An Artificial Intelligence based Approach to Assist Stage 1 to 4 (from no impairment to moderately declined) Alzheimer's Disease Patients and Caregivers

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Abstract—**The most common type of Dementia is Alzheimer's Disease (AD), targeting the aged population throughout the world and causing not only the memory weakness but is also a leading cause of death among them. AD progresses in seven stages; and each stage makes patient more reliant on the caregiver, making life troublesome not only for the patient but also very taxing for the caregiver. To cater this problem, we developed an Artificial Intelligence (AI) based Android application, having various AI and non-AI based features for the patient and the caregiver such as, face recognition, chatbot, voice navigation, location tracking, pill reminders, etc. This project is aimed to not only benefit the AD patient but, also to provide comfort for the caregivers in assisting and managing their loved ones with the use of a handy gadget like mobile phone accompanied with the benefits of modern Artificial Intelligence.**

Keywords—Artificial Intelligence, Android Application, Alzheimer's Disease, Alzheimer's Patients, Caregivers, Face Recognition, Chatbot, Voice Navigation, Location Tracking, Pill Reminders, Gaming.

I. INTRODUCTION

Alzheimer's Disease (AD) is an irreversibly progressive brain disorder that slowly weakens down the neural connection of the brain by the destruction of neurons, and consequently, slowly, and gradually the victim loses the ability to carry out even the simplest tasks of survival [1]. Alzheimer's is not just about losing memory, instead it can lead an individual to death in its severity. According to the Centers for Disease Control and Prevention (CDC), Alzheimer's is the sixth most common cause of death among U.S. adults. It is the fifth leading cause of death for people 65 years and older. Not only Alzheimer's is a live threatening disease, but it's also a costly disease. In 2020, Alzheimer's is expected to cost $305 billion to US nation. The disease also puts a heavy toll on the caregivers of patients, and it's estimated that more than 16 million caregivers provided an unpaid 18.6 billion hours of care worthy of approximately $244 billion [2], [3].

Alzheimer affects human brain in seven different stages, which are as follows:

A. *Stage#01: No Impairment.*

AD with its symptoms is not as much detectable here, but brain destruction starts.

B. *Stage#02: Very Mild Decline.*

Minor memory changes such as forgetting things around the house occur here.

C. *Stage#03: Mild Decline.*

Noticeable changes start appearing such as difficulty in recalling names, inability to find proper words for a conversation, lack of concentration, etc.

D. *Stage#04: Moderate Decline.*

This stage marks the noticeable symptoms such as short-term memory loss, inability to manage finances, forgetting their own life details and history, etc.

E. *Stage#05: Moderately Severe Decline.*

From this stage, proper attention from the caregiver is required for managing daily life activities, such as dressing appropriately, recalling phone numbers, etc.

F. Stage#06: Severe Decline.

At this stage, both the regular caregiver supervision and the professional care is required. The patient can get confused in its own environment, impotence to identify faces except closed ones, loss of bowel and bladder control, and requiring help in considerably basic life activities such as bathing, toileting, wandering, etc.

G. Stage#07: Very Severe Decline.

This is the final and terminal stage which leads people to death. At this stage, patient stops communicating and responding to the surrounding, and just utters meaningless words, patient also loses the ability to swallow food [4], [5].

To cater with this very dreadful, progressively life-threatening disease, so many research studies have been conducted and numerous digitized systems have been developed. Those systems can provide numerous features such as GPS location tracker, medicine warning reminder, schedule tracker, memory-based games, connections with healthcare professionals, facial recognition and many more. But there existed a void needed to be fulfilled, and that was to connect the patient with its caregiver, along with more enriched assisting features via a single application.

In this research work, we have implemented an android based mobile application to assist not only the patient itself but also its caregiver, by providing numerous Artificial Intelligent based and non-AI based features in their respective modules via a single app. The targeted patient level for this research-based project ranges from AD stage 1-4.

The organization of this research paper is in an order such that the first section gives the introduction of research and proposed solution, second section discusses the literature review of similar related systems and applications, third is the module design and architecture section which highlights the two main modules of project, fourth section illustrates about tools and techniques used in developing the project, fifth is about practical implementation of project along with visuals, and finally the sixth section of this research paper discusses the testing of project.

II. LITERATURE REVIEW

Alzheimer's patients and their caregivers are being provided with different digitized solutions in combating this deadly disease. Some of the proposed solutions are AI based and some are non-AI based. Following are the analyzed and studied related works similar to our research project.

