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Dear doc. Ing. Jaroslav Katolický,

This is a report on the thesis submitted by **Mgr. Michaela Honková** entitled **"NUMERICAL METHODS OF IMAGE ANALYSIS IN ASTROMETRY"**. I have read both the full PhD thesis and the short form submitted by the PhD candidate.

The work reported in the thesis concerns the mathematical manipulation of 2-D CCD images obtained by optical telescopes to remove both large-scale and small-scale brightness variations, with the aim of improving the measurement of absolute sky-frame positions (astrometry) of asteroids. This is an important problem in all-sky surveys as background estimation is critical to detecting faint Solar system bodies in optical images. While it is highly surprising that no flatfield calibration data was taken at the Klet observatory before 2018 - I have not encountered this previously - the research carried out in the thesis should be able to partially correct for this (it cannot correct for variations in the pixel-to-pixel quantum efficiency). It is also potentially very useful for data taken in non-optimal conditions such as strong moonlight or thin cloud, as stated in the thesis. Overall, the subject matter of the thesis is worthy of investigation at PhD level.

I received both the full thesis, and the short form. As I found I had to frequently refer to the full PhD thesis when reading the short version, I am reporting on the full thesis.

The thesis work starts with an overview of the background to the problem of the measurement of absolute positions in chapter 2. Chapter 3 contains relevant mathematical background. Chapters 4 & 5 describe the equipment used to obtain the data, and the various mathematical algorithms that can be applied to these data, to calibrate them and measure the astrometric positions. Chapter 6 then details the various techniques coded and used by the PhD candidate to process these data, with the aim of removing the variations in sensitivity and improving the ability to detect and measure positions of faint asteroids. These techniques are then compared in Chapter 7, with the goal of selecting the best technique to use given data of various quality. The thesis concludes with a very short report of the application of these techniques to a fact moving asteroidal object.

In terms of the individual chapters, I have the following comments.

Chapters 2 and 3 give good relevant background, although there are some errors. The PhD candidate says that fully automated astrometry of objects is not possible, when it is done every night on surveys such as Pan-STARRS and the Catalina Sky Survey (see Denneau et al., 2013. Pub. Astr. Soc. Pac. Vol 125, p357-395) I am also surprised at the continuing use of the UCAC4 star catalogue. The student says that new catalogues are used when available, but the GAIA DR1 catalogue has been available since 2017.

Chapters 4 and 5 give a full description of the origin of the data and the various processing

that takes place on it, or should be if the instrumental sensitivity function G(x,y) was measured via flat field images on the sky.

Chapter 6 describes in detail the various techniques the PhD candidate investigated to remove sensitivity variations across the CCD images. I found this to be a well-written chapter reporting a significant amount of work. I was surprised by the consideration of an unsharp masking filter, this is only used for image detail enhancement and is clearly unsuitable for the estimation of sensitivity variations across images. On the other hand, I was very impressed by the investigation of the Savitzky-Golay filter, this could be very useful with certain datasets.

Chapter 7 contains the comparison of the various techniques investigated, and it was here that I found a problem with the thesis. The candidate shows that some of the techniques resulted in a significant improvement in the signal-to-noise (detectability) of faint asteroids. Clearly, when this brings an object from undetectability to detectability, this is excellent, and gives a measurement when none existed before, so the improvement in accuracy is infinite! But a goal of the thesis was to generally improve astrometry for objects, and the PhD candidate does not present evidence that the accuracy was better for objects detected without filtering, nor whether fast computational techniques produced the same astrometric improvement as mathematical techniques slower to compute. Clearly some kind of astrometric analysis should have been done, looking at the improvement in rms residuals of measurements as a function of magnitude (brightness) and flatfield estimation technique. There was no quantitative measurement of this reported in the thesis, and therefore the PhD candidate does not report evidence about the effectiveness of these techniques for detected asteroids.

Similarly, in my opinion chapter 8 was hardly worth including as it does not have any quantitative comparison of the precision of the astrometry using the different techniques. As it is written, it could have been included as a final section to chapter 7. To keep it as a chapter, again the aim of the thesis should be carried out, and a comparison of the accuracy of astrometry after application of the different mathematical flattening techniques should be given.

However, I want to state clearly that the omissions I found in last two chapters are correctable, and overall there is a significant body of work presented in the PhD thesis.

The bibliography and CV included is fine.

In summary, I believe that the candidate Mgr. Michaela Honková has reported on sufficient work of high quality in her submitted thesis to progress to a full PhD thesis defence. If the PhD candidate could amend the thesis in a small manner to investigate any evidence of an improvement in astrometry after filtering, I believe it would be worthy of the award of a PhD.

Yours Sincerely,

Professor Alan Fitzsimmons
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