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Review

of PhD thesis titled "A method for measuring trust and attractiveness of presented faces based on brain activity measurements and machine learning" authored by mgr inż. Bernadetta Bartosik.

Thesis Supervisor(s): *Professor Grzegorz Marcin Wójcik (UMCS, PJATK)*

Professor Aneta Brzezicka (SWPS)

This review has been provided in response to invitation from **Prof. dr hab. Marii Elżbiety Orłowskiej, Head of Scientific Council for Computer Science Discipline**, issued on the 22nd of June 2023. The purpose of this review is to assess whether or not the PhD thesis presented by mgr inż. Bernadettę Bartosik satisfies the requirements defined in art. 13., ust. 1. Ustawy o stopniach i tytule naukowym.

1. Scope of the thesis

The scope of this thesis is located in the area of widely understood ML-based methods of classification and analysis of electrical brain activity using EEG signals.

Using brain waves acquired by the use of various kinds of EEG devices (starting with not quite sophisticated and of-the-shelf equipment such as Open BCI up to quite expensive, precise and advanced clinical EEG devices used for medical diagnostics) for acquiring information about processes occurring in the human's brain has become extremely popular and this is perfectly reflected by a huge increase of various kinds of research works (published in research papers but also being subject of for example PhD theses) appearing in both, conference proceedings but also very prestigious scientific journals. The increased popularity of this research domain is especially visible over the last decade when analysis of the EEG signals has advanced to the main method used for diagnostics and / or prevention (through screening tests or early-stage diagnostics) of various kinds of mental and / or neuro-degenerative diseases.

On one hand, this substantial increase of the popularity of this research domain can be attributed to equally substantial increase of processing power of nowadays computers allowing to use today very efficient technologies (e.g. machine- or deep learning) which were way too much processing power hungry for the computers available just a few years ago and as a consequence, these technologies

were not particularly useful especially in the context of analysis of some big data sets. On the other hand, which is even more important, over the last years one can observe a huge progress in the availability of tools and techniques for ML / DL (for example there are available many well-known Python libraries which can be used for data analysis / classification) as well as signal processing / filtration methods not available in the past (e.g. fractional order filters). Additionally, nowadays researchers have easy access to publicly available data sets so they can focus solely on the signal analysis / classification methods and skip the, sometimes very troublesome, data acquisition stage.

This dynamic growth of the aforementioned tools and methods is accompanied by equally dynamic growth of its application domains, including both, medical and non-medical applications. So, apart from a typical medicine-related analysis / diagnostics application (e.g. for hypothermia or anaesthesia assessment / monitoring) one can find numerous applications of EEG-related research results in other life domains, such as computer games, devices control and more.

In the reviewed thesis the EEG signals were used for assessing trust based on measuring brain activity and also determining the effect of face attractiveness on whether a person is trustworthy (more or less) or not.

Locating this thesis scope in this very dynamically growing research domain makes it **relevant and actual**.

2. Research goal(s) / research hypotheses

In the reviewed thesis the research goals were clearly defined in chapter 1.2. and research hypotheses were formed in chapter 1.3.

So, the research goals were split in two types of experiments: pilot and main ones. The pilot study was conducted to determine mainly trust and attractiveness based on the photo (survey-based assessment) while in the main experiment EEG signal was used for this purpose (the participants were asked the same questions regarding attractiveness and trust and while doing so the EEG signal was collected). In both experiments a corresponding ML model was built and the collected data were used for training purposes.

Along with the research goals one can find 5 research hypotheses (chapter 1.3) to be verified. Basically, they are strictly linked to the research goals and if they were all answered in a positive manner, then this would mean that the experiments design led to acquiring necessary data to train the ML model to be able to determine subject's attractiveness and trust based on a photograph and EEG (specifically, integrated Mean Electric Charge (MEC) of specific brain areas and evoked potentials) data.

I find all the research goals and hypotheses non-trivial and set at the level satisfying PhD-level problem requirements.

