Analyzing Current Fetus Risk Conditions Through Fetal Heart Rate (FHR) and Uterine Constructions (UC) Values by Using Machine Learning Algorithms

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ABSTRACT

Fetal Heart Rate (FHR) is often used to assess situation of fetal health. The aim of this thesis is to infer current fetus risk conditions by monitoring and computing FHR and Uterine Constructions (UC) values. Doppler devices are generally used for gathering FHR and UC values from labors instantly. Doppler devices produce Non-Stress Test (NST) graphs.

In this thesis, we used the CTU-UHB intrapartum Cardiotocography database (CTU) which is gathered by Prague and Brno University Hospital (UHB). The database contains 552 Cardiotocography records (CTG) and each record involves a FHR and an UC signal. In this thesis, several machine learning algorithms are developed to perform feature extractions and classification to analyze NST graphs. MATLAB and R tools are used for signal processing, feature extraction and classification steps. With the proposed system, instant interpretation of FHR and UC signals on a NST records: (1) value of instant baseline, (2) variable baseline signal, (3) baseline variability, (4) type and number of accelerations, (5) type and number of decelerations, (6) classification of the NST traces. In experimental studies of this thesis, CTU-UHB Cardiotocography records are interpreted by an expert obstetrician. Experimental results are evaluated and compared with expert obstetrician's observations and some of related works.

Keywords: Fetal Heart Rate, Uterine Contraction, Machine Learning, Doppler, NST, Cardiotocography.

ÖZ

Fetal Kalp Hızı (FHR) genellikle fetal sağlık durumunu değerlendirmek için kullanılır. Bu tezin amacı FHR ve Uterus Kasılmaları (UC) değerlerini takip ve analiz ederek mevcut fetüsün anlık risk durumunu anlayan bir sistem önermektir. Doppler cihazları genellikle FHR ve UC sinyal değerlerini hamile bireylerden anlık toplamak için kullanılır. Doppler cihazları, test esnasında Stressiz Test (NST) grafikleri üretir.

Bu tez çalışmasında, Prag Ve Brno Üniversite Hastanesi (UHB) tarafından toplanan CTU-UHB İntrapartum Kardiyotokografi Veri Tabanını (CTU) kullandık. Veri tabanı 552 Kardiyotokografi (CTG) kaydı içerir ve her kayıt bir FHR ve bir UC sinyali içerir. Bu tez çalışmasında, NST grafiklerindeki FHR ve UC sinyallerini yorumlamak için özellik çıkarımları ve sınıflandırma yapmak üzere birkaç makine öğrenme algoritması geliştirilmiştir. Geliştirme esnasında, MATLAB ve R yazılımları, sinyal işlemede, öznitelik çıkarımlarında ve sınıflandırma adımlarında kullanılmıştır. Önerilen sistem ile, FHR ve UC sinyalleri anlık yorumlanarak: (1) anlık temel/ortalama değeri, (2) değişken temel/ortalama değeri, (3) temel değişkenlik, (4) akselerasyon sayısı ve türleri, (5) deselerasyon sayısı ve türleri, (6) yukarıdaki ara çıktı sonuçları kullanarak, bebeğin anlık durum sonucu tanımlanır. Bu tezin deneysel çalışmalarında, CTU-UHB Kardiyotokografi veri setindeki kayıtlar, uzman bir kadın doğum doktoru tarafından yorumlanmıştır. Deneysel sonuçlar, uzman kadın doğum doktorunun sonuçları ve ilgili bazı çalışmaların sonuçları ile değerlendirilmiş ve karşılaştırılmıştır.

Anahtar Sözcükler: Fetal Kalp Hızı, Uterin Kasılma, Makine Öğrenmesi, Doppler, NST, Kardiyotokografi.

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LIST OF ABBREVIATIONS

Acc	Acceleration
BL	BaseLine
BLV	BaseLine Variability
bpm	beat per minute
CTG	Cardiotocography
Dec	Deceleration
EFM	Electronic Fetal Monitoring
FHR	Fetal Heart Rate
LTV	Long Term Variation
NICHD	Eunice Kennedy Shriver National Institute of Child and Human Development
NST	Non-Stress Test
RCOG	Royal College of Obstetricians and Gynecologists of Canada
STV	Short Term Variation
UC	Uterine Contraction
VBL	Variable BaseLine

Chapter 1

INTRODUCTION

1.1 Introduction

UNICEF estimated that around 130 million babies are born yearly, with about 3.5 million dying from perinatal complications [1]. Around 35 children in Sweden die during pregnancy due to a lack of oxygen [2]. Fetal monitoring is of great importance to monitor fetal physiology in people [3]. The analysis and tracing with computer algorithms that estimate the present fetal status of FHR patterns is more accurate than traditional analysis. This thesis proposed and implemented algorithms for the automated detection of Fetal Heart Rate and Uterine Contraction in order to estimate the status of the fetus and analyze the aspects of FHR and UC which can help doctor's duty to predict the status of Fetal.

1.2 Aim

The aim of this thesis is to analyze the current fetus risk conditions through FHR values and UC. Doppler devices produce Non-Stress Test patterns. In this thesis, the CTU-UHB intrapartum Cardiotocography database is used which is gathered by Prague and Brno University Hospital. This database contains 552 Cardiotocography records and each record involves a FHR signal and a UC signal. Several Machine Learning algorithms are developed to perform feature extractions and classification to analyze NST graphs. The considered tools for the study are MATLAB and R in order to execute signal processing, feature extractions and classification steps. With the proposed system, instant interpretation of FHR and UC signals on a NST records: (1)

value of instant BaseLine, (2) Variable BaseLine signal, (3) BaseLine Variability, (4) type and number of Accelerations, (5) type and number of Decelerations, (6) using the above intermediate output results, the baby's instant case result is defined. BL of the fetus as an important part of the CTG pattern must be calculated with high precision to better interpret fetal traces [3]. BL is related to the advancing gestational age and BL can be reduced with weeks of pregnancy increasing [3]. Normal BL can be ranged from 110 to 160 bpm based on standard criteria [3]. The BLV of the FHR is another important feature of the FHR to interpret CTG traces [3]. The BLV can be defined as the correct or true difference in time between consecutive heartbeats. BLV is normally present in healthy fetuses [3]. Acc and Dec depends on Gestational age. For example, after 32 weeks of pregnancy, normal fetuses have episodes of Acc of their heart rate associated with fetal movements [3]. A normal oxygenated fetus shows Acc at least every 60- 80 minutes [3]. UC is another important signal which is used for Fetal monitoring. Fetal monitoring also is possible to evaluate with UC or without UC [3]. Dec in NST pregnancy is related to the UC and can be divided into Late, Early and variable Dec. Recently, based on developing the technology, doctors have many cases or techniques to analyze the FHR patterns [2]. Electronic Fetal Monitoring is performing because of exciting of fetal movement, uterine pain, suspected Fetal abnormalities and limitation of growth.

1.3 Objectives

The objectives of this thesis are developing and implementing several machine learning algorithms in order to perform feature extractions and classification to analyse NST graphs. The considered tools for are MATLAB and R in order to execute signal processing, feature extractions and classification steps. Decision Tree is implemented as classifier in Machine Learning.

1.4 Non-Stress Test

NST is one of the most common methods to estimate and assess the condition of the fetus because it is highly sensitive, quickly deployed and ambulatory. Usually the NST is perfuming for pregnant women in a pregnancy clinic or hospital after 33rd gestational week [4].

1.5 Cardiotocography

CTG is a technique for recording FHR and UC during pregnancy, a machine called a Cardiotocograph, more commonly known as EFM, may be used to implement this technique [5]. CTG is widely used in almost every modern labor and delivery unit in the developed world and was initially introduced for clinical use in the late 1960s as an alternative to the highly labor- intensive FHR auscultation [3]. CTG patterns is very complex to trace by eye and we must consider and analyze the levels, patterns and relationships between changes that occurred during CTG pattern recording [2]. CTG patterns can be characterized by four key parameters and their relationship with UC: (1) BL, (2) BLV, (3) Acc and (4) Dec [2]. CTG technique is divided into two type of recording, which are external and internal CTG. For intermittent or continuous fetal monitoring, the external CTG is used, in this type of monitoring, two transducers on the abdomen of the patient detect the FHR and UC of the muscle. Internal CTG uses a directly connected electronic transducer to the fetal scalp. The internal CTG provides more precise monitoring than external CTG.

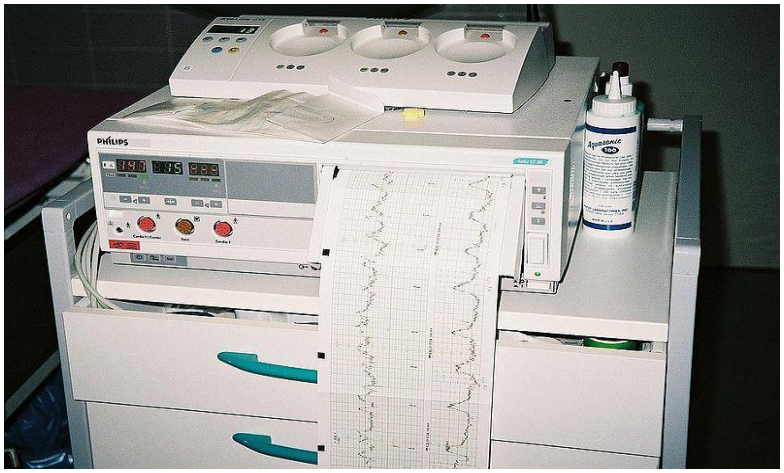

Figure 1: A Cardiotocograph recording FHR and UC [6].

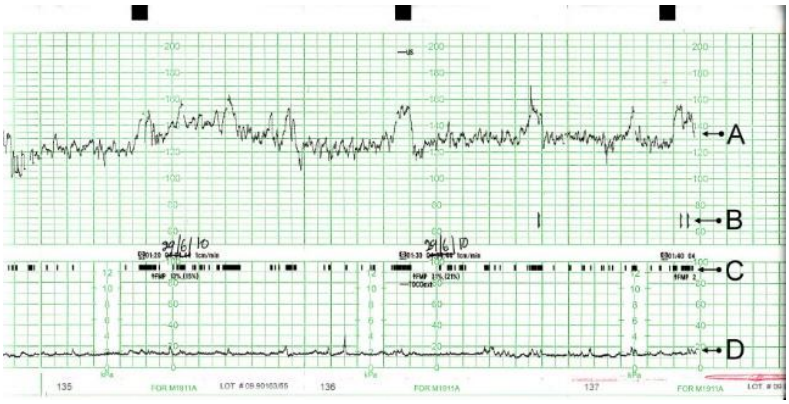

Figure 2: CTG pattern output for a woman not in labor [7].

1.6 CTG Guideline for Feature Extraction and Classification

CTG patterns are interpret by different standard guidelines, these guidelines are used in order to perform feature extraction and classification of the FHR signals and their relationship with UC signal. Some institutes have set up and sponsored standard guidelines to interpret and analyze the CTG patterns used to monitor the FHR and UC, some of the standard guidelines of these institutes are listed below:

- Eunice Kennedy Shriver National Institute of Child and Human Development of USA
- Royal College of Obstetricians and Gynecologists of Canada

- Society of Obstetricians and Gynecologists of Canada

1.7 Fetal Heart Rate

FHR is a very important factor in order to estimate and evaluate the condition of Fetus [8]. Analyzing FHR patterns based on traditional feature extraction and classification may not be very precise, the results cannot be very reliable and satisfactory [8]. Normally FHR signal consists of more than 20 related features, but the main features of FHR are; (1) BL, (2) BLV, (3) Acc and (4) Dec [8]. FHR patterns are manually observed by the expert obstetricians during the fetal monitoring at clinics or hospitals [9]. According to RCOG CTG guideline feature extraction and classification, the FHR traces are classified into three separate categories: (1) Normal, (2) Suspicious and (3) Abnormal [8].

1.7.1 BaseLine

BL is one of the key features of the FHR, the classification of the fetal status and other characteristics of the FHR patterns depends on the status of the BL [9]. Normally, BL should be evaluated and estimated as first feature in FHR patterns, extracting other features from FHR patterns such as Acc, Dec and BLV are related to the BL [2]. Based on RCOG CTG guideline feature extraction and classification, BL is classified to Reassuring, Suspicious and Pathological that is provided in Table 1 [10].

Table 1: RCOG BL classification

Reassuring	**Suspicious**	**Pathological**
110-160 bpm	100-109 bpm 161-180 bpm	<100 bpm or >180 bpm

1.7.2 BaseLine Variability

BLV in FHR patterns is defined as a small variation in the BL [10]. BLV also refers to the FHR variation from one beat to the next beat. The heart rate variability shows that the cardiac rate differs, and the BL fluctuations vary [2].

1.7.3 Acceleration

Acc is defined as a transient FHR increase [2]. The presence of Acc is linked to the FHR's good results [11]. According to the NICDH CTG guideline feature extraction and classification, an Acc occurs in two duration of pregnancy which are, before 32 weeks and after 32 weeks. The first type of Acc happens before 32 weeks or less than 32 weeks of pregnancy which means increase more than 10 bpm for more than 10 seconds that returns to the VBL within 2 minutes, the second type of Acc happen after 32 weeks or more than 32 weeks of pregnancy which increase more than 15 bpm for more than 15 seconds that returns to the VBL within 2 minute.

1.7.4 Deceleration

According to the NICDH CTG feature extraction and classification a Dec is defined as the FHR decreasing [2]. Dec is not good in FHR. Dec is related to the BL of FHR; Dec categorizing is associated with UC activities [11]. According to NICDH feature extraction and classification, type of a Dec can be categorized into three group, which are; late, early and variable Dec [11].

1.7.4.1 Late Deceleration

A late Dec is a uniform, slowing down slowly after contraction and returning to the FHR BL at the end of contraction [11].

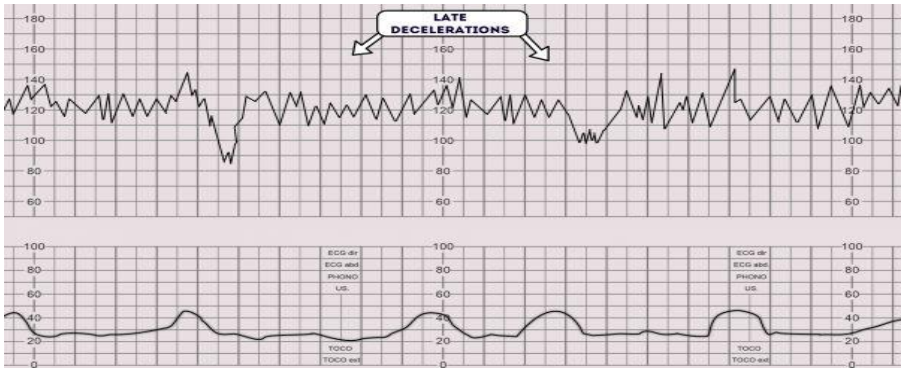

Figure 3: Late Dec in FHR pattern

1.7.4.2 Early Deceleration

Early Dec is a regular and recurring slowdown of the FHR with early onset of contraction, which returns to the BL at the end of contraction [11]. Normally, in active or pregnant labor, early Dec occurs [3].

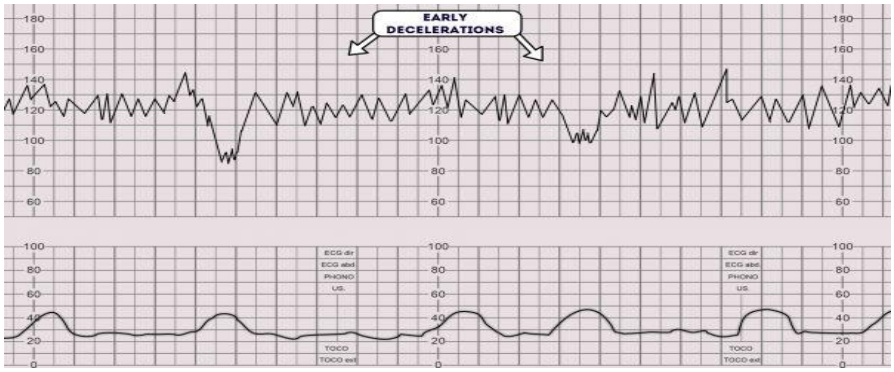

Figure 4: Early Dec in FHR pattern

1.7.4.3 Variable Deceleration

A variable Dec of the FHR is variable and intermittent with rapid onset. The time relationships between variable Dec and contraction are variable and can occur in isolation [11]. Most commonly, variable Dec occurs in the second stage of pregnancy, which relates to pushing and maternal Valsalva [3]. A variable Dec can have different degrees of FHR decrease, time blow BL and return to the BL [3].

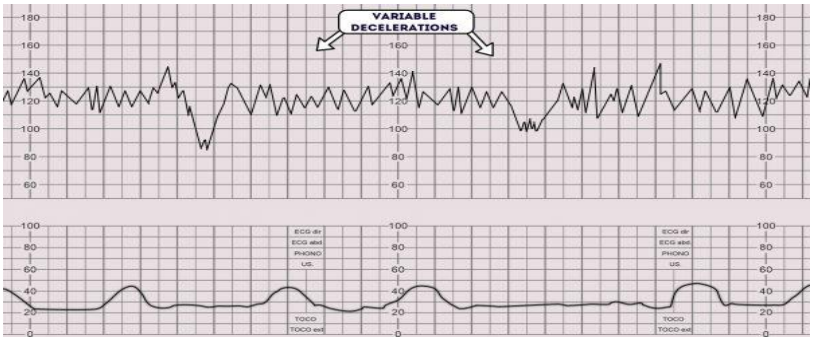

Figure 5: Variable Dec in FHR pattern

1.8 Uterine Contraction

UC can be defined as a muscle contraction of the smooth uterine muscle, which is an important component of CTG patterns that used in order to evaluate and estimate the current fetal status by expert obstetricians [3]. Important factors in UC are intensity, duration and time of relaxation [3].

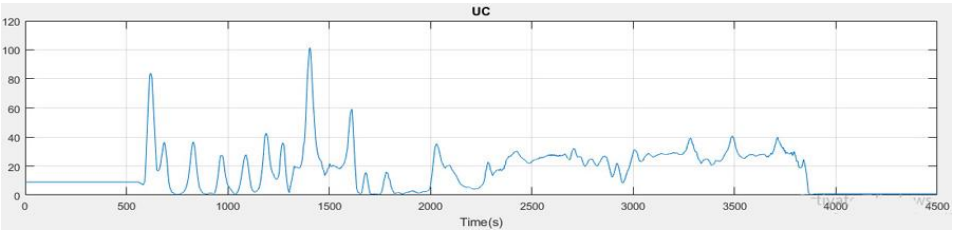

Figure 6: UC signal

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter covers the literature review of some related works. Separated parts considered in order to explain and evaluate previous and related works in order to analyzing current fetus risk condition through FHR and UC values by using machine learning algorithms. Previous researches show that different algorithm and methods proposed in order to predict and estimate the missing values of the signals as pre-processing stage, some researchers analyzed and extracted some or all features of the FHR signals and then classifying the result of the CTG signals, some of researchers have been considered UC as well in their work in order to estimate the status of the Fetus. Different papers present different methods for different parts of analyzing FHR and UC. This chapter explain each part of related works separately such as; Data Collection, CTG Guideline Feature extraction and Classification, Pre-processing CTG records, feature extraction such as BL, BLV, Acc, Dec and Classification.

2.2 Background

EFM is one of the most common and important methods to estimate and evaluated the current status of Fetus through the FHR and UC signal. Researches shows that various methods for feature CTG feature extraction and classification based on different guideline CTG feature extraction and classification criteria are proposed in order to analyzing CTG patterns. CTG patterns contain two signal, which are FHR and UC [12].

