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MASTER'S THESIS

Study program/specialization: **Cybernetics and Signal Processing**	Spring semester, 2022 Open / Confidential: **Open**
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Title of Master's thesis: **Analysis of ECG from resuscitation of asphyxial neonates**	
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Abstract

Aim: Due to a high mortality rate for neonates with asphyxia in low resource countries, studies like this emerge in hope to make a difference. Electrocardiogram (ECG) data is used in this project to examine and analyze the data automatic. This project is associated with the research program Safer Births `https://saferbirths.com/`. One goal of this project is to examine and obtain relevant information, which can predict feature outcomes or determine early to initiate treatment on neonates. By reacting early, asphyxiated neonates can be given a higher survival ratio.

Methods: Two methods are used to perform this project's analysis. The first method separate groups depending on how much the patient's ECG change during treatment. A change factor defines this change and is depending on the morphology of the early and late patient's ECG. Method number two, determine groups based on similarities of patients ECG. Groups are created is based on the correlation clustering method.

The project methods are used in two experiments. Both experiments are based on the correlation method in discrete time domain. Experiment one divide the ECG data into groups depending on the change factor. Three different parameter settings for the experiment is performed to examine relevant similarities or discrepancies. Experiment two creates ECG heartbeat category representations from clusters, early and late from the neonates ECG data.

By performing experiment one, it is obtained results regarding the number of changed segments and how much they change. With this knowledge in mind, experiment two examines the change (early to late) of the created category representations.

Both experiments extract manual recorded and automatic detected features from the created groups or categories. These features are analyzed with hypothesis tests with the aim of detecting difference between groups and categories. Tables are made to get obtain common factors and significant differences from the experiments.

Results: Experiment one presents that most of the studied patients ECG-data do not change. However, change of asphyxiated ECG symptoms can be observed in the different groups. Specific ECG related features can be problematic to detect automatically. The change factor in this study is mainly not due to changes in specific parts of the patient's ECG.

Experiment two indicates common occurrences in categories, which may be because all patients have a degree of asphyxia. However, it is concluded that with early initiated treatment ECG-segments can improve slightly, but will rarely change category.

Conclusion: An analysis program was developed and demonstrated on the data set. Results display the necessity for a sophisticated detection algorithm. Classification variables and results may require interpretation by clinicians as a quality assurance. Combining results from both experiments give the following conclusion: If a patient's ECG-segment correlate at an early stage in treatment with a category representation from this study (corr. coeff. $\geq$0.95), then the morphology of specific ECG parts will slightly improve with treatment, but do not leave that category.

Preface

The desire for this research study came from the thought of wanting to do something meaningful. This thesis marks the end of my period as a student at the University of Stavanger. While trying to balance family life and studying, I appreciated the time spent attaining knowledge. Learning about the Safer Births project gave me motivation and purpose while writing this thesis.

An exceptional large gratitude goes out to my family, Silje Kleiveland-Hanssen, Tilde and Tiril for the support and space they have given me. Tilde and Tiril were born pre-term and gave me an inspiration to pick the subject in this analysis. With a lot of hospital visits and examinations, I could relate to some struggles with pre-term births. Struggles were made easier with excellent guidance and love from my wife throughout the years as a student.

My parents and brothers have always cheered me up while pursuing an academic career. Without this support, I could not enjoy the years as a student! So a special thanks to you along with supporting friends in this academic endeavour.

I want to express gratitude to my supervisor Prof. Trygve C. Eftestøl for valuable guidance, feedback and thesis related discussions every week. Thank you for all the extra work you put in, outside the scheduled meetings.

Thanks to Joar Eilevstjønn, for replying to questions and the supply of knowledge about the data material. Much appreciation to the Safer Births project for letting me use their data.

Finally, I would like to thank UiS and student colleagues for five amazing years. Arrangements and environment have fulfilled all of my requirements. I would like to say thanks to Ståle Freyer and Romuald Karol Bernacki for providing guidance and assistance in everyday struggles as a student at UiS. A special thanks to Prof. Sven Ole Aase for interesting subjects and guidance outside the lecture hours. Subjects have been interesting and representing UiS as an exchange student were an unforgettable experience.

Contents

Content description

The project is divided into seven chapters. A descriptive list of figures, tables, listings and an abbreviation and glossary list is placed before chapter 1.

Chapter 1: Introduction

A brief introduction to what this paper is about, what is written, why it is written and what has been done. Finally, a more detailed chapter description.

Chapter 2: Background and theory

A short description of the background study and how data were collected. Subsequently, theory, methods and knowledge necessary to know in order to understand this paper will be explained (ECG, heart anatomy, treatment methods, analytic methods)

Chapter 3: Development

Used and implemented functions, program methods and choices are explained. A flowchart for the experiments are shown and explained. It is also stated why some parts were not implemented in the program as well or used before other functions.

Chapter 4: Experiments

Based on the considered options in chapter 3 some experiments are shown. The experiments are shown step by step with parameter inputs so that others can replicate for validation or do other experiments. Some temporary result figures are shown and explained for a more illustrative point in the program walk through.

Chapter 5: Results

A classdiagram illustrates the final program components. Some information in the results are explained and then the relevant results are shown.

Chapter 6: Discussion

This part will discuss the results and draw some conclusions. Afterwards some improvements, possible source of errors, future solutions, work for the future and a summary of the work will be discussed as well.

Parts after the discussion

A bibliography, figure of the poster representing the project, complete highlighted tables from results, boxplots of features from the experiments and a full program listing.

List of Figures

List of Tables

Listings

Abbreviations and glossary

Anoxia	Anoxia means without oxygen. The term is medically used for situation where the brain is without oxygen for a period of time or when tissue have a lack of oxygen [1].
Asphyxia	Asphyxia is a term for a general condition where the body's tissue lacks oxygen. It is a physiological result (of anoxia/hypoxia) due to lack of oxygen, usually because of low oxygen in the blood or bad blood flow. This is a most lethal condition for neonates and usual for preterm deliveries [2], [3].
BL	BL is short for an ECG-segment's baseline. In this project it is defined the median value of the ECG-segment..
BMV	BMV is short for bag mask ventilation.
DOE	DOE is short for design of experiments and is a structured efficient way of performing experiments which allows the examiner to understand the relationship between parameters and variables [4], [5].
DRM	DRM is short for deep reflex massage.
DRY	DRY is short for don't repeat yourself. In the dataprogramming world this statement is used as a reminder to keep the program clean, tidy and functional.
ECG	ECG is short for electrocardiography.
ECG-segment	Data of an ECG signal containing only one heartbeat (PQRST-complex).
HR	HR is short for heartrate.
HSD	HSD is an abbrevation for honestly significant difference.
Hypoxia	Hypoxia is a condition due to lack of oxygen to tissue/organ, in other words the supply is insufficient compared to the oxygen demand those cells need in order to operate normally. This condition can also develop due to ischemia [6].
Ischemia	The condition ischemia: a reduced or restricted blood flow in a part of the body or to an organ (including oxygen) [7].
Kruskal Wallis	KW is short for Kruskal Wallis.
Listings	Environment used to show relevant program parts in this document.
MAD	MAD is an abbrevation for median absolute deviation.
NaN	NaN is an abbrevation for Not a number in Matlab.
Notch filter	A notch filter is a type of band-stop filter, which is a filter that attenuates frequencies within a specific range while passing all other frequencies unaltered. For a notch filter, this range of frequencies is very narrow.

PA	PA is short for perinatal asphyxia which is the same as neonatal/birth asphyxia.
Pacemaker	A system that sends electrical impulses to the heart in order to set the heart rhythm [8].
PDF	pdf is short for probability distribution function.
Plot	plot is a function in Matlab to illustrate variables in different graphs. See `https://se.mathworks.com/help/matlab/creating_plots/types-of-matlab-plots.html` for different types of plotting functions..
Signal	A whole ECG-signal with multiple heart-beats.
SP	SP is short for statistical power. It is a measurement of a method's ability to detect true difference between groups.
Structure array	A structure array is a data type that groups related data using data containers called fields. Each field can contain any type of data [9].
SUS	SUS is short for Stavanger universitets sykehus.
Tinc	Tinc is short for T-wave's increase point.

Signal notations

- $b_i(n)$ $i \in [1, Nb]$: Patient number i's median ECG signal containing only one heartbeat (PQRST-complex). The letter b is short for beat (one heartbeat) and 'Nb' is the number of patients.
  - An 'E' or 'L' before index letters represent at which time period the ECG-segment is recorded/created.
- $C_{jk}(n)$, where $j \in [1, Ng]$, where $k \in [1, Ngel]$: $C_{jk}(n)$ are group number j's, patient number k's ECG-segment. Captial 'C' is short for change and refers to experiment one where change of beats are studied. if letter 'k' is not included (C_j) it denotes group number j. Ng is the number of groups while Ngel is the number of $b_i(n)$s in a group.

  In experiment two, similarities are studied instead of changes, and this is denoted with a captial 'S' (short for similarities) instead of 'C'. Example: $S_{jk}(n)$, where $j \in [1, Nc]$, where $k \in [1, Ncel]$, 'g' (groups) is switched with 'c' (clusters) at relevant locations.
- $\bar{b}_{Ci}(n)$ $i \in [1, Ng]$: is data of group i's median/mean representation ECG-signal containing only one heartbeat (PQRST-complex). As earlier mentioned 'Ng' is the number of groups in experiment 1.
- $\bar{b}_{Si}(n)$ $i \in [1, Nc]$: is data of cluster i's median/mean representation ECG signal containing only one heartbeat (PQRST-complex). As earlier mentioned 'Nc' is the number of clusters in experiment 2.
  - An 'E' or 'L' before the index letter represents if the group's/cluster's representation segment is created by patient's segments early (E) in BMV or after the treatment (L).
  - With the clustering method, $\bar{b}S_i(n)$s are based on $b_{Ei}(n)$s which are denoted $\bar{b}S_{Ei}(n)$s. These are also examined and created at a late time which is denoted $\bar{b}S_{ELi}(n)$.
  - The other case is where $\bar{b}S_i(n)$s are based on $b_{Li}(n)$s which are denoted $\bar{b}S_{Li}(n)$s. At an early creation time these are denoted $\bar{b}S_{LEi}(n)$ for examination.
- For some correlation measurements the letters representing time may be doubled or different, for example 'EL'. 'EL' will indicate that it is a correlation measure between an early segment and late, from early to late. 'LE' signifies a measure from late to early. 'EE' denotes two early segments, while 'LL' denotes two late segments.

1. Introduction

Initially, the task and the motivation behind it are described. This thesis is based on data obtained from an observational study of Størdal et al. in Tanzania, between 2013-2018 [10]. A research project called Safer Births is behind the study. A project division will also be presented at the end of this chapter.

1.1 Task description

After birth, some infants suffer from lack of oxygen. By stimulating the child to breathe through measures as massage and bag-mask-ventilation (BMV), recovery is possible. Used BMV equipment may be observed fig. 1.1. In an existent research alliance with SUS, the processes corresponding to the development of oxygen deficiency (asphyxia) in the baby, and the reaction of the treatment will be studied.

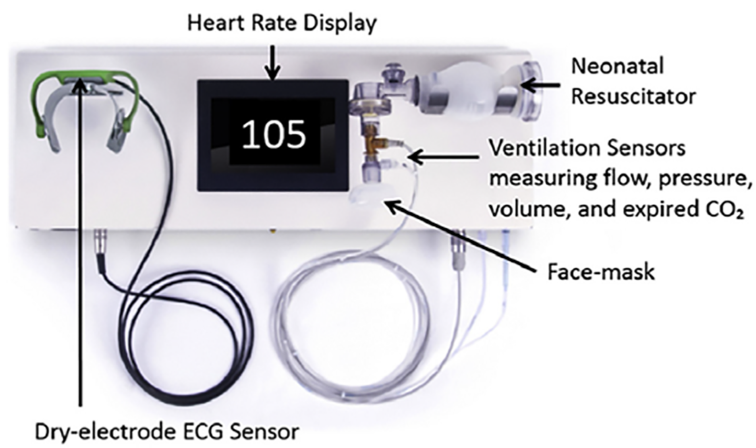


Figure 1.1: Equipment used for data acquisition. A newborn resuscitation monitor with dry-electrode ECG sensor (Laerdal Global Health, Stavanger, Norway) [10]).

In this thesis, the aim is to study changes in the electrocardiogram (ECG) in the newborn child. One should study how ECG characteristics alter or change with treatment. There is ECG accessible from newborns. The data materials are from resuscitated children.

It will be possible to study differences in children who have initially had the same degree of asphyxia and who after ventilation have different degrees of asphyxia. Subsequently, one can look at the ECG after ventilation to study the differences in ECG characteristics, and further study change from the start of ventilation. In addition, it may be possible to predict the end result of the ECG characteristics.

1.1.1 Task at hand

Data materials from the study of Linde et al. [11] will be used and analyzed in this project. Linde et al. used data from the study of Størdal et al.[10] to investigate ECG morphology in asphyxiated infants immediately after birth [11]. Organizing the data and setting up different grouping techniques, feature extraction and detection algorithms will be created. The algorithms are implemented in a program to be able to analyze the data. Correlation coefficients are used as a similarity measurement in this project. After collecting and processing the required data, some statistical hypothesis tests will be performed.

The first examination will group patients together by how much their ECG-segment changed. Data of an ECG-signal containing only one heartbeat is denoted an ECG-segment. Relevant change will be considered (in time) from early to after/late in the treatment. Questions that will be examined are whether there are any observable early features that make the end result predictable or give an indication of asphyxia? Does the change factor of the experiment depend on the shape of the ST-segment? The ST-segment is a specific part in a patient's ECG.

The second examination's starting point was proposed by this project's supervisor. Correlation clustering (read 2.2.3 or [12] for more information) is the principle behind this method. The examination, group early (with early) and late (with late) ECG-segments depending on the correlation coefficient between patient segments. Early ECG-segments will be grouped together if two requirements are met. The first will be the correlation coefficient, the similarity should be high. The second is the number of minimum group elements. One problem to inspect in this section is, can the early category representations be used to predict the future (late) category representations?

Relevant end result in this project will focus on ST-segment's features which is related to asphyxia according to the studies of Linde et al., Pal et al., Hanna et al. [11], [13], [14] and many more.

1.2 Motivation

Today, the third highest cause of newborn mortality is birth asphyxia (23% globally). When looking at long term injuries or effects of children experiencing asphyxia trauma, it may be clearly stated how important it is to capture the symptoms of these episodes as early as possible. An early detection will make it possible to react with the necessary treatment, so that the best possible result is achieved [10]. This thesis will focus on ECG-signals of neonates that have received little attention over the years. In contrast, ECG-signals on adults are widely used and have been researched to indicate heart diseases or other degenerates [15].

The first ECG was recorded in 1887. This recording led Willem Einthoven to win a Nobel Prize (1924) for discovering the importance of the mechanism of the ECG. In 1950, an article from Mathers et al. was published [16] who inspected if there is any correlation between the ECG, oxygen saturation in the blood, blood pressure and heart rate while performing anoxemia tests. The results showed changes occurring in the ECG due to asphyxia which may correlate to coronary heart disease. Mathers et al.'s article is an example that illustrates how the point of discovering the mechanisms later led to studies focusing on deep analysis of different ECG-segments and their waveforms. This thesis will similar to the study of Linde al. [11] extract ECG characteristics for specific parts of the neonates ECG [17].

Two aspects that should be considered is feature extraction methods and tools used to collect the data. In 2016 the study of Haritopoulos et al. published an article giving a summary of feature extraction algorithms for fetal welfare assessment [18]. This article summarizes steps that have been practiced in the field of pre-newborn, but can also provide an insight into the development of ECG evaluation. By observing and understanding the entire process, the loss of children can be prevented. The Safer Birth research focus on making the techniques and development accessible to everyone, especially low budget organizations.

1.3 Project divison

The project is further divided into four chapters: Background and theory, material and methods, results and discussion. First, background and theory provide insight into the background for this project and necessary knowledge. Chapter three, material and methods describe the data material and the methods used in this project. Last part of this chapter presents the experiments performed.

The following chapter presents this project's results. Some relevant results are compared with results from the study of Linde et al. [11]. Finally, in the discussion chapter, the results are evaluated in relation to the task description and a conclusion is drawn. The final chapter also provides a brief evaluation of potential problems with the program, results and opportunity for improvement to expand the project.

2. Background and Theory

This chapter present equipment, describe relevant medical and signal processing background, acquisition of data material and theory which is used in this project. How data is obtained can be read in a short summary, but for the complete description the reader should read the articles of Linde et al.[11] and Størdal et al.[10] which this project emerge from.

2.1 Medical background

This section will provide a brief summary and explanation of the techniques, methods, terms, software and other topics that are relevant in order to best understand this project.

2.1.1 Electrocardiogram

ECG is a fast and simple test that can be used to evaluate the heart. It is a measurement of the electrical activity of all the combined cardiac (heart) muscle cells. This project is based on the ECG-data of neonates. A neonate's ECG-data is commonly filled with noise and artifacts [19]. Nevertheless, when filtered and handled correctly, the ECG-data can still give early indications of asphyxia [11]. The goal is to utilize the information from the ECG-data to quickly respond and treat the neonate. An individual optimal treatment length will be preferred.

2.1.1.1 Heart anatomy and measurements

A human's heart consist of four chambers (see fig. 2.1a). Two upper chambers and two lower chambers. On the left, from upper to lower, the chambers are the left atria and ventricle. While on the right, they have the same just the right-side part included. Right side atria and ventricle delivers blood into the pulmonary circulation, while the left side delivers blood into the aorta. Aorta is the main artery of the body, which supplies oxygenated blood to the circulatory system.

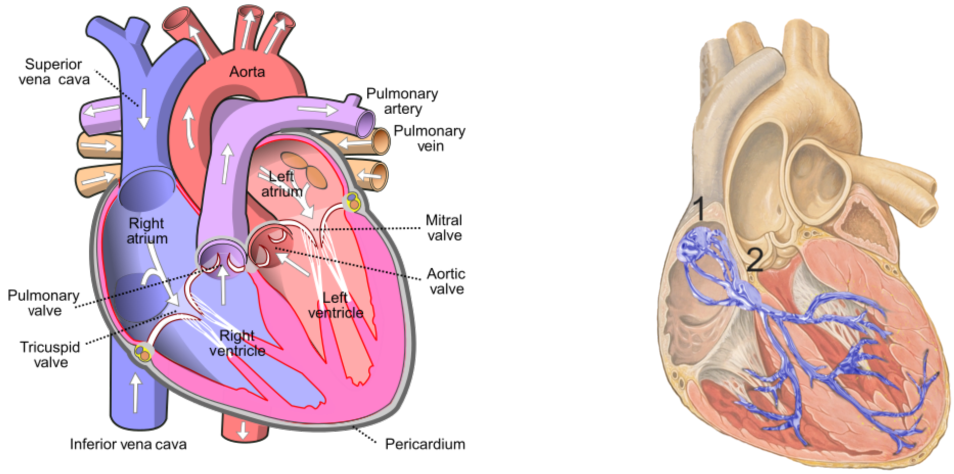
Steps of a heartbeat

The procedure of an ordinary, (healthy) average person's heartbeat will be described in these series of steps:

1. The right and left atrium will contract themselves, this results in the left and right ventricles getting filled with blood. In this step the ventricles are not actively doing anything.
2. After being filled with new oxygenated blood, the ventricles contract and closes the flaps leading to the atriums.
3. During the time when the atriums-ventricles flaps are closed, blood fills up the atriums with new oxygenated blood. Simultaneously, the blood is pumped out from the ventricles to the body's main circulatory system.

This process repeats itself over and over again in different paces depending on the situation the person is in. A relevant example to this project would be when the neonate is stressed, this pace (heartrate) is faster than usual.

Signals from the sinoatrial node (see fig. 2.1b) operates the heart to pump blood to the circulatory system. The sinoatrial node's main task is to control the heartbeats pace. By the English definition, the sinoatrial node is a pacemaker of the heart. Electrical signals of the heart can be recorded, for this case when heart muscles contract and not. A heart monitor can read these signals and the result depends on the quality of the monitor and measurement situation.



(a) Simplified picture of the left and right atriums and ventricles. Credit: `https://commons.wikimedia.org/w/index.php?curid=830253` / No changes were made. License: CC BY-NC-SA 3.0 [20], [21].

(b) Picture of the sinoatrial node at number 1. Credit: `https://commons.wikimedia.org/w/index.php?curid=1686121` / No changes were made. License: CC BY 2.5 [20],[22].

Figure 2.1: Some pictures to illustrate the anatomy of the heart [21], [22]

A preview of an ECG is illustrated below (Fig. 2.2). It can be observed that an ECG heartbeat period consist of multiple waves of different amplitude and frequencies. The amplitude and variance of the waves is dependant on which and how the atriums and ventricles emits electric signals [23], [24].

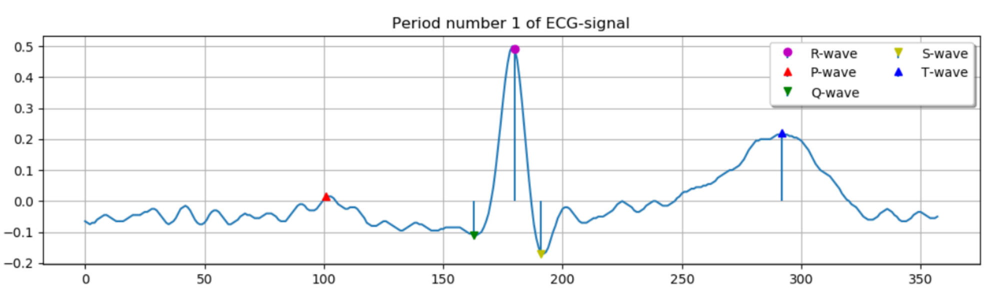


Figure 2.2: A heartbeat (PQRST-complex described in the next paragraph, signal retrieved from an ECG database on physionet [25]).

2.1.1.2 Need to know of a normal ECG

The different sinusoidal wave components in a normal ECG (see fig. 2.2 and 2.3) are denoted P, Q, R, S, T. The P-wave will occur because the atriums contract. Usually, the ventricles will be represented by three components: Q, R and S, where R is usually the peak with the largest positive amplitude. These waves are denoted as the QRS-complex and occurs when the ventricles contracts. The T-wave can be observed during the relaxation of the ventricles. These steps have been illustrated in figure 2.3. If fig. 2.2 is compared with fig. 2.3 it is easy to observe why preprocessing is important.

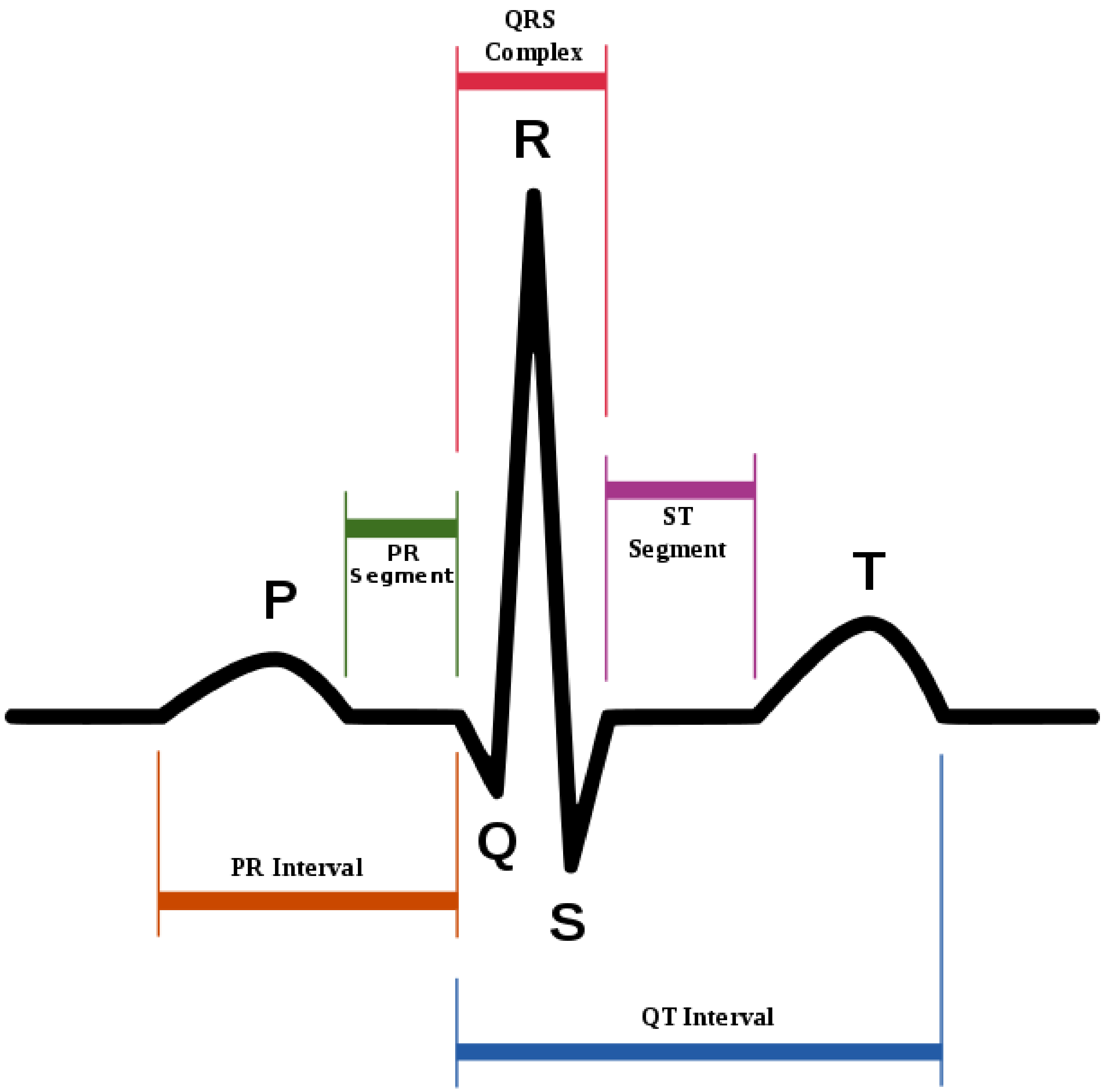


Figure 2.3: An ideal/theoretical heartbeat (PQRST-complex). Credits: `https://commons.wikimedia.org/wiki/File:SinusRhythmLabels.svg/` No changes were done. No CC [20]

Different techniques have been used when analyzing ECG-segments [18]. Within the subject physiology, different symptoms and heart diseases have been indicated by different distances between the waves (variance) and peak values (amplitudes). An ECG-segment can also indicate deviations of the heart rhythm. Finally, it is important to know that an ECG of a random person can vary from the normal ECG.

The guidelines on interpretations of neonatal ECG from the report of Schwartz et al. [19] will be used to interpret ECG from neonates as well as relevant ST-categories from the study of Linde et al. [11] (biphasic/abnormal, elevated, normal). From the guidelines in the report of Schwartz et al. [19], P-,R-,T-waves are commonly positive (above baseline) while Q- and S-waves should be below the baseline. The baseline will be denoted BL for the rest of the project. T-waves are also reported to vary a lot for neonates [19]. Normally the ECG-segment is dependent on age, physical condition, stress, heart disease and more. Figure 2.4 can illustrate typical differences in a random neonate's ECG with an adult's ECG [23], [24].

ECG-noise

One can never obtain noiseless ECG. By knowing what causes the noise makes it easier to filter much of the noise away, so that the signals is readable or adequate to work with. Noise within ECG-signals can be caused by:

- Loose or movement of electrodes (Example: movement artefacts from an uncontrollable neonate).
- Positioning of the electrodes.
- External noise, from equipment (BMV), powerline interference (grounding and shielding faults, ex.50Hz)

In this project's main patient data, the noise from BMV is marked. This BMV indication allows access to the ECG-signals under treatment (noise-full). These noise-full signals can be improved or the option to access the ECG-signals at a time without BMV treatment (less noise) can be made. Some noise ripples can be seen in fig. 2.4 and it is very usual to see more noise in neonates ECG-signals [26], [27].

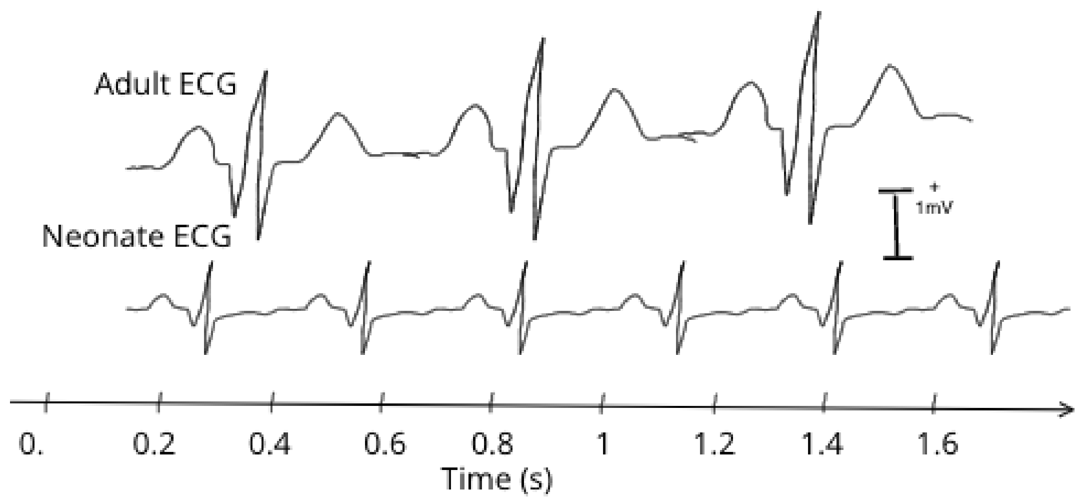


Figure 2.4: Illustrating some differences between neonates and adults common ECG (PQRST-complex [27]).

2.1.1.3 Asphyxia

By the definition in Abbreviations and glossary, it is easy to understand that asphyxia is the top third death reason of neonates. Hypoxia, anoxia, asphyxia and ischemia are closely related and is often used in wrong situations. To clarify the definitions, a simple description will be given (definitions can be found in Abbreviations and glossary).

- Hypoxia: Cells in the organ dies due to receiving too little oxygen (partial lack of oxygen).
- Anoxia: Related to brain damage, due to lack of oxygen (without oxygen) [28].
- Ischemia: Receiving too little blood (more severe than hypoxia).
- Asphyxia: Physiological result of hypoxia and anoxia.

The body depends on sufficient oxygen to function properly [16]. Asphyxia can also be a root cause of death of neonates before, during and immediately after birth. Fetus asphyxia (asphyxia before birth) can occur if the oxygen supply from the placenta through the umbilical cord is obstructed for some reason. In post-term deliveries of neonates, fetus asphyxia usually occurs because the placenta undergoes degenerative changes which obstructs the oxygen supply. If fetus asphyxia occurs then the fetus will either be delivered dead or alive with symptoms of asphyxia (low heart rate, acidosis [13], [29], bluish tone and others). Depending on the treatment and situation, the fetus may recover.

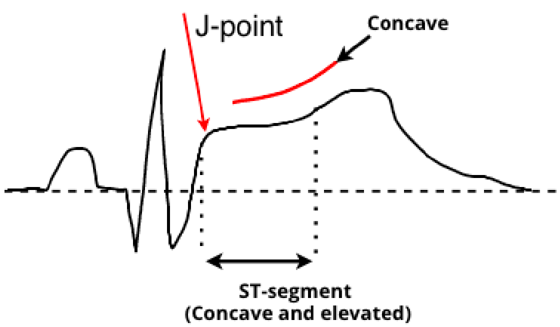
Congenital asphyxia can also occur because the newborn do not start to breathe after birth. This can be due to brain damage which paralyzes the brain-center that controls the respiratory activity. Other causes can be found due to different diseases that leads to oxygen deprivation in the brain.

Asphyxia can also emerge during the first days after birth. This is more usual for preterm delivers, which have a less developed regulation of the breathing activity [2], [7].

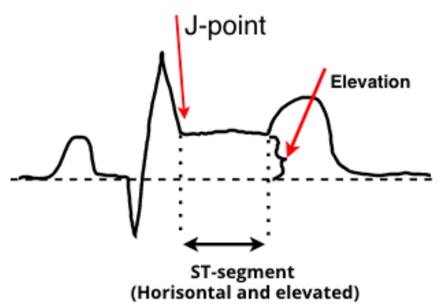
ST-segment

Previous studies [11], [16] have demonstrated a clear correlation between asphyxia and the ST-segment's morphology. The ST-segment is measured from the end of the R-wave, also called the J-point, to the start of the T-wave. However, this segment is elevated with regards to the BL, asphyxia can be identified. In the following figures 2.5 and 2.6 the BL is the dotted line and can be used as a measurement point with regards to elevation. In the study of Linde et al. [11], the analysis concerns this ST-segment.

The J-point is usually on the BL, but there are some exceptions. Figure 2.5a presents an example of an increasing ST-segment which is usually not a negative symptom. In many cases this ST-segment can also be found in young, well-trained men, due to early re-polarizing. If the elevated ST-segment is horizontal (fig. 2.5b), it indicates a typical sickness symptom. Ischemia is usually suspected when the BL is elevated or depressed, depending on the ECG-electrodes placement compared to the ischemic body area (area lacking blood).



(a) Elevated increasing ST-segment [23].



(b) Horizontally elevated ST-segment [23].

Figure 2.5: Different situations of ST-elevation [23]

Fig. 2.6 illustrates an ischemia situation when the ST-segment is below BL. It can also be a situation where the neonate is unable to respond or did not have enough time to respond. The latter is more commonly related to a biphasic segment (fig. 2.7).

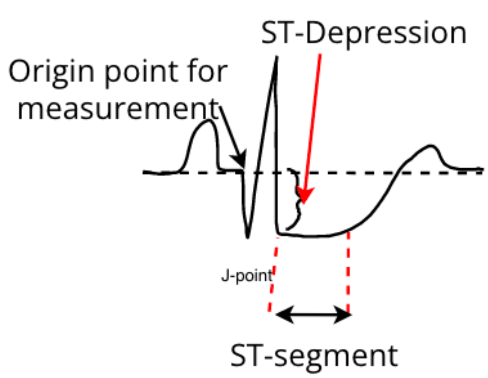
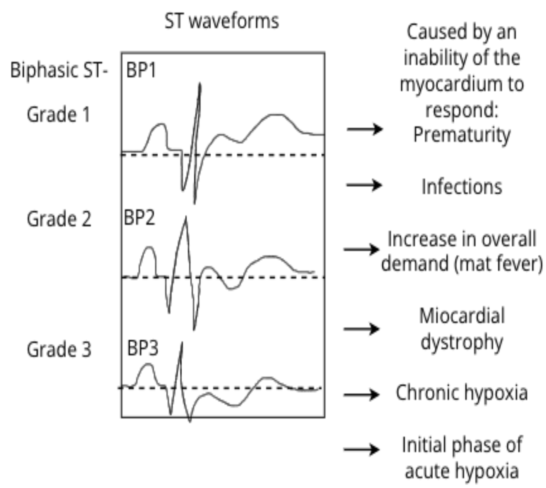
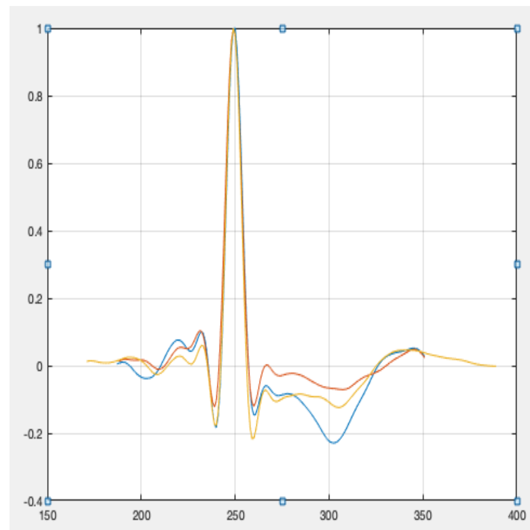


Figure 2.6: An example of ST-depression heartbeat [23].

A biphasic ST-segment is an alternating ST-segment. In other words shaped like a sinusoidal signal. Depending on how the ST-segment is placed according to the BL, it is denounced to three grades (biphasic 1, 2 and 3, fig.2.7a). It is called a grade one if the alternating ST-segment is above BL. Grade two is when the segment is crossing the BL, and grade three is if the segment stays below the BL. Figure 2.7b illustrates representative segments from this study which seems to be of grade three. Grade two and three can relate to the electrical flow between the three layers of the heart wall (endocardium-myocardium-epicardium). These grades are significant and can be found if the myocardium is thin, which is common for preterm fetuses. Hypoxia, myocardinal diesase and infection can also show biphasic 2 and 3 ST-shapes [30].



(a) ST-segments alteration with possible cause [30].



(b) Median representative ST-segment from the early measurement in this study.

Figure 2.7: ST-alteration, three grades of biphasic events compared to median representative of three groups during early measurements [30].

2.1.1.4 T-wave inversion

T-wave can vary the first weeks after birth. However, the common wave amplitude should be positive when using sensor configuration lead 1 [19], [23]. Abnormal amplitude results like low T-peak value (common for neonates) or T-wave inversion usually indicate a negative symptom. Myocardial ischemia is one of those symptoms which is usually observed on asphyxiated neonates [19], [23].

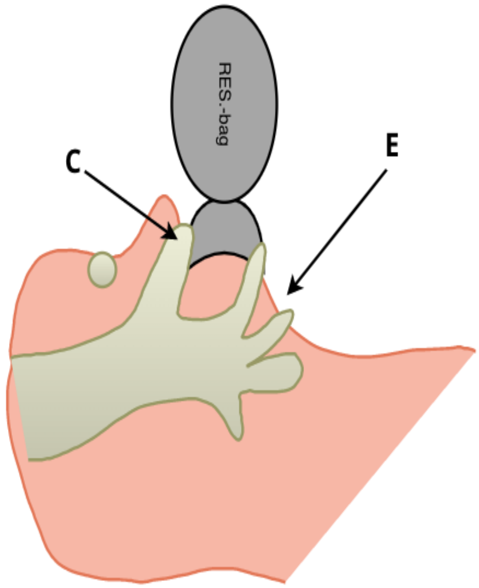
2.1.2 Treatment methods

Two methods to use in an asphyxiated birth situation is explained below. A short relevant description is given for more information, review the citations.

2.1.2.1 Bag mask ventilation

BMV is a method to deliver oxygen and breaths to an individual. In this study, the individuals is asphyxiated children. A self-inflating resuscitator bag is used which can be see in fig. 1.1. The bags come in different sizes (infant, child, adult) and should always be used accordingly. BMV should be initiated if the person is conscious, but have problem breathing. If the child is unresponsive and have stopped breathing, BMV should also be initiated. Next, some pointers to keep in mind when performing BMV. Use one hand on the face-mask and the other hand on the bag. Avoid pressure on the patient's throat, lift the jaw and keep an open airway ('CE' clamp grip, fig. 2.8b). The breaths should be delivered every third seconds, check if the chest rises and time to exhale. For more detailed information see instructions from: Seattle children's hospital research foundation [31].

(a) Example of standard BMV equipment. Credits: `https://commons.wikimedia.org/wiki/File:Bag_mask_ventilation_device.jpg/` No changes were done. License: CC BY-SA 4.0 [20]



(b) Thumb and index finger puts pressure on the mask with a 'C' shape, while the other three fingers is shaped in an 'E' to lift the jaw and open the airway.

Figure 2.8: Standard BMV equipment and recommended hand positioning on face mask when performing BMV [31].

2.1.2.2 Massage for asphyxiated neonates

Deep reflex massage (DRM) is the focus in the article of Turchaninov et al. [32]. In severe asphyxia, where brain damage is statistically irreversible, massage has been revealed to only maintain the quality of life [32]. In other cases with mild and low symptoms of asphyxia, massage can play a role in the child's recovery. If performed correctly and on time, it can increase brain perfusion and recover neurons.

DRM is a massage method accepted in some pediatric hospitals as a standard treatment procedure for asphyxiated children. This type of massage was developed for infants with perinatal asphyxia (PA) by professor Aksenova. Performing intense reflex stimulation of the soft tissues has shown to increase blood circulation in the brain and spinal cord, which is the main point of DRM. The massage performed in the study of Størdal et al. [10] is not the same as DRM by Aksenova. Nevertheless, the massage may have these effects on the neonates. In [11] the massage was not the main focus of the study. DRM treatment plan for PA neonates continues for several weeks with ten to twenty minutes several sessions daily, two to three times per week. This is neither monitored in the study [11], but a principal could be to see whether the early massage can correlate to any modification of the ECG [10], [11], [32].

2.1.3 Apgar score

An Apgar score is used in this project's analysis. Therefore, it is described in this paragraph. Apgar score result is a value related to a test, that examines the baby's muscle tone, heart rate, breathing effort, skin color and reflexes. The test is performed to check if extra emergency care is required. It was introduced in 1952 by Virginia Apgar and is now a standard examination on newborn babies. The Apgar scores is numerated from one to ten. A high number is indicating that the baby is in good condition, f.ex. seven and above is a usual sign among healthy newborn babies. This test method is performed after one and five minutes after childbirth. In a number of occurrences it is also performed after ten minutes depending on the conditions and child safety [33].

2.2 Signal processing background

The most essential methods used in this project is described below. They are important for the reader to know and understand before proceeding with the reading as much of the program's algorithm uses these methods.

2.2.1 Correlation

Correlation coefficients will be calculated and used in this project as a similarity measure. The similarity measure describes how similar the two ECG's under assessment are. Equation 2.1 display how the correlation calculations are performed. Equation 2.1 is used in this project's program and figure 2.9 illustrates an example.

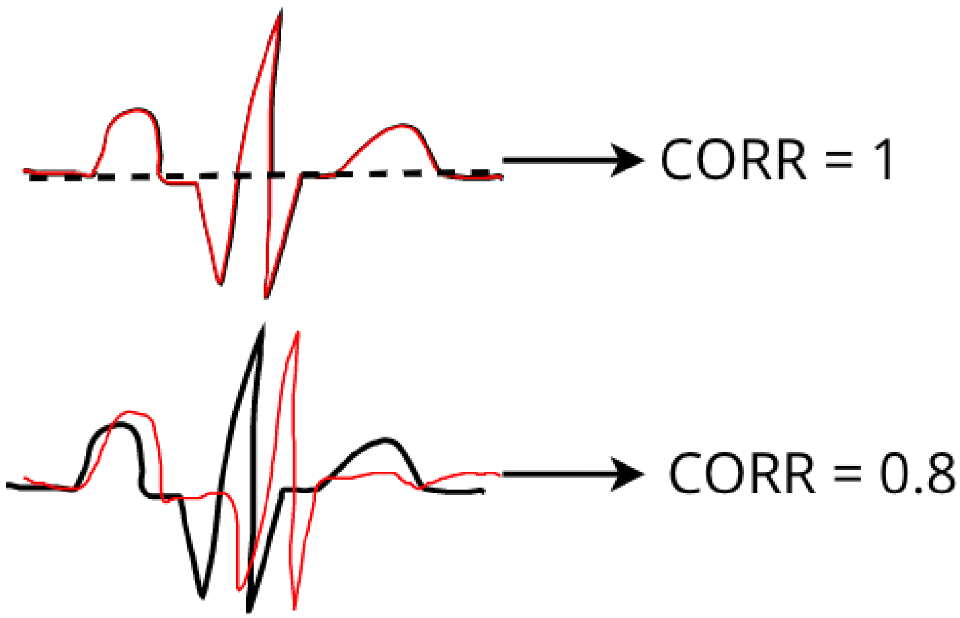


Figure 2.9: Illustrates an example of two and two segments correlated with each other

A correlation factor is always between zero and one, or minus one. The denominator in equation 2.1 make the correlation coefficient result normalized. If the value is zero, there is no correlation or similarity between the ECG-segments. If the value is between zero and one, the inputs have a positive correlation relation. In basic mathematics with two variables, this means that when one of the variable increases, so does the other. If the value is between zero and minus one, the variables correlate negatively. In other words, one variable increases and the other decreases, a relation where the variables are exactly opposite of each other. If the value is one, the variables are identical. If it is minus one, then it is the inverted variable. For this project, it is only interesting to see whether they correlate or not. Thus, the absolute value is being used in equation 2.1 [29], [34], [35].

$$\delta(x,y) = |\frac{\sum_{n=0}^{N-1} x(n)y(n)}{[\sum_{n=0}^{N-1} x(n)^2 * \sum_{n=0}^{N-1} y(n)^2]^{1/2}}| \tag{2.1}$$

2.2.2 Cross Correlation function

In this project, the cross-correlation function will be used to align ECG-segments. Equation 2.2 display how the cross-correlation function is defined between two signals (x(n) and y(n)). This function is often used as a time domain method. It is a sliding function of the normal correlation calculations. Figure 2.10 illustrate how the correlation coefficients are calculated while sliding two segments over each other.

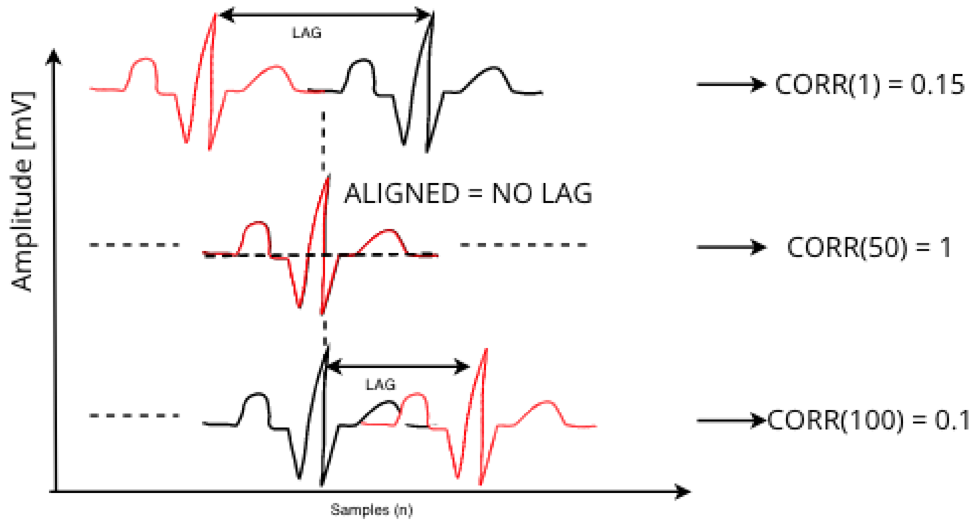


Figure 2.10: Illustrates an example of two segments sliding and calculating the correlation. For every shift/slide a coefficient is calculated, these are represented by the numbers for 'k' (corr(k)).

One ECG-segment slides on top of the other while at each index calculating the correlation coefficient at that position. The shift 'k' represents the lag (delay) between the assessed ECG-segments and the mean is subtracted to see how much the signals vary from the mean. In other words the numerator of equation 2.2 is the cross-covariance. The covariance describes how much the signals value vary from the expected value. In the project, a maximum cross-correlation factor is of interest because there may be displacement between the ECG-segments [36], [37].

$$\delta_{xy}(k) = \frac{\sum_{n=0}^{N-1}(x(n)-\bar{x})(y(n-k)-\bar{y})}{[\sum_{n=0}^{N-1}(x(n)-\bar{x})^2 * \sum_{n=0}^{N-1}(y(n-k)-\bar{y})^2]^{1/2}} \tag{2.2}$$

2.2.3 Correlation clustering

With regards to ECG-segments, this method cluster (groups) segments together that are similar to each other. An example from this project can be observed in fig. 3.10 where similar ECG-segments are clustered together in nine different groups (each subplot represent a group). The method separate groups based on a similarity demand set as a correlation coefficient. Figure 2.11 display the clustering principle where a sample of marbles is separated due to the color similarity [12].

Figure 2.11: Displaying the correlation clustering principle, marbles are separated by performing a correlation check focusing on the color (data value) of the marbles.

2.3 Statiscal background (hypothesis testing)

A Kruskal-Wallis test is performed between the group features in the project. This test is chosen due to: unequal variances and sample size, multiple group comparison, independent observations and it is assumed that the groups have the same distribution. The main hypothesis at 5% significance level used when comparing the feature groups are:

- H_0: There is no significant difference between any groups.
- H_1: There is significant difference between one or more groups.

If the null hypothesis is rejected a post-hoc pairwise comparison test is performed. The Scheffe method is not used due to its low statistical power. Next, the Bonferroni method is also not used due to its requirement of planned sets comparison. The groups are compared using Tukey Kramer's honestly significant difference (HSD) procedure. With Tukey's HSD, only the 5% significant comparisons in each feature are illustrated with tables (see e.g.,4.2. Results from Tukey's HSD tables will not all be compliant with the boxplots (view in 6.7) due to removal of the outliers in the boxplots [38], [39].

Some features are also tested for change after treatment, this required another test. A t-test examines if there is significant change in a feature between early and late. Due to the relationship and unequal variance of the groups, a paired t-test is chosen. Below are the features examined with a t-test [40]:

- ST-elevation
- Average R-peak amplitude

2.4 Data-material background

Depending on how the measurements were registered, the total ECG-segment can be inverted depending on how the measurement nodes are located. In this project, the placement of the sensor could vary (inverted polarity) which can be seen in the data. A dry electrode configuration was used as an ECG-sensor, similar to type lead I, standard ECG (over the torso). With an ECG bandwidth from 1-150Hz, the monitor is mainly designed for HR (heartrate) feedback. This measurement device was handled by trained non-medical research assistants. The newborn resuscitation monitors with dry-electrode ECG sensor have been developed by Laerdal Global Health. This equipment was installed for the observational study of Størdal et al. [10] in the operational theatre and delivery rooms. The Equipment used is displayed in fig. 1.1. Results from using this BMV equipment is examined in the study of Thallinger et al. [41].

Due to the results from 'The Helping Babies Breathe' program (2009-2012, `https://laerdalglobalhealth.com/partnerships-and-programs/helping-babies-breathe/`), a follow up study was conducted. The follow up study's main objective was to examine if reductions in perinatal mortality was sustained. Haydom Lutheran Hospital (HLH) is a referral hospital in Tanzania where the data was collected. With 3600-4600 annual deliveries, the study of Størdal et al. [10] was certain to provide relevant data. The data has been collected over a period of five years, between 01.07.13 and 30.06.18. For more information about HLH see `https://haydom.no/`. [10], [11].

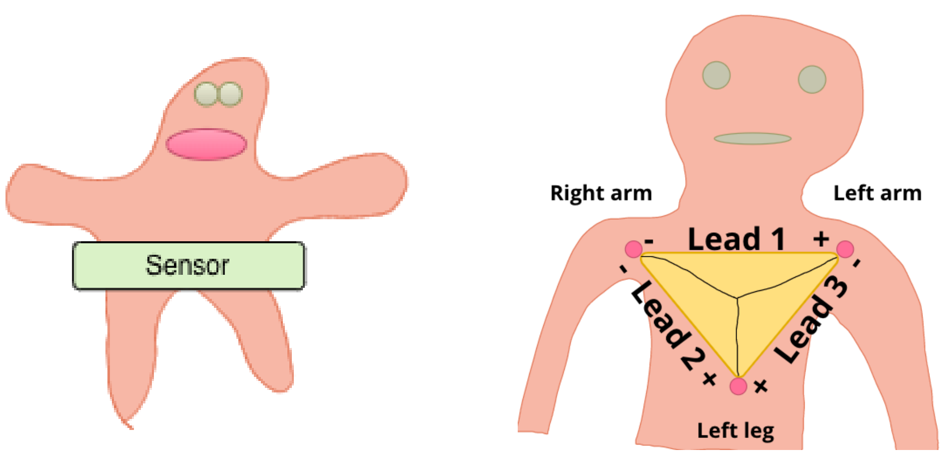
3. Materials and methods

This chapter describe the material, signal notations and methods used to get the results in chapter 4. Final section of the chapter contain some insight into the experiments that were performed. Methods are based on theory from chapter 2.

3.1 Data-material

The signals which are included in this study were obtained from infants around 34 weeks to term. The infants received BMV and had readable ECG graphs. All signals are sampled at 500Hz (sampling frequency) and samples are scaled to mV. Starting material in the study of Størdal et al. [10] were about 19 571 births which were monitored and stored. After preprocessing, about 547 readable signals were obtained which passed the requirements mentioned above. 53 of these signals are excluded in the study of Linde et al. [11] because a ST-interval morphology requirement (noise not interrupting the analysis) was not met. In this project the 53 signals are included because this project is using a correlation (see 2.2) measurement which will classify it's ST-segment status. A control group of 44 healthy newborns without resuscitation needs after birth were included in the article of Linde et al. [11]. 25 of these ECG-signals were "noiseless" and could be evaluated in the analysis. This control group is not included in this project because the results will be evaluated with regards to before and after the treatment. To sum up, all 547 neonates had asphyxia symptoms and were treated with positive pressure ventilation (PPV, with the BMV).

In the observational study of Størdal et al. [10], trained midwives were responsible for the newborn resuscitation. A detailed delivery procedure can be read in the published article of Størdal et al. [10], but for this project it was observed that some of the signals had inverted polarity readings (note, it was used a roughly lead I configuration). Commonly, lead I configuration is where the negative electrode is attached to the right shoulder and the positive electrode to the left shoulder (fig. 3.1b). By switching the electrodes, the signal will be inverted. In the study of Størdal et al. [10], the ECG sensor is placed around the newborn's torso (illustrated in fig. 3.1a). Delivery can be a difficult situation that makes it possible to invert the sensor without further consideration. The purpose of this siding should be noted before proceeding with an automated algorithm [10], [11], [42].



(a) Placement of a roughly Lead I configuration on a newborn).

(b) Einthoven's triangle with lead I to III placement indicated.

Figure 3.1: Situational vs theory, pictures of ECG sensor placement [11], [42]

3.1.1 Pre-processing of the data

Pre-processing is done in Matlab R2020a (MathWorks Inc., Natick, MA, USA) in the study of Linde et al. [11]. Data signals were filtered with a 50Hz band-stop filter (notch, hardware filter highpass (HP) and lowpass(LP)) and zero-phase forward. The last pre-processing technique is used to avoid phase distortion. Reverse filtering the current signals improves the phase-distortion [11].

In this project Matlab R2020b is used and the data has been filtered further. It was filtered with a digital version of the used hardware resistance-capacitance (RC) HP-filter. This was performed on the reversed signals to avoid the phase-distortion emerging from the use of the hardware filter. The fake ST-elevations emerging from the phase-distortion would then be reduced. In other words, it is important to note that the signals used in this project is not identical to the signals in the article of Linde et al. [11].

Two periods of every neonate's ECG was sorted, one early (first 30 successive QRS-complexes) and one late(last 30 successive QRS-complexes). In these periods the HR had to be less than twenty bpm (beats per minute) and the early period had to be recorded within three minutes after birth. Afterwards, a median QRS-complex was found to improve SNR (signal-to-noise-ratio) and have a good QRS representation complex from the neonate. This median representation is found for both the early and late periods [11].

All patient's ECG-signals that are used in this project are these created median segments mentioned above. These ECG-signals are further processed in this project's experiments. Notation used for relevant signals in the project will be explained in 3.2 but are also described in the signal notations section.

3.1.2 Feature results explanation

Features that are examined in the project require some insights. A short description of the notations are display in figures 3.2 and 3.3. Neonate's Apgar scores, ST-elevation, BMV duration and outcome were manually recorded in the study of Linde et al. [11]. Complete tables are observable in the appendix chapter 6. Those tables contain more features which are described in figure 6.31.

Notations	0	1	2	3	4	5	6
Features							
Outcome		Normal, infant survives	Admitted	Death(>24h)	Death(<24h)	Stillborn	
ST-elevation (startST/eSTel and endST/lSTel)		Not assessable (could not be examined)	Presumed Normal	ST-elevation	Other ST-segment (biphasic, downsloping, upsloping, etc)	Depressed	
ST-shape (eSTshape and lSTshape)	Unclassified	Biphasic	Biphasic	Flat, no rise from S-peak	Flat, rise from S-peak	Upsloping	Downsloping
'e' or 'l' in the name of the feature signifies whether the feature is registered from patient's ECG-segments early or late in BMV.							

Figure 3.2: Summary of feature result notations regarding outcome, ST-elevation and ST-morphology.

Feature	Descriptions:
Elements	The number of ECG-segments in a group (exp. 1) or category (exp. 2).
vent	Duration of a neonate's BMV treatment in seconds.
apg1 and apg5	The Apgar score of a neonate registered after 1 minute (apg1) and 5 minutes (apg5).
eCdetect and lCdetect	The number of times the detection algorithm run without program errors.
eSTint and lSTint	The number of samples in the ST-segment.
eSTintEST and lSTintEST	The number of samples in an estimated ST-segment. It is used as a backup measure when the ST-segment is not detected. The estimated segment is calculated from S-peak to T-peak.
eSTelN and lSTelN	The number of times where the ST-segment is detected to have a positive ST-elevation.
'e' or 'l' in the name of the feature signifies whether the feature is registered from patient's ECG-segments early or late in BMV.	

Figure 3.3: Summary of feature result notations which require a description.

3.2 Methodology

This section presents developed methods for automatic detection of features and conducting the experiments. The automatic detection methods which are essential to this project will be described before the experiments. These automatic detection methods are used in both experiments. Note, the ECG-segments are aligned and trimmed to equal size, before every group/cluster correlation calculation between patient's segments in this project. A summary of the aligning and trimming can be observed in figures 6.14 and 6.13. First, a summary of the developed program which implements methods presented in this section will be presented.

Figure 3.4 illustrate steps in this project's method and a summary of the developed program. Two of the steps (step 1 and 2) in figure 3.4 are important in the project's analysis. Step 3 is performed to verify the difference in data between this project and the study of Linde et al. [11].

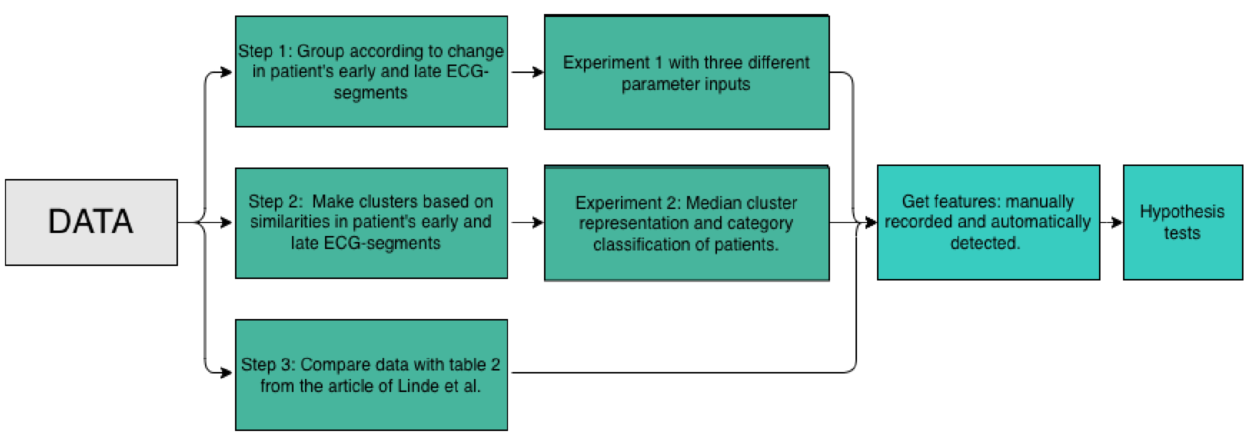


Figure 3.4: Flowchart summary of the program

3.2.1 Developed methods for the automatic detection

Standard peak detection methods are used to find the QRS-complex. The R-peak is chosen as the maximum value in the ECG-segment. Q-and S-peaks are found as the first minimum value from R-peak by searching in opposite directions of the segment (displayed in figure 3.5).

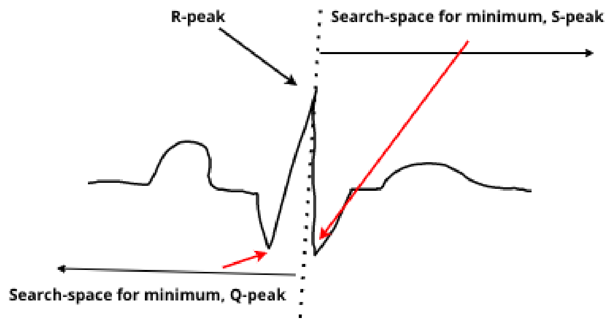


Figure 3.5: Search space for Q-peak and S-peak

Thereafter, T is found as the maximum value in the search space from S-peak to the end of the ECG-segment (illustrated in figure 3.6).

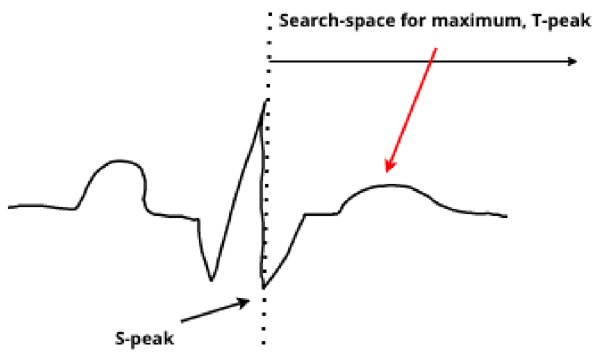


Figure 3.6: Search space for T-peak, from S-peak to end of ECG-segment

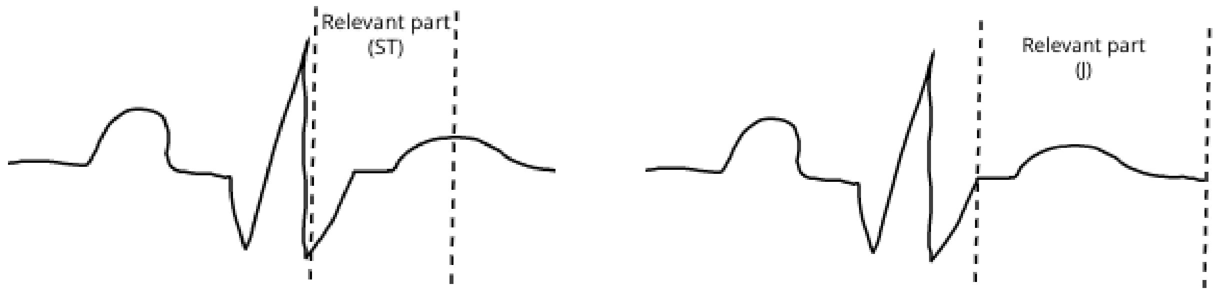
P-peak is neglected since this project focus is on the ST-segment. If any part of the automatic detection fails, the ECG-segment will not be used for feature extraction (used as unclassified ECG-segment).

