

AutoImpilo: Smart Automated Health Machine using IoT to Improve Telemedicine and Telehealth

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Abstract—This paper deals with the modalities of the Smart Automated Health Machine (AHM) using Internet of Things (IoT), a user-friendly health machine with an interactive graphical user interface for medical necessities. It is a virtual health check-up/self-screening/test system, aimed at being the first point of contact for patient screening, to monitor heart rate, blood pressure, ECG, oxygen saturation, and visual acuity of patients. In case of emergency, a doctor will be available online through a video call, based on the severity of patients' conditions, a call can be placed by a doctor to book an ambulance van or ambulance bike (based on the conditions). If a patient is unconscious, a direct call can be placed by any bystander or patient's carer to book an ambulance. In non-emergency cases, medical appointments can be booked - the system will also dispense medicines based on the health conditions and/or doctor's electronic prescription which can be selected among the list of available medicines. Each individual will be provided with a "smart health card", which will keep a record of patients' personal details, health conditions, prescriptions, and amount of tablets consumed. The AHM will provide all the necessary information, keep a record of different medical problems in different regions and different necessities required to be adopted. The system can also be called as "Self Healthcare Service (SHS)" or "Self Healthcare Units (SHU)" - the initiatives are part of sustainable development goals (SDG-3) proposed by United Nations.

We conducted a pilot evaluation with the patients, nurses and doctors. As an overall outcome, the practitioners feel the system can be adopted in an area where medical facility is not available immediately. Adopting this system in such regions not only help in medical emergencies/epidemic/pandemic such as COVID, it also increases the percentage of survival. The system can also be adopted in hospitals, pharmacies, schools, public places like bus/train stations, airports, markets or any commercial areas, zones prone to accidents in rural and urban areas and other places that can be quite useful and helpful to the public.

Index Terms—Healthcare; automated dispensing machine; automated dispensing device; automated dispensing cabinet; autospense; vending machine; telemedicine; telehealth; internet of things; coronavirus; COVID.

I. INTRODUCTION

Despite the huge differences between developing and developed countries, healthcare access is the major issue in rural parts around the world. Even in countries where the majority of the population lives in rural areas, the resources are concentrated on the cities. Thus, rural primary health care is one of the biggest challenges. Lack of quality infrastructure, poor health facilities, dearth of qualified medical functionaries, and

non-access to basic medicines and medical facilities thwarts its reach to 60% of population in India. Due to lack of adequate health facilities, morbidity, mortality rates, diseases are on the rise. So this technology can be leveraged for improving health care in Rural India. The aim of the paper is to develop an automated system that can connect to doctors, hospitals or healthcare professionals in a quick time, which will control the spread of diseases and reduce the growing rates of mortality in rural areas.

India's Prime Minister Narendra Modi launched the world's biggest experiment in universal healthcare in the early 2018, a scheme that the government might grant 500 million people the entitlement to free health insurance which will be the world's largest government funded health care programme. This new National Health Protection Scheme with a health coverage of up to INR 5 lakhs per family will be offered for secondary and tertiary care hospitalisation which could benefit several vulnerable and under-privileged families. Affordable and accessible healthcare is the need of the hour and it remains to be seen what kind of technologies and digitalisation can support Below Poverty Line (BPL), Community Health Centre (CHC), and Primary Health Centre (PHC). To support the Government initiatives, we have developed a prototype solution, smart automated health machines (AHM) to improve the quality of healthcare in the rural belts of India.

Automated Health Machines (AHMs), also called as Automated Dispensing/Vending Machines, are devices which store medications safely, promote meticulous recording and help to keep a track of medications used in healthcare settings. AHMs have been added with electronic prescribing systems as an integral part of dispensing medicines in many hospitals abroad. In this setting, reported benefits include a reduction in nursing time spent in retrieving and administering medications [1].

Autospense [2], a stand-alone machine embedded with a customised software solutions, has the ability to manage and securely disburse medicines. The machine empowers the store owner to relieve a large group of issues/problems and community concerns based on the automated features. It records money related exchanges and manages inventory tracking inside a vigorously secured framework of cameras, locks and sensors with security, transparency, store proficiency, financial analysis and supply chain which provides a safe,

lawfully agreeable, genuine, proficient and open intends to acquire medicines.

Health Kiosk [3] is also a small stand-alone device in providing healthcare information and services on an interactive device. This device helps in collecting patient's data and automate tasks that are time-consuming in the clinics and hospitals. The system gives patients quick access to a healthcare provider or service in places where medical access is limited. The patients can get connected via video to a provider or pointing out nearby products or services. In a hospital emergency department, this system enables staff to gather patient data symptoms, personal information, payment options before passing it to a nurse or doctor.

II. AUTOIMPILO

AutoImpilo is a smart automated health machine using IoT to Improve Healthcare in Rural Areas. Auto means "automated system" and Impilo means "health" in Zulu which is a South African language. In this paper, using the same principle as Autospense and Health Kiosk, we propose to use AHMs in public places (mainly rural areas) and in rural hospitals to provide health guidance/services and dispense medications to people who are in need. The power efficient design of AHM makes it available 24/7, providing instant services to people in rural and urban areas. We also intend to enhance the functionality of AHMs by adding additional features to it. The following features will be such as:

- 1) Live online medical consultation 24/7
- 2) Special COVID consultation for COVID affected areas
- 3) Prescription verification by online pharmacist
- 4) Self-screening (for breast cancer, eye disorders/diseases, etc.)
- 5) Screening of various other diseases
- 6) Provision of ambulance facilities in emergency settings
- 7) Tracking ambulance van and ambulance bikes (location tracking)
- 8) Referral services
- 9) Triage stations
- 10) Providing information of hospitals in close vicinity
- 11) Scheduling immediate & future healthcare appointments
- 12) Payment options for various services
- 13) Monitoring patient records
- 14) Multi-linguistic support system for patients with different language ability
- 15) Health information and guidance through instructions will be provided for patients with different diseases or disorders
- 16) Linking with health coverage and insurance companies
- 17) Connecting to healthcare charitable trusts (NGO network)
- 18) Linking with organ donors and hospitals (organ donation network)
- 19) Interactive GUI to guide patient/ bystander during emergencies or general Check up.

At present, the healthcare services rendered in rural areas in India is not sufficient. The biggest obstacle for most

rural people is accessing the healthcare services, geographical barriers or commuting. These hindrances can be overcome by installing many AHMs in various places in rural regions. This will provide a good platform for the rural people to utilize healthcare care services more effectively. AHMs can also be installed in rural hospitals and primary healthcare centres. This will help in addressing a major challenge which is meager number of healthcare professionals in rural India. Besides, it will aid doctors to provide services to rural people without the need of their physical presence. Also this device will lessen the burden of nurses in hospital by helping in dispensing medicine with the use of electronic prescription. In addition, patients who visit the hospitals where AHMs are installed can consult doctors online through video streaming and get a solution to their health ailments [4], [5], [6], [7], [8], [9].

AHMs will act like a first point of contact, between the people and healthcare. The AHMs will be installed in collaboration with primary healthcare centers and hospitals nearby. A health card will be provided by AHMs, which will be made available in local languages bearing patients details. Using this health card, people in rural areas will be able to avail healthcare services free of cost. The services of AHM can be accessed by a Smart Health Card along with the PIN number for each card to ensure privacy and security of each person. For ease of use, thumb impressions of individuals can be used instead of PIN number to access the AHM services for rural areas of India. It will initialise once it detects the person using IR sensors. On entering the PIN number, various services will be provided such as availing medicine for minor ailments, online medical consultations, screening for diseases (eye diseases, hypertension, diabetes), booking medical appointments, referral services and locating ambulances in emergencies. All these services proposed to be provided by AHMs will improve patient's satisfaction and will aid in provision of quality healthcare services to the below poverty line population who are mainly reside in rural areas [1], [10], [11]. Some of the working cases of our proposed system are discussed below:

A. For General Check Up

In this condition, various parameters of the person is monitored and uploaded to the patients cloud. This General Check up includes monitoring various parameter like Temperature, Heart Rate, Oxygen saturation, Blood pressure, Height and Weight of the person and Body Mass Index (BMI). Using dedicated medical grade sensors and access to these sensors in the AHM are notified to the patient using a dedicated LED for each sensor along with the GUI instructions which gets activated on selecting the test in the GUI display. After a General Check up, the person may get advice based on his/her body condition through SMS or can have an option to consult a doctor through video call to access their health. In addition to that, the patient can interact with the chat bot and asks for symptoms, illness details, allergies to medicines etc. The AI powered AHM will assess the users health based on the input and provide suitable medications. The medicines will be

delivered to the patients based on 3 types: (i) Based on the medicine availability in the AHM:

- 1) If medicines available and patient requires medicines, the AHM will dispense medicines based on the doctor's advice or by assessing patient's health condition using AI along with e-prescription.
- 2) If medicines are out of stock and Patient needed medicines, the nearby online pharmacists will be contacted about the needed medicines and It will be home delivered to the patient address. The prescription can be electronically printed from the AHM.
- 3) If medicines are available but patient not needs medicine, only the e-prescription will be generated and given to patients.

The flow diagram explains the overall work flow (Fig. 1) and the generalised work flow of AHM for non-emergency conditions (Fig. 2).

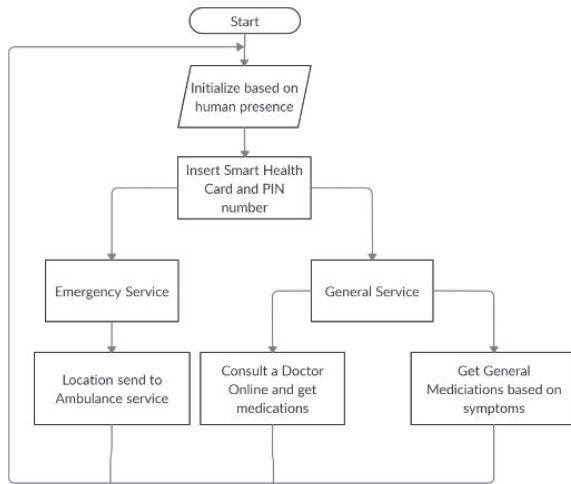


Fig. 1. Overall Work Flow of the Automated Health Machine

B. For Emergency Care

In this model, the person may be met with accident or any emergency situation, in such condition the use of Smart Health card will not be advisable. So a Physical Emergency button can be pressed and it can send alert the nearby hospital / health care center with the Emergency notification for Ambulance service. In the meanwhile, the type of emergency can be given as input to the AHM and the related First Aid procedures will be displayed in the GUI interface and this can assist the bystander/patient carer to give First Aid to the patient in need of emergency service. Also after calling the Ambulance, QR code will be generated in the GUI display which can be scanned by the patient mobile to track the patient location and accordingly location information will be sent to the predefined family member number. This can avoid confusions among the patient's family members and reach the hospital in time without any delay in information sharing. The earlier medications given, higher is the percentage of survival for

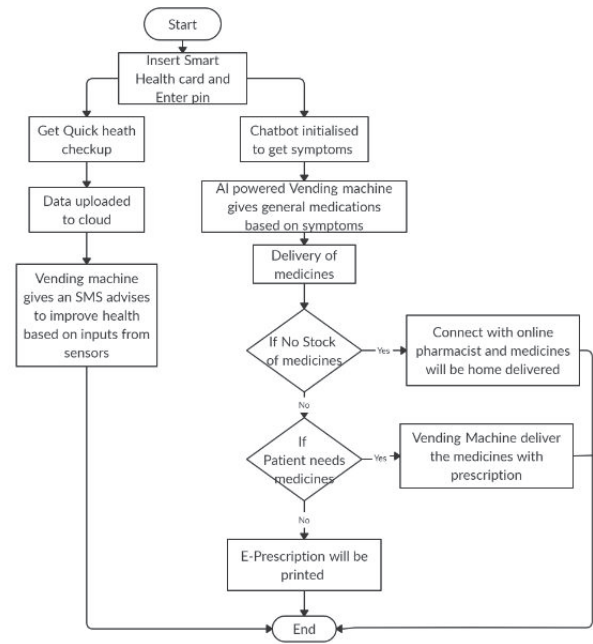


Fig. 2. Generalised Work Flow for Non-Emergency Condition in the Automated Health Machine

the patients. So this can save more lives in the emergency situation. The flowchart is shown in Fig. 3.

C. For COVID Screening

With close work on the current situation, this AHM can also give a hand in this current situation of pandemic. People in the quarantined area cannot move out of their area even in case of any health issues. Also, people fear that they could be a victim of COVID-19 if they visit hospitals. In rural areas the situation is worse than in urban areas. To make their lives easier, the AI powered AHM also can help to assess the patient with COVID-19 symptoms and give medications accordingly. For machines to be placed in COVID areas or rural areas where primary health centres or hospitals are a long way to reach, these AHMs can be a boon. On detecting a person using IR sensor, AHM will give a GUI instruction to sanitise the hands using UV-C lights to ensure sanitation before operating. Then the Person may enter the Smart health card and PIN number can be entered. The interactive Chat bot gets initialised and gets the symptoms of the patient. Simultaneously the Temperature sensor is triggered automatically to take non-contact temperature measurement of the patient. If the symptoms inlines with COVID-19 symptoms given by the UNO or Temperature is greater than 100, Automatic video call with the doctor will be connected and doctor may assess the patients based on the symptoms given as input in AHM. Based on severity of the condition, the Doctor may call for ambulance and book appointment for swab test/ rapid test at nearby health centers / hospitals. After the test, the results may reach the patient via SMS or email. The flowchart is shown in Fig. 4.

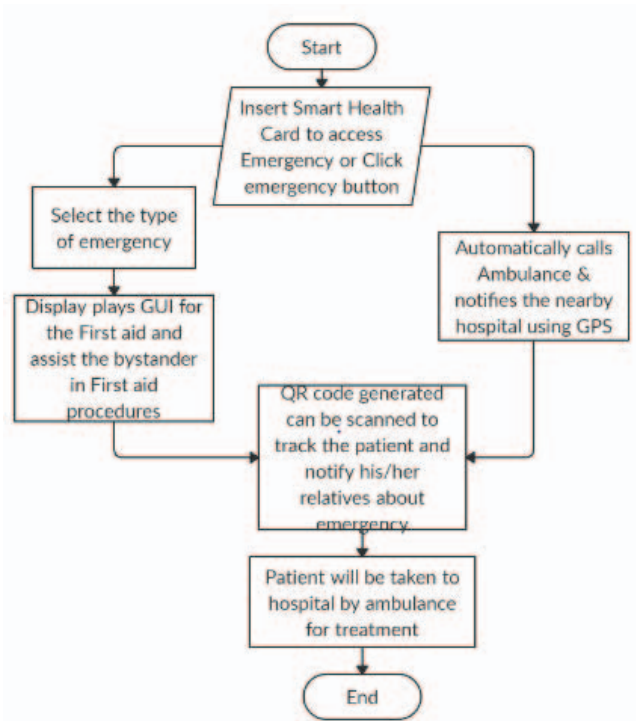


Fig. 3. Generalised Work Flow for Emergency Condition in the Automated Health Machine

Case 1: If the patient is Tested Positive: The link will be sent to the predefined family member number after the patient has been hospitalised. This dedicated link can help patients family members to track patients health status and location. This can avoid tears among the relatives because no attenders are allowed in the COVID ward and the health status of the person may remain unknown until the patient inform his/her family members.