In [6] Er. Zainab Pirania.et.al. discussed how the day-to-day activities of elderly people can be affected by Alzheimer's disease. They purposed to build an application that could facilitate the regular day-to-day existence of an individual influenced by Alzheimer's Disease with the application that gives different functionalities such as location tracking of patient, quizzes, medicine-timing warnings, etc. Through this application individuals experiencing Alzheimer's Disease have an assistance as free as could be expected under the circumstances. This application is patient oriented and not caretaker oriented.

Coppola.et.al. in [7] discussed their work about diseases like Alzheimer's and Dementia in this era are increasingly affecting the older generation and how caregivers are researching new solutions to mediate the crisis. They discussed in their research that one of the modern solutions is the use of mobile devices to stimulate the cognition of older generation or patients suffering from AD. The use of memory for solving problems and games help stimulate the brain and reduce symptoms of AD and brain and computer simulated games can help patients as well as caregivers and doctors. The application in this research paper includes voice inputs, games and quizzes for dementia patients, alerts for the medicines, music, and memory apps to ordinarily unresponsive dementia patients to be enriched with life and its activities.

Research conducted by Shooq Alharbi.et.al. in [8] proposes a system to help an important category of the society which is the Alzheimer's patients. This system gives them the ability to have small memory, which can help them to remember all tasks to live, which may contribute to the prevention of progression of the disease rapidly; the technology provides the best care because it is not susceptible to forgetfulness or damage. The design of the proposed system presented in this study includes reminding them of their families through memories and family photos and information, and the dates of their medications, the amount of medicine and hospital appointments. An AI based application named as "Timeless" developed by Emma young [9] is a simple, caregiver assisted modern IOS based mobile application for Alzheimer's patients which enables them to stay updated with their events, stay connected and engaged with friends and family, and aids in recognizing people through automatic facial recognition technology.

Work done by Z. A. Habash, W. Hussain.et.al concerning Alzheimer's disease talk about an Android Application namely, "Alzheimer's Patient Medical Care System (APMS)". The application provides the doctors with the facility to monitor their patients specially with regards to their medication. APMS also sends notification alerts to the patients to take their medicine according to the schedule set by doctor for them. The app also enables the doctors to review and monitor the health conditions of their patients with the help of the feedback provided by the patient's caregiver and can change medication schedule and suggest patient further treatments based on feedback. [10]

Irene- Maria Tabakis, Minas Dasygenis and Magda Tsolaki in [11] proposed and designed a complete system that consists of a wearable and an Android application to monitor, trace, and analyze Alzheimer's disease patient's location, heart rate and sleep patterns and organized them in a way that can help caregivers understand the needs of the patient. The Arduino based wearable contains a microcontroller, GPRS module, and motion tracking device to monitor sleep patterns and location of the patient. Via the application interface the caregiver can know about the Alzheimer disease, get alerts about frequency and amount of patient's treatment, can keep daily records related to

the patient and can keep the patient's history for his/her visits to the doctor.

Ongoing research presented in [12] by C. Giraldo, S. Helal, and W. Mann was focused on creating a presenting the architecture of a Mobile Patient Care-Giving Assistant (mPCA), which aimed to improve cognitive supervision of home-bound AD patients. This mPCA assistant is an indoor ultrasonic tracking system which is based on a smart phone (capable of interacting with different sensors within a smart space), and a home computer (serving as a server) connected to local sensors such as monitors, speakers and ultrasonic location tracking system.

EA Reminder by H. Abu-dalbouh, et al., is an Android based mobile application focusing the memory problems faced by the two main categories of society which are elderly people and Alzheimer's patients. The application assists the suffering ones by providing them the facility of reminders about medication, meals, friends and relatives, and important events. The application's architecture is built while considering three actors: Caregiver, Elderly people, and Alzheimer's patients. The caregiver has the authority to manage multiple patients and their drug lists. The application is responsible for managing all the data for these users and sending them alerts as per schedule [13].

