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Cooperation between Intelligent Autonomous Vehicles to enhance container terminal operations

Q1 *Nacera Bahnes**, *Bouabdellah Kechar*, *Hafid Haffaf*

Department of Computer Science, University of Oran 1 Ahmed Ben Bella, Research Laboratory in Industrial Computing and Networks (RIIR), PO. Box 1524 El M'Naouar, Oran, Algeria

HIGHLIGHTS

- Proposing a distributed IAV2IAV collision management in the intersection areas.
- Solving the collision between IAVs involves a reliable communication system.
- Broadcast data for surrounding IAVs depend to geographical location & reported events.
- Exchange specific information about the trajectory of the iav: position, speed, ...
- The simulation parameters have been chosen according to real situation in an ACT.

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ABSTRACT

Intelligent Autonomous Vehicles (IAVs) constitute one of the component systems of Intelligent Transportation System (ITS) that can operate in confined private spaces, as well as in open and public spaces. The seaports or container terminals are one of the important confined spaces that have attracted extensive research interests over the last decade in the use of information communication technology to improve the operation of ITS. The main goal of research works undertaken so far in this area was to improving the efficiency and cost-effectiveness of the indoor traffic, by transporting optimally and sustainably freight from ship to the logistics and unloading areas. The use of a team of IAVs with wireless communication capabilities by rearranging efficiently all operations of handling, routing,. . . is a strategic objective for seaport authorities and their customers. In this paper, we consider inter-Vehicles communication system in which IAVs can communicate and cooperate to avoid collision problem in the predetermined intersection areas in the yard. We investigate the performance of our solution through simulations using Omnet++/Veins Simulation framework. We show that the implemented cooperation mechanism can significantly reduce the unloading time in the seaport.

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* *Corresponding author.*
E-mail addresses: bahnes_nacera@yahoo.fr (N. Bahnes), kechar.bouabdellah@univ-oran.dz (B. Kechar), haffaf.hafid@univ-oran.dz (H. Haffaf).

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1. Introduction

A ship operation process consists of an unloading operation – during which containers are unloaded from a containership to a Storage Yard –, and loading operation – during which containers are handled in a reverse direction –. The development of new container ships of large capacities, modern technologies, and the introduction of container port automatic appliances at port terminals are considered to be the basic features of modern container transport trends. However, the main benefits provided by such system are cited in [1].

In a seaport terminal, there are various types of container-handling system: Linear Motor Conveyance System (LMCS), Overhead Grid Rail System (GR), High-Rise Automated Storage and Retrieval Structure (AS/RS). We can distinguish two types of automated vehicles in a container terminal: namely automated guided vehicles (AGVs) and automated lifting vehicles (ALVs) [2–4]. ALVs are often described as fully automated guided straddle carriers, while AGVs can be represented by fully automated guided primed movers. Multi-vehicle systems composed of AGVs (or ALVs) are largely used for seaport container applications. However, deployment of a team of AGVs raises management and coordination problems such as collision avoidance, conflict resolution and shared resources negotiation.

New cassette designs enable the C-AGV to enter and exit both transversally and longitudinally, which allows decoupling at the quayside that is the key to the system's cargo handling efficiency [5]. AGV with cassette system is superior in productivity in a container terminal because it reduces the waiting time in the buffer areas of the quay cranes and yard cranes. Intelligent Autonomous Vehicles (IAV) are considered as a new class of transporters designed for the InTraDE European project to improve the concept of AGV widely used before [6]. Coordination of a team of AGVs can be either centralized or distributed. In the majority of the implemented solutions, AGVs coordination is centralised where a single decision maker is responsible for solving task allocation, motion planning and coordination problems. This decision becomes a performance bottleneck with severe limitations in terms of scalability. On the contrary, decentralized approaches are most suitable for dealing with coordination problems among a large number of AGVs, making the scalability problem not limited. In this case, we talk about IAVs as the extension of AGVs by adding some additional capabilities that will be disclosed in this paper.

Mainly, Intelligent Transportation Systems (ITS) have transformed surface transportation networks through the integration of advanced communications and computing technologies into the transportation infrastructure. Different technologies are used for ITS such as WIFI, Zigbee, UWB, WIMAX, UMTS. Recently, we find WAVE (wireless access vehicular environment) standards on the dedicated short range communications (DSRC) [7]. It is the standard that meets the requirement for road safety messaging and control, and offer both V2V – vehicle to vehicle- and V2I – vehicle to infrastructure-communications. ITS technologies have improved the safety and mobility of the transportation system through advanced applications such as electronic toll collection, vehicle navigation, collision avoidance, traffic management, vehicles cooperation and advanced dedicated information systems. As previously mentioned, solving the collision between IAVs involves a reliable communication system to exchange specific information about the trajectory of the vehicle: position, speed, direction. . . .

Therefore, we proposed a reactive cooperation which contributes towards a distributed IAV2IAV collision management in the container terminal. Such cooperation can be performed through the communication of messages between IAVs using wireless technology. Vehicles will broadcast data that is probably valuable for multiple surrounding vehicles. This means that the targeted vehicles, which use normally unidirectional communication, depend on their geographical location and if they are interested in the reported event.

The rest of this paper is organized as follows: Section 2 presents the related work. Section 3 provides an overview of a typical layout in the automated container terminals (ACT) based on IAV and presents also collision problem. In Section 4, we propose a new cooperation mechanism. Section 5 presents an evaluation of our proposed algorithm and discussion of obtained results through OMNET++/SUMO simulation. Finally, conclusion and future work are given in Section 6.

2. Related work

In this section, we present some solutions which are proposed in fully autonomous vehicle control in intersection areas. Reservation approach, introduced by Dresner and Stone in [8], is based on an agent that manages an intersection. Each vehicle wishing to cross must book a passage time interval and a route. The advantage of this approach is that, if several vehicles want to pass and if their paths through the junction do not intersect, then, each of them can be satisfied. Otherwise, it is necessary to give priority to one vehicle over the others. The decentralized approach introduced by Rashe and Naumann [9] is based mainly on communication and negotiation between the vehicles to determine the sequence of passages and the exit from the intersection. The limit of this approach depends on the number of vehicles trying to negotiate their passage through the intersection. Tilg et al. [10] define control agents which are able to synchronize the multiple flows of vehicles in each intersection independently from the others, by alternating vehicles from both directions.

3. IAV based ACT

In this section, we present intelligent autonomous vehicle in an automated container terminal and possible collision situation at the junctions.

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