MASTER'S THESIS PROPOSAL

07/09/2022

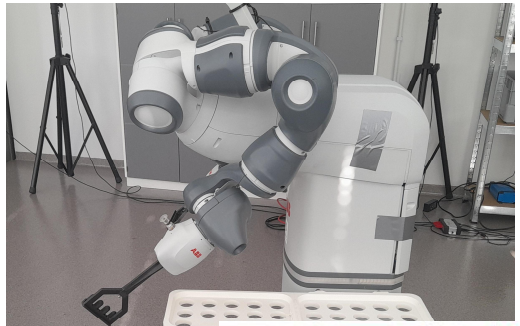
# Master's Thesis Proposals

Presentation material for potential MSc Student candidate

From ABB Research, Västerås

# Master Thesis Proposals

## Variable Impedance Control for Mobile YuMi



## Scope

Research topics: in this project, the student will work on variable impedance control for the base and arms of a mobile manipulator.

Goal(s):

1. Review the state of the art of variable impedance control and identify a promising method
2. Identifies which cost function (KPI) to optimize to tune the impedance parameter
3. Demonstrate the algorithm on mobile YuMi or mobile GoFa

## Description

When robots operates in unstructured and unpredictable environments, it is required that they can handle unexpected contacts with the environment without generating dangerous interaction forces and without shutting down, interrupting the task execution. A way to ensure that the robot handles wanted and unwanted contacts properly is impedance control. Impedance control allow the robot to have compliant contact with the environment, with desired stiffness, inertia, and damping. However, for a customer it can be difficult to tune this parameters in some application. Therefore, tuning impedance parameters automatically would improve significantly autonomy and ease of use.

## Approach

The work will address the following points:

- Identify, in the literature on reinforcement learning and iterative learning control, a suitable approach
- Implement the selected algorithm on the mobile YuMi
- Evaluate quantitatively the performance with KPIs to identify such as accuracy, stability , execution time

## Required background

- Good initial knowledge on robot control and control theory
- Proficient in C++. Additional knowledge on Python and Matlab is a plus.
- Knowledge about ROS2 is a plus

## Timeline

- Start: between November 2022 and January 2023
- Duration: 6 months
- Place: ABB CRC (Västerås)
- ABB will cover the accommodation in Västerås

Supervisor contact: Pietro Falco
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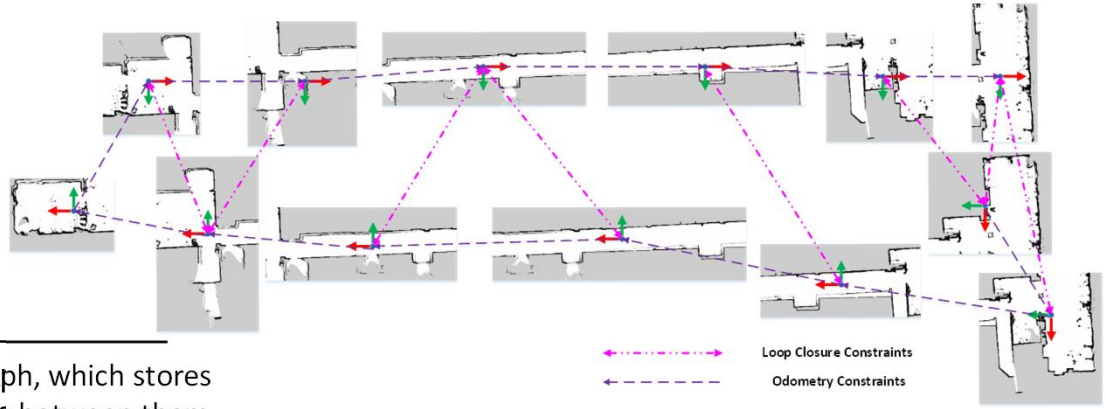
# Master's Thesis Proposals

## Lifelong mapping in Google Cartographer




## Scope

Research topics:

In this project we will examine optimal ways for reducing the graph complexity in the Cartographer SLAM:

Goal(s):

1. Identify the current graph and local map management strategy in Google Cartographer.
2. Research and propose optimal ways for improving the lifelong mapping strategy in Cartographer.
3. Update Cartographer with lifelong mapping capabilities.

