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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Alexander Menshchikov

PhD Program: Computational and Data Science and Engineering

Title of Thesis: Mathematical Modelling and Analysis of Intelligent Monitoring Platform for Precision Agriculture

Supervisor: Assistant Professor Andrey Somov

Name of the Reviewer: Gonzalo Ferrer

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	Signature: Date: 09-09-2020

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

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

The contributions of the present PhD thesis, presented by A. Menshchikov, lie in the areas of Systems Engineering and Mechanical Aerial Design. There are two other disciples that complement the research conducted in the thesis. Precision Agriculture (PA) is the thread that connects the diverse topics presented in the manuscript, aiming for a common objective. From Computer Vision, Convolution Neural Networks is the preferred tool for the algorithms deployed into the monitoring platforms.

There are four main contributions in the thesis:

1) Detection of Seeds During Germination (Sec. 3.2) and corresponding to Journal [2].
2) Detection of Plants in Greenhouse, in Sec. 3.3. and Journal [1].
3) Detection of Hogweed onboard of UAV, in Sec. 3.4

4) Morphing Wing for Control of the eVTOL in Sec. 3.5 and Journal [3,4]

The common research question in most of these contributions is "how to design a self-contained system capable of plant detection by using low-power computational devices and maintaining a high level of accuracy on the results?". This idea is embodied into the concept of edge computing, which is applied in the context of this thesis as just described. Each of these topics has its own peculiarities, which make them stand apart from each other. The quality of the research is significant and the amount of work required is considerable.

In my opinion, not all systems should be designed with the edge computing paradigm in mind, there are advantages of distributed computing, and it highly depends on the application. I understand that this is the general topic of the research group, but one expected to find a more open and objective discussion on this issue. After all, the reasons provided advocating for edge computing in precision agriculture are powerful enough.

The last topic on Morphing Wing design is not well aligned with the previous topics related to AP and CV. However, the author has made a great effort to include this topic from the very beginning of the thesis, making it a core component of the manuscript in conjunction with the third topic on weed detection. It is not an easy task to present a holistic view of the research done during the thesis dissertation when the topics studied are so diverse and a priori so unconnected.

One has to mention, that despite this effort on presenting a common view for all research topics, there is no experiment including the fixed wing and the weed detector, which is what the introduction of the thesis states as a motivating argument. This is a flaw in coherence of the research topics and the list of publications, some of them on non-related topics.

Regarding the structure of the dissertation, the manuscript is divided in 4 chapters: introduction, related work, methods and conclusions. This choice for structuring the thesis is unconventional. There are four very distinctive contributions (listed above) and in my opinion, each of them deserves a chapter, with proper introduction and its own conclusions. On its current state, the transition between contributions is too abrupt. In addition, there are repeated parts through the manuscript, such as the selection of the computing devices, their specifications and the motivation for PA using monitoring devices.

There is a point in the introduction which is misleading, since it motivates the work by discussing on future trends on food demands and the use of fertilizers, which is NOT used in any of the research reported in the manuscript. Proposing an application of PA by using modern algorithms of AI such as convnets in embedded systems is a strong enough motivation. Examples of applications are weed detection or seeds detection found in the thesis but there is a multitude of potential applications that might be used in PA with similar methodology.

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

The topic of the dissertation is a combination of many topics such "Mathematical Modeling", "Analysis of Intelligent Monitoring Platform" and "Precision Agriculture". Not surprisingly the actual content matches these topics. Computational Fluid Dynamics is used for modeling and designing the morphing wing. The term intelligent monitoring is most likely referring to the NN architectures used for object detection (1), growth prediction (2) and semantic segmentation (3). The chosen paradigm for processing information is on low-power devices which required a customized study on performance, energy, heat and multiple other criteria.

The relevance of the methods used in the dissertation

The methods used are very diverse and depend on the task at hand. For instance, on topic (1) on seed detection, a CNN detector is queried over multiple times on a sliding window of small patches of constant size. This is a classical approach in CV. There is not much discussion on other more modern methods for object recognition, such as Faster-RCNN or YOLO (used in another section) which make a more clever use of feature processing in the hole image compared to the sliding window which re-processes the same regions multiple times. If efficiency is an issue, network architectures should also improve on this regard.

The methods used in (2) for leave prediction seems solid, by using LSTM for sequences of images or the in topic (3) for weed semantic segmentation, where there is a comparative study among different methods before selecting one.

Remark: If algorithm efficiency and computational load are the main bottlenecks for algorithms to run on low-power devices, then why the thesis is not discussing on topics such as network compression or quantification? There is a vast sub-field inside the DL community striving for compression on NN for different reasons, such as cloud servers efficiency. Behind there are leading IT companies and electronic manufacturers, strongly investing on the issue.

On the aerial platform design, Computational Fluid Dynamics and the experimentation in the wind tunnel seem adequate tools and the techniques used are well reported. I am not an expert on this field.

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

The scientific results obtained during this thesis, as discussed at the beginning of this review, lie in the areas of Systems Engineering and Mechanical Aerial Design. They show that modern CV algorithms, in particular CNN can be embedded in low-power devices for applications in PA. The digitization of many other activities could benefit from embedded sensing devices and this work is an inter-disciplinary attempt to bring together AI, AP and Systems. In my opinion, the scientific value of this thesis is relevant, many other research groups in the world are looking at these topics right now.

The scientific significance of the aerial design, seems relevant as well (I am not an expert in thee area) although it is a little disconnected with other obtained results.

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

Potentially yes, the results could be applied. The seed germination and greenhouse monitoring could be transferred to a larger scale with some effort. However, the weed detection on a drone or morphing wing, I think, is far from being a prototype.

The quality of publications

The list of publications, checked in WoS for the 2020 year:

-[2] "IEEE Sensors journal" (Q1) IF=3 (Second author) There is a claim on being shared first authors but I could not see any information in the paper.

-[1] "IEEE Transactions on Instrumentation and Measurement" (Q1) IF=3 (Second author). Again, no mention indicating equal contribution, only being the corresponding author.

-"Physics of Fluids" (Q1) IF=2.6 (First author)

The quality of the publications is high and the scientific production as a result of this thesis is enough to fulfill the PhD requirements by the program.

There is an issue that MUST be addressed. Some of these works are in collaboration with a PhD student D. Shadrim co-author on some of the publications (first author in [1,2]). Proper distinction of the contribution of each student should be outlined very clearly at each of the corresponding sections in the thesis, otherwise one could consider it a flagrant lack of research ethics.

Other comments

Why discussing about fertilizer use in the intro chapter when the studied application is hogweed detection? To me this motivation is misleading.

The comparison on different embedded systems for NN is not well reported. Jetson Nano is presented but not compared (as proposed in 3.1). Is there a publicaiton behind this benchmarking? What is depth in this context and how is it related to the topic of research? Space is limited, but this point requires a paragraph for an introduction, otherwise the comparison is in vain. The following sections should refer to this section on platform comparison, but they don't, so what it its purpose?

Journals [2019a, 2019c] are cited twice in the bibliography.

If any section resulted in a publication/s this should be mentioned. A list at the beginning of the manuscript is not adequate.

Minor grammatical and punctuation mistakes which should be amended, I recommend an in-depth review of the manuscript.

p. 49, p.69, p.72 Fig.??

p.50 "For the" unfinished sentence. This is an alarming mistake, easy to fix though.

p.55 invalid ref.

Provisional Recommendation

☐ *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*