

ADVANCES IN SCIENCE, TECHNOLOGY, AND ENGINEERING

TRENDS AND APPLICATIONS

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Advances in Science, Technology, and Engineering: Trends and Applications

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**Advances in Science, Technology, and Engineering:
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PREFACE

This book offers a comprehensive exploration of cutting-edge technologies across diverse domains. Unlike works focusing on isolated technologies, this volume takes an integrative approach to examining how modern innovations converge to solve complex challenges.

"Advances in Science, Technology, and Engineering: Trends and Applications" covers a broad spectrum of emerging technologies, including Artificial Intelligence, Cybersecurity, Cloud Computing, Blockchain, and Internet of Things, as well as their applications in business, healthcare, education, and environmental sustainability. By presenting both theoretical foundations and practical implementations, we provide readers with actionable insights for immediate application and strategic perspectives for long-term planning.

Organized into seven sections spanning fifteen chapters, this volume progresses from foundational concepts to data-centric and emerging technologies, and to specific applications in science, business, healthcare, education, and sustainability. Each chapter not only presents current knowledge and best practices but also highlights future research directions.

This book serves a diverse audience, including students, practitioners, industry professionals, researchers, and educators working across multiple disciplines. Its comprehensive coverage makes it valuable for both specialists seeking depth in specific areas and professionals requiring breadth across technological domains.

Our aim is to provide worldwide visibility to novel ideas that drive innovation and create value through the integration of advanced technologies. As the technological landscape becomes increasingly interconnected, this integrative approach to understanding advances in science, technology, and engineering will prove invaluable for addressing tomorrow's challenges.

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CHAPTER 1

Identification of Fruit's States (Fresh and Rotten) Using Deep Convolutional Neural Networks

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Abstract: Fruits play an important role in our daily diet. Fruits are a primary source of vitamins, fiber, potassium, and antioxidants, which help protect us from various diseases by strengthening the immune system. As only fresh fruits are beneficial for health, keeping track of fruit freshness and monitoring their state is essential. Additionally, maintaining the quality standards involves recognizing and differentiating between rotten fruits, as the decay of one can impact others. This paper proposed a solution to this real-world problem using Deep Convolutional Neural Networks (DCNN). The dataset used in this research comprises 18,652 images across 20 distinct categories, including both fresh and spoiled versions of ten fruit types. The pre-trained architectures, MobileNet101, DenseNet121, and InceptionV3, followed by additional dense layers of these models, DenseNet121, MobileNet, and InceptionV3, delivered significant test accuracy of 99.67%, 99.67%, and 98.32%, respectively. Thus, the proposed solution is not based on traditional visual indicators such as color, weight, or aroma to detect fruit condition; instead, it efficiently differentiates between fresh and rotten fruit using artificial intelligence.

Keywords: Deep learning, Fruit classification, Fresh fruit, MobileNet, Rotten fruit.

INTRODUCTION

Computer vision combined with deep learning is a potent combination for any classification. With limited resources and data, we have used images despite real-time data. However, this dataset uses image input. Fruit's freshness classification is a technique for distinguishing fresh fruit from rotten ones. Fresh fruit is an essential part of people's regular diet, and the fresh fruit market holds billions of dollars in share. To maintain a healthy, fresh fruit balance, we need to monitor the fruit's health. Once food starts to harbor bacteria, it rots, so the key is to consume

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it before that. Fresh fruit retains more nutritional value, whereas rotten fruit contains bacteria and has a lower nutritional value.

There are many ways to keep track of fruit freshness, such as deep-freezing, using a sensor to detect odors and gases, and checking the fruit's color and skin. However, most of these techniques only detect rotten fruit; some modern techniques use robots with advanced learning capabilities to remove it from storage. To maintain the long life of fruits, we need to monitor storage conditions to reduce the risk of spoilage. Fruit freshness classification is a crucial aspect that holds significant importance for various stakeholders, including consumers, the agricultural and food industries, and economic considerations. Ensuring that fresh fruits reach consumers is vital to their health and satisfaction, as fresh produce contains more nutrients and tastes better, thereby improving overall dietary health. For the agricultural and food industries, accurate fruit freshness classification helps deliver high-quality products that meet consumer needs, boosting sales and market share. Automated detection techniques using DL (Deep Learning) and machine learning methods offer improved efficiency and accuracy over manual observation and subjective judgments.

Furthermore, automated fruit freshness classification eliminates human selection errors in production lines, thereby enhancing efficiency [1]. Beyond its direct applications, fruit freshness classification supports breeding of various fruit species in agriculture and significantly reduces human effort in fruit farming and sales. Computer vision-based approaches leveraging deep learning architectures are considered the most intelligent and cost-effective solutions for this job [2]. Ultimately, accurate classification methods play an important role in maintaining these essential attributes, underscoring the importance of fruit freshness classification for consumer health, quality assurance, economic benefits, and the overall well-being of the agricultural and food industries [3].

Motivation of the Study

The classification of fruit freshness, particularly distinguishing between fresh and rotten produce, is a critical task, with far-reaching implications for nutrition safety, public health, and the optimization of the food supply chain. This research aims to produce an automated system capable of precisely classifying the freshness of fruits, driven by the following motivations:

1. Ensuring the consumption of safe, healthy food is paramount to reducing the risk of foodborne illness and promoting public health. By accurately identifying rotten fruit, this system will help prevent the distribution and consumption of

contaminated produce.

2. Early detection and segregation of rotten fruit in the supply chain will prevent unnecessary transportation and disposal, thereby minimizing food waste and promoting sustainability.
3. An automated freshness classification system can streamline processes, saving time and resources in sorting and disposal and enhancing overall productivity in food supply chain operations.
4. Providing fresh fruits to consumers not only enhances their eating experience but also builds trust in the supplier, fostering customer loyalty and positive word-of-mouth referrals, which are central to occupational success.
5. The development of novel methods and approaches for fruit freshness classification will contribute to broader fields such as machine vision, image processing, and artificial intelligence, potentially leading to innovative applications and further advancements.

Through the successful implementation of this research, the proposed automated fruit classification system will play a significant role in enhancing food safety, reducing waste, improving supply chain efficiency, and promoting consumer satisfaction, while simultaneously advancing the state of the art in AI-driven classification techniques.

RELATED WORK

Deep Convolutional Neural Networks (DCNNs) together with transfer learning have proven effective for accurate classification, offering high accuracy and efficiency. This review examines recent studies on fruit freshness classification using DCNNs and transfer learning, with an emphasis on accuracy and performance metrics [4]. A study proposed a DCNN-based method for classifying apple freshness levels, achieving an accuracy of 94%. Their study demonstrated the superiority of deep learning in accurately discerning fruit freshness [5]. Another study utilized transfer learning with a pre-trained ResNet model to classify citrus fruits into fresh and decayed categories, achieving a precision of 92.5%. Their study demonstrated the efficiency of transfer learning in improving classification accuracy with limited labeled data [6]. Researchers proposed an ensemble of DCNN models for the assessment of mango freshness, achieving a correctness of 96.3%. Their study highlighted the ensemble's success [7].

A research work developed a fusion framework combining RGB images and hyperspectral data for mango freshness assessment, achieving a precision of 93.7%. Their approach demonstrated the benefits of combining complementary modalities to improve classification performance [8]. Another study proposed a domain-adversarial neural network for robust fruit freshness classification,

CHAPTER 2

Advancing Autonomous Vehicle Technologies: Integrating Transformer-siamese Network for Dynamic Traffic Sign Recognition with DC Motor Control Systems

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Abstract: This book chapter explores the use of the Transformer Siamese Network (TSN) for detecting and tracking traffic signs, a crucial component of self-driving cars and driver-assistance systems. Our method improves on traditional image processing techniques and reduces the delay in recognizing traffic signs. We combine the attention mechanisms of the transformer network with the learning capabilities of the Siamese network for better real-time recognition. A key part of our research is integrating these algorithms with Direct Current (DC) motor systems. This helps convert the recognition of traffic signs into actual movements of the vehicle. A control algorithm is developed for a DriveBot, enabling effective use of the TSN algorithm's output. The setup includes a Raspberry Pi, an L298 motor driver, and a DC motor, allowing the robot to adjust its motor responses in response to real-time traffic sign data, mimicking the behaviour of a real vehicle. The research combines complex systems for autonomous navigation, showing progress in both data processing and mechanical movement. It highlights the need for a smooth combination of recognition and action in intelligent transportation systems. This study contributes to the advancement of integrated, smart transportation systems.

