JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

SMART WAREHOUSE LOGISTICS: ROBOTIC NAVIGATION WITH IMAGE PROCESSING AND FULL-STACK E-COMMERCE PLATFORM

[1]Arunima Mehta, [2]Pranav N Athreya, [3]Sahana S, [4]Vineela K

[1]Student, [2]Student, [3]Student, [4]Student
[1]ECE Department,
[1]RV Institute of Technology and Management, Bengaluru, India

Abstract: The exponential growth of e-commerce has placed immense pressure on logistics systems to become faster, more accurate, and more intelligent. In this evolving domain, smart warehouses are emerging as critical infrastructural components for enabling efficient storage, retrieval, and dispatch of goods. This project focuses on Smart Warehouse Logistics, combining robotic navigation, image processing, and a full-stack e-commerce platform to revolutionize traditional warehouse systems. By integrating Lean Six Sigma principles with IoT-enabled robotics, the system aims to optimize package sorting, pathfinding, and inventory management. The system aims to streamline operations both within the warehouse and beyond, using macro-logistics and GIS-based navigation for last-mile delivery support. Current logistics systems suffer from manual warehouse operations, delayed order fulfillment, and poor integration with e-commerce platforms. These gaps lead to high costs, inefficient delivery, and limited adaptability, demanding a smarter, real-time automated solution. This project aims to automate warehouse navigation and package sorting using robotics, Image Processing, and hybrid Ant Colony–PSO algorithms for smart delivery. Lean Six Sigma tools help streamline operations and enhance process quality. A MERN-based e-commerce platform ensures smooth user experience and admin control, while Generative AI powers personalized shopping through chatbots and recommendations. The proposed system demonstrates improved warehouse efficiency through automated sorting, reduced human intervention, and real-time inventory synchronization. With its integrated design and intelligent features, the system shows strong potential for scalable, next-generation logistics and retail applications.

Index Terms **– Ant Colony Algorithm, Particle Swarm Optimization, Lean Six Sigma, GIS, MERN stack, Generative AI.**

I. INTRODUCTION

Optimizing warehouse logistics demands precision in navigation, sorting, and dispatch processes to meet modern e-commerce velocity. Traditional warehouses suffer from inefficiencies such as manual sorting, unclear cargo space division, leading to high operational costs and delayed order fulfillment [1]. To address these challenges, modern logistics systems leverage advancements in fields like Robotics and Digital Image Processing. Emerging solutions employ robotic micro-mobility—such as palm-sized, offboard-compute micro-mouse robots—paired with Digital Image Processing (DIP) to convert warehouse layouts into 2D color-coded pixel matrices, acting like navigable grid maps, where color-coded blocks denote paths, walls, and obstacles [2]. This enables real-time obstacle detection and PID-controlled navigation, as demonstrated in raster-based ant colony systems [3]. These align with Lean Six Sigma principles, integrated with IoT-enabled automation, have proven effective in minimizing waste and optimizing process quality in industrial settings [4]. Together, these technologies form a cohesive framework for scalable, automated warehousing—addressing gaps in prior robotic and software systems [5]. Further refinements to the traditional ACO, such as the introduction of dynamic multi-role adaptive collaborative strategies, have optimized path planning by adjusting pheromone update rules and incorporating heuristic information. Similarly, Particle Swarm Optimization (PSO) algorithms have been applied to optimize the routing of Automated Guided Vehicles (AGVs), offering benefits in terms of convergence speed and solution quality. The integration of PSO with other heuristic methods has shown promise in addressing the complexities of multi-objective path planning in warehouse settings. For instance, hybrid Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO) algorithms have demonstrated superior convergence speed and enhanced path safety in robotic navigation, reducing iterations by 82% compared to traditional methods [6]. However, a critical gap in current systems is the lack of real-time synchronization between warehouse robotics and e-commerce platforms. To bridge this gap, managing macro-logistics also becomes crucial. For macro-logistics, GIS-driven route optimization and satellite visibility analysis address urban navigation challenges. Techniques like DSM-based obstruction mapping [7] and adaptive ACO algorithms [8] mitigate signal blockages in last-mile delivery, reducing congestion rates by 9–13% [9]. At the software end, this automation is supplemented by a MERN-stack (MongoDB, Express.js, React.js, Node.js) e-commerce platform that marries frontend user interface with backend logistics. Customer-facing portal provides product browsing, filtering based on categories (e.g., clothing type or bestseller), and secure payment processing. Admin panel provides real-time tracking of inventory and synchronization of placed orders with robotic fulfillment processes. Also, Generative AI applications are incorporated into the platform to offer virtual shopping assistants and product recommendations based on personalization, encouraging increased user

engagement through conversational and contextual interactions. By integrating these technologies, the proposed system offers a scalable framework for warehouse automation, enabling real-time inventory visibility and seamless order fulfillment—while addressing key limitations identified in existing approaches.

I. RESEARCH METHODOLOGY

Y. Chen et al. [1] IEEE Access, 2023 suggests a more advanced ant colony optimization (ACO) approach to warehouse robot guidance, adding dynamic pheromone updates and heuristics adaptive to obstacles. The technique shortens average path length by 32% over conventional ACO, with improved energy efficiency of 15%. Experimental confirmation in a simulated 1000-node warehouse exhibits faster convergence speed, especially with high-density storage maps. The algorithm is equipped with real-time collision avoidance, which renders it suitable for dynamic environments.

O. Krawi et al. [2] IEEE Access, 2025 develop a hybrid YOLO-ViT framework for streetside building identification with 94.5% accuracy in Google StreetView datasets. Building façades are detected using YOLO and architectural style classified using Vision Transformer. The model runs at 22 FPS on a GPU for near-real-time urban mapping. Additionally, the system uses Transfer Learning with pre-trained ImageNet weights, significantly boosting ViT's classification ability across limited-label scenarios. It also achieves a 76% accuracy when tested against manually curated datasets with diverse urban conditions.

R. Kou et al. [3] IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 2025 introduce a virtual panoramic obstruction analysis technique to forecast GNSS signal visibility within urban canyons. Utilizing 3D city models of London and Berlin, the technique reaches 88% accuracy in detecting signal-blocking buildings. The system outputs panoramas at 12ms per view, allowing for scalable city planning.