Case 2: If the patient is Tested Negative: The Doctor can give the suitable medications for the symptoms and can advise the patient to be in home quarantine. If the symptoms given by the patient is not inlined with COVID-19 symptoms, based on the patients choice, video call with doctor can be connected or Automatically medicines can be dispensed by the AI- AHM based on the symptoms given as inputs by patient. When tested negative, results will be sent to the registered mobile phones.

III. IMPLEMENTATION

The block diagram and the circuit diagram of the AHM are shown in Fig. 5 and Fig. 6 respectively. ARM Processor provides a clean Graphical User Interface (GUI) Connected through the HDMI port of Thin film transistor (TFT) display. It repeatedly checks the state of Emergency call push button or the GUI button on the display, whenever it is triggered in a medical emergency it sends a message for ATmega328 controller to send an emergency message along with location through the GSMSIM800 engine which is controlled by send-

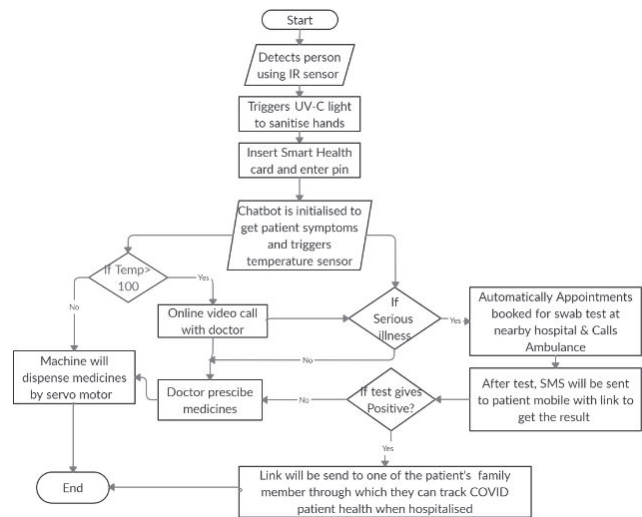


Fig. 4. Generalised Work Flow for COVID Screening in the Automated Health Machine

ing AT Command via its serial interface. Then it automatically powers up the pulse rate sensor and starts reading the analog pulse values, and sends it to the processor which calculate the total number of beat (pulse) per minute (BPM). It also displays the BPM values and the inter-beat-interval along with the pulse train graph. Simultaneously according to the pulse generated, LED (light emitting diode) is blinked with the same time rate. It also displays the list of medicines which are available and whenever any medicine is selected it activates the corresponding blocks which sends the PWM (pulse width modulation) wave to the corresponding motors either geared motor or servo motor belonging to that medicine. As both the motors are used for particular physical structure of the medicine. Along with dispensing the medicine, it also displays graphical instruction to be followed for particular medicine.

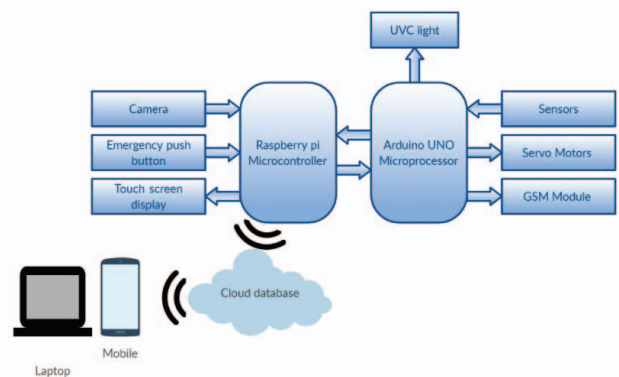


Fig. 5. Block Diagram of the Automated Health Machine (AHM)