The most essential methods for automatic feature detection are determined the ones concerning the ST-segment. Three different methods examine the ST-segment features. One inspect the sample size of the ST-segment's interval, the second estimates elevation and the third describes the morphology. The following paragraphs explain these three methods with an arbitrary patient's ECG-segment $\mathrm{b}_i(\mathrm{n})$. 'N' is used as the length of the segment and 'n' denotes the sample. The discrete derivative of $\mathrm{b}_i(\mathrm{n})$ is denoted $\hat{b}_i(\mathrm{n})$.

$$\hat{b}_i(n) = \frac{b_i(n+1) - b_i(n)}{\Delta} \tag{3.1}$$

In this description, letters in front of the patient's index represents a part of $\mathrm{b}_i(\mathrm{n})$. Two examples as an explanation:

- $\mathrm{b}_{STi}(\mathrm{n})$: ECG-segment part from S-peak to T-peak. Observe figure 3.7a for illustration.
- $\mathrm{b}_{Ji}(\mathrm{n})$: ECG-segment part from J-point to N. Observe figure 3.7b for illustration.



(a) b_{STi}(n) part of an ECG-segment illustrated with dotted lines.

(b) b_{Ji}(n) part of an ECG-segment illustrated with dotted lines.

Figure 3.7: Illustrations for ECG-segment parts b_{STi}(n) and b_{Ji}(n)

3.2.1.1 ST-segment interval detection

First part of the methods tries to find the interval starting from the J-point to the start of the T-wave. The J-point is found as the first sample in $\hat{b}_{Si}(n)$ which meet the following condition:

$$\text{J-point} = |\hat{b}_{Si}(n)| \leq 0.01 \tag{3.2}$$

The first sample which meet the condition mentioned in the equation above is illustrated in figure 3.8.

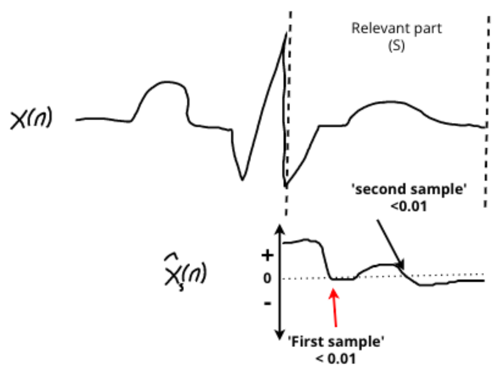


Figure 3.8: Search space for J-point, from S-peak to end of ECG-segment and the function first illustrated

Then the start of the T-wave is found as the steepest increase between J-point and T-peak, denoted Tinc. Thus, the ST-interval is found.

$$\text{ST-interval} = b_{JTinci}(n) \tag{3.3}$$

If this fails, an estimated ST-segment will be used as a backup measure, from S-peak to T-peak:

$$\text{Estimated ST-interval} = b_{STi}(n) \tag{3.4}$$

After determining the ST-interval, the segment's elevation and morphology can be found.

3.2.1.2 ST-segment elevation detection

This method depend on b_i(n)'s BL and the data values of b_{JTinci}(n). First the data values of the ST-segment are examined and put into the vectors **l**, **o** and **h**. These vector notations are from different conditions of ST-elevation and are described in the list below:

- **l**: Values which have a value more negative than a boundary around BL.
- **o**: Values which have a value around the BL.
- **h**: Values which have a value more positive than a boundary around BL.

A 20% boundary is set around the BL determining the groups limits. The decided boundary value is based on trial and error with the project's experiments. If BL is positive then:

$$\begin{aligned}\mathbf{l} &= b_{JTinci}(n) < 0.8 * BL \\ \mathbf{o} &= 0.8 * BL \leq b_{JTinci}(n) \leq 1.2 * BL \\ \mathbf{h} &= b_{JTinci}(n) > 1.2 * BL\end{aligned}$$

If BL have a negative value in the formulas above, then the 'less than' and 'greater than' (crocodile) signs are put in the opposite direction. In some cases the BL value is zero then the following limits are set:

$$\begin{aligned}\mathbf{l} &= b_{JTinci}(n) < BL \\ \mathbf{o} &= BL \leq b_{JTinci}(n) \leq 0.05 \\ \mathbf{h} &= b_{JTinci}(n) > 0.05\end{aligned}$$

The vectors length are found to determine how much of the ST-segment is above the BL:

$$\begin{aligned}\mathrm{N}_{low} &= |\mathbf{l}| \\ \mathrm{N}_{ok} &= |\mathbf{o}| \\ \mathrm{N}_{high} &= |\mathbf{h}|\end{aligned}$$

At this point the elevation of the ST-segment can be classified. The lengths of each group is compared against the ST-segment's length (N_{ST}). The categories for the ST-segment are denoted: depressed, elevated, normal, abnormal and Unclassified. The numbers in the the list below (1,2,3,4,5) denotes the ST-segment's elevation in the results chapter 4.

1. Unclassified: If any part of the method fails or if the segment is not put in any other category.
2. $$\text{Normal} = \mathrm{N}_{ok}/N_{ST} \geq 0.75 \tag{3.5}$$
3. $$\text{Elevated} = \mathrm{N}_{high}/N_{ST} \geq 0.75 \qquad \text{or if} \tag{3.6}$$
   $$= (\mathrm{N}_{ok}+\mathrm{N}_{high})/N_{ST} \geq 0.75 \tag{3.7}$$
4. $$\text{Abnormal (biphasic)} = (\mathrm{N}_{low}+\mathrm{N}_{high})/N_{ST} \geq 0.75 \tag{3.8}$$
5. $$\text{Depressed} = \mathrm{N}_{low}/N_{ST} \geq 0.75 \qquad \text{or if} \tag{3.9}$$
   $$= (\mathrm{N}_{ok}+\mathrm{N}_{low})/N_{ST} \geq 0.75 \tag{3.10}$$

3.2.1.3 ST-segment morphology detection

A simple wave generator was developed for this method. The ST-interval is denoted b_{ST}(n) for the description of this method. Generated signals have identical length as the ST-interval (N_{ST}). The different signal shapes which are generated are:

1. Biphasic signal modelled after a sinus wave.
2. Biphasic signal modelled after a cosine wave.
   - Both biphasic signals have an increasing amplitude which oscillate around the median value of the ST-interval which will be denoted ST_{BL}. Final amplitude size depends on ST_{BL}.
3. Flat signal, keeping the first value of the ST-interval.
4. Flat signal with rise in the start of the ST-interval.
5. Adaptable signal (for this explanation it is denoted x(n)), which starts with rise and increase/decrease to the ST-interval's last data value. Then the morphology is classified depending on:

$$\begin{array}{ll} \text{Upsloping} & \text{for } median(x'(n)) > ST_{BL} \\ \text{Downsloping} & \text{for } median(x'(n)) < ST_{BL} \\ \text{Flat with rise} & else \end{array}$$

Continuing, the generated signals are correlated with b_{ST}(n) and the highest correlation value is chosen. This value is traced back to a morphology category (Flat, biphasic, etc) which is denoted with a number from zero to six (notation described in 4). If any error occurs during this method, the morphology of b_{ST}(n) will be denoted with zero as unclassified.

3.2.2 Method for experiment 1, analysis of beat changes

To examine change in beats, patient's segments are correlated with their own late segment. This correlation procedure is illustrated with eq. 3.11:

$$\delta_{b_{ELi}} = \delta(b_{Ei}(n), b_{Li}(n)), \text{ where i = 1,2,3...Nb} \tag{3.11}$$

Depending on $\Delta_{b_{ELi}}$, this patient's number (i) will be put into a group. The factor Δ_C decides the value separating the groups. The letter 'C' is short for change as we study beat changes with this method As an example: 5 groups and $\Delta_C = 0.1$. Table 3.1 illustrates the separation values of the groups and their correlation value content limits. If $\delta_{b_{ELi}} = 0.85$, then this patient's index ('i') would be stored in the array belonging to group 2.

Table 3.1: An example with 5 groups and $\Delta_C = 0.1$

Group:	1	2	3	4	5
Group content values	1-0.9	0.9-0.8	0.8-0.7	0.7-0.6	0.6-0

After 547 patient's correlation measurements are calculated, 547 patient's identities should be separated in these 5 groups. These groups now contain a quantity of patients which is denoted in the following way:

$$\mathcal{C}_i = \{\mathcal{C}_1, \mathcal{C}_2 ...., \mathcal{C}_{Ng}\} \tag{3.12}$$

These quantities are used to find b_i(n)s and features of the groups. Groups containing b_{Ei}(n)s and b_{Li}(n)s are denoted in accordance with the time they were recorded (E or L):

$$C_{Ei} = \{b_{E1}(n), b_{E2}(n), ..., b_{ENgel}(n)\}, \qquad \text{where i=1,2,3...Ng} \tag{3.13}$$
$$C_{Li} = \{b_{L1}(n), b_{L2}(n), ..., b_{LNgel}(n)\}, \qquad \text{where i=1,2,3...Ng} \tag{3.14}$$

Every $b_i(n)$s can be observed in their respective groups. Figure 3.9 is illustrating the $b_{Ej}(n)$s (left side) and $b_{Lj}(n)$s (right side) in their C_{Ei} and C_{Li} which they are included in. Features can now be extracted and analyzed.

5 groups and Δ_C= 0.1

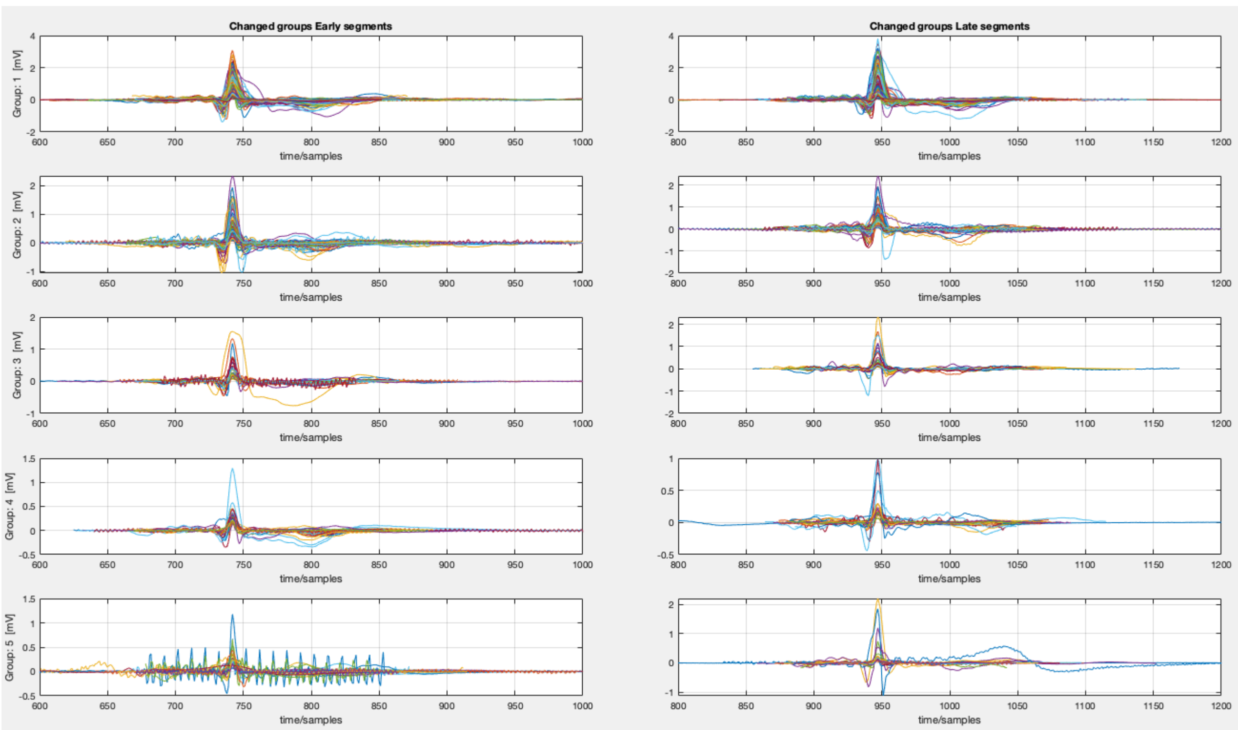


Figure 3.9: 5 groups with Δ_C=0.1 examined. Patient's early segments of every group are plotted on the left side and late segments on the right side.

Group representation segments from different periods (early and late) are also created for observing beat changes. The group representations are defined:

$$\bar{b}_{CEi}(n) = median(C_{Ei}), \qquad \text{for i=1,2,3...Ng} \tag{3.15}$$
$$\bar{b}_{CLi}(n) = median(C_{Li}), \qquad \text{for i=1,2,3...Ng} \tag{3.16}$$

The $\bar{b}_{CEi}(n)$s and $\bar{b}_{CLi}(n)$s are filtered before they are displayed, for a smooth ECG-segment (can be observed in fig. 6.25).

3.2.3 Method for experiment 2, analysis of similarities

In this method the data which is used as a similarity measure will be the registered amplitude levels of the patient's ECG-segment. Clusters in this method are created depending on the correlation coefficients and a minimum number of segments (Rb, required beats). A cluster is created if a correlation demand D_S and Rb are met. Due to similarities being the center of this method, the clusters were denoted $\mathcal{S}\_i$ for i=1,2,...Nc, where Nc are the number of clusters. If the letter 'E' or 'L' appears in Nc, it relates to which patient's segments were used while clustering (in regards to time). As an example: NcE represents the number of clusters created by b_{Ei}(n)s.

ECG-segments b_{Ei}(n)s and b_{Li}(n)s are correlated as displayed in equation 3.17 and 3.18:

$$\delta_{b_{EEij}} = \delta(b_{Ei}(n), b_{Ej}(n)), \qquad \text{where i and j = 1,2,3...Nb} \tag{3.17}$$

$$\delta_{b_{LLij}} = \delta(b_{Li}(n), b_{Lj}(n)), \qquad \text{where i and = 1,2,3...Nb} \tag{3.18}$$

These correlation values are contained in matrices which can be observed below:

$$M_E = \begin{bmatrix} \delta_{b_{EE11}} & \delta_{b_{EE12}} & \cdots & \delta_{b_{EE1Nb}} \\ \delta_{b_{EE21}} & \delta_{b_{EE22}} & \cdots & \delta_{b_{EE2Nb}} \\ \vdots & \vdots & & \vdots \\ \delta_{b_{EENb1}} & \delta_{b_{EENb2}} & \cdots & \delta_{b_{EENbNb}} \end{bmatrix}; a_{i,j} \in M_E$$

$$M_L = \begin{bmatrix} \delta_{b_{LL11}} & \delta_{b_{LL12}} & \cdots & \delta_{b_{LL1Nb}} \\ \delta_{b_{LL21}} & \delta_{b_{LL22}} & \cdots & \delta_{b_{LL2Nb}} \\ \vdots & \vdots & & \vdots \\ \delta_{b_{LLNb1}} & \delta_{b_{LLNb2}} & \cdots & \delta_{b_{LLNbNb}} \end{bmatrix}; b_{i,j} \in M_L$$

An example will be used to describe how the Rows and columns of the matrix are denoted: Rows are denoted $a_{i,*}$ and columns $a_{*,j}$ in matrix M_E.

Clusters are created automatically depending on the $\delta_{b_{EEij}}$ and $\delta_{b_{LLij}}$ values in the rows. Rows of M_E and M_L are examined whether there are enough similar segments which passes D_S, which make them a candidate cluster. Candidate clusters are considered vectors and are denoted $\mathcal{S}_{candEk}$ and $\mathcal{S}_{candLk}$ where k=1,2,...N_{candE} or N_*candL*. N_{candE} and N_{candL} are the number of candidates. The following procedure describes how candidate clusters are determined by examining all rows of M_E and M_L:

$$\mathcal{S}_{candEk} = a_{i,*} \geq D_S \qquad \text{where i=1,2..Nb and k=1,2,..,}N_{candE} \tag{3.19}$$

$$\mathcal{S}_{candLk} = b_{i,*} \geq D_S \qquad \text{where i=1,2..Nb and k=1,2,..,}N_{candL} \tag{3.20}$$

Then the clusters are decided by the following equations:

$$\mathcal{S}_{Ei} = \mathcal{S}_{candEk}, \qquad \text{if } |\mathcal{S}_{candEk}| \geq Rb \qquad \text{where i=1,2..NcE and k=1,2,..,}N_{candE} \tag{3.21}$$

$$\mathcal{S}_{Li} = \mathcal{S}_{candLk}, \qquad \text{if } |\mathcal{S}_{candLk}| \geq Rb \qquad \text{where i=1,2..NcL and k=1,2,..,}N_{candL} \tag{3.22}$$

This clustering procedure can be observed in figure 3.10. In this example, b_{Ei}(n)s are filtered and normalized and nine clusters (NcE=9) passed the requirements. Note $\mathcal{S}_{E7}$ in the first column, third row contain eleven b_{Ei}(n)s (Nb =11, number of beats in figure window). Clusters contain traceable identities of the b_i(n)s.

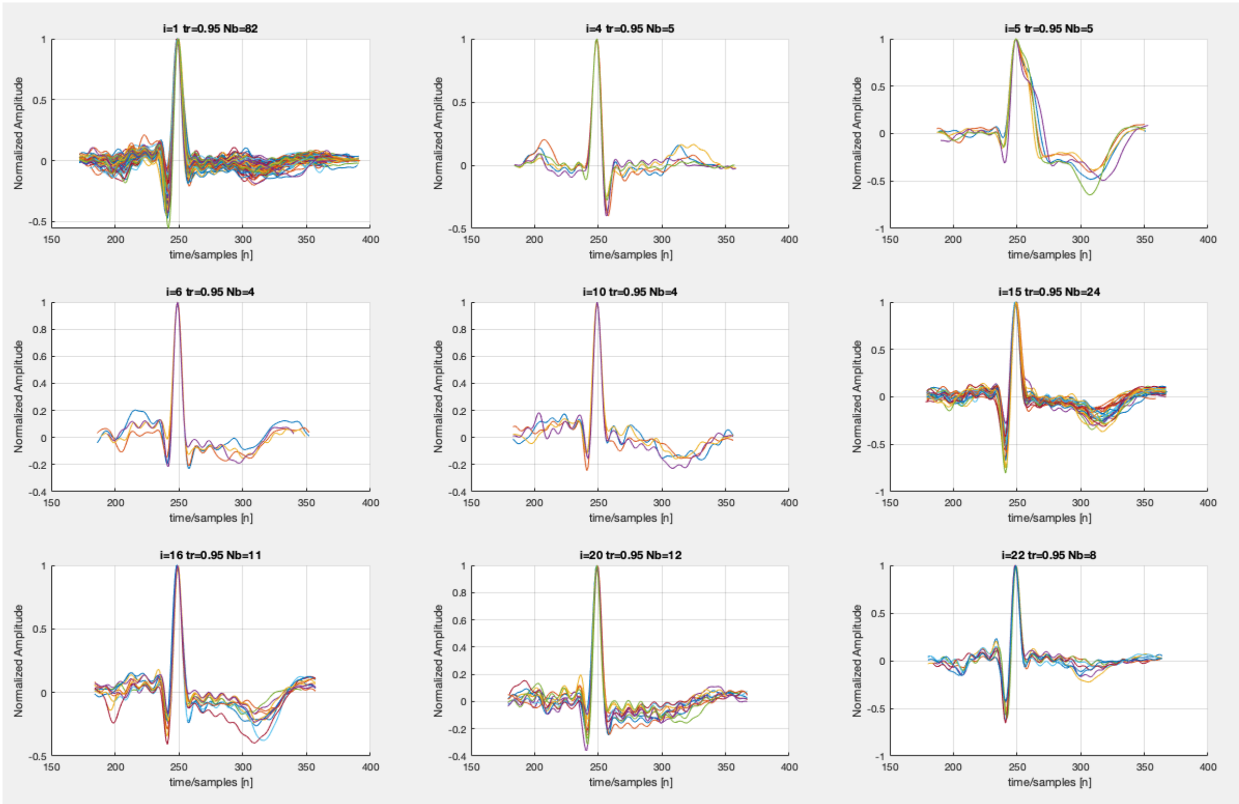


Figure 3.10: Clustering filtered and normalized (early) segments according to the $D_S = 0.95$ and Rb$= 4$

From these clusters features can be extracted, b_{Ei}(n) beat representations $\bar{b}_{SEi}$(n)s and $\bar{b}_{SELi}$(n)s can be created. The first letter represent whether the clusters were based on b_{Ei}(n)s or b_{Li}(n)s. Letter number two present $\bar{b}_{SEi}$(n)s and $\bar{b}_{SLi}$(n)s at another time. As an example: $\bar{b}_{SLE1}$(n)s is the representation created from cluster one based on b_{Li}(n)s at an early period. An expectation from this method is that the different clusters can be separated by their morphology. Identities in the clusters are used to create categories which contain the patient's segments. These categories were expected to contain segments with different ECG-segments characteristics and are denoted S_is where i=1,2,...Nc. Beat representations are created from these categories:

$$\bar{b}_{SEi}(n) = median(S_{Ei}) \qquad \text{where i=1,2,...NcE} \tag{3.23}$$
$$\bar{b}_{SELi}(n) = median(S_{ELi}) \qquad \text{where i=1,2,...NcE} \tag{3.24}$$
$$\bar{b}_{SLi}(n) = median(S_{Li}) \qquad \text{where i=1,2,...NcL} \tag{3.25}$$
$$\bar{b}_{SLEi}(n) = median(S_{LEi}) \qquad \text{where i=1,2,...NcL} \tag{3.26}$$

3.2.3.1 Exp. 2 classification methods

With these clusters as a basis, three classification methods were used for the analysis. These classification methods are described in the following paragraphs.

classification method 1

The first method analyze if $\bar{b}_{SEi}$(n)s or $\bar{b}_{SLEi}$(n)s change from early to late with treatment. Equations in 3.27 and 3.28 present how the correlation calculations are performed:

$$\delta_{\bar{b}_{SELj}} = \delta(\bar{b}_{SEj}(n), \bar{b}_{SELj}(n)), \qquad \text{j=1,2...NcE} \tag{3.27}$$

$$\delta_{\bar{b}_{SELj}} = \delta(\bar{b}_{SLEj}(n), \bar{b}_{SLj}(n)), \qquad \text{j=1,2...NcL} \tag{3.28}$$

There is also a classification only depending on $\bar{b}_{SEi}$(n)s and $\bar{b}_{SLEi}$(n)s ST-segment, using the above equations from J-point to Tinc. At last the correlation calculations are performed from late to early.

classification method 2

The second method correlate segments in S_{Ei},S_{ELi}, S_{LEi}, S_{Li} with $\bar{b}_{SEi}$(n)s, $\bar{b}_{SELi}$(n)s, $\bar{b}_{SLEi}$(n)s and $\bar{b}_{SLi}$(n)s treatment. These correlation calculations are performed to see if members of clusters correlate the most with their representative beat or not. Equations 3.29 and 3.30 display these calculations.

$$\delta_{S_{EEij}} = \delta(S_{Eij}(n), \bar{b}_{SEi}(n)), \qquad \text{where i=1,2,..NcE for all j=1,2...Ncel} \tag{3.29}$$

$$\delta_{S_{ELij}} = \delta(S_{ELij}(n), \bar{b}_{SELi}(n)), \qquad \text{where i=1,2,..NcE for all j=1,2...Ncel} \tag{3.30}$$

The case where clusters are created using patient's late ECG-segments can be observed in equations 3.31 and 3.32:

$$\delta_{S_{LLij}} = \delta(S_{Lij}(n), \bar{b}_{SLi}(n)), \qquad \text{where i=1,2,..NcL for all j=1,2...Ncel} \tag{3.31}$$

$$\delta_{S_{ELij}} = \delta(S_{LEij}(n), \bar{b}_{SLEi}(n)), \qquad \text{where i=1,2,..NcL for all j=1,2...Ncel} \tag{3.32}$$

classification method 3

The final method, classifies b_{Ei}(n)s with $\bar{b}_{SEi}$(n)s and b_{Li}(n)s with $\bar{b}_{SLi}$(n)s. Classification is based on correlation coefficients calculated with equations 3.33 and 3.34:

$$\delta_{S_{Eij}} = \delta(b_{Ei}(n), \bar{b}_{SEj}(n)), \qquad \text{where i=1,2,..Nb for all j=1,2...NcE} \tag{3.33}$$

$$\delta_{S_{Lij}} = \delta(b_{Li}(n), \bar{b}_{SLj}(n)), \qquad \text{where i=1,2,..Nb for all j=1,2...NcL} \tag{3.34}$$

To belong in a category, a demand ($\Delta_{cat} \in [0, 1]$) is set. Classification procedures is described with equations 3.35 and 3.36:

$$\text{Classified if: } \begin{cases} max(\delta_{S_{Ei}}) \geq \Delta_{cat}, & \text{where i=1,2,..Nb} \\ max(\delta_{S_{Li}}) \geq \Delta_{cat}, & \text{where i=1,2,..Nb} \end{cases} \tag{3.35}$$

$$\text{Uclassified if: } \begin{cases} max(\delta_{S_{Ei}}) \leq \Delta_{cat}, & \text{where i=1,2,..Nb} \\ max(\delta_{S_{Li}}) \leq \Delta_{cat}, & \text{where i=1,2,..Nb} \end{cases} \tag{3.36}$$

3.3 Experiments description

In the experiments hypothesis tests, p-values are significant different with 5% significance level. Both experiments can be performed with the attached files in Matlab 2020b. The file 'detFeatures.m' is the main program which is used to set parameters and select experiment. Read 6.3 for a more detailed program description. A summary of the performed experiments are described in the following sub-sections.

3.3.1 Experiment 1, analysis of beat changes

All change is based on the correlation measurement. A low correlation value describe more change in a patient's ECG-segment than a high correlation value. The segments were not normalized or filtered before the correlation calculations. Below are the different parameter settings in this experiment summarized:

1. 5 groups $\Delta_C = 0.1$.
2. 5 groups $\Delta_C = 0.2$.

3. 10 groups $\Delta_C = 0.05$.

First the correlation calculations are performed groups are created. Patient's ECG-segments are placed into their respective groups and features are extracted. This proceeds in accordance with the methods described in section 3.2 and 3.2.2. Group segments stacked on top of each other after aligning the R-peaks, can be observed in figure 3.9 (more in 6.15-6.17). It can also be important to notice that there are some segments in the groups which contain a lot of noise.

Finally, the hypothesis tests are performed and result tables created and stored in the struct variable `out` under the `exp1` field.

Exp. 1, summary of results presentation

$\bar{b}_{Cj}$(n)s will be presented in figure 4.2 and 4.3 (figures 6.25 and 6.26 for results with other parameters). Lastly, tables listing the findings of the features and if there are significant differences in tables 4.5-4.12 (tables 6.1-6.6 and 6.7-6.12 for results with other parameters). The findings from the manual recorded features will be listed first then the automatic findings.

An example description of what the tables display is listed below. The third experiment with parameter settings, nGroups=10 and diff=0.05 will be used as an example template. This description is the same for the automatic features:

1. Check for significant differences between the groups (KW-test). Observe example 4.5.
2. If there are significant differences, check which groups that have significant differences(Tukey HSD-test). Observe example 4.7.
3. Check for differences in time, early vs late relevant features (t-test). Observe example 4.8.

3.3.2 Experiment 2, analysis of beat similarities

Similarities are based on the correlation coefficients. Values closer to one express that beats resembles each other. The two sub-experiments can be summarized below:

1. Patient's ECG-segments are filtered and normalized.
2. Patient's ECG-segments are not filtered and normalized.

First correlation calculations are performed and values are placed in M_E and M_L. The clustering procedure creates clusters based on correlation values from the matrices. Similarity between cluster members are set to ≥ 0.95. Four cluster members are a minimum requirement to retain the cluster. Based on Patient's identities from the clusters, b_i(n)s are put into category groups and features are extracted. Methods for this experiment are described in section 3.2 and 3.2.3. Categories created from clusters after aligning the R-peaks, can be observed in figure 3.10 (For more temporary results read 6.18-6.22). Notice that some segments in the categories contain noise.

When categories are set up, the category representations are created. At this point the classification methods are used. First an examination to observe if the $\bar{b}_{SEi}$ and $\bar{b}_{SLE}$ change with BMV treatment.

Next point in the experiment is to inspect if the created representation segments are strong early in and after BMV. A representation strong if majority of segments in a category correlate the most with itself. By examining before and after treatment, change in segments can be indicated.

All of the patient's segments are correlated with the category representations in the last part of experiment two. To be classified to a category the correlation coefficient value have to be ≥ 0.9. In other words, $\Delta_{cat} = 0.9$. Unclassified will also be a category for this part. Final part of this experiment perform the same feature extraction and hypothesis tests as performed in experiment one. Now, a final analysis may indicate if the patient's ECG-segments can be predicted with the early category representations.

4. Results

This chapter begins with a comparison of the data in this project and in the study of Linde et al. [11]. Subsequently, this chapter highlights relevant results from the two main experiments. A significance value of 5% is set to see if there is any difference between the group/category features. Feature tables include feature data of the median (25,75 quantiles) extracted. The feature data which is marked with manually recorded is extracted from an Excel file 'STsegments_UiS'. Størdal et al. recorded these observations manually in the observational study [10].

The programs extract more features than displayed in the tables, but not all were relevant. By discussing with clinician, supervisor and reading the previously cited articles, the features listed in this chapter were determined. The presented features are most relevant to symptoms of asphyxia. Features that have not been determined relevant can be examined by repeating the experiments or examine the complete significant tables in 6. The average R-peak amplitude is an example of a feature that was omitted. In most experiment results it is significant difference which may be due to sensors loosening during measurement episodes.

Table features that are not applicable for hypothesis tests are not displayed in tables. It will appear as a blank space in the tables. Two examples can be observed in table 4.1.

The boxplot figures makes the different groups pdfs observable. For more information on how the data is spread, view the boxplots in figures 6.38-6.42, 6.43-6.47 and 6.48-6.52.

Automatically detected features were extracted using algorithms developed in this project based on methods described in 3.2. It is important to notice that the features from automatic detection: `eCdetect` and `lCdetect` count each time the detection algorithm runs without error. All features from early segments are denoted with 'e' in front of the feature, while features from the late ones are denoted with 'l'. In the study of Linde et al. [11] as the manual data was recorded, features were denoted with 'start' and 'end' instead of 'e' and 'l'. Features `eSTelN` and `lSTelN` only counts the detected segments with positive ST-elevation and not the segments containing depressed or other types of ST-segments. The features with `STint` in the name are extracted as a check to see whether the lengths of the ST-segments seems alike or if something has gone wrong in the detection algorithm. In some tables `vent` is short for ventilation times [seconds]. Observe figures 3.2 and 3.3 for a short description of the feature result notations:

4.1 Comparison with data from the study of Linde et al.

This section is a side-step to illustrate that there are differences in this project's data and the article of Linde et al. [11]. To observe the spread of the data values for the three groups, inspect boxplot figures 6.34-6.37

Table 4.1 present extracted manual recordings of the data. ST-elevation (from early to late) can be observed decreased in groups 'normal' and 'admitted', while increased in group 'death'.

Table 4.1: Characteristics of 547 infants with three outcomes from this project's data (manual recording)

Feature:	Normal (n=316)	Admitted (n=165)	Death (n=66)	p-value
ST-elevation (elements,early)	187	97	36	
ST-elevation (early)	3 (2,3)	3 (2,3)	3 (2,3)	0.179
ST-elevation (elements,late)	176	91	39	
ST-elevation (late)	3 (2,3)	3 (2,3)	3 (2,3)	0.014
Ventilation time [s]	97 (56,175)	236 (98,437)	581 (225,1348)	<0.001
Apgar score (1min)	7 (7,8)	6 (4,7)	3 (2,5)	<0.001
Apgar score (5min)	10 (10,10)	8 (6,10)	6 (3,10)	<0.001

Table 4.1 contain significant p-values. A further study was therefore performed with a Tukey's HSD test, and the results can be seen in table 4.2

Table 4.2: Only the significant different relations between the three outcomes are illustrated in this table (manual recording). For more details examine complete table 6.35.

Feature	Group	Control Group	Lower Limit	Difference	Upper Limit	P-value
endST	Normal	Death	-99.102	-54.277	-9.4516	0.013
endST	Admitted	Death	-101.79	-53.547	-5.3082	0.025
vent	Normal	Admitted	-148.1	-112.52	-76.946	<0.001
vent	Normal	Death	-261.32	-211.19	-161.06	<0.001
vent	Admitted	Death	-152.61	-98.665	-44.716	<0.001
apg1	Normal	Admitted	134.22	168.84	203.45	<0.001
apg1	Normal	Death	188.25	237.03	285.8	<0.001
apg1	Admitted	Death	15.701	68.191	120.68	0.007
apg5	Normal	Admitted	86.994	118.22	149.45	<0.001
apg5	Normal	Death	121.34	165.34	209.34	<0.001

Similar to the tables above, relevant features were extracted from this project's data. Observe table 4.3 to examine the automatic detected features of the three outcomes and compare with fig. 4.1 and tab. 4.1.

Table 4.3: Characteristics of 547 infants with three outcomes from this project's data (automatic detected). Complete table can be examine in attachments 6.36.

Feature:	**Normal (n=316)**	**Admitted (n=165)**	**Death (n=66)**	**P-value**
eCdetect	224	116	46	
eSTint	48 (20,60)	43 (28,57.75)	54 (38,67.75)	0.229
eSTintEST	87 (77,97)	86 (74,97)	88.5 (76,102)	0.630
eSTel	5 (1,5)	5 (1,5)	5 (1,5)	0.974
eSTelN	6	2	0	
eSTshape	2 (0,4)	2 (0,5)	1 (0,5)	0.979
lCdetect	211	99	47	
lSTint	48 (23,60.5)	28 (16.5,51)	46 (16,68)	0.036
lSTintEST	84 (74,95)	86 (74.25,94)	100 (81,109.75)	<0.001
lSTel	5 (1,5)	5 (1,5)	5 (1,5)	0.168
lSTelN	4	1	0	
lSTshape	1 (0,4)	1 (0,4)	2 (0,5)	0.218

The groups that had significant differences by automatic detection can be observed in table 4.4. Table 4.2 and tab. 4.4 can be examined to compare which of the three outcomes are statistically different.

Table 4.4: Only the significant different relations between the three outcomes are illustrated in this table (automatic detected). For more details examine complete table 6.37.

Feature	Group	Control Group	Lower Limit	Difference	Upper Limit	P-value
lSTint	Normal	Admitted	2.3513	25.876	49.401	0.027
lSTintEST	Normal	Death	-99.424	-60.422	-21.419	$<$0.001
lSTintEST	Admitted	Death	-105.56	-62.728	-19.894	0.002

Table 2 from the result chapter in the article of Linde et al. [11], can be observed in fig. 4.1 for a comparison.

Table 2

Characteristics of 494 infants with three outcomes.

Feature	Normal (n = 281)	Admitted (n = 154)	Death(n = 59)	*p*-Value [1]
FHR < 120 bpm or > 160 bpm	26 (9)	28 (18)	10 (17)	0.02
Caesarean section	96 (34)	71 (46)	35 (59)	<0.001
ST elevation	187 (67)	97 (63)	36 (61)	0.62
Other ST abnormalities	11 (4)	13 (8)	8 (14)	0.01
First HR < 60 bpm	24 (9)	25 (16)	20 (34)	<0.001
First HR 60–100 bpm	49 (17)	57 (37)	25 (42)	<0.001
First HR ≥ 100 bpm	208 (74)	72 (47)	14 (24)	<0.001
Apgar 1 min	7 (7, 8)	6 (4, 7)	4 (2, 6)	0.01
Apgar 5 min	10 (10, 10)	8 (6, 10)	6 (3, 10)	0.09
Duration of BMV [s]	95 (53, 172)	234 (96, 425)	479 (211, 1297)	0.002

[1] *p* values analyzed with Kruskal–Wallis or Chi-squared test. BMV—bag mask ventilation; bpm—beats per minute; FHR—fetal heart rate; HR—heart rate.

Figure 4.1: Table with relevant results from the article of Linde et al. [11].

4.2 Results, analysis of beat changes

Groups in this experiment (observe example in table 4.5) are sorted from least (low group number) to most (high group number) change. Unfiltered and unnormalized results are presented in this project, but multiple experiments were performed for the normalized and filtered settings. The normalized and filtered settings were not included due to approximately identical results.

Results from the third sub-experiment is listed in the following section. For more details about the two other sub-experiments read 6.5. The results are described and will be mentioned in the discussion chapter 5.

4.2.1 Parameter settings: ΔC =0.05 and 10 groups

Results from the sub-experiment with ten groups and $\Delta C = 0.05$ are listed in the following section. Some tables and figures are created as two tables/figures to get an overview of all the data.

Representatives of the 10 groups and ΔC= 0.05

T-wave inversion can be observed in all $\bar{b}_{CEj}$(n)s in figures 4.2 and 4.3. $\bar{b}_{CE8}$(n)'s morphology can be inverted, due to an algorithm error (inverted P- and T-wave, in accordance to the report of Schwartz et al. [19]). The algorithm in the developed program always try to find the correct the polarity for the ECG-segments.

ST-segments with downsloping can be observed in $\bar{b}_{CEj}$(n)s where j= 5, 7, 8 and 10. The downsloping ST-segment may be visual due to the T-wave inversion. Upsloping morphology can be observed in $\bar{b}_{CEj}$(n)s where j=1-4,6 and 9. All $\bar{b}_{CEj}$(n)s in figures 4.2 and 4.3 display biphasic ST-segments of grade two. Observe the $\bar{b}_{CLj}$(n)s, which indicate slight improvements of T-wave inversion for all j. Representatives j=7 and 9, $\bar{b}_{CLj}$(n)s resembles being influenced by noisy segments.

Flat or upsloping ST-segment can be observed for $\bar{b}_{CLj}$(n)s where j=1-8 and 10. $\bar{b}_{CL9}$(n) has an indication of downsloping and negative elevation according to the BL.

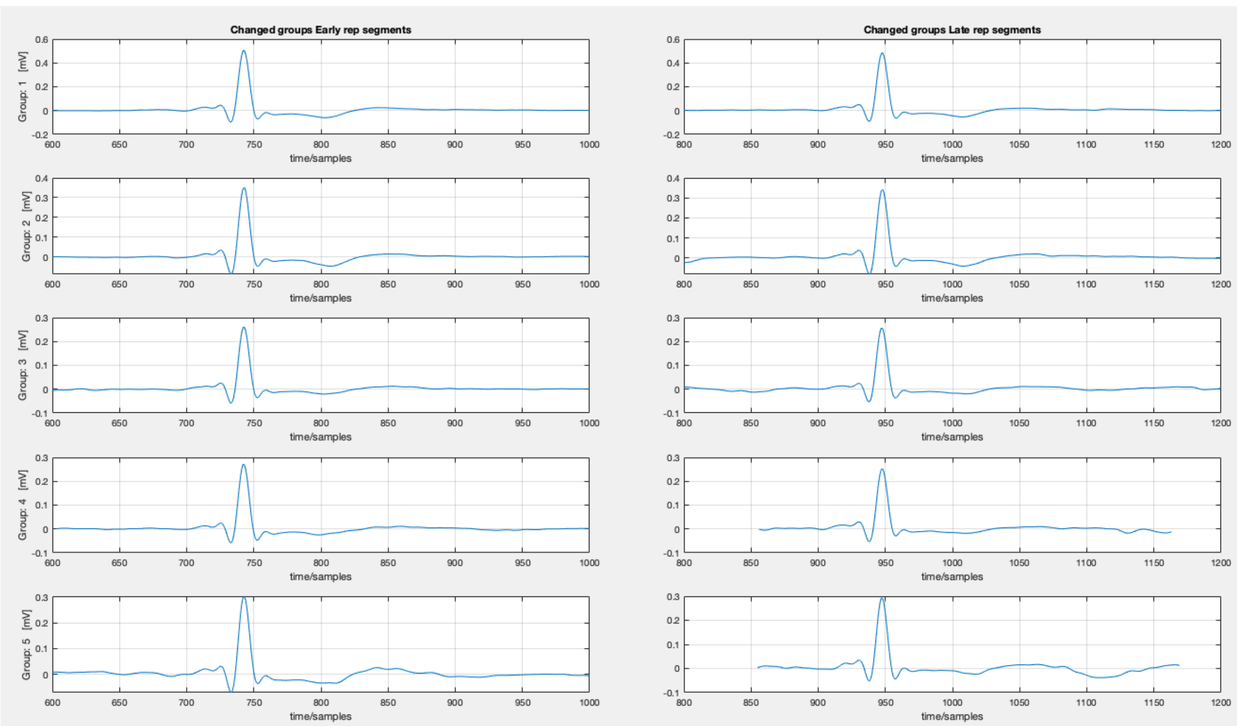


Figure 4.2: Median representatives of the sub-experiment with 10 groups and ΔC=0.05. Part 1, group 1-5.

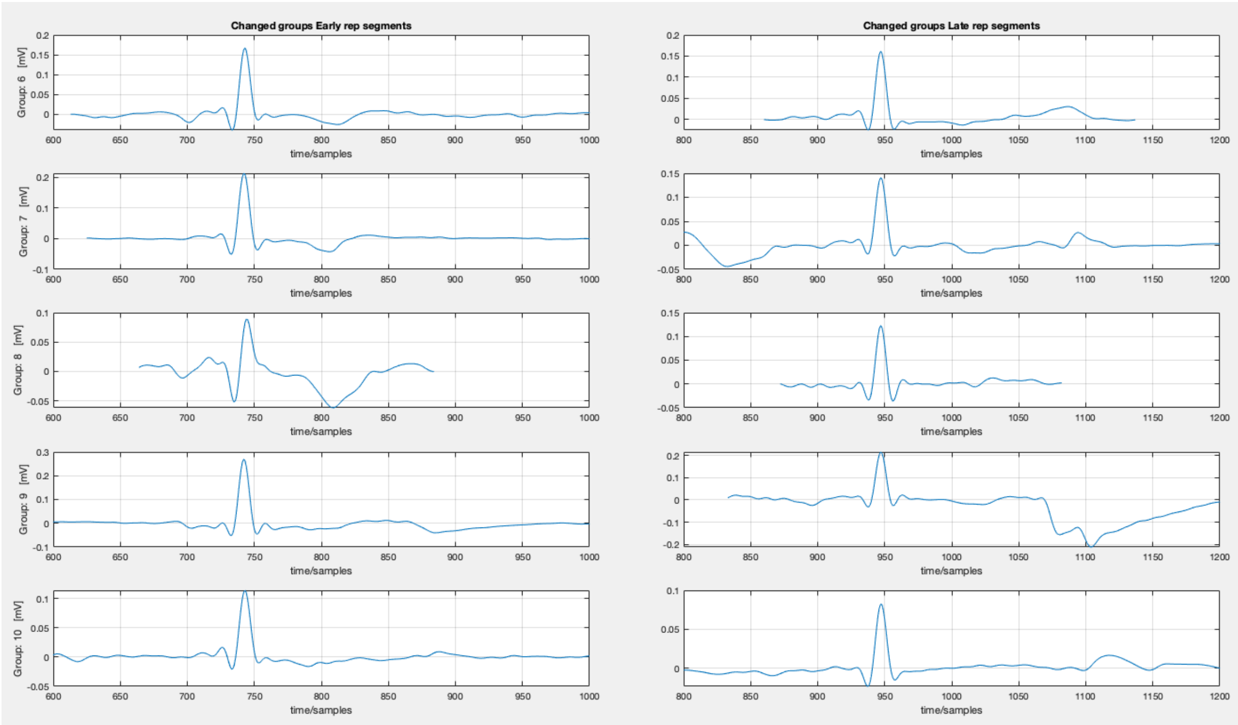


Figure 4.3: Median representatives of the sub-experiment with 10 groups and ΔC= 0.05. Part 2, group 6-10.

Feature tables from the manual recorded data

The manual recorded feature tables 4.5 and 4.6 present approximately identical group division compared with the other two sub-experiments in section 6.5. Group 1 includes the highest number of segments, indicating that most ECG-segments do not change much. From Group 1 to 10 the number of segments in the groups are generally decreasing. Note that group 10 contain ECG-segments which changed between 0.5-0, which logically is the reason why the feature 'Elements' number increases. The 'vent' feature indicate that groups with multiple changes include ECG-segments of patients that underwent longer BMV treatment.

It can be observed a higher proportion of admitted (denoted 2) neonate outcomes in groups with more change(6-10). Apgar scores (1min and 5min) display descending results with several changes. Finally the ST-elevation features indicate ECG-segment improvements in groups 3 and 5. The two groups contain 92 patient ECG-segments which is almost 20% of the total number of patients. A ST-elevation change is also listed in group 9, from abnormal (denoted 4) to indicate ST-elevation (denoted 3). All p-values indicate that there is significant difference between the groups.

Table 4.5: Experiment 1 with 10 groups and ΔC=0.05. Median values of the group's feature is listed below (part 1, features: manually recorded). For more information examine complete table 6.50.

Group: / **Feature:**	**1**	**2**	**3**	**4**	**5**
Elements	219	117	74	51	18
vent [s]	113 (60,234)	150 (69,292)	203 (92,448)	200 (102,361)	85 (45,247)
outcome	1 (1,2)	1 (1,2)	2 (1,2)	1 (1,2)	1 (1,2)
apg1	7 (6,8)	7 (6,8)	6 (4,7)	7 (4.3,7)	7 (6,8)
apg5	10 (8,10)	10 (9,10)	9 (7,10)	10 (7,10)	10 (10,10)
startST	3 (3,3)	3 (2,3)	3 (2,3)	2 (2,3)	3 (2,3)
endST	3 (3,3)	3 (2,3)	2 (2,3)	2 (2,3)	2 (2,3)

Table 4.6: Experiment 1 with 10 groups and ΔC=0.05. Median values of the group's feature is listed below (part 2, features: manually recorded). For more information examine complete table 6.51.

Group: / **Feature:**	**6**	**7**	**8**	**9**	**10**	**P-value:**
Elements	17	21	5	7	18	
vent [s]	147 (74,231)	129 (72,608)	146 (101,228)	168 (89,1119)	190 (91,940)	<0.001
outcome	1 (1,2)	2 (1,2)	1 (1,2)	2 (1,2)	2 (1,2)	0.034
apg1	6 (3,8)	6 (4.8,7)	5 (4.8,7)	6 (4.5,7.8)	6 (3,7)	0.013
apg5	10 (7,10)	10 (7,10)	9 (8,10)	10 (9.3,10)	8.5 (5,10)	0.009
startST	2 (1,3)	2 (1,3)	2 (1.8,2)	4 (2.3,4)	2 (1,2)	<0.001
endST	2 (1.8,3)	2 (1,3)	2 (1.8,2)	3 (1.3,3.8)	2 (2,3)	<0.001

Table 4.7 indicate which groups that have significant different results. Statements above, about the 'vent' feature included observations of the 3rd quantiles. The Tukey test give reason to believe that only group 3 is significantly different from group 1. The same observation can be seen in the outcome feature.

According to the ST-elevation (early and late) features, most groups show a significant difference from group 1.

Table 4.7: Significant results from the Tukey test are printed in this table. Experiment 1 with 10 groups and ΔC=0.05 (features: manually recorded). For more details examine complete table 6.52.

Feature	**Group**	**Control group**	**Lower limit**	**Difference**	**Upper limit**	**P-value**
vent	gr1	gr3	-150.06	-82.827	-15.595	0.0040
outcome	gr1	gr3	-124.484	-65.131	-5.778	0.019
startST	gr1	gr2	6.84	57.448	108.055	0.012
startST	gr1	gr3	11.432	70.856	130.279	0.0060
startST	gr1	gr4	26.249	94.962	163.675	<0.001
startST	gr1	gr6	22.34	133.609	244.878	0.0060
startST	gr1	gr7	23.596	124.553	225.51	0.0040
startST	gr1	gr8	16.43	216.315	416.2	0.022
startST	gr1	gr10	54.425	162.787	271.15	<0.001
startST	gr8	gr9	-529.917	-271.143	-12.369	0.031
startST	gr9	gr10	20.759	217.615	414.471	0.017
endST	gr1	gr2	16.065	67.263	118.46	0.0010
endST	gr1	gr3	36.156	96.272	156.389	<0.001
endST	gr1	gr4	46.474	115.988	185.501	<0.001
endST	gr1	gr7	52.055	154.188	256.322	<0.001
endST	gr1	gr8	11.65	213.864	416.079	0.028
endST	gr1	gr10	14.706	124.331	233.956	0.012

Table 4.8 list only one significant ST-elevation change. The significant difference can be found in group eight. Groups two and three would be significantly different with a ten percent significance level. ST-elevation observations based on tables 4.5 and 4.6 are disproved in table 4.8.

Table 4.8: Experiment 1 with 10 groups and ΔC=0.05. Inspects significant changes in features from early to late. P-values are listed below, where groups with p-values <0.05 are significant (features: Manually recorded). For more details examine complete table 6.53.

Group: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
ST-elevation	0.180	0.088	0.077	0.182	0.172	0.260	0.267	<0.001	0.103	0.331

Feature tables from the automatic detected data with ten groups and $\Delta C = 0.05$

In table 4.10 groups 8 and 9 are determined to be irrelevant. These groups contain few ECG-segments that went through automatic detection without errors (inspect eCdetect and lCdetect). Missing features can also be observed in these groups due to detection failing.

Similar results as the tables of the manually registered features can be examined for the other groups. Group one contains most ECG-segments here as well. The features concerning the length of the ST-interval (Features with 'STint' in the name) are similar, which indicates that features are extracted from a similar segment.

Depressed elevation (denoted 5) is detected as a common occurrence in ECG-segments of groups 1-4 and 7. ECG-segments in group 5 indicate depression early and a normal segment after BMV. Group ten display ECG-segments which are assumed to be normal early and then depressed after BMV. The other groups vary between, error during assessment and a depressed ST-interval.

Few ECG-segments have detected a ST-segment above baseline. This positive elevation is counted in the features 'eSTelN' and 'lSTelN'. The morphology recorded in features 'eSTshape' and 'lSTshape' reveal that most ECG-segments and groups (1-5,7 and 10) indicate biphasic morphology (denoted 1 and 2). Early morphology of group 6 is detected unclassified, while it is detected biphasic late.

Table 4.9: Experiment 1 with 10 groups and ΔC=0.05. Median values of the group's feature is listed below (part 1, features: automatically detected). For more details, examine complete table 6.54.

Group: / **Feature:**	**1**	**2**	**3**	**4**	**5**
Elements	219	117	74	51	18
eCdetect	167	85	47	36	12
eSTint	43 (18,55)	53 (31,67)	56 (30,74)	53 (28,78)	59 (53,64)
eSTintEST	87 (81,97)	92 (80,102)	88 (67,99)	80 (55,101)	94 (80,96)
eSTel	5 (5,5)	5 (1,5)	5 (1,5)	5 (1,5)	5 (1,5)
eSTelN	0	3	1	2	0
eSTshape	2 (1,4)	2 (0,5)	1 (0,4)	2 (0,5)	1 (0,4)
lCdetect	147	83	47	30	9
lSTint	48 (20,59)	43 (22,69)	33 (20,50)	44 (19,59)	37 (11,62)
lSTintEST	85 (78,95)	88 (75,97)	80 (70,95)	82 (62,96)	92 (73,98)
lSTel	5 (1,5)	5 (1,5)	5 (1,5)	5 (1,1)	2 (1,5)
lSTelN	0	1	1	1	1
lSTshape	2 (0,4)	2 (0,4)	1.5 (0,4)	1 (0,3.8)	0.5 (0,2)

Table 4.10: Experiment 1 with 10 groups and ΔC=0.05. Median values of the group's feature is listed below (part 2, features: automatically detected). For more details, examine complete table 6.55.

Group: / **Feature:**	**6**	**7**	**8**	**9**	**10**	**P-value:**
Elements	17	21	5	7	18	
eCdetect	8	15	0	2	9	
eSTint	54 (30,56)	53 (33,57)			31 (18,43)	0.002
eSTintEST	67 (37,84)	84 (50,88)		84 (74,94)	58 (41,81)	0.019
eSTel	1 (1,5)	5 (1,5)	1 (1,1)	1 (1,4)	2 (1,5)	<0.01
eSTelN	1	1	0	0	0	
eSTshape	0 (0,4.3)	2 (0,5.3)	0 (0,0)	0 (0,3.8)	1 (0,5)	0.071
lCdetect	10	14	2	2	11	
lSTint	46 (17,62)	42 (24,80)			21 (18,31)	0.603
lSTintEST	85 (58,102)	69 (51,107)	82 (81,82)	98 (89,106)	87 (64,107)	0.591
lSTel	5 (1,5)	5 (1,5)	1 (1,5)	1 (1,2.5)	5 (1,5)	0.101
lSTelN	0	0	0	1	0	
lSTshape	2 (0,5)	1 (0,5)	0 (0,5)	0 (0,0.8)	2.5 (0,5)	0.605

In table 4.11 The elevation of group 8 is detected significantly different. However, this should not be important due to program errors mentioned above. The Tukey test should not compare group 8, because no ECG-segments in group 8 went through the detection algorithm without errors.

Early elevation of group 6 was detected unclassified and looks significantly different from group one. The detected ST-elevation of group 6 is similar to the morphology detection. This similar detection may indicate difficulties with the elevation and morphology detection algorithm.

Table 4.11: Significant results from the Tukey test are printed in this table. Experiment 1 with 10 groups and ΔC=0.05 (features: automatically detected). For more details examine complete table 6.56.

Feature	**Group**	**Control group**	**Lower Limit**	**Difference**	**Upper Limit**	**P-value**
eSTint	gr1	gr2	-75.616	-38.629	-1.641	0.033
eSTel	gr1	gr6	1.218	104.455	207.692	0.045
eSTel	gr1	gr8	28.822	214.279	399.735	0.010
eSTel	gr2	gr8	10.381	197.632	384.884	0.029

Results from groups 8 and 9 are not relevant (described in paragraphs above) in table 4.12. Groups 2, 3, 5 and 6 have significant p-value for change in the length of the ST-segment. All 4 groups have reduced ST-segment length, which is a common occurrence for most groups in tables 4.9 and 4.10.

Observe in table 4.12 a significant change in the morphology of group one due unclassified ST-intervals late. The first quantile in 'eSTshape' is changed from one to zero in 'lSTshape' (observations in table 4.9). This indicate that late ECG-segments in group one contain more unclassified ST-segments, than early.

Table 4.12: Experiment 1 with 10 groups and ΔC=0.05. Investigating significant changes in automatically detected features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: automatically detected). For more details, examine complete table 6.57.

Group: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
ST-int size	0.875	0.022	0.026	0.355	<0.001	<0.001	0.178	<0.001	<0.001	0.089
ST-int est. size	0.275	0.760	0.141	0.739	0.702	0.558	0.932	<0.001	<0.001	0.075
ST-shape	0.013	0.932	0.864	0.214	0.261	0.287	1	0.178	0.766	0.399
ST-elevation	0.354	0.219	0.295	0.458	0.519	0.296	0.870	<0.001	<0.001	0.271

4.3 Results, analysis of beat similarities

Unfiltered and not normalized results are presented in 6.5.3. The category representations that were created are displayed first, followed by tables from the classifying procedures and hypothesis tests.

4.3.1 Exp. 2, filtered and normalized results

Explanations of which program parts the results are extracted from can be read in 6.4.2. From figure 3.10, the representations in 4.4 and 4.5 are created. Figure 4.5 illustrates how the categories in fig. 4.4 can be observed after BMV. Boxplots for the normalized and filtered part are presented in figures 6.61-6.68.

Representations created from filtered and normalized early segments visualized

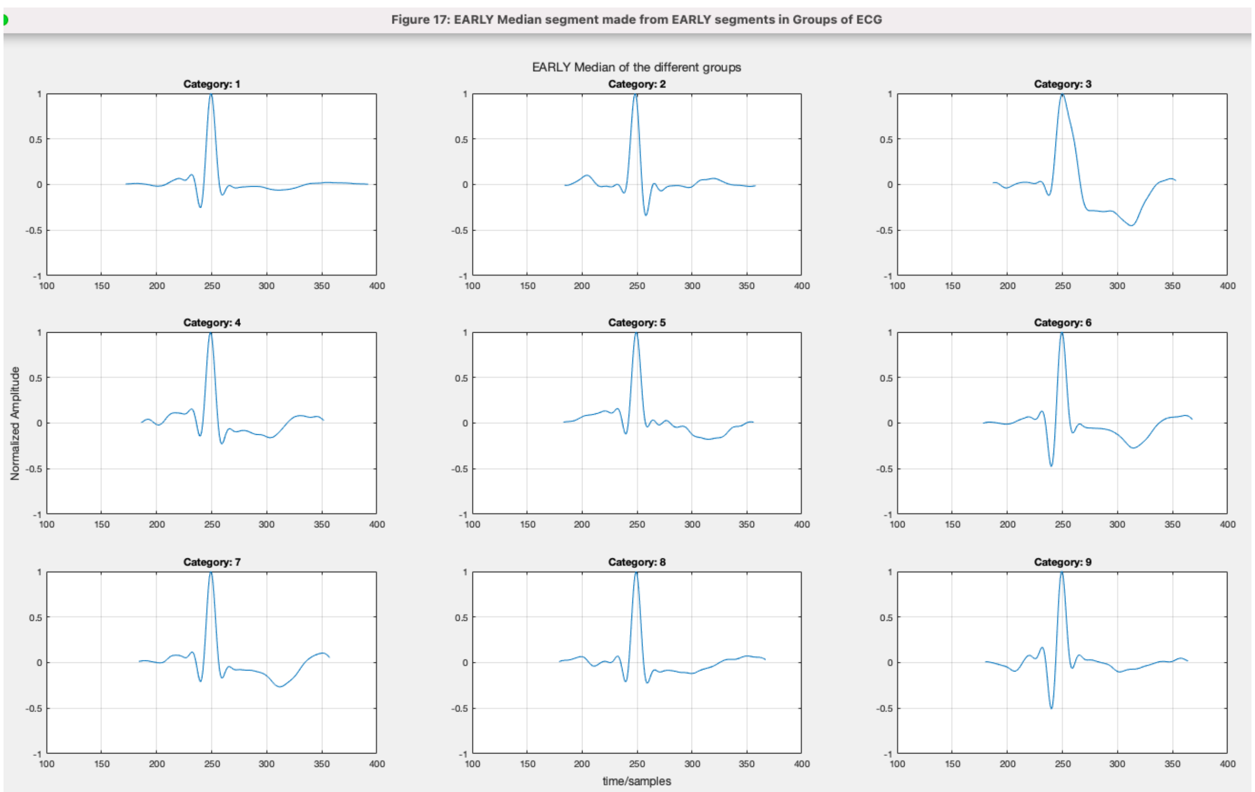


Figure 4.4: Early filtered and normalized category representations made from early segments with D_S= 0.95 and Rb= 4

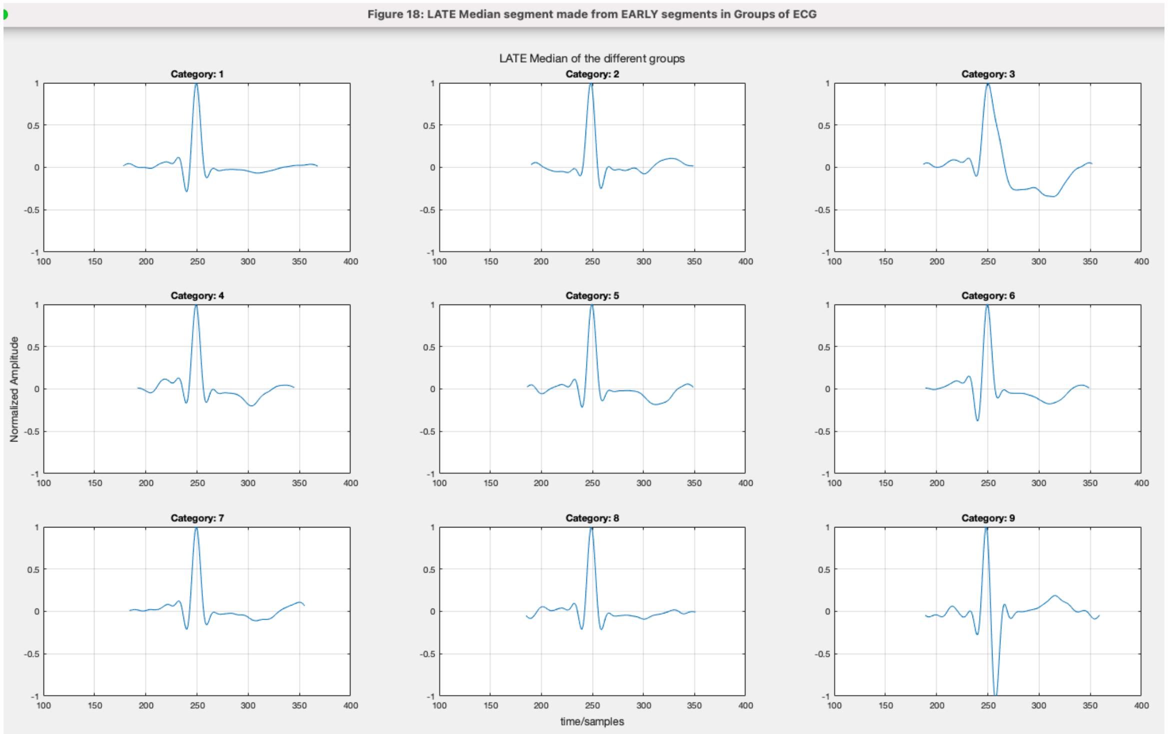


Figure 4.5: Late filtered and normalized category representations made from early ECG-segments with D_S= 0.95 and Rb= 4

Representations created from late filtered and normalized segments visualized

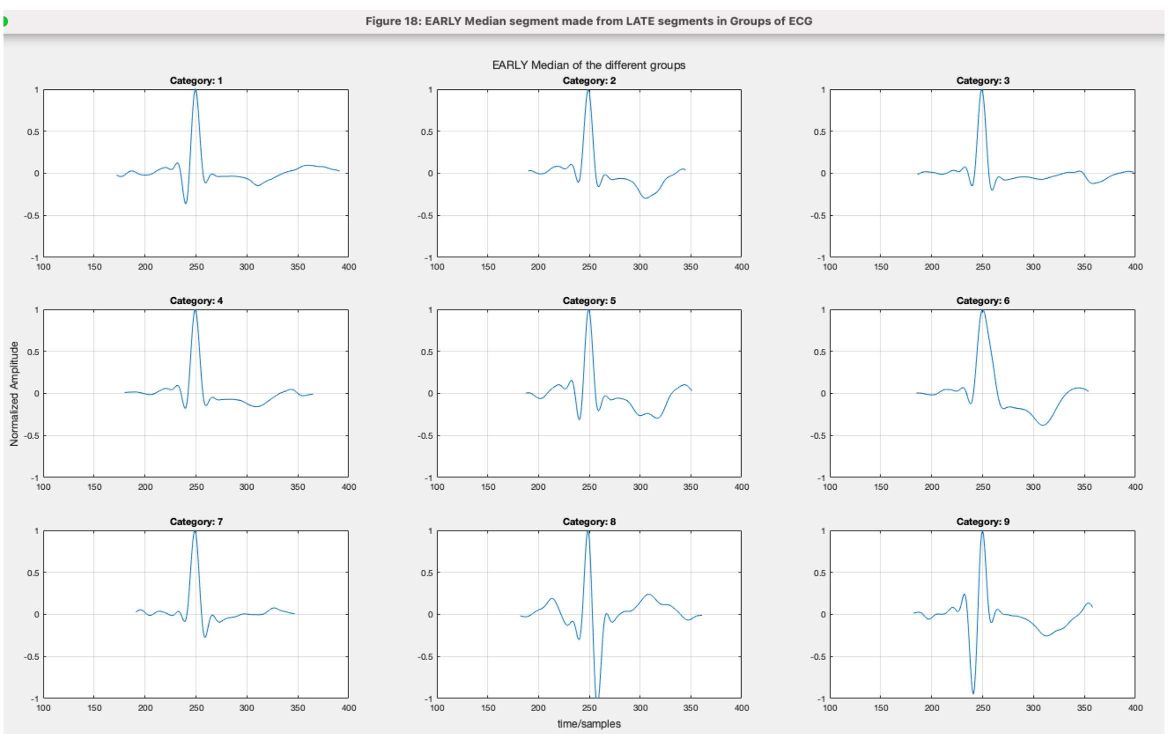


Figure 4.6: Early filtered and normalized category representations based on late segments with D_S= 0.95 and Rb= 4

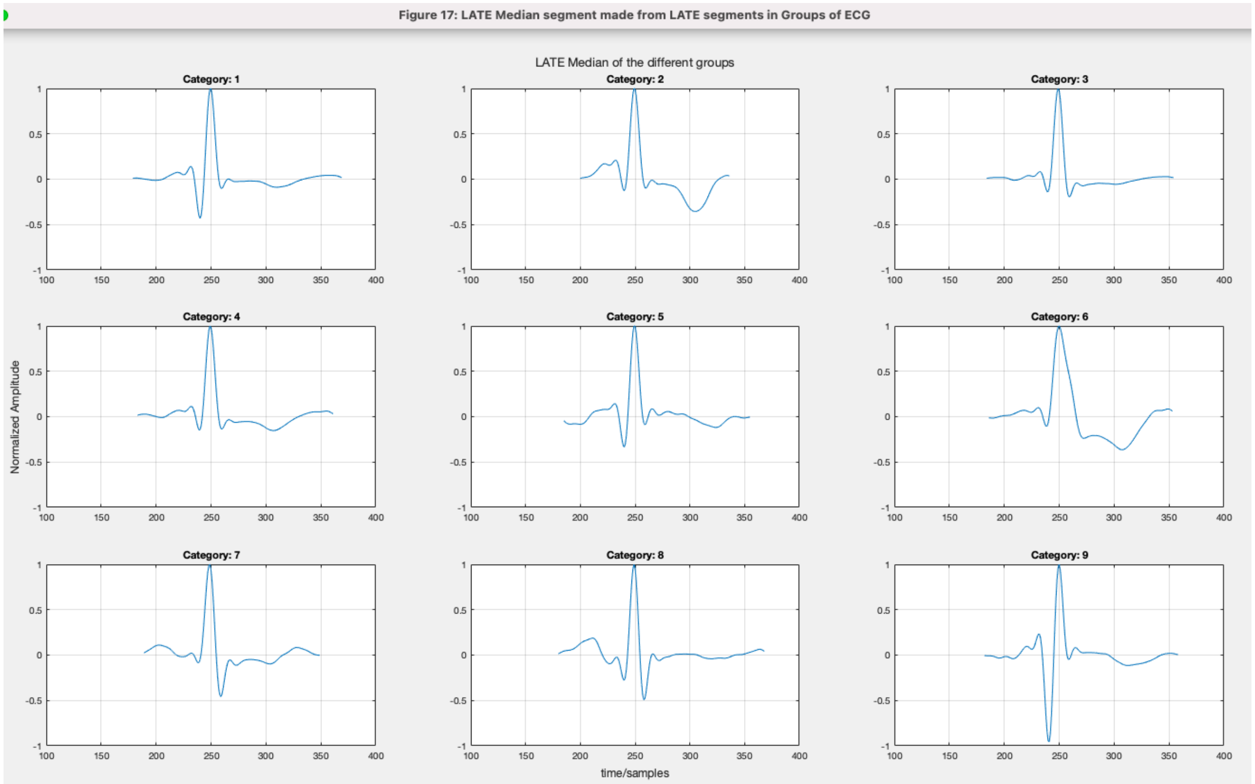


Figure 4.7: Late filtered and normalized category representations made from late segments with $D_S = 0.95$ and Rb= 4

4.3.1.1 Correlation of category representations (filtered and normalized) results

Category representations from early in BMV were correlated with category representations from late in treatment. These results are based on correlation values depending on the representations and only parts from S-peak to N.

