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PhD Thesis Review

Author: Monika Kaczorowska

Title: Measurement and Analysis of Cognitive Workload on the Basis of Eye-tracking Activity Using Machine Learning

After reviewing the document submitted by the candidate, I support the acceptance of the thesis. My recommendation is based on the methods and evaluation criteria suggested by the Polish-Japanese Academy of Information Technology (PJAIT), as per the comments presented hereinafter.

What are the research problems and objectives considered in the thesis, and have they been sufficiently clearly described by the author?

A consequence of modern societies is the significant increase in professional activities that require a high cognitive workload. Due to the importance of cognitive workload both in the outcomes of the work and in the health and quality of life of the work force, research in the field has actively pursued methods for estimating cognitive workload. While the gold standard for these studies is typically rooted in neuroscience and based in signals such as Electroencephalography (EEG), brain imaging, and related techniques, these are not easily transferred to everyday use scenarios. The research described in the thesis explores the use of eye tracking, in combination with explainable machine learning methods, to tackle recognized limitations of state-of-the-art methods. To achieve this broader aim, three main objectives have been established by the candidate, namely: 1) Investigating eye-tracking features and user performance for cognitive workload level classification; 2) Developing interpretable machine learning models for cognitive workload level classification; and 3) Improving the quality of cognitive workload level classification. Overall, both the research problems and objectives have been clearly explained and adequately addressed in the thesis.

Does the thesis contain an appropriate analysis of state of the art (based on global scientific literature, current knowledge and applications in industry)?

The thesis includes a chapter fully dedicated to the state-of-the-art, covering: 1) Cognitive workload definitions and application; 2) Cognitive workload assessment; 3) Eye-tracking; 4) Ex-Gaussian statistics in eye-tracking data; 5) Cognitive workload classification; 6) Cognitive workload classification based on non-eye-activity data; 7) Cognitive workload classification based on eye-activity data; 8) Cognitive workload classification based on combination of eye-activity and non-eye-activity data; and 9) Interpretable machine learning classification.

Due to the interdisciplinary nature of the work, in each of the topics the candidate only highlights the work considered to be of higher relevance to the addressed objectives, although more extensive work can be found the state-of-the-art. Nevertheless, the thesis provides an adequate analysis of state-of-the-art, considering the global scientific literature, current knowledge, and applications in industry.

Does the analysis of related work demonstrate sufficient expertise of the author?

Based on the information found in the thesis, the candidate shows a high level of expertise in the topics addressed in the thesis. In certain passages the thesis would benefit from a more summarized perspective over the related work (e.g. in the form of tables and figures). A more thorough theoretical and physiological background would have also been appreciated, to support the core hypothesis pursued in the thesis. However, due to the large amount of topics addressed in the work, it is also understandable why the candidate has chosen the presented format.

Have the conclusions of the review of related work been sufficiently clearly stated?

The thesis includes a section specifically written to guide the interested reader through the main conclusions and discussion of the related work. In this section, the most important gaps in the state-of-the-art are summarized, alongside the motivations that led the candidate to pursue certain hypothesis in the work. Overall, I believe that the conclusions of the review of related work been sufficiently clearly stated.

Does the research described in the thesis use a correct scientific methodology?

Across the scientific papers comprising the thesis there is some cyclicity and redundancy of ideas. Furthermore, in some passages it is not always clear why certain options have been taken. Nevertheless, the work uses an adequate scientific methodology. Relevant data has been collected and different algorithms have been explored using a satisfactory methodology. The algorithms were evaluated, and standard metrics were used to characterize the performance. The candidate guides the reader through the rationale for the performed experiments and adequately explains the results. The extensive validation resulting from the accepted publications further testifies the significance of the work.

What are the original and innovative contributions of the author, and what is the position of these contributions compared to the state of the art?

The work contributes primarily to the field of computer science, with core contributions centered on subject-independent classification of cognitive workload based on eye-tracking and user performance features. Within this topic, the candidate provides contributions on classification models based on Interpretable Machine Learning (IML), fuzzy aggregation functions, and Ex-Gaussian statistics. Contributions are also made to the field of cognitive sciences, through cognitive factor analysis using IML.

How do you evaluate the publication record of the candidate?

In relation with the thesis, the candidate presents 1 paper accepted in an international conference with scientific refereeing, and 3 journal papers accepted in indexed and peer-reviewed international journals. All publications have the candidate as first author. Within the journal publications, 1 paper has been published in a Q1/Q2 journal, while 2 papers have been published in a Q3 journal. Although a more robust publication record would be desirable, the scientific papers comprising the thesis greatly exceed the institutional requirements.

Did the author present his results correctly and convincingly? (Please evaluate the clarity, conciseness, correctness of the thesis or presented research articles).

Overall the results are presented in a clear and correct manner. A convincing discussion is also provided, highlighting the main conclusion and limitations of the work. Being mostly supported by scientific papers, the work is also concisely presented. However, rationale for certain options is not always clear nor is the comparison with previous work found in the state-of-the-art. Furthermore, across publications there is a certain degree of redundancy, although understandable in light of the format adopted for the thesis.

What are the weak and strong points of presented research results?

The strong points are the use of eye tracking features and user performance, for subject-independent classification of cognitive workload. This is explored using IML approaches, adding to the significance of the work. Centering the research on eye tracking features and user performance (as a potential alternative to more intrusive methods), further increases the significance of the work, since it may pave the way for deployment in real-world applications. The weak points are mostly related with the experimental design. On one hand, the number of participants enrolled in the study is fairly limited and covering only a restricted age span. On the other hand, the level of cognitive workload was fixed for all participants. Furthermore, a more extensive comparison with previous work found in the state-of-the-art (not necessary focused on eye tracking features and user performance) and further experiments with more recent machine learning methods would have been appreciated.

What is the contribution of the thesis to the discipline of information technology?

This thesis contributes to the field of information technology, by exploring physiological and behavioral data sources to assess cognitive workload using IML. Cognitive workload classification is a topic of growing interest both at an academic and industry level; previous work is mostly focused in data collected with highly intrusive equipment, and the use of IML has only recently gained momentum. A new set of algorithms for cognitive workload classification is evaluated in this thesis, together with a study of their performance.

Are the presented achievements of the author sufficient to grant him/her a doctoral degree in the field of technical sciences in the discipline of computer science or software engineering?

In my opinion, the presented achievements of the candidate are sufficient to grant a doctoral degree. The candidate has adequately reviewed the state-of-the-art, studied a problem of topical nature, conducted relevant experiments, and used appropriate methods. The results are presented and discussed in a satisfactory manner. Conclusions are in line with the main findings of the work and the most relevant limitations have been highlighted by the candidate.