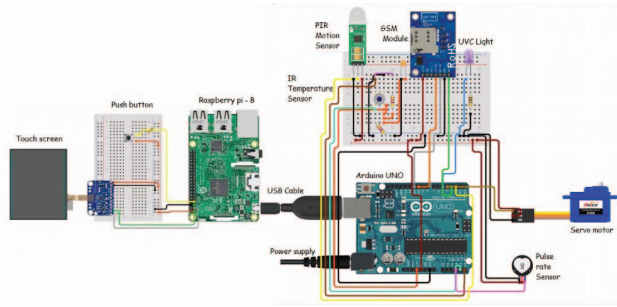


Fig. 6. Circuit Diagram of the Automated Health Machine (AHM)

A. PIR Sensor & UVC Sanitizer

The Energy efficient design of the AHM is achieved by connecting PIR sensor to the Arduino ATMEGA 328. The AHM recovers from the sleep state when the PIR sensor is triggered by human motion. When PIR modules senses the motion, the system turns to ON state, and the UVC light are powered to ensure sanitation before operating the machine. The UVC lights are connected to the digital pins of the ATMEGA 328 board.

B. IR Temperature Sensor

After the sanitation using UVC lights, The patient inserts the Smart health card and enters the PIN number to avail the AHM facility. For the COVID check-up or the general check-up the chatbot is initiated to get inputs about the symptoms of the patient. The IR Temperature sensor is triggered to check the patient's temperature while they are interacting with chatbot. The IR temperature sensor output pin is connected to the analog pin of the Arduino Board where ADC converter gets the digital signal and the readings are uploaded in Patients cloud and displayed on the Touch screen.

C. Pulse Sensor & Push Buttons

Whenever a patient is subjected to test by selecting button in TFT display, The ARM processor will send an acknowledgement to ATMEGA processor to start reading the signal from the sensor which is connected to the analog /digital pin of ATMEGA 328 board. The ADC converter converts analog input pulse into a digital format depending on the sensor input and is sends it to processor for higher calculations and to display readings in the TFT display. Push buttons are called emergency stop buttons. The one used here is normally in OFF switch mode, where there's no connection till a button is pressed. Currently, push button switch is used in this way, so that whenever a button is pressed for a couple of second or less, it triggers an interruption and calls a function which sends emergency call message using GSM SIM800 module to a nearby Ambulance along with the current location/address.

Interfacing with ARM Processor

Push button is connected to the GPIO pin of processor. Whenever a push button is pressed GPIO pin reads the logic HIGH, which interrupts the processor program and sends a

message to controller to call for a pre-set number through GSM module.

D. Other Components

We use many other components such as DC Motor, Servo Motor to vender medicines to patients, Raspberry Pi 3 Model B+, R-pi camera, pulse/heart rate sensor, blood pressure sensor, ECG sensor, oxygen saturation sensor, visual acuity sensor.

IV. RESULTS

Our prototype (as shown in Fig. 7), Smart Automated Health Machine (AHM), is a high end tool for expanding healthcare system across the world. It's the complete system capable of checking human heart rate, temperature, blood pressure, ECG and oxygen saturation. The system can send a call for ambulance in case of emergency. It is capable of vending the medicines the patient selects from the list displayed. It is also capable of streaming video to the doctor at distance place in case of emergency for primary healthcare conditions. All the data captured (both patients and doctors) will be sent to the cloud and stored securely. The system is user-friendly and simple to use.



Fig. 7. The Prototype Solution of Automated Health Machine (AHM)

Evaluation

We conducted a pilot evaluation with three patients, four nurses and four doctors (a cohort of 10). We compiled and summarised the observations made during the study. The patients subjected to the test were provided with our prototype. The nurses supported the patients by selecting a button in the TFT display of our prototype. The system detected the pulse signs and decided what action to take. In a couple of cases, emergency call message was sent to a nearby Ambulance along with the current location/address. For one of the case, we had a direct video call interaction with a doctor who took history and provided a management plan.

