CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE

REVIEWER'S OPINION OF FINAL THESIS

I. IDENTIFICATION DATA

Thesis name:	Automating 3D Scanning of Factory Hall by a Mobile Robot
Author's name:	Jakub Rozlivek
Type of thesis :	master
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Cybernetics
Thesis reviewer:	prof. Ing. Jan Faigl, Ph.D.
Reviewer's department:	Department of Computer Science

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment — challenging

Evaluation of thesis difficulty of assignment.

The topic of the thesis includes the whole navigation pipeline with the expected real experimental deployment. On the other hand, the student can build his solution on the existing solutions developed within the CTU-CRAS-NORLAB team with most of the components ready to use. Therefore, the assignment is considered to be challenging.

Satisfaction of assignment — fulfilled with minor objections

Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.

The guidelines mention "to propose a new exploration algorithm which will optimize the completeness of 3D data needed for the installation check," which seems to be only partially addressed. The text lacks analysis or discussion of what is needed for the installation check. One can imagine the important parts are bases of the robots, such as mobile manipulators and not entirely whole objects, as it showed to be a valid argument for workshops where the displacement of the manipulators' joints can be different the factory model. The focus of the work seems to be more steered on the completeness of 3D data to build as dense model as possible, which might not necessarily provide the best suitable data for installation check.

Method of conception — partially applicable

Assess that student has chosen correct approach or solution methods.

The propose methodology seems to be strictly following exploration methods, albeit the motivational scenario seems to be closer to the inspection tasks, where prior models of the area of interest is available. Although there can be some changes, it might be expected the changes would not be that significant to consider the environment unknown. The focus on exploration methods is not sufficiently justified, e.g., by argumentation why transportation corridors (usually found in workshops) cannot be utilized as motion constraints. Besides, the argumentation that ground truth is not available for a particular setup is weak. A ground truth localization can be easily provided within indoor environment, especially in experimental site such as tracking devices or Total station. Besides, reference localization can be supported by a precise map that can be prepared manually, e.g., using the already utilized imaging laser scanner BLK360, and then used for reference localization. Furthermore, the final model of the workshop is created by the BLK360 for which it is mentioned that the alignment software used needs some overlap between the scans. The requirements on the overlaps in the individual scans are not discussed, which might significantly affect the final model.

Technical level — D - satisfactory.

Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.

The text does not elaborate on the objective function in sufficient detail. The thesis goals in Section 1.2 are relatively vague. An explicit formal problem formulation is missing. The objective function being addressed seems to be the first sentence of Section 3.4. – "to be covered sufficiently to detect the deviations in the object positions and orientations compared to the factory model." There are reasonable simplifying

assumptions, such as a flat floor. However, the constraints to sufficiently detect deviations are not elaborated. A mention of sufficient data for ICP-based matching of the object models can be found in the results part, which seems to be related to the detection of the deviations. The discovered issue with arm joints indicates that more attention should be paid to the objective function and analysis of the possible real-life cases.

The text is relatively talkative at some parts and provides unnecessary details, such as using a remote controller to operate the robot. On the other hand, theoretical foundations for the suitability of the next-best-scan method are not discussed. One can expect it is built on the submodularity of the objective function, which is, however, not formally defined. Besides, techniques are known from the robot inspection planning, and sampling design is not discussed, e.g., kriging or randomized dual sampling methods. Since the workshop or manufacturing plant model is assumed to be available, thus even computationally demanding methods can be considered for finding the best set of scan locations.

Formal and language level, scope of thesis — A - excellent.

Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.

Only a very few minor typos have been found such as sped vs. speeded. A few typographical issues do not decrease readability or understandability. The only minor issue is a relatively high number of abbreviations that would deserve a list of abbreviations.

Selection of sources, citation correctness — E - sufficient.

Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.

The online sources lack date of the citation and some references do not have page numbers or even journal name, e.g., [2], 12]. Most importantly, the student does not refer to the works in inspection or coverage planning that might be considered relevant. For example, building precise 3D models using terrestrial laser scanners has been addressed by A. Nüchter ten years ago with the impressively detail 3D map of the city of Bremen. Besides, the problem of minimization of the number of scan locations also considering travel cost has been addressed years ago as the View Planning Problem by P. Wang's thesis in 2007. None of such related work is mentioned in the selected sources. It is pointed out, by referring to these more than ten years old work, the student missed that research stream in the literature, because the mentioned works have further developments and improvements.

Additional commentary and evaluation

Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.

The text is more descriptive than formal and provides a relatively talkative overview of the whole context that is not tightly related to the core of the addressed problem. On the other hand, the text is easy to follow.

In experimental deployment, the student fails in addressing practical scenarios. A possible lack of a ground truth model is not a significant drawback as it can be straightforwardly created by the equipment the student already used.

Some simplifying assumptions are made, such as a flat floor. However, it is then discussed without a clear reason for that in Section 5.3.1. Contrary to that, a discussion and possible assumptions of the expected maximal deviation of the objects from the model are missing. Similarly, the assumption on 2D placement seems to be valid, especially when the hypothesis on performance differences by changing the height of the scanning device supports that. Hence, the overall schema of the proposed method can be significantly simplified to sampling design of the 2D placement of the scanner with the evaluation of the expected model quality using 3D. However, the density of the 3D point cloud of the object of interest does not necessarily correspond to detection displacement from the model.

III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

Summarize thesis aspects that swayed your final evaluation. Please present apt questions which student should answer during defense.

Based on the presented text of the thesis, the student demonstrated his capacity to address the given problem and propose a solution that provides satisfactory results. Even though the proposed approach is more heuristic and ad-hoc than theoretically grounded, the achieved results indicate the student has been able to search the existing literature and propose a solution to the addressed challenging problem based on the found methods.

I evaluate handed thesis with classification grade C - good.

Question:

- In a typical workshop or manufacturing plant, there are corridors where the material is delivered, or service operates. Such corridors might be exploited to inform the method where possible scan locations can be placed. What do you think about using such corridors, e.g., as Voronoi diagram of the areas) for placement targeted to maximize information gain (or deviation detectability) by a minimal set of scan locations on the diagram with the required overlap in the scan to support 3D model reconstruction?

Date: 20.1.2022 Signature: