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Alzheimer assistant: a mobile application using Machine Learning

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Abstract: Alzheimer's disease is a condition characterized by a progressive symptomatic decline over several years. It causes memory loss and affects daily task performance. Memory loss leads to challenges including remembering people's names, faces, places, or other information. In Saudi Arabia, the prevalence rate for Alzheimer's disease is increasing and, accordingly, warrants attention and address. Thus, the objective of this work is to support Alzheimer's patients with mild (early-stage) and moderate (middle-stage) conditions to remain involved in society and continue to live independently. We propose a mobile application which utilizes facial recognition technology and location detection using Google maps. The application aims to improve daily communication, enhancing their ability to perform daily tasks by the embedding of a notification feature. It has location detection to maintain the safety of Alzheimer's patients, and help prevent them from getting lost by tracking their location. Results have shown that the application has benefited those living with the symptoms of Alzheimer's, and significantly support their daily lives. Therefore, this work highlights the importance of employing artificial intelligence (AI)-based features, i.e., face recognition in this specific case when developing healthcare applications which can have a significant impact on the community.

Keywords: Machine Learning, Mobile Application, Alzheimer's disease, face recognition.

1. Introduction

Alzheimer's disease is increasingly becoming an issue of public health concern, given that age is a known risk factor and, accordingly, prevalence rates are likely to rise with more people developing this condition in an ageing population. It is estimated that approximately 130,000 Saudi Arabians are living with Alzheimer's, and it is predicted that by 2050, this figure will double (Saudi Alzheimer's Disease Association, 2019). Some specialists describe it as the century disease as it occurs in older people. People with Alzheimer's experience challenges in accomplishing simple daily tasks, such as brushing their teeth or eating meals. They may even lose their sense of time and space, thus making it easy for them to get lost outside of the home. In addition, they may forget recent events or the names of some of the people close to them. Hence, not only do these challenges pose a difficulty for the patient him or herself, but also for the patient's caregiver.

Alzheimer's disease is an advanced chronic disease of the brain that begins with memory impairment and develops into concentration and attention, planning, thinking, language and cognition disorders (Cohen et al., 2019; Knopman, Petersen and Jack, 2019). Therefore, for the purposes of this application, we sought to assist Alzheimer's patients and their families in making their

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lives easier by creating a mobile application that facilitates machine learning via face recognition techniques. Face recognition currently has several real life applications, ranging from public to personal security. It is used for identity verification or in localizing and tracking a possible suspect in a crowd. Thus, our application acts as a smart assistant allowing Alzheimer's patients to recognize their family members' pictures and names, as well as establishing the nature of their relationship with them. In order to eliminate the possibility of incidents of getting lost outside the home occurring, we proposed developing a bracelet that can help locate the patient and send updates to the caregiver.

Alzheimer's patients suffer from memory loss, resulting in difficulty remembering people's names, faces, or some information about them, thus placing them in potentially embarrassing situations. They are also unable to remember some important tasks or appointments that they have to attend in their daily lives. Some patients leave their house and subsequently get lost, as they are unable to remember the way home. Consequently, the patient's family and friends may have to spend long periods of time searching for them without having any notion of their whereabouts. Thus, this application proposes the development of a smartphone application which has the capacity to identify people, by referring to the album on the application which has classified each person by their face, along with displaying information about the patient's relationship with that person. This motivates Alzheimer's patients to be more confident, thus improving their ability to continue to engage socially. This is aided by a feature in the application which sends notifications to remind patients of what they have to do on any specific day. It is also accompanied by a tracking bracelet which enables the patient's family to establish their exact location and will assist in finding them, in the event of patients losing their way.

The main purpose of this research is to assist Alzheimer's patients in Saudi Arabia in the early and middle stages of this condition by making it easier for them to remain involved in society than was previously the case, sending daily tasks reminders, providing a tracking mechanism, and increasing their confidence to remember each member of their family. In addition, the families do not need to worry as the application can help to monitor and support the Alzheimer's patients' movements. The main objective of the proposed application is to enhance the quality of Alzheimer patients' lives so as to make it easier for them and those around them to live with the condition. It also sets out how to prevent the onset of isolation or loneliness by using machine learning face recognition technology for communicating and remembering people's faces around them. Not only will these features improve the daily lives of those with Alzheimer's, but also of their caregivers, in multiple different ways. They include the following:

- Improving daily communication with people living around them;
- Reminding them of important daily tasks that have to be carried out;
- Detecting the location of those with Alzheimer's so as to maintain their safety and prevent them from getting lost in public places;
- Aiding and facilitating families or caregivers of people with Alzheimer's to maintain contact with them.

The proposed application has the scope to potentially assist every Alzheimer's patient with a mild-moderate condition, and their caregivers, by developing an application which contains features such as facial recognition-using machine learning. This helps Alzheimer patients to remember people around them, along with providing a GPS tracking wearable device to assist the caregivers to establish the patient's location.

The remainder of this paper is structured as follows. Section 2 provides a comprehensive summary of the literature, including a general overview of key features in the application developed, which include GPS (used for tracking), face recognition, and machine learning. This is followed by a summary of related work which includes similar applications, a descriptive outline of them, and undertaking a comparison with our proposed application. Section 3 describes the methodology in detail, which includes a description of the design, implementation, and testing phases. Section 4 sets out the results obtained and subsequent discussion of the findings. Finally, in Section 5, a conclusion is drawn, and recommendations are made regarding future work.

2. Literature review

Dementia is an umbrella term used to describe a range of conditions, typically associated with impairment in memory, speech, cognition, and problem-solving abilities. This results in reduced capacity to carry out daily functions. Alzheimer's disease is the most common cause of dementia, with prevalence rates rising in recent years (Cohen et al., 2019; Knopman, Petersen and Jack, 2019; Malek-Ahmadi et al., 2019; Slot et al., 2019). Increasingly, technological advancements have been found to make a significant impact on those living with Alzheimer's, especially at the initial onset of illness. Drawing on algorithms and relying upon smart devices can help to address some of the challenges Alzheimer's patients typically experience, as well as their caregivers involved in a supportive capacity.

2.1. Global Positioning System (GPS)

Originally developed by the United States Department of Defense (USDOD), using signals received from satellites, the Global Positioning System (GPS) is now a widely used international navigation tool (Jablonski, 2012). The system consists of a minimum of 24 satellites (Jr. et al., 2012; Parkinson et al., 2012). It is a highly versatile and cost-effective tool, in that no subscription or setup costs are associated with its usage, and it operates 24 hours per day, throughout all parts of the globe, and under all kinds of weather conditions. While the satellites were initially launched into space by the USDOD solely for military purposes, their scope was subsequently extended in the 1980s to include the general population (Mai, 2017). GPS has the ability to locate precise longitude and latitude coordinates at ground level. This is carried out by calculating and determining the current location, based on time differences between the signals being emitted from the orbit of 30 USDOD managed satellites, as well those operated by a number of commercial enterprises (Saigusa, 2010). GPS has also been found to be an effective tool in resolving outdoor localization difficulties, as its signals typically require an uninterrupted receiver-satellite line-of-sight (LOS) pathway (Hossain, 2019).

2.2. Face recognition

Automatic face recognition systems comprise one of the key developments shaping computer vision, machine learning, and biometrics (Zhao et al., 2003). Their influence has primarily been attributed to their broad application potential, coupled with being the subject of significant attention within the research world, in recent times. Essentially, as a technology, face recognition systems carry out two core functions, namely, a person verification process based on an image or video material stored on a database, and the subsequent identification of that individual (Rekha and Ramaprasad, 2017; Pathak and Khandelwal, 2019). In recent years, they have been employed as an access control measure within security systems. Consequently, these systems have been the focus of multiple studies, particularly given their wide application base.

2.3. Machine learning

The concept of machine learning was initially advanced by the Canadian psychologist, Donald Hebb (1949), and largely derived from examining the way in which brain nerve cells interact and communicate with one another through excited neuronal activity (Hebb, 1949). Since that time, machine learning models have gained popularity, largely due to their problem-solving capability. More recently, they have contributed to a number of extremely important technological developments.

Within the machine learning field, one of the key objectives is to construct computing systems that have the ability to automatically learn and advance following exposure to experience (Jordan and Mitchell, 2015). As a result, AI machine learning has evolved to become software developers' first choice option when working in the areas of face recognition, natural language processing, computer vision, robot control, and a wide range of other applications (Jordan and

Mitchell, 2015; Alpaydin, 2020). Therefore, machine learning is applied to solve all the key steps involved in the facial recognition process. This involves taking a number of factors into account, for example, that faces have a defined structure and symmetry and do not comprise a random series of pixel images. These systems have the ability to conduct an analysis of sample facial images stored on databases, while also recording their unique pattern features and verifying these against specific stored images (Alpaydin, 2020).

A face recognition grand challenge was first introduced in 2006 in order to establish whether face recognition systems, based on machine learning models, were achieving their stated goals. As part of this process, their capability was assessed in a number of areas, for example, 3D face scanning, iris images, and high-resolution face images. Results indicate that newly developed algorithms have demonstrated a hundredfold increase in accuracy levels, as compared to those first advanced in 1995, and a tenfold rise from 2002 onward. In addition, a number of these algorithms were found to be superior in terms of performance, as compared to human face recognition and, interestingly, this skill transferred to the identification of identical twins (Webmaster of National Institute of Standards and Technology, 2016). Other notable developments include: the machine learning algorithm Google X Lab, first introduced in 2012, which can autonomously browse and source cat videos (Jason and Kim-Kwang, 2015); and DeepFace, a system created by Facebook in 2014, which comprises an algorithm that can identify and verify human faces through digital imagery, and was found to demonstrate equal accuracy levels when compared to human capability (Regalado, 2014).

2.4. Related Work

In this section, we have identified several applications that have been developed to assist Alzheimer’s patients and we undertook a comparative analysis between these applications and ours. The results to emerge from this comparison are presented in Table 1. We have concluded that our application differs from these, in that it provides specific features to assist Alzheimer’s patients.

2.4.1. Timeless

Timeless (*Timeless*, 2019) is an application which was the first of its kind to specifically focus on Alzheimer's patients. This application is a simple, easy to use application for older people. It helps them to remember events, stay connected and engage with friends and family, and to recognize people. Similarly, it enables friends and family to remain connected with Alzheimer's patients. It is currently available for download on iOS iPhone and iPad devices in a number of countries, including the United States, Hong Kong, Singapore, Canada, and Japan. Unfortunately, it is not available in Saudi Arabia. Timeless application uses face recognition based on Artificial Intelligence to help patients recognize their family and friends.

The main features in Timeless:

- Rapid and secure login to the app through the use of facial ID and touch ID;
- Daily overview provided, including date, weather, details of the next daily activity event and appointments, and so on;
- Keeping the patients updated with videos and photos sent by family and friends, and generally facilitating ease of communication between all parties;
- Saving the photo sent by friends and family members in a dedicated folder for each person;
- Identifying people by taking a photo of them;
- It has three interfaces for the patient, caregivers who manage the app, and friends and family;
- Compatible with the iOS devices iPhone and iPad.