All the 4 nurses and 4 doctors expressed their happiness with the system. They felt the system will be useful and

helpful to the public, in case of emergency and helps during waiting times/delays. However, one doctor felt the system could strain patients and can create more stress and panic due to the process/instructions involved. As an overall outcome, the practitioners feel the system can be adopted in an area where medical facility is not available immediately. Adopting this system in such regions not only help in medical emergencies, it also increases the percentage of survival. The system can also be adopted in hospitals, pharmacies, public places like bus/train stations, markets or any commercial areas that can be quite useful and helpful to the public.

V. CONCLUSION AND FUTURE WORKS

We believe our system can be deployed not only in hospitals but also in a public setting such as a community center, jail, school, retail store, mall, office building or airport. During this pandemic situation, the use of AHM plays a vital role in treating millions of people by maintaining social distancing. There is also good scope for AHMs in emergency department (ED) in hospitals. Many overseas countries, have benefited by installing this device in accidents and emergency units. Time plays an important factor in treating patients in emergency settings. The time taken to initiate and administer medications to patients in such situations can have a huge impact on patients' outcome. The faster the initiation of medications in the ED hastens the improvement of patients. In cases, such as Meningitis timely initiation of antibiotics to patients can prevent various complications and save lives. Hence, using new smart technologies like AHMs which aims to improve the efficacy and speed of dispensing medications can be a boon in critical care.

Advantage of AHMs in rural areas

- Easy-to-use interface, web-based solution with wireless connectivity, interoperability and communications with other equipment.
- Enhanced access to healthcare services for rural India.
- Access to prescription medications easily, without difficulty of queuing in pharmacies .
- Online pharmacist can prescribe medications for simple ailments.
- Online Medical consultation can be provided, if required referral services will be made.
- Easy access to emergency medical care.
- Online scheduling of health appointments can be done using AHMs.
- Effective screening of diseases for aged population.
- Reduce medication errors and improve quality of care (aids in providing patient-centered care).
- Improve nursing and pharmacy staff efficiency by reducing manual steps and processes (free up staff time)
- Effective utilization of medical services.
- Travel time and out-of-pocket expenditures associated with visit to healthcare centers will be minimized.
- Improve patient safety
- Minimise redundant data entry
- Accurate tracking and management of medicines

- 24/7 tracking and electronic reporting capabilities
- Improve medication tracking and regulatory compliance
- Seamlessly integrate healthcare information systems (HIS)
- Can be used as a pharmacy management systems (PMS) or healthcare management system (HMS)

Challenges of AHMs in rural areas

A. Non-Ethical Challenges

- Local laws could pose as a challenge in establishing AHMs in rural areas.
- Operational difficulties of using the device
- In terms of cost, the device is expensive and needs good funding.
- Hesitancy of using technology by people.
- Continuity of care is questionable.
- Cabinet design and use must be carefully planned and implemented to eliminate opportunities for wrong drug selection and dosing errors, so systems can improve patient safety.
- Stringent regulations for the installation of automated dispensing systems
- High maintenance and repairing costs might be expected.

B. Ethical Challenges

- Misuse of the services by people. A good security system is required to curb such incidents.
- Quality of healthcare services provided by AHMs need to be verified.

Future Work

Increasing number of hospitalisation cases and improving healthcare infrastructure in the rural parts of India are the predominant drivers of the smart automated health machines. AHMs are centralized and decentralized medication distribution systems which provide various healthcare facilities and computer-controlled storage and dispensing of medications [13]. The system can track the patients for whom prescribed medications are administered and provide usage data to the management [14]. AHM can be further enhanced to make appointments or video calls with specific doctors based on specialization. The system also provides additional information support which enhances patient safety through integration with various medication history databases. Additional privacy can be provided by placing AHM inside a private room similar to ATM as patients may hesitate to express their illness in public. The complete system can be integrated using machine learning, deep learning and artificial intelligence. We will also consider a gesture recognition application for physiotherapy healthcare [15], [16], [17], [18] and build various other application related to breastcare awareness [19], [20].

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