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Romb Technologies – autonomous navigation in logistics sector

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1. Introduction

Romb Technologies is an academic spin-off company that commercializes autonomous navigation technologies in the logistics sector. Based on over 40 years of combined R&D experience in robotics and autonomous navigation, the company, founded in November 2018. as a spin-off of the Laboratory for Robotics and Intelligent Control Systems at the Faculty for Electrical Engineering and Computing at the University of Zagreb and incubated at the Zagreb Innovation Centre (ZICER), develops software for accurate and efficient automated material handling activities.

Romb Technologies offers a complete software suite for automated material handling, from map-building and localization to layout planning and path following. Localization algorithms are based exclusively on on-board sensing and do not require any additional infrastructure in the environment. The technology, when combined with patent-pending interactive map building methodology, reduces AGV deployment time from weeks to days. Developed a path-following method, based on model-predictive control (MPC), which works with all industrial kinematic configurations, ensures maximum vehicle utilization by optimizing velocity while maintaining high positioning accuracy. This is complemented with an intuitive layout-planning tool which optimizes vehicle paths and visualizes the interaction of the safety subsystem with the environment.

As a newly founded company with strong academic ties, Romb Technologies invests a significant portion of its resources in R&D, developing rich visual perception modules, powered by deep learning, which will endow the vehicles with semantic understanding of their environment and open up new use-cases for AGVs.

Automated Guided Vehicles

The automated warehouses are the facilities that can be equipped with both stationary and mobile robotic parts (e.g. palletization work cells and unmanned forklifts, respectively). The complexity of control increases as a number of involved robotic devices increases. Other goals to consider include overall system safety, effective adaptation to system faults, collision avoidance, and accommodation to dynamic changes within the manufacturing process itself, in addition to traditional goals such as maximum production throughput, efficient utilization of all robotic subsystems, and savings based on the elimination of human work in the process. AVG integration into automated materials handling systems requires the use of effective on-line supervisory control mechanisms capable of resolving conflict and deadlock issues in the system layout. This usually means that routing and scheduling algorithms used on-line for AGV's traffic and mission control must be executed in a very short time interval, which leads to the solving of an NP-hard computational problem.

Technologies

AGV delivery missions are often divided into the following parts: i) point-to-point motion, and ii) docking. During the point-to-point phase, the vehicle should take the shortest path from its current location to the docking station. During the docking phase, the vehicle must precisely match its orientation in order to position its forks accurately for pallet pickup.

The basic purpose of the point-to-point motion controller is to safely navigate the vehicle along the shortest obstacle- free path from an initial location towards a desired destination in the vehicle working space. Therefore, the initial step is to select and implement an acceptable path planning algorithm. Unlike most practical AGV systems in which the vehicles follow paths along predetermined path network, Romb Technologies implements a free-ranging motion that allows for motion planning and execution throughout the whole obstacle free environment. The free-ranging motion scheme is more appropriate sincerity allows for the easy definition of arbitrary motion sequences within any section of the dynamic working environment. Path feasibility is an important factor that had to be considered during the design of the path planning algorithm. due to the non-holonomic vehicle constraints. Taking into account the intended free-range properties as well as the path

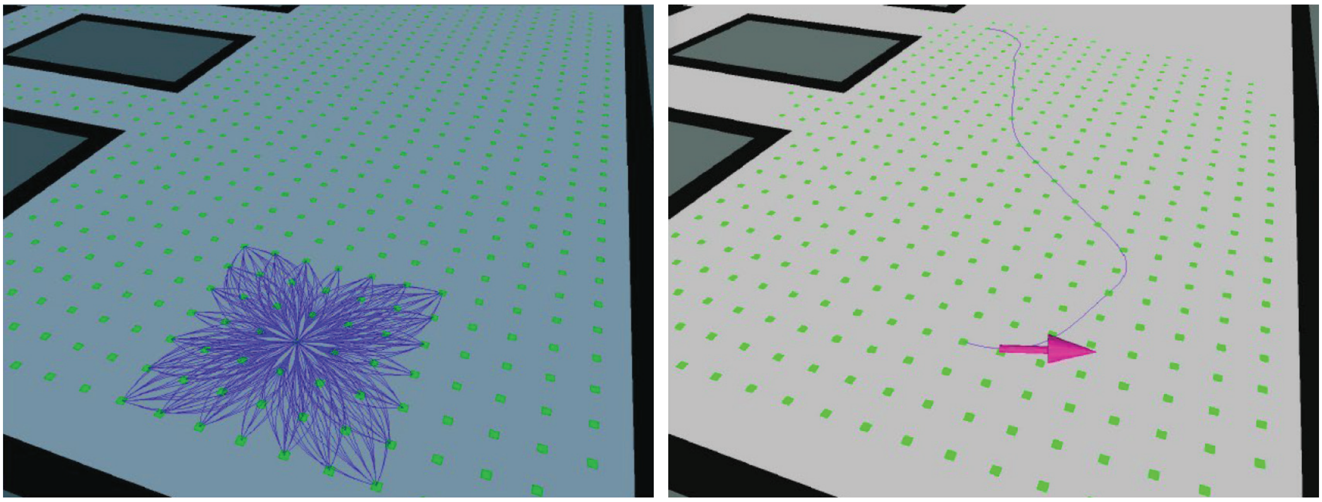

Figure A. The AGV state lattice and the final path

feasibility criteria, we implemented a sampled vehicle state space which encodes feasible motions by design, reducing the overall route planning problem to finding an appropriate sequence of motion primitives (latices), which represents the resulting vehicle path connecting the initial and desired vehicle states (Figure A).

Although there are various commercial systems that use autonomous ground vehicles (AGVs) t, significant improvements can be accomplished in terms of their level of autonomy and deployment cost. The current state of the art for vehicle localisation, in particular, necessitates extra infrastructure, typically in the form of reflective markers or electromagnetic guides, in order to accurately determine vehicle posture. This strategy has various drawbacks, including a high installation cost (up to 30% of system commissioning) and the need for many man-hours of work by experienced staff. Moreover, they are sensitive to environmental changes which may obstruct the field of view of the vehicle; in tough industrial conditions they might become damaged or soiled.

The capacity of AGVs to self-localize without the usage of extra infrastructure (markers, guides) is the essential technology that considerably improves their performance and adaptability, allowing them to be widely used. Wheel encoders, contact switches, sonar arrays, 2D and 3D laser scanners, mono, stereo, and RGBD cameras are among the most typical sensors used for this purpose. Romb Technologies developed real- time natural localization (using laser scanner – Figures 1 and 2) based on the robust AMCL (Adaptive Monte Carlo Localization) algorithm, which fuses odometry data with laser range readings providing a location of the AGV with a known covariance. The initial estimate for the scan matching ICP algorithm is based on this finding. Finally, the obtained result, which typically has a very good orientation estimate, is used as the initial estimate in a discrete Fourier transform method, which returns the final result of sub-centimetre localization accuracy in real-time, using only natural features in the environment.

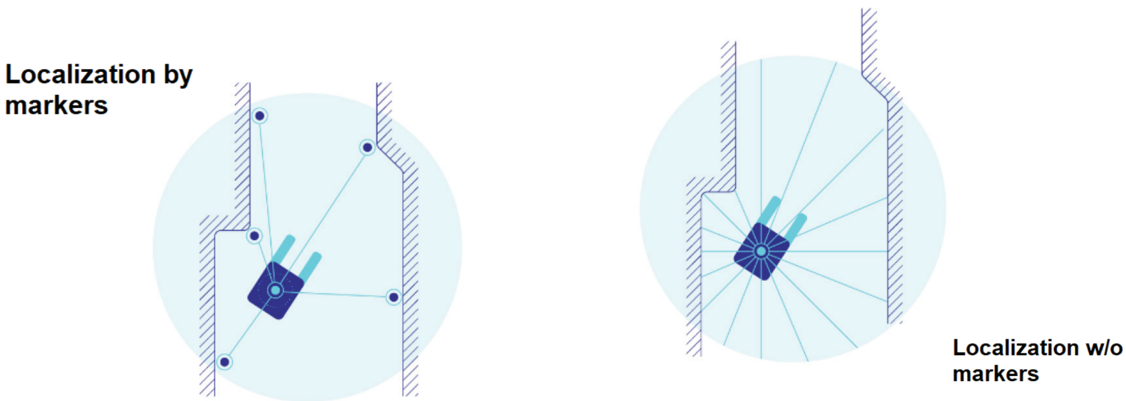

Figure 1. Standard localization with markers and natural localization without artificial markers positioned in the environment

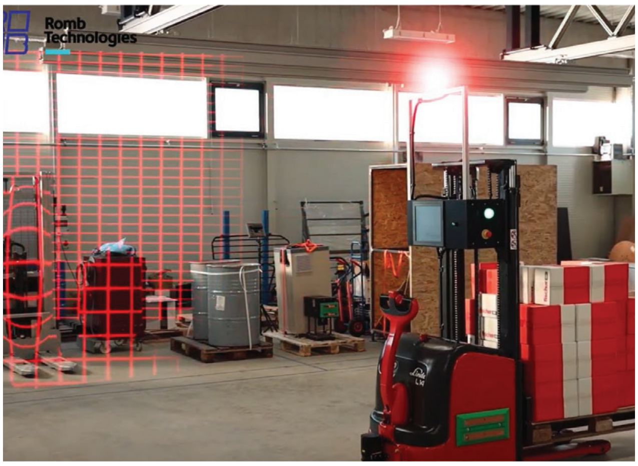

Figure 2. Natural localization (artistic depiction of laser scan). A laser on the top of the AGV measures distances from the objects surrounding the AGV, thus providing data for an algorithm that an artificial grid of occupied and free spaces around the vehicle

A further step toward improving environmental awareness is based on deep learning and AI models for real time object classification (Figure 3). This novel technology leverages deep learning and machine vision to provide human-like environment awareness to AGVs. It enables adaptive pallet pickup based on a rich visual perception of the environment, thus providing the pick-up of incorrectly positioned pallets enabling vehicles to better support human workers by operating in unstructured and unpredictable conditions. As a result, the method can be implemented without the use of mechanical pallet guides.

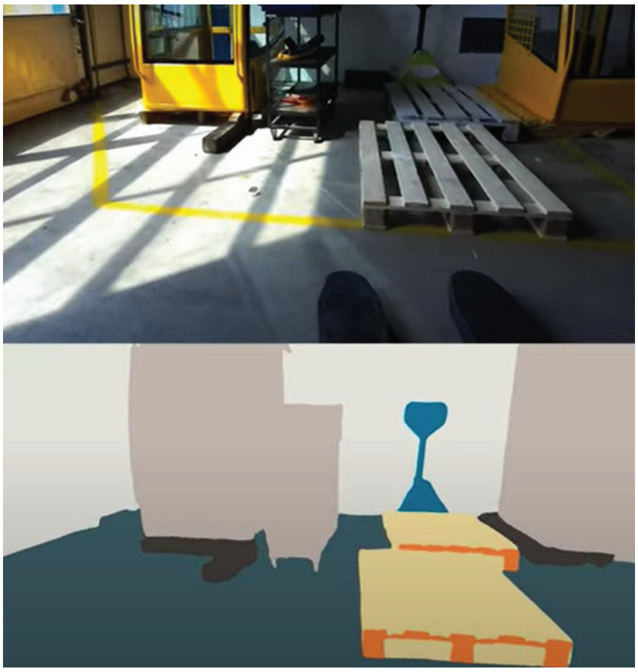

Figure 3. Visual perception for a pallet pickup

Accurate and effective path-following based on Model Predictive Control (MPC) with an optimum speed profile requires precise localization of an AGV and perception of the environment (Figure 4). This method, patented by Romb Technologies, provides better AGV utilization by allowing up to 20% faster movement on curved segments with sub-centimeter positioning accuracy. Furthermore, it allows for arbitrary vehicle kinematics with numerous actuated wheels.

Figure 4. An AGV passing next to an obstacle by using MPC-based path following