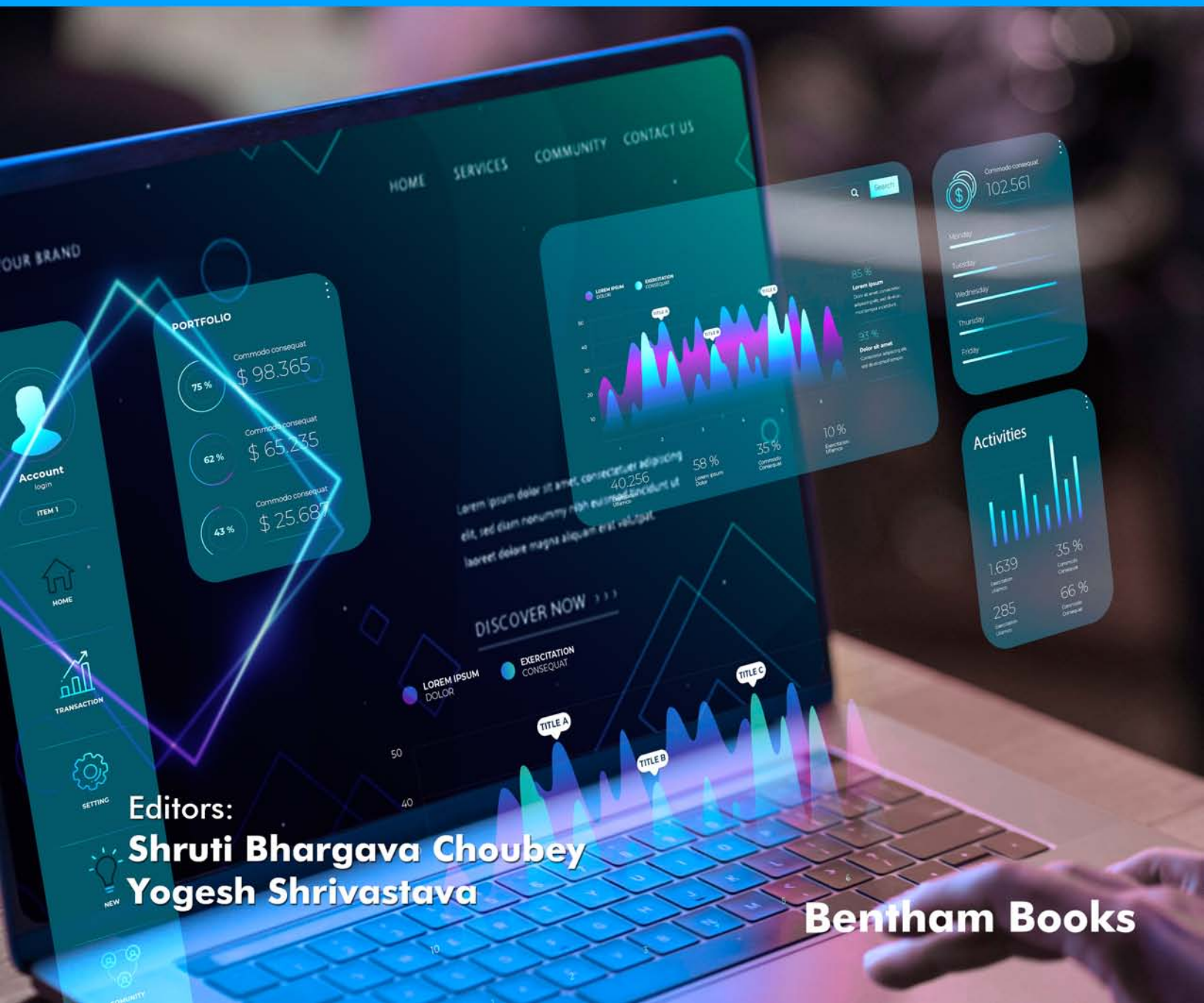
MODERN TRENDS IN PERVASIVE INTELLIGENCE



Editors:
Shruti Bhargava Choubey
Yogesh Shrivastava

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Modern Trends in Pervasive Intelligence

Edited by

Shruti Bhargava Choubey
Department of Electronics and Communication Engineering
Sreenidhi Institute of Science & Technology,
Hyderabad, Telangana
India

Yogesh Shrivastava
Department of Mechanical Engineering
Galgotias College of Engineering and Technology,
Greater Noida, Uttar Pradesh, India

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Editors: Shruti Bhargava Choubey & Yogesh Shrivastava

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FOREWORD

It gives me immense pride and satisfaction to present Modern Trends in Pervasive Intelligence, a scholarly volume that brings together the insights and expertise of distinguished authors from diverse domains. This work is the result of collective dedication, academic rigor, and an unwavering commitment to advancing knowledge in the field of pervasive intelligence.

