ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

SUPERVISOR'S OPINION OF FINAL THESIS

I. IDENTIFICATION DATA

Thesis name:	**Application of one-class classifiers in differential diagnosis of dysarthria**
Author's name:	**Tran Duc Minh**
Type of thesis :	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Control Engineering
Thesis supervisor:	Ing. Jan Hlavnička
Supervisor's department:	Department of Circuit Theory

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment — **challenging**

Evaluation of thesis difficulty of assignment.

This thesis represents a multidisciplinary topic that spans statistical analysis, machine learning, acoustic analysis of pathological speech, and neurology. Although the acoustic analysis of signals was not the subject of this thesis, the knowledge about acoustic features of dysarthria was required for the development of method for feature selection and interpretation of results. The discussion of practical application requires putting findings into a wider perspective, which can be challenging for any bachelor student.

Satisfaction of assignment — **fulfilled**

Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.

All points of the assignment were fulfilled. Student analyzed more classifiers than the assignment asked for, which increases the credibility and applicability of his findings.

Activity and independence when creating final thesis — **C - good.**

Assess that student had positive approach, time limits were met, conception was regularly consulted and was well prepared for consultations. Assess student's ability to work independently.

Student's work on the thesis had two stages. First, student had to study elementary knowledge of statistical analysis, machine learning, acoustic analysis, and neurology. Student met all the terms, performed exercises and fulfilled his homework tasks. Second, student received the data and performed analysis. Student worked independently and consulted his conceptions. However, there were periods that took months when he was not capable to work on the topic due to personal reasons, which caused some difficulties in connection to his previous consultations. The manuscript and final version of his methodology and results was provided to me 3 weeks before the deadline, which is excessively late for consultation of corrections and refinements.

Technical level — **B - very good.**

Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.

Student learned from recommended literature and searched for other relevant sources of knowledge. This thesis required to gain knowledge from diverse fields and student was capable to bridge these fields and find his own perspective. In addition, student showed ability to comprehend information from various sources and to transform the content into a logical message. Student was capable to interpret results of hypotheses testing as well as accuracy analysis. I appreciate very much that student tried to discuss his results in the context of findings of other authors.

It would be interesting if the overlap between symptoms of Huntington's disease and Parkinson's disease was enumerated–but it was not crucial part of the work. The metric used for accuracy analysis was illustrative enough and valid for this purpose.

I have identified only few weaknesses: There are phonatory features F0 mean and F0 range listed in the chapter 2.2 Method, page 17. These features were not included in the data–they just appear here for no apparent reason.

ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

SUPERVISOR'S OPINION OF FINAL THESIS

The feature selection had to be described in more details. For example, Bonferronni correction of multiple comparisons was applied according to diagram decision "p<0.05/44" but this was not described in the text.

The figure 5 seems to have a redundant decision whether or not the feature was "significant". Significance was obviously answered by decision "p<0.05/44" in the previous step.

Formal and language level, scope of thesis **B - very good.**

Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.

This thesis is written in clear and intelligible language. Some sentences did not conveyed the information correctly e.g., first sentence of the introduction give misleading information about Huntington's disease–it does not belong to the most common neurodegenerative disorders. The text is well structured. All items such as figures, tables, and equations were enumerated, described, and listed. Abbreviations and symbols were listed in nomenclature.

Half of the paragraph "phonation" in 1.2.1.Speech impairment is nonsense. It describes perception not phonation.

Anova1 is the name of MATLAB function nor a statistical test. This abbreviation can be found only in the abstract and Figure 5. Nevertheless, the Method section uses correct naming "one-way analysis of variance".

The equations and symbols are not described very well in the text. Reader must look into the list of symbols to know what some symbols mean–and not always could find the answer.

Student included the equation 8 that states "$n_{free_p} = 1$" in spite of my recommendation to not present the value of a parameter as equation–not many readers may share the same sense of humor with the author.

Selection of sources, citation correctness **C - good.**

Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.