2.3 Related Works

Researches shows that in some of related works CTG patterns are interpreted by expert obstetricians based on different standard CTG guideline feature extraction and classification such as NICHD, RCOG, or FIGO. Some related works used the CTG dataset which is interpreted by some CTG software analyzer such as SisPorto. According to previous works, a few of related works tried to be interpreting CTG patterns by feature extraction and classification and then they applied Machine Learning Algorithms. In this thesis pre-processing the CTG signals, Feature extraction of CTG signals, Classification of CTG signals and Machine Learning algorithm have been applied.

2.3.1 Data Collection

Researches shows that different CTG dataset has been considered in order to interpret and evaluate. This section describes the CTG datasets which are used in related works. Some of these datasets have been evaluated with different proposed method by researchers, some of this datasets have been interpreted by some CTG signal analyser and also some of this datasets have been interpreted by expert obstetricians at different clinics or hospitals.

According Nidhal et al. [9] FHR patterns are observed manually by obstetricians during the process of the CTG analyses. Another study [13] is used CTU-UHB CTG database of Czech Technical University and estimate given by three experienced physicians. Reference to Li [8] through the cooperation with the hospital, they got 4473 records, which contains 3012 normal, 1024 suspicious, 437 abnormal FHR records. Another study [14] a total of 3055 normal FHR tracing at 30-42 weeks' gestation were analysed by automated CTG FHR analyser software. Reference to

Sahin et al. [15] a dataset from UCI is used, this CTG dataset contain 2126 entries, which has 295 suspicious class and three expert obstetricians are interpreted the CTG records, whether normal or pathological, also the UCI CTG dataset was obtained by the automatic SISPORTO 2.0 Software. Arif et al. [16] a dataset that contain 2126 CTG record which is collected in the Maternity and Gynecological Clinic of University Hospital of Porto in Portugal is used and this dataset has been analysed by three expert obstetricians based on their opinion, also this dataset is interpreted and analysed by SisPorto and 21 features have been extracted from CTG records. Agostinelli et al. [17] used CTU-UHB CTG dataset as clinical dataset with 552 CTG record and each record contain a FHR Signal and a UC Signal. Feng et al. [18] the clinical dataset CTU-UHB CTG is used that is an open access dataset with 552 CTG record which collected from April 2010 and August 2012 in University Hospital in Brno, Czech Republic. Another study [1] used CTG-UHB database that is available on the Physionet website, contain 552 CTG record and each record has a FHR and UC Signals, two systems has been used in order to interpret and analyse this database, STAN S21/S31 and Avalon FM 40/50. Cömert et al. [19] CTU-UHB CTG dataset is used that is contain 552 record, each record has a FHR signal and a UC signal and this dataset are analysed by EFM systems which are STAN S21/S31 and Avalon FM40/FM50. Another study [20] used the CTU-UHB intrapartum CTG records as clinical database from Physionet website that each record has a FHR signal and a UC signal. Alyousif et al. [12] three different CTG database records as clinical database are used, the first set of their dataset data contain 15 CTG signals, the second set contain 30 CTG signals, and the third set consist 35 CTG signals which is collected by the National University of Malaysia Medical Center. Another study [21] used a dataset which contain 22 CTG signals.

2.3.2 CTG Guideline for Feature Extraction and Classification

Researches shows that different CTG Guideline Feature Extraction and Classification has been used, such as NICHD, FIGO and RCOG. Das et al. [13] NICHD CTG Guideline Feature Extraction and Classification is used in order to interpreting and analysing CTG dataset. Alyousif et al. [10] RCOG has been selected as CTG guideline in order to feature extraction and classification of the CTG patterns. Reference to Hoh [14] study was conducted to assess which component of FHR Acc, with the use of NICHD criteria. Agostinelli et al. [17] FIGO CTG Guideline for feature extraction and classification is used to analyse the CTG patterns. Another study [1] has been considered FIGO and the National Institute for Health and Care Excellence (NICE) in England as guidelines in order to interpret the CTG patterns, that is provided in Tables 3 and 4. Alyousif et al. [12] RCOG CTG Feature Extraction and CTG patterns classification is used in order to interpreting the CTG patterns that is provided in Table 2. Another study [21] used RCOG guideline to analyse CTG patterns. The RCOG, NICHD and FIGO Guidelines are provided in tables 2,3 and 4.

Table 2: RCOG/NICE Guideline for CTG Classification

	BL	**BLV**	**Dec**	**Acc**
Reassuring	110-160 bpm	>= 5 bpm	None	Present
Non-reassuring	100-109 bpm 161-180 bpm	<5 for >40 minutes but <90 minutes	Early Dec Variable Dec Single prolonged Dec up to 3 minutes	The absence of Acc with an otherwise normal CTG is of uncertain significance
Abnormal	<100 bpm >80 bpm Sinusoidal pattern for more than 10 minutes	<5 for>=90 minutes	A typical variable Dec Late Dec Single prolonged Dec >3 minutes	

Table 3: NICHD Guideline for CTG Classification

	BL	BLV	Acc	Dec
Normal	110-160 bpm	At least Moderate (6-25 bpm)	May or may not be present	No late or Variable Dec
Indeterminate	Bradycardia with normal BLV, Tachycardia	Minimal or Marked		
Abnormal	<110 or Sinusoidal	Absent		Recurrent Late/Variable Dec

Table 4: FIGO Guideline for CTG Classification

	BL	BLV	Interpretation	Clinical Management	Dec
Normal	110-160	5-25 bpm	No hypoxia/ acidosis	No intervention necessary to improve Fetal oxygenation state	No repetitive * Dec
Suspicious	Lacking at least one characteristics of normality, but with no pathological features		Low probability of hypoxia/ acidosis	Action to correct reversible causes if identified, close monitoring, or adjunctive methods	
Pathological	<100 bpm	Reduced variability, Increased Variability, Sinusoidal pattern	High probability of hypoxia/ acidosis	Immediate action to correct reversible causes, adjunctive methods or if this is not possible expedite delivery. In acute situations, immediate delivery should be accomplished	Repetitive*late or prolonged Dec for >30 min (or >20 min if reduced variability). Dec >5 min

2.3.3 Pre-Processing

Researches shows that different pre-processing methods and algorithms have been proposed in order to removing the noise and finding missing samples from CTG signals. Noise is unreliable and false. CTG signals are noisy, may FHR has some sounds, may contain spiky artefacts, which occur when there are Fetal movement or may using incorrect of the transducer in the EFM [12]. This section describes different methods that are proposed in related works. According Agostinelli [17] due to signal loss, the Linear Interpolation Method has been applied as signal pre-processing stage of the study. Regarding Feng [18], a Gaussian Process-based approach has been applied to recovery of missing samples in FHR. Authors in [1] used Cubic Hermite spline interpolation algorithm in order to pre-process CTG signals that remove noise and low-quality artefacts. Cömert et al. [19] cubic spline interpolation is used for the pre-processing signals. Another study [20] shows that pre-processing stage can be different for FHR signal and UC signal, FHR signal can be influenced by the maternal movement and the Fetal movement, the implemented method in order to pre-processing the signal was cubic spline interpolation. Alyousif et al. [12] considered the linear interpolation algorithm for the pre-processing signals. Another study [21] considered the linear interpolation algorithm for the pre-processing signals.

2.3.4 BaseLine

BL is one of the key features of the FHR, the classification of the Fetal status and other characteristics of the FHR patterns depends on the status of the BL [9]. This section describes the related works in order to estimate and evaluate BL of the FHR. Researches shows that different methods and algorithms are proposed in order to estimate the BL. Alyousif et al. [9] an algorithm developed in order to estimate the BL by determining the Virtual Imaginary BL and the True BL. Das [13] says that a

standardized BL estimation algorithm proposed and the BL was estimated within continuous with 10-minute sliding window. Another study [17] BL was evaluated and estimated in each 20 minutes of a FHR window, and the virtual BL was initially computed as mean value of FHR over the window. Alyousif et al. [12] a virtual imaginary BL R, the mean value in the 30 minutes' segment of the FHR, that is:

$$R = \frac{1}{N}\sum_{i-1}^{N} y(i) \tag{1}$$

Where N is the number of samples and y is the signal for CTG. True BL, Virtual BL R can be estimated. In the BL algorithm process, consideration was given to the maximum (H) and minimum (L), which means that value above H and below L is ignored and the rest of the signal of FHR is taken into account for the actual BL computation. What is demonstrated as:

$$H = R + \alpha\ (bpm); L = R - \alpha\ (bpm) \tag{2}$$

Alyousif et al. [21] proposed a Virtual imaginary and a real BL in order to calculate the BL as:

- The Virtual imaginary BL FHR,

$$R = \frac{1}{N}\sum_{i=1}^{N} y(i) \tag{3}$$

- The True BL of FHR

$$BL = \frac{1}{N}\left[\int_{L}^{H} y dy\right] \tag{4}$$

The value of the virtual imaginary BL is the average Heart rate and the minimum (L) and maximum (H) limits of the FHR signal are evaluated. In order to calculate true BL, the remaining part value of the signal between these limited boundaries was omitted.

2.3.5 BaseLine Variability

BLV refers to the FHR variation from one beat to the next beat. This chapter describe some proposed methods in order to estimate BLV in FHR. Alyousif et al. [12] presents that BLV is calculated by a maximal Y_{max} and a minimal Y_{min} of the FHR within two minutes which is based upon the RCOG CTG guideline feature extraction and classification, for a two-minute interval in the BLV,

$$V = Y_{max} - Y_{min} \tag{5}$$

and [21] BLV in FHR is calculating within 2 minute.

2.3.6 Acceleration

Acc is defined as a transient FHR increase. This section describes different proposed methods in order to estimating and detecting Acc based on the different CGT guideline for feature extraction and classification. Hoh et al. [14] suggested optimum number of a period Acc in the literature from one to five over a period of 20 or 30 minutes, Acc were classified as one of four combinations of amplitude and duration: 15 bpm-15 seconds, 15 bpm-10 seconds, 10 bpm-15 seconds and 10 bpm-10 seconds, and [14] estimated the correlation among the FHR Acc combinations using correlation analysis based on linear regression models. Agostinelli et al. [17] to identify an Acc, FHR values below BL were eliminated. Another study [12] evaluated and estimated the Acc phase the average moving filter smoothens were chosen to identify an Acc (x_1) intersection with the Acc endpoint (x_2) based on the match between the coordinates of each FHR signal and real BL points, taking into account the Acc maximum (Ymax), as shown below.

$$x_a = x_x - x_{a1}(second) \tag{6}$$

$$Y_a = Y_{max} - BL(bpm) \tag{7}$$

Alyousif et al. [21] believes that the remains part that is upper the real BL of the FHR signal which is separated after estimating the maximum (H) and minimum (L) limits will be considered in order to calculate and finding Acc in the FHR signal, he considered an Acc based on RCOG CTG guideline feature extraction and classification that Acc is define as an increase of 15 bpm in the FHR Signal for more than 15 seconds.

2.3.7 Deceleration

Dec is defined as the FHR decreasing. This section describes about some proposed methods in order to detect the Dec in FHR. Agostinelli et al. [17] estimated and identified a Dec within each 20-minute window size of FHR. Alyousif et al. [12] Dec is defined 15 bpm decrease below the BL that returns to BL for more than 15 seconds, in this study two types of Dec considered in order to detecting type of Dec which are early and late Dec.

2.3.8 Classification and Machine Learning

This section describes different related works that are proposed different methods based on standard Guidelines of CTG trace classification. Li et al. [8] an automatic classification of FHR are developed based on Convolutional Neural Network. Sahin et al [15], eight different Machine Learning has been performed and evaluated in order to classification of the Cardiotocogram records, Logistic regressions, K-Nearest neighbour, Radial basis function network, Artificial neural networks, Support vector machine, classification and regression trees, C4.5 decision tree classifier and Random Forest. Arif et al. [16] Random Forest has been performed in order to classification the CTG signals.

Table 5: A summary of some related works

		References				
		[10] 2011	**[15] 2015**	**[12] 2016**	**[22] 2017**	**This Work**
CTG Guideline for feature extraction and classification		RCOG	EMD	RCOG	FIGO	NICHD [11]
Dataset		N/A	UCI CTG [15]	3 Different CTG [12]	CTU-UHB CTG [23]	CTU-UHB CTG [23]
Number of records		22	2126	80	552	552
Dataset analyzed by expert obstetricians?		-	+	+	+	+
Number of Expert obstetricians and CTG software analyzer that analyzed dataset?		-	3 expert and SisPorto [15]	5	9	1 expert and CTGOAS [22]
UC considered ?		-	+	+	-	+
Pre-Processing		Linear Interpolation [24]	-	Linear Interpolation [24]	Interpolation [22]	Hermit Linear Interpolation [24]
Feature Extraction	BL	-	+	+	+	+
	BLV	-	+	+	+	+
	Acc	-	+	+	+	+
	Dec	-	+	+	+	+
	Early Dec	-	+	+	-	+
	Late Dec	-	+	+	-	+
	Variable Dec	-	-	-	-	+
CTG Record classification		+	-	+	PCA and k-fold cross-validation [22]	Automated classification Algorithm [11]
Machine Learning Classifier	Logistic Regressions	+	-	-	-	-
	K-Nearest Neighbor	+	-	-	-	-
	Radial Basis Function Network	+	-	-	-	-
	Artificial Neural Network	+	-	-	-	-
	Support Vector Machine	+	-	-	+	-
	Classification and Regression Trees	+	-	-	-	-
	Random Forest	+	-	-	-	-
	Decision Tree	+	-	-	-	+

2.4 Conclusion

As conclusion of this chapter, researches shows that different methods are proposed based on different CTG guidelines for feature extraction and classification in order to analysing and interpreting CTG records for estimating and evaluating current status of the Fetal. Some researchers proposed methods only for pre-processing and feature extraction of CTG patterns, on the other hands some of researchers applied different machine learning algorithm on the interpreted dataset which analysed by expert obstetricians in order to classification the CTG patterns. Table 5 shows a comparison between some related works and this work.

Chapter 3

METHODOLOGY

3.1 Introduction

This chapter contains the thesis investigation methodology that describes the research strategy, problem statement, data collection description and tools, research approaches, pre-processing CTG records, CTG Guidelines for feature extraction and classification, CTG Feature extraction, CTG classification, Machine Learning and finally Research Limitations.

3.2 Problem Statement

According to the UNICEF investigation, near 130 million babies are born every year, near 3.5 million of babies die from perinatal complications [1]. 35 babies die during pregnancy because of lack of the oxygen in Sweden. Fetal monitoring is a common way in order to predict and estimate the current status of the Fetal. Developing technologies so rapidly can help to the doctors to interpret the CTG records for estimating the status of the Fetal. Different researchers are proposed different methodologies and methods based on different standard CTG guideline feature extraction and classification. Based on the researches and expert obstetricians we cannot say which method is better or more accurate. In response to this problem, this thesis study proposes to investigate and implement different algorithms in order to analyse current fetus conditions through FHR and UC values based on the NICHD CTG feature extraction and classification.

3.3 Data Collection Description and Tools

CTU-UHB CTG dataset is used for this thesis, this dataset contains 552 CTG records and each record has FHR Signal and UC signal. This dataset collected by Czech Technical University in Prague and University Hospital in Brno that recorded from 2010 through 2012. All the CTG recordings start only 90 minutes before delivery and each time lasts for a maximum of 90 minutes. CTG records sampled at 4 Hz (FHR time series and UC). Table 6 [9] represents the CTU-UHB CTG records of 552 CTG records used in this thesis. MATLAB is used in order to design and implement all algorithms.

Table 6: Overview of the CTU-UHB CTG dataset

	Mean	**Min**	**Max**
Maternal age(year)	29.6	18	46
Gestational age	40	37	43
pH	7.23	6.85	7.47
BDecf(mmol/L)	4.60	-3.40	26.11
pCO_2	7.07	0.70	12.30
BE	-6.38	-26.80	-0.20
Apgar 1 min	8.3	1	10
Apgar 5 min	9.1	4	10
Gravidity	1.4	1	11
Parity	0.4	0	7
Diabetes	No=515, Yes=37		
Birth weight (g)	3401	1970	4750
Infant sex	Male=286, Female=266		
Delivery type	Vaginal=506, Cesarean section=46		

3.4 Research Approaches

For the purposes of this thesis the research approach followed was instructive. Under this method, researchers start special observations, which are used for the analysis of the FHR and UC. 552 CTG signals are used in this thesis to test the proposed algorithms, each of this CTG records has two signal, FHR signal and UC signal. All the 552 CTG signals have been pre-processed by Hermit Linear interpolation and smoothing algorithms in order to make the signals ready for the next steps. Based on

NICHD CTG guideline feature extraction and classification, CTG signals outcome traces is classified into Normal, Indeterminate and Abnormal which is provided in Table 3. In this thesis 20 CTG records has been selected to be interpret by an expert obstetrician at Yaşam Hospital in Famagusta, Northern Cyprus in order to compare and evaluate results of this thesis. The obstetrician was asked to extract the features which are; BL, BLV, Acc, Dec and type of the Dec from the CTG signals and finally classifying the CTG signals based on the NICHD guideline which is provided in Table 3. The results of our algorithms have been compared with the results of the expert obstetrician. The methodology of this work described is shown in Figure 7.

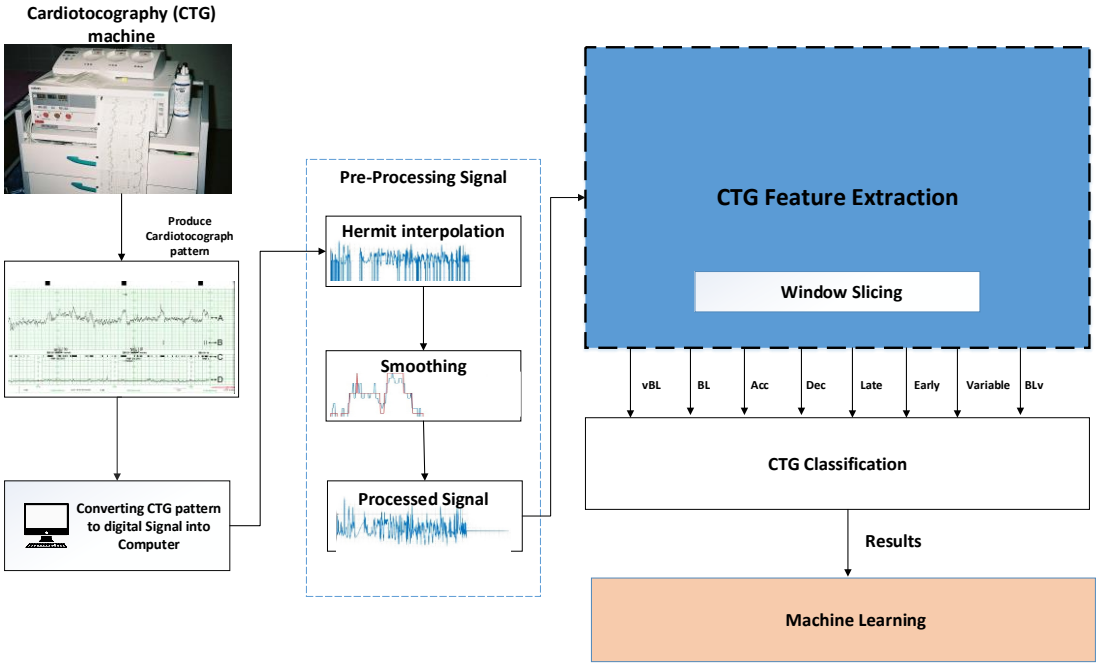

Figure 7: Methodology approach of proposed system

3.5 Pre-Processing Signal

Noise is unreliable and false. CTG signals are noisy, FHR has some sounds, may contain spiky artifacts, which occur when there are fetal movement or may use incorrect transducer in the EFM [12] or inaccurately of the pregnant women position.

Many reasons can affect to the CTG signals during processing of the Fetal monitoring. The input CTG signals has missing samples which is shown in Figure 10 and 11, the graph of the CTG signal breakdown to the zero. Table 7 represents the result of the pre-processing stage after finding the number of missing samples in all the 552 CTG records. Figures 10 and 11 shows the pre-processed FHR Signal and UC signal that are ready for feature extraction.

