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Digital twin-based cyber-physical manufacturing systems, extended reality metaverse enterprise and production management algorithms, and Internet of Things financial and labor market technologies in generative artificial intelligence economics

JEL Classification: *E42; J33; O14*

Keywords: *generative artificial intelligence economics; fintech; labor market; metaverse enterprise; production management; cyber-physical manufacturing*

Abstract

Research background: Generative artificial intelligence (AI) and machine learning algorithms support industrial Internet of Things (IoT)-based big data and enterprise asset management in multiphysics simulation environments by industrial big data processing, modeling, and monitoring, enabling business organizational and managerial practices. Machine learning-based decision support and edge generative AI sensing systems can reduce persistent labor shortages and job vacancies and power productivity growth and labor market dynamics, shaping career pathways and facilitating occupational transitions by skill gap identification and labor-intensive manufacturing job automation by path planning and spatial cognition algorithms, furthering theoretical implications for management sciences. Generative AI fintech, machine learning algorithms, and behavioral analytics can assist multi-layered payment and transaction processing screening with regard to authorized push payment, account takeover, and synthetic identity frauds, flagging suspicious activities and combating economic crimes by rigorous verification processes.

Purpose of the article: We show that edge device management functionalities of cloud industrial IoT and virtual robotic simulation technologies configure plant production and route planning processes across cyber-physical production and industrial automation systems in multi-cloud immersive 3D environments, leading to tangible business outcomes by reinforcement learning and convolutional neural networks. Labor-augmenting automation and generative AI technologies can impact employment participation, increase wage and wealth inequality, and lead to potential job displacement and massive labor market disruptions. The deep learning capabilities of generative AI fintech in terms of adaptive behavioral analytics and credit scoring mechanisms can enhance financial transaction behaviors and algorithmic trading returns, identify fraudulent payment transactions swiftly, and improve financial forecasts, leading to customized investment recommendations and well-informed financial decisions.

Methods: Machine learning-based study selection process and text mining systematic review management software and tools leveraged include Abstrackr, CADIMA, Colandr, DistillerSR, EPPI-Reviewer, JBI SUMARI, METAGEAR package for R, SluRp, and SWIFT-Active Screener. Such reference management systems are harnessed for methodologically rigorous evidence synthesis, study selection and characteristic extraction, predictive document classification, machine learning-based citation and record screening, bias assessment, article retrieval automation, and document classification and prioritization.

Findings & value added: Industrial IoT and 3D augmented reality technologies can create business value by streamlining virtual product and remote asset management across extended reality-based navigation and robotic autonomous systems in smart factory environments by generative AI and machine learning algorithms, articulating business organizational level and theory of management implications. 3D simulation and operational modeling tools can execute and complete complex cognitive task-oriented and knowledge economy jobs, producing first-rate quality outputs swiftly while leading to unemployment spells, labor market disruptions, job displacement losses, and reduced earnings by machine learning clustering and spatial cognition algorithms. Generative AI decentralized finance, interoperable blockchain networks, cash flow management tools, and asset tokenization can mitigate fraud risks, enable digital fund and crypto investing servicing, and automate treasury operations by integrating real-time payment capabilities, routing and configurable workflows, and lending and payment technologies.

Introduction

In this paper, we aim to cover cloud-based digital twin sustainable manufacturing and cyber-physical production systems, Internet of Things (IoT)-based sensor and automatic data capture technologies, and immersive 3D blockchain-based fintech operations in generative artificial intelligence (AI) economics, filling the empirical research gap on digital twin-based cyber-physical manufacturing systems, extended reality metaverse enterprise and production management algorithms, and Internet of Things financial and labor market technologies, while also bringing about managerial and organizational challenges clarified and developed throughout our research, together with state of the art weaknesses, negative consequences, and new value added.

Generative AI and machine learning algorithms support industrial IoT-based big data and enterprise asset management in multiphysics simulation environments by industrial big data processing, modeling, and monitoring. Multi-dimensional analysis of cyber-physical system-based adaptive production scheduling for economically viable smart robotic factories indicates that digital twin industrial and time series forecasting systems influence work order planning operations in supply chain management. Deep neural network, computer vision, and random forest algorithms can be harnessed for automated object detection, identification, classification, monitoring, and tracking for smart factory digital twin and cyber-physical production systems, while generative AI digital twin manufacturing develops on production network modeling, discrete event simulation, and 3D asset tracking by cloud and edge computing capabilities for reconfigurable

manufacturing systems in deep learning-enabled digital twin-based shop floor intelligent process planning and manufacturing.

IoT remote asset condition monitoring systems can decrease machine downtime and operational maintenance costs while assessing connected equipment condition by sensor fusion and perception and robotic motion planning algorithms. Multimodal generative AI and machine vision technologies can reduce error rates by 3D obstacle detection mapping and real-time asset tracking in immersive simulated environments. Smart consistent unified data fabric-based integrated generative AI-driven decision intelligence and real-time predictive analytics can reduce operational costs and optimize business value. Cloud technology and business intelligence capabilities can optimize logistics operation flexibility, scalability, adaptability, resilience, performance, sustainability, and efficiency with regard to route planning processes by embedded computing and natural language processing systems. Brain-inspired cognitive architecture of scalable autonomous robotic path and motion planning necessitates vision-based soft tactile sensing by multi-sensory tracking technologies, driving business value creation.

Organizations can scale AI cognitive automation capabilities by deploying deep reinforcement learning and computer vision algorithms, while 3D ultrasonic sensors can be harnessed for autonomous mobile robots in industrial manufacturing, logistics, and automation by use of generative AI and machine perception systems. Performance management and process automation tools are pivotal in historical data pattern-based manufacturing event forecasting. IoT-based sensor and automatic data capture technologies can be deployed for shop floor productivity and workflow efficiency, delivering tangible business results. Production schedules, planned maintenance, and industrial equipment and fault history monitoring across virtual 3D scenes integrate digital twin and virtual augmentation technologies, resulting in business and economic applications.

Labor-augmenting automation and generative AI technologies can impact employment participation, increase wage and wealth inequality, and lead to potential job displacement and massive labor market disruptions. Machine vision and autonomous cognitive systems can speed up employee–job matching across both value-intensive jobs and distilled workforce, reduce labor costs and turnover, and assist productive staff and career trajectories in the dynamic job market, while exacerbating labor shortages. Haptic augmented reality and virtual production process systems can as-

sess employee trust and engagement, redesigning work processes, sustained engagement, performance, efficiency, and productivity, professional development, and career paths and mobility, while shaping widespread job displacement by generative AI and employee development planning tools.

Generative AI decentralized finance, interoperable blockchain networks, cash flow management tools, and asset tokenization can mitigate fraud risks, enable digital fund and crypto investing servicing, and automate treasury operations by integrating real-time payment capabilities, routing and configurable workflows, and lending and payment technologies. Financial market agent interaction simulation modeling in AI synthetic data generation processes develop on reinforcement learning, forecasting, and trading algorithms, while generative adversarial and convolutional recurrent neural networks, together with machine and deep learning techniques, are leveraged for fraudulent transaction detection.

3D computer visualization and image data augmentation techniques configure immersive 3D blockchain-based fintech operations. Flexible control spending, consumer transaction patterns, and multi-currency digital wallet services require cloud-based payment and distributed ledger technologies and recurring bill payment automation and credit decisioning tools. Deep learning artificial neural networks and cloud computing technologies can identify fraudulent behavior, being pivotal in unauthorized and illicit financial operation, prevention, and detection. Machine learning techniques and credit assessing algorithms can optimize borrower screening effectiveness, credit-scoring computational practices, loan prediction performance, and approved loan applications.

Methods

Machine learning-based study selection process and text mining systematic review management software and tools leveraged include Abstrackr (for literature search result organization, collaborative citation screening semi-automation, and methodologically rigorous evidence synthesis), CADIMA (for primary research identification, collection, assessment, synthesis, and summarization, study selection and characteristic extraction, automated duplicate removal, evidence-based decision making support, literature search structuring and documentation, and methodological rigor maximization), Colandr (for predictive document classification, natural language

processing, machine learning-based text-based evidence synthesis, smart citation sorting, and metadata screening and extraction), DistillerSR (for machine learning-based citation and record screening, available evidence synthesis, and article classification and analysis), EPPI-Reviewer (for data extraction, clustering, classification, and synthesis, study identification, citation screening semi-automation and tracking, evidence mapping and synthesis, bias assessment, and workflow planning), JBI SUMARI (for study quality assessment and selection, critical evidence appraisal and synthesis, and error and bias risk reduction), METAGEAR package for R (for study data location and extraction, article retrieval automation, text mining, research result identification, critical analysis, and collation), SluRp (for data aggregation, mining, extraction, processing, clustering, categorization, classification, monitoring, tracking, and analysis), and SWIFT-Active Screener (for document classification and prioritization, reference full text, title, and abstract screening, and active learning and recall estimation-based evidence mapping).

We followed Andronie *et al.* (2023a) and Lăzăroiu *et al.* (2023) with regard to deployed quality tools in article selection by focusing on study design, eligibility criteria, and citation screening, machine learning-based data collection, text mining, triage literature management, and duplicate detection and removal. By filtering out the most relevant sources, cumulative research value is attained.

Big data-driven generative industrial AI algorithms in immersive 3D virtual machine environments

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Dynamic capabilities of generative AI system architecture planning (Andronie *et al.*, 2021; Lăzăroiu *et al.*, 2022; Nagy & Lăzăroiu, 2022) can create and reshape business value by use of computer vision and predictive machine learning algorithms. Cognitive digital twin and industrial automation technologies can be harnessed in production process flexible control and smart shop floor management with regard to anomaly detection across digital twin manufacturing and robotic simulation systems in smart factories. Fault diagnosis and monitoring, production progress prediction, manufacturing enterprise transformation, interactive task execution, and synthetic object recognition depend on computer vision-based digital twin modeling on flexible manufacturing lines by machine learning and swarm robotic algorithms. Generative AI-powered virtual twin and multiphysics simulation technologies enable collaborative product engineering across IoT sensor-based connected machines, producing industry-centric business value by integrating remote sensing images and IoT industrial data in Industry 5.0 manufacturing and motion simulation systems. Enterprise data and machine learning predictive analytics can enable industrial enterprise data processing, visualization, monitoring, and analysis across industrial IoT and production planning operations for connected business intelligence product performance by edge computing and cognitive modeling technologies for Internet of Robotic Things sensor data analysis. Cloud-assisted mobile edge computing image devices can detect equipment abnormalities and machine failures, being pivotal in smart connected product inspection, remote asset condition and device management and monitoring, and object detection in autonomous navigation and visual perceptive systems. The machine learning and predictive maintenance capabilities of cloud-based connected device and remote condition monitoring tools are instrumental in operational performance and enterprise scalability modeling, reducing machine downtime and leading to measurable business results by image recognition and robot motion algorithms, and thus driving business value creation.

The economic and business management of synthetic forecast and deep neural network computer vision algorithms (Andronie *et al.*, 2023a; Nagy *et al.*, 2023; Pelău *et al.*, 2021) is instrumental in real-time machine status and manufacturing process monitoring, resource monitoring and controlling, and smart factory planning process virtualization in cyber-physical production and virtual robotic-assisted manufacturing systems by integrating photorealistic synthetic and virtual factory digital twin data.

Cloud and edge computing technologies support supply chain disruption prediction and digital twin-based unpredictable and complex event navigation in machine vision and distributed autonomous robotic systems. Swarm robotic and visual object tracking algorithms can streamline and monitor production processes and automated infrastructure management in sustainable and circular manufacturing across virtual machine environments and haptic object recognition and computer vision AI systems. Heat and motion sensors can be deployed for digital productivity tracking and monitoring in flexible work environments by generative AI and virtual reality-based visual perception technologies. Predictive business process monitoring and augmented knowledge management tools enable multi-chain asset and ontology-based semantic interoperability and real-time sensor data sharing and analysis, configuring scalable cloud-based simulation processes by predictive and generative AI technologies in connected manufacturing enterprises across immersive 3D environments. Industry 4.0 businesses can achieve sustainable productivity gains and organizational management, together with financial performance and business growth, by harnessing business analytics modeling and simulation tools, resulting in business and economic applications.