2.4.2. It's done

It's done *(It's do*ne, 2019) is a smartphone application specifically developed to support users to carry out their daily activities. It removes all the difficulties typically associated with remembering to do all the necessary tasks, by offering an alternative where users are prompted by this application, which can be easily downloaded to their phone or another device.

The main features in It's done:

- Manage your tasks;
- Remember your tasks;
- Track your tasks.

2.4.3. MindMate

The MindMate App is a mobile application *(MindMat*e, 2019) that can guide its users towards a multifaceted, holistic lifestyle change that may help curtail some of the effects of cognitive decline.

The main features in MindMate:

- Games and other mentally invigorating tasks;
- Workout with free personal trainer for each patient via the Internet;
- Facility to add daily tasks, notes, and even a 'to do' list;
- Facility to add pictures;
- Facility to add patient information.

2.4.4. Remember Me

Remember me *(Remember* me, 2019) is an interactive mobile application aimed at Alzheimer's family members. It is a household manager which aims to share tasks and remove the burden of caring for a dependent person alone.

The main features in Remember Me:

- Scheduling events or activities;
- Being updated in relation to all events that are occurring;
- Alerting everyone in the family when a new event is created in patient memories;
- Inserting and updating the patient data.

2.4.5. Alzheimer's Helper

Alzheimer's Helper is a mobile application that offers an alternative to more traditional paper-based systems, by assisting in the recording and storage of personal information on family and friends, for example, their contact details *(Alzheimer's Helper*, 2019).

The main features in Alzheimer's Helper:

- Facility to add a picture;
- Facility to add patient information.

2.4.6. AngelSense

AngelSense *(AngelSen*se, 2019) was specifically designed to aid those living with dementia, Alzheimer's, and other cognitive impairments by safeguarding them from potential abuse or wandering off. An evaluation of this application has revealed positive outcomes in terms of reduced anxiety, with increased confidence and a sense of greater autonomy. Furthermore, it reassures caregivers, in that they know that this software has the capacity to locate, protect, and support their loved ones, regardless of their geographical location.

The main features in AngelSense are:

- Daily timeline at a glance: locations, routes, and transit speed;
- Wide cellular coverage;
- Multiple forms of GPS wearables;
- Unknown place alert;
- Multiple interfaces for caregivers;
- Two-way voice auto pickup speakerphone.

2.4.7. Our Proposed Solution: Alzheimer's Assistant

Our application, known as the Alzheimer's Assistant application, helps patients in Saudi Arabia to remain more independent and to assist them in their daily lives. This is achieved by sending reminders of daily tasks, identifying people using cameras, and incorporating a tracking bracelet which enables patients and their families to know their exact location, in the event of the patient getting lost. The proposed application will incorporate both face recognition and GPS bracelet for tracking purposes. We conducted a comparative analysis among the related work and the proposed application as shown in Table 1.

The main features in Alzheimer's Assistant:

- Daily overview including date, reminders for daily tasks, and prompts with next events in the day;
- Saving a photo of each person in a dedicated folder;
- Recognizing people by steering the camera on them so as to identify them;
- Two interfaces for the patient and caregiver;
- Bracelet which provides real-time location.

Table 1. Comparative analysis of applications

Applications	**Face recognition**	**Task reminder**	**Multiple interface**	**Adding pictures**	**Arabic language**	**Alert notification**	**GPS tracking device**
Timeless *(Timeless*, 2019)	✓	✓	✓	✓			
It's done *(It's done*, 2019)		✓					
MindMate *(MindMate*, 2019)		✓				✓	
Remember Me *(Remember* me, 2019)		✓				✓	
Alzheimer's Helper *(Alzheimer's Helper*, 2019)				✓			
AngelSense *(AngleSense*, 2019)			✓			✓	✓
Alzheimer's Assistant	✓	✓	✓	✓	✓	✓	✓

Based on the above comparison between the related work and the proposed application, there are some differences between them. The proposed application incorporates both tracking and face recognition to help and support Alzheimer's people in Saudi Arabia. It supports the Arabic language, while other solutions are mainly in English.

3. The proposed application

The methodology for this application has been specifically designed to achieve the application objective. Therefore, the phases involved are data collection, application design including the interface and the database, implementation and testing. Each phase is described below.

3.1. Data collection

For the purposes of this study, an online questionnaire was designed and disseminated to gather data from the caregivers of those living with Alzheimer's, who are the primary target audience for this application. The questionnaire specifically sought to compile data on technology as an aid for Alzheimer's patients and family members. The survey was developed using Google Forms (Google Forms: Online Form Builder for Business | G Suite, 2019), and was subsequently disseminated to a wide geographical area in Saudi Arabia using group messages, with the ultimate aim of reaching a large caregiver cohort. This sixteen-item questionnaire was sub-divided into four main sections.

We also interviewed a specialist in neurology at a mental health hospital in Jeddah, who helped us to determine patient needs from a medical perspective. The interview format devised comprised ten questions, which elicited information on patient abilities, as well as identifying what technology might have to offer to both patients and their families.

3.1.1. Functional requirements

The functional requirements set out the tasks a system should be capable of performing (Pressman and Maxim, 2015). Essentially, they outline how a system should perform, in particular circumstances (Ian, 2016):

- The application should display a list of related pictures, along with background information on their relationship to the patient;
- The application should remind and notify the patient of important tasks that need to be carried out;
- The application should notify the patient's caregiver when a signal received from the tracking bracelet indicates that the patient has crossed a predefined safe zone.