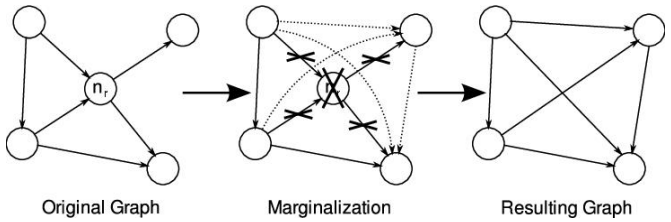
## Approach

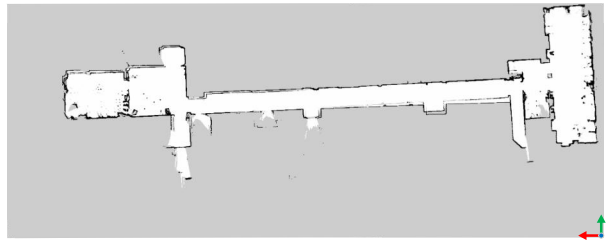
The work will address the following points:

- Perform literature review on the current problem and suggest optimal approaches for Bayesian Graph management.
- Examine Cartographer code and suggest ways for updating the code with graph management techniques.
- Update and test open-source Cartographer code.

## Description

In mobile robotics graph-SLAM, the pose graph, which stores the poses of the robot and spatial constraints between them, is the central data structure. The size of the pose graph has a direct influence on the runtime and the memory complexity of the SLAM system and typically grows over time. A robot that performs lifelong mapping in a bounded environment must limit the memory and computational complexity of its mapping system. The student will be requested to research potential methods and techniques for eliminating unnecessary graph-nodes and performing optimal map management.



## Required background

- Good initial knowledge on estimation theory and mobile robot SLAM.
- Proficient in C++. Additional knowledge on Python and Matlab is a plus.
- ROS-knowledge and preferably experience with ROS navigation stack

## Timeline

- Start: between November 2022 and January 2023
- Duration: 6 months
- Place: ABB CRC (Västerås)
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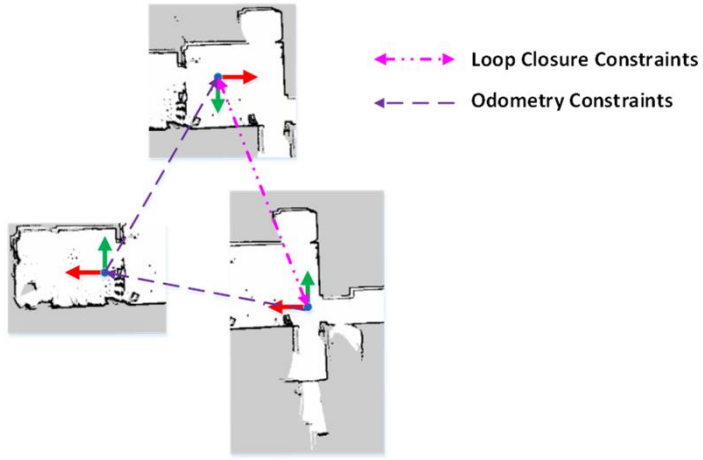
# Master's Thesis Proposals

## Improving Loop Closure Detection in Google Cartographer




## Scope

Research topics:

In this project we will examine optimal ways improving the performance of Loop-Closure Mechanism in the Cartographer SLAM:

Goal(s):

1. Improve the real-time performance of the Cartographer's Loop-Closure mechanism by either enhancing the already-in-place Fast Correlation algorithm or substituting it with another technique.
2. Benchmark the improvements of the new technique in comparison to the previous one.