Early filtered and normalized segments representations results

Table 4.13 indicate which early category representations correlate most with in the late category representations. Both representations are based on the clustering procedure using the $b_{Ei}(n)$s.

From the results in 'Late cat' it can be observed that most of the representations correlate with their own representation late. Category 5 and 7 are the only exceptions. Five's T-wave inversion is equal to seven late T-wave inversion, and the segment parts leading to S-peak are also equal. Category seven correlates most with the late representation of category one. Parts from the start of each segments to the J-point look similar, but the T-wave inversions are different.

From the third row in table 4.13, classifications from the S-peak display more variety in the results. Observe the categories 2, 3, 4 and 5, these results can not be verified visually and may be due to errors in the program.

Table 4.13: Classification results, based on early filtered and normalized segments. This table present which early category representation were classified as in the late category representations. Correlating categories from figure 4.4 with categories in figure 4.5 is a step to obtain this table.

Early cat.:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Late cat.:	1	2	3	4	7	6	1	8	9
Late cat. from S	1	6	1	7	6	6	7	8	2

Table 4.14 indicate which late category representations correlate most with the early category representations. Based on the complete ECG-segments most representations correlate most with themselves. Categories seven and nine are similar with different representations. Representation seven and nine results concur with visual inspections.

Correlation from S-peak gives results that can not be verified visually. This gives reason to believe that there are some difficulties in extracting the S-peak. An example can be observed by inspecting late category one and comparing it with category six early representation. From S-peak they are visually different.

Table 4.14: Classification results, based on early filtered and normalized segments. This table display which late category representations are classified as in the early category representations. Correlating categories from 4.5 with 4.4 is a step in obtaining this table.

Late cat.:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Early cat.:	1	2	3	4	5	6	5	8	1
Early cat. from S	6	9	1	1	5	6	6	8	5

Similar results as mentioned above were examined in the section based on representations made from the patient's late ECG-segments. For more details, inspect these results in section 6.5.4.

4.3.1.2 Exp. 2 classification of members in category representations (filtered and normalized) results

Results from correlating members belonging to a category with category representations are presented in this section. The Deviation results in tables 4.15-4.18 present how many members deviates from their original category.

Tables based on early filtered and normalized segments

Tables 4.15 and 4.16 display the results where the representations are based on the patient's early segments.

A strong diagonal (high numbers) can be noted in table 4.15, which indicate low deviation percentages. Naturally table 4.15 should have a higher diagonal than table 4.16, because the late categories representations based on early segments are not required to meet the demand set with D_S. This will be the same situation for table 4.18 based on late segments. Similar results can be found in the unfiltered part in section 6.5.3.

Table 4.15: Classification results, based on early filtered and normalized segments representations. This table illustrate the number of early filtered and normalized segments in a category representation that are classified as the same category which made the category or not. Correlating $S_{Ejk}(n)$s with $\bar{b}_{SEj}(n)$s where k=1,2,...Ncel and j=1,2,...Nc.

Elements from category: / **Classified as:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Cat: 1	64	0	0	0	0	0	0	0	0
Cat: 2	0	5	0	0	0	0	0	0	0
Cat: 3	0	0	5	0	0	0	0	0	0
Cat: 4	0	0	0	4	0	0	0	1	0
Cat: 5	0	0	0	0	4	0	0	0	0
Cat: 6	1	0	0	0	0	21	0	0	0
Cat: 7	2	0	0	0	0	2	10	1	0
Cat: 8	4	0	0	0	0	0	1	10	0
Cat: 9	11	0	0	0	0	1	0	0	8
Deviation [%]:	22	0	0	0	0	12.5	9.1	16.7	0

Note in table 4.16 that the diagonal is weaker than in table 4.15. Deviation percentages are high for many of the categories. Table 4.16 have a diagonal similar to the diagonal in the unfiltered table 6.18.

Table 4.16: Classification results, based on early filtered and normalized segment representations. This table illustrate the number of late filtered and normalized segments in a category representation, which are classified as the same origin category or not. Correlating S_{Ljk}(n)s with $\bar{b}_{SLj}$(n)s where k=1,2,...Ncel and j=1,2,...Nc.

Elements from category: / **Classified as:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Cat: 1	33	0	0	0	0	2	1	1	0
Cat: 2	3	4	0	0	0	0	2	3	0
Cat: 3	1	0	4	0	0	0	0	0	1
Cat: 4	4	0	0	3	0	1	1	1	0
Cat: 5	2	0	0	0	1	2	0	0	0
Cat: 6	9	0	0	0	1	14	4	1	4
Cat: 7	8	0	0	0	2	3	1	1	0
Cat: 8	14	0	1	1	0	1	2	3	0
Cat: 9	8	1	0	0	0	1	0	2	3
Deviation [%]:	60	20	20	25	75	42	91	75	63

Tables based on late segments

Tables 4.17 and 4.18 present the results where the representations are based on patient's late filtered and normalized segments. Observe the diagonal in table 4.17 to find similar results as displayed in table 4.16. However, the diagonal is weaker. Categories 3 and 4 contain ECG-segments which are better represented with other category representations. High deviation percentages can be observed.

Table 4.17: Classification results, based on late filtered and normalized segments representations. This table illustrate the number of early filtered and normalized segments in a category representation that are classified as the origin category or not. Correlating S_{Ejk}(n)s with $\bar{b}_{SEj}$(n)s where k=1,2,...Ncel and j=1,2,...Nc.

Elements from category: / **Classified as:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Cat: 1	47	0	7	18	2	0	1	1	0
Cat: 2	3	4	2	18	0	0	0	0	0
Cat: 3	3	0	21	9	0	0	1	0	0
Cat: 4	4	0	10	31	0	0	0	0	0
Cat: 5	7	2	1	11	2	1	0	0	1
Cat: 6	1	0	1	1	0	7	0	0	0
Cat: 7	1	0	12	5	0	0	2	0	0
Cat: 8	2	0	1	0	0	0	0	3	1
Cat: 9	6	0	0	2	0	0	0	0	4
Deviation [%]:	37	33	62	67	50	13	50	25	33

Similar to the results in table 4.15 the diagonal in table 4.18 are strong. A deviation can be observed in category four in table 4.18. This deviation explain the weak representation of category four in table 4.17.

Table 4.18: Classification results, based on late filtered and normalized segment representations. This table illustrate the number of late filtered and normalized segments in a category representation that are classified as the origin category or not. Correlating S_{Ljk}(n)s with $\bar{b}_{SLj}$(n)s where k=1,2,...Ncel and j=1,2,...Nc.

Elements from category: / **Classified as:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Cat: 1	70	0	3	10	0	0	0	0	0
Cat: 2	0	6	0	8	0	0	0	0	0
Cat: 3	0	0	51	19	0	0	0	0	0
Cat: 4	0	0	0	57	0	0	0	0	0
Cat: 5	0	0	0	1	4	0	0	0	0
Cat: 6	0	0	0	0	0	8	0	0	0
Cat: 7	0	0	1	0	0	0	4	0	0
Cat: 8	0	0	0	0	0	0	0	4	0
Cat: 9	4	0	0	0	0	0	0	0	6
Deviation [%]:	5	0	7	40	0	0	0	0	0

Tables 4.15-4.18 from this section verify changes of category members ECG-segments.

4.3.1.3 Exp. 2 patients correlated with category representations (filtered and normalized) results

In the first part, patient's early ECG-segments were correlated with the category representations based on clustering patient's early ECG-segments. The second part, patient's late ECG-segments were correlated with the category representations based on clustering patient's late ECG-segments.

Patients correlated with early representations from early segments results

Tables 4.19 and 4.20 contain manual recorded features of patients highly correlated with the category representations. Without counting ECG-segments which were not unclassified, cat. one includes most members in table 4.19. This category can be observed with depressed elevation and T-wave inversion in figures 4.4 and 4.5. It concurs with 'startST' and 'endST' from the manual records. The 'vent' feature show similar results between categories even though visual inspection of figure 4.4 expected higher ventilation times of categories with worse ECG-segments characteristics.

Category three and five have downsloping and negative elevation in figure 4.4. The feature 'outcome' from table 4.19 display the expected 'admitted' (denoted 2) result in categories two and three. There is no significant difference between the categories except in the ST-feature categories. Visual inspection of the figures 4.4 and 4.5 illustrates this ST-segment difference, but it can be difficult to read this in the tables if the p-value is not noted.

Table 4.19: Early patients correlated with early category representations based on early filtered and normalized segments. Median values of the categories features are listed below (part 1, features: manual recorded). For more details, examine complete table 6.74.

Category: / **Feature**	**1**	**2**	**3**	**4**	**5**
Elements	102	17	10	33	16
vent	156 (71,329)	140 (68,237)	203 (52,269)	140 (62,230)	184 (35,227)
outcome	1 (1,2)	1 (1,2)	2 (1,2)	1 (1,2)	2 (1,2)
apg1	7 (5,7)	7 (6,7.3)	6.5 (4,7)	7 (6,8)	6 (5,7)
apg5	10 (8,10)	10 (9,10)	10 (6,10)	10 (9,10)	9 (6.5,10)
startST	3 (3,3)	2 (2,2)	3 (3,3)	3 (3,3)	3 (2.5,3)
endST	3 (2,3)	2 (2,2)	3 (3,3)	3 (3,3)	3 (2.5,3)

Table 4.20: Early patients correlated with categories based on early filtered and normalized segments. Median values of the categories features are listed below (part 2, features: manual recorded). For more information, examine complete table 6.75.

Category: / Feature:	6	7	8	9	Unclassified	P-value
Elements	38	75	65	41	150	
vent	191 (83,399)	133 (66,220)	147 (68,359)	150 (69,294)	130 (69,324)	0.787
outcome	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	0.442
apg1	6 (3,7)	7 (6,8)	7 (5,7)	7 (5,7.3)	7 (5,7)	0.469
apg5	10 (7,10)	10 (8,10)	10 (8,10)	10 (8,10)	10 (8,10)	0.678
startST	3 (2,3)	3 (3,3)	3 (3,3)	2 (2,3)	2 (2,3)	<0.001
endST	3 (2,3)	3 (3,3)	3 (2,3)	2 (2,3)	2 (2,3)	<0.001

The Tukey test can be observed in table 6.76 for a closer examination of which category median values are significantly different.

Table 4.21 display the categories two, five, seven and eight with significant change, which corresponds to the visual changes in T-wave inversion and ST-segment elevation in figures 4.4 and 4.5.

Table 4.21: Inspecting significant changes in features from early to late (filtered and normalized). The P-values are listed, where categories with p-values <0.05 are significant (features: Manually recorded). For more details, examine complete table 6.77.

Category: / Feature	1	2	3	4	5	6	7	8	9	Unclassified
ST-elevation	0.072	<0.001	0.343	0.325	<0.001	0.254	0.045	0.015	0.534	0.493

Exp. 2, patients correlated to categories (early) automatic detection

Tables 4.22 and 4.23 lists that the detection algorithm gives a good representation of the categories (observe 'eCdetect' and 'lCdetect'). However, the features concerning the length of the ST-interval ('eSTint' and 'lSTint') are low in some categories (1,2,8 and 9). Nevertheless, features that contain information about the estimated ST-interval ('eSTintEST' and 'lSTintEST') can be observed to have reliable lengths.

All categories have detected depressed elevation (early and late) that are consistent with inspection of figures 4.4 and 4.5. The elevation detected is not identical with the manual recordings.

The morphology detected in the ST-segment is mostly biphasic (denoted 1 and 2), but category two, three and four present other results. Category three and four have characteristics that are considered negative ECG-segment symptoms. Upsloping can be observed early in category two, but late flat with rise from S-peak. The positive morphology result can be related to the feature 'outcome' for category two in table 4.19 (normal outcome).

P-values from KW-tests in table 4.23 are all significant. The most interesting p-values, which should not be related to program errors are differences in ST-elevation and ST-morphology.

Table 4.22: Early patients correlated with categories based on early filtered and normalized segments. Median values of the category's feature is listed below (part 1, features: automatic detected). For more details, examine complete table 6.78.

Category: / **Feature:**	**1**	**2**	**3**	**4**	**5**
Elements	102	17	10	33	16
eCdetect	76	12	8	32	13
eSTint	20 (11,57)	11 (11,11)	41 (34,44)	47 (43,55)	60 (10,76)
eSTintEST	90 (73,104)	64 (53,69)	77 (71,79)	85 (78,90)	103 (94,117)
eSTel	5 (1,5)	5 (1,5)	5 (5,5)	5 (5,5)	5 (3,5)
eSTelN	3	0	0	0	2
eSTshape	2 (0,4)	5 (0,5)	6 (1,6)	3 (1.8,6)	1 (1,1)
lCdetect	75	14	8	26	11
lSTint	17 (11,49)	21 (15,37)	44 (37,47)	50 (44,59)	17 (10,42)
lSTintEST	85 (71,97)	62 (57,71)	72 (68,82)	86 (78,96)	90 (81,98)
lSTel	5 (1,5)	5 (4.5,5)	5 (5,5)	5 (5,5)	5 (1,5)
lSTelN	1	1	0	0	0
lSTshape	2 (0,4)	4 (1,5)	3.5 (1,6)	2 (1,5)	2 (0,5)

Table 4.23: Early patients correlated with categories based on early filtered and normalized segments. Median values of the category's feature is listed below (part 2, features: automatic detected). For more details, examine complete table 6.79.

Category: / **Feature:**	**6**	**7**	**8**	**9**	**Unclassified**	**P-value:**
Elements	38	75	65	41	150	
eCdetect	30	71	53	25	119	
eSTint	60 (52,67)	56 (52,62)	36 (11,51)	30 (10,56)	42 (21,60)	$<$0.001
eSTintEST	96 (89,105)	92 (85,98)	86 (79,95)	88 (70,100)	76 (57,95)	$<$0.001
eSTel	5 (5,5)	5 (5,5)	5 (5,5)	5 (1,5)	5 (3,5)	$<$0.001
eSTelN	0	0	0	1	12	
eSTshape	1 (1,3)	2 (1,5.8)	2 (1,4)	1 (0,2.3)	2 (1,5)	$<$0.001
lCdetect	26	66	49	24	108	
lSTint	48 (13,57)	52 (45,61)	38 (21,48)	11 (10,61)	46 (22,62)	0.007
lSTintEST	90 (79,104)	90 (84,97)	83 (77,96)	91 (59,104)	81 (68,92)	$<$0.001
lSTel	5 (1,5)	5 (5,5)	5 (2.5,5)	5 (1,5)	5 (1,5)	$<$0.001
lSTelN	1	1	2	3	4	
lSTshape	1 (0,4)	2 (1,5)	2 (0.8,4.3)	1 (0,2)	2 (0,5)	$<$0.001

The complete Tukey tests table can be examined in table 6.80.

Morphology change in category four and ST-elevation change in category seven are relevant in table 4.24. Closer inspections of figures 4.4 and 4.5, can visually verify these changes.

Table 4.24: Investigating significant changes in features from early to late (normalized and filtered). The P-values are listed, where the categories with p-values <0.05 are significant (features: automatic detected). For more details, examine complete table 6.81.

Category: **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Unclassified**
ST-int size	0.874	<0.001	0.787	0.611	0.375	0.008	0.302	0.970	0.338	0.673
ST-int est. size	0.259	0.383	0.232	0.667	0.361	0.139	0.660	0.079	0.711	0.732
ST-shape	1	0.332	1	0.012	0.684	0.221	0.132	0.191	0.585	0.341
ST-elevation	0.310	0.209	0.392	0.284	0.240	0.112	0.060	0.801	0.280	0.088

Patient's late segment correlated with representations from late segments results

Tables 4.25-4.26 present similar distributed beats of patients in categories as in the previous section. According to the p-values, a significant change between categories can be examined in the ST-elevation features.

The representation of category 8 in figure 4.7 has a biphasic grade 3 and a small T-wave inversion morphology. This morphology may explain the feature results in table 4.29. The outcome result of category 8 display admitted and its ventilation feature contain some high numbers.

By inspecting representations in figure 4.7, categories 2 and 6 illustrate the worst ECG-characteristics. Severe negative ST-elevation and T-wave-inversion can be observed. Tables 4.25-4.26 do not give any of these indications except in the ST-features.

Table 4.25: Late patient's segments correlated with categories based on late filtered and normalized segments. Median values of the categories features are listed below (part 1, features: manual recorded). For more details examine complete table 6.82.

Category: **Feature**	**1**	**2**	**3**	**4**	**5**
Elements	116	27	108	83	18
vent	132 (64,308)	121 (68,257)	168 (80,282)	133 (72,231)	117 (46,310)
outcome	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)
apg1	7 (5,7)	7 (6,7.8)	7 (6,7)	7 (6,7)	7 (5,8)
apg5	10 (8,10)	10 (7.3,10)	10 (8.5,10)	10 (8.3,10)	10 (9,10)
startST	3 (2.5,3)	3 (3,3)	3 (3,3)	3 (3,3)	3 (2,3)
endST	3 (2,3)	3 (3,3)	3 (2.5,3)	3 (3,3)	3 (2,3)

Table 4.26: Late patient's segments correlated with categories based on late filtered and normalized segments. Median values of the categories features are listed below (part 2, features: manual recorded). For more details, examine complete table 6.83.

Category: **Feature:**	**6**	**7**	**8**	**9**	**Unclassified**	**P-value**
Elements	8	18	6	15	148	
vent	198 (52,485)	164 (48,340)	295 (63,757)	97 (56,282)	142 (77,366)	0.852
outcome	1.5 (1,2)	1 (1,2)	2 (2,3)	1 (1,2)	1 (1,2)	0.445
apg1	6.5 (3,7)	7 (6,8)	7 (7,7)	7 (5.3,8)	7 (5,7)	0.502
apg5	9 (5,10)	10 (9,10)	9.5 (8,10)	10 (7.5,10)	10 (7.5,10)	0.743
startST	3 (3,3)	2 (2,3)	2 (2,2)	2 (2,3)	2 (2,3)	<0.001
endST	3 (3,3)	2 (2,3)	2 (2,2)	2 (2,2)	2 (2,3)	<0.001

For more details on which categories have significant different ST-features, examine complete Tukey table 6.84.

Significant change of category 1 and 9 (at 10%) regarding the ST-features concur with observations from figures 4.6 and 4.7. The significant change in ST-features of category 6 can be observed as worse ECG-characteristics. Table 4.29 give no indication if it is worse or better.

Table 4.27: Inspecting significant changes in features from early to late (filtered and normalized). The P-values are listed, where categories with p-values <0.05 are significant (features: Manually recorded). For more details, examine complete table 6.85.

Category: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Unclassified**
ST-elevation	0.019	0.327	0.551	0.596	1	<0.001	0.187	0.363	0.055	0.212

Exp. 2, patients correlated with categories (late) automatic detection

From tables 4.25 and 4.26 the need for a more sophisticated detection algorithm can be observed. Detection of features in category 8 can be observed to have errors. Category 9 has the same problem for late segments, which makes both categories 8 and 9 irrelevant due to few error free feature extractions.

Most ST-intervals can be observed normal except late in categories 1,3,7 and unclassified. Considering that the backup estimate (lSTintEST) can be observed reasonable the feature observations can be trusted.

Depressed ST-elevation is detected as a common occurrence for all relevant categories early. This elevation concur with visual observations in figure 4.7 and most of the inspected categories of the manual recordings in tables 4.28 and 4.29. All relevant categories except five, have depressed ST-elevation late. Category five show ST-elevation which is positive and concur visually with figure 4.7.

The morphology presented in tables 4.25 and 4.26 of most categories early and late can be observed biphasic. Exceptions are categories 6 and 7. Patient's early segments in category 6 display a flat with rise from S-peak (the value should be rounded). This morphology can not be found by inspection of figures 4.6 and 4.7. Detected morphology late in category 7 and early in category 6 are the same (flat with rise from S-peak), but can neither be observed in figure 4.7.

P-values present that all features have significant differences between categories.

Table 4.28: Late patient's segments correlated with categories based on late filtered and normalized segments. Median values of the categories features are listed below (part 1, features: automatic detected). For more details, examine complete table 6.86.

Category: / **Feature:**	**1**	**2**	**3**	**4**	**5**
Elements	116	27	108	83	18
eCdetect	93	25	88	76	10
eSTint	53 (19,63)	58 (47,69)	37 (15,54)	53 (36,58)	53 (35,62)
eSTintEST	94 (83,104)	86 (80,97)	87 (75,96)	90 (84,99)	93 (82,97)
eSTel	5 (5,5)	5 (5,5)	5 (5,5)	5 (5,5)	5 (1,5)
eSTelN	1	0	2	2	0
eSTshape	2 (1,5)	2 (1,2)	2 (1,4)	2 (1,5)	1 (0,1)
lCdetect	84	24	88	72	10
lSTint	21 (10,58)	51 (48,61)	20 (10,37)	54 (44,61)	46 (13,76)
lSTintEST	93 (85,104)	86 (81,94)	83 (73,92)	87 (82,96)	58 (27,106)
lSTel	5 (1,5)	5 (5,5)	5 (5,5)	5 (5,5)	3 (1,5)
lSTelN	2	0	0	0	3
lSTshape	1 (0,2)	2 (1,6)	2 (1,4)	2 (1,5)	1 (0,5)

Table 4.29: Late patient's segments correlated with categories based on late filtered and normalized segments. Median values of the categories features are listed below (part 2, features: automatic detected). For more details, examine complete table 6.87.

Category: / **Feature:**	**6**	**7**	**8**	**9**	**Unclassified**	**P-value:**
Elements	8	18	6	15	148	
eCdetect	7	14	3	9	114	
eSTint	44 (43,49)	58 (37,60)	24 (10,37)	16 (13,35)	42 (18,58)	$<$0.001
eSTintEST	78 (70,85)	73 (57,86)	56 (49,78)	86 (69,98)	79 (56,96)	$<$0.001
eSTel	5 (5,5)	5 (5,5)	2 (1,5)	5 (1,5)	5 (3,5)	$<$0.001
eSTelN	0	0	1	0	11	
eSTshape	3.5 (1,6)	2 (1,5)	0.5 (0,5)	1 (0,5)	2 (1,5)	$<$0.001
lCdetect	6	14	2	2	106	
lSTint	44 (38,48)	36 (18,47)		42 (31,52)	39 (16,62)	$<$0.001
lSTintEST	72 (70,83)	68 (67,79)	90 (48,132)	77 (58,95)	79 (56,93)	$<$0.001
lSTel	5 (3,5)	5 (5,5)	1 (1,5)	1 (1,1)	5 (1,5)	$<$0.001
lSTelN	0	0	0	0	8	
lSTshape	1 (0.5,6)	4 (1,5)	0 (0,5)	0 (0,0)	2 (0,5)	$<$0.001

Observe between which categories there were a significant difference in Tukey table 6.88.

Table 4.27 present significant ST-elevation change in categories 1, 2 and 9 and ST-morphology changes in 7 and 9. Category nine concurs with the 10% significance from the manual table 4.30. However, cat. 9 were determined irrelevant previously. T-wave inversion may be the reason the morphology of category 9 is detected changed. ST-elevation changes in category 1 concurs with the manual recordings and visually. The ST-elevation of Category 2 can not be verified visually and neither by the manual recordings in table 4.30.

Table 4.30: Checking for significant changes in features from early to late (normalized and filtered). The p-values are listed, where categories with p-values $<$0.05 are significant (features: automatic detected). For more details, examine complete table 6.89.

Category: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Unclassified**
ST-int size	0.151	0.954	0.066	1	0.791	0.087	0.086	$<$0.001	$<$0.001	0.566
ST-int est. size	0.601	0.828	0.246	0.469	0.895	0.072	0.242	0.486	$<$0.001	0.925
ST-shape	0.076	0.327	0.841	0.464	0.660	0.598	$<$0.001	0.695	0.029	0.373
ST-elevation	$<$0.001	0.028	0.391	0.752	0.266	0.221	0.199	0.189	$<$0.001	0.061

5. Discussion

This chapter's key points are to compare and examine the results in chapter 4 with the questions from section 1.1. After discussing the results, some suggestions of improvements and project extensions (marked with headlines) are presented. These suggestions may be used for further work in similar studies. Some observations from the sidestep of comparing data will be introduced first.

5.1 Comparison between data

Observe in section 4.1, the table in figure 4.1, the tables 4.1 and 4.3 display similar results. However, there are 53 more subjects included in this study.

It can be noted a reduction of patients that have an elevated ST-segment from early to late in BMV. This reduction indicate that the treatment is working, but observe that the ST-elevation median for all outcomes early and late are the same. In figure 4.1 and table 4.1 the ST-elevation median values display that all outcomes mostly contain segments with ST-elevation. The automatic detection in table 4.3 display the ST-elevation medians early and late to be depressed. In other words, similar ST-elevation results are detected automatically as manually. It is important to note that automatic detection fails about one-third of the attempts for all the outcomes. Detected lengths of the ST-segments are approximately the same, which indicate ST-segment feature results use the same material. Observations based on ST-elevation features are more or less identical.

The increasing results of ventilation duration make sense, because the treatment is extended in the worst cases (admitted,death). Apgar scores are about the same for tables 4.1 and table in figure 4.1. By examining the Tukey table 4.2 it can be observed that the difference between the medians are significant which could be expected due to the outcomes. This sidestep of a comparison should verify that results in this study could be relevant for post studies of the article of Linde et al. [11].

5.2 An interpretation of experiment 1

An unexpected result from this experiment which requires attention reveals that in most cases the $b_i(n)$s (patient's heartbeats) does not change much despite getting BMV treatment. The three sub-experiments confirm this observation. The largest group is always the one that contains $b_i(n)$s with the least change.

By inspecting figures 3.9 and 6.15-6.17, most of the noisy $b_i(n)$s can be observed in the higher numbered groups. This observation is indicating that noise affects the coefficient of change (correlation). There is less noise in the $b_{Li}(n)$s than the $b_{Ei}(n)$s (many of the $b_{Li}(n)$s are extracted after BMV).

The boxplots from the three parameter settings give reason to believe that the automatic detection algorithm is insufficient. Most of the groups ST-elevation are detected 'depressed' which does not correspond to the manually registered ST-elevation.

Figures 4.2, 4.3, 6.25 and 6.26 verify visual improvements in T-wave inversion and ST-segment elevation. The least changed groups are most interesting, because they do not include many noisy $b_i(n)$s. Examples of improved T-wave inversion can be inspected in:

1. The three first subplots (groups 1,2 and 3) of figure 6.25.
2. The two first subplots (groups 1 and 2) of figure 6.26.

3. The six first and number ten subplots (groups 1-6 and 10) of figures 4.2 and 4.3.

The ST-segments are also improved in these figures. ST-elevation can be observed closer to the segments BL, while the morphology still correspond with downslope characteristics.

The manual recorded feature tables 4.5 and 4.6 indicate that $\mathrm{b}_{Ei}(\mathrm{n})$s with a change factor of more than 0.4 will likely be admitted or have a worst outcome scenario. This observation can possibly be used to predict the feature outcome. Outcome admitted or worse will be predicted if a $\mathrm{b}_{Ei}(\mathrm{n})$ are strongly correlated to $\bar{b}_{CEi}(\mathrm{n})$s with change factor more than 0.4. These $\mathrm{b}_{Ei}(\mathrm{n})$s should receive extra attentive treatment. Low Apgar scores and problems with assessing the ST-elevation early should also coincide in this conclusion.

In most cases, the duration of BMV is significant different and increases with a group's change factor. Thus, more ventilation time more change in the ECG. To note, the early to late tables 6.3,6.9 and 4.8 display the change in ST-elevation. In the largest groups (with least change), the change is significant, which concur with the study of Linde et al. [11].

By examining the automatic detected feature tables, one can reach the same conclusion as previously stated. The features detected automatically indicate similar results as the manually registered features, but from another perspective. Groups with a lot of change can be observed to have worse results.

The change factor obtained in this experiment is not solely due to asphyxia symptoms in the ECG. This can be seen throughout all the experiment's feature tables (examples in tables 4.5 and 4.6). Features 'eSTshape' or 'eSTel' can be used in early BMV treatment to indicate asphyxia. In most cases, these features do not have a positive measurement (ST-elevation = 2 or ST-shape =5).

Experiment 1 was done to analyze beat changes. Questions that required investigation will be listed and concluded.

- Does the change factor of the experiment depend on the shape of the ST-segment?

Experiment one's results give no indication that changes in a neonate's ECG-segments solely depend on the ST-segment features. However, the average R-peak amplitude feature is highly relevant to the change. This R-peak feature can be observed in the complete tables from chapter 6. The groups with the most change usually have lower valued amplitude values and often have significant changes in R-peak amplitude from early to late. This R-peak amplitude feature is determined to be related to noise or loose sensors. By reading ECG-relevant articles, no association was found between the R-peak amplitude and asphyxia, therefore it has been removed from the relevant result tables in chapter 4.

- Are there any observable early features that make the end result predictable or give an indication of asphyxia?

Common results among groups in the features related to Apgar scores, ST-segment's elevation and morphology may at an early stage in BMV indicate asphyxia. Some of these features have been correlated in other asphyxia and ECG-related articles. To confirm the significance of the results from this experiment, single-feature experiments should be performed. These single feature experiments should be based on the design of experiments (DOE) systematic method (for more information read [4], [5]).

Further work which could improve or verify results from this experiment is summarized in the following list:

1. Experiment 1 could have been done with focus on change in the ST-segment or T-wave inversion, which can be related to asphyxia [11], [13]. Now, full-length ECG-segments were correlated instead of only the ST-segment or T-wave part, which could provide more relevant results/groups.

2. To verify significance of this experiment results, single feature experiments based on DOE could be performed.

5.3 An interpretation of experiment 2

This section provides some deductions of experiment two. Both sub-experiments (unfiltered, not normalized and filtered,normalized) have been examined. The different table results in all parts of the experiment will be discussed in the following paragraphs.

From figures 3.10, 6.18,6.19 and 6.22 it should be noted that most of the $\bar{b}_{Sj}(n)$s (category representations) are based on less than fifty b_i(n)s. This concur for both the sub-experiments. Nevertheless, by inspecting figures 6.20,6.21,6.23 and 6.24 it occurs that b_i(n)s fit and there are not many visual discrepancies.

Both sub-experiments maintain the common ECG-segment's morphology. Expectantly, the normalized and filtered ECG-segments do not have traces of noise ripples in the category representations. The normalized $\bar{b}_{Sj}$(n)s in figures 4.4 and 4.7 have more morphology differences than the not normalized representations in figures 6.27 and 6.30. By examining the unfiltered $\bar{b}_{Sj}$(n)s, it is determined that correlation clustering strongly depend on the ECG-segment's amplitude. Slight improvements in some ST-segments can be found in both sub-experiments by observing $\bar{b}_{SEj}$(n)s and $\bar{b}_{SLj}$(n)s. The visual improvements concur with results from the article of Linde et al. [11].

5.3.1 Correlation of category representations

Tables 4.13-4.14, 6.13-6.16 and 6.33-6.34 display that by using the whole ECG-segment the $\bar{b}_{SEi}$(n)s are mostly the same as their respective $\bar{b}_{SLj}$(n)s. By shifting the focus to the ST-segment different classifications can be found. Some of these different classifications are determined to emerge from program errors.

An example is presented in the following paragraph that display errors in the ST-segment estimation. This example demonstrate why this classifying algorithm require some improvement. Variable `C2` in the `'checkreps'` mode, in function `asph_scr.m` contain an estimated ST-segment's correlation matrix. Inspect 6.2 for a description of the function or read the attached program files pseudocode for more information related to the program. Figure 5.1 display the values of `C2` as an example with `k`=2, from the unfiltered sub-experiment. The `NaN` values represent where the detection algorithm has failed. Those `NaN` values are not used when classifying the ST-segments in calculations based on `C2`. Improving the main detection function `detQRST` or implementing other detection algorithms can be beneficial for further work. Classifications should be more accurate with better detection.

C2

7x7 double

	1	2	3	4	5	6	7
1	0.8773	0.9419	NaN	NaN	0.9172	NaN	0.8646
2	NaN	0.5354	NaN	NaN	0.4515	NaN	0.3367
3	0.5488	0.2712	NaN	NaN	0.8206	NaN	0.1546
4	0.9281	0.8814	NaN	NaN	0.8040	NaN	0.7370
5	0.8285	0.6733	NaN	NaN	0.8972	NaN	0.6891
6	0.9410	0.8966	NaN	NaN	0.6591	NaN	0.7642
7	0.8720	0.8828	NaN	NaN	0.4554	NaN	0.9265

Figure 5.1: An example of the correlation matrix C2 from the mode `'checkreps'`. `NaN` values represents where the category representations ST-segment have not been successfully detected.

Figure 5.2 illustrates how the correlation matrix can be observed for the filtered sub-experiment. The detection algorithm works better when there is less noise.

out.exp2.classified.reps(2).C2med

	1	2	3	4	5	6	7	8	9
1	0.9731	0.9632	0.2790	0.9794	0.7920	0.9058	0.5864	0.6721	0.9252
2	0.9510	0.9871	0.1423	0.9634	0.8786	0.8750	0.5010	0.5790	0.9041
3	0.8318	0.8986	0.4762	0.9732	0.9166	0.9386	0.5583	0.6001	0.9240
4	0.8864	0.9325	0.3425	0.9942	0.7182	0.9626	0.3029	0.5332	0.9486
5	0.9336	0.9113	0.2237	0.9208	0.7883	0.8986	0.2442	0.4082	0.9593
6	0.9772	0.9451	0.3541	0.9934	0.7365	0.9492	0.3503	0.5746	0.9211
7	0.6415	0.4927	0.9491	0.4732	0.4220	0.4326	0.9233	0.9391	0.5789
8	0.7416	0.6312	0.9640	0.6389	0.7380	0.6287	0.9919	0.9943	0.5667
9	0.8450	0.9277	0.0486	0.9604	0.8489	0.9196	0.3877	0.5588	0.9424

Figure 5.2: An example of the correlation matrix C2 from the mode `'checkreps'` for the filtered and normalized part. No `NaN` values are present which mean the category representations ST-segment have been successfully detected.

In short, this examination supports the claim of slight ECG-characteristics improvement from the treatment.

5.3.2 Classification of members in a category representation

Tables 4.15, 4.18, 6.17, and 6.20 display strong representations. ECG-segments in a category correlates most with its own category, at the time it is created. Therefore, the experiment was not repeated with other parameter settings.

From tables 4.16, 4.17 , 6.18 and 6.19 , display numbers stating that b_i(n)s change with treatment. The high deviation values can be observed, which confirm the statement above.

5.3.3 Patients correlated with representations

The manual recorded feature tables 4.22-4.24 and 6.24-6.26 verify the different ST-segments in the categories statistically. An unexpected result can be observed by inspecting the manual recorded feature tables and the category representations visually. Patients that correlate with $\bar{b}_{Sj}$(n)s that have severe ST-segment ECG symptoms (big scale T-inversion, flat or downsloping, etc.), have approximately the same outcome, ventilation duration, Apgar scores or ST-features as other categories. As an example from fig. 4.4:

- Category 6 and 7 representing the severe categories (downsloping, T-wave inversion and negative elevation).
  - Median outcome: Normal.
  - Median ventilation duration: cat. 6, 191s and cat. 7, 133s.
  - Median Apgar score after 1min: result for cat. 6 is 6 and 7 is the result of category 7.
  - Median Apgar score after 5min: cat. 6 and 7 have 10 as the result.
- Category 1 and 2 representing small indications of asphyxia (flat or upsloping, no severe elevation)
  - Median outcome: Normal.
  - Median ventilation duration: cat. 1, 156s and cat. 2, 140s.
  - Median Apgar score after 1min: cat. 1 and 2 have 7 as the result.
  - Median Apgar score after 5min: cat. 1 and 2 have 10 as the result.

In other words, the category representation may not predict the outcome, Apgar scores or the duration of the ventilation.

In tables 4.19-4.20 p-values confirms no significant difference between the categories except for the 'startST' and 'endST' features. These features are significant due to S_2, but all the other features do not have significant differences. This example can represent a summary from inspecting the tables regarding the problem stated in the introduction. Predicting end results solely on early features from categories, proves to be statistically uncertain.

The tables with automatically detected features give too much uncertainty. This can be observed from features related to `STint` which usually have significant different p-values in the KW-tests. Before relying on the results in these tables, it may be important to perform some cross-validation checks. The cross-validation check, examines how well a model can predict new data that was not used to create the model. Currently, these automatic tables contain too many uncertain results. The interesting parts are especially where all categories contain common feature results (example: ST-elevation).

One problem to discuss is the lack of elements in certain categories. Changing the similarity focus only on the ST-segment or the end-part (S to end) of the ECG-segment could improve the uncertainty. Setting the demand lower would only allow more distinct ECG-segments in the categories. Results from the two sub-experiments display reason to believe that $\bar{b}_{SEj}$(n)s can be used in predicting $\bar{b}_{SLj}$(n)s. A neonate correlated to a $\bar{b}_{SEj}$(n) will remain in its category with small improvements, given BMV.

5.4 Overall conclusion

The combined results of this project present: If a patient's ECG-segment correlate at an early stage in BMV with a category representation from this study ($\Delta_S \geq 0.95$) the morphology of the ST-segment will slightly improve with BMV, but remain in its category.

Almost all beat representations created in this project display downsloping ST-morphology, depressed ST-elevation and T-wave inversion. These features are displayed in asphyxiated neonate's ECG-segments. This result support claims which associate the features mentioned above as asphyxia related ECG-characteristics in previously published research articles [11], [13], [14].

5.5 Improvements for further work

After learning a great deal from this project, some thoughts on improvements emerged. First, instead of applying these two experiments to all the data, it may be interesting to perform the experiments only on specific feature outcomes. An example that can be relatively easy to perform with the program is to study only the worst outcomes versus the best outcome. Some features may occur more often than others.

Different settings with a variety of cluster requirements can lead to the creation of a database with asphyxiated classification segments for conventional use (similar to the databases on `https://www.physionet.org/`). A narrow analysis of some features and their related segments can also be done for further work.

Implementing more sophisticated and robust detection algorithms would limit the uncertain results in the automatic detection tables. Morphology detection could be improved by implementing a sample scaling algorithm which do not loose information in the ST-segment. This sample scaling will generate signals that are more similar in amplitude and bias than those used in this project. To put it another way, generating more realistic signals for the classification function `checkShape` (see Attachments 6.4) could improve this project's results. Experiments in this project could be solely performed regarding each patient's ST-segment or from S-peak to N (a patient's ECG-segment length).

To be a more user friendly analysis program, a graphical user interface (GUI) could have been created. The initial plan was to create a GUI, but the results piled up and the analysis took longer than expected. The program would be simple where the user could just insert parameters in text-boxes and a figure window to display different results. It should allow the user to inspect groups, categories and patient's ECG-segments individually.

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6. Attachments

This chapter contain a poster presentation, functions descriptions, a program description, extra results, complete tables and boxplots from the experiments.

6.1 Presentation of project poster

Figure 6.1 display the downscaled version of the poster which was used to present the project.

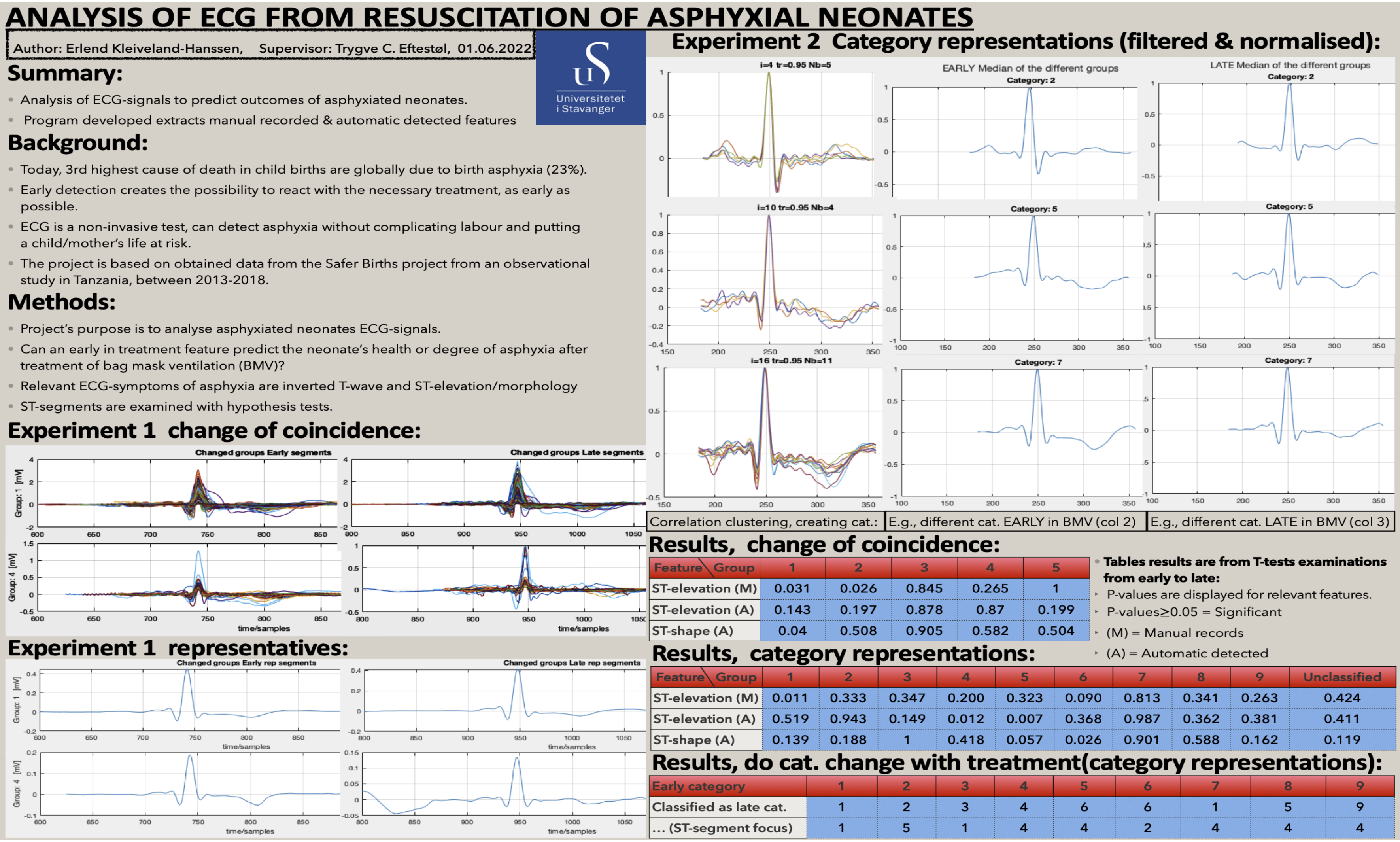

Figure 6.1: Downscaled poster which was used to present the project

6.2 Full program listings

In this following section all functions that are used is described in figures and in alphabetical order. Pseudocode can be read in the project's attached program files, along with description of the steps in the algorithm and the function's summary in the `docstring`. Figures 6.2-6.5 describe functions used in this project's program.

Function	**Description:**		
asph_scr	A function that returns a struct containing information depending on the mode that is inputted.		
	Input desctiptions:		
	k=	1, ECG-segments early in treatment are used	2, ECG-segments late/after treatment are used
	input=	A structure file that will be used as the input-object.	
	mode=	which mode function you want to use. Allowed inputs and descriptions below:	
		sgr	Load the segments into a structure variable where the ECGs before and after ventilation can be used or the length of each segment can be found.
		corrcoinc	Separating the segments in according to how much they have changed from early to late. RT, is in this mode the differential value which separates the groups in nGroups. (EXP. 1)
		simcalc	Calculates the correlation of segments before or after treatment (k=1 or 2).
		corrs	Chekcing som correlations between them, If a demand is met, then they are put into a cluster and displayed in a plot (before/after ventilation).
		getrep	Making a mean (if mean=1) or median representation from a correlation demand (RT).
		checkreps	Checking if all early/late rep segment belong to the same category after/before treatment.
		checkelreps	Checking if early/late elements that make the representations change their category after/before treatment.
		corrtocat	Individual patient correlation with representatives. Patient's early segments correlated to early representations and late segments to late representations.

Figure 6.2: Program description for the function `asph_scr`, part 1.

	RT	Demand value for different modes [0,1].	
	nGroups	How many groups 'corrcoinc' separates.	
	mean=	1, use an averaging method when comparing or finding a representative segment.	
		0, use the median method.	
	norm=	1, use normalized segments.	
		0, use unormalized segments.	
	filt=	1, use filtered segments.	0, use raw segments.
	fig=	1 then figures will be shown.	
	dispT=	1 then tables and information will be shown.	

Figure 6.3: Program description for the function `asph_scr`, part 2.

Function	Description:
boxplotChanges	A plotting function to show boxplots of different features
checkElevation	A function that categorize a segment's elevation depending on a correlation coefficient measurement.
checkKWfeature	Do a Kruskal Wallis p-test for the uneven struct with features (structwfeats).
checksegINFO	Examine spesific features of patients
checkShape	Categorize a segment's shape depending on a correlation coefficient measurement.
containIND	Check which elements are in both input lists.
corPol	Shifts an ECG segment if the poles are wrongly put when doing the ECG-signal recording.
corrsegs	Give out a correlation matrix which can focus on spesific parts of the segment.
detFeatures	Main program, which can repeat experiment one and two.
detQRST	Detection of QRST and morphology features in an ECG-segment.
findMAXseglength	To find each group in a cell with groups (cellwG)longest segment.
findOwnFeaturesfLOC	Finding own features from a list of cells (listoc) and a list of segments (listos).
findREP	Finding a median or mean segment which can be used as a representation segment.
focST	A function that only extracts a segment around the ST-part of an ECG-segment.
frameSegs	Make a frame around the segments for each group in a cell with groups (cellwG).
getData	A function to access some data according to a list of numbers.
getownFeatures	Get spesific features from ECG-segments contained in a cell with groups (cellwG).
getsegINFO	Get the index of patients with spesific features

Figure 6.4: Program description for the functions used in the project, part 1.

Function	Description:
getSEGS	Find the segments which belong in groups from groups containing idents.
getSignificants	Get the significant information depending on the p-values (sigVal).
getspesifics	Get spesific features and gathers everything in a structure as output (spesifics).
loadFilt	loads the necessary data and filters the segments for use in the rest of detFeatures script.
makeEvsLtable	Compare features in groups/categories, early vs late. Have they changed significantly or not.
makeOwnFeatsTable	From the input struct make a table containing a summary of the data.
makeOwnStruct	A function that make a structure that can be used in hyp-testing and table making.
makeStruct2compTable	Make two structures containing the necessary data to make a table showing the significant data as in the ST-delivery article.
makeTKtable	Do some statistical tests on features and their groups/categories (structwfeat) and returns a table as a summary. A Krusk Wallis test is performed, if KW-test find significant difference between groups/categories a post-hoc test is performed. Tukey HSD is chosen as the post-hoc test and it is a pairwise comparison of every group/category for each feature listed in structwfeat.
normfilt	Filteres segments containing nanvalues and normalizes them.
plotchangedGroups	Plots groups that are changed in experiment 1.
plotgroups	Plotting function which shows the different group/category segments.
plotQRST	plot a ECG-segment in a list or compare early and late segments.
plotrepsQRST	A plotting function of the representatives in experiment 2, for a closer look at the feature or representatives found.
showChange	Display how segments have changed after ventilation treatment.
trimxy2	Inverts depending on maximum value and a correlation measurement, and gives two segments out with the same length.
xy2XY	Aligns and get a frame around segments with different lengths.

Figure 6.5: Program description for the functions used in the project, part 2.

6.3 Program development

The program and functions are written while trying to maintain the DRY-principle. All functions and scripts have helpful `docstrings` included. These `docstrings` are used in Matlab as information text about that written function/script. The `docstrings` may be read by opening the functions file or by writing: help function-/script-name to make Matlab display the `docstring` in Matlab's command window.

6.3.1 Early development

After importing the data, the path leading to the final product was done experimentally. The script is created to have customize able parameters. It was made to be a user-friendly program which could be used to repeat the experiments.

The main script `detFeatures` was early in development just relying on the `asph_scr` function. After the program developed and became larger, more general functions were created. The general functions were determined more useful than to produce everything inside the `asph_scr` function's switch mode. With general functions the program should be easier to understand and readable. Also, it should make it simpler to replicate the experiments or perform different experiments with other parameters.

6.3.2 Flowchart description

Step 1 fig. 3.4 is a starting check. Have the ECG-segments changed after treatment. In this step, the correlation measurement is between a patient's segment at the early ($b_{Ei}(n)$) and late ($b_{Li}(n)$) stage. The indexes ('i') of the segments are put into groups depending on how different they have become after ventilation. This is the base of experiment 1, which is performed with different parameter inputs. The crucial point is to examine the possibility that the change factor affects relevant features or is related to changes in the ST-segment. This can give early hints to predict feature end-results or early indication of asphyxia. Figure 6.6 illustrates a flowchart of the program used to perform experiment 1.

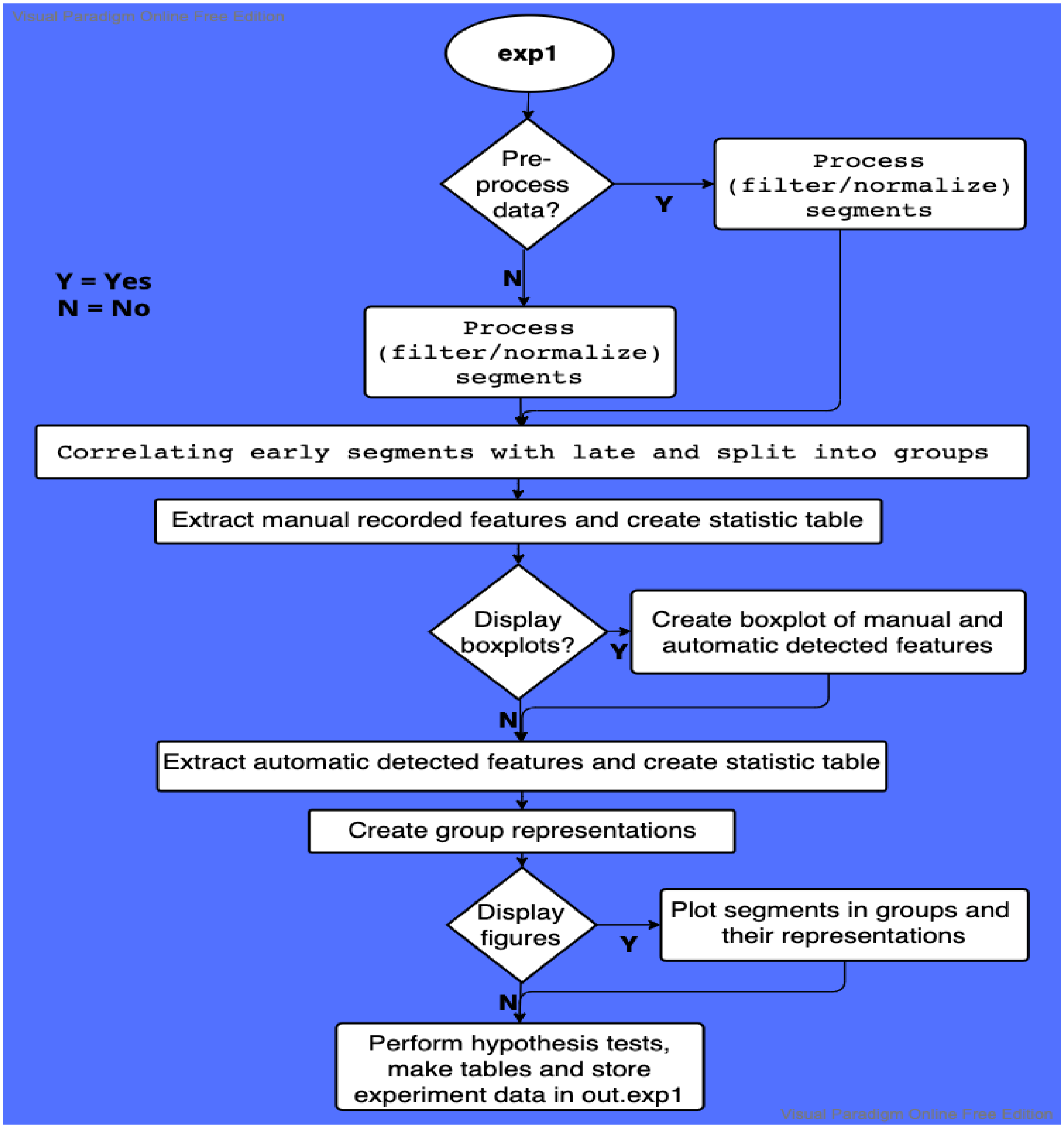

Figure 6.6: Flowchart of the program for experiment 1

In step 2 from fig. 3.4 two correlation matrices, one for all early and one for all late segments are created.

Both matrices are the size of 547X547 (547 patients). It is also made a normalized correlation measure, RMS (Root mean square) and a normalized RMS measurement. The RMS values can be used for some extension experiments, but the experiments in chapter 3 have used correlation coefficient values. These correlation values determines the cluster groups before creating health category representations. Figure 6.7 illustrates a flowchart of the program used to perform experiment 2.

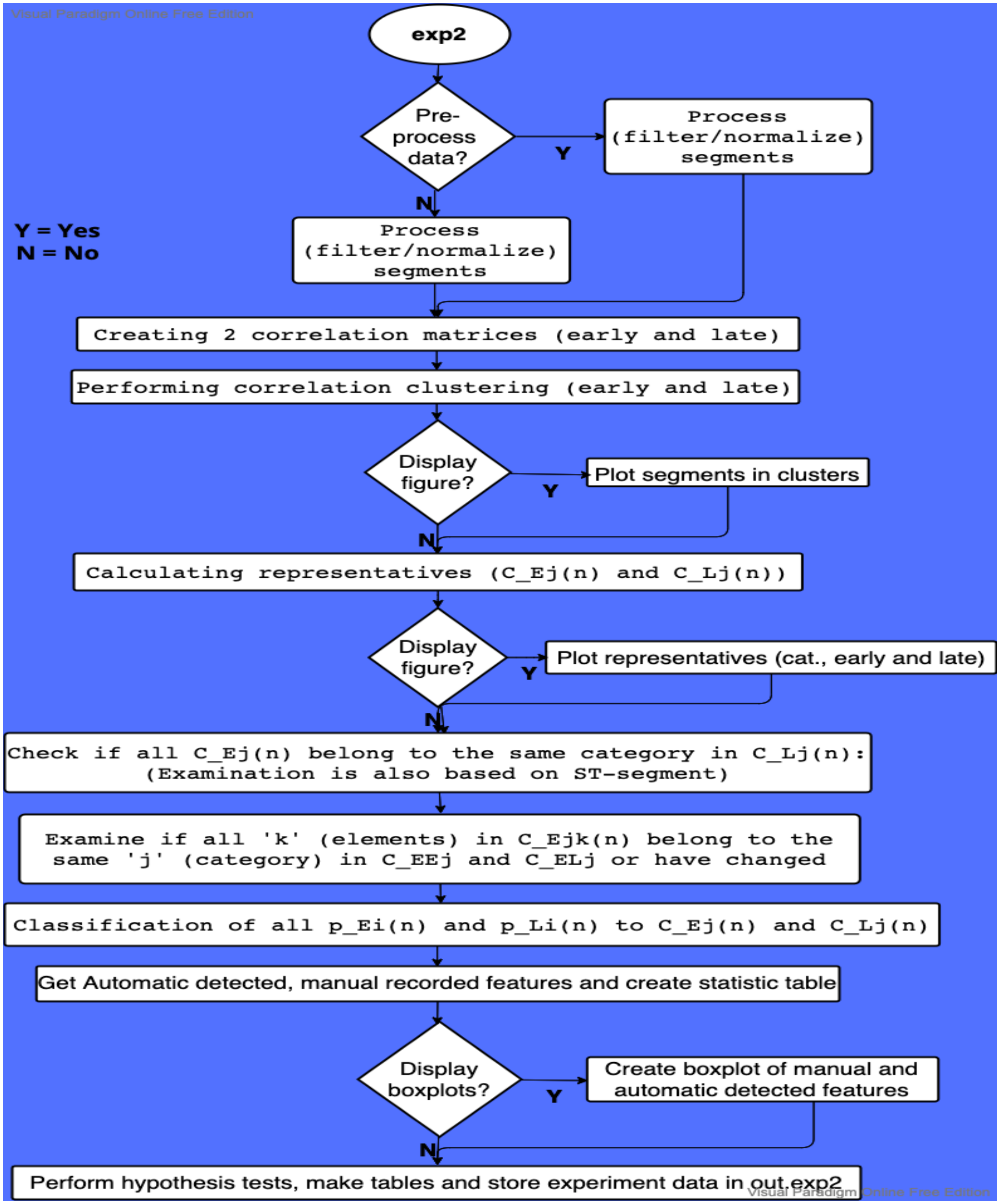

Figure 6.7: Flowchart of the program for experiment 2

Step 3 from fig. 3.4 is a data examination. This step is mainly done to produce the same results as in table 2, from the article of Linde et al. [11]. This comparison will verify that it is almost the identical data used and how well the automatic feature detection algorithm work. Figure 6.8 illustrates a flowchart of the algorithm used for the comparison.

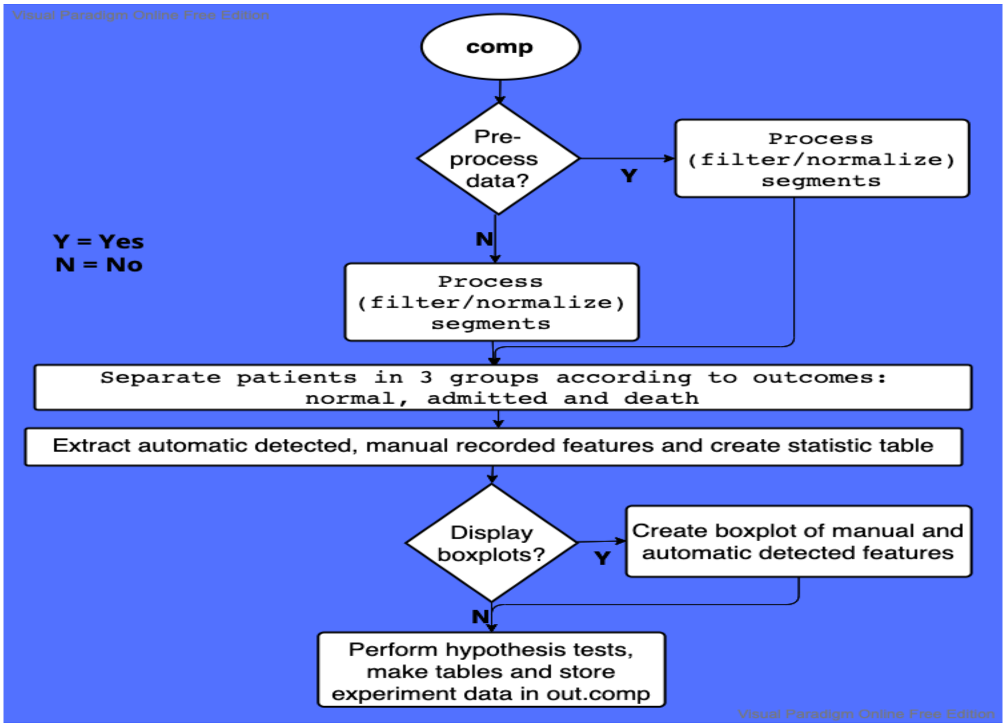

Figure 6.8: Flowchart of the comparison algorithm

In all of the different parts mentioned above, manual and automatic detected features are extracted. Lastly, these extracted features will be compared and examined through the statistical view with different hypothesis tests. Groups and categories will be compared to display which features have changed with given BMV treatment. Figure 6.9 illustrates hypothesis tests that are performed for all the different steps.

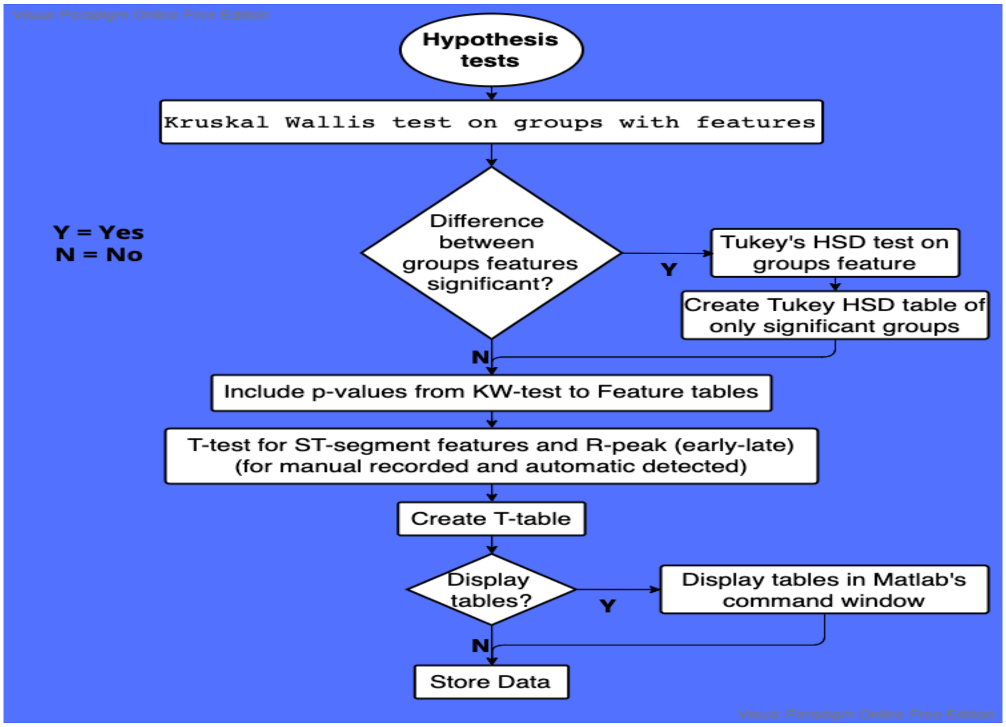

Figure 6.9: Flowchart of the program for hypothesis tests

6.3.3 Group/category setting and classifying

In the equations 2.1 and 2.2, δ represents this project's correlation factor. The value of δ decides how the various groups/categories to be analyzed are structured. A median and average segment representing the groups/categories are created. These group/category representations are denoted $C_j(n)/S_j(n)$. As an example $C_{Ej}(n)$ refers to a group representation segment created by $b_{Ei}(n)$s (segments from early in ventilation) while $S_{Lj}(n)$ refers to a category representation segment created by $b_{Li}(n)$s (segments late in ventilation). To be able do distinguish elements in a group/category the letter 'k' represents a member of the group/category. As an example: $S_{Ejk}(n)$, a $b_{Ei}(n)$ belonging to category 'j'. The groups/categories will be analyzed for relevant asphyxia features and other features. It will be examined if $C_j(n)/S_j(n)$ changes with resuscitation treatment.

6.3.4 `asph_scr.m` function summary

The Matlab file `asph_scr.m` contains most of the program. It is a Matlab function created early in the project, with a switch setting. Depending on the input `mode`, the file loads the patient data, calculate the correlation, plots the correlated segment groups together and create representative ECG-segments. One `mode` input, calculates correlation coefficients early and late of segments against its respective time representatives. This is done for each member, for every segment in the representative categories and also only for the representative segments.

6.3.5 Functions repeatedly used description

As stated in 6.3.3, `asph_scr.m` contains most of the program, but `detFeatures.m` is the main file. It is inside `detFeatures.m` the user must define parameters to extract results.

The data is imported along with relevant patient information (ventilation times, neonate outcome, etc.) which was manually analyzed. Pre-filtering of the segments is done to smooth out the signals (to avoid irrelevant ripples or noise artifacts). A Matlab file ('filtered_segments.mat') is loaded to avoid spending time on the filtering of segments before performing experiments. This can be changed if the user would like to try perform experiments with other filter parameters.

6.3.5.1 Filters in the program

Figure 6.10 illustrates the difference between the early filtering (use of filtered segments) and the parameter **filt** option in **asph_scr.m**. Listing 6.1 reveal the command which generated this example. The segment is first HP-filtered (40Hz), then plotted and then HP-filtered (20Hz) and then plotted. The 20Hz HP-filtering is used later in the program to attain a good group representation signal. A group representation is selected to focus on the ECG-morphology without ripples. The morphology was determined to have greater significance than retaining the amplitude values. Most of the peak-values were changed relatively much if the pre-filtering was performed with 20Hz as the cutoff frequency, as illustrated in fig. 6.10.

Listing 6.1: Illutstrating command for comparing meaningful filter options

```
figure();plot(out.S{100,1});hold on;plot(out.filt{100,1})
```

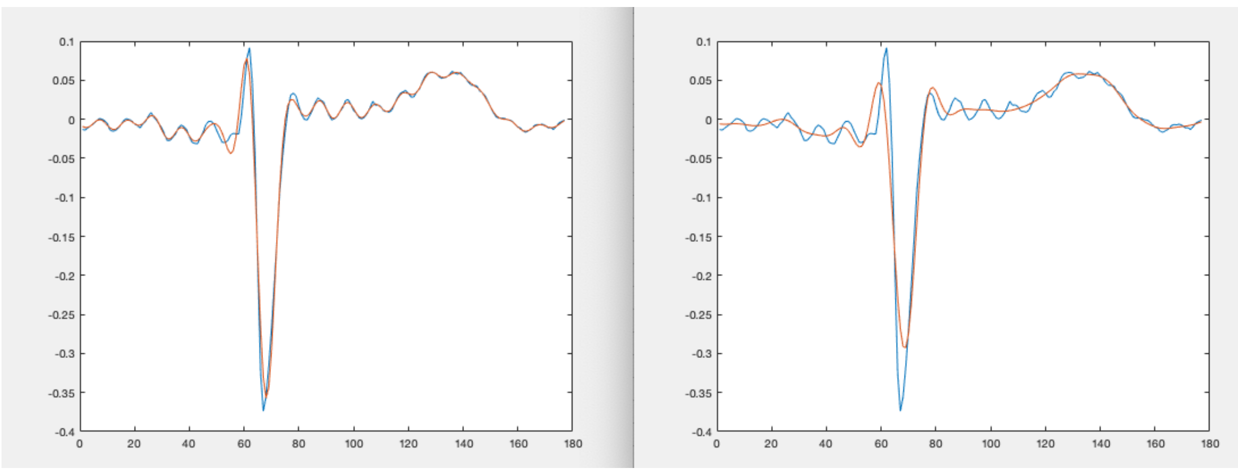

Figure 6.10: Illustrating the difference between pre-filtering (left graph) and the **filt** option (right graph) in the program. The original signal is marked with blue while the filtered line is orange.

6.3.5.2 Pre-calculating the correlation values

The correlation value between b_i(n) and $b_j(n)$ (i$\neq$j) is used multiple times in this program. Two steps are performed before calculating the correlation values.

First b_i(n) and b_j(n) have their polarity matched. The segments are positioned with their absolute max peak value in the positive polarity (see fig. 6.11). According to the report of Schwartz et al. [19] the P-peak is supposed to be positive while the T-peak can be found negative with sensor placement in V_1 and positive in V_5-V_6. The P-peak can be difficult to detect and is therefore not used for alignment. Guidelines of Schwartz et al. [19] also lists that the T-peak commonly varies the first weeks and that the ST-segment is not usually above the baseline. Considering information from the report of Schwartz et al. [19], knowing T-wave inversion is common among neonates with asphyxia [13] and examining the data material for the project. It is decided that the polarity alignment should be based on the R-peak (as positive). The most important point is that the two segments should be aligned in the most similar way. Next, two correlation measurements are calculated.

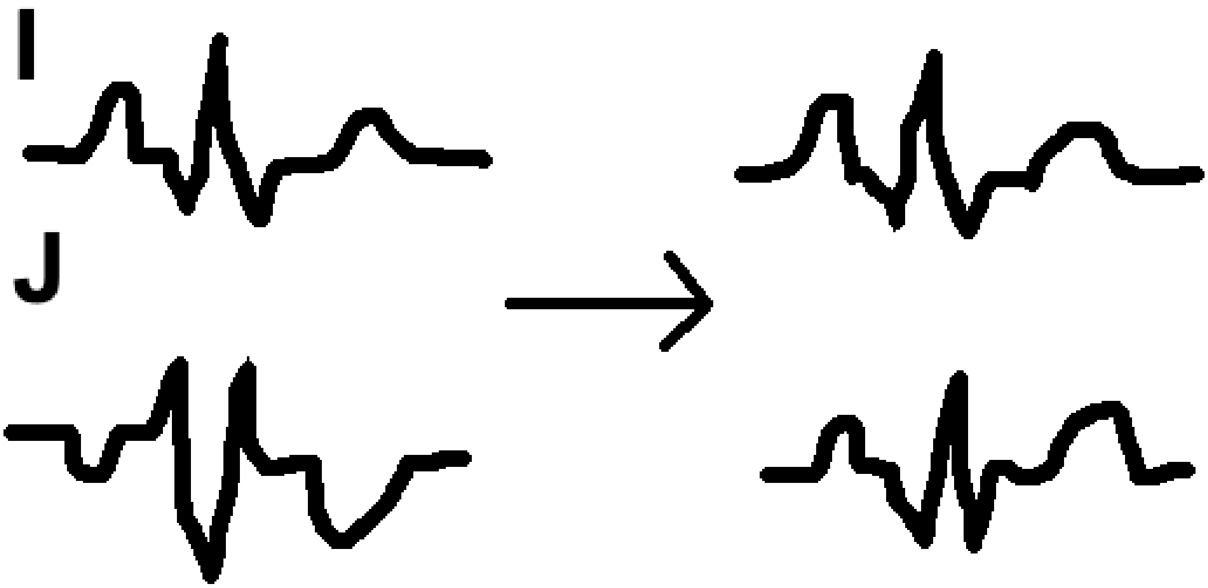

Figure 6.11: Illustrating the polarity match depending on the highest amplitude value:

The correlation measurements are calculated because some segments contain spikes where the R-peak is not measured the largest value. b_i(n) is kept still, a correlation coefficient is calculated for all time shifts (Matlab's `xcorr` function [37]). Then b_j(n) is inverted and the correlation coefficients are again calculated. Whichever variable contain the absolute highest correlation value will decide b_j(n)'s polarity. Now, both segments should have the same polarity. This procedure is illustrated in figure 6.12

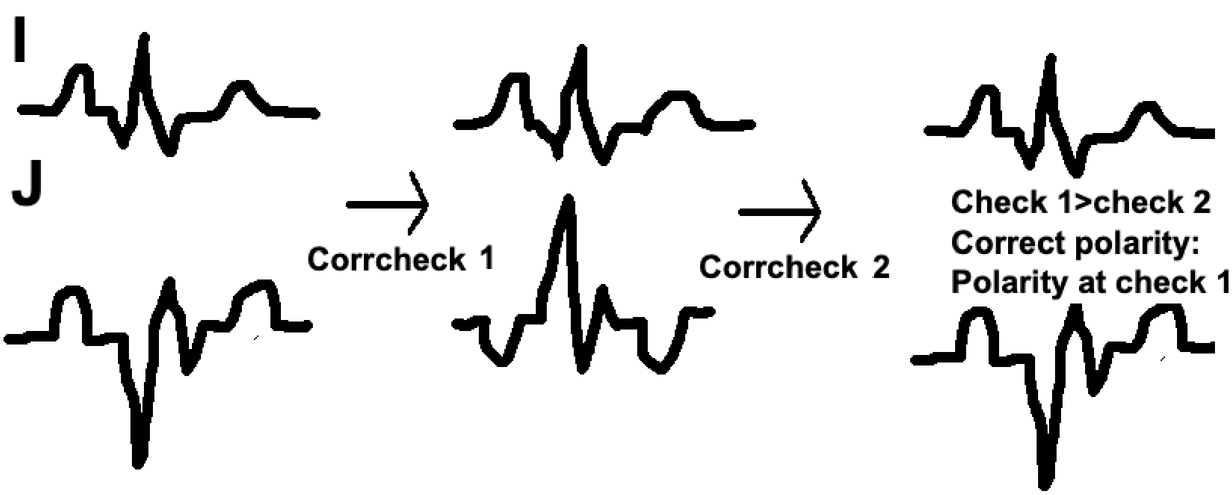

Figure 6.12: Illustrating the polarity match depending on the corr. value

Secondly, the segments are aligned on top of each other with their R-peaks and trimmed to the same length N. Aligning the segments usually happens with the R-peaks, but the deciding factor is where the segments correlate the most. Segments b_i(n) and b_j(n) aligns, then the trimming start in one end of a segment depending on the lag value from `xcorr`. Trimming of the signals continue on until $N_{b_i(n)}$ and $N_{b_j(n)}$ are equal. Figure 6.13 illustrates this step.

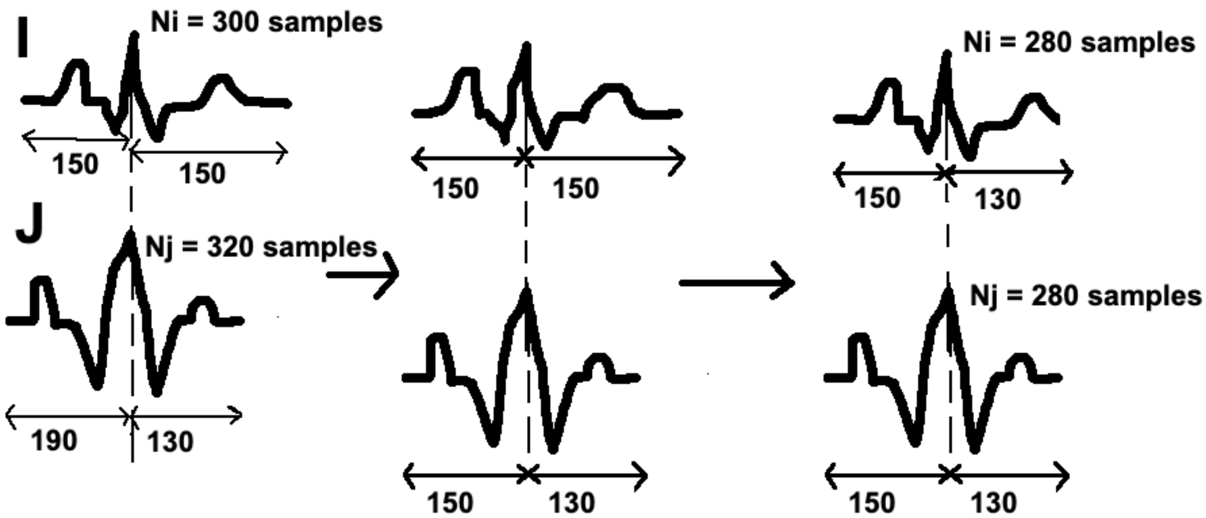

Figure 6.13: Illustrating the length matching depending on the corr value

These two steps mentioned above are performed with the use of function `trimxy2` (see 6.5). The function `trimxy2` is used before every correlation measure in the program.

6.3.5.3 Frame making

To get better observational plots, the segments are put into frames with their R-peaks aligned. The function `xy2XY` (see function in listing 6.5) aligns the R-peaks and puts a frame around with `NaN` values depending on the lengths of the segments. R-peaks are centered around the frame's center. A maximum size of the frame can be chosen. Then the function `xy2XY` crops the frame to the input size or the longest segment will decide the frame-size. This makes it possible to compare segments of different lengths without using the `trimxy2` function.

The `trimxy2` function is mostly used instead of `xy2XY`, because it is easier to manipulate and use the segments post-`trimxy2` without handling the `NaN` values (post-`xy2XY`). Many functions in Matlab can not ignore the `NaN` values. Therefore, by using the output segments from `xy2XY` one would have to remove the `NaN` values every time before using some Matlab functions on them. In short, `xy2XY` is used before plotting. Figure 6.14 illustrates the point of the frame making (function `xy2XY`). By looking at figure 6.18 or 6.19 it can be observed that some of the segments in the different categories are of different lengths.

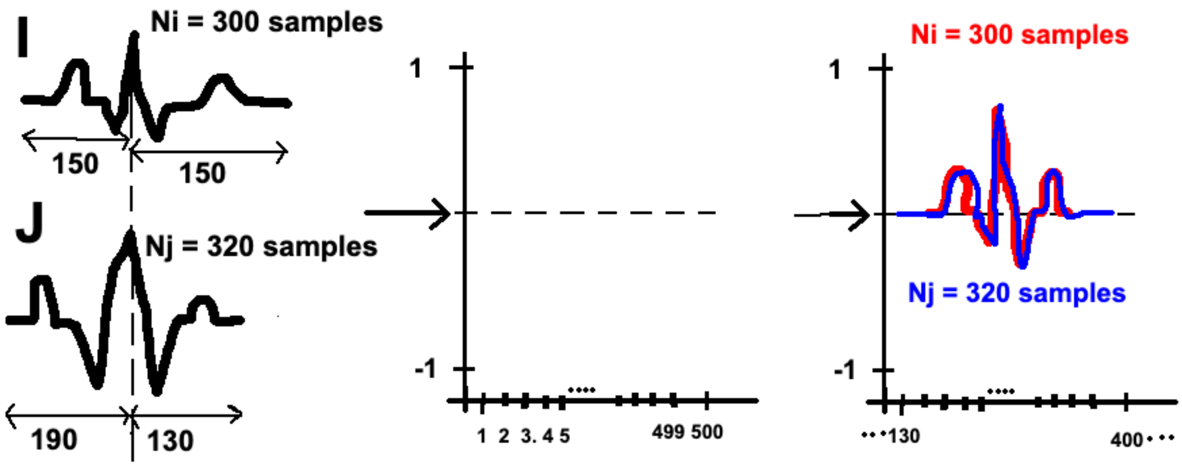

Figure 6.14: Illustrating the frame making concept. Segments with different lengths inside the same frame.

6.4 Program description

This section describes the performed experiment, parameters set, functions in use and illustrates key parts. Matlab R2020b (MathWorks Inc., Natick, MA, USA) was used and is required to perform the experiments without unknown errors. Two main experiments are performed which are divided into different parts. All experiments and the comparison part of the script (step 3, figure 3.4) extracts the result in the Matlab variable structure `out`. Depending on the user set parameters figures, tables and boxplots can be plotted as well.

The main purpose of this section is to give the reader enough information so that they may repeat the experiments themselves or use other parameters and do some new experiments. It can also give insight into which functions controls what if there is an error occurring. This is to make error tracking easier.

Pre-determined parameters:

- filter cutoff frequency (fc) at 20Hz and type of filter (LP or HP). These are both used by the user-defined parameter filt =1.
- Sampling frequency (fs): 500Hz in accordance with the article of Linde et al. [11].
- 40 Hz for the low pass cut off frequency which the filtered segments are filtered with.
- Features that were determined relevant for extraction (Outcome, St-elevation, etc).
- Which type of hypothesis tests that are used.
- The size of the time windows for the plotted graphs.
- Boxplot outliers are removed for better visualizing the data between the 1st and 3rd quantile.

Global user defined parameters

- mean: if mean = 1 the average method will be used or if mean = 0, the median method will be used in the experiments.
- norm: if norm = 1, normalized segments will be used in the experiments. unormalized segments will be used by setting norm = 0.

- filt: if filt = 1, filtered segments will be used in the experiments. unfiltered segments will be used by setting filt = 0. May be filtered for better visuals.
- sigVal: Sets the significance level for the hypothesis tests.
- fig: if fig = 1, figures will be shown.
- dispT: if dispT = 1, tables will be shown.
- modus2:
  1. modus2 = 'exp1': Performs experiment 1.
  2. modus2 = 'exp2': Performs experiment 2.
  3. modus2 = 'comp': Perform a comparison with table 2 in the article of Linde et al. [11].
  4. modus2 = anything else: A displayed message may say the user should try to change parameters.

Experiments, general walkthrough

Independent of the choice of the variable `modus2` a general program description is made in this part. First the choice of data to use has to be made. The global parameters determine which data will be used. For example if `filt` is chosen 1, then the segments will be filtered leading on to the chosen experiment's further processing and calculations. If the variable `norm` is set to 1, normalized segments will be used. When the variable `mean` is set to 0, the median will be used as the method when analyzing the data.

Then the correlation calculations and classification/grouping can be performed depending on the chosen experiment and parameters. At this point all relevant data is stored and is utilized to plot relevant figures or perform hypothesis tests. Figures can be observed at this point if the variable `fig`=1.

If `boxP`=1, a notched boxplot (read 6.7.1 for details) will illustrate the distribution of the data features belonging to each group with the outliers removed. The features which can be observed in the boxplot is depending on the functions `boxplotChanges`, `findOwnFeaturesfLOC` and `getspesifics` (functions described in figures 6.4 and 6.5).

If `dispT`=1, the tables will be displayed in the command window. The last part of every program part is storing the results in the `out` variable under its respective `field`.

6.4.1 Experiment 1, Analysis of beat changes

This experiment is meant to examine the relationship between the change of segments in time and specific features. In short, is the change of beats in time and of features only a coincidence from a statistical point of view. Therefore three different parameter settings of the `corrcoinc` command in `asph_scr` were run. The results are stored in the `out` variable under the field `changes`. First a description of the available user defined parameters:

- diff: How much separate the groups in the Matlab value of type `double` (ΔC =diff in section 3.2.2). The input is valid as long as the value is: diff $\exists(0,1) \subset \Re$. The variable is denoted ΔC in 3.2.2.
- nGroups: How many groups the segments from the experiment should be divided into.
- If (diff*nGroups)$>$ 1: This will lead to a displayed suggestion for new parameters and that diff*nGroups can not be greater than 1.

6.4.1.1 Visualizing some temporary results

Figures from the experiment with different parameter settings will be illustrated below. The parameter settings are written in headlines above their respective figure.

5 groups and ΔC= 0.2

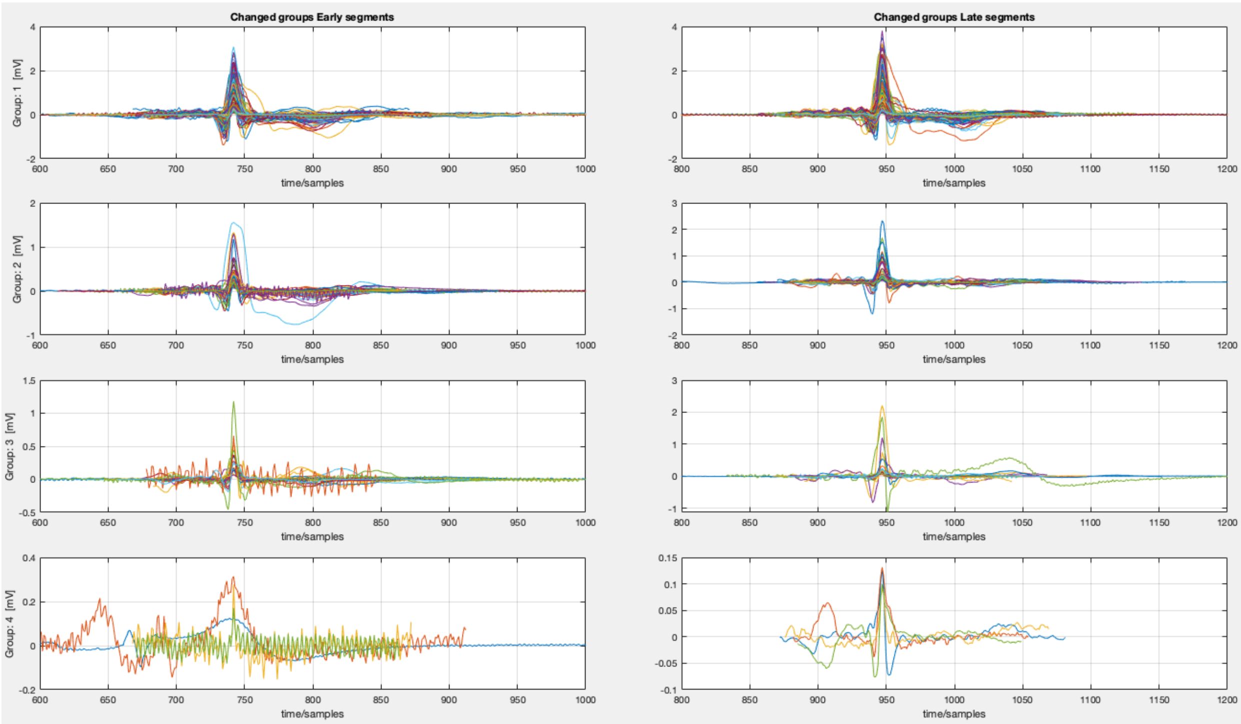

Figure 6.15: 5 groups with ΔC=0.2 examined. Patients segments of every group is plotted early (left) and late (right).

10 groups and ΔC= 0.05

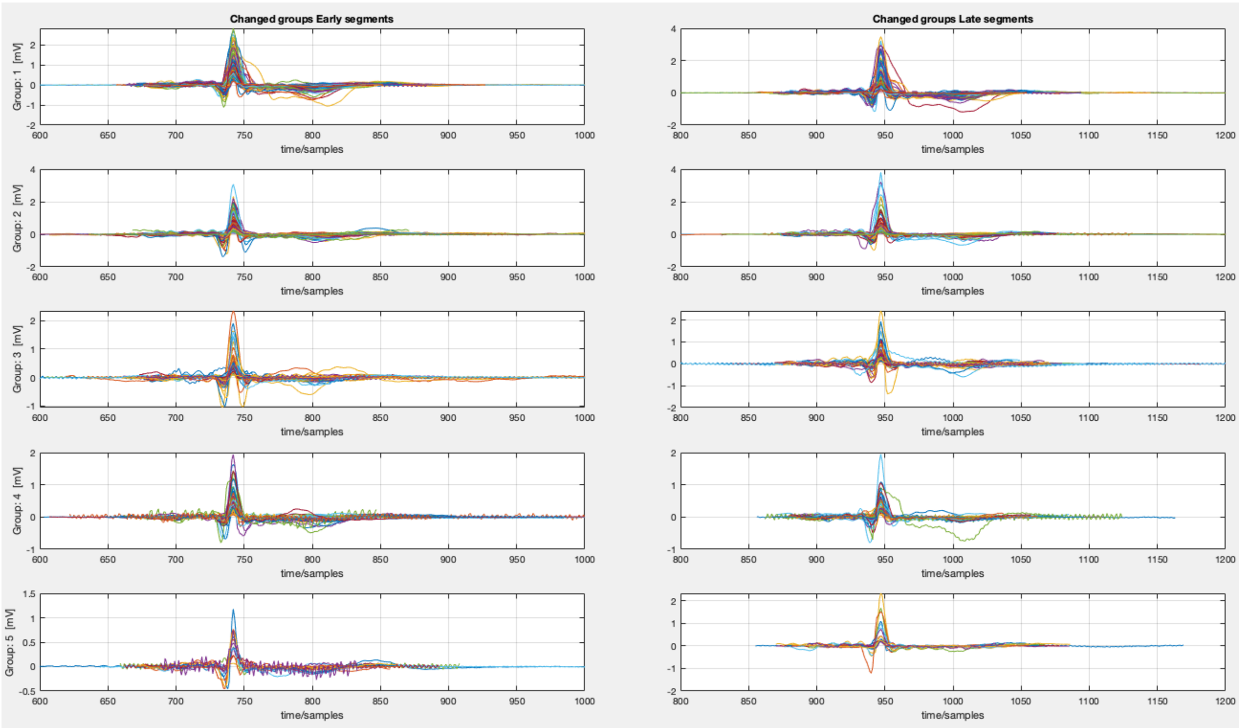

Figure 6.16: 10 groups with ΔC=0.05 examined. Patients segments of every group is plotted. Groups from 1 to 5.

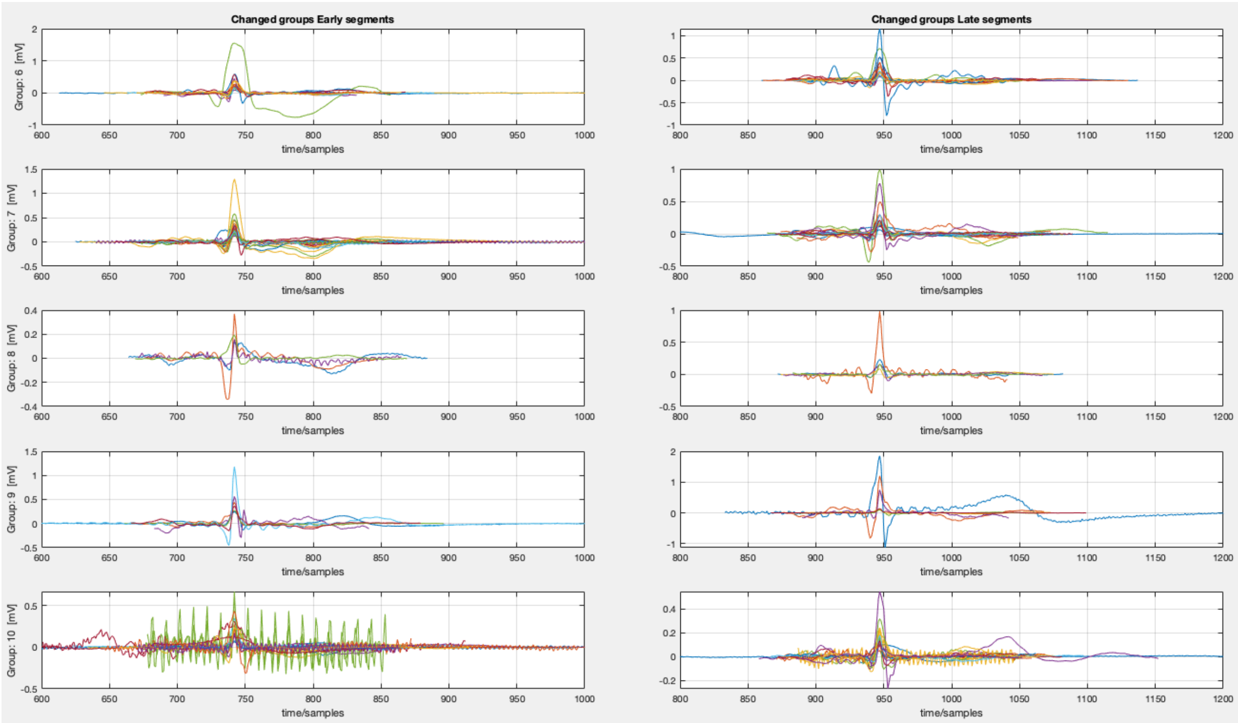

Figure 6.17: 10 groups with ΔC=0.05 examined. Patients segments of every group is plotted. Groups from 6 to 10.

6.4.2 Exp. 2 program description

To get unprocessed results of the data, this experiment is divided into two parts. In one part, the data is normalized and filtered. In the other part, it is not. A reason to divide the experiment is to let a clinician interpret the unnormalized results. Segments that are similar in shape but have different amplitudes will be grouped together in the normalized part, which we are pursuing.
For this experiment the following variables can be chosen: `RT` and `corr2catRT` ((D_S and Δ_{cat} in section 3.2.3). User defined parameter are described below:

- `RT`: The initial correlation demand for this experiment. Called D_S in 3.2.3. Segments in the categories have a correlation coefficient with each other $\geq$ `RT`. With a low value there will be a lot of groups containing similar segments with regards to the morphology.
- `corr2catRT`: A correlation demand for the late part of the experiment where segments are correlated with the category representatives.
-
- for both: The variables are of Matlab's type `double` and the input is valid as long as the value is: `RT` and `corr2catRT` $\exists(0,1) \subset \Re$. Both variables should be set close to 1. If it is not there will be segments that are not that similar in the same category.

When the data is chosen, a correlation matrix for early and late segments is made with function `asph_scr` and the mode `'simcalc'`. Clustering of the segments at an early and late time is done with `asph_scr` and the mode `'corrs'`. The `case 'corrs'` use the correlation matrices to choose according to `RT` which segments should be clustered together. Index of the segments and segments are stored in the `out` variable under the field `groups2cat`. Figure 6.18 and 6.19 shows the different segments in each category before it is made into a median representative. Input `'getrep'` in `asph_scr` calculates and stores the median representations in the variable `out`. The median representatives created by patients early segments are denoted S_{Ej}(n)

At this point in the script some analysis are done. The mode inputs are described, used sequentially and listed below:

1. `'checkreps'`: Examines if all $\bar{b}_{SEj}$(n)s belong to the same category after ventilation. The opposite examination is also done, where $\bar{b}_{SLj}$(n)s is correlated with the $\bar{b}_{SLEj}$(n)s. The method is illustrated in equations 3.27 and 3.28:
2. `'checkelreps'`: Examines if all b_{Ei}(n)s of a category belongs to the same category at the same time and after BMV. It also checks the opposite, if b_{Li}(n)s in a category belongs to the same category at the same time and early in BMV. Calculations are illustrated in equations 3.29 and 3.30.
3. `'corrtocat'`: An individual patient's segment is correlated with the representatives from the same time. The correlation coefficient is required to be a larger value than the user set parameter `corr2catRT` or else it will be put in the unclassified category. Equation 3.33 and 3.34 illustrate an example of how the correlation calculations are performed.

After these steps, features are extracted from the categories, hypothesis tests are performed, tables are created and everything is stored in the `out` variable inside the field exp2. Below are the two different parameter settings summarized:

1. - `norm` = 0.
   - `filt` = 0.
2. - `norm` = 1.
   - `filt` = 1.

For both parts of the experiment the demands below are set:

- `RT` = 0.95 RT is the variable for D_s in 3.2.3
- `corr2catRT` = 0.9

6.4.3 Exp. 2 visualizing the categories:

Figures from the experiment with different parameter settings are illustrated below. The `norm` and `filt` parameter settings are written in headlines above their respective figure. Figures6.18-display the plotted elements in their respective categories. One category is represented with one axe window in the figures.

`norm`=0 and `filt`=0

Observe that the amplitudes are different, in the following figures. Still, the similarity (morphology) is present in some categories. Also note some of the b_i(n)s contain noise, but the shape is not ruined (see example in figure 6.18, the center subplot, i=16). Figure 6.18 display b_{Ei}(n) in their respective category window.

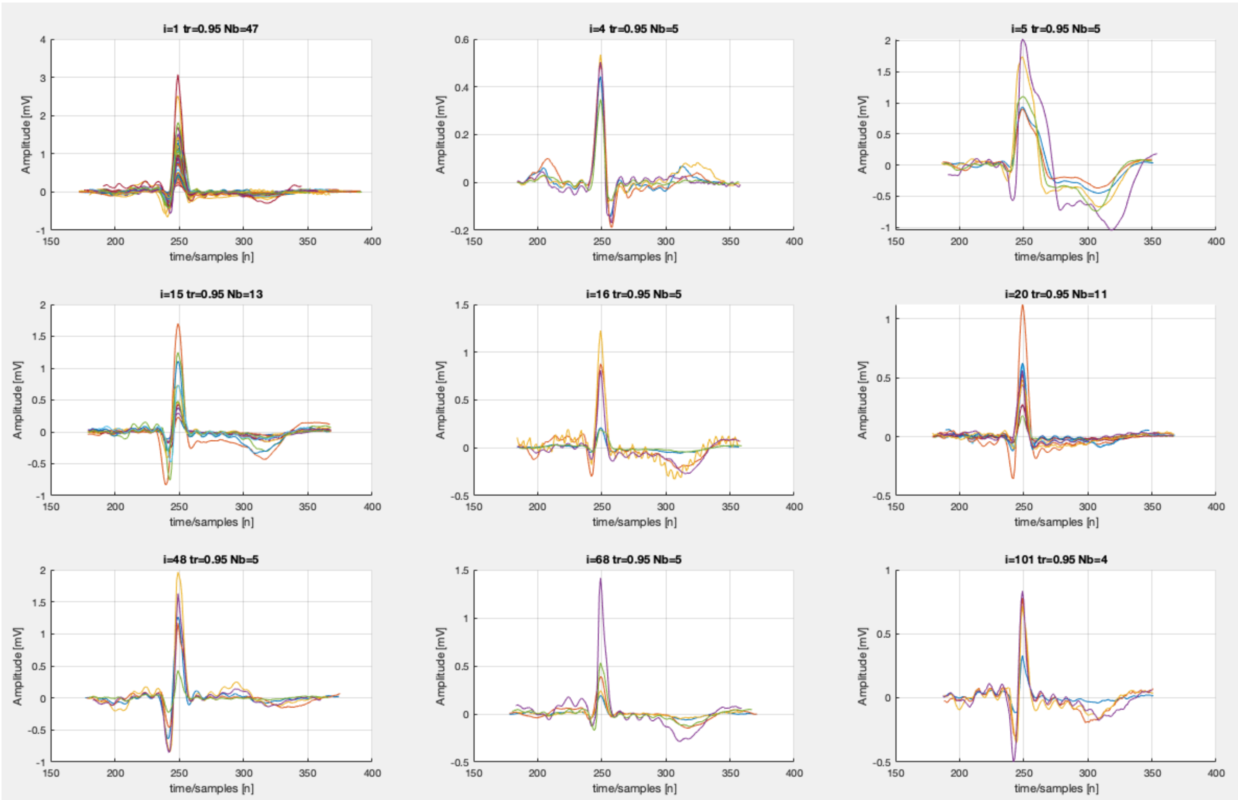

Figure 6.18: Clustering unfiltered and unnormalized (early) segments according to $D_S = 0.95$ and $Rb = 4$

$b_{Li}(n)$s are displayed in figure 6.19 in their determined categories. Note that it only emerged seven categories due to low correlation relations.

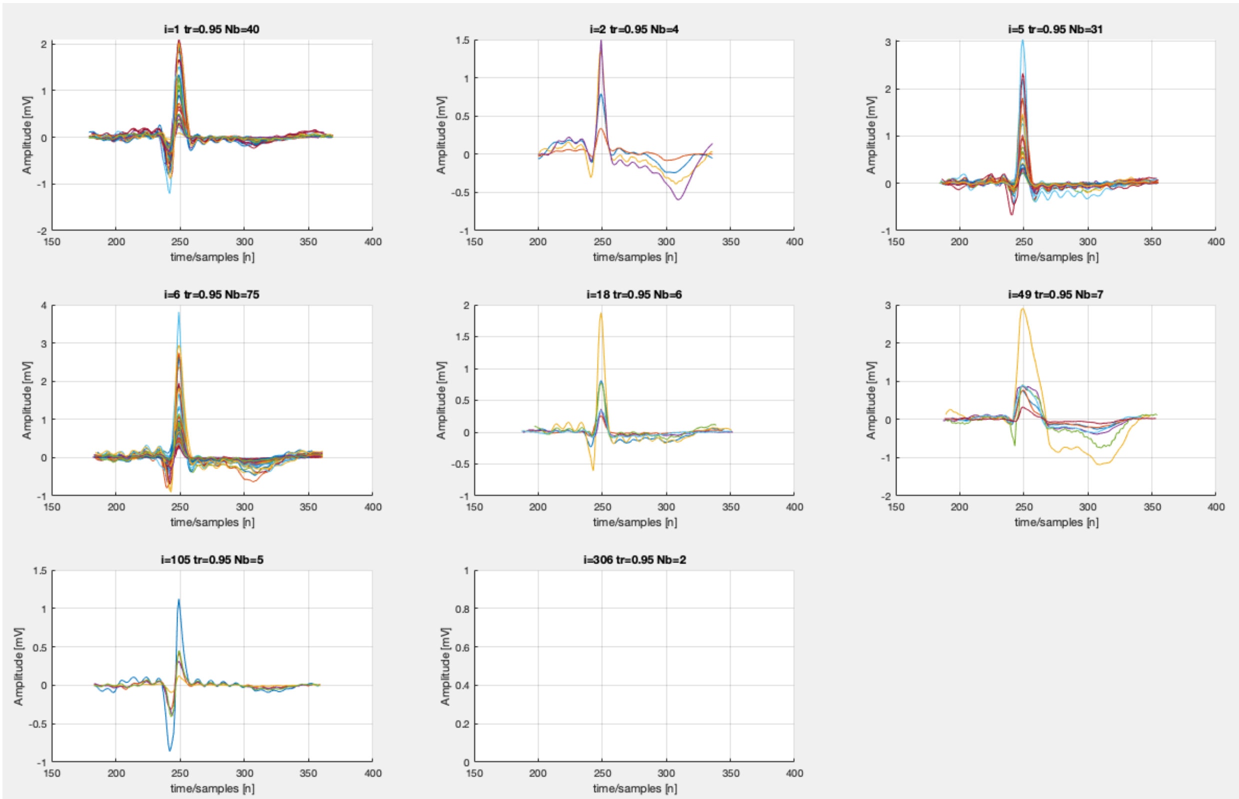

Figure 6.19: Clustering unfiltered and unnormalized (late) segments according to $D_S = 0.95$ and $Rb = 4$

Figures 6.20 and 6.21 illustrate classified patient segments in a category according to the calculations done in the mode `'corrtocat'`. The demand for being classified to a group is determined by the user set parameter `corr2catRT`. Amplitude levels differ greatly from the figures 6.18 and 6.19.

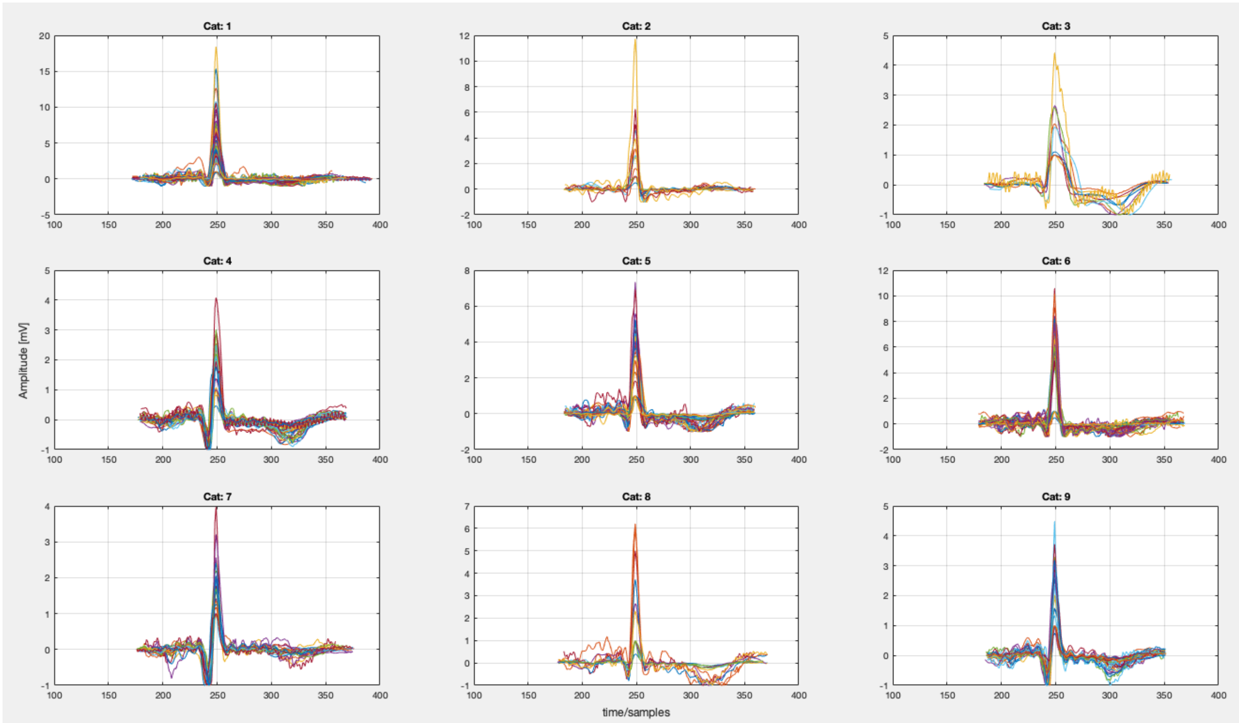

Figure 6.20: Clustering unfiltered and unnormalized early segments according to the correlation demand 0.9 with early category representations based on early segments.

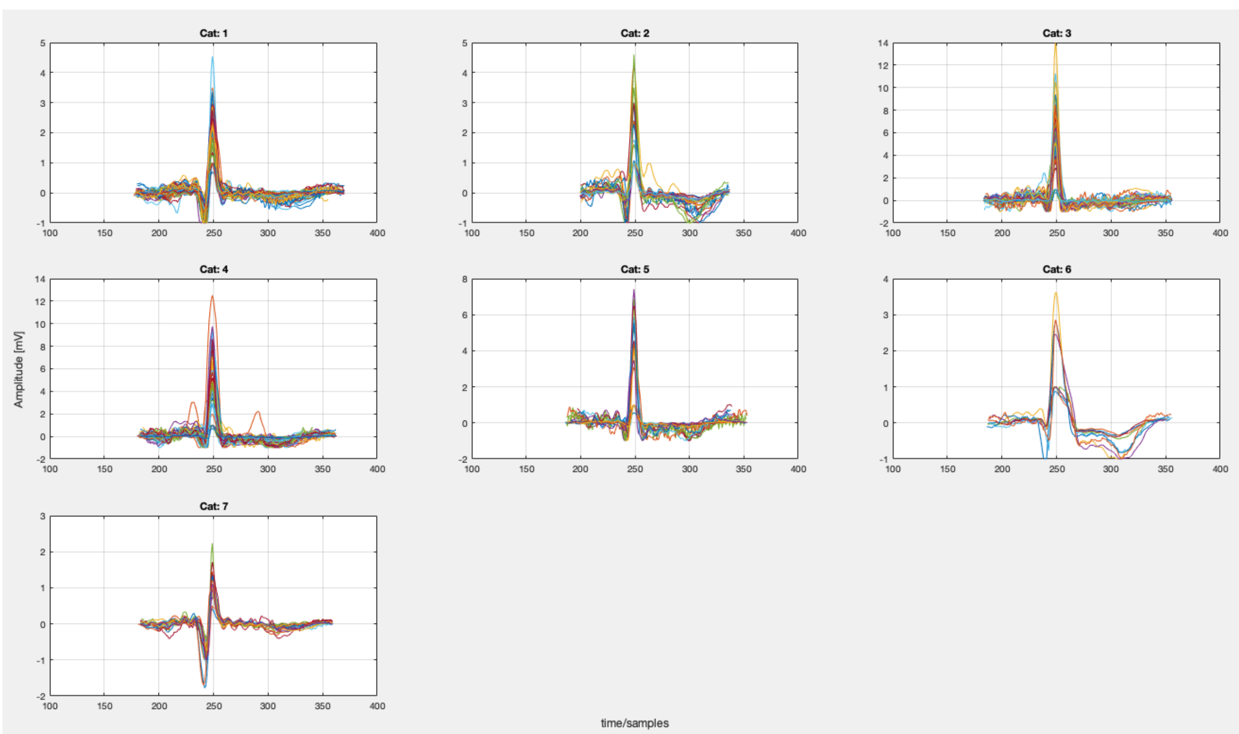

Figure 6.21: Clustering unfiltered and unnormalized late segments according to the correlation demand 0.9 with late category representations based on late segments.

`norm`=1 and `filt`=1

Normalized and filtered $b_{Li}(n)$s are displayed in figure 6.22 in their determined categories. Note that it emerged seven categories in the unfiltered section, now nine categories are present.

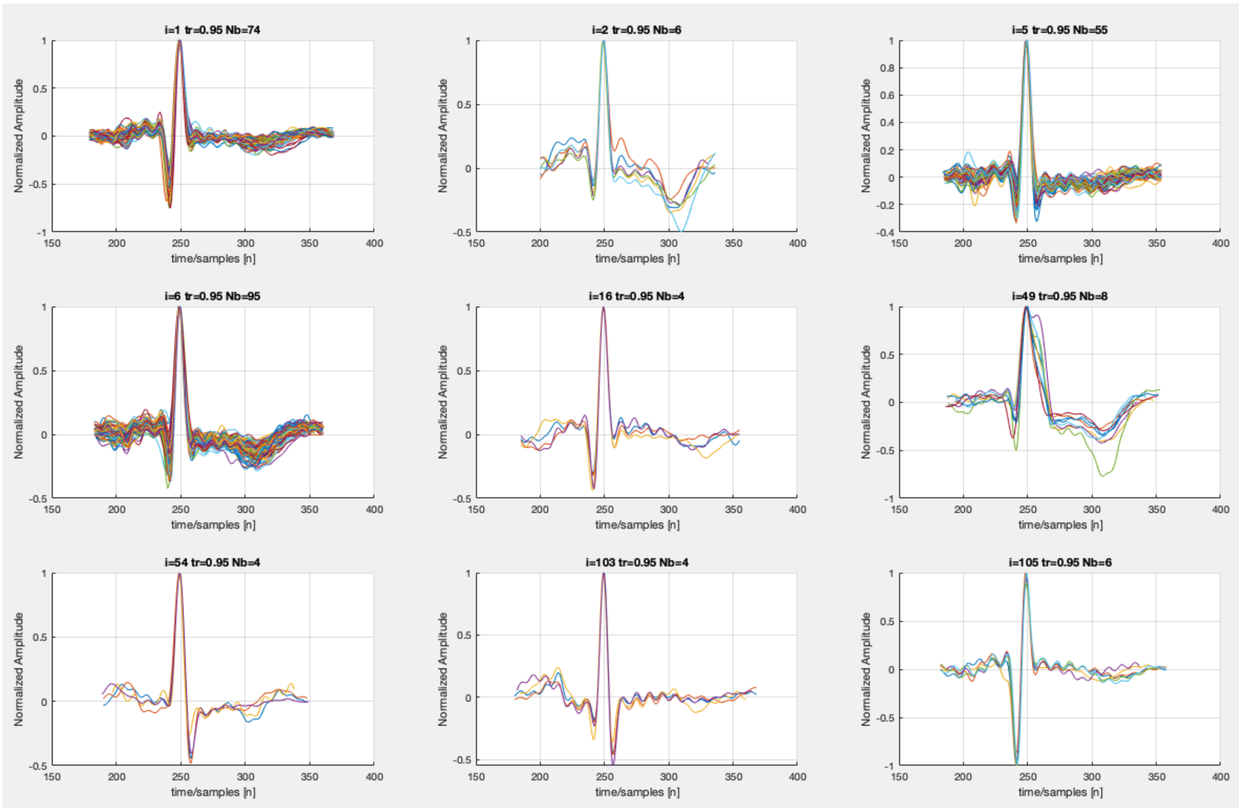

Figure 6.22: Clustering filtered and normalized (late) segments according to D_S= 0.95 and Rb= 4

Figures 6.23 and 6.24 illustrate classified patient segments in a category according to the calculations done in the mode `'corrtocat'`. All the segments are normalized and filtered to dedicate focus to the ECG-segments morphology. The demand `corr2catRT` still determines the lower limits for the similarity measurement. Amplitude levels should be noted are no problem with these parameter settings.

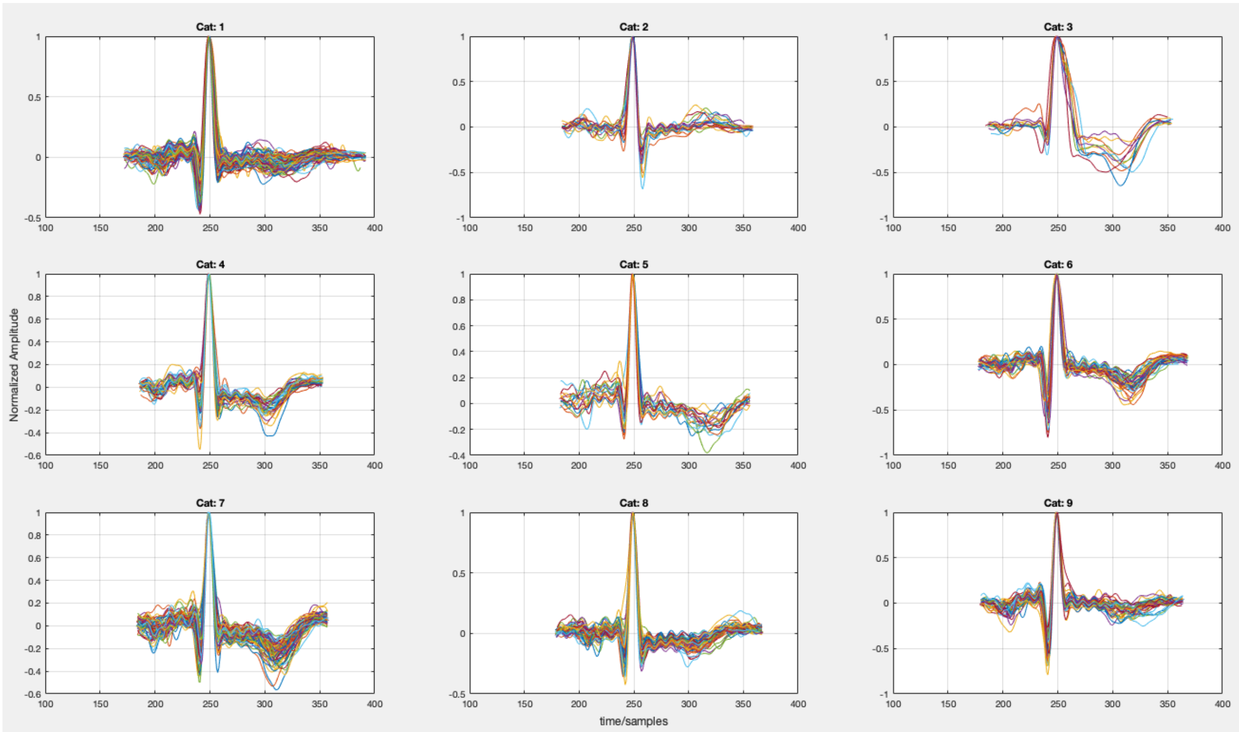

Figure 6.23: Clustering normalized and filtered early segments according to the correlation demand 0.9 with early category representations based on early segments.

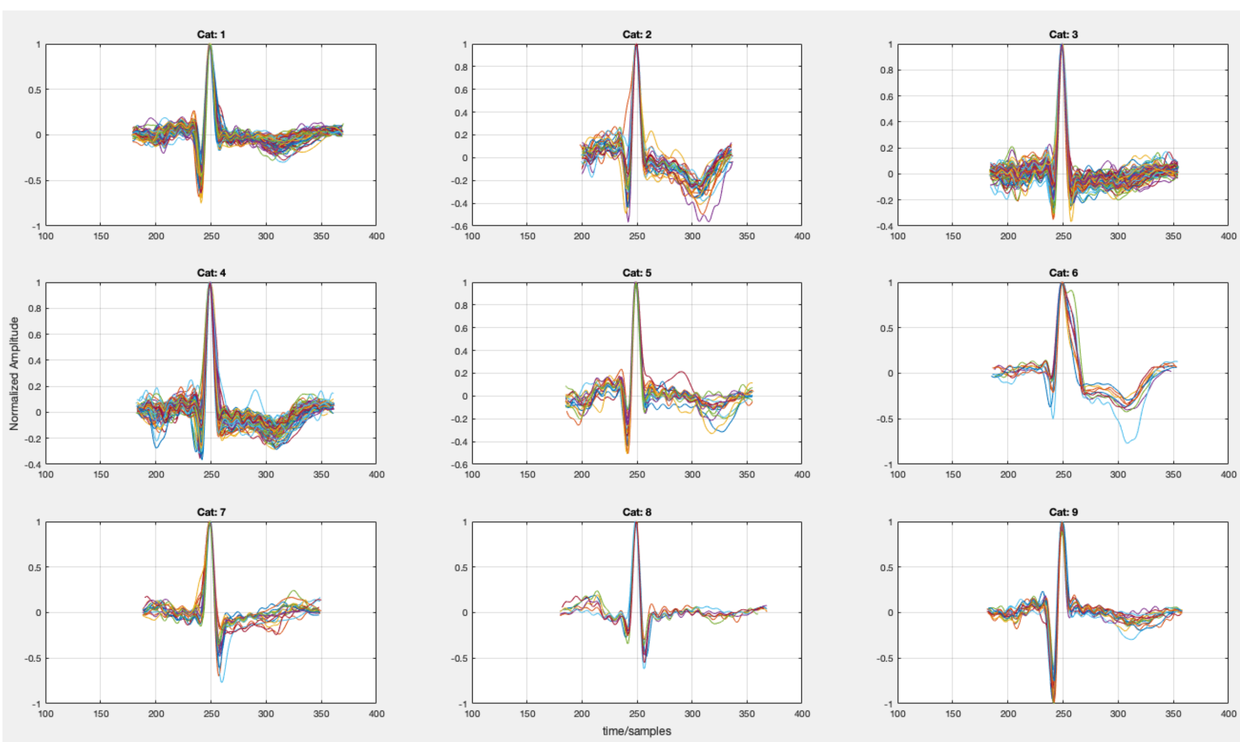

Figure 6.24: Clustering normalized and filtered late segments according to the correlation demand 0.9 with late category representations based on late segments.

6.5 Extra observation results from experiment 1

6.5.1 Parameter settings: ΔC=0.1 and 5 groups

Results from the sub-experiment with five groups and ΔC= 0.1 are listed in the following section.

Representatives of the 5 groups when ΔC= 0.1

T-wave inversion and a downsloping ST-segment can be observed in all $\bar{b}_{CEj}$(n)s in figure 6.25. The downsloping ST-segment can visually be due to the T-wave inversion. In $\bar{b}_{CLj}$(n)s slight improvements, upsloping ST-segment (groups 3-5) and no T-wave inversion (group 4 and 5) can be observed. Group 4 and 5 $\bar{b}_{Cj}$(n)s morphology can be an indication of noise.

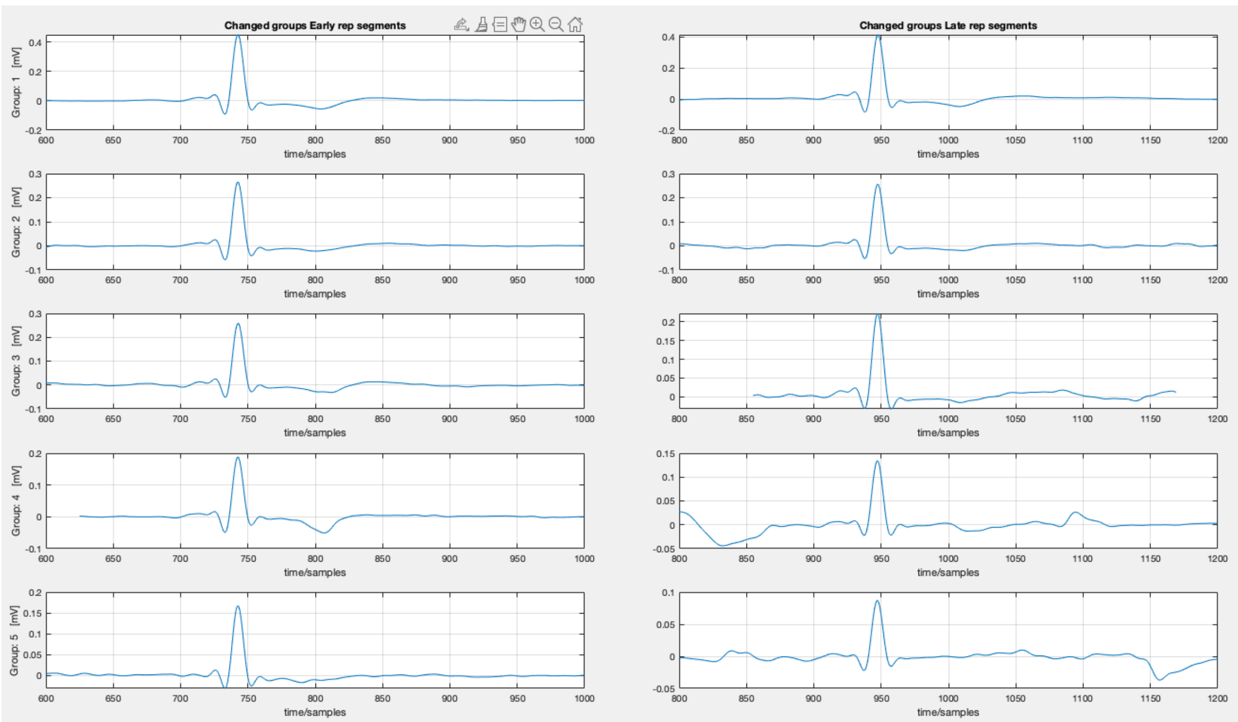

Figure 6.25: Median representatives of the 5 groups with ΔC= 0.1.

Feature tables from the manual recorded data

Table 6.1 illustrates that the groups are of unequal sample size and that all of the p-vales are significant. The KW-tests presents significant difference between all the groups and features. It can also be noted how 'startST' and 'endST' changes in groups 1 and 2 which can be confirmed as a significant change in table 6.3. The features 'outcome', 'apg1' and 'apg5' have no interesting differences except the quantiles of group 5's 'apg1' scores which have the highest variance. This high variance may be relative to the noise (displayed in group 5 figure 3.9). Segments with much noise usually correlate high with patients that required longer BMV, in other words a child with worse conditions.

Table 6.1: Experiment 1 with 5 groups and ΔC= 0.1. Median values of the group's feature is listed below (features: manually recorded). For more interest examine complete table 6.38.

