Review of Master's Thesis

Student: Li You
Title: Multispectral Image Processing (id 23829)
Reviewer: Juránek Roman, Ing., Ph.D., DCGM FIT BUT

1. Assignment complexity — average assignment

The thesis deals with multispectral imaging. The aim was to find or develop a multispectral image processing and fusion tool and perform series of experiments. This task involves image registration and fusion of images to a multichannel representation containing multispectral data (the specific process may be application- and user-specific based on the task). The student developed a simple application with well known image processing algorithms which I consider as quite basic and easy.

2. Completeness of assignment requirements — assignment almost fulfilled with serious reservations

In my opinion, the student did not thoroughly research the current tools for multispectral image processing (point 2). For example, there is *ImageJ* (open source software not mentioned in the thesis) which offers many tools and plugins working with image stacks and can be extended with user plugins. I also do not think the proposed tool meets the requirements for multispectral image processing and it is definitely not usable in practice. The fulfilment of points 2-4 are therefore at least questionable.

3. Length of technical report — in usual extent

4. Presentation level of technical report — 50 p. (E)

The thesis starts with a description of what is multispectral image, how such images are acquired and what existing software tools can be used for the analysis of such data. What I did not get is the difference of sections 2.2 and 2.3 which cover basically the same topic. I acknowledge the presence of section about applications in industry with few examples.

In Section 3, the thesis continues with image processing methods that can be applied on images. The section covers very basic algorithms like conversion to grayscale, smoothing, sharpening and thresholding. More advanced topics include keypoint detection. Image fusion methods (the main topic of the thesis) are explained on very high level. The algorithmic details on the method actually used in the implemented tool are missing. The PCA method is introduced in detail but without any relation to the topic (how is it applied to multispectral images?). There is also mathematical definition for PCA, but the symbols or their meaning are not explained.

The Section 4 starts with the analysis of properties of existing software tools (from Section 2) and summarizes requirements for the new system which is described in Section 5 where the individual modules are shown. It also presents a dataset of images. But the details are missing. How many images? What were the spectral bands? Did you try other data as well? The evaluation in section 5.3 states that all requirements are implemented and presents a study with 7 users where users evaluated factors like Aesthetics or Reasonability. But there is no description of the metrics or what were the choices. And there is no comparison to other tools so conclusions of the study could be drawn.

5. Formal aspects of technical report — 40 p. (F)

Some figures would be better as vector graphics instead of raster. Contents of the figures is left unexplained (what do we see IN the figure, what is important?). The text was sometimes challenging to read. There were wrong words or formulations, missing punctuation, errors in equations, unexplained abbreviations. Some sentences (and even paragraphs!) did not make any sense or were confusing.

6. Literature usage — 70 p. (C)

The used literature contains relevant research papers. But it must be said that most of the papers are outdated (more than 15 years old) and cannot be considered state of the art. There were few recent papers though.

7. Implementation results — 45 p. (F)

The main result is an application (Qt, C++) which can apply few basic filters to images and *"fuse"* images and apply PCA on image channels. By the *fusion* here is meant the registration to a common coordinate system (using a homography, not explained in the thesis) and processing in wavelet domain. The application is very simple and its functionality is demonstrated on *three* images from dataset. There is nothing what can be

considered *multispectral* (or I did not find it). Everything is implemented on top of RGB images, no multispectral representation is build in order to do some advanced processing. Honestly, I cannot find any relation between the developed application and the imaging and fusion methods or software tools described in Section 2.

Besides other problems in the code (like repeating the same code over and over), the following stands out. The image fusion (implemented in function Fusion::on_load_img_btn_4_clicked), operating over 3 input images, does not work as expected and is wrong on algorithmic and conceptual level. It does a sequence of three fusion/registration steps. The first step should register and fuse image 1 and image 2, the second step should do the same on image 1 and image 3 and the last step works with the results of the previous two steps (fusing previous fusion results). In each step *the first action is the fusion of two yet unaligned images!* The result of this "fusion" is *immediately overwritten* with the image registration, resulting in the warping of *one of the source images*. The whole so called fusion then results in just warping of image 1 in RGB domain. No fusion is done. This is shown in figures 5.9 and 5.11.

PCA analysis module can load only RGB images and display 3 components. Where is the multispectral image? Where is some false color representation for display (which is presumably the reason for the PCA in the first place)?

8. Utilizability of results

The tool implements few very basic image processing algorithms (thresholding, smoothing, sharpening, conversion to grayscale). I do not comprehend why these functions were implemented since their fast, correct and easily usable implementation can be found in many libraries (like OpenCV which the student actually used!). The implementation presented in this work cannot be used elsewhere - the parameters cannot be set (e.g. fixed threshold, etc.) and they are not correct (e.g. border conditions in convolution). As I see it, the core of the thesis was not in re-implementation of known algorithms but in using them to do "something interesting" so the use out-of-the-box implementation would be more than sufficient.

The application itself can not be used in practice since the core of its functionality - the multispectral image fusion - does not work as expected.

9. Questions for defence

- Did you try to process your dataset with IDCube and Epina ImageLab? What were the results?
- Explain what is a multispectral image and how is it represented in your algorithms.
- Explain how the PCA is applied to a *multispectral* image (e.g. with 10 spectral bands) and how would you *display* the result on screen.

10. Total assessment **45 p. failed (F)**

From the text and the code, it is clear that the student did not acquire very deep understanding of the topic of multispectral imaging or image processing. The text is from the large part incomprehensible with stylistic and language errors. To summarize the implemented application:

- There is no possibility of loading/saving *multispectral images* (despite claims in the text, everything is done in RGB).
- Image processing algorithms are re-implemented which was totally unnecessary since there are existing implementations. Not mentioning how bad the implementation is.
- Some algorithms are not used in context of the work - why is edge detection or thresholding needed for the fusion and analysis?
- Image fusion does not work and is wrong on conceptual level. At any point of processing there is no trace of multispectral image representation. Everything is done in RGB.
- PCA analysis works. But only for RGB image can be loaded as an input.

For the reasons described above, as I see it, the thesis does not meet the requirements of master thesis.

In Brno 18 August 2021

Juránek Roman, Ing., Ph.D.
reviewer