

MINDGUARD: An AI-Powered Smart Assistant for Alzheimer's Patients using Voice and Activity Recognition

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ABSTRACT

Alzheimer disease (AD) is a progressive neurological condition, which causes loss of memory, cognitive and impairment of daily functions. Faced with the current increase in the prevalence of AD globally, it is imperative to develop assistive technologies that would help to improve patient autonomy, safety, and caregiver burden. The modern innovations in artificial intelligence (AI), Internet of Things (IoT), mobile applications, and wearable devices have made it possible to create smart help systems to support Alzheimer patients. These systems use facial recognition, activity recognition, real time monitoring and location tracking to provide independent living and enhance communication. The review offers an in-depth analysis of the state-of-the-art assistive systems and compares methodologies and technological solutions as well as outcomes. The results indicate that AI-based diagnostic systems and IoT-based monitoring tools have a great potential to alleviate the issues related to AD care. Nevertheless, the challenge of usability, scalability, data imbalance, and patient privacy are critical and still cause difficulties. The paper wraps up by providing research analysis that include the framework suggested will be the integration of the Artificial Intelligence (AI), Internet of Things (IoT), and wearable technology to deliver the real-time assistance based on a platform that is related to a smartwatch. The system applies a voice recognition model trained with Mel Frequency Cepstral Coefficients (MFCC) features and a Convolutional Neural Network (CNN) on a self-created dataset of 345 voice samples categorized into family, friends, and unknown Speakers. This makes the device to identify familiar voices and provide contextual notifications and alerts. Furthermore, IoT-based modules monitor movement and activity in real-time, facilitating caregiver- patient communication. The results of the experiment indicate that the proposed model achieves encouraging results when it comes to the identification of the speaker, which confirms that it can be utilized in the real world. In the subsequent work, the optimization of the model will be determined so that lightweight processing on the device will be possible, data balance, and scalability will be improved, and it will be ensured that the model does not violate the ethics in long- term patient monitoring and in nature with clinical validation that fits well into the lifestyle of the patients.

Keywords

Alzheimer's Disease; Assistive Technology; Facial Recognition; Activity Recognition; Machine Learning; IoT in Healthcare; Early Diagnosis; Wearable Devices

1. INTRODUCTION

One of the most complicated and debilitating neurodegenerative disorders is Alzheimer Disease (AD) the major cause of dementia in the global context. Dementia is a clinical syndrome of progressive cognitive dysfunction,

memory loss, speech difficulties and loss of capacity to engage in daily activities. AD is the most common and most studied type of dementia with almost up to 60-80 percent of cases [1][2]. It is generally recognized as a degenerative disease which progresses with time and impairs cognitive, behavioral, and functional functions to the extent of complete reliance of patients on their care givers. The manifestation of the illness may start with mild impaired memory and memory loss, followed by severe disorientation, lack of judgment, behavioral abnormalities and complete loss of autonomy [2]. The pathology of AD occurs with the development of beta-amyloid plaques and neurofibrillary tortoise made of distorted tau proteins in the brain, which cause impairment of the functions of synapses and neuronal death [3]. These pathological changes disrupt memory, communication, reasoning and social interactions over the course of time. Though the symptoms can be insidious and can go unnoticed over the years, they finally exhibit themselves in a form that causes a tremendous conflict in the personal, social, and professional life of the individual imposing considerable burden to the family and health care systems [4].

Alzheimer disease is becoming more worrisome by the day, particularly with the change in demography and the resultant increase in lifespan around the globe. It is estimated that over 82 million people will be living with dementia by 2030 and it is further projected that over 152 million people will be living with dementia by 2050 and this is with respect to the fact that every three seconds, a new case of dementia is being developed according to Alzheimer Disease International [5].

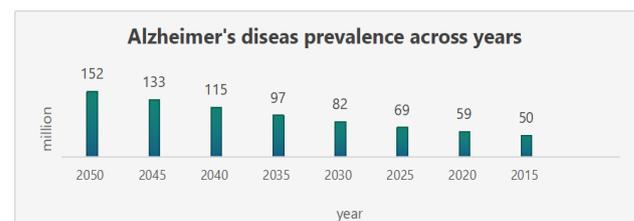


Figure 1. Alzheimer's disease prevalence (2015–2050)

The increased rates are mainly attributed to increasing age, because the older age is the one most important risk factor of the disease. Statistics show that people constitute an almost two-thirds proportion of the patients diagnosed with AD as they have a higher average age at death as compared to men, but some studies have found opposite results in terms of gender-specific prevalence [6], [7]. Dementia is already one of the most urgent issues of the public health in many countries, and its economic, medical, and social implications are growing every year.

The socioeconomic impact of Alzheimer disease is immense and complex. The United States alone is estimated to spend approximately 305 billion USD in 2020 alone on the cost of

care and treatment. This number consists of direct medical costs, long-term nursing services, hospital transfers, medicine, ambulance services, and specialist consultation [8]. In a case that indirect costs like informal home care services,

transportation of patients, loss of productivity, and any other adaptations needed to make lifestyle changes are taken into consideration, the amount of money spent would be even higher. It is estimated that by 2050, the economic burden of the Alzheimer on the United States will surpass one trillion dollars annually, in addition to financial costs, the psychological and physical burden of Alzheimer's disease is also significant to caretakers who, in many cases, experience stress, depression and diminished quality of life when dealing with the needs of others 24-hour care [10]. The AD also became especially vulnerable in the light of the COVID-19 pandemic, as the number of excess mortality cases in older patients with dementia has been reported to be disproportionately high, as well [11]. The medical risks, the social disruption and emotional strain are combined to demonstrate the magnitude of the crisis and to explain why innovative solutions are highly needed and can reduce the burden on families, medical professionals, and society in general.

To summarize, Alzheimer disease remains to be one of the most significant medical, social, and economic issues of the twenty-first century. Given the lack of a cure, there is a pressing need to develop the best technologies to help preserve the safety of patients, improve their daily operations, and help reduce the burden on caregivers. The opportunities provided by artificial intelligence are unlike any others in this respect, and mobile apps, voice technologies, chatbots, robot assistants, and camera-based monitoring systems have much potential. With the help of such innovations, it can be hoped that one day we will be able to enter a phase where the lives of patients with Alzheimer can be kept safer and more independent, and caregivers will have the resources they require to deal with the dynamics of long-term care. The one offered in this paper can be seen as a step towards this direction, which unites several AI models to form an integrated, dependable, and scalable monitoring platform that meets the peculiarities of working with Alzheimer.

2. LITERATURE REVIEW

An overview of the literature on Alzheimer's care technologies, smart assistants, machine learning in healthcare, and IoT-based health monitoring systems. In this part, previous solutions will be compared, and the need for a more efficient AI-powered solution will be noted. Dementia costs more than 560 billion per year in the country alone, and the aging population of developed and developing countries will indicate that the number of people with dementia will only continue to increase in the next 15 years. However, most patients are diagnosed in the moderate to severe stages as a result of a lack of knowledge about AD, which deprives these individuals of the most effective time frame in which to intervene. Therefore, there is a dire need to develop models of identifying Alzheimer's disease to allow for the accurate identification of AD and Mild Cognitive Impairment (MCI) at the earliest stage to develop interventions that are the most cost-effective in future treatments. Several smart assistance solutions have been proposed for patients with AD. Summarizes key systems, their technologies and performance.

Dr. Arlene Astell [17] conducted extensive research on the application of electronic tagging, smart technologies, and other assistive measures to promote communication between subjects with dementia and their caregivers. Her work

highlights the importance of technology in creating a supportive relationship, which helps patients retain constructive relationships in addition to decreasing caregiver's burden. The results, however, also make it evident that there might be some issues with the depersonalization aspect, i.e. the overdependence on technology can put the more human side of the care process at risk.

A thorough study was carried out by Dr. Bharucha [18] to examine the use of environmental sensors and cognitive assistive devices in the care of dementia. Such technologies as a range of sensors and detectors have demonstrated the possibility to compensate for patient disabilities and improve physical and mental health. A notable weakness however is that some devices take a long time to develop training before they can successfully adapt and properly identify the user's routine or navigation pattern.

Bantry and Paul [19] did electronic research. tracking with the help of GPS and a location gadget to track individuals. and wanders with dementia. It makes people with dementia feel safe and sort out such emergencies. situations promptly. The data security and privacy issues. lead to some issues. And also, The GPS tracking technique investigated by Sara Paiva. [20] proposes a cheap monitoring system of patients. It is a way that the caregivers can monitor. medical patients and information servers.

A. Balaji and Dr. S Kanithan [6] use Internet of Things (IoT) devices, sensors, smartwatch and actuators have found extensive application in monitoring the movement of patients and monitoring their health conditions. These systems have been shown to enhance the accuracy of monitoring, but these systems also present serious issues concerning the security and privacy of data. Some of the gadgets that have been suggested are used to track vital health metrics including blood pressure, calories burnt, number of steps, and exercise time. Though useful in terms of continuous health monitoring, these systems do not have the capability to track the location of the patient, which greatly restricts their use in wandering situations, a frequent complication among patients with Alzheimer.

Moreover, the assistive system has been created to detect the intention of patients and helps them in accomplishing the necessary everyday activities, especially taking medications. This system albeit with useful support in routine operation is limited to medication management and simple activity monitoring and thus as limited to its wider applicability in overall Alzheimer care. Saleh, Ali and Ezzat (2022) [15] developed a smart glass system based on face recognition to support the moderate stage AD patients. The system consists of two main parts, including software and hardware. In hardware design, the smart glass is a combination of Raspberry Pi 4, Pi camera, ultrasonic sensor and GPS. The camera and processor have the primary purpose of carrying out face recognition to recognize familiar faces. In software design it used Viola-Jones algorithm to detect faces. As a feature extraction technique, Local Binary Pattern (LBP) was used, and Support Vector Machine (SVM) and K-Nearest were used as classification methods. To enhance usability, a mobile app was developed with three main functions are medication reminders, Photo-based interaction, and patient location tracking.

W. Ben Taleb, A. S. Noun, T. Bouchrika, and O. Jemai [7] They came up with a new support system to support patients with Alzheimer's to accomplish their daily living tasks, such as taking a drink, in an independent manner. It consists mostly of two parts, an activity recognition system (ARS), which relies on analysis of video sequences, and a reinforcement learning

system, which is focused on furnishing the patient with alerts, depending on his current behavior. Their paper they have four types of actions: remain silent, unfinished action alert, forgetfulness alert, and timeout alert.[7]

Several smart assistance solutions have been proposed for patients with AD. Summarized and compared in key systems in TABLE 1.

Table 1: Comparative Analysis of Smart Assistance Systems.

Paper Name	Technology Used	Accuracy (%)
Abhishek, Balaji H. V. et.al. [6]	IoT Sensors, Arduino, GPS	75 %
Wafa Ben Taleb,et.al. [7]	LSTM, PoseNet, Reinforcement Learning (RL)	97.33%
Z. Wang, et.al. [3]	XGBoost, Random Forest (RF), SVM, IQR	90%
Lavanya N, et.al. [4]	CNN, RNN, LBPH	92%
C. Bhat, et.al. [5]	MLP, RF, SVM	82 %
N. Saleh, et.al. [15]	SVM, LBP, Viola-Jones Algorithm	84.45%
N. Saleh, et.al. [15]	K-NN, LBP, Viola-Jones Algorithm	93.36%

3. REVIEW METHODOLOGY

This review surveyed recent publications from IEEE, PubMed, and Google Scholar between 2015 and 2025. The inclusion criteria focused on studies involving smart systems for Alzheimer’s detection, monitoring, or patient support. Over 25 relevant papers were analyzed and compared. Several smart assistance solutions have been compared and summarized methodology, data source, tools in key systems in TABLE 2.