Keywords: Autonomous navigation, Intelligent transportation systems, Real-time recognition, Self-driving cars, Transformer-Siamese Network (TSN), Traffic sign detection.

INTRODUCTION

Transportation is a necessity nowadays, but it also has issues that affect the safety of the population, economic performance, and environmental sustainability [1, 2].

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The World Health Organization (WHO) states that the number of deaths and injuries in the world due to road accidents is 1.2 million and 50 million annually, respectively [2]. The U.S. National Highway Traffic Safety Administration (NHTSA) links a significant number of these accidents to human mistakes, especially in the identification and compliance with the road signs [3]. This case highlights the technological requirements for driver assistance and the advancement of vehicle automation. The automotive industry has reacted to this by incorporating Advanced Driver Assistance Systems (ADAS) and Automated Driving Systems (ADS) into cars [4, 5]. These systems include Traffic Sign Recognition (TSR), which has helped in alleviating the burden on drivers, reducing decision-making errors, and lowering the rate of accidents [6].

TSR entails Traffic Sign Detection (TSD) [7]. TSR techniques used the special properties of signs, including the shape and colour, but performed poorly under difficult circumstances, such as low-light environments or distractions. The TSR has been enhanced by using computer vision and Artificial Intelligence (AI)-based approaches, which offer better performance than traditional methods. Moreover, the replacement of simple feature-based methods with complex DL technologies has changed the TSR technology [8]. In comparison to previous techniques, which were constrained by prior features and conditions of the environment, DL approaches are capable of learning the data with the help of neural networks. This enhances precision and stability, facilitating scalability of real-time processing in Autonomous Vehicles (AV). Despite their complexity, DL and machine vision have been integrated into vehicle systems, driven by improvements in computing capabilities and the accurate identification of road markers [9]. These advancements are in line with the need to rapidly make decisions while driving. Table 1 provides a full comparison of conventional and TSN-based methods for TSR, considering aspects such as underlying strategies, feature engineering, computational requirements, and applicability in real-time.

Table 1. Comparative evaluation of conventional TSD (Traffic Sign Detection) & TSC (Traffic Sign Classification) Techniques vs. TSN (Transformer Siamese Network) Methodology.

Feature	Conventional TSD & TSC Techniques	TSN Methodology
Underlying Strategy	Depend on geometric and photometric characteristics; employ hand-engineered features such as HOG, LBP, SIFT, SURF.	Utilize composite neural network structures that assimilate data sequences with minimal manual oversight.
Feature Synthesis	Require manual construction and discernment of pertinent features for sign classification.	Facilitate autonomous feature extraction during model training, reducing manual input.
Computational Demand	Variable; basic algorithms are expedient but less accurate, whereas complex engineering is computationally onerous.	Higher due to intricate model architectures; nonetheless, efficiencies are realized through GPU acceleration.

(Table 1) *cont....*

Feature	Conventional TSD & TSC Techniques	TSN Methodology
Detection Precision	Moderate, contingent on the quality of feature engineering, with vulnerability to sign variability.	Superior; adept at generalizing to unencountered signs and variations, thanks to profound feature extraction capabilities.
Scalability	Incorporating new sign categories or adjusting to environmental shifts often mandates extensive feature redevelopment.	Streamlines expansion and adjustment to novel signs and environmental changes through retraining with additional data.
Stability in Diverse Conditions	Susceptible to performance decline under environmental perturbations such as lighting variations and obstructions.	Demonstrates robust stability in the face of environmental changes, derived from the hierarchical feature learning process.
Real-Time Applicability	Compatibility with real-time requirements is limited due to delays from manual feature extraction and classification.	Once trained, they exhibit rapid inference capabilities, suitable for real-time deployment in autonomous vehicular systems.
Model Transparency	More interpretable owing to the use of explicit features, which can be elucidated and visualized by specialists.	Often perceived as less transparent due to complex internal operations and reduced interpretability.
Data Intensiveness	Less dependent on large datasets, yet necessitate considerable expertise in feature design.	Rely on extensive, annotated datasets for optimal training outcomes, reducing the dependence on expert knowledge.
Versatility	Transition to new environments typically entails significant feature reengineering, requiring domain-specific insight.	Offer adaptability through fine-tuning with data from diverse environments, thereby enhancing versatility.
Investment Considerations	Initially more cost-effective computationally, yet potentially higher long-term expenditure due to manual engineering and maintenance.	The initial investment in computation and data acquisition is higher, but potential for reduced long-term costs through system automation.
Integration with Existing Systems	Integration is generally straightforward and compatible with systems that have limited computational capacity.	Require robust hardware to manage complex calculations, often dependent on GPUs for efficient performance.

This chapter discusses the evolution of traditional computer vision applications into new DL applications in TSR. We will show that these developments are both significant and essential to the development of AV and ADAS. We will speak about the crucial role these technologies play in advancing the automotive industry to the next stage of safety and autonomy.

RELATED WORK

The development of automated vehicles has experienced significant success in TSR, which is essential for improving car intelligence and road safety [10]. In its

CHAPTER 3

A Novel Method for Text-to-Image Generation Using RVT-C-GAN Algorithm

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Abstract: The problem of text-to-image synthesis is a challenging task in generating semantically related and visually appealing images from text descriptions. In this article, a new model, the recurrent Visual-Text GAN (RVT-C GAN), is proposed to overcome the challenges of semantic alignment and image quality. By incorporating a recurrent neural network, RVT-C GAN is capable of processing and encoding difficult text sequences effectively, enabling the creation of high-quality images. The attention mechanism additionally improves the presentation of the model by concentrating on the most important regions of the text during the image generation process, ensuring that the generated images are more aligned with the text descriptions. The proposed model is tested on several benchmark datasets, including Oxford-102 Flowers and CUB-200-2011, and has achieved remarkable improvements over existing models such as StackGAN and AttnGAN. The experimental results show that RVT-C GAN outperforms existing models in terms of Inception Score (IS), Fréchet Inception Distance (FID), and semantic alignment metrics. This paper is a significant contribution to overcoming the challenges of text-to-image synthesis and is a more accurate and reliable method for generating images from text.

Keywords: Attention mechanism, Deep learning, Generative models, Image generation, Image quality metrics, Natural Language Processing (NLP), Recurrent Generative Adversarial Networks (R-GANs), Recurrent Visual-Text GAN (RVT-C GAN), Semantic alignment, Text-to-image synthesis.

INTRODUCTION

Text-to-image synthesis has recently been accepted as a critical application area in the realms of computer vision and natural language processing, with the objective of creating high-quality images that are semantically appropriate to the given text

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descriptions. This application has received considerable attention due to its potential uses in diverse areas, such as design, content design, and e-learning, where the effective creation of visual content is essential from natural language inputs [1]. Text-to-image combination has the potential to greatly simplify the process of generating figures, designs, and data ideas by enabling routine generation of visual content.

Generative Adversarial Networks (GANs) [2] have been involved in the expansion of text-to-image synthesis. GANs consist of two neural networks, a generator and a discriminator, which are trained jointly in a competitive method. The generator seeks to create images from noise or conditioned data, and the discriminator seeks to differentiate real images from the generated ones. GANs were originally challenged with the task of creating high-resolution images that had the semantic meaning of the textual sketch, but recent progress has demonstrated marked improvements in image quality and semantic relevance using conditional variants of GANs, such as Conditional GANs (CGANs) [3]. In CGANs, the supplementary information, such as text or class labels, is provided to both the generator and the discriminator, enabling the network to create images based on particular textual descriptions.

One of the major issues with text-to-image creation is the ability to maintain a high level of semantic coherence between the input text and the synthesized image. Previous GAN models for image synthesis, such as the Generative Adversarial Text-to-Image Synthesis (T2I-GAN) model, made significant efforts to address this issue by using a two-stage training approach that improved the diversity and quality of synthesized images from text descriptions [4]. However, these models have conventionally had difficulty with complex text descriptions and image details.

Recurrent architectures have witnessed a substantial boost in the field of text-to-image synthesis, with the ability to professionally process sequential data, like text, using Recurrent Neural Networks (RNNs) [5]. The issue of processing sequential data and the complex relationships between words in text was addressed with the advent of the Recurrent Conditional GAN (RC-GAN) [6]. However, to additionally improve the semantic interpretation of textual descriptions and create high-quality images with enhanced detail and consistency, the Recurrent Visual-Text Conditional GAN (RVT-C GAN) has been proposed [7]. Although substantial development has been made, the task of producing images that accurately depict compound and abstract textual descriptions still remains a challenge. Specifically, the production of fine-grained details like texture, lighting conditions, and relationships between objects still remains a challenge for current state-of-the-art models. Moreover, the task of achieving

real-time processing in resource-constrained settings remains a critical challenge for the large-scale deployment of these models in applications such as e-learning platforms and substance generation tools [8].

This paper presents the Recurrent Visual-Text Conditional GAN (RVT-C GAN) as a remedy for the aforementioned challenges. The proposed method combines various recurrent models to enhance semantic matching and image quality. The performance of the proposed model is tested using diverse quantitative metrics such as the Inception Score (IS) and Frechet Inception Distance (FID), as well as qualitative evaluation through user reactions. The results show extensive improvement in producing semantically coherent and high-quality images from complex text input compared to the presented state-of-the-art techniques.

LITERATURE REVIEW

The emergence of Generative Adversarial Networks (GANs) has been a major breakthrough in the computer vision community, particularly in the text-to-image synthesis task. Text-to-image synthesis is a method of generating images from text descriptions. This task has gained enormous popularity due to its use in content creation, plan, and assistive technology.

Early Developments in GAN-Based Text-to-Image Synthesis

The unique GAN model introduced by Goodfellow *et al.* [1] was the first step towards building a generative model capable of synthesizing images. However, the task of generating high-quality and semantically correct images from text remains a challenge due to the difficult nature of text data. To deal with this challenge, Mirza and Osindero [2] introduced the Conditional GAN (CGAN), an alternative to GANs in which the generator and discriminator are trained together on additional information, such as text descriptions. The CGAN model enables the creation of images related to a particular set of input circumstances, such as text descriptions, thereby improving alignment between the generated images and text. This success was a significant milestone in the text-to-image generation community.

A significant milestone in text-to-image synthesis was achieved with the introduction of StackGAN by Zhang *et al.* [3], which produces higher-quality images using a two-stage preparation approach. This model enabled the generation of sensible images by first synthesizing low-resolution images and then refining them to produce higher-resolution images. StackGAN established that hierarchical GAN models can considerably enhance the quality of

CHAPTER 4

Blockchain for Education: Transforming Digital Credentials and Academic Records

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Abstract: This chapter discusses how blockchain technology will transform the education sector by enabling digital credentials and academic records. Blockchain is known for its decentralisation, immutability, transparency, and security, which offer new pathways to addressing long-standing problems in academic credentialing. It begins by highlighting current challenges in education, including credential fraud, inefficiencies in record-keeping, and the absence of a single system for tracing lifelong learning. It also shows how blockchain can be harnessed to issue, store, and verify digital credentials, securing and making them available. MIT diplomas and Blockcerts are used to demonstrate real-world implementations of blockchain-based credentialing systems. Moreover, it enables the development of secure, tamper-proof academic records, thereby increasing interoperability among institutions while reducing administrative burdens. This chapter promises blockchain in education by underscoring the technology's potential to revolutionise how educational credentials are verified, shared, and trusted across borders.

Keywords: Academic records, Blockchain, Credential fraud, Digital credentials, Education.

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INTRODUCTION

Background and Context

The education sector currently faces significant challenges, including credential fraud, inefficiencies in record-keeping, and interoperability issues. These issues undermine the veracity of academic qualifications and, hence, create barriers for learners, employers, and institutions [1, 2]. For example, degrees and certificates have become a global issue, as employers struggle to verify the authenticity of academic credentials [3]. UNESCO has noted that the rise in fraudulent qualifications poses a grave threat to the integrity of educational systems worldwide [4]. In this case, Van Noy also notes that employers find it difficult to distinguish between legitimate and fraudulent credentials [5]. The fragmentation of information systems for academic records increases administrative costs and delays access to critical information [6]. The challenges that have so far beset the management of digital credentials and academic records in the education sector can be addressed by blockchain technology, characterised by decentralisation, immutability, transparency, and security. This would allow the education sector to create a more efficient, secure, and trustworthy system for managing digital credentials and academic records. Grech and Camilleri have indeed underscored this potential in relation to students' credential fraud and the transparency of academic records. An illustration of this is the Blockchain Certificates Project at MIT Media Lab, which demonstrates how it could be used to issue tamper-proof digital diplomas, thereby restoring trust while reducing administrative burden [7]. Real-world implementations provide evidence of this technology's transformative potential to address inefficiencies plaguing the education sector and improve interoperability. Sony Global Education has launched a blockchain-based platform, and Malta has designed a national blockchain strategy for education. The global drive to use blockchain in education is bolstered by prominent organisations such as the World Economic Forum and the OECD [8]. These institutions are promoting blockchain solutions, specifically lifelong learning passports and new credentialing ecosystems, to create more straightforward, trustworthy frameworks for verifying and sharing academic credentials. Such initiatives demonstrate the growing recognition of blockchain as a fundamental tool for enhancing trust, efficiency, and innovation in the educational sector [9].

Purpose and Scope of the Chapter

This chapter explores the transformative potential of blockchain technology to address the myriad challenges that plague credentialing and academic record-keeping. Its focus is primarily on how blockchain can enhance the security,

transparency, and accessibility of education while also empowering learners and institutions. It presents discussion points and excerpts of real-world applications and case studies that concretely demonstrate the benefits of blockchain to education.

CHALLENGES IN THE CURRENT EDUCATION SYSTEM

Credential Fraud and Verification Issues

Credential fraud undermines the growing basis of fake degrees and certificates. As reported by a study [10], the diploma mill industry is expanding, making it difficult for employers and other institutions to verify academic credentials accurately. The problem is compounded when cross-border verifications are involved, given significant disparities in educational standards and systems across countries. Academic certificates are highly valued because they form one of the primary means of indicating an individual's human capital. According to another study [11], credentials denote skills, competencies, knowledge, and aptitudes acquired through formal education. In employment contexts, qualifications provide assurance that extends beyond knowledge and expertise to encompass an individual's trustworthiness, commitment, and overall capability [12]. Yet this high demand for academic certificates has also facilitated degree fraud. People frequently falsify their qualifications to secure employment or promotion. Several studies [13, 14] point out five main ways fake academic certificates come about:

Degree Mills: These are fraudulent organisations that sell fake degrees to individuals. They often run without proper accreditation or legal permission.

Fabricated Documents: These are fraudulent certificates that show incorrect degrees or college and university names.

Altered Documents: This is where valid credentials are modified, such as incorrect changes to dates of enrollment or graduation, grades, course content, or personal details such as date of birth.

In-House-Produced Certificates: These are fraudulent documents produced by employees of legitimate companies, sometimes on official paper and bearing authentic seals, stamps, and signatures.

Bad Translations: These occur when original documents are poorly translated into another language to conform to the receiving nation's rules, resulting in a distorted representation of qualifications. The existence of fraudulent academic certificates has significant and enduring effects. It undermines the value of educational

CHAPTER 5

A Novel Method for Centralized Healthcare Recommendation System

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Abstract: Patients who usually face problems in dealing with the multifaceted healthcare system and searching for appropriate healthcare providers matching their needs can now take advantage of a revolutionary doctor referral system implemented by this project. Leveraging advanced data and algorithms, this technology has been developed to make the entire process smoother, thereby enabling patients to make informed decisions based on their personal requirements and preferences. The suggestions are carefully crafted after evaluating many parameters such as the level of expertise, experience, patient reviews, location, communication patterns, and compatibility with insurance plans. This technology utilizes highly advanced machine learning algorithms, such as collaborative filtering and content-based filtering, to make recommendations more accurate and relevant. Additionally, the intuitive interface provides a seamless experience to the users, enabling them to easily enter their symptoms, filter, and view comprehensive profiles of suggested doctors. With its emphasis on simplicity and technological accuracy, this approach not only simplifies the process of choosing healthcare providers but also seeks to improve the entire process of healthcare decision-making for patients. The process of navigating the complex healthcare system and identifying a suitable healthcare provider is a daunting task for patients. This project brings forth an intelligent doctor referral system that seeks to simplify this process by making use of advanced data analytics and machine learning algorithms. By utilizing approaches such as collaborative filtering and content-based filtering, the system provides patients with highly personalized suggestions based on a variety of parameters, such as the doctor's expertise, experience, patient reviews, geographical location, communication skills, and insurance compatibility. The system also utilizes Natural Language Processing (NLP) to analyze patient symptoms and filter search results, thereby improving accuracy and relevance.

Keywords: Collaborative filtering, Content-based filtering, Doctor referral system, Geographical proximity, Personalized recommendations.

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INTRODUCTION

The recent technological improvements in the healthcare sector have triggered revolutionary shifts that are greatly impacted by the development and application of new technologies, such as the Centralized Healthcare Recommendation System (CHRS), which uses patient evidence to bring about a paradigm shift in the delivery of healthcare services [1].

The conventional method of making healthcare choices has been largely influenced by expert opinions, clinical trial data, and recognized medical practices. Although this method has its own advantages, it tends to ignore the individuality of patients, their personal practices, and varied reactions to healthcare [1]. On the contrary, the CHRS combines medical expertise with the power of advanced AI algorithms [2].

One of the key supporting columns of this revolutionary system is the use of patient evidence. This includes a broad range of information, such as a wide range of medical histories, past treatment outcomes, lifestyle considerations, and direct patient input. The use of big data analytics and machine learning in the CHRS allows for the detection of multifaceted patterns and correlations [3].

The overall objective of this research is to assess the far-reaching effects of the CHRS in the healthcare sector. By coordinating medical advice with comprehensive patient evidence, the CHRS seeks to enhance the accuracy and efficacy of treatments. This patient-oriented strategy not only leads to enhanced treatment outcomes but also promotes higher levels of patient trust and cooperation with healthcare specialized [4].

In the end, the CHRS is a major step towards a more modern and data-driven healthcare system. The capability of the CHRS to combine advanced technology with human-centered care principles promises to transform the healthcare system and usher in a new era of innovation in the medical field [5].

The potential of the CHRS is not limited to the field of patient care. The completion of the CHRS has the potential to bring about a revolution in the healthcare system. The CHRS has the capacity to automate tasks such as data analysis and suggestion generation, which will enable healthcare professionals to devote more time to patient communication and complex decision-making. Furthermore, the centralized system makes sure that there is seamless integration between various healthcare providers and institutions [6].

The purpose of this study is to assess the long-term implications of the CHRS in the healthcare sector. By aligning healthcare recommendations with strong patient evidence, the CHRS aims to improve the accuracy and efficiency of action. This study explores the technical structure of the CHRS and its ability to align with the existing healthcare infrastructure and to set a new standard for optimal healthcare delivery [7].

EXISTING WORK

The current systems for managing appointments in the healthcare sector include a number of valuable functionalities that make it easier to handle certain aspects of patient care. However, they also have some significant shortcomings in dealing with the complex needs of contemporary healthcare services. EHR-integrated systems, for instance, act as an interface between patient data and the availability of doctors, making it easy to carry out the appointment process. Such systems enable healthcare professionals and patients to schedule appointments seamlessly while ensuring continuity of care [1].

Similarly, online appointment services such as Practo and Zocdoc have increased accessibility to healthcare by allowing users to search for healthcare providers, view basic information about specialists, and schedule appointments with little effort. Although they perform remarkably well in terms of convenience and ease of access, these services may not have the ability to perform deep personalization. Moreover, they are also faced with issues of poor integration with the internal hospital appointment management system, leading to inefficiencies such as double booking or delayed status inform for appointments [2].

Machine learning-based scheduling systems give a glimpse of the possibilities of advanced healthcare solutions. These systems use complex algorithms to forecast patient no-shows, optimize the allocation of appointments, and increase the utilization of healthcare resources. However, the use of these systems is generally inadequate in terms of scope, focusing on specific tasks such as optimizing the schedule without taking into consideration the larger context, including patient preferences, urgency, and iterative reaction. This makes them incapable of providing a holistic answer to the interrelated problems of healthcare delivery [3].

Fig. (1) illustrates that the project presents a new method for a centralized healthcare suggestion system using Generative Adversarial Networks (GANs) for text-based medical data processing. The healthcare suggestion system uses a pipeline approach, starting with raw text data, followed by pre-processing and encoding with Recurrent Neural Networks (RNNs). A Convolutional Neural Network (CNN) generator provides healthcare recommendations, while a

Technology for Sustainability in Agriculture

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Abstract: Sustainable agriculture is very important to achieve food security worldwide without negative environmental impacts. The integration of advanced digital technologies—such as Artificial Intelligence (AI), the Internet of Things (IoT), blockchain, and data analytics—is fundamentally reshaping agricultural systems, enabling data-driven decision-making, improved productivity, efficient resource management, and long-term sustainability. It is based on the conceptualization of the role that innovative technology can play in establishing a sustainable agriculture system, drawing upon recent research insights. One of the critical aspects of sustainable agriculture is optimizing water usage. Studies on wastewater irrigation and aquifer storage highlight the new approaches that could be considered in water conservation. Rural infrastructure, such as roads, also forms an important backbone of efficient resource distribution and sustainable agricultural practice. AI and IoT applications in precision farming also ensure the optimization of water and nutrient management, wherein crop yield is enhanced without waste.

The integration of circular economy principles into sustainable farming practices is progressively advancing, facilitating closed-loop resource management, minimizing waste generation, and strengthening the ecological and economic resilience of agricultural systems. Rice husk management, agroforestry, and residue management techniques have proven effective in reducing carbon footprints and improving soil health. Innovations in biogenic silica extraction from agro-waste and the application of biochars open great opportunities for environmental sustainability. Industry 4.0 adoption in agriculture, supported by blockchain and digital platforms, increases the transparency of the supply chain and efficient use of resources. Some climate-smart agricultural strategies include long-term sustainability, conservation tillage, and organic fertilizer use. All these developments show how modern technologies, when combined with sustainable practices, offer promising ways forward for the future of agriculture. When smart solutions are combined with circular economy models and climate-resilient strategies, sustainability in agriculture would significantly improve, ensuring food security and protecting natural resources.

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Keywords: AI, Blockchain, Environment, IoT, Sustainable agriculture.

INTRODUCTION TO SUSTAINABLE AGRICULTURE AND TECHNOLOGY

Sustainable agriculture is a farming method that focuses on producing food while preserving the environment, supporting farmers, and ensuring economic viability. It brings together environmentally friendly practices such as crop rotation, organic farming, and efficient use of water for soil health and biodiversity. It also involves modern technology like precision agriculture, drones, and Analytics powered by AI to increase efficiency while minimizing the impact on the environment. It also includes the use of renewable energy sources like solar-powered irrigation systems. Genetic engineering and biotechnology are some of the reasons crops have become resistant to diseases and have increased yields. Vertical farming and hydroponics are space- and resource-saving methods, particularly in urban settings. Sustainable livestock management is important in reducing greenhouse gas emissions and promoting animal welfare. Government policies and incentives encourage sustainable farming practices. Education and research are constantly driving innovation to ensure a resilient and food-secure future.