A. Andreou et al. [4] IEEE Access, 2025 combines IoMT wearables with ceiling-mounted sensors for the monitoring of ICU patients, with data sampling rates enhanced by 40%. The system gains 99.1% data fidelity by combining multi-modal vitals (ECG, SpO2). The system leverages Twin-Delayed DDPG and Soft Actor-Critic algorithms, achieving 15% better adaptability and 20% faster convergence in hospital simulations. Its energy-efficient design aligns with sustainability goals while ensuring real-time responsiveness across ICU scenarios.

O. S. Deepa [5] IEEE Access, 2024 guarantees 99.2% regulation conformity in plastic manufacturing effluent analysis. The process lowers manual audits by 50% by automating criteria weighting. Deepa's study combines Six Sigma methodology and Complex Fuzzy AHP (CFAHP) to minimize effluent analysis in plastic production. The compound approach is 99.2% compliant with environmental standards while cutting manual quality audits by 50%. The system manages uncertain production parameters more efficiently by blending linguistic variables and standard Six Sigma metrics. In a 12-month pilot in a PVC pipe factory, it showed uniform reduction in waste in all sampling points.

M. L. Duc et al. [6] IEEE Access, 2023 develops a cost-effective Industry 4.0 solution for CNC machining that combines Six Sigma with IoT-enabled process monitoring. Their system reduces production defects by 27% while achieving $8,000 annual cost savings per machine. The implementation uses Raspberry Pi-based sensors to collect vibration, temperature, and tool wear data, feeding into a statistical process control dashboard. Field tests on Fanuc CNC machines showed effectiveness in milling operations.

J. Li et al. [7] Tsinghua Science and Technology, 2021 presents a hybrid approach combining GPS trajectories with GIS data to classify transportation modes (walking, cycling, driving, bus, metro) with 94.2% accuracy. Their method enhances traditional GPS-only classification by incorporating road network topology and transit stop locations from OpenStreetMap. The algorithm processes speed, acceleration, and stop-rate features ($R_{stop} = N_{stop}/T_{total}$) through an XGBoost classifier with GIS-weighted loss functions. Evaluation on 12,000+ Shanghai trajectories show improvement in distinguishing buses from cars (91% precision) in congested urban conditions.

D. Krumins et al. [8] IEEE Transactions on Learning Technologies, 2024 develop a web-based platform integrating physical robots (UR3, TurtleBot3) with Gazebo simulations for ROS education. Their Docker-containerized solution allows students to test code in simulation before queuing for hardware access, achieving 94% task completion rates in hybrid mode versus 72% in simulation-only. The system features Jupyter Notebook integration and real-time telemetry dashboards, supporting 15 concurrent users. A survey of 112 students showed 87% satisfaction with the authentic development environment.

S. Moslem et al. [9] IEEE Access, 2023 examines 156 AHP applications (2003-2022) within transportation decision-making by applying PRISMA methodology. Their bibliometric analysis indicates fuzzy-AHP (38% of the studies) and hybrid models (29%) are the prevalent methodologies of recent research, especially in planning public transport and the assessment of road safety. The taxonomy pinpoints cost (72%), safety (65%), and environment (58%) as most common criteria. Although exhaustive, the study cites geographical bias (68% Asian/European cases) and inadequate exploration of AHP for emerging mobility technologies.

R. Karthik et al. [10], IEEE Access, 2024 introduces a Dual PID-based Low-Cost Navigation System (DPLNS) to counter the limitations of encoder-based warehouse robots. With the integration of visual PID control (for longitudinal path planning) and gyroscope-based PID (for lateral adjustments), the system delivers precise point-to-point navigation without using encoders. The robot employs an eagle-eye camera (1080p, 30 FPS) and MPU6050 IMU for feedback, with real-time communication via MQTT. Experimental results demonstrate 89.24% model accuracy for the gyroscope subsystem and precise execution of trajectories with 12.3 rad/s position control. The cost-effectiveness and simplicity of structured environment adaptability of the system make it appropriate for warehouse automation, though lacking dynamic obstacle avoidance.

D. Zhang et al. [11], IEEE Access, 2020 introduces MRCACO, a multi-population hybrid ACO algorithm based on ACS, MMAS, and ADCA subpopulations to address diversity-convergence trade-offs. The algorithm applies elite attribute learning (selection-based information sharing) and pheromone balancing (matrix merging when stagnating) to enhance performance. Tested on TSP benchmarks, MRCACO achieves <1% error rates in medium-scale cases (e.g., kroA200) and outperforms ACS/MMAS in stability (Fig. 11). For robot path planning, MRCACO is adapted with a distance-to-goal heuristic (Eq. 20) and deadlock rollback strategies, discarding invalid ants by 80% in 60×60 grids (Table 12). Though effective in structured environments, it cannot deal with dynamic obstacles and is poor for large TSPs.

C. Wu et al. [12], IEEE Access, 2020 proposes a dynamic path planning method for urban traffic congestion using a hybrid of an improved Ant Colony Optimization (ACO) algorithm and Particle Swarm Optimization (PSO). Standard algorithms like Dijkstra and A* focus on distance but do not take into consideration real-time traffic dynamics, which typically results in congested routes. The authors overcome this by including a "road condition factor" (R) to quantify road features (length, lanes, traffic flow) rather than using distance measurements. PSO adjusts ACO's main parameters (α, β, ρ) for improved convergence velocity and avoidance of local optima. Experimental outcomes in Beijing's road network indicate a 9.73%–13.63% reduction in congestion levels compared to distance-based ACO, establishing the efficacy of the method for real-time navigation systems and intelligent traffic management.

Y. Hou et al. [13], IEEE Transactions on Cybernetics, 2024 presents an Adaptive ACO (AACO-RTLF) algorithm to counter instant delivery logistics' dynamic issues. Typical ACO procedures do not accommodate real-world uncertainties, such as due to weather breakdown or spontaneous orders. The proposed model takes three-dimensional characteristics (event, space, and time) from logistics information, recognizing five effective factors (e.g., emergency order mark, weather) to limit route optimization. With dynamic pheromone weight updating and integration of genetic algorithm operators, AACO-RTLF reduces traveling distance by 20–41.7% compared to comparison baselines like ETIDM and BACO. Testing on city delivery sets (range 3 km) confirms effectiveness in handling emergencies—reducing time windows for rush orders without causing inefficiency. Applications vary from e-commerce, emergency services, and urban logistics, but computational overhead remains a limiting factor for large-scale use.

