Original Research Article

Digital Framework strategy for patient medication adherence and improvement in Medical Healthcare Centre Offa, Kwara State

Abstract

The prospect behind digital transformation strategies makes the healthcare systems more safe, affordable, and accessible with remarkable opportunities. The reasons why patients decided to have negative medication adherence became a critical challenge in the healthcare system. This study presents a Digital Framework Strategy DSF for patient medication adherence to improve patient health during the treatment regime. A case study of the Federal Polytechnic Medical centre and clinical activities of Offa General Hospital examines the existing treatment of chronic diseases. The cloud-based server revolves around Convolution Neural Network (CNN) feature to perform a real-time collection of data and analytics of patient information. When thoroughly combined, the CNN of the neural network has a model of the application, which will form part of the desired output. This output presents a level of patient medication adherence within the parameters—the data around the enclosed sources. The approach data was aquired with the patient wearing a sensor and smartphone devices. The model throughputs presented the details analytics of individual patient adherence behaviours. The result of CNN performance revealed 96.99% accuracy of medication adherence level on a tested dataset collation, and the essence of digital framework analytics helped the healthcare workers (HCW) and healthcare providers to make prompt decisions on patients' medical conditions

Keywords: Digital Transformation, Medication Adherence, healthcare provider, chronic diseases.

Introduction

Digital Framework Strategy (DFS) is gaining global recognition due to digitalization and advanced technology [1]. Over the past two to three years, healthcare organizations in the private and public sectors have had a big data analytics framework to analyze a lot of data. The big data system is a short and critical developing research scope covering a wide range of industrial innovations and exerts researchers in the medical domain with an extraordinary potential [2 -5].

Generally, patients tend to have improved medical outcomes from chronic ailments when they strictly follow medication schedules set by medical experts. Improving patient health conditions is becoming a significant concern when dealing with chronic diseases like HIV and AIDS, Cardiovascular disease, Tuberculosis (TB) and relative cases of pandemics. The issue of rural settings is overwhelming due to social factors that contribute to medication adherence of patience living in such a domain. Health experts find it difficult to monitor patients' medication adherence related rural settings and unable to create technological intervention that could lead to encourage them towards good adherence. In the light of these findings, existing tracking and monitoring strategies like Direct Observation Therapy (DOT), Video Observation Therapy (VOT), and Indirect Monitoring Technological (IMT) for Medication Adherence and Improvement (MAI) have not embraced a big data analytic framework [5-9]. The weakness of the existing medication monitoring method failed. Because it does not include critical human and ergonomic factors, for instance, motivation, encouragement, negotiation and determinant elements that can revolve around the daily lifestyle of a patient in the design of a medication adherence monitoring scheme which limits the chance of health recovery [10], [11]. These existing methods have limited their patients' self-sufficiency. They have not created any adherence improvement as a central core of their design that is supportive of the patient in the end.

In resource-limited settings, the responsiveness of positive adherence behaviour is significantly low due to social-economic problems. The factors vary from illiteracy, low income, poverty, poor infrastructure, and Insufficient good medical facilities. In this scenario, the researcher observed the difficulties of healthcare providers in effectively monitoring patients' medication adherence in the Offa town and encouraging them towards good adherence behaviour. In light of these findings, existing Medication Adherence and Improvement MAI strategies have not been embraced into the digital framework. Strategies DTS for medication adherence involves cascading two or more devices, a cross-platform integration framework to execute heterogeneous activities and multitasking from remote terminals [6],[12].

Many factors lead to the negative impact of Medication Adherence and Improvement of MAI in a patient's life [13]. A patient can decide to have negative adherence behaviour if there is no consistent timing or unconditional intent to deviate from medical agreement. It could occur due to environmental stigma, unfriendly cross-platform for medication adherence, close relative negligence, emotional illness, and working conditions. The existing MAI poses limitations and constraints that result in a patient's unhealthy lifestyle and does not include Artificial Intelligence (AI) to support the patient's health recovery [18-22]. The research DTS framework, which presented low-cost hybrid technology, creates a synergy workforce amongst stakeholders who have symmetrical working alignment and provide flexible medication adherence and improved life of patience in Offa Medical Centres.

The effect helps health providers and other health agencies to make good decisions in the life of affiliate patients with the different observed levels of medication adherence [3];[23].

The reasons existing technology failed to measure consistent positive results in behavioural patient patients in the long run. Is there any tendency for every patient to comply with mobile health considering the availability of applied? If a phone and email could replace DOT, then the perspective on the wireless communication model could be a defined solution in the treatment of patients. This work is concerned with the relationship between patients, relatives, government, health workers and the technology approach.

Several studies have been conducted on applied big data analytics in the healthcare system and others. In contrast, these studies offer importance to highlight foresight on the chances that exist in the application of big data analytics in the treatment of chronic diseases and the scope cantered on patient medication adherence and improvement [24-27]. However, dealing with prevailing factors hinders medication adherence and the way back from the existing adherence monitoring methods that do not feature a big data analytic framework approach. Yet reality has proven that the big data analytics framework dealing with chronic disease is inefficient in the resource setting[17].