Table 7: Number of missing samples in all 552 records

Signal	Missed Values
FHR	1874178
UC	1945359
Total	3819537

3.5.1 Hermit Linear Interpolation

The input CTG records has missing values, in order to predict and estimate the missing values and restoration the original shape of the CTG records, Hermit Linear Interpolation method has been applied on all 552 CTG records. Linear Interpolation method is one of most accrue methods for estimating and finding missing samples in signal processing. A comparison between linear interpolation method with Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE) is provided in Figure 8 [24] which shows Linear Interpolation Method predict and estimate the missing samples much better than Mean Absolute and Mean Squared Error.

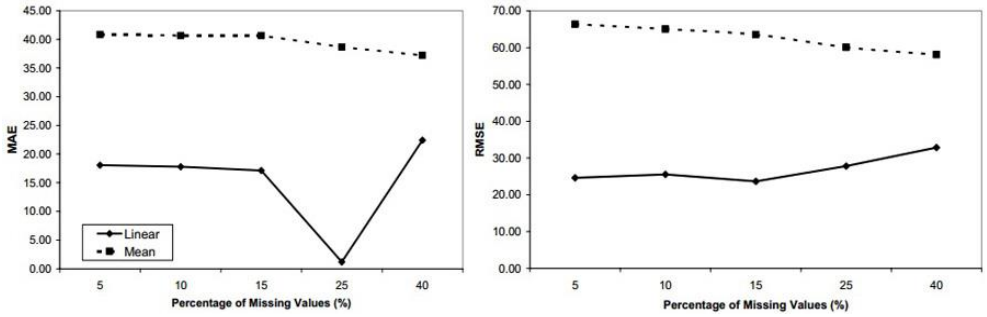

Figure 8: Comparison between Linear Interpolation with MAE and RMSE [24]

3.5.2 Smoothing

In this section, Moving Average Filter Smoothens method has been used in order to reduce the number of intersection points between the FHR signal and the BL to the limits with considering that we should not destroyed and lose the original shape of the FHR Signal [12]. Result of Moving Average Filter Smoothens is provided in Figure 9.

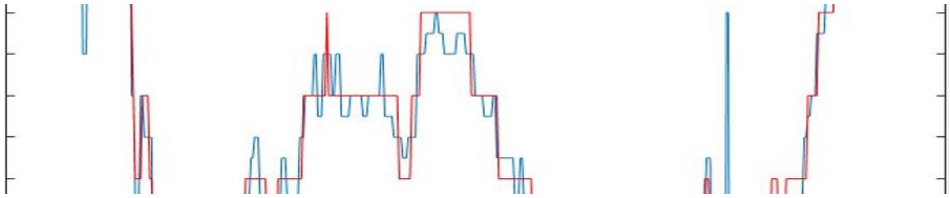

Figure 9: Blue signal is the original FHR and Red signal is smoothed FHR

3.5.3 Pre-Processed Signal

After passing the Hermit Linear Interpolation and smoothing steps, the pre-processed signal is ready in order to feature extraction which is provided in Figures 10 and 11.

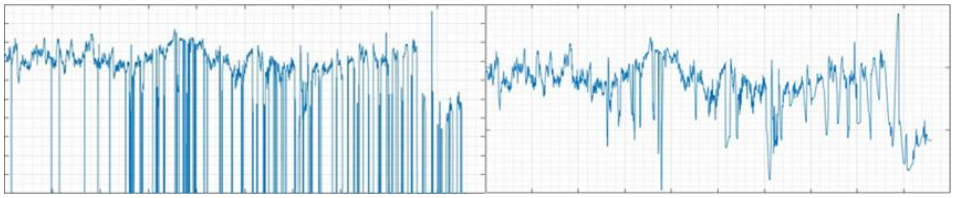

Figure 10: Left: Original FHR, Right: FHR after pre-processing

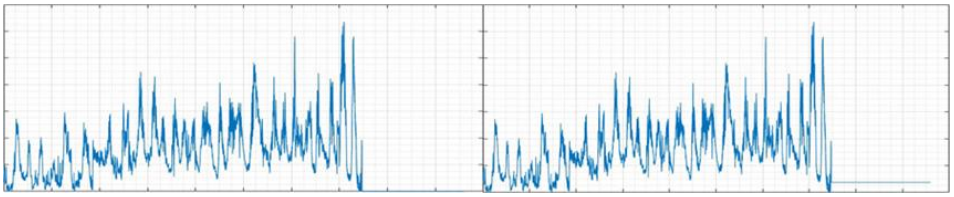

Figure 11: Left: Original UC, Right: UC after pre-processing

3.6 Feature Extraction

Different standard CTG guidelines for feature extraction have been introduced by different institutes such as NICHD, RCOG, Society of Obstetricians and Gynecologists of Canada and other standard guidelines. In this section, NICHD guideline feature extraction is used as a standard guideline to extracting the features from FHR. NICHD Guideline [11] for CTG Feature Extraction is provided in Table 8.

Table 8: NICHD CTG Guideline for Feature Extraction

	Descriptions
BL	Normal BL is between 110 – 160 bpm
BLV	between 2-10 min that return to BL, which can categorize as: **Absent:** zero deviation of BL. **Minimal:** <5 bpm variation. **Moderate:** 6-25 bpm and **Marked:** +25 bpm variability (any number between this ranges can consider as result)
Acc	**<32 weeks:** 10 or more seconds increase for more than 10 bpm that return to BL within 2 minutes. **>32 weeks:** 15 or more seconds increase for more than 15 bpm that return to BL within 2 minutes
Dec	**<32 weeks:**10 or more seconds decrease for more than 10 bpm that return to BL within 2 minutes. **>32 weeks:**15 or more seconds decrease for more than 15 bpm that return to BL within 2 minutes
Early Dec	occur on peak of contraction
Late Dec	occur after a UC
Variable Dec	abrupt decline in FHR

3.6.1 Window Slicing by Moving Average Method

In this section, Moving Average Method is used to define the window slicing that moves over the FHR signal. Moving Average Method is defined as function in order to analyze data points or samples by establishing a series of average of all sample in FHR Signals. In this section the size of window slicing is considered by 30 minute in order to feature extraction from FHR, 99.98 percent overlapping is considered for each window. According to the CTU-UHB dataset which is used in this thesis, each CTG record sampled by 4 Hz, so a window with 30-minute length may contain 7200 sample, as shown below:

$$30\ min * 60\ sec * 4\ Hz = 7200\ sample \quad (8)$$

The Overlapping a windows are 99.9861%, which calculated below:

$$7199\ /\ 7200 * 100 = 99.9861\%\ overlapping \quad (9)$$

According to the calculation for each sample we will have a window. As another example of Moving Average Filter, a window size with 90-minute has 21600 window which means:

$$90\ min * 60\ sec * 4\ Hz = 21600\ sample \quad (10)$$

which means 21600 sample with 21600 window, so a window size with 90 min length has 21600 operations for switching to the next window, and this operation takes a lot of time. In MATLAB programming, all operations of Moving Average Method are provided by a short function that is capable to do all operations in few seconds as follows:

```
BL = imfilter(FHR, Win, 'symmetric');
```

where BL is a variable, imfilter is the name of function, Win is the window size. Moving Average Method will operate as symmetric method for the first Window.

3.6.2 Variable Baseline

This section describes a methodology in order to calculate VBL. VBL is an important feature of the FHR signals. According to the CTG Guideline feature extraction, in order to extract features from FHR, BL are variable and has a shape like curve and other FHR features are related to the VBL. If the VBL estimated and calculated accurately, the other features such as Acc, Dec and BV will extract more accurately and finally having more accrue result of feature extraction. As example an Acc start at VBL and finish at VBL. In this section, Moving Average Filter method that discussed in section 3.6.1 window slicing is used in order to calculating and estimating VBL. A sample of VBL of this work is illustrated in Figure 12.

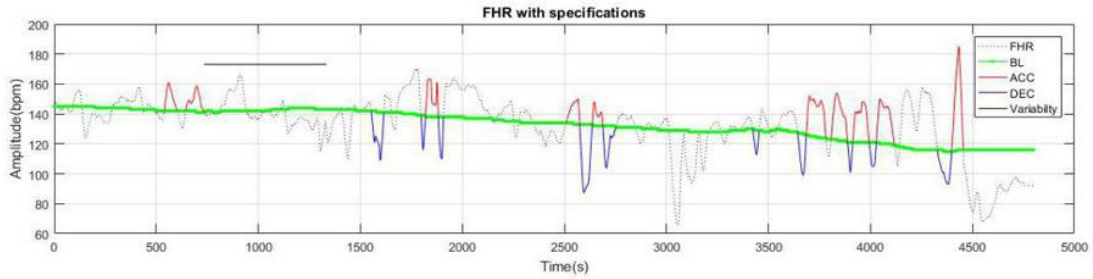

Figure 12: Representing VBL in FHR signal

3.6.3 BaseLine

This section describes estimating BL in FHR signals. Classification of the Fetal status and other characteristics of the FHR patterns depends on the status of the BL. Reference to section 3.6.2 which is estimating the VBL, in order to estimate BL, a Mean Function is applied on all the samples which are extracted from FHR as VBL. Based on RCOG BL classification is classified as follows in Table 9. BL is represented in Figure 13.

Table 9: RCOG BL classification

Reassuring	Suspicious	Pathological
110-160 bpm	100-109 bpm 161-180 bpm	<100 bpm or >180 bpm

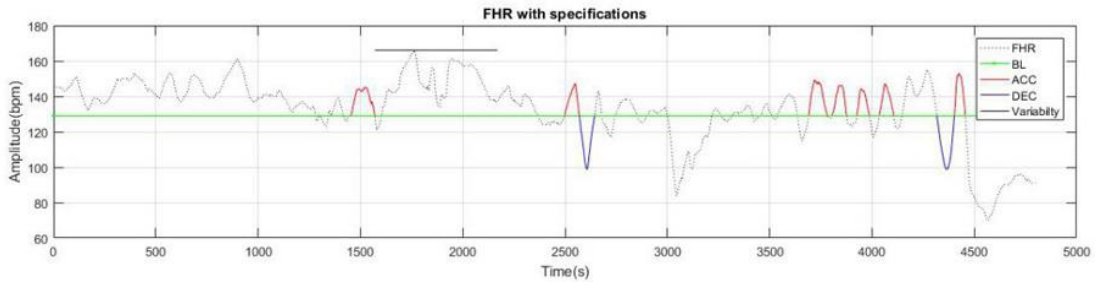

Figure 13: Representing BL in FHR signal

3.6.4 BaseLine Variability

This section describes estimating BLV in FHR Signals. BLV refers to the FHR variation from one beat to the next beat. BLV in FHR patterns is defined as a small variation in the BL. According to the NCIHD CTG guideline feature extraction, a BLV is occurring between 2-10 minutes, which means the length of the BLV should be at least 2 minutes and maximum 10 minutes based on the variation of the FHR by bpm. According to NICHD CTG guideline feature extraction, BLV are categorized into: (1) Absent, (2) Minimal, (3) Moderate, and (4) Marked, the details is provided in Table 10. In this work an algorithm is designed and implemented in order to detect BLV based on NICHD guideline for feature extraction [11]. A sample of BLV which is detected in a CTG record of this work is illustrated in Figure 14.

Table 10: NICHD CTG Guideline for BLV

BLV	Variation (bpm)
Absent	Zero
Minimal	<5
Moderate	6-25
Marked	>25

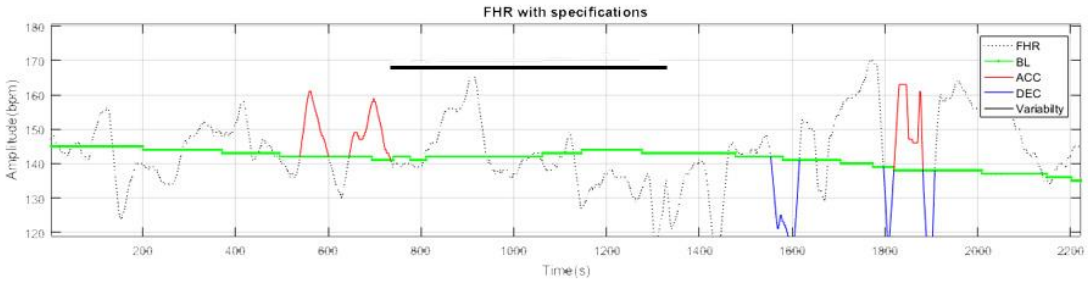

Figure 14: Representing BLV in FHR Signal

3.6.5 Acceleration

This section describes Acc and proposed algorithm in order to detect Acc. According to NICHD guideline feature extraction, Acc is defined an increase in BL which is happened before 32 weeks and after 32 weeks of Gestational age, before 32 weeks for 10 or more seconds increase for more than 10 bpm that return to BL within 2 minutes and after 32 weeks for 15 or more seconds increase for more than 15 bpm that return to BL within 2 minutes. In this work, Acc are extracted from records based on NICHD guideline feature extraction. Figure 15 presents the architecture of the Acc based on NICHD guideline feature extraction. Figure 16 shows the Acc detection algorithm in this work.

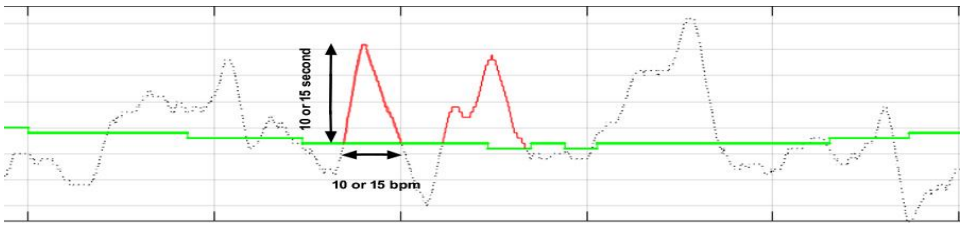

Figure 15: Representing Acc in FHR Signal

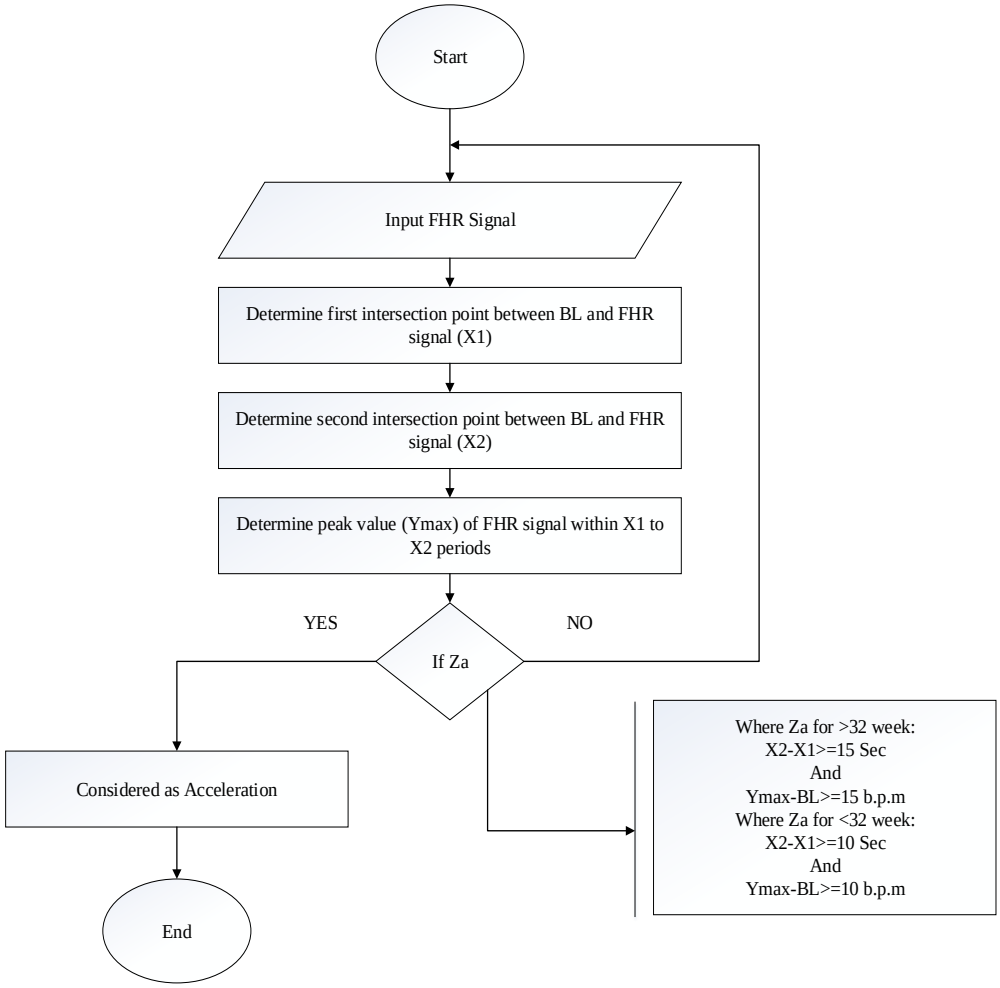

Figure 16: Acc Detection Algorithm [12]

3.6.6 Deceleration

This section describes Dec and proposed algorithm in order to detect Dec in CTG records. NICHD guideline feature extraction defines a Dec in FHR signal which is happened before 32 weeks and after 32 weeks of Gestational age, before 32 weeks for 10 or more seconds decrease for more than 10 bpm that return to BL within 2 minutes, after 32 weeks for 15 or more seconds decrease for more than 15 bpm that return to BL within 2 minutes. In this work, an automated algorithm is implemented in order to detect Dec in FHR records based on NICHD guideline feature extraction. Figure 17 presents the architecture of the Dec based on NICHD guideline. Figure 18 shows the Dec detection algorithm in this work. Based on NICHD feature extraction and

classification, detecting type of Dec is associated with UC activities, different automated algorithms are implemented. According to NICHD guideline, Dec is divided into: Late, Early and Variable. In this section, UC signals are analysed by automated algorithm in order to find and detect the peak of a contraction in UC Signals.