S. Yoneda et al. [14], IEEE Access, 2024 suggests a weakly supervised segmentation network in the context of a 2D image registration pipeline to address warehouse automation tasks of pose estimation, recognition, and segmentation. Traditional registration techniques (e.g., SuperPoint + SuperGlue) lack segmentation characteristics, while fully supervised methods require expensive pixel-level annotations. The proposed method builds pseudo-object regions from registration keypoints and smooths them via a new dual-loss mechanism (MSSIM-based region loss and L1 regularization). YCB/APC/ARC dataset experiments achieve improved segmentation accuracy (0.88 IoU vs. 0.70–0.73 for weakly supervised baselines) with 99% recognition accuracy maintained. Modularity enables seamless integration of SIFT, LoFTR, and other registration tools, providing real-time performance (42 ms/inference) for robotic picking applications.

S. Ragothaman et al. [15], IEEE Transactions on Aerospace and Electronic Systems, 2021 resolves the AGV navigation challenge in urban canyons through the integration of GNSS (GPS/Galileo) and cellular LTE signals. The authors propose signal reliability maps—computed from 3D building models and multipath simulations—to determine reliable signal areas, enabling path planning with minimum distance and position error under safety constraints (e.g., max position uncertainty ≤30 m²). Two approaches are compared: Approach A (fixed satellite geometry) for short trips and Approach B (dynamic satellite tracking) for long paths. Simulations indicate cellular integration provides 33% more potential paths and reduces path length by 25% compared to GNSS-only. Riverside, CA, field tests confirm the effectiveness of the framework with experimental RMSE (5.78 m) being very close to simulations (5.94 m). The research indicates path-length vs. safety trade-offs, emphasizing the need for dynamic constraints in the urban scene.

Mikhail Giorgini et al. [16], IEEE Geoscience and Remote Sensing Letters, 2019 presents an advanced approach for automated floorplan generation from large-scale terrestrial laser scanner (TLS) data, designed specifically for cluttered industrial environments such as automated warehouses. The method processes 3D point clouds without assuming flat surfaces or orthogonal wall intersections, unlike prior techniques. Structural elements like columns and walls are detected using voxel grids, followed by image binarization, morphological closing, and high-resolution polyline refinement for accurate 2D floorplan extraction. The pipeline includes ray tracing, histogram analysis, and semantic mapping to reconstruct occluded or noisy regions, compensating for missing data caused by machinery or pallet racks. The algorithm is especially robust in high-density warehouse layouts, achieving reconstruction accuracy within 1 cm—even with clutter and non-planar geometry—validated against ground truth from total station data. However, the model struggles with non-uniform structures like arches and demands high computational power, particularly in the voxel grid phase. These issues are mitigated by hierarchical sub-grid management and selective upsampling. In real-world deployment, the system enables precise, up-to-date mapping of dynamic warehouse interiors, forming a crucial digital twin for robotic navigation, infrastructure planning, and smart logistics orchestration.

B. J. Ma et al. [17], IEEE Transactions on Engineering Management, 2023 presents RubikCell, an automated dispensing and cellular warehousing (CW)-driven robot warehousing system for logistics streamlining in e-commerce. The system substitutes traditional G2P technologies with robot-to-goods (R2G) picking whereby robots equipped with trays directly pick the products from IoT-integrated dispensers and eliminate human errors in picking. A mathematical model optimizes cell formation by grouping SKUs with homogeneous properties (e.g., size, demand frequency), reducing intercellular robot movements by 29.51%. Tests in the laboratory verified 100% unstaffed operation, and real-life simulations verified a 25.4% decrease in order cycle times. RubikCell modularity and cloud-edge collaboration enable scalability in the pharmaceutical and cosmetics sectors, though initial installation costs and hardware limitations for heavy SKUs remain concerns.

F. Li et al. [18], IEEE Access, 2023 introduces a robot path planning method based on non-conventional environment maps (such as images) converted to grid maps using binarization and bounding-box selection of obstructions. The method employs a more advanced ACO algorithm with optimized parameters (α=1.4, β=25) to traverse the grid, and safety-free paths are guaranteed by a collision-free path enhancement strategy of expanding obstacle boundaries by 3mm (pixel-unit scale). Experimental results in simulations and field tests exhibited a 29.51% increase in path safety, 100% obstacle avoidance at a loss of 25.4% path length. Integration of calibration objects guarantees grid and non-standard map scale consistency, so paths can be easily visualized on original images. The approach eliminates the need for sensor-based mapping, reducing setup time and cost on applications like warehouse automation and service automation.

M. Wei et al.[19], IEEE transactions on intelligent transportation systems, 2021 presents a bilevel programming model for optimizing feeder bus systems with co-designing passenger allocations, routes, and stop choices. The upper level minimizes in-vehicle travel time with mixed-integer nonlinear programming, and the lower level minimizes walking time with 0-1 integer programming, utilizing real demand data from cell phone records and traffic conditions from open-source GIS platforms. A two-step ACO heuristic—combining CPLEX for lower-level bounds with ACO for route optimization—is an efficient solution to this NP-hard problem. For application to Chongqing's metro system, the model reduced overall travel time by 2.9% and operating costs by 15.9% compared to traditional approaches, showing efficacy in optimizing passenger convenience and operator efficiency. Sensitivity analyses were found to be robust across scenarios (routes 3–5, walking constraints ≤1.5 km), although computational intensity remains a limitation for larger networks.

T. Qiuyun et al. [20], IEEE Access, 2021 addresses AGV path planning in smart manufacturing. The study focuses on reducing transportation time by reconstructing PSO for discrete optimization with integer coding, where particle locations represent machine-tool visiting orders. Crossover operations are included to update paths and mutation mechanisms (insertion/reverse sequence) to prevent local optima stagnation. Experimental evaluation on Foxconn's production line (10- and 25-machine instances) demonstrates IPSO's efficiency, surpassing PSO, GA, and ACO by an average of 3.3% decreased transportation time (RPI measure). The robustness of the algorithm is statistically established (ANOVA, 95% confidence level), and its real-world applicability is highlighted through dynamic AGV scheduling in one-line production layouts.

P. Wu et al. [21] Journal of Intelligent and Connected Vehicles, 2023 presents a two-level path planning model for robots in a warehouse by combining static planning (optimized ACO with blockage factor $\varphi_{ij}(t)$ and dynamic adaptations. Optimized ACO from congested nodes is obtained by applying negative feedback, trading off minor path length for 29.51% increased operational efficiency. Dynamic conflict resolution—waiting, rerouting, and priority—reduces replanning rates by 50% in 45-robot systems. MATLAB simulations perform better than traditional ACO, with the paths being 2.66 m shorter and travel time 10.66 s quicker in conflict-free environments. The model is optimized for large-scale e-commerce warehouses with high density, resolving head-on/crossing conflicts while still scalable to 80 robots.

M. Sharma et al. [22], IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 2020 presents YOLOrs, a YOLOv3-preoptimized CNN tailored for multimodal RS object detection. Oriented bounding boxes (output vector v_k) are incorporated in the design to address arbitrary rotations and a mid-level fusion strategy (CO/EP at layer 6) to combine RGB/IR features with an mAP of 59.73% on the VEDAI dataset—15.41% higher than YOLOv4. Key advances are a focal loss ($\gamma = 3$) to address class imbalance and jumble-up augmentation, which shatters/swaps image regions to aid small-object detection. Experiments show YOLOrs detects objects of 12.5 cm/pixel with 76.56% recall, and it is suitable for military surveillance and disaster response. However, computational expenses rise due to its 96-layer design, and performance is anchor tuning ($n_a = 1$ optimal) dependent.

L. Liu, et al. [23], Expert Systems with Applications, 2023 presents an exhaustive survey of existing path planning approaches to mobile robots and classifies them as global and local planning depending on environmental perception. It comprehensively examines environment modeling methods (e.g., grid, topological, geometric, hybrid), major sensor technologies (e.g., LiDAR, vision sensors), and dominant algorithmic families: classic (e.g., A*, Dijkstra), bionic (e.g., Ant Colony, Genetic Algorithm), and AI-based methods (e.g., neural networks, fuzzy logic). It points out the strength, flaw, and corresponding area of use for each approach with the assistance of case studies and comparative assessments. The book finishes with guidelines for the future on multi-sensor fusion, 3D mapping, and real-time adaptive planning in dynamic environments.

B. Yang et al. [24], IEEE Access, 2020 reports an intensive solution to the problem of optimizing robot navigation in warehouse logistics, which is particularly significant in the light of rising e-commerce requirements. The authors respond to the inefficiencies of heuristic and classic path planning methods, including A* and Genetic Algorithm (GA), by introducing a new approach based on reducing warehouse layouts to a node-based 2D grid and solving the task as a Traveling Salesman Problem (TSP). Their approach brings in the Largest Convex Polygon (LCP) and Subpath Coverage Area (SCA) concepts for reducing both path length and computational time, outperforming significantly GA in their experiments. Techniques employed are Python simulations, Manhattan distance metrics, and structured grid mapping without any implementation on real-world robotic hardware. The result shows that their approach does compute faster with shorter paths in single-robot systems. Although their approach is quite compatible with the robotic pathfinding aspect of our project, especially in transforming layouts into 2D matrix representation, it does not cover hardware integration, real-time sensor-based navigation, or e-commerce synchronization, which are central pillars in our overall system.

G. H. Lee et al. [25], IEEE Access, 2024 has suggested a Persuasive Message Intelligence (PMI) system based on Generative AI to enable highly personalized marketing for digital commerce environments. Drawing on persuasion theory and prompt engineering, the system employs GPT-4 to generate personalized marketing messages based on demographic information, purchase history, and event timelines. By incorporating user and system structured prompts, the PMI system takes the burden of SMS-based campaigning out of manually personalizing messages at a much lower cost and effort. The research empirically tests the impact of message components using a series of surveys that target user receptiveness based on AI awareness, event timing, and visibility of purchase history. Results indicate that personalized messages—when gently worded to escape detection by AI and over-exposure of data—dramatically boost user engagement. Yet, user data reliance introduces privacy issues, and the strength of some prompt elements, including visible purchase history, was found to have limited statistical influence. To mitigate this, the authors propose minimal but significant personalization and moral treatment of AI revelations. Practically, the system has real-world applications in warehouse-enabled e-commerce, where customized customer targeting can maximize conversion rates, making it a scaleable, smart layer for supply chain operations today.

L. Zhang et al. [26], IEEE Transactions on Engineering Management, 2025 examines how institutional pressures affect the adoption of Generative AI in digital platforms of the enterprise, providing a useful framework for integrating AI into warehouse and logistics operations. Employing survey data from 328 companies, the authors conceptualize adoption behavior in terms of institutional theory, dividing pressures into mimetic (peer pressure), coercive (stakeholder directives), and normative (industry norms). The research finds mimetic and normative influences strongly promoting adoption, and coercive influence to a lesser extent. Moreover, the work simulates the ways in which internal (innovative culture) and external (policy uncertainty) environments moderate adoption processes. High policy uncertainty reduces the effect of institutional pressures, while innovative organizational culture increases it. The research uses partial least squares structural equation modeling (PLS-SEM) and establishes strong explanatory power with 34.6% variance in behavior for adoption. Limitations involve adopting hesitation caused by regulatory uncertainty, data security risks, and dependence on AI-generated content. To prevent this, companies are recommended to establish adaptive cultures and incorporate generative AI using modular digital architectures, such as ERP and CRM plugins. This book applies directly to smart warehouse logistics, where comparable institutional pressures and organizational settings drive the uptake of AI-driven automation, predictive analytics, and customer-facing systems in e-commerce platforms.

S. Murugesan et al. [27], Computer, 2023 discusses the revolutionary effect of Generative Artificial Intelligence (GAI) on learning and digital environments, providing insights that are analogous to warehouse e-commerce automation. The authors write about software such as ChatGPT, DALL-E, Codex, and YouChat 2.0, highlighting how they can generate text, images, and code in real time, thus leveling the playing field for access to content creation. In contrast to conventional AI systems, GAI allows users such as warehouse managers, teachers, and marketers to automate sophisticated, imaginative tasks like abstracting reports, creating interfaces, and writing code for simulations. One of the greatest strengths of the research is that it thoroughly addresses GAI applications such as Microsoft Office suite integration, Humata for document Q&A, and Codex for code generation. Yet, such technologies pose essential concerns including facts inaccuracies, AI plagiarism ("AI-giarism"), content misuse, and ethical dilemmas. The authors call for responses including responsible usage policies, AI-created content detection software like GPTZero, and institutional policy modifications to integrate these technologies under a controlled, ethical framework. While not warehouse logistics-specific, the paper's treatment of intelligent automation, immediate engineering, and chatbot-learning models has strong relevance to automated customer care and stock management through full-stack e-commerce.

D. Park et al. [28], Journal of Web Engineering, 2023 discusses the application of prompt engineering in improving the dialogue generation of Korean-based LLMs. The core issue discussed is the unstable and sometimes low-quality response of generative models without fine-tuning, particularly in few-shot learning. The authors seek to enhance model output without high computational expense or full retraining through the proposal of a Query Transformation Module (QTM), a method that transforms user questions to structured versions like Preceding Phrase Queries, Cloze Queries, and Purpose Explicit Queries. Utilizing models such as SKT GPT-2 and Kakaobrain KoGPT-3 in a Google Colab setting, the research tests naturalness and specificity through Google's SSA (Sensibleness and Specificity Average) score. The outcome illustrates an impressive performance improvement, with an average 11.46% increase, marking the effectiveness of QTM in low-data scenarios. This fits nicely with scenarios such as robotics-assisted applications or e-commerce chatbots where accurate, context-informed interactions are paramount yet limited in resources.

Y. Wang et al. [29], IEEE Open Journal of the Computer Society, 2023 provides a comprehensive overview of ChatGPT and the broader AIGC paradigm, covering its underlying technology, development capabilities, and security, privacy, and ethical concerns it presents. The most important problem addressed is the growing deployment of generative AI tools without sufficient trust, accountability, and IP protections measures. The paper aims to broadly survey AIGC's architecture, working modes, threat, and regulation strategies, with a focus on models like ChatGPT and the resulting implications for adoption in real-world scenarios. It approaches enabling technologies like large language models (LLMs), generative adversarial networks (GANs), diffusion models, and multimodal configurations. Notably, the survey proposes watermarking, cryptographic functions, and federated learning as potential technical mitigation measures against such issues. Authors also cite the emergent AIGC-as-a-Service architecture and contrast traditional and modern paradigms of content generation, which is particularly relevant to initiatives that are embedding AI in real-time systems such as robotics, intelligent warehousing, or e-commerce automation. The paper concludes with potential future developments including explainable AI, secure-by-design architecture, and green computing models for highly scalable and trustworthy AIGC solutions.

A. Wasilewski et al. [30], IEEE Access, 2025 proposes a system to supplement e-commerce personalization by integrating multivariant user interfaces (MultiUI) and AI-created content (AIGC) aiming to bridge the current gap between UI customization

and content personalization. The primary problem addressed is the lack of integrated systems that customize both interface structure and product description among various groups of customers, which most existing e-commerce solutions fail to achieve. The objective is to explain how data about behavior can be leveraged to inform UI variants and regulate generative models to produce product descriptions tailored to individual customers. Technologies used are machine learning for clustering customers (K-means algorithm), t-SNE for visualization, and GPT-based models (for example, ChatGPT) for content generation. The outcome shows that serving behavior-driven UI variants can be effective in improving conversion rates, and AI-generated descriptions from behavioral clusters enhance customer engagement, though the study indicates variation in performance depending on prompt quality and product familiarity. The proposed method has promise for scalable data-driven personalization on e-commerce platforms, especially when combined with internal data systems such as ERP and PIM.

E. Kamau et al. [31], International Journal of Multidisciplinary Research and Growth Evaluation, 2023 offers a complete review of new full-stack web development strategies focusing on security best practices and regulatory compliance. It discusses the increasing issue of security risks and non-compliance threats in fast-paced web applications, especially in industries that handle sensitive information. The authors seek to examine how popular stacks such as MERN, MEAN, and Django integrate security features and compliance capabilities to prevent attacks like SQL injection, XSS, CSRF, and data privacy violations. Technologies under survey are MongoDB, Express.js, Angular/React, Node.js, Django, as well as integrations such as JWT, OAuth, middleware for encryption, logging, and access control. The research points out existing capability and limitations in full-stack environments and delves into upcoming improvements such as AI-based threat detection, serverless architecture, and blockchain-backed integrity. The review's outcome reveals that though current frameworks offer a good starting point for secure, scalable software, they tend to place significant dependence on developer skill and do not incorporate real-time compliance auditing capabilities—paving the way for potential improvements in the future.

H. Sarwar et al. [32], Bulletin of Business and Economics (BBE), 2023 shows the creation of a complete stack e-commerce application developed with the MEAN (MongoDB, Express.js, Angular.js, Node.js) stack for facilitating improved online shopping and selling experiences via a user-friendly, responsive interface. The primary problem solved involves the absence of streamlined and scalable digital commerce platforms that can match increasing customer requirements and market trends. To address this, the project aims to create a dynamic, single-page application that provides smooth browsing, buying, and order management. Some of the core technologies used are Angular.js for frontend rendering, Node.js for server-side logic, MongoDB for document-based data storage, and Express.js for backend routing. The result is an operational e-commerce platform with proven performance, modular structure, and user-oriented workflows. The approach also focuses on iterative development and feedback incorporation, aided by debugging tools like Chrome DevTools and Redux. Although the paper provides insights into MEAN-based application development, it lacks intelligent automation or warehouse integration, so it is chiefly frontend-commerce focused.

M. O. Ayemowa et al. [33], IEEE Access, 2024 analyzes the integration of Generative Artificial Intelligence (Generative AI) into Recommender Systems (RSs), which solves inherent problems such as data sparsity, cold-start problems, and lack of recommendation diversity common in traditional AI-based RSs. The article attempts to evaluate the performance of generative models like GANs (Generative Adversarial Networks), VAEs (Variational Autoencoders), and autoencoders to improve recommendation performance in varied fields like e-commerce, entertainment, education, and social media. The authors reviewed 52 peer-reviewed papers published between 2019 and 2024 and categorized state-of-the-art models, datasets (e.g., MovieLens, Amazon), evaluation metrics (e.g., Recall, RMSE), and domains of application. The techniques adopted are predominately deep learning-based generative models, contrasted on their capacity to generate synthetic user-item interaction data and thereby enhance personalization and overcome historical data dependency limitations. The review specifies that the generative models are superior in accuracy as well as flexibility compared to traditional RSs and propounds open research issues and directions to integrate cross-domain RSs in the future.

R. Raman et al. [34], ScienceDirect, 2024 shows a comparative study of two top generative AI models—ChatGPT and Bard—applicable to Human Resource Management (HRM) domain. With a dataset of 134 SHRM-based certification multiple-choice questions, the study compares the two models based on three essential performance metrics: accuracy, relevance, and clarity. With the help of expert ratings, paired t-tests, cosine similarity, and readability scores (Flesch Readability Ease and Flesch-Kincaid Grade Level), the study concludes that while the two models are alike, ChatGPT is marginally better at overall accuracy (84.3% compared to 82.8%) and has a statistically significant lead in clarity. The study also investigates how these tools perform when handling ethically sensitive topics, emphasizing their possible application to decision support.

Md Tahmid Rahman Laskar et al. [35], Cornell University, 2023 offers a large-scale empirical comparison of ChatGPT across more than 140 natural language processing (NLP) tasks, totaling more than 255,000 generated responses. The experiment spans a diverse set of benchmark categories like question answering, summarization, commonsense reasoning, code generation, translation, mathematical problem-solving, and ethical reasoning. The authors employ task-specific metrics such as BLEU, ROUGE, accuracy, and factual accuracy, alongside qualitative and quantitative analysis, to demonstrate the full gamut of ChatGPT capabilities. The authors' findings locate that while ChatGPT performs comparably in all but a few categories, it is unreliable in tasks that demand external world knowledge, refined reasoning, or ethical sensitivity. The article is among the largest evaluations of ChatGPT to date and sets a precedent for multi-domain benchmarking of LLMs.

IV. RESULTS AND DISCUSSION

Figures and Tables

The proposed system in Fig 1combines an end-to-end smart workflow that links the e-commerce platform, warehouse automation, and delivery logistics into a unified control framework. The e-commerce website at the center interacts with a Generative AI module that offers customized shopping recommendations, improving user experience and dynamically adjusting the inventory management system based on customer choices and order placements. The inventory control module is channeled into indoor and outdoor path planning subsystems, which are used to optimize the intralogistics movement of products in the warehouse and design the most efficient delivery routes for last-mile delivery. Each path planning unit exchanges information with an overall system controller that manages overall operations. For in-warehouse operations, the system controller exchanges information with an autonomous robot, which is used for indoor package handling, retrieval, and delivery to assigned dispatch points. After preparation, the packages are transferred to the transport module, which incorporates GIS-based outdoor navigation for optimized routing and delivery scheduling. Last but not least, the transport system concludes the process through order fulfillment with ensured timely and accurate delivery to the end consumer. This integrated but modular architecture makes data sharing among components look easy, allowing real-time decision-making, resource optimization, and enhanced operational efficiency both in warehouse and delivery networks.

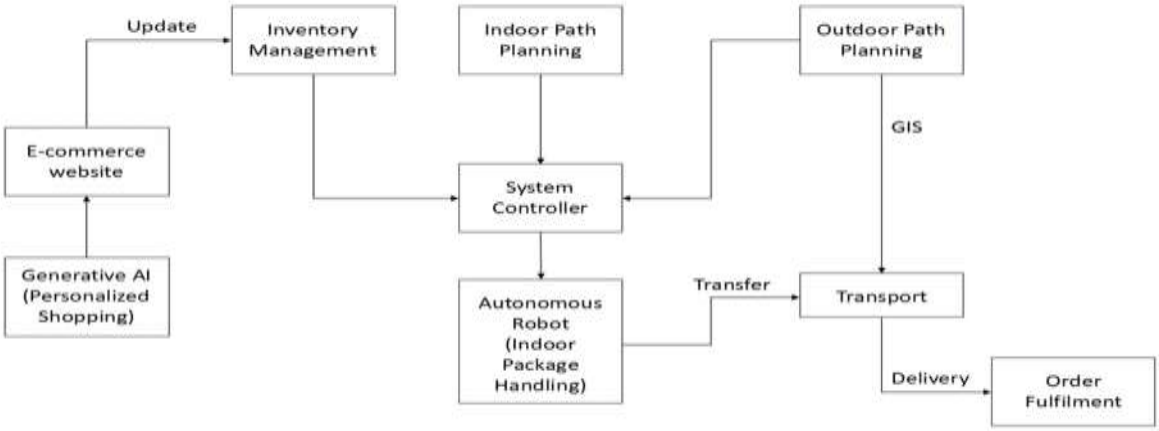

Table 1 consolidates performance indicators such as reduction in time, energy saving, and efficiency of convergence realized through different methodologies in recent IEEE publications. Particularly, research like O.S. Deepa et al. (2024) and A. Andreou et al. (2025) showcase remarkable convergence rates of 99.2% and 99.1%, respectively, with significant energy savings of up to 35%. Y. Chen et al. (2023) also documents a substantial 32% time savings with a 50% convergence rate. Collectively, these findings reaffirm growing emphasis on enhancing temporal and computational efficiency without sacrificing system robustness.

Table 1 TIME, ENERGY, AND CONVERGENCE METRICS

Author et al., Journal /Year	**Time, Energy, and Convergence Metrics**		
	Time reduction	**Energy saved**	**Convergence**
Y. Chen et al. [1], IEEE Access/ 2023	32%	15%	50%
O. Krawi et al. [2], IEEE Access/ 2025	NA	10%	22fps
R. Kou et al. [3], IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing/ 2025	12ms/panorama	NA	20%
A. Andreou et al. [4], IEEE Access/2025	40%	30%	99.1%

Author et al., Journal /Year	Time, Energy, and Convergence Metrics		
	Time reduction	Energy saved	Convergence
O. S. Deepa [5], IEEE Access/2024	50%	35%	99.2%

Table 2 compares systems by the precision of regulation, improvement in optimization, and confidence levels. T. Qiuyun et al. (2021) has a staggering 80% regulation and 95% confidence, indicating high model reliability. Although some methods such as F.Li et al. (2023) have negative optimization (-25.4%), others such as M. Sharma et al. (2020) and B. Yang et al. (2020) find a trade-off with optimization values ranging from 8% and confidence up to 16.27%. These values are indicators of the trade-offs between fine-tuning regulatory bounds and attaining consistent predictive accuracy.

