Research Article

CarrGo® Sorter: Parcel Sorting System with Autonomous Multi-Robots

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Reference: Gülyurt, C. A., Polat, A. H., Kaya, S. E., Barış, S., Kaya, Y., & Değirmencioğlu, İ. (2025). CarrGo® sorter: Parcel sorting system with autonomous multi-robots. *The European Journal of Research and Development, 5*(1), 434–441.

Abstract

This paper presents the design, development, and validation of the CarrGo® Sorter System, an autonomous multi-robot sorting system for logistics and cargo handling environments. The system automates parcel classification, routing, and transferring operations using a fleet of Automated Guided Vehicles (AGVs) controlled by a software. Each robot is equipped with embedded sensors, magnetic line follower, and RFID-based localization to navigate a structured grid platform. By integrating barcode reader and real-time communication protocols, the CarrGo® Sorter System achieves high sorting throughput with reduced dependency on human operators.

Simulation and field tests demonstrated that the system can increase sorting speed while avoiding collision risk through centralized traffic management. The results support the potential of multi-agent robotic platforms to improve intralogistics by combining embedded control, intelligent coordination, and autonomous navigation.

Keywords: Autonomous Robots, AGV, Route Optimization, Warehouse Automation, Logistics Robotics, Traffic Management, Smart Sorting System.

1. Introduction

Automation in logistics and distribution sector has become a critical enabler of operational efficiency in Industry 4.0. Sorting processes, traditionally labor-intensive, can benefit greatly from robotic systems that combine intelligence, precision, and scalability. Researches on robotic mobile fulfillment systems demonstrate significant performance improvements when autonomous vehicles coordinate through centralized algorithms [1, 2]. These approaches reduce cycle time, improve sorting consistency, and minimize safety risks in high-throughput environments. The CarrGo® Sorter project built on these concepts by introducing a modular, grid-based platform where multiple AGVs deliver parcels to designated unloading zones. Unlike conventional conveyor-based sorters, CarrGo® Sorter combines flexibility with spatial efficiency, allowing quick reconfiguration and incremental scalability. The goal is to design a cost-effective system that autonomously manages sorting process, reduces operator involvement, and accelerates overall processing speed.

2. Materials and Methods

The CarrGo® Sorter system is a semi-autonomous parcel-handling system designed to optimize parcel sorting operations in logistics environments. It minimizes manual handling while maximizing throughput. The system comprises three primary subsystems: (1) Main Controller Box, (2) Robot Subsystem, and (3) Grid-based Sorting Platform. Each subsystem performs specific tasks related to perception, control, and communication, following the distributed coordination principles of multi-agent systems [1, 2].

2.1. Materials

2.1.1. Main Controller Box

The Main Controller Box (MCB) supervises robot coordination and data processing. It contains a Single-Board Computer (SBC) and a custom RF communication module based

on the IEEE 802.15.4 protocol. This configuration ensures low-latency communication and high reliability between the MCB and robots. The MCB is designed to have access to database that contains information about the parcels and their corresponding destination points.

2.1.2. Robot Subsystem

A CarrGo® Sorter Robot as shown in Figure 1, performs transporting, unloading, and charging processes under central supervision of MCB. The mechanical structure includes a lifting tray driven by a linear motor and two BLDC motors for motion. A custom Electronic Control Unit (ECU) manages sensor data, power management and motion control. A 16-sensor Magnetic Line Follower enables path tracking along the grids, while an RFID reader identifies intersection tags for localization. Robots are powered by 24V LiFePO$_4$ batteries and use IEEE 802.15.4 communication protocol by using RF module.

Figure 1: Robot Subsystem

2.1.3. Sorting Platform

The sorting platform used in this project, as shown in Figure 2, consists of a 60×60cm^2 grid with 5cm width magnetic strips for navigation and RFID tags for localization at intersections. Several unloading baskets are used to store parcels sorted by the system and each of them corresponds to a destination zone from the logistics database. Barcode

scanners mounted at the robot's loading points to read package IDs and transmit them to the MCB.

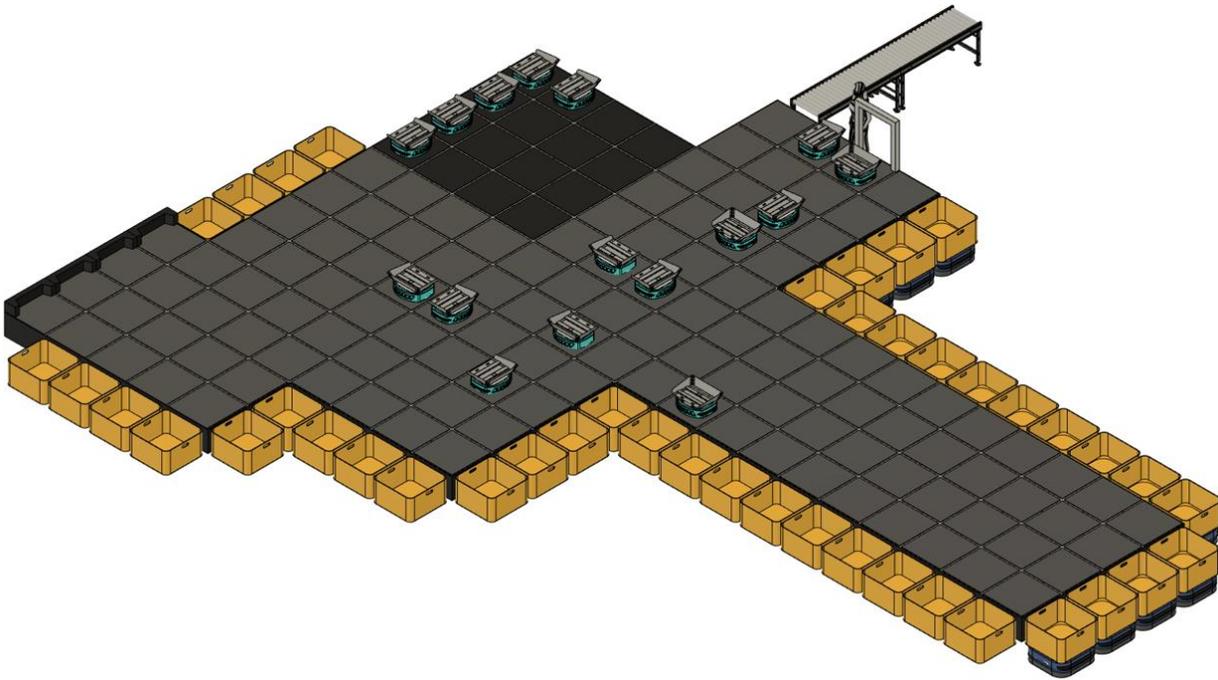A 24V charging unit that is available on the sorting platform for the robots that need to be charged.

Figure 2: An example of Sorting Platform

2.2. Methodology

2.2.1. Operational Workflow

Operators place parcels on the robot subsystem's tray. A barcode scanner reads the parcel code and sends to MCB which is responsible to retrieve the target unloading point from the database. The MCB assigns an optimal route and sends to the robots. Traffic management ability of the MCB is responsible for collision avoidance of each robots on the sorting platform. The robots which reached to the destination zone, commanded to unload their parcel into the unloading basket. Then robots are directed for new task. This workflow has centralized task allocation models used at [1].

2.2.2. Motion and Traffic Management

Robots navigate orthogonal paths defined by magnetic lines, avoiding diagonal movement to prevent crashes. Each robot sends its position detected by RFID reader and RFID tags.

An algorithm for shortest path, shortest duration and global traffic is optimized by MCB for grid utilization. The MCB features an integrated route planning/optimizing/managing that manages robot coordination by determining where and which robot has to wait, when each robot has to continue to its task.

The movement of robots can be monitor on the System along with their direction and destination.

When a robot - at the charge station or at the pending area - assigned for a new task, the route optimization and traffic management of whole system have to be iterated by MCB. This agile ability allows the CarrGo® Sorting System to run multiple robots efficiently.

The Main Controller Box is capable of emergency stop for all the robots.

2.2.3. Energy and System Monitoring

Each robot's battery level is continuously monitored by the MCB. At low-charge level robots are directed to the charging station before depletion, ensuring operational continuity.

The MCB has to determine that when each robot should move to the charging station and which robot(s) should be prioritized. The MCB computes these decisions to ensure that charging operations are performed efficiently and without disrupting overall system performance.

The main purpose of this system is to keep robots in action and maximize the efficiency of the sorting system.

2.2.4. Simulation and Optimization

A dedicated simulation software was developed to evaluate the performance of the CarrGo® Sorting System under varying parameters such as grid layout, robot count, number of parcels, parcel per hour (PPH), and number of operators. The simulation

implemented A* pathfinding and stochastic load modeling to estimate system throughput, following digital-twin practices commonly used in smart logistics [3]. The results from these simulations enabled the system to optimize route planning, traffic management and to reduce sorting time, leading to more efficient payload handling.
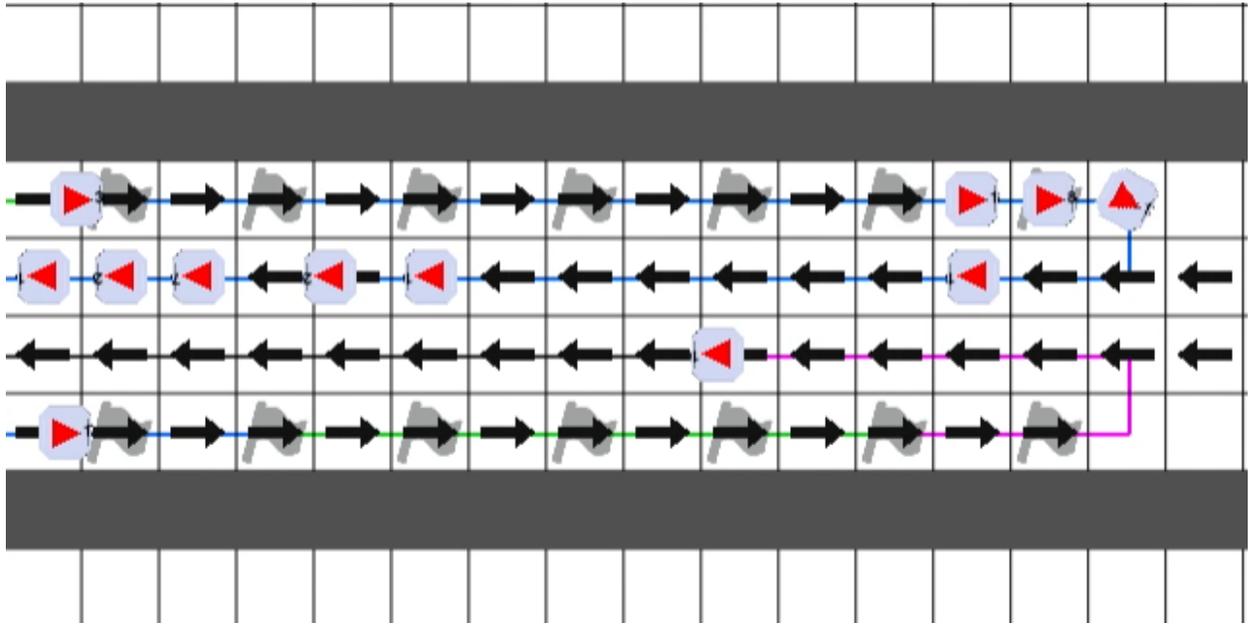

Figure 3: Scene of the Simulation Software

The Scene of the CarrGo® Sorting System Simulation can be seen on Figure 3. The gray square objects represent robots and the red triangles on top of them indicate their direction. The black colored arrow icons on the grids represent mandatory movement direction for robots. The gray flag icons are for indicating the grids where robots will unload the parcel on their tray to the related unloading basket.

3. Results

The CarrGo® Sorter System illustrates the feasibility of integrating embedded robotics, RFID localization, and intelligent coordination into logistics automation. The system's modular design allows scalability, while centralized control ensures predictable performance even under high task density. Compared to conventional conveyor-based sorters, CarrGo® Sorter System offers scalability and reduced infrastructure costs. The results align with existing research emphasizing multi-agent coordination and adaptive routing in robotic fulfillment centers [1, 2].

The CarrGo® Sorter prototype demonstrated substantial performance improvements during simulation and physical testing. Sorting throughput increased by approximately 60% compared to previous implementations lacking optimized route planning.

The system maintained reliable communication across all robots, achieving synchronization delays of less than 50 milliseconds.

The RFID-based localization achieved an average positional accuracy of ±2 cm on a 60 × 60 cm² grid with 5 cm-wide magnetic strips, which was sufficient for robust grid navigation. The magnetic guidance system successfully preserved trajectory stability under variable load conditions up to 15 kg.

In addition, automated charging significantly reduced downtime by eliminating the manual effort required for docking robots at charging stations.

Overall, the CarrGo® Sorter System achieved a high degree of autonomy, reducing operator dependency while improving both time efficiency and system reliability.

4. Discussion and Conclusion

Future works should be focused on implementing dynamic task reassignment, and advanced scheduling for heterogeneous robot fleets. The system demonstrates the viability of multi-robot frameworks as key enablers of next-generation automated logistics.

It may be more efficient to include basket-carrying robots to the sorting system. To give an example as in Figure 2, there will be additional basket-carrying robots under the baskets in order to take them to distribution area. Thus, the efficiency of the sorting system will be expected to increase.

5. Acknowledge

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