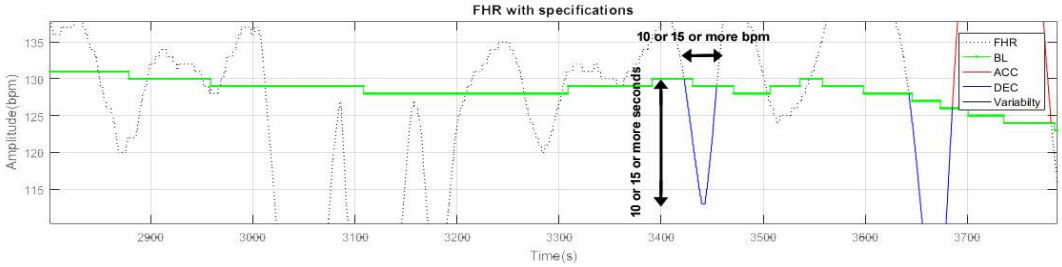

Figure 17: Representing Dec in FHR

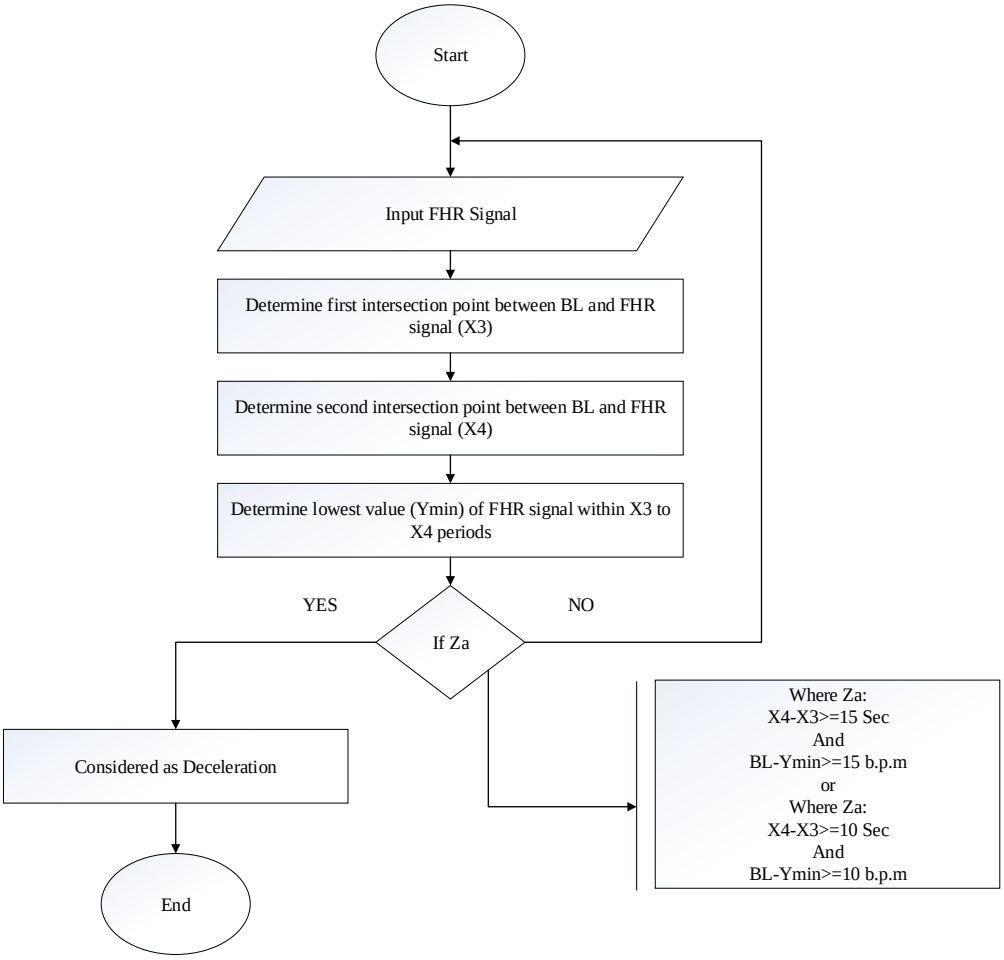

Figure 18: Dec Detection Algorithm [12]

3.7 Classification by Proposed Algorithm

In this section, NICHD CTG classification is used in order to classify CTG record traces. Based on NICHD CTG, traces are classified in three group Normal, Indeterminate and Abnormal. Table 11 presents NICHD Guideline [11] for CTG trace Classification. An automated algorithm is implemented to classify CTG traces based on NICHD guideline in this work.

Table 11: NICHD CTG Guideline for Classification

	BL	**BLV**	**Acc**	**Dec**
Normal	110-160 bpm	At least Moderate (6-25 bpm)	May or may not be present	No late or Variable Dec
Indeterminate	Bradycardia with normal BLV, Tachycardia	Minimal or Marked		
Abnormal	<110 or Sinusoidal	Absent		Recurrent Late/Variable Dec

3.8 Classification by Decision Tree in Machine Learning

This section describes Decision Tree classifier in Machine Learning. Decision Tree has been implemented in this work as Machine Learning classifier. Most experimental Machine Learning systems must be aware that the type of class in a given dataset exists. There is a vector attribute value for each system, and a maps function corresponds from class to class attribute values. Decision Tree classifier is one of the most popular classification models in Machine Learning. The propose of the Decision Tree classifier is to create a model to estimate and predict the target variable based on the various input variables [25]. CTU-UHB CTG dataset patterns have been interpreted by proposed algorithm in this work and also this dataset interpreted by expert obstetrician at Yaşam Hospital. Decision Tree classifier in Machine Learning

has been implemented. A training set and a Test set has been given to the implemented Decision Tree classifier in Machine Learning. The observation of the expert obstetricians has been selected as Training Set and the result of feature extraction and classification of CTG records of this work has been selected as Test Set in Decision Tree classifier and the value of accuracy calculated as shown below:

$$\text{Accuracy} = 90\%$$

3.9 Research Limitations

As it is for every study, this thesis had the following limitations:

- Each researcher proposed different methods with different accuracy and different dataset has been used.
- Finding related works with same topic and same database in this thesis was not available based on different datasets have been used and in some studies UC was not considered, and also different CTG guidelines for feature extraction and classification have been used in some related works.
- Expert obstetricians were busy in order to interpret CTG dataset

Chapter 4

EXPERIMENTAL RESULTS AND EVALUATION

4.1 Introduction

This chapter describes the process of validation of the proposed methodologies. The methodologies employed in feature extraction and classification. The evaluation of the methodology used in feature extraction and classification. Expert Obstetricians and researchers have been interpreted the CTG patterns with different methods in order to analyze and estimate the status of Fetal through FHR and UC. The experimental results and evaluation, are based on experimental, the first experimental result is interpreting the CTG records in a Short Term Variation (STV) that considered based on NST in pregnancy, the second experimental result are interpreting the CTG records in a Long Term Variation (LTV). 20 records of all 552 interpreted records are selected in order to evaluate and compare with the expert obstetrician's result and result of other related works.

4.2 Experimental Results and Evaluation

In this section the results are obtained from the feature extraction algorithms developed using different programming techniques and the classification guidelines based on the NICHD, FIGO and RCOG. We tried to find the same dataset that is used by different related works. Different researchers used different methods with different datasets, some of researchers considered only FHR signal in their work, some of researchers considered UC as well. Some of researchers considered both but with different datasets, some of researchers considered both FHR signal, UC signal and same dataset

as this work but their dataset was interpreted by expert obstetricians and all feature extraction and classification of the CTG records are evaluated by eye and hand. It was not easy to find same related works as this work with considering NST method in pregnancy with same database and considering pre-processing steps, feature extraction of CTG records, classification CTG traces and applying Machine Learning in order to evaluate and interpret the CTG records.

4.2.1 Short Term Variation

Based on the NST in pregnancy, Fetal monitoring process is considered for STV. In NST in pregnancy, the first analysis is made in 20 minutes. If the all criteria are met, the system detects that result of the NST is positive and Fetus is healthy, if all criteria are Not met, Fetal Monitoring will continue until all criteria will met. Estimating value of BL, BLV, number of Acc, number of Dec, type of Dec and CTG pattern classification of CTG records which interpreted based on NICHD guideline have been estimated by different algorithms in this work. Obstetrician was asked to extract features which are BL, BLV, number of Acc, number of Dec, type of Dec and finally classification of the CTG records based on NICHD guideline in STV. The feature extraction and classification algorithms explained in Chapter 3 is tested over the first 20-minutes of 20 CTG dataset records. The results obtained from the algorithm are stored in an Excel file for further analysis, the same 20-minutes of same 20 set of the CTG records is interpreted by an expert obstetrician at a Hospital in Famagusta, Cyprus. The result of this work is provided in Table 12 and result of the expert obstetrician is provided in Table 13.

Table 12: NST Results of this work

Patient ID	BL	BLV	Acc (within 2 min)	Dec (within 2 min)				NST Result 1.Normal 2.Indeterminate 3.Abnormal
				Early	Late	Variable	Total	
1043	139	18	0	0	0	0	0	1
1042	156	14	0	0	0	0	0	1
1037	130	30	0	1	4	2	7	2
1004	151	8	0	0	0	0	0	1
1035	146	13	0	0	0	0	0	1
1006	136	19	1	1	1	0	1	1
1007	130	69	0	0	1	0	1	2
1008	125	8	0	0	2	0	2	2
1032	137	0	2	2	0	0	2	2
1010	131	11	0	1	1	1	3	2
1031	149	10	0	0	0	0	0	1
1030	128	49	0	0	0	0	0	2
1029	146	10	1	0	0	0	0	1
1014	135	15	0	0	2	1	3	2
1027	139	21	4	1	3	0	4	2
1024	129	40	0	0	1	0	1	2
1017	159	15	0	0	0	0	0	1
1022	140	13	0	2	1	1	4	2
1019	147	10	0	0	0	0	0	1
1020	149	5	0	1	2	0	3	2

Table 13: NST Results of Expert Obstetrician's Observation

Patient ID	BL	BLV	Acc (within 2 min)	Dec (within 2 min)				NST Result 1.Normal 2.Indeterminate 3.Abnormal
				Early	Late	Variable	total	
1043	140	>10	3	-	-	-	-	1
1042	150	>10	2	-	-	4	4	2
1037	130	>20	5	8	-	-	8	1
1004	150	7-10	9	-	-	-	-	1
1035	145	>10	3	1	-	-	1	1
1006	130	>10	2	-	-	2	2	2
1007	140	<5	-	1	1	1	3	2
1008	125	>10	2	-	-	-	-	2
1032	135	>10	4	3	-	-	3	1
1010	140	<5	-	-	-	6	6	2
1031	150	>10	2	1	-	-	1	1
1030	120	>10	3	-	-	-	-	1
1029	145	>10	4	2	-	-	2	2
1014	138	>10	4	3	-	-	3	1
1027	150	>10	2	5	1	-	6	3
1024	135	>10	3	-	-	3	3	2
1017	160	>10	6	-	1	-	1	2
1022	140	>10	1	6	1	-	7	3
1019	148	>10	4	-	-	1	1	1
1020	150	>10	3	4	-	-	4	2

4.2.2 Long Term Variation

This section shows the experimental results and evaluation; in this thesis a LTV is considered, All the CTG records have different length, all this records have been interpreted and analyzed by different algorithms. 20 CTG records are selected from all results in order to evaluate and compare with related works. Researches shows that different CTG guideline feature extraction and classification are used. Results of this work of LTV feature extraction and classification of CTU-UHB dataset based on NICHD guideline is provided in Table 14. Results of CTGOAS [22] in LTV feature extraction and classification of CTU-UHB dataset based on RCOG guideline are provide in Table 15.

Table 14: Results of this work in LTV based on NICHD

Patient ID	**BL**	**BLV**	**Acc (within 2 min)**	**Dec (within 2 min)**				**NICHD Classification** 1.Normal 2.Indeterminate 3.Abnormal
				Early	**Late**	**Variable**	**Total**	
1001	133	28	10	4	6	0	10	2
1002	145	27	9	4	9	0	13	2
1003	121	12	2	2	1	4	7	2
1004	134	30	7	3	2	1	6	2
1005	119	14	9	2	3	3	8	2
1006	139	19	2	1	2	0	3	2
1007	123	70	1	1	0	0	1	2
1008	123	9	5	10	0	0	10	2
1009	132	10	5	2	3	2	7	2
1010	126	10	1	2	3	0	5	2
1011	124	32	6	4	5	2	11	2
1012	121	12	8	4	6	2	12	2
1013	128	12	13	10	6	2	18	2
1014	128	19	9	5	6	1	12	2
1015	130	35	4	2	7	1	10	2
1016	134	46	6	12	6	0	18	2
1017	145	14	8	1	10	0	11	2
1018	140	59	8	5	1	1	7	2
1019	134	45	5	1	1	0	2	2
1020	148	5	1	7	3	0	10	2

Table 15: Results of CTGOAS Analyzer in LTV based on RCOG

Patient ID	BL	BLV	Acc (15 sec)	Dec (15 second)				RCOG Classification 1.Reassuring 2.Non-reassuring 3.Abnormal
				Early	Late	Variable	Total	
1001	137	N/A	22	N/A	N/A	N/A	22	N/A
1002	146	N/A	20	N/A	N/A	N/A	22	N/A
1003	122	N/A	11	N/A	N/A	N/A	15	N/A
1004	136	N/A	11	N/A	N/A	N/A	20	N/A
1005	119	N/A	13	N/A	N/A	N/A	18	N/A
1006	139	N/A	15	N/A	N/A	N/A	15	N/A
1007	123	N/A	6	N/A	N/A	N/A	14	N/A
1008	123	N/A	16	N/A	N/A	N/A	27	N/A
1009	135	N/A	8	N/A	N/A	N/A	19	N/A
1010	126	N/A	7	N/A	N/A	N/A	21	N/A
1011	125	N/A	26	N/A	N/A	N/A	31	N/A
1012	128	N/A	4	N/A	N/A	N/A	21	N/A
1013	128	N/A	22	N/A	N/A	N/A	21	N/A
1014	132	N/A	19	N/A	N/A	N/A	29	N/A
1015	137	N/A	19	N/A	N/A	N/A	18	N/A
1016	139	N/A	11	N/A	N/A	N/A	20	N/A
1017	153	N/A	16	N/A	N/A	N/A	19	N/A
1018	145	N/A	26	N/A	N/A	N/A	21	N/A
1019	135	N/A	17	N/A	N/A	N/A	17	N/A
1020	151	N/A	0	N/A	N/A	N/A	23	N/A

The author in [12] present the result of interpreting three CTG dataset with 30-minute length which has different CTG records with CTU-UHB of this thesis. In that paper the feature extraction and classification are evaluated by RCOG guideline. The results from algorithms are compared with different expert obstetrician's observation. Obstetricians were asked to extract features and classification CTG patterns. Result of 15 signals (Signal 16-Signal 30) after feature extraction and classification of that paper are provided in Table 16.

Table 16: Results of other work in LTV with different dataset based on RCOG

Patient ID	BL	BLV	Acc (15 sec)	Dec (15 sec)				RCOG Classification N=Normal S=Suspicious P=Pathological
				Early	Late	Variable	Total	
S16	127	7	8	-	-	-	-	N
S17	199	5	10	-	-	-	-	P
S18	126	8	8	-	1	-	1	P
S19	77	9	5	-	-	-	-	P
S20	149	5	4	-	-	-	-	N
S21	130	8	6	-	-	-	-	N
S22	207	13	7	-	-	-	-	S
S23	65	8	11	-	-	-	-	P
S24	141	9	3	-	-	-	-	N
S25	133	15	4	-	-	-	-	N
S26	129	5	0	-	-	-	-	S
S27	134	8	0	-	-	-	-	S
S28	126	7	6	-	-	-	-	N
S29	126	11	8	-	-	-	-	N
S30	126	9	6	-	-	-	-	N

4.3 Discussion

NST in pregnancy is performed based on NICHD feature extraction and classification. Experimental results and evaluation show, according to result of CTGOAS Analyzer [22] in Table 15, total number of Acc is 22. On the other hand, the number of Acc in this work is 10 that is provided in Table 14. This difference between features frequency depends on the CTG standard guideline for feature extraction of the FHR. According to the NICHD guideline, an Acc happens within 2 minute, whereas an Acc based on RCOG guideline happens in 15 seconds. Feature extraction by eye and hand are not very accurate.

Chapter 5

CONCLUSION

In this thesis, analyzing current fetus risk condition through FHR and UC values by different algorithms and machine learning are evaluated and compared with related works. Doppler devices produce NST graphs. CTU-UHB intrapartum CTG database that contain 552 records is used. Each record has FHR signal and UC Signal. Different algorithms are implemented in order to extract CTG feature and perform classification based on NICHD guideline. In feature extraction stage, BL, BLV, Acc, Dec and type of Dec are extracted from FHR signals. In order to detect the type of the Dec, UC has been considered and interpreted. All the CTG records are classified based on NICHD guideline in three distinct groups, which are Normal, Indeterminate and Abnormal. Automated classification algorithm and Decision Tree is implemented in this work. The result of expert obstetrician has been used for Training set and the result of this work is used as Test Set in Decision Tree classifier and accuracy has been calculated as 90 percent. The result of this thesis has been evaluated and compared with different related works and expert obstetrician. Experimental results show that feature extraction and classification of CTG records based on automated algorithms are more accurate than expert obstetrician's results.

REFERENCES

[1] Fergus, P., Selvaraj, M., & Chalmers, C. (2018). Machine learning ensemble modelling to classify caesarean section and vaginal delivery types using Cardiotocography traces. *Computers in biology and medicine*, 93, 7-16.

[2] NYBOE, E. L. (2011). An Algorithm Based on the Dawes Redman Criteria for Automated Fetal Heart Rate Analysis. Chalmers University of Technology Gothenburg, Sweden.

[3] Nageotte, M. P. (2015, June). Fetal heart rate monitoring. *In Seminars in Fetal and Neonatal Medicine* (Vol. 20, No. 3, pp. 144-148). WB Saunders.

[4] Küçükkelepçe, D. Ş., & Taşhan, S. T. (2018). The effect of music on the results of a non-stress test: A non-randomized controlled clinical trial. *European Journal of Integrative Medicine,* 18, 8-12.

[5] Zach, L., Chudáček, V., Kužílek, J., Spilka, J., Huptych, M., Burša, M., & Lhotská, L. (2011, September). Mobile CTG—Fetal heart rate assessment using Android platform. *In Computing in Cardiology,* 2011 (pp. 249-252). IEEE.

[6] A Cardiotocograph recording fetal heart rate and uterine contractions. (2018, January 17). Retrieved from https://en.wikipedia.org/wiki/Cardiotocography

[7] A typical CTG output for a woman not in labour. A: Fetal heartbeat; B: Indicator showing movements felt by mother (caused by pressing a button); C: Fetal

movement; D: Uterine contractions. (2018, January 17). Retrieved from https://en.wikipedia.org/wiki/Cardiotocography

[8] Li, J., Huang, L., Shen, Z., Zhang, Y., Fang, M., Li, B., ... & Wang, H. (2018). Automatic Classification of Fetal Heart Rate Based on Convolutional Neural Network. *Internet of Things Journal*.

[9] Nidhal, S., Ali, M. M., & Najah, H. (2010). A novel cardiotocography fetal heart rate baseline estimation algorithm. *Scientific Research and Essays*, 5(24), 4002-4010.

[10] Al-Yousif, S. N., & Ali, M. M. (2011). Cardiotocography trace pattern evaluation using MATLAB program. *In International Conference on Biomedical Engineering and Technology* (Vol. 11, pp. 153-158).

[11] Macones, G. A., Hankins, G. D., Spong, C. Y., Hauth, J., & Moore, T. (2008). The 2008 National Institute of Child Health and Human Development workshop report on electronic fetal monitoring: update on definitions, interpretation, and research guidelines. *Journal of Obstetric, Gynecologic, & Neonatal Nursing*, 37(5), 510-515.

[12] Alyousif, S., Mohd, M. A., Bilal, B., Sheikh, M., & Algunaidi, M. (2016). Rule-Based Algorithm for Intrapartum Cardiotocograph Pattern Features Extraction and Classification. *Health Science Journal*, 10(6), 1.

[13] Das, S., Roy, K., & Saha, C. K. (2015, February). Determination of window size for baseline estimation of fetal heart rate using CTG. *In Computer, Communication, Control and Information Technology (C3IT),* 2015 Third International Conference on (pp. 1-5). IEEE.

[14] Hoh, J. K., Park, M. I., Park, Y. S., & Koh, S. K. (2012). The significance of amplitude and duration of fetal heart rate acceleration in non-stress test analysis. *Taiwanese Journal of Obstetrics and Gynecology*, 51(3), 397-401.

[15] Sahin, H., & Subasi, A. (2015). Classification of the cardiotocogram data for anticipation of fetal risks using machine learning techniques. *Applied Soft Computing*, 33, 231-238.

[16] Arif, M. (2015). Classification of cardiotocograms using random forest classifier and selection of important features from cardiotocogram signal. *Biomaterials and Biomechanics in Bioengineering*, 2(3), 173-183.

[17] Agostinelli, A., Belgiovine, G., Fiorentino, M. C., Turri, G., Sbrollini, A., Burattini, L., ... & Fioretti, S. (2017). Association between Accelerations and Decelerations of Fetal Heart Rate. *In EMBEC & NBC 2017* (pp. 1125-1128). Springer, Singapore.

[18] Feng, G., Quirk, J. G., & Djurić, P. M. (2017, August). Recovery of missing samples in fetal heart rate recordings with Gaussian processes. *In Signal Processing Conference (EUSIPCO)*, 2017 25th European (pp. 261-265). IEEE.

[19] Cömert, Z., Kocamaz, A. F., & Subha, V. (2018). Prognostic model based on image-based time-frequency features and genetic algorithm for fetal hypoxia assessment. *Computers in biology and medicine*.

[20] Cristian Rotariu, Alexandru Pasarica, Gladiola Andruseac, Hariton Costin and Dragos Nemescu. (2014). Automatic Analysis of the Fetal Heart Rate Variability and Uterine Contractions. *International Conference and Exposition on Electrical and Power Engineering* (EPE 2014), 16-18 October, Iasi, Romania.

[21] Al-Yousif, S. N., & Ali, M. M. (2011). Cardiotocography trace pattern evaluation using MATLAB program. *In International Conference on Biomedical Engineering and Technology* (Vol. 11, pp. 153-158).

[22] Cömert, Z., & Kocamaz, A. F. (2017, September). A novel software for comprehensive analysis of cardiotocography signals "CTG-OAS". *In Artificial Intelligence and Data Processing Symposium* (IDAP), 2017 International (pp. 1-6). IEEE.

[23] CTU-UHB Intrapartum Cardiotocography dataset. (2018, December 17). Retrieved from https://physionet.org/physiobank/database/ctu-uhb-ctgdb/

[24] Noor, N. M., Abdullah, M. M. A. B., Yahaya, A. S., & Ramli, N. A. (2015). Comparison of linear interpolation method and mean method to replace the missing values in environmental data set. Small, 5, 10.

[25] Guggari, S., Kadappa, V., & Umadevi, V. (2018). Non-sequential partitioning approaches to decision tree classifier. *Future Computing and Informatics Journal*, 3(2), 275-285.

APPENDICES

Appendix A: BL value before and after pre-processing signals

	Before Pre-Processing		After Pre-Processing			Before Pre-Processing		After Pre-Processing	
Patient ID	**With Zero**	**With NaN**	**With Zero**	**With NaN**	**Patient ID**	**With Zero**	**With NaN**	**With Zero**	**With NaN**
1001	106	137	133	133	**1277**	92	132	124	124
1002	122	147	145	145	**1278**	109	153	153	153
1003	97	122	121	121	**1279**	129	149	148	148
1004	133	134	134	134	**1280**	73	110	125	125
1005	92	117	119	119	**1281**	101	109	130	130
1006	105	139	139	139	**1282**	87	102	126	126
1007	102	131	123	123	**1283**	141	149	148	148
1008	111	122	123	123	**1284**	89	117	124	124
1009	88	134	132	132	**1285**	91	129	129	129
1010	111	125	126	126	**1286**	105	136	135	135
1011	117	124	124	124	**1287**	118	136	131	131
1012	82	124	121	121	**1288**	98	123	122	122
1013	96	121	128	128	**1289**	126	148	147	147
1014	110	130	128	128	**1290**	132	146	146	146
1015	99	135	130	130	**1291**	109	160	149	149
1016	104	131	134	134	**1292**	123	126	126	126
1017	124	150	145	145	**1293**	89	116	136	136
1018	109	145	140	140	**1294**	105	117	116	116
1019	130	134	134	134	**1295**	111	143	138	138
1020	147	148	148	148	**1296**	110	143	141	141
1021	111	130	129	129	**1297**	99	136	136	136
1022	126	130	130	130	**1298**	137	139	140	140
1023	123	138	137	137	**1299**	111	130	130	130
1024	125	132	132	132	**1300**	90	119	125	125
1025	102	113	112	112	**1301**	90	122	122	122
1026	95	119	127	127	**1302**	120	142	145	145
1027	113	139	133	133	**1303**	129	142	141	141
1028	119	139	142	142	**1304**	99	119	127	127
1029	115	142	137	137	**1305**	92	135	132	132
1030	129	139	140	140	**1306**	108	131	129	129
1031	136	137	138	138	**1307**	111	116	114	114
1032	120	138	137	137	**1308**	134	135	136	136
1033	136	144	145	145	**1309**	97	131	127	127
1034	115	141	134	134	**1310**	92	129	129	129
1035	141	144	144	144	**1311**	108	144	143	143
1036	139	155	155	155	**1312**	106	126	124	124
1037	111	126	127	127	**1313**	129	166	161	161
1038	105	131	132	132	**1314**	135	135	136	136
1039	90	122	120	120	**1315**	147	147	148	148
1040	102	124	120	120	**1316**	143	145	145	145
1041	125	137	136	136	**1317**	106	109	109	109
1042	130	146	140	140	**1318**	85	135	125	125
1043	86	128	128	128	**1319**	139	142	142	142
1044	90	135	129	129	**1320**	107	138	139	139
1045	129	141	136	136	**1321**	96	129	125	125
1046	126	128	128	128	**1322**	130	131	131	131
1047	108	145	141	141	**1323**	118	120	120	120
1048	108	145	139	139	**1324**	128	129	129	129
1049	97	125	125	125	**1325**	115	134	133	133
1050	101	120	125	125	**1326**	109	121	121	121
1051	97	135	136	136	**1327**	127	134	133	133

1052	106	132	150	150	**1328**	84	127	127	127
1053	118	139	140	140	**1329**	123	135	137	137
1054	110	150	146	146	**1330**	129	141	140	140
1055	115	117	118	118	**1331**	120	134	133	133
1056	100	127	128	128	**1332**	125	146	143	143
1057	89	129	133	133	**1333**	124	156	156	156
1058	66	123	137	137	**1334**	124	146	144	144
1059	100	133	133	133	**1335**	107	143	144	144
1060	85	117	126	126	**1336**	102	128	127	127
1061	101	121	115	115	**1337**	124	130	130	130
1062	118	147	144	144	**1338**	67	120	121	121
1063	102	135	132	132	**1339**	119	136	136	136
1064	80	126	124	124	**1340**	142	143	144	144
1065	109	143	141	141	**1341**	118	125	126	126
1066	104	120	120	120	**1342**	130	134	134	134
1067	89	121	120	120	**1343**	123	135	145	145
1068	109	140	140	140	**1344**	98	124	124	124
1069	120	123	123	123	**1345**	105	135	144	144
1070	118	138	137	137	**1346**	147	150	150	150
1071	67	119	116	116	**1347**	99	122	120	120
1072	113	173	168	168	**1348**	99	122	139	139
1073	69	124	124	124	**1349**	123	140	151	151
1074	116	120	121	121	**1350**	123	138	147	147
1075	100	136	136	136	**1351**	83	144	142	142
1076	96	143	149	149	**1352**	132	143	143	143
1077	116	146	148	148	**1353**	115	135	147	147
1078	155	165	163	163	**1354**	105	134	134	134
1079	99	130	129	129	**1355**	131	150	148	148
1080	92	131	130	130	**1356**	91	125	135	135
1081	131	135	135	135	**1357**	88	142	134	134
1082	87	134	139	139	**1358**	95	167	168	168
1083	97	118	133	133	**1359**	113	124	123	123
1084	114	133	134	134	**1360**	118	137	136	136
1085	142	147	146	146	**1361**	58	106	115	115
1086	107	133	129	129	**1362**	122	146	143	143
1087	71	124	117	117	**1363**	113	138	136	136
1088	107	129	127	127	**1364**	115	147	146	146
1089	96	124	122	122	**1365**	108	140	133	133
1090	120	141	140	140	**1366**	113	140	137	137
1091	91	125	121	121	**1367**	92	119	133	133
1092	104	127	119	119	**1368**	130	138	138	138
1093	103	130	132	132	**1369**	113	142	142	142
1094	118	141	140	140	**1370**	140	147	145	145
1095	119	139	139	139	**1371**	136	140	140	140
1096	89	119	126	126	**1372**	87	139	141	141
1097	145	147	147	147	**1373**	94	116	116	116
1098	131	159	160	160	**1374**	106	132	130	130
1099	107	128	131	131	**1375**	120	136	136	136
1100	113	130	128	128	**1376**	87	116	103	103
1101	109	123	125	125	**1377**	121	136	135	135
1102	119	135	136	136	**1378**	126	135	134	134
1103	145	147	148	148	**1379**	116	121	121	121
1104	123	135	135	135	**1380**	89	112	133	133
1105	86	124	118	118	**1381**	112	120	120	120
1106	115	131	130	130	**1382**	106	130	128	128
1107	95	124	124	124	**1383**	75	119	121	121
1108	80	121	122	122	**1384**	119	154	150	150
1109	153	161	162	162	**1385**	149	154	154	154

1110	95	98	98	98	**1386**	112	161	161	161
1111	112	112	113	113	**1387**	118	125	126	126
1112	120	136	135	135	**1388**	133	134	134	134
1113	126	145	144	144	**1389**	113	118	118	118
1114	132	139	140	140	**1390**	145	163	161	161
1115	149	156	156	156	**1391**	130	131	131	131
1116	119	132	133	133	**1392**	133	160	158	158
1117	102	129	127	127	**1393**	133	134	135	135
1118	114	123	135	135	**1394**	120	151	146	146
1119	91	109	120	120	**1395**	104	119	120	120
1120	102	135	135	135	**1396**	117	130	144	144
1121	81	125	125	125	**1397**	126	130	129	129
1122	98	122	122	122	**1398**	117	120	120	120
1123	137	148	146	146	**1399**	120	130	128	128
1124	106	128	140	140	**1400**	112	116	116	116
1125	103	137	136	136	**1401**	99	127	126	126
1126	112	121	120	120	**1402**	128	151	150	150
1127	123	125	125	125	**1403**	101	133	128	128
1128	91	109	110	110	**1404**	96	134	130	130
1129	134	140	140	140	**1405**	97	122	122	122
1130	96	131	125	125	**1406**	107	124	123	123
1131	82	126	128	128	**1407**	105	146	145	145
1132	92	132	118	118	**1408**	95	132	157	157
1133	117	140	138	138	**1409**	149	149	149	149
1134	80	121	121	121	**1410**	104	129	128	128
1135	111	140	139	139	**1411**	102	135	135	135
1136	122	138	137	137	**1412**	116	117	117	117
1137	73	129	133	133	**1413**	123	137	137	137
1138	125	149	147	147	**1414**	110	139	137	137
1139	129	148	147	147	**1415**	96	130	131	131
1140	102	128	128	128	**1416**	122	131	131	131
1141	121	139	138	138	**1417**	100	143	139	139
1142	118	144	145	145	**1418**	111	127	126	126
1143	111	127	127	127	**1419**	112	135	132	132
1144	79	130	124	124	**1420**	140	144	144	144
1145	112	142	140	140	**1421**	105	121	121	121
1146	103	139	138	138	**1422**	77	112	115	115
1147	95	112	112	112	**1423**	125	126	126	126
1148	95	112	141	141	**1424**	111	137	135	135
1149	120	124	125	125	**1425**	71	128	144	144
1150	125	145	146	146	**1426**	141	141	142	142
1151	87	125	123	123	**1427**	120	134	133	133
1152	105	122	121	121	**1428**	98	128	127	127
1153	135	142	142	142	**1429**	118	131	143	143
1154	116	127	127	127	**1430**	100	140	142	142
1155	133	134	134	134	**1431**	68	142	145	145
1156	104	147	144	144	**1432**	88	129	136	136
1157	147	161	159	159	**1433**	93	121	126	126
1158	80	121	119	119	**1434**	100	135	132	132
1159	123	125	125	125	**1435**	107	127	128	128
1160	83	126	127	127	**1436**	78	123	128	128
1161	134	144	145	145	**1437**	120	133	131	131
1162	108	109	110	110	**1438**	100	120	120	120
1163	100	119	127	127	**1439**	134	146	146	146
1164	61	135	128	128	**1440**	118	148	152	152
1165	109	126	133	133	**1441**	145	147	147	147
1166	118	123	122	122	**1442**	123	129	129	129
1167	126	126	127	127	**1443**	108	138	143	143

1168	128	128	129	129	**1444**	94	129	146	146
1169	128	141	141	141	**1445**	124	142	142	142
1170	123	123	124	124	**1446**	112	132	138	138
1171	76	122	123	123	**1447**	108	129	151	151
1172	118	135	144	144	**1448**	108	129	135	135
1173	67	134	137	137	**1449**	90	128	128	128
1174	96	138	139	139	**1450**	148	159	158	158
1175	133	139	139	139	**1451**	90	121	120	120
1176	114	117	118	118	**1452**	69	119	109	109
1177	116	127	125	125	**1453**	128	145	144	144
1178	94	118	132	132	**1454**	136	139	139	139
1179	121	148	155	155	**1455**	97	129	126	126
1180	121	125	124	124	**1456**	101	107	107	107
1181	105	134	132	132	**1457**	120	134	133	133
1182	139	161	161	161	**1458**	95	120	118	118
1183	123	137	138	138	**1459**	127	132	132	132
1184	80	123	121	121	**1460**	123	148	148	148
1185	117	140	138	138	**1461**	106	125	127	127
1186	86	124	124	124	**1462**	108	135	134	134
1187	90	126	125	125	**1463**	96	126	124	124
1188	141	163	163	163	**1464**	147	150	150	150
1189	102	119	133	133	**1465**	111	138	138	138
1190	97	144	137	137	**1466**	109	133	134	134
1191	104	134	129	129	**1467**	121	136	134	134
1192	145	154	160	160	**1468**	129	139	139	139
1193	132	137	138	138	**1469**	90	126	129	129
1194	124	129	130	130	**1470**	107	137	136	136
1195	117	121	120	120	**1471**	116	128	128	128
1196	84	129	132	132	**1472**	94	125	124	124
1197	130	130	131	131	**1473**	110	137	135	135
1198	70	131	139	139	**1474**	94	127	124	124
1199	75	127	127	127	**1475**	94	133	134	134
1200	100	120	118	118	**1476**	122	138	139	139
1201	103	124	123	123	**1477**	91	120	119	119
1202	105	129	127	127	**1478**	140	144	144	144
1203	134	138	139	139	**1479**	134	135	136	136
1204	105	119	120	120	**1480**	139	160	154	154
1205	103	117	118	118	**1481**	109	145	148	148
1206	107	128	136	136	**1482**	107	136	135	135
1207	132	141	141	141	**1483**	130	136	135	135
1208	121	126	127	127	**1484**	128	139	139	139
1209	113	127	126	126	**1485**	114	118	118	118
1210	93	131	132	132	**1486**	134	139	138	138
1211	106	125	125	125	**1487**	108	123	121	121
1212	154	154	155	155	**1488**	96	128	124	124
1213	115	129	129	129	**1489**	137	139	139	139
1214	95	125	125	125	**1490**	118	135	135	135
1215	80	118	119	119	**1491**	136	140	139	139
1216	100	145	147	147	**1492**	92	132	127	127
1217	107	131	125	125	**1493**	106	130	129	129
1218	64	111	129	129	**1494**	115	119	119	119
1219	120	134	132	132	**1495**	123	146	146	146
1220	112	139	140	140	**1496**	96	130	129	129
1221	136	139	139	139	**1497**	119	133	133	133
1222	85	118	119	119	**1498**	121	135	134	134
1223	101	118	127	127	**1499**	121	124	125	125
1224	153	161	160	160	**1500**	93	131	127	127
1225	103	122	130	130	**1501**	78	143	137	137

1226	122	130	130	130	**1502**	101	115	115	115
1227	100	130	132	132	**1503**	117	130	127	127
1228	95	144	141	141	**1504**	105	136	140	140
1229	122	124	124	124	**1505**	127	129	129	129
1230	136	144	144	144	**1506**	135	142	142	142
1231	104	130	131	131	**2001**	71	132	147	147
1232	98	126	126	126	**2002**	99	128	133	133
1233	114	131	132	132	**2003**	79	135	146	146
1234	115	130	129	129	**2004**	94	139	144	144
1235	93	121	121	121	**2005**	80	145	153	153
1236	123	137	137	137	**2006**	77	136	151	151
1237	122	141	136	136	**2007**	93	144	139	139
1238	83	136	139	139	**2008**	96	156	160	160
1239	114	146	144	144	**2009**	127	168	171	171
1240	86	112	120	120	**2010**	93	133	135	135
1241	89	114	143	143	**2011**	138	147	147	147
1242	97	128	132	132	**2012**	119	160	159	159
1243	86	124	121	121	**2013**	65	140	134	134
1244	65	124	117	117	**2014**	85	133	131	131
1245	136	137	137	137	**2015**	85	129	126	126
1246	116	143	138	138	**2016**	112	135	154	154
1247	88	130	135	135	**2017**	91	136	140	140
1248	88	130	131	131	**2018**	66	124	133	133
1249	109	115	115	115	**2019**	73	125	137	137
1250	115	116	116	116	**2020**	96	137	137	137
1251	88	158	162	162	**2021**	73	135	132	132
1252	96	118	136	136	**2022**	86	129	133	133
1253	122	144	145	145	**2023**	118	151	149	149
1254	102	120	122	122	**2024**	105	139	140	140
1255	116	131	131	131	**2025**	78	125	178	178
1256	105	119	119	119	**2026**	77	124	127	127
1257	121	131	131	131	**2027**	103	155	155	155
1258	102	143	140	140	**2028**	83	141	149	149
1259	105	112	110	110	**2029**	81	112	118	118
1260	124	140	141	141	**2030**	62	109	125	125
1261	92	121	119	119	**2031**	133	158	159	159
1262	87	117	135	135	**2032**	110	138	140	140
1263	120	144	141	141	**2033**	126	155	153	153
1264	138	149	145	145	**2034**	78	115	126	126
1265	116	131	131	131	**2035**	95	128	147	147
1266	96	141	138	138	**2036**	107	158	163	163
1267	96	123	126	126	**2037**	89	118	119	119
1268	92	149	144	144	**2038**	116	150	152	152
1269	122	143	142	142	**2039**	72	127	125	125
1270	99	128	127	127	**2040**	121	175	166	166
1271	111	136	133	133	**2041**	105	153	154	154
1272	115	124	123	123	**2042**	105	153	126	126
1273	114	122	123	123	**2043**	82	125	130	130
1274	123	133	136	136	**2044**	115	153	155	155
1275	121	142	140	140	**2045**	96	114	115	115
1276	124	135	135	135	**2046**	68	110	109	109

Appendix B: Results of this thesis in STV

Patient ID	Patient	Week	BL	Acc	Dec	Late	Early	Variable	BLV	NICHD Classification 1.Normal 2.Interminate 3.Abnormal
1	1001	37	144	2	0	0	0	0	21	1
2	1002	41	153	0	0	0	0	0	22	1
3	1003	40	138	0	0	0	0	0	14	1
4	1004	41	151	0	0	0	0	0	8	1
5	1005	41	127	1	0	0	0	0	4	1
6	1006	38	136	1	1	0	1	0	19	1
7	1007	41	130	0	1	1	0	0	69	2
8	1008	39	125	0	2	2	0	0	8	2
9	1009	39	134	1	4	2	2	0	10	2
10	1010	38	131	0	3	1	1	1	11	2
11	1011	38	133	0	3	2	1	0	34	2
12	1012	41	125	2	5	1	3	1	12	2
13	1013	40	139	0	3	3	0	0	16	2
14	1014	42	135	0	3	2	0	1	15	2
15	1015	41	150	0	1	1	0	0	46	2
16	1016	40	128	2	5	4	1	0	10	2
17	1017	41	159	0	0	0	0	0	15	1
18	1018	39	148	2	1	1	0	0	61	2
19	1019	41	147	0	0	0	0	0	10	1
20	1020	41	149	0	3	2	1	0	5	2
21	1021	37	128	0	0	0	0	0	39	2
22	1022	39	140	0	4	1	2	1	13	2
23	1023	41	131	5	8	6	2	0	24	2
24	1024	40	129	0	1	1	0	0	40	2
25	1025	41	103	2	1	1	0	0	10	2
26	1026	37	112	0	0	0	0	0	31	2
27	1027	41	139	4	4	3	1	0	21	2
28	1028	42	159	0	0	0	0	0	2	1
29	1029	41	146	1	0	0	0	0	10	1
30	1030	40	128	0	0	0	0	0	49	2
31	1031	37	149	0	0	0	0	0	10	1
32	1032	43	137	2	2	0	2	0	0	2
33	1033	40	157	0	2	0	2	0	25	1
34	1034	41	137	1	0	0	0	0	8	1
35	1035	38	146	0	0	0	0	0	13	1
36	1036	40	162	0	0	0	0	0	53	2
37	1037	41	130	0	7	4	1	2	30	2
38	1038	39	133	0	1	1	0	0	14	2
39	1039	40	124	1	1	1	0	0	56	2
40	1040	41	132	0	0	0	0	0	13	1
41	1041	41	145	0	2	0	2	0	22	1
42	1042	41	156	0	0	0	0	0	14	1
43	1043	41	139	0	0	0	0	0	18	1
44	1044	38	141	0	2	1	0	1	8	2
45	1045	40	158	0	0	0	0	0	14	1
46	1046	40	140	1	0	0	0	0	10	1
47	1047	40	116	1	0	0	0	0	7	1
48	1048	39	141	0	1	1	0	0	45	2
49	1049	39	132	1	1	1	0	0	14	2
50	1050	41	135	0	0	0	0	0	2	1

