

## I. IDENTIFICATION DATA

Thesis title:	Indoor robot localization using up-looking camera
Author's name:	Elgourany Eslam
Type of thesis :	master
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of control engineering
Thesis reviewer:	Ing. Vojtech Vonasek, Ph.D
Reviewer's department:	Department of cybernetics

## II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment	easy
<i>How demanding was the assigned project?</i>	
Solving the assignment requires standard knowledge of robotics (mapping, SLAM, localization) that are covered by main lectures at FEE. No comparison with state-of-the-art method/methods is required neither their implementation, therefore the topic can be considered as easy.	

Fulfilment of assignment	unfulfilled
<i>How well does the thesis fulfil the assigned task? Have the primary goals been achieved? Which assigned tasks have been incompletely covered, and which parts of the thesis are overextended? Justify your answer.</i>	
<p>1. <i>Study existing methods for visual localization of mobile robot from up-looking camera.</i> The related work (section 2.5, page 13) discusses only three references [8,23,24] from years 2012, 2009 and 2005. <b>Many research papers has been published about this topic (see e.g. [1-8] at the end of this section), that are not even mentioned.</b> Moreover, it's not clear from the assignment if the robot has to move indoor (which is assumed in the thesis) or it can move outdoor. In the latter case, also literature about marine navigation may be relevant.</p> <p>2. <i>Design and implement method for localization of mobile robot in a known map.</i> Despite the the experimental section describes some kind of localization, the term 'known map' is not used in the whole thesis. The robot moves in a large obstacle-free area, not even close to borders of the lab. <b>It seems that no 'known map' was used during the experiments. Also, it is not clear what kind of map the proposed method creates.</b></p> <p>3. <i>Perform experiments with real robot.</i></p> <p>4. <i>Evaluate properties of the implemented method using a reference localization system.</i> <b>The experiments</b> are described in the chapter 4 (page 35), however <b>without showing any numerical results about precision and speed of the localization. Mapping is not evaluated correctly, the resulting graphs (4.8 and 4.9) are not understandable.</b> The comparison with reference localization system is shown by graphs (4.10, 4.11 and 4.12). <b>The graphs have no units, no axes description. This type of results 'presentation' is not acceptable for a master thesis.</b> It is not clear, how the proposed system works and how it really behaves.</p> <p>The text of the thesis is chaotic, it is difficult to find out what are contributions of the student. <b>The quality of the thesis, the text and the experiments and their evaluation is way below standard at FEE and it is questionable, if the proposed system works at all. Based on these comments, I conclude that the goals of the thesis were not fulfilled.</b></p> <p>Selection of references, that are missing:</p>	

- [1] S. Lee, G. Tewolde, J. Lim and J. Kwon, "QR-code based Localization for Indoor Mobile Robot with validation using a 3D optical tracking instrument," 2015 IEEE International Conference on Advanced Intelligent Mechatronics (AIM), Busan, 2015, pp. 965-970, doi: 10.1109/AIM.2015.7222664.
- [2] Hyukdoo Choi, Dong Yeop Kim, Jae Pil Hwang, Euntai Kim and Young-Ouk Kim, "CV-SLAM using ceiling boundary," 2010 5th IEEE Conference on Industrial Electronics and Applications, Taichung, 2010, pp. 228-233, doi: 10.1109/ICIEA.2010.5516788.
- [3] Y. Fukutani, T. Takahashi, M. Iwahashi, T. Kimura, S. S. Salbiah and N. B. Mokhtar, "Robot vision network based on ceiling map sharing," 2010 11th IEEE International Workshop on Advanced Motion Control (AMC), Nagaoka, Niigata, 2010, pp. 164-169, doi: 10.1109/AMC.2010.5464005.
- [4] S. Hwang and J. Song, "Monocular vision-based global localization using position and orientation of ceiling features," 2013 IEEE International Conference on Robotics and Automation, Karlsruhe, 2013, pp. 3785-3790, doi: 10.1109/ICRA.2013.6631109.
- [5] H. Chen, D. Sun, J. Yang and J. Chen, "Localization for Multirobot Formations in Indoor Environment," in IEEE/ASME Transactions on Mechatronics, vol. 15, no. 4, pp. 561-574, Aug. 2010, doi: 10.1109/TMECH.2009.2030584.
- [6] Z. Gu, H. Liu and G. Zhang, "Real-time indoor localization of service robots using fisheye camera and laser pointers," 2014 IEEE International Conference on Robotics and Biomimetics (ROBIO 2014), Bali, 2014, pp. 1410-1414, doi: 10.1109/ROBIO.2014.7090531.
- [7] F. Carreira, J. Calado, C. Cardeira and P. Oliveira, "Navigation System for Mobile Robots Using PCA-Based Localization from Ceiling Depth Images: Experimental Validation," 2018 13th APCA International Conference on Automatic Control and Soft Computing (CONTROLO), Ponta Delgada, 2018, pp. 159-164, doi: 10.1109/CONTROLO.2018.8514298.
- [8] WooYeon Jeong and Kyoung Mu Lee, "CV-SLAM: a new ceiling vision-based SLAM technique," 2005 IEEE/RSJ International Conference on Intelligent Robots and Systems, Edmonton, Alta., 2005, pp. 3195-3200, doi: 10.1109/IROS.2005.1545443.