There is another system by D. I. Tapia and J. M. Corchado, ALZ-MAS [14], is an AI-based multi-agent system aimed at enhancing the assistance and health care for Alzheimer patients. It takes advantage of the cooperation among autonomous agents and the use of context-aware technologies providing a ubiquitous, non-invasive, high-level interaction among users, system, and environment. The main user interface of ALZ-MAS
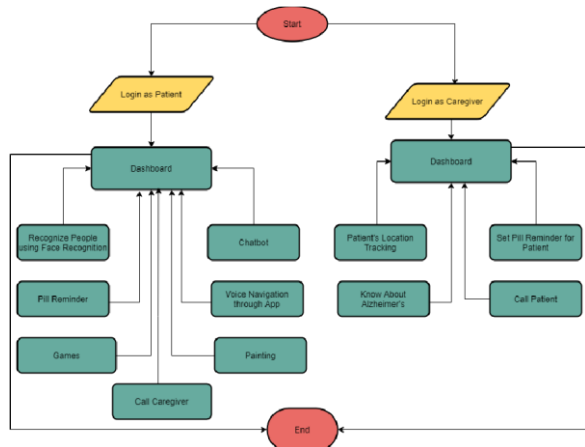

Fig. 1.   Workflow of Application

displays basic information about nurses and patients (name, tasks that must be accomplished, schedule, location inside the residence, etc.) and the building (outside temperature, specific room temperature, lights status, etc.). The information is provided to all nurses and doctors in a user-friendly format using mobile devices to see their corresponding tasks.

Ammara Farooq.et.al. presented a paper on "Artificial intelligence based smart Diagnosis of Alzheimer's Disease and

Mild Cognitive Impairment" [15] in which they presented a fast and reliable artificial intelligence-based solution for diagnosing brain patterns from MRI images. Specifically, it detected Alzheimer's disease and its probable early stages. The experiments were performed on standard ADNI data in three phases.

We all have been using native system calendars on our phones since ages, all of them are mostly hand-handled. In 2018, Ferland, Libby, Li, Ziwei, Sukhani.et.al. presented research in workshop for people suffering with memory loss problems [16]. They presented the difficulty to handle important events on calendar manually, so the need for a voice input-based calendar was increasing day by day. The authors of this paper have developed an AI based personal assistant for specialized calendar handling and tasks scheduling. The sole idea behind this application is to enable people to interact with the assistant by using just the voice. However, the application still needs modifications such as resolving conflicts between two or more events, understanding, and interpreting the speech command given by the user, etc.

To assist people with Mild Cognitive Impairment (MCI) Y. Tsai and W. Lin designed an intelligent cognition assistant (iCA) in their research using latest AI technologies, accompanied with open-source software tools and cloud services. The three major functionalities provided by the system are: cognitive rehabilitation and evaluation, companion, and day-to-day activities assistance. [17]

The research above shows the existence of several systems and applications designed for the assistance of Alzheimer's patients. Some were providing an AI based solution while the others were non-AI based, a few systems were providing complex hardware support too. After studying each one of them, we realized that there is a gap and lack of support for the caregivers of the patients. Most of the applications are only patient based (i.e., contains only the patient interface), whereas caregivers of those patients need to be helped too with the power of digitization and AI. Keeping this fallback in mind, we developed our android based project to contain two modules simultaneously. One for the assistance of Alzheimer's patients, and the other for helping the caregivers, using AI as well as non-AI based features.

III. MODULE DESIGN AND ARCHITECTURE

The figure below shows the workflow diagram for the project.

A. Modules of Application

In our developed application for the assistance of Alzheimer's patients, we have two modules.

1) Caregiver Module. 2) Patient Module.

The features and details for both modules are discussed in this section.

1) Caregiver Module

The caregiver module of the application consists of different features that can be helpful in assisting an Alzheimer's disease patient.

The features in the caregiver module are as follows:
- Setting pill reminders for patient.
- Patient's location tracking.
- Call the patient.
- Voice navigation through app.
- Know about Alzheimer's (Alzheimer's disease guide).

2) Patient Module

The patient module of the application is used by the patient, and it contains the following features:
- Face Recognition.
- Chatbot.
- Check pill reminders and receive alerts.
- Call the caregiver.
- Painting.
- Memory enhancing games.
- Voice navigation through app features.

IV. TOOLS AND TECHIQUES

A. Android Studio

This is the most widely used Integrated Development Environment (IDE) built by JetBrains's IntelliJ IDEA for Android application development. For the development of this project, we used Java12 as the development language and XML for designing purpose, using Android Studio IDE.

B. Material Design

A rich library with comprehensive guide providing lots of visually appealing and interactive designs for different platforms and devices. We used many flexible and interactive views (such as Text fields, edit texts, and buttons, etc.) by Material Design to design the interfaces of our android application.

C. SQLite Database

This is an open-source relational database, already integrated in android to help perform CRUD (Create, Retrieve, Update, Delete) operations in applications. We used this database to store the offline data of patient and caregiver login.

D. Firebase Realtime Database

To connect a patient with its caregiver independent of their geographical locations, it was required to keep all of the needed data on some cloud-hosted database. For this purpose, we used Firebase Realtime Database to store the patient's and caregiver's registration data, and the pill reminder data in JSON format.

E. Firebase Firestore

Google cloud's firebase firestore is a NOSQL, flexible, and scalable database, it keeps data in synchronization across the applications through real-time listeners. In the project, firebase firestore is used to save the location of the patient. The Realtime document for the current user (patient) is created on the basis of the patient's email and the location of that patient is saved in that document based on the email of the patient.

F. MS Azure Face API

MS Azure provides various cloud-based services, one of those is its Face API which comes under the umbrella of Cognitive services. Face API allows an application to primarily detect, identify and recognize a face based on certain attributes of perceived image. We used this API in patient module for real-time face detection and recognition of patient's loved one by clicking few pictures.

G. Dialogflow API

Dialogflow is a platform for natural language understanding. It is used to analyze the user inputs in the form of text or audio, and then it responds back either through text or with artificial(synthetic) speech.

In this project, dialogflow is used to train the model for the chatbot feature which is then integrated with another API to complete this feature.

H. Kommunicate API

Kommunicate provides the functionality to integrate the third-party API-. Through kommunicate API bots can handle all the conversation and when bots cannot understand and unable to answer, they can assign the conversation to humans. In this project Kommunicate API is used to assign conversation to the bot and provide interface for the bot, which made the chatbot feature more interactive and easily navigable.

I. Maps SDK for Android

Through Maps SDK for android, one can add google maps to the application. This API automatically handles the access to google maps servers, display of maps, maps with markers at locations, etc. In this project Maps API is used for location sharing by the patient and then the location tracking feature in the caregiver module.

V. IMPLEMENTATION

A. Caregiver Module

As mentioned earlier, AlzCure has a separate module for the caregivers of patients, where they are provided with multiple efficient and easy to use features to manage the daily life of their loved ones with ease and flexibility. Following are the implementation details of caregiver module features.

1) Sign Up and Login

To use the application, a caregiver must first register itself by going through sign up process. The activity will prompt the caregiver for various details related to himself and related to the patient.

After successful sign up, the caregiver is now able to attempt login to the application using login activity which only asks for its email and password.

2) Setting Pill Reminder

From the dashboard of application, the caregiver can set the medicine reminders for its patient using the very first option of "Set Pill Reminder" as depicted in Fig. 2. (a). The pill reminder can then be set specifically by entering a text message, date, and time for the notification to be generated at patient's device, as demonstrated in Fig. 2. (b), (c).

3) Location Tracking

The caregiver can locate the patient using this feature, provided that the patient has enabled its location tracking. The caregiver is only required to enter the patient's email address as Id and then using GPS, Firebase Firestore, and Google Maps Android SDK the location of the patient would be fetched in real-time, as shown in Fig. 2. (d).

4) Call Patient

On the dashboard of application, the caregiver has this facility of calling its associated patient without navigating through entire phone call book. This feature will fetch the mobile number of patient provided during sign up process. from firebase real-time database to dial the call. *5) Read about Alzheimer's Disease*

This feature offers a guide about Alzheimer's disease and its seven stages. This guide can help the caregiver in identifying the disease level of its loved one who is suffering from AD. This is depicted in Fig. 2. (e).

6) Voice Navigation

This feature allows the user of the application (caregiver in this case) to navigate through the application by giving voice commands. Observe the working in Fig. 2. (f).

B. Patient Module

This is the second independent module of AlzCure application, aimed to facilitate the Alzheimer's disease patients. This module offers various AI and non-AI based features to assist the patient with its daily life activities, with a focus on user interactivity and ease of use. Following is the demonstration of its features.

1) Sign Up and Login

Likewise, caregiver, the patient must also register or sign up into the application prior to start using it. This sign-up process is a one-time process and can also be carried out by caregiver of the patient on his/her behalf. This activity also asks the patient for various data fields about himself/herself and the caregiver.

After successful login the patient can continue using the application via simple login process.

2) Face Recognition

This is an Artificially intelligent feature of patient module, aimed to help the patient to differentiate among known and unknown people. For proper detection, identification, and recognition of a face the user of the application (patient in this case) is required to provide a few pictures of a person. This will register the person's face in the repository and a machine learning model will be trained with various techniques namely, Support Vector Classifier (SVC), Neural Network (NN), Decision Tree (DT), and K-Nearest Neighbors (KNN). After registering a face, the patient will be able to recognize it on runtime by clicking a single picture. On the backend, the model will calculate the probabilistic results of all the techniques mentioned above, and the result of the technique having greatest confidence will be returned. The working is demonstrated in Fig. 3. (a).

3) Chatbot

This is another AI-powered feature of patient interface, built to assist the patient with his/her queries. The chatbot is trained to answer queries regarding Alzheimer's, telling motivational quotes, telling jokes, suggesting games for fun, etc. It's demonstrated in Fig. 3. (b).

4) Pill Reminders

This activity will contain all the reminders for the patient, set by its caregiver. A notification will be generated on patient's device at the time of reminder/alert. This is shown in Fig. 3. (c).

5) Call Caregiver

Through this feature the patient can directly call its caregiver without any trouble to go through the entire call book of the phone. This feature will fetch the caregiver's contact number on runtime from firebase to dial the call.

6) Painting

This is included in the patient module as part of fun activities to entertain the patient. This feature will help the patient to keep its creative memory in action by making drawings with different colors, as shown in Fig. 3. (d).

7) Gaming

It is researched that memory-based games and exercises can boost a patient's memory ultimately benefiting the patient to fight against the disease. The patient can play various memory-based games using this feature from the dashboard. The provided games are Match the pictures, Crossword Puzzle, Match the Words, and Daily Sudoku. Refer to Fig. 3. (e) for demonstration.
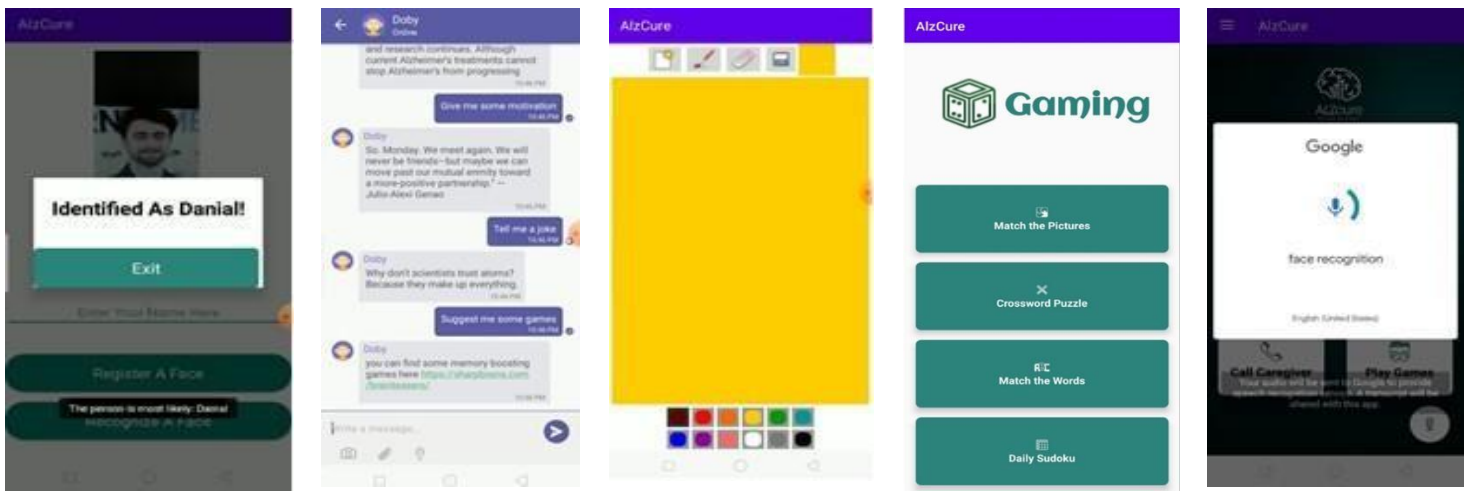
8) Voice Navigation