3.1.2. Non-functional requirements

Non-functional requirements specify the criteria through which the system will be appraised, coupled with the limitations associated with its performance (Pressman and Maxim, 2015; Ian, 2016). Key non-functional requirements include:

- **Usability**: The application is easy to use and learn for beginners;
- **Accessibility**: The application is easy to navigate, and it provides menus on each page to help the users access the sections they need easily;
- **Performance**: The application has a fast response time of approximately one to two seconds when the users are navigating it.

3.1.3. The architecture

The architecture shows the correspondence between the requirements and the constructed system (Hasselbring, 2018). Thus, Figure 1 presents the architecture of the proposed application. The architecture has two different parts for the patient and the caregiver. From the patient perspective, the application has the user interface components for capturing the photo; add the photo and comparison of photo. The photos are kept in a central database that can be retrieved by other components. From the caregiver perspective, the application has set reminder, add photo, comparison of pictures and define and view the location.

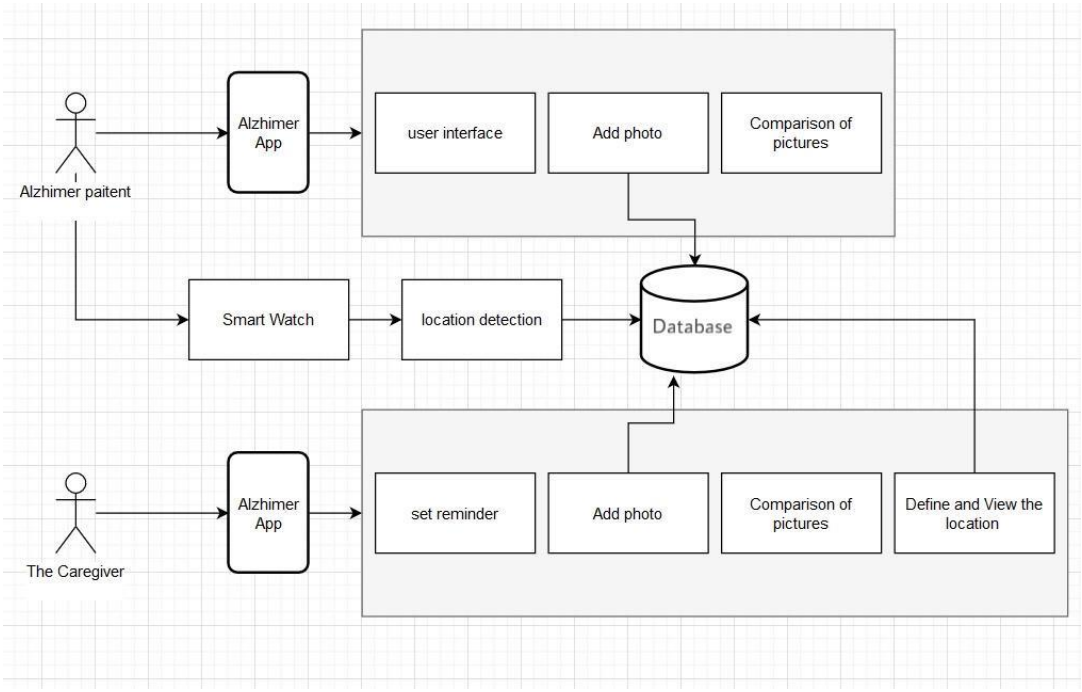

Figure 1. The architecture of the proposed application

3.2. Application design

The design phase supports the process by drawing on the requirements specified in the analysis phase and capturing them in an architecture chart. This graphical representation sets out the components required, along with the way in which they operate and how they interface with one another. In addition, this phase assists in resolving how to design the most effective solution, aided through the development of prototypes (Design Phase - ZMQ Development, 2019). Thus, the overall goal of the design phase is to facilitate the construction of an interface, which enables the systems and its various functions to operate effectively (Maryland, 2009).

Within a software development context, a prototype describes an early sample or preliminary model, which is subsequently used to inform the creation of a new model or an updated version of an existing one. This design process conveys multiple benefits, most notably, acquiring important feedback from potential end users and key stakeholders prior to commencement of the application in earnest (Arnowitz, Arent and Berger, 2007).

- **Home page:** The patient and caregiver home page displays a summary of the most important events of the day, such as reminders and the latest picture sent by the patient's caregiver. The page enables them to navigate the entire application with ease.
- **Photo album page:** This page contains all the key people whose photos have been uploaded and saved to the application and they can subsequently be identified using facial recognition. Everyone has their own dedicated, named folder and all their images are contained within this folder. It appears on both the patient's and the caregiver's interface.
- **Add photo page:** This feature is available on the caregiver's interface, thus enabling the caregiver to upload a photo so as to identify the person in it and add it to the photo album in the correct folder so that the patient can view it.
- **Reminders page:** The caregiver and patient can see the reminders for each day. The caregiver can create a reminder for the patient and it can also be programmed to send a notification.
- **Location page:** This feature is only available on the caregiver's interface if the tracking bracelet is connected to the application. The caregiver can track the patient's location, and also identify if the patient has traveled outside a specified geographical area, where it then sends an alert to the caregiver.

The database design involves logical and physical design. The logical database design refers to the process of deciding how to arrange the entity attributes in a given business environment into database structures (Hoffer, Venkataraman and Topi, 2016). Having collected the data specification from users, the basic goal was to organize and structure the real-world entity for our mobile applications into a relational database. The main five entities in our application are as follows: first, the caregiver, who has been provided with higher control within the application; second, the Alzheimer's patient, who is the target user and who will gain basic benefits; third, reminders which include a list of today's tasks to be carried out; fourth, face recognition, which includes an automatically sorted album of machine learning algorithms; and, finally, tracking information will send an alert to the caregiver through a wearable GPS bracelet. A diagram illustrating the entity relationship is shown in Figure 2.

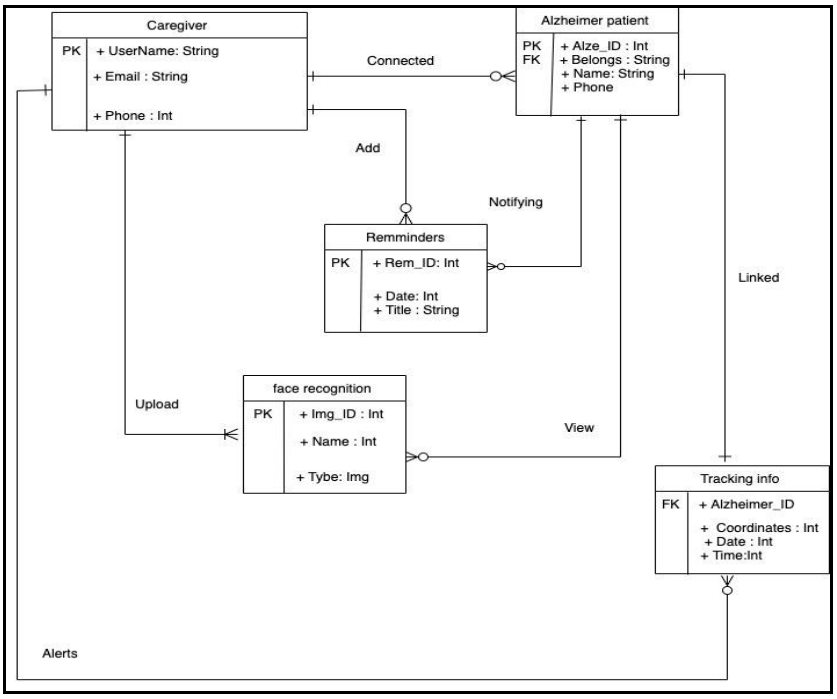

Figure 2. Diagram of the entity relationship

In terms of the physical design of the database, a table was created for each entity in the relational database. We specifically selected a firebase platform in that it uses real-time data synchronization techniques, and is both cloud-based and user accessible. In addition, we selected Cloud Firestone *(Cloud Firesto*re, 2020), as it was deemed to be the most appropriate database to adopt at the outset of a new application. Furthermore, from an infrastructural perspective, it has sufficient capability to incorporate additional powerful features in future editions, while also providing greater scalability, functionality, and performance capacity. The Cloud Firestore presents and models the data in a hierarchical structure, as it is easier to organize at scale, and store data as a collection of documents, with each collection representing a table within its document, which describes the attribute. All that is required was for us to link the fire store database with our application and import the functions that will insert or update the attributes inputs data automatically.

A user interface design sets out the visual layout in order to assist users to design and develop an application which accomplishes their goals and is also user-friendly (Shneiderman et al., 2016). The user interface design adopted for this specific system is underpinned by five core principles (Ambler, 2014). These include:

- Structure: The user interface design should be set out in a constructive manner, so that the model adopted is unambiguous, user-friendly and well-structured;
- Simplicity: The key objective is to design a system that is intuitive, using clear language, incorporating useful shortcuts, and where any unnecessary complexity is avoided;

- Visibility: User options should be clearly visible, minimalist, purely functional, and not accompanied by other superfluous detail. Therefore, effective designs are usually clear and do not overwhelm users with a multiplicity of options;
- Feedback: Feedback in relation to activities, amendments, mistakes, or exceptions to the rule, should be provided to users on an ongoing basis, using clear and concise language;
- Reuse: The reuse principle is founded on the premise that the same components should be designed to be used in different systems, thus minimizing the need to continuously recall or reconsider their usage.

3.3. Implementation

In this phase, we primarily used the Android Studio to build the application. Android Studio IDE *(Android Stud*io, 2020) was used in the programming, designing interfaces, and testing of the application. The Android studio emulator, a tool provided by Android studio, was used for the purposes of running and testing the application on virtual smartphones and smart watches. We selected the firebase platform on which to build the database. The application consists of the following pages, while the interfaces are shown in Figures 2–5 below:

- Registration pages:
  1. The first step in the registration page (sign up) requires the caregiver to add his or her name, password, phone number, email, and address,
  2. The second step in the registration page (sign in) requests the adding of an email address and password;
- Reminder pages: the caregiver and patient can see the reminders appearing for each day. The caregiver can create a reminder for the patient and request that a notification be sent;
- Location page with bracelet using simulator: the location page contains a map with the specific location, which is then connected to the bracelet;
- Add photo page: this feature is available on the caregiver's interface, enabling him or her to upload a photo from his own phone to identify the person or choose an instant image from the camera, such as selfies;
- Photo album page: this page contains all the people whose photos have been uploaded and saved onto the application, so that they can be identified using facial recognition. Everyone has their own named, dedicated folder, and all their images can be stored within the folder.

3.3.1. Android resource used in this application

In order to implement the face recognition features, we conducted an android resources investigation in order to find the suitable for our application. There are several libraries dealing with the complex process of facial recognition and this indicate that the development of these libraries are becoming demanding in the market (Dospinescu and Popa, 2016). The result of the investigation has indicated the following libraries for android resources for face recognition:

- OpenCV Face Recognizer - OpenCV (Open Source Computer Vision Library) is a free library under a BSD license which includes hundreds of computer vision algorithms;
- Rekognition - Substitute to Face.com, Rekognition can make facial detection, crawling, facial recognition and scene understanding. It can be automatically trained using images and tags just like on Facebook;
- CERT (Computer Expression Recognition Toolbox) - is a fully automated system for recognizing facial expression that operates in real time;
- FaceRect - is a powerful and free API for face detection. It finds faces (both front and profile) on the image specified by a URL or uploaded as a file and is able to find multiple faces in a single shot, the result being provided in JSON format with a bounding box for each face which is found;

- Face++ - uses the latest technology of computer vision and data mining to provide three basic services (detection, recognition and analysis). This API provides detection and Landmark analysis;
- FaceReader - is a tool that is able to automatically analyse facial expressions, giving users an objective assessment of a person's emotions;
- Realtime face recognizer - demonstrates real-time face recognition on Android. The application is based on the FaceNet. It is licensed under Apache 2.0 and available under GitHub platform.

After the comprehensive investigation and review the advantages and disadvantages of these libraries, we decided the best choice and most suitable for our application is Realtime face recognizer. It is heavily inspired by FaceNet, MediaPipem Android LibSVM and Tensorflow Android Camera Demo. The code can recognize people faces and allow adding new person using photo.

We used the Realtime face recognizer library and linked it with the database, where we built in two methods by which to add pictures of family or friends. Firstly, this was through the photo album, where the user uploads the image to the application and saves the features of the person's face, and then saves them in the album. Secondly, it operates through the front camera, where the application takes 20 pictures of the same person at slightly different angles to become familiar with the person's features, and then saves the image to the album. Having added a photo of the same person that had been previously saved, the user will automatically recognize the person and store it in his folder in the album. If the patient meets a person that he or she did not recognize, he or she can photograph them through the camera. We tested this feature by uploading pictures of seven different people, and included different photos for each of them. The system identified two of the seven people. We concluded that the accuracy level of the model is 7/2, (i.e. 28.5%). As this is very low, this is an identified limitation in how the application works.

The tracking feature, which tracks the location of the patient, did not develop in the way that we had originally expected. Initially, we decided to work on a virtual clock, and import Google maps API to our application. However, we could not connect the Google maps on the application with a virtual watch. The tracking depends on a connection being formed with the watch to the application. Due to time-related constraints, we could not source a physical smartwatch that was compatible with the application. Determining the boundaries of what is deemed to be a safe area must be individually defined within a specific, small geographical area, as opposed to limits being set on Google maps. This exercise cannot be carried out without first establishing the location of the patient and then tracking him or her. This resulted in the use of a world map only on the application, and whereby the tracking feature was not fully completed due to these obstacles arising.

3.4. Testing

The purpose of testing the proposed application is to verify if the application is functioning correctly and that it is returning the expected results. In this chapter, we will perform unit testing, integration testing, compatibility testing, and system testing. Unit testing checks the validity of each function individually, while integration testing is testing multiple components to see how they interact together when carrying out a function. Compatibility testing is applied to ensure that the application operates correctly on the devices, and, finally, system testing tests how the entire system is functioning. We conducted some tests having completed the implementation of the application, while others were undertaken during implementation. We used Samsung phones to test the application, as well as the simulations available on the Android Studio.

Additionally, we tested the accuracy of the face recognition method. We tested this feature by uploading pictures of samples of seven people, along with different photos of each of them. The system identified two of the seven people. We concluded that the accuracy of the model is 2/7 (i.e., 28.5%). As the accuracy levels are very low, this will impact on the functionality of the application.

4. Result and discussion

4.1. Data analysis

This section describes the data analysis process, as well as presenting the results of applying the proposed application. We conducted an online survey specifically to understand the needs of Alzheimer's patients and caregivers. Tables 2 and 3 below show the demographic data of caregivers and Alzheimer's patients, respectively.

Table 2. Distribution of caregiver demographic data

	Number	**%**
Distribution of caregivers by gender		
Female	143	81%
Male	34	19%
Total	177	100%
Distribution of caregivers by age group		
20 or younger	8	5%
21 – 25	20	11%
26 – 30	38	21%
31 – 35	34	19%
36 – 40	29	16%
41 – 45	17	10%
46 – 50	14	8%
51 or greater	17	10%
Total	177	100%
Distribution of caregivers by education		
High school	9	5%
Bachelor's degree	129	73%
Master's degree	14	8%
Doctorate	7	4%
Other	18	10%
Total	177	100%

Table 3. Distribution of patient demographic data

	Number	**%**
Distribution of Alzheimer's patients by gender		
Female	117	66%
Male	60	34%
Total	177	100%
Distribution of Alzheimer's patients by age group		
41- 50	6	3%

51 – 60	13	7%
61 - 70	34	19%
71 - 80	66	37%
81 - 90	45	26%
91 or greater	13	7%
Total	177	100%
Distribution of patients by stage of condition		
First	36	20%
Second	72	41%
Third	69	39%
Total	177	100%

Table 4 presents the analysis of the caregiver results. It reveals that most caregivers do not know any other friends or relatives with Alzheimer and they are unsure as to whether technology usage has a large role to play in helping people with Alzheimer's. Most of the caregivers strongly agree that if an application was developed, ideally it should be able to:

- Identify people by placing the camera on them and display their personal information;
- Send notifications to Alzheimer's patients reminding them of daily tasks;
- Incorporate a wearable tracker (tracking bracelet) which enables the patient's family to establish the patient's location.

