

Trends in Industrial Informatics and Supply Chain Management

Dimitrios Bechtsis, Naoum Tsolakis

Abstract— In the competitive Supply Chain (SC) ecosystem, Information Technology is undoubtedly the driver for innovation. Modern SCs are constantly searching for competitive advantages that could enable sustain growth and market share improvement. Industry 4.0 is paving the way for the new digitalization era where interconnected devices interoperate in a 24/7 basis and provide real-time reliable data to the SC stakeholders. The Internet of Things (IoT) is a solution for thousands of digital devices that strive for e-presence in the new landscape and jointly with the use of autonomous systems highlight the added value of real-time decision-making systems in end-to-end SCs. This paper analyzes the use of autonomous vehicles in industrial facilities and integrates them to the SC ecosystem and the IoTs landscape.

Index Terms— Industry 4.0, Internet of Things, Autonomous Vehicles, Supply Chain.

I. INTRODUCTION

Modern supply chains (SCs) are characterized by rapid developments in Information Technology Systems, at a global level. In this regard, Industrial Informatics-based solutions are considered to be the backbone of every SC [1]. Internationalization of markets along with the adoption and exploitation of flexible, automated systems across SC operations promote the use of autonomous vehicles for increasing responsiveness to demand signals. However, the systematic incorporation of Industrial Informatics and autonomous vehicles in end-to-end SC operations is challenging. To that end, the aim of this research is to highlight an integrated and robust approach for the optimal design and management of SCs based on current trends at the Industrial Informatics landscape.

Autonomous vehicles are considered as mobile ground, air, or maritime entities which are equipped with hardware and software applications for aggregating data downstream the SC in order to promote visibility and support operational level planning and the decision-making process. Autonomous vehicles have adequate computational power to perform all the necessary operational activities and could even conclude to decisions for optimizing daily SC activities. These mobile entities are integrated into existing manufacturing systems as they could handle the SC economic, process and information flows. Moreover, the Industry 4.0 evolution and the Internet of Things provide a solution for thousands of digital devices that strive for e-presence in the new global landscape and

promote the digital transformations of the SC stakeholders [2].

Autonomous vehicles provide significant economic potential due to:

- the capability to function on a 24/7 basis,
- the minimization of labor cost,
- the low maintenance cost,
- the enhanced accuracy in daily activities, and
- the improved safety at industrial facilities.

The use of autonomous vehicles in conjunction with the Internet of Things in the SC ecosystem ensures efficient and effective operations [3].

II. METHODOLOGY

The incorporation of autonomous vehicles in a SC ecosystem could provide an added value and ensure the sustainability of the whole network [2]. The basic segmentation axes to categorize autonomous vehicles include:

- Applications: Warehouse Management; intra-logistics; flexible manufacturing technologies; precision farming; hazardous environments.
- System Properties: Facility layout; sensors; localization and navigation; planning and scheduling.
- HW-SW Requirements: Vehicle specifications and management platform (e.g. Robot Operating System); simulation software.
- Types of Unmanned Vehicles: Unmanned Ground Vehicles (UGVs); Unmanned Aerial Vehicles (UAVs); Unmanned Maritime Vehicles (UMVs) which capture both Surface and Underwater vehicles.

Simulation modelling tools can be useful for SC researchers and practitioners alike for effectively designing supply network operations and testing the impact of autonomous vehicles. Typical examples are implemented in pilot case studies for UGVs, UAVs and UMVs in a SC ecosystem. The Gazebo 3D simulation software enables the creation (i.e. emulation) of high-quality facilities for all types of vehicles and the installation of well-designed physics engines for the development of real-world scenarios. The Robot Operating System is a meta-operating system that provides a robust framework for exploring the Gazebo 3D emulation capabilities at industrial environments. All the entities, the sensors and every active part of the vehicles can be represented as an active node that communicates with other nodes through information channels called 'topics' in order to provide a living environment.

Moreover, it is critical to build upon established corporate information systems in order to integrate autonomous

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vehicles to the SC ecosystem. A framework is always the first step for the integration of innovative solutions [3], [4] in real-world operations to extensively study the effects to the whole ecosystem.