However, The proposed study makes use of a big data analytic framework to monitor patient medication adherence in real-time and determine personalized treatment of patient adherence behaviour via AI [26 -28].

This study aims to develop a framework that can improve medication adherence by patients with chronic diseases in low-resource settings.

This research is to identify resource-limited settings attributes associated with the big data analytic framework. Emback on the design the mechanism-based data-driven attributes that can identify the difference in patients' behaviour toward medication adherence.

2.0 Literature Review

The digital frame research field is yet to be fully defined, and most of the research is case driven and multi-disciplinary [27]. Some data framework studies, especially in medicine and biology, have failed to provide conceptual contexts to which they are applied. With the rising interest in big data analytics, the impression to understand the problems to be solved with predictable scientific methods of inquiry. Numerous measuring adherence monitoring methods have been revolving for many centuries with different approaches. The existing ones are categorized into direct and indirect monitoring methods [28].

A: Direct Measure of medication adherence

The use of direct monitoring involves direct contact with patients to know if taken the drugs administered at a time. The other way through laboratory tests is to examine the patient body fluids in the laboratory, blood or urine and evaluate the presence of a biological marker given with the drug and direct observation of the patient's medication-taking behaviour [29];[30].

B: Indirect Measure of medication adherence

The indirect monitoring methods use technology devices to engage the activities that support the patient during the treatment journey and the trigger signal if the patient takes medicines or not in real-time. Technologies like sensors involve acquiring information. Employing detection and converting it into readable signals, these technology devices are device-facilitated. These exist in three types: sensor-based, vision-based, proximity-based, and fusion-based systems [31]. The sensor-based methods include smart pill containers, wearable sensors, and ingestible biosensors that can aid in monitoring activities regarding pre-set conditions. The intelligent pill containers exist in the nine-stage sub-system of the programmable system that enables medical caretakers or clients to determine the pill amount through the cap opening and bottom pick up to track adherence, timing to take pills and the service times for every day.

Daramola [32-24] has proven that the prototype of this nature includes Wisepills, Mem- scap, GlowCap, Evrimed, and Amiko, respectively [33];[34] is use to monitor patient adherence in the literature. Hence, Wearable sensor technologies gather physiological and movement data, thus medically enabling patient status monitoring. Sensors are implemented and deployed according to the clinical application of interest in the major concern related to motion relationship with twisting, tracking hand-to-mouth, pouring the pill into the hand, and pill swallowing. neck-worn sensors and wrist-worn sensors [25]. This kind of device, in the form smartwatch, has been incorporated to track mediation adherence. A signal-based smartwatch sensor that detects accelerometer hand gesture data and use to convey the data collected to a central cloud database using AI-based technology like neural networks [18],[22],[34].

2.3 Tag Dispatch System

Google developed the tag dispatch system for the Android platform. The system manages the reading of NDEF data from an NFC tag. Whenever an Android device scans an NFC tag, the tag dispatch system determines which applications are interested in receiving the message instead of asking the user to select an application from an application selector [35].

The app receives an NFC event without interfering or creating conflicts with other NFC apps on the device; it is essential to understand how the NFC dispatch system on Android prioritizes and chooses which applications can receive the scanned NFC tag or NDEF message. The conflict presented as an application picker to the user to decide to dispatch the scanned NFC to an app [36].

There are two systems that Android provides to identify which Activity should handle the NFC tag: the intent dispatch system and the foreground Activity dispatch system.

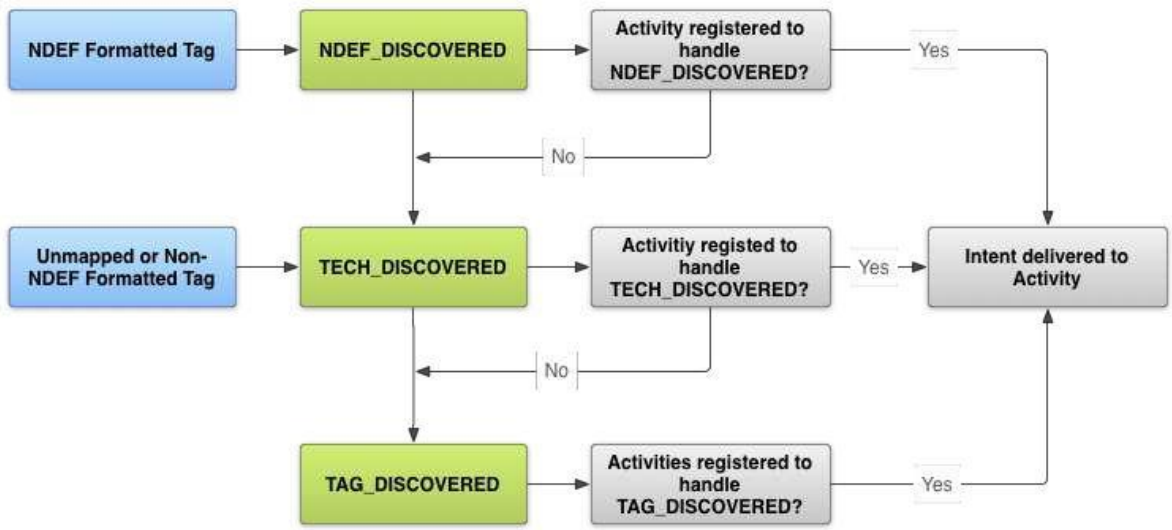

Figure 1: Tag dispatch system.

