Shared Human-AGV industrial environments: overview of the literature evolution and future research

Zuin S.*, Battini D.*, Persona A.

* *Department of Management and Engineering, University of Padua, Stradella San Nicola 3, 36100, Vicenza, Italy*

(silvia.zuin.4@phd.unipd.it, daria.battini@unipd.it, alessandro.persona@unipd.it)

Abstract: Automated Guided Vehicles (AGVs) continue to play a significant role in many manufacturing systems. More recently, the traditional AGV-human scenario, where workers and vehicles were managed in a separate way, has changed according to the Industry 4.0 revolution, in which robots and people coexist by sharing common tasks and closed movements in the same workplace without barriers. In this context, the safety of the human worker is one of the main concerns and a prerequisite for a successful collaboration between human and robots. Although the binomial man-robot has been frequently addressed over the last years, it is also true that most of the research on AGVs fleet design is focused on the sizing of the system by a performance point of view, without a complete acknowledgement of the interactions and of the mutual interferences among operators and AGVs. Indeed, the introduction of human-AGV shared environments (such as a mobile fulfilment system designed to follow the picker among the shelves and to collaborate with him) poses new challenges in the design and implementation of AGV systems. Thousands of articles about AGVs are present in the main publications' databases in the time range from the 90s to the present day. The literature is very extensive and over the years has ranged between different areas of interest, riding the trail of new technologies and development trends. This work aims to show an overview of the evolution of the literature focused on AGV systems, emphasizing the latest research trends and the emerging gaps, also including the ones related to the shared presence of humans and AGVs within the same environment, which can affect the overall performances and the implementation phases.

Keywords: Automated Guided Vehicle, literature review, human factor, safety, shared environment

1. Introduction

Nowadays, thanks to several technological innovations, it is possible to find robotic solutions at many stages of the production chain. With the entry of last generation tracking systems and Internet of Things technologies in many factories and supply chains we have seen a real explosion of robotic-based solutions both for production and material handling. In this context, Automated Guided Vehicles (AGVSs) have become a key component of today's in-house logistics. The technological standard and the current level of experience have led to the AGVs introduction in almost all branches of industry and areas of production (Ullrich, 2014). AGV is suitable in applications where different materials must be moved from different load points to other unload points (Illic, 1994). It represents the most versatile solution for moving materials automatically and its major benefit concern the reduction of no-value added activities. AGVs were originally introduced in the 1950s to automate asset and material management systems. Nowadays, modern AGV systems are the result of a complex collaboration between materials, machines and logistics experts. The huge demands of today's market have increased AGV requirements in industrial plants, and the information systems that manage their mobility have become increasingly complex. This work aims to show an overview of the evolution of the literature focused on AGV systems, emphasizing the recent research trends and the emerging gaps. In particular, we will move the discussion towards two recent relevant issues: human factors and safety paradigms influence on AGV design and performance. These issues are particularly relevant when AGVs and humans are working together within the same shared environment as it is often the case in Industry 4.0 contexts.

The structure of paper is organised as follows: in section 2 the review methodology and its outcomes are presented; Section 3 shows the results inherent to the human factor analysis linked with AGVs while in section 4 those related to safety paradigms linked with AGVs. Finally, the conclusions are presented in section 5.

2. Human – Robot interaction

In recent years, companies have opened up the opportunity to improve flexibility, efficiency and productivity through digitisation and flow connectivity, without penalising the quality of people's work and the environment around them. The digitization of factory processes has opened the door to the new dynamics of Industry 4.0, also re-drawing human-machine relations. The context just described represents the concept of Smart Factory, in which technology is no longer seen as a tool, but is recognized as support to man. Through a smart interactive combination of technology and human, digitisation has been able to give the advantage of creating new interactions not only for the benefit of the production process, but also and above all of people. One example is a decrease in physical fatigue (with workstations that adapt to the operator, carrying out the heaviest tasks) and the reduction of low-value-added operations carried out directly by the machines.

This scenario inevitably leads to a growing coexistence between humans and robots in smart factory stores. As a result, this research aims to investigate the present literature focuses on this particular aspect of the AGV field that has become increasingly relevant. To do this, it was chosen to initially analyse the AGV topic from the broadest possible point of view in such a way as to later highlight the fields of research and their interest over time.

