Chapter 7

Summary and Outlook

7.1 Summary

This thesis has been organised in two parts. The major objective of the first part, is to use machine learning techniques for the task of the identification of the chromosomal abnormalities during the first trimester of pregnancy. More specifically, classifiers such as Artificial Neural Networks (ANNs), support vector machines and k-nearest neighbours had been applied to a large dataset of pregnant women that underwent a pre-natal screening. The results of this study are presented in Chapter 2. Currently, in the literature it has been reported that a statistical mixture model (SMM) is used as a classifier to estimate a risk for T21. In this thesis it is shown that ANNs achieve better results than the SMM in both the diagnostic rate (DR) of the T21 at a lower false positive rate (FPR). In addition to this, in the proposed methodology, other chromosomal abnormalities (OCA) such as trisomies 13 and 18, triploidy and Turner syndrome are identified. In the literature, the identification of the OCA is not clearly reported and the commercial use of the pre-natal diagnosis is done only for T21. In the same chapter, the data are visualized and analyzed with standard statistical methods.

In addition to the goal of identifying the fetal chromosomal abnormalities, other technical questions were addressed in Chapter 3. In the literature, it is shown that biochemical parameters from the blood test improve their seperability when they are normalized with the multiples of their medians. Several experiments were held in order to explore the possible use of raw data for training the ANNs. Furthermore, in the same Chapter 3 clustering techniques were used to split the normal (euploid) cases in a number of subclusters and representative instances were collected around the prototypes of the k-means for creating a balanced training set. We showed that better results are achieved for the DR of the OCA, but the difference of the results for the DR of T21 for the balanced and the imbalanced training sets is not significant.

In Chapter 4 a two stage approach for the identification of fetal chromosomal abnormalities was proposed. Following the findings from Chapter 3 it is shown that all pregnant women can perform at a first stage a pre-natal diagnosis test using 4 parameters from the ultrascan and the blood test. From the results in stage 1, all the T21 (100% TPR) and 77% of the OCA are identified with a cost of a relatively
high FPR of about 20%. In stage 2, all the cases that are ranked positive in stage 1 are advised to proceed with an additional examination to get the values of two additional parameters, the ductus venosus and the tricuspid flow. The output of stage 2 is separated in “no risk”, “moderate risk” and “high risk” areas. The cases that are ranked as “moderate risk” are suggested to perform another non-invasive test, called cell-free fetal DNA, while the cases in “high risk” are suggested to proceed with one of the invasive tests, the amniocentesis or the chorionic villus sampling.

In conclusion, in this work, we show that ANNs perform significantly better than other existing non-invasive tests.

In the second part of this thesis, two applications in the field of computational ethnomusicology had been presented. The first application identifies important motifs in 1D signals from melodic sequences and converts a song into a symbolic representation that is based on the similarity and the repetition of the appearing motifs. We introduce the concept of the two-layers COSFIRE approach that are configured using properties from the fundamental frequency of the audio signal and are tuned with several parameters. The COSFIRE filters have been effective in 2D signals and particularly in images (Azzopardi and Petkov 2013, Azzopardi and Petkov 2014). We adapted the 2D COSFIRE filters for 1D signals and we report their effectiveness in a benchmark dataset of 38 songs (X motifs). The results are measured in terms of precision and recall for the motif identification. For the symbolic representation we use the minimum hamming distance between the string given in the ground truth and the resulting string from the application. We compare our method with other existing methods such as dynamic time warping (DTW) and cross correlation. The COSFIRE approach as shown in Chapter 5 are more effective and more efficient than the other existing methods that are compared with the same dataset.

In Chapter 6, the task of the identification of ornamentations in folk singing songs is addressed. We have used the theoretical frequencies of the third octave of the Western music theory to configure 12 COSFIRE filters that are applied to the fundamental frequency of the audio signal of five Cypriot folk songs with total duration of 403 seconds containing 428 ornamentations. A cut-off value is used to binarize the response signals of the 12 COSFIRE filters and dynamic programming is applied for the identification of ornamentations. The proposed method classifies a detected ornamentation in one of six categories that are based on the literature and in music theory. We applied the same procedure by using another similarity distance, the cross correlation, and is found that COSFIRE filters perform significantly better.
7.2 Outlook

The work presented in this thesis can be extended in several directions. It is discussed in the scientific community through the fetal medicine foundation world congress and other relevant conferences that the use of characteristics coming from the father could possibly contribute to the detection of chromosomal abnormalities. So far, none of the biological or other features of the father is used in the existing methods for the pre-natal diagnosis test for chromosomal abnormalities. Essentially, this is an open question that has practical obstacles to be researched, such as the doubt of the identity of the father.

The pre-eclampsia is a serious and at some cases fatal disease that can be developed to the mother during pregnancy. It is reported in the literature that the symptoms of pre-eclampsia are related to a fetus with chromosomal abnormality. For instance, the two biomarkers that are extracted from the maternal blood respond in a similar manner in both situations either the evolution of pre-eclampsia, either a fetal chromosomal abnormality, either both. After several meetings with the collaborating doctors, we have made a model for future work that will use the parameters of the pre-natal examinations and will predict whether a case is developing pre-eclampsia, or carries a fetus with chromosomal abnormality.

Considering the second part of this thesis, it is shown that the use of COSFIRE filters in 1D ethnomusicological sequences is promising for solving several tasks such as motif repetition and ornamentation detection. However, more work needs to be done in order to improve the initial segmentation that is currently done manually. Moreover, in both methods that are proposed in Chapters 5 and 6, the parameters for tuning and optimizing the COSFIRE filters have to be done using a greed search approach. Automated setup of the parameters can be achieved, depending on the task. For instance, the parameters for the amplitude tolerance can be set according to the mean and the standard deviation of the input signal.

From the experiments done in Chapter 6, it is shown that the filter approach is promising for note-level segmentation. However, some limitations of this work are identified. First, the dataset used is narrowed into monophonic songs by male performers. In order to capture the melodic characteristics of these songs, we configured COSFIRE filters that are selective only for the frequency range of a male singer. It would be interesting to widen the dataset by including female singers and make the method to be selective in the entire frequency range of the Western music theory. Finally, the systems in Part II can be improved by extracting the fundamental frequency of polyphonic music. This can be done using existing algorithms such as MELODIA (Salamon and Gómez 2012).

Another application where COSFIRE filters could possibly become applicable, would be a pairwise similarity measure between two entire songs. For this task, a lot of work has been done in the MIR community and it has a particular interest
in the field of computational ethnomusicology. From the properties of the COSFIRE filters as has been designed to allow temporal and frequency tolerance, it is expected that they can achieve good results but not necessarily better than other methods.