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A Survey of Explainability, Interpretability and Fairness in Artificial Intelligence

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Abstract

Artificial Intelligence (AI) is reshaping divergent industries, influencing both operational practices and strategic decision-making. The need for this paper arises from the lack of a systematic approach to developing robust, interdisciplinary AI applications across various sectors. This paper addresses the problem by providing a structured analysis of AI's impact using MEASUR's Collateral Analysis (MCA) framework, identifying key gaps in application development and risk management. A structured literature review examines AI applications across industries such as fashion, education, law enforcement, neuroscience, environmental science, and agriculture, alongside applying MCA to evaluate AI system effectiveness. We contribute to integrating insights from multiple sectors and proposing MCA as a structured method to strengthen AI development processes. Major findings reveal that AI significantly enhances creativity, decision-making, operational efficiency, and sustainability when guided by structured frameworks. We recommend practitioners adopt MCA combined with risk analysis from the Spiral software development methodology to improve AI deployment and adaptability. For researchers, we suggest exploring interdisciplinary integration and expanding ethical considerations in AI system design. The broader impact on society includes promoting more sustainable, efficient, and ethical AI practices, fostering innovation, and addressing global challenges. Future research should focus on merging MCA with dynamic risk management techniques and extending sustainable AI frameworks to emerging industries.

Keywords: Artificial Intelligence, MEASUR's Collateral Analysis, Explainability in AI, Interoperability in AI.

Introduction

The evolution and adaptation of Artificial Intelligence (AI) across various domains have significantly increased over recent decades (Ahmed, N, et al.; [1]), creating a competitive environment that enhances productivity, scalability, and connectivity (Juric, M et al., [2]). AI, along with Machine Learning (ML) and Deep Learning (DL), plays a central role in digital transformation, often in combination with technologies like IoT, Cyber-Physical Systems, and the Physical Internet (Woschank, M et al., [3]). Defined as an engineering discipline that simulates human thinking (Yuan, S et al., [4]), AI contributes to smart perception, reasoning, and decision-making, forming Industrial Artificial Intelligence (IAI) (Ding, H et al., [5]). It is now viewed as a general-purpose technology shaping future innovations (Zhao, S, et al., [6]). AI methods such as Expert Systems, ML, Fuzzy Logic, and Meta-heuristic techniques are widely applied (Le Berve, C et al. [7])—notably in medical diagnostics for gastroenterology and hepatology, identifying cancerous lesions via endoscopy (Le Berve, C et al. [7]), and in earthquake prediction using pattern recognition through ML, DL, and knowledge systems (AL BANNA, et al. [8]). These innovations benefit science, manufacturing, and natural systems (Xu, Y et al., [9]), and AI has also impacted IT, energy, healthcare, agriculture, and business management, including HR, project monitoring, SEO, and safety (Cubric, M et al., [10]). In education, AI supports pedagogical advancements via ML and neural networks (Bozkart, A et al., [11]). However, integration across systems raises challenges in productivity and interoperability (Rehm, G et al., [12]), which is being addressed by initiatives like AI4EU and LYNX (Rehm, G et al., [12]) and by APIs that support AI execution (Borgogno, O et al. [13]). Interoperability in Systems of Systems (SoS) is also critical (Nilsson, J et al., [14]), and understanding AI decisions through explainability is essential (Arrieta, A et al. [15]). Transparency in AI and ML is being pursued with consistent frameworks (Shin, D et al., [16]), while fairness is supported through tools that analyze bias and suggest mitigation strategies (Bird, S et al., [17]). AI outperforms humans in fairness in both algorithmic and human decision domains (Bird, S et al., [17]), and its growth spans information processing, navigation, leisure, and services (Marcinkowski, F et al., [18]), with increasing autonomy in learning and decision-making (Williamson, B et al., [19]). Although adoption is still below 50%, AI's role in large organizations continues to rise (Benbya, H et al., [20]).

AI in Industries

AI enhances industrial efficiency and decision-making through automation, predictive analytics, and tailored solutions, with applications across healthcare, finance, tourism, fashion, and manufacturing. It supports tasks like diagnostics, customer personalization, and process optimization. In manufacturing, methods such as Fake Defect Feature Augmentation (FDFA) and Hardness-aware Cross Entropy Loss (HCELoss) deliver consistent anomaly and localization detection, improving performance on datasets like MVTec AD (Tang et al. [21]). Challenges include infrastructure costs, data security, and the need for skilled labor. In medical device manufacturing, AI integration requires aligning objectives with long-term goals; Semi-GAN, a GAN-based imputation technique, significantly improves data accuracy for missing values under 20% (Sweeney et al. [22]). Sensor failures in semiconductor manufacturing also raise missing data issues, applicable across the medical and automotive sectors. In construction, AI adoption involves robotics, computer vision, and NLP, while ML is considered mature; slow integration of deep learning signals a need for more research in areas like BIM and IoT (Lee et al. [23]; Abioye et al. [24]). For SMEs in Korea, an AI-powered smart factory model using big data and CNN enhances productivity and energy efficiency through human-centered workstations (Park et al. [25]). AI also strengthens Robotic Process Automation (RPA) by boosting accuracy and performance in both open-source and proprietary systems (Ribeiro et al. [26]). In Industry 5.0, cybersecurity is addressed with a novel intrusion detection system (IDS) utilizing BiLSTM, Bi-GRU, and SHAP, achieving strong results on the CICDDoS2019 dataset (Javeed et al. [27]). In automotive manufacturing, LSTM models support predictive maintenance and promote error-free production, while in mining, AI is leveraged for sustainability and reduced environmental impact, emphasizing ethical, socially responsible practices and clean energy support via multi-objective optimization (Corrigan et al. [29]). Lastly, the integration of block-chain and AI in supply chains and predictive maintenance enhances sustainability and operational efficiency in Industry 4.0 (Soori et al. [30]). For a detailed comparison of AI tools, see Table 1.

Tools/Methods	Aim of Use
FDFA, HCELoss	Detect manufacturing flaws and enhance performance
AI-Enabled Industry 4.0	Tackle challenges in medical device manufacturing (cost, security, skills)
Semi-GAN	Impute missing data in semiconductor manufacturing (effective <20% missing rate)
AI, ML, Robotics, CV, NLP	Assess AI adoption in construction; highlight BIM and IoT integration gaps.
CNN, Big Data, AI	Propose a smart factory model for Korean SMEs to boost efficiency
AI-enhanced RPA	Increase accuracy and productivity in Industry 4.0 automation.
BiLSTM, Bi-GRU, SHAP	Improve cybersecurity through interpretable IDS for Industry 5.0
LSTM	Predict maintenance in automotive robot cells for zero-error production
AI, Multi-objective Optimization	Promote sustainable mining and ethical AI for clean energy
Blockchain, AI	Integrate for smarter supply chains and predictive maintenance.

Table 1 : AI Tools and Methods

Table 1 outlines AI-driven methods across various industries to address targeted challenges. FDFA and HCELoss detect defects in manufacturing, while AI in Industry 4.0 supports medical device manufacturing by managing infrastructure and data security concerns. GAN-based imputation handles missing data in semiconductor production. In construction and Korean smart factories, AI technologies enhance efficiency, and AI-powered RPA systems increase productivity. For cybersecurity, BiLSTM and Bi-GRU improve intrusion detection, while LSTM models enable predictive maintenance in automotive robotics. AI also supports sustainable mining practices, and its integration with blockchain boosts supply chain and maintenance operations.

AI in Education

AI significantly enhances education by offering personalized learning, adaptive systems, and administrative automation, while also posing ethical and legal challenges. AI applications span classroom robots, content filtering, academic data analysis, and digital mentors, with tools like ML and DL improving engagement and performance (Göcen et al. [31]; Chen et al. [32]). Analysts highlight the need for legal frameworks to guide ethical AI use. AI fosters individualized learning, real-time feedback, and student motivation but requires stakeholder trust for successful integration (Vincent-Lancrin et al. [33]; Fitria et al. [34]). It also supports diversified instructional methods and predicts a growing reliance on AI in future education systems (Huang et al. [35]). With improved ML algorithms, AI enables customized student guidance, auto-assessment, and teaching refinement, though ethical concerns remain (Nguyen et al. [36]). Big data and AI jointly elevate educational and industrial capabilities but introduce implementation barriers, prompting analyst-educator collaborations to ensure effective adaptation (Luan et al. [37]). Human rights protection, privacy, and transparency are critical in deploying AI tools in education (Berendt et al. [38]). From 1970–2020, AI's role in pedagogy has evolved through ML, DNN, and online systems, culminating in the COVID-19 era where adaptive and remote learning became central (Bozkurt et al. [39]; Pantelimon et al. [40]).

AI in Government

AI in government emphasizes ethical, transparent, and accountable practices through sustainable governance frameworks (Wilson et al. [41]; Straub et al. [42]). Effective deployment requires understanding operational, epistemic, and normative factors (Noordt et al. [43]). In Canada, AI governance initiatives reveal gaps in ethics and social services, offering methodological insights for global contexts (Attard-Frost et al. [44]). E-government in Saudi Arabia highlights digital infrastructure challenges and the role of AI and IoT in smart city development (Hashim et al. [45]). Integration frameworks like TACT and TOE reveal AI's public sector adoption barriers and affordances (Maragno et al. [46]). European approaches stress experimental standardization and safe testing for responsible AI lawmaking (Prifti et al. [47]). Formal institutions and ambidextrous strategies shape AI adoption in public organizations (Selten et al. [48]). Broader reviews emphasize implementation, governance, and AI impact on public services (Zuiderwijk et al. [49]). Finally, ethical concerns such as surveillance capitalism and privacy risks must be addressed in government AI use (Saura et al. [50]).

AI in Tourism

AI has revolutionized tourism, particularly through applications like ChatGPT, which enhances customer service, language translation, and personalized recommendations (Al-yasiri et al. [51]). AI-based counterfactual reasoning aids in uncovering causal relationships and improving tourism management (Xia et al. [52]). Generative AI (GenAI) and LLMs, fine-tuned with tourism-specific data, offer personalized travel assistance but raise concerns regarding data limitations, ethical issues, and biases (Hsu et al. [53]). Robotics and AI improve customer experience, and more studies are needed to address the challenges in these areas (Samala et al. [54]). AI tools in cultural tourism and smart destinations provide valuable insights, though privacy concerns and data quality issues remain (Kalvet et al. [55]). AI-based service encounters, such as AI-assisted, AI-generated, and AI-mediated interactions, significantly impact customer service in hospitality and tourism (Li et al. [56]). The CACT Lanzarote app, a collaboration with IBM Watson, showcases AI's potential in delivering personalized tourism experiences (Ferràs et al. [57]). Additionally, AI, GIS, mobile apps, and VR/AR technologies are enhancing tourism by offering real-time information and improving accessibility and personalization (Gaafar et al. [58]). AI's omnipresence in personalization, robotics, and forecasting transforms the tourism industry (Gidumal [59]). Big data and AI models, such as Hadoop and Python-based recommendation algorithms, significantly enhance travel experiences by providing more accurate, personalized suggestions (Pei et al. [60]).

Tools/Methods	Aim of Use
ChatGPT	Language translation, customer service, and cultural sensitivity in tourism
Counterfactual reasoning AI algorithms	Improve decision-making by identifying causal links in tourism.
GenAI and LLMs	Enhance recommendations, marketing, and customer experiences
AI and Robotics (FRT, VR, Chatbots, Robots)	Improve hospitality services and tourist interactions
AI-based Service Encounters	Analyze AI's impact on customer service outcomes in tourism
IBM Watson AI, Beacon Technology	Personalize tourist experiences at attractions
GIS, Mobile Apps, Social Media, VR, AR	Boost accessibility, personalization, and service quality in tourism
NLP, ML, DL, Neural Networks (NN)	Streamline operations and drive personalization and innovation
Hadoop, Web Scraping (BeautifulSoup, Requests), Python (Sklearn, Numpy)	Predict and recommend tourist attractions based on preferences

Table 2: AI tools and Methods in Tourism

This table 2 highlights various AI tools that enhance customer experiences and streamline operations in the tourism industry. ChatGPT aids in language translation and customer service, while counterfactual reasoning and GenAI optimize decision-making and personalized recommendations. AI and robotics, including facial recognition, VR, and chatbots, simplify interactions and enhance travel experiences. AI-mediated service encounters, IBM Watson, and beacon technology personalize tourist services. Additionally, GIS, mobile apps, and VR/AR improve accessibility, while NLP, ML, and Hadoop-based systems predict tourist preferences to enhance personalization and service quality.

AI in Design and Fashion Industry

AI has significantly transformed the fashion industry, enhancing design, production, and user experiences. Tools like Gay and Proud (GAP) Virtual Dressing Room and Nike Fit leverage computer vision and ML for virtual try-ons and accurate sizing (Csanák et al. [61]). AI algorithms, such as Amazon's fashion design tool, generate styles and assist with trend analysis and sustainable design (Csanák et al. [61]). Collaborative efforts, like those between Samsung C&T Fashion Groups and a university, have integrated AI-based design processes using CNNs and AI-based Creativity Support Tools to generate prototypes and foster creativity (An et al. [62]). StyleGAN2 and GAN-based systems further enhance design efficiency by generating fashion sketches and automating design tasks (Choi et al. [63][64]). User acceptance of AI in fashion, particularly through Amazon's Echo Look, is influenced by performance risks, impacting purchasing decisions (Liang et al. [65]). Tools like FashionQ boost creative decision-making, and Stylumia demonstrates AI's potential in trend forecasting and business optimization (Jeon et al. [66]; Banerjee et al. [67]). Chat-to-Design allows users to customize designs through natural language and interactive editing (Zhuang et al. [68]). AI also addresses overstock issues in fast fashion, reducing waste and carbon footprints (Renaningtyas et al. [69]). Innovations like AI-based Service Oriented Architecture (SOA) enable collaborative fashion design, enhancing speed and creativity (Chanda et al. [70]). Legal challenges, such as copyright ownership of AI-generated designs, suggest the need for policy reforms to protect designers' rights (Dennis et al. [72]). Midjourney, an AI-powered tool, aids fashion designers in concept generation by rapidly creating visual concepts (Zhang et al. [73]). Tools like CNNs and GANs personalize fashion choices, improving retail efficiency and customer satisfaction (Marku et al. [74]). In conclusion, a review of 521 papers categorizes AI applications in fashion into seven groups: Overview, Evaluation, Basic Tech, Styling, Selling, Design, and Buying. The analysis highlights regions like China, the USA, and India as leaders and identifies expanding markets and future research directions (Zou et al. [75]).

Tools/Methods	Aim of Use
Data mining, virtual assistants, predictive analytics, Virtual Dressing Room, Nike Fit, AI algorithms	Enhance customer experience, trend analysis, inventory, sustainable design
CNN model, Creativity Support Tool (CST)	Generate prototypes, enhance creative problem-solving
StyleGAN2, internal data, global trend extraction	Develop AI-based automated fashion design systems
StyleGAN2, multi-conditional feature interaction (CFI)	Improve designer efficiency with controlled, random fashion design
Amazon's Echo Look, ML, Alexa	Study consumer attitudes toward AI in fashion
FashionQ system, AI for attribute detection, clustering, forecasting	Boost creativity through cognitive operations and visualization tools
AI forecasting, computer vision, ML, DL, NLP	Predict trends, improve product creation and business performance
Chat-to-Design, NLU, multimodal retrieval, generative models	Personalize design, virtual try-on, metaverse applications
Computer vision, ML, DL	Improve sustainability, efficiency, and virtual fashion try-ons
AI-based SOA, SaaS frameworks, Blackboard Architecture	Support collaborative fashion design, enhance agility and innovation
Computational co-creativity tools	Assist creative processes and AI behavior in game design
AI tools for model and fabric creation	Address legal and copyright issues in AI-generated works
Midjourney AI image-generation tool	Support concept generation, enhance e-commerce design
CNNs, GANs, recommendation systems	Improve retail efficiency, customer satisfaction, drive innovation
AI research impact analysis	Identify key areas and future research in AI for fashion

Table 3: AI tools and Methods for Design and fashion industry

Table 3 summarizes the role of AI in fashion, enhancing creativity, customer experience, and operations. Tools like **data mining**, **CNN models**, and **StyleGAN2** assist with style generation, trend analysis, and inventory management. AI creativity tools help designers prototype, while predictive models forecast trends. **Virtual try-ons**, personalized designs, and AI-driven forecasting boost consumer engagement and business performance. AI also enables collaborative design via **SaaS frameworks** and raises legal issues in AI-generated works, suggesting future research opportunities.

AI as an Interdisciplinary Field

AI integrates computer science, mathematics, cognitive science, and engineering to mimic human intelligence. Its applications span healthcare, finance, education, and more. The TRACE project equips law enforcement and financial units with AI tools for tackling ICT-enabled crimes, ensuring ethical compliance (Turksen et al. [76]). In Mathematics Education (ME), AI tools support problem-solving and personalized learning (Van Vaerenbergh et al. [77]), while in neuroscience, AI enhances understanding of brain mechanisms (Bermudez-Contreras et al. [78]). AI also aids environmental science in tackling global challenges like climate change (Shuford et al. [79]) and supports agriculture in enhancing sustainability and food security (Ryan et al. [80]). These applications highlight AI's broad potential and the need for interdisciplinary collaboration and ethical considerations. Table 4 details AI tools used in these fields.

Tools/Methods	Aim of Use
AI tools for data analysis, visualization, info sharing	Support law enforcement by combating ICT crimes and illegal money flows
AI calculators, ITS, data-driven models	Personalize math education, predict student performance
DL, RL, neuroscience methods	Understand intelligent behavior, especially in spatial navigation
AI, predictive modeling, SAAIF	Tackle environmental sustainability issues with innovative AI solutions
Interdisciplinary AI in agriculture	Boost food security, sustainability, and economic viability

Table 4: AI tools and Methods for Interdisciplinary field

Table 4 summarizes AI tools across sectors. In law enforcement, AI aids in fighting ICT crimes and illegal money flows. In education, AI personalizes learning and predicts performance. In neuroscience, AI enhances understanding of intelligent behavior. In environmental science, AI tackles sustainability issues with predictive modeling. In agriculture, AI improves food security and sustainability.

Building AI Applications with MCA

MEASUR's Collateral Analysis (MCA) method is designed to capture user requirements in system and software engineering. It stands for "The Method for Eliciting, Analyzing, and Specifying Users' Requirements." The framework provides a systematic strategy for identifying and specifying user demands. Key contributions to the MEASUR framework include the integration of semiotic theories in requirements engineering by Baranauskas et al. [81], who emphasized the cultural and social context of user needs. Simoni et al. [82]

developed the Collateral Analysis component, ensuring thorough examination by considering both social and organizational aspects through case studies.

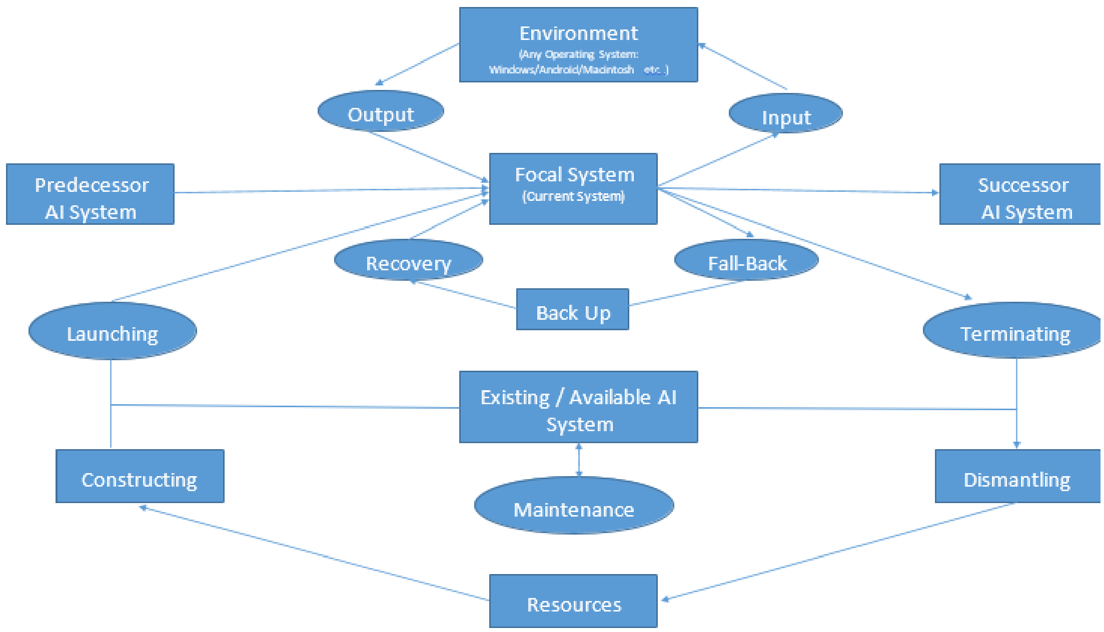

Figure 1: MCA for Building AI Applications

Collateral Analysis (MCA) in the MEASUR framework identifies and assesses secondary factors affecting user requirements, such as external systems, regulations, and future changes. It ensures comprehensive requirement collection, risk mitigation, stakeholder engagement, and enhanced documentation. MCA is used in software engineering to capture dependencies and in business process management to align with organizational goals and compliance.

Conclusion and future work

This research explores the application of AI in various areas such as industries, education, government, tourism and the design and fashion industry, describing AI as an interdisciplinary and multi-disciplinary field. The research also gives an insight into MCA for the development of AI applications in different fields. MCA strengthens the creation of robust and optimal AI tools and applications for addressing complex problems and improving industry practices. By merging insights from existing research and applying thorough evaluation criteria. our study aims to understand the evolving landscape of AI and its potential to drive Advancements across industries. This paper provides a comprehensive investigation of AI's transformative impact, focusing on its definition, importance, and the breadth of existing literature. The future of AI is huge in fields like cybersecurity, the gaming industry, agriculture, and IoTs. Creating applications for AI can be enhanced using Risk analysis (A combination of spiral and MCA) at different points.

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