MF2071 Literature study (Revised)

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Introduction

Simultaneous Location And Mapping (SLAM) is the ability for a autonomous device or vehicle to start at an unknown location, in an unknown environment, and incrementally build a map of this environment. This map is simultaneously used to compute an absolute vehicle location [3]. The project owner, AVL [1], want to investigate which localization and mapping (SLAM) algorithm that is suitable to use from a cost/performance perspective. More specifically, different SLAM algorithms have different performance and different demands on sensors and hardware calculation capacity. Also, some algorithms perform well in simulation but not in the field. There is both a technical aspect of the information need, the investigation of different SLAM algorithms and their pros and cons, and a subjective aspect in the choice of what makes a suitable algorithm for this specific purpose. For this report, the technical aspect is chosen to be expanded upon since the largest part of the thesis will be the gathering and investigation of different algorithms.

Research Question

The research question given by AVL is *What are the pros and cons of different SLAM algorithms which are suitable for autonomous vehicles?*. In the thesis description, there is a stated desire for a comprehensible comparison between different SLAM algorithms, both on the performance of the algorithm and the price of the needed hardware. The final deliverable will be a comprehensive comparison of performance (in simulation and in real life) and the cost associated with needed sensors. Being rather wide in scope, the research question can be divided into more specific questions that will help in answering the more abstract research question. The algorithms computing cost will depend on both the needed processing power and on what kind of inputs are needed, affecting which sensors that need to be fitted to the vehicle. The more specific questions that will need to be answered are therefore,

- What is the definition of a SLAM algorithm?
- Which SLAM algorithms are available and relevant in the usage scope of an autonomous vehicle?
- What is the theoretical performance of each algorithm?

[1] AVL is the world's largest independent company for the development of powertrain systems with internal combustion engines as well as instrumentation and test systems.

- What input and processing power are needed for each algorithm?

Search Method

This project focuses on comparing different methods for a vehicle to localize itself in the world. The comparison will be made using experimental design methodology with a post-positivistic world view. This means that the data should be collected and analyzed objectively, proving or disproving one or several hypothesis[1]. To be able to make an objective assessment of the different methods, extra weight will be given to sourcing well defined assessment criteria and requirements from the project owner, AVL. These criteria will then be used to create a testing framework for the different methods, reducing the risk for result bias.

Using multiple sources will help in getting an as complete picture of the method as possible. When looking for preliminary sources, a database that covers many subjects is queried. For this report, Scopus was used for finding preliminary sources. Wide search terms are used to capture as many sources as possible and a wide variety of sources are allowed. For example, conference proceedings can give good insight into what is happening within a subject but may not be suitable to use as a primary source.

The preliminary data is then used to refine the search in a more targeted search engine. These databases only gather documents from specific areas of research. Being a project focused in electrical engineering, mechatronics and computer science, the IEEE Xplore database is used for in depth searching.

While the subject of self controlling cars has many ethical concerns attached to it, most are about what choice to make in a situation like the *trolley problem*[2]. This does not directly affect the localization and mapping part of the car control, though it can be argued that a better situational awareness can be a way to avoid fail state situations. As an example, consider that an autonomous car comes to a crossing and a pedestrian walks out in front of the car. The car then has to make a decision: should it just break and risk hitting the pedestrian or should it veer to the side and potentially crash but save the pedestrian? If the car has a good knowledge about its surroundings (i.e. an efficient SLAM algorithm), it can make a more informed decision. Also, should the system have a good map of the area, there are possibilities that the car can be programmed to avoid busy crossing and will therefore also greatly reduce the risk of being caught in that kind of situations at all.

[2]The trolley problem is a philosophical question about choosing which life/lives to save/sacrifice in a two-choice situation.

SLAM does not in any large way affect the fuel consumption of the car so it is not affected by ecologic sustainability concerns. It does however directly influence of an autonomous vehicle. It is, in fact, critical to the functionality of the product and therefore there are both social and economic sustainability attached to finding good SLAM algorithms.

Literature review and motivation

It can be rather difficult to find good primary sources when searching for scientific material of the overview kind. Usually, scientific journals and articles focus on deepening existing knowledge and are therefore very specific by nature. Still, some good material was found.