Group: / **Feature:**	**1**	**2**	**3**	**4**	**5**	**P-value:**
Elements	336	125	35	26	25	
vent	122 (63,266)	200 (97,417)	113 (49,245)	130 (73,448)	168 (90,988)	<0.001
outcome	1 (1,2)	2 (1,2)	1 (1,2)	1.5 (1,2)	2 (1,2)	0.005
apg1	7 (6,8)	7 (4,7)	7 (4.3,8)	5.5 (5,7)	6 (3.8,7.3)	0.002
apg5	10 (8,10)	9 (7,10)	10 (8,10)	10 (8,10)	9 (7,10)	0.006
startST	3 (2.5,3)	3 (2,3)	3 (2,3)	2 (1,3)	2 (1.8,3)	<0.001
endST	3 (2,3)	2 (2,3)	2 (2,3)	2 (1,2)	2 (1.8,3)	<0.001

Result from the Tukey test present that group 1 differentiates from the other groups in all features. The Group 1 contains most elements with the least change in the ECG-segment. Observe 'gr1' as a common factor in the 'Group' column in table 6.2.

Table 6.2: Significant results from the Tukey test are printed in this table. Experiment 1 with 5 groups and ΔC= 0.1 (features: manually recorded). For more interest examine complete table 6.39.

Feature	**Group**	**Control Group**	**Lower Limit**	**Difference**	**Upper Limit**	**P-value**
vent	gr1	gr2	-114.84	-69.674	-24.507	<0.001
outcome	gr1	gr2	-86.331	-46.457	-6.5832	0.013
apg1	gr1	gr2	6.5125	50.458	94.404	0.015
apg5	gr1	gr2	9.7495	49.395	89.041	0.006
startST	gr1	gr2	20.766	60.687	100.61	<0.001
startST	gr1	gr4	44.629	122.2	199.76	<0.001
startST	gr1	gr5	2.8572	81.851	160.84	0.038
endST	gr1	gr2	40.508	80.895	121.28	<0.001
endST	gr1	gr3	0.5879	69.057	137.53	0.047
endST	gr1	gr4	63.772	142.24	220.71	<0.001

Groups 1 and 2 have significant change of elevation in the ST-segment with BMV. Improvement could be observed in figure 6.25, but statistic analysis on the manual records disproves this improvement in groups 3-5.

Table 6.3: Experiment 1 with 5 groups and ΔC= 0.1. Checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: Manually recorded). For more interest examine complete table 6.40.

Feature:	**Group: 1**	**Group: 2**	**Group: 3**	**Group: 4**	**Group: 5**
ST-elevation	0.031	0.026	0.845	0.265	1

Feature tables from the automatic detected data with 5 groups and $\Delta C = 0.1$

Features 'eCdetect' and 'lCdetect' should be noted in table 6.4. About two-thirds of the patients ECG-segments are inspected with the detection algorithm without errors. In other words the results should deviate from the manual recorded results. Most interesting feature with significant p-value in this table is 'eSTel'. Indicated with the manual records as well, it can be observed that group 5's elevation is determined not assessable which can be related to noisy ECG-segments. The other groups presents ST-segments with ST-elevation (depressed), as is the same as the manual records. The low values in 'eSTelN' and 'lSTelN' display how many of the group's segments have elevation above the baseline, which is expected to be few as well. Most of the shape features display expected results, indicating ECG symptoms of asphyxia.

Table 6.4: Experiment 1 with 5 groups and ∆C= 0.1. Median values of the group's feature is listed below (features: automatically detected). For more interest examine complete table 6.41.

Group: / **Feature:**	**1**	**2**	**3**	**4**	**5**	**P-value:**
Elements	336	125	35	26	25	
eCdetect	253	83	21	15	12	
eSTint	46 (20,59)	54 (29,75)	57 (49,61)	53 (33,57)	31 (19,40)	0.019
eSTintEST	87 (80,99)	87 (60,100)	88 (59,95)	84 (50,88)	62 (40,84)	0.008
eSTel	5 (3,5)	5 (1,5)	5 (1,5)	4 (1,5)	1 (1,5)	<0.001
eSTelN	4	6	2	2	1	
eSTshape	2 (1,4)	2 (0,4)	1 (0,4)	1 (0,5)	0 (0,5)	0.411
lCdetect	231	77	20	16	14	
lSTint	47 (20,59)	42 (19,56)	39 (13,62)	42 (24,80)	21 (18,31)	0.298
lSTintEST	86 (77,96)	81 (68,95)	89 (64,99)	77 (55,103)	89 (75,106)	0.210
lSTel	5 (1,5)	5 (1,5)	5 (1,5)	5 (1,5)	5 (1,5)	0.160
lSTelN	1	4	1	0	1	
lSTshape	2 (0,4)	1 (0,4)	1 (0,4)	1 (0,5)	2 (0,5)	0.860

Group 1 and 5 compared in the Tukey test are expected to find significant p-values. Group 1 contains most elements and least change, thus it should be possible to get results from the detection algorithm. Group 5 have the least amount on elements and can also be observed to include most noisy segments which makes detection hard. Therefore, the results presented in 6.5 should be expected.

Table 6.5: Significant results from the Tukey test are printed in this table. Experiment 1 with 5 groups and ∆C=0.1 (features: automatically detected). For more interest examine complete table 6.42.

Feature	**Group**	**Control group**	**Lower Limit**	**Difference**	**Upper Limit**	**P-value**
eSTintEST	gr1	gr5	8.382	97.807	187.232	0.024
eSTel	gr1	gr5	9.133	82.100	155.067	0.018

An interesting discovery from table 6.6 are the 'ST-shape' significant change value in group 1. It concurs with the manual records and even though it is group with least change, it hints to an experiment revolving around the ST-segment. The feature ST-in est-size' can be expected to get a significant result in group 5 due to more noise in early segments of that group than in the late segments.

Table 6.6: Experiment 1 with 5 groups and ∆C=0.1. Checking for significant changes in automatically detected features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: automatically detected). For more interest examine complete table 6.43.

Feature:	**Group: 1**	**Group: 2**	**Group: 3**	**Group: 4**	**Group: 5**
ST-int size	0.201	0.025	0.934	0.178	0.089
ST-int est. size	0.347	0.229	0.936	0.932	0.023
ST-shape	0.04	0.508	0.905	0.582	0.504
ST-elevation	0.134	0.197	0.878	0.87	0.199

6.5.2 Parameter settings: ∆C=0.2 with 5 groups

Results from the sub-experiment with five groups and ∆C =0.2 are listed in the following section.

No ECG-segment had a change factor between [0.2,0]. This is the reason why the fifth group is either blank or not displayed in boxplots, graphs and tables related to these settings.

Representatives of the 5 groups with ΔC= 0.2

T-wave inversion and a downsloping ST-segment can be observed in all $\bar{b}_{CEj}$(n)s in figure 6.26. The downsloping ST-segment can visually be due to the T-wave inversion. In $\bar{b}_{CLj}$(n)s slight improvements (group 1), upsloping ST-segment (groups 2-4) and no T-wave inversion (group 3 and 4) can be observed. Group 4 $\bar{b}_{CEj}$(n)'s morphology indicates a lot of noisy segments in the group.

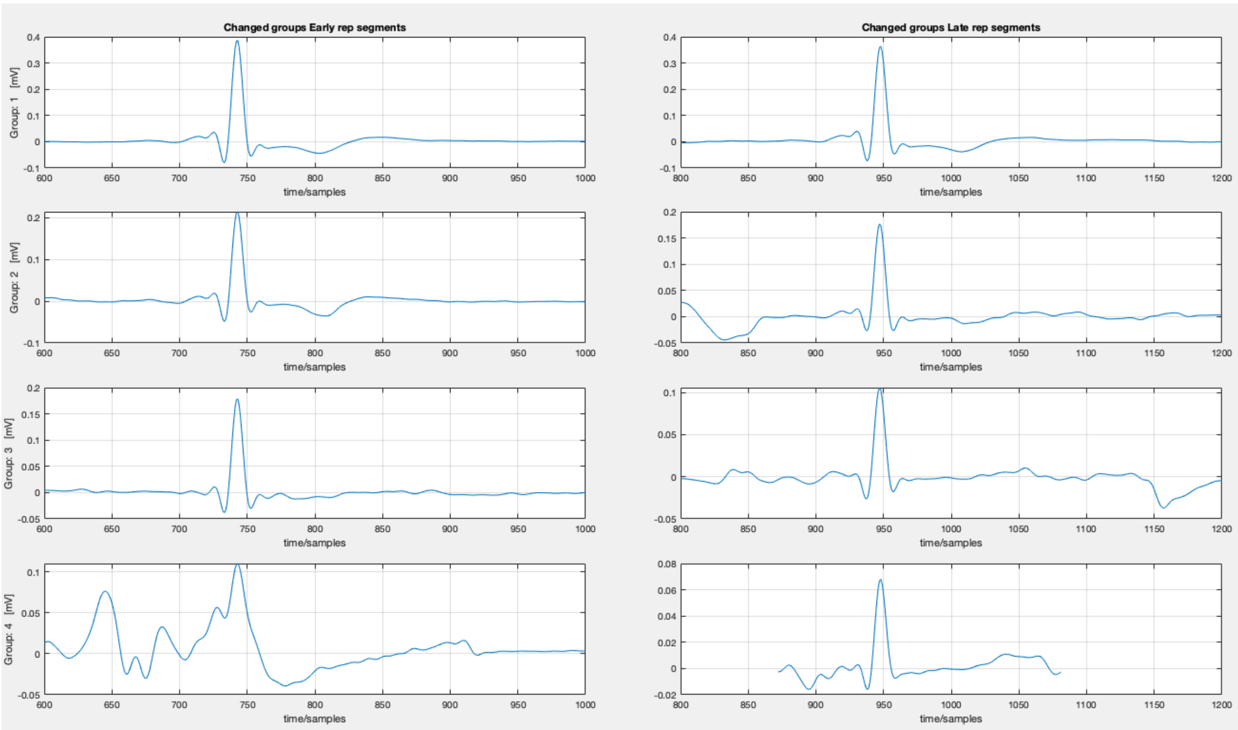

Figure 6.26: Median representatives of the 5 groups with ΔC=0.2.

Feature tables from the manual recorded data

It is observed that most elements do not change. Group 4 should be noted contain only five elements with a relatively larger variance in features than the other groups.

Table 6.7: Experiment 1 with 5 groups and ΔC=0.2. Median values of the group's feature is listed below (features: manually recorded). For more interest examine complete table 6.44.

Group: / **Feature:**	**1**	**2**	**3**	**4**	**P-value:**
Elements	461	61	20	5	
vent	144 (67,293)	128 (62.3,312.8)	162 (88,868.5)	595 (97.3,987.8)	0.265
outcome	1 (1,2)	1 (1,2)	2 (1,2)	2 (1,2.3)	0.267
apg1	7 (5,7)	7 (4.8,7)	6 (3.5,7.5)	6 (4.3,6.5)	0.170
apg5	10 (8,10)	10 (8,10)	9.5 (7,10)	9 (6.8,10)	0.545
startST	3 (2,3)	2 (1.8,3)	2 (2,3.5)	1 (1,2.3)	<0.001
endST	3 (2,3)	2 (2,3)	2 (2,3)	1 (1,2.5)	<0.001

Group 1 is again a common factor in the Tukey test, but is also the group including most elements. Table 6.8 display groups 2 and 4 compared significant different to group 1 which should be of no surprise due the group 4's feature variances and group 2's median results in table 6.7.

Table 6.8: Significant results from the Tukey test are printed in this table. Experiment 1 with 5 groups and ΔC=0.2 (features: manually recorded). For more interest examine complete table 6.45.

Feature	Group	Control group	Lower Limit	Difference	Upper Limit	P-value
startST	gr1	gr2	21.65	70.544	119.44	0.001
startST	gr1	gr4	11.295	172.66	334.02	0.03
endST	gr1	gr2	28.852	78.316	127.78	<0.001

Table 6.9 verify almost identical results presented in sub-experiment 1 and the article of Linde et al. [11]. The ST-segment changes significantly with BMV (group 1 contains most of the $b_i(n)$s).

Table 6.9: Experiment 1 with 5 groups and ΔC=0.2. Checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: Manually recorded). For more interest examine complete table 6.46

Feature:	Group: 1	Group: 2	Group: 3	Group: 4
ST-elevation	0.002	0.484	0.834	0.374

Feature tables from the automatic detected data with 5 groups and $\Delta C = 0.2$

Group 4's automatic feature results are unreliable due to a low value in 'eCdetect' and 'lCdetect'. Therefore, group 4's feature results are not reliable in this automatic part. Also, the feature containing 'STint' in group 3 and 4 is also unusual low, which make the results from those groups not reliable. A ST-segment interval can be observed from most representative plots to be approximately fifty samples.

Table 6.10: Experiment 1 with 5 groups and ΔC=0.2. Median values of the group's feature is listed below (features: automatically detected). For more interest examine complete table 6.47.

Group: / Feature:	1	2	3	4	P-value:
Elements	461	61	20	5	
eCdetect	336	37	11	1	
eSTint	47 (23,61)	56 (40,59)	26 (18,43)	31 (31,31)	0.146
eSTintEST	87 (77,100)	85 (57,94)	58 (39,78)	128 (128,128)	<0.001
eSTel	5 (1,5)	5 (1,5)	4 (1,5)	1 (1,2)	0.002
eSTelN	10	4	1	0	
eSTshape	2 (0,4)	1 (0,5)	3 (0,5)	0 (0,1)	0.2
lCdetect	308	36	10	3	
lSTint	46 (20,59)	39 (19,65)	21 (19,35)	21 (13,29)	0.466
lSTintEST	85 (75,96)	83 (58,100)	90 (87,112)	80 (54,90)	0.252
lSTel	5 (1,5)	5 (1,5)	2 (1,5)	5 (1,5)	0.213
lSTelN	5	1	1	0	
lSTshape	2 (0,4)	1 (0,5)	0.5 (0,4.5)	2 (0,4.5)	0.92

Table 6.8 only significant comparison result is of the feature 'eSTintEST'. This feature is stored every time the algorithm fails to detect 'eSTint', in other words it is an error handling measure. Due to the result in table 6.8 being significant it verifies the initial observation of unreliability in group 3's results.

Table 6.11: Significant results from the Tukey test are printed in this table. Experiment with 5 groups and ΔC=0.2 (features: automatically detected). For more interest examine complete table 6.48.

Feature	Group	Control group	Lower Limit	Difference	Upper Limit	P-value
eSTintEST	gr1	gr3	29.135	116.71	204.28	0.003

Below in table 6.12, some p-values can be noted while irrelevant ones are not pointed out. 'ST-shape' and 'ST-elevation' change significantly which concurs with the manual records (table 6.9).

Table 6.12: Experiment with 5 groups and ΔC=0.2. Checking for significant changes in automatically detected features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: automatically detected). For more interest examine complete table 6.49.

Feature:	**Group: 1**	**Group: 2**	**Group: 3**	**Group: 4**
ST-int size	0.011	0.192	0.323	<0.001
ST-int est. size	0.128	0.415	0.003	<0.001
ST-shape	0.042	0.928	0.681	0.178
ST-elevation	0.047	0.614	0.214	<0.001

6.5.3 Exp. 2, unfiltered and unnormalized results

Below are the not filtered and normalized experiment two results displayed. From figure 6.18, the representations in 6.27 and 6.28 are created. Figure 6.28 illustrates how the categories in fig. 6.27 can be observed after BMV. Boxplots for the unormalized and unfiltered part can be observed in figures 6.53-6.60.

Representations created from early segments visualized

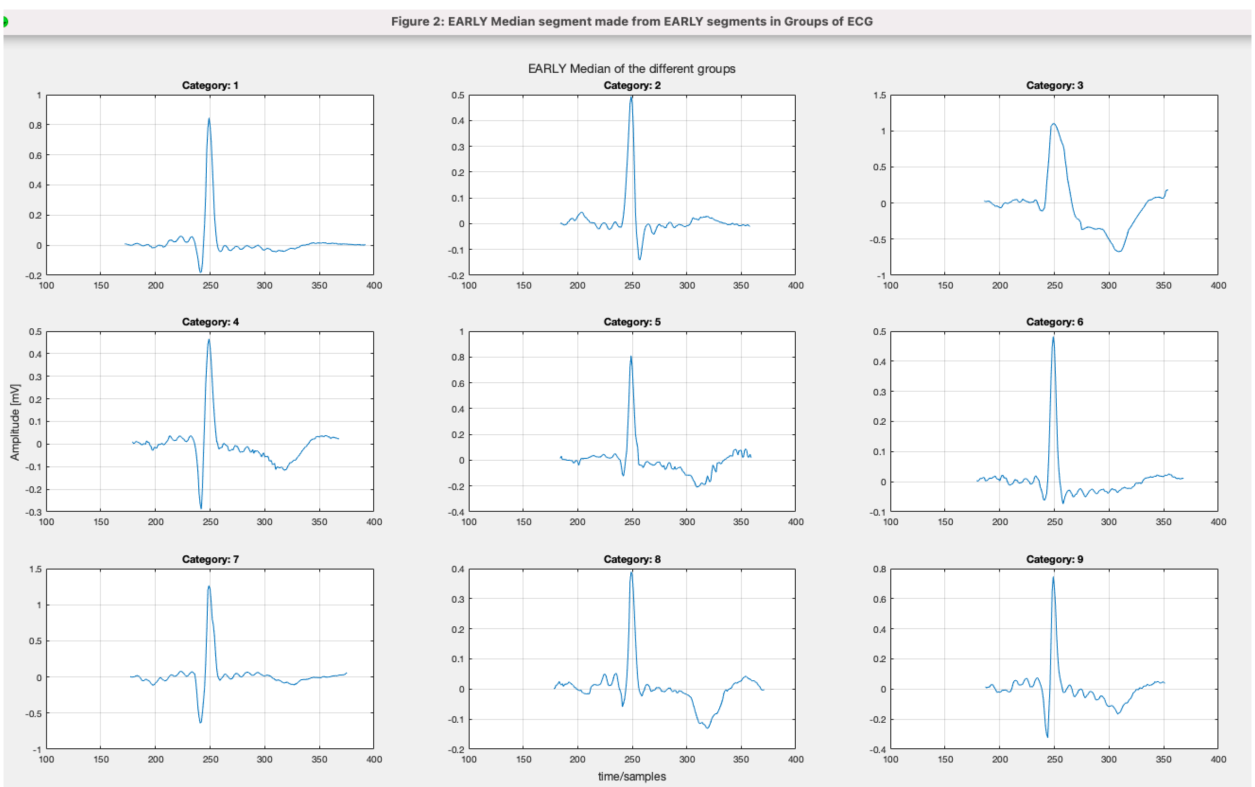

Figure 6.27: Early category representations made from early segments according to the correlation demand 0.95 and minimum 4 number of cluster members

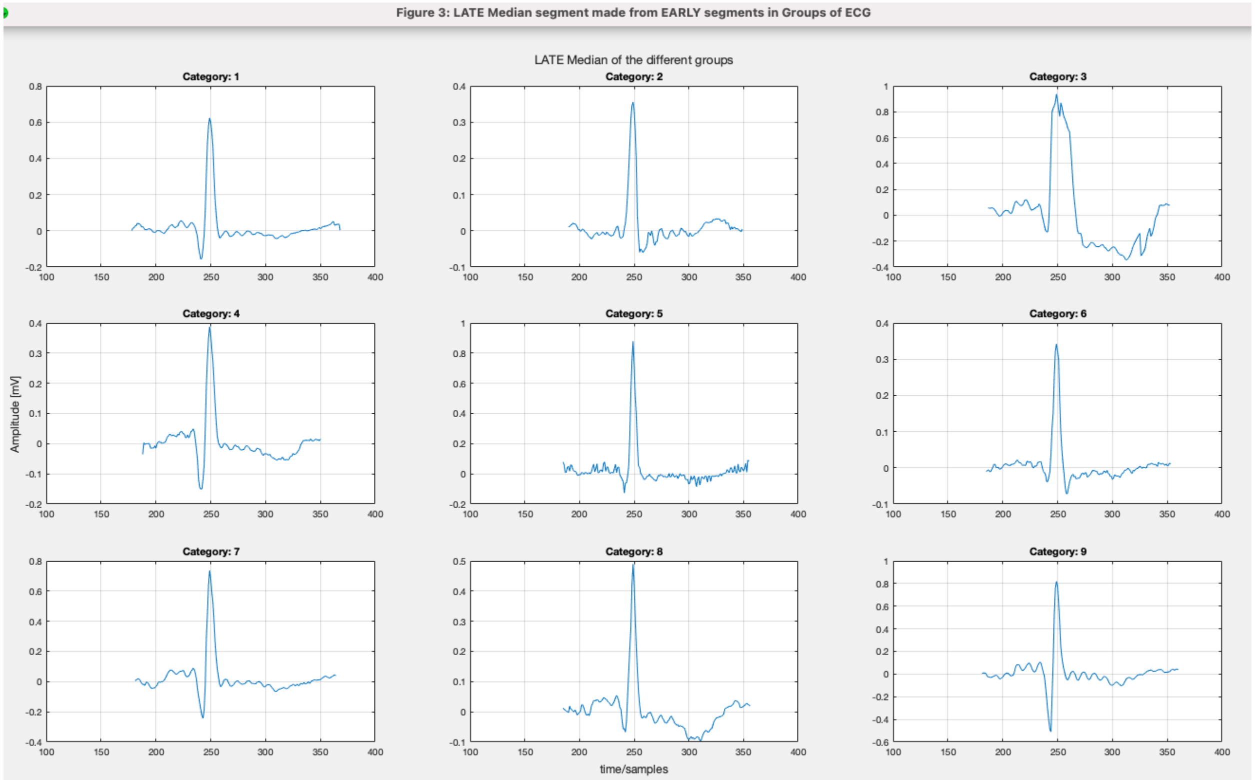

Figure 6.28: Late category representations made from early segments according to the correlation demand 0.95 and minimum 4 number of cluster members

Representations created from late segments visualized

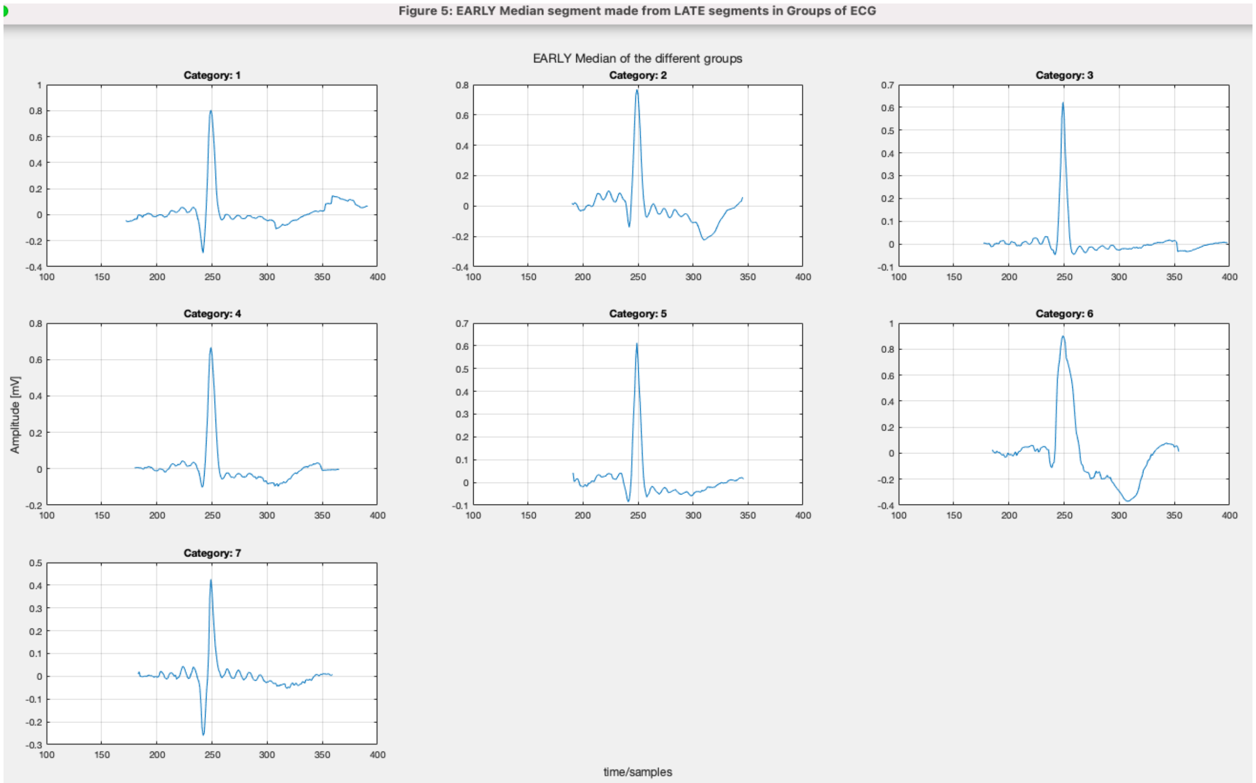

Figure 6.29: Early category representations made from late segments according to the correlation demand 0.95 and minimum 4 number of cluster members

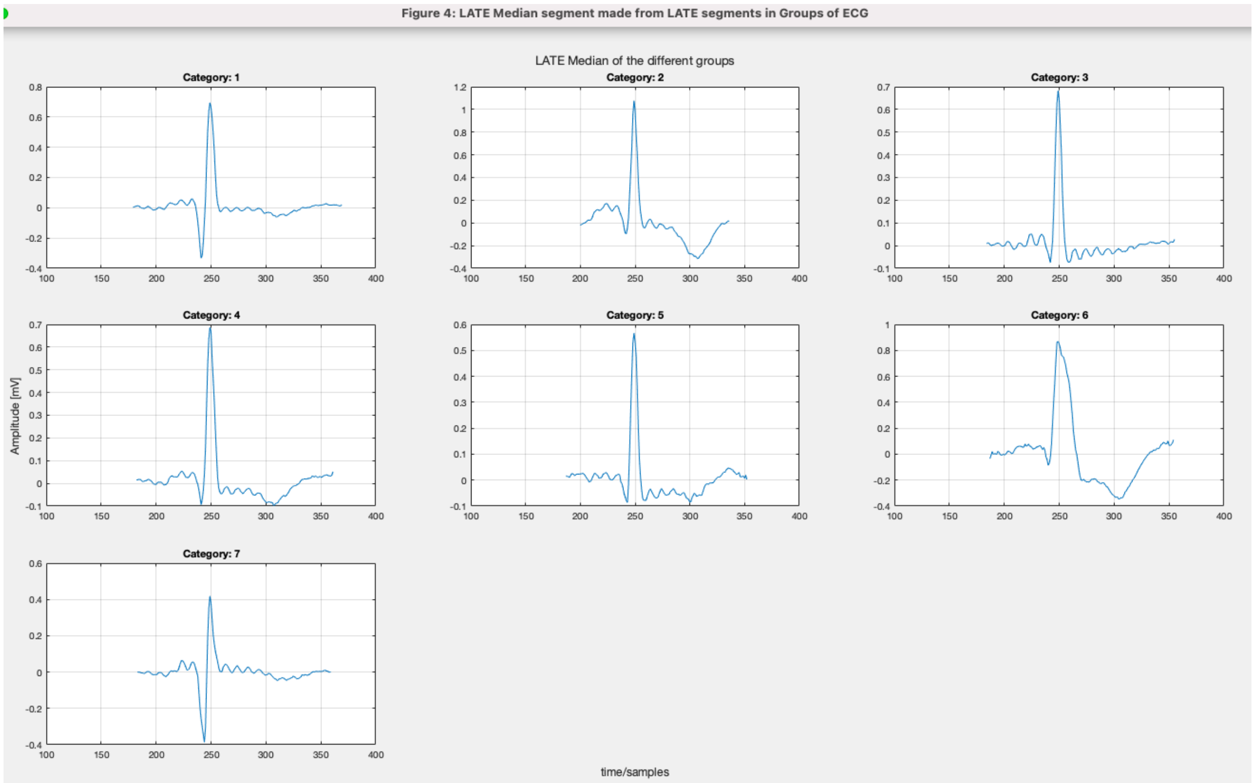

Figure 6.30: Late category representations made from late segments according to the correlation demand 0.95 and minimum 4 number of cluster members

6.5.3.1 category representations vs category representations results

This section present results from the unfiltered and unnormalized experiment, where only the representation and their elements were correlated against each other. First correlating the categories in regards to time is presented. Mode `'checkreps'` with `k`=1 in `asph_scr.m` obtains these classifying results. 'Late from S' describes when estimated ST-segment are correlated. An ST-segment from $C_{Ej}(n)$ is correlated with an ST-segment from $C_{Lj}(n)$. Results from equations 3.27 and 3.28 are summarized in tables 6.13-6.16. These tables are stored in the variable `out` with the path: `out.exp2.classified.reps.gruppermedEL(k)` and `out.exp2.classified.reps.gruppermedLE(k)`, for `k`= 1,2. Table 6.13 indicate which early category representations correlate the most with in the late category representations.

Early segments representations results

Table 6.13: Classification results, based on early segments. This table show which early category representation is classified as in the late category representations. Correlating categories from 6.27 with 6.28 is a step in obtaining this table.

Early cat:	Rep: 1	Rep: 2	Rep: 3	Rep: 4	Rep: 5	Rep: 6	Rep: 7	Rep: 8	Rep: 9
Late cat:	1	2	3	4	6	6	1	5	9
Late from S	1	5	1	4	4	2	4	4	4

The other way, based on early segments. Table 6.14 indicate which late category representations correlate the most with in the early category representations.

Table 6.14: Classification results, based on early segments. This table show which late category representation is classified as in the early category representations. Correlating categories from 6.28 with 6.27 is a step in obtaining this table.

Late cat:	Rep: 1	Rep: 2	Rep: 3	Rep: 4	Rep: 5	Rep: 6	Rep: 7	Rep: 8	Rep: 9
Early cat:	1	2	3	4	8	6	7	8	9
Early from S	9	6	4	8	4	7	4	8	8

Late segments representations results

Based on representations from LATE segments tab. Table 6.15 indicate which early category correlate the most with in the late category reps. Notice the 'Late from S' classifications for the parts below (reason explained in 5.3.1).

Table 6.15: Classification results, based on late segments. This table show which early category representation is classified as in the late category representations. Correlating categories from 6.29 with 6.30 is a step in obtaining this table.

Early	Rep: 1	Rep: 2	Rep: 3	Rep: 4	Rep: 5	Rep: 6	Rep: 7
Late	1	2	3	4	5	6	7
Late from S	6	1	1	1	1	1	7

Table 6.16 indicate which late category representation segment correlate the most with in the early category representations.

Table 6.16: Classification results, based on late segments. This table show which late category representation is classified as in the early category representations. Correlating categories from 6.30 with 6.29 is a step in obtaining this table.

Late	Rep: 1	Rep: 2	Rep: 3	Rep: 4	Rep: 5	Rep: 6	Rep: 7
Early	4	2	3	4	3	6	7
Early from S	2	2	5	1	5	1	7

6.5.3.2 Exp. 2 classification of elements in a category representations results

Mode `'checkelreps'` in function `asph_scr.m` stores two important tables: `tabCee` and `tabCll`. These tables present how strong the median category representation is early and late. The segments in every category is examined if it is still most similar to to its category representation or another. The numbers on the diagonal of `tabCee` and `tabCll` expose how similar the segments of that category representation are. Both tables are stored in the variable `out` with the path: `out.exp2.classified.reps(k).corrELmat` (k=1,2). This part of the experiment is to determine if the experiment should be repeated with other parameters. If the category representations are deemed weak, change parameters and repeat.

Tables based on early segments

Tables 6.17 and 6.18 display the results where the representations are based on the early segments.

Table 6.17: Classification results, based on early segments representations. This table illustrate the number of early segments in a category representation that are classified as the same category which created the category or not. Correlating $S_{Ejk}(n)$s with $\bar{b}_{SEj}(n)$ where k=1,2,...Ncel and j=1,2,...Nc..

Elements from category: / Classified as:	1	2	3	4	5	6	7	8	9
Cat: 1	44	0	0	0	0	1	0	0	0
Cat: 2	0	5	0	0	0	0	0	0	0
Cat: 3	0	0	5	0	0	0	0	0	0
Cat: 4	1	0	0	12	1	0	0	0	0
Cat: 5	0	0	0	1	4	0	0	0	0
Cat: 6	0	0	0	0	0	10	0	0	0
Cat: 7	2	0	0	0	0	0	5	0	0
Cat: 8	0	0	0	0	0	0	0	5	0
Cat: 9	0	0	0	0	0	0	0	0	4
Deviation [%]:	6.4	0	0	7.7	20	9.1	0	0	0

Notice in table 6.18 that diagonal is similar to the diagonal in the filtered and normalized table 4.16.

Table 6.18: Classification results, based on early segments representations. This table illustrate the number of late segments in a category representation that are classified as the same category which made the category or not. Correlating $S_{Ljk}(n)$s with $\bar{b}_{SLj}(n)$ where k=1,2,...Ncel and j=1,2,...Nc..

Elements from category: / Classified as:	1	2	3	4	5	6	7	8	9
Cat: 1	16	0	0	1	0	1	1	0	0
Cat: 2	1	4	0	0	0	2	0	0	0
Cat: 3	0	0	4	0	0	0	0	0	0
Cat: 4	10	1	0	7	0	3	0	0	0
Cat: 5	1	0	0	0	1	1	0	0	0
Cat: 6	4	0	1	0	1	4	0	1	0
Cat: 7	12	0	0	3	2	0	4	1	0
Cat: 8	1	0	0	2	1	0	0	3	0
Cat: 9	2	0	0	0	0	0	0	0	4
Deviation [%]:	66	20	20	46.2	80	63.6	20	40	0

Tables based on late segments

Tables 6.19 and 6.20 display the results where the representations are based on the late segments. Observe the diagonal in table 6.19 to find the equal results as is represented in table 6.18.

Table 6.19: Classification results, based on late segments representations. This table illustrate the number of early segments in a category representation that are classified as the same category which made the category or not. Correlating $S_{Ejk}(n)$s with $\bar{b}_{SEj}(n)$ where k=1,2,...Ncel and j=1,2,...Nc..

Elements from category: / Classified as:	1	2	3	4	5	6	7	8	9
Cat: 1	12	0	3	6	0	0	1	0	0
Cat: 2	2	4	2	15	0	1	1	0	0
Cat: 3	0	0	9	4	1	0	0	0	0
Cat: 4	5	0	3	31	2	0	0	0	0
Cat: 5	11	0	13	17	3	0	0	0	0
Cat: 6	1	0	1	0	0	6	0	1	0
Cat: 7	9	0	0	2	0	0	3	1	0
Cat: 8	1	0	0	2	1	0	0	3	0
Cat: 9	2	0	0	0	0	0	0	0	4
Deviation [%]:	72.1	0	71	59.7	57.1	14.3	40	40	0

Similar to the results in table 6.17 the diagonal in table 6.20 have high numbers.

Table 6.20: Classification results, based on late segments representations. This table illustrate the number of late segments in a category representation that are classified as the same category which made the category or not. Correlating $S_{Ljk}(n)$s with $\bar{b}_{SLj}(n)$ where k=1,2,...Ncel and j=1,2,...Nc..

Elements from category: / Classified as:	1	2	3	4	5	6	7	8	9
Cat: 1	39	0	0	2	0	0	0	0	0
Cat: 2	0	4	0	1	0	0	0	0	0
Cat: 3	1	0	29	3	0	0	0	0	0
Cat: 4	0	0	0	65	0	0	0	0	0
Cat: 5	0	0	2	4	6	0	0	0	0
Cat: 6	0	0	0	0	0	7	0	1	0
Cat: 7	0	0	0	0	0	0	5	1	0
Cat: 8	1	0	0	2	1	0	0	3	0
Cat: 9	2	0	0	0	0	0	0	0	4
Deviation [%]:	9.3	0	6.5	15.6	14.3	0	0	40	0

6.5.3.3 Exp. 2 results, patients vs category representations

Below are results from the experiments where the patients were correlated with the representations. A demand of `corr2catRT`= 0.9 is set to avoid classification mistakes. A patient can only belong to the one category which it correlates the highest with. The other patients are categorized as unclassified. This section contains tables with extracted features from manually recorded and automatic detection along with the hypothesis tests. In this experiment it were determined to examine if there were significant values from the KW-tests. Complete Tukey HSD tests are located in chapter 6 for further interest.

Patients vs representations from early segments results

Tables 6.21-6.26 are based on the classification procedure in the mode `'corrtocat'` when `k`=1. The data below are early segments categorized with early category representations.

Table 6.21: Early patients correlated with categories based on early segments. Median values of the group's feature is listed below (part 1, features: manual recorded). For more interest examine complete table 6.58.

Group: / Feature:	1	2	3	4	5
Elements	128	16	9	49	44
vent	156 (62,311)	107 (48,223)	185 (52,377)	142 (64,299)	111 (68,247)
outcome	1 (1,2)	1 (1,2)	2 (1,2)	1 (1,2)	1 (1,2)
apg1	7 (5,8)	7 (6,8)	6 (3.5,7)	7 (4.8,8)	7 (5,8)
apg5	10 (8,10)	10 (8.5,10)	10 (5.8,10)	10 (8.8,10)	10 (8,10)
startST	3 (3,3)	2 (1.5,3)	3 (3,3)	3 (3,3)	3 (3,3)
endST	3 (2,3)	2 (2,3)	3 (3,3)	3 (2.8,3)	3 (3,3)

Table 6.22: Early patients correlated with categories based on early segments. Median values of the group's feature is listed below (part 2, features: manual recorded). For more interest examine complete table 6.59.

Group: / Feature:	6	7	8	9	Unclassified	P-value:
Elements	74	28	11	36	152	
vent	149 (68,303)	213 (76,422)	151 (97,199)	116 (64,230)	149 (77,359)	0.584
outcome	1 (1,2)	1 (1,2)	2 (1,2.8)	1 (1,2)	1 (1,2)	0.367
apg1	7 (6,7)	6 (4.5,7)	7 (6,7)	7 (6,7)	7 (4,7)	0.346
apg5	10 (8,10)	10 (7,10)	10 (7.5,10)	10 (8,10)	10 (7,10)	0.747
startST	3 (3,3)	2 (2,3)	3 (3,3)	3 (2,3)	2 (2,3)	<0.001
endST	3 (2,3)	2 (2,3)	3 (2.3,3)	3 (2,3)	2 (2,3)	<0.001

The Tukey test can be observed in table 6.60 for a closer examination of which group's median values are significant different.

Table 6.23: Checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: Manually recorded). For more interest examine complete table 6.61.

Group: / Feature	1	2	3	4	5	6	7	8	9	10
ST-elevation	0.011	0.333	0.347	0.2	0.323	0.09	0.813	0.341	0.263	0.424

Automatic detection:

Table 6.24: Early patients correlated with categories based on early segments. Median values of the group's feature is listed below (part 1, features: automatic detected). For more interest examine complete table 6.62.

Group: / Feature:	1	2	3	4	5
Elements	128	16	9	49	44
eCdetect	92	7	7	37	42
eSTint	46 (20,60)	25 (14,33)	40 (33,43)	59 (49,67)	56 (47,59)
eSTintEST	90 (75,101)	63 (52,66)	74 (70,76)	97 (91,104)	92 (85,95)
eSTel	5 (1,5)	1 (1,5)	5 (4,5)	5 (4,5)	5 (5,5)
eSTelN	3	0	0	0	0
eSTshape	2 (0,5)	0 (0,4.5)	6 (0.8,6)	2 (0.8,6)	1.5 (1,3)
lCdetect	80	10	7	34	36
lSTint	48 (13,61)	48 (16,58)	45 (39,47)	55 (22,66)	59 (40,70)
lSTintEST	87 (78,100)	70 (62,86)	74 (68,75)	93 (85,98)	87 (83,100)
lSTel	5 (1,5)	5 (1,5)	5 (4,5)	5 (1,5)	5 (5,5)
lSTelN	0	0	0	1	0
lSTshape	1 (0,4)	1.5 (0,4.5)	5 (0.8,6)	1 (0,2.3)	2 (1,4.5)

Table 6.25: Early patients correlated with categories based on early segments. Median values of the group's feature is listed below (part 2, features: automatic detected). For more interest examine complete table 6.63.

Group: / Feature:	6	7	8	9	Unclassified	P-value:
Elements	74	28	11	36	152	
eCdetect	61	17	9	23	85	
eSTint	29 (15,51)	19 (14,51)	67 (64,71)	55 (38,65)	49 (30,69)	<0.001
eSTintEST	86 (81,97)	85 (44,99)	97 (95,108)	85 (82,95)	80 (52,94)	<0.001
eSTel	5 (5,5)	4 (1,5)	5 (5,5)	5 (1,5)	5 (1,5)	<0.001
eSTelN	0	2	0	0	3	
eSTshape	2 (2,4)	1 (0,4)	1 (1,1)	1 (0,2)	1 (0,4)	<0.001
lCdetect	52	15	8	18	94	
lSTint	35 (17,51)	26 (19,40)	53 (34,63)	45 (33,46)	42 (19,59)	0.112
lSTintEST	84 (74,95)	84 (61,103)	92 (87,103)	84 (81,96)	82 (69,94)	<0.001
lSTel	5 (1,5)	4 (1,5)	5 (2,5)	2 (1,5)	5 (1,5)	<0.001
lSTelN	2	1	0	0	1	
lSTshape	2 (0,4)	1 (0,3)	1 (0.3,1.8)	0.5 (0,1.5)	2 (0,5)	<0.001

Complete Tukey tests table can be examined in table 6.64 for a closer observation of which group's median values are significant different.

Table 6.26: Checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: automatic detected). For more interest examine complete table 6.65.

Group: / Feature	1	2	3	4	5	6	7	8	9	Unclassified
ST-int size	0.906	0.317	1	0.040	0.375	0.876	0.460	<0.001	0.232	0.091
ST-int est. size	0.381	0.007	0.396	0.142	0.300	0.140	0.291	0.005	0.408	0.971
ST-shape	0.139	0.188	1	0.418	0.057	0.026	0.901	0.588	0.162	0.119
ST-elevation	0.519	0.943	0.149	0.012	0.007	0.368	0.987	0.362	0.381	0.411

res, patients vs representations from late segments

Tables 6.27-6.32 are based on the classification procedure in the mode `'corrtocat'` when `k`=2. The data below are late segments categorized with late category representations.

Table 6.27: Late patient's segments correlated with categories based on late segments. Median values of the group's feature is listed below (part 1, features: manual recorded). For more interest examine complete table 6.66.

Group: / **Feature:**	**1**	**2**	**3**	**4**	**5**
Elements	114	26	89	112	24
vent	116 (53,318)	154 (63,368)	158 (70,288)	135 (75,237)	155 (39,283)
outcome	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)
apg1	7 (5,7)	7 (6,7)	7 (6,7)	7 (6,8)	7 (7,8)
apg5	10 (8,10)	10 (8,10)	10 (8,10)	10 (8,10)	10 (9,10)
startST	3 (2,3)	3 (3,3)	3 (2,3)	3 (3,3)	3 (2.5,3)
endST	3 (2,3)	3 (3,3)	3 (2,3)	3 (3,3)	3 (2.5,3)

Table 6.28: Late patient's segments correlated with categories based on late segments. Median values of the group's feature is listed below (part 2, features: manual recorded). For more interest examine complete table 6.67.

Group: / **Feature:**	**6**	**7**	**Unclassified**	**P-value**
Elements	8	24	150	
vent	198 (52,485)	111 (66,199)	147 (85,390)	0.571
outcome	1.5 (1,2)	1 (1,2)	1 (1,2)	0.931
apg1	6.5 (3,7)	7 (6,7)	7 (4,7)	0.272
apg5	9 (5,10)	10 (8,10)	10 (7,10)	0.532
startST	3 (3,3)	2 (2,3)	2 (2,3)	<0.001
endST	3 (3,3)	2 (2,2)	2 (2,3)	<0.001

Tukey table can be examine in table 6.68.

Table 6.29: Checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: Manually recorded). For more interest examine complete table 6.69.

Group: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Unclassified**
ST-elevation	0.011	0.327	0.854	0.798	0.714	<0.001	0.017	0.258

Automatic detection:

Table 6.30: Late patient's segments correlated with categories based on late segments. Median values of the group's feature is listed below (part 1, features: automatic detected). For more interest examine complete table 6.70.

Group: / Feature:	1	2	3	4	5
Elements	114	26	89	112	24
eCdetect	84	20	65	89	19
eSTint	51 (20,64)	50 (43,67)	33 (19,55)	51 (24,62)	35 (15,59)
eSTintEST	94 (82,103)	90 (84,96)	85 (75,96)	90 (84,101)	87 (76,96)
eSTel	5 (1,5)	5 (5,5)	5 (1,5)	5 (5,5)	5 (5,5)
eSTelN	1	0	2	0	0
eSTshape	2 (0,4)	1 (1,4)	2 (0,4)	2 (1,4)	3.5 (1,5)
lCdetect	69	23	62	82	17
lSTint	31 (18,69)	52 (46,66)	27 (16,67)	51 (22,59)	31 (14,48)
lSTintEST	94 (84,103)	85 (82,93)	87 (74,95)	85 (81,96)	77 (73,87)
lSTel	5 (1,5)	5 (5,5)	5 (1,5)	5 (1,5)	5 (1,5)
lSTelN	1	0	0	0	0
lSTshape	1 (0,2)	2 (1,3)	2 (0,4)	2 (0,4)	2 (0,3)

Table 6.31: Late patient's segments correlated with categories based on late segments. Median values of the group's feature is listed below (part 2, features: automatic detected). For more interest examine complete table 6.71.

Group: / Feature:	6	7	Unclassified	P-value:
Elements	8	24	150	
eCdetect	6	11	88	
eSTint	45 (41,54)	29 (28,68)	48 (29,61)	$<$0.001
eSTintEST	74 (69,86)	86 (43,99)	83 (57,95)	$<$0.001
eSTel	5 (3,5)	1 (1,5)	5 (1,5)	$<$0.001
eSTelN	0	0	4	
eSTshape	1 (0.5,6)	0 (0,2)	1 (0,5)	$<$0.001
lCdetect	5	11	86	
lSTint	45 (42,47)	24 (21,26)	44 (22,59)	0.533
lSTintEST	74 (71,78)	62 (56,97)	81 (58,97)	$<$0.001
lSTel	5 (1,5)	1 (1,5)	5 (1,5)	$<$0.001
lSTelN	0	0	4	
lSTshape	1 (0,6)	0 (0,2)	1 (0,5)	$<$0.001

Tukey table can be examine in table 6.72.

Table 6.32: Checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: automatic detected). For more interest examine complete table 6.73.

Group: / Feature	1	2	3	4	5	6	7	Unclassified
ST-int size	0.0610	0.670	0.462	0.310	0.737	0.423	0.516	0.477
ST-int est. size	0.653	0.112	0.820	0.471	0.353	0.671	0.301	0.240
ST-shape	0.0180	0.185	0.732	0.238	0.491	0.685	0.888	1
ST-elevation	<0.001	0.392	0.237	0.471	0.0190	0.895	0.126	0.792

6.5.4 Exp. 2, extra normalized and filtered results

Similar results which have already been described, were placed in this section. This way the reader would not have to read the same statements, but can inspect the results for more interest.

Late normalized and filtered segments representations results

Table 6.33 indicate which early category correlate the most with in the late category representations. Representations are created from patient's late segments. Notice the 'Late from S' classifications for the parts below and compare it with the unfiltered results (reason explained in 5.3.1).

Description of the results can be read in the part based on representations created from patient's early ECG-segments. Similar results were found in this part, these are described in 4.3.1.1.

Table 6.33: Classification results, based on late filtered and normalized segments. This table display which early category representation is classified as in the late category representations. Correlating categories from 4.6 with 4.7 is a step in obtaining this table.

Early cat.:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Late cat.:	1	2	3	4	1	6	7	7	9
Late cat. from S	6	2	8	4	3	4	8	8	5

Table 6.34 indicate which late category representation segment correlate the most with in the early category representations.

Table 6.34: Classification results, based on late filtered and normalized segments. This table display which late category representation is classified as in the early category representations. Correlating categories from 4.7 with 4.6 is a step in obtaining this table.

Late cat.:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Early cat.:	1	4	3	4	2	6	3	9	9
Early cat. from S	4	2	4	4	9	4	3	8	4

6.6 Results, full tables

Below are complete tables of the shortened relevant tables in the results chapter 4. Only the ones that have been simplified are listed in the following sections. The headlines refer to which experiment they are extracted from. Figure 6.31 describe the feature result notations of the features which were not determined relevant.

Feature	Descriptions:
timeEseg and timeLseg	Estimated time since birth in seconds which the patient's ECG-segment is extracted. In the feature name, 'E' refers to the early time the ECG-segment were extracted and 'L' to the late ECG-segment's extraction.
startRamp and endRamp	The average R amplitude in mV of the extracted ECG-segment.
eSTCshape and lSTCshape	The correlation coefficient of the morphology measurement in the detection algorithm.
eRampown and lRampown	The project's detected average R amplitude in mV of the ECG-segment.
'e'/'start' or 'l'/'end' in the name of the feature signifies whether the feature is registered from patient's ECG-segments early or late in BMV.	

Figure 6.31: Summary of feature result notations which were determined not relevant.

6.6.1 Attachments, comparison of data

Manual recorded features:

Table 6.35: Full table of the Tukey test between the three outcomes are illustrated in this table (manual recordings). For comparison examine significant table 4.2.

Feature	Group	Control Group	Lower Limit	Difference	Upper Limit	P-value
endST	gr1	gr2	-32.542	-0.72959	31.082	0.998
endST	gr1	gr3	-99.102	-54.277	-9.4516	0.013
endST	gr2	gr3	-101.79	-53.547	-5.3082	0.025
vent	gr1	gr2	-148.1	-112.52	-76.946	$<$0.001
vent	gr1	gr3	-261.32	-211.19	-161.06	$<$0.001
vent	gr2	gr3	-152.61	-98.665	-44.716	$<$0.001
apg1	gr1	gr2	134.22	168.84	203.45	$<$0.001
apg1	gr1	gr3	188.25	237.03	285.8	$<$0.001
apg1	gr2	gr3	15.701	68.191	120.68	0.007
apg5	gr1	gr2	86.994	118.22	149.45	$<$0.001
apg5	gr1	gr3	121.34	165.34	209.34	$<$0.001
apg5	gr2	gr3	-0.23887	47.115	94.469	0.052

Automatic detected features:

Table 6.36: Full table of characteristics of 547 infants with three outcomes from this project's data (automatic detected). For comparison examine relevant significant table 4.3

Feature:	**Normal (n=316)**	**Admitted (n=165)**	**Death (n=66)**	**P-value**
eCdetect	224	116	46	
eFdetect	92	49	20	
eSTint	48 (20,60)	43 (28,57.75)	54 (38,67.75)	0.229
eSTintEST	87 (77,97)	86 (74,97)	88.5 (76,102)	0.630
eSTel	5 (1,5)	5 (1,5)	5 (1,5)	0.992
eSTelN	11	3	1	
eSTshape	2 (0,4)	2 (0,5)	1 (0,5)	0.979
eSTCshape	0.896 (0.801,0.951)	0.907 (0.756,0.959)	0.922 (0.813,0.974)	0.273
eRampown	0.499 (0.314,0.818)	0.437 (0.286,0.704)	0.474 (0.316,0.964)	0.301
lCdetect	211	99	47	
lFdetect	105	66	19	
lSTint	48 (23,60.5)	28 (16.5,51)	46 (16,68)	0.036
lSTintEST	84 (74,95)	86 (74.25,94)	100 (81,109.75)	<0.001
lSTel	5 (1,5)	5 (1,5)	5 (1,5)	0.169
lSTelN	5	2	0	
lSTshape	1 (0,4)	1 (0,4)	2 (0,5)	0.218
lSTCshape	0.882 (0.758,0.948)	0.87 (0.785,0.956)	0.863 (0.723,0.966)	0.660
lRampown	0.466 (0.252,0.757)	0.401 (0.253,0.714)	0.51 (0.258,0.881)	0.465

Table 6.37: Full table of the Tukey test between the three outcomes are illustrated in this table (automatic detected). For comparison examine relevant significant table 4.4.

Feature	**Group**	**Control Group**	**Lower Limit**	**Difference**	**Upper Limit**	**P-value**
lSTint	gr1	gr2	2.3513	25.876	49.401	0.027
lSTint	gr1	gr3	-26.347	6.947	40.242	0.877
lSTint	gr2	gr3	-55.188	-18.929	17.33	0.439
lSTintEST	gr1	gr2	-27.151	2.306	31.763	0.982
lSTintEST	gr1	gr3	-99.424	-60.422	-21.419	<0.001
lSTintEST	gr2	gr3	-105.56	-62.728	-19.894	0.002

6.6.2 Attachments, experiment 1 change of coincidence

Manual recorded features, diff=0.1 and nGroups=5:

Table 6.38: Complete table from, experiment with 5 groups and 0.1 difference. Median values of the group's feature is listed below (features: manually recorded). Can be compared with relevant table 6.1.

Group: / **Feature:**	**1**	**2**	**3**	**4**	**5**	**P-value:**
Elements	336	125	35	26	25	
vent	122 (63,266)	200 (97,417)	113 (49,245)	130 (73,448)	168 (90,988)	<0.001
timeEseg	118 (92,146)	119 (96,148)	113 (91,133)	122 (97,135)	125 (97,160)	0.540
timeLseg	330 (213,513)	448 (291,663)	426 (330,1007)	400 (278,818)	600 (316,965)	<0.001
outcome	1 (1,2)	2 (1,2)	1 (1,2)	1.5 (1,2)	2 (1,2)	0.005
apg1	7 (6,8)	7 (4,7)	7 (4.3,8)	5.5 (5,7)	6 (3.8,7.3)	0.002
apg5	10 (8,10)	9 (7,10)	10 (8,10)	10 (8,10)	9 (7,10)	0.006
startST	3 (2.5,3)	3 (2,3)	3 (2,3)	2 (1,3)	2 (1.8,3)	<0.001
endST	3 (2,3)	2 (2,3)	2 (2,3)	2 (1,2)	2 (1.8,3)	<0.001
startRamp	0.8 (0.5,1.3)	0.5 (0.3,0.9)	0.5 (0.3,0.8)	0.5 (0.4,0.6)	0.5 (0.3,0.9)	<0.001
endRamp	0.8 (0.5,1.3)	0.5 (0.3,0.9)	0.5 (0.3,0.9)	0.4 (0.3,0.6)	0.2 (0.2,0.6)	<0.001

Table 6.39: Complete table, Significant results from the Tukey test are printed in this table. Experiment with 5 groups and 0.1 difference (features: manually recorded). Can be compared with relevant table 6.2.

Feature	**Group**	**Control Group**	**Lower Limit**	**Difference**	**Upper Limit**	**P-value**
vent	gr1	gr2	-114.84	-69.674	-24.507	<0.001
timeLseg	gr1	gr2	-120.85	-75.688	-30.52	<0.001
timeLseg	gr1	gr3	-173.68	-97.102	-20.527	0.005
timeLseg	gr1	gr5	-202.12	-112.75	-23.373	0.005
outcome	gr1	gr2	-86.331	-46.457	-6.5832	0.013
apg1	gr1	gr2	6.5125	50.458	94.404	0.015
apg5	gr1	gr2	9.7495	49.395	89.041	0.006
startST	gr1	gr2	20.766	60.687	100.61	<0.001
startST	gr1	gr4	44.629	122.2	199.76	<0.001
startST	gr1	gr5	2.8572	81.851	160.84	0.038
endST	gr1	gr2	40.508	80.895	121.28	<0.001
endST	gr1	gr3	0.5879	69.057	137.53	0.047
endST	gr1	gr4	63.772	142.24	220.71	<0.001
startRamp	gr1	gr2	32.504	77.672	122.84	<0.001
startRamp	gr1	gr3	11.016	87.59	164.16	0.016
startRamp	gr1	gr4	49.181	136.94	224.7	<0.001
startRamp	gr1	gr5	24.681	114.06	203.43	0.005
endRamp	gr1	gr2	28.807	73.974	119.14	<0.001
endRamp	gr1	gr4	55.498	143.26	231.02	<0.001
endRamp	gr1	gr5	62.883	152.26	241.63	<0.001

Table 6.40: Complete table from experiment with 5 groups and 0.1 difference. Checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: Manually recorded). Can be compared with relevant table 6.3.

Feature:	**Group: 1**	**Group: 2**	**Group: 3**	**Group: 4**	**Group: 5**
ST-elevation	0.031	0.026	0.845	0.265	1
Mean R-peak amp	0.373	0.651	0.501	0.919	0.855

Automatic detected feautures, diff=0.1 and nGroups=5:

Table 6.41: Complete table from Experiment with 5 groups and 0.1 difference. Median values of the group's feature is listed below (features: automatically detected). Can be compared with relevant table 6.4.

Group:	**1**	**2**	**3**	**4**	**5**	**P-value:**
Feature:						
Elements	336	125	35	26	25	
eCdetect	253	83	21	15	12	
eSTint	46 (20,59)	54 (29,75)	57 (49,61)	53 (33,57)	31 (19,40)	0.019
eSTintEST	87 (80,99)	87 (60,100)	88 (59,95)	84 (50,88)	62 (40,84)	0.008
eSTel	5 (3,5)	5 (1,5)	5 (1,5)	4 (1,5)	1 (1,5)	<0.001
eSTelN	4	6	2	2	1	
eSTshape	2 (1,4)	2 (0,4)	1 (0,4)	1 (0,5)	0 (0,5)	0.411
eSTCshape	0.9 (0.8,1)	0.9 (0.8,0.9)	0.9 (0.7,0.9)	0.9 (0.9,1)	0.8 (0.6,0.9)	0.103
eRampown	0.6 (0.4,1)	0.4 (0.3,0.6)	0.4 (0.3,0.5)	0.3 (0.2,0.5)	0.3 (0.1,0.4)	<0.001
lCdetect	231	77	20	16	14	
lSTint	47 (20,59)	42 (19,56)	39 (13,62)	42 (24,80)	21 (18,31)	0.298
lSTintEST	86 (77,96)	81 (68,95)	89 (64,99)	77 (55,103)	89 (75,106)	0.210
lSTel	5 (1,5)	5 (1,5)	5 (1,5)	5 (1,5)	5 (1,5)	0.160
lSTelN	1	4	1	0	1	
lSTshape	2 (0,4)	1 (0,4)	1 (0,4)	1 (0,5)	2 (0,5)	0.860
lSTCshape	0.9 (0.8,1)	0.8 (0.7,0.9)	0.9 (0.7,0.9)	0.8 (0.8,1)	0.9 (0.8,0.9)	0.016
lRampown	0.5 (0.3,0.9)	0.3 (0.2,0.5)	0.3 (0.2,0.7)	0.2 (0.1,0.3)	0.1 (0.1,0.3)	<0.001

Table 6.42: Complete table with significant results from the Tukey test are printed in this table. Experiment with 5 groups and 0.1 difference (features: automatically detected). Can be compared with relevant table 6.5.

Feature	**Group**	**Control group**	**Lower Limit**	**Difference**	**Upper Limit**	**P-value**
startSTintEST	gr1	gr5	8.382	97.807	187.232	0.024
startSTel	gr1	gr5	9.133	82.100	155.067	0.018
startRampown	gr1	gr2	31.604	69.902	108.201	<0.001
startRampown	gr1	gr4	25.174	105.633	186.092	0.003
startRampown	gr1	gr5	32.724	122.175	211.626	0.002
endSTCshape	gr1	gr2	6.713	43.861	81.009	0.011
endRampown	gr1	gr2	24.804	61.952	99.099	<0.001
endRampown	gr1	gr4	54.306	127.284	200.261	<0.001
endRampown	gr1	gr5	41.486	119.186	196.885	<0.001

Table 6.43: Complete table from experiment with 5 groups and 0.1 difference. Checking for significant changes in automatically detected features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: automatically detected). Can be compared with relevant table 6.6.

Feature:	Group: 1	Group: 2	Group: 3	Group: 4	Group: 5
ST-int size	0.201	0.025	0.934	0.178	0.089
ST-int est. size	0.347	0.229	0.936	0.932	0.023
ST-shape	0.04	0.508	0.905	0.582	0.504
ST-shape C_val	0.109	0.583	0.948	0.785	0.893
ST-elevation	0.134	0.197	0.878	0.87	0.199
Mean R-peak amp	0.865	0.35	0.995	0.473	0.261

Manual recorded features, diff=0.2 and nGroups=5:

Table 6.44: Complete table from experiment with 5 groups and 0.2 difference. Median values of the group's feature is listed below (features: manually recorded). Can be compared with relevant table 6.7.

Group: / Feature:	1	2	3	4	5	P-value:
Elements	461	61	20	5	0	
vent	144 (67,293)	128 (62.3,312.8)	162 (88,868.5)	595 (97.3,987.8)		0.265
timeEseg	118 (93,147)	118 (91.8,133.3)	123.5 (100.5,158)	148 (82.8,165.5)		0.726
timeLseg	353 (232,550.3)	423 (306.8,855.3)	557 (305.5,1042)	625 (357.3,971.8)		<0.001
outcome	1 (1,2)	1 (1,2)	2 (1,2)	2 (1,2.3)		0.267
apg1	7 (5,7)	7 (4.8,7)	6 (3.5,7.5)	6 (4.3,6.5)		0.170
apg5	10 (8,10)	10 (8,10)	9.5 (7,10)	9 (6.8,10)		0.545
startST	3 (2,3)	2 (1.8,3)	2 (2,3.5)	1 (1,2.3)		<0.001
endST	3 (2,3)	2 (2,3)	2 (2,3)	1 (1,2.5)		<0.001
startRamp	0.7 (0.5,1.2)	0.5 (0.4,0.7)	0.4 (0.3,0.7)	0.9 (0.3,1.2)		<0.001
endRamp	0.7 (0.4,1.2)	0.5 (0.3,0.8)	0.4 (0.2,0.9)	0.2 (0.2,0.3)		<0.001

Table 6.45: Significant results from the Tukey test are printed in this table. Experiment with 5 groups and 0.2 difference (features: manually recorded). Can be compared with relevant table 6.8

Feature	Group	Control group	Lower Limit	Difference	Upper Limit	P-value
timeLseg	gr1	gr2	-122.12	-66.804	-11.484	0.01
startST	gr1	gr2	21.65	70.544	119.44	0.001
startST	gr1	gr4	11.295	172.66	334.02	0.03
endST	gr1	gr2	28.852	78.316	127.78	<0.001
startRamp	gr1	gr2	32.244	87.564	142.88	<0.01
startRamp	gr1	gr3	15.725	108.47	201.21	0.014
endRamp	gr1	gr2	26.982	82.302	137.62	<0.001
endRamp	gr1	gr3	11.955	104.7	197.44	0.02
endRamp	gr1	gr4	59.654	242.22	424.79	0.004

Table 6.46: Complete table from experiment with 5 groups and 0.2 difference. Checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: Manually recorded). Can be compared with relevant table 6.9.