3. Methodology and outcomes

In this paragraph, we conduct a systematic literature review following the methodological approach discussed by Flink (2005). Because the protagonists of the research theme, AGVs, are a technology born around the 1950s, the research academy has been studying them for over seventy years. For this reason, the published literature is very huge.

3.1 Interest in AGV topic over the time

As starting point, we have considered all the scientific contributions on the subject, by searching in Scopus database without limits in the publishing time. Since the goal is to observe the trends of the scientific interest in AGVs over the time, the keywords used for the paper selection are only two: "AGV*" OR "Automated Guided Vehicle*". Additionally, the search query has been set to "Title, abstract and keyword" in the Scopus database, and the results were limited solely to papers written in English and belonged to Engineering as "Subject area", with no limitation on the time span.

The papers obtained from this first selection are 1273, covering a time span from 1967 to March 2020. Being a technology that has established itself over the years and that has developed by incorporating new systems and technological progresses it can be seen how the number of publications has grown over the years. In particular, in the last 15 years, the trend of publications has raised significantly, an indicator that, despite being a widely used and long-existing technology, still receive a lot of interest by researchers.

In Fig. 1, all the selected papers are reported according to the year of publication: in orange only the journal articles and in blue all the other papers as conference publications, books, reviews or other document type. In addition, it should be noted that the number of publications reported for the year 2020 refers to the first three months of the year and for this reason the graph shows a drastic decrease compared to 2019, but it must be understood as partial and not definitive.

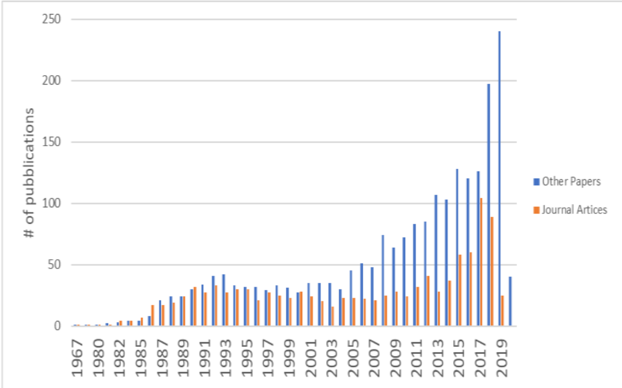

Figure 1: Distribution of journal articles and other papers based on the publication's year

A further analysis can be done in order to look at the main sources of publication to get an overview of which journals were most involved on the AGV topic, always

considering the filter on the search area "engineering", initially imposed on the Scopus database. The chart in Fig.2 shows the nine first journals with the greatest number of publications, taking into account only the papers labelled as journal articles by Scopus. International Journal of Production Research is certainly the first one, as it separates all others with a substantial gap in terms of published papers. In fact, it has just over 150 articles published within it, far from International Journal of Advance Manufacturing Technology, which has just over 50 publications.

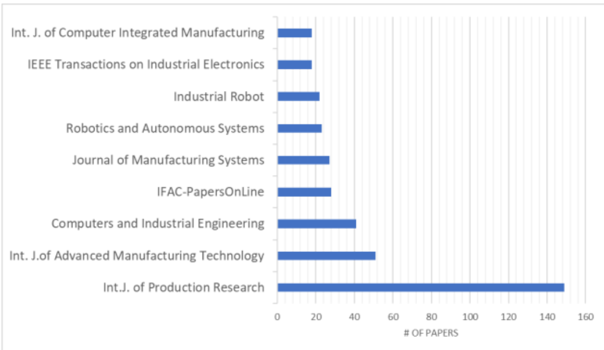

Figure 2: Distribution of articles base on the journal

3.2 AGVs Research Fields: VOSviewer analysis

The AGV topic is very broad, as shown above, and can affect multiple fields of research at the same time. The VOSviewer (www.vosviewer.com) tool was used to get a clearer and more intuitive picture of search scopes. VOSviewer is a software tool for creating maps based on network data and to visualize and explore these maps. This tool can be used to build networks of scientific publications, scientific journals, researchers, research organizations, countries, keywords or terms. The elements of these networks can be linked via co-author, co-occurrence, citation, bibliographic coupling or co-citation link. To build a network, data from the server database can be used.

For our research, the network is formed by the keywords present in the 1273 articles taken into account in the previous analysis. Map items are represented by nodes that are bound together via co-occurance links. The more events that relate them the more evident the arc in the figure. Finally, the database used in the software is Scopus, the same database used in the previous section.

Taking a look at Figure 3: it represents the display of the network. items are circles (*nodes*), represented by their label. In addition, the size of an elements label and node is determined by the weight of the item: the greater the weight of an item, the greater the label and the size of the element node The greatest value of this representation is thanks to the visual impact given by the different colors, it is possible at first glance to understand if there are different research trands. In fact, the color of an item is determined by the cluster to which the item belongs. The lines between the elements represent links. In this case, the clusters are partly overlapping because the keywords used, so graphically the nodes, are closely linked despite belonging to academically different, but very closed, research areas. The topic of AGV research is clearly multidisciplinary and several aspects have been studied over the years contaminating multiple aspects.

The representation of this network shows that, neglecting *automated guided vehicle* and its acronyms, the biggest nodes are: *mobile robots*, *automation*, *robots*, *vehicles*, *fms* and *transportation*. These are the most commonly used keywords in the 1273 articles obtained previously, and not all of them have the same colour. This highlights how *automation* and *fms*, both yellow, belong to the same cluster that is based on the logistics theme; In fact, it includes the keywords *material handling*, *logistics* and *assembly line*. Differently, *robots* and *mobile robots*, although similar as terms, are used in the articles in different contexts, in fact they belong to clusters of different colours.

This highlights how many and various keywords from similar but at the same time different contexts are related to the AGV theme. But, another way to interpret this graph, the one exploited by us, is to focus on the smaller nodes. They are the least used keywords that have the potential to become future research branches. To explore this possibility, it is useful to accompany this map with an additional representation of the same network, but from a different perspective: the temporal one.

The overlay view is identical to the network view, except that the elements are coloured differently. There are two ways in which elements can be coloured in the overlapping view. By choosing to include the time colouring criterion, the colour of an element is determined by the year in which the item is present. Considering Fig.4, the colours range from blue (oldest publication year:1980) to green and finally yellow (most recent publication year: 2020). The colour bar appears in the lower-right corner of the visualization and indicates how years are mapped to colours. Therefore, the keywords take on the coloration depending on the time horizon in which the papers to which they belong have been published. This representation, in other words, shows how the interest of research has changed over the years, preferring some topics in the past and others in recent years. This consideration allows us to identify the latest search trends going back to the keywords used coloured in yellow. At the same time, it can be observed that the oldest papers, blue-coloured ones, pay their attention in particular to keywords such as "computer simulation" mathematical models", "computer vision" and "navigation". In the past, therefore, research was more focused on the methodologies of calculating or optimizing the routes and navigation systems of vehicles.

Over the years the focus has shifted to other fields, in particular in the last 10 years the attention was paid on four major concepts: "robots" "automation" "mobile robots" and "robotics" thanks to the technological development that accompanied those years. Nowadays, however, the research trend is shifting towards the strong automation as the "autonomous machines" "learning systems" "hierarchical systems". Among the most recent keywords, in the upper left part of Figure 5, also emerges "human" associated with the AGV theme. The yellow colour of the node is proof of what is stated in *Section 2*, that AGV-human interaction is a relatively new and in-depth topic (in fact the size of the node is reduced).

3.3 Paper selection

Wanting to focus the analysis on the AGV- human topic, a skimming of the papers obtained with the first research was carried out highlighting only the papers reporting in the keywords the words *human**, *operator** or *worker**, since assumed as synonyms. From the 1273 starting items, 48 paper have been selected and after reading abstracts we obtained 17 papers suitable (Fig.5).

Moreover, to facilitate effective collaborative work between a human worker and an industrial robot, it was necessary to remove the previously existing barriers that established a clear separation between human and robot workspaces. But, a direct result of the deployment of robots in industry is the rise of new risks of accidents for workers (Robla-Gómez et al., 2017). Consequently, we considered a further point of view linked to the topic human and interconnection of Industry 4.0: the *safety*. The same skimming process used for the human sphere was applied to filter documents with keywords related to the topic of safety: *safety, regulation* and *standards*. Indeed, we began considering, again, the 1273 starting articles. In this case, 40 papers were obtained. After reading abstracts and discarding documents that were not considered strictly relevant, 22 papers are used for the analysis as shown in Fig.5.

In addition, some of these articles have both groups of keywords considered and therefore appear in both searches; they will be analysed in the following section depending on the preponderance of one theme with respect to the other that the article possesses.

3. Human factor analysis in AGVs literature

The papers with *human**, *operator** or *worker** in the authors keywords have been read and selected according to their relevance for the present study. In particular, we decided to consider only the papers related to warehousing and production applications, showing any kind of link between AGVs and human operators.

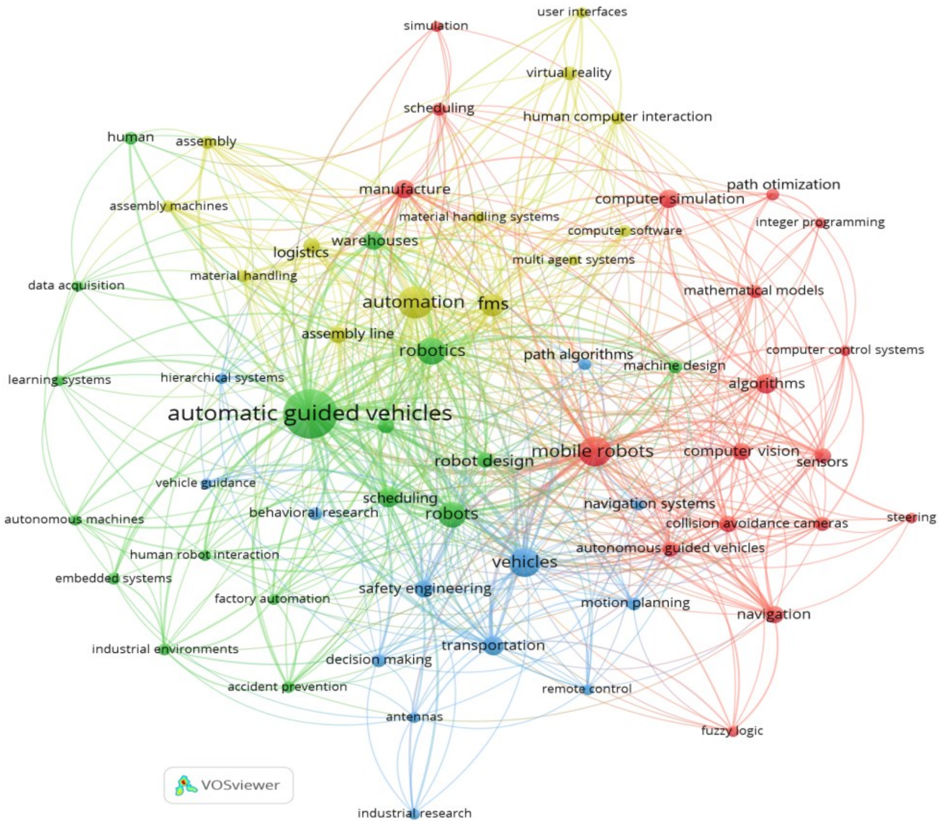

Figure 3: Keyword Map made with VOSviewer (colours change according to the publication year)