This feature allows the user of the application (patient in this case) to navigate through the application by giving voice commands. Observe the working in Fig. 3. (f).
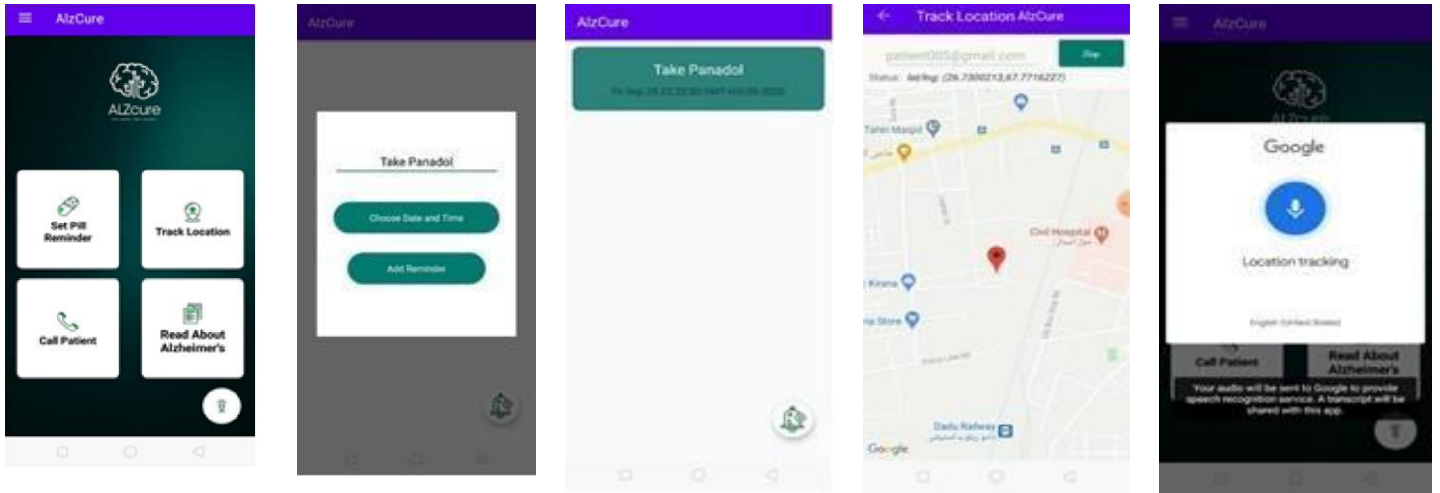
(a)　　　　　　　　(b)　　　　　　　　(c)　　　　　　　　(d)　　　　　　　　(e)

Fig. 2.　　　Implementation of Caregiver Module

(f)　　　　　　　　*(g)*　　　　　　　　*(h)*　　　　　　　　*(i)*　　　　　　　　*(j)*

Fig. 3.　　　Implementation of Patient Module

VI. TESTING

This section illustrates the tests conducted on the application.

A. *Robo Testing*

Robo testing is a testing technique offered by Google Firebase. It focuses on testing the User Interface (UI) of

the application by making a robot (simulated user) to use the application as a normal conventional user, and provides multiple graphs, screenshots, and video-based results.

Following are some graphs generated from robo testing:
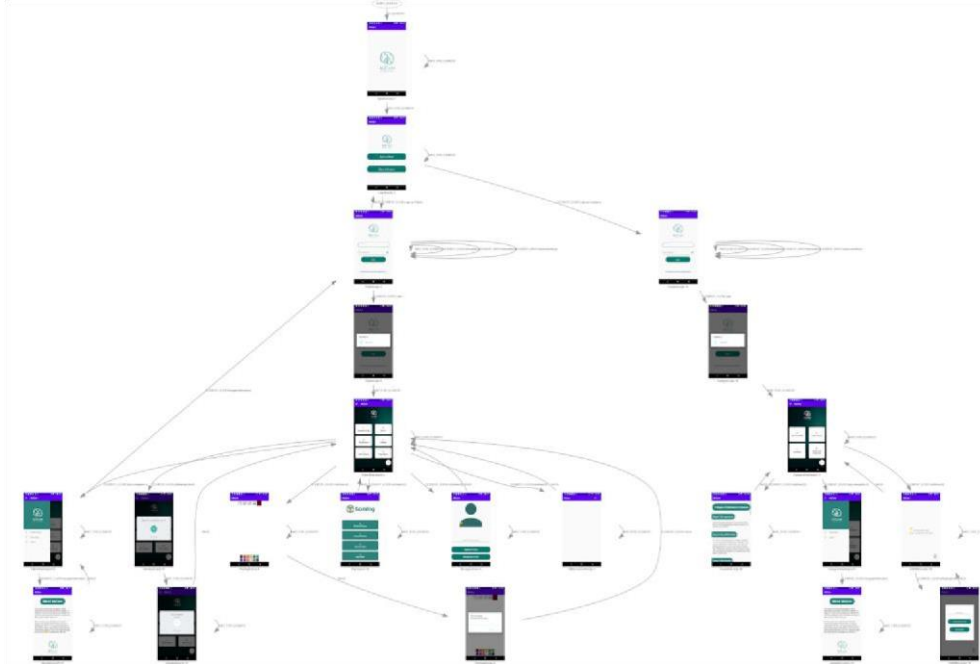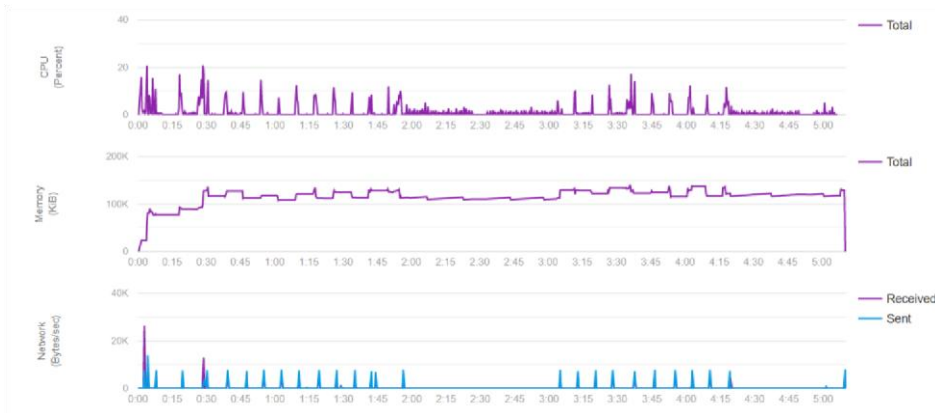

Fig. 4 (a). Crawl Graph

Fig. 4 (b). Performance Graphs

B. Crashlytics

Crashlytics is an API by firebase to report runtime crashes of applications, while also providing meaningful insights into the issues which are causing the crashes. It also tells us the quantity of application users affected by the crash. We carried out this test on AlzCure, and the results are depicted in Fig. 5 (a), and Fig. 5 (b).
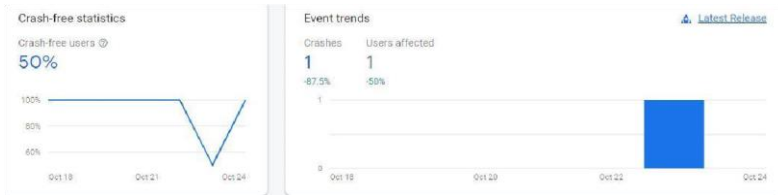

Fig. 5 (a).   Crashlytics Dashboard and Statistics

Fig. 5 (b). Crashlytics Reported Issues

VII. CONCLUSION

This paper explains the idea and implementation of an AI based android application named as AlzCure developed to aid elderly people dealing with Alzheimer's disease and their caregivers. The application will not only be helping the patients with daily life tasks but will also be very useful for their family members who want to keep vigilant eye on their loved ones' activities facing Alzheimer's disease. The app is built to target Android operating system for now and is equipped with some AI features as well as few non-AI features to serve the purpose on ground levels. The features are designed to help them with day-to-day common activities like communicating with each other, tracking the location of patient, reminding them of their medicines, engaging them with some memory boosting games, helping them in recognizing people, etc. We hope this idea can bring change and easiness in the targeted audience life and help them combat this deadly disease.

IX. FUTURE WORK

Alongside the existing features of the application discussed in this paper, the app can be further extended with some more powerful and intelligent features such as, the facial recognition feature can be extended with the help of images already present on patient's mobile phone gallery. Other than that, patient can be suggested with music options based on his/her mood

detection as an addition to their fun activities. Moreover, the application could be made capable of keeping a patient's medical history recorded which may help him/her in consulting a different doctor in the times of need, as well as it will be of use in case the patient's caregiver has to be changed. Extensively, the app can be built to target more platforms like iOS and web.

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