Navigation framework for trackless autonomous guided vehicle

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ABSTRACT – As the flexible technology becomes more affordable and easier to use on assembly lines, many manufacturers are deploying driverless carts, robotic parts bins and autonomous tuggers. This paper proposes a conceptual design in developing a high-performance Automated Guided Vehicle (AGV) navigation by fusing position information from various sensor technologies that work with a constrained on-board resources. This project will lead to fully automated navigation of the AGV without relying on physical guidance systems such as tape or paint that increases the performance system of the AGV.

1. INTRODUCTION

Convergence technologies towards implementing Industry 4.0 catalysts the development and growth of smart factories. Many modern manufacturing plants adopt automation in the production phases which leads to a high level of productivity and efficiency. To achieve automatic manufacturing and supply chain management, large quantities of AGV is one of the solutions for materials handling.The AGV is a part of highly flexible, intelligent, and versatile material handling systems used to transport materials from various loading stations to various unloading locations throughout the facility. Figure 1 shows a type of AGV used in a manufacturing line.

Figure 1 Example of AGV manufactured by Automation & Modular Components, Inc. [1]

Most AGVs depend on guidance systems such as magnetic tape, wire guide and colorless fluorescent paint. The selection will depend on need, application and environmental constraints. The use of camera vision or laser which are common in AGVs are less popular because these sensors require high end computational technology that will increase the overall robot's cost. Furthermore, those guidance systems make the AGVs less flexible in rerouting their paths especially when there is a need to change the production layouts.

In the recent advancements, researchers have reported good tracking performance using on-the-shelf Inertial Measurement Unit (IMU) [2] as well as wireless-based positioning technologies [3]. Therefore, a new generation of AGV is making a way into the production lines which is appealing to small and mid- sized manufacturers due to its affordable in price and small form factor.

Therefore, this work envisions a trackless AGV that based on a high-performance navigation by fusing position information from various sensor technologies. The AGV is expected to apply a smart system that will allow it to perform flexible tasks due to its small form factor especially in cramped areas such as retail shops and hospitals.

2. METHODOLOGY

The current study proposed a unit of trackless AGV equipped with a unit of industrial grade Micro-machined ElectroMechanical System (MEMS) IMU which comprises of tri-axial accelerometers and tri-axial gyroscopes. The IMU costs less than RM 1000 and has sufficient specifications for indoor navigation purposes. The accelerometers and gyroscopes will measure the accelerations and angular velocities of the AGV, respectively. The data from the IMU will be computed in a navigation mechanization equation [4] that will translate into a relative position information. However, this position information will drift over time due to accumulated errors.

To reset the accumulated error, an absolute based positioning needs to be fused into the system. An Ultra-Wide Band (UWB) positioning system will be implemented which will provide the absolute position. The UWB positioning uses Time-of-Arrival (ToA) to compute the position. In one-way ranging, the sender transmits a packet and records the time of transmission tt. The receiver receives the packet and records the time of arrival ta. If the sender and receiver are time synchronized, the range between them can be estimated as $r = c \cdot (ta - tt)$ where c is the propagation speed of the signal.

A UWB wireless transceiver will be installed on the AGV to receive wireless transmission from three wireless base stations with known locations. Based on a predetermined map and the proposed localization method, the AGV can locate itself and at the same time resetting the IMU's accumulating error. Kalman filter that fuses the position information from IMU and UWB will be used to estimate and track the position of the AGV. There are two stages in Kalman filter: 1) prediction stage which computes the priori estimates of the current position state and error covariance; 2) measurement update stage which incorporates a new measurement into the priori estimates to obtain improved posteriori position estimates. In the measurement update stage, an error measurement known as Zero Angular Update (ZAU) will be implemented. ZAU considers the fact that the heading is unchanging if the AGV is static. Based on this constraint, any non-zero angular rate measured is considered as error that will cause bias.

The navigation model will be developed and simulated using MATLAB and Simulink, which later will be validated using the actual AGV with aforementioned sensors.

3. RESULT AND DISCUSSION

The trackless AGV is expected to carry lightweight parts, weigh up to 30 kg. The AGV will be designed with a futuristic outlook as shown in Figure 2. The AGV's structure will be constructed using aluminium profiles and the body will be covered with ABS sheets. The IMU will be placed at the top, centre of the AGV. The position of UWB transmitter to be installed is shown in the figure as well.

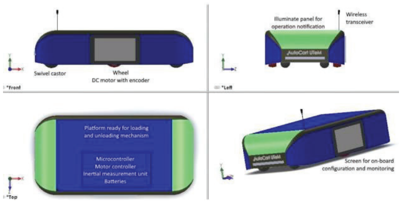

Figure 2 Proposed AGV Design

The absolute positioning will be acquired using the alteration technique as shown in Figure 3. The technique will estimate the position after receiving signal from the three base stations which their locations are known. The overall navigation system is depicted in Figure 4. The Kalman filter framework will fuse the position information from the heterogeneous sensors.

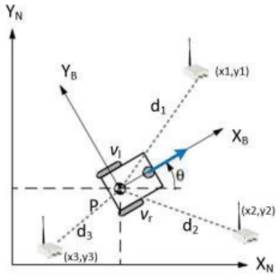

Figure 3 Example of the lateration technique using three base stations with known positions

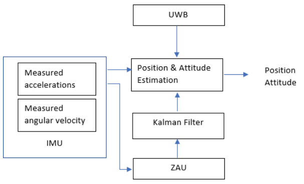

Figure 4 Kalman filter framework for trackless AGV

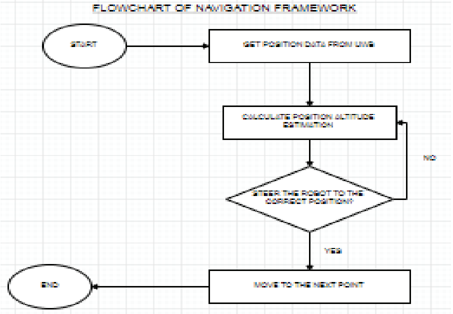

Figure 5 Flowchart for Navigation Framework

4. CONCLUSION

As conclusion, AGVs are an optimal way to automate a facility with the flexibility of autonomous material transfer system by adopting to fully automated navigation will help to improve the technology of the AGV to be a better help for the industry. Hence, routing process of the AGV can be done through software and can be easily integrated with other automation systems as unified solutions. In accordance, this project is taking up the aspiration of the university in pioneering engineering technology, specifically in advanced manufacturing, which will be a great demand in a near future.

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