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Opponent's review of the Doctoral Thesis

Candidate   Ing. Paulina Lyubenova Raeva

Title of the doctoral thesis   Implementation of RPAS in Vegetation Monitoring and Analysis

Study Programme   Geodesy and Cartography

Tutor   prof. Dr. Ing. Karel Pavelka

Opponent   prof. Dr. of Eng. Sci. Roman Shults

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Topicality of the doctoral thesis theme

Commentary: Since the beginning of the century, unmanned aerial vehicles (UAVs), unmanned aerial systems (UASs), or another well-common name, drones have become one of the leading surveying technologies. Their development went hand in hand with achievements in global navigation satellite systems (GNSS), inertial navigation systems (INS), and digital photography. Today, the UAV application has gone beyond traditional surveying works. It is hardly possible to find a branch where UAVs have not demonstrated their outstanding opportunities and effectiveness. Mapping, emergency, environmental monitoring, and military tasks are just a few examples of UAV applications. Among others, the employment of UAVs for agricultural applications is widespread. It is especially crucial with the modern concept of precision farming. The UAVs data in the visible and multispectral bands ensure the information about current crop status and crop management. Imagery data could help generate current plant state maps and yield maps. However, despite the various applications, first of all, UAVs are being considered as a part of photogrammetry. That, in turn, means that it is compulsory to consider the questions of photogrammetric data gathering, their pre-processing, and processing with appropriate output. The problems and tasks given above are especially relevant for NIR data operation. Given the above, I consider the dissertation research topic relevant and one that has not only scientific value but also great practical significance.

| ☒ excellent | ☐ above average | ☐ average | ☐ below average | ☐ poor |

Fulfilment of the doctoral thesis objectives

Commentary: Based on the author's topics, one may define the following objectives that were rationale and achieved in the doctoral thesis.

1. The development and study of the photogrammetric workflow for processing infrared imageries for vegetation analyses.

2. Multitemporal analysis over arable areas and the study of the correlation between vegetation indices and the thermal index.

3. The analysis of various strategies of NIR imageries processing and practical recommendations development.

4. The workflow refinement of the imageries radiometric correction for multitemporal vegetation analyses and its evaluation.

5. The comparative study of different aerial infrared sensors and in-site measurements using the values from vegetation indices.

6. The examination of the influence of solar irradiance on thermal photogrammetric mapping.				
☐ excellent	☒ above average	☐ average	☐ below average	☐ poor

Research methods and procedures

Commentary: Validity and reliability are provided by a detailed analysis and theoretical developments, which are confirmed by the results of experimental research. The author has developed and applied several workflows and approaches to achieve the thesis's goal. Powerful research methods were used, including methods of mathematical statistics, digital imageries processing, and various photogrammetric and geodetic methods. To confirm the scientific results, the thesis presents a significant amount of experimental observations, ensuring the author's theoretical results.

☐ excellent	☒ above average	☐ average	☐ below average	☐ poor

Results of the doctoral thesis – dissertant's concrete achievements

Commentary: The primary stress in work has been made on practical aspects. Due to that, one cannot find math models or new methods here. However, the technological part looks very persuasive.

1. Technological scheme of the photogrammetric processing of infrared imageries for vegetation analyses. This scheme encompasses all stages from image adjustment up to computation of vegetation indexes and their analysis.

2. Proposed the workflow for creating a vignetting mask for thermal images. A vignetting elimination procedure was established using a correction mask based on the most spread intensity values of a raw image of a white surface. Two correction methods were considered based on the subtraction of the raw image from the correction mask or their ratio.

☐ excellent	☒ above average	☐ average	☐ below average	☐ poor

Importance for practice and for development within a branch of science

Commentary: The primary practical value of the work is the development of valuable recommendations and technological workflows. All experimental results related to the functional improvement of the various UAV data processing. In this context, it should be noted:

- technological scheme of UAV images processing aimed at vegetation monitoring and analysis;

- instructions and recommendations on field surveying procedures and correct surveying parameters selection;

The critical application of the work can be photogrammetric software development, being that the results should be employed for software refinement. Especially considering that the author has convincingly shown the drawbacks of the state-of-the-art software. The doctoral thesis results can be primarily recommended for implementation in the agricultural economy to support the concept of precise farming and overall improvement of crop management.

☒ excellent	☐ above average	☐ average	☐ below average	☐ poor

Formal layout of the doctoral thesis and the level of language used

Commentary: The thesis contains seven sections and appendixes. I do not have any remarks regarding the thesis formal layout. The work is well-structured. The scientific language and English particularly are understandable and clear. The application of scientific terms and definitions is correct. However, the treatment of some terms is questionable and may be subject to discussion or needs additional explanations.

☐ excellent ☒ above average ☐ average ☐ below average ☐ poor

Statement on compliance with citation ethics

The results presented in the thesis are fully covered in peer-reviewed publications and many scientific conference presentations. Two or more publications with identical content are missing. I have not noticed any violations of citation ethics.

Remarks

1. I would not say that this sentence is correct " Despite the great abundance of sensors and remotely piloted aircraft systems (RPAS) on the market, farmers and agronomists often cannot afford buying equipment for themselves." Today's prices are very affordable, even for small agricultural enterprises.

2. (p. 25) Image adjustment is not based on the relationship between the intensity of a surface element and the pixel values in the particular image. The sense of the adjustment is purely geometric.

3. (p. 26) I did not get the definition of "correct software". Which one is correct, which one - is not, and why?

4. (p. 39) "If a lower value had been selected, then probably some images would have been left unprocessed." sounds like a premise or guess. Any such sentences make your study and result less reliable. The values of the overlap are not reasoned scientifically (80% or 90%, why not 85% or 87.5%?).

5. (p. 42) "Flight parameters indicated that almost all the near-infrared imagery was oriented and included in the processing. Unfortunately, this is not the case with thermal imagery." How can one conclude it from flight parameters?

6. Author declares that the results in sub-section 4.7 can be used for prediction models. At the same time, it is evident that the volume of data is not enough for any statistical analysis. How were generated the curves in Fig. 39, 40, 41, etc.?

7. Author suspects that the reason for the low correlation between NIR and TIR datasets was a lack of georeferencing. How do you think what accuracy level of georeferencing would be appropriate?

8. Regarding the correlation between in-situ and aerial vegetation indices, the data should have probably been tested for blunders that would improve your correlation estimation.

9. There are many typos in the text.

Final assessment of the doctoral thesis

Based on the study of the doctoral thesis, I believe that the dissertation of Paulina Lyubenova Raeva, "Implementation of RPAS in Vegetation Monitoring and Analysis" is a completed scientific work devoted to solving an important and topical scientific task of UAV data photogrammetric processing for vegetation monitoring and analysis. The carried out studies have scientific novelty and practical value. The dissertation corresponds to the topics and scientific directions of the study program "Geodesy and Photogrammetry", and its author Paulina Lyubenova Raeva deserves the Doctor of Philosophy degree award.

Following a successful defence of the doctoral thesis I recommend the granting of the Ph.D. degree

yes ☒ | *no* ☐

Date: 07.06.2022

Opponent's signature: ....