The intent dispatch system is made to find the best activity to handle the NFC tag. This is done by checking the intent filters and supported data types of all the Activities. The activity chosen will be presented, If there are multiple Activities with the same intent filters and data types.

The tag dispatch system defines three types of intents:

- NDEF_DISCOVERED
- TECH_DISCOVERED
- TAG_DISCOVERED

The foreground dispatch system allows an activity to have high priority over other activities registered to handle the same intent, and it will enable override of the intent dispatch system when an NFC tag is scanned [16]. The foreground dispatch is used while the application runs without making the application shutdown if another application has a similar intent dispatch setup. When the application is running, it can discover an NFC tag and handle intent over other apps on the phone. The phone will not provide an app picker for the user to choose from [17].

3.0 Methodology

A Big Data Analytics Framework for Medication Adherence and Improvement (BIDAFMAI) presented with technical derivative components. Implementation of a big data analytics framework for medication adherence and improvement will enable healthcare organizations and associate stakeholders to be highly dedicated and accountable for the following;

- Concurrently improving motivation bond between the patients and the supporters.
- Holistically improving patients' medication adherence behaviours in a continuous process.
- Managing and maintaining a high level of medication adherence among patients
- Enabling reliable treatment outcomes concerning acceptable medication adherence behaviours.

The need for developing a Mobile Application called DTS is required in the case study to provide interfaces for participants and create a statutory profile in categories. The app modules allow intercommunication using hierarchy modules and enable participants to send or receive information via structured data; this will track the activities of patients, patient supporters and other health care providers concerning server requests. The DTS implementation involves the use of integrated software and pairable hardware devices. The devices "smartwatch and phone" must be charged regularly to ensure their effectiveness for the research study.

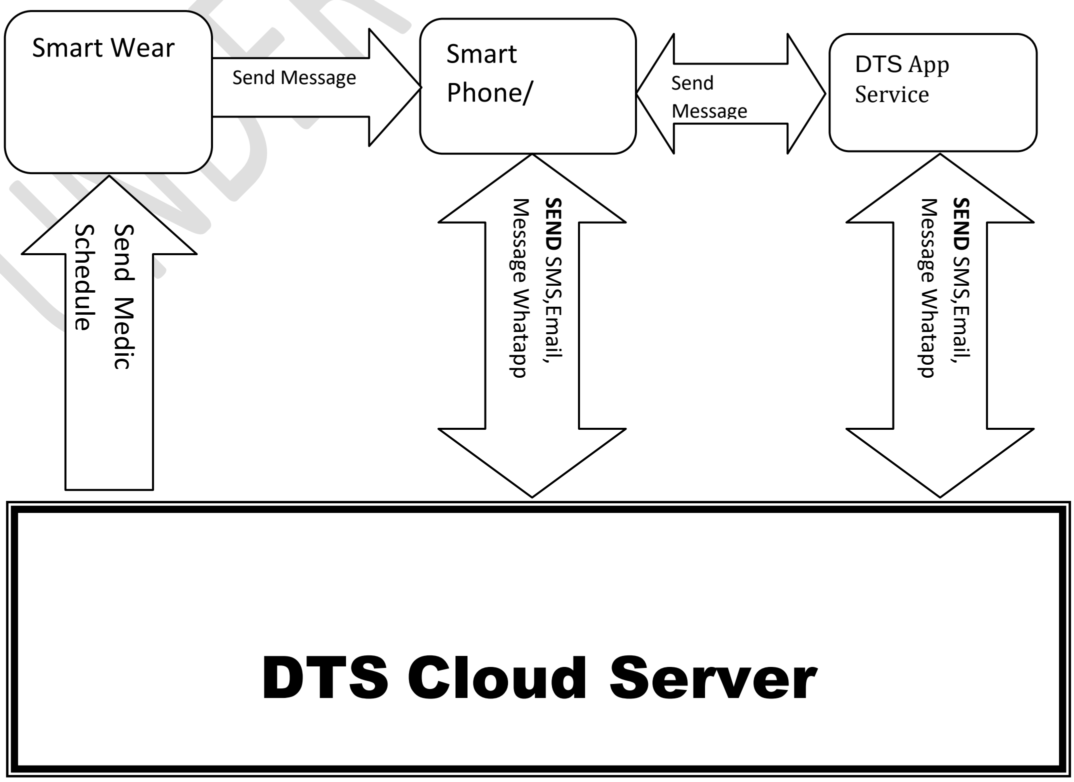

Figure 2: An overview of the research entity of DTS work-flow for improve medication adherence

DTS in the case study in figure 2; the composite tools and resources include email, WhatsApp, the DTS app and SMS. All connected with aid IoT enable all participants (health care providers, patient supporters, patients, stakeholders) to create a workflow in the line of duties. In most cases, all stakeholders gained statutory of receiver/sender, consolidate action by driving data from remote server for decision making. Treatment strategies depend on the level of adherence observed by the healthcare providers. Therefore, all these are based on a modular architecture that will take care of the research problems and seek a way to suit different contexts in the case study of medication adherence monitoring and improvement.