Student actively searched the literature and used the references appropriately in most cases. His thoughts were distinguishable from references.

The biggest weakness is that references were not ordered alphabetically and that complete bibliographic information is provided in the label of the Table 1 instead of referencing–student ignored my recommendations. In addition, some references were not listed in bibliography, e.g. Harel et al. 2004, Rusz et al. 2015, Watson and Munson 2008.

Reference Apraxia Kids (2018) titled as "Disordered prosody and articulation in children with childhood apraxia of speech" is currently unavailable, but the title itself raises a question whether the reference is appropriate source of information about Parkinson's disease.

Additional commentary and evaluation

Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.

Student achieved all the primary goals of his thesis and presented trustworthy results. Student designed a feature selection methodology based on testing of hypotheses, which is valid and appropriate, because it allows to check quality of the model by comparing findings with other studies. Student also conducted a classification experiment and evaluated his results using relevant metrics. Student provided all the codes and data used for evaluation as well as a brief documentation. His findings are interesting and have a publication potential.

ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

SUPERVISOR'S OPINION OF FINAL THESIS

III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

Summarize thesis aspects that swayed your final evaluation.

Here I have to highlight that student wrote a consistent thesis that covers a very complex topic. Since one-class classifiers are used for the analysis of pathological speech only sporadically, student could not base his solution on existing literature. Findings presented in this study are unique and no such an experiment with acoustic speech features of dysarthria was previously published. Student also demonstrated his results on a practical example, interpreted his results, and provided answers to fundamental questions on applicability of one class classifiers for assessment of dysarthria. Presented results could inspire further research as they illustrate how to overcome limited availability of speakers using one-class models. Apart from several small errors, I am satisfied with his work. There was some room for improvement, but the fundamental goals were met very well.

I evaluate handed thesis with classification grade **B - very good.**

Date: **29.1.2019**

Signature:

ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

REVIEWER'S OPINION OF FINAL THESIS

I. IDENTIFICATION DATA

Thesis name:	**Application of one-class classifiers in differential diagnosis of dysarthria**
Author's name:	**Tran Duc Minh**
Type of thesis :	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Cybernetics
Thesis reviewer:	Ing. Tomáš Lustyk, Ph.D.
Reviewer's department:	Digiteq Automotive, s.r.o

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment **challenging**

Evaluation of thesis difficulty of assignment.

The bachelor thesis assignment is on an interesting and up-to-date theme - early diagnosis of speech dysarthria, speech impairment related to the Parkinson's (PD) and Huntington's disease (HD). It had a sufficient extent and was chosen appropriately to the year of the study. I really appreciate that the student could apply his knowledge from the university classes and knowledge learned from literature (mainly machine learning) on a real problem with possible outcome in praxis.

Satisfaction of assignment **fulfilled**

Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.

Yes, the presented thesis fulfilled the assignment in all aspect. There are some minor flaws, but they should not prevent from successful defense of the thesis.

Method of conception **outstanding**

Assess that student has chosen correct approach or solution methods.

The student used appropriate approach to the assigned problem.

Firstly, he needed to get familiar with possible machine-learning methods and what one-class classifiers are available. Also, he learned what are the unique speech and voice features that look for early signs of PD and HD is speech recordings (provided by supervisor).

Then, he proposed statistical test to select appropriate features. Also, he reduced number of speech/voice features that were correlated (four features were withdraw). He suggested criteria to evaluate the performance of classifiers in areas of general, hypokinetic and hyperkinetic dysarthria. Trained the classifiers on training data and performed the tests. The data came from 156 Czech native speakers. Also the most suitable classifiers were identified.

The evaluation was made with the result, that one-class classifiers would be suitable for use in clinical practice in the area of general dysarthria (distinguish between healthy speaker and patients with early signs of PD and HD). Their performance is comparable to multiclass classifiers. To find a difference between hypokinetic and hyperkinetic dysarthria there are better options (multiclass classifier) or more research and data would be needed. This all is summarized in section Discussion.

