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# **6 Implementation**

## **6.1 Chapter Overview**

This chapter covers the implementation of the proposed system. Identifying the suitable language and the development tools are documented. Then the libraries/ frameworks selection and APIs are documented. Also the selected datasets were discussed.

## **6.2 Technology selection**

### **6.2.1 Language Selection**

The languages that we used to develop the system were Python and R. Python is a perfect choice for machine learning and data science. It is a minimalistic and intuitive language with a full-featured library line. And also we used it for developing the back end and RESTful API service. R is used to develop machine learning programs. Any techniques for data analysis, sampling, visualization, supervised learning and model evaluation are provided in R and also it is an open source software and runs on any workstation platform.

For the front end development Angular was chosen. Angular is a web development platform built in TypeScript that provides developers with robust tools for creating the client side of web applications.

### **6.2.2 Libraries/ Frameworks selection**

Angular is used in front-end development. It is specialized in building rich single-page applications. Bootstrap is selected for developing responsive websites. It is a most popular CSS Framework for developing responsive and mobile-first websites. It saved us from writing lots of CSS code.

## **6.3 Dataset**

## **6.4 Implementation**

### **6.4.1 Front-end**

### **6.4.2 Machine Learning Engineering**

#### **6.4.2.1 OBTAINING THE DATA**

Each recording of the patients was taken carefully: a sound-proofed room was provided by the hospital. Microphone was used to record the audio and the patient was required to repeat the sounds such as sounds of the vowels and were required to read some sentences. Then, Praat software was used to extract the acoustic features from the sound that was recorded.

#### **6.4.2.2 FEATURE SELECTION**

In creating a suitable machine learning model, the most important step is selecting the features that need to be analyzed in order to obtain an accurate model. The features that have to be analyzed are:

* Jitter
  + local
  + Local, absolute
  + rap
  + ppq5
  + ddp
* Shimmer
  + local
  + apq3
  + apq5
  + apq11
  + dda
* AC
* NDH
* HTM
* Pitch
  + Median
  + Mean
  + Standard Deviation
  + Minimum
  + Maximum
* Periods
  + Number of pulses
  + Number of periods
  + Mean
  + Standard Deviation
* Fraction of locally unvoiced frames
* Number of voice brakes
* Degree of voice breaks
* Status

Other than the feature **status**, other features are the features of the voice that are extracted. Praat software was used in order to extract the features. The status feature is the dependent variable: which indicates whether the row (audio extracted from patient) is diagnosed with Parkinson’s disease or not.

Feature selection is critical in order to create the model. As it can be seen in the features, Jitter and Shimmer are measured in different scales (local, ppq5, apq5, etc.). Including all of those features would severely affect the model, as each scale basically measures the same feature. Therefore, one scale of measurement from Jitter and one scale of measurement from Shimmer is selected in order to develop the model, and after the development, then another pair from Jitter and Shimmer are selected and the model is developed, and this steps are continued until all the scales of Jitter and Shimmer are analyzed. When considering the Pitch feature, it has 2 different measurements of locations: mean and median. Therefore, again one of the features is used for development and then the other is selected for another development. Standard deviations of both Pitch and Period are dropped. 2 examples of how the features are selected and grouped are given:

* **'Jitter(local, absolute)','Shimmer (dda)'**,'AC', 'NDH', 'HTM', '**Mean Pitch**', 'Minimum pitch', 'Maximum pitch', 'Number of pulses', 'Number of periods', 'Mean period' , 'Fraction of locally unvoiced frames', 'Number of voice breaks', 'Degree of voice breaks'.
* **'Jitter(ddp)','Shimmer (apq11)'**,'AC', 'NDH', 'HTM', '**Median Pitch**', 'Minimum pitch', 'Maximum pitch', 'Number of pulses', 'Number of periods', 'Mean period', 'Fraction of locally unvoiced frames', 'Number of voice breaks', ‘Degree of voice breaks ’.
* **The above feature selections are just 2 of the selections that are considered. The total possible number of groups of features selected:**

**5C1 \* 6C1 \* 2C1 = 60 possible combinations of features**

Since features from many different measurements are present, it would be unwise to input then directly as it would cause complications. Therefore, the features are scaled in order to output effective results. The function StandardScaler (makes the distribution’s mean and standard deviation as 0 and 1 respectively, i.e. a normal distribution) and MinMaxScaler (transforms each value within the range from 0 to 1 and preserves the shape of the initial distribution).

#### **6.4.2.3 MACHINE LEARNING ALGORITHMS**

##### **6.4.2.3.1 CLASSIFICATION**

The objective of the machine learning model is to detect whether a patient is diagnosed with Parkinson’s or not. Therefore, this is a classification problem. Currently, there are many traditional algorithms that can be used for classification and those algorithms are implemented for each feature group that was extracted in the feature engineering section. The algorithms are:

* Logistic Regression
* Decision Tree Classifier
* Gradient Boosting Classifier
* k-Nearest Neighbors classifier
* Random Forest Classifier
* Support Vector Machines
* XGBoost (extreme Gradient Boosting) algorithm

Also, a deep learning method: Artificial Neural Network is implemented too.

Before training the model, the dataset for training was split into training set and testing set. Training set is used to train the machine learning model with the algorithm, and the testing set is to test the predictions that can be obtained using a trained model and to cross-check the predictions made by the model. As a general rule of thumb, the dataset was split in 80:20, where 80% is the training set and the 20% is the testing set. A total of 1036 rows exist; therefore, it creates a training set of about 828 samples and a testing set of about 208 samples.

Since features from many different measurements are present, it would be unwise to input then directly as it would cause complications. Therefore, the features are scaled in order to output effective results. The function StandardScaler (makes the distribution’s mean and standard deviation as 0 and 1 respectively, i.e. a normal distribution) and MinMaxScaler (transforms each value within the range from 0 to 1 and preserves the shape of the initial distribution).

###### **6.4.2.3.1.1 MACHINE LEARNING ALGORITHM ANALYSIS FINDINGS**

**LOGISTIC REGRESSION**

Logistic regression can be stated as the basic classification algorithm in Machine Learning and it provides a linear classification. The library, sci-kit learn of python provides machine learning algorithms that can be directly used, and logistic regression is present in the library. Models created here use a set of features and the entire features depicted model with high bias compared to models that would be discussed later. Therefore, logistic regression was rejected.

**k-NEAREST NEIGHBORS**

KNN is another supervised machine learning algorithm that classifies a data point based on how its neighbors are classified. Validation was used in order to determine what best accuracy could be obtained with the best value for k (between 1-100). And then, the model was created using the sci-kit library and the training and test sets accuracies were recorded. KNN performed well. Using the entire features, the training set accuracy and test set accuracy are at around 73%. Therefore, k-Nearest Neighbors classification model can be used for prediction.

**DECISION TREES**

Decision Trees is a machine learning classification algorithm that takes the target variable as categorical variables (Classification Trees). Here, the sci-kit library is used in order to obtain the classifier model. Testing the model with the entire features gave a training set accuracy of 0.92% and a test accuracy of 0.60%. Here, it can be seen there is a high variance in the test set accuracy, therefore overfitting the model. When selecting group-wise (as mentioned in the feature selection section), the model did not show any improvement, as it still severely overfits. Therefore, Decision Trees classification was rejected.

**GRADIENT BOOSTING**

Gradient Boosting model is a supervised machine learning algorithm that can be used for classification purposes, and this model creates a prediction model in the form of a collection of weak prediction models, like the decision trees. Models were created using the sci-kit library and initially a model was created by fitting the entire features. It had a high training set accuracy of 0.89 but a significantly lower test-set accuracy of 0.74. This clearly indicates overfitting of the model. Also, grouping features as mentioned in feature selection did not provide any improvement, as overfitting was visible throughout the results. Therefore, the Gradient Boosting algorithm cannot be accepted as a valid model for the dataset and was rejected.

**RANDOM FORESTS**

Random Forests is a popular machine learning algorithm, known for its accuracy, and performance. Sci-kit was used to implement this model, and models were created for the entire features and the grouped features. Models created depicted high variance and high bias for all the combinations. Therefore, this model is not suitable for predictions.

**EXTREME-GRADIENT BOOSTING**

Extreme Gradient Boosting, commonly known as xgboost, is a very popular and powerful algorithm based on the gradient boosting algorithm. xgboost was used in order to create a model for the dataset. Entire features were used to fit the model created by xgboost, and it showed high variance, resulting in overfitting of the model(training set accuracy of 87% and test-set accuracy of 72%). Also, when grouping the features as mentioned in the feature selection section did not show any improvement, as each model created showed overfitting. Therefore, xgboost was also rejected.

**SUPPORT VECTOR MACHINES**

SVM is another widely popular algorithm that can be used for supervised machine learning classification. Sci-kit library was used to implement the model and the entire features as well as group of features was used to develop models. Training accuracy of 71% and a testing accuracy of 68% was obtained when using the entire features and this shows good fitting of the data to the mode. Therefore, this model can be selected for predictions.

**NEURAL NETWORKS**

Deep learning models are prediction models that are very powerful and can be used in an effective method. Here, the Artificial Neural Network was implemented in order to create the model and here the entire feature set was used in order to create the model. Tensorflow framework and the keras library was used to implement the neural network. Hidden layers were created (from 1 layer to 3 layer), and in the hidden layer, the activation function used was the Rectified Linear Unit. In the output layer, sigmoid activation function was used, as it is a classification. The iterations were set from 100 and modified up to 1000. In order to monitor the loss, binary cross entropy was used. Using neural networks did not give a satisfying result, the training accuracy obtained was good, but the test accuracy was pretty low, overfitting the model. Increasing the iterations or increasing/decreasing the number of hidden layers or increasing the nodes in hidden layers proved futile too. Therefore, deep learning was not selected to create a model in this project.

|  |  |  |
| --- | --- | --- |
| **ALGORITHM** | **TRAINING ACCURACY** | **TEST ACCURACY** |
| Logistic Regression | 64.58% | 64.42% |
| **KNN** | **73.94%** | **73.08%** |
| Decision Trees | 92.08% | 60.58% |
| SVC | 71.14% | 67.79% |
| Gradient Boosting | 88.89% | 73.56% |
| XGBoost | 87.64% | 72.59% |
| Random Forest | 51.45% | 64.42% |
| Neural Network | 73.79% | 66.34% |

*Table 1 - Accuracy for Entire Features*

Using the models created for these algorithms and comparing the accuracies by predicting the test set, it can be clearly seen that k-Nearest Neighbors provide a strong fitting of the model. Therefore, KNN is used for the predictions.

### **6.4.3 Back-end**

## **6.5 Chapter Summary**

This chapter concludes the technologies selected in the project such as languages, libraries and frameworks, dataset, implementation of front-end, machine learning engineering and back-end.

# **7 Testing**

## **7.1 Chapter Overview**

This chapter covers the testing done on the system to maintain.

## **7.2 Goals and objectives of testing**

## **7.3 Testing functional requirements**

## **7.4 Testing Non-functional requirements**

## **7.5 Unit testing**

## **7.6 Performance Testing**

## **7.7 Chapter Summary**

# **8 Evaluation**

## **8.1 Chapter Overview**

In this chapter we are going to discuss the methodology and approach taken for the evaluation and self evaluation.

**8.2 Evaluation methodology and approach**

As identified in the requirement gathering process, the target audience of the system are doctors and more specifically Neurologists. So we conducted a questionnaire survey to get some ideas from the target audience. From the results of the survey most of the respondents say that it would be beneficial for doctors if there is a software to predict Parkinson’s disease by using speech analysis.

|  |  |
| --- | --- |
| **Criteria** | **Purpose to evaluate** |
| Project concept | To get feedback on the system from the target audience |
| Scope and depth of the project | The scope needs to be evaluated by the domain experts in neurology. |
| System design, architecture and implementation | Examine whether the system, architecture and implementation are at a standard level |
| Solution and protype | To evaluate whether proposed solution is satisfied |
| User interface and user experience of the application | To evaluate whether user experience is satisfied |
| Suitability for learners | To evaluate whether it is at satisfactory level |

*Table 8.2.1 - Evaluation criteria*

## **8.3 Self-evaluation**

## **8.6 Chapter Summary**

This chapter concludes that whether the stake holder of the system is satisfied with the system and the evaluation methodologies taken and the approach.

# **9 Conclusion**

## **9.1 Chapter Overview**

The main focus of this chapter is the conclusion of the project. Achievement of project aims and objectives, the legal, ethical and professional issues, how the knowledge is utilized from course modules of the degree program,the skills gained and the problems faced are documented.

## **9.2 Achievement of project aim and objectives**

## **9.2.1 Aim of the project**

*●* ***Our aim of the product is to create a system that can accurately predict Parkinson’s disease by analyzing speech patterns.***

*Our main aim is to develop a framework which tracks an individual’s speech pattern example to analyze Parkinson's infection. So, the malady can be identified as right on time as could be expected under the circumstances and this item will be valuable for the general population, since many get basic because recently identification of the illness. In this way, with our item we plan to limit hazards so individuals could get brisk truly necessary restorative consideration which will decrease the damages.*

The aim of the project was successfully achieved during the development process. The system will detect whether a person is diagnosed with Parkinson’s or not, based from the track of speech pattern of the person.

### **9.2.2 Completion of objectives of the project**

|  |  |  |
| --- | --- | --- |
| **Objective** | **Description** | **Status** |
| Project proposal | After researching about the Parkinson’s and existing products to diagnose, a project proposal was prepared and approved | Completed |
| Literature review | An in-depth review was conducted to gather information about the problem, technologies and existing products. | Completed |
| Requirement gathering | Identified the stakeholders with their specific roles and the requirements are gathered by conducting surveys with the targeted audience, brainstorming and literature review. | Completed |
| Preparation of the Software Requirement Specification | The gathered information was analyzed to identify functional and non-functional requirements of the system. | Completed |
| Selection of software development methodology | Agile methodology was selected for the as it is more suited for handling requirements changes. | Completed |
| Selection of software resources | After analyzing the requirements suitable technologies were chosen. | Completed |
| Design | High level, low level designs, system architecture, class diagram system process flow diagram, sequence diagram and UI wireframes are designed | Completed |
| Development | Prototype was developed with the core functionalities | Completed |
| Testing | Prototype was tested and evaluated, to ensure the core functionalities | Completed |

*Table 9.2.2.1 - Completion of objectives of the project*

## **9.3 Legal, ethical and professional issues**

### **9.3.1 Legal**

In order to create machine learning models for the analysis, data is of utmost importance. It was required to get voice recordings from patients who are diagnosed with Parkinson’s disease and also healthy patients and some patients who have vocal issues similar to Parkinson’s but are not diagnosed with Parkinson’s. Since, there are no public datasets available in Sri Lanka that give speech recordings of the Parkinson’s patients, data collection had to be done manually. The National Hospital of Sri Lanka, in Colombo, was chosen, as it has the highest number of Parkinson’s patients admitted in Sri Lanka.

Initiating the data collection part was not a straightforward task as it required many legal and ethical permissions from the Hospital, as it is a Government-controlled institution, and also the safety of the patient is of utmost importance. Therefore, to initiate the data collection process, an official letter from the Informatics Institute of Technology was requested from our team, which states the nature of the project and the guarantee that the data obtained would not be misused and would be sorely used in order to build the project. Around the end of November 2019, our team visited the Ministry of Health in order to obtain permission in order to conduct tests in the National Hospital of Sri Lanka, and an official letter was provided to us, validating our project. Then, our team contacted the Deputy Director General of the National Hospital of Sri Lanka with the letter from IIT, the permission provided by the Ministry of Health, and an early draft of our project proposal.

The Deputy Director General forwarded our request along with the project proposal to Dr. Pradeep De Silva, a reputed physician at the NHSL, in order to validate the proposal. Dr Pradeep proposed some changes to the proposal that would make the project effective, and then around the starting week of December, the proposal was corrected and was submitted to Dr. Pradeep, who validated the proposal. Our team also acquired the services from Ms. Aberame Thevapalan, a medical student at the Faculty of Medicine, University of Colombo, in order to help us in the problem domain, and her help was useful in getting approval from Dr. Pradeep. Then the validated proposal was forwarded to the Deputy Director General, who informed that he would submit the proposal to the committee board meeting. The approval was delayed because of the Christmas and the New Year holidays.

In the early week of January, our proposal got approved by the committee board, and we were forwarded to visit the Neurological Department of the National Hospital of Sri Lanka in order to collect the data. Dr. Sunethra Senanayake, one of the administrative heads of the Neurological Department and the specialist in the neuro-related diseases, was contacted and as she was intrigued about our project, she guaranteed that she would extend her full support to the project. She directed us to the doctors related to the Parkinson’s disease channeling and also informed us the dates in which we can meet the patients: that is on each Thursdays, Parkinson’s patients would visit the hospital and on the second Thursday of each month, there would be a special clinic for the Parkinson’s patients. From February to the mid of March, our team regularly visited the Neurological Department on Thursdays, from morning to noon, and collected the speech data from the patients, and our process of collecting data was halted by the spread of COVID-19.

**All the documents and the permissions that were obtained/submitted can be viewed at the Appendix section of the document.**

### **9.3.2 Ethical**

A research project like our one poses a lot of ethical issues that needs to be solved before collecting data from the patients. We assured the Deputy Director General of National Hospital of Sri Lanka, and Dr. Sunethra, one of the heads of the Neurological Department, that we would adhere strict rules when collecting data (i.e. the voice recordings) of the patients and also the data obtained would not be used publicly for financial gain.

Before recording the voices of the patients, consent forms were created in order to assure the patient that he or she would not be put through physical or emotional stress and only if the patient willingly participates in the session that we would be collecting the data. Consent forms were prepared in all three main languages of Sri Lanka (Sinhala, Tamil and English), therefore it ensures that the patient would get a clear understanding of why the test is being performed and would be able to clearly understand the measures that are being taken to protect the data. Only the patient’s name, age, the severity rating of Parkinson’s and the recordings were obtained from each patient, and sensitive information was not obtained.

The recordings were stored securely in the local storage of the computer and was only used in order to extract the acoustic features using Praat and was stored in the csv file.

Implementing the web application faced ethical issues that needed to be resolved. Since the main user is the doctor, the details of the doctors need to be stored, so the user can log in, perform analysis, and so on. Therefore, in order to store the data securely, such as email and password, Firebase was used and also Google Sign In was implemented, which minimizes privacy issues. And, when the user inserts the recording of the patient, as soon as the acoustic features are extracted, the audio file would be removed, ensuring that the audio obtained from the patients would not be used for purposes other than the research.

**All the consent forms and other necessary documents are attached in the appendix.**

### **9.3.3 Professional**

One of the main concerns the doctors had was whether our project would replace the role of doctors in detecting Parkinson’s Disease. But our project is far from that, it is just a useful tool that would inform the user whether the patient has a chance of being diagnosed with Parkinson’s, and the user (in this case, a doctor), would use this as just one of the analysis value and conduct other measures (scans, physical test) that would ensure the patient is diagnosed with Parkinson’s. Therefore, our product does not explicitly state that the patient is 100% diagnosed with Parkinson’s but provides information that the patient might have Parkinson’s or not, based on the results that are being obtained and recommends the user to perform additional tests.

## **9.4 Utilizing knowledge from course modules**

|  |  |
| --- | --- |
| **Module** | **Description** |
| Software Development Group Project | This module taught us to identify a problem and to come up with new ideas. Additionally we learnt new technologies and frameworks for system development . |
| Computer Science Practice, Database systems | The basic documentation of a report is introduced in this module and also the data storing concepts are introduced. |
| Programming Principles I and II, Object oriented programming | This module taught the most fundamental programming principles and basic object oriented skills. |
| Web Design and Development, Client Server Architecture, Server side Web Development | Our system required a UI development and we decided it to be a web application from the survey we did. These modules helped us with HTML, CSS, JavaScript and server architectural designs. |

*Table 9.4.1 - Utilizing the knowledge from modules in the degree*

## **9.5 Learning outcomes**

Prior to starting the project, none of the team members had a strong knowledge in implementing client side and server side, and also conducting the research in data science and implementing the machine learning models. Therefore, in order to create a working implementation of our project, these skills have to be learned. Two members were assigned to each field: that is client-side development, server-side development and the data science component. Each member had to learn how to execute their tasks from scratch, and this provided great experience and hands-on knowledge for the members.

Main problem of members working in 3 different fields is merging the separate components as one. This proved to be a tough objective, and this hurdle was successfully achieved by hours of group meetings, discussions and referring to many sources. This project demonstrated to us how organizations and companies start a product from scratch and how they work until successfully deploying it.

Another new experience that none of the team members expected was the issues that needed to be addressed when collecting data. Official permissions from the ministries, government hospitals, departmental heads and doctors have to be present in order to successfully collect data and this seemed daunting at the beginning and near impossible. Early submission of our draft of the proposal to the National Hospital of Sri Lanka was rejected, but then, with proper planning and with confidence, all the permissions were obtained, and legal and ethical issues were handled well during the process of data collection. Although this experience does not directly coincide with the technical skills, it certainly increased each member’s confidence and showed each member how to solve a problem professionally and methodically, a skill that cannot be taught or learned through studying.

Overall, we faced a lot of shortcomings and stumbled across few of them but managed to solve a lot of issues that arose from conducting the project, both technical problems and problems that have to be solved using our soft skills and this enabled each team member to learn new skills and sharpen the existing ones.

## **9.6 Limitations and problems faced**

From the start of the project to the end of the project we faced many problems and limitations. Most of them were solved easily but some were challenging for us. Below listed are some of the main limitations and problems faced in the whole project:

## **9.7 Future Enhancements**

The project has a very vast scope in future. Even though it can diagnose Parkinson’s through speech analysis the result is constant with another test. This is because of the nature of each individual. But it is necessary to identify the limitations and address them in the future enhancements.

* More speech tests, like rapid speech movements through sequence by the diadochokinetic task.
* Additional information is worth considering by monitoring in a stance test of standing still or holding a device in a hand with an arm extended.
* Drawing of an Archemedian spiral which could be recorded using a hand-held device.
* The system can provide medical advice after the assessment.
* Improving performance and accuracy. Due to the limited number of dataset the accuracy is not enough.

## **9.8 Chapter Summary**

This chapter concludes the project by discussing whether the aim and objectives of the project were met. Legal, ethical and professional issues faced are covered. How the knowledge is utilized from the course modules are documented. Also the learning outcomes and problems faced and limitations are discussed. Finally the future enhancements are recommended.