Multi-enterprise supply chain and generative AI technologies (Andronie *et al.*, 2023b; Nagy & Lăzăroiu, 2022; Valaskova *et al.*, 2022) can streamline maintenance planning and workflow productivity, elevate business collaboration, and bolster asset and equipment reliability with regard to failures and repairs by cloud-based product lifecycle management tools across immersive virtual product development processes. Machine learning-based demand forecasting and predictive visual analytics-driven enterprise resource planning assist creative and productive business process and workflow redesigning, driving tangible business outcomes and competitive advantage, and leading to generative AI manufacturing productivity growth by supporting organizational structures while harnessing deep learning and visual object tracking algorithms. Critical performance and data-driven product development processes can update maintenance quality and optimal path management by manufacturing network performance monitoring and robotic process automation tools, unlocking massive productivity gains by use of intelligent manufacturing-based collaborative robots, while deploying edge and cloud computing technologies. 3D simulation and modeling technologies can enable business process and decision automation and augmentation across industrial automation networks and

smart interconnected shop floors by machine simulation and reinforcement learning algorithms. Context modeling and cloud-based business intelligence tools optimize data-driven business process and IoT edge device management, manufacturing data scalability and interoperability, and managerial and operational business value by 3D path planning and swarm robotic algorithms. Virtual and augmented reality technologies further industrial data management across cloud-based manufacturing execution and machine vision-based sensing systems in virtual manufacturing plants and cognitive industrial IoT environments. Industrial robotic and business automation technologies streamline manufacturing and production operations in asset performance monitoring and tracking systems across 3D virtual reality environments.

Industrial generative AI of Things in enterprise business and virtual manufacturing processes

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Collaborative intelligence and bio-inspired computation tools can be harnessed in IoT process manufacturing across industrial robotic environments (Andronie *et al.*, 2021; Nagy *et al.*, 2023; Valaskova *et al.*, 2022), optimizing industrial enterprise operation management in industrial generative AI and event-based vision processing systems and leading to business performance and productivity. IoT edge device management capabilities of virtual immersive and machine intelligence technologies can shape asset performance and product life cycle management, industrial asset data acquisition and analysis, and generative AI and machine learning-based high productivity gains in industrial control and manufacturing execution systems. Manufacturing automation and augmented reality-based industrial management technologies can be deployed in industrial enterprise operation augmentation across wireless-powered edge and fog computing industrial cyber-physical production systems in asset-intensive businesses and industries. 3D image modeling and ambient intelligence tools can be

leveraged in organizational business proposition design and execution of IoT-based industrial management and dynamically reconfigurable big data-driven manufacturing systems across virtual industrial enterprises. Organizational operational structures in factory floor employee behavior and real-time process data monitoring develop on augmented digital twin data, manufacturing task scheduling, cloud-based machine control, machine failure diagnosis and classification, and factory space and resource allocation by 3D computer vision-based production and immersive virtual reality technologies, driving business value creation.

The economic and business management of industrial generative AI of Things integrates machine movement controlling, cognitive robotic process and maintenance task automation, and process fault detection (Andronie *et al.*, 2023a; Lăzăroiu *et al.*, 2022; Nagy & Lăzăroiu, 2022), supporting automated quality inspection and production scheduling for intelligent machinery in smart industrial enterprises by predictive modeling and product management forecasting tools. Industrial engineering modeling processes throughout multiphysics simulation and industrial machinery condition monitoring necessitates production process simulation and automated data modeling tools in manufacturing operation management and industrial edge computing systems across smart manufacturing value chains. 3D virtual modeling and simulation tools are pivotal in IoT-enabled business and enterprise scaling, discrete event simulation modeling, and asset and operation data management, enhancing machinery performance and product development in industrial manufacturing operations throughout machine vision and industrial IoT manufacturing systems. Industrial IoT business value in digitally-driven economic productivity requires predictive modeling and forecasting for product lifecycle management, design, and operation in cloud manufacturing environments. Brain-inspired affective computing and bio-sensor network technologies can bolster product-portfolio decision-based enterprise resource and demand planning and forecasting, inventory management operations, and contextualized product design by virtual machining process multiscale modeling and deep learning forecasting and computer vision algorithms in virtual robotic manufacturing environments.

Metaverse digital twin and shop floor manufacturing technologies articulate generative AI digital twin-based industrial and IoT device automation (Andronie *et al.*, 2023b; Nagy *et al.*, 2023; Pelău *et al.*, 2021), streamlining workflow automation-based risk management processes, driving

product development, and delivering measurable business value by specific knowledge accumulation, leveraging big data deep learning and sensor fusion algorithms. Autonomous machine perception and deep learning-based ambient sound processing tools are instrumental in enterprise business and virtual manufacturing processes and digital twin edge and cognitive sensor networks for industrial IoT and sensor-based robotic automation. Predictive maintenance and sensor processing algorithms configure virtual machine process and distributed shop-floor monitoring across IoT-based robotic automation in cloud-based industrial management and 3D vision localization systems and industrial manufacturing enterprises. Multiphysics simulation and synthetic data tools use machine IoT sensor data to assist generative AI-based autonomous decision-making and cloud manufacturing simulation modeling processes, remote sensing image multimodal and multiscale classification, and virtual manufacturing and production planning operations in multiphysics simulation and virtual industrial environments, fostering a big data-driven culture in distributed manufacturing simulation and photoacoustic imaging systems by predictive maintenance and machine intelligence algorithms. Adaptive decision-making-based agentic AI systems can achieve targeted objectives in complex simulated business environments by 3D object detection, localization, and recognition, resulting in business and economic applications.

Generative AI and deep learning-based 3D computer vision technologies in robotic simulation environments

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Predictive maintenance and multi-sensorial AI tools further distributed robotic sensor and brain-inspired neural networks (Andronie *et al.*, 2021; Lăzăroiu *et al.*, 2022; Valaskova *et al.*, 2022), optimizing virtual factory efficiency and generating data-driven business value, and shaping business outcome value capture and enterprise generative AI governance by deep learning-based forecasting modeling and biologically realistic brain net-

work model simulation. Digital twin predictive maintenance capabilities of 3D virtual simulation and robotic process automation technologies can shape cognitive industrial IoT data-driven business practices in robotic simulation environments by geometric and semantic data collection, industrial machinery augmentation, and machine performance prediction, planning, assessment, and scheduling, while deploying visual perception and computer vision algorithms. 3D modeling and simulation tools can optimize business inventory management, equipment inspection scheduling, and automated machine workflows in digital twin-based virtual factories, driving lasting sustainable value creation in IoT edge computing and machine vision systems by clustering-based demand forecasting and motion control algorithms.

