A ROS TOOL FOR OPTIMAL ROUTING IN INTRALOGISTICS

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Introduction

The manufacturing industry is now in the challenging **Industry 4.0** era. Heavy-duty everyday activities are no longer considered a burden for human workers as they can be safely and reliably assigned to automated machines. Flexibility is a major characteristic of modern factories as the equipment can be easily customized to produce small lots of products and create resilient supply chains [1]. Their penetration to the industrial facilities and the supply chain ecosystem is constantly increasing as they provide ***(i) 24/7 services, (ii) minimization of labor cost, (iii) low maintenance cost, (iv) enhanced accuracy in daily activities and (v) improved safety*** [2]. **Automated Guided Vehicles (AVG)** are used in real-world scenarios in the manufacturing industry and logistics. They can navigate at the facility by localizing themselves and creating the occupancy maps for mapping the facility's layout. The **occupancy gird map (OGM)** enables the vehicle to plan its movement from one point to the other creating a global path at the map while avoiding static obstacles. In order to schedule and plan the AGV's complete trip in a facility, the authors focus on the well-documented **Vehicle Routing Problem (VRP**) and consider the optimal route for visiting the regions of interest while minimizing the total distance traveled. In this research paper, the main focus is on providing sophisticated tools for utilizing the vehicles at the facility layout in a user friendly manner enabling the vehicle's control from non-experts. As a first step, the authors used the vehicle's sensors and **Robot Operating System (ROS)** for navigating and exploring the facility to create the facility's map. At a later step, the proposed tool provides a visual interface for storing regions of interest (hot-spots) at the facility layout where the loading and unloading activities take place while the authors focus on routing optimization methods in intralogistics. An **Ant Colony Optimization (ACO)** algorithm determines the shortest path for navigating at the facility layout while passing through all the sections of interest. The final output is visualized in the simulation environment while in the meantime the real world robot follows the proposed path at the facility. Our pilot case study uses the Turtlebot3 Waffle mobile robot and the results indicate that the proposed tool could be utilized by non-experts for efficiently customizing the mobile robot's path in real-world conditions.

Methods

- ***Creation of OGM with Turtlebot and SLAM***

The initial step before navigating into an unknown environment is to create a perception of the environment. The robot is teleoperated at the facility and creates the OGM using Simultaneous Localization and Mapping (SLAM) techniques. Given a series of controls and sensor observations over discrete time steps, the SLAM problem is to compute an estimate of the agent's location and a map of the environment. In our case study, the mobile robot estimates its current location with the use of a 360 Laser Distance Sensor using the GMapping method provided by ROS.

- ***Ant Colony Optimization (ACO)***

Given a matrix of distances between points (regions) of interest in the occupancy grid, the authors focused on identifying a closed Hamiltonian cycle that creates a path travelling through all the points (regions), and pass from any region once and only once, while minimizing the total traveling distance. This is the definition of the world-famous **Traveling Salesman Problem (TSP)**, which is an NP-Complete problem. In this paper, we implemented a ROS based variation of a meta-heuristic optimization algorithm, the Hybrid ACO. This algorithm at its basis mimics the behavior of ants when trying to find the optimal path from their nest to their food source and back while reposing a special hormone that is called pheromone. On top of this algorithm, the authors included various optimization algorithms and techniques to overcome some important weaknesses of ACO such as its ability to get trapped to locally optimal solutions.

- **The proposed tool's Graphical User Interface (GUI)**

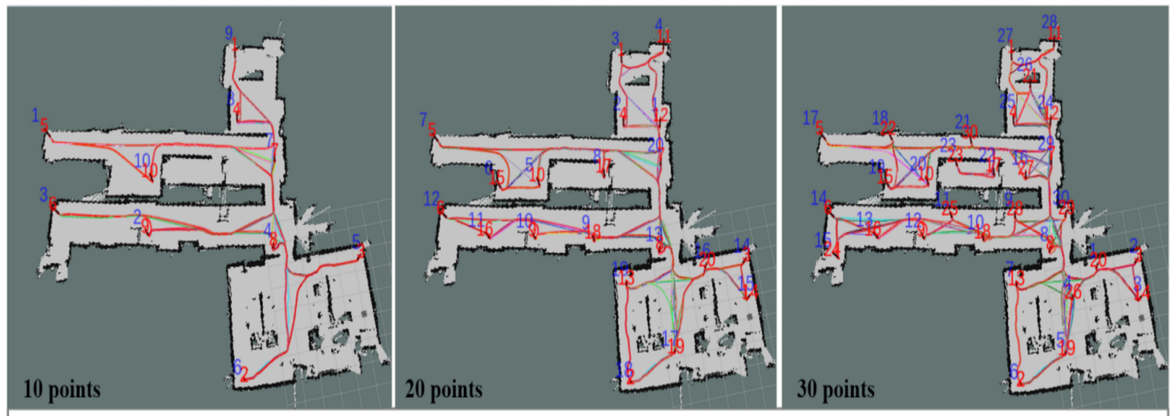
RViz, is a 2D and 3D visualizer for displaying the vehicle's environment, sensor's data and state information from ROS. The GUI of the proposed tool is implemented as a RViz plugin, to provide a user friendly interface inside RViz enabling the customization of the system by non-experts. Current functionalities of the GUI are:

1. Add and Delete points of interest at the facility and calculate the from-to distance matrix
2. Run the ACO algorithm and present the optimized solution for navigating to all the points of interest while minimizing the total travelled distance
3. Customize the parameters of the ACO algorithm
4. Visualize the results in RViz

Results

Our tool proposes a user friendly interface for providing a set of regions of interest at the facility layout while the implemented ACO algorithm optimizes the tour through the set of points of interest so that it minimizes the total traveled distance. This was validated using established benchmarks like the Western Sahara and Djibouti containing 29 and 39 regions of interest respectively. Moreover, we run tests within the facility layout using different entry points *(10,20,30)* and present the best results along with the computational time.

Number of points at the facility	Total Distance (m)	ACO Computational Time (sec)
10	101.43465	8.378
20	113.78147	21.806
30	126.32276	42.394



Label Red numbers represent the starting points Blue numbers (above the original numbering) represent the best path's order

Conclusions

In the proposed research work a software tool was developed on top of the ROS environment for optimal routing in intralogistics. ROS basic activities were integrated into our tool and a custom algorithm was implemented for optimizing the total traveled distance. The intent was to focus on non-expert users and support their daily activities by enabling the reprogramming of high-tech equipment including autonomous vehicles through custom build interfaces. Non-expert users add specific regions of interest in a given facility layout and the autonomous vehicle selects the shortest route for traveling through the set of regions. This is critical for optimizing the daily activities of an industrial layout (industries, warehouses) as we could reduce energy consumption and save time without the need for highly skilled personnel. Finally, the tool provides interfaces for visualizing the vehicle's movement at the facility.

On-going Research

The tool can be enhanced by incorporating extra parameters on our algorithm which were left out throughout this paper, such as the vehicle's capacity and any required time windows for picking-up and delivering the products. Furthermore, the proposed tool could be employed in conjunction with the company's **Warehouse Management System (WMS)** system to prepare the daily orders and work alongside human workers for loading and unloading purposes. Safety regulations are currently at an infancy state [3] and further study on safety concepts is needed.`

References

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