## Methodology

partially applicable

*Comment on the correctness of the approach and/or the solution methods.*

The student used standard robot with a classic up-looking camera. Image features using AKAZE algorithm are found (via OpenCV library). The camera is calibrated also using OpenCV. The robot is localized using particle filter. Student chose a standard approach using techniques that are taught at the main robotic curses. No state-of-the-art method was implemented (or used if available) to compare the selected way of localization. However, this was not required by the guidelines and therefore, it is not mistake of the student.

There are several issues that are not clear from the text:

a) usage of Vicon localization system is problematic.

According to guideline No. 4, this localization system should be used only to evaluate the quality of localization. However, the student used it to partially estimate the position of the robot and also to measure the traveled distance of the robot. If the distance from last-localized position is more than 30cm, new localization is made (Alg. 2, line 1, also in section 3.3.4 – page 25 bottom). **Why is localization of the robot performed every 30cm and not continuously? Why do you use Vicon to estimate that 30cm instead of your localization system?**

Anyway, **using Vicon this way is against the guidelines and also in contradiction to the following sentence** in the Section 1.2 – Aim and objective of the theses: "In the underlying meaning, a camera ... the robot should know the exact position and orientation of itself in the map **using only the camera**".

b) Triangulation of points (section 3.3.3). **It's not clear from the text, why are the image features triangulated.** It is not clear, if all points from the images (features) are used for the triangulation or only some of them. Also, the text does not specify how are the triangulated points later used. How is parameter B (Fig. 3.5) estimated?

The text of the section 3.3.3 is typical example of text without any information. The thesis is full of similar

paragraphs/sections. The reader can only guess how and why is the triangulation used.

c) it is not clear what kind of map the student builds from the triangulated points (if they are used for the mapping, which is not clear)

d) it is not clear what kind of 'known map' the student uses (No. 2. of the guidelines).

e) the usage of AKAZE descriptor is not argued. Why did you choose this one?

## Technical level

F - failed.

*Is the thesis technically sound? How well did the student employ expertise in the field of his/her field of study? Does the student explain clearly what he/she has done?*

The thesis employes basic tools/methods/algorithms known from bachelor/master robotic courses to localize the robot. **It is not clear what is the real contribution of the student - if any - and what is based/used from literature.** The organization of **the text also resembles topics from robotic lectures and it includes parts that are not relevant to the thesis at all.** The text seems to be filled with random topics from the lectures just to make enough pages.

The biggest issue is that the reader a) can hardly understand what exactly the student did and what is his contribution; b) **the reader can hardly judge that the system works based on the presented experiments** (Chapter 4). The experiments are both badly designed and even worse, not evaluated correctly.

a) bad design of the experiments for localization

The robot moves in a large open area (Fig. 4.7). Moreover, the robot performs short trajectories, where the effect of good/bad localization cannot be observed. Due to repeating pattern at the ceiling, it may happen that even the particle filter localization gets confused when the pattern start to repeat again, which requires longer trajectories.

The evaluation is also wrong: as the graphs (4.9-4.12) do not contain any numeric values and no units, we do not know anything about the localization. Is the precision in mm, cm or worse? How many features must be detected at the image to enable good/bad localization? Is the performance of localization same in each part of the environment? How the robot speed influences it? What is the optimal localization frequency? There is nothing like discussion about these topics in the thesis. No conclusions can be made based on these graphs.

b) bad design of the experiments for mapping

It is not clear which map the robot has to built. It is not clear how the map is later used. The presentation of 'map' (Fig 4.8 and 4.9) does not say much.

Chapter 5: conclusion:

"It was concluded that the mapping algorithm is effective even with such a repetitive ceiling ..."

No, nothing like that was concluded; moreover, such a 'conclusion' cannot be made based on the graphs 4.9-4.12.

The term 'effective' is used for the first time in the conclusion.

".. and it was proved that the sensor model which includes ... is more effective".

Is more effective than what? Moreover, nothing like that was proved and it cannot be proved based on the graphs 4.9-4.12.