In [4], the authors present SLAM from a users perspective, covering the practical aspects of the algorithms. This is suitable since it does not focus too much on specific algorithms but focuses on giving a practical overview. The authors work within the field, making the it a valuable primary source. Likewise, [7] focuses on a capturing SLAM as a wide overview. Finally in [5], the author writes about collective robotics which is a bit too specific but it also gives an wide look at SLAM algorithms.

In this search, sources from course material has been avoided. These give a good personal understanding but it can be difficult to confirm the validity of the data in the source. One of these is a course from MIT OCW.

It is important to put the algorithm in an implementation perspective, [2] gives some early implementation aspects and also an overview on how to overcome some of the hurdles related to the implementation. To be able to put all of the theory in a perspective and describe the fundamental problem and also a solution, [3] is a good source since it really unveils all the fundamental problems and gives a layout of the solutions. It has been cited over a thousand times, which can be a good implication on that this is a real fundamental article.

The fundamental knowledge is all very important, and it is really helpful to have the base of the problem well figured out and defined. With this in mind, the paper is being written with the state of the art of today. [6] gives a review of the field as of 2015, this paper can be used as one good indication on where the field is today and where to pickup for the future.

Search iteration

For learning about SLAM in general, the following search string was used in Scopus:

$$\begin{aligned}&((\text{slam}) \text{ OR } (\text{simultaneous near localization near mapping}))\\&\text{AND SUBJAREA (comp, engi)}\end{aligned} \tag{1}$$

This limited search results to SLAM sources within computer science and engineering. It yielded 7617 results. Since a general overview was wanted,

$$\text{AND (overview OR tutorial OR primer OR basics)} \tag{2}$$

was added to search string (1). The result was 1471 results. Often, books might be better at giving an overview of a subject than scientific papers, so

$$\text{AND DOCTYPE (bk)} \tag{3}$$

was added. This yielded 8 results and one source, [5]. It also yielded a synonym to "overview" *fundamentals*. Finding nothing more on Scopus, a tentative search is also made in KTH Primo. Starting simply with searching for

$$\text{slam AND overview.} \tag{4}$$

This gave 198 results, many irrelevant but 2 relevant sources were found, [4] and [7].

Another approach can be to try and find the earlier publications that is describing the problem or the solution to SLAM. The search term,

$$\text{slam AND (problem OR solution)} \tag{5}$$

gives 335 results and even though the search term was short, it yielded some relevant results, both [3] and [2]. It can also be interesting to look at the implementation part of the problem, so the search term

$$\text{slam AND (problem OR solution) AND implementation} \tag{6}$$

gave 42 results where a good review from 2015 was found [6].

References

[1] John W. Creswell. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications, Inc, 3rd edition, July 2008.

[2] G. Dissanayake, H. Durrant-Whyte, and T. Bailey. A computationally efficient solution to the simultaneous localisation and map building (slam) problem. In *Proceedings 2000 ICRA. Millennium Conference. IEEE International Conference on Robotics and Automation. Symposia Proceedings (Cat. No.00CH37065)*, volume 2, pages 1009–1014 vol.2, 2000.

[3] M. W. M. G. Dissanayake, P. Newman, S. Clark, H. F. Durrant-Whyte, and M. Csorba. A solution to the simultaneous localization and map building (slam) problem. *IEEE Transactions on Robotics and Automation*, 17(3):229–241, Jun 2001.

[4] Udo Frese, René Wagner, and Thomas Röfer. A slam overview from a user's perspective. *KI - Künstliche Intelligenz*, 24(3):191–198, 2010.

[5] S. Kernbach. *Handbook of collective robotics - fundamentals and challenges*. 2013. cited By 1.

[6] A. R. Khairuddin, M. S. Talib, and H. Haron. Review on simultaneous localization and mapping (slam). In *2015 IEEE International Conference on Control System, Computing and Engineering (ICCSCE)*, pages 85–90, Nov 2015.

[7] L. Qu and H. Wang. An overview of robot slam problem. In *2011 International Conference on Consumer Electronics, Communications and Networks (CECNet)*, pages 1953–1956, April 2011.