

A Comprehensive Healthcare System to Detect Depression

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Abstract

Objectives: To develop a home-based healthcare unit that uses smart phones to monitor depression statistics. **Methods:** To tackle depression, we propose a mechanism which systematically monitors the user's behavior on a daily basis. We make use of a Smartphone to obtain GPS and phone usage data from the user and employ a clinically approved survey (PHQ-9) to monitor their mental state. The result obtained from computation determines the level of depression of the given user which is then sent to the consulting physician. **Findings:** Depression is one of the major psychological issues present in today's world, which often goes unnoticed because of its subtle symptoms and social stigma. Also, that people are too engrossed within their daily duties does not help them realize the problem even when depression related symptoms prevail. A study based on the World Health Organization's World Mental Health Survey Initiative has said that India has the highest rate of major depression in the world. An untimely detection of depression related symptoms may prove to be detrimental to several vital parameters of the body. By the proposed implementation, the physician can conveniently monitor the user's health status periodically without spending much time explicitly being a part of the process. The application of this healthcare system is to detect the onset of depression and prevent drastic results such a suicide and help the patient be in contact with their physician at all times. **Improvements:** Future improvements include, making the whole process less invasive by implementing Medical Imaging (Brain Scans) and incorporating IoT to increase parameters in the decision making matrix of depression detection.

Keywords: Cluster, DBSCAN, PHQ-9, GPS, Phone Usage

1. Introduction

Depression is a state of low mood and aversion to activity that can affect a person's thoughts, behavior, feelings and sense of well-being. People with depressed mood can feel sad, anxious, empty, hopeless, helpless, worthless, guilty, irritable, ashamed or restless. It is also the major cause of insomnia, excessive sleeping, fatigue, aches, digestive problems etc. Out of every 10 Indian professionals, 4 suffer from general anxiety disorder or depression. In the list of the top diseases that affect corporate executives, depression (42%) ranks at the top, followed by obesity (23%), high blood pressure (9%) and diabetes (8%). Over half (55% to be precise) are under the age of 30 and a quarter are between 30 and 40 years¹. A study based on the World Health Organization's World Mental Health

Survey Initiative has said that India has the highest rate of major depression in the world²⁻⁴. Depression is most commonly treated using psychotherapy and antidepressants. Antidepressants cannot cure depression, but only make it easier for you to deal with it^{5,6}. However, antidepressants given at the wrong time can lead to adverse effects that go unnoticed⁷. Antidepressants are not always the correct solution for curing depression. It is important to determine the level of depression a person is suffering from in order to provide them with the appropriate treatment. Thus to determine this, we aim at developing a home-based healthcare unit that uses Smartphone to monitor statistics and hence, detecting depression at the right time with the right parameters.

Sensors available in Smartphone give an accurate account of the user's behavior. Global Positioning System or

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GPS sensor available on the phone tracks the movements of the user to determine his home, work and other frequently visited places⁸. We also extract other information like phone usage frequency, phone usage duration, apps used and first and last usage times to determine the behavior pattern of the user. A periodic update of these data to the server allows the system to compute the appropriate results and display it at the physician's end. The user is also required to fill in a survey that is clinically approved. This survey determines the mental status of the patient. The Phone Usage statistics is also represented graphically for easier understanding of the data. The computed value from the phone usage along with the answers provided by the user is monitored by the consulting physician periodically, hence giving the automated system a human eye for monitoring.

The phases involved in the process are:

1. Data Pre-processing
2. Feature Extraction
3. Estimating Level of Depression

The following are the assumptions made for the working of the proposal:

1. System is targeted towards detection of onset of depression.
2. Target patients are of the ages between 18 and 33.
3. Night shift workers are not considered.
4. Made for a developing country with the infrastructure supporting Wi-Fi connectivity on the go.
5. Used to detect the depression level based on Smartphone Usage of an individual.

2. Materials and Methods

2.1 Mind At Ease-android Application

Mind At Ease is an open-source Android Application. It is developed with an aim to make user data collection easier and efficient. Mind At Ease employs a store and forward architecture which collects the phone usage data and stores it in the local device memory and then forwards it to the server when internet becomes available. This helps us in keeping track of the phone usage data even when the user does not find intermittent access to network facility and thus preventing data loss.

Mind At Ease keeps the identity of the user anonymous before storage and transmission. It makes use of the AES encryption algorithm to achieve the same. After encryption the data is stored in the user's device and deleted once it is

uploaded to the server. At the physician's end the decryption is performed before displaying the information.

Overall, it collects user's location context using GPS, various application usage and other phone usage statistics. The GPS is recorded every 5 minutes and other information is collected through screen lock events and phone usage data per day⁸.

The interface of the app is shown in Figures 1-4 represents PHQ-9 survey.



Figure 1. Start. Screen

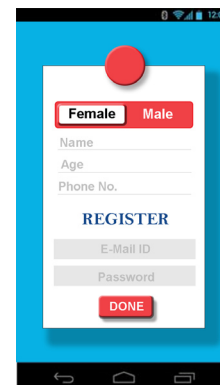


Figure 2. Registration screen.



Figure 3. Time remaining for the survey.

PATIENT HEALTH QUESTIONNAIRE (PHQ-9)

NAME: _____ DATE: _____

Over the last 2 weeks, how often have you been bothered by any of the following problems?
(use “/” to indicate your answer)

	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself...or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed. Or the opposite—being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead, or of hurting yourself	0	1	2	3

add columns + +

(Healthcare professional. For interpretation of TOTAL, please refer to accompanying scoring card). TOTAL: _____

10. If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?	Not difficult at all	_____
	Somewhat difficult	_____
	Very difficult	_____
	Extremely difficult	_____

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Figure 4. PHQ- 9 Survey.

2.2 Data Preprocessing

In this phase we look to collect data from the user’s Smartphone. We divide this approach into two parts; Manual and automatic. In the manual approach we collect the data in the form of a self-reported survey which is a combination of PHQ-9 Survey and a set of questions recommended by psychiatrists. The PHQ-9 Survey is a set of ten questions that are clinically approved and is primarily used to detect depression symptoms in a user. The other set of questions are based on the user’s lifestyle such as academic or work related achievements, goals, alcohol consumption etcetera. Survey is self-reported weekly by the user.

The automatic approach uses the phone usage as the foundation. Phone usage includes the following features:

1. GPS data
2. Phone Usage Frequency
3. Phone Usage Data
4. Apps used by the patient
5. First and Last Phone Usage times

Unlike the Survey data, these usage statistics are collected daily. Once collected the data is uploaded periodically

to the server. Furthermore, as it involves confidential medical information, the data is encrypted and sent.

2.3 Feature Extraction

The next step in the procedure is to extract various features from the information derived using the Smartphone sensors⁹. Location Data extracted is used to identify the various places visited by the user in that week. This is done by identifying the different location clusters formed from the latitude and longitude values of the places visited in the week. This is achieved using the clustering algorithm through which the GPS information collected will be segregated into separate clusters and its centroid point will be plotted on to a map. These cluster points are of high importance when extracting features from the same. For this process we have used DBSCAN (Density-based spatial clustering of applications with noise). When provided a set of points in space, it groups them on the basis of how closely they are packed together and marks as outliers, points that lie alone in low-density regions¹⁰.

The features extracted from the Phone statistics are

1. Location Variance
2. Number of Clusters
3. Entropy
4. Normalized Entropy
5. Home Stay
6. Phone Usage Frequency
7. Phone Usage Duration

2.3.1 Location Variance

We measure the variability in a participant’s GPS location. To calculate this, we use the location data of stationary states. It is computed as the logarithm of the sum of the statistical variances of the latitude and the longitude components of the location data:

$$\text{Location Variance} = \log_{10}(\sigma_{\text{lat}}^2 + \sigma_{\text{long}}^2)$$

The logarithm has been applied to compensate for the skewness in the distribution of location variance.

2.3.2 Number of Clusters

It is the number of clusters found by the DBSCAN algorithm in the preprocessing stage.

2.3.3 Entropy

Entropy is the measure of the variability of the time a participant spends at the location clusters. It is given as:

$$\text{Entropy} = -\sum_i P_i (\log_{10} P_i)$$

where,

$i = 1, 2, \dots, N$ represents a location cluster

N = denotes the total number of location clusters

P_i = Percentage of time the participant spent at the location cluster 'i'

High entropy indicates that the participant spent time more uniformly across different location clusters and lower entropy indicates greater inequality in the time spent across the clusters.

2.3.4 Normalized Entropy

We divide the entropy by its maximum value, which is the logarithm of the total number of clusters.

$$\text{Normalized Entropy} = \text{Entropy} / \log_{10} N$$

Normalized entropy is invariant to the number of clusters and thus depends solely on the distribution of the visited location clusters. The value of normalized entropy ranges from 0-1, where 0 indicates that all location data points belong to the same cluster and 1 implies that they are uniformly distributed across all the clusters.

2.3.5 Home Stay

We Measure the percentage of time a participant spends at home relative to other location clusters. For this we find the participant's home cluster. The home cluster is identified based on two heuristics:

1. The home cluster is among the first to the third most visited clusters
2. The home cluster is the cluster most visited during the time period between 12 a.m. and 6 a.m. (participants having night shift are not taken into account)

2.3.6 Phone Usage Frequency

It is on average, how many times during a day a participant interacts with their phone.

2.3.7 Phone Usage Duration

It is on average, the total time in seconds that a participant spends each day interacting with their phone.

2.4 Correlating Features with Level of Depression

Once the data is collected, we aim to correlate each feature with the PHQ-9 score of the user. The PHQ-9 is used

as a provisional diagnosis method based on the user's self-reported survey answers which return a scaled score. The score defines the level of depression of the user. If the user is classified as not depressed his PHQ-9 < 5, else he is classified with depressive symptoms (PHQ-9 ≥ 5). Finally, the correlation is applied to determine how strongly each feature maps to the PHQ-9 scores^{11,12}.

3. Results and Discussion

Once the listed features are extracted and processed, we estimate the level of depression. This is done by standard feed-forward Back Propagation Neural Network. The input layer contains 21 Input Neurons and the output layer contains 1 output neuron. The numbers of hidden layer neurons are determined through trial and error. The network undergoes a training process where the output is compared to a desired output; the computed error is then used to correct the weights. The weights are set to the following inputs:

1. A set of ten questions suggested by the psychiatrist.
2. Location Variance
3. Entropy
4. Normalized Entropy.
5. Home Stay
6. Phone Usage Frequency
7. Phone Usage Duration
8. Sleep Duration
9. Gender
10. Age
11. Type of App Used
12. PHQ-9 score

The activation function is the sigmoid function. It is given as:

$$S(t) = 1 / (1 + e^{-t})$$

Its range contains values between zero and one. And thus, we normalize all inputs to the same range. A threshold is chosen in such a way that the output neuron fires for the given input neurons. The output value is mapped and displayed on the web application to the physician^{13,14}.

3.1 Physician's Portal

The web application forms the physician's portal wherein he can keep a periodic track of the user's movement and phone usage. Apart from these, the physician can also view the answers given to the survey questions by the user

along with the scaled score¹⁵. The web application provides a detailed and structured layout of the information. It also allows the physician to have a list of all his patients and a comprehensive perspective of each patient's data. In addition, the physician can also view and analyze weekly data in a systematic manner. In case of any anomalies, the physician can e-mail the user to meet him for a check-up.

The graphical representations are shown in Figures 5 and 6.

3.2 Future Enhancements

The scope of the above explained concept is beyond this project. Incorporated with Internet of Things¹⁶ and machine learning algorithms, implemented from the physician side will make this real time project helpful to a wide range of public struggling with the starting stages of depression. The future enhancements include

1. Embedding IoT in the household furniture such as the bed, the lamp and the windows to monitor sleep time and active time.
2. Interconnection of all the appliances such as television, media players and computers to sort out the mood and activities of the user.
3. Transmission of all this data to the physician's side and timely suggestions on health care improvement.

On reaching a threshold limit, when the depression level is increasing, the physician will suggest the patient to take a brain scan. A machine learning algorithm will be employed on the physician's end to classify the severity or depression and also detect other neurological problems. This ultimately results in a 100% accurate and non invasive method to detect chronic depression and start appropriate treatment immediately.

4. Conclusion

Depression is one of the most documented conditions in the world but one of the least discussed topic. It is important to understand that it is not something to be ignored. Only 20% of the World's depressed population seeks help for treatment due to the stigma and social opinions attached to it. This paper is the first step towards overcoming this situation. An automated system that keeps track of the user behavior to compute the depression level without much of an interaction makes the functioning of the physician easier as compared to a session of therapy or a dose of antidepressants. Also, the periodic monitoring of the extracted data allows the physician to suggest the appropriate remedy required instead of providing treatment that might have catastrophic effects on the patients in the long run.

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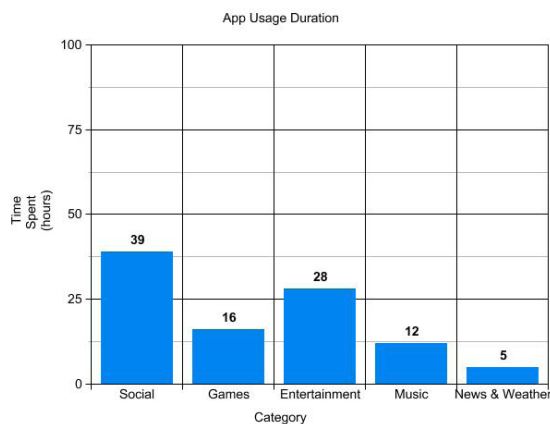


Figure 5. App Usage Duration.

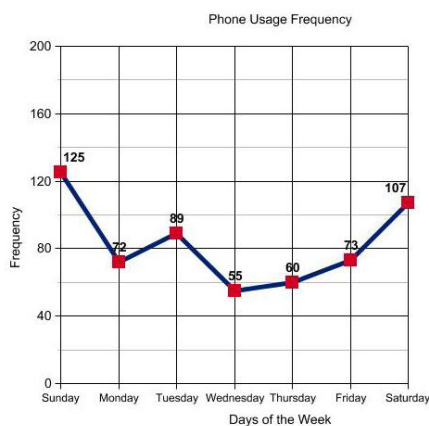


Figure 6. Phone Usage Frequency.

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