The proposed work on the development of medication adherence applications is divided into different screens, as presented in figure 3 gives an overview of the composition of the Digital framework for improved medication adherence. Each screen must be implemented according to the design specification and tested before executing the next screen. The proposed application's different screens will follow the state chart presented in Figure 2, subject to modification in due course.

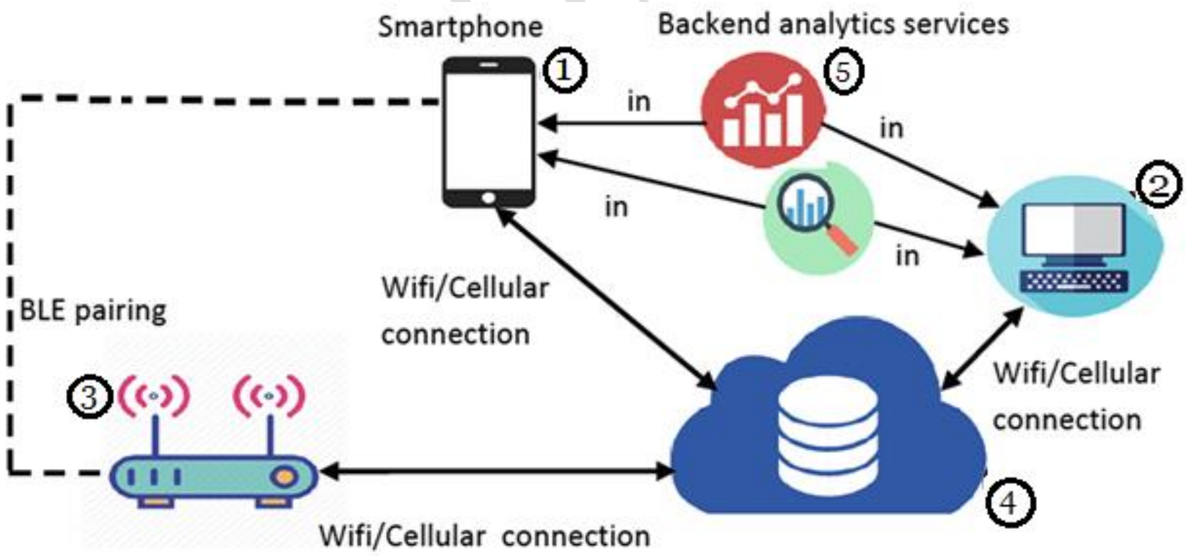

Figure 3: An overview of the composition of the Digital framework for improved medication adherence

This description used in figure 3 is a composition of digital framework strategy adoption in the study area. These include Bluetooth technology, smartwatch, smartphone, cloud database, and backend analytic services.

Smartphone involves patient enrolled on the programme and healthcare provider accredited to participate in the treatment of medication adherence. The essence of the smartphone allows the healthcare provider to remotely monitor patients and share information about patients with other stakeholders assigned to collaborate in monitoring patient adherence over time.

Backend analytic service is a small tool for a healthcare provider that enables data analytics service to be done. The path analytics include medication adherence of personalised treatment of patients over time. The fact remains that a lot of data are sent to the backend server from smartphone and the analytics tool is used to collate the report of the patient medication adherence on scheduled (weekly, monthly and yearly) in periodical order.

Cloud Database is a centralise repository in the study that stores data collected and retrieved during each session of the mobile app service. The cloud database takes the patient details, caregiver detail, healthcare worker information, transactions (date, time, adherence values) and reminder schedule. All instances of medication adjustment and renegotiation between patients and healthcare providers are stored for future analytics. The future data from the data collected are used to precede patient adherence in the analytics view for decision making.

Internet of a thing (IoT) is an existing facility in the study area used to provide internet access within the Federal polytechnic Offa campus. The usage of IoT goes beyond campus since the cloud database is positioned in the cloud. IoT enables all participants enrolled on the medication adherence system to participate remotely from the localised region fully.

3.1 Near Field Communication (NFC)

Near field communication (NFC) is a short-range wireless communication standard between devices such as smartphones and tablets. The development of this standard was based on RFID (Radio-frequency Identification). The RFID technology is recognizable from its usage in passports or bus cards used here in Sweden (SL Access card).

For quite some years now, NFC technology has been built and used in mobile phones, and the long-term promise is to replace all electronic cards with NFC-enabled devices. NFC allows the user to send and receive data safely and simply without needing to go through multiple steps to set up the connection. This can be done by defining a way to establish a peer-to-peer (P2P) communication between NFC-enabled devices, where at least one device is transmitting, and the other is receiving the signal. NFC enables the communication between devices by using a magnetic field induction when devices are placed close to each other. The communication between NFC-enabled devices is established when they are within 4cm or less of each other since NFC operates in the 13.56 MHz radio frequency licensed ISM band.

3.2 NFC and security

One of the most significant advantages in terms of security when using NFC is that the range is quite limited. Even if all security and other protective measures have been violated, the individual that has initiated the breach must be close to doing that, and it requires that both devices have their NFC functionality enabled [15].

But still, new users of this technology may not know how dangerous it is with these security breaches, especially for payment purposes where users store their credit card information on their smartphones [18].

4.0 Results

The development process has resulted in an application that can be used to communicate with an intelligent pillbox by using NFC. The application provides a way for healthcare providers to "tap and go" model, where all they require is to touch the pillbox to start and perform a brief communication where information can be added or retrieved based on the user's need.

The application has been developed based on the requirements defined by MIT App, as shown in figure 4. These requirements have been met throughout the development process of each function and have been evaluated through tests with the help of healthcare professionals. The application contains seven screens, as mentioned in the previous chapter. There each screen will provide different information. A welcome screen, login screen, and two screens will allow the user to add information about the patient, medication, alarm, and x-alarm, and three screens will be used to retrieve information from the pillbox. The application is designed to be launched by clicking on the app icon found in the phone app drawer.

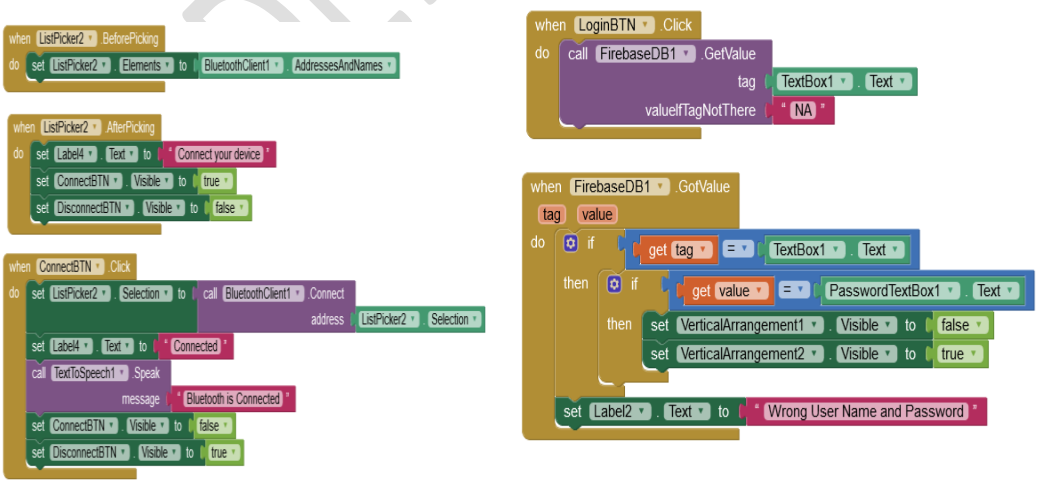

Figure 4: User The login Method with feature of Bluetooth

4.2 Adding and retrieving information

The user must first enable the NFC from the phone settings to retrieve information about the patient, medication, or missed pills. Afterwards, placing the phone on top of the pillbox will display a short message on-screen, letting the user know that the NFC tag module has been successfully scanned and awaits the user's input to retrieve information. Depending on the information the user wants to recover, the retrieved data will be placed in either the text fields or the calendar. The user cannot modify the retrieved information once it has been retrieved.

Adding information about the patient, medication, and setting the alarm, x-alarm, and time is achieved by providing this information through text fields and time pickers. After providing this information, the user must place the phone on top of the pillbox and then clicks on a button to add this information to the pillbox. A message will be displayed letting the user know that the information has been added successfully or indicates when the app is connected to the pillbox, then indicates when the NFC tag is detected. Figure 5 displays the connectivity between the pillbox and the mobile application.

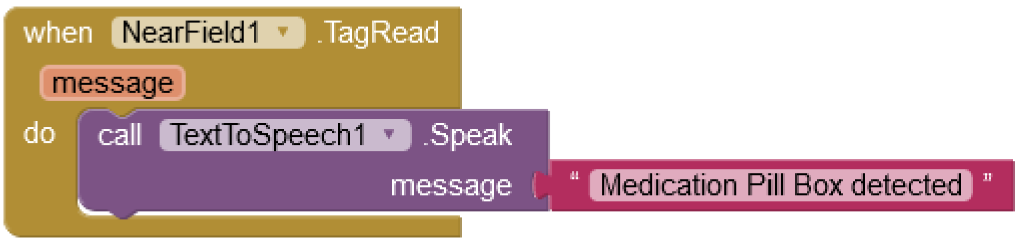

Figure 5: Near Field Communication Connection API

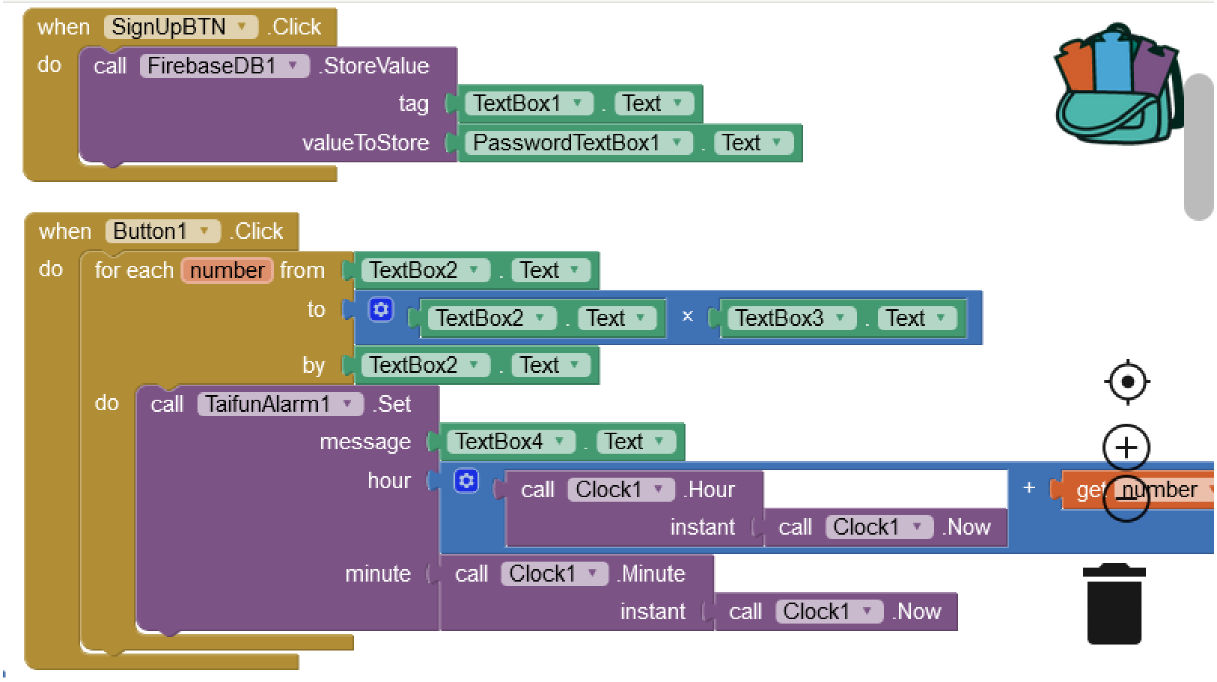

Figure 6: Button Click Response Connection String

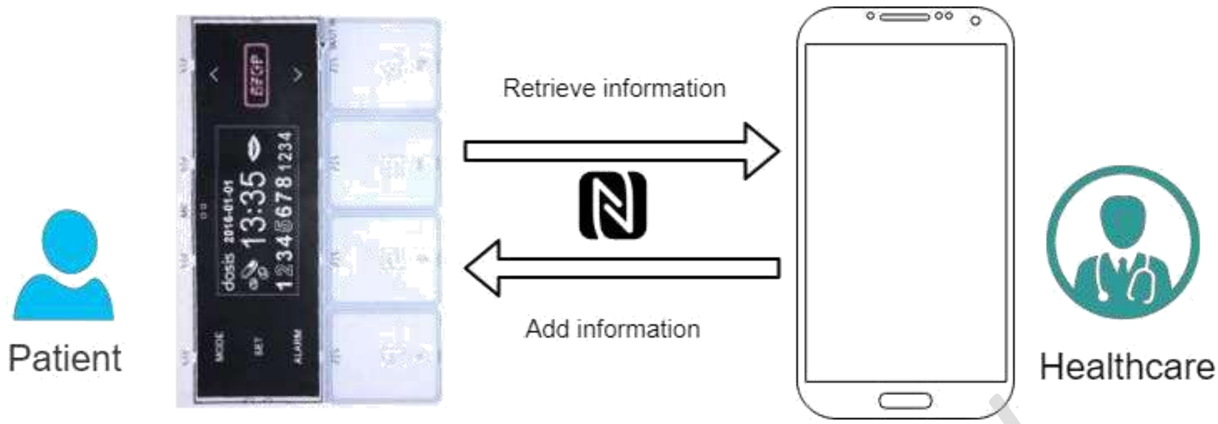

Figure 7: Retrieve information from pillbox

4.3 Application UI structure

The UI structure of the application is comprised of multiple elements that are broadly used in today's application design. Figure 8 displays the structure of the missed pill screen and the design elements that have been used during the development of that screen. As mentioned previously, there will be two main navigation ways when using the application. The first option is by using tabs which are indicated in red. Each tab displays different information, and each tab has been assigned a symbol (icon) that reflects the content with which they have been associated.

Clicking on the button will retrieve information about missed pills from the pillbox and display them on the calendar. The user can swipe left or right on the calendar to change between different months. Clicking on a day with a missed pill will reveal detailed information about which time a pill was missed and the id of the alarm that started reporting a missed pill to the NFC tag [19].

4.4 Prototype vs final implementation

There have been many changes in functionalities and design, moving from the prototype to the final implementation. These changes are due to some complications and limitations in knowledge in both NFC and Android development when designing the first and second iterations of the prototype.

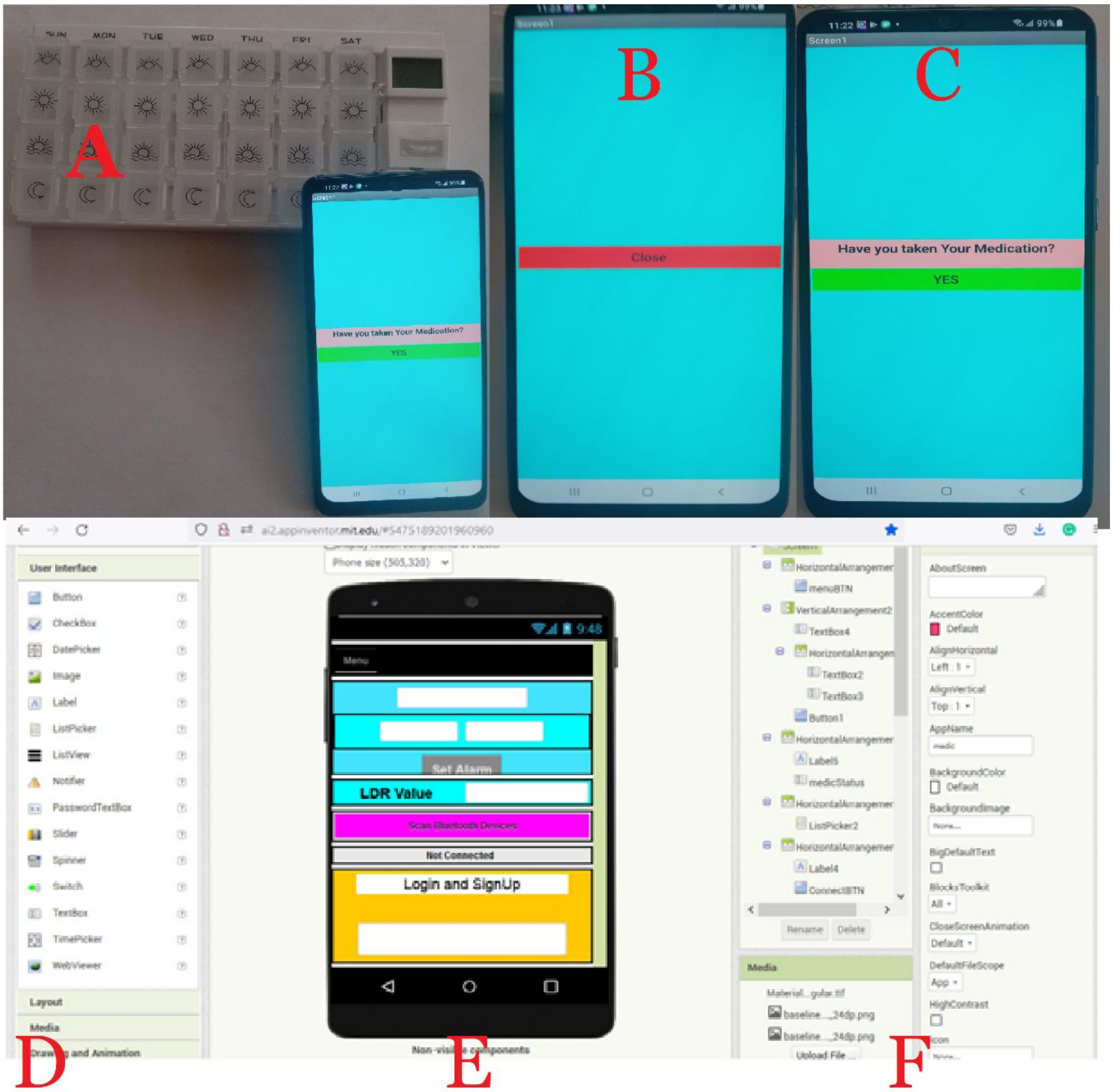

Figure 8: User interface with pillbox featuring connection string of NFC embedded with smartphone.

A front end of android app develop on MIT app where indicate how app interacted with pill to prompt user if medication is taken. The B area shown indicate close button when patient bring mobile app close to pill box as shown in C. The D reveal details of UI layer on MIT app with corresponded feature block code shown in fig 7 and 8 respectively.

These changes in the internal structures of the application the followings:

- Display missed pills as red dots instead of red circles in the calendar.
- Time pickers are both analog and digital instead of only one of the two.

- Time picker is displayed when an alarm is set, it will not be presented otherwise.
- Side navigation menu contains more options.
- Some screens were skipped and other were merged into one.
- Buttons were added to the bottom of each screen indicating the ability to either retrieve or add information to the pillbox.

Despite all these changes the final implementation has some design elements that are common with both iterations.

4.5 Evaluation

The application will be provided to MIT App which could improve and evaluate the application even further outside the scope of this thesis with the help of healthcare organizations and hospitals in Sweden. However, evaluating the application regarding connectivity with the smart pillbox has been achieved through manual testing. These manual tests were conducted by healthcare providers and a mobile application developer during which several open-ended questions were asked to get feedback of their thoughts and experience when navigating the application, how the information is being displayed, which features are missing that could have been included, naming of input fields, and lastly their overall impression about the application, how it would be improved, and what benefits it can generate. These questions were important as they were related to user experience and how would they use the application in their line of work on a daily basis.

To create an understanding of what the application is trying to achieve regarding communication with a smart pillbox. A short introduction to the app was presented where the overall assessment was that there is a noticeable problem in patient medication adherence which needs to be improved with the help of healthcare professionals. Some real-life cases were also introduced to enforce the need for a mobile application that could fetch information about the patient and their medication.

By providing the application to healthcare providers for accessing patient information and monitoring patient medication intakes when using the pillbox can help healthcare to provide feedback and tips to patients during their treatment as it will allow them to improve their medication adherence. The application is also serving as a way to remind patients to take their pills by setting alarms for every cartridge and x-alarms in case the patient has a tendency to forget getting pills.

5. Discussion

The expected outcome of DTS will solve medication adherence monitoring and improvement in the treatments of patient patient's medication during the execution phases. The adherence to patient treatment will be measure using a peer smartwatch, smartphone and NFC (Near Field Communication) tag on drug casing. The composition of this pairable device consists of software and hardware modules.

The essence of these modules will enable communication of the multitask holders and help in the continuous monitoring and decision making. The stage in the phases of implementation indicated, would bring about the application of AI in the mindset of programming languages (android application option) and database structure. Java application is one of the suitable programming languages for the implementation phases of a mobile application. SMS API is required to perform messaging protocols, then XML to create the front and back end of the application interface. The Firebase Database with features a cloud-hosted NoSQL *Database; this* stores stakeholder information and handle all server requests. Sequential processes of achieving this include;

1. Phase Test different phases of the design and evaluation of prototype application.
2. Modelling, simulation modules and integration of application
3. Preparing user requirements and system requirement documents
4. Promoting within the content of social, economic and technological benefits

The significance of the study is to provide the solution to hold promise flexible and low-cost innovation to deliver positive response patient medication adherence monitoring system. A necessary context to optimised data set for decision making for medical practice, therefore, DTS to become a healthcare tool to remove barriers affecting patient treatment.

Table 1. Use case mapping of affordances to specific actors

1	**Digital framework of multiple stakeholders**	**Receiver/Beneficiary** **Patient:** motivation, encouragement, negotiation, flexibility

		HCW: timely update on the patient's progress
2	**Medication adherence monitoring**	**Initiator** **Patient:** initiates action Wearable device: smartwatch Mobile device: smartphone, cellphone Software: cloud-based Adherence monitoring service Receiver/Beneficiary Stakeholders: HCW, friends. **family member(s):** timely update on patient's medication adherence
3	**Data-driven decision making**	**Initiator HCW:** takes decision-based on analysis of gathered data, and observed patterns Health Sector: take decisions based on generally observed patterns on adherence behaviour for various patients **Government:** make plans and policies regionally, and nationally Receiver/Beneficiary Patients: improved healthcare HCW (Doctors, Nurses, etc.): decision support for improved service delivery Health Sector: data for improvement of healthcare services Government: data for planning and development Society: a healthier society, improved healthcare
4		**Initiator** **HCW** devise person-specific methods and strategies to help a patient based on the observed adherence behaviour **Receiver/Beneficiary** **Patient:** receives the right attention and care that is necessary **HCW:** improved success rate in healthcare
5	**Medication Adherence behaviour data archiving and curation**	**Initiator** DFS: an automated process of storing relevant data for future use **Receiver/Beneficiary** Health Sector: data-driven process improvement in the healthcare sector Government: data stored will be used for policy development. Statistics

5.1 Background of the chronic diseases in life of Patient

Mr Tope is a chronic TB patient, 48 years old, that works at The Federal Polytechnic Offa. He lives with his wife and four children in a mining community/ City of Offa, Kwara State. Mr Tope has been enrolled for TB treatment for six months in the local hospital in Medical Healthcare Centre Offa, and he is expected to take his medication twice a day at six h intervals. Mr Tope has agreed with the healthcare worker to take his drug at 7 am every morning and at 1 pm during the lunch break while at work and maintain the same schedule on non-work days.

The medication schedule was agreed upon with the healthcare worker in the presence of the wife of Mr Tope (Mrs Tope) and Ade, a close friend and associate of Mr Tope at work. Mrs Tope and Ade have been enrolled as co-monitors and patient supporters to aid Mr Tope in adhering to the agreed schedule. A challenge with Mr Tope is that lunch breaks at work vary depending on the work schedule. For instance, there are times when Mr Tope and his colleagues need to spend more extended periods in the mine, which would require that lunchtime be postponed.

6 Conclusion

In this paper, we have presented the concept of a digital framework strategy for medication adherence and improvement in the context of chronic disease using the Medical Health centre Offa case study. In contrast to existing medication adherence monitoring approaches, which focus mainly on adherence tracking and measurement, DFS seeks to integrate both medication adherence and adherence improvement of the patient. To achieve this, the notion of multiple stakeholder collaboration driven by sensor-based adherence tracking and data analytics was introduced to support the patient in the treatment journey. Although DSF is still at the conceptual stage, the imperatives for its implementation were also discussed, as well as the plausibility of its adoption for medication adherence monitoring and improvement in low resource settings. The immediate plan is to commence the execution of the DSF based on the research fund that is currently available to us. After that, an evaluation in terms of the usability of the framework from the perspective of the participants will be undertaken, and its effectiveness in monitoring medication adherence and endanger improvement of medication adherence.

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