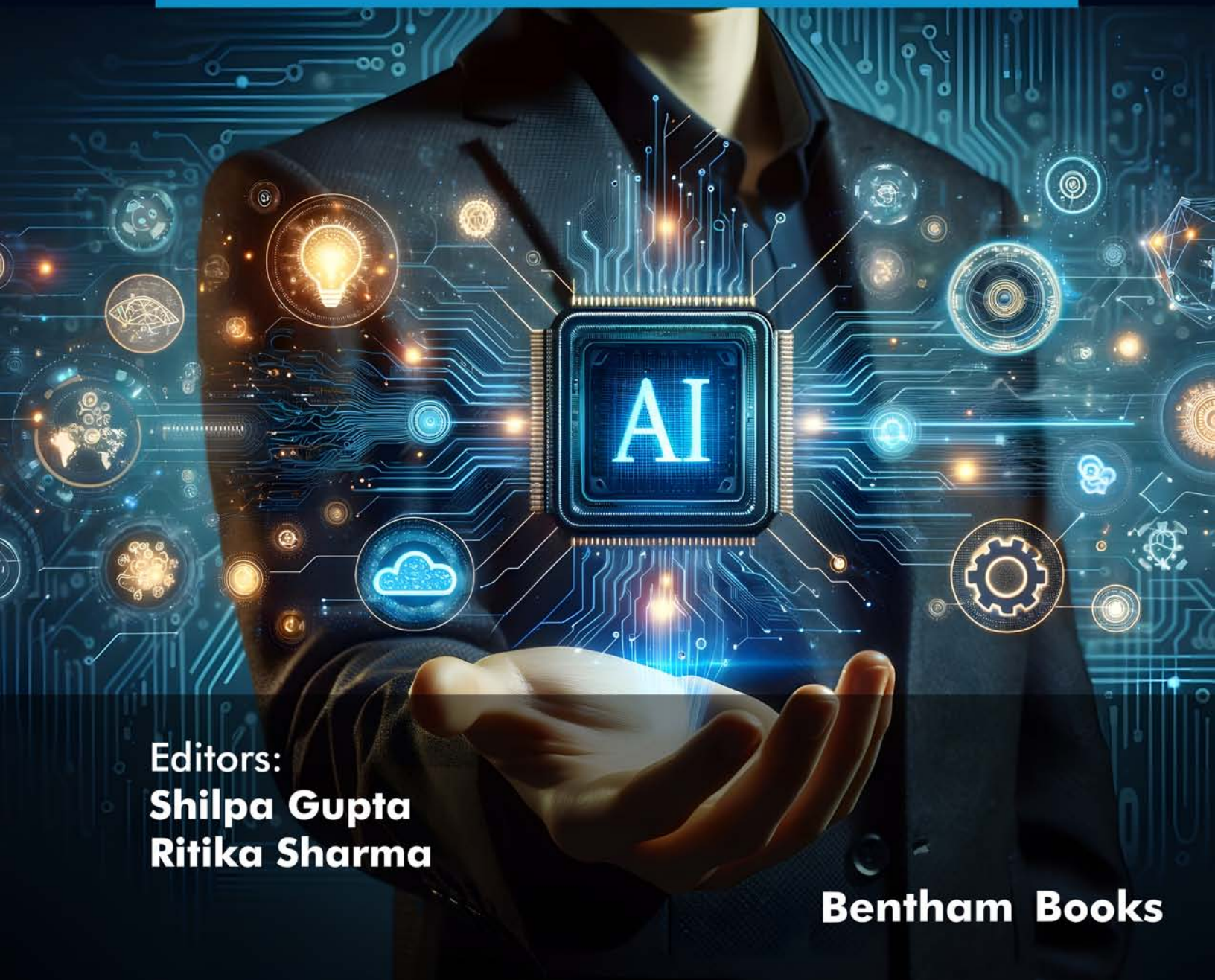


TECHNOLOGICAL APPLICATIONS OF AI IN THE DEVELOPMENT OF A SUSTAINABLE FUTURE



Editors:
Shilpa Gupta
Ritika Sharma

Bentham Books

AI and Emerging Technologies for a Sustainable Future

(Volume 2)

Technological Applications of AI in the Development of Sustainable Future

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FOREWORD

In a world characterized by unprecedented technological progress and compounding global challenges, the quest for a sustainable future has never been more compelling. Artificial Intelligence (AI), which had long been the reserve of science fiction, has become an all-pervasive force across sectors and societies, presenting unparalleled opportunities to address the world's most critical sustainability challenges, ranging from global warming and environmental degradation to social injustice and resource limitation.

Where Volume I laid the groundwork by underlining seminal AI trends in energy, agriculture, water, etc., this volume builds upon that vision by pushing frontiers and giving voice to boundary-breaking thinkers across disciplines.

This volume, “**Technological Applications of AI in the Development of Sustainable Future,**” is a crucial and timely addition to the discussion regarding the applications of AI as part of the book series, “**AI and Emerging Technologies for a Sustainable Future**”, it gathers top scholars, inventors, and practitioners who examine the nexus of AI technology, and sustainability extensively and comprehensively. The chapters shed light on how AI can maximize energy systems, transform sustainable agriculture, enhance disaster relief, and facilitate smarter cities, as well as critically analyse the ethical, societal, and environmental implications of these technologies.

I hope that this book will become a go-to resource for scholars, policymakers, business leaders, and anyone dedicated to unlocking the potential of AI to make a more equitable, resilient, and sustainable future a reality.

May this work inspire collaboration between disciplines and sectors, and remind us that the future of technology can never be separated from the future of human beings and the planet we live on.

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PREFACE

As sustainability becomes the solution to modern engineering, artificial intelligence has rapidly evolved from a niche technological tool to a unifying force that can address most of the complex sustainability challenges of our time. In this transformative age, Volume II of AI-Driven Technologies for Sustainable Engineering continued to explore how AI engages with sustainability, forging new avenues toward a regenerative world.

Where Volume I set the stage by highlighting foundational AI trends in energy, agriculture, water, *etc.*, this volume takes that vision further by exploring new frontiers and amplifying voices breaking boundaries across disciplines.

This volume, “Technological Applications of AI in the Development of Sustainable Future,” of the book series, “AI and Emerging Technologies for a Sustainable Future”, presents a wider canvas capturing how AI combines with renewable infrastructure planning, healthcare systems, fabric detection systems, and sustainable materials discovery. With the ongoing focus on interdisciplinary collaboration, the book dissects the ethical, technical, and societal implications of intelligent systems integrated into sustainable frameworks.

Chapters are enhanced with new case studies, new perspectives from developing AI methodologies, and prospective scenarios, providing a roadmap for sustainable engineering in theory and practical application. The book focuses not only on technological development but also on the cultural and institutional changes necessary for actual sustainable transformation.

Our heartfelt thanks to the authors, the visionary thinkers who are creating the next generation of sustainable engineers. Their contributions make this volume an indispensable guide for engineers, innovators, policymakers, and learners dedicated to employing AI not only as a tool but as a collaborator in creating a more sustainable world.

We wish that this book will be informative and inspirational.

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CHAPTER 1**Real-Time Fabric Defect Detection Utilizing Deep Learning-Based Convolutional Neural Networks****Kaushik Adhikary^{1,*}, Sherin Angelina¹, Anil Kr. Shaw¹ and Sayani Jana¹**¹ *Department of Computer Science and Engineering, JIS University, Agarpara, Kolkata, India*

Abstract: Considering the reduction in labor costs and associated benefits, investment in automated fabric defect detection proves to be highly cost-effective. A robust and efficient algorithm is essential for the development of a fully automated web inspection system. The examination of genuine fabric flaws is particularly difficult because of the multitude of defect categories, which are defined by their ambiguity and indistinctness. This work aims to classify and describe several strategies developed for detecting fabric faults. This work also provides the inaugural survey on methodologies for fabric defect detection, referencing around 160 sources. The categorization of fabric defect detection methodologies is beneficial for assessing the characteristics of the identified features. The characterization of authentic fabric surfaces through their structure and primitive set has not yet demonstrated success. Consequently, the characteristics derived from fabric surfaces have led to the classification of the proposed methodologies into three categories: statistical, spectral, and model-based. To evaluate the state-of-the-art, the constraints of several prospective techniques have been identified, and their performance has been appraised based on demonstrated findings and proposed applications. The results of this work indicate that integrating certain statistical, spectral, and model-based methodologies may produce superior outcomes compared to any individual strategy, warranting additional investigation into this matter.

Keywords: Fabric defect detection, automation, detection accuracy, image representation, convolutional neural network.

INTRODUCTION

Fabric quality inspection plays a crucial role in the textile and yarn industries. Surface imperfections can significantly impact garment quality, leading to customer dissatisfaction and potential losses [1]. Therefore, there is an urgent need for a high-performance, fast, and reliable automated inspection system [2]. Currently, most textile manufacturers rely on manual defect identification, which

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is time-consuming and inefficient. Human inspection typically detects only 60–70% of defects in real-time systems [2, 3]. Distractions encompass visual distractions (diverting one's gaze), cognitive distractions (being preoccupied with thinking), auditory distractions (being interrupted by a colleague), and weariness during garment testing. Consequently, human agility is crucial as distractions can result in considerable losses [4, 5]. Furthermore, obstacles have escalated from an industrial perspective [6]. The industry must uphold both the quality and quantity of production to preserve its credibility in the market. Consequently, people are unable to do this inspection work for extended periods while maintaining the necessary precision.

Textile manufacturing companies globally require automation of the inspection process [7]. This inspires us to address this complex issue as a research statement. Digital image processing is utilized for the processing, storage, and display of human-interpretable visual information.

