Respected Examiner,
Thank you for reviewing my thesis.

Thesis Title: Implementation of an Autonomous Star Recognition Algorithm using Hardware-Software Co-processing Approach

Firstly, I would like to thank you for your insightful comments. These excellent comments have helped significantly improve my thesis. This letter addresses each of the raised points and notes precisely how I have responded and included the comments into my revised thesis.

Sincerely yours,
Dang Le Dang Khoa

Examiner: 1

1. There are some obvious typos and format problems in the thesis. For example, in Page 7, the caption table 2.1 is written, but the whole table is given in Page 8. Please check and correct them.

   Thanks for pointing these out. In my previous submission, while fixing some typos, I forgot to check the configuration of the LaTeX compiler leads to missing table captions.

   I have checked and fixed them all.

   Table 2.1 shows how star centroids in an image, as in Figure 2.3 are stored under a list of Cartesian coordinates. Besides, star trackers may use other coordinate systems like the Polar coordinate system, Cylindrical or Spherical coordinate systems.

   A star pattern is spread over an area so we can calculate its centroid by applying

   8

   Table 2.1: A list of star centroids in an image

Star	Coordinates(X,Y)
Star 1	(X_1, Y_1)
Star 2	(X_1, Y_1)
...	...
Star N	(X_N, Y_N)

2. In this thesis, the author shows some figures such as Fig. 2.2, 2.3 without any explanation. Please add some explanation to these figures in the thesis content.

   Thanks for pointing out again. I have added explanations of those figures in pages 7 and 8

2.2 Centroiding Algorithm

The first step is to acquire the image which is accomplished by the image sensor. The image acquired has to be processed for estimating the coordinates of the stars in the image plane as shown in Figure 2.2. This is completed by applying the centroiding

7

process on the image. The input of this step is a star image with multiple star clusters. The output is the coordinate of every star presenting. Due to distributed energy surface, a star projection is spread over a 3x3 to 11x11 square area[14], and the star projection is a group of connected pixels. Therefore, the best way to identify the star clusters is to apply the connected component algorithm.

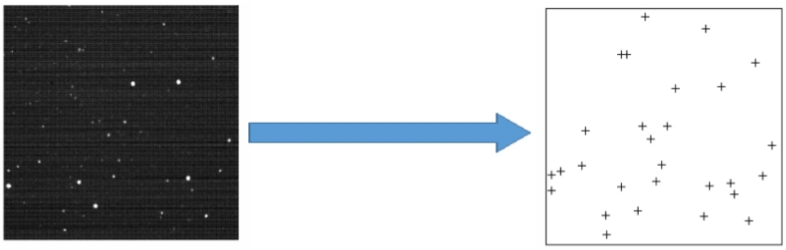

Figure 2.3: Centroid of stars in an image

Table 2.1 shows how star centroids in an image, as in Figure 2.3 are stored under a list of Cartesian coordinates. Besides, star trackers may use other coordinate systems like the Polar coordinate system, Cylindrical or Spherical coordinate systems.

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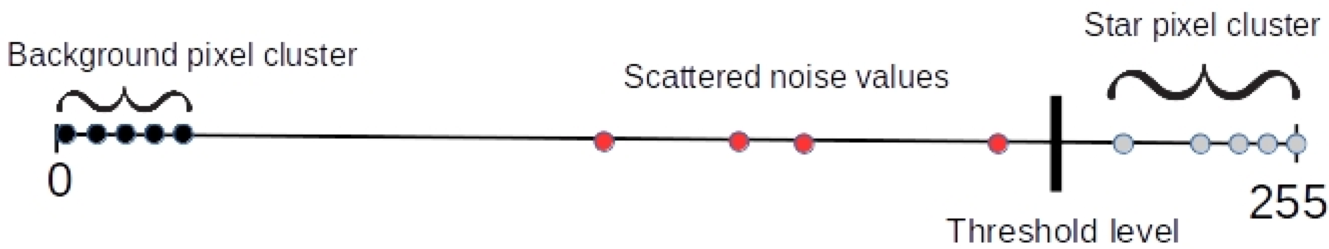
3. In Chapter 3.3.1, the author applied thresholding technique in order to eliminate the noise and separate star clusters from the background. But the author did not explain how to choose the threshold.

   I have amended a precise explanation to chapter 3.3.1 Centroiding (pages: 28,29,30). To summarize how to choose the threshold value:

   - Firstly, I perform an analysis by averaging and counting the occurences of all pixel values in the star image dataset.
   - The result of the analysis would form a pattern which is shown like the below image. It includes 2 significant clusters: the first cluster is the

background pixel values which formed near 0 Intensity value and the second cluster is the star pixel value which formed near the 255 Intensity value and scattered data points in between(which represent the noise)

- Based on the analysis, We know the range of threshold value is in between the noise values and the star pixel cluster.
- Finally, while carrying out experiments on the test dataset, we fine-tune and optimize the threshold value to produce the highest possible accuracy.



4. The author claimed that the proposed prebuilt tree structured star pattern database (SPD) was able to reduce space complexity while maintaining high accuracy and robustness, so this optimized algorithm could be used for nanosatellites which have limited memory. However, there is no comparison between the SPD algorithm and traditional algorithm on accuracy, storage consumption, and robustness in this thesis.

   The advantages of the proposed prebuilt tree structured star pattern database (SPD) over traditional algorithms in terms of space complexity, accuracy and robustness have been studied and proved by the previous research "An Autonomous Star Recognition Algorithm with Optimized Star Catalogue for Fast Search Performance"[1]

5. In Chapter 4.2, the author compares runtime spent by traditional methods and the proposed method in this thesis. He lists specific software runtime and hardware software co-processing runtime when the same image dataset is used. Details of images used in experiments are also provided. However, the author only lists tables and figures to show image specifications and runtime. He does not give even one word to explain or conclude his experiment results.

   I have amended detailed explanations to Chapter "Runtime experiments" (re-structured to Chapter 4.3) from page 49 to page 56.

6. In Chapter 4.1, the author gives experiment results showing hardware consumption and power consumption when the proposed method is applied. But he does not give comparison on consumption between traditional methods and his own method, therefore, readers do not know how to evaluate his experiment results. If he could add experiment results about power and hardware consumption when traditional methods are used (under the same experimental

conditions), and then give a comparison between traditional methods and his method, the advantages of his proposed method would be clearer.

In Chapter Hardware design(restructured to Chapter 4.2 from page 45 to page 48), I have performed a Power Analysis of the design and proved that the Processing System (the ARM A9 processor) consumes 77% of the power supplied while the Programmable Logic consumes 23% of the total power. To clarify, the power consumption is measured indirectly through the number of hardware components (Logic gates, Lookup Tables, BRAM, etc.) used for the implementation and the specification of the processor (ARM A9), not directly through experiments. Therefore, I can only compare the power consumption between running an algorithm on hardware and running an algorithm on software. Based on the Power Analysis of the design, we can imply the hardware-software co-processing approach is advantageous than the software-only approach in term of power consumption.
In my thesis, the parts I implemented on hardware are the DMA Data Streaming and the Centroiding modules which are the common tasks for all star tracking algorithms. Therefore, A comparison in term of power consumption between the traditional methods and the proposed method is redundant.

Reference

[1] M D Pham, K S Low, Shoushun Chen, and Y T Xing. A star pattern recognition algorithm for satellite attitude determination. In ISIEA 2012 - 2012 IEEE Symposium on Industrial Electronics and Applications, number ISIEA 2012 - 2012 IEEE Symposium on Industrial Electronics and Applications, pages 236241, School of Electrical and Electronic Engineering, Nanyang Technological University, 2012.