3. Structure and organisation of the thesis

The reviewed PhD thesis counts in total of 85 pages and comprises of 6 chapters (including Discussion / Summary chapter). Additionally, there is a bibliography section listing 102 references. According to the references list, the thesis Author published 2 (one as leading Author and one as co-author) and one of the papers is in review.

As for the chapters contents, the main chapter containing design of the research experiments is chapter 4. In chapter 5 there are presented results while in chapter 6 there is a discussion on the results (separately for each of the experiments – the pilot and main one). The discussion is purely results-oriented and does not identify any potential problems to be solved in the future (no future work is outlined). Apart from that, there are 3 other chapters, chapter 1 defining the research goals / hypotheses, chapter 2 describing encephalography and chapter 3 addressing the signal (per)processing methods. Additionally, separate sections with list of figures and tables are provided.

The thesis was written as whole in English, the language is comprehensible, and I have no reservation over the presentation quality. In general, it is visible quite an attention to detail and despite the fact that I have found some small issues which are mainly presentation related (use of English does not leave anything to be desired), I have found really just a few issues of this kind and they are definitely not affecting the overall work quality. All of them are gathered in section 5 of this review, together with some substantive remarks.

4. Achievements of the research

As for the **novel and original** achievements of this work – they can mainly be found **in chapter 4** where the Author has **presented research tools and procedures** and **in chapter 5** where the **ML model(s) details allowing to classify trust and attractiveness cases were presented**. Which is also worth emphasising, one can qualify as the overall thesis achievement also **proper identification of brain areas which were particularly useful for trust and attractiveness assessment**. I tend to agree with the Author's statement that the angle of investigation presented in this thesis is not to be found in the literature.

In the reviewed thesis the Author has shown a very good understanding of the research process comprising of ability to properly define some research problems, proposing some valid methodologies to resolve them and experiment-based verification of the proposed methodology. In order to do all of the above the Author has particularly done the following:

- provided a very good and exhaustive review of existing machine learning and classification methods, potentially useful for the specified research goals,

- formulated and then successfully verified 5 non-trivial research hypotheses using for this purpose machine learning algorithm(s),
- formulated and then successfully verified procedures experimentally allowing to collect data crucial to solve the defined problems,
- identified brain areas responsible for trust and attractiveness assessment,
- obtained and experimentally verified ML model(s) useful for trust and attractiveness assessment.

The above achievements are **important and valuable contribution** to the research domain and as such **fully justify positive assessment of this work**.

5. Drawbacks of the thesis and aspects to discuss

With respect to the drawbacks of this thesis – all my remarks are of both, substantive and editing nature. However, none of them does not effect the final assessment and are only provided in order to identify areas where this thesis could be potentially improved, especially with as far as its clarity is concerned.

5.1. Editing / use of English related remarks

1. After looking at the table of contents - many chapters / section titles are just one word, e.g. “1.6 Trust” or “3.2.4 Averaging” or even acronym, e.g. “3.3.2 MEC”. Usually, it should be kept in mind that chapters / sections titles should be informative and leaving no space for ambiguity (this especially applies to chapters / section titles being just acronyms where an acronym can be potentially understood in many different ways).
2. Page 17 – it is untypical that a new section / subsection title appears out of nowhere. I mean, If the section title is “Encephalography” and just after that appears subsection title “2.1 Brain anatomy” without any kind of introduction, then it is unclear why at all a new section is needed. So, at least one or two sentences of introduction would be of help.
3. Page 24 – first paragraph – there is unclosed parenthesis “(Figure 2.4.”.
4. Page 35 – in the equations 3.1 and 3.2 – some symbols are not explained (e.g. T , K , H).
5. Page 55 – Figure 4.8 – some descriptions are hardly readable. And when providing a screenshot with the key software used for the research, it would be good to provide some explanation of its core functions.
6. Page 60 – just as an example (Table 5.1 or Table 5.2) – usually, figures captions are positions underneath the figure while table captions should be placed above the table (so that in case a table does not fit one page, it is still clear what it is about).