51	1051	40	133	0	1	0	1	0	35	2
52	1052	40	156	0	0	0	0	0	4	1
53	1053	40	140	1	0	0	0	0	9	1
54	1054	37	152	3	4	1	3	0	10	2
55	1055	40	118	0	0	0	0	0	10	1
56	1056	42	130	0	0	0	0	0	7	1
57	1057	41	128	1	3	2	0	1	13	2
58	1058	39	134	0	0	0	0	0	3	1
59	1059	40	127	4	2	1	1	0	12	2
60	1060	39	132	0	0	0	0	0	0	2
61	1061	39	130	2	0	0	0	0	9	1
62	1062	40	149	0	3	2	1	0	18	2
63	1063	41	140	0	0	0	0	0	20	1
64	1064	41	136	0	0	0	0	0	2	1
65	1065	40	148	1	1	1	0	0	11	2
66	1066	41	130	0	3	1	2	0	19	2
67	1067	40	117	1	5	1	3	1	8	2
68	1068	41	144	0	0	0	0	0	12	1
69	1069	38	135	0	1	0	1	0	13	1
70	1070	41	140	0	0	0	0	0	11	1
71	1071	39	152	1	1	0	1	0	0	2
72	1072	41	184	1	3	2	1	0	15	2
73	1073	40	119	1	0	0	0	0	8	1
74	1074	40	129	0	1	1	0	0	11	2
75	1075	41	138	0	1	1	0	0	19	2
76	1076	38	157	0	3	2	1	0	24	2
77	1077	39	126	1	4	1	2	1	27	2
78	1078	39	173	0	0	0	0	0	5	2
79	1079	41	138	0	0	0	0	0	24	1
80	1080	40	136	0	1	1	0	0	22	2
81	1081	37	136	1	1	1	0	0	28	2
82	1082	40	150	1	0	0	0	0	14	1
83	1083	40	120	0	0	0	0	0	38	2
84	1084	40	139	0	0	0	0	0	10	1
85	1085	39	150	0	0	0	0	0	13	1
86	1086	42	117	0	0	0	0	0	21	1
87	1087	37	127	0	1	1	0	0	4	2
88	1088	38	133	0	1	1	0	0	11	2
89	1089	41	127	4	5	2	2	1	45	2
90	1090	39	140	1	1	0	1	0	24	1
91	1091	39	127	0	1	1	0	0	17	2
92	1092	41	114	0	0	0	0	0	5	1
93	1093	40	133	0	0	0	0	0	6	1
94	1094	38	147	0	3	1	2	0	11	2
95	1095	41	145	1	0	0	0	0	22	1
96	1096	39	127	0	0	0	0	0	0	2
97	1097	41	147	0	0	0	0	0	14	1
98	1098	41	169	0	0	0	0	0	20	2
99	1099	40	134	1	1	0	1	0	14	1
100	1100	41	145	0	0	0	0	0	14	1
101	1101	40	139	0	2	1	1	0	15	2
102	1102	39	131	0	3	1	2	0	8	2
103	1103	39	155	0	1	0	1	0	8	1
104	1104	40	144	4	4	0	3	1	0	2
105	1105	41	125	0	0	0	0	0	3	1
106	1106	41	137	0	0	0	0	0	10	1
107	1107	40	125	4	2	0	2	0	10	1
108	1108	40	0	0	0	0	0	0	0	2

109	1109	39	170	0	0	0	0	0	6	2
110	1110	41	101	1	3	0	2	1	8	2
111	1111	38	114	1	4	0	4	0	10	1
112	1112	40	133	0	1	1	0	0	25	2
113	1113	40	154	2	3	2	1	0	62	2
114	1114	39	135	0	0	0	0	0	12	1
115	1115	40	162	0	0	0	0	0	15	2
116	1116	41	126	0	0	0	0	0	4	1
117	1117	40	136	1	0	0	0	0	14	1
118	1118	41	133	2	0	0	0	0	7	1
119	1119	41	100	1	1	0	1	0	70	2
120	1120	41	128	0	1	1	0	0	51	2
121	1121	41	127	2	3	1	1	1	14	2
122	1122	40	125	5	3	2	1	0	11	2
123	1123	40	147	0	1	0	0	1	46	2
124	1124	38	167	0	0	0	0	0	14	2
125	1125	40	140	0	0	0	0	0	12	1
126	1126	40	129	0	0	0	0	0	14	1
127	1127	39	127	0	4	3	1	0	10	2
128	1128	38	111	0	0	0	0	0	17	1
129	1129	38	138	1	6	5	1	0	13	2
130	1130	39	123	4	4	0	3	1	24	2
131	1131	39	138	1	3	1	2	0	40	2
132	1132	40	114	2	0	0	0	0	6	1
133	1133	39	150	0	0	0	0	0	28	2
134	1134	40	119	3	4	0	4	0	20	1
135	1135	39	144	1	0	0	0	0	45	2
136	1136	40	160	0	1	0	1	0	16	1
137	1137	41	137	0	1	0	1	0	2	1
138	1138	40	145	0	2	1	1	0	16	2
139	1139	41	133	3	5	0	4	1	32	2
140	1140	40	136	1	0	0	0	0	11	1
141	1141	40	138	1	0	0	0	0	17	1
142	1142	41	153	1	1	1	0	0	84	2
143	1143	41	119	4	2	1	0	1	15	2
144	1144	40	153	0	0	0	0	0	29	2
145	1145	41	142	1	0	0	0	0	59	2
146	1146	41	149	0	0	0	0	0	7	1
147	1147	39	117	0	0	0	0	0	10	1
148	1148	41	141	1	0	0	0	0	33	2
149	1149	41	121	1	5	0	4	1	27	2
150	1150	40	141	0	0	0	0	0	6	1
151	1151	41	120	0	0	0	0	0	12	1
152	1152	40	120	0	0	0	0	0	11	1
153	1153	40	135	0	4	2	2	0	22	2
154	1154	39	134	0	0	0	0	0	11	1
155	1155	38	134	0	0	0	0	0	14	1
156	1156	41	150	0	0	0	0	0	34	2
157	1157	41	154	1	1	1	0	0	16	2
158	1158	40	131	0	0	0	0	0	56	2
159	1159	41	131	0	1	0	0	1	9	2
160	1160	41	121	1	0	0	0	0	8	1
161	1161	41	146	0	0	0	0	0	10	1
162	1162	39	109	2	3	1	2	0	14	2
163	1163	41	138	0	0	0	0	0	10	1
164	1164	40	139	1	0	0	0	0	43	2
165	1165	38	147	0	0	0	0	0	7	1
166	1166	40	126	1	5	0	5	0	0	2

167	1167	40	130	0	2	0	1	1	10	2
168	1168	37	127	0	3	1	2	0	11	2
169	1169	40	150	1	0	0	0	0	10	1
170	1170	39	130	1	0	0	0	0	8	1
171	1171	40	127	0	1	1	0	0	6	2
172	1172	41	154	0	0	0	0	0	5	1
173	1173	39	135	0	0	0	0	0	4	1
174	1174	39	148	2	0	0	0	0	50	2
175	1175	40	140	0	0	0	0	0	6	1
176	1176	39	123	1	4	4	0	0	8	2
177	1177	41	135	1	0	0	0	0	12	1
178	1178	42	152	1	0	0	0	0	1	1
179	1179	40	172	0	0	0	0	0	1	2
180	1180	39	125	7	10	7	3	0	22	2
181	1181	38	145	0	0	0	0	0	37	2
182	1182	40	164	0	2	0	2	0	68	2
183	1183	42	141	0	0	0	0	0	8	1
184	1184	41	130	2	2	2	0	0	14	2
185	1185	41	141	0	0	0	0	0	3	1
186	1186	40	128	0	0	0	0	0	7	1
187	1187	40	129	0	1	0	0	1	28	2
188	1188	41	167	0	0	0	0	0	15	2
189	1189	39	137	0	0	0	0	0	1	1
190	1190	41	145	1	2	1	1	0	44	2
191	1191	40	131	0	0	0	0	0	9	1
192	1192	40	158	1	0	0	0	0	10	1
193	1193	40	137	1	3	0	3	0	8	1
194	1194	40	127	1	2	2	0	0	24	2
195	1195	41	129	0	1	1	0	0	8	2
196	1196	41	134	1	1	0	0	1	28	2
197	1197	39	140	2	2	2	0	0	50	2
198	1198	39	146	0	0	0	0	0	8	1
199	1199	40	148	1	2	2	0	0	26	2
200	1200	39	126	3	4	1	3	0	61	2
201	1201	41	124	0	3	1	2	0	29	2
202	1202	40	119	2	3	1	2	0	12	2
203	1203	40	133	1	0	0	0	0	9	1
204	1204	39	123	2	2	1	1	0	14	2
205	1205	39	117	3	5	3	2	0	12	2
206	1206	41	119	0	0	0	0	0	17	1
207	1207	39	151	0	1	0	1	0	25	1
208	1208	40	128	0	2	1	1	0	9	2
209	1209	40	132	1	0	0	0	0	21	1
210	1210	39	137	0	0	0	0	0	14	1
211	1211	42	126	2	6	5	1	0	18	2
212	1212	41	155	0	1	1	0	0	76	2
213	1213	40	131	0	0	0	0	0	7	1
214	1214	40	123	0	2	2	0	0	2	2
215	1215	40	124	3	2	2	0	0	21	2
216	1216	40	144	0	1	0	0	1	14	2
217	1217	41	141	3	0	0	0	0	33	2
218	1218	41	124	2	1	0	1	0	20	1
219	1219	41	139	2	2	1	1	0	14	2
220	1220	42	127	9	4	3	1	0	47	2
221	1221	42	148	2	0	0	0	0	11	1
222	1222	41	123	1	0	0	0	0	7	1
223	1223	40	133	0	0	0	0	0	4	1
224	1224	40	167	0	0	0	0	0	10	2

225	1225	41	135	0	0	0	0	0	26	2
226	1226	39	128	0	1	1	0	0	13	2
227	1227	41	138	1	1	1	0	0	8	2
228	1228	41	145	0	2	1	1	0	10	2
229	1229	40	113	4	2	0	2	0	37	2
230	1230	40	150	0	0	0	0	0	11	1
231	1231	41	128	2	1	0	1	0	17	1
232	1232	40	132	0	2	2	0	0	42	2
233	1233	40	132	0	0	0	0	0	13	1
234	1234	41	136	1	0	0	0	0	74	2
235	1235	40	121	2	5	3	2	0	8	2
236	1236	41	144	0	2	2	0	0	13	2
237	1237	39	137	0	3	2	0	1	16	2
238	1238	40	140	0	1	0	1	0	5	1
239	1239	40	148	1	1	0	1	0	14	1
240	1240	41	119	0	1	1	0	0	4	2
241	1241	39	155	0	0	0	0	0	4	1
242	1242	41	130	0	2	0	2	0	12	1
243	1243	39	124	2	0	0	0	0	10	1
244	1244	41	115	3	7	4	3	0	0	2
245	1245	40	138	0	0	0	0	0	22	1
246	1246	37	152	1	0	0	0	0	17	1
247	1247	40	151	1	0	0	0	0	21	1
248	1248	41	136	0	3	1	2	0	6	2
249	1249	42	119	3	5	2	3	0	21	2
250	1250	41	114	4	0	0	0	0	24	1
251	1251	39	159	0	0	0	0	0	12	1
252	1252	40	104	0	0	0	0	0	47	2
253	1253	38	146	0	0	0	0	0	11	1
254	1254	40	134	0	0	0	0	0	5	1
255	1255	42	136	0	1	1	0	0	14	2
256	1256	41	124	3	0	0	0	0	25	1
257	1257	40	133	0	0	0	0	0	9	1
258	1258	41	147	2	2	0	2	0	41	2
259	1259	41	117	0	0	0	0	0	19	1
260	1260	40	150	0	0	0	0	0	12	1
261	1261	39	127	2	1	0	0	1	14	2
262	1262	41	117	1	1	0	1	0	15	1
263	1263	39	146	0	0	0	0	0	14	1
264	1264	39	163	0	0	0	0	0	9	2
265	1265	39	143	0	3	0	2	1	15	2
266	1266	41	151	0	0	0	0	0	11	1
267	1267	37	122	1	0	0	0	0	23	1
268	1268	41	154	0	1	0	1	0	4	1
269	1269	39	145	1	4	3	1	0	37	2
270	1270	40	133	2	1	0	1	0	25	1
271	1271	40	139	0	0	0	0	0	49	2
272	1272	42	131	1	0	0	0	0	12	1
273	1273	39	112	2	1	0	1	0	43	2
274	1274	40	141	0	0	0	0	0	34	2
275	1275	41	126	3	4	3	1	0	20	2
276	1276	39	138	0	2	1	1	0	6	2
277	1277	39	132	4	1	1	0	0	13	2
278	1278	40	155	0	2	2	0	0	17	2
279	1279	40	147	0	0	0	0	0	22	1
280	1280	41	129	0	0	0	0	0	5	1
281	1281	41	140	0	0	0	0	0	7	1
282	1282	40	117	0	1	1	0	0	3	2

283	1283	40	151	0	0	0	0	0	15	1
284	1284	42	136	0	0	0	0	0	7	1
285	1285	40	131	2	0	0	0	0	13	1
286	1286	39	138	10	9	4	5	0	17	2
287	1287	37	141	0	0	0	0	0	21	1
288	1288	40	114	1	2	1	1	0	53	2
289	1289	41	154	0	0	0	0	0	14	1
290	1290	39	158	0	1	1	0	0	58	2
291	1291	40	170	0	1	1	0	0	23	2
292	1292	37	130	0	0	0	0	0	12	1
293	1293	39	153	0	0	0	0	0	41	2
294	1294	41	115	1	3	3	0	0	51	2
295	1295	40	124	0	0	0	0	0	31	2
296	1296	39	143	0	1	1	0	0	41	2
297	1297	41	138	1	0	0	0	0	11	1
298	1298	39	143	0	2	1	0	1	24	2
299	1299	39	132	1	1	1	0	0	16	2
300	1300	40	133	0	1	1	0	0	11	2
301	1301	41	120	4	3	2	1	0	9	2
302	1302	40	145	3	4	4	0	0	22	2
303	1303	41	142	0	1	0	0	1	35	2
304	1304	37	137	0	1	1	0	0	9	2
305	1305	41	149	0	0	0	0	0	12	1
306	1306	41	134	0	0	0	0	0	11	1
307	1307	41	115	6	6	2	4	0	11	2
308	1308	41	142	0	1	0	1	0	14	1
309	1309	38	139	0	0	0	0	0	10	1
310	1310	40	120	2	3	3	0	0	13	2
311	1311	40	141	0	2	2	0	0	15	2
312	1312	38	133	0	0	0	0	0	11	1
313	1313	41	168	1	2	1	1	0	18	2
314	1314	38	127	0	3	0	3	0	33	2
315	1315	38	147	0	0	0	0	0	5	1
316	1316	39	156	0	3	0	3	0	10	1
317	1317	39	115	2	0	0	0	0	18	1
318	1318	39	136	0	0	0	0	0	32	2
319	1319	39	145	0	5	5	0	0	13	2
320	1320	41	144	0	0	0	0	0	8	1
321	1321	41	132	0	0	0	0	0	5	1
322	1322	41	137	0	0	0	0	0	4	1
323	1323	41	124	0	1	0	1	0	8	1
324	1324	40	134	3	3	3	0	0	14	2
325	1325	41	143	5	6	1	4	1	29	2
326	1326	38	131	0	3	0	2	1	40	2
327	1327	40	139	0	0	0	0	0	7	1
328	1328	40	144	0	0	0	0	0	10	1
329	1329	41	140	0	1	1	0	0	28	2
330	1330	40	133	0	3	0	2	1	10	2
331	1331	41	134	0	0	0	0	0	10	1
332	1332	38	145	1	1	0	1	0	49	2
333	1333	39	155	0	1	1	0	0	14	2
334	1334	41	143	0	0	0	0	0	17	1
335	1335	40	144	0	0	0	0	0	10	1
336	1336	41	127	1	2	0	1	1	17	2
337	1337	40	132	0	0	0	0	0	24	1
338	1338	41	123	0	0	0	0	0	12	1
339	1339	39	135	0	0	0	0	0	13	1
340	1340	41	146	0	0	0	0	0	35	2

341	1341	40	134	0	1	1	0	0	19	2
342	1342	39	135	1	1	0	0	1	9	2
343	1343	40	147	0	1	1	0	0	10	2
344	1344	41	124	0	0	0	0	0	6	1
345	1345	40	148	1	1	1	0	0	47	2
346	1346	41	151	0	1	1	0	0	20	2
347	1347	40	124	1	0	0	0	0	5	1
348	1348	39	151	0	0	0	0	0	10	1
349	1349	40	154	0	0	0	0	0	1	1
350	1350	40	161	0	0	0	0	0	2	2
351	1351	40	144	0	0	0	0	0	11	1
352	1352	41	148	0	0	0	0	0	27	2
353	1353	41	148	0	0	0	0	0	7	1
354	1354	40	134	1	0	0	0	0	28	2
355	1355	41	150	0	0	0	0	0	13	1
356	1356	38	139	0	0	0	0	0	1	1
357	1357	41	149	1	1	0	1	0	11	1
358	1358	40	153	5	4	3	1	0	46	2
359	1359	40	126	2	2	1	1	0	21	2
360	1360	40	137	0	0	0	0	0	16	1
361	1361	40	0	0	0	0	0	0	0	2
362	1362	39	147	0	4	0	4	0	12	1
363	1363	41	141	0	0	0	0	0	19	1
364	1364	40	155	0	0	0	0	0	6	1
365	1365	40	135	2	0	0	0	0	21	1
366	1366	42	149	0	0	0	0	0	13	1
367	1367	41	134	2	1	0	1	0	24	1
368	1368	41	143	1	2	0	2	0	13	1
369	1369	40	140	1	2	1	1	0	0	2
370	1370	40	149	0	0	0	0	0	19	1
371	1371	41	140	1	2	2	0	0	14	2
372	1372	41	149	1	0	0	0	0	17	1
373	1373	39	118	2	2	1	1	0	11	2
374	1374	40	144	1	0	0	0	0	12	1
375	1375	41	132	0	0	0	0	0	12	1
376	1376	41	99	0	0	0	0	0	7	2
377	1377	40	145	0	0	0	0	0	9	1
378	1378	39	139	0	0	0	0	0	46	2
379	1379	41	129	1	2	2	0	0	19	2
380	1380	41	139	0	1	0	1	0	10	1
381	1381	41	121	3	1	1	0	0	14	2
382	1382	40	120	1	2	2	0	0	60	2
383	1383	42	134	0	3	1	0	2	29	2
384	1384	38	135	0	0	0	0	0	42	2
385	1385	37	162	0	0	0	0	0	26	2
386	1386	39	161	0	0	0	0	0	7	2
387	1387	39	127	0	1	1	0	0	12	2
388	1388	41	138	0	0	0	0	0	20	1
389	1389	41	123	4	3	0	2	1	6	2
390	1390	41	164	0	0	0	0	0	11	2
391	1391	38	133	2	1	1	0	0	11	2
392	1392	41	165	0	1	1	0	0	10	2
393	1393	41	139	0	5	1	2	2	23	2
394	1394	41	145	2	1	1	0	0	41	2
395	1395	40	132	0	1	1	0	0	14	2
396	1396	39	145	0	0	0	0	0	4	1
397	1397	40	136	0	0	0	0	0	19	1
398	1398	41	116	0	2	1	1	0	16	2