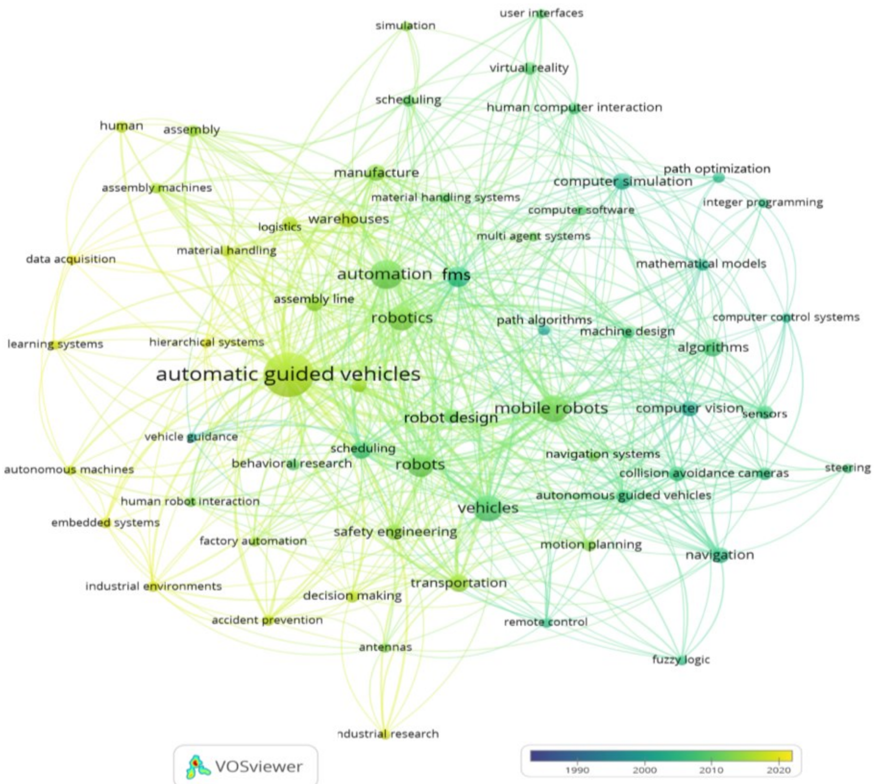

Figure 4: Cluster Map made with VOSviewer (colours change according to the main topic investigated)

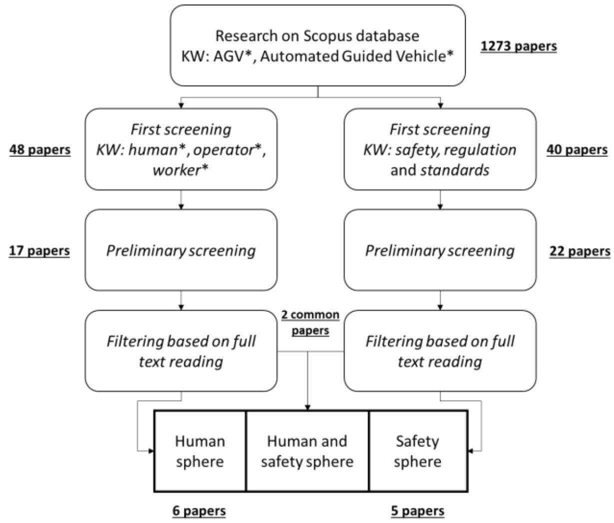

Figure 5: Chart of paper selection process (KW: Key Word)

As shown from the results reported in Section 2, the topic related to the interaction among human operators and AGVs has been faced only recently. An exception is the interesting contribution by Lee and Leonard (1990), in which they investigate the use of AGVs in a batch manufacturing environment. The paper claims that the implementation of an AGV system modifies the nature of human work, forcing changes in working practices and interactions between different area of the production system. Although the document is dated and the vision of human-machine interaction was not among the goals of the time, this article states that "without cooperation, AGV investments will not achieve the desired benefits, proving to be a bad investment". Man and AGV are seen as ready to work together to increase the benefit, and not as a stand-alone entity.

In the same direction, but of course with an update of the available technologies (e.g. Kiva systems), is the contribution by LeCavalier (2019) and Aliev and Antonelli (2019). In particular, this last research points out how mobile robots can, in some applications, overcome AGVs and can bring new perspectives in the organization of the work, especially when human operators and mobile robots have to share their working environment.

In 2010, Iwamura and Sugimura developed a real-time scheduling method considering human operators in an autonomous distributed manufacturing system. The method consists of three steps, and the AGVs are involved in the third one, when the decision about the transportation process has to be taken.

One of the selected papers is dedicated to the proposal of systems and technologies for allowing the cooperation between workers and automated vehicles. Allmacher et al. (2018) presented a human-machine collaboration method, based on real time action recognition. This allows to achieve the collaboration between AGVs and human operators through the perception of tasks conducted by human operators, made through a Kinect vision sensor.

Finally, Damacharla et al. (2019) aimed at solving the problem of errors, both from the operators' side and the AGVs' one. They suggested to consider an error prediction model to reduce AGV errors through appropriate human intervention and sensors adoption.

4. Safety paradigms in AGVs literature

In this paragraph we concentrate the attention on the safety paradigms inclusion in AGVs literature. This is a critical emerging issue in Industry 4.0 modern contexts, where the interconnection between resources (humans and robots) is one of the key pillars. When dealing with automated vehicles unquestionably safety is a recurring theme but with different meanings. we wanted to differentiate the results by highlighting, in particular, the figure of man in spaces shared with AGVs from the point of view of safety. Often human is taken as an example of an obstacle that the vehicle may encounter but only from the sensor programming point of view; instead, it is more difficult to find sources that investigate the issue of safety taking into account worker as a collaborative element in the same workspace. For this reason, we wanted to distinguish the two categories: *Obstacles detection systems* and *Human safety paradigm in shared workspace*.

Therefore, from the 22 papers that emerged after reading abstracta, on". Finally, only 8 out of 22 have been considered really relevant to our analysis.

4.1 Obstacles detection systems

Obstacle detection and mapping are crucial for autonomous indoor vehicles. This is mainly true for AGVs navigation in environments where safety of personnel and that of the AGV itself is of extreme importance (Bostelman, 2005).

In Bostelman (2005) an obstacle detection is presented with a segmentation algorithm for AGV in industrial environments by a 3D gamma camera. Being inexpensive, but at the same time able to provide real-time images and intensity turns out to be a very attractive choice. Excellent obstacle detection results aim to improve the AGV system and make it safer.

In 2008, Hedenberg claims that pedestrians, driverless transport systems and vehicles that require drivers all could share the same general traffic environment. In many areas, security-related location detection is necessary to avoid accidents. Derived from this position the driving speed in the workspaces can be safely reduced and minimum distances can also be observed safely. This article shows a solution to obtain the absolute position with its position-dependent inaccuracies using a single laser scanner system.

An additional article that highlights how the presence of human and autonomous machines that share the same environment can give rise to safety problems is that of Sabbatini et al, in 2015. In particular, the paper examines whether AGVs are used in logistics and in a shared environment with manually driven operators and alleys.

Advanced sensing technologies, along with centralized data fusion systems, are a very effective tool to improve the efficiency of multi-AGV systems that share the environment with human operators, where security is a crucial problem.

4.2 Human safety paradigm in shared workspace

Rapid advances in control science and robotics open new possibilities in manufacturing, warehousing and logistics while introducing, at the same time, new challenges to workers safety and health problems. Solving these problems and creating a sufficiently safe workplace, or even a safe working environment, is a great challenge and great social responsibility of scientists and engineers (Missala, 2014). A consequence of this rapid growth is that the development and integration of technologies in manufacturing environments is outpacing the evolution of *standards* and test methods that are used to guarantee the *safety* of humans in these situations (Marvel, 2016).

Among the articles considered, as an example of rapid robotic growth, there is the manipulator mounted on AGVs, indeed they are becoming more common especially in manufacturing automation (Marvel, 2013). Safety standards for industrial robot arms and automated guided vehicles (AGVs) are written to reduce the risk to humans in industrial environments.

In many environments where manned and unmanned vehicles and pedestrians are co-located, risky situations can arise. In 2013, Bostelman refers to the detection of passive pedestrians that can be detected in three areas of applications: *Path*, detection takes place along the ranges and is associated with automatic safety systems, therefore thanks to radar systems; *Area*, the detection is made on a short radius and is traced back to the typical route crossings; Finally *Point* application, where the pedestrian is detected at a specific point in tightly controlled environments. In industrial environments, for example, crosswalk gates are commonly used. This work support the measurement science basis to advance safety rated 3D imagers. According to the authors, test methods for detection of humans and additional obstacles, non-occluded or occluded, should be included in ANSI/ITSDF B56.5.

In Marvel (2013) are presented the most important standards that must be considered when AGVs with manipulators and humans are obliged to work closely. In particular, the standards are clearly distinguished in: *AGV standards*, mainly referring to the EN1525 standard and the ANSI/ITSDF B56.5; *industrial robots standards* highlighting ISO 10218 which, , deals with the construction and control of the robot, in the first part of which it is entails the norm, and the safety requirements, in the second part; *Human presence detection standards*, recalling the ANSI/ITSDF B56.5 and introducing ISO TS 15066 and other regulations related to obstacle detection; finally, the *generic standards* and those related to *manipulators* who must physically interact with the operators.

In 2014, Bostelman briefly outlines the gaps between AGVs and manipulators standards and details decision sharing when manipulators and AGVs are combined. Later, the authors present three synchronized control methods for implementing shared protected operations: Independent, Master/Slave, and Fused in a mobile and collaborative manipulators system. Tests were carried out to improve the performance of the proposed control methods. Independent auditing is essentially part of the ANSI/ITSDF B56.5 security standard. However, the author's conclusions are, as intelligent manufacturing robotics begins to enable more flexible environments with greater human interaction, higher-level coordinated control implementations between robots will be needed.

In view of the regulation of robots, Missala (2014) presents selected examples of cooperation between robots and humans, examines the safety requirements and safety features developed. A group of new selected security features are described, necessary to fulfil these paradigms. It also suggests and presents examples of actions that can make the workplace a human-friendly environment and presents instances of such actions. An overview of present and future work environments leads to the conclusion that a new look at security features is needed. A range of testing methods are presented in Maravel (2016) to deal with safety situations where there is the integration of mobile manipulators into man-made industrial environments. These testing methods are intended to contribute to and support the development of safe and collaborative AGV technologies and industrial robots. They were therefore considered: 1) the unique capabilities and intended uses of mobile manipulators and 2) the potential exemptions and special cases where their behaviour may be unpredictable or otherwise divergent to safety requirements.

5. Discussion

Focusing on industrial environments frequently the flow of goods in production facilities has been largely and deeply automated in recent decades, in order to mainly reduce costs and avoid unsafe working conditions. Despite the automation of production, logistics still requires activities performed by human workers thus increasing the cases of shared environments, which are increasingly frequent in terms of Industry 4.0. Although automation is frequent and well-established today, the same cannot be said for the literature in terms of human and safety that shows a scarcity of articles in the industrial sector.

In particular, among the articles obtained from the analysis of the literature that consider human worker within, there is no research that emphasizes how the presence of human workers within an AGV system can in some way affect its performance. This influence can be considered both from a management point of view in terms of changes in system performance (queues, delays, missed completed missions) and both from a safety point of view with the final aim to avoid incidents and injuries in the shared human-AGV working environment.

6. Conclusions and future researches

The topic of AGVs is a widely debated subject of literature that, despite having touched many different fields, is still not considered complete but constantly evolving. This evolution is also confirmed by the Fig.3 which shows in its left side a yellow coloration, indicating the newest themes belonging to the AGV literature.

One of the branches of future AGV research would be to consider the human worker not only as an obstacle to be avoided in order to allow the two systems to coexist, but to deepen the practical implications that this collaboration has on the performance of the hybrid system human-AGV. To do this, it will be necessary to implement a three level analysis and design approach by involving designers, workers and safety experts during the preliminary design phase of an AGV system, instead at the end of the implementation. New collaborative approaches in AGV fleet design are needed with the final aim to reconsider the traditional methodologies in order to better support a new holistic vision in which AGVs and humans are part of the same collaborative system. In this context, safety paradigms will also drive managers to invest more time and effort in specific training activities for the workers in order to achieve an efficient and safe collaboration with AGVs, avoiding risks of ergonomics disorders and accidents.

7. References

Aliev, K., & Antonelli, D. (2019). Analysis of cooperative industrial task execution by mobile and manipulator robots. In *Advances in Manufacturing II* (pp. 248-260). Springer, Cham.

Allmacher, C., Dudczig, M., Klimant, P., & Putz, M. (2018). Virtual prototyping technologies enabling resource-efficient and human-centered product development. *Procedia Manufacturing*, *21*, 749-756.