5.2. Substantive remarks

In general – I am not going to list all the doubts / questions I have regarding this work and will stick to only a few but the most important ones:

I have a big problem with understanding of certain aspects of this thesis. Basically, when reading this work, structurally, I can see the introduction chapter, then 2 theoretical chapters where vast majority of the relevant theory is described (including ML algorithmic, signal filtering, segmentation, etc.) and then we have the three chapters with methodology, results and discussion. The trouble is that I can't really see any details (or I am missing something) of the actual implementation. So, please find below the list of my substantive remarks.

1. The first part of the work (pilot experiment) was done using a survey(s) which is mentioned in many places and even some questions from the survey are being provided. Even if the survey was lengthy (it is mentioned that it contained 240 questions) then why not to include such a key element in the appendix section so that it was at hand when someone would like to understand the experiment somewhat better. There is enough space in the thesis to accommodate this (it would add some more meaningful material).
2. It is mentioned that the 61 participants involved into the research were all man and right handed. Even if I understand the rationale for this (e.g. women have usually long hair which impairs signal acquisition) then I would like to know any thoughts as to how the results can be extrapolated to a generic population?
3. How actually the photographs were selected. Was there any kind of randomisation in the selection of the 100 photographs used in the study (later reduced to 24 photographs) or the selection was purely subjective to meet certain proportions (meaning gender, ethnicity, etc.)? Because there is a statement saying that "By analysing all the collected information (...)" suggests that it might have been otherwise (objective) so it would be good to clearly state based on which specific criteria the selection was made?
4. Depending on various factors, such as cultural background or even personal experience, the same face for one person may look trustworthy whereas for another person as not trusted at all. Have factors like cultural background or personal experience of the participants been recognised (a.g. in the survey). Was there anything in the whole research design to take such factors into account and if yes – how was it done?
5. If any filtration of the EEG signal was needed (and I believe it was), then where are the details regarding the filters used (I presume that before even using a filter there was a study / testing needed including some filters test, their tuning, etc.). So my question is – where do I find any information about signal filtration / conditioning?

6. I believe that the machine learning part of the dissertation was done using Python programming language. If yes, then it would be really good to show some kind of trial and error steps showing how the model was being calculated. It is difficult to believe that the model was calculated in the first go and with the default parameters the designated ML functions are configured for. The Python functions related to model calculation (e.g. *LogisticRegression()* or *models.append()* function) have some design parameters (usually, the default values can be altered through passing parameters into the function at the function call). Showing some code snippets would clarify many things with respect to how the model(s) was obtained or most of all – if the whole training process was performed as best as possible (and has no space for improvement).

The main reason why I have raised the above points is that nowadays there is a tendency noticed when submitting a research paper into some highly ranked journals that the paper should provide enough implementation details to allow replication at least the key results. Not including such details into this PhD dissertation seems to me as quite an underestimation of their importance. Of course, this is not disqualifying the final outcomes of this work, yet it makes the whole picture a bit unclear.

6. Recommendation

In my view, the reviewed PhD dissertation prepared by the PhD candidate, mgr inż. Bernadette Bartosik, constitutes a **valid and important achievement in the development of technical sciences** and that the proposed research methodology and the included results make it **relevant** for the **computer science** discipline. Although the PhD candidate publication record is leaving a bit to be desired– the candidate has very few publications overall, then following the “quality over quantity” principle (meaning that those few publications have already been or will be published in some prestigious journals) I think that the candidate satisfies requirements in this aspect, too.

Therefore, **this dissertation satisfies the requirements** established in the current regulations (Rozporządzenie Ministra Nauki I Szkolnictwa Wyzszego w sprawie szczegółowego trybu i warunków przeprowadzania czynności w przewodzie doktorskim (...)) and can be subject of public defence in the **computer science** discipline.

Reviewer



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