## Approach

The work will address the following points:

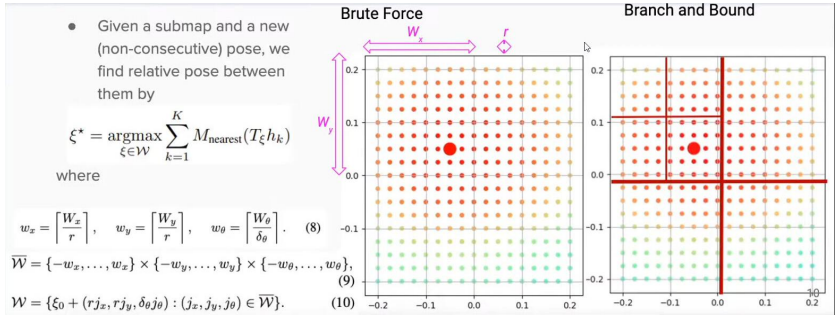
- Perform literature review on the current problem and suggest optimal approaches for Loop-Closure detection.
- Examine a method where simple semantic information could be extracted on the map (e.g. detecting lines, corners and circles using Hough Transform) and assist finding valid Loop-Closures.
- Examine Cartographer code and suggest ways for updating the code with the new Loop-Closure technique.

## Description

In mobile robotics graph-SLAM, the pose graph, which stores the poses of the robot and spatial constraints between them, is the central data structure. To correct previously recorded erroneous poses, which are the graph nodes, their accumulated error needs to be minimized by a back-end optimization algorithm (Ceres in Cartographer). This graph optimization usually takes place when the mobile robot revisits a previously traversed location. At that instance we define that the graph is closing the loop and a registration algorithm is responsible for detecting this Loop-Closure. The student will be requested to research potential methods for improving the Loop-Closure technique in Cartographer.

## Required background

- Good initial knowledge on estimation theory and mobile robot SLAM.
- Proficient in C++. Additional knowledge on Python and Matlab is a plus.
- ROS-knowledge and preferably experience with ROS navigation stack




## Timeline

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- Place: ABB CRC (Västerås)
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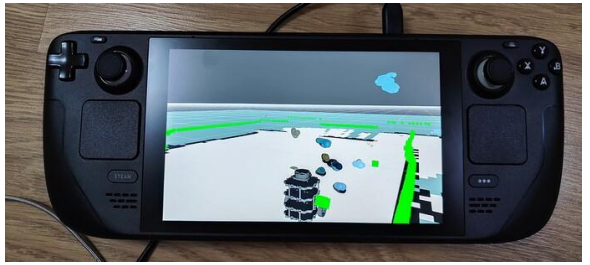
# Master Thesis Proposals

## Human Machine Interface for Autonomous Mobile Manipulator

## Scope

Research topics: in this project, the student will work on the development of an HMI for controlling mobile manipulators, including navigation, manipulation and perception.

Goal(s):

1. Implement a modular HMI that includes controlling and visualization of an AMMR
2. Demonstrate on a Steam Deck

## Description

Mobile manipulators cannot be teleoperated on tethered controllers. Due to their many degrees of freedom and capabilities, advanced controllers are required that operate wirelessly and can communicate all required information with the operator with many different interfaces. Handheld portable computers have become inexpensive and popular, allowing human operators to perform advanced tasks with AMMRs without needing to use desktops or laptops.

## Approach

The work will address the following points:

- Review state of the art of HMI for AMMR
- Design HMI Mockups – Evaluate, interview and rank
- Implement the HMI utilizing various output (screen, audio, rumble) and input (joysticks, touchpads, touchscreens, microphones) interfaces.

## Required background

- Good knowledge on Linux and ROS
- Proficient in C++ and Python. Additional knowledge on Qt, Gtk or other GUI frameworks is a plus.
- Knowledge on Arch Linux is a plus

## Timeline

- Start: between November 2022 and January 2023
- Duration: 6 months
- Place: ABB CRC (Västerås)
- ABB will cover the accommodation in Västerås

Supervisor contact: Aris Synodinos
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# Master Thesis Proposals

## Haptic Spherical Joint for Simulated Robot Interaction

### Scope

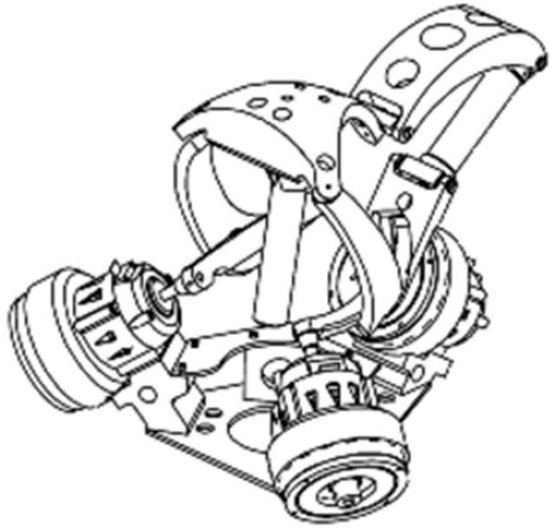
Research topics: in this project, the student will design one or more haptic devices to allow a human operator to control motions while being subjected to force feedback.

Goal(s):

1. Design and testing of haptic interfaces for simulated interaction with robots.
2. Demonstration in Gazebo for a compliantly controlled (mobile) manipulator.

### Description

Impedance-based control laws allow the robot to interact with humans and the environment in a compliant and safe way. While the stable behaviour of the robot can be guaranteed with a proper analysis, the tuning of the gains highly depends on the perceived compliance during the experimental validation on the robot. The goal of this thesis is to realize haptic interfaces that will allow the control designer to have a good estimate of the perceived compliance already during the simulation phase. This will reduce the gap between experiments and simulations and speed-up the deployment of control laws on the real hardware.



SHaDe - Laboratoire de robotique, Université Laval

### Approach

The work will address the following points:

- Review state of the art of haptic devices.
- Use of 3D input device to test the connection with Gazebo.
- Design of haptic interfaces.
- Validation on a simulated compliantly controlled robot in Gazebo.

### Required background

- Good knowledge of Linux and ROS.
- Good knowledge of robot kinematics and dynamics.
- Knowledge of robotic impedance control is a plus.
- Good knowledge of Solidworks (3D CAD).
- Good knowledge of mechatronics.

### Timeline

- Start: between November 2022 and January 2023
- Duration: 6 months
- Place: ABB CRC (Västerås)
- ABB will cover the accommodation in Västerås

Supervisors contact:

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# MSc Project Proposal

## Mobile robot motion capability evaluation

### Scope

Research topics:

How to objectively evaluate different mobile motion capabilities with respect to use-case scenarios/requirements

Goal(s):

1. Find KPI's to compare different motion capabilities of mobile robots
2. Quantify difference between differential-drive, and omni-motion mobile robots for selected use-cases

### Approach

The work will address the following points:

- Review literature on the topic
- Identify KPI's to be evaluated for the purpose to compare different motion capabilities (and thereby value)
- Develop simulation environment in ROS/Gazebo and quantify the identified KPI's with respect to variations in application requirements

### Description

There are several different kinematics solutions to achieve mobility motion of robots. These differences leads to different characteristics of the motion capability.

The present project targets to find ways to be able to quantitative evaluate and compare different motion capabilities of mobile robots and its impact on (manipulation) application performance. A first step is to identify and decide on KPI's that characterize mobile robot application performance. A second step is to use available simulation platform Gazebo to make quantitative evaluation of the KPI's for differential- and omni motion type of robots. The evaluation should be made considering selected use-cases and variations in application requirements such as environment size/shape, size/shape of robot, re-orientation requirements etc.


https://blog.pal-robotics.com/omnidirectional-vs-differential-drive-robots/

### Required background

- Suitable for students with interest in mobile robotics in general and mechanical systems simulation in particular
- Basic SW skills in C++ and Linux
- Prior ROS/ROS2-knowledge is an advantage

### Timeline

- Start: 2022
- Duration:
- Place: LiU with visit(s) to ABB CRC (Västerås)

Supervisor contact: Jonas Larsson
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Aris Synodinos
aris.synodinos@se.abb.com

# MSc Project Proposal

## Hand-mounted camera for GoFa (OBS this would require ROS driver for RWS2.0)

### Scope

Research topics:

For swift calibration of robot arm to a workplace using tags and/or to inspect objects

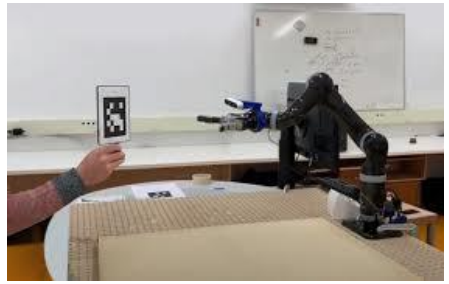
Goal(s):

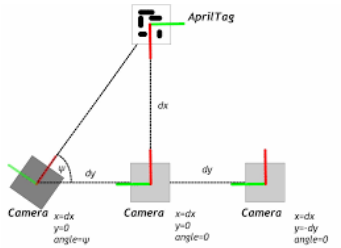
1. Choose suitable camera meeting requirements on size, weight, sensor performance
2. Propose mechanical integration
3. Use camera to calibrate robot towards tags and for example to scan objects.

### Description

Vision sensors are an enabler for many robot applications.

The present project aims to develop an integrated vision system for ABB GoFa robot. First part is the mechanical integration of a suitable camera. Second part is SW integration of camera into ROS2, deploy






### Approach

The work will address the following points:

- Review requirements and suitable cameras
- Development of mechanical integration
- (Integration of camera into ROS2)
- Develop vision-based application where hand-camera stream is needed.

### Required background

- Suitable for students with interest in mobile robotics in general
- SW/Vision skills, ROS2 knowledge is an advantage

### Timeline

- Start: 2023
- Duration: 6 months
- Place: ABB CRC (Västerås)

Supervisor contact: Jonas Larsson
jonas.larsson@se.abb.com

# MSc Project Proposal

## Vehicle dynamics of mobile robot based on steerable wheels

### Scope

Research topics:

Study vehicle dynamics for mobile robot based on steerable wheels

Goal(s):

1. Specification of test cases based on customer use-cases (i.e. lab tests that emulates real use scenarios)
2. Quantify vibrations appearing in specific mobile YuMi robot
3. Develop sensitivity analyses for relevant design choices, e.g. wheel properties, structural stiffness, …

### Description

A successful mechanical design of a mobile arm robot enables the robot to be accurate, fast and stable.

In the present project we aim to study vehicle dynamics for a specific robot concept with multiple steerable wheels. For the robot to be stiff and stable it is crucial to find the balance of minimal suspension and durability.

Based on use scenarios the project will design relevant lab tests, conduct experiments with support of ABB, develop simulation model, and study sensitivity with respect to relevant design choices like structural stiffness and tire material.

### Approach

The work will address the following points:

- Review vehicle dynamics methodologies from automotive domain. Identify important design aspects
- Design/specification of controlled tests
- Conduct instrumented experiments (with support from ABB)
- Develop dynamics model that efficiently capture the dynamics of interest.

### Required background

- Suitable for students with interest in mobile robotics in general and mechanical simulation in particular
- Ansys skills is an advantage

### Timeline

- Start: 2023
- Duration: 6 months
- Place: ABB CRC (Västerås)

Supervisor contact: Jonas Larsson
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