Feature:	Group: 1	Group: 2	Group: 3	Group: 4	Group: 5
ST-elevation	0.002	0.484	0.834	0.374	
Mean R-peak amp	0.585	0.555	0.349	0.07	

Feature tables from the automatic detected data with nGroups=5 and diff = 0.2

Table 6.47: Complete table from experiment 1 with 5 groups and 0.2 difference. Median values of the group's feature is listed below (features: automatically detected). Can be compared with relevant table 6.10

Group: / Feature:	1	2	3	4	5	P-value:
Elements	461	61	20	5	0	
eCdetect	336	37	11	1		
eSTint	47 (23,61)	56 (40,59)	26 (18,43)	31 (31,31)		0.146
eSTintEST	87 (77,100)	85 (57,94)	58 (39,78)	128 (128,128)		<0.001
eSTel	5 (1,5)	5 (1,5)	4 (1,5)	1 (1,2)		0.002
eSTelN	10	4	1	0		
eSTshape	2 (0,4)	1 (0,5)	3 (0,5)	0 (0,1)		0.2
eSTCshape	0.9 (0.8,1)	0.9 (0.8,1)	0.9 (0.6,0.9)	0.7 (0.7,0.7)		0.388
eRampown	0.5 (0.3,0.9)	0.4 (0.2,0.5)	0.2 (0.1,0.4)	0.3 (0.3,0.3)		<0.001
lCdetect	308	36	10	3		
lSTint	46 (20,59)	39 (19,65)	21 (19,35)	21 (13,29)		0.466
lSTintEST	85 (75,96)	83 (58,100)	90 (87,112)	80 (54,90)		0.252
lSTel	5 (1,5)	5 (1,5)	2 (1,5)	5 (1,5)		0.213
lSTelN	5	1	1	0		
lSTshape	2 (0,4)	1 (0,5)	0.5 (0,4.5)	2 (0,4.5)		0.92
lSTCshape	0.9 (0.8,1)	0.9 (0.8,0.9)	0.8 (0.8,0.9)	0.9 (0.8,0.9)		0.663
lRampown	0.5 (0.3,0.8)	0.2 (0.2,0.5)	0.2 (0.1,0.5)	0.1 (0.1,0.1)		<0.001

Table 6.48: Complete table with significant results from the Tukey test are printed in this table. Experiment 1 with 5 groups and 0.2 difference (features: automatically detected). Can be compared with relevant table 6.11.

Feature	Group	Control group	Lower Limit	Difference	Upper Limit	P-value
eSTintEST	gr1	gr3	29.135	116.71	204.28	0.003
eRampown	gr1	gr2	20.325	69.845	119.37	0.002
eRampown	gr1	gr3	16.167	103.77	191.37	0.013
lRampown	gr1	gr2	26.912	73.611	120.31	<0.001
lRampown	gr1	gr4	19.574	173.39	327.2	0.02

Table 6.49: Complete table from experiment 1 with 5 groups and 0.2 difference. Checking for significant changes in automatically detected features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: automatically detected). Can be compared with relevant table 6.12.

Feature:	Group: 1	Group: 2	Group: 3	Group: 4
ST-int size	0.011	0.192	0.323	<0.001
ST-int est. size	0.128	0.415	0.003	<0.001
ST-shape	0.042	0.928	0.681	0.178
ST-shape C_val	0.103	0.97	0.342	0.338
ST-elevation	0.047	0.614	0.214	<0.001
Mean R-peak amp	0.82	0.567	0.223	<0.001

Feature tables from the manual recorded data, nGroups=10 and diff=0.05:

Table 6.50: Complete table from experiment 1 with 10 groups and 0.05 difference. Median values of the group's feature is listed below (part 1, features: manually recorded). Can be compare with relevant table 4.5.

Group: / **Feature:**	**1**	**2**	**3**	**4**	**5**
Elements	219	117	74	51	18
vent	113 (60,234)	150 (69,292)	203 (92,448)	200 (102,361)	85 (45,247)
timeEseg	120 (97,147)	115 (83,143)	125 (96,152)	115 (94,140)	115 (83,142)
timeLseg	307 (198,484)	368 (246,562)	462 (291,667)	428 (290,639)	459 (358,1105)
outcome	1 (1,2)	1 (1,2)	2 (1,2)	1 (1,2)	1 (1,2)
apg1	7 (6,8)	7 (6,8)	6 (4,7)	7 (4.3,7)	7 (6,8)
apg5	10 (8,10)	10 (9,10)	9 (7,10)	10 (7,10)	10 (10,10)
startST	3 (3,3)	3 (2,3)	3 (2,3)	2 (2,3)	3 (2,3)
endST	3 (3,3)	3 (2,3)	2 (2,3)	2 (2,3)	2 (2,3)
startRamp	0.8 (0.6,1.3)	0.7 (0.4,1.2)	0.5 (0.3,0.8)	0.6 (0.4,1)	0.6 (0.5,1.2)
endRamp	0.8 (0.5,1.5)	0.7 (0.4,1)	0.5 (0.3,0.9)	0.6 (0.4,0.8)	0.8 (0.4,1.3)

Table 6.51: Complete table from experiment 1 with 10 groups and 0.05 difference. Median values of the group's feature is listed below (part 2, features: manually recorded). Can be compared with relevant table 4.6.

Group: / **Feature:**	**6**	**7**	**8**	**9**	**10**	**P-value:**
Elements	17	21	5	7	18	
vent	147 (74,231)	129 (72,608)	146 (101,228)	168 (89,1119)	190 (91,940)	<0.001
timeEseg	106 (97,133)	121 (96,134)	134 (120,167)	107 (98,114)	150 (97,162)	0.301
timeLseg	365 (313,739)	394 (276,814)	429 (331,986)	714 (248,1336)	557 (350,885)	<0.001
outcome	1 (1,2)	2 (1,2)	1 (1,2)	2 (1,2)	2 (1,2)	0.034
apg1	6 (3,8)	6 (4.8,7)	5 (4.8,7)	6 (4.5,7.8)	6 (3,7)	0.013
apg5	10 (7,10)	10 (7,10)	9 (8,10)	10 (9.3,10)	8.5 (5,10)	0.009
startST	2 (1,3)	2 (1,3)	2 (1.8,2)	4 (2.3,4)	2 (1,2)	<0.001
endST	2 (1.8,3)	2 (1,3)	2 (1.8,2)	3 (1.3,3.8)	2 (2,3)	<0.001
startRamp	0.4 (0.3,0.7)	0.5 (0.4,0.6)	0.5 (0.3,0.6)	0.5 (0.5,0.9)	0.3 (0.3,0.9)	<0.001
endRamp	0.4 (0.3,0.6)	0.4 (0.3,0.6)	0.3 (0.3,0.6)	1 (0.2,2.7)	0.2 (0.2,0.4)	<0.001

Table 6.52: Complete table with significant results from the Tukey test are printed in this table. Experiment 1 with 10 groups and 0.05 difference (features: manually recorded). Can be compared with relevant table 4.7.

Feature	Group	Control group	Lower limit	Difference	Upper limit	P-value
vent	gr1	gr3	-150.06	-82.827	-15.595	0.0040
timeLseg	gr1	gr3	-163.585	-96.353	-29.12	<0.001
timeLseg	gr1	gr4	-164.888	-87.145	-9.402	0.014
timeLseg	gr1	gr5	-264.754	-142.151	-19.549	0.0090
timeLseg	gr1	gr10	-258.088	-135.485	-12.882	0.017
outcome	gr1	gr3	-124.484	-65.131	-5.778	0.019
startST	gr1	gr2	6.84	57.448	108.055	0.012
startST	gr1	gr3	11.432	70.856	130.279	0.0060
startST	gr1	gr4	26.249	94.962	163.675	<0.001
startST	gr1	gr6	22.34	133.609	244.878	0.0060
startST	gr1	gr7	23.596	124.553	225.51	0.0040
startST	gr1	gr8	16.43	216.315	416.2	0.022
startST	gr1	gr10	54.425	162.787	271.15	<0.001
startST	gr8	gr9	-529.917	-271.143	-12.369	0.031
startST	gr9	gr10	20.759	217.615	414.471	0.017
endST	gr1	gr2	16.065	67.263	118.46	0.0010
endST	gr1	gr3	36.156	96.272	156.389	<0.001
endST	gr1	gr4	46.474	115.988	185.501	<0.001
endST	gr1	gr7	52.055	154.188	256.322	<0.001
endST	gr1	gr8	11.65	213.864	416.079	0.028
endST	gr1	gr10	14.706	124.331	233.956	0.012
startRamp	gr1	gr3	33.967	101.2	168.433	<0.001
startRamp	gr1	gr4	5.525	83.268	161.011	0.025
startRamp	gr1	gr6	31.602	157.494	283.385	0.0030
startRamp	gr1	gr7	35.325	149.55	263.774	0.0010
startRamp	gr1	gr10	24.24	146.843	269.447	0.0060
endRamp	gr1	gr3	22.629	89.862	157.095	<0.001
endRamp	gr1	gr4	16.06	93.803	171.546	0.0050
endRamp	gr1	gr6	27.853	153.745	279.636	0.0040
endRamp	gr1	gr7	42.24	156.464	270.689	<0.001
endRamp	gr1	gr10	98.421	221.024	343.627	<0.001
endRamp	gr2	gr10	44.183	170.78	297.377	<0.001
endRamp	gr5	gr10	25.577	192.25	358.923	0.010

Table 6.53: Complete table from experiment 1 with 10 groups and 0.05 difference. Checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: Manually recorded). Can be compared with relevant table 4.8.

Group: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
ST-elevation	0.180	0.088	0.077	0.182	0.172	0.260	0.267	<0.001	0.103	0.331
Mean R-peak amp	0.034	0.291	0.780	0.153	0.385	0.845	0.799	0.767	0.149	0.041

Feature tables from the automatic detected data with nGroups=10 and diff = 0.05

Table 6.54: Complete table from experiment 1 with 10 groups and 0.05 difference. Median values of the group's feature is listed below (part 1, features: automatically detected). Can be compared with relevant table 4.9.

Group: / **Feature:**	**1**	**2**	**3**	**4**	**5**
Elements	219	117	74	51	18
eCdetect	167	85	47	36	12
eSTint	43 (18,55)	53 (31,67)	56 (30,74)	53 (28,78)	59 (53,64)
eSTintEST	87 (81,97)	92 (80,102)	88 (67,99)	80 (55,101)	94 (80,96)
eSTel	5 (5,5)	5 (1,5)	5 (1,5)	5 (1,5)	5 (1,5)
eSTelN	0	4	4	2	0
eSTshape	2 (1,4)	2 (0,5)	1 (0,4)	2 (0,5)	1 (0,4)
eSTCshape	0.9 (0.8,1)	0.9 (0.8,0.9)	0.9 (0.7,1)	0.9 (0.8,0.9)	0.9 (0.7,1)
eRampown	0.7 (0.4,1)	0.5 (0.3,0.8)	0.4 (0.3,0.6)	0.4 (0.2,0.6)	0.4 (0.4,0.5)
lCdetect	147	83	47	30	9
lSTint	48 (20,59)	43 (22,69)	33 (20,50)	44 (19,59)	37 (11,62)
lSTintEST	85 (78,95)	88 (75,97)	80 (70,95)	82 (62,96)	92 (73,98)
lSTel	5 (1,5)	5 (1,5)	5 (1,5)	5 (1,5)	2 (1,5)
lSTelN	0	1	2	2	1
lSTshape	2 (0,4)	2 (0,4)	1.5 (0,4)	1 (0,3.8)	0.5 (0,2)
lSTCshape	0.9 (0.8,1)	0.8 (0.7,0.9)	0.8 (0.7,0.9)	0.9 (0.7,0.9)	0.9 (0.7,0.9)
lRampown	0.6 (0.4,0.9)	0.4 (0.3,0.7)	0.3 (0.2,0.6)	0.3 (0.2,0.5)	0.3 (0.2,1)

Table 6.55: Complete table from experiment 1 with 10 groups and 0.05 difference. Median values of the group's feature is listed below (part 2, features: automatically detected). Can be compared with relevant table 4.10.

Group: / **Feature:**	**6**	**7**	**8**	**9**	**10**	**P-value:**
Elements	17	21	5	7	18	
eCdetect	8	15	0	2	9	
eSTint	54 (30,56)	53 (33,57)	31 (18,43)	0.002	59 (53,64)	0.146
eSTintEST	67 (37,84)	84 (50,88)	84 (74,94)	58 (41,81)	0.019	<0.001
eSTel	1 (1,5)	5 (1,5)	1 (1,1)	1 (1,4)	2 (1,5)	<0.01
eSTelN	2	2	0	0	1	
eSTshape	0 (0,4.3)	2 (0,5.3)	0 (0,0)	0 (0,3.8)	1 (0,5)	0.071
eSTCshape	0.8 (0.6,0.9)	0.9 (0.9,1)	0.7 (0.5,0.8)	0.9 (0.7,0.9)	0.059	0.388
eRampown	0.3 (0.2,0.4)	0.3 (0.2,0.5)	0.7 (0.2,1.2)	0.1 (0.1,0.4)		<0.001
lCdetect	10	14	2	2	11	
lSTint	46 (17,62)	42 (24,80)	21 (18,31)	0.603	37 (11,62)	0.466
lSTintEST	85 (58,102)	69 (51,107)	82 (81,82)	98 (89,106)	87 (64,107)	0.591
lSTel	5 (1,5)	5 (1,5)	1 (1,5)	1 (1,2.5)	5 (1,5)	0.1
lSTelN	0	0	0	1	0	
lSTshape	2 (0,5)	1 (0,5)	0 (0,5)	0 (0,0.8)	2.5 (0,5)	0.605
lSTCshape	0.9 (0.7,0.9)	0.9 (0.8,1)	0.8 (0.8,0.8)	0.9 (0.8,0.9)	0.9 (0.8,0.9)	0.007
lRampown	0.2 (0.2,0.5)	0.2 (0.1,0.3)	0.1 (0.1,0.2)	1 (0.1,1.9)	0.1 (0.1,0.2)	<0.01

Table 6.56: Complete table with significant results from the Tukey test are printed in this table. Experiment 1 with 10 groups and 0.05 difference (features: automatically detected). Can be compared with relevant table 4.11.

Feature	Group	Control group	Lower Limit	Difference	Upper Limit	P-value
eSTint	gr1	gr2	-75.616	-38.629	-1.641	0.033
eSTel	gr1	gr6	1.218	104.455	207.692	0.045
eSTel	gr1	gr8	28.822	214.279	399.735	0.010
eSTel	gr2	gr8	10.381	197.632	384.884	0.029
eRampown	gr1	gr2	3.543	49.057	94.57	0.023
eRampown	gr1	gr3	24.135	80.539	136.943	<0.001
eRampown	gr1	gr4	30.964	93.733	156.502	<0.001
eRampown	gr1	gr7	29.664	121.739	213.813	0.001
eRampown	gr1	gr10	45.091	161.983	278.875	<0.001
lSTCshape	gr1	gr3	11.212	65.617	120.021	0.005
lRampown	gr1	gr2	0.39	44.967	89.543	0.046
lRampown	gr1	gr3	14.042	68.447	122.851	0.003
lRampown	gr1	gr4	27.196	92.24	157.284	<0.001
lRampown	gr1	gr7	43.531	134.34	225.15	<0.001
lRampown	gr1	gr10	72.67	174.158	275.646	<0.001
lRampown	gr2	gr10	25.015	129.192	233.368	0.003

Table 6.57: Complete table from experiment 1 with 10 groups and 0.05 difference. Checking for significant changes in automatically detected features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: automatically detected). Can be compared with relevant table 4.12.

Group: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
ST-int size	0.875	0.022	0.026	0.355	<0.001	<0.001	0.178	<0.001	<0.001	0.089
ST-int est. size	0.275	0.760	0.141	0.739	0.702	0.558	0.932	<0.001	<0.001	0.075
ST-shape	0.013	0.932	0.864	0.214	0.261	0.287	1	0.178	0.766	0.399
ST-shape C_val	0.192	0.392	0.788	0.255	0.331	0.468	0.848	0.178	0.476	0.678
ST-elevation	0.354	0.219	0.295	0.458	0.519	0.296	0.870	<0.001	<0.001	0.271
Mean R-peak amp	0.665	0.877	0.553	0.148	0.553	0.989	0.473	<0.001	<0.001	0.968

6.6.3 Attachments, experiment 2 category representations

6.6.3.1 Experiment 2, patient vs category representations, unfiltered and unnormalized results

patients vs representations from early segments, filt = 0 and norm= 0

Table 6.58: Complete table from early patients correlated with categories based on early segments. Median values of the group's feature is listed below (part 1, features: manual recorded). Can be compare with relevant table 6.21.

Group: / Feature:	1	2	3	4	5
Elements	128	16	9	49	44
vent	156 (62,311)	107 (48,223)	185 (52,377)	142 (64,299)	111 (68,247)
timeEseg	112 (87,140)	121 (104,148)	134 (98,163)	110 (96,140)	110 (86,133)
timeLseg	389 (238,634)	322 (238,418)	415 (274,763)	358 (204,547)	311 (239,475)
outcome	1 (1,2)	1 (1,2)	2 (1,2)	1 (1,2)	1 (1,2)
apg1	7 (5,8)	7 (6,8)	6 (3.5,7)	7 (4.8,8)	7 (5,8)
apg5	10 (8,10)	10 (8.5,10)	10 (5.8,10)	10 (8.8,10)	10 (8,10)
startST	3 (3,3)	2 (1.5,3)	3 (3,3)	3 (3,3)	3 (3,3)
endST	3 (2,3)	2 (2,3)	3 (3,3)	3 (2.8,3)	3 (3,3)
startRamp	0.8 (0.5,1.3)	0.6 (0.4,0.8)	1.4 (1,2.3)	0.7 (0.5,1.3)	0.7 (0.5,1)
endRamp	0.7 (0.5,1.2)	0.6 (0.4,0.8)	1.2 (1,1.5)	0.7 (0.5,1.3)	0.6 (0.5,1.2)

Table 6.59: Complete table from early patients correlated with categories based on early segments. Median values of the group's feature is listed below (part 2, features: manual recorded). Can be compared with relevant table 6.22.

Group: / Feature:	6	7	8	9	Unclassified	P-value:
Elements	74	28	11	36	152	
vent	149 (68,303)	213 (76,422)	151 (97,199)	116 (64,230)	149 (77,359)	0.584
timeEseg	119 (86,148)	129 (103,153)	138 (123,168)	126 (100,144)	125 (97,153)	0.040
timeLseg	369 (216,553)	418 (266,634)	296 (215,449)	361 (272,546)	372 (249,664)	0.427
outcome	1 (1,2)	1 (1,2)	2 (1,2.8)	1 (1,2)	1 (1,2)	0.367
apg1	7 (6,7)	6 (4.5,7)	7 (6,7)	7 (6,7)	7 (4,7)	0.346
apg5	10 (8,10)	10 (7,10)	10 (7.5,10)	10 (8,10)	10 (7,10)	0.747
startST	3 (3,3)	2 (2,3)	3 (3,3)	3 (2,3)	2 (2,3)	<0.001
endST	3 (2,3)	2 (2,3)	3 (2.3,3)	3 (2,3)	2 (2,3)	<0.001
startRamp	0.7 (0.5,1.3)	0.9 (0.5,1.6)	0.4 (0.3,0.7)	0.9 (0.6,1.2)	0.5 (0.3,0.8)	<0.001
endRamp	0.7 (0.5,1.3)	0.7 (0.5,1.5)	0.8 (0.5,0.9)	0.9 (0.5,1.4)	0.4 (0.3,0.8)	<0.001

Table 6.60: Complete table from early patients correlated with categories based on early segments. Significant results from the Tukey test are printed in this table (features: manually recorded).

Feature	Group	Control group	Lower Limit	Difference	Upper Limit	P-value
startST	gr1	gr2	7.719	124.906	242.093	0.026
startST	gr1	gr7	33.159	125.362	217.564	<0.001
startST	gr1	gr10	49.271	102.288	155.305	<0.001
startST	gr2	gr4	-261.949	-134.698	-7.446	0.028
startST	gr2	gr5	-279.775	-150.756	-21.737	0.0080
startST	gr2	gr6	-258.438	-136.593	-14.747	0.014
startST	gr3	gr7	3.301	172.643	341.985	0.041
startST	gr4	gr7	30.457	135.153	239.85	0.0020
startST	gr4	gr10	39.478	112.079	184.68	<0.001
startST	gr5	gr7	44.373	151.211	258.049	<0.001
startST	gr5	gr10	52.481	128.137	203.793	<0.001
startST	gr6	gr7	38.993	137.048	235.103	<0.001
startST	gr6	gr10	51.33	113.974	176.619	<0.001
startST	gr9	gr10	5.667	87.583	169.499	0.025
endST	gr1	gr10	38.983	92.618	146.252	<0.001
endST	gr3	gr7	5.233	176.548	347.863	0.037
endST	gr3	gr10	27.432	180.81	334.189	0.0070
endST	gr4	gr10	32.214	105.661	179.107	<0.001
endST	gr5	gr7	13.325	121.407	229.49	0.014
endST	gr5	gr10	49.133	125.67	202.208	<0.001
endST	gr6	gr7	1.801	100.998	200.195	0.042
endST	gr6	gr10	41.887	105.261	168.635	<0.001
startRamp	gr1	gr10	54.443	114.427	174.411	<0.001
startRamp	gr3	gr8	28.551	253.293	478.035	0.013
startRamp	gr3	gr10	70.443	241.98	413.516	<0.001
startRamp	gr4	gr10	27.665	109.807	191.949	<0.001
startRamp	gr6	gr10	44.6	115.477	186.353	<0.001
startRamp	gr7	gr10	40.038	142.868	245.699	<0.001
startRamp	gr9	gr10	38.548	131.23	223.911	<0.001
endRamp	gr1	gr10	28.85	88.835	148.819	<0.001
endRamp	gr3	gr10	23.658	195.194	366.73	0.012
endRamp	gr4	gr10	14.889	97.031	179.173	0.0070
endRamp	gr6	gr10	21.615	92.491	163.368	0.0020
endRamp	gr9	gr10	21.096	113.777	206.459	0.0040

Table 6.61: Complete table from checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: Manually recorded). Can be compared with relevant table 6.23.

Group: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
ST-elevation	0.011	0.333	0.347	0.2	0.323	0.09	0.813	0.341	0.263	0.424
Mean R-peak amp	0.861	0.616	0.524	0.441	0.087	0.894	0.367	0.096	0.976	0.116

Exp. 2, patients vs categories (early) automatic detection,filt=0 and norm=0:

Table 6.62: Complete table of early patients correlated with categories based on early segments. Median values of the group's feature is listed below (part 1, features: automatic detected). Can be compared with relevant table 6.24.

Group: / **Feature:**	**1**	**2**	**3**	**4**	**5**
Elements	128	16	9	49	44
eCdetect	92	7	7	37	42
eSTint	46 (20,60)	25 (14,33)	40 (33,43)	59 (49,67)	56 (47,59)
eSTintEST	90 (75,101)	63 (52,66)	74 (70,76)	97 (91,104)	92 (85,95)
eSTel	5 (1,5)	1 (1,5)	5 (4,5)	5 (4,5)	5 (5,5)
eSTelN	4	0	0	0	0
eSTshape	2 (0,5)	0 (0,4.5)	6 (0.8,6)	2 (0.8,6)	1.5 (1,3)
eSTCshape	0.9 (0.7,0.9)	0.9 (0.9,1)	1 (1,1)	0.9 (0.9,1)	0.9 (0.9,1)
eRampown	0.5 (0.4,1)	0.4 (0.3,0.6)	1.1 (0.8,1.7)	0.5 (0.4,0.9)	0.5 (0.3,0.7)
lCdetect	80	10	7	34	36
lSTint	48 (13,61)	48 (16,58)	45 (39,47)	55 (22,66)	59 (40,70)
lSTintEST	87 (78,100)	70 (62,86)	74 (68,75)	93 (85,98)	87 (83,100)
lSTel	5 (1,5)	5 (1,5)	5 (4,5)	5 (1,5)	5 (5,5)
lSTelN	1	0	0	1	0
lSTshape	1 (0,4)	1.5 (0,4.5)	5 (0.8,6)	1 (0,2.3)	2 (1,4.5)
lSTCshape	0.9 (0.7,1)	0.9 (0.8,0.9)	1 (1,1)	0.9 (0.7,0.9)	0.9 (0.8,1)
lRampown	0.5 (0.4,0.8)	0.5 (0.2,0.6)	0.8 (0.7,1)	0.5 (0.3,0.9)	0.5 (0.3,0.9)

Table 6.63: Complete table of early patients correlated with categories based on early segments. Median values of the group's feature is listed below (part 2, features: automatic detected). Can be compared with relevant table 6.25.

Group: / **Feature:**	**6**	**7**	**8**	**9**	**Unclassified**	**P-value:**
Elements	74	28	11	36	152	
eCdetect	61	17	9	23	85	
eSTint	29 (15,51)	19 (14,51)	67 (64,71)	55 (38,65)	49 (30,69)	<0.001
eSTintEST	86 (81,97)	85 (44,99)	97 (95,108)	85 (82,95)	80 (52,94)	<0.001
eSTel	5 (5,5)	3 (1,5)	5 (5,5)	5 (1,5)	5 (1,5)	<0.001
eSTelN	0	4	0	0	7	
eSTshape	2 (2,4)	1 (0,4)	1 (1,1)	1 (0,2)	1 (0,4)	<0.001
eSTCshape	0.9 (0.8,1)	0.8 (0.6,0.8)	0.9 (0.8,0.9)	0.9 (0.8,1)	0.9 (0.7,0.9)	<0.001
eRampown	0.6 (0.4,1)	0.6 (0.3,1.2)	0.4 (0.3,0.6)	0.6 (0.4,0.9)	0.3 (0.2,0.5)	<0.001
lCdetect	52	15	8	18	94	
lSTint	35 (17,51)	26 (19,40)	53 (34,63)	45 (33,46)	42 (19,59)	0.112
lSTintEST	84 (74,95)	84 (61,103)	92 (87,103)	84 (81,96)	82 (69,94)	<0.001
lSTel	5 (1,5)	4 (1,5)	5 (2,5)	2 (1,5)	5 (1,5)	<0.001
lSTelN	2	1	0	1	1	
lSTshape	2 (0,4)	1 (0,3)	1 (0.3,1.8)	0.5 (0,1.5)	2 (0,5)	<0.001
lSTCshape	0.9 (0.8,1)	0.8 (0.7,0.9)	0.9 (0.8,0.9)	0.8 (0.7,0.9)	0.9 (0.8,0.9)	<0.001
lRampown	0.6 (0.3,0.8)	0.3 (0.2,0.8)	0.4 (0.3,0.6)	0.5 (0.4,0.8)	0.3 (0.2,0.5)	<0.001

Table 6.64: Complete table of early patients correlated with categories based on early segments. Significant results from the Tukey test are printed in this table (features: automatic detected)

Feature	**Group**	**Control group**	**Lower Limit**	**Difference**	**Upper Limit**	**P-value**
eSTint	gr4	gr6	12.127	70.941	129.755	0.0050
eSTint	gr6	gr8	-229.947	-119.274	-8.601	0.023
eSTint	gr7	gr8	-254.231	-128.45	-2.669	0.041
eSTintEST	gr1	gr4	-136.372	-68.745	-1.117	0.043
eSTintEST	gr2	gr4	-342.901	-199.714	-56.528	<0.01
eSTintEST	gr2	gr5	-293.574	-151.75	-9.926	0.025
eSTintEST	gr2	gr8	-406.286	-231.214	-56.143	0.0010
eSTintEST	gr3	gr4	-322.901	-179.714	-36.528	0.0030
eSTintEST	gr3	gr8	-386.286	-211.214	-36.143	0.0050
eSTintEST	gr4	gr10	43.666	112.088	180.51	<0.01
eSTintEST	gr8	gr10	21.813	143.588	265.363	0.0070
eSTel	gr1	gr5	-143.956	-72.196	-0.436	0.047
eSTel	gr2	gr5	-265.168	-145.29	-25.412	0.0050
eSTel	gr5	gr7	25.495	124.763	224.031	0.0030
eSTel	gr5	gr10	49.543	119.839	190.135	<0.01
eSTel	gr6	gr10	25.041	83.247	141.453	<0.01
eSTshape	gr6	gr10	9.564	78.904	148.243	0.012
eSTCshape	gr1	gr3	-345.885	-209.637	-73.388	<0.01
eSTCshape	gr1	gr4	-140.173	-72.525	-4.876	0.024
eSTCshape	gr1	gr5	-167.516	-102.803	-38.09	<0.01
eSTCshape	gr3	gr6	28.487	167.162	305.836	0.0050
eSTCshape	gr3	gr7	114.865	270.924	426.983	<0.01
eSTCshape	gr3	gr8	19.336	194.46	369.585	0.016
eSTCshape	gr3	gr9	32.132	182.137	332.141	0.0050
eSTCshape	gr3	gr10	74.75	211.395	348.039	<0.01
eSTCshape	gr4	gr7	31.994	133.812	235.631	0.0010
eSTCshape	gr4	gr10	5.84	74.283	142.726	0.021
eSTCshape	gr5	gr7	64.198	164.091	263.984	<0.01
eSTCshape	gr5	gr10	39.019	104.562	170.104	<0.01
eSTCshape	gr6	gr7	8.458	103.763	199.068	0.020
eRampown	gr1	gr10	45.264	97.545	149.825	<0.01
eRampown	gr3	gr10	67.515	204.16	340.804	<0.01
eRampown	gr4	gr10	21.74	90.183	158.625	0.0010
eRampown	gr5	gr10	14.569	80.112	145.655	0.0040
eRampown	gr6	gr10	45.063	103.375	161.687	<0.01
eRampown	gr9	gr10	26.999	108.675	190.351	0.0010
lSTCshape	gr1	gr3	-294.592	-166.982	-39.372	0.0010
lSTCshape	gr3	gr4	33.569	167.945	302.321	0.0030
lSTCshape	gr3	gr5	1.592	135.329	269.067	0.045
lSTCshape	gr3	gr6	18.282	148.626	278.971	0.012
lSTCshape	gr3	gr7	60.128	208.324	356.519	<0.01
lSTCshape	gr3	gr9	37.922	182.135	326.347	0.0030
lSTCshape	gr3	gr10	49.121	175.964	302.806	<0.01
lRampown	gr1	gr10	21.499	70.747	119.994	<0.01
lRampown	gr3	gr10	10.961	137.804	264.647	0.021
lRampown	gr5	gr10	6.074	69.53	132.986	0.019
lRampown	gr6	gr10	27.782	83.735	139.689	<0.01

Table 6.65: Complete table of checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: automatic detected). Can be compared with relevant table 6.26.

Group: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Unclassified**
ST-int size	0.906	0.317	1	0.040	0.375	0.876	0.460	<0.001	0.232	0.091
ST-int est. size	0.381	0.007	0.396	0.142	0.300	0.140	0.291	0.005	0.408	0.971
ST-shape	0.139	0.188	1	0.418	0.057	0.026	0.901	0.588	0.162	0.119
ST-shape C_val	0.043	0.734	0.908	0.025	0.439	0.059	0.793	0.295	0.357	0.102
ST-elevation	0.519	0.943	0.149	0.012	0.007	0.368	0.987	0.362	0.381	0.411
Mean R-peak amp	0.164	0.979	0.763	0.274	0.056	0.117	0.274	0.294	0.163	0.251

Exp. 2, patients vs categories (late) automatic detection,filt=0 and norm=0:

Table 6.66: Complete table of late patient's segments correlated with categories based on late segments. Median values of the group's feature is listed below (part 1, features: manual recorded). Can be compared with relevant table 6.27.

Group: / **Feature:**	**1**	**2**	**3**	**4**	**5**
Elements	114	26	89	112	24
vent	116 (53,318)	154 (63,368)	158 (70,288)	135 (75,237)	155 (39,283)
timeEseg	118 (92,145)	121 (100,137)	116 (95,148)	113 (87,143)	124 (105,148)
timeLseg	427 (257,668)	310 (213,451)	405 (236,673)	339 (242,491)	364 (254,481)
outcome	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)
apg1	7 (5,7)	7 (6,7)	7 (6,7)	7 (6,8)	7 (7,8)
apg5	10 (8,10)	10 (8,10)	10 (8,10)	10 (8,10)	10 (9,10)
startST	3 (2,3)	3 (3,3)	3 (2,3)	3 (3,3)	3 (2.5,3)
endST	3 (2,3)	3 (3,3)	3 (2,3)	3 (3,3)	3 (2.5,3)
startRamp	0.8 (0.5,1.5)	0.6 (0.4,0.9)	0.7 (0.4,1)	0.8 (0.6,1.3)	0.8 (0.6,1.2)
endRamp	0.8 (0.5,1.4)	0.6 (0.4,0.9)	0.6 (0.4,1)	0.8 (0.5,1.3)	0.8 (0.5,1.5)

Table 6.67: Complete table of late patient's segments correlated with categories based on late segments. Median values of the group's feature is listed below (part 2, features: manual recorded). Can be compared with relevant table 6.28.

Group: / **Feature:**	**6**	**7**	**Unclassified**	**P-value**
Elements	8	24	150	
vent	198 (52,485)	111 (66,199)	147 (85,390)	0.571
timeEseg	118 (94,154)	132 (112,163)	120 (95,149)	0.551
timeLseg	295 (264,599)	486 (285,925)	366 (236,614)	0.062
outcome	1.5 (1,2)	1 (1,2)	1 (1,2)	0.931
apg1	6.5 (3,7)	7 (6,7)	7 (4,7)	0.272
apg5	9 (5,10)	10 (8,10)	10 (7,10)	0.532
startST	3 (3,3)	2 (2,3)	2 (2,3)	<0.001
endST	3 (3,3)	2 (2,2)	2 (2,3)	<0.001
startRamp	1.1 (0.9,1.9)	0.8 (0.4,1.2)	0.5 (0.3,0.7)	<0.001
endRamp	1.2 (0.8,1.7)	0.8 (0.6,2.1)	0.4 (0.3,0.7)	<0.001

Table 6.68: Complete table of late patient's segment correlated with categories based on late segments. Significant results from the Tukey test are printed in this table (features: manually recorded).

Feature	**Group**	**Control group**	**Lower Limit**	**Difference**	**Upper Limit**	**P-value**
startST	gr1	gr8	43.737	96.344	148.95	<0.001
startST	gr2	gr8	28.043	117.985	207.927	0.002
startST	gr3	gr4	-126.693	-66.571	-6.4490	0.018
startST	gr3	gr8	20.736	77.386	134.035	<0.001
startST	gr4	gr7	17.886	113.121	208.355	0.008
startST	gr4	gr8	91.083	143.956	196.83	<0.001
startST	gr5	gr8	6.4420	99.523	192.605	0.026
startST	gr6	gr8	3.6430	157.273	310.904	0.04
endST	gr1	gr4	-131.534	-74.549	-17.564	0.002
endST	gr1	gr7	15.442	111.637	207.832	0.01
endST	gr1	gr8	30.811	84.031	137.251	<0.001
endST	gr2	gr7	30.613	151.857	273.102	0.004
endST	gr2	gr8	33.261	124.252	215.242	<0.001
endST	gr3	gr4	-130.391	-69.568	-8.7460	0.012
endST	gr3	gr7	18.101	116.618	215.134	0.008
endST	gr3	gr8	31.702	89.012	146.322	<0.001
endST	gr4	gr7	89.842	186.186	282.53	<0.001
endST	gr4	gr8	105.091	158.58	212.069	<0.001
endST	gr5	gr7	14.479	138.125	261.771	0.016
endST	gr5	gr8	16.353	110.519	204.685	0.009
endST	gr6	gr7	25.784	200.646	375.508	0.012
endST	gr6	gr8	17.619	173.04	328.461	0.017
startRamp	gr1	gr8	76.907	136.428	195.948	<0.001
startRamp	gr3	gr8	7.2760	71.370	135.464	0.017
startRamp	gr4	gr8	61.785	121.606	181.428	<0.001
startRamp	gr5	gr8	11.485	116.798	222.112	0.018
startRamp	gr6	gr8	35.228	209.048	382.868	0.007
endRamp	gr1	gr8	78.568	138.088	197.608	<0.001
endRamp	gr3	gr8	19.659	83.753	147.847	0.002
endRamp	gr4	gr8	73.885	133.707	193.528	<0.001
endRamp	gr5	gr8	31.554	136.868	242.181	0.002
endRamp	gr6	gr8	28.985	202.805	376.625	0.01
endRamp	gr7	gr8	51.200	156.513	261.827	<0.001
eRampown	gr5	gr10	14.569	80.112	145.655	0.004
eRampown	gr6	gr10	45.063	103.375	161.687	<0.01
eRampown	gr9	gr10	26.999	108.675	190.351	0.001
lSTCshape	gr1	gr3	-294.592	-166.982	-39.372	0.001
lSTCshape	gr3	gr4	33.569	167.945	302.321	0.003
lSTCshape	gr3	gr5	1.592	135.329	269.067	0.045
lSTCshape	gr3	gr6	18.282	148.626	278.971	0.012
lSTCshape	gr3	gr7	60.128	208.324	356.519	<0.01
lSTCshape	gr3	gr9	37.922	182.135	326.347	0.003
lSTCshape	gr3	gr10	49.121	175.964	302.806	<0.01
lRampown	gr1	gr10	21.499	70.747	119.994	<0.01
lRampown	gr3	gr10	10.961	137.804	264.647	0.021
lRampown	gr5	gr10	6.074	69.53	132.986	0.019
lRampown	gr6	gr10	27.782	83.735	139.689	<0.01

Table 6.69: Complete table of checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: Manually recorded). Can be compared with relevant table 6.29.

Group: / Feature	1	2	3	4	5	6	7	Unclassified
ST-elevation	0.011	0.327	0.854	0.798	0.714	<0.001	0.017	0.258
Mean R-peak amp	0.258	0.633	0.787	0.311	0.376	0.567	0.020	0.256

Exp. 2, patients vs categories (late) automatic detection,filt=0 and norm=0:

Table 6.70: Complete table of late patient's segments correlated with categories based on late segments. Median values of the group's feature is listed below (part 1, features: automatic detected). Can be compared with relevant table 6.30.

Group: / Feature:	1	2	3	4	5
Elements	114	26	89	112	24
eCdetect	84	20	65	89	19
eSTint	51 (20,64)	50 (43,67)	33 (19,55)	51 (24,62)	35 (15,59)
eSTintEST	94 (82,103)	90 (84,96)	85 (75,96)	90 (84,101)	87 (76,96)
eSTel	5 (1,5)	5 (5,5)	5 (1,5)	5 (5,5)	5 (5,5)
eSTelN	3	0	2	0	0
eSTshape	2 (0,4)	1 (1,4)	2 (0,4)	2 (1,4)	3.5 (1,5)
eSTCshape	0.9 (0.8,1)	0.9 (0.9,1)	0.9 (0.7,1)	0.9 (0.9,1)	0.9 (0.8,0.9)
eRampown	0.6 (0.4,1.1)	0.4 (0.3,0.7)	0.5 (0.3,0.8)	0.6 (0.4,1)	0.6 (0.4,0.8)
lCdetect	69	23	62	82	17
lSTint	31 (18,69)	52 (46,66)	27 (16,67)	51 (22,59)	31 (14,48)
lSTintEST	94 (84,103)	85 (82,93)	87 (74,95)	85 (81,96)	77 (73,87)
lSTel	5 (1,5)	5 (5,5)	5 (1,5)	5 (1,5)	5 (1,5)
lSTelN	2	0	0	0	0
lSTshape	1 (0,2)	2 (1,3)	2 (0,4)	2 (0,4)	2 (0,3)
lSTCshape	0.8 (0.7,0.9)	0.9 (0.9,1)	0.8 (0.7,0.9)	0.9 (0.9,1)	0.9 (0.8,1)
lRampown	0.5 (0.4,0.9)	0.4 (0.3,0.6)	0.5 (0.3,0.7)	0.5 (0.4,0.9)	0.5 (0.3,1.5)

Table 6.71: Complete table of late patient's segments correlated with categories based on late segments. Median values of the group's feature is listed below (part 2, features: automatic detected). Can be compared with relevant table 6.31.

Group: / **Feature:**	**6**	**7**	**Unclassified**	**P-value:**
Elements	8	24	150	
eCdetect	6	11	88	
eSTint	45 (41,54)	29 (28,68)	48 (29,61)	<0.001
eSTintEST	74 (69,86)	86 (43,99)	83 (57,95)	<0.001
eSTel	5 (3,5)	1 (1,5)	5 (1,5)	<0.001
eSTelN	0	2	8	
eSTshape	1 (0.5,6)	0 (0,2)	1 (0,5)	<0.001
eSTCshape	1 (1,1)	0.9 (0.7,0.9)	0.9 (0.8,0.9)	<0.001
eRampown	0.9 (0.7,1.2)	0.3 (0.2,0.6)	0.3 (0.2,0.5)	<0.001
lCdetect	5	11	86	
lSTint	45 (42,47)	24 (21,26)	44 (22,59)	0.533
lSTintEST	74 (71,78)	62 (56,97)	81 (58,97)	<0.001
lSTel	5 (1,5)	1 (1,5)	5 (1,5)	<0.001
lSTelN	0	1	4	
lSTshape	1 (0,6)	0 (0,2)	1 (0,5)	<0.001
lSTCshape	1 (1,1)	0.8 (0.7,0.9)	0.8 (0.7,0.9)	<0.001
lRampown	0.8 (0.4,1.4)	0.4 (0.3,0.9)	0.2 (0.1,0.4)	<0.001

Table 6.72: Late patient's segments correlated with categories based on late segments. Significant results from the Tukey test are printed in this table (features: automatic detected).

Feature	**Group**	**Control group**	**Lower Limit**	**Difference**	**Upper Limit**	**P-value**
eSTintEST	gr1	gr8	6.591	57.626	108.66	0.014
eSTintEST	gr4	gr8	6.134	56.43	106.725	0.015
eSTel	gr1	gr7	1.057	89.151	177.246	0.045
eSTel	gr4	gr7	22.189	110.42	198.651	0.004
eSTel	gr4	gr8	19.643	68.628	117.613	<0.001
eSTCshape	gr1	gr6	-311.243	-169.821	-28.40	0.007
eSTCshape	gr3	gr6	-329.013	-186.221	-43.428	0.002
eSTCshape	gr4	gr6	-286.789	-145.633	-4.477	0.037
eSTCshape	gr4	gr8	1.394	51.704	102.015	0.039
eSTCshape	gr5	gr6	-333.44	-176.719	-19.999	0.015
eSTCshape	gr6	gr7	45.546	215.394	385.242	0.003
eSTCshape	gr6	gr8	56.13	197.337	338.544	<0.001
eRampown	gr1	gr8	43.622	94.672	145.722	<0.001
eRampown	gr3	gr8	10.218	64.952	119.686	0.008
eRampown	gr4	gr8	49.41	99.721	150.031	<0.001
eRampown	gr6	gr8	25.096	166.303	307.51	0.009
lSTintEST	gr1	gr8	13.312	63.569	113.826	0.003
lSTel	gr2	gr7	12.087	125.476	238.865	0.018
lSTel	gr2	gr8	5.864	90.958	176.053	0.026
lSTCshape	gr1	gr2	-179.687	-104.797	-29.907	<0.001
lSTCshape	gr1	gr4	-149.494	-98.681	-47.868	<0.001
lSTCshape	gr1	gr6	-347.503	-203.449	-59.396	<0.001
lSTCshape	gr2	gr3	20.408	96.348	172.287	0.003
lSTCshape	gr2	gr7	6.324	120.348	234.372	0.03
lSTCshape	gr2	gr8	10.065	83.08	156.096	0.013
lSTCshape	gr3	gr4	-142.579	-90.232	-37.884	<0.001
lSTCshape	gr3	gr6	-339.602	-195	-50.398	0.001
lSTCshape	gr4	gr7	14.357	114.232	214.106	0.012
lSTCshape	gr4	gr8	28.956	76.964	124.972	<0.001
lSTCshape	gr6	gr7	51.237	219	386.763	0.002
lSTCshape	gr6	gr8	38.644	181.733	324.821	0.003
lRampown	gr1	gr8	48.881	99.151	149.421	<0.001
lRampown	gr3	gr8	35.782	87.603	139.423	<0.001
lRampown	gr4	gr8	58.667	106.676	154.684	<0.001
lRampown	gr5	gr8	23.769	106.328	188.886	0.002
eRampown	gr9	gr10	26.999	108.675	190.351	0.001
lSTCshape	gr1	gr3	-294.592	-166.982	-39.372	0.001
lSTCshape	gr3	gr4	33.569	167.945	302.321	0.003
lSTCshape	gr3	gr5	1.592	135.329	269.067	0.045
lSTCshape	gr3	gr6	18.282	148.626	278.971	0.012
lSTCshape	gr3	gr7	60.128	208.324	356.519	<0.01
lSTCshape	gr3	gr9	37.922	182.135	326.347	0.003
lSTCshape	gr3	gr10	49.121	175.964	302.806	<0.01
lRampown	gr1	gr10	21.499	70.747	119.994	<0.01
lRampown	gr3	gr10	10.961	137.804	264.647	0.021
lRampown	gr5	gr10	6.074	69.53	132.986	0.019
lRampown	gr6	gr10	27.782	83.735	139.689	<0.01

Table 6.73: Complete table of checking for significant changes in features from early to late. The P-values are listed, where groups with P-values <0.05 are significant (features: automatic detected). Can be compared with relevant table 6.32.

Group: / Feature	1	2	3	4	5	6	7	Unclassified
ST-int size	0.0610	0.670	0.462	0.310	0.737	0.423	0.516	0.477
ST-int est. size	0.653	0.112	0.820	0.471	0.353	0.671	0.301	0.240
ST-shape	0.0180	0.185	0.732	0.238	0.491	0.685	0.888	1
ST-shape C_val	0.0160	0.683	0.664	0.854	0.140	0.938	0.360	0.916
ST-elevation	<0.001	0.392	0.237	0.471	0.0190	0.895	0.126	0.792
Mean R-peak amp	0.126	0.874	0.666	0.267	0.986	0.342	0.820	0.180

6.6.3.2 Experiment 2, patient vs category representations, filtered and normalized results

patients vs representations from early segments, filt = 1 and norm= 1

Table 6.74: Complete table from early patients correlated with categories based on early segments. Median values of the group's feature is listed below (part 1, features: manual recorded). Can be compare with relevant table 4.19.

Group: / Feature	1	2	3	4	5
Elements	102	17	10	33	16
vent	156 (71,329)	140 (68,237)	203 (52,269)	140 (62,230)	184 (35,227)
timeEseg	114 (88,148)	137 (108,152)	131 (101,162)	120 (85,149)	137 (93,168)
timeLseg	407 (235,665)	316 (200,475)	365 (276,757)	330 (205,462)	334 (235,594)
outcome	1 (1,2)	1 (1,2)	2 (1,2)	1 (1,2)	2 (1,2)
apg1	7 (5,7)	7 (6,7.3)	6.5 (4,7)	7 (6,8)	6 (5,7)
apg5	10 (8,10)	10 (9,10)	10 (6,10)	10 (9,10)	9 (6.5,10)
startST	3 (3,3)	2 (2,2)	3 (3,3)	3 (3,3)	3 (2.5,3)
endST	3 (2,3)	2 (2,2)	3 (3,3)	3 (3,3)	3 (2.5,3)
startRamp	0.8 (0.5,1.3)	0.4 (0.2,0.7)	1.3 (1,2.3)	0.8 (0.5,1.2)	0.5 (0.4,0.7)
endRamp	0.7 (0.4,1.2)	0.5 (0.3,0.6)	1.1 (0.8,1.5)	0.8 (0.5,1.1)	0.5 (0.4,0.9)

Table 6.75: Complete table from early filtered and normalized patient's segments correlated with categories based on early filtered and normalized segments. Median values of the group's feature is listed below (part 2, features: manual recorded). Can be compared with relevant table 4.20.

Group: / Feature:	6	7	8	9	Unclassified	P-value
Elements	38	75	65	41	150	
vent	191 (83,399)	133 (66,220)	147 (68,359)	150 (69,294)	130 (69,324)	0.787
timeEseg	111 (98,139)	121 (93,140)	121 (90,137)	112 (83,140)	121 (96,152)	0.478
timeLseg	393 (235,595)	342 (256,516)	362 (217,611)	402 (225,540)	372 (254,636)	0.808
outcome	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	0.442
apg1	6 (3,7)	7 (6,8)	7 (5,7)	7 (5,7.3)	7 (5,7)	0.469
apg5	10 (7,10)	10 (8,10)	10 (8,10)	10 (8,10)	10 (8,10)	0.678
startST	3 (2,3)	3 (3,3)	3 (3,3)	2 (2,3)	2 (2,3)	<0.001
endST	3 (2,3)	3 (3,3)	3 (2,3)	2 (2,3)	2 (2,3)	<0.001
startRamp	0.7 (0.5,1.2)	0.8 (0.5,1.3)	0.7 (0.5,1.4)	0.7 (0.5,1.3)	0.5 (0.3,0.9)	<0.001
endRamp	0.7 (0.5,1)	0.7 (0.5,1.2)	0.6 (0.5,1.4)	0.5 (0.3,0.9)	0.6 (0.3,0.9)	0.001

Table 6.76: Complete table from early patients correlated with categories based on early filtered and normalized segments. Significant results from the Tukey test are printed in this table (features: manually recorded).

Feature	Group	Control group	Lower Limit	Difference	Upper Limit	P-value
startST	gr1	gr2	23.951	139.725	255.5	0.005
startST	gr1	gr9	27.61	109.332	191.055	<0.001
startST	gr1	gr10	27.633	84.351	141.068	<0.001
startST	gr2	gr3	-373.213	-197.088	-20.963	0.015
startST	gr2	gr4	-324.404	-192.467	-60.53	<0.001
startST	gr2	gr6	-276.58	-147.628	-18.675	0.011
startST	gr2	gr7	-301.449	-182.735	-64.021	<0.001
startST	gr2	gr8	-271.901	-151.511	-31.122	0.003
startST	gr3	gr9	10.827	166.695	322.563	0.025
startST	gr4	gr9	58.719	162.074	265.429	<0.001
startST	gr4	gr10	52.118	137.092	222.066	<0.001
startST	gr6	gr9	17.718	117.235	216.751	0.007
startST	gr6	gr10	11.992	92.253	172.514	0.01
startST	gr7	gr9	66.506	152.342	238.178	<0.001
startST	gr7	gr10	64.86	127.36	189.86	<0.001
startST	gr8	gr9	32.979	121.118	209.257	<0.001
startST	gr8	gr10	30.51	96.136	161.763	<0.001
endST	gr1	gr2	7.082	124.206	241.329	0.027
endST	gr1	gr10	19.244	76.623	134.001	<0.001
endST	gr2	gr3	-395.177	-217	-38.823	0.005
endST	gr2	gr4	-321.626	-188.152	-54.677	<0.001
endST	gr2	gr6	-260.942	-130.487	-0.032	0.05
endST	gr2	gr7	-283.537	-163.44	-43.343	<0.001
endST	gr3	gr9	16.779	174.463	332.148	0.017
endST	gr3	gr10	23.398	169.417	315.436	0.009
endST	gr4	gr9	41.056	145.615	250.174	<0.001
endST	gr4	gr10	54.604	140.568	226.532	<0.001
endST	gr6	gr10	1.707	82.904	164.1	0.041
endST	gr7	gr9	34.067	120.903	207.74	<0.001
endST	gr7	gr10	52.629	115.857	179.085	<0.001
endST	gr8	gr10	5.833	72.224	138.616	0.021
startRamp	gr1	gr10	10.132	74.304	138.475	0.009
startRamp	gr2	gr3	-434.983	-235.712	-36.441	0.007
startRamp	gr2	gr8	-285.253	-149.043	-12.832	0.019
startRamp	gr3	gr10	15.891	179.197	342.502	0.019
startRamp	gr7	gr10	3.71	74.423	145.137	0.03
startRamp	gr8	gr10	18.276	92.527	166.779	0.003
lSTCshape	gr3	gr4	33.569	167.945	302.321	0.003
lSTCshape	gr3	gr5	1.592	135.329	269.067	0.045
lSTCshape	gr3	gr6	18.282	148.626	278.971	0.012
lSTCshape	gr3	gr7	60.128	208.324	356.519	<0.01
lSTCshape	gr3	gr9	37.922	182.135	326.347	0.003
lSTCshape	gr3	gr10	49.121	175.964	302.806	<0.01
lRampown	gr1	gr10	21.499	70.747	119.994	<0.01
lRampown	gr3	gr10	10.961	137.804	264.647	0.021
lRampown	gr5	gr10	6.074	69.53	132.986	0.019
lRampown	gr6	gr10	27.782	83.735	139.689	<0.01

Table 6.77: Complete table from checking for significant changes in features from early to late (filtered and normalized). The P-values are listed, where groups with P-values <0.05 are significant (features: Manually recorded). Can be compared with relevant table 4.21.

Group: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Unclassified**
ST-elevation	0.072		0.343	0.325		0.254	0.045	0.015	0.534	0.493
Mean R-peak amp	0.833	0.819	0.515	0.709	0.232	0.197	0.129	0.633	0.067	0.045

Exp. 2, patients vs categories (early) automatic detection,filt=1 and norm=1:

Table 6.78: Complete table of early patients correlated with categories based on early filtered and normalized segments. Median values of the group's feature is listed below (part 1, features: automatic detected). Can be compared with relevant table 4.22.

Group: / **Feature:**	**1**	**2**	**3**	**4**	**5**
Elements	102	17	10	33	16
eCdetect	76	12	8	32	13
eSTint	20 (11,57)	11 (11,11)	41 (34,44)	47 (43,55)	60 (10,76)
eSTintEST	90 (73,104)	64 (53,69)	77 (71,79)	85 (78,90)	103 (94,117)
eSTel	5 (1,5)	5 (1,5)	5 (5,5)	5 (5,5)	5 (3,5)
eSTelN	3	0	0	0	2
eSTshape	2 (0,4)	5 (0,5)	6 (1,6)	3 (1.8,6)	1 (1,1)
eSTCshape	0.9 (0.8,1)	0.9 (0.8,0.9)	1 (1,1)	1 (0.9,1)	0.9 (0.9,1)
eRampown	0.5 (0.3,0.7)	0.3 (0.1,0.4)	1 (0.7,1.6)	0.6 (0.4,0.9)	0.3 (0.2,0.4)
lCdetect	75	14	8	26	11
lSTint	17 (11,49)	21 (15,37)	44 (37,47)	50 (44,59)	17 (10,42)
lSTintEST	85 (71,97)	62 (57,71)	72 (68,82)	86 (78,96)	90 (81,98)
lSTel	5 (1,5)	5 (4.5,5)	5 (5,5)	5 (5,5)	5 (1,5)
lSTelN	1	1	0	0	0
lSTshape	2 (0,4)	4 (1,5)	3.5 (1,6)	2 (1,5)	2 (0,5)
lSTCshape	0.9 (0.7,0.9)	0.8 (0.8,0.9)	1 (1,1)	0.9 (0.9,1)	0.9 (0.8,1)
lRampown	0.4 (0.3,0.6)	0.2 (0.1,0.6)	0.8 (0.5,1)	0.5 (0.3,0.8)	0.3 (0.2,0.4)

Table 6.79: Complete table of early patients correlated with categories based on early filtered and normalized segments. Median values of the group's feature is listed below (part 2, features: automatic detected). Can be compared with relevant table 4.23.

Group: / **Feature:**	**6**	**7**	**8**	**9**	**Unclassified**	**P-value:**
Elements	38	75	65	41	150	
eCdetect	30	71	53	25	119	
eSTint	60 (52,67)	56 (52,62)	36 (11,51)	30 (10,56)	42 (21,60)	<0.001
eSTintEST	96 (89,105)	92 (85,98)	86 (79,95)	88 (70,100)	76 (57,95)	<0.001
eSTel	5 (5,5)	5 (5,5)	5 (5,5)	5 (1,5)	5 (3,5)	<0.001
eSTelN	0	0	0	1	13	
eSTshape	1 (1,3)	2 (1,5.8)	2 (1,4)	1 (0,2.3)	2 (1,5)	<0.001
eSTCshape	0.9 (0.9,1)	0.9 (0.9,1)	0.9 (0.8,1)	0.8 (0.7,0.9)	0.9 (0.8,0.9)	<0.001
eRampown	0.5 (0.4,0.8)	0.5 (0.3,0.8)	0.5 (0.4,0.9)	0.4 (0.2,0.7)	0.2 (0.2,0.4)	<0.001
lCdetect	26	66	49	24	108	
lSTint	48 (13,57)	52 (45,61)	38 (21,48)	11 (10,61)	46 (22,62)	0.007
lSTintEST	90 (79,104)	90 (84,97)	83 (77,96)	91 (59,104)	81 (68,92)	<0.001
lSTel	5 (1,5)	5 (5,5)	5 (2.5,5)	5 (1,5)	5 (1,5)	<0.001
lSTelN	1	1	2	3	4	
lSTshape	1 (0,4)	2 (1,5)	2 (0.8,4.3)	1 (0,2)	2 (0,5)	<0.001
lSTCshape	0.9 (0.8,1)	0.9 (0.8,1)	0.9 (0.8,1)	0.8 (0.6,1)	0.8 (0.8,0.9)	<0.001
lRampown	0.4 (0.3,0.6)	0.5 (0.3,0.8)	0.4 (0.3,0.7)	0.4 (0.2,0.5)	0.2 (0.1,0.5)	<0.001

Table 6.80: Complete table of early patients correlated with categories based on early filtered and normalized segments. Significant results from the Tukey test are printed in this table (features: automatic detected)

Feature	Group	Control group	Lower Limit	Difference	Upper Limit	P-value
eSTint	gr1	gr6	-124.864	-67.467	-10.069	0.008
eSTint	gr1	gr7	-115.143	-66.578	-18.014	<0.001
eSTint	gr7	gr8	2.352	64.549	126.746	0.035
eSTintEST	gr1	gr2	30.154	154.805	279.456	0.003
eSTintEST	gr2	gr5	-390.838	-230.196	-69.554	<0.001
eSTintEST	gr2	gr6	-357.156	-220.092	-83.027	<0.001
eSTintEST	gr2	gr7	-311.381	-186.133	-60.885	<0.001
eSTintEST	gr2	gr8	-277.526	-149.24	-20.954	0.009
eSTintEST	gr3	gr5	-368.037	-187.716	-7.396	0.033
eSTintEST	gr3	gr6	-337.288	-177.613	-17.937	0.016
eSTintEST	gr4	gr6	-204.248	-102.269	-0.29	0.049
eSTintEST	gr5	gr10	15.646	132.864	250.082	0.012
eSTintEST	gr6	gr10	40.78	122.76	204.741	<0.001
eSTintEST	gr7	gr10	28.625	88.802	148.978	<0.001
eSTel	gr1	gr7	-119.369	-63.5	-7.63	0.012
eSTel	gr4	gr9	21.319	107.217	193.115	0.003
eSTel	gr7	gr9	29.361	100.699	172.038	<0.001
eSTel	gr7	gr10	10.473	62.417	114.36	0.006
eSTshape	gr1	gr4	-201.195	-102.737	-4.279	0.033
eSTshape	gr4	gr5	14.886	164.654	314.423	0.018
eSTshape	gr4	gr6	6.591	123.574	240.556	0.029
eSTshape	gr4	gr9	33.731	148.707	263.683	0.002
eSTCshape	gr1	gr3	-378.502	-229.309	-80.116	<0.001
eSTCshape	gr1	gr4	-216.269	-131.684	-47.1	<0.001
eSTCshape	gr1	gr7	-156.849	-90.6	-24.35	<0.001
eSTCshape	gr2	gr3	-404.498	-221.292	-38.085	0.005
eSTCshape	gr3	gr6	5.809	165.525	325.241	0.035
eSTCshape	gr3	gr8	47.833	200.078	352.323	0.001
eSTCshape	gr3	gr9	121.582	284.625	447.668	<0.001
eSTCshape	gr3	gr10	66.601	213.205	359.808	<0.001
eSTCshape	gr4	gr8	12.595	102.453	192.311	0.012
eSTCshape	gr4	gr9	79.86	187	294.14	<0.001
eSTCshape	gr4	gr10	35.651	115.58	195.508	<0.001
eSTCshape	gr5	gr9	17.058	154.308	291.557	0.014
eSTCshape	gr6	gr9	10.404	119.1	227.796	0.019
eSTCshape	gr7	gr9	52.569	145.915	239.262	<0.001
eSTCshape	gr7	gr10	14.304	74.495	134.687	0.004
eRampown	gr1	gr10	50.643	109.581	168.52	<0.001
eRampown	gr2	gr3	-414.623	-231.417	-48.21	0.003
eRampown	gr2	gr4	-287.38	-151.51	-15.641	0.015
eRampown	gr3	gr5	19.096	199.462	379.827	0.017
eRampown	gr3	gr10	78.044	224.647	371.251	<0.001
eRampown	gr4	gr10	64.812	144.741	224.669	<0.001
eRampown	gr6	gr10	32.813	114.814	196.815	<0.001
eRampown	gr7	gr10	57.526	117.717	177.909	<0.001
eRampown	gr8	gr10	51.249	117.534	183.819	<0.001
lSTint	gr1	gr7	-102.614	-56.955	-11.295	0.003
lSTintEST	gr2	gr6	-248.753	-125.418	-2.082	0.042
lSTintEST	gr2	gr7	-248.615	-139.14	-29.664	0.002
lSTintEST	gr7	gr10	9.216	67.346	125.476	0.009
lSTel	gr7	gr9	18.854	94.674	170.495	0.003
lSTCshape	gr1	gr3	-313.612	-175.193	-36.775	0.003
lSTCshape	gr1	gr4	-185.968	-101.27	-16.572	0.006
lSTCshape	gr2	gr3	-365.014	-200.071	-35.129	0.005
lSTCshape	gr2	gr4	-249.518	-126.148	-2.779	0.04

Table 6.81: Complete table of checking for significant changes in features from early to late (filtered and normalized). The P-values are listed, where groups with P-values <0.05 are significant (features: automatic detected). Can be compared with relevant table 4.24.

Group: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Unclassified**
ST-int size	0.874	<0.001	0.787	0.611	0.375	0.008	0.302	0.970	0.338	0.673
ST-int est. size	0.259	0.383	0.232	0.667	0.361	0.139	0.660	0.079	0.711	0.732
ST-shape	1	0.332	1	0.012	0.684	0.221	0.132	0.191	0.585	0.341
ST-shape C_val	0.330	0.773	0.626	0.088	0.141	0.763	0.969	0.920	0.518	0.126
ST-elevation	0.310	0.209	0.392	0.284	0.240	0.112	0.060	0.801	0.280	0.088
Mean R-peak amp	0.038	0.615	0.736	0.721	0.793	0.140	0.430	0.838	0.652	0.398

Exp. 2, patients vs categories (late) Manual recorded features,filt=1 and norm=1:

Table 6.82: Complete table of late patient's segments correlated with categories based on late filtered and normalized segments. Median values of the group's feature is listed below (part 1, features: manual recorded). Can be compared with relevant table 4.25.