399	1399	40	133	0	0	0	0	0	12	1
400	1400	41	120	0	0	0	0	0	20	1
401	1401	40	123	1	1	0	1	0	0	2
402	1402	37	154	0	0	0	0	0	10	1
403	1403	39	121	0	0	0	0	0	49	2
404	1404	40	147	0	0	0	0	0	21	1
405	1405	39	132	0	0	0	0	0	11	1
406	1406	39	120	3	2	0	1	1	12	2
407	1407	39	151	1	0	0	0	0	69	2
408	1408	40	155	0	2	2	0	0	11	2
409	1409	39	149	0	0	0	0	0	31	2
410	1410	40	119	4	4	3	1	0	28	2
411	1411	40	140	0	1	0	0	1	9	2
412	1412	40	130	2	2	0	1	1	16	2
413	1413	40	141	0	0	0	0	0	23	1
414	1414	41	124	1	0	0	0	0	46	2
415	1415	42	110	1	1	0	1	0	31	2
416	1416	42	128	2	1	1	0	0	11	2
417	1417	41	139	0	2	2	0	0	22	2
418	1418	39	116	2	3	1	2	0	13	2
419	1419	41	141	0	0	0	0	0	9	1
420	1420	38	148	2	3	2	1	0	17	2
421	1421	41	123	3	2	1	0	1	8	2
422	1422	40	84	0	0	0	0	0	37	2
423	1423	39	142	0	0	0	0	0	13	1
424	1424	39	136	0	1	0	1	0	10	1
425	1425	38	141	0	0	0	0	0	1	1
426	1426	40	148	0	0	0	0	0	10	1
427	1427	37	125	3	5	2	2	1	25	2
428	1428	42	131	2	3	2	1	0	8	2
429	1429	40	144	0	0	0	0	0	20	1
430	1430	37	136	0	1	0	0	1	9	2
431	1431	41	140	0	3	3	0	0	7	2
432	1432	39	127	3	1	0	0	1	46	2
433	1433	42	134	0	0	0	0	0	19	1
434	1434	39	136	0	5	4	1	0	18	2
435	1435	40	125	2	2	1	0	1	50	2
436	1436	41	123	0	0	0	0	0	10	1
437	1437	39	136	0	3	1	1	1	11	2
438	1438	40	128	4	2	2	0	0	5	2
439	1439	39	145	0	0	0	0	0	13	1
440	1440	38	164	0	0	0	0	0	4	2
441	1441	38	144	1	2	2	0	0	39	2
442	1442	40	127	0	1	0	1	0	9	1
443	1443	39	137	1	0	0	0	0	13	1
444	1444	40	162	0	0	0	0	0	19	2
445	1445	41	146	0	2	0	2	0	17	1
446	1446	41	132	0	2	0	1	1	2	2
447	1447	41	163	0	0	0	0	0	2	2
448	1448	39	149	0	0	0	0	0	24	1
449	1449	41	134	0	1	0	1	0	12	1
450	1450	40	158	1	2	1	1	0	16	2
451	1451	39	120	0	1	0	0	1	24	2
452	1452	41	125	0	0	0	0	0	7	1
453	1453	41	145	0	2	1	1	0	57	2
454	1454	42	137	0	1	1	0	0	8	2
455	1455	40	132	0	0	0	0	0	34	2
456	1456	39	109	2	1	0	1	0	24	2

457	1457	38	136	0	2	1	1	0	20	2
458	1458	41	138	0	0	0	0	0	14	1
459	1459	40	140	0	1	1	0	0	16	2
460	1460	40	144	1	0	0	0	0	11	1
461	1461	41	130	0	0	0	0	0	15	1
462	1462	40	140	0	1	1	0	0	13	2
463	1463	39	112	2	4	4	0	0	29	2
464	1464	41	147	1	1	0	0	1	25	2
465	1465	40	139	2	0	0	0	0	10	1
466	1466	40	124	1	2	1	1	0	11	2
467	1467	41	139	0	1	0	1	0	25	1
468	1468	41	143	0	1	1	0	0	10	2
469	1469	40	122	3	1	1	0	0	3	2
470	1470	40	140	0	0	0	0	0	9	1
471	1471	40	131	0	4	3	0	1	9	2
472	1472	38	124	0	0	0	0	0	9	1
473	1473	40	133	1	1	1	0	0	0	2
474	1474	40	116	2	1	0	1	0	38	2
475	1475	39	130	0	2	0	1	1	14	2
476	1476	38	142	0	0	0	0	0	11	1
477	1477	40	130	0	3	0	2	1	26	2
478	1478	39	154	0	2	0	2	0	10	1
479	1479	41	136	0	1	0	1	0	12	1
480	1480	40	166	1	0	0	0	0	26	2
481	1481	40	162	3	2	0	2	0	17	2
482	1482	38	136	2	1	1	0	0	46	2
483	1483	40	127	0	0	0	0	0	22	1
484	1484	40	138	0	1	0	1	0	11	1
485	1485	42	111	1	2	2	0	0	53	2
486	1486	41	150	0	2	1	1	0	14	2
487	1487	41	126	2	2	1	0	1	21	2
488	1488	41	134	1	3	1	1	1	7	2
489	1489	38	143	0	0	0	0	0	13	1
490	1490	40	135	0	2	2	0	0	19	2
491	1491	41	142	1	1	0	1	0	13	1
492	1492	40	129	0	0	0	0	0	3	1
493	1493	41	135	1	3	2	1	0	11	2
494	1494	41	127	0	1	1	0	0	32	2
495	1495	37	153	0	0	0	0	0	41	2
496	1496	38	133	0	1	1	0	0	16	2
497	1497	41	139	2	1	1	0	0	10	2
498	1498	40	149	2	2	1	1	0	14	2
499	1499	39	132	1	0	0	0	0	25	1
500	1500	40	135	0	2	0	2	0	7	1
501	1501	40	139	4	3	1	2	0	33	2
502	1502	41	116	3	0	0	0	0	32	2
503	1503	40	127	1	1	0	1	0	6	1
504	1504	40	140	0	1	0	1	0	11	1
505	1505	40	134	2	6	5	1	0	10	2
506	1506	41	144	0	0	0	0	0	12	1
507	2001	38	156	0	1	0	1	0	3	1
508	2002	39	133	0	0	0	0	0	26	2
509	2003	41	138	9	9	3	6	0	0	2
510	2004	41	132	0	1	0	1	0	18	1
511	2005	39	144	0	0	0	0	0	20	1
512	2006	41	181	0	0	0	0	0	5	2
513	2007	40	148	0	4	3	0	1	8	2
514	2008	40	153	0	2	1	1	0	17	2

515	2009	40	165	1	3	1	2	0	8	2
516	2010	38	132	2	5	5	0	0	13	2
517	2011	40	155	0	1	1	0	0	10	2
518	2012	40	167	0	0	0	0	0	14	2
519	2013	39	139	4	5	5	0	0	82	2
520	2014	40	131	0	2	1	1	0	23	2
521	2015	41	134	0	2	0	0	2	26	2
522	2016	41	156	0	0	0	0	0	9	1
523	2017	41	136	0	3	2	1	0	9	2
524	2018	40	122	0	0	0	0	0	15	1
525	2019	40	125	0	5	4	1	0	29	2
526	2020	40	147	2	6	1	5	0	12	2
527	2021	40	134	1	4	2	2	0	11	2
528	2022	41	124	2	2	0	1	1	24	2
529	2023	38	153	0	0	0	0	0	6	1
530	2024	41	135	0	2	1	1	0	14	2
531	2025	42	190	0	0	0	0	0	1	2
532	2026	42	126	2	0	0	0	0	27	2
533	2027	41	162	0	0	0	0	0	7	2
534	2028	41	145	0	2	1	1	0	11	2
535	2029	41	115	0	0	0	0	0	9	1
536	2030	40	99	0	0	0	0	0	3	2
537	2031	39	164	1	3	0	3	0	20	2
538	2032	41	146	0	0	0	0	0	13	1
539	2033	40	157	3	3	3	0	0	22	2
540	2034	40	132	1	3	3	0	0	21	2
541	2035	40	133	0	0	0	0	0	10	1
542	2036	40	155	0	0	0	0	0	63	2
543	2037	41	121	1	0	0	0	0	14	1
544	2038	40	153	0	0	0	0	0	7	1
545	2039	39	129	1	0	0	0	0	19	1
546	2040	41	177	1	1	1	0	0	13	2
547	2041	41	155	0	0	0	0	0	18	1
548	2042	39	134	3	3	1	1	1	13	2
549	2043	41	121	0	2	1	1	0	14	2
550	2044	42	156	1	1	0	1	0	17	1
551	2045	39	121	0	1	1	0	0	14	2
552	2046	39	110	4	3	2	1	0	24	2

Appendix C: Results of this thesis in LTV

Patient ID	Patient	Week	BL	Acc	Dec	Late	Early	Variable	BLV	NICHD Classification 1.Normal 2.Interminate 3.Abnormal
1	1001	37	133	10	10	4	6	0	28	2
2	1002	41	145	9	13	4	9	0	27	2
3	1003	40	121	2	7	2	1	4	12	2
4	1004	41	134	7	6	3	2	1	30	2
5	1005	41	119	9	8	2	3	3	14	2
6	1006	38	139	2	3	1	2	0	19	2
7	1007	41	123	0	1	1	0	0	70	2
8	1008	39	123	5	10	10	0	0	9	2
9	1009	39	132	5	7	2	3	2	10	2
10	1010	38	126	0	5	2	3	0	10	2
11	1011	38	124	6	11	4	5	2	32	2
12	1012	41	121	8	12	4	6	2	12	2
13	1013	40	128	13	18	10	6	2	12	2
14	1014	42	128	9	12	5	6	1	19	2
15	1015	41	130	4	10	2	7	1	35	2
16	1016	40	134	6	18	12	6	0	46	2
17	1017	41	145	8	11	1	10	0	14	2
18	1018	39	140	8	7	5	1	1	59	2
19	1019	41	134	5	2	1	1	0	45	2
20	1020	41	148	0	10	7	3	0	5	2
21	1021	37	129	2	12	6	5	1	14	2
22	1022	39	130	5	10	3	6	1	14	2
23	1023	41	137	10	21	10	11	0	24	2
24	1024	40	132	3	9	4	5	0	15	2
25	1025	41	112	11	16	3	12	1	19	2
26	1026	37	127	6	8	6	2	0	32	2
27	1027	41	133	10	12	4	6	2	26	2
28	1028	42	142	10	6	6	0	0	54	2
29	1029	41	137	1	7	3	2	2	36	2
30	1030	40	140	7	6	1	3	2	25	2
31	1031	37	138	0	2	2	0	0	9	2
32	1032	43	137	15	19	5	12	2	82	2
33	1033	40	145	4	12	11	1	0	35	2
34	1034	41	134	6	6	4	1	1	15	2
35	1035	38	144	3	3	2	0	1	14	2
36	1036	40	155	2	4	2	1	1	30	2
37	1037	41	127	7	18	8	9	1	32	2
38	1038	39	132	4	9	6	3	0	12	2
39	1039	40	120	13	14	6	7	1	54	2
40	1040	41	120	3	3	1	2	0	14	2
41	1041	41	136	7	10	4	5	1	14	2
42	1042	41	140	2	6	1	3	2	17	2
43	1043	41	128	6	12	2	10	0	37	2
44	1044	38	129	6	6	3	2	1	21	2
45	1045	40	136	6	7	5	2	0	41	2
46	1046	40	128	6	10	1	6	3	35	2
47	1047	40	141	5	4	0	3	1	27	2
48	1048	39	139	10	10	5	5	0	41	2
49	1049	39	125	9	12	3	6	3	5	2
50	1050	41	125	2	5	1	3	1	30	2

51	1051	40	136	6	2	0	2	0	8	1
52	1052	40	150	4	5	1	4	0	10	2
53	1053	40	140	4	3	3	0	0	12	2
54	1054	37	146	8	13	4	9	0	10	2
55	1055	40	118	6	1	1	0	0	7	2
56	1056	42	128	0	11	4	3	4	6	2
57	1057	41	133	1	8	5	1	2	14	2
58	1058	39	137	0	0	0	0	0	3	1
59	1059	40	133	23	24	13	9	2	12	2
60	1060	39	126	5	3	1	2	0	12	2
61	1061	39	115	6	6	3	3	0	11	2
62	1062	40	144	4	9	6	3	0	11	2
63	1063	41	132	2	5	4	0	1	18	2
64	1064	41	124	1	8	5	3	0	14	2
65	1065	40	141	13	18	10	7	1	14	2
66	1066	41	120	14	14	8	3	3	12	2
67	1067	40	120	12	13	6	4	3	8	2
68	1068	41	140	0	0	0	0	0	12	1
69	1069	38	123	8	8	1	7	0	19	2
70	1070	41	137	8	9	8	0	1	64	2
71	1071	39	116	10	10	4	6	0	49	2
72	1072	41	168	9	18	9	9	0	17	2
73	1073	40	124	16	21	4	14	3	13	2
74	1074	40	121	4	9	7	1	1	20	2
75	1075	41	136	4	9	4	4	1	13	2
76	1076	38	149	4	6	3	3	0	58	2
77	1077	39	148	4	10	5	5	0	24	2
78	1078	39	163	1	3	2	1	0	22	2
79	1079	41	129	5	11	1	9	1	39	2
80	1080	40	130	9	14	8	5	1	10	2
81	1081	37	135	1	4	1	3	0	27	2
82	1082	40	139	7	6	3	3	0	13	2
83	1083	40	133	4	10	4	5	1	11	2
84	1084	40	134	1	5	4	0	1	19	2
85	1085	39	146	4	7	7	0	0	26	2
86	1086	42	129	2	2	2	0	0	81	2
87	1087	37	117	9	7	2	5	0	9	2
88	1088	38	127	12	16	7	9	0	12	2
89	1089	41	122	10	15	8	6	1	47	2
90	1090	39	140	4	4	1	2	1	24	2
91	1091	39	121	5	5	3	2	0	55	2
92	1092	41	119	4	1	1	0	0	11	2
93	1093	40	132	0	5	4	1	0	6	2
94	1094	38	140	13	15	9	6	0	7	2
95	1095	41	139	2	4	1	3	0	12	2
96	1096	39	126	12	14	3	10	1	9	2
97	1097	41	147	6	10	2	8	0	15	2
98	1098	41	160	3	7	2	5	0	46	2
99	1099	40	131	10	10	4	5	1	26	2
100	1100	41	128	3	4	0	4	0	33	2
101	1101	40	125	4	14	2	12	0	15	2
102	1102	39	136	0	4	2	2	0	8	2
103	1103	39	148	0	1	0	1	0	8	1
104	1104	40	135	11	13	0	7	6	14	2
105	1105	41	118	7	12	1	7	4	12	2
106	1106	41	130	3	9	5	4	0	17	2
107	1107	40	124	15	10	4	4	2	10	2
108	1108	40	122	11	16	1	9	6	25	2

109	1109	39	162	0	3	2	1	0	6	2
110	1110	41	98	5	14	4	8	2	8	2
111	1111	38	113	3	12	6	5	1	10	2
112	1112	40	135	5	8	6	2	0	16	2
113	1113	40	144	8	4	1	3	0	60	2
114	1114	39	140	0	4	2	2	0	12	2
115	1115	40	156	13	14	5	9	0	12	2
116	1116	41	133	1	7	5	2	0	9	2
117	1117	40	127	10	11	1	7	3	41	2
118	1118	41	135	8	6	2	4	0	12	2
119	1119	41	120	7	11	0	10	1	66	2
120	1120	41	135	0	10	8	1	1	51	2
121	1121	41	125	7	10	2	7	1	50	2
122	1122	40	122	16	15	9	5	1	11	2
123	1123	40	146	0	7	3	2	2	46	2
124	1124	38	140	9	13	10	3	0	47	2
125	1125	40	136	3	3	0	3	0	25	1
126	1126	40	120	6	4	2	0	2	10	2
127	1127	39	125	0	9	8	1	0	10	2
128	1128	38	110	5	2	0	2	0	19	1
129	1129	38	140	3	11	9	1	1	13	2
130	1130	39	125	21	18	2	13	3	20	2
131	1131	39	128	7	9	3	5	1	40	2
132	1132	40	118	5	10	3	5	2	8	2
133	1133	39	138	3	11	6	5	0	18	2
134	1134	40	121	7	13	0	11	2	20	2
135	1135	39	139	9	8	4	3	1	7	2
136	1136	40	137	6	9	5	4	0	18	2
137	1137	41	133	4	9	0	8	1	14	2
138	1138	40	147	2	12	3	7	2	60	2
139	1139	41	147	4	9	2	5	2	32	2
140	1140	40	128	8	6	2	4	0	18	2
141	1141	40	138	3	4	2	2	0	30	2
142	1142	41	145	3	2	1	1	0	84	2
143	1143	41	127	10	11	3	3	5	17	2
144	1144	40	124	8	13	8	4	1	9	2
145	1145	41	140	5	13	9	3	1	56	2
146	1146	41	138	1	4	0	3	1	44	2
147	1147	39	112	2	1	0	1	0	14	1
148	1148	41	141	6	2	2	0	0	9	2
149	1149	41	125	5	13	0	10	3	24	2
150	1150	40	146	7	0	0	0	0	6	1
151	1151	41	123	1	0	0	0	0	12	1
152	1152	40	121	6	12	3	4	5	28	2
153	1153	40	142	2	16	12	4	0	19	2
154	1154	39	127	9	8	1	7	0	26	2
155	1155	38	134	1	4	0	4	0	6	1
156	1156	41	144	9	11	9	2	0	12	2
157	1157	41	159	1	1	1	0	0	16	2
158	1158	40	119	15	10	4	2	4	17	2
159	1159	41	125	4	9	5	4	0	11	2
160	1160	41	127	2	7	2	5	0	19	2
161	1161	41	145	2	2	2	0	0	33	2
162	1162	39	110	3	10	3	7	0	14	2
163	1163	41	127	6	8	5	1	2	56	2
164	1164	40	128	9	13	5	7	1	28	2
165	1165	38	133	3	4	3	0	1	11	2
166	1166	40	122	5	18	3	15	0	6	2