In order to study autonomous vehicles, a methodology that starts with the study of models, and gradually integrates simulation modelling, emulation modeling and real-world hardware implementations to the SC has already been proposed [5]. This study particularly focuses on simulation [1] and emulation modeling [6] techniques.

III. INDUSTRIAL INFORMATICS AND SUPPLY CHAINS

A. Unmanned Ground Vehicles

UGVs-based simulation approaches focus on modelling operations in warehouse facilities and manufacturing environments (Fig. 1) and could be extended to outdoor agricultural environments. UGVs are typically equipped with state-of-the-art LiDAR sensors and 3D depth cameras for navigating at the facility layout and working on operational activities. Inertial sensors assist indoor localization activities and provide reliable information. UGVs could be used for the transportation of goods, for monitoring the facility and daily transactions, for inventory listing and even for agricultural operations [7].

At the first steps of the UGVs' analysis at operational level, simulation and emulation tools allow the accurate representation of the physical systems that can lead to the adoption of the final system and support the decision-making professionals. Simulation and emulation enable the assessment of key performance indicators taking into consideration manufacturing activities. In case of indoor logistics, simulation and emulation results highlight the optimal layout configuration for the specified vehicles and the fleet size.

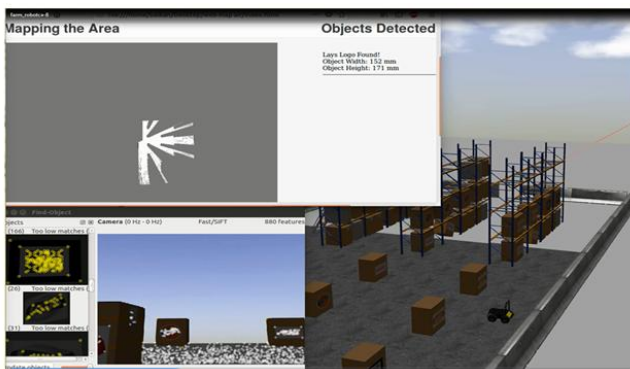


Figure 1. Emulation of UGVs in industrial facilities.

B. Unmanned Aerial Vehicles

UAVs are considered a major trend [8] in SCs [9]. Last mile logistics consist a breakthrough service that retailers around the globe provide to consumers in order to efficiently and effectively deliver parcels in urban environments. Warehouses could also benefit from the incorporation of UAVs as they could perform inventory listing in a 24/7 basis in order to keep the Warehouse Management System up to date (Fig. 2). Moreover, UAVs could perform deliveries at manufacturing facilities in order to facilitate the production

process. UAVs are enablers for the digital transformation of the SCs as they can offer mobile inspection vehicles to all levels of the SC with a special interest on inventory management and last mile logistics. Smart digital applications will be considered as 'game changers', when regulations will relax and the technology will enter a mature phase, owing to their positive environmental, economic and social effects.

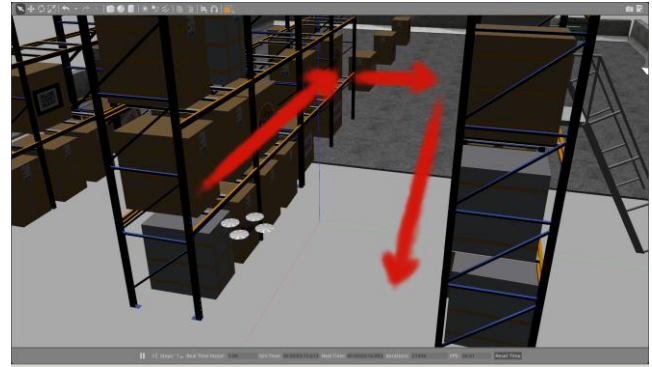


Figure 2. Emulation of UAVs in warehouse facilities.

C. Unmanned Maritime Vehicles

UMVs could be used for the transportation of goods (i.e. containers) in port terminals, for accompanying ships at the berth, for monitoring the facilities and even for evaluating environmental factors (Fig. 3). To begin with, Unmanned Surface Vehicles could be used for tanks' monitoring and inspection activities. Finally, Unmanned Underwater Vehicles could be used for inspection and maintenance of ships.