## Formal and language level, scope of thesis

F - failed.

*Are formalisms and notations used properly? Is the thesis organized in a logical way? Is the thesis sufficiently extensive? Is the thesis well-presented? Is the language clear and understandable? Is the English satisfactory?*

The thesis is written in English at a very good level. However, the text itself is chaotic with many issues:

a) the text contains huge number of unrelated text just to fill the pages of the thesis. Example are:

Chapter 2 describes various types of maps (grid,polygonal,topology,etc.) but it is not clear which one is used in the experiments. The same chapter also contains sections about ICP (Section 2.4.1), Kalman filter (Section 2.4.2) that are not used at all in the thesis. The related work (section 2.5) is at the end of the chapter. The better would be to have related work at the beginning and avoid all unrelated sections (such as 2.4.1. and 2.4.2) and also sections about maps (Section 2.2.)

Chapter 3 – Algorithms description – contains many unrelated topics. For example: section 3.1 covers topics like Linux, ROS, Python, OpenCV – all these tools are widely used in robotics (and not only there) and as they are also ‘only used in default way’ in the thesis, their description can be avoided. The same is valid for Section 3.3.1 – calibration of camera – it is implementation detail and it does not make sense to describe it. Similarly, section 3.4.4 - Resampling (also referred to as ‘re-sampling’ in the text) is about generating random numbers from a known distribution. There is no need to describe how exactly it is done, as it is a basic knowledge that each engineering should know.

Section 3.4.2: It is not clear why the student used the described motion model. Anyway, it's description is very poor and not acceptable for master thesis. Explaining atan2 function is not acceptable neither. Again, this seems that this section was written just to generate enough pages. The whole section can be replaced by saying that differential-drive model is used for robot/particle movements.

b) Images have varying, mostly low quality. Some images are reused from other works or internet without an acknowledgment (e.g. Fig . 2.4. coming from <http://metro.angrenost.cz/map.php> ). The images use various fonts (compare e.g. Fig 2.5, 2.10 and 3.10). Image 2.11 overflows the page (page 15).

c) Graphs are not plot correctly – without description of axes and without specifying units! Such graphs would not be accepted for homeworks or semestral reports and definitively not for a master thesis. **All graphs in the thesis are therefore useless and no conclusion can be made using them.**

d) Some equations does not make sense. For example, see Eq. 3.6 (page 24). This seems rather like a line of pseudocode than an equation.

e) mathematical typesetting is wrong. For example, eq. 3.32 uses wrong font for sin/cos functions. Sometimes, the mathematical font is used incorrectly (e.g., page 31 top, “From the equation ... ‘theoutputu\_i’ ). Another example of poor typesetting: the algorithm 3 uses ‘M^-1’, while the text uses ‘M-1’ (page 32).

f) The text contains many false claims or even contradictory statements.

For example, in section 3.2.2 Features definition we read: “Image features are the unique places in any image frame”. This is not true – there are features – e.g. corners – that can be found more than once in the same image.

Section 2.2.2: “If the movement between large areas is uniform, then ..” → What is ‘uniform movement’?”

Section 2.4: “There are no moving objects around the robot in a static environment, and if there is, it will be following a specific trajectory without changing it with time. The environment is constant for the robot”.

This specification of a 'static map' is not correct.

## Selection of sources, citation correctness

F - failed.

*Does the thesis make adequate reference to earlier work on the topic? Was the selection of sources adequate? Is the student's original work clearly distinguished from earlier work in the field? Do the bibliographic citations meet the standards?*

No, many references to state-of-the-art literature are missing. See section "Fulfillment of assignment" of this review. The reference to particle filter (Section 2.4.3) is missing. The citation style varies in the thesis from simple "... in [3]" to "Author work [23], De Xu, Liwei Han ..." (page 15). The style should be same.

## Additional commentary and evaluation (optional)

*Comment on the overall quality of the thesis, its novelty and its impact on the field, its strengths and weaknesses, the utility of the solution that is presented, the theoretical/formal level, the student's skillfulness, etc.*

Please insert your comments here.

## III. OVERALL EVALUATION, QUESTIONS FOR THE PRESENTATION AND DEFENSE OF THE THESIS, SUGGESTED GRADE

*Summarize your opinion on the thesis and explain your final grading. Pose questions that should be answered during the presentation and defense of the student's work.*

To conclude

- the text is full of unrelated text, the thesis organization is chaotic
- the contribution of the student is not clear - what exactly the student programmed/designed?
- the experiments are not correct, their evaluation is below standards of the master theses at FEE
- related work is poor, typography and images too
- the assignment guidelines are not fulfilled

The grade that I award for the thesis is

Date:

Signature: