ADM Group Project
Precise localisation and advanced control for high-speed AGVs

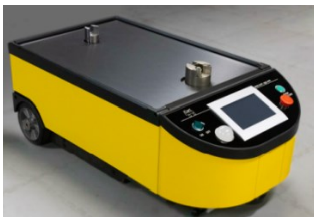
Background and Motivation

Automated Guided Vehicles (AGVs) are mobile robots that navigate around the factory by following a predefined path (identified by a pre-installed magnetic/visual strips or indoor localisation systems) and preform the material transportation task in a manufacturing or warehouse facility. In approaching to the era of Industry 4.0, smarter AGVs are highly demanded for enabling more agile manufacturing, where AGVs collaborate with each other as a fleet of autonomous robots to carry out complicated tasks in a complex and rapid-changing environment. In particular, in the pandemic, AGVs help industries mitigate the shortfalls in labours and productivities due to the restrictions in personal mobility to control the epidemic's spread. The AGV market size was $1.83b in 2020 and is expected to grow from $2.00b in 2021 to $3.72b in 2028, at a compound annual growth rate (CAGR) of 9.3% in the 2021-2028 period.

Project Overview

This group project is based on the collaboration with our industrial partner ADM Automation. ADM develop and manufacture the iCart automated guided vehicle. As part of their research and development activities they need to explore potential technologies that can improve the performance of the iCart, reduce costs and expand the operator interface capabilities. The five projects identified below would assist ADM in achieving their objectives.

1. Charging Management for AGV fleets
2. LiDAR-aided Precise Localisation of AGVs for Open Path following in Complex Industry Environment
3. Vision Encoder for AGVs
4. Advanced Navigation Control for High-speed AGVs
5. Operator-friendly Communication and Command AGV System via WiFi
6. Object detection via LiDAR for Load and Workstation Monitoring




1. Charging Management for AGV fleets

This project is to explore the possibility of increasing manufacturing capacities in the short run through smart charging management of automated guided vehicles (AGVs). Lead acid battery is the most widely used battery type for AGVs, and it receives most of its charge during the initial phase (time) of charging as opposed to the later phase. The key concept is that more productive hours can be obtained from the AGVs by reducing the duration of each charging occurrence (i.e., by recharging the batteries to less than full capacity). As a result, an AGV needs to be recharged more frequently, but the total productive hours available from the AGVs can increase. The questions to be addressed in this project is how the duration of battery charging for AGVs can be varied to increase flexibility of a manufacturing system.

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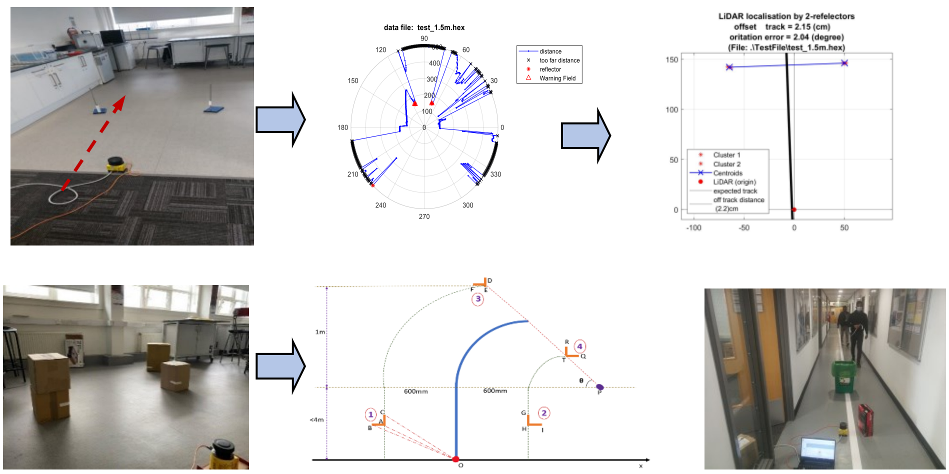
2. LiDAR-aided Precise Localisation of AGVs for Open Path following in Complex Industry Environment

The recent development in LiDAR (Laser imaging, Detection, and Ranging), also known as Laser Scanner, make it is possible to localise a subject at a high precision, such that an Automated Guided Vehicle (AGV) can move precisely following a "virtual" open path without using an identification magnetic strip or visual tags along the workshop floor to indicate the path. In this LiDAR-aided indoor localisation project, you will build an LiDAR localisation system by using the Sick S300 LiDAR, where the S300 is installed at the front of a AGV and periodically scan the area by using infrared laser beams scanning a sector of about 5m radius and 275 degrees at a resolution of 0.5 degree. A group of reflector tags will be set on the workshop floor to specify the expected 'virtual' path. The target is to use the S300 to precisely calculate the location of the AGV with respect to the expected path, (i.e. how far the AGV is off the central line of the expected track, at what angle of orientation).

You are expected to develop a software (e.g. using MATLAB or C) to communicate with the S300, receive the cloud point data, process the data to retrieve the distance and angle of the reflectors, identify the virtual path and estimate the location of the AGV with respect to the central line of the virtual track. A data fusion method may be developed to improve the localisation accuracy.



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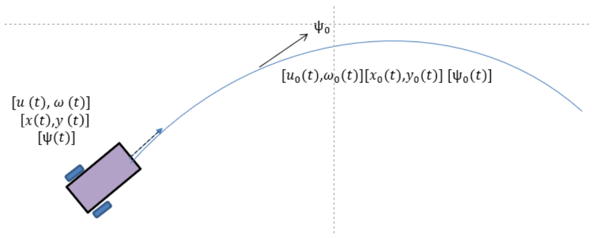
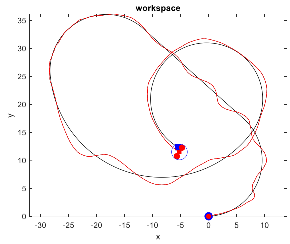
3.Model-based Steering Control for High-speed AGVs

For next generation of Automated Guided Vehicles (AGVs), higher travelling speed is favourited for the efficiency of material transportation and handling. Traveling at higher speed and accurate path tracking are two conflicting factors, which raises a challenge to the steering control. AGV's steering control usually adopt the a Proportional Integral Differential (PID) controller and, in practice, the parameters of the PID controller are usually tuned empirically in the trial-and-error manor. This requires a lot of experiments that results in a longer R&D duration and time to the market, as well as increasing cost, It is also difficult to achieve an optimal solution to the control parameters. The existing AGV usually run at 50% of its maximum motor speed because of the difficulties in steering control at high speed. AGV may run outside of the track at high speed, in particular, when turning at a corner, which causes safety issues. With the advances of computer and control technology, a better solution is the model-based hardware-in-loop controller design, in which a mathematical model of the AGV is first developed, and the controller is design by using computer-aided advanced optimization tools to find the optimal values of control parameters. Highspeed steering control under various load is a challenge to research communities.

In this project, you are expected to develop a model-based AGV steering controller to control the both the linear speed, rotation angular speed of the AGV to ensure the AGV travels along the expected path, i.e. trajectory tracking. Tasks include: (1) User Requirement Analysis Report, covering AGV system configuration, current performance, expected function and accuracy requirement etc. (2) Mathematical model of a AGV with differential driving. (3) Design of a feedback controller in state space. (4) Development of a realistic MATLAB simulation of the AGV by using both kinematic and dynamic controllers in different turns and step changes. and verification of the proposed method.





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4. Vision Encoder for Automated Guided Vehicles

In Automated Guided Vehicles (AGVs) and mobile robots that can autonomously navigate in indoor environments (e.g. a workshop or warehouse), encoders are a critical device to provide the location of a AGV for a variety of applications including material transport in workshop or warehouse. Precise localization is critical in order to achieve high performance movement and to interact with the environment [1][2]. Although there are different approaches to AGV navigation, each system must translate its trajectory into physical rotary motion and directional control. The key sensors used in AGV motion and directional control are incremental encoders. Generally, there are three methos for encoder-based dead reckoning localisation: (1) Discrete Integration; (2) Euler integration, and (3) Runge-Kutta integration [3]. Discrete Integration is the simplest and widely used. However, it is possible to diverge when the angular velocity is close to zero. In such cases, Runge-Kutta integration is better for calculating the position with less the accumulation errors.

In this project, you will use a low-cost camera together with the RFID tags on the workshop floor to calculate the position of the AGVs at sub-centimetre accuracy. In this Vision Encoder project, you will build a vision-based localisation system by using the camera system, where an camera is attached to the AGV and facing down to the floor. Then a dead reckoning method will be developed to calculate the localisation according to the data provided by the vision encoder. It periodically detect the image of the floor to calculate its position. You will understand the principles and implement the algorithm and carry out experiments to demonstrate the accuracy by series of testing either in the university lab environment or the ADM’s test facility.

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5. Operator-friendly Communication and Command AGV System via WiFi

Automated Guided Vehicles are autonomous by nature and requires communication not only for navigating safely in a complex industrial environment, but also be accessed remotely for human operator to command. By introducing a reliable tactile communication and command system, AGVs that are running dynamic missions along production lines can work with remote operators. With the communication and command system, operators can remotely interact with AGVs, monitor and control them to run special missions that may not be included in day-to-day operations of the factory.

In this project, you are expected to develop an easy to use interface from a tablet device that allows an operator to select a destination that an iCart should travel to. The two main commands required are:

(1) Request an iCart AGV from a station to go to the operator station.
(2) Send an iCart from the current operator station to another station.

Arduino based in iCart with standard TABLET/PHONE as operator interface.

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6. Object detection via 2D LiDAR for AGV Load and Station Monitoring

In many workshop material transport applications, detecting and tracking objects, such as the payload trolley, is an essential task for safe and efficient operation of Automated Guided Vehicles (AGVs). However, workshops are especially dynamic areas and the decision of how a AGV moves is determined not only by where the AGV is, but also by if the situation of payload trolley and the load station. For example, the AGV should wait until the conveyor is free before off-loading its payload trolley to the conveyor. If the conveyor at the load station has been occupied by a payload trolley (e.g. a payload trolley already presented on the conveyor waiting in a queue for being transfer by the conveyor), the AGV should not off-load its payload trolley ot the conveyor. The key is to detect if where the payload trolley is.

This project is to develop a low computation cost and robust payload trolley object detecting and monitoring system which uses only the 2D LiDAR (Laser imaging, Detection, and Ranging) scanning data. The first step is a model-free segmentation by using clustering method to separate the 2D LiDAR scan data of the scene [1]. The second step is feature extraction. Two features will be considered: the symmetry and the shadow. From the segmented cloud point data, the boundary shape and the symmetric property is determined by searching for its symmetrical axis. The object shadow is recognized by using Sobel boundary detection [2]. The third step is stereo matching to pair segmented elements from a sequence of LiDAR cloud points data with the payload trolley. You are expected to develop the algorithm to detect the payload trolley, implemented on a embedded system and evaluate the object detection system with real data collected in both a university lab and a real industrial environment. The full system is evaluated in real scenarios producing solid results.

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