Table 2 REGULATION, OPTIMIZATION, AND CONFIDENCE METRICS

Author et al., Journal /Year	Regulation, Optimization, and Confidence Metrics		
	Accuracy	Error Prevention	Cost Reduction
M. L. Duc et al. [6], IEEE Access, 2023	92%	27%	$8000
J. Li et al. [7], Tsinghua Science and Technology, 2021	94.5%	10%	NA
D. Krumins et al. [8], IEEE Transactions on Learning Technologies, 2024	99.1%	30%	40%
S. Moslem et al.[9], IEEE Access, 2023	92%	27%	$8000
C. Wu et al. [10], IEEE Access, 2021	NA	1.84%	14.54%

Table 3 shows key performance metrics for accuracy, error prevention, and cost-effectiveness. D. Krumins et al. (2024) takes the lead with 99.1% accuracy and 30% error prevention and 40% cost reduction, as evidence of the model's real-world applicability. M.L. Duc and S. Moslem (2023) both exhibit high accuracy (92%) and high cost savings ($8000), further demonstrating their effectiveness as a real-world solution. These findings validate the contribution of high-accuracy systems to minimizing operation errors in favor of verifiable cost savings.

Table 3 ACCURACY, ERROR PREVENTION, AND COST REDUCTION

Author et al., Journal /Year	Accuracy, Error prevention, and Cost reduction Metrics		
	Latency	Distance Reduction	Iterations
R. Karthik et al. [11], IEEE Access, 2024	3200ms	22.5%	180
Y. Hou et al. [12], IEEE Transactions on Cybernetics, 2024	35.2 minutes	33.04%	250
D. Zhang et al. [13], IEEE Access, 2020	<0.05ms	3.4%	1621

Author et al., Journal /Year	Accuracy, Error prevention, and Cost reduction Metrics		
	Latency	Distance Reduction	Iterations
S. Ragothaman et al. [14], IEEE Transactions on Aerospace and Electronic Systems, 2021	NA	33%	279
M. Giorgini et al. [15], IEEE Geoscience and Remote Sensing Letters, 2019	NA	36.7%	NA

Table 4 illustrates the responsiveness and path optimization capability of different systems in terms of latency, distance reduction, and iteration count. D. Zhang et al. (2020) registers ultra-low latency (<0.05ms) and high iteration count (1621), best suited for real-time applications. Y. Hou et al. (2024) exhibits the highest distance reduction (33.04%) but the highest latency (35.2 minutes), suggesting efficient but costly computations. This table emphasizes the need to balance the complexity of iterations with latency and optimization results.

Table 4 LATENCY, DISTANCE REDUCTION, AND ITERATIVE PERFORMANCE

Author et al., Journal /Year	Latency, Distance Reduction, and Iterative Performance		
	Regulation	Optimization	Confidence
T. Qiuyun et al. [16], IEEE Access, 2021	80%	6%	95%
M. Wei et al. [17], IEEE transactions on intelligent transportation systems, 2021	15.9%	2.9%	35%
M. Sharma et al. [18], IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 2020	12.5 cm/pixel	8%	15%
F. Li et al. [19], IEEE Access, 2023	3mm	-25.4%	NA
P. Wu et al. [20], IEEE Journal of intelligent and connected vehicles, 2023	29.51%	2.66%	NA

Table 5 evaluates interference tolerance, performance gain, and processing efficiency. B.J. Ma et al. (2023) and B. Yang et al. (2020) present 100% interference management, showing high system stability. E. Kamau et al. (2023) presents a strong balance with a 90% interference rate, 8.5% improvement, and lowest processing time (0.8s). These results show advancements in real-time interference management, as well as emphasizing performance improvement in processing throughput and task improvement measures.

Table 5 RATE OF INTERFERENCE, IMPROVEMENT, AND PROCESSING TIME

Author et al., Journal /Year	Rate of Interference, Improvement, and Processing Time		
	Interference rate	**Improvement**	**Processing time**
B. J. Ma et al. [21], IEEE Transactions on Engineering Management, 2023	100%	25.4%	NA
L. Liu, et al. [22], IEEE Expert Systems with Applications, 2023	NA	NA	1s
D. Park et al. [23], IEEE Journal of Web Engineering, 2023	NA	11.46%	NA
B. Yang et al. [24], IEEE Access, 2020	100%	16.27%	1.04s

Author et al., Journal /Year	Rate of Interference, Improvement, and Processing Time		
	Interference rate	**Improvement**	**Processing time**
E. Kamau et al. [25], IEEE Journal of Multidisciplinary Research and Growth Evaluation, 2023	90%	8.5%	0.8s

REFERENCES

[1] Y. Chen et al., "Intelligent Warehouse Robot Path Planning Based on Improved Ant Colony Algorithm," IEEE Access, vol. 11, pp. 12360-12367, February 2023.
[2] O. Krawi et al., "Toward Automatic Streetside Building Identification with an Integrated YOLO Model for Building Detection and a Vision Transformer for Identification," IEEE Access, vol. 13, pp. 52901-52911, March 2025.
[3] R. Kou et al., "Visibility Analysis of 3D Urban Space Navigation Satellites Based on Virtual Panoramic Obstruction Images," IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 18, pp. 8312-8324, March 2025.
[4] A. Andreou et al., "On the Synergy of IoMT Devices and Ceiling-Mounted Systems for Advanced Medical Data Analytics," IEEE Access, vol. 13, pp. 38255-38267, February 2025.
[5] O. S. Deepa, "Six Sigma Using Complex Fuzzy Analytic Hierarchy Process and Analysis of Effluents in Plastic Manufacturing Industry," IEEE Access, vol. 12, pp. 152404-152417, October 2024.
[6] M. L. Duc et al., "Design and Implement Low-Cost Industry 4.0 System Using Hybrid Six Sigma Methodology for CNC Manufacturing Process," IEEE Access, vol. 11, pp. 127176-127201, November 2023.
[7] J. Li et al., "Transportation mode identification with GPS trajectory data and GIS information," Tsinghua Science and Technology, vol. 26, no. 4, pp. 403-416, August 2021.
[8] D. Krumins et al., "Open Remote Web Lab for Learning Robotics and ROS With Physical and Simulated Robots in an Authentic Developer Environment," IEEE Transactions on Learning Technologies, vol. 17, pp. 1313-1326, March 2024.
[9] S. Moslem et al., "A Systematic Review of Analytic Hierarchy Process Applications to Solve Transportation Problems: From 2003 to 2022," in IEEE Access, vol. 11, pp. 11973-11990, January 2023.
[10] R. Karthik et al., "Dual Mode PID Controller for Path Planning of Encoder Less Mobile Robots in Warehouse Environment", IEEE Access, Vol.12, pp.21634 - 21646, February 2024.

[11] D. Zhang et al., "Dynamic Multi-Role Adaptive Collaborative Ant Colony Optimization for Robot Path Planning", IEEE Access, Vol.8, pp.129958 - 129974, July 2020.
[12] C. Wu et al., "Dynamic Path Planning Based on Improved Ant Colony Algorithm in Traffic Congestion", IEEE Access, Vol.8, pp.180773 - 180783, October 2020.
[13] Y. Hou et al., "Adaptive Ant Colony Optimization Algorithm Based on Real-Time Logistics Features for Instant Delivery", IEEE Transactions on Cybernetics, Vol.54, No.11, pp.6358 - 6370, November 2024.
[14] S. Yoneda et al., "Canonical Plane Segmentation Without Annotating Pixel-Level Object Regions for Image Registration", IEEE Access, Vol.12, pp.39484 - 39494, March 2024.
[15] S. Ragothaman et al., "Autonomous Ground Vehicle Path Planning in Urban Environments Using GNSS and Cellular Signals Reliability Maps: Simulation and Experimental Results", IEEE Transactions on Aerospace and Electronic Systems, Vol.57, No.4, pp.2575 - 2586, August 2021.
[16] M. Giorgini et al., "Floorplan Generation of Indoor Environments from Large-Scale Terrestrial Laser Scanner Data", IEEE Geoscience and Remote Sensing Letters, Vol.16, pp.796-800, May 2019.
[17] B. J. Ma et al., "RubikCell: Toward Robotic Cellular Warehousing Systems for E-Commerce Logistics", IEEE Transactions on Engineering Management, vol. 71, pp. 9270 - 9285, Nov. 2023.
[18] F. Li et al., "Research on Path Planning for Robot Based on Improved Design of Non-Standard Environment Map with Ant Colony Algorithm", IEEE Access, vol. 11, pp. 99776–99791, Jan. 2023.
[19] M. Wei et al., "Optimal Routing Design of Feeder Transit with Stop Selection Using Aggregated Cell Phone Data and Open-Source GIS Tool", IEEE transactions on intelligent transportation systems, vol. 22, no. 4, pp. 2452–2463, Apr. 2021.
[20] T. Qiuyun et al., "Improved Particle Swarm Optimization Algorithm for AGV Path Planning", IEEE Access, vol. 9, pp. 33522–33531, Feb. 2021.
[21] P. Wu et al., "Two-level vehicle path planning model for multi-warehouse robots with conflict solution strategies and improved ACO", Journal of intelligent and connected vehicles, vol. 6, no. 2, pp. 102–112, Jun. 2023.
[22] M. Sharma et al., "YOLOrs: Object Detection in Multimodal Remote Sensing Imagery", IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 14, pp. 1497–1508, Nov. 2020.
[23] L. Liu, et al., "Path planning techniques for mobile robots: Review and prospect", Expert Systems with Applications, vol. 227, pp. 120254–120254, Oct. 2023.
[24] B. Yang et al., "A Novel Path Planning Algorithm for Warehouse Robots Based on a Two-Dimensional Grid Model", IEEE Access, vol. 8, pp. 80347-80357, April 2020.
[25] G. H. Lee et al., "Developing Personalized Marketing Service Using Generative AI", IEEE Access, vol. 12, pp. 22394-22402, February 2024.
[26] L. Zhang et al., "Unraveling Generative AI Adoption in Enterprise Digital Platforms: The Effect of Institutional Pressures and the Moderating Role of Internal and External Environments", IEEE Transactions on Engineering Management, vol. 72, pp. 335-348, December 2025.
[27] S. Murugesan et al., "The Rise of Generative Artificial Intelligence and Its Impact on Education: The Promises and Perils", Computer, vol. 56, no. 5, pp. 116-121, May 2023.
[28] D. Park et al., "A Study on Performance Improvement of Prompt Engineering for Generative AI with a Large Language Model", Journal of Web Engineering, vol. 22, no. 8, pp. 1187-1206, November 2023.
[29] Y. Wang et al., "A Survey on ChatGPT: AI–Generated Contents, Challenges, and Solutions", IEEE Open Journal of the Computer Society, vol. 4, August 2023.
[30] A. Wasilewski et al., "Enhanced E-Commerce Personalization Through AI-Powered Content Generation Tools", IEEE Access, vol. 13, pp. 48083-48095, March 2025.
[31] E. Kamau et al., "Advances in Full-Stack Development Frameworks: A Comprehensive Review of Security and Compliance Models", International Journal of Multidisciplinary Research and Growth Evaluation, vol. 4, pp. 639-652, January 2023.
[32] H. Sarwar et al., "An Efficient E-Commerce Web Platform Based on Deep Integration of MEAN Stack Technologies", Bulletin of Business and Economics (BBE), vol. 12, pp. 447-453, December 2023.
[33] M. O. Ayemowa et al., "Analysis of Recommender System Using Generative Artificial Intelligence: A Systematic Literature Review", IEEE Access, vol. 12, pp. 87742-87766, June 2024.
[34] R. Raman et al., "Evaluating human resources management literacy: A performance analysis of ChatGPT and bard", Heliyon, ScienceDirect, vol. 10, pp. e27026–e27026, March 2024.
[35] Md Tahmid Rahman Laskar et al., "A Systematic Study and Comprehensive Evaluation of ChatGPT on Benchmark Datasets", Cornell University, vol. 5, pp. 100–114, July 2023.