Evolution of Information Technology: A Comprehensive Review

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

Review Article

ABSTRACT

Pervasive computing, wireless sensor networks, and M2M communication have fuelled the Internet of Things. The IoT connects and interacts with many physical items using unique internet addresses. This article covers the structure and technologies of the Internet of Things (IoT). The Internet of Things (IoT) needs a standard structure. Thus, it begins with a complete explanation of architectural designs and then discusses communication protocols and standards. The article also includes a succinct review of common IoT protocols and standards, helping the reader comprehend the topic. It also provides concrete solutions and tactics for addressing Internet of Things issues. The essay culminates by demonstrating the practical applications of the Internet of Things (IoT). Nolan's Stages Theory offered a new perspective on commercial IT development in 1973. The rapid digital revolution has changed its underlying foundation, despite its continuous use. The initial idea

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focused on IT in production. Later, it expanded to include the complex relationship between IT and organisational strategy. Since its inception, the methodology has helped business and IT leaders navigate IT adoption without technical details. Nolan's Stages Theory still applies, but cloud computing, artificial intelligence, big data, and the Internet of Things require a more evolved approach. The rapid progress of technology has blurred the barriers between IT and other company functions, requiring a complete digital transformation strategy. Information systems and organisational structures have grown in importance and interconnection. As firms gained independence and flexibility, IT systems developed. IT integration into key company activities has transformed it into a strategic enabler. Nolan's strict methodology provides valuable insights into history, but it limits understanding of the dynamic and transformational forces altering the digital landscape. Contemporary studies emphasise the need for flexible and adaptive frameworks to accommodate the rapid pace of technological advances and their impact on organisational structures and business models. Nolan's Stages Theory is still significant in IT administration, although it has limitations in today's networked and data-driven business contexts. Future research should develop sophisticated and forward-thinking models to help organizations navigate the digital transition.

Keywords: Technology; digital; research; organisation; computer; transformation.

1. INTRODUCTION

1.1 Information Technology: A Brief Overview

Information Technology (IT) is an expansive domain encompassing the study, design, development, implementation, support, and management of computer-based systems, software, and networks. At its core, IT is about harnessing the power of technology to manage and distribute information effectively. It has permeated every facet of modern life, from business operations and healthcare to education and entertainment [1].

Fig. 1. Impact of technology

1.2 The Imperative of Understanding IT Evolution

Comprehending the evolution of IT is crucial for several reasons:

1. **Historical Perspective:** It provides a foundation for understanding the current IT landscape and anticipating future trends. [2]
2. **Technological Innovation:** By tracing the trajectory of IT, we can identify patterns of innovation and disruptive technologies. [3]
3. **Economic Impact:** The evolution of IT has been a primary driver of economic growth and societal change [4].
4. **Strategic Planning:** Understanding IT history helps organizations make informed decisions about technology investments [5].
5. **Educational Pursuits:** For students and researchers, it offers a rich field of study and exploration [6].

1.3 Scope and Objectives of the Review

This comprehensive review delves into the chronological progression of information technology, from its rudimentary beginnings to the cutting-edge advancements of today. It aims to:

1. Trace the development of key IT components, including hardware, software, and networks [7].
2. Analyse the impact of significant technological breakthroughs on society, economy, and culture [8].
3. Explore the convergence of IT with other disciplines, such as biology, physics, and social sciences [9].
4. Identify emerging trends and their potential implications for the future [10].
5. Critically evaluate the ethical, social, and environmental challenges posed by IT advancements.

1.4 Pre-Computer Era: The Foundation of Computation

Before the advent of electronic computers, humans relied on various manual methods for calculation and information management.

1. **Abacus and Other Manual Calculation Tools:** The abacus, originating in ancient Babylon, was one of the earliest computational devices. It consisted of a frame with beads strung on wires, allowing users to perform arithmetic operations. Other tools like the astrolabe, used for astronomical calculations, and the slide rule, for mathematical computations, also played significant roles. These devices, while limited in complexity, were essential for trade, navigation, and scientific exploration [11].
2. **Early Methods of Information Storage and Retrieval:** Information was primarily stored on physical media such as clay tablets, papyrus, parchment, and paper. Libraries and archives emerged as repositories of knowledge, with cataloguing systems developed to facilitate information retrieval. However, access to information was restricted, and search processes were time-consuming [12].

1.5 First Generation Computers (1940-1956): The Dawn of Electronic Computation

The first generation of computers marked a revolutionary leap forward, replacing human computation with electronic processing.

1. **Vacuum Tube Technology:** These early computers relied on vacuum tubes as their primary electronic components. While slow and prone to overheating, they enabled the execution of complex calculations at unprecedented speeds [13].
2. **ENIAC and UNIVAC:** The Electronic Numerical Integrator and Computer (ENIAC) was one of the first electronic general-purpose computers. Initially designed for military purposes, it was later adapted for scientific and engineering calculations. The Universal Automatic Computer (UNIVAC) was the first commercial computer, used for business data processing. These machines represented ground-breaking achievements but were colossal in size, consumed vast amounts of power, and generated immense heat [14].
3. **Limitations and Challenges:** First-generation computers suffered from several limitations. They were expensive to build and operate, had limited memory capacity, and were prone to frequent

breakdowns. Programming these machines was a complex and time-consuming task, requiring specialized knowledge. Moreover, input and output operations were slow and inefficient [15].

1.6 Second Generation Computers (1956-1963): The Transistor Era

The invention of the transistor ushered in a new era of computing, characterized by smaller, faster, and more reliable machines.

1. **Transistors:** Replacing bulky vacuum tubes, transistors significantly reduced the size and power consumption of computers. They enabled the development of more compact and efficient systems [16].
2. **Improved Speed, Reliability, and Efficiency:** Second-generation computers exhibited substantial improvements in speed, reliability, and efficiency compared to their predecessors. They could perform calculations much faster and with fewer errors [17].
3. **Early Programming Languages (FORTRAN, COBOL):** The emergence of high-level programming languages like FORTRAN (Formula Translation) and COBOL (Common Business Oriented Language) simplified programming and made computers more accessible to a wider range of users. These languages allowed programmers to write code using English-like statements, reducing the need for detailed machine-level instructions [18].

1.7 The Rise of Mainframes and Minicomputers

Third Generation Computers (1964-1971): The Integrated Circuit Era: The third generation of computers marked a pivotal shift in computing technology, characterized by the widespread adoption of integrated circuits.

1. **Integrated Circuits:** The advent of integrated circuits (ICs) revolutionized computer hardware. These tiny chips, capable of holding multiple transistors, dramatically reduced the size and power consumption of computers while increasing their processing speed and reliability. The integration of numerous components onto a single chip led to the development of

more complex and powerful systems [19].
2. **Development of Operating Systems:** To manage the increasing complexity of computer systems, operating systems emerged. These software programs acted as intermediaries between users and hardware, streamlining computer operations and providing essential services. Early operating systems, such as IBM's OS/360, introduced multitasking and memory management capabilities, enhancing system efficiency [20].
3. **Time-Sharing and Multiprogramming:** Time-sharing allowed multiple users to share the resources of a single computer simultaneously. By rapidly switching between users, the illusion of dedicated computer access was created. Multiprogramming enabled computers to execute multiple programs concurrently, improving system utilization. These advancements transformed computing from a resource-intensive activity to a shared service accessible to many users [21].

1.8 Mainframes: The Powerhouse of Computation

Mainframe computers, characterized by their large size, immense processing power, and high cost, became the backbone of large organizations in the mid-20th century.

1. **Centralized Computing Power:** Mainframes centralized computing resources, enabling organizations to consolidate data processing tasks and reduce operational costs. They were capable of handling massive amounts of data and performing complex computations, making them ideal for applications such as financial transactions, airline reservations, and census data processing [22].
2. **Use in Large Organizations:** Mainframes were predominantly used by governments, large corporations, and research institutions. They supported critical business operations, scientific research, and administrative tasks. The centralized nature of mainframe computing fostered the development of large-scale databases and data management systems [23].

1.9 Minicomputers: Decentralization of Computing Power

In contrast to mainframes, minicomputers were smaller, less expensive, and more flexible computers that emerged in the late 1960s.

1. **Smaller, More Affordable Computers:** Minicomputers offered a more affordable alternative to mainframes, making computing accessible to a wider range of organizations. They were compact enough to be installed in individual departments or offices, enabling decentralized computing [24].

2. **Decentralized Computing:** Minicomputers facilitated the distribution of computing power throughout organizations, allowing departments to process data locally and make independent decisions. This approach enhanced responsiveness, reduced reliance on central IT departments, and promoted innovation [25].

1.10 The Impact of Mainframes and Minicomputers

The rise of mainframes and minicomputers had a profound impact on society and business. Mainframes transformed industries by enabling efficient data processing and management on a massive scale. They played a crucial role in the development of early information systems and laid the foundation for modern enterprise computing. Minicomputers democratized computing by making it accessible to smaller organizations and departments, fostering innovation and empowering end-users.

1.11 Personal Computing and Networking

Fourth Generation Computers (1971-1980): The Microprocessor Revolution: The fourth generation of computers ushered in an era defined by the microprocessor, a single integrated circuit that could perform all the functions of a computer's central processing unit (CPU).

Microprocessors: The microprocessor, invented by Intel in 1971, marked a watershed moment in computing history. Its compact size, low power consumption, and increased processing speed paved the way for the development of personal computers and embedded systems.

1. **Personal Computers (PCs):** The microprocessor enabled the creation of personal computers, standalone computers designed for individual use. Early PCs were relatively simple machines with limited capabilities, but they offered unprecedented access to computing power for individuals. Pioneers like the Altair 8800 and Apple II laid the foundation for the PC revolution [26].

2. **Development of Software Applications:** The emergence of personal computers spurred the development of software applications tailored to individual needs. Word processors, spreadsheets, and database management systems became essential tools for productivity. Game development also flourished, creating a new entertainment medium [27].

1.12 The PC Revolution

The widespread adoption of personal computers transformed individuals' lives and reshaped the business landscape.

1. **Impact on Individuals:** PCs empowered individuals by providing access to information, communication tools, and entertainment. They facilitated home-based work, education, and personal productivity. The ability to process information and create content independently led to a surge in creativity and innovation [28].

2. **Spread of Personal Computing:** The popularity of personal computers grew rapidly as prices declined and capabilities expanded. The introduction of user-friendly operating systems, such as Microsoft Windows, simplified computer use and broadened the user base. PCs became ubiquitous in homes, schools, and offices, transforming the way people interacted with technology [29].

1.13 Personal Computing and Networking

Personal computing refers to the use of computers for a variety of individual activities, ranging from work-related responsibilities to recreational purposes. Networking establishes connections between computers and devices, facilitating communication, sharing of resources, and global access to information. Collectively, they constitute the fundamental basis of contemporary technology.

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Table 1. Personal computing

Feature	Recent Advances	Impact
Processors	Advanced node process technologies (3nm, 5nm), heterogeneous chip architectures (combining CPU, GPU, AI accelerators), increased core counts and clock speeds, energy efficiency improvements	Enhanced performance, power efficiency, AI capabilities
Memory	Higher density DRAM and NAND flash, persistent memory (combining DRAM and SSD characteristics), faster data transfer rates	Improved system responsiveness, larger storage capacities
Storage	Increased SSD capacities, faster data transfer speeds, emerging technologies like Optane, Z-NAND	Faster boot times, improved application loading, better overall system performance
Displays	Higher resolutions (4K, 8K), OLED, Mini-LED, MicroLED, higher refresh rates, touchscreens, foldable displays	Enhanced visual experience, improved gaming and content consumption
Form Factors	Thin and light laptops, 2-in-1 devices, foldable devices, wearables (smartwatches, smart glasses), AR/VR headsets	Increased portability, versatility, and immersive experiences
Operating Systems	Enhanced security features, AI integration, cloud integration, cross-platform compatibility	Improved user experience, data protection, and productivity