Group: / **Feature**	**1**	**2**	**3**	**4**	**5**
Elements	116	27	108	83	18
vent	132 (64,308)	121 (68,257)	168 (80,282)	133 (72,231)	117 (46,310)
timeEseg	120 (93,143)	124 (108,146)	118 (97,150)	112 (86,142)	127 (96,139)
timeLseg	459 (256,685)	278 (215,357)	374 (225,549)	337 (237,462)	280 (212,758)
outcome	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)	1 (1,2)
apg1	7 (5,7)	7 (6,7.8)	7 (6,7)	7 (6,7)	7 (5,8)
apg5	10 (8,10)	10 (7.3,10)	10 (8.5,10)	10 (8.3,10)	10 (9,10)
startST	3 (2.5,3)	3 (3,3)	3 (3,3)	3 (3,3)	3 (2,3)
endST	3 (2,3)	3 (3,3)	3 (2.5,3)	3 (3,3)	3 (2,3)
startRamp	0.8 (0.5,1.5)	0.6 (0.4,0.8)	0.8 (0.5,1.1)	0.7 (0.5,1.2)	0.9 (0.6,1.3)
endRamp	0.8 (0.5,1.4)	0.6 (0.4,0.9)	0.7 (0.5,1.1)	0.8 (0.5,1.3)	0.8 (0.4,0.9)

Table 6.83: Complete table of late patient's segments correlated with categories based on late segments. Median values of the group's feature is listed below (part 2, features: manual recorded). Can be compared with relevant table 4.26.

Group: / **Feature:**	**6**	**7**	**8**	**9**	**Unclassified**	**P-value**
Elements	8	18	6	15	148	
vent	198 (52,485)	164 (48,340)	295 (63,757)	97 (56,282)	142 (77,366)	0.852
timeEseg	118 (94,154)	111 (87,139)	114 (97,120)	133 (101,163)	119 (92,148)	0.667
timeLseg	295 (264,599)	430 (299,815)	668 (412,961)	481 (300,860)	372 (249,607)	0.00500
outcome	1.5 (1,2)	1 (1,2)	2 (2,3)	1 (1,2)	1 (1,2)	0.445
apg1	6.5 (3,7)	7 (6,8)	7 (7,7)	7 (5.3,8)	7 (5,7)	0.502
apg5	9 (5,10)	10 (9,10)	9.5 (8,10)	10 (7.5,10)	10 (7.5,10)	0.743
startST	3 (3,3)	2 (2,3)	2 (2,2)	2 (2,3)	2 (2,3)	<0.001
endST	3 (3,3)	2 (2,3)	2 (2,2)	2 (2,2)	2 (2,3)	<0.001
startRamp	1.1 (0.9,1.9)	0.7 (0.5,1.2)	0.5 (0.3,1.4)	0.5 (0.3,0.9)	0.5 (0.3,0.8)	<0.001
endRamp	1.2 (0.8,1.7)	0.5 (0.4,0.9)	0.5 (0.3,0.8)	0.8 (0.3,1.8)	0.5 (0.3,0.8)	<0.001

Table 6.84: Complete table of late patient's segment correlated with categories based on late filtered and normalized segments. Significant results from the Tukey test are printed in this table (features: manually recorded).

Feature	Group	Control group	Lower Limit	Difference	Upper Limit	P-value
timeLseg	gr1	gr2	2.217	109.059	215.901	0.041
startST	gr1	gr10	49.295	104.099	158.902	<0.001
startST	gr2	gr10	6.877	99.361	191.846	0.024
startST	gr3	gr10	34.409	90.338	146.268	<0.001
startST	gr4	gr10	59.806	120.41	181.014	<0.001
endST	gr1	gr9	12.026	134.701	257.376	0.018
endST	gr1	gr10	40.932	96.374	151.816	<0.001
endST	gr2	gr9	0.9640	144.941	288.917	0.047
endST	gr2	gr10	13.051	106.613	200.176	0.012
endST	gr3	gr9	15.867	139.061	262.255	0.013
endST	gr3	gr10	44.153	100.734	157.315	<0.001
endST	gr4	gr7	32.665	148.912	265.158	0.002
endST	gr4	gr8	36.656	225.662	414.668	0.006
endST	gr4	gr9	54.675	180.112	305.548	<0.001
endST	gr4	gr10	80.474	141.784	203.094	<0.001
endST	gr6	gr8	8.627	250.083	491.54	0.035
endST	gr6	gr9	8.798	204.533	400.268	0.032
endST	gr6	gr10	3.920	166.206	328.492	0.04
startRamp	gr1	gr10	44.307	106.312	168.317	<0.001
startRamp	gr3	gr10	16.98	80.259	143.539	0.002
startRamp	gr4	gr10	22.285	90.853	159.421	0.001
startRamp	gr5	gr10	0.3820	125.199	250.016	0.049
startRamp	gr6	gr10	10.464	191.963	373.461	0.028
endRamp	gr1	gr10	55.946	117.951	179.956	<0.001
endRamp	gr3	gr10	24.081	87.36	150.64	<0.001
endRamp	gr4	gr10	45.319	113.887	182.456	<0.001
endRamp	gr6	gr10	3.617	185.115	366.613	0.041

Table 6.85: Complete table of checking for significant changes in features from early to late (filtered and normalized). The P-values are listed, where groups with P-values <0.05 are significant (features: Manually recorded). Can be compared with relevant table 4.27.

Group: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Unclassified**
ST-elevation	0.019	0.327	0.551	0.596	1	<0.001	0.187	0.363	0.055	0.212
Mean R-peak amp	0.933	0.224	0.273	0.247	0.050	0.567	0.332	0.477	0.040	0.587

Exp. 2, patients vs categories (late) automatic detection,filt=0 and norm=0:

Table 6.86: Complete table of late patient's segments correlated with categories based on late filtered and normalized segments. Median values of the group's feature is listed below (part 1, features: automatic detected). Can be compared with relevant table 4.28.

Group: / Feature:	1	2	3	4	5
Elements	116	27	108	83	18
eCdetect	93	25	88	76	10
eSTint	53 (19,63)	58 (47,69)	37 (15,54)	53 (36,58)	53 (35,62)
eSTintEST	94 (83,104)	86 (80,97)	87 (75,96)	90 (84,99)	93 (82,97)
eSTel	5 (5,5)	5 (5,5)	5 (5,5)	5 (5,5)	5 (1,5)
eSTelN	1	0	2	2	0
eSTshape	2 (1,5)	2 (1,2)	2 (1,4)	2 (1,5)	1 (0,1)
eSTCshape	0.9 (0.8,1)	0.9 (0.9,1)	0.9 (0.7,1)	0.9 (0.9,1)	0.9 (0.8,1)
eRampown	0.5 (0.3,0.9)	0.4 (0.2,0.5)	0.5 (0.3,0.7)	0.5 (0.3,0.9)	0.6 (0.5,0.8)
lCdetect	84	24	88	72	10
lSTint	21 (10,58)	51 (48,61)	20 (10,37)	54 (44,61)	46 (13,76)
lSTintEST	93 (85,104)	86 (81,94)	83 (73,92)	87 (82,96)	58 (27,106)
lSTel	5 (1,5)	5 (5,5)	5 (5,5)	5 (5,5)	3 (1,5)
lSTelN	2	0	0	0	3
lSTshape	1 (0,2)	2 (1,6)	2 (1,4)	2 (1,5)	1 (0,5)
lSTCshape	0.8 (0.7,0.9)	1 (0.9,1)	0.9 (0.8,0.9)	0.9 (0.9,1)	0.9 (0.7,0.9)
lRampown	0.4 (0.3,0.7)	0.4 (0.2,0.6)	0.4 (0.3,0.7)	0.5 (0.4,0.8)	0.5 (0.2,0.6)

Table 6.87: Complete table of late patient's segments correlated with categories based on late filtered and normalized segments. Median values of the group's feature is listed below (part 2, features: automatic detected). Can be compared with relevant table 4.29.

Group: / Feature:	6	7	8	9	Unclassified	P-value:
Elements	8	18	6	15	148	
eCdetect	7	14	3	9	114	
eSTint	44 (43,49)	58 (37,60)	24 (10,37)	16 (13,35)	42 (18,58)	<0.001
eSTintEST	78 (70,85)	73 (57,86)	56 (49,78)	86 (69,98)	79 (56,96)	<0.001
eSTel	5 (5,5)	5 (5,5)	2 (1,5)	5 (1,5)	5 (3,5)	<0.001
eSTelN	0	0	1	0	12	
eSTshape	3.5 (1,6)	2 (1,5)	0.5 (0,5)	1 (0,5)	2 (1,5)	<0.001
eSTCshape	1 (1,1)	0.8 (0.8,0.9)	1 (0.9,1)	0.9 (0.8,0.9)	0.9 (0.8,0.9)	<0.001
eRampown	0.8 (0.5,1.3)	0.4 (0.3,0.5)	0.2 (0.1,0.3)	0.2 (0.2,0.4)	0.3 (0.1,0.5)	<0.001
lCdetect	6	14	2	2	106	
lSTint	44 (38,48)	36 (18,47)		42 (31,52)	39 (16,62)	<0.001
lSTintEST	72 (70,83)	68 (67,79)	90 (48,132)	77 (58,95)	79 (56,93)	<0.001
lSTel	5 (3,5)	5 (5,5)	1 (1,5)	1 (1,1)	5 (1,5)	<0.001
lSTelN	0	0	0	0	8	
lSTshape	1 (0.5,6)	4 (1,5)	0 (0,5)	0 (0,0)	2 (0,5)	<0.001
lSTCshape	1 (1,1)	0.9 (0.8,1)	0.8 (0.7,0.9)	0.8 (0.8,0.8)	0.8 (0.8,0.9)	<0.001
lRampown	0.8 (0.4,0.9)	0.3 (0.3,0.5)	0.2 (0.2,0.3)	0.9 (0.1,1.7)	0.2 (0.1,0.4)	<0.001

Table 6.88: Late patient's segments correlated with categories based on late filtered and normalized segments. Significant results from the Tukey test are printed in this table (features: automatic detected).

Feature	Group	Control group	Lower Limit	Difference	Upper Limit	P-value
eSTintEST	gr1	gr7	13.71	128.747	243.784	0.015
eSTintEST	gr1	gr10	14.91	70.982	127.054	0.003
eSTintEST	gr4	gr7	7.714	124.423	241.131	0.026
eSTintEST	gr4	gr10	7.233	66.658	126.083	0.014
eSTel	gr4	gr5	1.228	96.441	191.654	0.044
eSTel	gr4	gr10	3.365	53.581	103.798	0.026
eSTCshape	gr1	gr6	-321.893	-164.578	-7.262	0.032
eSTCshape	gr3	gr4	-140.62	-77.766	-14.912	0.004
eSTCshape	gr3	gr6	-359.883	-202.255	-44.627	0.002
eSTCshape	gr4	gr10	13.569	73.009	132.449	0.004
eSTCshape	gr6	gr7	30.552	216.357	402.162	0.009
eSTCshape	gr6	gr9	5.578	207.857	410.136	0.038
eSTCshape	gr6	gr10	41.20	197.497	353.795	0.003
eRampown	gr1	gr10	36.653	92.739	148.824	<0.001
eRampown	gr3	gr10	36.304	93.26	150.217	<0.001
eRampown	gr4	gr10	52.652	112.092	171.532	<0.001
eRampown	gr5	gr10	9.979	142.358	274.737	0.023
eRampown	gr6	gr10	31.575	187.872	344.17	0.006
lSTint	gr1	gr4	-79.743	-41.035	-2.326	0.028
lSTint	gr2	gr3	20.239	76.323	132.408	<0.001
lSTint	gr3	gr4	-110.055	-66.953	-23.85	<0.001
lSTintEST	gr1	gr3	7.428	64.321	121.213	0.013
lSTintEST	gr1	gr7	11.155	118.821	226.488	0.017
lSTintEST	gr1	gr10	28.39	82.872	137.354	<0.001
lSTintEST	gr4	gr10	0.9010	57.86	114.819	0.043
lSTel	gr1	gr9	55.015	161.908	268.801	<0.001
lSTel	gr2	gr5	8.790	127.333	245.877	0.024
lSTel	gr2	gr9	86.101	211.556	337.01	<0.001
lSTel	gr3	gr5	7.412	106.593	205.773	0.024
lSTel	gr3	gr9	83.469	190.815	298.16	<0.001
lSTel	gr4	gr5	20.044	121.336	222.628	0.006
lSTel	gr4	gr9	96.259	205.558	314.858	<0.001
lSTel	gr6	gr9	2.112	172.667	343.221	0.044
lSTel	gr7	gr9	44.248	180.444	316.64	0.001
lSTel	gr9	gr10	-257.742	-152.18	-46.618	<0.001
lSTshape	gr1	gr4	-142.601	-72.02	-1.439	0.041
lSTshape	gr2	gr9	53.739	211.837	369.935	<0.001
lSTshape	gr3	gr9	27.083	162.36	297.637	0.006
lSTshape	gr4	gr9	42.89	180.629	318.369	0.001
lSTshape	gr7	gr9	29.971	201.606	373.24	0.008
lSTshape	gr9	gr10	-288.269	-155.24	-22.211	0.008
lSTCshape	gr1	gr2	-223.296	-136.946	-50.597	<0.001
lSTCshape	gr1	gr4	-165.03	-105.113	-45.196	<0.001
lSTCshape	gr1	gr6	-382.057	-224.405	-66.753	<0.001
lSTCshape	gr2	gr3	15.478	101.39	187.303	0.007
lSTCshape	gr2	gr10	37.987	122.322	206.656	<0.001
lSTCshape	gr3	gr4	-128.842	-69.557	-10.272	0.008
lSTCshape	gr3	gr6	-346.262	-188.848	-31.435	0.006
lSTCshape	gr4	gr10	33.513	90.488	147.463	<0.001
lSTCshape	gr5	gr6	-397.921	-205.267	-12.612	0.026
lSTCshape	gr6	gr10	53.222	209.78	366.338	<0.001
lRampown	gr1	gr10	59.193	113.69	168.188	<0.001
lRampown	gr2	gr10	3.415	87.75	172.085	0.034
lRampown	gr3	gr10	55.47	109.273	163.075	<0.001
lRampown	gr4	gr10	85.58	142.556	199.531	<0.001

Table 6.89: Complete table of checking for significant changes in features from early to late (normalized and filtered). The P-values are listed, where groups with P-values <0.05 are significant (features: automatic detected). Can be compared with relevant table 4.30.

Group: / **Feature**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Unclassified**
ST-int size	0.151	0.954	0.066	1	0.791	0.087	0.086	<0.001	<0.001	0.566
ST-int est. size	0.601	0.828	0.246	0.469	0.895	0.072	0.242	0.486	<0.001	0.925
ST-shape	0.076	0.327	0.841	0.464	0.660	0.598	<0.001	0.695	0.029	0.373
ST-shape C_val	0.003	0.150	0.935	0.762	0.313	0.654	0.084	0.892	0.123	0.750
ST-elevation	<0.001	0.028	0.391	0.752	0.266	0.221	0.199	0.189	<0.001	0.061
Mean R-peak amp	0.511	0.438	0.434	0.259	0.412	0.192	0.296	0.739	<0.001	0.037

6.7 Results, Boxplots

Below are boxplot figures relevant to the data used in the results chapter. These figures display the pdf of the data for a closer examination of the data. The headlines refer to which experiment the figure belong to. First some theory to understand the type of boxplot used in the following illustrations.

6.7.1 Notched boxplots

Some results in 4 are illustrated with boxplots. The boxplot shows the distribution of the data and figure 6.32 describes the different features of the plot. In the experiments (read description in 6.3), outliers that are scaled absolute three times the median (MAD) and higher are removed to improve the visualization of the plots. In some boxplots (the data) the first or third Quantile looks like it is folded over the notch interval. This folding (can be observed in 6.49 as an example) is due to the uncertainty of the true median value. This usually transpire if the sample size is small (notch height is calculated by dividing with $\sqrt{n}$).

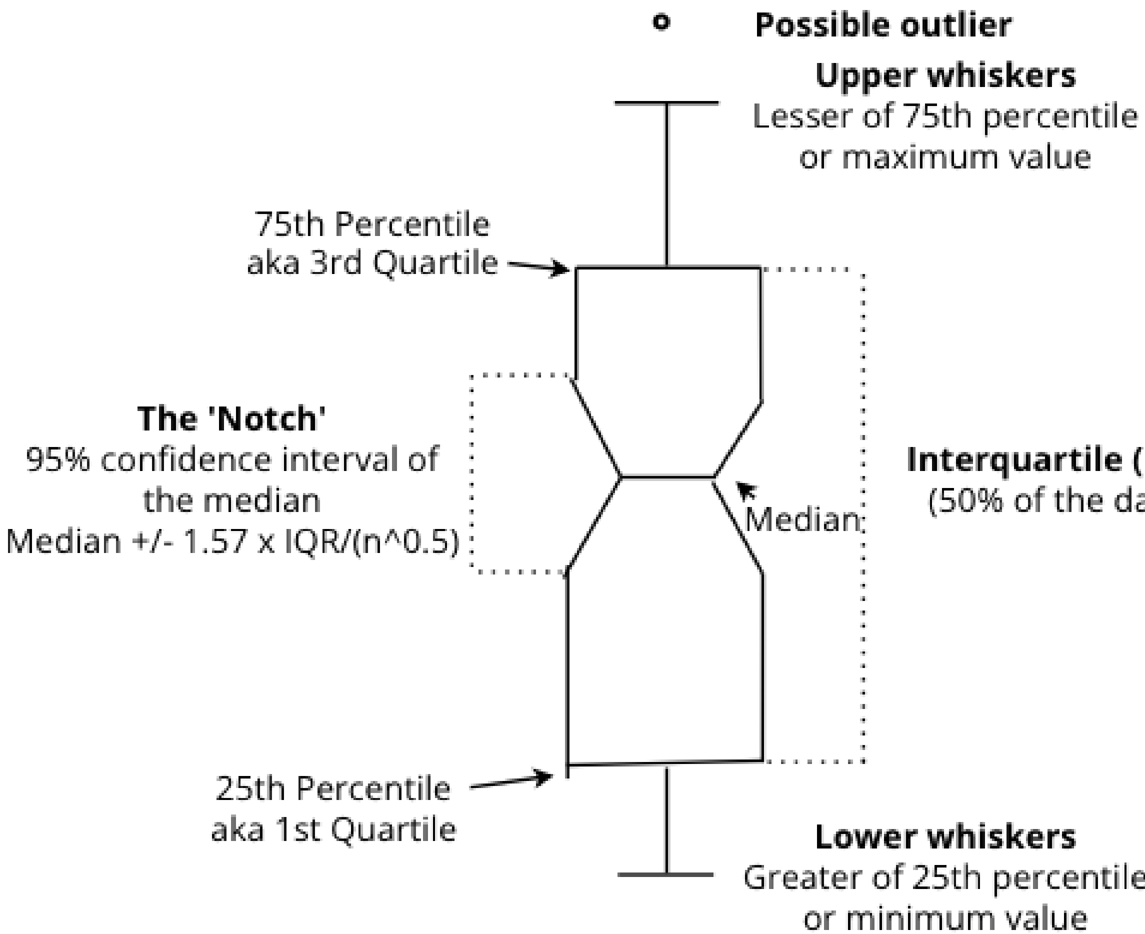

Figure 6.32: Description of a notched boxplot which can be created with Matlab [43], [44]).

Statistically, if the data is a sample the notches illustrate which values of the median that can most probably be expected. Comparing different groups will determine if there is a statistically significant difference between the groups medians. This statistical significance can be observed if the notch ranges overlap or not. To elaborate, if some groups notch areas overlap there is most likely no difference between the groups medians or that feature. If there is no overlapping, it can be said with confidence that the true medians are different. Relevant to this project, features of the different groups are compared.

If there are a large number of outliers the data/distribution represented is skewed (see figure 6.33). The skewness indicates how the data diverge from the normal distribution [43], [44].

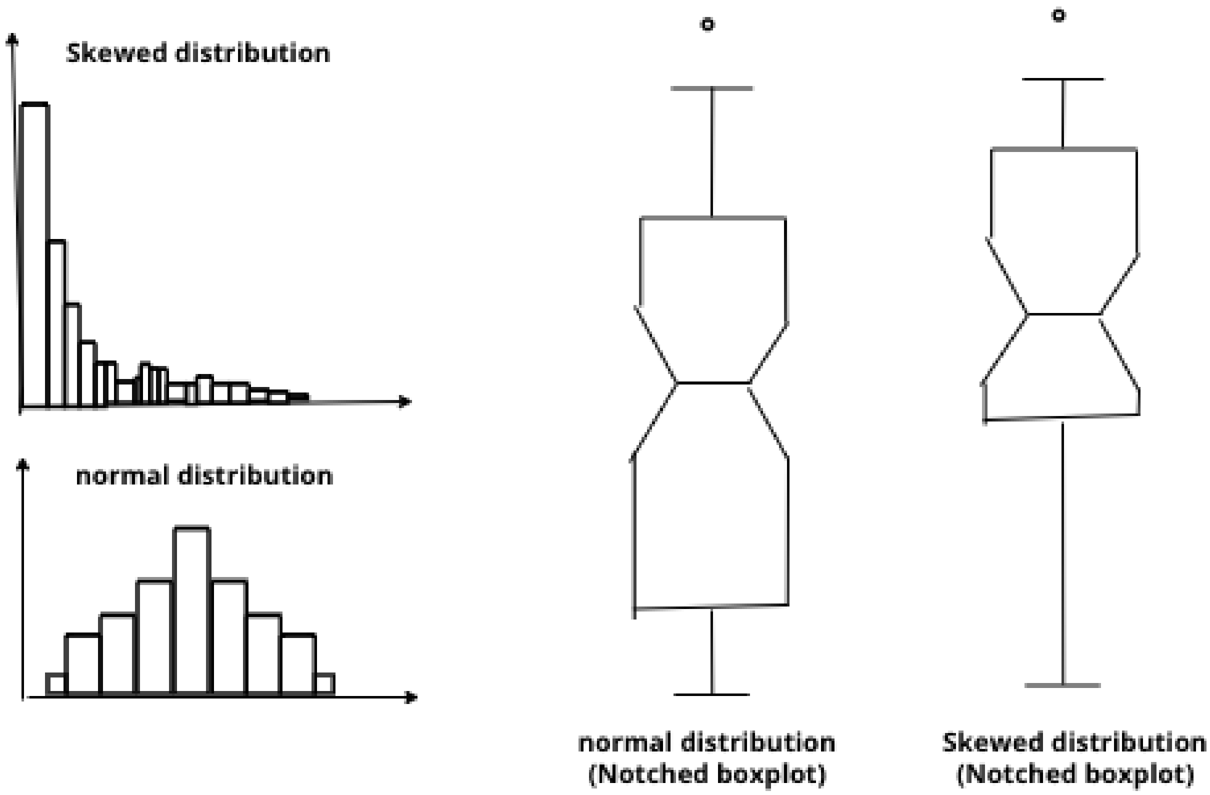

Figure 6.33: Illustration of skewed data in a notched boxplot and histogram [43]).

6.7.2 Comparison with Joar's table

Boxplot data extracted from the manual recorded data

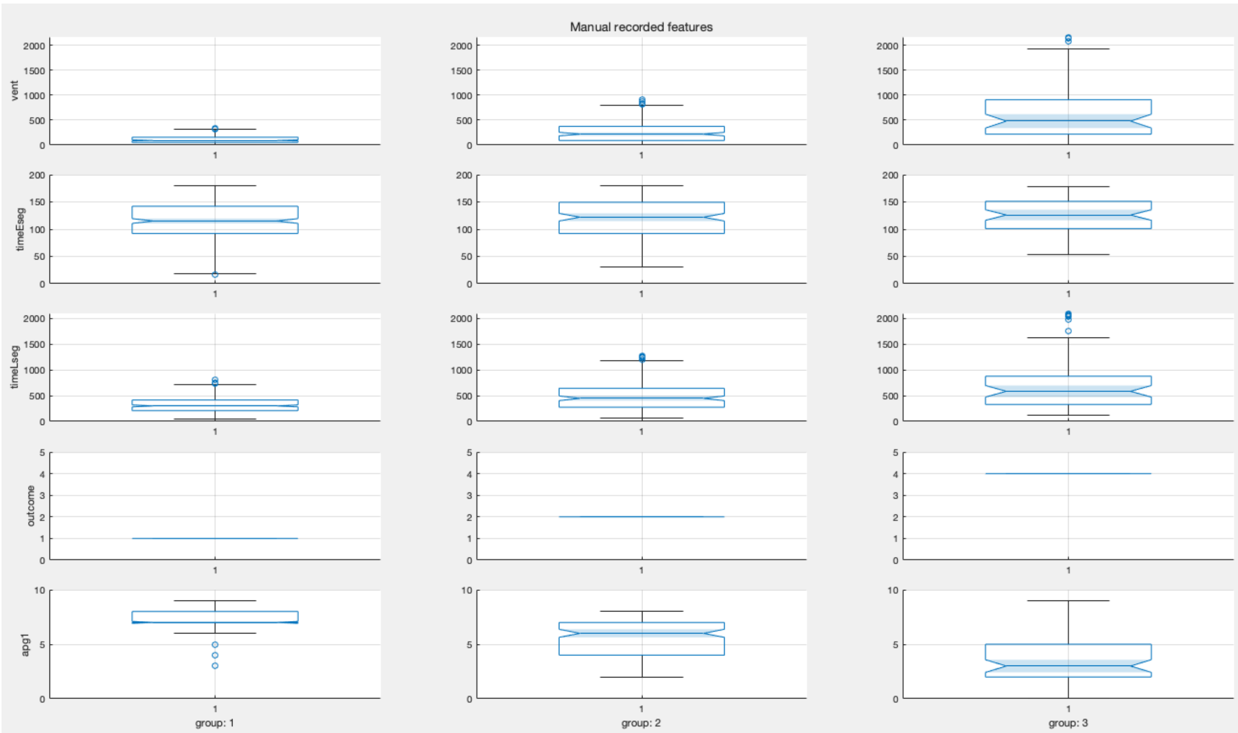

Figure 6.34: Boxplot of manual recorded features part 1. Illustrates the 3 groups spread of data values.

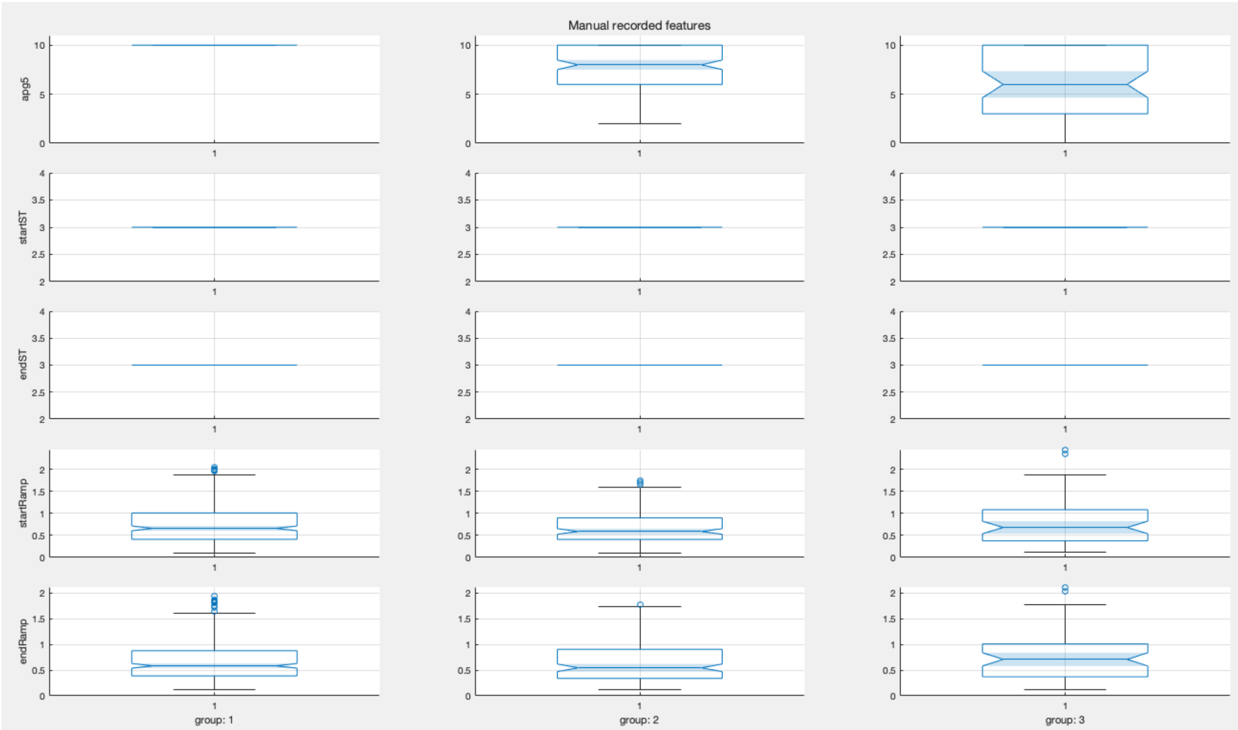

Figure 6.35: Boxplot of manual recorded features part 2. Illustrates the 3 groups spread of data values.

Boxplot data extracted from the automatic detected data

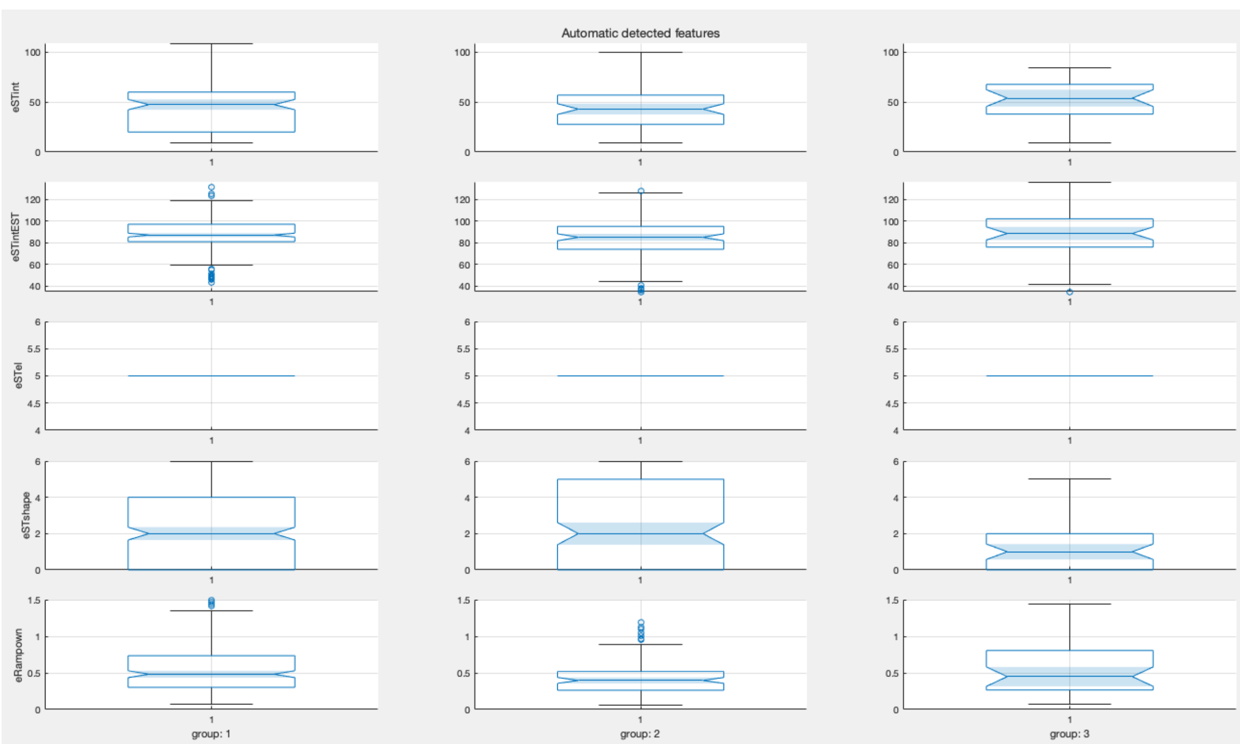

Figure 6.36: Boxplot of automatic detected features part 1. Illustrates the 3 groups spread of data values.

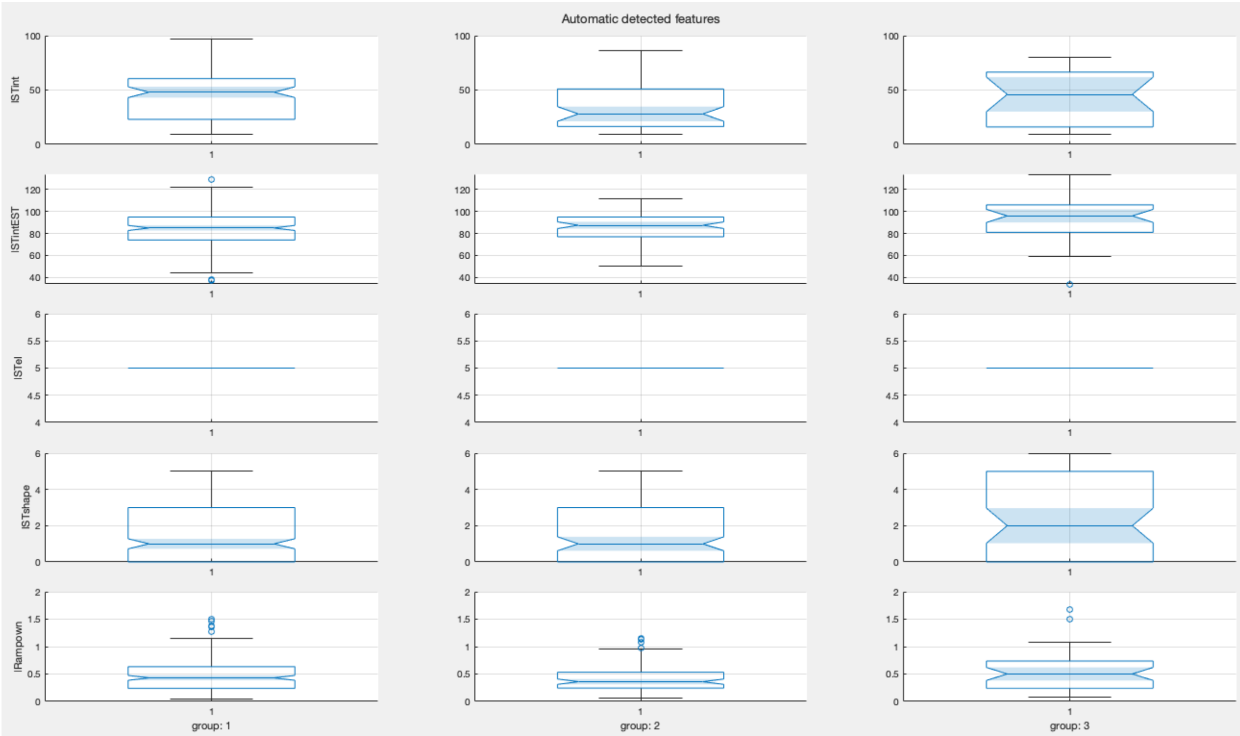

Figure 6.37: Boxplot of automatic detected features part 2. Illustrates the 3 groups spread of data values.

6.7.3 Experiment 1, Change of coincidence (BP)

6.7.3.1 Parameter settings: ΔC= 0.1 and 5 groups

Boxplot data extracted from the manual recorded data

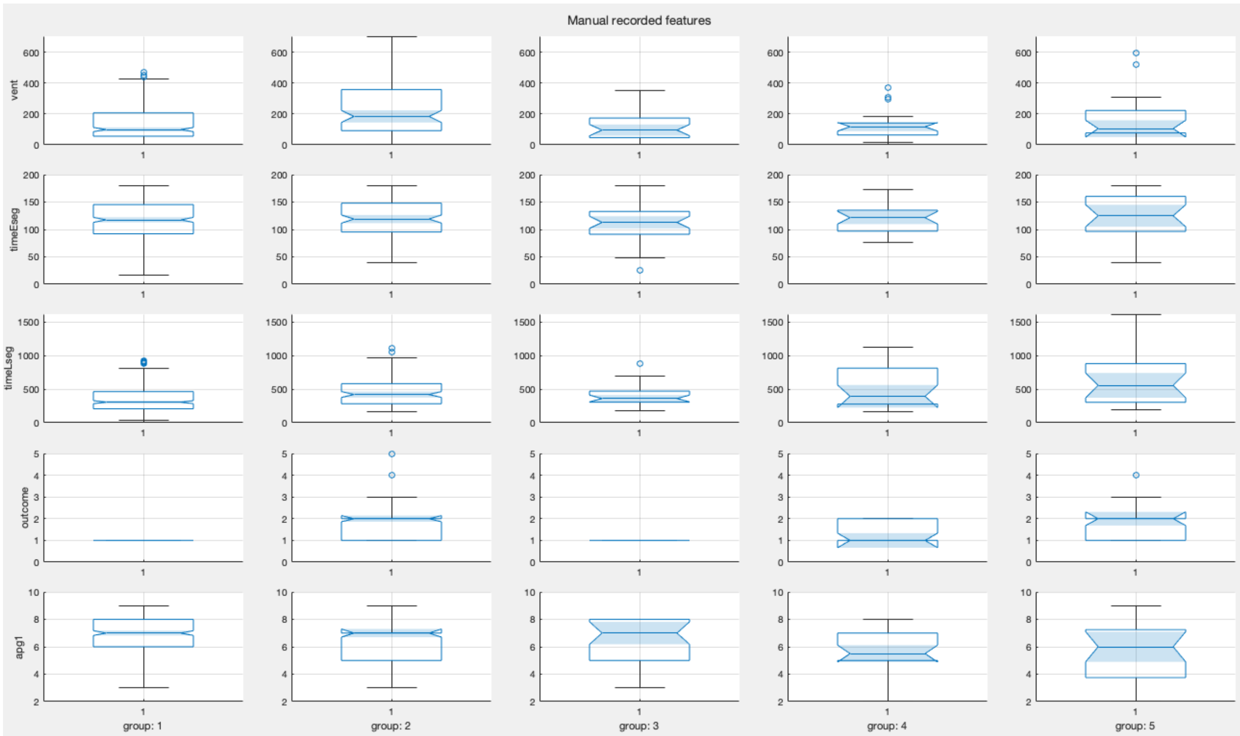

Figure 6.38: Boxplot of manual recorded features part 1. Illustrates the 5 groups with ΔC= 0.1 in the analysis of beat changes experiment.

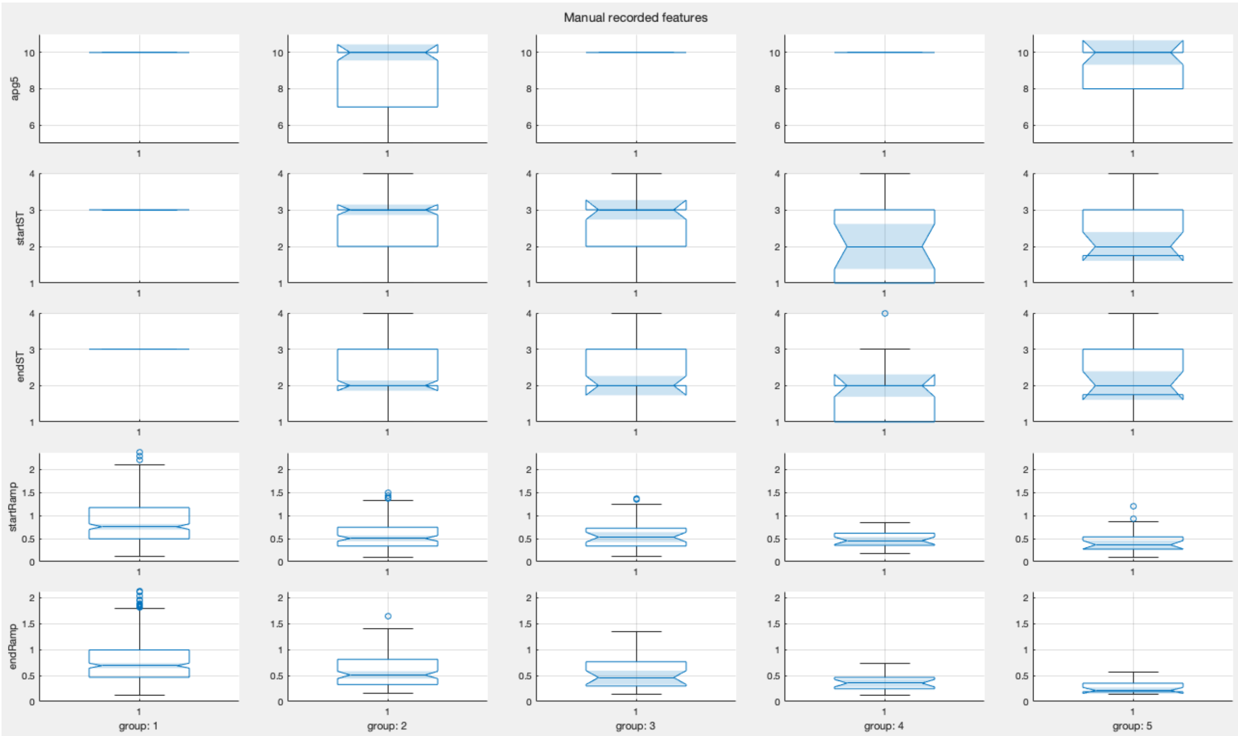

Figure 6.39: Boxplot of manual recorded features part 2. Illustrates the 5 groups with ΔC=0.1 in the analysis of beat changes experiment.

Boxplot data extracted from the automatic detected data

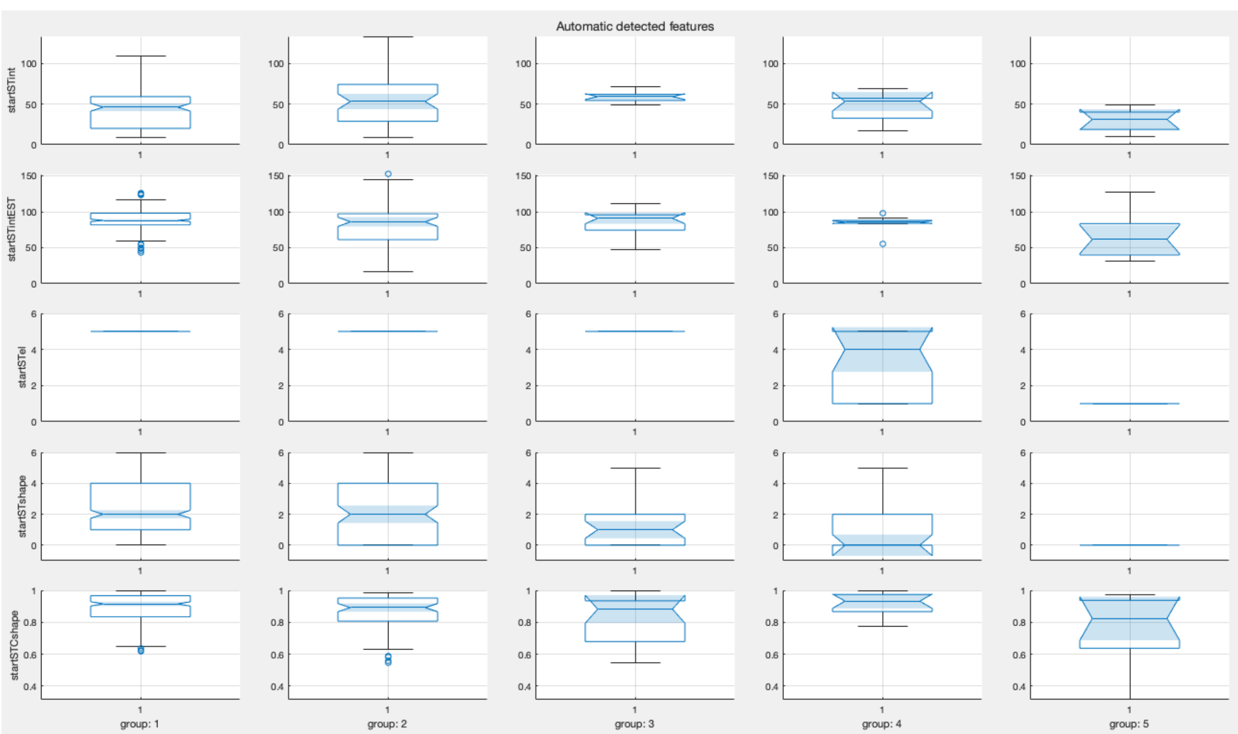

Figure 6.40: Boxplot of automatic detected features part 1. Illustrates the 5 groups with ΔC=0.1 in the analysis of beat changes experiment.

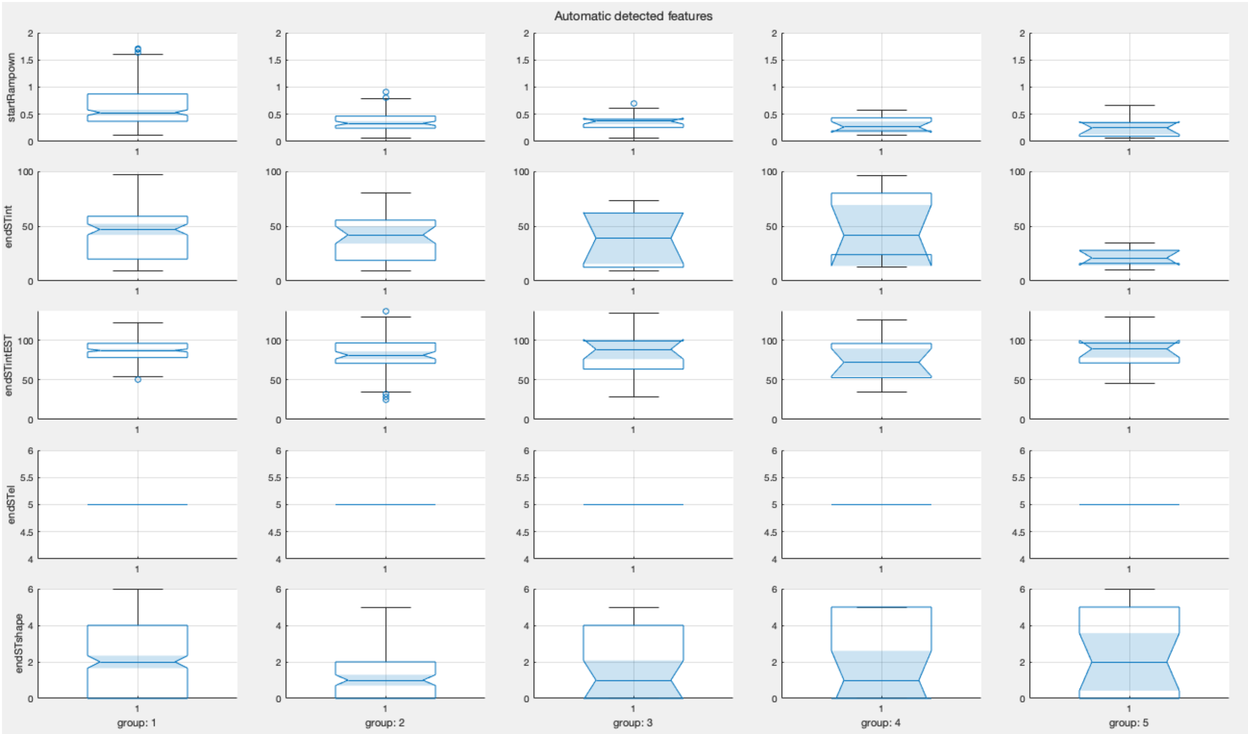

Figure 6.41: Boxplot of automatic detected features part 2. Illustrates the 5 groups with ΔC=0.1 in the analysis of beat changes experiment.

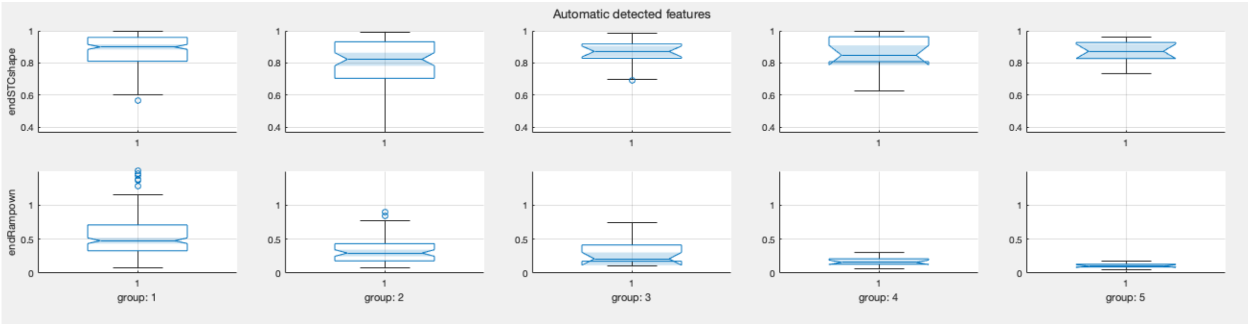

Figure 6.42: Boxplot of automatic detected features part 3. Illustrates the 5 groups with ΔC=0.1 in the analysis of beat changes experiment.

6.7.3.2 Parameter settings: ΔC= 0.2 and 5 groups

Boxplot data extracted from the manual recorded data

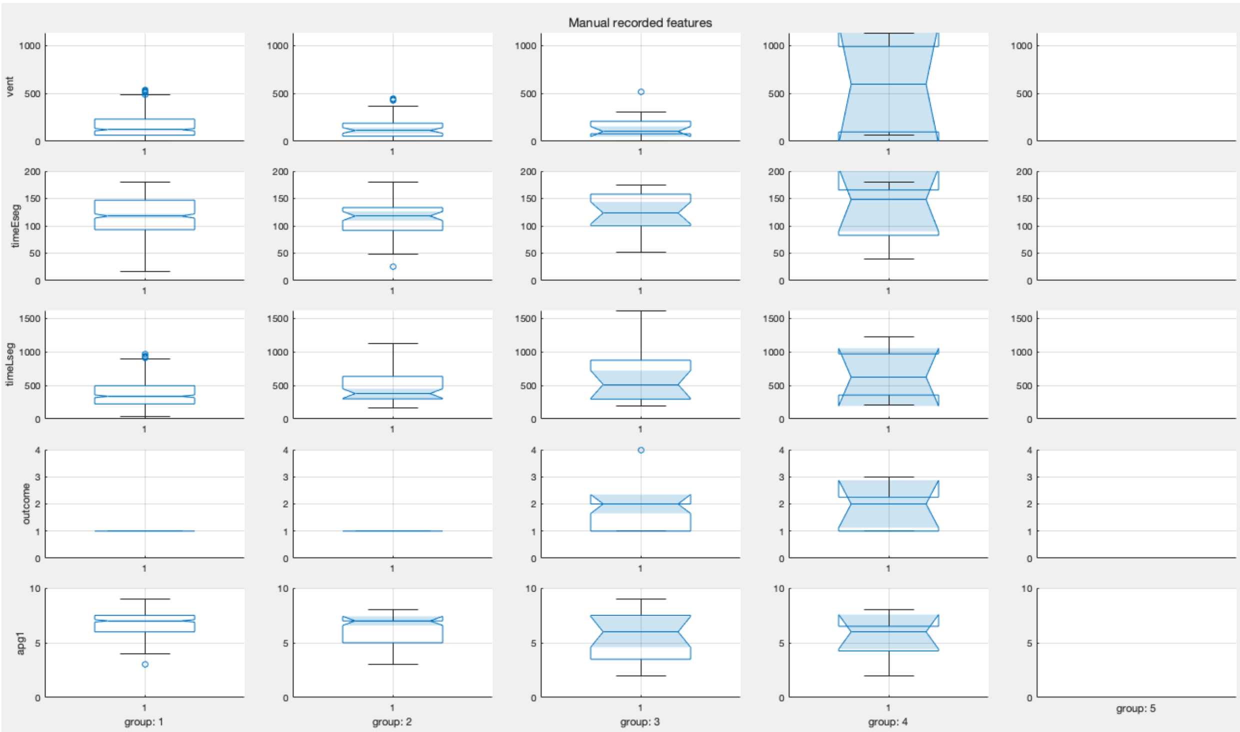

Figure 6.43: Boxplot of manual recorded features part 1. Illustrates the 5 groups with ΔC=0.2 in the analysis of beat changes experiment.

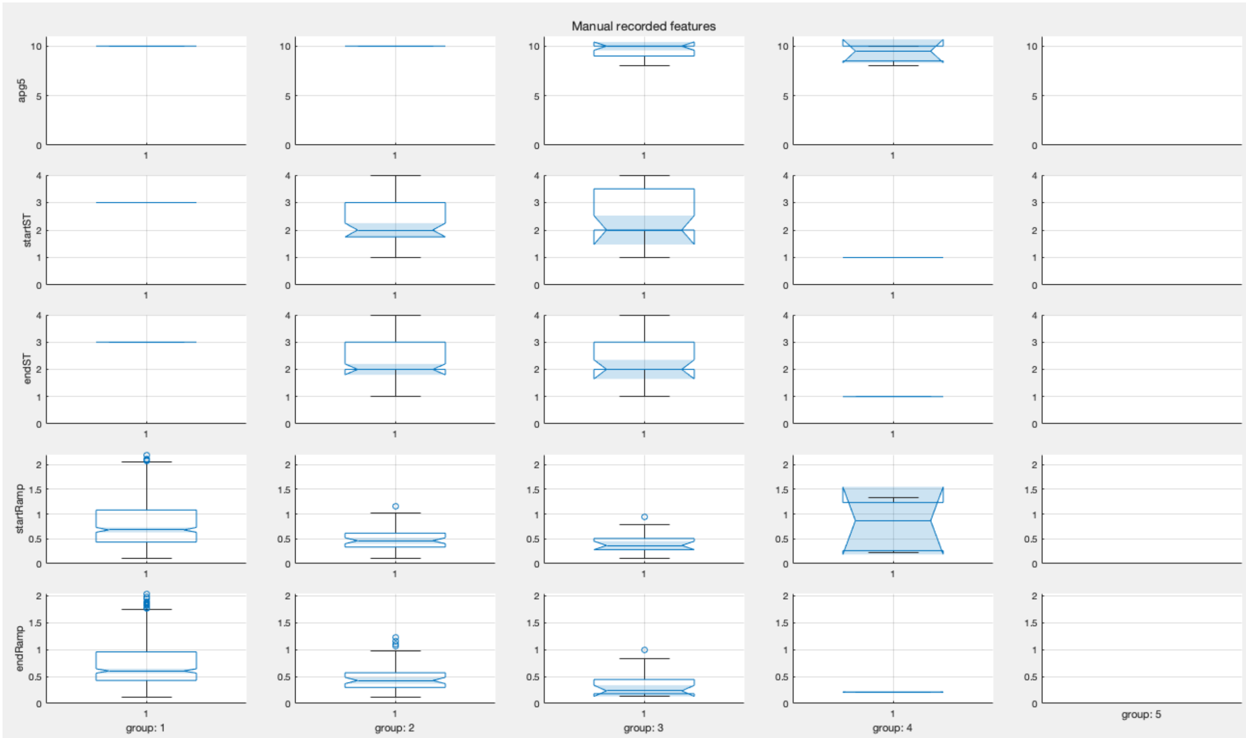

Figure 6.44: Boxplot of manual recorded features part 2. Illustrates the 5 groups with ΔC=0.2 in the analysis of beat changes experiment.

Boxplot data extracted from the automatic detected data

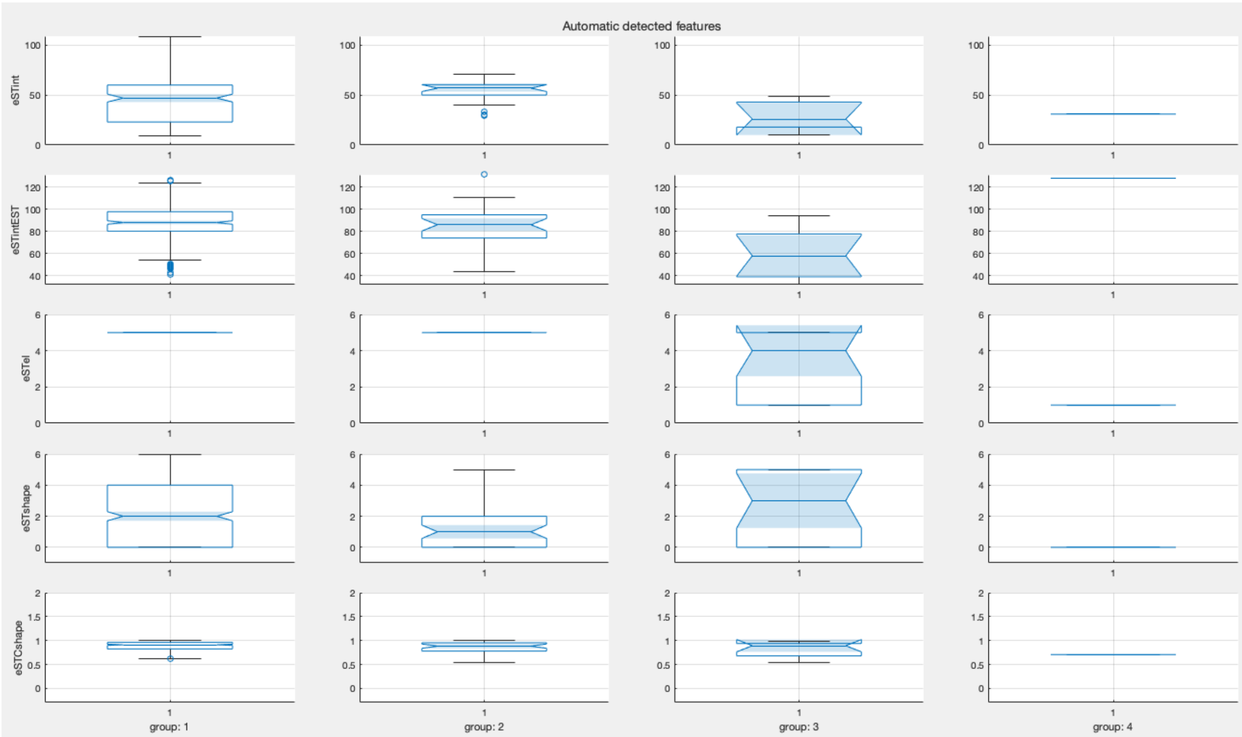

Figure 6.45: Boxplot of automatic detected features part 1. Illustrates the 5 groups with ΔC=0.2 in the analysis of beat changes experiment.

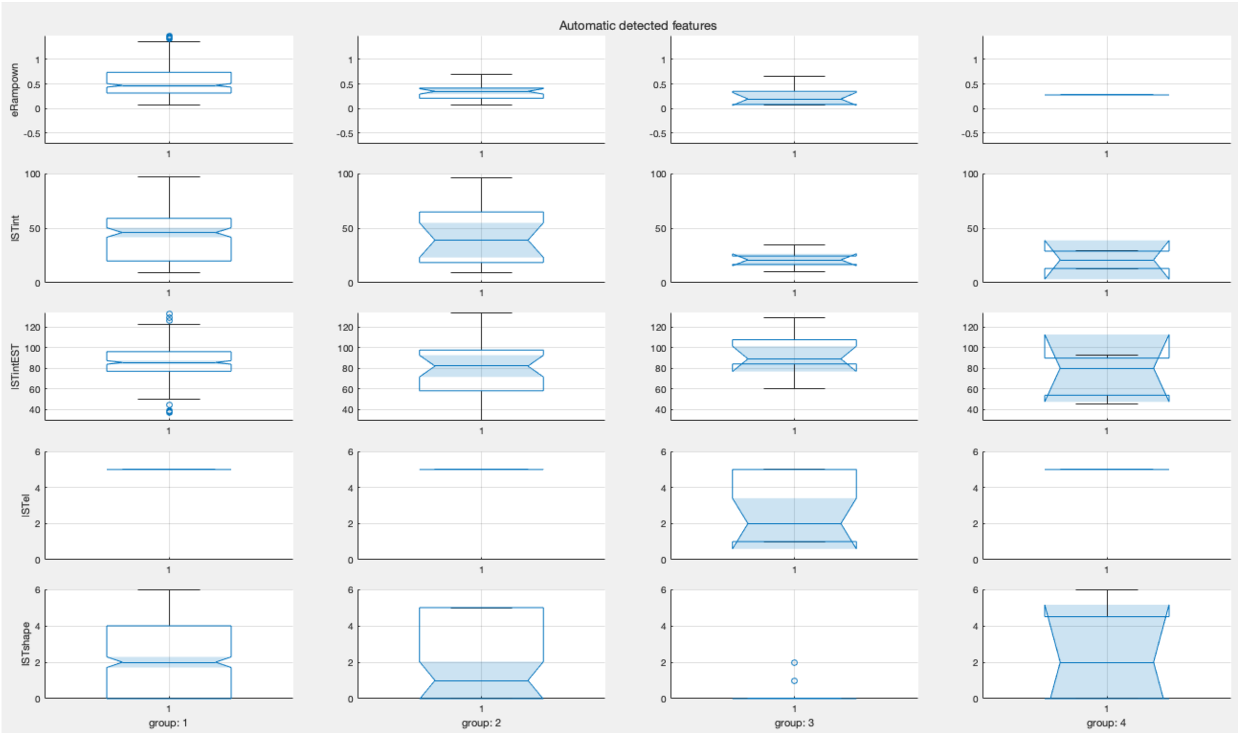

Figure 6.46: Boxplot of automatic detected features part 2. Illustrates the 5 groups with ΔC=0.2 in the analysis of beat changes experiment.

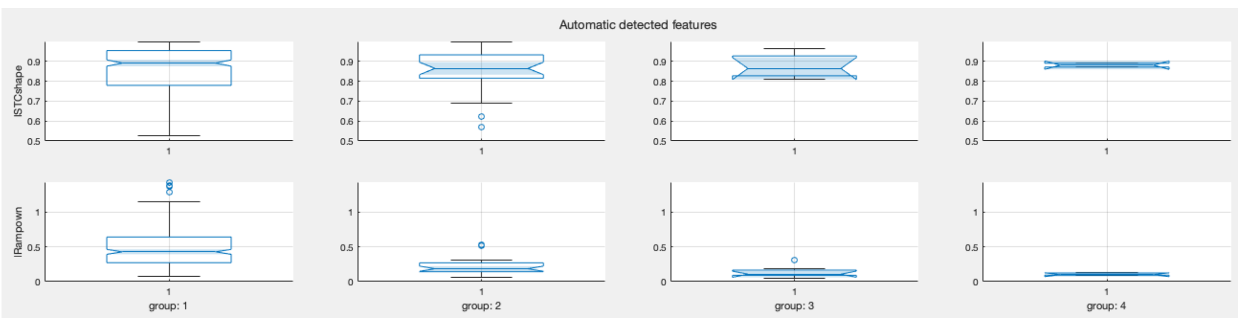

Figure 6.47: Boxplot of automatic detected features part 3. Illustrates the 5 groups with ΔC=0.2 in the analysis of beat changes experiment.

