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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Aleksei Shcherbak

PhD Program: Computational and Data Science and Engineering

Title of Thesis: Diagnosis of the human neurological movement disorders based on the analysis of heterogeneous data using ML methods

Supervisor: Associate Professor Andrey Somov

Name of the Reviewer: Maxim Sharaev

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: 07-11-2024**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.

The thesis is a high quality well-structured and easy to comprehend work.
In Chapter 1 the motivation and task setting are specified: why it is important to develop a multimodal diagnostic tool for Parkinson disease
Chapter 2 presents a very interesting and extensive literature review. Evidence for use of video as well as wearable sensor and hand writing data is reviewed as well as different ways to analyze single- and multimodal datasets
Chapter 3 outlines the methodology of the study and describes the patient cohort that participated in the study as well as methodology of data collection and curation. Here specific devices and digital signal processing techniques were used to overcome obvious data collection issues like between sensor time synchronization.

Chapter 5 is dedicated to comparison of sensors, video and handwriting data analysis with the conclusion that only first two modalities are needed for a good diagnostic model, thus the following chapters are focused on these modalities:
Chapter 5 thoroughly describes sensors data analysis and results
Chapter 6 thoroughly describes viseo data analysis and results
Chapter 5 adds the joint sensors+video data analysis and results
Finally, there is a Conclusion section which summarizes the goals and results.

- The relevance of the topic of dissertation work to its actual content

The topic of the thesis is fully consistent with its content

- The relevance of the methods used in the dissertation

There are two kinds of methods presented in the thesis: 1) IoT methods for data collection and curation 2) signal processing and ML/AI methods for multimodal data analysis. Both groups of methods are fully relevant to the tasks solved in thesis

- The scientific significance of the results obtained and their compliance with the international level and current state of the art

The results of the thesis are unique due to several facts: the obtained dataset to the best of my knowledge is unique in terms of data modalities and data quality. The models created and evaluated showed a very good diagnostic score for different diagnostic subtasks, with up to 0.95 F1-score when both video and sensors data modalities were used. This is really impressive and places the work on the Parkinson disease diagnostic frontier.

- The relevance of the obtained results to applications (if applicable)

Undoubtedly, the results of the work could and must be tested in real clinical setup and then implemented for Parkinson disease diagnostics.

- The quality of publications

To date, this thesis has already produced 8 peer-reviewed publications including 6 Q1 publications, two of them are first author, which is enough for thesis defense

The summary of issues to be addressed before/during the thesis defense

I'd like to mention several questions and make comments on what can be improved.

General questions:

In Intro section there are two statements "Symptoms overlapping with other diseases especially ET" and "Diagnosis can be confirmed after an autopsy only". Moreover, next "State-of-the-art diagnostic practices in fact have probabilistic character and cannot guarantee success." How this relates to labelling by clinicians, i.e., if it is hard to solve diagnostic task manually - how you can be sure that your labelling is correct?

In Section 1.2 again "there were many attempts to use additional instruments to diagnose PD such as positron emission tomography (PET), computed tomography (CT) with a radioactive tracer (SPECT), magnetic resonance imaging (MRI), electroencephalography (EEG) and others." – in these attempts the aim is to differentially diagnose the reason, i.e. true Parkinson disease. So, how exactly this is connected to symptoms?

Section 1.2 "Additionally, proposed in this work ML-based approaches potentially can register not visible tremor and promotes early PD diagnostic," How exactly this works? Should be justified (invisible tremor diagnostics)

Specific questions:

Section 3.1 "the collected data and medical conclusion from neurologists, who examined the patients before experiments" Info about clinical objectiveness and concordance between neurologists should be provided.

"In such situations, clearly defined clinical diagnoses came later and expressed a group opinion of several neurologists (3-5 persons), relying on additional comprehensive examinations." Here at least a bit of discussion will be valuable

Section 4.1.1 " For bradykinesia, the related features were extracted within a range from 0 to 3 Hz." Before it was stated that high-pass filter was used from 0.5Hz

"For this, the mean and standard deviation (STD) of all the amplitudes and frequencies of the full range of spectrum (mean and STD of amplitudes)". Is there any clinical interpretation for other than frequency features? please elaborate more on clinical meaning?

Section 4.1.3. "Image analysis is the most complicated part here." Why? For me it is not clear. Why not to compare versus standard image classification methods (DL without feature extraction?)

Section 4.2.2 "For video data collection and analysis, all exercises except for 3, 6, 10, 11 and 15 were used." Why? Some statements lack explanation.

Section 4.2.3 "..are not applicable in practice due to the poor result on the Parkinson Drawing Dataset." Why? Could you show the figures with examples of misclassification? For me it seems strange, the difference between HC and PD writing looks huge (fig 4.5).

Section 7.1.3 For future tests I'd suggest intermediate fusion (not early or late) with smth like autoencoders

Conclusions. “Clinical checkup time matters in healthcare and it can be further reduced by relying on them.” I think here comparison with traditional examination will be valuable: can this methods find early stages when clinician fails?

Minor:

Several typos, i.e. Section 2.1 “gate” – gait, “data dollection”, “all acientific” and etc.

Figures quality could be improved (see fig. 4.4 – low resolution)

Nevertheless, my remarks do not detract from the overall high level of work. So, I recommend this thesis to be defended now.

Provisional Recommendation

X *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate’s thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*