FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

# Artificial intelligence for automated headache diagnosis through self-reported data

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PREPARAÇÃO DA DISSERTAÇÃO


Mestrado em Engenharia Informática e Computação

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# Abstract

Primary headaches are extremely frequent and highly disabling disorders that affect modern society. Although, from a societal point of view, headaches are still regarded as harmless and innocuous entities. This could not be further from the truth as, in Portugal, headaches cause thousands of years of quality life is lost due to disability per year and produce an estimated annual cost of hundreds of millions of euros.

This project was created due to a problem neurologists face when dealing while diagnosing headaches. When a patient with headaches decide to go on a medical appointment, a great loss of information prior to this point in time. This happens because the patient didn't register all the symptoms, or correctly registered, their intensity and when they began. This information is vital to diagnose of headaches, as there is more than 12 different types of them.

This work is being done with collaboration of Serviço de Neurologia, Hospital Pedro Hispano. It will be done using an app called "MyHealthDiary", which has been used ever since. The objective is changing the app so that each patient could use it as a diary for their symptoms, also stated as their self-reported data. Later by using machine learning methods, more specifically, an artificial neural network, with the information provided by the patient, a diagnose of what type of headache will be provided, which will improve and accelerate the diagnosis process.

After the diagnosis, the patients with the headache can be followed-up, by seeing their diaries, and by providing them the correct treatment.

This work will speed up the headache diagnosis, making it more reliable, without the direct need of a neurologist. More work will be done by the patient and the neurologist will only have to accompany the process so he can confirm the diagnosis and offer the correct treatment.

***Keywords—*** Headache Diagnosis, Self Reported Data, Machine Learning, Artificial Neural Network

# Acknowledgements

I like to thank all that took part in this chapter I now finally am ending.

Álvaro Francisco Barbosa Miranda

*"You should be glad that bridge fell down.*
*I was planning to build thirteen more to that same design"*

Isambard Kingdom Brunel

# Contents

# List of Figures

# List of Tables

# Abbreviations and Symbols

| | |
|---|---|
| Mi | Migraine |
| TTH | Tension-Type Headache |
| CTTH | Chronic Tension-Type Headache |
| MwA | Migraine with Aura |
| MwoA | Migraine without Aura |
| MAwoH | Migraine Aura without Headache |
| CH | Cluster Headache |
| MOH | Medication Overuse Headache |
| TAC | Trigeminal Autonomic Cephalalgia |
| CTTH | Chronic Tension-Type Headache |
| EH | Epicranial Headache |
| EH | Thunderclap Headache |
| TAwM | Typical aura with migraine |
| TAwoM | Typical aura without migraine |
| FHM | Familial hemiplegic migraine |
| SHM | Sporadic hemiplegic migraine |
| BTA | Basilar-type aura |
| SH | Secondary Headache |
| HPSS | Headache Prediction Support System |
| ICHD | International Classification of Headache Disorders |
| CCIHS | Classification Committee of The International Headache Society |
| KBS | Knowledge Based System |
| CDSM | Clinical Decision Support Mechanisms |
| LFE | Learning from Examples |
| DAG | Directed Acyclic Graph |
| NB | Naive Bayes |
| SVM | Support Vector Machine |
| RF | Random Forest |
| KNN | K-Nearest Neighbors |
| DT | Decision Tree |
| BN | Bayesian Network |
| ANN | Artificial Neural Network |
| NN | Artificial Neural Network |
| MLP | Multi-Layer Perceptron |
| SCM | Stacked Classifier Model |
| XGBoost | Extreme Gradient Boost |
| ROM | Random Oracle Model |
| LNN | Linear Neural Network |
| LEVNN | Levenberg Neural Network |
| PNN | Probabilistic Neural Network |
| FFN | Feed-Forward Network |
| LVQ | Learning Vector Quantization |
| DDN | Distributed Delay Network |
| LR | Logistic Regression |

# Chapter 1

# Introduction

This chapter introduces the dissertation and the work conducted on the project. Its motivation and scope are presented. The problem statement, with the project's objectives and requirements is described. A brief summary of it's context environment is presented. Finally, the structure of the document is also detailed.