6.7.3.3 Parameter settings: $\Delta C = 0.05$ and 10 groups

Boxplot data extracted from the manual recorded data

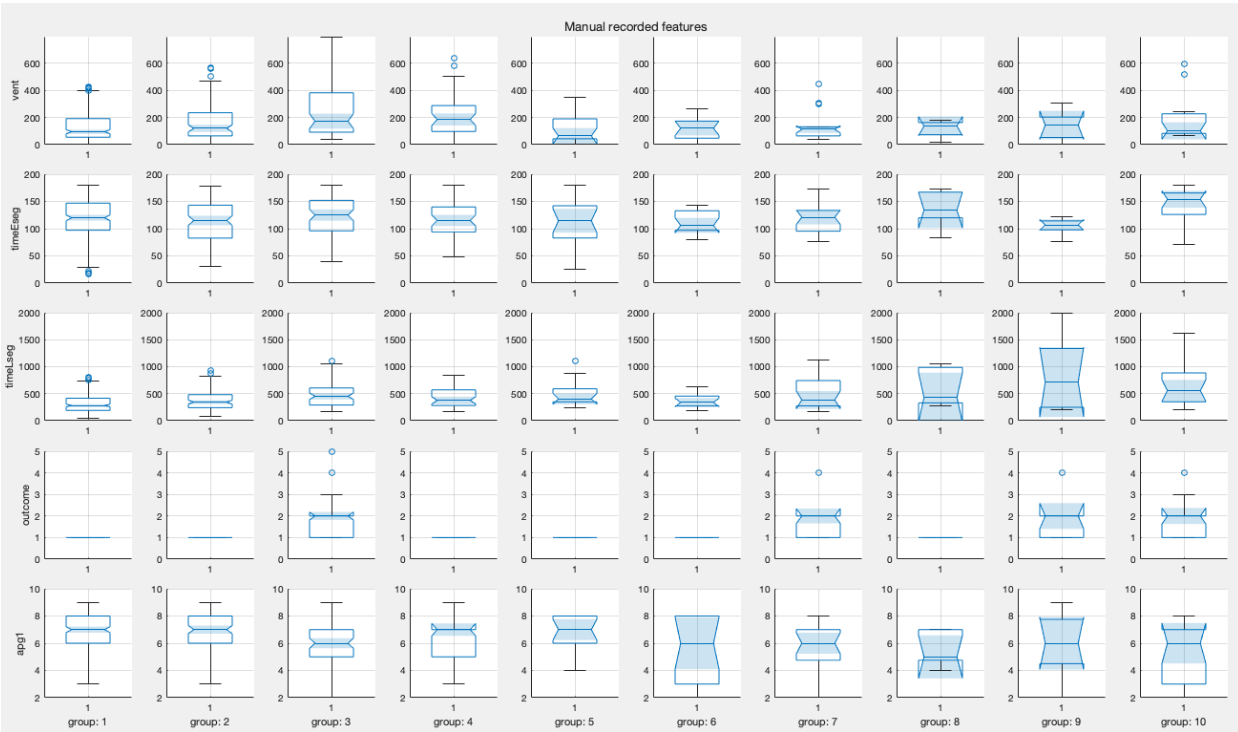

Figure 6.48: Boxplot of manual recorded features part 1. Illustrates the 10 groups with ΔC=0.05 in the analysis of beat changes experiment.

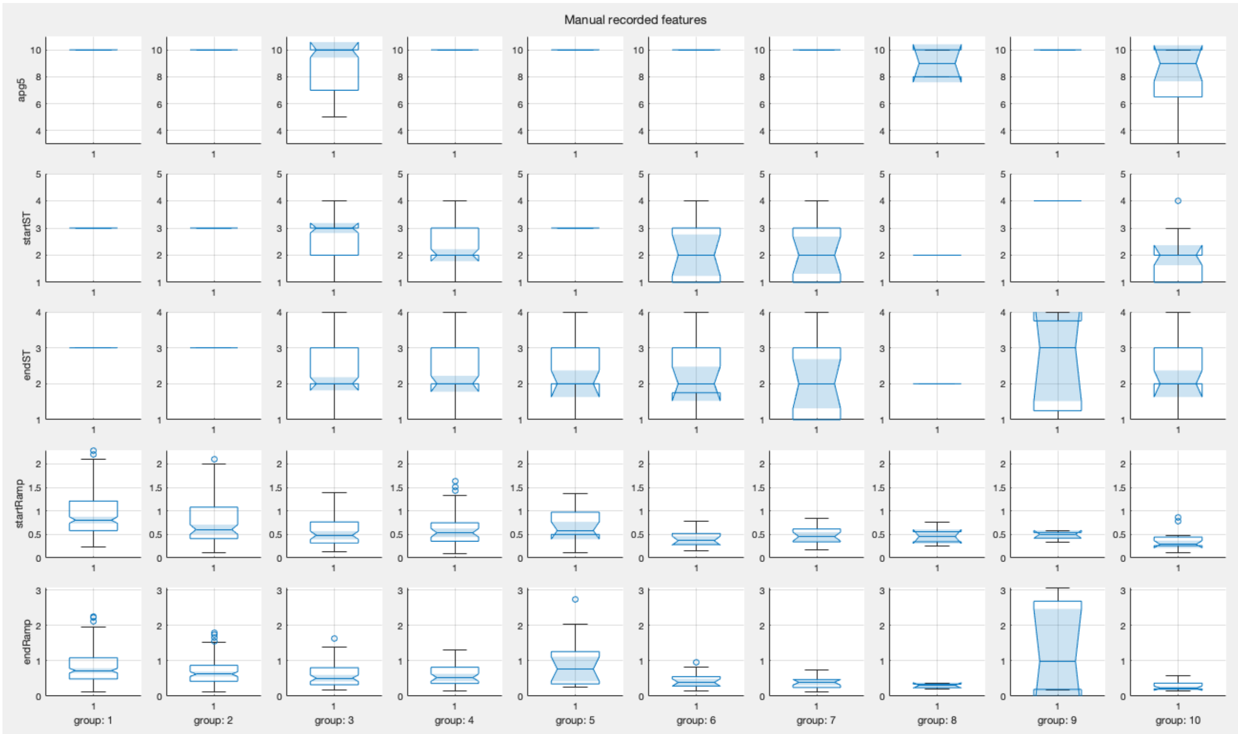

Figure 6.49: Boxplot of manual recorded features part 2. Illustrates the 10 groups with ΔC=0.05 in the analysis of beat changes experiment.

Boxplot data extracted from the automatic detected data

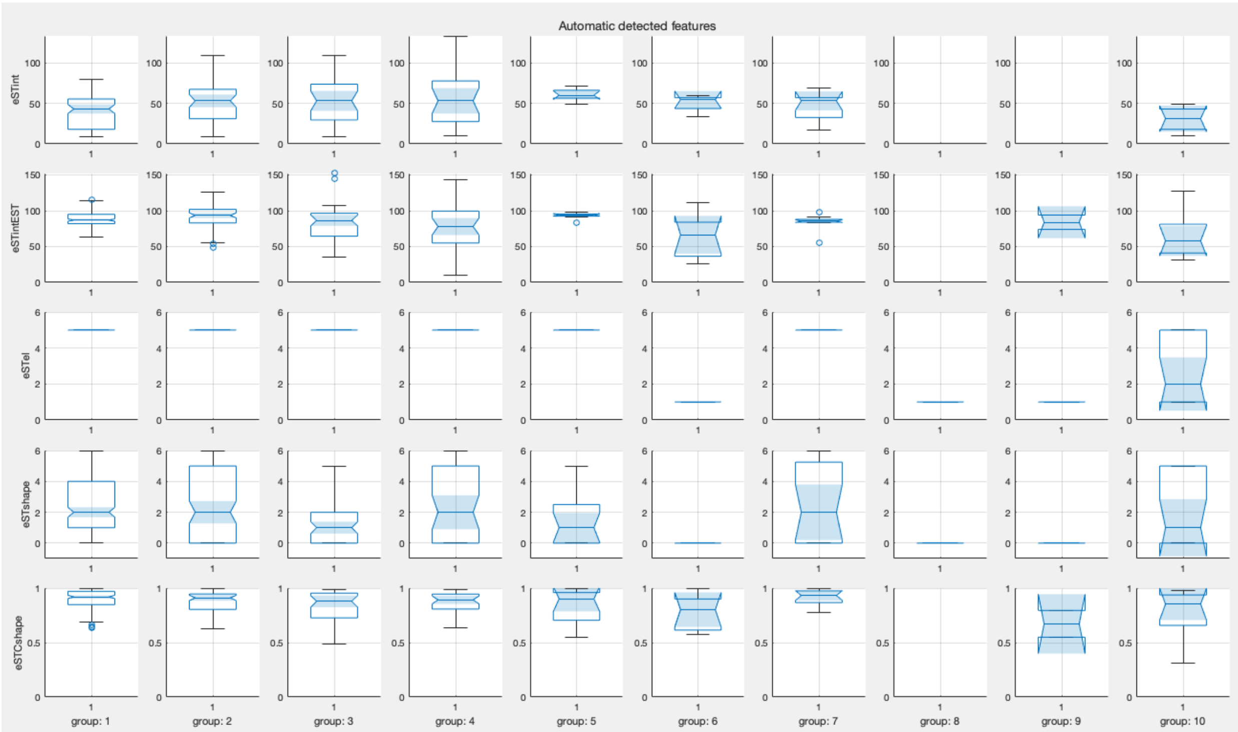

Figure 6.50: Boxplot of automatic detected features part 1. Illustrates the 10 groups with ΔC= 0.05 in the analysis of beat changes experiment.

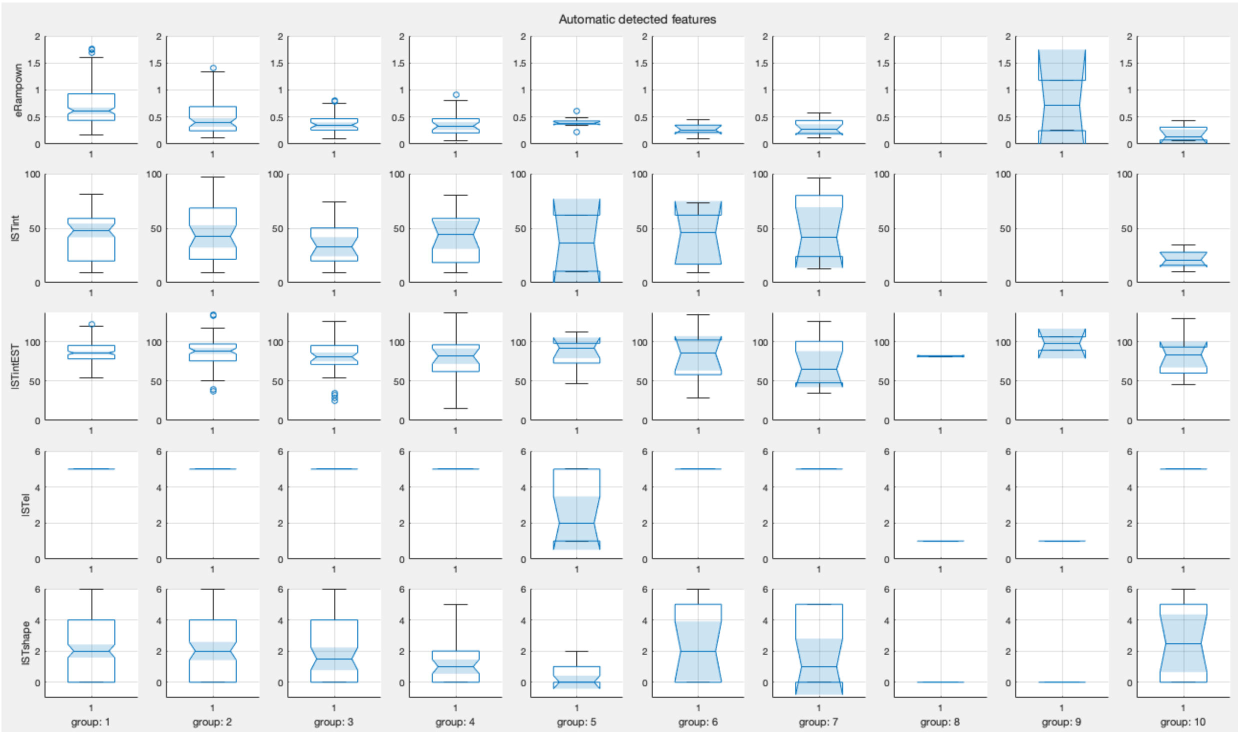

Figure 6.51: Boxplot of automatic detected features part 2. Illustrates the 10 groups with ΔC=0.05 in the analysis of beat changes experiment.

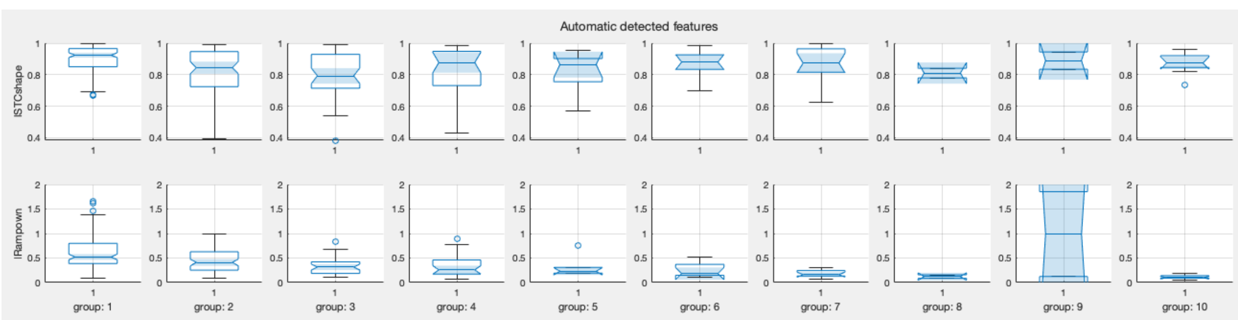

Figure 6.52: Boxplot of automatic detected features part 3. Illustrates the 10 groups with ΔC=0.05 in the analysis of beat changes experiment.

6.7.4 Experiment 2, Category representation (BP)

6.7.4.1 Experiment 2, unfiltered and unnormalized results

Boxplot data extracted from the manual recorded data (Based on early segments)

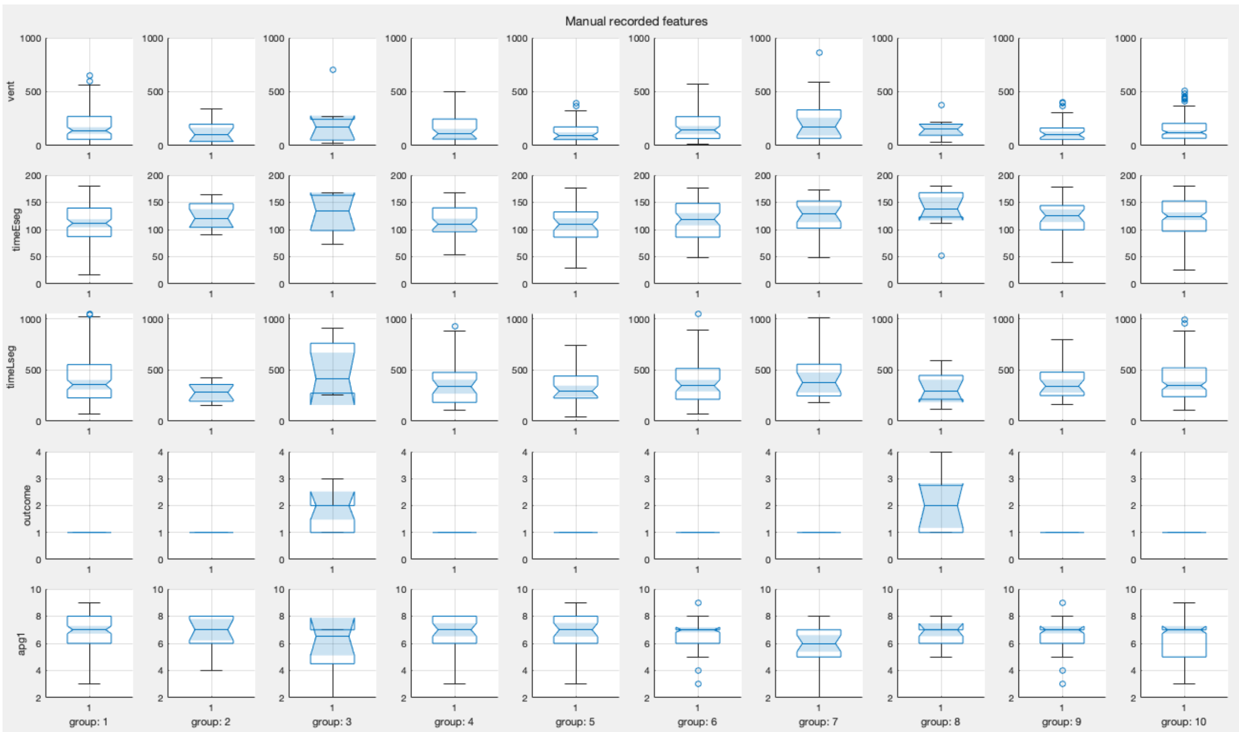

Figure 6.53: Boxplot of manual recorded features part 1. Illustrates the 10 groups spread of data values based on early segments.

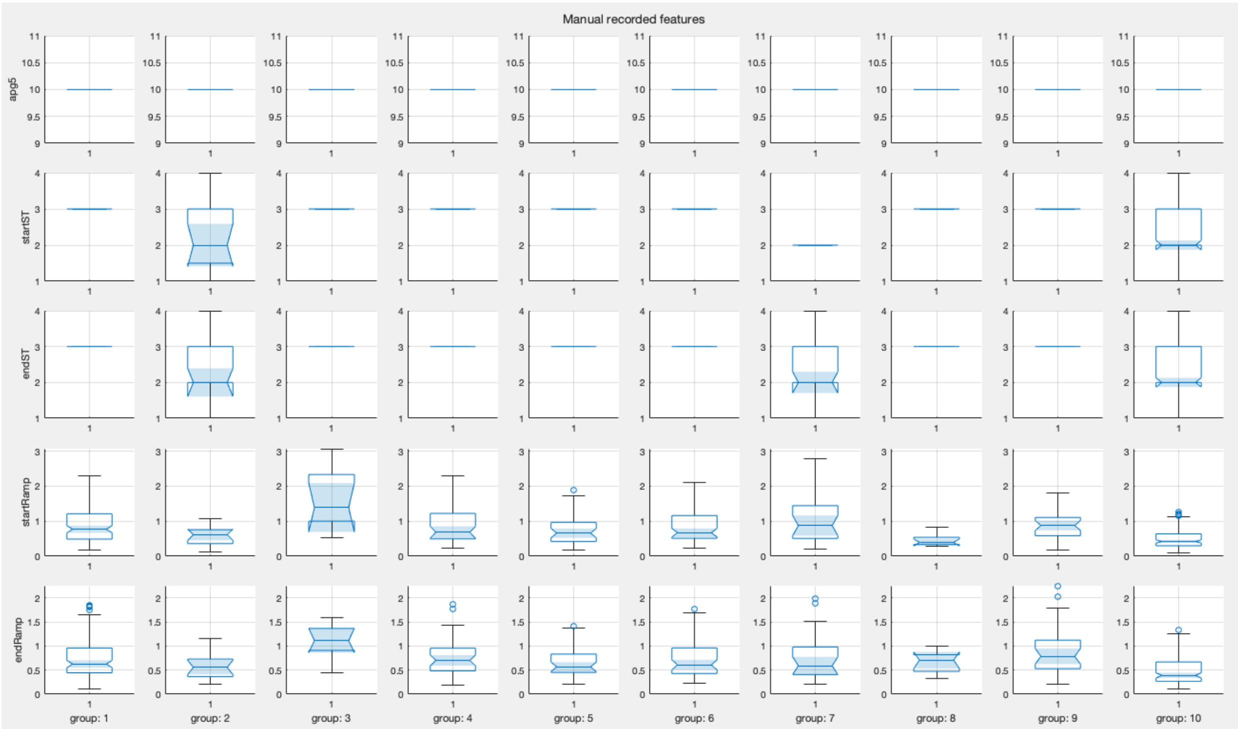

Figure 6.54: Boxplot of manual recorded features part 2. Illustrates the 10 groups spread of data values based on early segments.

Boxplot data extracted from the automatic detected data (Based on early segments)

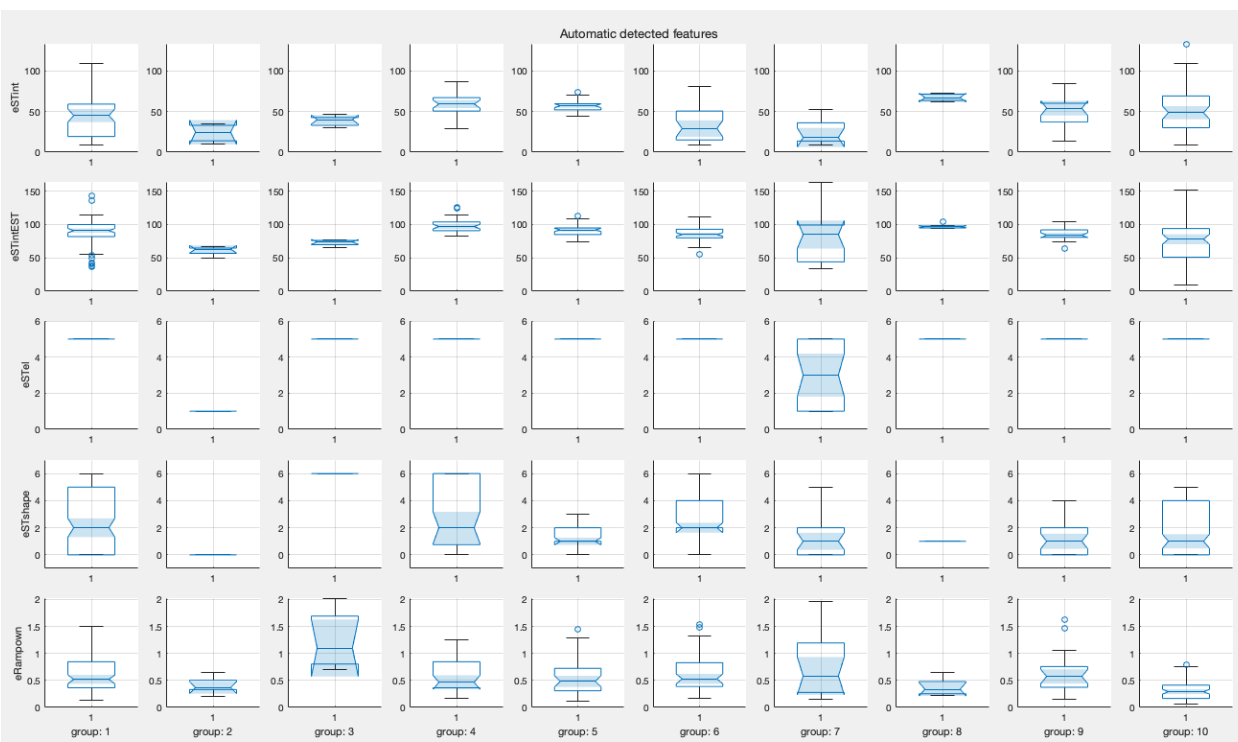

Figure 6.55: Boxplot of automatic detected features part 1. Illustrates the 10 groups spread of data values based on early segments.

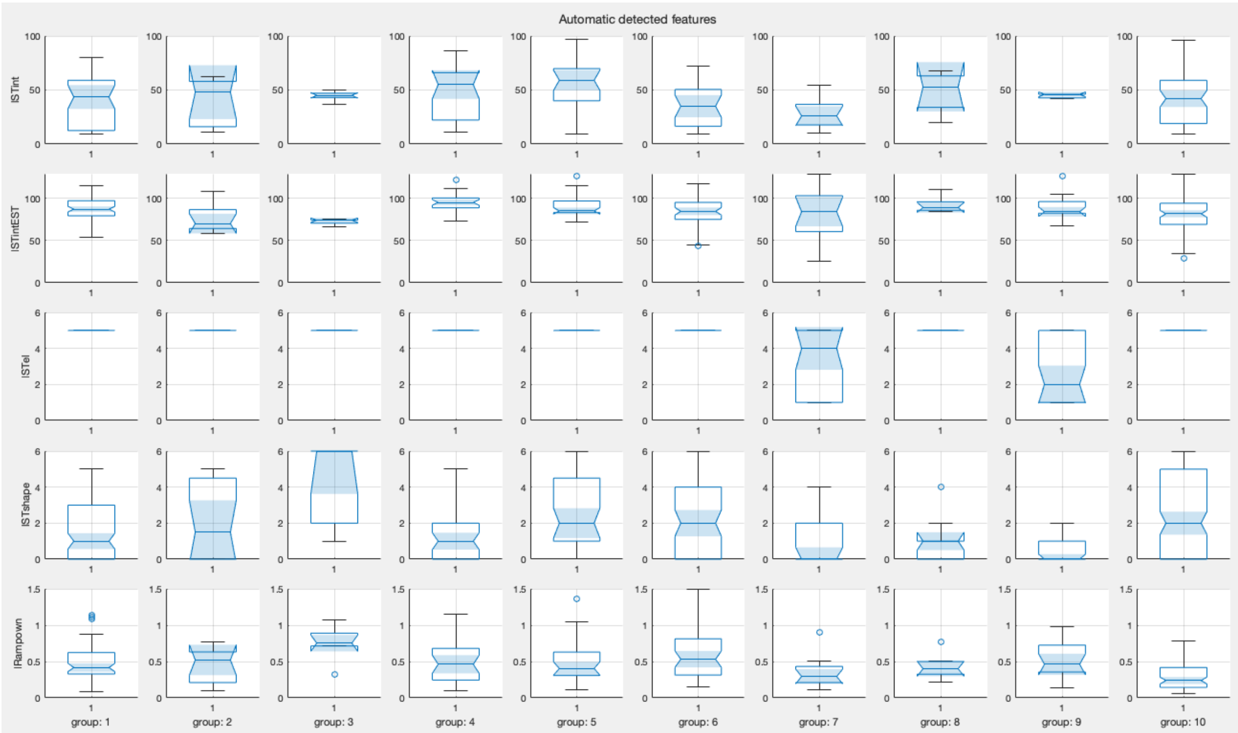

Figure 6.56: Boxplot of automatic detected features part 2. Illustrates the 10 groups spread of data values based on early segments.

Boxplot data extracted from the manual recorded data (Based on late segments)

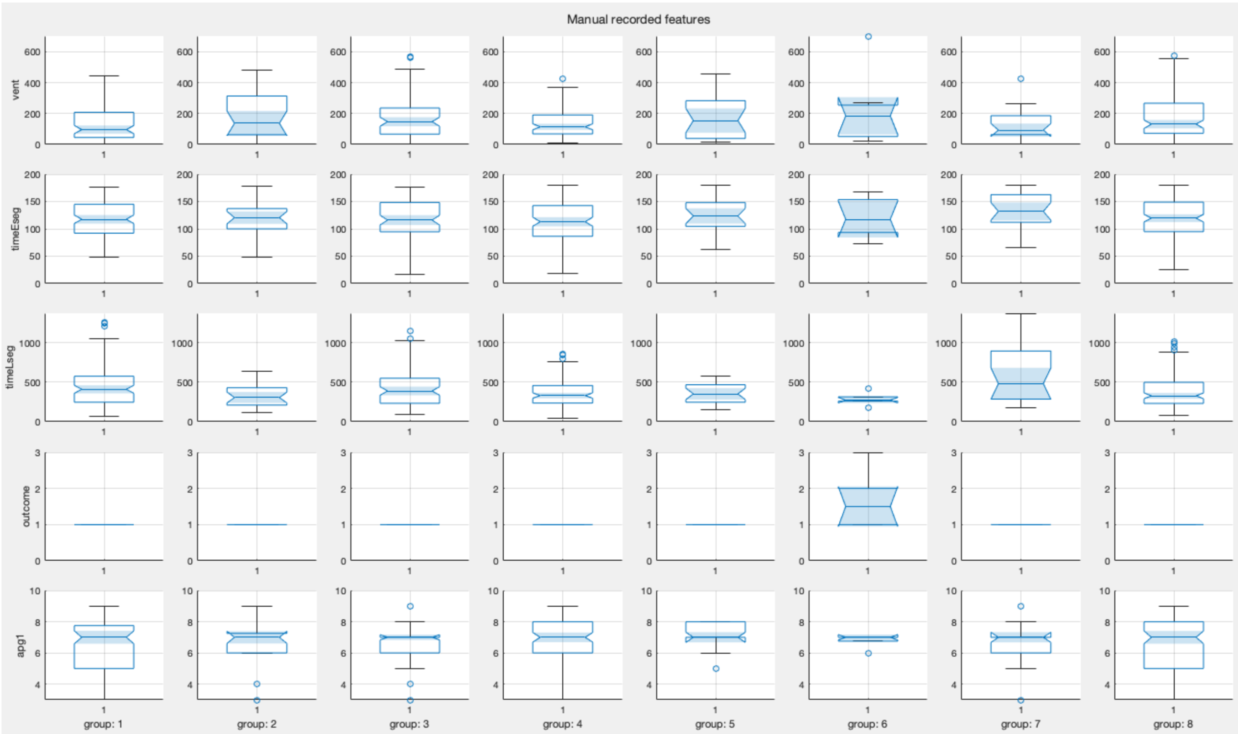

Figure 6.57: Boxplot of manual recorded features part 1. Illustrates the 10 groups spread of data values based on late segments.

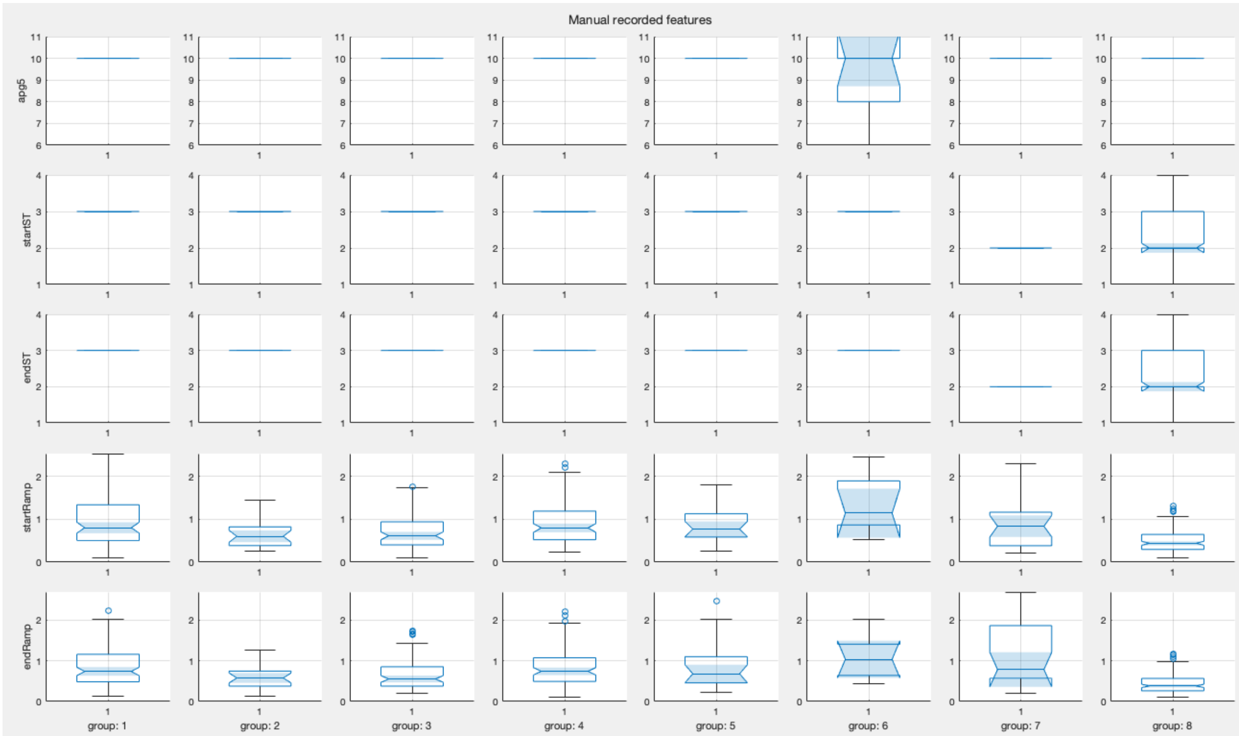

Figure 6.58: Boxplot of manual recorded features part 2. Illustrates the 10 groups spread of data values based on late segments.

Boxplot data extracted from the automatic detected data (Based on late segments)

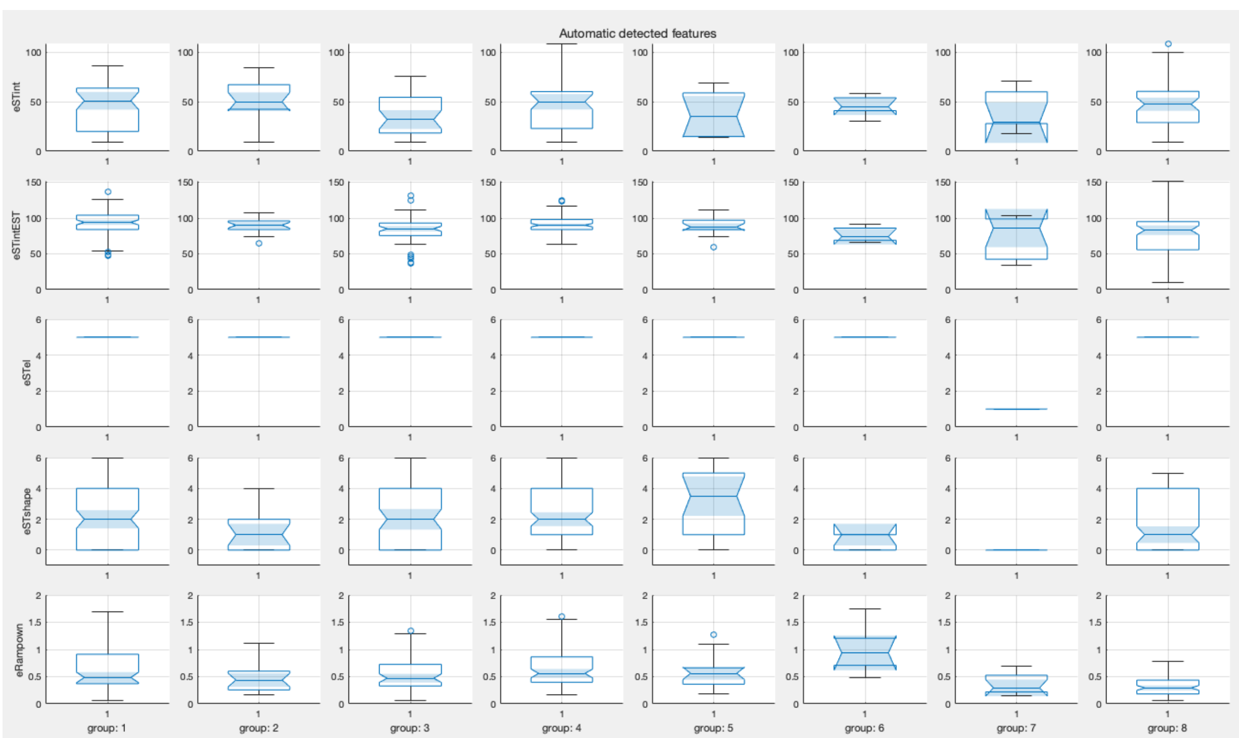

Figure 6.59: Boxplot of automatic detected features part 1. Illustrates the 10 groups spread of data values based on late segments.

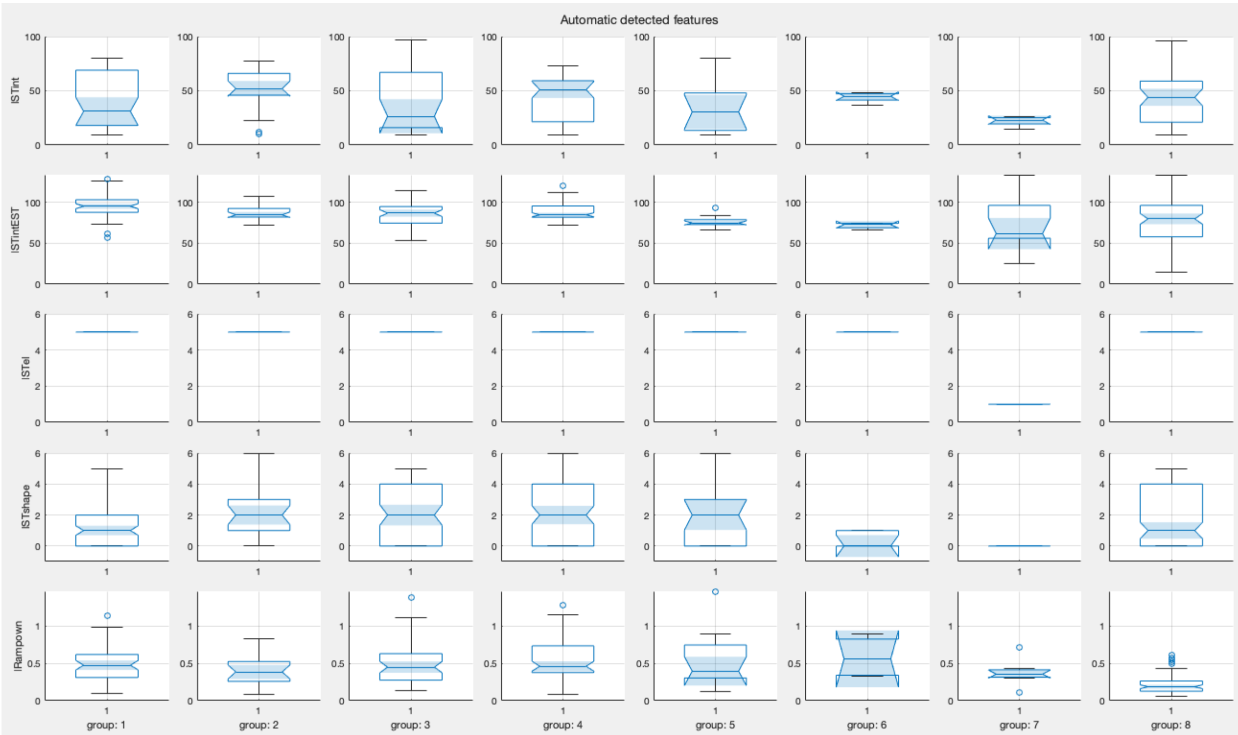

Figure 6.60: Boxplot of automatic detected features part 2. Illustrates the 10 groups spread of data values based on late segments.

6.7.4.2 Experiment 2, filtered and normalized results

Boxplot data extracted from the manual recorded data (Based on early segments)

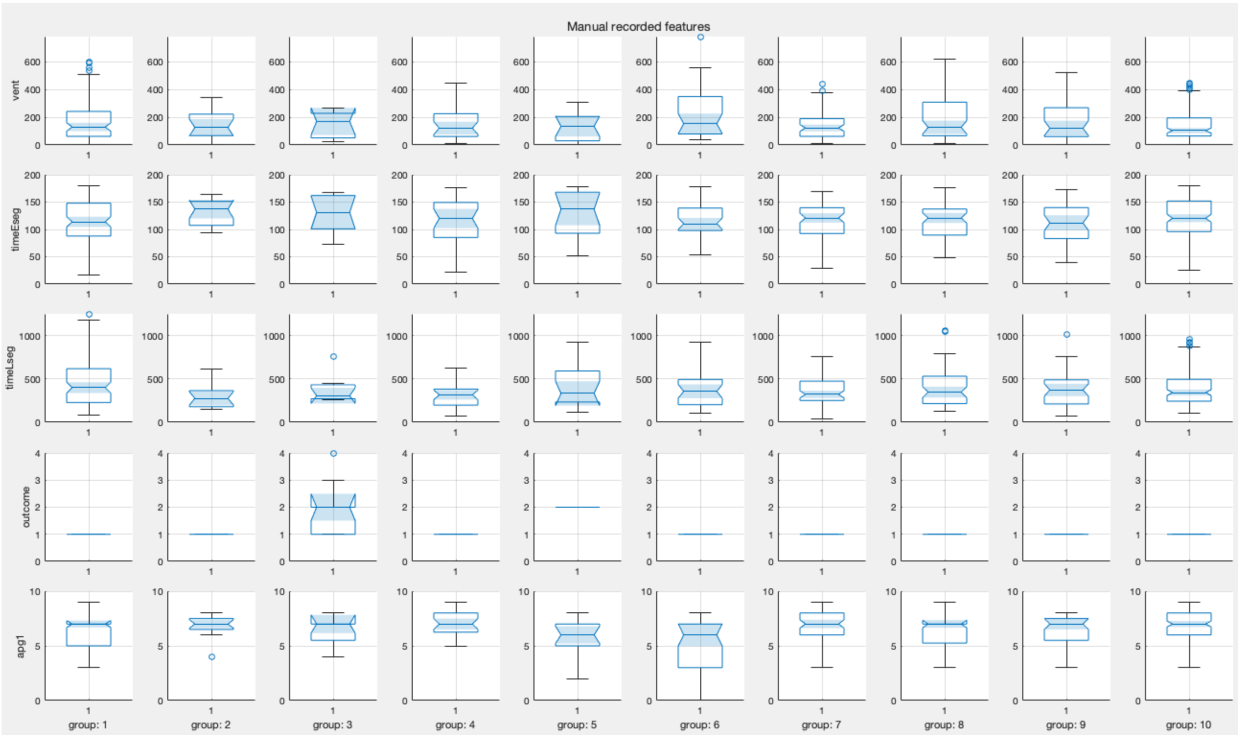

Figure 6.61: Boxplot of manual recorded features part 1. Illustrates the 10 groups spread of data values based on early segments.

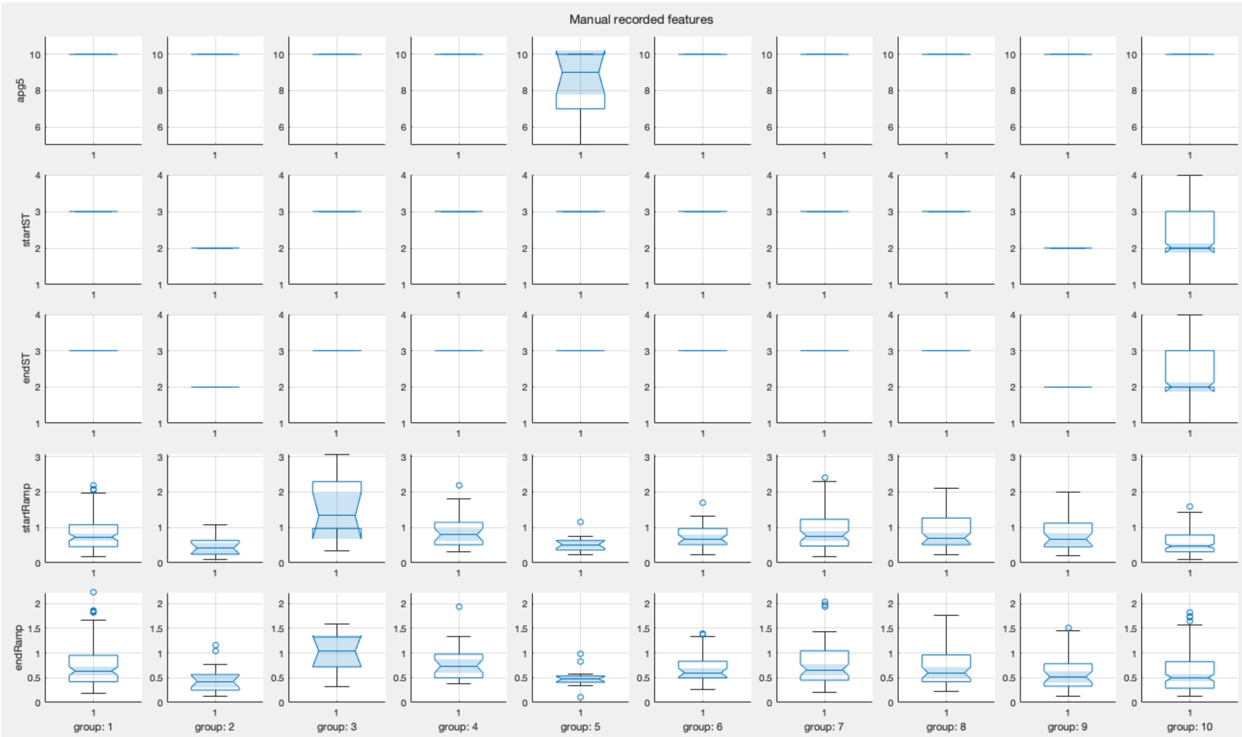

Figure 6.62: Boxplot of manual recorded features part 2. Illustrates the 10 groups spread of data values based on early segments.

Boxplot data extracted from the automatic detected data (Based on early segments)

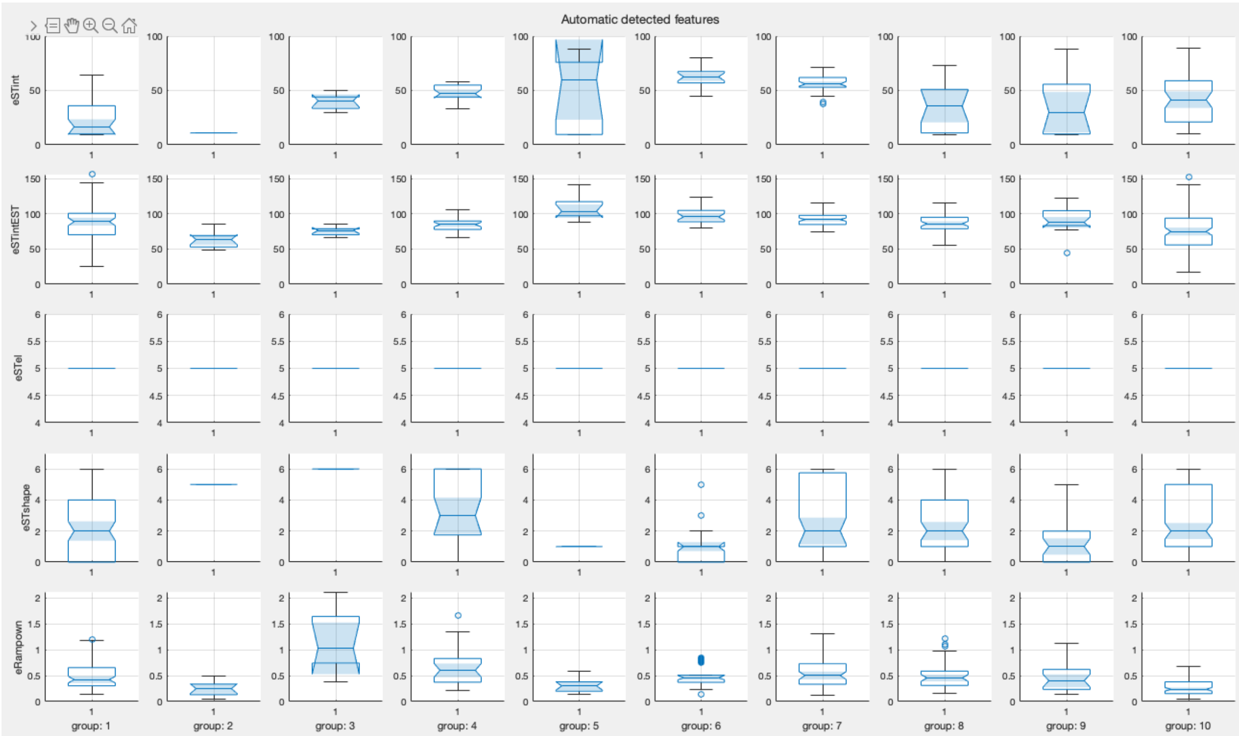

Figure 6.63: Boxplot of automatic detected features part 1. Illustrates the 10 groups spread of data values based on early segments.

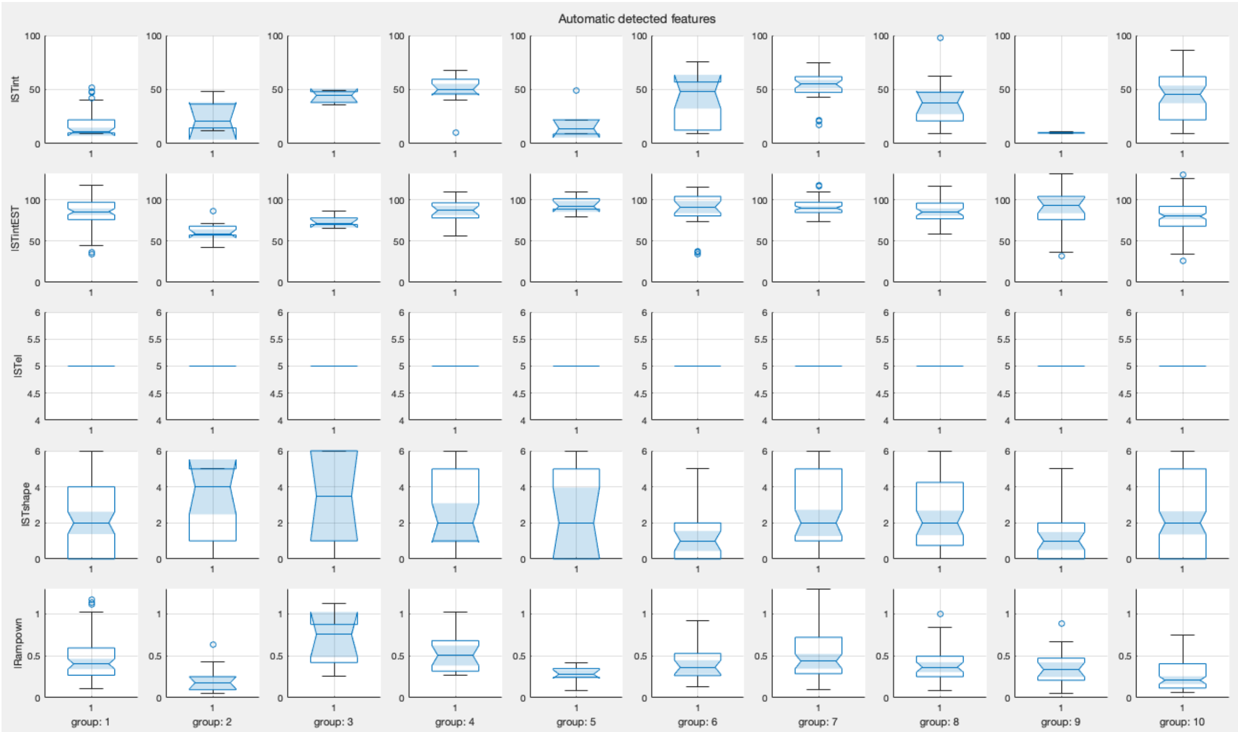

Figure 6.64: Boxplot of automatic detected features part 2. Illustrates the 10 groups spread of data values based on early segments.

Boxplot data extracted from the manual recorded data (Based on late segments)

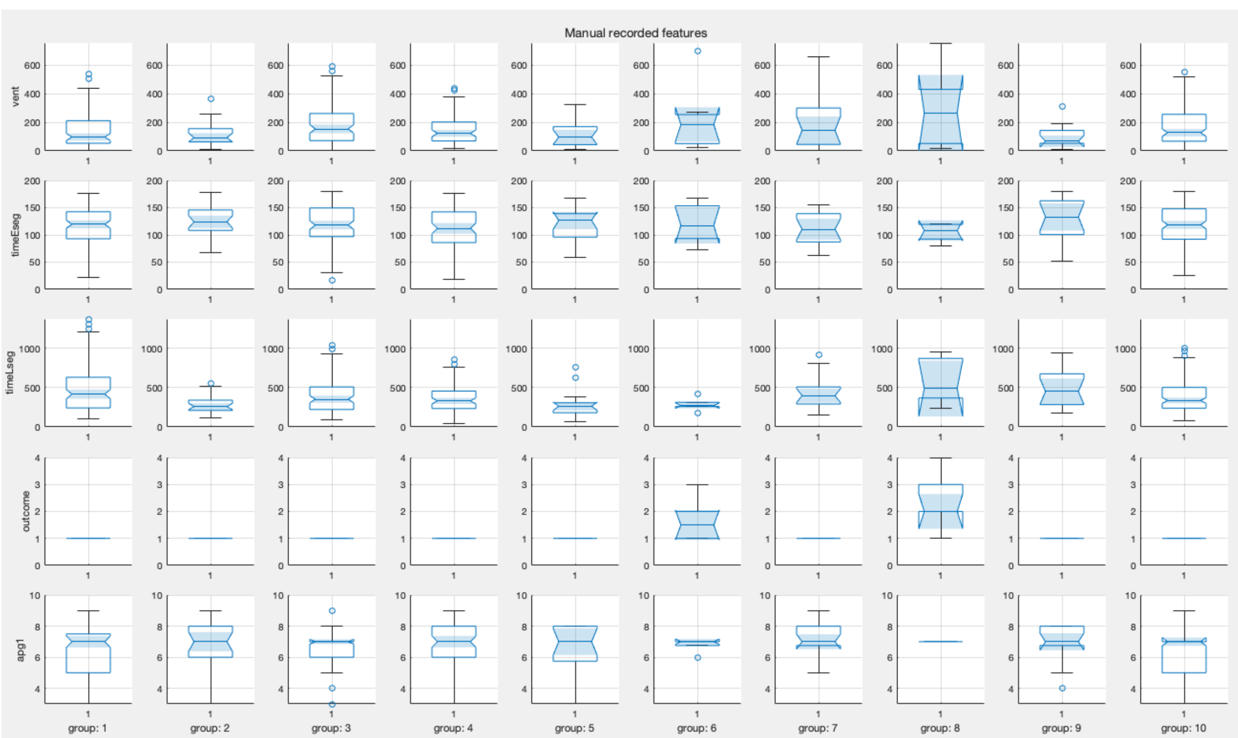

Figure 6.65: Boxplot of manual recorded features part 1. Illustrates the 10 groups spread of data values based on late segments.

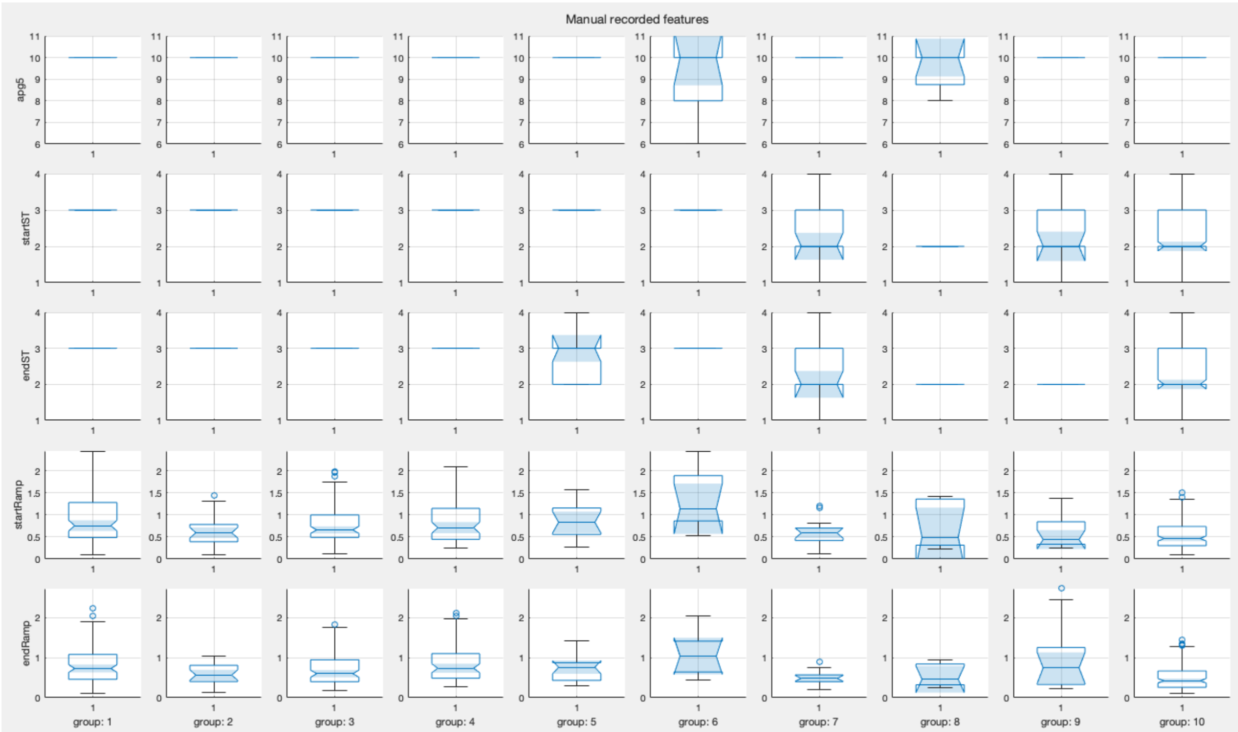

Figure 6.66: Boxplot of manual recorded features part 2. Illustrates the 10 groups spread of data values based on late segments.

Boxplot data extracted from the automatic detected data (Based on late segments)

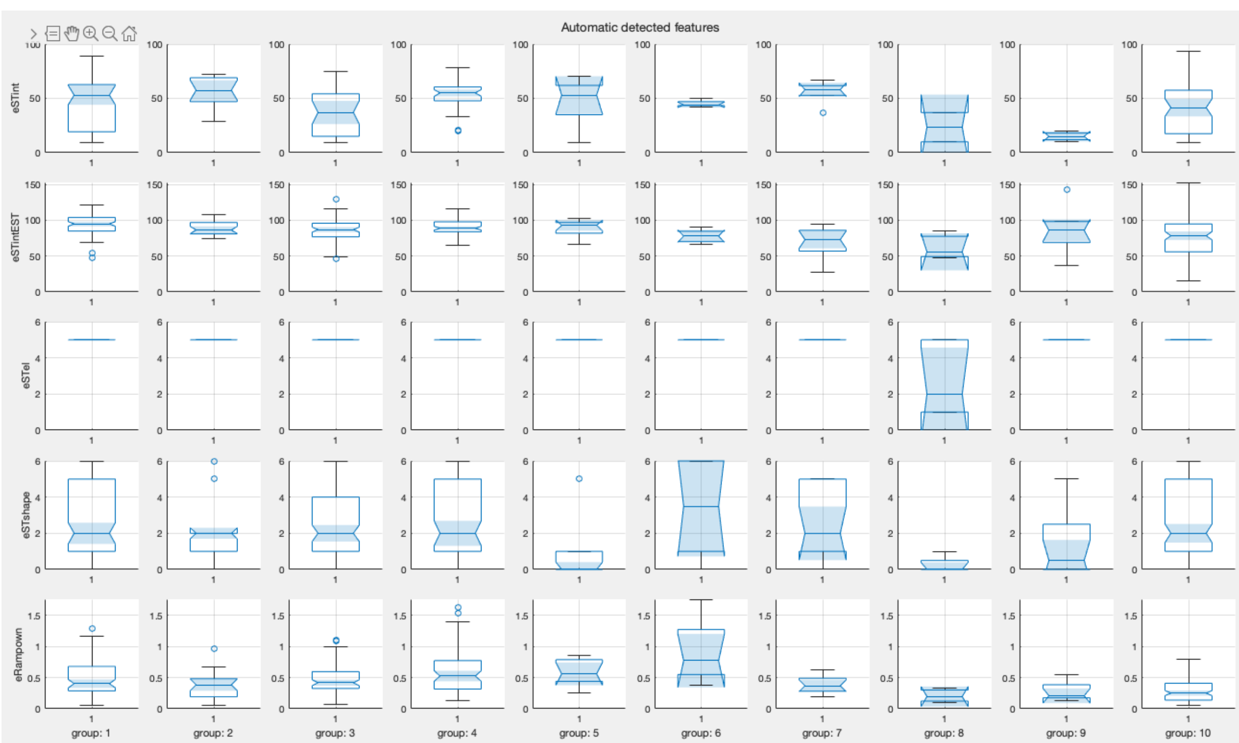

Figure 6.67: Boxplot of automatic detected features part 1. Illustrates the 10 groups spread of data values based on late segments.

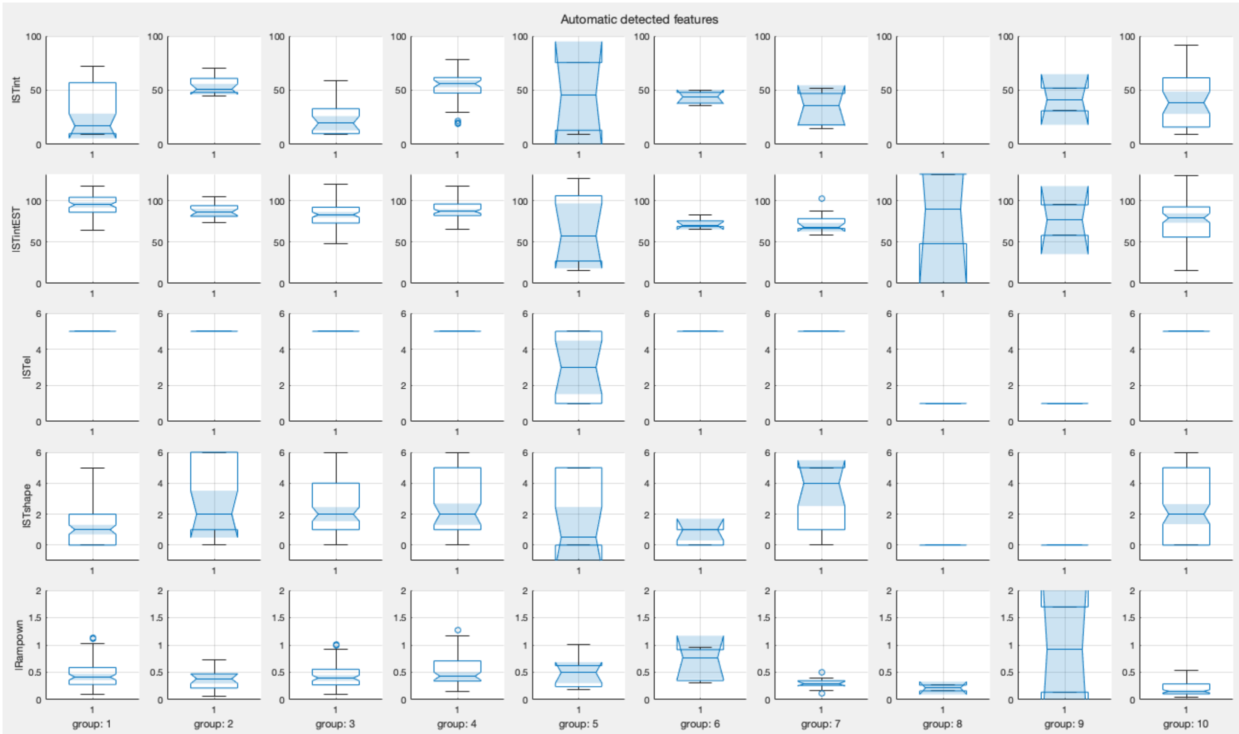

Figure 6.68: Boxplot of automatic detected features part 2. Illustrates the 10 groups spread of data values based on late segments.