Project context

In the field of automatic robot exploration, multiple different exploration strategies exist, i.e., different paradigms, methods, and software. One strategy is better applicable than one other in a certain situation, yet it is hard to analyse which strategy is best applicable in which situation and why. (Ramakrishnan et al., 2021) However, all strategies aim for the same goal: construct a model of the environment (the *map*) and estimate the state of the robot moving within it, known as Simultaneously Localization and Mapping (SLAM). (Cadena et al., 2016) Maps are useful for two reasons; (i) for path planning and to provide an intuitive visualization for a human operator and (ii) to allow limiting the error committed in estimating the state of the robot (Cadena et al, 2016).

According to Cadena et al. (2016), SLAM is entering a new era, called *robust-perception age*, in which challenges await. These challenges are regarding (i) *robustness*, (ii) *high-level understanding*, (iii) *resource awareness*, and (iv) *task-driven perception*. A lot of research is now done and could be done to overcome these challenges. (Cadena et al., 2016)

Stakeholder analysis

In robot exploration multiple stakeholders could be distinguished, namely:

- Discrete Technology and Production Automation (DTPA); the DTPA is the main stakeholder in this project, as it is the problem owner, and therefore has high interest in this project. The DTPA has also relatively high power in this project, as they can intervene if desired.
- Overall users of SLAM; this stakeholder entails all people that make use of SLAM. They could be interested in this project since a new method of robot exploration will be designed. Other users of SLAM have very low power in this project, as they are not involved in the design of the new exploration method. However, these users do have interest in this project, as it contributes to the development of SLAM.

No competitors are considered in this project, as most of the SLAM libraries are open source. (Cadena et al., 2016)

System description

The integrated system concerning robot exploration is considerably large, as it is interdisciplinary in many research fields, involves manifold aspects and contains numerous sub-systems (Cadena et al., 2016). Although, the SLAM could be distinguished in two main interacting sub-systems: *front end* at a lower level and *back end* at a higher level. At the front end, the system naturally intersects with other research fields, such as computer vision and signal processing. Here, all information and data are gathered, which is processed at the back end. At the back end, SLAM integrates geometry, graph theory, optimization, and probabilistic estimation to construct the map (Cadena et al., 2016). The back end has a feedback loop with the front end, as information is exchanged. The output of the robotic system is the map itself and the movement of the robot. A simplified overview of this system is given in figure 1:

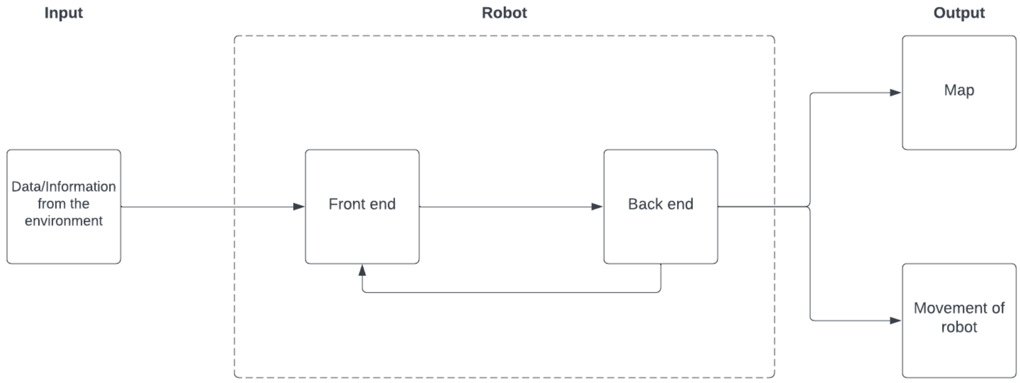

Figure 1 - Overview of simplified system

This project will merely focus on unknown environments, which means that no prior knowledge in any way is known. This excludes both manually built map of artificial beacons in the environment and GPS systems (the GPS satellites can be considered as moving beacons at known locations) (Cadena et al., 2016). Thereby, only indoor environments will be considered since this is a demarcated area and GPS has little function within indoor areas (Cadena et al., 2016). Moreover, the popularity of the SLAM problem relates to the emergence of indoor applications of mobile robotics. (Cadena et al., 2016)

Problem statement

Currently, while entering the new age of SLAM, there exist challenges to overcome, which are regarding (i) *robustness*, (ii) *high-level understanding*, (iii) *resource awareness*, and (iv) *task-driven perception*.

Goal statement

The first objective of this design science project is to compare traditional exploration methods to each other. The second objective is to design an exploration method based on reinforcement learning and compare this with the traditional methods. The third objective, if time allows, is to implement the designed exploration method in the real world.

These objectives result in the following goal statement:

This research aims to design an exploration method based on reinforcement learning which overcomes the challenges that come with the robust-perception age, within a time span of 15 weeks.

This goal could be regarded as SMART, as is specifically aims at designing a new exploration method, measurable due to the challenges, attainable due to the broad variance of existing literature, relevant due to increasing popularity of indoor environment exploration by robots, and time-bound due to the time-restriction of 15 weeks. The creation of SMART goals is based on Williams (2012).

Main research question

How to design an exploration method based on reinforcement learning which overcomes the challenges of the *robust-perception age*?

References

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