Consequently, computer vision, along with MATLAB, OpenCV, and Keras, is essential and demonstrates efficacy in addressing issues posed by the contemporary industrial landscape [8]. A portion of the fabric that fails to satisfy the specified standards or characteristics is classified as a defect, leading to customer unhappiness and potentially significant losses for the textile industry [9]. Various sorts of fabric flaws include missing yarn, broken yarn, double yarn, stains, and holes. Occasionally, the yarn becomes entangled during preparation, leading to holes, which is the most unattractive flaw. The machine's malfunction may result in problems, including absent yarn. A significant disadvantage is the presence of stain marks [10].

Deep learning is a cutting-edge approach utilized for the detection of flaws in fabric. The system employs a high-resolution camera for picture capture and a stepper motor for the conveyor mechanism. Moreover, enough illumination is crucial, as insufficient lighting can result in substandard digital photos. The suggested system will employ a neural network to recognize and categorize the photos. The implementation of neural networks can enhance system performance. Processing speed can be improved using a high-performance GPU or CPU, hence decreasing computing time [11].

Deep learning is an advanced approach utilized for identifying faults in cloth. The system employs a high-resolution camera to capture images and a stepper motor for the conveyor mechanism. Furthermore, an adequate illumination source is essential, as insufficient lighting may lead to substandard digital photos. The suggested system would employ a neural network to recognize and categorize

photos. Neural networks enhance system efficiency. Utilizing advanced GPUs or CPUs can enhance processing performance and diminish computing time [12].

RELATED WORK

An efficiently automated system facilitates reduced labor costs and minimizes manufacturing time. This issue draws considerable attention from researchers, resulting in numerous articles that have developed fabric flaw-detecting systems employing diverse methodologies. Ouyang *et al.* [13] have investigated the detection of fabric defects through the utilization of an embedded convolutional neural network activation layer, employing fabric image autocorrelation to define fabric motifs and leveraging it as a prominent feature. They forecasted elevated precision and introduced PPAL-CNN.

Hanbay *et al.* [14] introduced an optical-based fabric fault detection method. The quantity of yarns and fibers functions as essential units. Nonetheless, prospective fabric imperfections can be mitigated by evaluating yarns and fibers prior to fabric production. Wenninger *et al.* [15] suggested a flaw detection system for plain woven fabrics utilizing a fully convolutional network alongside yarn tracking. A method for fabric fault identification has been described. The fibers of the fabric might be identified and monitored without any conditional parameters. Subsequently, the ripple faults were identified. This issue was previously addressed using a neural network, but was limited to grey fabric exclusively. This research introduced a sophisticated colored fabric defect detection system utilizing deep learning, featuring a camera positioned above the moving fabric at an appropriate distance, accompanied by an illumination source. The system would collect the image and input it for processing (testing). In the event of an error, the motor will cease operation instantaneously. Consequently, this system would be highly beneficial in both small-scale and large-scale textile enterprises that aim to minimize labor costs while achieving superior fabric quality in the quickest possible timeframe.

Liu *et al.* [16] conducted a systematic analysis of contemporary variants of low back pain and presented a taxonomy to more distinctly categorize the notable alternatives. The advantages and disadvantages of the different LBP traits and their interrelations were also examined. A comprehensive performance evaluation was conducted for texture classification, empirically analyzing forty texture features, which comprised thirty-two recent and promising LBP variations and eight non-LBP descriptors derived from deep convolutional networks across thirteen widely-utilized texture datasets. The tests aimed to assess their resilience to various classification problems, encompassing alterations in rotation, scale, illumination, viewpoint, class quantity, diverse forms of image degradation, and

CHAPTER 2

Revolutionizing Learning: The Role of AI in Modern Education

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Abstract: Artificial intelligence is revolutionizing education by enhancing learning results, accessibility, and engagement. AI is changing education by fostering diversity, streamlining administrative tasks, and enabling individualized learning. AI-powered tools that simplify complex subjects and provide individualized learning include virtual reality, adaptive learning platforms, and intelligent tutoring systems. This chapter explores the applications, benefits, challenges, and ethical quandaries of artificial intelligence as it relates to education. It investigates how teaching strategies in educational institutions are impacted by care ethics. These methods have been found to improve accuracy, efficiency, and resource allocation. Teachers may spend more time discussing concepts and communicating with students because administrative automation reduces administrative burden. Additionally, with the help of AI-supported simulation, students can practice technologies, evaluate ideas, and work through issues in a dynamic yet controlled setting. It imagines a future where artificial intelligence enhances human creativity and collaboration by looking at these opportunities and challenges, making education an inclusive, learner-centered, and lifelong experience.

Keywords: Artificial Intelligence, Virtual Reality, Digital Transformation, Lifelong Learning, Learning Analytics, Educational Equity.

INTRODUCTION

Artificial intelligence is transforming education by offering methods and technologies that enhance training, personalize learning, and make knowledge more accessible. AI can be applied to solve global problems, such as democratizing access to high-quality education, assisting children with disabi-

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lities, and bridging the digital divide. Social constructivism, which emphasizes a student-centered approach to learning, is where the ethics of care can be found. This allows teachers to engage pupils in learning in a reciprocal relationship. It looks at how normative ethics of care practices, which are portrayed in schools as culturally neutral, maintain social reproduction. It argues for a critical examination of how the teaching-learning relationship is shaped and constrained by the white ethics of care paradigm in education [1]. The paradigm is changing in favor of services that are driven by problem-solving and assessed by the attainment of favorable results. Examine key policy and reform statements, compare and contrast various approaches to the planning and provision of school psychology services, and assess issues with the conventional delivery system, the body of information, fundamental ideas, and methods that support psychological services that prioritize functional evaluation, problem-solving, and educational responsibility. The Best Practices in School Psychology theme was a paradigm shift. We were before because several states have successfully implemented system reform; research has shown that IQ is irrelevant in identifying students with high incidence disabilities, which make up 85–90% of all students with disabilities; It is learning more about effective academic and social/behavioral interventions; reputable reports and the government is increasingly supporting systems that use non-categorical eligibility and functional assessment [2]. The dynamics of embracing changes in the educational system, such as shifting toward digital solutions, adopting a new paradigm, and changing delivery methods, it is the online learning management system's difficulties, problems, obstacles, and success criteria. The degree is significant from the planning stage to the real deployment of the learning system in higher education. The commercial sector stepped up to provide learning continuity by offering basic, secondary, and higher education [3]. The ability of a teacher to impart knowledge in their field of expertise was the main criterion used to evaluate their excellence in previous pedagogies. The development of pedagogical capacity in educational institutions was of secondary importance. The majority of the time, “teaching strategies” referred to direct instruction. Technology has been used for content distribution in recent years, mostly to help students grasp the material that is required for their courses. A relevant education extends outside the classroom to contextualize the issues by the local communities and individuals as elements of the learning environment. With the advent of ICT and online learning, there is an abundance of possibilities for growth and a shift from basic classrooms to sophisticated virtual learning environments where students may work together at any time or location [4]. AI is computer software that simulates human intellect. It is composed of several algorithms, including reinforcement learning, machine learning, decision support systems, and deep learning. Models that reflect knowledge about the real world are created using these methods. Models are

created in digital education to comprehend the subject being acquired (learning), assess the learner's understanding, and comprehend the teacher's expertise (teaching). AI is used to generate digital learning, as shown in Fig. (1). AI is made up of several algorithms, including DSS, ML, DL, and RL. The teaching, learning, and assessment process is supported by these algorithms in terms of feedback analysis, adaptive and personalized learning, learning analytics and knowledge distribution, and course assessment. In order to comprehend the function of AI in education from the standpoints of instruction, learning, and evaluation, six data analysis goals are outlined [5]. Table 1 lists the emphasis and study objectives in addition to the dataset mapping, which is shown in Fig. (1).

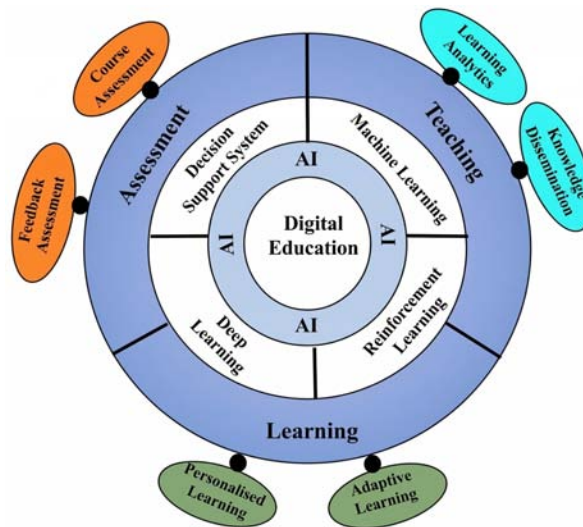


Fig. (1). Role of AI in education [5].

Table 1. Intelligence Assistance in Teaching, Learning, and Assessment [5].

Perspective	Focus	Study objective
Teaching	Learning analytics	To examine how various teaching philosophies affect students' arithmetic performance.
	Knowledge dissemination	To comprehend the reactions to various UdeMy course levels.
Learning	Adaptive learning	To forecast exam results at the end of the semester.
	Personalized learning	To comprehend how test preparation affects students' performance.
Assessment	Feedback assessment	To comprehend how students behave online and how they are graded in advance of class.
	Course assessment	To use a virtual learning environment to forecast students' success in online courses.

Heart Stroke Disease Prediction Using Metaheuristic Techniques of Machine Learning

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Abstract: Heart disease remains one of the most prevalent causes of death worldwide, highlighting the critical need for early diagnosis and preventive measures. This chapter focuses on developing a heart stroke risk prediction system using machine learning-based models. A publicly accessible heart disease dataset that includes important health markers like age, sex, type of chest pain, resting blood pressure, cholesterol, fasting blood sugar, electrocardiogram readings, maximum heart rate, and other pertinent variables is used to train the algorithms. Several machine learning algorithms, including Random Forest, Logistic Regression, and SVM, were used to analyze the dataset that contained all of the patients' health-related data in order to determine which one best fit the data and could most effectively forecast risk. The study's main conclusion is that the Random Forest algorithm performs the best, as shown by important metrics including accuracy, precision, recall, and f1-score.

Keywords: Heart stroke disease, Logistic regression, SVM, cross-validation, Machine learning.

INTRODUCTION

One of the most serious consequences of cardiovascular illness, heart stroke, continues to be a major source of morbidity and death worldwide. Early detection of individuals at risk of heart stroke can significantly reduce the rate of severe health complications and fatalities. Clinical examinations based on a number of health markers, including age, blood pressure, cholesterol, and other cardiovascular variables, are traditionally used to determine the risk of stroke [1]. However, it is frequently challenging to reliably predict stroke using traditional approaches due to the complexity and variability of these clinical variables. With its capacity to evaluate vast datasets, find trends, and offer predictive insights, machine learning has become a potent instrument in the medical field in recent

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years [2]. These capabilities can be applied to the early detection and prevention of heart attacks. Heart stroke is hard to forecast because it's a complicated condition. The risk of stroke is influenced by a wide range of clinical factors, many of which are interrelated and vary significantly from patient to patient. The models that are now in use are either too basic or not sufficiently generalizable to other populations. Additionally, the need for an accurate, interpretable, and scalable model to predict heart stroke risk is critical for healthcare providers to make informed decisions and prioritize patients at high risk [3]. The complexity of analysing clinical data remains a significant hurdle in developing reliable prediction models, particularly in identifying which variables have the most predictive power [4].

According to WHO data, heart attacks or strokes account for four out of five fatalities, with one-third of those deaths occurring before the age of 70. According to another 2016 report, approximately 17.9 million individuals died that year, accounting for 31% of all deaths, with heart attacks and strokes accounting for 85% of these deaths. Factors that mostly increase the chance of a stroke or any heart disease in a person include blood pressure, blood sugar level, cholesterol level, obesity, lifestyle, and any blood flow abnormalities like thalassemia. Also, it can happen all of a sudden without any of these factors or symptoms.

Literature Review

Stroke is one of the leading causes of mortality across the globe, thereby requiring a critical need for accurate and early prediction systems. Machine learning algorithms, when combined with metaheuristic optimization algorithms, result in enhanced predictive accuracy, feature selection, and model generalizability in healthcare applications [5]. In 2019, several researchers demonstrated the effectiveness of various classifiers, such as SVM, logistic regression, decision trees, and random forest, on the UCI heart disease dataset. It was found that these models often face challenges in terms of feature redundancy and parameter tuning. Table 1 shows the various works along with the different methodologies used by researchers for the prediction of heart stroke.

METHODOLOGY

Dataset Description

This heart illness dataset, which includes details on the characteristics associated with cardiovascular health, was extracted from the UCI Machine Learning Repository for the purpose of studying and analyzing the prediction of heart stroke, typically for a classification job. The collection includes information on 14 distinct traits from 1500 individuals. Age, gender, kind of chest discomfort,

cholesterol, fasting blood sugar, maximum heart rate attained, thalassemia, and other characteristics are included. In feature engineering, data is generated synthetically as the available dataset is only of 300 rows, and for better accuracy of the models, we needed a large dataset. Moreover, no real data is readily available, so we generated synthetic data. Scaling of data is done as a preprocessing step by applying normalization and an integrated mean cross-validation score.

Table 1. Methodologies used by various researchers for the prediction of heart stroke, along with the accuracies obtained.

S.No	Paper Title	Authors	Objective	Method Used	Parameter	Accuracy
1	Machine Learning Developments for Stroke Prediction: An Extensive Analysis [6]	F. Mohammed Arshad; K. Sharmila	To assess and contrast different machine learning models' performance in predicting strokes.	K-Nearest Neighbors (KNN), Random Forest, and Logistic Regression are the three main machine learning models.	Age, BMI, Hypertension, Heart Disease, Smoking Status, and Glucose Levels	Random Forest: 96.97%
2	A comparative analysis of machine learning methods for predicting heart attacks [1]	Sharmistha Bhattacharjee; Miraz Al Mamun; Partha Pratim Pandit; Fariha Tabassum; Fatema Tabassum Liza; Madhab Chandra Das	To identify the most accurate algorithm for predicting stroke risk.	Decision Tree, k-Nearest Neighbor	Depth, minimum samples split, Number of neighbors (k)	~85%-90%

AI-guided Agriculture Shaping the Future of Farming Practices

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Abstract: The agriculture industry is severely suffering due to climate variation, high investment, low returns, and manpower shortage. Furthermore, agricultural land is contracting due to rapid industrialization and urbanization. These challenges have affected the sustainable agricultural growth and raised a serious concern about food security for growing populations. Therefore, investing in innovative tools and techniques in agricultural practices has become a necessity to reduce farming costs, minimize labour dependency, optimize water needs in irrigation, and enhance crop yield. The learning capabilities of AI algorithms can significantly analyze historical patterns of environmental data to predict weather patterns and anticipate climate change impacts. The integration of IOT with AI technology provides valuable insights into soil quality, seed selection, irrigation scheduling, weed management, and pesticide use. AI-enabled farming robots and drones are improving the detection of weeds and crop diseases, and enabling precise pesticide application, thereby reducing farming costs and enhancing crop yields. Research has shown that AI-enabled robots and drones can enhance crop productivity by up to 30%. In this context, this chapter highlights the transformative role of AI in crop monitoring, irrigation management, yield prediction, disease and pest detection, weed control, and weather forecasting.

Keywords: AI algorithms, crop disease detection, pest detection, irrigation management, imaging robots, precision farming, weather forecasting, weed control.

INTRODUCTION

Agriculture is the backbone of the economy for many developing countries, providing food to over one billion people worldwide. In India, the agricultural sector itself employs nearly half of the population and contributes approximately

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18% to the national Gross Domestic Product (GDP) [1, 2]. Over the past decade, modern tools and technologies have been progressively adopted in agriculture to boost crop yields and meet growing global food demands. With the world population expected to touch ten billion by 2050, ensuring food security has become more critical than ever [3]. However, increasing crop yield is a complex challenge, mired by factors such as climate change, global warming, declining soil fertility, and unpredictable weather conditions [4, 5]. The integration of Artificial Intelligence (AI) with the Internet of Things (IoT) offers promising solutions to these challenges. AI-powered algorithms can analyze vast and complex agricultural datasets to support informed decision-making, helping farmers optimize resource utilization and enhance productivity [6]. Agriculture 4.0, which clamped cutting-edge technologies such as machine learning, deep learning, blockchain, and smart autonomous systems, is revolutionizing traditional farming practices [7, 8]. These innovations are paving the way for more efficient, sustainable, and resilient agricultural systems.

AI technology has emerged as a powerful data processing tool through Machine Learning (ML) algorithms such as Artificial Neural Networks (ANN) and Support Vector Machines (SVM), Deep Learning (DL), computer vision, chatbots, and Natural Language Processing (NLP) [9]. Advanced AI algorithms, such as generalized AI, have led to more accurate and effective weather forecasting, irrigation management, disease and pest detection, and yield prediction [10]. Generative AI algorithms process complex datasets collected from high-resolution imagery obtained through drones, robots, satellites, and field sensors to generate insightful solutions for farmers [11]. AI-powered robots are accurately performing manual tasks such as weeding, harvesting, and fruit picking, thus significantly reducing labour costs [12, 13]. Thus, innovative tools and computer technologies in farming systems have mitigated crop losses while ensuring sustainable agricultural practices [14, 15]. Research has shown that AI and IoT applications, along with drip-based irrigation systems, have improved water efficiency by up to 50% [16 - 18]. Ongoing research continues to focus on developing more versatile and reliable IoT-based irrigation systems to minimize water wastage.

Thus, the recent advancements in farming practices, utilizing the analytical and statistical potential of advanced AI algorithms, can further enhance crop productivity, promote sustainability in agriculture, and ensure food security for future generations. Thus, AI-powered solutions could help to improve agricultural yields and ultimately enhance farmers' income in countries like India, where most of the population is based on agriculture for their livelihood [19, 20]. By systematic solving the challenges in the agriculture sector with the power of AI-based innovations, it can switch from reactive solving to proactive and sustainable methods. In this context, this chapter presents a comprehensive overview of the

progress and applications of AI in agriculture, along with the associated challenges and potential solutions.

INNOVATIONS IN PRECISION FARMING USING AI

Precision farming, utilizing the analytical and predictive solutions of AI and IoT applications, enhances agricultural practices and helps farmers shift from losses to profitability. Fig. (1) presents the extensive usage of AI technology across different sectors of agriculture. The figure shows that weather forecasting, smart irrigation, disease detection and pest management, weed detection, crop monitoring, and yield prediction are the key areas where AI is revolutionizing farm practices.

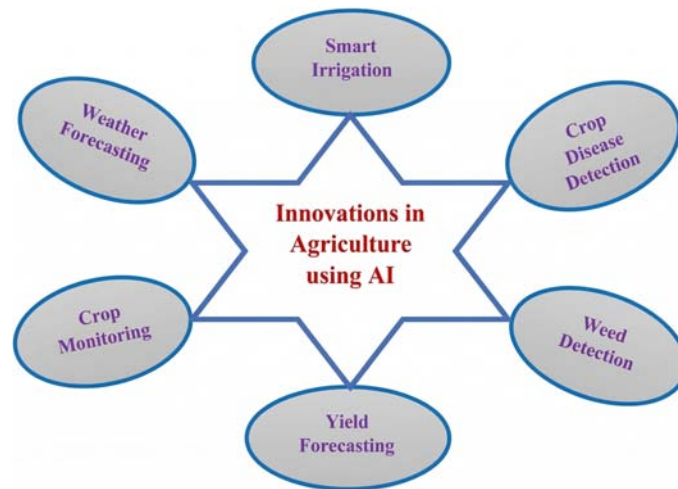


Fig. (1). Transformative AI applications across agricultural domains.

AI-DRIVEN CROP MONITORING

Drones and robots with high pixel cameras and AI enable decision-making capabilities, assist farmers in detecting crop health, soil quality, weather conditions, and eventually crop yield. Using multispectral and hyperspectral cameras, the drones take high-resolution aerial images that are analysed by AI algorithms to detect crop diseases, water stress, and pest infestations [11, 14]. Firms like Precision Hawk in the US use AI technology to give farmers actionable information that minimizes crop loss and reduces pesticide use. Fig. (2) illustrates a drone-based crop monitoring system developed by Zena Drones. It has a high-definition camera for capturing images, video, and data for smart surveillance solutions. All-Terrain Vehicles (ATVs) having multiple sensors and imaging technology offer ground-level information on crop health conditions. These autonomous vehicles and drones are assembled with advanced sensors to monitor

CHAPTER 5

AI-Powered Maintenance Planning and Hydrogen Energy Performance in Cargo Drones**Surbhi Gupta^{1*}, Rekha Devi¹ and Sarbjeet Kaur¹**¹ *Department of Electrical Engineering, Chandigarh University, Gharuan, Mohali, Punjab, India*

Abstract: Drones powered by hydrogen fuel cells, which have longer flight durations and emit less carbon emissions, are emerging as a sustainable alternative for intercity cargo transportation. However, there are still issues related to reliability and fuel efficiency, as well as achieving optimal fuel efficiency. This study examines the development and application of hydrogen-powered drones for cargo delivery between cities. Because of their high energy density and zero emissions, hydrogen fuel cells provide an attractive alternative to traditional modes of transportation, which have decreased their sustainability benefits due to worries regarding carbon emissions. Because of the development, construction, and operation of hydrogen-powered drones, this endeavour aims to reduce dependency on conventional air and road transportation, and these drones will be able to transport supplies between cities. The study begins with a presentation of current drone technology, emphasizing the limitations of battery-powered drones in terms of range and cargo capacity. After that, a thorough analysis of hydrogen fuel cell technology is presented, with a focus on how it might improve drone endurance and operation. The challenges and useful benefits of implementation are illustrated through case studies and real-world applications. The findings of this study support the broader goal of developing effective and environmentally friendly transportation networks and set the stage for future developments in drone technology.

Keywords: Drone technology, Hydrogen Fuel cells, Intercity cargo transport.

INTRODUCTION

Rapid developments in drone technology are opening new avenues for creative thinking across a range of sectors, including logistics and transportation. Among these developments, the creation of hydrogen-powered drones for intercity cargo transportation stands out as a potentially practical replacement for traditional drones that are battery-operated.

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Utilizing the benefits of hydrogen fuel cells, this novel approach improves the efficiency, range, and sustainability of cargo drone operations. Hydrogen fuel cells- potentially more effective and environmentally friendly power sources than lithium-ion batteries are used in drones that run on hydrogen. These drones are designed to transport goods between cities, meeting the growing need for faster and greener delivery methods in the logistics sector. By using drones with hydrogen fuel cells, there is a reduction in carbon emissions, an increase in the flight distance and a reduction in downtime.

In the logistics industry, there is a growing need for prompt and dependable delivery services due to the growth of e-commerce and rising customer expectations. Traditional drones that run on batteries have been crucial in meeting these expectations by offering quick delivery choices over short distances.

However, the limitations of alternative fuels in terms of flying time and payload capacity have prompted research into them. Hydrogen fuel cells offer a potential solution to those problems because of their increased electricity density and faster refuelling times. Hydrogen-powered drones are superior to battery-powered drones in several ways.

Hydrogen fuel cells offer a higher energy density than lithium-ion batteries, which enables longer flight times and greater payload sizes. Hydrogen-based drones are therefore the best option because intercity goods delivery requires greater flying ranges. Additionally, hydrogen fueling takes a lot less time than battery recharging, which reduces downtime and increases operational efficiency. Rechargeable lithium-ion or lithium-polymer batteries, which are lighter and simpler to charge than other battery types, are used in drones that run on batteries. They often only fly for 20 to 30 minutes, though they are suited for lighter payloads and shorter trips. Hydrogen fuel cells, which have a higher energy density and enable longer flight time enable longer flight times, often several hours, are used by drones that run on hydrogen. These drones are ideal for longer missions and larger payloads, but they face more complex challenges for refuelling. Also, manufacturing batteries and disposal pose a risk to the environment. Since hydrogen fuel cells only emit water vapour, a more environmentally friendly option than batteries, which have a large environmental impact due to mining and disposal issues.

This is in line with international initiatives to promote sustainable technologies and reduce carbon footprints. Drones driven by hydrogen have the potential to drastically reduce greenhouse gas emissions during cargo delivery, which will aid in the shift to more environmentally friendly logistics systems. Drones, having greater flight ranges, faster refuelling, and less of an environmental impact,

probably overcome the shortcomings of their battery-powered competitors. The use of drones powered by hydrogen could be crucial to determining the future of freight delivery and advancing greener and more effective modes of transportation as logistics continually develop.

LITERATURE REVIEW

The literature survey shows differing opinions from various authors. The first paper, based on Hybrid Fuel Cell Powered Drones, focuses on the challenges in the fuel economy while extending the sources' lifespans in persistent missions. The off-the-shelf drone powered by a 650 W fuel cell can be extended by 37 minutes. The study involved using an electric fuel cell/battery-based drone. The paper outcome shows that power sources operated below their rated capacity, leading to 5.1% of fuel consumption. The Operating cost was achieved at 1450€ for one fuel cell stack lifecycle [1]

Hybrid fuel cell-powered drones have attracted a great deal of attention based on the prospect of extended flight times and improved efficiency. This review combines recent literature in the field to emphasize the principal developments, system architectures, and performance studies.

Energy Management Strategies: Efficient energy management is important for maximizing the performance of hybrid fuel cell drones. Energy management strategies for hydrogen conservation and efficiency enhancement. Based on real flight test data, they proved that a more advanced energy management system could extend drone endurance by about 21.81 minutes [1].

System Architectures: To balance the supply and demand of power, several hybrid system architectures have been studied. Three topologies using lithium-polymer batteries and proton exchange membrane fuel cells (PEMFCs) were examined in a 2020 study by an unnamed author. The study indicated the design factors that must be considered for fixed-wing UAVs to operate at their best [2, 3].

Integration with Renewable Energy: Improving UAV endurance by the integration of fuel cells with renewable energy sources has shown promise. According to recent research, tiny UAV flight times can be nearly doubled by combining solar and fuel cell technologies. For instance, Gang et al. achieved extremely long flying periods by using a hybrid system that included an 80 W solar cell system, a battery, and a 300 W PEMFC [4].

Practical applications have proven the feasibility of hybrid fuel cell drones. The Hybrid Tiger UAV by the Naval Research Laboratory combines a PEMFC system

A Study of Blockchain, IoT, and Cryptography in the Healthcare Sector: An Extensive Review

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Abstract: With a secure distributed ledger system, blockchain technology helps to shape the healthcare sector in terms of transparency and accountability. This research paper highlights the transformational impact that blockchain technology plays in the healthcare sector. It focuses on a variety of technologies, including patient data security, real-time monitoring enabled Internet of Things (IoTs). This paper also addresses the revolutionary impact that current technology, such as cryptography and Zero Knowledge Proofs (ZKPs), has played in shaping modern technology and improving privacy and security in the health care system. This study contrasts existing blockchain technologies with emergent developments that aid in the creation of a decentralized, safe ecosystem that promotes accountability. Blockchain provides a decentralized, immutable, and transparent ledger. It enhances security, privacy, and trust in data transactions without relying on centralized servers.

Keywords: Blockchain, Cryptography, Zero Knowledge Proofs (ZKPs), Internet of Things (IoT), Decentralized Ledger, Data Privacy, Smart Contracts, Electronic Health Record.

INTRODUCTION

Blockchain technology is a modern database mechanism that allows information sharing within a network with transparency [1]. A blockchain is a database that stores data in block format that is linked together within a chain. The data is chronologically consistent because it cannot be deleted or modified in the chain without consensus from the network. So, the blockchain can be used to create an unalterable ledger for tracking orders. It can also be used for tracking payments, accounts, and other transactions.

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Blockchain is a digital system that executes and records transactions, which can be visualized as a building block, constructed from intelligent algorithms and secured by cryptography. In multiple fields like financial markets, military, or healthcare, private companies as well as governments are using blockchain technologies to design high-tech paradigms [2]. This is because trust is built into a model through immutable records on a distributed ledger. Many people consider blockchain technology as the most significant invention after the internet, and it is widely considered to resolve the trust issues of people using the internet using peer-to-peer networking and public key cryptography solutions [3]. It is commonly agreed that the technology currently needs time to mature, but we need to be ready for the adoption of this unprecedented archetype. There is a huge potential for Blockchain technology to radically transform interactions, raising critical questions for governments and society.

IMPLEMENTATION OF BLOCKCHAIN IN THE MEDICAL INDUSTRY

Blockchain can be applied in the healthcare sector due to its high-level security and patients' medical data exchange, which will lead to ultimate cost reduction and new ways to access patients' healthcare and maintain privacy [4]. The combination of the compounding nature of data and future-proofing technology can be applied to foster an era of innovation [5, 6]. Many companies are laying the foundations for a blockchain revolution. Discussing different types of blockchain with their advantages and disadvantages.

Table 1. Different types of blockchain.

SUBJECT	PUBLIC	PRIVATE	HYBRID	SECTORS
ADVANTAGES	<ul style="list-style-type: none"> ● Independence ● Transparency ● Trust 	<ul style="list-style-type: none"> ● Access Control ● Performance 	<ul style="list-style-type: none"> ● Access Control ● Performance ● Scalability 	<ul style="list-style-type: none"> ● Access Control ● Scalability ● Security
DISADVANTAGES	<ul style="list-style-type: none"> ● Performance ● Scalability ● Security 	<ul style="list-style-type: none"> ● Trust ● Audit ability 	<ul style="list-style-type: none"> ● Transparency ● Upgrading 	<ul style="list-style-type: none"> ● Transparency
USE CASES	<ul style="list-style-type: none"> ● Crypto currency ● Document Validation 	<ul style="list-style-type: none"> ● Supply Chain ● Asset Ownership 	<ul style="list-style-type: none"> ● Medical Sectors ● Real Estate 	<ul style="list-style-type: none"> ● Banking ● Research ● Supply Chain

Public Blockchain: A public blockchain is a decentralized and open network where anyone can join, access, and participate without restrictions. All transactions and data are recorded on a transparent ledger visible to all participants. These blockchains rely on consensus mechanisms such as Proof of Work (PoW) or Proof of Stake (PoS) to validate transactions and maintain security. Public blockchains are highly secure and resistant to tampering due to

their decentralized nature, though they may face issues related to scalability and energy consumption. Examples include Bitcoin and Ethereum, which are widely used for cryptocurrencies, decentralized applications, and smart contracts, as shown in Table 1.

Private Blockchain: A private blockchain is a permissioned network where only authorized participants can access and contribute to the system. It is typically controlled by a single organization or a consortium of entities. Unlike public blockchains, private blockchains are more centralized and offer greater control over data access, privacy, and transaction speed. These features make private blockchains suitable for enterprise use cases such as supply chain management, internal auditing, banking, and healthcare systems. Hyperledger Fabric and R3 Corda are popular examples of private blockchain platforms.

Hybrid Blockchain: A hybrid blockchain combines elements of both public and private blockchains to provide a balanced solution. It allows certain data to be kept private while enabling other information to be shared on a public ledger. This structure is ideal for organizations that need both transparency and confidentiality. Hybrid blockchains offer flexibility, scalability, and controlled access while still benefiting from the security and immutability of blockchain technology. Use cases include government services, healthcare data sharing, and enterprise collaboration. Examples include Dragon Chain and XinFin (XDC).

DISTRIBUTED LEDGER TECHNOLOGY

A Blockchain is a system that records whatever is shared between participants. It records all the transactions carried out by any of the members, and all participants will have a copy of the ledger. This system is known as replication. Each transaction is enclosed in a block. A block may contain multiple transactions and is the basic unit to be verified by all the members. Each block contains a hash value of the previous block's header and thus forms a hash chain or blockchain. All the blocks are chained, so the order of the blocks is maintained. Each block serves as a timestamp of the enclosed transaction. Each member maintains a copy of the blockchain [6]. In a network, one could distinguish between permissioned and permissionless blockchain systems.

IMPORTANCE OF ZKPS (ZERO-KNOWLEDGE PROOFS) IN BLOCKCHAIN TECHNOLOGY

Zero-Knowledge Proofs (ZKPs) have received a lot of focus in blockchain research, acting as crucial instruments to improve privacy, scalability, and security. Zero-Knowledge Proofs (ZKPs) are advanced techniques that provide multiple ways for a prover to show a verifier that a statement is true without

Artificial Intelligence in Healthcare: A Guide to Strategic and Sustainable Integration

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Abstract: The advent of Artificial Intelligence (AI) is revolutionizing healthcare and reshaping diagnostics, treatment, and patient care. This chapter explores AI's transformative role in modern medicine, emphasizing its ability to enhance precision, streamline processes, and make healthcare more accessible. Through algorithms that analyze vast amounts of data, AI enables early detection of diseases, accurate diagnosis, and personalized treatment plans tailored to individual genetic profiles and health histories. It optimizes workflows, reducing the administrative burden on healthcare professionals and allowing them to focus more on patient care. AI-driven tools, such as predictive analytics, assist in identifying at-risk populations, aiding in preventative care and resource allocation. Robotics and AI-powered surgical systems enhance the accuracy and outcomes of complex procedures, reducing recovery times and complications.

Additionally, AI-driven telemedicine platforms increase access to healthcare in remote and underserved areas, breaking geographical barriers. However, the rapid integration of AI presents ethical and regulatory challenges, including concerns about data privacy, algorithmic biases, and the need for human oversight in critical decision-making. This chapter delves into these issues, discussing the evolving role of AI in clinical settings and research and the collaborative efforts required to ensure AI is used responsibly and effectively in healthcare. By examining case studies and current applications, the chapter aims to comprehensively understand how AI shapes a future where healthcare is more innovative, faster, and patient-centered.

Keywords: AI, Healthcare, Natural language processing, Robotics surgery.

INTRODUCTION

Artificial intelligence (AI) in the healthcare sector encompasses various applications, from image recognition technology that detects disease in images to

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predictive models that extrapolate patient outcomes. Key components of AI in this domain include Machine Learning (ML), Natural Language Processing (NLP), and robotics. Simply machine learning allows computers to learn from data, identify patterns, and improve accuracy without human intervention. Deep learning (a machine learning subtype based on artificial neural networks) is an essential player in complex tasks such as image and speech recognition, making it useful for medical image interpretation (*e.g.*, X-rays, MRIs) [1].

Natural Language Processing (NLP), the second pillar of AI, enables computers to understand human language and is used in many applications like Electronic Health Records (EHRs) and clinical documentation. NLP, which derives meaningful information from unstructured data like physician notes and medical literature, enhances the capacity to analyze medical records and research in real time. Although separate from AI, robotics includes automation and precision technologies driven by AI to improve surgical procedures, rehabilitation, and routine patient care tasks. Unlike humans, AI has the capability of processing and analysing data at speeds and scales that no human can handle, notably in healthcare, where the increasing amount of patient data exceeds our human ability to interpret it. Using genomic data, AI can predict disease risk, track vital signs in real time, and help clinicians identify the best treatment approach [2]. Therefore, AI serves as a partner for healthcare professionals, providing support to enhance human capabilities rather than being a replacement. We want to highlight the perfect blend of human intelligence and AI-driven insights with numerous untapped potential to improve healthcare outcomes.

AI in healthcare started with early research aimed at automating medical tasks and interpreting data in the mid-20th century. AI was first introduced into medicine in the 1960s when early experiments in clinical decision-making were carried out. For example, systems such as MYCIN and INTERNIST-I, which were developed in the 1970s, employed rule-based algorithms to help physicians diagnose infections and complex internal diseases. These systems showed that AI was possible, but at the time, their limited computing power and hard-coded rules made them impossible to apply widely anyway. The 1990s saw stumbling blocks in computing and data storage get knocked down, supporting more complex healthcare applications. While this happened, we were in the earlier stages of building AI-assisted tools to interpret medical images, including mammograms and CT scans. AI applications have also started in diagnostic labs, assisting pathologists with automated blood sample and cell image analysis [3]. Pioneering usage of artificial intelligence paved the way for considerations that would lead to modern AI: better computational capacity, more sophisticated algorithms, and datasets measured in petabytes. Widespread EHRs in the 2000s have facilitated access to clinical data, thus accelerating AI implementation.” With the initiation

of EHR systems, machine learning had a large new storehouse of patient data to operate on: digitized records that would enable algorithms to learn patterns, predict future outcomes, or make clinical recommendations. The proliferation of AI-based tools started managing patient records, reviewing medical literature, and helping physicians make evidence-based decisions [4]. AI applications have been proliferating over the last decade in almost every aspect of healthcare, from diagnostics and treatment planning to patient monitoring. Today, radiologists use AI to help them detect imaging anomalies, predict patient outcomes based on past data, and provide virtual care *via* telemedicine. Indeed, the COVID-19 pandemic served as an additional push for AI in healthcare, where AI models were used to forecast virus transmission, create vaccines, and detect vulnerable patients [5]. This undeniably emphasizes that technology may merely need a crisis to showcase its importance and potential adaptability.

AI's transformative role in healthcare is highlighted, with a particular emphasis on diagnostics, personalized medicine, Workflow optimization, Surgical precision, automation (assistance), Telemedicine, and Accessibility. Looking at all these aspects, this chapter aims to paint a holistic picture of the capabilities AI has adopted in transforming the healthcare space and bettering human lives.

AI-ENHANCED DIAGNOSTICS AND DISEASE DETECTION

AI has also changed diagnostics and disease detection, especially in the fields of radiology, pathology, and genomics, where it assists health professionals in early detection and the accuracy and operational efficiency of other types of upstream technology. AI has demonstrated its promise in the real world by supporting healthcare professionals in delivering high-quality, timely, and personalized patient care. By refining the basic frameworks of existing automated tools, AI plays a critical role in diagnostic pathways, offering accurate detection of some diseases, and through this process, alleviating the burden on healthcare services, ultimately allowing for more timely and accurate diagnostics in the future [6]. With the growth of AI, we could find it playing an even larger role in diagnostics, bringing incredible advancements to modern medicine that will further enhance global patient outcomes.

Identifying illnesses is vital for effective treatment and good results for patients. If a disease is diagnosed early, its spread can be reduced to some extent, survival rates can also increase, and the cost of treatment becomes lower. AI further ensures better early detection of diseases by examining medical images, lab results, and even patient history to spot potential indicators or patterns that are sometimes missed by human vision. Utilizing AI algorithms that identify deviations in data measurement, clinicians can be alerted to upcoming health

CHAPTER 8

Histogram Based Quantitative Analysis for Steganographic Detection

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Abstract: This chapter provides an overview of histogram-based steganography detection techniques, one of the earliest methods in contemporary steganalysis. Despite its early development, this technique did not receive the recognition it deserved, with more focus on methods like LSB, DWT, and DCT. To address this, the histogram model is revisited to enhance its performance and efficiency. Using small datasets, we demonstrated that this approach is versatile, faster, and capable of detecting hidden information with minimal data. Additionally, the histogram technique offers potential for further technical improvements, such as integration into widely used platforms like Google Gmail, Microsoft Outlook, and Google Messages. This would enhance security in media-sharing applications by preventing the transmission of harmful hidden information. Our research confirms the efficiency of the histogram technique, particularly in comparison to other steganography detection methods, making it a clear and easily implementable solution for current digital security challenges.

Keywords: Algorithm, Contemporary steganalysis, DWT (Discrete Wavelet Transform), DCT (Discrete Cosine Transform), Histogram steganography detection, LSB (Least Significant Bit), Steganographic detection.

INTRODUCTION

In past centuries, steganography was commonly used to transmit sensitive information in concealed formats, such as invisible ink on letters or messages embedded in wax tablets [1]. In the digital age, steganography has evolved into a critical technique for ensuring secure communication and protecting digital rights. Modern digital media—including images, audio, and video—can potentially harbor hidden data. Various techniques have emerged for embedding information,

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such as adaptive steganography, transform domain methods, LSB (Least Significant Bit) substitution [2], spread spectrum techniques, patchwork methods, and masking or filtering approaches.

As the importance of data security grows, steganalysis—the process of detecting concealed information—has become increasingly vital. Advanced steganalysis leverages statistical analysis, machine learning, and deep learning techniques to uncover hidden content [3]. These technological advancements have simultaneously increased the complexity of both steganographic techniques and their detection.

Emerging innovations such as quantum computing and artificial intelligence further expand the scope of steganography. These developments promise new applications in Digital Rights Management (DRM), privacy, and secure communication by enhancing the capacity, stealth, and robustness of data embedding techniques [4]. According to Pevný, Bas, and Fridrich, future steganographic systems will integrate advanced detection mechanisms capable of identifying even highly complex data hiding strategies [5].

As technology progresses, steganography and steganalysis will play a key role in areas such as law enforcement, digital forensics, and cybersecurity. The continuous advancement of steganographic tools necessitates robust detection mechanisms to prevent misuse. Thus, ongoing research exploring the relationship between steganography and steganalysis is essential to maintaining secure communication systems.

This study focuses on histogram-based steganalysis as a technique for detecting hidden information in digital images. Histogram steganalysis identifies anomalies in the statistical distribution of pixel values that may result from data embedding. Our work enhances traditional histogram analysis by integrating a pretrained machine learning model, further fine-tuned with a curated dataset to improve domain-specific detection. By leveraging the pretrained model's feature extraction capabilities and adapting it to our dataset, the model's sensitivity to subtle pixel distribution changes is improved, which is indicative of steganographic content. Our results show a marked improvement in detection accuracy over conventional histogram methods. Performance was evaluated using standard metrics such as accuracy, precision, recall, and F1-score, confirming the effectiveness of our approach.

The covert nature of steganographic content poses significant challenges to security analysts. Because the modifications made to carrier media (*e.g.*, images) are often imperceptible, conventional detection methods may fail. This highlights the need for innovative steganalysis techniques tailored to expose hidden patterns.

Our proposed approach addresses this gap by offering a reliable, efficient method for detecting steganography in images.

RELATED WORK

Classical Spatial-Domain Approaches: Edge Detection with LBP

Early spatial domain methods embed data in the Least Significant Bits (LSBs) of pixel intensities; however, LSB schemes are easily detected or manipulated. Recent work, therefore, combines edge detection (Canny, Sobel, Prewitt) with Local Binary Pattern (LBP) codes to raise both capacity and imperceptibility. By watermarking only edge pixels and exploiting local texture information, these hybrid methods achieve higher payloads without visible artefacts and remain resilient to common image processing attacks [6]. These methods restrict embedding to high-frequency regions (edges) and leverage local texture features to resist distortion and attacks. Logical OR operations and morphological dilation are often used to refine edge maps and embedding zones.

Despite these advancements, spatial techniques remain vulnerable to geometric transformations, noise, and filtering attacks [7]. Additionally, methods based on LBP may struggle with image textures that lack contrast, reducing embedding opportunities and making the payload detection-prone in smooth regions.

Frequency-Domain Techniques: Histogram Shifting and DCT Integration

Bandyopadhyay *et al.* integrate histogram shifting with the Discrete Cosine Transform (DCT) to hide text in greyscale images while preserving perceptual quality [8, 9]. Quantitative evaluation with PSNR and BER shows high fidelity (PSNR > 40 dB) and low extraction error for payloads up to 60 characters. Despite these strengths, PSNR drops steadily as payload grows and robustness declines under aggressive compression. Subsequent studies combine spatial histogram adjustment with DCT domain embedding to balance capacity and invisibility, but they still inherit the transform domain's computational overhead and are less effective against deep learning steganalysers.

Learning-Based Detection Models: Neural Networks for Steganalysis

Recent steganalytic models learn histogram anomalies directly from data. Symmetric histogram neural networks outperform hand-crafted detectors on LSB and histogram shifting payloads by exploiting deep features from both spatial and transform domains [10, 11]. However, detection accuracy degrades as payload size grows, and models remain sensitive to adversarial image perturbations.

Empowering Green Futures: The Role of AI in Renewable Energy Transformation

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Abstract: Artificial Intelligence (AI) is revolutionizing the renewable energy sector by providing innovative solutions to challenges related to energy production, storage, and distribution. Due to increasing demand and the need for an uninterrupted supply to consumers, AI applications have become essential for optimizing Renewable Energy Systems (RES). Renewable energy sources like solar energy, wind power, hydro, geothermal, and biomass generate clean energy without emitting greenhouse gases, hence reducing global warming. AI technologies, including Machine Learning (ML), Deep Learning (DL), and robotics, enable better forecasting of weather conditions, energy production, and distribution while optimizing energy storage systems to address intermittency issues. AI algorithms enhance grid management by dynamically balancing supply and demand, ensuring efficient energy distribution, and reducing environmental impact. In addition to this, AI plays a crucial role in predictive fault diagnosis and maintenance, maximizing the lifespan of RES and minimizing repair and operational costs. Despite these benefits, challenges, such as qualitative data availability, the high cost of AI implementation, and the difficulty of replacing existing energy infrastructure remain. However, by improving decision-making through advanced AI algorithms such as reinforcement learning, generative AI, and edge computing, efficient energy generation, grid stability, and energy distribution can be achieved, and environmental harassment can be avoided. In this context, this chapter provides a comprehensive roadmap to incorporate AI benefits in renewable energy systems for efficient and sustained green energy production and its distribution.

Keywords: AI technology, Energy storage management system, Grid management, Predictive maintenance, Renewable energy system.

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INTRODUCTION

The world is currently seeking innovative solutions to reduce its dependency on fossil fuels and embrace clean, sustainable energy sources [1]. It is now essential to transition into renewable energy systems due to the escalating impacts of climate change and escalating worldwide energy usage [2, 3]. Renewable energy, including solar, wind, hydropower, and geothermal, offers the potential to not only prevent climate change but also provide secure and sustainable energy for future generations [4]. Infrastructure efficiency and resource variability are the primary challenges facing Renewable Energy Systems (RES). The aging grid systems designed for traditional energy systems need to be modified to accommodate the dispersed and variable character of RES. AI, when incorporated with renewable energy, opens up new possibilities for resolving issues with grid connection and variability. By enhancing data analysis, prediction, and optimization, Artificial Intelligence (AI) helps address these problems and promises more seamless integration and reliability of renewable energy [5, 6].

For instance, in solar energy, AI is applied to optimize photovoltaic panel placement, predict solar irradiance, and optimize maintenance schedules for better energy integration and operational efficiency [7, 8]. Similarly, in wind energy, AI-powered predictive models allow for more accurate forecasts of wind speeds, optimization of turbine performance, and effective layout design to maximize energy capture [6, 7, 9]. Hydropower, being an old renewable energy source, is not left behind by AI innovations. AI in hydropower systems helps improve the management of the reservoir, optimal turbine operation, and predictive maintenance based on the analysis of hydrological data [7, 10, 11]. On the other hand, in geothermal energy, AI-driven models help streamline the exploration process through the analysis of geophysical and geochemical data, thereby improving resource identification and optimizing energy extraction [12].

Through analysing huge amounts of data collected from resources including solar radiation, weather patterns, and wind speeds, AI plays a critical role in the renewable energy industry by enhancing predictions of energy output [13]. AI helps to predict variations in supply and demand by utilizing machine learning, which makes grid management and energy distribution more efficient [14]. Furthermore, by capturing energy trends that improve energy production, storage, and overall efficiency, AI-driven data analysis optimizes RES [15, 16]. By providing accurate estimates, sophisticated prediction models using AI can further boost energy management by empowering grid operators to make effective decisions that ensure a robust and reliable energy infrastructure [17]. This further strengthens the potential of AI when brought together with emerging technologies such as Blockchain and smart grids. AI can enhance the transparency and security

of energy transactions, support demand-response systems, and improve energy storage capabilities to ensure a reliable and sustainable source of energy [17, 18]. In the future, AI will be expected to play a greater role in renewable energy. The future innovations will be based on reinforcement learning, hybrid energy systems, and advanced energy storage solutions [19 - 21]. Therefore, AI is poised to play a central role in the global transition to a clean, sustainable energy future, driving efficiency and resilience across renewable energy systems.

This chapter describes the comprehensive application of AI in renewable energy sectors, providing insights into how AI has emerged as a transforming agent to answer global energy demands. Finally, the challenges, opportunities, and possibilities of AI innovations in the renewable energy sector are summarised.

GLOBAL AND INDIA'S RENEWABLE ENERGY GENERATION CAPACITY

The percentage share of different renewable energy sources: According to the report by the International Renewable Energy Agency, at the end of 2023, RE capacity globally witnessed an increase of a whopping 473 GW, with an increase of 13.9% [22]. In leading this expansion, solar energy achieved a tremendous surge of 346 GW, amounting to 32.2% growth and approaching 1419 GW; wind energy amounted to 116 GW with 12.9% growth and approaches 1017.2GW; in contrast, the growth in hydropower, bioenergy, and geothermal energy is moderate. Hydropower generation approaches 1,267.9 GW, thus second to renewable sources, and the generation of biomass, waste, and geothermal energy together approaches 165.3 GW. Fig. (1) depicts the share of each source of renewable energy. It is presented that solar power production has the maximum share, *i.e.*, it produces 37% of global renewable energy output.