Concept and Importance of Sustainable Agriculture

Sustainable agriculture is a form of farming that provides for present food needs without compromising the ability of resources and ecosystems to sustain and meet future food needs. It increases environmental health, economic profitability, and social equity. The impact of farm-scale Natural Resource Management (NRM) interventions in Karnataka, India, between 2005 and 2020 was studied. The interventions included soil health management, resource use efficiency, and improved crop cultivars. The results showed that these practices significantly improved crop yield, reduced irrigation requirements, and lowered cultivation costs. It emphasizes the importance of integrating NRM practices with crop demonstrations to bridge yield gaps and address land degradation, food insecurity, and poverty in dryland regions in South Asia and globally [1]. Drought in India affects over a fifth of the country's land, affecting 21.06% of the area. This is 62% larger than last year's 7.86% drought-affected area. Groundwater vulnerability assessment is crucial for sustainable strategies to escape hazardous situations. It aims to estimate drought vulnerability in changing climates, affecting food security. MaxEnt and ANN models were used to estimate vulnerability, with MaxEnt being the most optimal for predictive accuracy. The western, south, and middle regions are highly susceptible to drought, requiring regional planning for sustainable planning [2]. Several studies have evaluated the effects of Rice Husk

Biochar (RHB) amendments on soil physicochemical properties, methanotrophic diversity, and the abundance of the functional *pmoA* gene in paddy soils. The findings indicate that RHB significantly enhances soil physicochemical characteristics and positively influences both the structure and abundance of methanotrophic communities. Furthermore, RHB application alters methanotrophic community composition in paddy soils, with a notable enrichment of genera such as *Methylovulum* and *Methylobacter* within the family *Methylococcaceae*. Overall, the RHB application substantially improves soil quality and increases methanotroph abundance in nutrient-depleted and degraded paddy agricultural soils [3]. Biomass, as a renewable energy source, has attracted significant global attention due to the excessive consumption and environmental consequences of fossil fuels. It accounted for approximately 14% of the global energy supply in 2016 and is projected to contribute nearly 44% by 2030. This review systematically examines the various types of biomass, their characterization techniques, and the associated conversion technologies, with particular emphasis on agricultural biomass utilization and its contribution to achieving the Sustainable Development Goals (SDGs). Furthermore, biosensors play a crucial role in optimizing biomass conversion processes and monitoring environmental impacts, thereby enhancing efficiency and sustainability [4].

The adoption of organic fertilizers in India's Indo-Gangetic Plain focuses on factors such as the policy environment, socioeconomic conditions, farmers' attitudes, and revenue expectations. The findings indicate that only 32% of farmers use organic fertilizers, with membership in farmer organizations, training, and education being key factors. The results point to the necessity of effective extension initiatives and legislative changes that support group learning among farmers [5]. Analysing production disparities and factors reveals that apple fruit is not very productive in temperate locations, including India. Data from 300 apple growers was collected, and the results showed a sigmoidal pattern, with an average yield of 9.43 t/ha in the current season. The root cause of low productivity was identified as socioeconomic factors, credit, pests and diseases, technology, extension, and market, making this is of interest to authorities and global areas with similar agro-climatic conditions, urging them to address these issues through sustainable policy decisions [6]. Sustainable indigenous agricultural methods have been developed by indigenous communities for generations, focusing on their relevance to achieving the Sustainable Development Goals (SDGs). They explore the implementation of indigenous technologies, incentives for sustainable practices, and initiatives proposed by the G20 summit 2023. They highlight the importance of valuing and integrating traditional indigenous practices to address agricultural challenges and achieve sustainable global economic growth [7].

CHAPTER 7

Innovative Technologies Transforming Education and E-Learning

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Abstract: Advanced digital technologies are ushering in the next generation of education and e-learning, marking a transformative shift driven by continuous innovation. These technologies enhance teaching methodologies, enrich learning experiences, and improve administrative efficiency within educational institutions. The integration of Artificial Intelligence (AI), Augmented Reality (AR), Virtual Reality (VR), adaptive learning systems, blockchain, and data analytics is fundamentally reshaping the educational landscape, fostering connected, inclusive, and accessible learning environments tailored to diverse learner needs.

AI-powered tools enable personalized learning pathways, predictive analytics, and intelligent content generation, while AR and VR technologies provide immersive and interactive experiences that bridge theoretical knowledge with practical application. Blockchain technology further ensures secure and transparent management of academic credentials and records. Collectively, these innovations support remote and hybrid learning models and equip learners with essential digital literacy and information management skills required in the evolving global workforce.

This chapter critically examines the role of emerging technologies in transforming education and e-learning. It presents a systematic review of technological tools and platforms developed over the past five years, supported by relevant case studies demonstrating their impact across diverse educational contexts. Additionally, the chapter explores the associated challenges, opportunities, and policy implications of technological integration in education. Overall, this study contributes to a deeper understanding of the rapidly evolving digital educational ecosystem driven by intelligent and immersive technologies.

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Keywords: Artificial Intelligence (AI), Adaptive learning systems, Augmented Reality (AR), Blockchain, Educational technology, E-Learning, Education, Hybrid learning, Personalized learning, Virtual Reality (VR).

NOVELTY OF THE CHAPTER

This chapter provides a comprehensive and updated synthesis of how emerging technologies such as AI, AR/VR, adaptive learning systems, blockchain, and IoT are reshaping education and e-learning. Unlike existing literature, it integrates both theoretical perspectives and practical case studies from the past five years, highlighting real-world applications and their impacts on teaching, learning, and accessibility. The chapter contributes by:

- Mapping the evolution of educational technologies and their pedagogical significance.
- Presenting case studies (*e.g.*, Coursera, interactive whiteboards, mobile apps) to demonstrate practical effectiveness.
- Identifying challenges such as the digital divide and teacher readiness, and suggesting opportunities for inclusive growth.
- Outlining future trends that can guide researchers, educators, and policymakers in adopting innovative tools for sustainable and equitable education.

This integrated approach distinguishes the chapter as both a scholarly and practice-oriented contribution to the field of educational technology.

INTRODUCTION

The integration of technology into education has revolutionized the manner in which knowledge is imparted and acquired. Learning facilitated by electronic technologies has gained substantial prominence as an effective means of delivering curricula beyond the constraints of centrally controlled educational environments; this approach is commonly referred to as e-learning. This chapter provides a comprehensive overview of the e-learning platforms, tools, and methodologies that have emerged over the past five years and continue to evolve within the contemporary technological landscape [1, 2].

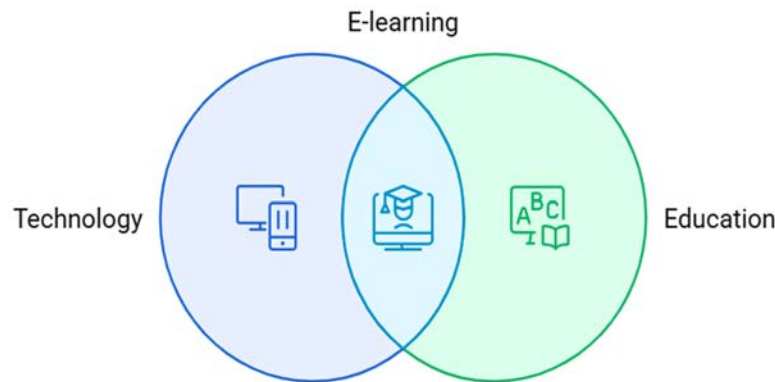


Fig. (1). Synergy of technology and education.

Fig. (1) illustrates a Venn diagram representing the relationship among technology, education, and e-learning. Technology and education are depicted as distinct yet interrelated domains, each represented by a separate circle indicating their respective scopes and functions. E-learning is positioned within the overlapping region, signifying the integration of technological tools and infrastructures into educational processes. This intersection reflects the application of digital technologies to facilitate online learning, virtual classrooms, and interactive educational platforms. [3, 4].

The Evolution of Technology in Education

Fig. (2) presents the historical progression of technology in education from 1900 to 2025 [5, 6]. The graph illustrates a steady and transformative evolution of instructional technologies, beginning with the use of chalkboards in the early 20th century. By the mid-1900s, radio and television emerged as influential tools for mass educational broadcasting. The introduction of computers around 1980 marked a significant technological shift, facilitating digital learning environments. The advent of the Internet in the early 2000s further revolutionized education by enabling global connectivity and access to online resources, ultimately leading to the widespread adoption of e-learning platforms by 2010. By 2020, advanced technologies such as Artificial Intelligence (AI) and Virtual Reality (VR) significantly enhanced learning experiences through personalization, immersion, and interactive engagement [8].

CHAPTER 8

Build an AI/ML Tennis Analysis System with YOLO, PyTorch, and Key Point Extraction

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Abstract: This document summarizes essential computer vision and deep learning technologies using two main tools: OpenCV and PyTorch, which operate through their Python interface, cv2. The Python module cv2 of OpenCV is a powerful library that enables users to perform various image and video processing operations, including object detection, feature extraction, and real-time video analysis. PyTorch stands out as a deep learning framework that enables developers to create and train machine learning models through its dynamic computation graphs, user-friendly interface, and effective GPU support. The combination of these two software applications provides a strong foundation for researchers to develop new solutions in real-time object detection, autonomous system development, and natural language processing research. The paper demonstrates how these technologies function through their main features, which contribute to the advancement of computer vision and artificial intelligence applications.

Keywords: Autonomous vehicles, Explainable AI (XAI), LIME, Object detection, SHAP.

INTRODUCTION

The Tennis Analysis System employs artificial intelligence and machine learning, leveraging its advanced computer vision and deep learning capabilities to assess tennis player performance. The project employs the YOLO object detection system together with the PyTorch framework to track player movements while forecasting ball trajectories and evaluating player movements, postures, and their current state of competition. The system provides valuable insights for coaches, players, and analysts, who can use them to create better training programs that help athletes perform at their best and develop successful strategies for their upcoming matches [1]. The Streamlit platform enables users to interact with data

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through its interface, helping them understand complex information during downtime between operational activities. Traditional tennis performance analysis requires a complete manual assessment, which consumes considerable time and increases the risk of assessors making mistakes. The high costs of advanced sports analytics systems create financial barriers that prevent amateur athletes and small training academies from using these technologies. The project provides a solution to these problems by developing an automated system that businesses can use to conduct tennis analysis. The system provides real-time player movement analysis and ball trajectory tracking, with its economical design, which assesses users' physical performance. The system aims to provide professional-grade analytics to all users, which allows them to access data-driven performance insights. The project will create an advanced “AI/ML-based Tennis Analysis System” that uses “YOLO (You Only Look Once)” for object detection and PyTorch for deep learning model creation and keypoint extraction to analyze player movements and ball trajectories during tennis matches. The Tennis Analysis System is an AI-powered platform that enables better tennis match analysis by collecting real-time match information and providing practical solutions. The system tracks ball paths and player movements and helps in match analysis by delivering performance data that players and coaches can use to develop better gameplay strategies [2], [21]. The system implements advanced machine learning and computer vision capabilities to deliver interactive tennis match analysis, which creates an innovative tool for sports analytics [3]. The primary objective of this paper includes:

- Real-time detection of tennis players and the ball to provide actionable insights during matches or training sessions.
- Posture and joint movement analysis of players through key point detection, capturing essential details on player technique and biomechanics.
- Automatic performance metric generation provides players and coaches with tools to enhance their techniques and strategic approaches through accuracy, precision, and recall, and F1-score measurements.
- The project aims to create an AI-based system that uses **YOLO and PyTorch** for real-time player detection and ball tracking.
- Biometric analysis of players using keypoint detection enables researchers to study their posture and technique.
- The system generates ball-trajectory predictions that help players analyze their shot performance.

LITERATURE REVIEW

The research provides an overview of existing studies and academic research on the selected subject, presenting essential research outcomes, academic methods, and theoretical approaches from multiple scholarly disciplines as mentioned in the Table 1. The study helps researchers acquire current knowledge in their field by identifying research deficiencies and developing a theoretical framework for their investigation.

The recent research study investigates object detection using deep learning methods, describing the developed methods and implementation challenges while demonstrating how these findings can improve system performance. The research provides a strong foundation that helps people understand how the field has developed over time as they search for new solutions to existing challenges. The research shows that deep learning has changed object detection, but researchers still need to address problems that affect system performance and object detection capability, which can be tested through the development of mixed system architectures and domain adaptation approaches. The researchers study advanced detection techniques that handle both low-quality images and moving objects through their comparison of three algorithms, YOLO, SSD, and Faster R-CNN, while some of their work focuses on developing detection systems for remote sensing applications, which need to handle high object density and intricate background details.

Deep learning shows performance improvements over traditional methods through its combination of feature extraction, proposal generation, and classification, which currently investigates convolutional neural networks, region-based approaches, and anchor-free models while addressing ongoing challenges in occlusion handling, scale variation, and real-time processing. Our project creates an innovative hybrid system that uses CNN backbone features alongside transformer modules to improve detection performance while reducing computational demands. We created a specialized data augmentation system that addresses problems that arise in urban surveillance under low-light conditions and partial object obstruction. Our method achieves better results than existing detectors by improving small-object detection accuracy while reducing inference time. The system maintains strong performance across different environmental conditions, including changes in lighting conditions, various weather patterns, and different camera angles. Our system uses attention mechanisms that adjust feature weights based on the current context to improve object detection in crowded environments.

The Future of Cryptography: Preparing for Post-Quantum Threats

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Abstract: Cryptography has already become an essential part of the contemporary digital environment, as it is the foundation of the security and privacy of communication, transactions, and data storage. The paper discusses the development history of cryptographic methods, classical approaches, and modern approaches, and their use in diverse fields, such as secure communications, digital signatures, and blockchain technology. With the threat of quantum computing on the horizon, the paper also discusses the challenges this new paradigm poses, including post-quantum cryptography and its potential to protect digital infrastructure in the future. In an in-depth discussion of current trends and new technologies, this paper identifies the ongoing struggle to achieve a balance among security, efficiency, and accessibility in cryptographic systems. The results emphasize the importance of cryptography in ensuring the integrity and confidentiality of digital communications and also highlight the important future research and development. This branch has been divided into symmetric-key cryptography, where encryption and decryption are performed with a single key, and asymmetric-key cryptography, where two keys are involved: the public and the private key. Secure digital interactions, including online banking, e-commerce, and communication, are supported by cryptographic protocols such as RSA, AES, and elliptic curve cryptography. Cryptography is used to encrypt and decrypt information using mathematical algorithms and computational techniques, transforming plaintext into ciphertext and *vice versa*.

Keywords: Blockchain, Bitcoin, Cryptocurrency, Cryptography, Ethereum kryptos, Post-Quantum cryptography, Proof of Work (PoW), Proof of Stake (PoS), Zero-Knowledge Proofs (ZKPs).

INTRODUCTION

Security and privacy of information are key issues in the digital age across all fields of life, including the personal sphere of communication and international financial dealings. The science of cryptography, which is concerned with protecting information from unauthorized access, is significant for maintaining

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the confidentiality, integrity, and authenticity of data in a globalized world. Traditionally, cryptography has been used by governments and military institutions to secure confidential communications, *e.g.*, the Caesar cipher in the Roman Empire and the Enigma machine in World War II. But in the digital age, the extent and use of cryptography have multiplied by a thousand. Nowadays, it supports numerous technologies, such as secure email, online banking, e-commerce, and even digital currencies such as Bitcoin. Its principles are fundamental to securing the internet, using protocols such as SSL/TLS, which means that the normal operations of the internet, including internet shopping and social networks, are carried out safely [1].

The RSA cryptosystem, a public-key cryptosystem, can be used to transfer data safely by encrypting plaintext with a public key and decrypting it with a private key, as shown in Fig. (1).

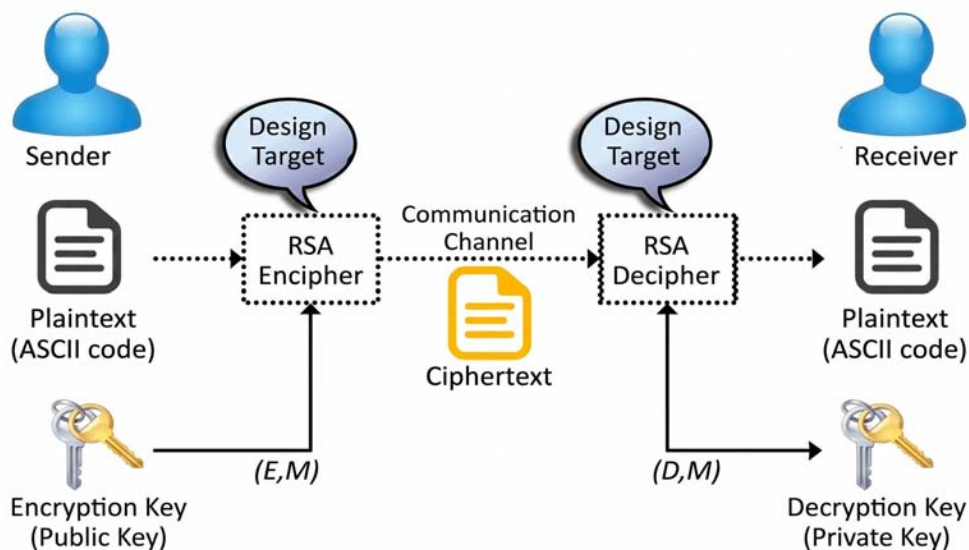


Fig. (1). Cryptographic arrangement.

Cryptography ensures the security of key functions of confidentiality, integrity, authentication, and non-repudiation using a variety of cryptography methods. These are symmetric encryption, in which the same key is used for both encryption and decryption, and asymmetric encryption, in which there are two keys: the public key and the private key. Furthermore, cryptographic hash functions are critical to data integrity, as they generate distinct digital fingerprints of data that are important for authenticity checking of messages and documents.

With the evolution of technology, new challenges arise, especially the emergence of quantum computing, which will render many existing cryptographic algorithms useless. Quantum computers can break popular cryptographic protocols, including RSA and ECC, approximately as quickly as a classical computer, casting doubt on the future of digital security. The privacy and security dilemma is a controversial topic, as governments and law enforcement agencies pressure developers of encrypted communications to include backdoors to enable law enforcement to combat crime and terrorism. The paper under discussion examines the ethical and legal aspects of cryptography in society, highlighting the tension between the need to protect individual privacy and national security. It provides a general overview of cryptography, including its historical evolution, basics, and current uses. It will also delve into the new issues arising from quantum computing and the ethical issues raised regarding the application of encryption. This paper aims to highlight the importance of cryptography in contemporary society and the current efforts to develop secure, efficient, and resilient cryptographic systems [2]. The picture shows a comparison of old and new cryptography, with its operations, principles of security, and key management differing. It reveals how traditional cryptography is based on the secrecy of means, whereas the new cryptography is based on mathematical algorithms and secret keys to ensure the security of communication.

Table 1 presents a concise comparison between classic and modern cryptography. Classic cryptography mainly manipulates letters and digits and often depends on the secrecy of the method, whereas modern cryptography operates on binary data and relies on publicly known mathematical algorithms with security ensured through secret keys. It also highlights that modern systems require only the key to remain confidential for secure communication.

Post-Quantum Cryptography

As quantum computing advances rapidly, the digital communications currently secured by conventional cryptographic algorithms may be compromised. Post-Quantum Cryptography (PQC) is concerned with developing cryptographic techniques resistant to quantum-computer attacks. The purpose of these sophisticated methods is to safeguard sensitive information, even during the period when quantum computers become the predominant practice [3]. The concept of post-quantum cryptography is depicted in Fig. (2) and summarized in Table 1.

CHAPTER 10

Edge AI: Decentralized Intelligence at Scale**Prabhneet Kaur^{1,*} and Akanksha Negi²**¹ *Department of Artificial Intelligence and Data Science, Vivekananda Institute of Professional Studies -Technical Campus, GGSIPU, Delhi, India*² *Department of Computer Science, Institute of Information Technology and Management, GGSIPU, Delhi India*

Abstract: This chapter focuses on the evolving concept of Edge AI, which is a form of artificial intelligence that processes data locally and reduces reliance on primary cloud systems. The three significant challenges in the deployment of AI on a large scale, namely latency, privacy issues, and energy consumption, are addressed by Edge AI by enabling real-time data processing and localized decision-making. This does not imply a departure from core AI principles; rather, Edge AI builds upon advancements in edge computing, neuromorphic technologies, and brain-inspired models. Edge AI systems enable faster, more efficient decision-making, which is rather amazing because their ability to process localized, adaptive information is similar to that of the brain. At the same time, such systems also significantly decrease the risk of extensive data transfers. The benefits of a decentralized structure include significant improvements in privacy, making Edge AI one of the best tools for the most sensitive industries, including healthcare, finance, and industrial automation. Edge AI has valuable outcomes in sustainability. At least 20 per cent energy savings and a quantifiable reduction in ecological impact are achieved by these systems by moving much of the computational load to local devices and offloading numerous tasks to cloud infrastructures, which typically consume large amounts of energy and place a heavy burden on energy resources. The researchers analyzed at least five practical cases of applying Edge AI across various industries. These fields are autonomous vehicles, smart cities, healthcare diagnostics, and industrial manufactures. The work of the researchers demonstrates the capabilities of Edge AI to become an innovator and adapt to the Sustainable Development Goals. The chapter also analyses the weaknesses and limitations of Edge AI, such as security issues, integration difficulties, and hardware constraints. It concludes by outlining various possible future directions, demonstrating that combining at least three advances in neuromorphic computing and at least two edge-device technologies can result in the development of smart, ecologically friendly AI systems at scale.

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Keywords: Decentralized intelligence, Distributed systems, Energy-efficient AI, Edge AI, Edge computing, Localized data processing, Neuromorphic computing, Real-time AI processing.

INTRODUCTION OF EDGE AI

The growing use of Internet of Things devices drives enormous demand for mobile and ubiquitous services. These demands can be managed effectively at the network edge, where they are generated, without being offloaded to the cloud. Edge Intelligence refers to the integration of intelligent capabilities at the edge of the network, aligning with the aims and prospects of AI [1, 2]. It offers an infinite number of opportunities and has been recognized as increasingly important in next-generation networks. Nevertheless, the scale and diffusion of this new technology [3] are extremely complex and involve analyses at multiple levels. Massive use of Internet of Things devices has driven a huge demand for mobile and ubiquitous services. Demands should be properly met at the network edge where they are generated, and they should not be offloaded to the cloud. Arming the edge with smart intelligence is referred to as Edge Intelligence [4], which aligns with the objectives and potential of AI at the network edge. It creates unlimited opportunities that can be exploited and has been considered of great importance to next-generation networks. Nevertheless, this process of adopting and scaling this new technology is very nontrivial and involves substantial systematic research across various dimensions.

Edge computing is also seen as a technology with the potential to offer more distributed, network-aware, and policy-based processing functions, especially in radio access networks and their backhaul segments. Here, the availability of computational resources is the initial architectural design domain for implementing edge intelligence. The platforms provide an environment for executing applications and services close to the end user. Nevertheless, it is also a requirement of this platform to access the network state at runtime. Also, edge intelligence introduces new requirements for the underlying network, such as dynamically adjusting QoS policies and transforming connectivity configurations. Scalability addresses a number of intersecting issues related to the widespread use of edge intelligence, *e.g.*, how to ensure that edge intelligence-based networks scale effectively with the number of edge nodes and user equipment. The attempts of all three network ranks will be made in concert to pass the knowledge, context, and signaling between the ranks. Scalability is an important aspect of the implementation of intelligent capabilities and has been used to spur research to transcend the boundaries of existing selected lines of research.

In this chapter, the authors review the central concepts of Edge AI [5], discuss its advantages, and examine its impact across various fields. It also examines current problems and potential future developments, with an emphasis on how Edge AI will revolutionize the deployment of AI at scale and the development of AI solutions that prioritize sustainability and privacy.

CORE PRINCIPLES OF EDGE AI

The shift to Edge AI is enormous, as it concerns the rapidly evolving discipline of Artificial Intelligence (AI), and introduces a new era of decentralized intelligence. By directly transmitting intelligence to the device, Edge AI also removes the need to stay connected to the internet, particularly for traditional AI models whose processing is largely performed offline *via* cloud computing [6]. Edge AI enables interpretation and real-time decision-making by combining advances in edge computing [7], neuromorphic technologies, and brain-inspired models. Edge AI can be implemented at the device level and is significantly faster, more efficient, and more secure than standard AI systems that rely on cloud-based computing [8]. This chapter is concerned with the operational and technological merits associated with this decentralization.

Localized Processing and Edge Computing

Edge computing, where data processing is done closer to its origin rather than being transferred to distant data centers, [9] is the essence of edge AI. Since this localized processing reduces data transfer latency, which is a major bottleneck it is by far the most significant in cloud-dependent systems.

- **Reduced Data Exchange Time:** Traditional AI platforms must send raw data to a cloud provider, which will undoubtedly introduce delays due to slower, more stable calculation and transmission rates. A major benefit of Edge AI [10] is that it increases responsiveness in real time by analyzing data, thereby eliminating time-intensive data transfers. In localized processing, almost instantaneous judgments can be made, whether it be an industrial IoT device detecting significant anomalies or a self-driving vehicle haggling over traffic.
- **Better Real-Time Responsiveness:** Edge AI enables unbelievably fast feedback loops and data interpretation [11] at the point of origin. This capability is needed in cases where snap decisions can matter, such as in healthcare (*e.g.*, real-time patient vital signs monitoring), robotics (*e.g.*, real-time reactions to environmental changes), and autonomous systems (*e.g.*, real-time obstacle detection and avoidance).

CHAPTER 11

Machine Learning Models for Personalized Medicine: Revolutionizing Patient Care through Data-Driven Insights

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Abstract: Data about individual patients is at the core of personalised medicine, which transforms healthcare into an efficient treatment system that is both focused and specialized. This transformation is greatly aided by Machine Learning (ML), which makes it possible to analyze vast amounts of intricate healthcare data in order to enhance and guide decision-making. ML models are able to predict the likelihood of a disease, optimize treatment plans, and improve health outcomes by integrating numerous datasets such as genetic information, clinical data, lifestyle choices, and current health status. To develop specialized treatment plans for patients, this research investigates the fusion of several machine learning algorithms, including supervised, unsupervised, as well as reinforcement learning. Alongside data confidentiality, model explainability, ethical issues, and other primary challenges, this paper presents vital issues in clinical decision support systems, disease forecasting, and treatment optimization. Moreover, the paper discusses the prospects of personalized medicine for improving clinical trust in ML for automated decision-making through advanced real-time monitoring solutions, multi-omics data, and explainable AI (XAI). This study illustrates the potential of these data to revolutionize patient care through personalized, enhanced, and precise medical intervention.

Keywords: Clinical decision support, Disease prediction, Data-driven healthcare, Machine learning, Personalized medicine, Patient-specific data, Treatment optimization.

INTRODUCTION

Thanks to advances in data science and technology, the healthcare industry is undergoing a massive transformation. The arrival of personalized medicine, which aims at tailoring medical care to the characteristics of each patient, is one of the

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most interesting trends. Personalized medicine, in contrast to conventional one-size-fits-all methods, uses medical history, lifestyle, genetics, and environmental factors to generate more individual and successful treatment regimens. However, healthcare professionals have great difficulty making sound judgments about patient data due to the enormous volume and complexity. The effectiveness of this method over conventional ways has made AI a revolution in this field. ML models can detect patient-specific data, predict health hazards, propose specialized treatments, and ensure patient recovery by using massive threads of complex algorithms and big data. The integration of multimodal data sources, model interpretability, and data privacy concerns stands out as the principal barriers to personalized medicine despite its promise. This investigation explores how ML approaches can provide more patient-tailored approaches to care that tailor the treatment regimens based on the personal information of the patient. In this research, we will focus on the application of supervised, unsupervised, and reinforcement learning algorithms in clinical decision support, disease prediction, and treatment optimization, among other healthcare domains. The study's main aim is to examine the role of Machine Learning (ML) in building responsive, data-centric healthcare solutions that not only improve patient outcomes but also increase the accuracy of medical decisions. This study's core objective is to determine to what extent Machine Learning (ML) can be instrumental in developing dynamic, data-driven healthcare solutions that not only improve patient outcomes but also support the right medical decisions. An attempt has also been made to tackle the situation in which machine learning is applied in clinical settings with difficulty, and to search for further potential that machine learning could have in the future of personalized medicine.

LITERATURE REVIEW

The capability of personalized medicine to upgrade patient care by tailoring treatment based on the individual traits is one area that has attracted significant notice. With the processing of a large dataset of varying complexities, such as genomic, EHRs, and demographic ones, through the use of AI techniques, like machine learning, the realization of the gift of personalized medicine has become a core part of the healthcare industry. This literature review provides an extensive description of previous research in the field and identifying the areas the current research seeks to support, as well as presenting the most important findings and the methodologies used.

Prior Research in Personalized Medicine and Machine Learning

There has been extensive research confirming the outstanding performance of machine learning models in enhancing clinical decision-making, personalizing treatments, and predicting patient outcomes. In particular, machine learning techniques such as supervised learning (*e.g.*, support vector machines, random forests) and unsupervised learning (*e.g.*, clustering, dimensionality reduction) have been employed across many domains for data pattern recognition and patient stratification, and for disease classification and prognosis prediction.

Discussion of Findings

1. **Prediction of Drug Response:** Based on the genomic data, Zhang *et al.* applied deep learning algorithms to predict responses to chemotherapy. While the study demonstrated a potential application of deep learning to achieve personalized care, it highlighted the necessity of clinical validation across diverse patient cohorts before broad implementation can occur [1].
2. **Cancer and Recurrence Prediction:** Smith *et al.* used random forests to predict breast cancer recurrence based on clinical and genomic data. The model had a good prediction accuracy but was only relevant to breast cancer [2].
3. **Diabetes Management with Reinforcement Learning:** Lee *et al.* applied a deep reinforcement learning model for the management of diabetes (Lee *et al.*, 2019). While the strategy was successful, it also suffered from interpretability problems, which is an important requirement for clinical adoption [3].
4. **Cardiovascular Disease Stratification:** The study was able to identify new subgroups of patients; however, their model lacked depth because it neglected to incorporate even genomic or environmental variables [4].
5. **Personalized Cancer Treatment:** They combined clinical, genetic, and lifestyle data with ensemble learning to create personalised cancer treatments. Despite demonstrating the strength of integrative multi-omic approaches, the model provides only a foundation for establishing associations, not for inferring causality, particularly because it is trained on the data obtained [5].

Gaps and Opportunities for Further Research

Although these studies demonstrated how machine learning could be applied in personalized medicine, some gaps remain:

1. **Generalisable Across Diseases:** The majority of current models are disease-specific, such as diabetes or cancer. Models that are more generalisable, which

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