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Review on Optimization Techniques for AGV's Optimization in Flexible Manufacturing System

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Highlights

- This paper focuses on detail studies of AGV's.
- Need of AGV's in flexible manufacturing system.
- Summarized Optimization Techniques used for AGV's.

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Abstract

Production systems have been growing exponentially in size in recent decades. One of the problems in the manufacturing system is that a need of effective and efficient materials transportation between the workstations. Auto-mated guided vehicles (AGV's) can provide a satisfactory solution to this issue. Because of this, AGV's is a one of the most important material handling tool used in flexible manufacturing system (FMS). The designing, scheduling and routing of the AGV's are the key issues for the reason that performance of AVG's in flexible manufacturing system depends on these parameters. The failure of AGVs may significantly impact the operation and efficiency of the entire system, and it is a critical issue. In this paper the aims to answer How the reliability of individual AGVs in the system assessed? , and How AGVs affects the performance of the whole FMS system?. It was also discussed that optimizing techniques to improve the performance of AGV in FMS. This paper discussed the details studies of approaches and optimization techniques used for optimizing AGV's in FMS including design and their control.

1. INTRODUCTION

The performance of a manufacturing plant significantly depends on the effective design and implementation of material handling system. The material handling includes the movement of and controls of the materials between various workstations in manufacturing plant. The material handling represents one third of the cost of manufacturing a product. However, one forth of total staff engaged for the material handling activities. Furthermore, it occupies approx half of the total plant space and all material handling activities consume about 80% of total time. The material handling is considered an appropriate source of opportunities that provide significant challenges to the industry. Now a day, Flexible Manufacturing System (FMS) is a very promising technology because it provides the variety of flexibility needed in the construction of real-time planning of equipment and AGVs in a dynamic and flexible environment. The type of FMS is completely different from the conventional job shop due to the new FMS scenarios in addition to the conventional job shop. It offers new capabilities that offer new challenges to planning. The flexibility in manufacturing enables the system for free movement of parts with in shop floor without any delay within various working stations. The AGV system is well-known and well-known in automated management systems that are widely used in flexible production systems (FMS). The world's first AGV was invented by Barrett Electronic Company, Northbrook for the industrial applications in 1954 in name of product "Guide-O-

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Matic". Around 1980, the term "Guide-O-Matic" became Automated Guided Vehicle. The AGV's moves along predefined and pre-programme path from one workstation to another. The AGV's navigate in manufacturing through wired embedded in the floor and wireless sensors. AGVs provide flexibility in the parts of the route between the elements in the production system to move an object from one point to another. Mainly there are three types of AGV's, towing AGV, fork AGV and heavy load AGV. The main purpose of the merger of FMS with AVG's is to eliminate the high cost of purchasing single used conveyors. There has been a lot of research done on the equipment and AGV systems separately in the FMS area to find the appropriate schedule and control of FMS and AGV's. Various methods and approaches have been used for the optimization, planning and management of AGV's in FMS such as Mathematical programming, Multi-criteria decision making, Heuristics-focused, Control the theory, and Artificial intelligence. The failure of AGVs may significantly impact the operation and efficiency of the entire system. This issue becomes more critical particularly when the size of AGV systems is much larger and operating environment is more complex. This issue motivates to survey AGVs scheduling and routing problem and find out solution through optimization techniques to improve the performance of AGV's in FMS.

2. MATERIAL METHOD

The current state of the methods and techniques used by various researchers has been reported as Fazlollahtabar et al. [1] discussed mathematical methods such as heuristics methods, meta-heuristics methods and artificial intelligence to improve AGV systems for planning and route construction in production, distribution, and transportaion systems.They found that most researchers addressed single AGV problems in production systems. The relationship between AGV systems and other material movement equipments were much not expored. Mostly, planning systems and routes were studied separately. However, the planned aspects of route planning and direction are a challenge. Duinkerken et al. [2] investigated the benefits of a free flexible approach with a simulation model. They compared the ability to read terminals using a fixed route with terminals using a direct crossing method. They have found that alternative crossings are safe as shown in Figure 1. Fazlollahtabar et al. [3] have proposed a self-employed workshop to improve the flow of materials in accordance with demand and equipment specifications. They used a numerical model to find the right balance between shops in terms of sequence of operations, cycle time, and AGV capability issues. The literatures have suggested that GA as a powerful tool for the combined scheduling of equipment and automated guided vehicles in FMS areas.

