Thesis Changes Log

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

The thesis document includes the following changes in answer to the external review process.

Reviewer: Ivan Oseledets

Comment #1. Secton 3.1 "Development of embedded system with AI capabilities" describes a useful testng of a CNN model on two embedded devices. It is followed by Section 3.2 "detection of seeds during germination", which is an application and does not logically follow from the previous section (no connection). Section 3.2.1 seems to be a copy-paste from the paper "In this section the methodology used in the present work is described."

Answer. The structure of section 3.1 was significantly improved – the Introduction and Conclusion sections were added. Section 3.1.2, the trade-off, was reworked and complemented with additional data. All the experimental data from the section was restructured and split into two subsections: 3.1.3 and 3.1.4. Tables 3.2, 3.3, 3.4, and 3.5 were added to represent better the results and a more logical, comprehensible narration.

Comment #2. On page 60, the Movidius is described again, however it was already studied in 3.1. No need to discuss it again.

Answer. The repetition was removed.

Comment #3. Section 3.3. is "detection of plants in greenhouses" without any connection to 3.2. It is a separate story. It is better to define all concepts in one place, and not discuss general concepts of AI again.

Answer. The AI-related concepts and discussions on Embedded Systems were removed from the section and complemented the section 3.1 to avoid repetitions.

Comment #4. Table 3.11 again studies embedded devices, but why we need to do it again?

Answer. The data was moved to section 3.1 to avoid repetitions.

Comment #5. Section 3.5 is Morping Wing. I agree that these are useful results, but better structure is obviously needed. By the way, I have no idea what is eVTOL. The content of Section 3.5 falls outside the topic of the thesis. It talks about Navier-Stokes, meshes, grids, etc. These are serious research topics, that is not good to present in 3-4 pages. Correct formulation of the 3.7 - 3.13 requires, at least, boundary conditions to be specified as well as functions in (3.12) and (3.13). Numerical simulations should be done on grids being refined in order to estimate the quality of obtained numerical solutions. It is also not mentioned, what software have been used for this particular modelling.

Answer. The name of the section was improved and accompanied by the crossreference to the glossary. The numerical simulation was performed on appropriate meshes in the OpenFOAM software.

Comment #6. I think, this thesis should be restructured. It is now written as "state-of-the art" -> methodology, but it will much be]er perceived if it is structured by topics (which also correspond to the papers) + notations and basic studies. The results are presented in Section 3, which could be split into chapters, and also basic notations/facts chapter introduced, which contains the definitions, the study of performance of different mobile platforms and prospective applications. I have doubts that the wind tunnel part is actually needed in this thesis, since it falls outside the general concept.

Answer. The sections in the Chapter 3 Methodology were profoundly improved to avoid repetitions regarding embedded platforms trade-off studies and benchmarks. Most of the material was moved to section 3.1 to complement the experimental results to evaluate embedded systems with AI capabilities.

Comment #7. Minor comments:
- on p. 50 there is an unfinished sentence
- p.55: ??
- p.60 Nural network -> neural network.
- p.72: ??
- p.79, Platfrom

Answer. All minor changes were improved.

Reviewer: Roberto Passerone

Comment #1. Some references are broken. Section 3.1.1 is not finished.

Answer. All the broken references were improved. Section 3.1.1 was improved and finished appropriately.

Comment #2. On page 55, it is mentioned that "performance is more than six times higher with the same power consumption.". However, looking at Table 3.3, the power consumption for RPi + NCS (3.675 W) is significantl higher than that of RPI alone (2.659 W).

Answer. The typo in the Table was improved.

Comment #2. In general, Section 3.1 looks a bit confusing. It starts with a discussion of the platforms. One then expects that all the experiments are conducted on all platforms. However, there is no result for the Jetson Nano, nor for RPI + NCS2. It is confusing, for instance, that FPS is analyzed twice (once on page 51, and then again on page 54). I suggest that this section be reorganized to make it more systematic. Also, what are the conclusions after these experiments?

Answer. The sections in the Chapter 3 Methodology were deeply reworked to avoid repetitions regarding embedded platforms trade-off studies and benchmarks. Most of the material was moved to section 3.1 to complement the experimental results to evaluate embedded systems with AI capabilities. Moreover, all the sections were complemented with Introduction and Conclusion subsections for better understanding the logic of the narration.

Comment #3. In the following Section 3.2, you mention the Myriad GPU. This appears to e the same as the NCS? If so, you should use consistent terms. If not, then you should explain the difference.

Answer. The data about GPU was rewritten to avoid the readers confusion.

Comment #4. Figure 3-9 is not very clear. I would use more contrasting colors for the windows with respect to the image.

Answer. The figure was adjusted with more contrast colors.

Comment #5. Page 62: what are "containers #8-11"?

Answer. The misleading and unnecessary information was removed.

Comment #6. In figure 3-11: blue is the ground truth, and green the estimated bounding box?

Answer. Additional information on bounding boxes' colours was added to the caption of the figure.

Comment #7. Page 65: there is no discussion about the accuracy of germination detection. Does the proposed algorithm perform well?

Answer. The structure of section 3.2 was significantly improved – the Introduction and Conclusion sections were added. "Intellectual Monitoring Platform Evaluation" subsubsection was added to the subsection "3.2.4 Experimental Results". This data is not new. It has already been published but was not included in the Ph.D. Thesis draft. The improved section contains the results of germination detection accuracy.

Comment #8. Page 72: The Hardware section repeats the characteristics of the Movidius. These should be collected only once somewhere at the beginning of section 3. Is this the same architecture as the precious section? In the same section, it is mentioned that the Movidius consumes 1 W, and the battery is only 2550 mAh, which certainly won't be able to support the operations for two months if the system is constantly operating. I suggest that the duty cycle technique is already mentioned here. In fact, later on Table 3.7, the operation time is limited to 7.5 hours.

Answer. The sections in the Chapter 3 Methodology were deeply reworked to avoid repetitions regarding embedded platforms trade-off studies and benchmarks. Most of the material was moved to section 3.1 to complement the experimental results on the evaluation of embedded systems with AI capabilities. Besides, the issue regarding power consumption and the continuous operation period was added to the end of section 3.2.4 and 3.3.4.

Comment #9. I don't understand why you have results at the end of Section 3.3.2, and then again Experimental Results in Section 3.3.3. Reading Section 3.3.3 it sounds like there is one more prototype, or is this simply a repetition of what was said before? In general, I would try to better structure the text. On page 78 you say that "The mean power consumption during the investigation is 2.23 W; the median is 2.184 W, and the modal value of power consumption is 1.7578 W". These values are different from what is reported on Table 3.9 on the previous page. Do they refer to different systems? The same goes for CPU load and RAM.

Answer. The section 3.3 was deeply reworked to avoid. Most of the material was moved to section 3.1 to complement the experimental results on evaluation of embedded systems with AI capabilities. There are no additional prototype in section 3.3. The issue regarding the table was also resolved.

Comment #10. Please give the details of how you find 180 days of continuous operation.

Answer. The additional details were added to the Section 3.3.4

Comment #11. Page 85: using the term "crops" to indicate the size of the image, in the context of precision agriculture, is dangerous, since "crop" can also refer to a plant!

Answer. The "crops" were substituted by synonyms "frames" and "cuts" all over the text if necessary.

Comment #12. Please explain Figure 3-23 better. How does it represent "performance"? What do the colours mean?

Answer. The corresponding colormap was added to the image to prevent misleading. A piece of additional information was added to the text and the image's caption for a better explanation.

Comment #13. Page 88: you say, that the platform has 4 Gb of RAM, and that 4K input frame with all the rest takes 100 MB. Now, this is a tiny fraction of the 4 Gb. Why do you have to divide it in smaller chunks?

Answer. There are two possible approaches to fit 4K images to the FCNN's input: (i) rescaling and (ii) cutting the frame into tiles. The second approach is better for two reasons. Firstly, training of the neural network (especially FCNN type) usually requires much more training parameters, therefore, a bigger computational capacity of the computer, which is a limiting factor. Furthermore, it leads to a bigger size of the resulting pre-trained FCNN, which can easily reach several Gb. However, in our case, it is not a problem, since UNet occupies 100 Mb RAM. Secondly, rescaling leads to a reduction in the input sample's number of features, which easily leads to underfitting. In the case of cutting the image into tiles, we preserve the features from the original photo. Therefore, we have better output results - higher IoU. It is essential in the case of semantic segmentation of hogweed, which usually has a green background. This approach also reduces the number of trainable parameters, reducing the required RAM and inference time. Therefore, the image is split into smaller chunks for realizing one-by-one processing. This answer was also added to the subsection "Implementation of the FCNNs on Embedded System" of the section 3.4.2.

Comment #14. The last paragraph of page 94, and the first of page 95 repeat what was said earlier in the thesis. In particular, the first of page 95 seems exactly identical to what is written between page 34 and 35.

Answer. The duplication of the text was removed from pages 34 and 35.

Comment #15. Page 108: "Thirdly, they are easy to substitute in case of the brake." What does "in case of the brake" mean? Perhaps it means "in case they break?"

Answer. The typo was improved.

Reviewer: Gonzalo Ferrer

Comment #1. 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.

Answer. This point in the Introduction was improved.

Comment #2. 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.

Answer. The sections in the Chapter 3 Methodology were deeply reworked to avoid repetitions regarding embedded platforms trade-off studies and benchmarks. Most of the material was moved to section 3.1 to complement the experimental results on the evaluation of embedded systems with AI capabilities. Moreover, all the sections were complemented with Introduction and Conclusion subsections for better understanding the logic of the narration.

Comment #3. 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.

Answer. All the unnecessary information from the introduction was removed to prevent the misleading.

Comment #4. [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.

Answer. The authorship was checked and improved to be "corresponding author".

Comment #5. [1] "IEEE Transactions on Instrumentation and Measurement" (Q1) IF=3 (Second author). Again, no mention indicating equal contribution, only being the corresponding author.

Answer. The authorship was checked and improved to be "corresponding author".

Comment #6. 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.

Answer. This issue was addressed in the Thesis. All the necessary information about Dmitrii's contribution and reasons to add part of his research in the current Thesis were included in the introduction of corresponding sections (3.2 and 3.3).

Comment #7. Why discussing about fertilizer use in the intro chapter when the studied application is hogweed detection? To me this motivation is misleading.

Answer. All the misleading information in the Introduction chapter was removed.

Comment #8. 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 publication 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?

Answer. All the issues were improved, and section 3.1 was complemented with the missing data. The structure of section 3.1 was significantly improved – the Introduction and Conclusion sections were added. Section 3.1.2, the trade-off, was reworked and complemented with additional data. All the experimental data from the section was restructured and split into two subsections: 3.1.3 and 3.1.4. Tables 3.2, 3.3, 3.4, and 3.5 were added to represent better the results and a more logical, comprehensible narration.

Comment #9. Journals [2019a, 2019c] are cited twice in the bibliography.

Answer. The second reference was deleted from the bibliography.

Comment #10. If any section resulted in a publication/s this should be mentioned. A list at the beginning of the manuscript is not adequate.

Answer. In the introduction of sections 3.1, 3.2, 3.3 and 3.5 all relevant publications were mentioned.

Comment #11. 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.

Answer. All the minor mistakes, invalid references and cross-references were improved.

Other changes

Improvement #1. Publications (p.4): The conference proceeding in IEEE 25th International Conference on Emerging Technologies and Factory Automation (IEEE ETFA 2020) was added as the most recent publication.

Improvement #2. Chapter 3. Methodology. The introduction of the chapter was accompanied by additional two sentences for consistency of the narration: *"The common research question of all the sections 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." The first three sections address this question from the hardware and algorithmic perspective, the latter from the power consumption perspective, which is closely connected to the overall platform's aerodynamic aspects."*

Improvement #3. The section 3.4 the Table 3.10 was improved – the Input current column was substituted by Power consumption and Time column was removed.