Chapter 1

Introduction

1.1 Brief overview over the History of Blood Pressure

Although there can be little doubt that simple palpation of the pulse was carried out by the early Egyptians, actual mensuration of the pressure in parts of the circulation really started in the middle of the *XVIII* century with the experiments of Stephen Hales [8].

The blood pressure could be understood as the pressure in the blood due to the beating heart. But this simple thought did not arouse the curiosity of physiologists long before the *XVIII* century, maybe the idea that blood was not constantly produced in the body raised doubts about the benefit of bloodletting, a popular medical practice at the time. The first historic register of a blood pressure measure is dated in 1733 by this british veterinary and phisiology Stephen hales, in front of the especulation about the existence of a BP (blood pressure). Johannes Müller, one of the greatest physiologists of the XIX century, said that *"the discovery of the blood pressure was more important than the discovery of the blood"*.

Nineteenth-century Experiments: the First Physician-Physicist. It was not until the XIX century when the accurate study of blood pressure began, with the introduction by Poiseuille in 1828 of a mercury manometer.

Poiseuille may be described as one of the first physician-physicists. He qualified as a doctor in 1828, and in the same year he won the gold medal of the Royal Academy of Medicine for his doctoral dissertation on the use of a mercury manometer for the measurement of BP.

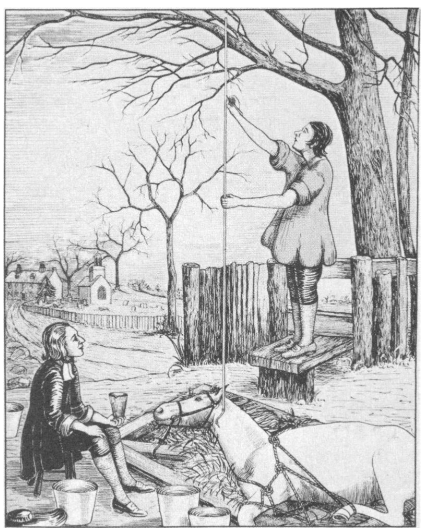

Figure 1.1: Stephen Hales experiments

He connected the manometer to a cannula filled with potassium carbonate which acted as an anticoagulent and the cannula was inserted directly into an artery in the experimental animal. Poiseuille's innovation enabled Carl Ludwig, Professor of Comparative Anatomy at Marburg, to develop the *kymograph* in 1847. The cannula and mercury manometer remained the same, but now a float with a writing pen attached was pushed up by the open mercury column and the pen arranged to write on a revolving, smoked drum. With this kymograph, Ludwig founded the graphic method of recording clinical data, which was to have profounds effects on experimental physiology and medicine in the latter half of the XIX century.

Non-invasive Techniques: the First Sphygmomanometer. In view of the necesity of finding a non-invasive method for measuring the arterial pressure, many scientists started researching. Since puncture of an artery was necessary before a reading, it was not till 1855, when Kart Vierordt postulated that an indirect non-invasive technique might be used, by measuring the counter pressure which would be neccesary to cause the pulsation in the artery to cease. He put this theory by attempting to measure the needed pressure to cause this obliteration of the radial pulse, by a weight attached to the lever of a sphymograph. He had not very much success due to the bulky design of his mechanism.

Some years later, in 1860, Etienne Jules Marey improved the technique of graphic recording, and also the accuracy of establishing the blood pressure in patients. He applied the same Vierordt's principle, but in this time the arm was enclosed in a glass chamber filled with water. It was connected to a sphygmograph and to a kymograph which recorded the arterial pulsations in the arm. The chamber pressure was varied, by adding more water, and it was also supplied with a manometer. The task of measuring blood pressure with Marey's apparatus was too complicated for most doctors and also rather unwieldy.
However Marey's sphygmograph gained acceptance in the medical world for recording and studying the pulse. After that the researching of most doctors generally consisted in attaching weights to the spring of the manometer, with the pressure being considered as equal to the force needed to overcome manometric movement. Then Potain observed that the force needed to move the spring in the manometer depended also from the resistance of the arterial wall, hence he concluded that spring manometers should be avoided in blood pressure measurement.

Advancement of Non-invasive Techniques. In 1881 Samuel Siegfried Karl Ritter von Basch, was who finally dispensed with the arterial puncture and the direct registration of the blood pressure by a column of fluid. He invented the tensiometer, which consisted in a rubber bag filled with water conected to a manometer, mercury filled. This sphygmomanometer was more accurate than previous devices, as Zadek demostrated, experimenting with dogs, and comparing the measures with cannulation of the carotid artery. However it was without success in this time. Potain, in 1889, improved von Basch's sphygmomanometer, making it more adequate to clinical use, replacing water with air for compression.

Althoug during this years there was a gradual improvement in the style of measuring blood pressure, it was not till mid 1890s when a very important contributor emerged, he was Scipione Riva-Rocci.

Development of Present-day Technique. In 1896 Riva-Rocci developed the method which present day technique is based. Riva-Rocci's techniques involved compression of the arm around its whole circunference, by means of a rubber bag, surrounded by a cuff. This bag was inflated by means of an attached rubber bulb. The pressure in the cuff was registered by the usual mercury

manometer, and was increased until the radial pulse could no longer be palpated. As he published in the report "Un nuovo sfigmomanometro". It was based on the principle established by Vierordt and improved on by Marey and von Basch in turn. Due to many advantages, like: easy of application; precision; rapidity; and harmless, it was widely accepted.
However there was a defect in Riva-Rocci's technique, it was that he used a cuff only 5 cm wide. The dimension of the cuff, rendered the measures mildly inaccurates. This problem was realized and corrected by the doctor von Recklinghausen in 1901, who replaced the narrow armband with one about 12 cm wide.

In this yearsit was still used the palpation method to realize when there was no pulse. The problem with this method is that it was useless for an accurate determination of the diastolic blood pressure. This is why the clinicians started to use the oscillometric metod. For this task, they had to observe the oscillations which were transmitted to the mercury in the manometer from the artery. Since both pressures, in the cuff and in the artery, were equal, then the artery would throw, thus causing small regular fluctuations in the cuff pressure. The transition from large to small vibrations would define the diastolic pressure.

Twentieth Century. In 1905 a new technique was devised for determining systolic and diastolic blood pressures (SBP and DBP).
It was Nikolai Sergeievich Korotkov who developed this technique of blood pressure measurement. It was reported in less than a page of the "Izvestie Imp. Voiennomedicinskoi Akademii" (Reports of the Imperial Military Medical Academy). In this report he said that placing the cuff of Riva-Rocci on the middle third of the upper arm; raising up quickly the pressure within the cuff to complete cessation of circulation below the cuff and then, letting the mercury of the manometer fall it could be listened the artery just below the cuff with a stethoscope. At first there were no sounds. With the falling of the mercury in the manometer down to a certain height, the first short tones appeared, their appearance indicates the passage of part of

Figure 1.2: Nikolai Sergeievich Korotkov

the pulse wave under the cuff. It follows that the manometric measure at which the first tone appears corresponds to the maximal pressure. With the further fall of the mercury in the manometer one hears the systolic compression murmurs, which pass again into tones (second). Finally, all sounds disappear. The time of the cessation of sounds indicates the free passage of the pulse wave. In other words, at the moment of the disappearance of the sounds the minimal blood pressure (DBP) within the artery predominates over the pressure in the cuff. It follows that the manometric measures at this time correspond to the minimal blood pressure.

Korotkov's important contribution to medicine was the devising of this accurate and easy method of determining the blood pressure. His technique has stood the test of time as it has been used for more than half a century with practically no changes made to it.

Currently, this auscultatory method, and the previos oscillometric method are the fundamental techniques implemented in the majority of blood pressure monitors. Some of them employ both methods, auscultatory and oscillometric, using one method as a primary measurement and the other for verification, to minimise the inherent disadvantages of each one (Section 2.2.2).

1.2 Motivation

Non-invasive Blood Pressure measuring methods sacrifice a degree of accuracy for patient safety, comfort and convenience. Their use is convenient for giving us an idea of how the patients find themselves in certain precise and crucial moments. However, if what is wanted is to monitor the continuous evolution of patients in certain situations as, for instance, under the anaesthetic, in state of coma, or generally in patients where rapid variations in arterial pressure must be anticipated, it would be a better idea to use invasive catheterization procedures. These methods, which are seldom used exclusively for blood pressure measurement, are sometimes (due to bad interpretation and bad use of the equipment) associated with complications such as thrombosis, infection, embolism, and there is a danger of severe bleeding if the line becomes disconnected.

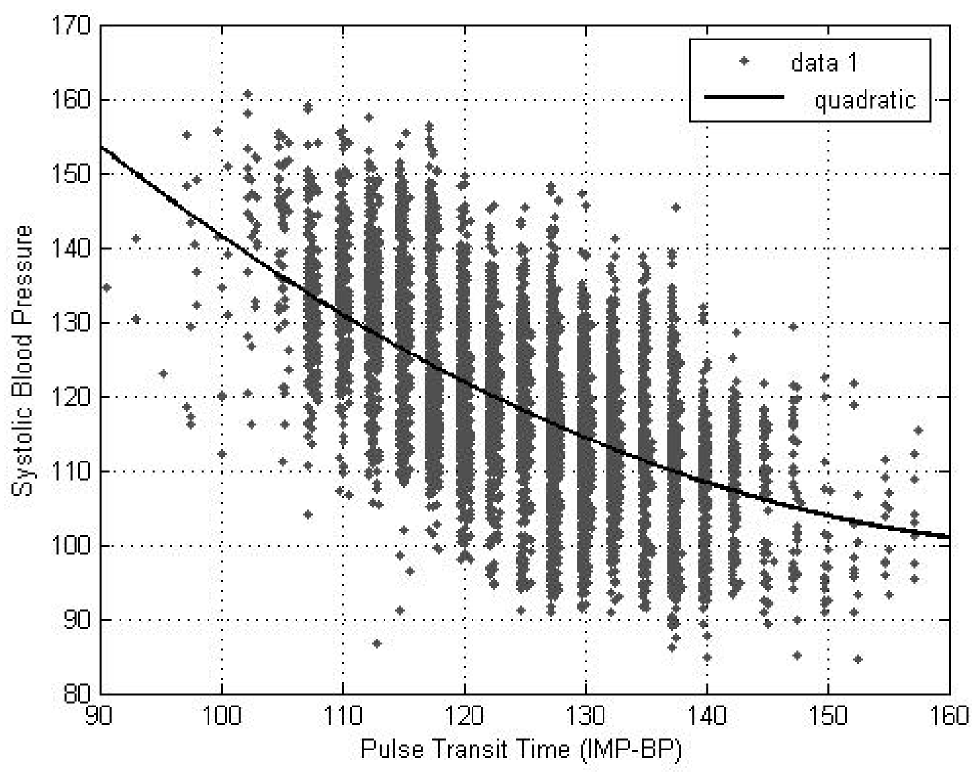

Figure 1.3: Pulse Transit Time versus Systolic Blood Pressure

The search of a non-invasive technique with the same or at least similar features of the invasive proceedings, in terms of accuracy and velocity regarding taking measures, entails the emergence of this project's main idea. What it is expected from this research is to determine the Blood Pressure by means of an automatically learning procedure, such as an *Atificial Neural Network* (ANN) and a set of data provided in *comma separated values* format (.csv). The patterns which constitute the dataset consist of features obtained from cardiovascular measuring techniques and blood pressure measures by means of invasive methods, necessaries for training and evaluation tasks. The most representative attribute within the patterns will be the*Pulse Transit Time* (PTT). It represents the taken time of the pulse wave to travel between two different points of the patient's body. The importance of this parameter falls on the idea that the pulse transit time and the blood pressure are related.

There must exist a relation between both parameters, but it seems, that many aspects influence the real relation (Figure fig:motivfgraph): position of the patient in which the measures are taken, place where the measures are taken, elasticity of the arterial walls or even other cardiovascular parameters such as hearth rate. This is why, as well as the PTT parameters, some other attributes will be considered. The complete set of available attributes will be described in Section 2.3.

ANN are a biologically inspired class of universal function aproximators capable of learning from experience. The designed Neural Network should be able to learn the relation explained above, using labelled data and afterwards calculating the BP itself.

1.3 Proceedment of the Work

In this thesis the most relevant tasks will be: deciding for an ANN simulation, select the features which can be used for detecting blood pressure and learning the best configuration for the network. After that will be done the learning (with labeled data) and will be tested the success using more labeled data.

Note 1 *All the simulations were carried out with the next softwares of Free License: javaNNS, from the University of Stuttgart, and Weka, from the University of Weikato. It was also necessary the aid from Matlab, specifically the Neuronal Network Toolbox.*

What it was made first of all, was an exhaustive documentation about how labeled data is obtained, and what does every parameter in the set of data means. Also a brief overview of how the different features are obtained is presented in Section 2.3. After that, it was the moment to learn the possibilities that the learning machines algorithms offer. The common fundamentals of ANN, are presented in the Chapter 3, without focus on the mathematical ideas, but only a general overview.

The provided set of data, carried out with the available equipment, Niccomo and Infinity measuring equipment, it could not be used immediately to train an ANN. Before this task, is necessary a data pre-processing. This is because, the data could contain outliers or incoherent instances, (each instance is a vector consist of values from all the attributes), empty values. Also because it could be a good idea, to apply different mathematical constructions to the instances, with the idea of test if any other works better. Also it seems to be needed to do a normalization of all the data, to make easier the learning periode. And the last, and most important task, it was the Feature Selection. It was needed to reduce considerably the number of inputs attributes, twenty-four for each transformation.
There were carried out two different algorithms, both with Weka. These were *Principal Component Analysis* (PCA), as non-supervised method, and Wrappers Simulations as supervised method. All these tasks will be carried out with Weka, and the results will be reported in the chapter 4. With the results from these

algorithms, it was the moment to start the simulations, and to determine which of the different input features collection, and output attributes, were the best. This was also done with Weka, and tested with a specific configuration of Neuronal Network.

In Chapter 5 will be the time to find the ANN configuration that minimizes the error of predictions. This configuration involves the learning algorithm, the number of hidden neurones, the activation functions, the number of epochs to train, and the connections between the neurones. The best configurations will be selected and brought to the next step in the research.

So it can be concluded that basically this research is a problem of finding an efficient subset from available dataset and after that the best configuration of parameters for training the artificial neural network with this data.

In Chapter 6, it will be compared, training the network with a subset of instances, which of the selected configurations has more ability to generalize from examples, and which need less number of instances to learn. Then it will be tested with a bigger set of data to check if it still works good. All the results and impressions of these simulations will be reported. And finally in the Chapter 7, all the conclusions observed during the realization of this thesis will be reported, and the results on estimation of Blood Pressure, compared with the official standards of measuring equipment.