Technical level **B - very good.**

Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.

According to the assignment the student should get familiar with at least three one-class classifier and at least three multi-class classifier. The student worked with six one-class and six multi class classifiers. Therefore, he needed to search in literature and get familiar with chosen classifiers and by this, extend his knowledge. This surely needed some effort and work with specific classification-based/machine learning literature.

ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

REVIEWER'S OPINION OF FINAL THESIS

Also, the proposal of feature selection, evaluation of feature and classifiers performance would not be possible with just a small insight into problematic. So, the student proved to be able to work with literature, to program software to compute results, and to evaluate and discuss the results.

Shortcomings:
Maybe this is also related to the formal side of the thesis. There is some imbalance in description of classification methods (chapter *1.4 Classification*). Some of the methods are described more into details than others ... there is more detailed text, higher number of equation. For example: *Multiclass classifiers – Naive Bayes classifier* has two important equations, but *Nearest neighbor classifier* has only one short paragraph of text, no equation. Similar with one-class classifiers *Parzen density estimation* has four equations (one is $n_{free\ p}= 1$), but *PCA* has only one equation. Moreover, in some equation there are some of the symbols that are not defined (for example: page 9, *Parzen Density estimation*, Equation 7, $\Sigma_i = hI$, what is I?).

One of the things that I am missing in the thesis is: were all the calculations done by hand on paper? :) Or what software was used for computations? Matlab? SPSS? Were any of the statistical methods implemented by the student or were all the methods used as they are implemented in the used software?

Formal and language level, scope of thesis **C - good.**

Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.

The thesis is at the first sight formally at good level, typographically at high level. It is appropriately divided into individual part and following the structure of the thesis is easy (*Introduction, Material and Methods, Results, Discussion*). All is supplemented tables, figures, and equations which are listed in *List of Table, Figures, Equations, and Nomenclature*.

In some way, the thesis seems to be very compressed and in my opinion less compressed information would contribute to better readability and clarity.

As the abstract and motivation follow each other, they seem to repeat the same information. This should be avoided.

There are 6 tasks in the recording protocol. And there are 44 speech/voice features to evaluate the performance of participants in individual task which are described in the *Method* chapter. Which of the features were measured on which tasks? A table that would clearly state on what task a feature X was measured would add to clarity.

I do not dare to evaluate the language side of the thesis as I am not English native speaker. However, I found several issues that are related to language and these confused me. *(not necessary to read at the thesis defense)* Here is a short list from the first few pages:
(page, part, paragraph) – issue
(1, *Parkinson's disease*, 2) – "Previous studies show that in average PD effects (correctly - affects?) ..."
(2, *Parkinson's disease*, 2) – "The patient's life expectancy is individually (correct – individual?) ..."
(3, *Huntington's disease*, 1) – "HD is defined as a chronic, degenerative, progressive neuropsychiatric disorder, characterized by progressively increasing (correctly – progressive increase?) of chloreiform movements."
...Maybe most of them are auto-correction mistakes?

Or others:
(2, *Speech impairment*, 2) – "Phonation problem - trouble learning the sound system..." + "Articulation problem – difficulty learning to physically..." (I thought, that these people can talk and that they know how to use their voice, so they are losing their ability to articulate and recognize sound contrast. The use of word "learning" seem to be inappropriate, or is it related to the intensive speech therapy?).

(35, Discussion, 3) – "PCA classifier performed well ... and this method is NOT so sensitive to the scaling of the feature."
(12, Principal component analysis, 1) – "PCA is relatively sensitive the scaling of the features, it directly influences the feature variance." What is correct from the previous two lines? Is PCA sensitive or not to feature scaling?
(15, Subjects, 2) – "All participants were on stable dopaminergic medication for at least 4 weeks before examination, which were conducted on-medication state. All the PD participants were examined immediately after the diagnosis was made and before symptomatic treatment was initiated." What is correct? Were the PD patients under medication or were

they free of medication? If there were different types of examination (on medication x free of medication), it should be clearly stated. On what state were the speech recordings made?