Table 2. Networking

| Feature	Recent Advances	Impact
Connectivity	Faster Wi-Fi standards (Wi-Fi 6E, Wi-Fi 7), 5G and 6G cellular networks, satellite internet (Starlink, OneWeb)	Increased speeds, lower latency, wider coverage, improved connectivity in remote areas
Networking Hardware	Faster routers and switches, advanced network security features (firewalls, intrusion detection/prevention systems), network virtualization	Improved network performance, security, and flexibility
Network Protocols	IPv6 adoption, network virtualization (SDN, NFV), quality of service (QoS) advancements	Enhanced network scalability, flexibility, and performance
Network Security	Advanced threat detection and prevention, AI-powered security solutions, zero-trust architecture	Improved protection against cyberattacks, data breaches
IoT and Smart Homes	Increased IoT device connectivity, home automation systems, smart home hubs	Enhanced home convenience, energy efficiency, and security
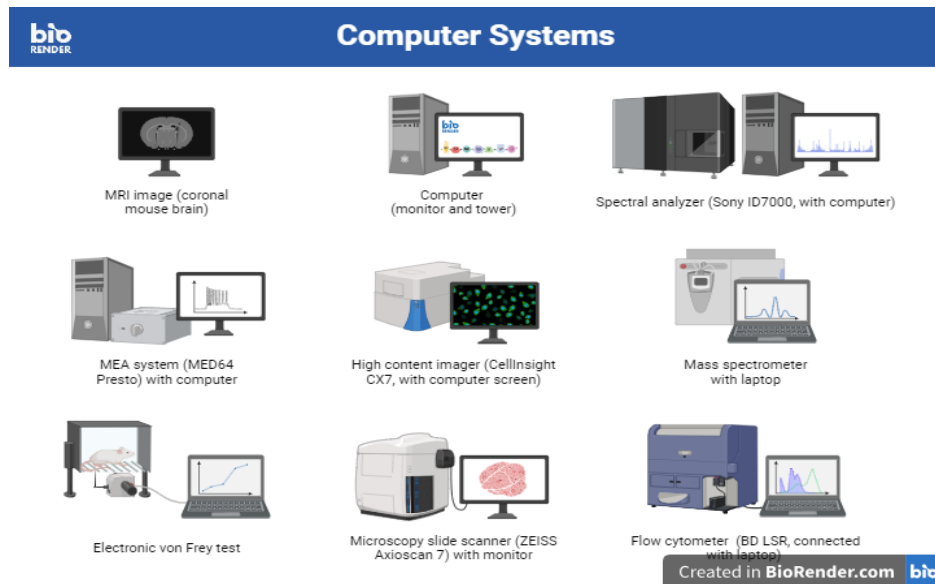
Fig. 2. Types of computers

3. **Development of Software Applications:** The emergence of personal computers spurred the development of software applications tailored to individual needs. Word processors, spreadsheets, and database management systems became essential tools for productivity. Game development also flourished, creating a new entertainment medium [32].

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1.16 Networking: Connecting Computers

The interconnectedness of computers through networks became increasingly important as the number of PCs grew.

1. **ARPANET and the Birth of the Internet:** The Advanced Research Projects Agency Network (ARPANET), initially developed by the U.S. Department of Defence, laid the groundwork for the internet. It connected computers across different locations, enabling researchers to share data and collaborate. The development of TCP/IP (Transmission Control Protocol/Internet Protocol) provided the foundation for the internet's global reach [35].

2. **Local Area Networks (LANs) and Wide Area Networks (WANs):** LANs connected computers within a limited geographical area, such as an office building or campus. They allowed for file sharing, resource sharing, and communication between users. WANs connected computers over larger distances, enabling communication and data transfer between remote locations. These networks facilitated collaboration, information exchange, and the growth of distributed computing [36].

Fig. 3. Scientist with Microscope (Back ground)

1.17 The Impact of Networking

Networking transformed the way people communicated, collaborated, and accessed information. The internet revolutionized commerce, education, and entertainment, creating a global digital ecosystem. LANs and WANs enabled businesses to operate more efficiently and effectively by connecting employees, departments, and offices.

1.18 The Information Age

Internet and World Wide Web: The advent of the internet and the World Wide Web marked a transformative era in human history, revolutionizing communication, commerce, and information sharing.

1. **Development of the World Wide Web:** The World Wide Web, conceived by Tim Berners-Lee in the late 1980s, emerged as a graphical interface for the internet. It introduced hypertext, allowing users to navigate between interconnected documents through clickable links. The development of HTML (Hypertext Mark-up Language) and HTTP (Hypertext Transfer Protocol) provided the foundation for the web's structure and communication. The early web was primarily a text-based environment, but the introduction of multimedia elements, such as images and sound, enhanced user experience. The World Wide Web catalysed the growth of e-commerce, transforming traditional business models and creating new opportunities [37].

2. **The Rise of Online Retail:** E-commerce emerged as a powerful platform for selling goods and services directly to consumers. Online retailers like Amazon, eBay, and Alibaba disrupted traditional brick-and-mortar stores by offering a wider selection of products, competitive prices, and convenient shopping experiences. The development of secure payment gateways and logistics infrastructure facilitated the seamless flow of transactions [38].

3. **Digital Marketplaces:** Online marketplaces emerged as platforms for connecting buyers and sellers. These platforms created opportunities for individuals and small businesses to reach a global audience. The sharing economy, enabled by platforms like Airbnb and Uber, disrupted traditional industries and created new revenue streams [39].

4. **Online Advertising:** Digital advertising became a cornerstone of the online economy. Search engine advertising, display advertising, and social media advertising emerged as powerful channels for reaching target audiences. The ability to track user behaviour and preferences allowed for highly targeted advertising campaigns [40].

5. **Challenges and Opportunities:** While e-commerce has brought numerous benefits, it also presents challenges such as online fraud, cybersecurity threats, and intense competition. The COVID-19 pandemic

accelerated the shift towards online shopping, highlighting the importance of digital transformation for businesses. Social media platforms revolutionized communication and social interaction, creating new channels for information sharing, relationship building, and community formation [41].

6. **Social Networking Platforms:** Platforms like Facebook, Twitter, Instagram, and LinkedIn connected billions of people worldwide. They facilitated the creation and sharing of content, enabling individuals and businesses to build personal brands and engage with audiences. Social media transformed the way people communicate, consume news, and interact with brands [42].

7. **Influence and Marketing:** Social media influencers emerged as powerful figures capable of influencing consumer behaviour. Brands leveraged social media for marketing, customer engagement, and reputation management. The ability to measure engagement and track campaign performance provided valuable insights for businesses [43].

8. **Challenges and Concerns:** Social media also raised concerns about privacy, misinformation, and addiction. The spread of fake news and hate speech became significant challenges. Efforts to regulate social media platforms and promote digital literacy have been ongoing [44].

1.19 Emerging Technologies and Future Trends

The convergence of technology, data, and human ingenuity is propelling us into an era of unprecedented innovation. This section explores some of the most significant emerging technologies and their potential impact on society.

1.20 Artificial Intelligence (AI)

Artificial Intelligence, once the realm of science fiction, is now a tangible reality reshaping industries and daily life.

1. **Machine Learning and Deep Learning:** Machine learning, a subset of AI, enables systems to learn from data without explicit programming. Deep learning, a specialized form of machine learning, utilizes artificial neural networks to mimic the human brain's structure and function. These techniques have driven breakthroughs in image recognition, natural language processing, and predictive analytics [45].

2. **Applications Across Industries:** AI is being deployed across various sectors, from healthcare to finance. In healthcare, AI aids in disease diagnosis, drug discovery, and personalized treatment plans. In finance, AI-powered algorithms optimize trading strategies and detect fraud. Autonomous vehicles, powered by AI, are poised to revolutionize transportation [46].
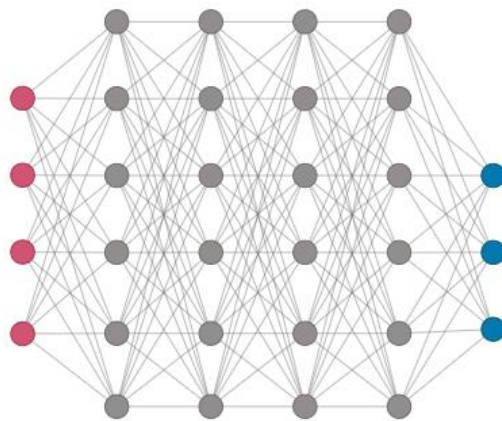
Created in **BioRender.com** bio

Fig. 4. Deep learning neural network

1.21 Big Data and Analytics

The exponential growth of data has created both challenges and opportunities. Big data analytics involves collecting, storing, processing, and analysing vast datasets to extract valuable insights.

1. **Data Collection, Storage, and Processing:** Advancements in data storage technologies, such as cloud computing and data lakes, have enabled organizations to accumulate massive amounts of data. Data processing frameworks like Hadoop and Spark facilitate the efficient handling of big data [47].
2. **Business Intelligence and Decision Making:** By analysing large datasets, organizations can uncover hidden patterns, trends, and correlations. This information empowers businesses to make data-driven decisions, optimize operations, and identify new market opportunities. Predictive analytics, a subset of big data analytics, enables forecasting future trends and outcomes.

1.22 Internet of Things (IoT)

The IoT refers to the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these objects to connect and exchange data.

1. **Connected Devices and Networks:** IoT devices generate vast amounts of data, which can be collected, analysed, and used to optimize processes and create new services. The proliferation of low-power wide-area networks (LPWANs) has expanded the reach of IoT applications.
2. **Applications in Smart Homes, Cities, and Industries:** IoT is transforming homes into smart environments with automated systems for lighting, temperature control, and security. Smart cities leverage IoT to optimize traffic management, waste management, and public services. In industries, IoT enables predictive maintenance, supply chain optimization, and enhanced operational efficiency [48].

1.23 Cybersecurity

As technology advances, so do cyber threats. Cybersecurity focuses on protecting digital assets from unauthorized access, use, disclosure, disruption, modification, or destruction.

1. **Threats and Challenges:** Cyberattacks, including ransomware, phishing, and data breaches, pose significant risks to individuals and organizations. The evolving threat landscape necessitates continuous adaptation and investment in cybersecurity measures.
2. **Importance of Data Protection:** Protecting sensitive data is paramount. Data privacy regulations like GDPR and CCPA have enforced stringent data protection standards. Organizations must implement robust security measures to safeguard customer data and maintain trust.

1.24 Future Directions

The future holds immense potential for technological advancements that will reshape our world.

1. **Quantum Computing:** Quantum computing harnesses the principles of quantum mechanics to perform calculations that are beyond the capabilities of classical computers. With the potential to revolutionize fields like cryptography, drug discovery, and materials science, quantum computing has the power to solve complex problems that are currently intractable [49].
2. **Augmented and Virtual Reality:** Augmented reality (AR) overlays digital information onto the real world, while virtual reality (VR) creates immersive simulated environments. These technologies have applications in gaming, education, training, and healthcare.
3. **Ethical Considerations:** The rapid pace of technological advancement raises ethical questions. Issues such as AI bias, data privacy, autonomous weapons, and job displacement require careful consideration. Developing ethical frameworks and guidelines is crucial to harness the benefits of technology while mitigating potential harms [50].

2. CONCLUSION

Human inventiveness has driven the rapid advancement of information technology (IT),

leading to significant transformations in communities and economies. Throughout this journey, innovation and change have consistently characterised the progression from the abacus to artificial intelligence. Information technology today permeates modern organisations, providing the energy for many functions such as efficient supply chains and engaging consumer interactions. The emergence of e-commerce, social networking, and cloud computing has fundamentally transformed sectors and fundamentally altered business structures. Nevertheless, this swift evolution poses both advantages and disadvantages. While numerous opportunities present themselves, we must also confront significant challenges. Cybersecurity dangers, data privacy concerns, and the persistent digital gap overshadow the digital landscape. As technologies such as AI and biotechnology grow more integrated into our lives, it is important to carefully address the ethical concerns that arise. Accountability, openness, and any biases need to be thoroughly examined. In order to fully use the potential of IT while minimising dangers, it is critical to adopt a comprehensive approach. Collaboration is vital among governments, businesses, and individuals. It is critical to have strong cybersecurity standards, ensure personal data protection, and strive to close the gap in access to digital technology. Ethical principles and legislation should ensure responsible technology development and deployment. Education and training investments are essential to prepare the workforce for the digital era. Furthermore, information technology (IT) presents significant opportunities to address global issues such as climate change, poverty, and healthcare inequalities. The utilisation of data analytics, artificial intelligence, and the Internet of Things can be employed to create inventive solutions that contribute to a more sustainable and fair world. IT advancement is a continuous and dynamic process. Striking a balance between innovation and responsibility is of utmost importance. By seizing opportunities and tackling obstacles, society can build a future where IT becomes a positive force, leading to global growth and improved quality of life.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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