Table 4. Analysis of caregiver responses

Questions \ Answers	**Yes %**	**Maybe %**	**No %**		
1 - Do you know if any of your relatives or friends have Alz-heimer's?	48%	-	52%		
2 - Do you think tech-nology plays a big role in helping those with Alzheimer's?	45%	49%	9%		
3 - Does the patient use phone applications?	9%	-	91%		
	Strongly effective %	**Effective %**	**Neutral %**	**Neutral Inef-fective %**	**Strongly ineffective %**
4 - How effective is the patient in using the applications?	4%	4%	14%	9%	69%
	0	**1-2**	**3-4**	**5 or more**	
5 - How many family members are living with the patient?	5%	33%	33%	29%	
	Strongly agree %	**Agree %**	**Neutral %**	**Disagree %**	**Strongly disagree %**
6 - Identify people by placing	31%	11%	26%	8%	23%

the camera on them and display their personal information					
7 - Send notifications to Alz-heimer's pati-ents reminding them of daily tasks	52%	9%	17%	8%	14%
8 - A wearable tracker (tracking bracelet) enabling the patient's family to establish the patient's location	74%	6%	10%	1%	9%

4.2. Result

The findings from this Alzheimer Assistant application indicate that it has the capacity to identify people by referring to the album that has classified each person by their face, along with displaying information on their relationship. Thus, the user interfaces for this application are shown in Figures 3, 4, 5 and 6 below.