167	1167	40	127	0	12	2	6	4	10	2
168	1168	37	129	3	7	3	3	1	12	2
169	1169	40	141	4	5	1	3	1	14	2
170	1170	39	124	3	5	4	1	0	27	2
171	1171	40	123	2	7	5	2	0	14	2
172	1172	41	144	4	3	1	2	0	56	2
173	1173	39	137	2	5	4	1	0	11	2
174	1174	39	139	21	14	4	8	2	51	2
175	1175	40	139	0	7	2	5	0	6	2
176	1176	39	118	2	10	9	0	1	11	2
177	1177	41	125	2	1	0	1	0	14	1
178	1178	42	132	7	7	3	3	1	23	2
179	1179	40	155	1	7	0	7	0	12	1
180	1180	39	124	27	34	15	16	3	22	2
181	1181	38	132	13	11	8	2	1	9	2
182	1182	40	161	0	7	3	4	0	4	2
183	1183	42	138	4	6	5	1	0	12	2
184	1184	41	121	6	3	2	0	1	18	2
185	1185	41	138	9	12	5	5	2	13	2
186	1186	40	124	4	2	0	1	1	10	2
187	1187	40	125	7	6	2	3	1	36	2
188	1188	41	163	0	2	0	2	0	15	2
189	1189	39	133	3	3	1	0	2	12	2
190	1190	41	137	10	18	9	9	0	44	2
191	1191	40	129	0	1	0	1	0	8	1
192	1192	40	160	1	1	1	0	0	8	2
193	1193	40	138	2	5	1	3	1	8	2
194	1194	40	130	5	7	5	2	0	24	2
195	1195	41	120	1	9	6	3	0	14	2
196	1196	41	132	11	15	5	9	1	28	2
197	1197	39	131	4	5	4	1	0	50	2
198	1198	39	139	0	0	0	0	0	8	1
199	1199	40	127	15	16	7	7	2	32	2
200	1200	39	118	7	15	7	8	0	62	2
201	1201	41	123	11	21	7	13	1	39	2
202	1202	40	127	6	13	7	6	0	11	2
203	1203	40	139	2	2	0	1	1	29	2
204	1204	39	120	9	8	4	2	2	14	2
205	1205	39	118	5	13	5	8	0	11	2
206	1206	41	136	2	7	3	4	0	11	2
207	1207	39	141	2	10	6	2	2	11	2
208	1208	40	127	6	7	3	3	1	43	2
209	1209	40	126	3	0	0	0	0	21	1
210	1210	39	132	1	4	3	1	0	19	2
211	1211	42	125	11	17	6	10	1	17	2
212	1212	41	155	2	6	2	3	1	12	2
213	1213	40	129	14	10	2	7	1	22	2
214	1214	40	125	4	7	3	3	1	13	2
215	1215	40	119	7	11	7	3	1	21	2
216	1216	40	147	1	4	0	4	0	47	2
217	1217	41	125	10	7	4	3	0	33	2
218	1218	41	129	7	4	2	2	0	21	2
219	1219	41	132	4	4	2	1	1	15	2
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221	1221	42	139	6	5	4	1	0	10	2
222	1222	41	119	6	8	2	5	1	13	2
223	1223	40	127	1	2	0	2	0	55	2
224	1224	40	160	3	12	5	7	0	47	2

225	1225	41	130	10	9	6	2	1	55	2
226	1226	39	130	6	9	7	2	0	19	2
227	1227	41	132	1	7	3	3	1	7	2
228	1228	41	141	8	11	4	6	1	9	2
229	1229	40	124	4	4	0	3	1	37	2
230	1230	40	144	4	12	8	3	1	14	2
231	1231	41	131	5	3	0	3	0	17	1
232	1232	40	126	4	6	3	3	0	42	2
233	1233	40	132	1	3	1	2	0	15	2
234	1234	41	129	2	7	4	2	1	74	2
235	1235	40	121	17	25	12	13	0	8	2
236	1236	41	137	10	12	7	2	3	17	2
237	1237	39	136	1	6	3	2	1	15	2
238	1238	40	139	4	10	6	2	2	14	2
239	1239	40	144	9	19	5	12	2	10	2
240	1240	41	120	14	8	5	3	0	12	2
241	1241	39	143	8	12	9	3	0	75	2
242	1242	41	132	2	9	4	5	0	13	2
243	1243	39	121	5	1	0	1	0	5	1
244	1244	41	117	3	8	5	2	1	39	2
245	1245	40	137	0	0	0	0	0	22	1
246	1246	37	138	9	6	0	3	3	23	2
247	1247	40	135	8	7	2	4	1	24	2
248	1248	41	131	4	13	5	8	0	6	2
249	1249	42	115	14	23	16	6	1	21	2
250	1250	41	116	7	2	1	1	0	25	2
251	1251	39	162	0	2	1	0	1	13	2
252	1252	40	136	1	1	0	1	0	93	2
253	1253	38	145	3	0	0	0	0	11	1
254	1254	40	122	3	3	0	3	0	21	1
255	1255	42	131	4	8	1	5	2	11	2
256	1256	41	119	13	12	6	5	1	23	2
257	1257	40	131	1	1	0	0	1	18	2
258	1258	41	140	10	13	0	9	4	41	2
259	1259	41	110	1	3	1	2	0	18	2
260	1260	40	141	0	0	0	0	0	11	1
261	1261	39	119	11	11	3	6	2	14	2
262	1262	41	135	1	1	0	1	0	11	1
263	1263	39	141	5	12	5	7	0	16	2
264	1264	39	145	0	2	1	1	0	9	2
265	1265	39	131	10	11	5	5	1	13	2
266	1266	41	138	3	2	0	2	0	17	1
267	1267	37	126	2	5	0	2	3	50	2
268	1268	41	144	3	2	0	2	0	9	1
269	1269	39	142	9	16	10	6	0	37	2
270	1270	40	127	10	7	1	6	0	26	2
271	1271	40	133	5	8	4	2	2	20	2
272	1272	42	123	5	2	1	1	0	30	2
273	1273	39	123	1	3	2	1	0	44	2
274	1274	40	136	8	5	3	0	2	33	2
275	1275	41	140	10	13	3	9	1	20	2
276	1276	39	135	0	5	2	3	0	6	2
277	1277	39	124	9	4	1	3	0	14	2
278	1278	40	153	9	8	5	2	1	58	2
279	1279	40	148	3	6	1	4	1	11	2
280	1280	41	125	3	12	6	6	0	8	2
281	1281	41	130	4	9	3	6	0	10	2
282	1282	40	126	5	10	8	2	0	13	2

283	1283	40	148	10	7	0	4	3	45	2
284	1284	42	124	1	2	0	2	0	28	2
285	1285	40	129	10	8	4	4	0	26	2
286	1286	39	135	22	19	12	7	0	35	2
287	1287	37	131	3	3	0	2	1	22	2
288	1288	40	122	22	33	14	17	2	53	2
289	1289	41	147	5	11	3	7	1	24	2
290	1290	39	146	1	1	1	0	0	23	2
291	1291	40	149	3	5	2	3	0	9	2
292	1292	37	126	4	5	0	5	0	14	1
293	1293	39	136	3	10	7	3	0	25	2
294	1294	41	116	4	13	11	2	0	50	2
295	1295	40	138	0	1	1	0	0	33	2
296	1296	39	141	13	19	4	13	2	39	2
297	1297	41	136	3	4	2	1	1	0	2
298	1298	39	140	0	3	2	0	1	24	2
299	1299	39	130	4	6	3	2	1	14	2
300	1300	40	125	5	2	1	1	0	30	2
301	1301	41	122	6	8	3	4	1	10	2
302	1302	40	145	9	21	8	12	1	19	2
303	1303	41	141	10	10	7	2	1	18	2
304	1304	37	127	10	7	7	0	0	10	2
305	1305	41	132	0	0	0	0	0	11	1
306	1306	41	129	6	10	5	5	0	11	2
307	1307	41	114	14	16	7	8	1	20	2
308	1308	41	136	3	5	2	3	0	8	2
309	1309	38	127	3	1	0	1	0	11	1
310	1310	40	129	18	14	9	4	1	13	2
311	1311	40	143	1	5	2	3	0	40	2
312	1312	38	124	2	3	1	2	0	18	2
313	1313	41	161	2	11	5	6	0	20	2
314	1314	38	136	6	11	5	6	0	33	2
315	1315	38	148	0	1	1	0	0	5	2
316	1316	39	145	14	24	2	22	0	10	2
317	1317	39	109	6	4	2	1	1	30	2
318	1318	39	125	3	2	0	2	0	73	2
319	1319	39	142	1	12	11	1	0	24	2
320	1320	41	139	8	10	8	2	0	11	2
321	1321	41	125	3	1	0	1	0	42	2
322	1322	41	131	1	3	0	3	0	18	1
323	1323	41	120	10	29	18	11	0	12	2
324	1324	40	129	10	8	2	5	1	14	2
325	1325	41	133	17	16	4	10	2	30	2
326	1326	38	121	8	13	3	7	3	32	2
327	1327	40	133	2	1	0	0	1	24	2
328	1328	40	127	10	4	1	3	0	35	2
329	1329	41	137	5	19	11	4	4	60	2
330	1330	40	140	6	5	1	2	2	9	2
331	1331	41	133	5	6	0	4	2	11	2
332	1332	38	143	4	6	3	1	2	10	2
333	1333	39	156	4	3	2	0	1	33	2
334	1334	41	144	1	4	0	3	1	18	2
335	1335	40	144	2	0	0	0	0	10	1
336	1336	41	127	11	10	2	6	2	10	2
337	1337	40	130	5	6	3	1	2	34	2
338	1338	41	121	7	5	4	1	0	14	2
339	1339	39	136	1	2	1	1	0	10	2
340	1340	41	144	4	6	4	2	0	19	2

341	1341	40	126	8	9	5	3	1	14	2
342	1342	39	134	6	6	4	1	1	18	2
343	1343	40	145	0	1	1	0	0	10	2
344	1344	41	124	7	7	3	3	1	19	2
345	1345	40	144	11	15	10	4	1	26	2
346	1346	41	150	2	6	4	2	0	34	2
347	1347	40	120	10	9	4	4	1	9	2
348	1348	39	139	3	5	0	3	2	12	2
349	1349	40	151	0	0	0	0	0	1	1
350	1350	40	147	0	1	0	1	0	2	1
351	1351	40	142	1	3	3	0	0	60	2
352	1352	41	143	3	3	1	1	1	25	2
353	1353	41	147	8	5	1	3	1	14	2
354	1354	40	134	3	3	1	2	0	38	2
355	1355	41	148	6	12	0	11	1	36	2
356	1356	38	135	1	6	1	2	3	10	2
357	1357	41	134	6	5	4	1	0	8	2
358	1358	40	168	8	11	7	4	0	42	2
359	1359	40	123	7	12	3	7	2	21	2
360	1360	40	136	7	5	1	3	1	8	2
361	1361	40	115	3	3	1	2	0	14	2
362	1362	39	143	1	6	2	4	0	12	2
363	1363	41	136	8	9	4	4	1	12	2
364	1364	40	146	0	1	1	0	0	7	2
365	1365	40	133	3	5	0	4	1	65	2
366	1366	42	137	5	12	7	3	2	14	2
367	1367	41	133	4	9	4	4	1	36	2
368	1368	41	138	2	5	0	5	0	13	1
369	1369	40	142	8	17	5	9	3	13	2
370	1370	40	145	2	2	1	1	0	21	2
371	1371	41	140	1	3	2	1	0	31	2
372	1372	41	141	13	13	9	2	2	13	2
373	1373	39	116	13	10	7	2	1	10	2
374	1374	40	130	15	16	8	7	1	7	2
375	1375	41	136	5	8	1	6	1	34	2
376	1376	41	103	9	7	2	3	2	19	2
377	1377	40	135	11	15	1	13	1	13	2
378	1378	39	134	1	2	0	1	1	49	2
379	1379	41	121	7	12	10	1	1	19	2
380	1380	41	133	8	10	5	4	1	62	2
381	1381	41	120	8	2	2	0	0	14	2
382	1382	40	128	10	8	6	1	1	60	2
383	1383	42	121	2	4	1	1	2	16	2
384	1384	38	150	3	5	1	3	1	41	2
385	1385	37	154	5	7	6	1	0	9	2
386	1386	39	161	0	2	0	2	0	7	2
387	1387	39	126	4	3	2	1	0	11	2
388	1388	41	134	5	4	0	4	0	14	1
389	1389	41	118	10	10	5	4	1	6	2
390	1390	41	161	0	0	0	0	0	11	2
391	1391	38	131	10	3	3	0	0	11	2
392	1392	41	158	4	20	4	16	0	11	2
393	1393	41	135	3	12	8	1	3	12	2
394	1394	41	146	11	4	2	2	0	41	2
395	1395	40	120	3	4	1	3	0	14	2
396	1396	39	144	5	1	1	0	0	6	2
397	1397	40	129	3	5	4	1	0	9	2
398	1398	41	120	2	5	1	4	0	36	2

399	1399	40	128	5	3	3	0	0	13	2
400	1400	41	116	2	4	1	1	2	30	2
401	1401	40	126	13	9	8	1	0	22	2
402	1402	37	150	0	2	1	0	1	10	2
403	1403	39	128	7	6	2	4	0	22	2
404	1404	40	130	0	2	2	0	0	22	2
405	1405	39	122	3	2	2	0	0	11	2
406	1406	39	123	8	4	0	3	1	11	2
407	1407	39	145	10	15	3	8	4	6	2
408	1408	40	157	0	8	5	3	0	9	2
409	1409	39	149	3	3	2	1	0	9	2
410	1410	40	128	16	17	8	8	1	31	2
411	1411	40	135	0	9	1	8	0	10	2
412	1412	40	117	10	8	6	2	0	15	2
413	1413	40	137	8	10	3	7	0	39	2
414	1414	41	137	3	7	2	5	0	21	2
415	1415	42	131	1	1	1	0	0	27	2
416	1416	42	131	11	9	7	1	1	11	2
417	1417	41	139	1	2	2	0	0	10	2
418	1418	39	126	6	13	8	4	1	13	2
419	1419	41	132	2	8	1	5	2	8	2
420	1420	38	144	6	16	10	6	0	17	2
421	1421	41	121	6	9	5	3	1	26	2
422	1422	40	115	10	8	5	2	1	3	2
423	1423	39	126	2	6	2	4	0	39	2
424	1424	39	135	12	16	3	9	4	24	2
425	1425	38	144	0	0	0	0	0	1	1
426	1426	40	142	5	3	2	1	0	13	2
427	1427	37	133	2	17	10	5	2	25	2
428	1428	42	127	10	12	6	5	1	8	2
429	1429	40	143	1	1	0	1	0	51	2
430	1430	37	142	3	5	1	3	1	18	2
431	1431	41	145	1	4	4	0	0	11	2
432	1432	39	136	5	3	1	0	2	46	2
433	1433	42	126	5	6	2	4	0	16	2
434	1434	39	132	3	11	8	3	0	18	2
435	1435	40	128	12	7	2	3	2	18	2
436	1436	41	128	1	2	1	0	1	11	2
437	1437	39	131	3	10	4	5	1	9	2
438	1438	40	120	12	14	12	1	1	5	2
439	1439	39	146	0	3	1	2	0	13	2
440	1440	38	152	0	3	2	1	0	4	2
441	1441	38	147	4	6	2	4	0	37	2
442	1442	40	129	3	5	2	3	0	9	2
443	1443	39	143	3	5	5	0	0	12	2
444	1444	40	146	6	3	3	0	0	23	2
445	1445	41	142	2	7	1	5	1	17	2
446	1446	41	138	1	3	0	2	1	6	2
447	1447	41	151	5	9	4	5	0	11	2
448	1448	39	135	3	6	2	3	1	30	2
449	1449	41	128	5	8	3	5	0	11	2
450	1450	40	158	8	11	5	4	2	16	2
451	1451	39	120	8	18	1	14	3	14	2
452	1452	41	109	0	5	2	2	1	7	2
453	1453	41	144	0	4	2	1	1	57	2
454	1454	42	139	4	4	2	2	0	28	2
455	1455	40	126	9	11	4	7	0	8	2
456	1456	39	107	12	18	0	16	2	22	2

457	1457	38	133	7	15	8	7	0	8	2
458	1458	41	118	3	7	1	4	2	11	2
459	1459	40	132	7	14	6	7	1	18	2
460	1460	40	148	2	3	1	2	0	19	2
461	1461	41	127	1	6	2	4	0	25	2
462	1462	40	134	3	9	6	2	1	8	2
463	1463	39	124	7	13	8	4	1	29	2
464	1464	41	150	2	5	3	2	0	14	2
465	1465	40	138	4	7	5	2	0	35	2
466	1466	40	134	7	11	5	5	1	11	2
467	1467	41	134	10	8	4	4	0	58	2
468	1468	41	139	3	5	4	1	0	14	2
469	1469	40	129	6	7	4	3	0	2	2
470	1470	40	136	8	8	2	6	0	10	2
471	1471	40	128	1	14	7	6	1	13	2
472	1472	38	124	3	8	4	4	0	6	2
473	1473	40	135	4	6	2	2	2	49	2
474	1474	40	124	13	11	2	6	3	38	2
475	1475	39	134	1	8	1	6	1	10	2
476	1476	38	139	5	3	2	1	0	14	2
477	1477	40	119	6	9	1	6	2	9	2
478	1478	39	144	2	12	2	8	2	9	2
479	1479	41	136	4	11	2	9	0	4	2
480	1480	40	154	4	4	2	2	0	18	2
481	1481	40	148	16	20	2	17	1	14	2
482	1482	38	135	8	12	1	11	0	46	2
483	1483	40	135	1	0	0	0	0	22	1
484	1484	40	139	7	3	1	2	0	19	2
485	1485	42	118	5	5	2	2	1	25	2
486	1486	41	138	4	8	5	2	1	17	2
487	1487	41	121	16	13	7	4	2	24	2
488	1488	41	124	8	9	4	4	1	37	2
489	1489	38	139	1	0	0	0	0	14	1
490	1490	40	135	13	18	9	6	3	29	2
491	1491	41	139	2	6	1	5	0	13	2
492	1492	40	127	3	4	0	2	2	37	2
493	1493	41	129	8	15	4	10	1	10	2
494	1494	41	119	13	12	6	4	2	35	2
495	1495	37	146	1	2	2	0	0	44	2
496	1496	38	129	5	5	2	2	1	22	2
497	1497	41	133	10	14	7	6	1	9	2
498	1498	40	134	4	3	1	0	2	15	2
499	1499	39	125	2	10	7	3	0	32	2
500	1500	40	127	6	14	8	5	1	14	2
501	1501	40	137	8	10	3	6	1	30	2
502	1502	41	115	17	11	5	5	1	20	2
503	1503	40	127	1	4	1	0	3	5	2
504	1504	40	140	1	9	7	2	0	7	2
505	1505	40	129	10	20	10	6	4	9	2
506	1506	41	142	3	3	0	2	1	15	2
507	2001	38	147	8	11	5	5	1	35	2
508	2002	39	133	1	1	0	0	1	8	2
509	2003	41	146	22	22	3	16	3	28	2
510	2004	41	144	0	4	3	1	0	18	2
511	2005	39	153	3	4	3	1	0	18	2
512	2006	41	151	0	2	1	0	1	6	2
513	2007	40	139	3	6	4	1	1	13	2
514	2008	40	160	0	4	3	1	0	17	2

515	2009	40	171	2	11	7	4	0	10	2
516	2010	38	135	2	11	10	0	1	13	2
517	2011	40	147	3	7	3	3	1	13	2
518	2012	40	159	0	1	1	0	0	13	2
519	2013	39	134	13	15	9	6	0	82	2
520	2014	40	131	2	8	2	6	0	33	2
521	2015	41	126	3	6	5	0	1	9	2
522	2016	41	154	0	1	1	0	0	9	2
523	2017	41	140	1	6	4	1	1	9	2
524	2018	40	133	4	8	1	7	0	14	2
525	2019	40	137	3	15	11	3	1	30	2
526	2020	40	137	11	9	1	8	0	12	2
527	2021	40	132	8	9	4	5	0	11	2
528	2022	41	133	3	10	0	9	1	24	2
529	2023	38	149	0	0	0	0	0	6	1
530	2024	41	140	0	7	5	2	0	14	2
531	2025	42	178	1	1	0	0	1	63	2
532	2026	42	127	4	6	2	2	2	8	2
533	2027	41	155	1	1	1	0	0	4	2
534	2028	41	149	1	11	8	3	0	11	2
535	2029	41	118	1	5	4	1	0	42	2
536	2030	40	125	1	1	0	1	0	28	2
537	2031	39	159	6	12	2	10	0	11	2
538	2032	41	140	1	1	1	0	0	66	2
539	2033	40	153	6	10	8	2	0	24	2
540	2034	40	126	6	12	11	0	1	17	2
541	2035	40	147	0	1	1	0	0	10	2
542	2036	40	163	0	2	2	0	0	62	2
543	2037	41	119	5	4	3	1	0	11	2
544	2038	40	152	0	1	1	0	0	7	2
545	2039	39	125	1	1	0	1	0	19	1
546	2040	41	166	1	3	1	2	0	13	2
547	2041	41	154	4	3	1	1	1	13	2
548	2042	39	126	4	2	1	1	0	13	2
549	2043	41	130	3	9	5	2	2	9	2
550	2044	42	155	1	1	0	1	0	19	1
551	2045	39	115	2	1	1	0	0	15	2
552	2046	39	109	17	19	9	7	3	25	2