## 1.1 Motivation

Diagnosing a headache is a long and complicated process, as there exists many different kinds of headaches. Firstly, they are separated in primary and secondary. The primary type has no known underlying cause, so it is not created by other diseases, where secondary headaches are created because of other disease.

It is very time consuming, as the the process only begin when the patient goes the first time to a neurologist. After this first appointment, the patient will go home and register in a diary his symptoms, their location and intensity. This process can take as long as six months until the correct diagnose can be provided. And only after the diagnose, can a treatment be provided. So it can disturb the patient for a long amount of time before it can be correctly treated.

Also as time is passing, after the first appointment, the diagnostic can be altered, when the decision is not one-hundred percent certain. With this the neurologist can always give the best treatment according to the current diagnose. If it changes, the treatment can also change. This follow-up is essential in the headache treatment.

## 1.2 Context

This work will be done in partnership with Serviço de Neurologia of Pedro Hispano hospital in Matosinhos.

An application name MyHealthDiary will be used. This application was developed in Laboratório de Gestão de Projetos at FEUP. This app is already being used by the patients of the hospital which is very important, as it allows the gathering of real data.

## 1.3 Problem Definition

In this section are presented the questions that this work will try to resolve.

Can the headache diagnosis process be improve? Will the neurologist have his work reduced, or will it remain the same as he will still have to double check the diagnosis? Will the diary improve the data collect? Will the diary allow the neurologist to notice if an serious problem happen to a patient? Will this improve the quality of life of those that suffer from headaches?

## 1.4 Objectives

When talking about people health, if a method is not 100% effective it can not be used alone. So the main objective of this work is not creating an neurologist independent, reliable primary headache diagnose tool, but an helper to the neurologist in the diagnose, and an easy way to help him in the patient's follow-up and treatment.

After the first appointment, a initial diagnose will be given by the app. As the time goes by this diagnose will probably change and become more accurate. Nonetheless, the neurologist will always have to check it. With this information the best treatment can be provided.

The application will also allow for the patient use it as a diary for their symptoms, their intensity and their location, so that the neurologist maintain a close follow-up. With this he can be alerted if at some point and more serious symptom or alert is discovered.

Only primary headaches will be addressed in this work, as what causes other kinds of headaches is a completely different disease, which is not relevant in this context.

## 1.5 Structure of the document

Beyond the Introduction, this thesis contains 5 chapters more.

In Chapter 2, the subjects that are necessary to understand the rest of the document are explained. Also the state of the art is presented presented. It is also talked about the Self Reported Data, and the application MyHealthDiary.

In Chapter 3, a solution is proposed, and the methodology to achieve it is also detailed by listing the tasks necessary and by providing a Gantt Diagram to see the predicted schedule of them.

In Chapter 4 the data previously gathered, from already existing databases previously obtained, or the data gathered from the app MyHealthDiary, will be separated in training and testing so that we can train an decision tree and a Bayesian network to and later test it's efficiency. After this the decision tree will be trained and tested with this data. With it we can prune it from the unnecessary features.

In Chapter 5 the same process done with the Decision Tree will be applied to a Bayesian Network so that later the results can be used in comparison with other methods

In Chapter 6 it will be explained how the use of the Artificial Neural Network. How it will be trained, it's structure, the experiments to obtain the best results.

In Chapter 7 it will be analysed the results previously obtained so that we can retrieve information from the experiments done before.

In Chapter 8 conclusions will be made to see if any of the methods can achieve a high efficiency capable of being used in the headache diagnosis in the MyHealthDiary application.

# Chapter 2

# Literature Review

In this chapter it is reviewed the state of the art of the subject at hand. Everything that is necessary to understand what will be talked and used will be in this section.

## 2.1 Headaches

In this section will be talked about the definition of an headache, what types exists and those who will be more relevant in this study and it's diagnosis process.

### 2.1.1 Definition

Headache is a discomfort or pain in the head, face or neck. They vary in terms of location, intensity, and how often they occur. The brain doesn't feel pain, because it's tissue doesn't have pain-sensitive nerve fibers. So other parts of the head must be responsible for feeling the headache like face or neck muscles; nerves from the mouth, from the throat or the top of the head; blood vessels from the head. The pain felt by there parts will be what will help to identify what kind of headache it is.

### 2.1.2 Classification

The classification of headaches is defined in the International Classification of Headache Disorders(ICHD) [1]. Its latest version, the third, was released in 2018, and it serves as a dictionary for all kinds of headaches. As it is an extensive document, it is referred by its authors knowing every detail of the document is not necessary, as even them don't know all of it. It serves to be consulted to help identifying and diagnosing the kind of headache.

To every single kind of headache is attributed an ICHD-3 code. This code serves as an identifier but also serves to show the level of detail of the headache, as this code creates an hierarchy. For example, the code 1 refers to Migraine, where the code 1.2 refers to Migraine with Aura which is a sub-type of migraine. It can go to 5 levels of detail, for example 1.2.3.1.2 called Familial hemiplegic migraine type 2 is a sub-type of migraine, and also an sub-type of migraine with aura, and

so go on, a sub-type of the 1.2.3 headache (Hemiplegic migraine) and 1.2.3.1(Familial hemiplegic migraine).

Before entering in more detail to each type of headache, it exists an important distinction t clarify. There exists primary and secondary headaches. The primary are the problem itself, even thought other problems can contribute in its appearance. The secondary type are caused by others problems, diseases, infections. The primary type uses the ICHD-3 code from 1 to 4, and the secondary uses from 5 to 14.

In this work only the diagnose of primary types will be addressed, but in the study of the state of the art both will be taken in account. In the following sections, it will be explained in more detail the types necessary to later understand the different studies presented.

#### 2.1.2.1 Migraine

Usually symptoms like noise, movement or light sensibility, dizziness, nausea or vomiting can accompany this kind of headache. The pain usually moderate to severe, during from 4 hours to 3 days more or less. Can have auras that are some sensory, motor or visual symptoms like hallucinations, dis-articulated sounds and words, or muscle numbness, that occur before the headache. During the attack is common to feel pain on one or both sides of the head, fatigue or anxiety, as difficulty to concentrate.

Some of its sub-types which will be referred later in this document are:

1.1 Migraine without aura;

1.2 Migraine with aura;

1.2.1.1 Typical aura with headache;

1.2.1.2 Typical aura without headache;

1.2.2 Migraine with brainstem aura or Basilar-type headache;

1.2.3.1 Familial hemiplegic migraine;

1.2.3.2 Sporadic hemiplegic migraine;

1.3 Chronic migraine;

1.5 Probable migraine or Migrainous disorder;

#### 2.1.2.2 Tension-Type Headache (TTH)

This is the most common type of headache. Light muscles and stress are factors in it. Other symptoms are: the head hurting from both sides; the back of the head or the neck hurting as well, the pain not being much severe, is mild or moderate feels like a pressure on the head and lasts from 30 minutes to several hours; usually don't cause nausea, vomiting or light sensibility.

Some of its sub-types which will be referred later in this document are:

2.1 Infrequent episodic tension-type headache;

2.2 Frequent episodic tension-type headache;

2.3 Chronic tension-type headache;

2.4 Probable tension-type headache;

#### 2.1.2.3 Trigeminal autonomic cephalalgias (TACs)

Cluster headaches usually occur in a series that may last weeks or months. The pain strictly one-sided is focused in the eye or the face temple, and it is usually severe. Its episodes usually lasts from 15 minutes to 3 hours and can happen from 1 to 8 times a day. It can cause a running nose or congestion, forehead and facial sweating.

Some of its sub-types which will be referred later in this document are:

3.1 Cluster headache;

3.1.1 Episodic cluster headache;

3.1.2 Chronic cluster headache;

3.5 Probable trigeminal autonomic cephalalgia;

#### 2.1.2.4 Other primary headache disorders

4.4 Primary thunderclap headache: High-intensity headache of abrupt onset, mimicking that of ruptured cerebral aneurysm, in the absence of any intracranial pathology.

- Epicranial headaches characterized by the head pain over the scalp. Is a category of headaches that contains the following ones:

4.7 Primary stabbing headache;

4.8 Nummular headache;

A4.11 Epicrania fugax;

#### 2.1.2.5 Headache attributed to a substance or its withdrawal

8.2 Medication-overuse headache (MOH)

## 2.2 Machine Learning

In this section will be talked about machine learning, what models are relevant to later understand the state of the art and the ones planed to be used later. Also it is referred in each type which document uses the respective model.

### 2.2.1 Neural Networks

[2, 3, 4]

A neural network is a series of algorithms that endeavors to recognize underlying relationships in a set of data through a process that mimics the way the human brain operates. In this sense, neural networks refer to systems of neurons, inputs and outputs.

- **Linear Neural Network** Is th neural network without any activation function in any of its layers; [5]
- **Levenberg Neural Network** A neural network with Levenberg-Marquardt Backpropagation Training; [5, 6]
- **Multilayer Percepton** It is a fully connected class of feed-forward artificial neural network. Consists of the input, the hidden layer composed of perceptrons that uses a nonlinear activation function and the output. It is trained with backpropagation; [7, 8]
- **Probabilistic neural network** PNN is a feedforward neural network usually used to handle classification and pattern recognition problems. [9]
- **Feed-Forward Network** is an ANN where it's connections between nodes do not form a cycle, so information always moves on one direction never comming back. [9]
- **Learning Vector Quantization** It is meant for statistical classification and recognition method. The only purpose it has is to define class regions in the input data space. [9, 10]

### 2.2.2 Bayesian Networks

[11, 3]

A Bayesian network consists in a probabilistic graphical model for representing knowledge about a domain. Each node represents a random variable and each edge represents the conditional probability for the corresponding random variables via a directed acyclic graph(DAG).[12]

They are ideal for predicting from several causes, what was the most probable to cause a certain consequence. For example from they can represent the probabilistic relationship between symptoms and diseases. This show it's perfect in the subject at hand.

### 2.2.3 Decision Trees

Decision Trees can be used for both regression and classification. It represents choices and decisions to make. Like the name says it is a tree-like model commonly used in machine learning to predict many different things.

- **Random Forest**: - like bagging it uses heterogeneous classifiers. However adding to the bootstrap samples, it also chooses random features. Each classifier (decision tree) is trained on different objects and different features; [13, 5, 14]

- **C4.5**: - is a algorithm used to create a decision tree. It chooses the a feature to test at each node of the tree. It then learns what feature produce the better classification score and build a new decision tree based on this information; [13]
- **XGBoost**: - it stands for eXtreme Gradient Boosting. As the name suggest it is a quicker version of the Gradient Boosting, which in turn works with little differences from the normal Boosting; [5]
- **Bagging**: - instead of choosing the original dataset, choose a set of new bootstrap object samples from the original dataset and train one classifier per subset. Then models are built using the created bootstrap samples. Each classifier is trained on the same features but on different objects; [13, 14]
- **Boosting**: - like bagging improves the quality of weak predictors. It consists of iteratively learning weak classifiers with respect to a distribution and adding them to a strong classifier. With this at each iteration the weight of misclassified examples is increased and the weight of correctly labelled samples decreases. AdaBoostM1 is a boosting method. [13, 14]
- **GENESIM(Genetic Extraction of a Single, Interpretable Model)**: - it transforms in a group of decision trees into a one with an enhanced predictive performance, using a genetic algorithm . [3]
- **CART(Classification and Regression Tree)**: - is a predictive model, that tries to explain the a variable outcome value based on other values.
- **Gini Algorithm**: - it selects a random feature and then calculates if the probability of it being classified with the wrong classe. [9]

### 2.2.4 Others

- **Naive Bayes**: - is a probabilistic classifiers, based on applying the Bayes theorem, assuming the features are independent; [11, 13, 14]
- **Support Vector Machine**: - it constructs hyper-planes to separate data in space in order to maximise the distance of the nearest training data points of any class. New points are mapped into that same space and are predicted to belong to the category of the side they are; [13, 5]
- **KNN**: - the k-nearest neighbors is a classifier, which uses proximity to make predictions and classifications of a single data point by giving it a group(class); [5]
- **Random Oracle Model**: - is a way to modularize formal security proofs by assuming that all pseudo-random used by an algorithm or protocol were replaced by random oracles, which return truly random values upon invocation; [15, 16]

- **Linear discriminant analysis**: - it finds a linear combination of features that separates two or more classes of objects. The results may be used as a linear classifier or transforming the high-dimensional data in more low-dimensional; [16]
- **Logistic Regression**: - it is used to calculate or predict the probability of a binary (yes/no) event occurring [7]
- **K-Means Clustering**: - It is a algorithm that tries to partition the dataset into K distinct non-overlapping groups called clusters, where each data point only belongs to one cluster. [17]

## 2.3 Feature Selection

In this section we will talk about some feature selection methods that are applied in some of the research explored and which can be use full in future work.

- **Consistency measure filter** : - consists of: in a dataset if two objects belonging to it, are similar, their classes labels should also be similar; [13]
- **ReliefF**; [13]
- **Genetic algorithm wrapper** : - through first choosing feature subsets thyen following cross-over and mutation operations searches the optimal solution; [13]
- **Least absolute shrinkage and selection operator (LASSO)**: - In [5] was used LASSO which is selecting the minimum number of features that the kind of headache will be dependable. To do this it was applied stratified tenfold cross-validation and the features that appeared in at least 3 times from the 10 fold were chosen;

## 2.4 Knowledge-Based Systems

In this chapter we explore more methods to use in the headache diagnosis. This time outside ot the Machine Learning area.

A knowledge based system (KBS) uses a set of rules, usually simple rules like “if-then-else” statements, to achieve conclusions using induction. It will arrive to a conclusion based on its knowledge and rules.

As we can see in [18], first it is defined the headaches classes that will be used in the process according to standardized terminology. After that it is identified the characteristics of each type preciously chosen. Following this step, some procedural functions are created to help in the classification of primary headaches. After being completed, everyone, don’t even need to be a doctor can do a headache diagnosis. It is only necessary to run the functions in the right way, and in the end it will give the diagnosis.

In [19], an app made with Delphi, can diagnose several classes of headache. And hot this app does it is by using a rule based expert system. The app has a diary where the patient can put his symptoms, and with this information, the app runs a series of If statements like "If symptom X and Symptom Y Then Migraine with Aura".

In [20] even though is not exclusive to headaches, a flow chart was created to do a diagnose any diseases. It starts with any major symptoms. Then searches for any disease that provokes that symptom. Then do a cycle with a new symptom until only one disease remains and that is the disease that the patient will be diagnosed.

As we can see this methods can function without the need of a machine. With this, it can be very simple and straightforward as it can be done with natural language. However, the logic behind systems like this can be very hard to create. Also it is not very adaptable, as it will always give the same diagnose unless the symptoms change which is a downside.

## 2.5 Self Reported Data

In this section we will talk about the data collection.

In some researches like [3, 19, 16] applications are presented some applications that present questionnaires to its users so that the headaches characteristics can be know for the diagnostic. In some case the application serves only for the collect of data. In others the diagnose is also presented.

In this work what is pretended is to first present the questions necessary to the patients so that this information can be saved. As this questions are presented, the diary can also be used which will improve the quality of the data. As the information grows, the chance of a correct diagnose will also grow.

The questions that will be presented in MyHealthDiary are listed below. It is the same questions used in [7] and like in this research the number of questions can vary if evidence of useless features appear.

1. Patient's age;
2. duration of last episode;
3. Frequency of episodes per month;
4. Unilateral or bilateral pain location;
5. Throbbing or constant pain;
6. Pain intensity, i.e., mild, medium, or severe;
7. Nauseous feeling;
8. Vomiting;

9. Noise sensitivity (Phonophobia);
10. Light sensitivity (Photophobia);
11. Reversible visual symptoms;
12. Reversible sensory symptoms;
13. Lack of speech coordination (Dysphasia);
14. Dis-articulated sounds and words (Dysarthria);
15. Dizziness (Vertigo);
16. Ringing in the ears (Tinnitus);
17. Hearing loss (Hypoacusis);
18. Double vision (Diplopia);
19. Simultaneous frontal eye field and nasal field defect and in both eyes (Visual defect);
20. Lack of muscle control (Ataxia);
21. Jeopardized conscience (Conscience);
22. Simultaneous bilateral paresthesia (Paresthesia);
23. Family background;

## 2.6 State of the Art

Table 2.1: State of the Art

| Paper | Methods | Features | Data | Classes | Best Efficiency |
|---|---|---|---|---|---|
| [13] | NB, C4.5, SVM, Bagging, RF | General and Headache Questionnaire | 1022 from both sexes | Mi, TTH, Others | RF with 81.00 ± 2.67 |
| [5] | ROM, LNN, SVM, KNN, RF | 75 questions | 2162 patients | TTH, CTTH, MwA, MwoA, TAC | 0.985 |
| [16] | SCM, 4 layers of XGBoost, KNN, DT, RF, LEVNN, Others | 65 features | 836 patients | TTH, CTT TAC, EH, TH | XGBoost with 0.8071 |
| [14] | 23 models | 19 in the beginning, 15 after pruning | 614(199 male, 415 female) | Mi, SH, TTH, CH, TAC | Random Forest 0.927 |
| [11] | BN, ANN | 14 variables | 2177 patients | TTH, MwoA, MwA, MOH, Others | both around 0.76 |
| [7] | ANN(MLP), LRM, SVM, KNN, DT | 23 in the beginning, 18 after pruning | 400 patients | TAwM, TAwoM, MwoA, FHM, SHM, BTA, Others | 1 Hidden Layer and 10 Hidden neurons: 0.975 |
| [9] | DT(Gini Algorithm), DDN, PNN, FFN, LVQ | 8 variables | 535 from the age 18-22 | Mi, Probably Mi, No Mi | DDN with 0.9545 |
| [17] | K-Means Clustering | 20 variables | 353 students | MwoA, PMwoA, no Migraine | from clusters with 0.45.24 to clusters with 0.8889 |
| [8] | Fuzzy Expert System(Using LFE algorithm), MLP, SVM | 12 variables | 190 patients | Mi, TTH, MOH, EH | all around 0.9 but Fuzzy < MLP < SVM |
| [2] | ANN | 16 questions | 190 patients | CH, Chronic Headache, MwA, MwoA | all around 0.9 but Fuzzy lower than MLP lower than SVM |
| [3] | Decision Tree(GENESIM, C4.5, RF, XGB, CART), LR, SVM, KNN, NN | 10 variables | Migbase Dataset 849 patients | Mi, TTH, CH | Higher: GENESIM:0.983510 ± 0.0095 |
| [4] | Neural Network | 9 variables | 2,177 patients | MwA, MwoA, TTH, MOH, Others | around 0.95 |

# Chapter 3

# Proposed Solution

## 3.1 Proposed Solution

In the beginning, the most important thing is to have a well composed data-set with all patients data, and a neurologist diagnostic of the correspondent diagnosed type.

With this information, it is a good idea to initially train a decision tree to see visually what features correspond to each type of headache, to help identify the crucial symptoms for each type. Also it can be also seen if there exists features that are useless, so that they can be removed, which will improve the quality of the questionnaire as only the essential questions will remain.

After this is a good experiment to try using the decision tree to diagnose headaches. With a test data-set without the final diagnose, using the decision tree, we will get a rudimentary diagnostic. If the real type of headache, given by a neurologist, we can see the efficiency of the decision tree. With this we also can see if all of the initially pretended types of headaches will be used. Probably if some are not being used in the diagnose, it's better to remove them or form a larger class with more than one type of headache, so that in the end we have all the types pretended but without having unused classification classes.

With this white-box method it can be seen the process of diagnosing the different types, the decision making and the logic behind it. On the other hand, the next step, an artificial neural network, is a black-box method. Certainly it will have a better efficiency than the decision tree, but the logic behind the diagnose can't be seen so it's harder to understand. This is why first, we started by the decision tree, to understand more about the diagnose, the feature selection and the better classification classes.

The next step is do the training of a Bayesian Network and then testing it,

The following step is to train a artificial neural network with the same data-set used before for training. And later for testing so that later we can compare the efficiency. Also in here we can change many things to compare, like removing some features, removing some classification classes, using forward or back propagation or even by changing the layers or the neurons of the hidden layer of neural network. This will reveal the way we can achieve the best score in efficiency.

Also if the number of inputs of the neural network would change because of a change in the questionnaire, it would be necessary o train the network again so that it can give the best diagnose.

In the end, and if the time allow it, some more models like Random Forest or a Bayesian Networks can be used to test against the neural network to see if it is in fact the best method for the diagnostic.

## 3.2 Tasks

1. **MyHealthDiary development**: - using the already in use app MyHealthDiary, create a new feature for the patients to use it has a diary for their headache symptoms, to respond to the questionnaires, to save this information;
2. **Data Collect**: - After the new features being deployed, the patients of Hospital Pedro Hispano use it, to collect real data for the database;
3. **Decision Tree Development**: - Using previous obtained free data-sets, train a decision tree, and test it afterwards. Learn more about the diagnosis process, and feature prunning;
4. **Bayesian Network development**: - Using previous obtained free data-sets, train a bayesian network, and text it afterwards. Compare the results with those obtained with the decison tree;
5. **Neural Network Development**: - Using previous obtained free data-sets, train a artificial neural network, and text it afterwards. Compare the results with the ones previously obtained;
6. **Testing**: - Change some factors in each model previously used to see changes in the efficiency or accuracy to obtain the best results possible. If the data-set obtained from the app MyHealthDiary is already sufficient to test, use for more experiments;
7. **Results Analysis**: - Understand the results obtained, to see if were the ones expected or not;
8. **Results Conclusion**: - Draw conclusions from the experiments and their results;
9. **Dissertation Writing**: - Finish the writing of the dissertation document;
10. **Presentation and Defense**: - Present the work done and then defend the thesis of it.

## 3.3 Gantt Diagram

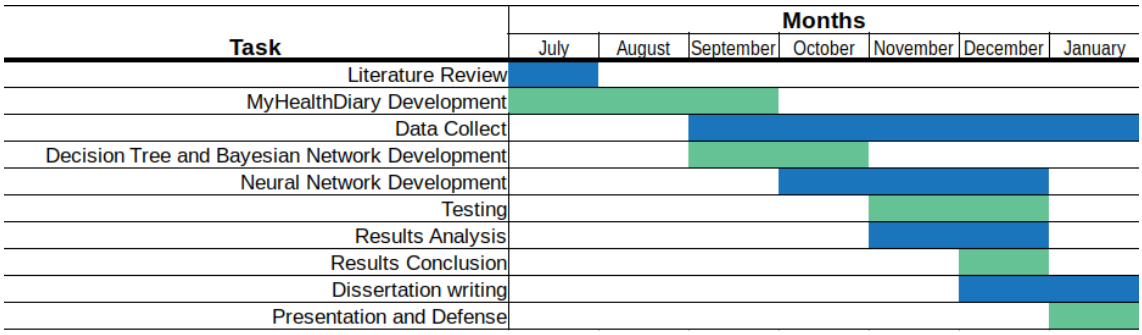


Figure 3.1: Gantt Diagram

# Chapter 4

# Decision Tree Development

# Chapter 5

# Bayesian Network Development

# Chapter 6

# Neural Network Development

# Chapter 7

# Neural Network Development

# Chapter 8

# Conclusions

In this chapter we retrieve some usefull information.

After the investigation the the state of the art is safe to conclude that the proposed work is feasible. More, it can achieve a great efficiency if it can came close of some of the results already obtained by other researchers.

By observing the variance of the efficiency of different methods, or even the efficiency of the same methods but done by difference people, it is difficult to predict which model will give the best results, even though before the investigation, the neural network seemed the favourite to the best results.

The writing of this document served as as a good starting point to put this work in a good way to be concluded in time and with quality.

## 8.1 Future Work

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# Appendix A

# Lorem Ipsum

Depois das conclusões e antes das referências bibliográficas, apresenta-se neste anexo numerado o texto usado para preencher a dissertação.