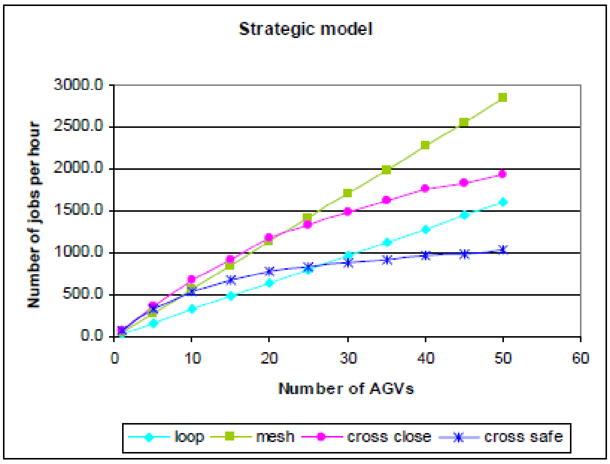

Figure 1. *Comparison of routing strategies for AGV systems [2]*

Badakhshian et al. [4] used the Fuzzy logic controller (FLC) system to control the performance of the Genetic Algorithm (GA) while solving the AGV problem in planning. The aim of their studies was to reduce the time interval. The makepan is defined as the interval between the time to take the first part from the loading / unloading station to complete the final operation. The Flow chart of fuzzy logic controller which based GA is shown in Figure 2. Udhaykumar et al. [5], using the GA and the Ant colony optimization algorithm (ACO) to obtain an ideal shedule for two AGV system based on workload and short travel time for maximum utilization. The result obtained by the ACO algorithm was more promising and encouraging than GA. Gondran et al. [6], studied the comparative quality of solutions related to makepan obtained from consecutive methods with TLH (Time-Lag based Heuristic). They found that the sequential method improves the quality of the solution compared to the solution other than Time-Lag based Heuristic. The integrated method has better quality terms and scope, but requires a calculation of at least three times. The sequential method provides consistency between high quality solutions and low calculation time. Gutjahr et al. [7], have addressed the problems of AGV sheduling in a cyclic flexible production system and used Heuristic methods for this. Their results showed that the proposed local search method (VNS) was commonly used in local search (ILS) which did not increase the size of the area.

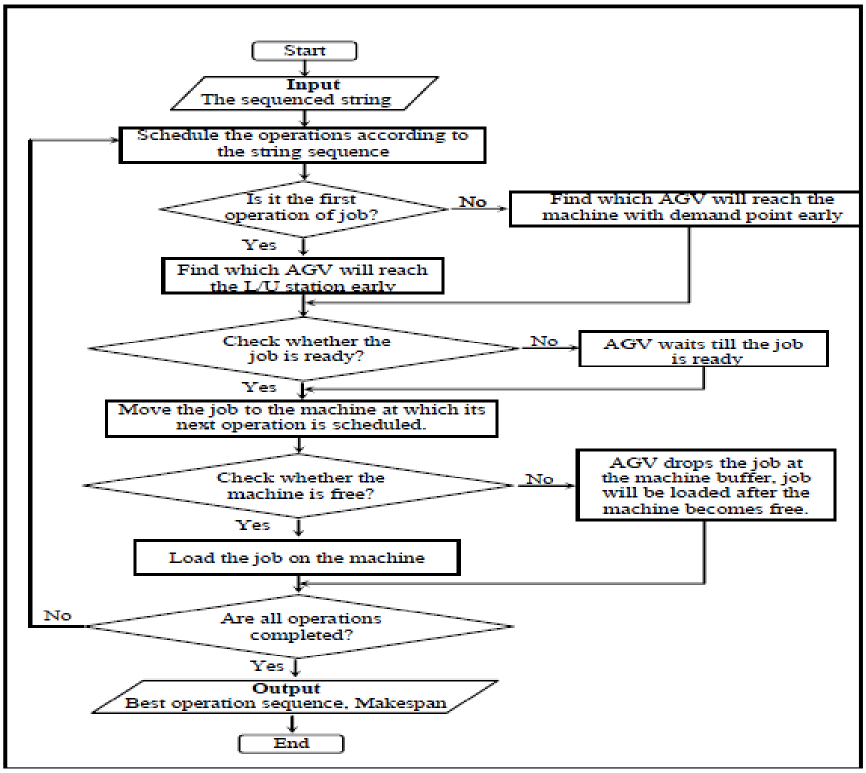

Figure 2. *Flow chart of fuzzy logic controller based genetic algorithm [4]*

Zhang et al. [8], they proposed a hybrid-load Auto-mated guided vehicle dispatching model to reduce the overall cost of the operating system by increasing the distribution of different tasks. The delivery model of the hybrid-load AGV shown is shown in Figure 3. Heger et al. [9], used a neural implant network and study the effects of interactions between a combination of different sequencing rules, dispatching, and routing based on priority rule and computation time. They found that trained network improved combination of rules and reduced the downtime of services. Bocewicz et al. [10] defines a multidisciplinary transport network (MTN) where multiple network networks (Auto-mated guided vehicles, hoists, lifts, etc.) communicate with each other through common shared work stations. The materials management systems provide the flow of work fragments between workstations on their production lines on MTN. The Figure 4 indicates the Scenario, aspects routing, sequencing and dispatching.