TABLE II Comparative Analysis of Methodologies in Reviewed Studies

Paper / Study	Data Source and Tools	Methodology Summary
Abhishek, Balaji H. V. et al. [6]	IoT sensors, Arduino, GPS modules	Implemented a wearable IoT system for real-time patient monitoring and alert generation using GPS and biomedical sensors.
Wafa Ben Taleb et al. [7]	Public human activity datasets, PoseNet model	Applied LSTM and Reinforcement Learning for human pose estimation and activity recognition to assist elderly users.
Z. Wang et al. [3]	Alzheimer’s Disease Neuroimaging Initiative (ADNI) dataset	Used XGBoost, Random Forest, and SVM models for early Alzheimer’s diagnosis based on neuroimaging and clinical biomarkers.
Lavanya N. et al. [4]	Custom patient monitoring dataset	Developed CNN-RNN hybrid model for fall detection and alert transmission in real time through IoT framework.

C. Bhat [5]	Speech datasets, IoT device integration	Utilized MLP and SVM for audio-based Alzheimer’s diagnosis using voice pattern analysis and IoT enabled sensors.
N. Saleh et al. [15]	Custom facial image dataset	Combined Viola-Jones, LBP, and K-NN/SVM classifiers for real-time face recognition in Alzheimer’s patient assistance systems.
Our paper	Voiced ataset, Gps, MFCC, and IoT for Alzheimer’s detection, monitoring, and support.	Compared AI, IoT, and wearable-based smart assistance systems; analyzed model, accuracy, and datasets, and IoT for implementation frameworks.

4. DISCUSSION

The analysis shows that wearable devices and IoT-based monitoring provide real-time assistance but often face challenges such as battery limitations and patient compliance. AI- driven diagnosis offers high accuracy but requires large, annotated datasets. Privacy and security remain critical concerns in patient monitoring.

5. PROPOSED METHODOLOGY

The suggested system will aim to support Alzheimer’s patients with real-time recognition, monitoring, and communication capabilities via a smartwatch-based system. The approach is composed of some of the main features, such as data gathering, voice recognition, person identification, and health tracking. The smartwatch records the voice and activity data of the patient and uses machine learning models with this data to inform the caregiver via a mobile app connected to the watch. The system combines sensor data with recognition algorithms to provide the correct identification and time alerts.

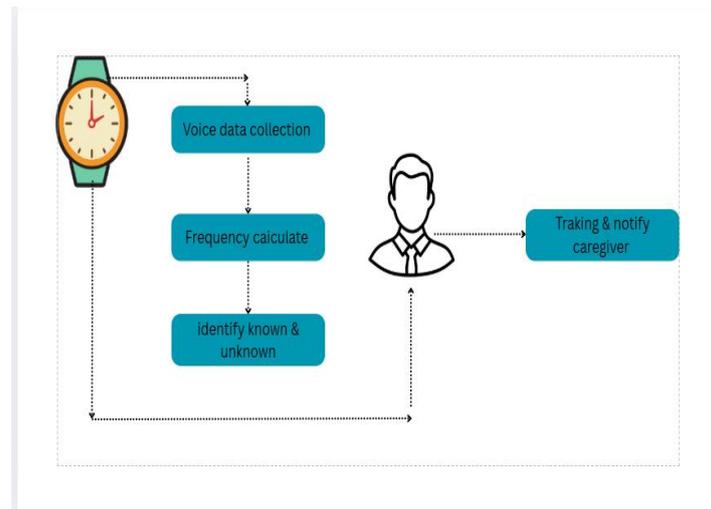


Figure 2. A general block diagram of the Mind Guard smartwatch for Alzheimer's patients.

The overall architecture, as shown in Fig 2. The general architecture, as illustrated, depicts the communication between the smartwatch, cloud storage, and mobile application. The smartwatch will have a microphone, sensors and GPS to gather updated data. The gathered data is locally processed and uploaded to the cloud partly to monitor it in the long-term. The mobile application offers caregivers an interface to monitor patient activity, location, and be alerted when abnormal events happen.

The working process of the proposed Smartwatch-Based Assistive System to Alzheimer-Patients is shown in Fig 3. the following flowchart. The system starts by obtaining voice and activity information using smartwatch sensors. The data gathered is then preprocessed to eliminate noise and get meaningful representations of the data like MFCCs. These data are then processed with machine learning voice recognition, speaker recognition, and activity detection models.

The voice identified is matched with the existing database to identify whether it is known or unknown. Should any foreign voice or anomalous action be identified, a notification is sent automatically to the caregiver via a mobile application or cloud service connected to the system.

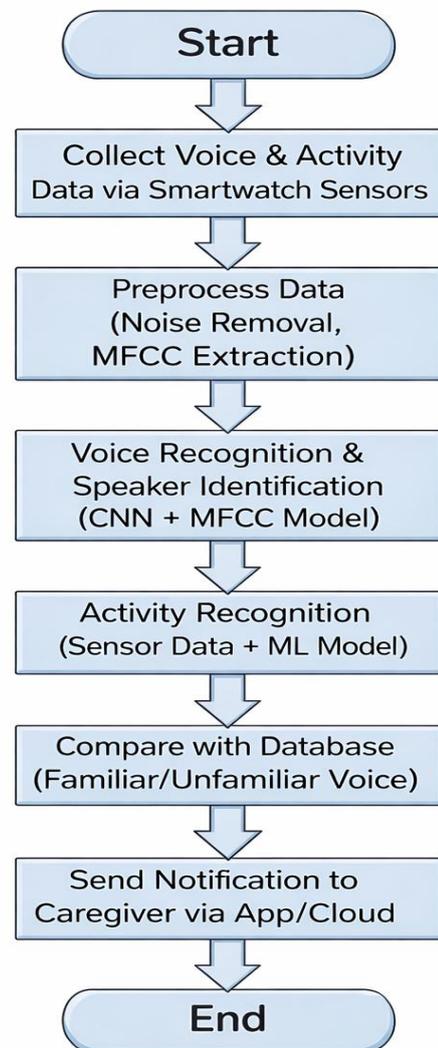


Figure 3. Flow Chart

Smartwatch-Based Assistive System Algorithm for Alzheimer's Patients

Step 1: The patient should wear the assistive device smartwatch.

Step 2: The device will collect voice data and calculate frequency.

Step 3: If the patient will not know any person, the device takes input from the sensor and helps the patient to recognize the person.

Step 4: If the Alzheimer’s patient has any problem, input from the sensor and send an alert to the caretaker through the caretaker app.

Step 5: The caretaker can get the patient’s location on Google Maps through the GPS module.

Step 6: All collected details are uploaded to the cloud for monitoring and record keeping.

Step 7: The caretaker can access the patient’s all condition through the caretaker app.

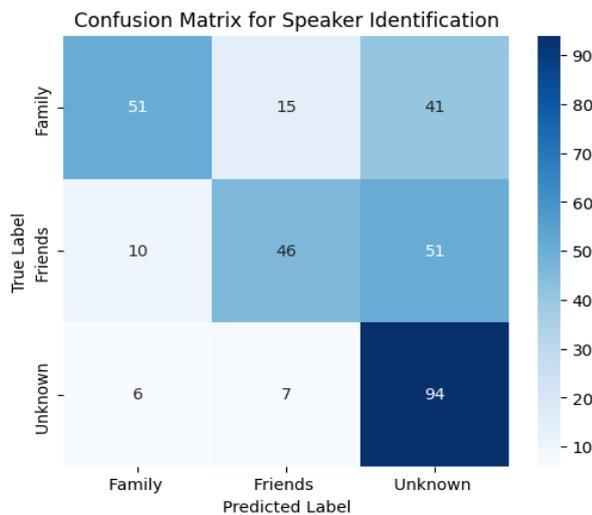


Figure 4. Confusion Matrix

6. EXPERIMENTAL RESULTS

To assess the performance of the proposed voice recognition and speaker identification model, the confusion matrix was used to show the performance as in Fig 4. The confusion matrix gives us a clear visual representation of the accuracy of the system that categorized the test samples to three classes: Family, friends, and unknown. It is useful to know how many predictions were made correctly and incorrectly by the model in each class. Based on the matrix, it can be seen that the model has a high accuracy in identifying the actual friends and unknown categories and has some misclassifications between the Friends and unknown categories. It means that the system works effectively in familiarizing unstable and unfamiliar voices, which is important to support Alzheimer patients in real life.

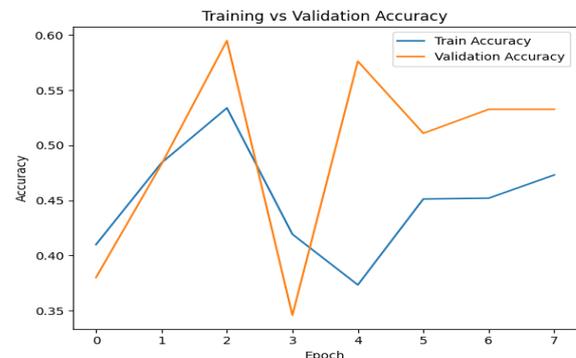
6.1 Used Dataset

This study utilized a self-created voice corpus to test and train the suggested speaker recognizer model. The data has been recorded using a smartphone in controlled acoustic settings to provide clarity and minimize the possibility of background noise. The total voice samples obtained was 400 and this was categorized into three classes; Family, Friends and Unknown. It consists of short speech segments of about 10 to 15 seconds in the 16-bit PCM and 16 kHz format in the Family class and recording of voices of non-family friends in the Friends class. The Unknown category contains samples of non-related speakers, and that imitates the real-life situation where the

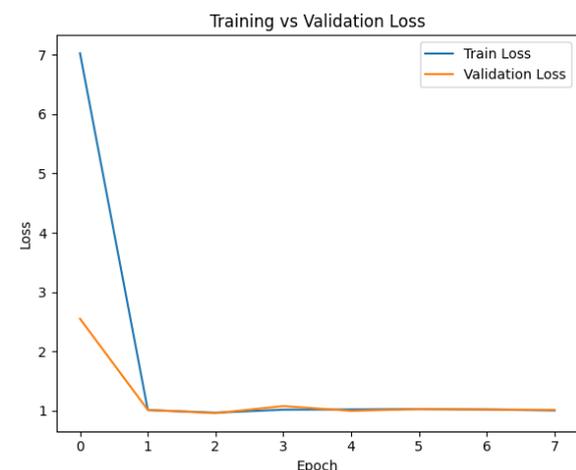
system may be vulnerable to unknown voices. To increase diversity of datasets, pre-processing of the audio samples to equalize the level and remove silence has been done using the library of librosa and pydub. MFCCs were used to obtain features with an aim of preserving both spectral and time characteristics of any given voice signal. The MFCC feature vectors were obtained and then inputted in the convolutional neural network (CNN) model during the training process that is not publicly available due to the privacy consideration but can be made available on a fair consideration request to be used in studies.

6.2 Model Performance Evaluation

Accuracy and loss graphs were employed to analyze the performance of the proposed CNN + MFCC-based voice recognition model, as illustrated in Fig.5. The graph below, the Accuracy Graph, shows the change in training and validation accuracy as the number of epochs increases to 30. As can be seen, the accuracy of the model slowly improved with the increasing number of epochs and in the end, the accuracy of the model was found to be over 60 percent on the training data and approximately 80 percent on the validation data, i.e., it has a good generalization capability.



(a)



(b)

Figure 5. (a). Training and Validation Accuracy Graphs
(b) Loss Graphs of the Proposed Model

Conversely, the Loss Graph illustrates that both training and validation loss decreased sharply at the first epochs and became stabilized, which proves that the model minimized the error and reached a convergence point. The agreement between training and validation trends indicates that the model is not excessively

overfitted and can also learn strong speech representations to support Alzheimer patients.

6.3 Web Application Development and implementation.

In order to ensure that the smart assistant system that is proposed is practical in the real world, a web-based application is created and dubbed as MindGuard Smart Voice Recognition System. The main purpose of such application is to recognize the communicators of the Alzheimer patients automatically, and categorize them into Family, Friends and Unknown. It is a real time-based system and it will give immediate feedback and one does not have to mediate it manually.

The interface of the trained speaker recognition model is carried out in the application to the ultimate users who are the caregivers and the medical personnel. It can also easily and conveniently incorporate voice communication that will be suitable to non-technical and the elderly patients as well.

6.4 Technology Stack

Making the web application was done with the help of technologies:

Frontend Framework: Steamlit **Backend Framework:** Steamlit

Form of the machine learning model: TensorFlow lite (TFLite).

Audio Processing Library: Librosa.

Lightweight inference: One of the models that is deployed on inference engines is TFLite Interpreter deployment.

Supported Audio Format: WAV

Streamlit is selected because it is light and it can be deployed within a relatively small amount of time, besides, it can be easily compatible with machine learning models. The Tensorflow Lite was also adjusted to allow that successful inference is achieved with low computational requirements that will render the system practical in the future to be linked to wearables and mobile devices.

6.5 Application Architecture

The application that is designed is built on the base of the modular architecture which comprises of four enormous components:

- User Interface Module
- Audio Preprocessing Module
- Speaker Recognition Module
- Prediction and Output Module.

The voice capture and automatic speaker recognition is the general tendency of the work.

6.6 User Interface Design

The application interface was scaled down in order to make it user friendly. The architectural scheme is that of the two columns:

Left Panel:

- Voice sample upload section
- Status indicator upload Processing Prediction real time.

Right Panel:

- Prediction output display
- Categorized speaker type.

It possesses a professional header banner, that is found in the upper section of the interface, that is referred to as MindGuard Smart Voice Recognition System. It has a thematic background image on the title and also it has more concentrated on the appearance of the title but it is not covering the text simultaneously. What is curious to observe however is that the application does not have a button press that can be done manually so that it can provide some form of prediction. After the voice file was uploaded, the system then automatically processes the input and displays the result.

6.7 Audio Input Handling

It supports the pre-recorded voice samples that are of WAV format. It will also be consistent with the dataset that will be taken during the training of the model, and it will not be required to encounter overheads in formatting the model. The following is automatically done on the uploading of the system: 16 kHz audio loading, Signal normalization. Audio quality validation, audio duration validation. The design option will also take into consideration the fact that there is similarity in the features that were extracted besides providing a high degree of predictive reliability.

6.8 Resultant Prediction and Automatic Learning

Automatic prediction is one of the major peculiarities of MindGuard application. Instantly on uploading, a voice file is uploaded: It has automated feature extraction, The model makes inferences, The kind of speaker that will be recommended is on a dataset basis. The outcome will be presented in a comprehensible text which will resemble:

- Identified Speaker: Family,
- Identified Speaker: Friends

This imperativeness of the design is especially pertinent to the Alzheimer patients, because the design will be less interactive to the users and less cognitively intensive.

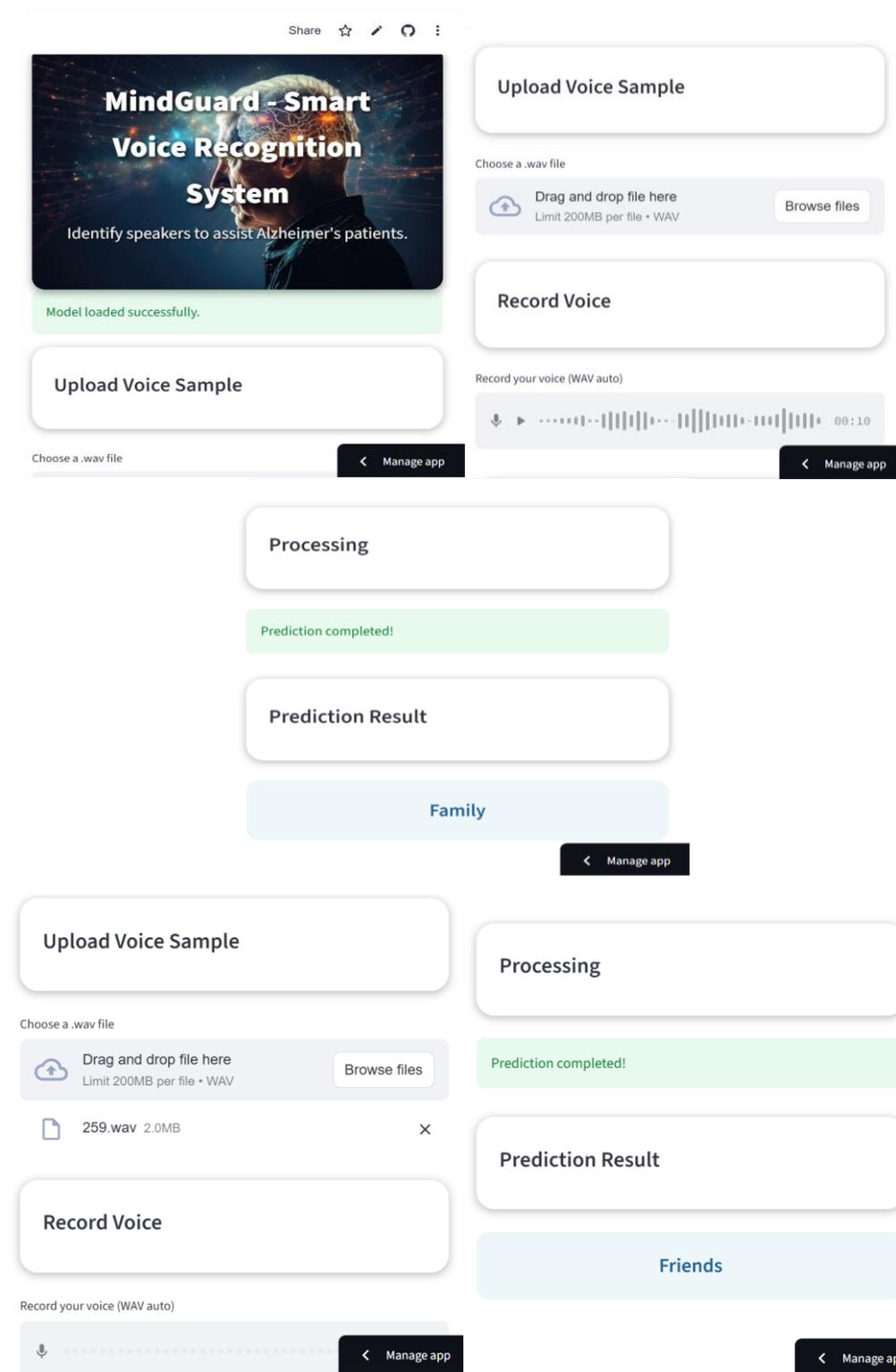


Figure 6. Web app development and implementation prediction

7. CONCLUSION AND FUTURE WORK

The smart assistance systems are holding a tremendous potential in enhancing the quality of life of the Alzheimer patients besides minimizing the burden of the caregivers. An upward light in this paper is the significance of smart, situational adept technologies and voice-based and wearable technologies in particular in supporting memory management, safety management, and the daily activity management.

Future research should concentrate on the use of the multimodal help systems with the offline tracking, activity recognition, and situational alerting. In addition to that, the capability of reducing lightweight AI models by integrating them with wearable gadgets such as smartwatches will enable real-time operations at a reduced energy cost. Ethical and privacy consideration should also be done through continuous monitoring in order to be deployed in a manner that is responsible. Finally, but not the least, it must undergo a wide

range of clinical validation and longitudinal studies to ensure that it is checked against real-life performance reliability and acceptability by both the caregivers and the patients.

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