According to the statistics until October 2024, India has a total of 452.69 GW in electricity generation, out of which renewable energy generation has reached up to 203.18 GW, which forms more than 46.3% of total electricity generation in the country. Solar power leads with 92.12 GW, harnessing abundant sunlight, followed by wind energy at 47.72 GW, utilizing coastal and inland wind corridors. Hydropower contributes 52 GW, combining large (46.93 GW) and small (5.07 GW) hydro projects. Bio power, derived from biomass and biogas, and geothermal, adds 11.34 GW, further enhancing the renewable mix [23]. Fig. (2) showcases the installed renewable energy capacity in India, with solar power generation accounting for 45% of the total renewable energy installations. Table 1 shows the installed renewable energy capacity for both the global and India. These efforts highlight India's commitment to sustainable and diverse energy solutions. This capacity is expected to grow significantly in India and globally to

Secure Monitoring of an IoT Smart Office Using Wire Guard VPN Protocol

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Abstract: The Internet of Things (IoT) is not a new thing today. The networks used in offices, homes, shopping complex, railways, etc., can be made smart by using IoT technologies. Once a smart network is designed, the network admin and the owner may access the smart network from a far location. For example, the tech admin on a business tour or the owner at their home. The proposed network is designed to deal with these security issues of the network. The proposed network is about the secure remote monitoring of an IoT-enabled smart office using VPN (Virtual Private Network) technology. The network makes use of the Wire Guard protocol framework to secure the data of the IoT network on the internet.

Keyword: IOT, Remote access, Smart office, Virtual private network.

INTRODUCTION

IoT makes the ordinary devices ‘smart’. Normal wrist watches are now smart watches, speakers are now smart speakers, and cars are self-driving smart cars, illustrating the technology's widespread application. The evolution of the IoT has enabled the automatic control of previously manually controlled electronic devices, giving rise to automated devices. Many places, such as homes, campuses, offices, and shopping malls, are made IoT-enabled smart by using smart nodes and IoT technologies [1].

The smart network chosen for the proposed network is an IoT-enabled smart-connected office network [2, 3]. Users can operate different appliances locally within the campus or a closed area by using a smart network. This network doesn't make use of the internet. It mainly focuses on the control and automation of basic services such as light, doors, security devices, and other electronic and electrical devices within the campus. On the other hand, the proposed smart

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connected network allows for remote control and management of appliances, typically over IP-based networks (*e.g.*, the Internet). This type of network provides services promoting and supporting security, energy management, and healthcare. Additionally, it includes a central hub (gateway) from which the system can be controlled, together with a graphical user interface that can be operated through a smartphone. Hence, a smart connected network merges the functionality of both the smart network and the connected network. The proposed network is shown in Fig. (1). Smart devices have different types of sensors equipped in them and have been given computing capabilities. These devices sense and collect data from the environment, like temperature and pressure, from human behaviour, like walking and speaking, user inputs, or usage patterns. This collected data can then be used to monitor and control nodes remotely.

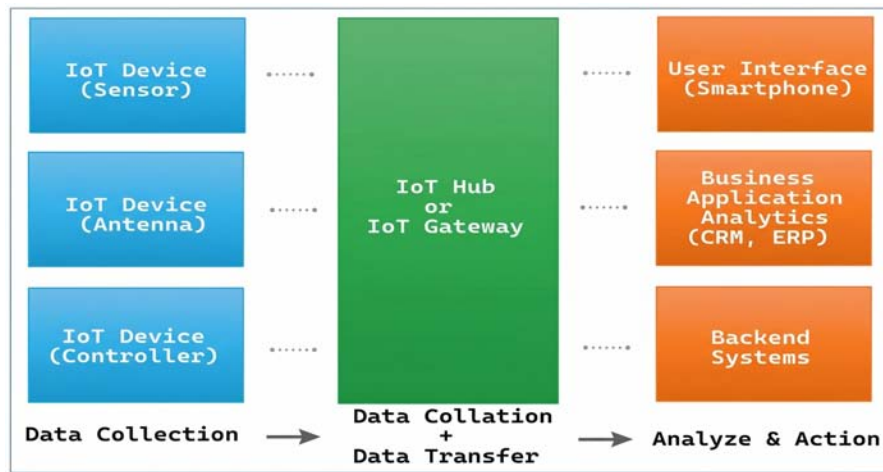


Fig. (1). Proposed network system.

A gateway device interconnects all the smart nodes together and makes them part of a single infrastructure. There are many options available to be used as an IoT gateway, for example, MCU (Microcontroller Unit, like Arduino Uno), SBC (Single Board Computer, like Raspberry Pi), and Wi-Fi routers. The choice of IoT gateway for this network is a Wi-Fi router with VPN capabilities.

The IoT registration server has the application and services enabled, so that it can be used to register all the IoT devices with it. It acts as a channel between the remote controlling device and the IoT end devices for smart functions. An IoT infrastructure may have the IoT server at the company's premises itself, or the company may rely on cloud solutions like AWS, Azure, Cisco, or some other similar IoT cloud service provider. An-house registration server is used in the

given network design. The role of these remote monitoring devices will be to get the data over the internet, which was collected by the IoT smart nodes and was sent to the gateway, and then internet.

Introduction to VPN

Security is the major issue when monitoring IoT nodes *via* the Internet from a distant place [4]. Communication between two internal networks of an organization used to be a costly method in the past, a frame-relay and MPLS WAN connection [5].

VPN is an alternative technology that may be used to connect one private network with another private network over the public Internet. VPN make use of a variety of security protocols, like SSL and IPSec etc., to provide secure data transmission at lower costs than dedicated, private links. VPN is a private network as represented in Fig. (2) [6] created over a public network for safe & secure communication [7].

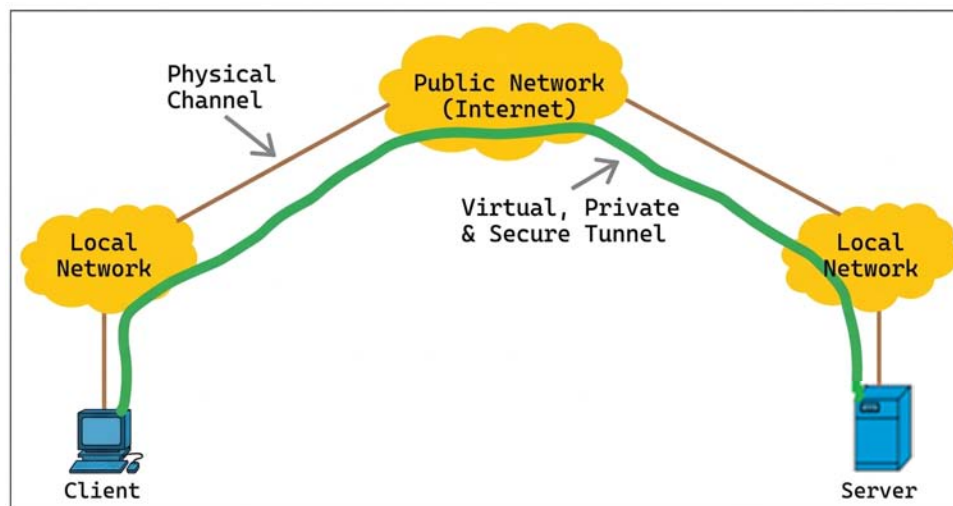


Fig. (2). Virtual private network [6].

VPN technology relies on the concept of tunnelling. Tunnelling involves establishing and maintaining a logical network association. So, a VPN is a private tunnel over an insecure path that allows users/systems to connect securely, a tunnel to allow remote users to access the organization's private network [8]. VPN uses network security protocols like IPSec and WireGuard [9] to provide privacy and data integrity.

CHAPTER 11

Artificial Intelligence in Communication: Transforming Human Interaction in the Digital Age

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Abstract: Artificial Intelligence (AI) is transforming the way communication occurs, altering how individuals, businesses, and societies interact. This chapter aims to examine the technology's impact regarding its applications, challenges, and potential in communication, based on existing research. AI enhances human contact and business communication through NLP-driven chatbots, automated content generation, deep learning, and machine learning-based translation tools. Despite having advantages, these advancements raise ethical issues such as privacy concerns linked to large-scale data collection, discrimination in automated decision-making, and the spread of AI misinformation, like deepfakes. This chapter provides a thorough overview of AI integration into communication systems by reviewing the relevant literature, highlighting research gaps, and emerging trends. Key topics include AI in customer service, personalised media, data security, and the challenge of reduced human engagement. The review also considers potential future developments such as brain-computer interfaces and AI's role in addressing misinformation. By offering a comprehensive overview, this chapter aims to inform researchers, practitioners, and policymakers about AI's influence on global communication, emphasising the importance of responsible development and regulation. This chapter demonstrates that AI's growing role as a facilitator of communication simultaneously introduces socio-economic challenges, making it crucial to understand how to manage this evolving landscape.

Keywords: Artificial intelligence, Communication technology, Emotional intelligence, Deep fakes, Misinformation detection.

INTRODUCTION

From the very beginning, communication has played a vital role in human civilisation. It has evolved through various technological phases, starting with oral

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communication, then written texts, the printing press, the telegraph, the telephone, and now the internet. Each innovation has reshaped how humans connect, share information, and build communities. Today, we are in the era of Artificial Intelligence (AI), which is the latest major advance in technology. Unlike previous advancements, AI has boosted our ability to process and generate information beyond what was imaginable. Communication AI involves using sophisticated systems with Natural Language Processing (NLP), machine learning, and deep learning technologies to assist, improve, or automate communication at various levels within different settings. This chapter explores how AI is transforming communication, its practical applications, challenges, and future implications. Fig. (1) shows the evolution of communication from oral to AI-led systems:

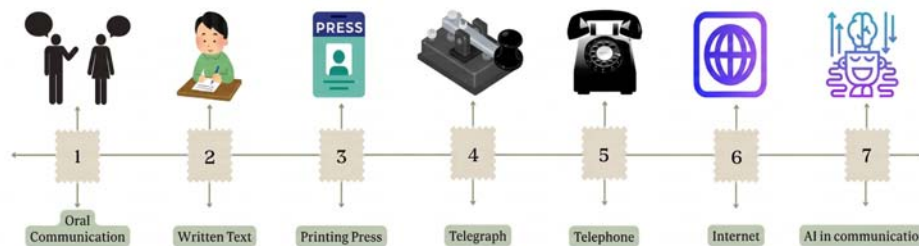


Fig. (1). Evolution of communication technologies.

The influence of AI as a communication tool is broad and intricate. Virtual assistants such as Amazon's Alexa and Apple's Siri, along with chatbots like Bank of America's Erica, offer instant responses to questions, improving convenience and AI accessibility. AI adoption in media and journalism is clear in Netflix's viewership data, where 80% of users rely on the recommendation engine, with content automation exemplified by The Associated Press's thousands of sports articles produced annually [1]. AI supports businesses in customer service, sentiment analysis, and internal communication coordination, where, in 2023, Statista reported that 70% of firms now utilise AI communication tools [2]. Beyond efficiency, AI also enhances service inclusivity; for instance, Microsoft's Seeing AI app, which describes surroundings for users with visual impairments, was downloaded more than 500,000 times in 2023.

However, there are still some challenges that come along with the transformation. There is a problem with privacy when it comes to AI systems and their use of data. For example, Amazon was sued for the Alexa voice recordings issues that dealt with consent [3]. There is a risk of social inequities being worsened by bias in algorithms, which can be seen in moderation systems that inaccurately identify some groups and overlook others. Additionally, AI-created fake material, like deepfakes, is damaging to communication reliability; such content has surged by

30% since 2019, according to a study in 2023 [4]. As these problems show, AI serves as both a unifier and a disruptor.

This chapter examines the most important works of research on AI in communication and answers the questions of how AI is expected to change the future course of human interaction and its implications in society. It focuses on the actual work and assesses the current problems of ethics, politics, technology, and many other areas. The chapter is structured as follows: Section II contains the review of the literature, Section III describes the applications in the fields of interpersonal relations, media, and business, Section IV delineates the certain challenges together with the ethics, Section V outlines the discussion on the future advancements of the subject, and finally on Section VI is the conclusion together with the suggested solutions. This document combines statistical records, case studies, and expert opinions—including McLuhan’s well-known saying “the medium is the message” [5]—to help researchers, practitioners, and policymakers understand the dynamics of AI in communication and its consequences for the work of current and future policymakers.

LITERATURE REVIEW

The integration of artificial intelligence into communication systems has gained quite a bit of attention in the various disciplines that interact with the systems in question and deal with their underlying components, such as computer science, linguistics, and media studies. This literature review aims to synthesise key studies—rung on a kind of ladder leading up to understanding AI’s transformative role in communication—to lay a foundation for that understanding among the various disciplines interacting with these systems. In this respect, the review is interdisciplinary.

Foundational Studies and Theoretical Frameworks

The foundational works in computational linguistics and Human-Computer Interaction (HCI) connect the study of AI in communication to something much older. Turing’s seminal 1950 paper introduced the concept of machine intelligence through the “imitation game,” laying the groundwork for conversational AI [6]. Weizenbaum’s ELIZA, developed in 1966, demonstrated early NLP capabilities; in a sense, it was the first chatbot [7]. The potential for machines to mimic human dialogue was clear. Of course, true understanding requires something more. The adoption of AI communication tools may be explained by theoretical frameworks such as Rogers’ Diffusion of Innovations Theory [8]. This particular model highlights the innovative qualities of technology that make it appealing to users. For example, AI might be adopted because it is efficient, accurate, and accessible in comparison to other communication tools. Furthermore, the increase in the

CHAPTER 12

A Case Study on Long-Term Wind Forecasting at the Muppandal Wind Farm in Tamil Nadu based on Regression and Neural Network

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Abstract: Wind energy potential regions such as Tamil Nadu, India, need precise long-term wind forecasts to enhance wind farm energy production and efficiency. The Muppandal Wind Farm case study showcases how advanced forecasting techniques can accurately predict local wind patterns across extended periods. Meteorological variables and previous wind data can be analyzed through Machine Learning (ML) and statistical methods to enhance a precise forecast of wind speed and its direction. Energy produced can be increased with improved precision, which results in reduced operational downtime. Temperature data at two meters above ground, wind speed data above five meters above ground have been incorporated for wind forecasting, which were collected between 2018 and 2024. According to the long-term forecast data, the chosen area maintains reliable wind energy so as to provide seamless wind energy integration with the electrical grid. By this analysis, the usefulness of predictive modeling in wind farm management and shed light on how sophisticated computational tools has been shown which can raise wind energy systems' dependability and profitability.

Keywords: MATLAB, Neural Network, Regression, Wind forecast.

INTRODUCTION

To meet an uninterrupted electricity supply and to optimize wind farm performance, a precise long-term wind forecast remains crucial. Advanced Forecasting technology has been applied in the Muppandal Wind Farm in Tamil Nadu, India, which possesses abundant wind resources. As the wind availability is unpredictable, it requires a better forecasting mechanism to maintain grid efficiency and optimize maintenance schedules.

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Located in the Kanyakumari district of Tamil Nadu, the Muppandal Wind Farm is among the largest onshore wind farms in Asia. It is located at a geologically and topographically higher region, which receives strong and persistent seasonal wind currents funneled through the mountain passes. With an installed capacity exceeding 1,500 megawatts (MW), Muppandal plays a pivotal role in Tamil Nadu's renewable energy mix, supporting the state's ambitious energy targets.

Despite its favourable location, the efficiency and reliability of power generation at Mappandal strongly rely on accurate wind predictions. Long-term wind forecasts, including monthly, seasonal, or annual views, are essential for several reasons, such as Energy Production Planning, Grid Integration, Operational and Maintenance Planning, and Investment and Policy Decisions.

This case study examines the development and evaluation of various long-term wind forecasting techniques at Mappandal Wind Park. Through analysis of historical wind data and the use of a set of statistical, mechanical learning, and hybrid models, this study aims to identify the best methods for accurate predictions in this particular topography and climate zone. The present study utilizes statistical (regression) and machine learning (neural network) methods to boost energy output efficiency and reliability through improved forecasting accuracy.

Motivation

The favourable outcome of wind energy production at the Muppandal Wind Farm depends on precise long-term wind predictions. Precision and regularity in wind forecasts are crucial in defiance of wind's unpredictability to improve wind energy production so as to maintain operational effectiveness with a reduction in cost. Better decision-making and grid reliability can be enhanced by incorporating statistical and machine learning methods, as they assist in maintenance planning, which propels the global adaptability of renewable energy sources.

RELATED LITERATURE REVIEW

- A study introduces a novel method combining “data graph” reconstruction with long short-term memory, which comprises fundamental aspects, namely a pre-processing module for interval-valued wind speed, a model library, a model selection module, and a multi-objective ensemble module [1]. The system enhances prediction accuracy by breaking down forecasting and selecting optimal models.
- LSTM networks enhance the accuracy and reliability of multi-step wind speed forecasting [2]. Time series data were converted into matrix-like “data graphs,” which bestow masked correlations within wind speed patterns. Convolutional

Neural Networks (CNNs) were employed for feature extraction from these “data graphs” to boost computational efficiency and prediction precision. A bidirectional LSTM (bi-LSTM) network module was then utilised for the processing of the extracted features.

- Another study explores the impact of incorporating a decomposition phase on enhancing wind speed forecasting accuracy. It evaluates two techniques, namely Singular Spectral Analysis (SSA) and Variational Mode Decomposition (VMD) [3]. SSA and VMD deal with the time domain and frequency domain—within a hybrid forecasting framework. Considering hourly wind speed predictions over 24-hour, 48-hour, and 72-hour horizons, the techniques achieved 51.16% improvement in forecasting accuracy, considering Mean Absolute Percentage Error (MAPE) of 10.92% for the 72-hr forecast in 2015.
- In the interest of assurance of wide application, the research [4] proposed a hybrid forecasting model that combines a deep learning algorithm with pre-processing methods. The pre-processing step handles missing values, removal of outliers, decomposition, and filtering in order to improve data reliability. The forecasting method was then optimized while reducing overall model complexity by applying Recurrent Neural Network (RNN), Gated Recurrent Unit (GRU), and LSTM models to distinct subseries according to their unique properties.
- A study introduces a hybrid forecasting framework that combines deep learning and pre-processing methods to guarantee broader applicability [5]. Data accuracy can be improved by resolving quality concerns using decomposition, Kalman filtering, and smoothing techniques. The model utilised RNN, GRU, and LSTM networks to improve forecasting performance and efficiency, choosing the best architecture depending on the features of each subseries.
- Real-time wind speed forecasting using a hybrid Bidirectional Long Short-Term Memory (BiLSTM) model was presented. A three-stage feature selection procedure that includes autocorrelation analysis, RReliefF filtering, and Boruta with Random Forest (Boruta-RF) has been employed, which makes use of wind speed data and climate index from nearby stations [6].
- Precise forecasting of wind speed time-series data becomes extremely difficult due to its nonlinearity, intermittency, and high variability. These difficulties can be overcome by utilising deep learning models that offer strong and trustworthy predictions, making them ideal for handling [7]. This study employs a direct forecasting approach to analyse long-term wind speed forecasting over the period of six months, one year, and five years using LSTM, GRU, CNN, and a hybrid CNN-LSTM model [7].
- A study introduces a deep learning hybrid model utilizing mixed-frequency modelling to improve forecasting accuracy by harnessing the advantages of mixed-frequency data [8]. The process begins with a data pre-processing module

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