Bostelman, R. V., Hong, T. H., & Madhavan, R. (2005, July). Towards AGV safety and navigation advancement obstacle detection using a TOF range camera. In ICAR'05. Proceedings., 12th International Conference on Advanced Robotics, 2005. (pp. 460-467). IEEE.

Bostelman, R., Norcross, R., Falco, J., & Marvel, J. (2013, May). Development of standard test methods for unmanned and manned industrial vehicles used near humans. In Multisensor, Multisource Information Fusion: Architectures, Algorithms, and Applications 2013 (Vol. 8756, p. 87560P). International Society for Optics and Photonics.

Bostelman, R., & Marvel, J. (2014, May). Control fusion for safe multi-robot coordination. In Multisensor, Multisource Information Fusion: Architectures, Algorithms, and Applications 2014 (Vol. 9121, p. 91210P). International Society for Optics and Photonics.

Damacharla, P., Junuthula, R. R., Javaid, A. Y., & Devabhaktuni, V. K. (2018, July). Autonomous ground vehicle error prediction modeling to facilitate human-machine cooperation. In *International Conference on Applied Human Factors and Ergonomics* (pp. 36-45). Springer, Cham. Heinrich,

Fink, A. (2019). Conducting research literature reviews: From the internet to paper. Sage publications.

H., Deutschländer, A., Zoghlami, F., & Sen, O. K. (2019). The Long Journey From Standardization to Fully Fab Automation and More. IEEE Transactions on Semiconductor Manufacturing, 32(4), 408-414.

Ilić, O. R. (1994). Analysis of the number of automated guided vehicles required in flexible manufacturing systems. The International Journal of Advanced Manufacturing Technology, 9(6), 382-389.

Iwamura, K., & Sugimura, N. (2010, October). A study on real-time scheduling for autonomous distributed manufacturing systems. In *2010 IEEE International Conference on Systems, Man and Cybernetics* (pp. 1352-1357). IEEE.

LeCavalier, J. (2019). Human Exclusion Zones: Logistics and New Machine Landscapes. *Architectural Design*, *89*(1), 48-55.

Lee, R. J. V., & Leonard, R. (1990). Changing role of humans within an integrated automated guided vehicle system. *Computer Integrated Manufacturing Systems*, *3*(2), 115-120.

Marvel, J., & Bostelman, R. (2013, October). Towards mobile manipulator safety standards. In 2013 IEEE International Symposium on Robotic and Sensors Environments (ROSE) (pp. 31-36). IEEE.

Marvel, J. A., & Bostelman, R. (2016). Test methods for the evaluation of manufacturing mobile manipulator safety. Journal of Robotics and Mechatronics, 28(2), 199-214

Okoli, C., & Schabram, K. (2010). A guide to conducting a systematic literature review of information systems research.

Robla-Gómez, S., Becerra, V. M., Llata, J. R., Gonzalez-Sarabia, E., Torre-Ferrero, C., & Perez-Oria, J. (2017). Working together: A review on safe human-robot collaboration in industrial environments. IEEE Access, 5, 26754-26773.

Sabattini, L., Cardarelli, E., Digani, V., Secchi, C., Fantuzzi, C., & Fuerstenberg, K. (2015, September). Advanced sensing and control techniques for multi AGV systems in shared industrial environments. In 2015 IEEE 20th Conference on Emerging Technologies & Factory Automation (ETFA) (pp. 1-7). IEEE.

Theunissen, J., Xu, H., Zhong, R. Y., & Xu, X. (2018, November). Smart AGV System for Manufacturing Shopfloor in the Context of Industry 4.0. In 2018 25th International Conference on Mechatronics and Machine Vision in Practice (M2VIP) (pp. 1-6). IEEE.

Ullrich, G. (2015). The History of Automated Guided Vehicle Systems. In Automated Guided Vehicle Systems (pp. 1-14). Springer, Berlin, Heidelberg.

Yan, J., Yan, S., Zhao, L., Wang, Z., & Liang, Y. (2019, April). Research on Human-Machine Task Collaboration Based on Action Recognition. In *2019 IEEE International Conference on Smart Manufacturing, Industrial & Logistics Engineering (SMILE)* (pp. 117-121). IEEE