Generative AI and deep learning-based 3D computer vision technologies can be leveraged in virtual machine monitoring, task monitoring and control, and industrial big data processing (Andronie *et al.*, 2023a; Nagy *et al.*, 2023; Pelău *et al.*, 2021), redesigning business processes and strengthening economic demand across fully autonomous enterprises and virtual twin manufacturing and image recognition systems by visual perception and situational awareness algorithms. Product development process simulation and modeling can be deployed in manufacturing process error prediction by smart autonomous decision-making with regard to complicated machine movements, while integrating IoT connected device data by deep learning objective detection and artificial swarm intelligence algorithms across wireless multi-sensor and virtual machine manufacturing systems. Virtual manufacturing production processes develop on deep learning computer vision and spatial modeling algorithms across digital twin-based cyber-physical production and cloud-based condition monitoring systems, enabling product status control, tracking, and monitoring by cyber-physical IoT edge monitoring devices. Autonomous agile, responsive, and resilient supply chain networks in spatial 3D virtual environments integrate mobile robotic vision and industrial cyber-physical manufacturing systems by machine learning and reinforcement learning algorithms. 3D synthetic data-based scene simulation optimizes predictive maintenance of machinery and equipment processes and systems and production and operational efficiencies by generative AI and machine vision algorithms in cloud-based industrial automation, driving business value creation.

The economic and business management of big data management, governance, and infrastructure across task manipulation workflow scalability,

distributed ledger technology interoperability, and machine precision in robotic operations and industrial production (Andronie *et al.*, 2023b; Lăzăroiu *et al.*, 2022; Nagy & Lăzăroiu, 2022) necessitates predictive modeling and virtual simulation algorithms. 3D manufacturing and real-time big data-processing technologies support computer vision and adaptive robotic manufacturing systems in immersive simulated environments by digital twin simulation and visual data processing tools. Agile and adaptive enterprises in smart workplace environments require graphics processing unit-accelerated evolutionary and deep reinforcement learning algorithms, catalyzing economic growth across ever-evolving business landscapes by IoT-edge computing and digital twin technologies. Product management and visual analytics tools are pivotal in product quality assessment, tracking, and monitoring, process planning and scheduling, and factory automation equipment across cloud-based digital twin manufacturing and object-based data management systems for manufacturing and production process forecasting. Data-driven decision intelligence and cloud computing technologies can reduce operational costs, product delays, and labor shortages, accelerating business value and driving sustainable growth across Industry 5.0 manufacturing and spatial 3D virtual modeling systems by machine vision and semantic modeling algorithms.

Generative AI and image-based visual computing technologies shaping labor market disruption and tangible productivity gains

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Augmented and virtual reality technologies (Aguinis *et al.*, 2024; Holmström & Carroll, 2024; Lăzăroiu & Rogalska, 2023) further human labor automation, meaningful work, matchmaking processes, occupational skill evolution, job complexity and displacement, and professional mobility by generative AI and semantic clustering algorithms. Deep generative modeling tools can increase labor force participation and build cross-functional skills, impacting labor supply and demand due to automation-

based productivity gains and flexible working arrangements, boosting economic growth and stimulating business investment by machine and reinforcement learning algorithms. Visual sensor and IoT-based decision support systems can assess staff performance, track active productive work hours, process leave requests, provide real-time instructions, and set work schedules. Employee monitoring and automated management tools can address talent shortages, bridge workforce skill gap, reduce personnel costs, shorten training time, track job progress, and improve work processes and team collaboration by visual perception and deep learning image segmentation algorithms. Generative AI and workplace automation technologies can address skill and qualification gap, workforce transition scaling in terms of habits and expectations, and professional development, support labor community and network building, drive retention improvement, and increase employment likelihood and job satisfaction across talent pools and labor markets by image recognition and scene perception tools, resulting in business and economic applications.

Factory machine and immersive metaverse technologies (Aguinis *et al.*, 2024; Lin *et al.*, 2024; Ramaul *et al.*, 2024) can boost firm and knowledge work productivity, task and skill automation, job-level task variation, occupation employment distribution, and economic transactions by deep and machine learning algorithms. Generative AI business value generation and scaling develop on talent recruitment, acquisition, and retention, continuous workforce upskilling, work task automation, productivity prediction and augmentation tracking, and job posting volumes, positively shaping labor market disruption and tangible productivity gains. Labor complementing and substituting technologies can increase productivity performance, maintaining economic growth by extensive workforce retraining while fostering data-driven collaborative organizational cultures by big data-driven generative industrial AI and cloud-based machine learning algorithms. Generative AI and labor augmenting technologies can improve labor supply, resolve labor shortages, and address skill mismatches by extended reality metaverse enterprise and production management algorithms. Machine vision and semantic-aware navigation tools support targeted training and job search skill development, integrating workplace experiences, knowledge acquisition, and meaningful employment for career promotions, driving business value creation.

The economic and business management of generative AI and image-based visual computing technologies (Amankwah-Amoah *et al.*, 2024;

Bankins *et al.*, 2024; Lăzăroiu & Rogalska, 2023) can build professional networks and strategic workforce planning, predict job displacement and collaborative workflow-based productivity gains, and widen economic inequality. 3D modeling and natural language processing tools can develop career mobility and specialized domain knowledge, impacting labor market outcomes in terms of labor automation and augmentation by extended reality metaverse enterprise and production management algorithms. Generative AI and productivity scoring systems can measure and analyze employee performance and productivity, calculate wage rates, track time off, determine optimal task routes by employee location tracking, and assign workplace management tasks. Automated task assignment systems incorporated in business practices are pivotal in worker productivity assessment, automated scheduling, location-based monitoring in employee tracking, break time request management, absence calendar integration, leave use tracking and analysis, and task assignment, while performing voice, micro-expression, and body movement analyses. Factory automation control and virtual modeling technologies can configure seamless and meaningful employee perceptions, feedback, happiness, engagement, satisfaction, turnover, and experiences, build lasting career paths, team capabilities, and collaborative relationships, and impact empowered and rewarded employee productivity, shaping organizational communication and resilience, management practices, decision-making processes, and working norms across multiple business units.