Selection of sources, citation correctness **D - satisfactory.**

Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.

The thesis has a long and extensive list of reference for bachelor thesis (> 90 references!). Maybe, it would be even better to shorten the list to a half or lower, to keep it to the minimum. In spite of the high number of references, they seem to be suitably used.

However, the main formal shortcoming of the thesis is, that it is not possible to orient in the reference list. What is the idea behind the order of the references? The list is neither in order of appearance nor in alphabetical order of authors. It makes really difficult to find something in the reference. It also makes almost impossible to check whether all references are paired (they appeared in the text + in the reference list).

As an example: One of the references in the thesis assignment suggested by the supervisor is *Rusz et al. (2015)*, but this research is not stated in the reference list. Is it used in text? It is in the text. The other works of Jan Rusz and his joint authors appear in text and reference list, but the one listed in assignment seem to be missing.

Additional commentary and evaluation

Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.

A good example of the insight into the problem could be the one given in the section *Discussion*. The student discusses the results and performance of the classifiers, but additionally to the information about the accuracy of the classifiers, he provides a simple example on what impact would have an accuracy of 80% for the best one-class classifiers and 89% for the multiclass classifiers on classification when the screening for PD would be done on population of 1.28 million inhabitants in Prague. I like this example.

III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

Summarize thesis aspects that swayed your final evaluation. Please present apt questions which student should answer during defense.

The bachelor thesis is on an interesting and topical theme - early diagnosis of speech dysarthria, speech impairment related to the Parkinson's and Huntington's disease. I appreciate that the student could apply his knowledge from the university classes and knowledge learned from literature on a real problem with possible outcome in praxis.

The main aspects that affected my evaluation are listed below:

Positive

- The approach to the given problem seems to be really good, and hopefully the obtained results will be applicable in the following research in the area.
- Suitable methods for selection and evaluation of acoustic features and performance of classifiers.

ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

REVIEWER'S OPINION OF FINAL THESIS

- According to the assignment, the student should get familiar with at least three one-class and three multiclass classifiers, he examined six one-class and six multiclass classifiers. Which allows to see results from wider range of possible methods for clinical practice.

Negative

- References - no order, not easy to follow the references, maybe too high number of reference.
- The thesis seems to be really compressed sometimes, which make it less readable and it is not easy to clearly understand, what the author wanted to say. Imbalance in description of classification methods.

The negatives are more formal and they are not related how the student solved the given problem. The positive aspects of the thesis highly overcome the negatives. Therefore, I recommend the thesis for a defense.

The questions:

1) The range of age was 61 +/- 12 years for PD patients, 46 +/- 14 years for HD patients. The age of healthy speakers (HC) was 55 +/- 12 (youngest participant was 29, the oldest was 80 years old). The researches on speech and voice features says, that there is ***age-dependency*** of speech/voice features. There is 15 years gap between PD and HD, plus high range in HC speakers. Can this 15 years age difference play any role in the obtained results? Are the speech and voice features of a 46 years old HD patient comparable in some way to a 61 years old PD patient? What about the healthy speakers? Was the age-dependency taken into account when assembling the database for this thesis?
2) The thesis is focused on the differential diagnosis of dysarthria. However, did you do some ***initial experiments with one-class classifiers on separated groups*** of HC x PD, HC x HD, and/or PD x HD? If yes, what was the results?
3) There are 48 PD participant, 43 HD participants, and 65 healthy subjects. How much the ***sample size*** affected the results? Would a higher number of PD and HD subject lead to better performance of one-class classifiers? Can you estimate what sample size would be necessary to apply the one-class classifiers in clinical practice on dysarthria screening?

I evaluate handed thesis with classification grade **B - very good.**

Date: **28.1.2019**

Signature: