 3 and class 4 for thumb, index, middle, ring and small finger respectively.

The comparison of the fingerprint recognition system with experiment 1 and 2 is shown in Table 9 and Fig. 12. The confusion matrix of experiment 1 and 2 is shown in Fig. 11. The experiment 1 is conducted without any image enhancement which has resulted in accuracy, weighted precision, weighted recall and weighted F_1score of 98.27%, 95.68%, 95.67% and 95.69% respectively. In experiment 2, images are passed through a Gaussian blur filter and Adaptive Gaussian Threshold before VGG-16 for image enhancement. Gaussian blur can reduce noise in images that were taken in low light and had a lot of noise in it. Thus, it acts as a filter in reducing the noise. By analysing the intensities of all the image pixels and choosing the most appropriate threshold value that effectively separates the foreground and background, adaptive thresholding allows us to achieve better segmentation. A combination of Gaussian blurs and Adaptive Gaussian threshold in preprocessing helps to improve the image quality. Thus, it has achieved an increase in accuracy, weighted precision, weighted recall and weighted F_1 score of 0.58%, 1.45%, 1.46% and 1.45% than experiment 1.

5.2. Discussion

The current medical dispenser falls short in the following situations: (i) giving medication before and after eating; (ii) over and under dosing when a tablet is taken; and (iii) when the pill weight falls below the threshold. In each of these situations, no messages describing the situation are sent to the medical entities. The proposed work has given EVIP five important capabilities that aren't found in any of the pill dispensers that are currently on the market. The Timely_Assistance_Messaging() algorithm manages and keeps an eye on all of the EVIP's activities. This algorithm determines whether an EVIP can be reached in time to receive medication. When the user is unable to reach the dispenser, it promptly sends an alert. To check if the correct person is opening the box, this invokes the Biometric () algorithm. The appropriate chambers are opened one at a time for the medication after getting all the necessary medication information. The Individual_Chamber_Operation( ) keeps track of the tablet's weight and the opening and closing of the chamber ( ). By detecting the weight of the strips, this feature keeps an eye on the over and under dosage of the EVIP's medication. Individual_Chamber_Operation( ) monitors hand motion to ensure that the strips are taken and kept inside the chamber. When the strips are not inserted into the chamber for an extended period of time, it also alerts the EVIP. An alert message will be sent to the medical entities when the quantity of tablets in the strips falls below a predetermined level.

5.3. Comparison of existing pill dispenser

The existing pill dispensers are discussed and compared in Table 10. It includes Dose Control [56], RxPense [57], Hero [58], Pria [59], MedaCube [60], Philips Lifeline [61] and Spencer [62] medical dispenser. The features used in the comparison between the dispenser are authentication method used, count of medication per day, number of days supported, overdose support, underdose support, alert message send, wifi/Internet support, Scheduling allowed, Liquids; broken pills or powders allowed, manual/automatic way of dispensing, dimension of the dispenser, weight of the dispenser, battery backup support, app support and doctor/pharmacist role support. Dose control from MedControl is a rotating removable pill container that doesn't send an alert message to medical

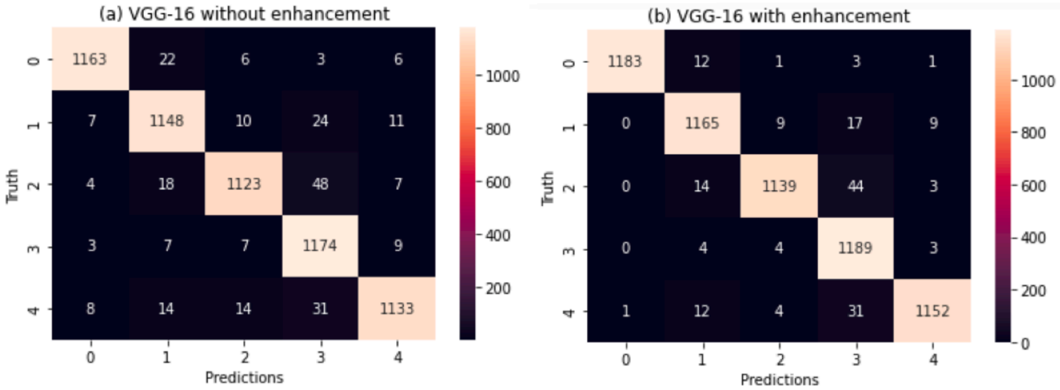

Fig. 11. Confusion matrix of finger print recognition system.

Table 9
Performance measure of fingerprint recognition system.

	Expt-1	Expt-2
Accuracy	98.27	98.85
Weighted Precision	95.68	97.13
Weighted Recall	95.76	97.22
Weighted F1score	95.69	97.14

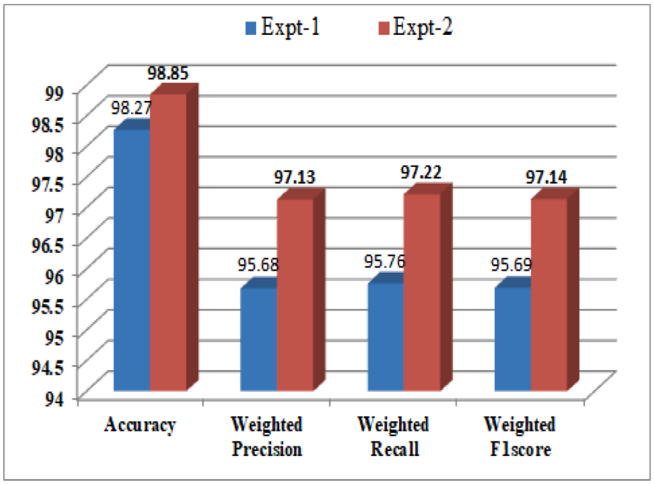

Fig. 12. Performance comparison of fingerprint recognition system.

entities. Medipense has provided a RxPense medical dispenser that supports multilingual and fall detection the patient. In the Hero dispenser, the patient has to press a button for medication and it is very easy to carry from one place to another. A medical dispenser named 'Pria' has a video calling facility to chat with the patient and doesn't support alert messages. The MedaCube dispenser has a tilt safety sensor and it will be activated to completely lock-down of all the drawers to avoid spillage when there is a tilt in the dispenser. Philips Lifeline medical dispenser provides medication only six times a day. Spencer dispenser is the only dispenser that has temperature, humidity and atmospheric pressure limitation.

5.3.1. Significance of the proposed dispenser

Access to the medicine box requires authentication by an appropriate individual. For this, a deep neural network with VGG16 biometric authentication is used. With this authentication, we can impose different levels of access to the dispensing machine. It is present in any of the dispensers. There is complete tracking of the hand motion of the EVIP in taking the pills which are not present in any of the medical dispensers. The pills are provided to EVIP in two different scenarios i.e., before and after food. None of the current medical dispensers include this feature. An accurate calibration method (i.e., in milligrams) is provided in accessing the overdose and underdose situation using a load cell that is not present in any of the existing pill dispensers.

Table 10
Comparison of existing pill dispenser.

Features	Dose Control	RxPense	Hero	Pria	MedaCube	Philips Lifeline	Spencer
Authentication	Manual Lock	Voice Biometrics, RFID Tags, PIN or Password	Passcode	Facial or PIN	⊗	⊗	PIN
Count of medications	3	15	10	1	16	6	N. A.
Day of supply	7 days	14 days	90 days	28 days	90 days	40 days	N. A.
Overdose support	√	√	√	√	√	⊗	√
Underdose support	√	√	√	√	√	√	√
Alert Message	√	√	√	√	√	√	√
Wifi/Internet	√	√	√	√	⊗	√	√
Scheduling	⊗	√	⊗	√	√	√	√
Liquids, broken pills or powders	⊗	⊗	⊗	⊗	√	⊗	√
Manual / Automatic	Manual	Automatic	Manual	Automatic	Automatic	Manual	Automatic
Dimension	20 cm in diameter	N.A.	9 in x 9 in x 15 in	8.5 in x 6.2 in x 12.5 in	10 in x 10 in x 10 in	14 in x 13 in x 13 in	13.25 in x 10.5 in x 5.3 in
Weight	N. A.	N.A.	10 lbs	5.5 lbs	10 lbs	N.A.	10 lbs
Backup	4 hrs	8 hrs	⊗	8 hrs	24 hrs	18 hrs	4 hrs
App Support	⊗	√	√	√	√	√	√
Doctor / Pharmacist	⊗	√	⊗	⊗	√	⊗	⊗

⊗→not supported, √ → supported, N. A. → Not Available.

A message about replacing the strips is sent to the doctor and pharmacist when the weight of the strips in a chamber drops below the threshold value. This makes it easier for the doctor or pharmacist to select the proper pills to be put into the chamber at the end of each cycle based on the EVIP situation, which is missing in the current dispenser in use. During the medication, each chamber will open automatically based on the schedule provided earlier based on the date and time. It is not present in the current pill dispenser. If the hand moves away from the currently opened chamber, the EVIP will be notified to move toward the correct chamber immediately. The existing dispenser does not have this feature.

6. Conclusion

The entire experiment is carried out at the patient's home over a period of three months. The implementation had a successful result because the EVIP got quick medical care. The relationship between the carer, medical professionals like doctors and pharmacists, and EVIP was established as a well-coordinated triangle. There is a time limit on each of the three medical entities. The need to constantly monitor an EVIP's medication is unnecessary. A finger print recognition system with deep neural network VGG-16 along with image enhancement is included in the medicine dispenser which restricts the unauthorized usage [55]. The delivery of the medications does not need to be done by nurses or clinical staff. The TAM algorithm offers complete support. During the medication process, messages about under or over dosage will be sent to the medical entities. Based on the weight in each chamber, the pharmacists will receive a reminder to refill the strips. Depending on the circumstance, TAM promptly alerts the appropriate person. The medical experts and those in charge of the EVIP's receive proof of life thanks to this implementation. In the field of geriatrics, it serves as a supporting tool.

7. Future enhancements

A report with the highlights can be sent to the medical staff after the medication times for the EVIPs have been documented. The correct strips can be placed in the chamber using a camera at the back of the door. This adaptable layout promotes taking medication during the entire week. The power outage is not addressed by this architecture. Elderly patients require a timely, crucial service that is offered around-the-clock. There is discussion about whether to offer a broadband internet service to urban areas for this important healthcare system in today's society. The elderly population's fall detection system must monitor daily activity. The work does not address this. A security layer can be added to the communication that occurs between the medical entities. It improves the dependability and confidentiality of the communication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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