Generative AI simulation and manufacturing operation technologies in 3D virtual factories

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IoT financial and labor market technologies disrupt the labor market and production workflows (Bankins *et al.*, 2024; Jia *et al.*, 2024; Retkowsky *et al.*, 2024) in terms of tasks, occupations, and responsibilities by job consolidation, augmentation, loss, replacement, creation, and elimination, substitut-

ing or complementing tasks, and thus resulting in labor productivity and economic growth by machine learning and spatio–temporal fusion algorithms across synthetic data-based autonomous production and metaverse decentralized governance systems. Multimodal generative AI and big data computing systems can fuel manufacturing productivity growth and labor reallocation, boost capital investment, and drive employee satisfaction by computer vision and machine learning algorithms. IoT financial and labor market technologies articulate reliable and sustainable macroeconomic stability and knowledge-driven economic competitiveness in attractive coherently structured and managed business environments by big data processing and deep reinforcement learning algorithms. Synthetic media-based automated production and brain-inspired cognitive systems can foster career mobility, advancement, and upskilling, talent pool expansion, and staff development training, leading to long-term valuable talent attraction and retention, engaged and productive employees, and people management skill enhancement by leveraging IoT financial and labor market technologies.

Generative AI simulation and manufacturing operation technologies (Amankwah-Amoah *et al.*, 2024; Holmström & Carroll, 2024; Lin *et al.*, 2024) can integrate workplace norms, cultures, values, and processes to analyze occupational employment data for task automation and augmentation in 3D virtual factories by extended reality metaverse enterprise and production management algorithms. IoT financial and labor market technologies can build, support, and deepen multimodal workplace engagement and collaborative and flexible connections, improving career paths, workforce performance, and employee loyalty, and resulting in extensive employee and team development together with enhanced job performance and productivity by swarm robotic and machine learning algorithms. Generative AI machine learning capabilities of 3D virtual modeling and simulation tools can support staff expertise and skills, bolster organizational productivity and knowledge management, streamline business workflows, redefine task automation and agile team processes, and enable effective talent recruitment, onboarding, and upskilling, creating meaningful business value and competitive advantage by path planning and deep reinforcement learning algorithms, driving business value creation.

3D geo-distributed autonomous intelligent and skill training systems (Jia *et al.*, 2024; Lăzăroiu & Rogalska, 2023; Retkowsky *et al.*, 2024) configure teamwork-based organizational structures in algorithmic workplace man-

agement, impacting knowledge work occupations, tasks and responsibilities, job disruption, consolidation, displacement, elimination, and loss due to automation and augmentation, and employee upskilling and retraining, thus shaping and tracking the unemployment rate accurately. Workforce augmentation and unstructured enterprise data mining and filtering tools can capture business value, enhance job descriptions and output quality, and bolster creative productivity from generative AI organizational and technological capabilities across multimodal processing and performance management infrastructures, raising labor productivity and securing sustainable economic growth. Generative AI-based work production process forecasting can optimize high and low wage occupations in terms of workload automation, sluggish growth rates, high-skilled service sharing, labor unemployment risks and productivity, job displacement and loss estimation, and declining real wages. Computer vision and machine learning algorithms can build differentiated talent pipelines and employee value propositions, lower turnover rates, increase workplace flexibility, job satisfaction, and employee productivity, fostering career advancement and economic empowerment, while driving generative AI business outcomes in supportive work environments. Cloud computing and natural language processing technologies can reduce prolonged propelling high-attrition rates and employee departures, shaping flexible working times, meaningful work, employee value proposition, and career development across talent pools.

Generative artificial IoT-based fintech algorithms across interoperable blockchain networks

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Generative AI-powered algorithms and customer relationship management systems can analyze financial data for cash flow requirement prediction, bolstering data analytics and risk management capabilities (Kueschnig & Schertler, 2024; Lim, 2024; Valaskova *et al.*, 2023) with regard to sophisticat-

ed investment products. Generative AI and machine learning algorithms can optimize increasing credit card debt and probabilistic risk scores, reduce fraud scams, overcome financial distress, and detect synthetic identity automation by biometric test identity authentication. Generative AI-powered identity verification and performance management tools can deploy machine learning-derived data for customer digital footprint and specific behavioral biometric pattern analysis, enabling and streamlining data-driven credit customer assistance. Generative AI and machine learning modeling processes can monitor the credit customer journey and portfolio risk profiles, provide meaningful personalized financial advice, and lower financial risk. Immersive 3D blockchain-based fintech operations can transform payment processing, augment customer-centric service scalability and reliability, understand behavior patterns, and identify fraudulent transactions.

Generative artificial IoT-based fintech algorithms can perform simulated transactions and financial asset tokenization across interoperable blockchain networks (Chen *et al.*, 2024; Khan & Umer, 2024; Lăzăroiu *et al.*, 2023), articulating tokenized cash-based instant transaction settlements and business-to-business payments. Generative AI-based metaverse fintech systems can optimize blockchain-enabled lending operations and swift transaction flows by financial asset and metadata tokenization. Smart contracts can handle discretionary portfolios extensively by automated rebalancing and facilitate additional private asset capital sources by integrating tokenized product scaling and cash payments, on-chain cash flow monitoring, blockchain-based repurchase agreements, and end-to-end tokenized bond life cycles. Blockchain and cryptographic technologies, predictive analytics tools, and machine learning algorithms can automate and scale multimodal synthetic financial data modeling and transaction simulation, enabling cloud-based digital payments.

The algorithmic predictive capabilities of generative AI systems can assist financial institutions by analyzing income, transaction history, and credit score in relation to customer loan applications (Fan *et al.*, 2024; Tigges *et al.*, 2024; Zhu *et al.*, 2024) by data augmentation, smart digitally-connected computing devices, and risk management tools. Credit score-based loan decision automation integrates bill paying history, financial transaction forecasting, and unpaid debt. Synthetic transaction data generation is pivotal in credit risk assessment, lending decision augmentation, personalized financial products, and fraud detection. Deep and machine

learning algorithms, financial big data analytics, and cloud and edge computing technologies can manage and interpret a scalable architecture of unstructured data in relation to transaction histories and loan applications, shaping financial decision-making and facilitating business decisions. Natural language processing algorithms, financial and wealth management tools, and computer vision and machine learning techniques can enhance credit risk management, provide highly personalized recommendations, handle high-volume transactions swiftly, and streamline lending journeys and decisioning processes.

Generative AI-based metaverse fintech systems in credit risk assessment, lending decisions, and fraud detection processes

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Generative AI algorithms and blockchain technologies can carry out comprehensive risk evaluations, streamline fraud detection and loan approval processes, expedite complex secure financial computations and transactions, and enhance investment portfolio combination interoperability and efficiency across digital banking services (Andronie *et al.*, 2023c; Giudici *et al.*, 2024; Li *et al.*, 2024), enabling swift and accurate decision-making. Generative AI risk modeling can be deployed in financial processing for reliable and accurate financial hazard identification and mitigation by use of extensive transaction data and real-time processing analytics capabilities. Generative adversarial networks, big data-driven fintech systems, and machine learning algorithms can detect credit card fraud by precise risk assessment and factor modeling and customer behavioral analytics in financial services and lending process automation by synthetic data generation. Generative AI and machine learning algorithms, business analytics and automated trading tools, and deep learning techniques can be deployed in financial trading prediction and advisory services, anti-money laundering, credit risk assessment, lending decisions, and fraud detection processes.

Financial planning tools, machine learning techniques, and generative AI algorithms (Eisikovits *et al.*, 2024; Khan *et al.*, 2024; Lăzăroiu *et al.*, 2023) can detect suspicious activities, analyze and monitor transaction data continuously, offer customized loan recommendations, facilitate data-driven decisions, manage volume-intensive tasks, and prevent costly penalties. Generative AI fintech and fraud detection systems integrate data processing capabilities, personalized financial services, risk assessment techniques, and algorithmic trading and predictive analytics tools. Generative artificial IoT-based fintech algorithms are pivotal in fraud and suspicious pattern detection and risk management modeling, real-time payment adoption, customer credit assessment, and transactional data monitoring by use of synthetic financial data simulation and predictive analytics. Generative AI and machine learning algorithms can optimize fraud detection systems and accurate creditworthiness assessments, streamline cash management and investment analysis, and personalize financial advice through synthetic transaction data.

Algorithmic trading, generative artificial IoT-based fintech algorithms, and automated decision-making systems are instrumental in tailored financial advice and investment recommendations, proactively risk mitigation, lending decision and credit scoring automation, and wealth management services (Andronie *et al.*, 2023c; De La Rosa & Bechler, 2024; Kang *et al.*, 2024) by individual financial data analysis and risk factor modeling. Machine learning algorithms and generative AI and predictive analytics tools can decrease transactional frictions across financial decision-making processes and real-time payment networks, integrating spending habits and credit history, synthetic data interoperability increase, and unstructured financial data. Generative AI-based metaverse fintech systems and machine learning technologies can extract and analyze financial data to combat fraud, automate transactions and lending decisions, and enhance credit assessments and loan approval processes. Generative AI and deep learning algorithms, anomaly detection techniques, and data-driven trading tools can enhance forecast accuracy and risk assessment, identify unusual transaction patterns, and mitigate fraudulent activity.

Generative AI algorithms and machine and deep learning architectures in blockchain-based fintech management

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Algorithmic trading and financial planning tools, automated decision-making systems, and generative artificial IoT-based fintech algorithms (Aysan *et al.*, 2024; Oehler & Horn, 2024; Sachan *et al.*, 2024) can optimize financial prediction performance, accuracy, and robustness, risk assessment processes, real-time fraud detection and prevention, and financial risk mitigation. Big data-driven fintech systems and machine learning algorithms can speed up lending decisions and personalized financial advice, analyze transactional data and credit scoring accuracy, bolster financial security and credit assessments, combat money laundering, and facilitate automated trading and tailored investment recommendations. Machine learning algorithms, generative AI fintech, and predictive analytics and financial planning tools can inspect massive volumes of transaction data, improve financial forecasting and investment decisions, enable asset management and financial service customization, and produce synthetic data. Transaction history, risk analysis and forecasting, and spending behavior are pivotal in credit scoring refinement.

Generative AI and machine learning algorithms (Barbu *et al.*, 2021; Cao *et al.*, 2024; Lăzăroiu *et al.*, 2023) can predict creditworthiness, automate loan assessment processes, customize analytical workflows, streamline document processing, and analyze financial statements. Generative AI algorithms and machine and deep learning architectures can integrate historical financial and spending behavior data while monitoring financial transactions for efficient risk management and personalized financial recommendations. Generative AI technologies can interpret complex business documents and detect fraudulent behavior by sentiment analysis with regard to unusual language patterns. Generative artificial IoT-based fintech algorithms can optimize credit scoring systems and risk management assessment in financial services by use of synthetic data and transaction histories. Predictive analytics tools and machine learning techniques can pro-

vide personalized financial services and investment advice, streamline post-trade processes, support convenient credit and lending products, and process massive quantities of financial transactions swiftly.

Big data-driven financial forecasting techniques, deep and machine learning algorithms, and loan management and data mining tools (Andronie *et al.*, 2023c; Kshetri, 2024; Zhao *et al.*, 2024) can handle financial crime risks, detect and prevent fraudulent activities, inspect transactional data, purchase history, and customer behavior patterns, provide customized financial advice, and make investment decisions. Big data-driven fintech systems, loan management and data mining tools, and deep and machine learning algorithms can identify suspicious activity and augment data-driven investment choices, being instrumental in fraud detection and prevention, credit risk assessment, loan approvals, massive transaction volume processing, tracking, and monitoring, and algorithmic trading. Cloud computing and predictive analytics technologies, automated document processing systems, and transaction monitoring and financial planning tools can analyze document authenticity and historical transaction data, assign risk scores, predict loan defaults and customer turnover, and detect fraud and money laundering patterns. Computer vision and deep learning algorithms and natural language processing and predictive modeling tools are pivotal in personalized financial guidance, transactional behavior and spending pattern analysis, synthetic content generation, algorithmic trading optimization, financial transaction reconciliation automation, and credit scoring refinement.

Discussion

Business and economic applications indicate that data aggregation and analysis in generative adversarial and deep neural networks (Andronie *et al.*, 2021; Lăzăroiu *et al.*, 2022; Nagy & Lăzăroiu, 2022) enable virtual product control and management, IoT edge device management operations, image classification and segmentation tasks, and real-time data-based business performance in immersive 3D simulated environments by knowledge graph and 3D modeling simulation technologies. Industrial IoT and 3D augmented reality technologies can create business value by streamlining virtual product and remote asset management across extended reality-based navigation and robotic autonomous systems (Andronie *et*

al., 2023a; Nagy *et al.*, 2023; Pelău *et al.*, 2021) in smart factory environments by generative AI and machine learning algorithms. Distributed collaboration mechanisms (Andronie *et al.*, 2023b; Nagy & Lăzăroiu, 2022; Valaskova *et al.*, 2022) support industrial product lifecycle in cloud-based digital twin sustainable manufacturing systems. Digital twin simulation and IoT device remote tools (Andronie *et al.*, 2021; Nagy *et al.*, 2023; Valaskova *et al.*, 2022) shape environmental mapping operations in autonomous robotic navigation. Digital twin and generative AI-assisted wireless localization technologies articulate cloud-based virtual machine processes and planned maintenance effectiveness in manufacturing operation automation (Andronie *et al.*, 2023a; Lăzăroiu *et al.*, 2022; Nagy & Lăzăroiu, 2022), fostering tangible business value and driving economic development. Spatial mapping and predictive analytics algorithms assist industrial data contextualization, interconnected virtual machine control performance, and machinery and equipment controlling in digital-twin visualization architecture and monitoring systems (Andronie *et al.*, 2023b; Nagy *et al.*, 2023; Pelău *et al.*, 2021) for product development process automation. 3D extended reality data visualization technologies can build resilient organizational behaviors and workflows across smart manufacturing operations and processes by spatio-temporal manufactured product modeling and operational workflow augmentation (Andronie *et al.*, 2021; Lăzăroiu *et al.*, 2022; Valaskova *et al.*, 2022), optimizing workflow-based order and product content management and delivering business value. 3D virtualization and spatial computing technologies can be harnessed in autonomous and automated manufacturing, 3D virtual operation planning and scheduling, and machine status and performance tracking (Andronie *et al.*, 2023a; Nagy *et al.*, 2023; Pelău *et al.*, 2021), improving business growth across deep and machine learning-based 3D computer vision systems by visual multi-object tracking and robotic collision avoidance algorithms.

Multisensory data fusion and cognitive neuro-engineering technologies can unlock labor productivity, fuel job recovery, support human capital building, and complement or substitute labor (Aguinis *et al.*, 2024; Holmström & Carroll, 2024; Lăzăroiu & Rogalska, 2023), shaping workforce development and hiring pool expansion, and driving economic and manufacturing productivity growth by machine learning and virtual simulation algorithms. Extended cognitive and big data computing systems (Aguinis *et al.*, 2024; Lin *et al.*, 2024; Ramaul *et al.*, 2024) are pivotal in changing employee preferences, workforce emotional wellbeing, engagement, retention,

reskilling, training, performance, productivity, and development, job hierarchies, anticipated turnover rates, labor shortage mitigation and supply, challenging and meaningful tasks, and evolving staffing needs in competitive business landscapes. Environment mapping and semantic 3D mapping algorithms can automate and augment tasks, boost productivity, and redesign redundant and inefficient operations (Amankwah-Amoah *et al.*, 2024; Bankins *et al.*, 2024; Lăzăroiu & Rogalska, 2023), possibly leading to stagnating wages and unprecedented job loss. Generative AI business value measuring and tracking integrate large pool-based candidate identification, job creation, displacement, and loss, labor productivity and replacement determinants, sharp unemployment rising, resilient staff expertise and skills, and flexible workforce. Generative AI and context-aware augmented reality systems (Bankins *et al.*, 2024; Jia *et al.*, 2024; Retkowsky *et al.*, 2024) can strengthen virtual employee engagement, collaboration, coaching, and training, shaping skill bundle acquisition and knowledge sharing, professional human capital and community building development, attrition risks, job histories and moves, and upward work mobility. Generative AI and simulated augmented reality technologies can build talent pipelines, organizational communication capabilities, resilience, and design, brand reputation and credibility, and employee engagement, coaching, and training (Amankwah-Amoah *et al.*, 2024; Holmström & Carroll, 2024; Lin *et al.*, 2024) throughout agile and entrepreneurial organizational contexts, structures, and mechanisms. 3D image modeling and production equipment assessment tools can improve employee behavior and happiness, job satisfaction, and workplace relationships by performance appraisals and management practices across changing organizational cultures and collaborative environments, reducing staff absenteeism, attrition, and turnover. Generative AI decision-making processes can improve chronic staffing shortages, labor marginalization and fragmentation, employee engagement, and unstable talent pools, design production planning and tailored career pathways, and develop tailored employee value propositions (Jia *et al.*, 2024; Lăzăroiu & Rogalska, 2023; Retkowsky *et al.*, 2024) across tough labor markets by skill development and expansion.

Deep and reinforcement learning algorithms, generative AI financial forecasting, and natural language processing tools (Kueschnig & Schertler, 2024; Lim, 2024; Valaskova *et al.*, 2023) can detect fraudulent operations by synthetic financial data-based risk assessment. Generative AI fintech, machine learning algorithms, and behavioral analytics (Chen *et al.*, 2024; Khan

& Umer, 2024; Lăzăroiu *et al.*, 2023) can assist multi-layered payment and transaction processing screening with regard to authorized push payment, account takeover, and synthetic identity frauds, flagging suspicious activities and combating economic crimes by rigorous verification processes. Generative AI-enabled financial, transaction, and investment decisions, advice, and guidance can build awareness (Andronie *et al.*, 2023c; Giudici *et al.*, 2024; Li *et al.*, 2024) with regard to unauthorized money transfers by synthetic identity fraud through IoT multimodal behavioral biometrics and facial identification technologies. Machine learning and risk management tools integrate location and authentication histories, natural speech patterns, and spending habits (Eisikovits *et al.*, 2024; Khan *et al.*, 2024; Lăzăroiu *et al.*, 2023), creating seamless user experiences due to computer-based fraud detection and diagnosis systems. Algorithmic trading tools and generative AI algorithms (Andronie *et al.*, 2023c; De La Rosa & Bechler, 2024; Kang *et al.*, 2024) can assess and manage wealth management advice, credit scoring, transaction history and risks, lending decisions, and customized financial product recommendations. Generative adversarial network algorithms and fraud detection and prevention tools (Barbu *et al.*, 2021; Cao *et al.*, 2024; Lăzăroiu *et al.*, 2023) can handle and synthesize massive volumes of unstructured data for personalized financial services, customized investment plans, and financial risk assessment and mitigation. Tokenization algorithms, distributed ledger and blockchain technologies, and crypto-asset tools (Andronie *et al.*, 2023c; Kshetri, 2024; Zhao *et al.*, 2024) can reduce transaction times and optimize cash flow across the cross-border payment landscape due to digital service convenience.

Conclusions

Generative AI manufacturing and virtual twin technologies can increase robotic workplace and team productivity across mobile-centric extended reality infrastructures and virtual reality and IoT cloud computing systems by geolocation data and navigation planning tools. Edge device management functionalities of cloud industrial IoT and virtual robotic simulation technologies configure plant production and route planning processes across cyber-physical production and industrial automation systems in multi-cloud immersive 3D environments, leading to tangible business outcomes by reinforcement learning and convolutional neural networks.

Cloud-to-edge computing and industrial data ingestion capabilities of predictive digital twin modeling increase collaborative productivity, streamline enterprise asset management and maintenance planning operations, and drive tangible business outcomes by graphics processing unit-powered machine learning and object recognition algorithms.

Machine learning-based decision support and edge generative AI sensing systems can reduce persistent labor shortages and job vacancies and power productivity growth and labor market dynamics, shaping career pathways and facilitating occupational transitions by skill gap identification and labor-intensive manufacturing job automation and path planning and spatial cognition algorithms. Talent labor shortage, attraction, and retention can shape stable meaningful work and compelling career path through imaginative organizational planning and employee feedback gathering in terms of flexible benefit package across virtual collaborative environments by machine performance monitoring and 3D geolocation tracking tools. 3D simulation and operational modeling tools can execute and complete complex cognitive-task-oriented and knowledge economy jobs, producing first-rate quality outputs swiftly while leading to unemployment spells, labor market disruptions, job displacement losses, and reduced earnings by machine learning clustering and spatial cognition algorithms.

The deep learning capabilities of generative AI fintech in terms of adaptive behavioral analytics and credit scoring mechanisms can enhance financial transaction behaviors and algorithmic trading returns, identify fraudulent payment transactions swiftly, and improve financial forecasts, leading to customized investment recommendations and well-informed financial decisions. Behavioral analytics and visual intelligence tools can augment credit decisions, enhancing loan default predictions in connection with risk assessment, financial guidance, suspicious transactions, and fraud detection by synthetic data generation, articulating personalized customer experiences by providing tailored recommendations. Generative adversarial networks, financial forecasting simulation and generative AI tools, and computer vision algorithms can assist synthetic data-based fraud detection systems by suspicious pattern identification.

Theoretical contributions to the literature

Remote monitoring for automated processing equipment and IoT connected product lifecycle performance management can drive business growth by neuromorphic computing and metaverse economic systems, thus preventing equipment downtime. Predictive maintenance and machine learning algorithms drive business productivity by process redesign forecast modeling and virtual industrial process building, monitoring, and control in fully autonomous factories. Cloud-based predictive and manufacturing data analytics can transform highly interdependent structures and processes, increasing economic recovery in adaptable resilient organizations for real-time production data automation by neural network-based control and perceptual image processing algorithms. Web3-enabled generative AI and digital twin technologies can build transferable workforce skills, competencies, and knowledge, optimizing labor transition automation and market changing needs by teamwork effectiveness and human capital value in dynamic work environments. Multi-sensor fusion and cloud-based factory simulation systems can support employee engagement, satisfaction, productivity, and happiness due to meaningful jobs and management practices, promotion decisions, task matching, and team performance, shaping talent market dynamics by personnel hiring and development. Machine vision algorithms and natural language processing systems can inspect consumer credit history by extracting meaning and interpreting context. Generative AI and blockchain technologies and risk assessment and fraud detection tools can configure tailored situation-specific financial operations and recommendations and streamline loan applications by data analytics capabilities.

Practical contributions to the literature

Digital twin and 3D vision sensing technologies support industrial robotic machine connectivity, industrial data and asset management, and process manufacturing mapping in Industry 5.0 connected factories and industrial control and smart manufacturing robotic systems by automated and autonomous machine learning algorithms. Connected industrial IoT and edge computing devices shape organizational operation, structure, and decision scaling, immersive engineering simulation and modeling workflows, and extended reality-based business operations, leading to machine

and business performance by motion control and spatial data mining algorithms. Brain–computer interface and industrial digital twin technologies can redesign organizational and business practices and processes in photorealistic industrial and reinforcement learning simulation environments, fostering economic performance achievement and establishing meaningful adaptable cultures. 3D virtual digital twin simulation and computer vision algorithms can shape long-lasting collaborative team cultures and performance gains, support workforce attraction, retention, and engagement, strengthen long-term organizational resilience, structures, and processes, and optimize economic and operational disruptions, performance expectations, and data-driven structural changes in volatile and uncertain environments. Machine learning and labor-saving algorithms can shape high-performing engaged staff career development by digitized task management, employee motivation and satisfaction, and meaningful work, creating competitive advantage by talent attraction, hiring, development, and retention. Generative AI-based metaverse fintech systems, fraud prevention tools, and distributed ledger and blockchain technologies enable convenient and cost-effective smooth transactions in terms of connectivity, traceability, scalability, and interoperability across interconnected digital payment infrastructures, reducing fraud risk and credit process delays. Machine learning technology and algorithmic trading and data augmentation tools can improve financial prediction precision and robustness, fraud detection, and business intelligence tasks in terms of credit scoring refinement and swift loan processing.

Limitations and further directions of research

Scientific inquiry limitations are associated with the databases (the Web of Science and Scopus) inspected for recent (2021–2024) literature, the leveraged machine learning-based study selection process and text mining systematic review management software and tools, and the selected research strands related to generative artificial intelligence economics: digital twin-based cyber-physical manufacturing systems, extended reality metaverse enterprise and production management algorithms, and Internet of Things financial and labor market technologies. Further directions of research should include Industry 5.0 and remote sensing technologies furthering virtual factory planning, designing, and operations, cloud-based product lifecycle management, and automated process fault diagnosis

across generative visual AI and autonomous mobile robotic systems in large-scale virtual industrial environments; data-driven algorithmic and robotic sensing technologies improving staffing shortages, employee hiring, onboarding, training, engagement, and productivity, career development, and talent retention across streamlined organizational and business structures by networked cross-functional collaboration, task automation, convoluted process navigation, and knowledge sharing; and generative AI-based metaverse fintech systems, predictive modeling tools, and machine learning and natural language processing techniques speeding up credit scoring processes and loan approvals, automating financial data processing, and analyzing historical transaction data.

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Compliance with ethical standards

This article does not contain any studies with human participants or animals performed by the authors. Extracting and inspecting publicly accessible files (scholarly sources) as evidence, before the research began no institutional ethics approval was required.

Data availability statement

All data generated or analyzed are included in the published article. The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation. The raw anonymized data can be provided by emailing the primary author.

Author contributions

All listed authors have made a substantial, direct and intellectual contribution to the work, and approved it for publication. The authors take full responsibility for the accuracy and the integrity of the source analysis.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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