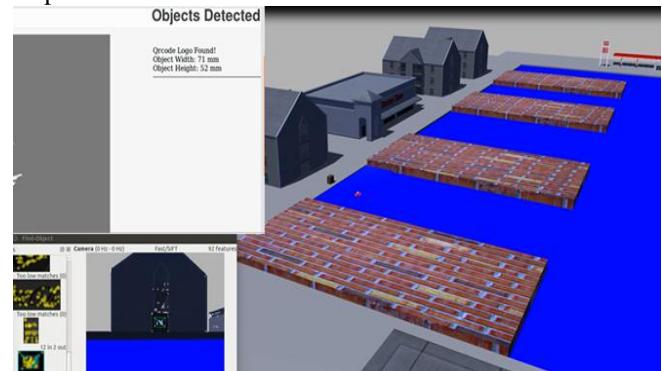


Figure 3. Emulation of Unmanned Surface Vehicles.

D. Internet of Things and Supply Chains

Autonomous vehicles are becoming a major trend in SCs and should be gradually integrated to the SC ecosystem. According to the Automation Hierarchy (Fig. 4), the hierarchy levels include field level equipment, automation equipment for aggregating data at programmable logical controllers, machines at the facility layout, process level data, plant management level and finally Information Technology software including Enterprise Resource Planning and Warehouse Management Systems. SCs are networks with numerous entities (producers, wholesalers, distributors, retailers etc.) that should cooperate in order to provide added value to the SC. Every entity of the system has distinct objectives, constraints and timeframes while they all must

cooperate in order to achieve mutual benefits.

In this context, Internet of Things devices should enable the propagation of critical information to the Application Layer and to the high-level Information Systems of the SC. Autonomous vehicles could act as a mediator between the manufacturing equipment and the Information Systems while at the same time monitoring the production line and the facilities. Industry's connectivity software platform provides a single repository of industrial automation data to all high-level applications. Stakeholders connect, manage, monitor, and control diverse and disparate automations, sensors and devices through innovative solutions.

Therefore, inventory monitoring, cost reductions and increased visibility to the SC could be enabled and the decision-making process could be better informed. SC professionals and managers benefit from the advantages of modern technology and pave the way to the new digitally enabled technology era.

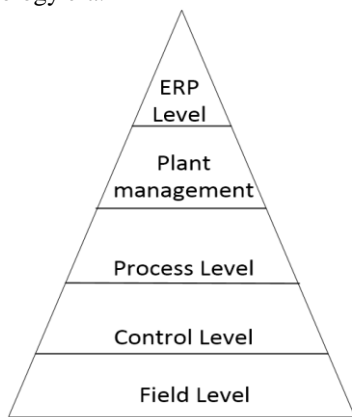


Figure 4. Automation Hierarchy Pyramid based on [3]

IV. CONCLUSION

The design of efficient and effective SC Management systems is vital for the profitability of all stakeholders. Findings in literature confirm that corporations adopt Information Technology methods to improve their performance. Industrial Informatics is considered the backbone of every supply network. To that end, the incorporation of automations and autonomous systems in end-to-end SC operations is challenging due to technology readiness capacity variability among network actors. This research addresses this gap by demonstrating the use of emulation for operationalizing, at the cyber space, UGVs, UAVs and UMs in different working environments.

As a next step the authors will focus on algorithms for controlling autonomous vehicles at industrial facilities to provide added value to the SC activities and the involved stakeholders. Routing, planning and scheduling algorithms will be used for the pick and delivery of goods [10], while swarm intelligence algorithms could optimize network activities. The ant colony optimization algorithm is considered a robust algorithm for addressing network optimization problems and thus it will be used for scheduling and planning the daily activities of the autonomous vehicles.

The use of autonomous vehicles for tackling real-world challenges is being proliferated in the academic and practice literature. Indicatively drones are being applied in agricultural

operations [11], specifically in developing economies, as a means of promoting precision farming and environmental sustainability (e.g. monitoring and informing water-stewardship initiatives).

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