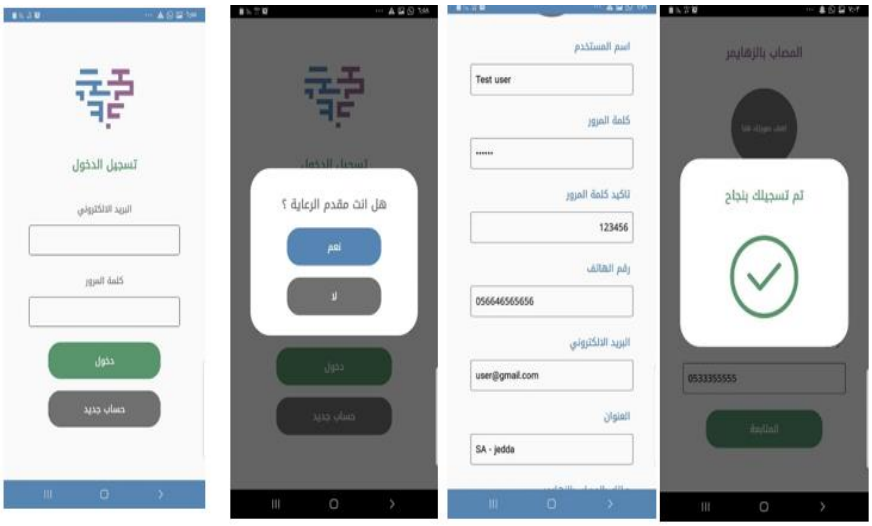

Figure 3. Registration page of caregiver

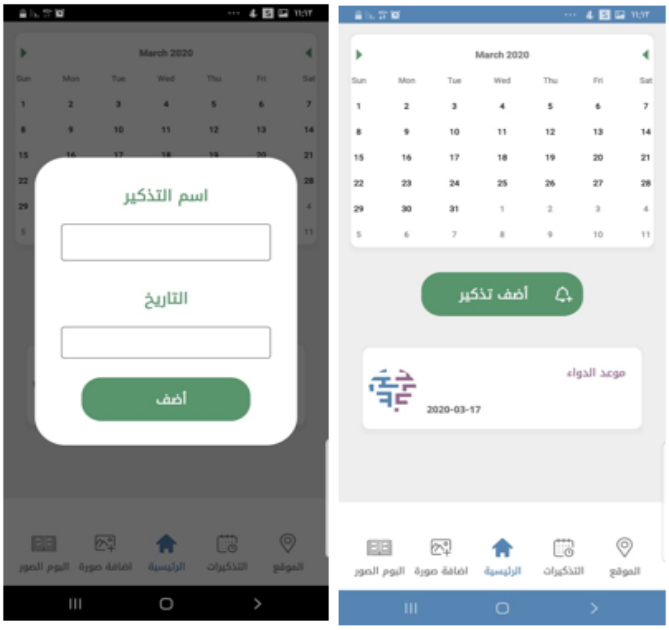

Figure 4. Reminder page

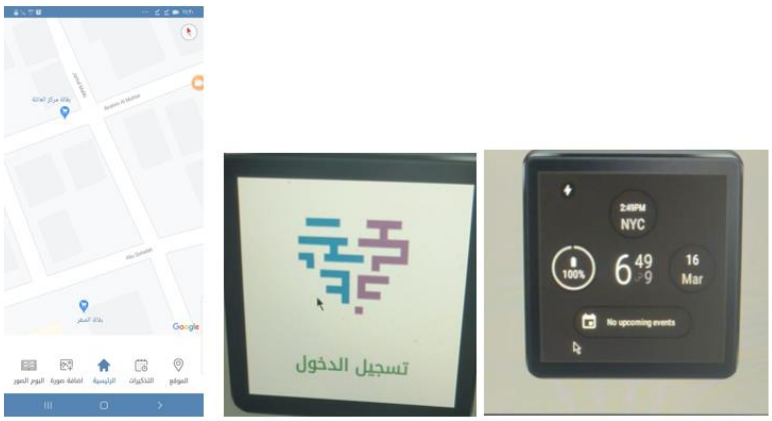

Figure 5. Location page with bracelet using simulator

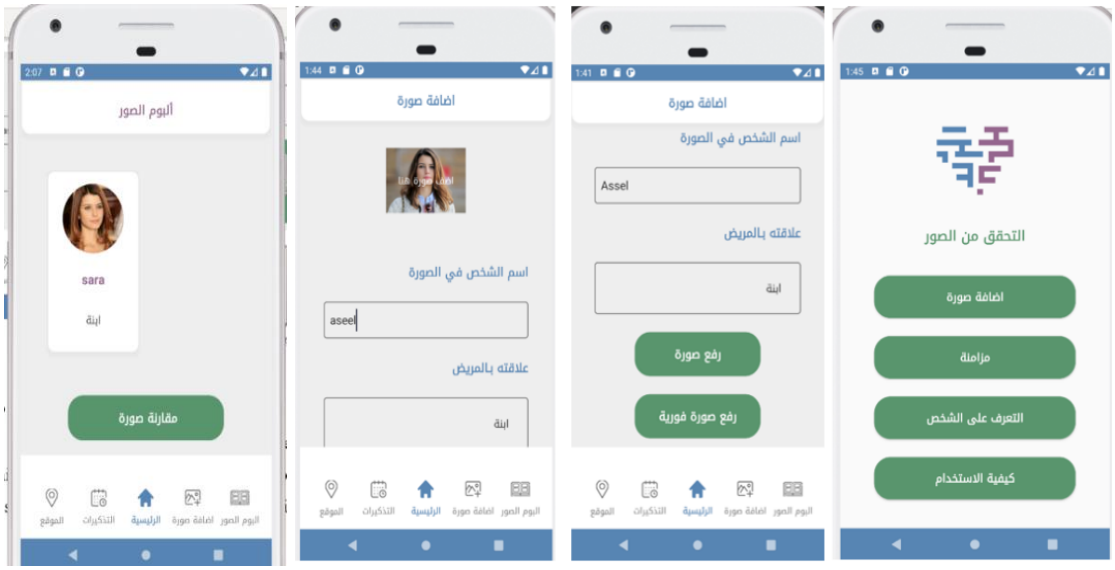

Figure 6. Add photo page

The usability of an application is an important consideration in ensuring that its users can optimize and reap the benefits associated with its usage (Whitehead, 2006). In order to gain a greater understanding of the usability of this application, an experimental use survey was conducted with one hundred users. The users are required to use this application and a series of questions were subsequently distributed to them seeking their opinions on usability-related aspects of the application. The questionnaire items, underpinned by Mclaughlin and Skinner's principles (Mcaughlin and Skinner, 2000), were used to determine the usability of the application, based on six criteria, as described in Table 5 below.

The following findings emerged from the usability testing process:

- Alzheimer Assistant has an verification system in place in order to check the accuracy of data either being entered or extracted;
- Users expressed confidence in their ability to use it and they also believed that the system itself is effective;
- Users reported being able to manage the system, especially when either inputting or extracting data;
- The application was found to be user-friendly;
- It was considered to be a fast and efficient system;

- Both the application and the information that it produces were found to be easy to understand.

Table 5. Results of usability testing

Measure	Strongly Agree	Agree	Disagree	Strongly Disagree	No Opinion
Checkability: There is a verification process in place, where any data either being entered into or extracted from the system can be checked for accuracy.	67%	25%	8%	0%	0%
Confidence: This is a good system and users feel confident in their ability to use it.	67%	17%	8%	0%	8%
Control: This system is easy to manage, especially any data that users are either inputting or extracting from it.	83%	17%	0%	0%	0%
Ease of Use: This is a user-friendly system.	58%	25%	8%	8%	0%
Speed: The system is fast and efficient.	75%	17%	0%	0%	8%
Understanding: Both the system itself and the information that it produces are easy to understand.	83%	8%	8%	0%	0%

5. Conclusion and future work

Alzheimer Assistant is an application specifically developed to assist Alzheimer's patients by: helping to identify people by referring to the album on the application that has classified each person by their face, along with displaying information regarding their relationship; sending notifications to remind patients of what they have to do on any given day; and providing them with a tracking bracelet which enables the patient's family to establish their exact location and find them, in the event of them losing their way. Hence, this application motivates Alzheimer's patients to be more confident when participating in everyday activities, thus improving their ability to engage in social events on a daily basis. This application has clearly demonstrated its capacity to provide assistance to the caregivers and families of Alzheimer's patients.

The limitation of this application is the lack of a facility for caregivers to monitor patients remotely, so that this application can be officially endorsed by the Alzheimer's Patients Association in Saudi Arabia. Thus, the development and incorporation of this additional feature into the application would enrich its functionality and it will, accordingly, be included in future editions. Future work will also focus on face recognition through the use of deep learning algorithms, given their significant impact in terms of face recognition, evidenced by their delivery of superhuman performance and high accuracy output results.

The Alzheimer Assistant application builds on the existing suite of software solutions currently available to support those with Alzheimer's to continue to participate in social activities with their family and friends. Accordingly, the necessary knowledge, skill levels and enthusiasm have been resolutely applied in the design of this application, so as to address the challenges associated with this condition in society today. In addition, this application highlights the benefits in adopting advanced technologies, most notably, face recognition to achieve this goal, given that, over the last number of years, there is growing evidence to suggest that such systems can be used in multiple settings.

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