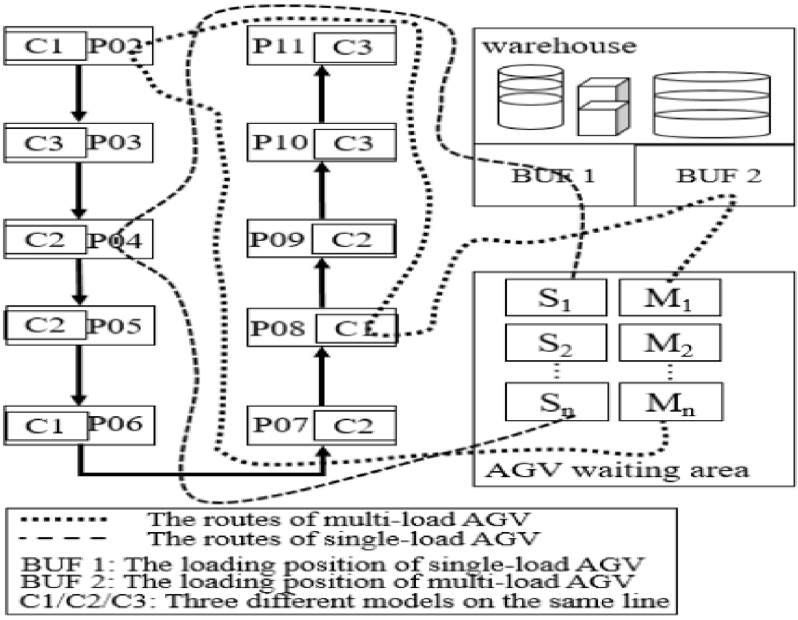

Figure 3. *Hybrid-load AGV dispatching model [8]*

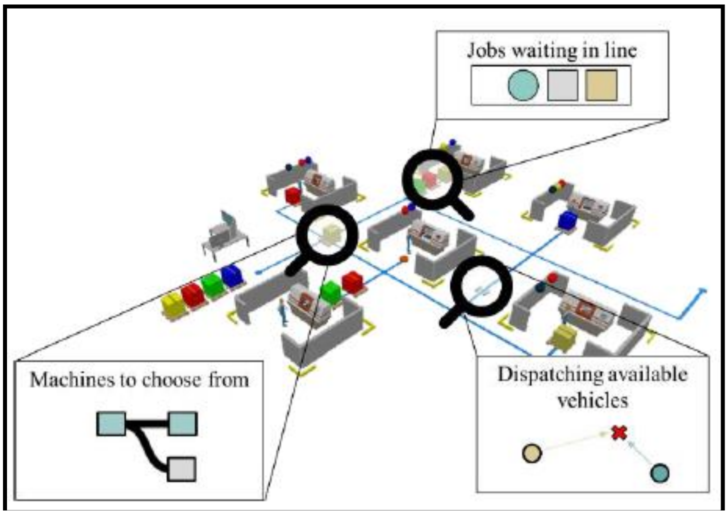

Figure 4. *Scenario, aspects routing, sequencing and dispatching [9]*

Scholz et al. [11], has used an AGV tracking system based on multiple rooftop cameras. Cameras capture tracking data for the purpose of getting a complete view of the complete tracking area. Object recognition data is sent from each camera to the central tracking unit. Through link conversion, dynamic data is converted into a global system. The resulting material is traced using a combination of the Kalman filter and the Hungarian method. Depending on the trajectory the velocity vector is calculated. Single-board computers with power similar to FPGA are used to increase tracking accuracy. Herrero-Perez et al. 2008 [12] worked on architecture that was tasked with solving the problem of interaction between multiple AGVs in the industrial environment and used the polar kinematic bug method for this work. Gonzalez et al. [13], used a semi-heterarchical structure to create adjustable AGV independence within FMS. The proposed module incorporates and integrates functions such as dynamic environmental performance, easy integration of production, and intelligence of the production system as shown in Figure 5.

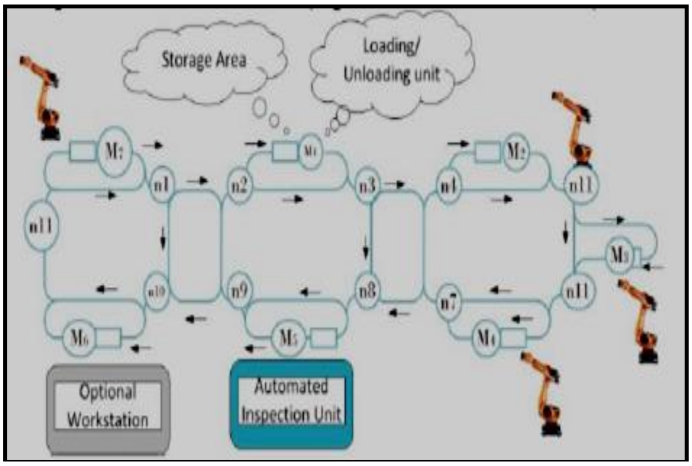

Figure 5. *Semi-heterarchical architecture [13]*

Carlos et al. [14], discussed bio-inspired strategies for linking and controlling X-independent vehicles (AXVs) to improve future production and transportation of complex FMS. Salehipour et al. [15], a mixed-use system (MIP) method was used to locate activity channels in the AGV zones cycle. The aim was to reduce the total waiting time for all operating facilities and to reduce the arrival time of each facility.Tuma et al. [16], has proposed simulation tools to analyze the order system in which AGVs are adopted to move the finished products from production lines to the loading dock. Sedehi et al. [17], they applied two ideas of production planning in production systems. The first was a new GA chromosome that made the algorithm more likely to stick to the problem. The second was a combination of globle search (GA / AGA) and local search (TS) to reduce makepan. Global search by local search (AGA + TS) gets better results than just global search (GA and AGA). Gebennini et al. [18], proposed a simulation based approach for supporting the AGVs. The BDI model buildings were used by AGVGs to make their own regulatory decisions. Erola et al. [19], a multi-agent based scheduling approach has been used for AGVs and equipment. It has been found that this method creates better schedules in real time compared to optimization algorithms and dispatching rules. Löfving et al. [20], suggest that Autonomous intelligence vehicle's (AIV) is the best solution for reducing material handing time. The concept of an AIV-integrated management system is to directly connect the production equipment, deliver the product meetings directly to the assembly cells, and then collect them at the cell output and deliver the next process. Mehami et al. [21], they said, Industry 4.0 uses online technology to control automation systems and production processes to make system simplification, minimal human interventions, and decision-making. They suggested the use of Radio Frequency Identification (RFID) technology for making smart AGV system and makes AGV’s more interactable in Industry 4.0 environment. RFID technology has been used to direct or control the movement of AGVs. RFID enabled robotic Karl and Jimmy AGVs are in Industry 4.0 environment. Karl AGV is an robotic AGV having arm and gripper. It is used to manage objects and RFID controls movements and idenfying the object. In Jimmy AGV, the robot followed a predefined approach with the RFID control movement of AGV's. It was found that RFID technology makes AGV's AGV's smart decisions. Morinaga et al. [22], addressing the concept of high-density production systems (HDMS), in which each facility operated electronically and self-regulated by interacting with other facilities and transporting the AGV into a distributed framework. Quadrini et al. [23], have suggested open communication channels for connecting AGVs to the Fleet Management System (FMS) to be as compatible with the largest AGV manufacturer / supplier as possible. Gebennini et al. [24] presented a framework for the use of imitation tools for AGVs used to transport the finest finishes from the production line to the loading area. Viharos et al. [25], developed a discrete event simulation model (DES) for automated assembly systems that can be developed by robot assembly and AGV’s.The purpose of developing a model was to support the planning and evaluation of the systems. The purpose of the scheduling module was to reduce the total time to makespan time of products. The heuristic algorithm manages a variety of automated assembly systems integrated with robotic assemblystation and AGV-based material management. AGV Control manages AGV’s in accordance with priority rules. Li et al. [26], it was suggested fault-tolerant cooperative control (FTCC) method for automated vehicles passing through a signal-free and lane-free intersection. Fault-Tolerant Co-operative Control (FTCC) can handle unexpected errors in the system of multiple robots. Beji et al. [27] studied the vehicle flexibility model for path planning and control studies. They suggested how to create a smooth AGVs movement in a given path when considering the challenges of kinematics and dynamics. Gawrilow et al. [28], the AGV algorithm algorithm has been proposed in the default system for signal-alignment of the vessel. Bilge et al. [29] discussed responses to automated guided vehicle dispatching. They design test settings in such a way that the critical device in the system alternates between movement and processing systems, which poses a challenge to responding to such changes and staying stable in a variety of systems. Demonstrate the importance of identifying critical resources when deploying AGVs and implement the response process in place so that critical resources can be used effectively. Das et al. [30] focused on the design and maintenance of automated vehicle systems (AGV). They found that if AGVs turned sharply or drifted and lost track that an AGV could not find, it could be improved using an algorithm response. Umar et al. [31] introduced an algorithm based on the weight crossover map and the inclusion of the controversial Automated Guided Vehicle (AGV) roadmap to reduce travel time and overall work delays. Conflict detected and avoided using route time for each component. Numerical tests was performed and presented in an devepoed algorithm. Kumar et al. 2012 [32] designed a completely independent “AGV line” that follows a pre-marked pattern on the surface. It uses measurements taken from sensors and compares them with values given by the system. Khedkar et al. [33], studied to find a solution routing and in-house traversal. They used a collision prevention system that could detect living / inanimate objects and respond appropriately. Their proposed solution could help create such an AGV system that would avoid collisions. AGVS performance is evaluated by measuring both parameters representing the AGVs operation and parameters representing the manufacturing system operation as a whole. The AGVS operation measures includes for the evaluation of performance are AGV idle time, AGV utilization, AGV empty travel times and number of AGVs required for meeting the production demands. The determination of AGV vehicle requirements in a FMS has a great impact on the system performance. As the complexity and size of AGVS applications increase, evaluating performance becomes more difficult. Fu et al. [34] developed response surface methodology simulation model (RSMSM) for determining AGVs requirement. This method is simulation-based analytic methodology which includes discrete event simulation (DES), sensitivity analysis, fractional factorial design (FFD) and response surface methodology (RSM) features. The RSMSM method reduced more than 80% of number of simulation experiments. This advantage can reduce cost and improve efficiency in practical engineering application. Yokota [35], used Heuristic Algorithm for evaluating performane of AGVs used in Warehouse.An algorithm was proposed that produced a very low interaction schedule for both AGVs and human pickers. The performance of the algorithm has been evaluated by computer simulation. The proposed algorithm can produce sub-scheduled AGV schedules with pickers with approximately a minimum completion time in a very short time. Berman et al. [36] they developed evaluation methodology for evaluating AGVS control which incorporated with quantitative analysis and structured qualitative analysis.The performance ratings include features from both multi-robot and AGV fields. The methodology promotes the inclusion of quality analysis to assess system attributes that can be easily assessed by quantitative analysis. Provides a systematic approach to modeling, evaluating, analyzing, and comparing different AGVS control methods. Choobineh et al. [37] used multi-phase closed-line networks to model AGV movement in the production area. Comparison results between the analysis and simulation model showed that the analysis model provided a good estimate of the required number of vehicles in approximately 90% of cases. Kabir and Suzuki [38] developed event simulation models to explore how different routes for AGVs battery management can affect system performance. The four methods of heuristics are approaching namely selecting the nearest battery station (NBS), selecting the low-speed battery station (MDBS), selecting the nearest battery station from the starting point (NBSIP), and selecting the nearest battery dump station (NBSDP). The results showed that MDBS did better in system production because this process selects a battery channel that will reduce the total travel and waiting time in the battery station.

3. THE RESEARCH FINDINGS AND DISCUSSION

AGVs are gaining popularity in the modern industry because they provide a safe, efficient and uninterrupted management of materials in industry. It is much easier to install as compared to conveyor belts. The only issue with AGVs is their huge financial costs and their effective integration, structure and controls. Various methods and approaches have been used to implement AGV's in FMS by researchers are presented in Table 1.

Table 1. *The researchers reported on AGVs*

Optimization Methods/ Algorithm/Approaches	Number of AGVs	Findings	Reference
Fuzzy logic genetic algorithm	02	FGA enhanced the performance of GA for Scheduling machines and AGVs jointly.	[4]
The cross, loop and Mesh variant strategies.	25	The cross-variants strategies is better than the mesh-variant when number of AGVs is less then 20 to avoid collision of AGVs..	[2]
Genetic Algorithm (GA) and Ant colony optimization (ACO) algorithm.	02	Minimizes traveling time for maximum utilization of AGVs. The result obtained by the ACO algorithm was promising and encouraging.	[5]
MSP, Sub-problem: Conflict-free routing.	06	Simultaneous work with a non-controversial vehicle route.	[39]
Mathematical Model.	01	This model provides optimal material flow while considering constraints such as job sequence, cycle time, and AGV.	[3]
Artificial intelligence techniques.	05	Produce a Prototype with operational capabilities in a small and flexible structure.	[40]
Multi-objective genetic algorithm approach.	03	This algorithm provides conflict-free AGV routing by reducing travel time and overall work delays.	[31]
Multi Agent Model	12	Multi-agent Building Distributed and Provides Possible Solution.	[41]
Adaptive Genetic Algorithm	02	This approach was ues for Jobs Modeling and AGVs. It minimizing makespan for the problem of reactive production scheduling in a FMS with AGVs .	[16]

Meta-heuristic algorithms	01	It was used for designing material handling for single-loop AGV systems to reduce the total flow distance of materials. This algorithm works both for the the objective function value and the runtime.	[17]
Spreadsheet-based genetic algorithm approach.	02	Concurrent scheduling model of machines and AGVs was developed considering problems of 82 samples.	[42]
Heuristics approaches.	01	The problems of integration of scheduling and routing aspects were addressed. Heuristics were proposed to overcome high computation times.	[1]
Network Simplex Method	12	It reduced the cost flow and provides a better solution.	[43]
Meta-heuristic gravitational search algorithm	02	Lower the makespan and complete tasks faster, the potential savings of AGV use.	[44]
Integrated approach and sequential approach.		This approach provides high quality solutions in terms of makespan but requires a lot of calculation time. However, the sequential method allows to find a solution to maximize QoS during low calculation.	[6]
Simulation Based Approach	9-12	This approach was used to design and evaluate the performance of AGV systems. The finding suggested that 10 AGVs is enough to manage entire logistic system.	[18]
P S O Algorithm.	20	Particle Swarm Optimization (PSO) algoritham was used to slove for the multi-load AGVs.	[45]
Heuristic approaches Brute force enumeration algorithm.	05	The heuristic approaches and brute force enumeration algorithm reduces number of AGVs and total makespan time.	[7]
Simulated Annealing Method (SAM)	50	SAM provides a better initial solution for Multi-load AGVs.	[46]
Multi-agent based approach	02	The dynamic scheduling of machines and Automated Guided Vehicle were carried out by this approach in FMS. It was found that it improved the performance AGVs scheduling.	[19]
Genetic algorithm (GA)	12	This algoritham was used in hybrid-load Automated Guided	

		Vehicle dispatching model. The GA reduced appromimately one third of travel distance and number of Automated Guided Vehicle used.	[8]
Adaptive Lyapunov approach	01	This Adaptive Control Method was used to control the balancing forces acting on the vehicle in the perpendicular and trasverse directions with respect to torques and kinematic conditions.	[27]
Network Simplex methods.	50	It was uesd get Optimal Solution for static and dynamic Problems of AGVs.	[47]
Priority-based rules	05	It was used for dispatching AGVs.	[9]
Meta-heuristic-based algorithms.	20	This approach algorithm reduces the differences time between appointment and actual operation for delivery container.	[48]
Multimodal Transportation Network.	20	Delivery and number of AGVs were reduced.	[10]
Smart AGVs for Industry 4.0.	02	It is a configured, flexible, and customized AGV system.	[21]
Highly-distributed simulation.	02	In this system, AGVs was simulated by segmenting transportation routes into multiple zones considering it as intelligent agents.	[22]
Decentralized motion planning	25	It was used for Scheduling of automated guided vehicles.	[49]
Algorithm for Dynamic Rutting of AGVs.	20	This algorithm prevents collisions, deadlock closures and livelocks during route calculation. Futhermore, this algorithm added the visual features of AGVs and other security features specified by a specific application.	[28,32]
Non-linear integer mathematical programming model.	01	It was used for Scheduling of AGV alongwith a group of machines.Reduce system penalty cost up to 44%	[50]
Decentralized architecture.	04	The architecture has capability to coordinate a large number of AGVs through heuristic based on priorities and prevent collisions.	[12]
Distributed multi-agent system	15	Controlling and Scheduling Robotic Flexible Assembly Cells. The effectiveness and the robustness of the system	[51]

Semi-heterarchical architecture.	3	It was used for Controlling AGVs' autonomy. It makes them less dependent and independent decision-making control.	[13]
Mixed-integer programming (MIP)	25	The proposed construction of the MIP was highly competitive and capable of resolving up to 25 workstations at a high level in a timely manner.	[15]
Real-Time-Holonic Scheduling	01	This method provides effective sheduling of Automated Guided Vehicle for Handling materials in logistics warehouses where operational area is large and mixed with lower-volume of picking orders.	[52]
DES model based on flexible heuristic algorithm.	02	DES Model was used for scheduling of AGV in an assembly system.This model can handle a variety of automated integration systems developed for robotic assembly and AGV based material handling.	[25]
Mathematical and dynamic model (A bio-inspired approach)	02	The development method provides better performance in planning AGVs.	[53]

Throughout the review, work reported by investigators taking into account factors such as proximity, production facilities and solutions to AGV design and control systems. The efficiency, planning and control of AGV's, especially methods such as Mathematics systems, Multi-criteria decisions, Heuristics oriented, Control theoretic, Simulation based, Artificial intelligence (AI) were used. GA has proposed it as a powerful tool for the simultaneous planning of equipment and AGVs in FMS areas. The Fuzzy logic controller system is used to control the performance of the Genetic Algorithm during the resolution of the AGV problem in planning. The result obtained by the ACO algorithm was more promising and encouraging than GA. The integrated approach (in conjunction with Time-Lag based Heuristic) offers the best quality of service process with the same scope. The hybrid-load dispatching model AGV has reduced the total cost of the material handling. The bio-inspired process helps to coordinate and control the independent X vehicles to travel through complex FMS. The concept of Radio Frequency Identification (RFID) technology inbuilt smart AGV system was proposed in industry 4.0. The discrete event simulation (DES) and distributed discrete event simulation (DDES) (DDES) was developed for automated redesign systems consisting of robotic assembly stations and automated vehicle (AGV). Future AGVs may be designed to have a variety of functions to meet a variety of needs. Both single-loading and multi-loading AGVs can operate simultaneously on the same AGV system in the future. How the functioning of the AGV system can be enhanced using new approchess, algorithms, and simulation methods is also a matter for future research.

CONFLICTS OF INTEREST

No conflict of interest was declared by the author.

REFERENCES

[1] Fazlollahtabar, H., and Saidi-Mehrabad, M., "Methodologies to optimize automated guided vehicle scheduling and routing problems: a review study", Journal of Intelligent & Robotic Systems, 77(3): 525-545, (2015).

[2] Duinkerken, M.B., Ottjes, J.A., and Lodewijks, G., "Comparison of routing strategies for AGV systems using simulation", In Proceedings of the 2006 winter simulation conference, IEEE, 1523-1530, (2006).

[3] Fazlollahtabar, H., Rezaie, B., and Kalantari, H., "Mathematical programming approach to optimize material flow in an AGV-based flexible job shop manufacturing system with performance analysis", The International Journal of Advanced Manufacturing Technology, 51(9): 1149-1158, (2010).

[4] Badakhshian, M., Sulaiman, S.B., and Ariffin, M.K.A.B.M., "Performance optimization of simultaneous machine and automated guided vehicle scheduling using fuzzy logic controller based genetic algorithm", International Journal of Physical Sciences, 7(9): 1461-1471, (2012).

[5] Udhayakumar, P., and Kumanan, S., "Task scheduling of AGV in FMS using non-traditional optimization techniques", International Journal of Simulation Modelling, 9(1): 28-39, (2010).

[6] Gondran, M., Huguet, M. J., Lacomme, P., and Tchernev, N., "Comparison between two approaches to solve the Job Shop Scheduling Problem with Routing", IFAC-PapersOnLine, 52(13): 2513-2518, (2019).

[7] Gutjahr, M., Kellerer, H., and Parragh, S.N., "Heuristic approaches for scheduling jobs and vehicles in a cyclic flexible manufacturing system", Procedia Computer Science, 180: 825-832, (2021).

[8] Zhang, L., Hu, Y., and Guan, Y., "Research on hybrid-load AGV dispatching problem for mixed-model automobile assembly line", Procedia CIRP, 81: 1059-1064, (2019).

[9] Heger, J., and Voss, T., "Reducing mean tardiness in a flexible job shop containing AGVs with optimized combinations of sequencing and routing rules", Procedia CIRP, 81: 1136-1141, (2019).

[10] Bocewicz, G., Nielsen, I., and Banaszak, Z., "Automated guided vehicles fleet match-up scheduling with production flow constraints", Engineering Applications of Artificial Intelligence, 30: 49-62, (2014).

[11] Scholz, M., Steinkamp, J., Zwingel, M., Hefner, F., and Franke, J., "Distributed Camera Architecture for Seamless Detection and Tracking of Dynamic Obstacles", Procedia CIRP, 91: 342-347, (2020).

[12] Herrero-Perez, D., and Matinez-Barbera, H., "Decentralized coordination of autonomous AGV's in flexible manufacturing systems", International Conference on Intelligent Robots and Systems, 3674-3679, (2008).

[13] Gonzalez, S.R., Zambrano, G.M., and Mondragon, I.F., "Semi-heterarchical architecture to AGV adjustable autonomy within FMSs", IFAC-Papers OnLine, 52(10): (2019).

[14] Caruntu, C.F., Pascal, C.M., Maxim, A., and Pauca, O., "Bio-inspired Coordination and Control of Autonomous Vehicles in Future Manufacturing and Goods Transportation", IFAC-Papers OnLine, 53(2): 10861-10866, (2020).

[15] Salehipour, A., and Sepehri, M.M., "Optimal location of workstations in tandem automated-guided vehicle systems", The International Journal of Advanced Manufacturing Technology, 72(9-12): 1429-1438, (2014).

[16] Tuma, C.C., Morandin, O., and Caridá, V. F., "Minimizing the makespan for the problem of reactive production scheduling in a FMS with AGVs using a new structure of chromosome in a hybrid GA with TS", IEEE 18th Conference on Emerging Technologies & Factory Automation (ETFA), 1-6, (2013).

[17] Sedehi, M.S., and Farahani, R.Z., "An integrated approach to determine the block layout, AGV flow path and the location of pick-up/delivery points in single-loop systems", International Journal of Production Research, 47(11): 3041-3061.

[18] Gebennini, E., Dallari, S., Grassi, A., Perrica, G., Fantuzzi, C., and Gamberini, R., "A simulation based approach for supporting automated guided vehicles (AGVs) systems design", Winter Simulation Conference, IEEE, 2156-2163, (2009).

[19] Erol, R., Sahin, C., Baykasoglu, A., and Kaplanoglu, V., "A multi-agent based approach to dynamic scheduling of machines and automated guided vehicles in manufacturing systems", Applied soft computing: 12(6), 1720-1732, (2012).

[20] Löfving, M., Almström, P., Jarebrant, C., Wadman, B., and Widfeldt, M., "Evaluation of flexible automation for small batch production", Procedia Manufacturing, 25: 177-184, (2018).

[21] Mehami, J., Nawi, M., and Zhong, R.Y., "Smart automated guided vehicles for manufacturing in the context of Industry 4.0", Procedia manufacturing, 26: 1077-1086, (2018).

[22] Morinaga, E., Yasuda, D., Imagawa, Y., Wakamatsu, H., Tsumaya, A., Inoue, T., and Fujii, S., "A study on highly-distributed manufacturing system simulation", Procedia Manufacturing, 39: 50-57, (2019).

[23] Quadrini, W., Negri, E., and Fumagalli, L., "Open interfaces for connecting automated guided vehicles to a fleet management system", Procedia Manufacturing, 42: 406-413, (2020).

[24] Gebennini, E., Dallari, S., Grassi, A., Perrica, G., Fantuzzi, C., and Gamberini, R., "A simulation based approach for supporting automated guided vehicles (AGVs) systems design", In 2008 Winter Simulation Conference, IEEE, 2156-2163, (2008).

[25] Viharos, A. B., and Németh, I. "Simulation and scheduling of AGV based robotic assembly systems", IFAC-PapersOnLine, 51(11): 1415-1420, (2018).

[26] Li, B., and Zhang, Y., "Fault-tolerant cooperative motion planning of connected and automated vehicles at a signal-free and lane-free intersection", IFAC-PapersOnLine, 51(24): 60-67, (2018).

[27] Beji, L., and Bestaoui, Y., "Motion generation and adaptive control method of automated guided vehicles in road following", IEEE, Transactions on intelligent transportation systems, 6(1): 113-123, (2005).

[28] Gawrilow, E., Köhler, E., Möhring, R.H., and Stenzel, B., "Dynamic routing of automated guided vehicles in real-time", In Mathematics–Key Technology for the Future, Springer, Berlin, Heidelberg, 165-177, (2008).

[29] Bilge, Ü., Esenduran, G., Varol, N., Öztürk, Z., Aydın, B., and Alp, A., "Multi-attribute responsive dispatching strategies for automated guided vehicles", International Journal of Production Economics, 100(1): 65-75, (2006).

[30] Das, S. K., and Pasan, M. K., "Design and methodology of automated guided vehicle-a review", IOSR, Journal of Mechanical and Civil Engineering, 29-35, (2016).

[31] Umar, U.A., Ariffin, M.K.A., Ismail, N., and Tang, S.H., "Conflict-free automated guided vehicles routing using multi-objective genetic algorithm", Research Journal of Applied Sciences, Engineering and Technology, 6: 2681-2684, (2013).

[32] Kumar, K.K., Krishna, M.S., Ravitej, D., and Bhavana, D., "Design of Automatic Guided Vehicles", International Journal of Mechanical Engineering and Technology (IJMET), 3: 24-32, (2012).

[33] Khedkar, A., Kajani, K., Ipkal, P., Banthia, S., Jagdale, B. N., and Kulkarni, M., "Automated Guided Vehicle System with Collision Avoidance and Navigation in Warehouse Environments", Sensors, 7(05): (2020).

[34] Fu, J., Zhang, J., Ding, G., Qin, S., and Jiang, H., "Determination of vehicle requirements of AGV system based on discrete event simulation and response surface methodology", Proc IMechE Part B: J Engineering Manufacture, 235(9): 1425–1436, (2021).

[35] Yokota, T., "Heuristic Algorithm for the Co-Operative Picking with AGVs in Warehouse", SICE Journal of Control, Measurement, and System Integration, 13(3): 057–065, (2020).

[36] Berman, S., Edna, S., Yael, E., "Evaluation of automatic guided vehicle systems", Robotics and Computer-Integrated Manufacturing, (2008). DOI: 10.1016/j.rcim.2008.02.009

[37] Choobineh, F., Asef-Vaziri, A., and Huang, X., "Fleet sizing of automated guided vehicles: A linear programming approach based on closed queuing networks", International Journal of Production Research, 50(12): 3222-3235, (2012).

[38] Kabir, Q.S., Suzuki, Y., "Comparative analysis of different routing heuristics for the battery management of automated guided vehicles", International Journal of Production Research, 57(2): 624-641, (2019).

[39] Corréa, A.I., Langevin, A., and Rousseau, L.M., "Scheduling and Routing of Automated Guided Vehicles: A Hybrid Approach", Computers & Operations Research, 34: 1688–1707, (2007).

[40] Barberá, H.M., and Herrero-Perez, D., "Development of a flexible AGV for flexible manufacturing systems", Industrial Robot, 37(5): 459-468, (2010).

[41] Thurston, T., and Hsu, H., "Distributed agent architecture for port automation", Proceedings of the 26th annual international computer software and applications conference (COMPSAC'02), Oxford, August 26–29. IEEE Computer Society, Los Alamitos, 81–87, (2002).

[42] Chaudhry, A.C., Mahmood, S., and Shami, M., "Simultaneous scheduling of machines and automated guided vehicles in flexible manufacturing systems using genetic algorithms", Journal of Central South University of Technology, 18(5): 1473-1486, (2011).

[43] Cheng, Y., Sen, H., Natarajan, K., Teo, C., and Tan, K.,"Dispatching Automated Guided Vehicles in a Container Terminal", Technical Report, National University of Singapore, (2003).

[44] Nageswararao, M., Narayanaraobd, K., and Ranagajanardhana, G., "Simultaneous Scheduling of Machines and AGVs in Flexible Manufacturing System with Minimization of Tardiness Criterion", Procedia Materials Science, 5: 1492-1501, (2014).

[45] Chawla, V.K., Chanda, A.K., Angra, S., "Scheduling of Multi-Load AGVs In FMS By Modified Memetic Particle Swarm Optimization Algorithm", Journal of Project Management, 3: 39–54, (2018).

[46] Rashidi, H., Kabir, A., “Scheduling Single-Load and Multi-Load AGVs in Container Terminals”, Journal of Science and Technology, 42(2): 1–10, (2010).

[47] Rashidi, H., and Tsang, E.P.K., “Vehicle Scheduling in Port Automation: Advanced Algorithms for Minimum Cost Flow Problems”, Second Edition, CRC Press, New York, (2016).

[48] Rahman, H., and Nielsen, I., “Scheduling Automated Transport Vehicles for Material Distribution Systems”, Applied Soft Computing, 82: 1-17, (2019)

[49] Demesure, G., Defoort, M., Bekrar, A., Trentesaux, D., and Djemaï M., ‘‘Decentralized motion planning and scheduling of AGVs in an FMS’’, IEEE Transactions on Industrial Informatics, 14(4): 1744–1752, (2018).

[50] Rahimikelarijani, B., Saidi-Mehrabad, M., and Barzinpour, F., “A Mathematical Model for Multiple-Load AGVs in Tandem Layout”, Journal of Optimization in Industrial Engineering, 13(1): 67-80, (2019).

[51] Maoudj, A., Bouzouia, B., Hentout, A., Kouider, A., and Toumi, R., “Distributed multi-agent scheduling and control system for robotic flexible assembly cells”, Journal of Intelligent Manufacturing, 30(4): 1629-1644, (2019).

[52] Yoshitake, H., Kamoshida, R., and Nagashima, Y., “New Automated Guided Vehicle System Using Real-Time Holonic Scheduling for Warehouse Picking”, IEEE Robotics and Automation Letters, 4(2): 1045-1052, (2019).

[53] Gu, W., Li, Y., Zheng, K., and Yuan, M., “A bio-inspired scheduling approach for machines and automated guided vehicles in flexible manufacturing system using hormone secretion principle”, Advances in Mechanical Engineering, 12(2): 1-17, (2020).