The chapters contained within this book cover a wide spectrum of contemporary themes, ranging from intelligent sensing and context-aware computing to edge AI, IoT, and smart environments. Each contribution reflects not only deep research and analysis but also a vision for how these technologies can shape the future of intelligent systems and their integration into everyday life.

This endeavor has been marked by close collaboration between editors and contributors, and I wish to acknowledge the professionalism, responsiveness, and intellectual engagement that each author has brought to the process. Their work has given this volume both depth and relevance, making it a valuable resource for researchers, students, and practitioners alike.

In many ways, this book is more than a collection of chapters, it is a reflection of interdisciplinary collaboration and the shared pursuit of innovation. It demonstrates how collective scholarship can address pressing challenges and open new pathways in the rapidly evolving landscape of pervasive intelligence.

I extend my heartfelt congratulations to the editors and authors for their commitment and excellence. I am confident that this book will serve as an important reference for years to come, inspiring further research and practical applications in this dynamic field.

Bhagat Singh
Department of Mechanical Engineering
Jaypee University of Engineering and Technology,
Guna, Madhya Pradesh
India

PREFACE

The rapid evolution of artificial intelligence and its integration into every aspect of our lives has given rise to a new era of pervasive intelligence. Modern Trends in Pervasive Intelligence is a timely and comprehensive volume that brings together cutting-edge research and thought leadership from academics, practitioners, and industry experts working at the forefront of this dynamic field.

This edited book explores the multifaceted dimensions of pervasive intelligence, from ubiquitous computing and sensor networks to AI-driven automation, edge computing, and intelligent decision-making systems. The chapters presented herein highlight novel methodologies, emerging technologies, and practical applications that are transforming sectors such as healthcare, manufacturing, smart cities, education, and beyond.

Our goal in compiling this volume is to provide readers, including researchers, graduate students, and technology professionals, with a deeper understanding of the challenges, opportunities, and future directions of pervasive intelligence. Each chapter has been carefully selected and peer-reviewed to ensure high academic and technical quality.

We express our sincere gratitude to all the contributing authors for their valuable insights and scholarly rigor. Their expertise has enriched the content of this book and contributed to its relevance in the current landscape of intelligent systems. We are also thankful to the reviewers and technical advisors for their constructive feedback throughout the editorial process.

We hope this book serves as a useful resource and a catalyst for further exploration and innovation in the field of pervasive intelligence.

Shruti Bhargava Choubey
Department of Electronics and Communication Engineering
Sreenidhi Institute of Science & Technology,
Hyderabad, Telangana
India

Yogesh Shrivastava
Department of Mechanical Engineering
Galgotias College of Engineering and Technology,
Greater Noida, Uttar Pradesh
India

List of Contributors

Ashutosh Choubey Department of Electrical and Electronics Engineering, Baderia Global Institute of Engineering & Management, Jabalpur, Madhya Pradesh, India

Abhishek Choubey Department of Electronics and Communication Engineering, Sreenidhi Institute of Science & Technology, Hyderabad, Telangana, India

Anurag Agarwal Department of MBA, IMS Engineering College, Ghaziabad, Uttar Pradesh, India

A. Sathiya Department of Electronics and Communication Engineering, M. Kumarasamy College of Engineering, Karur, Tamil Nadu, India

A. Sridevi Department of Electronics and Communication Engineering, M. Kumarasamy College of Engineering, Karur, Tamil Nadu, India

A. Sangeetha Department of Electronics and Communication Engineering, M. Kumarasamy College of Engineering, Karur, Tamil Nadu, India

A.K. Richharia Department of Mechanical Engineering, Galgotia College of Engineering and Technology, Greater Noida, Uttar Pradesh, India

Brijesh Verma Department of Mechanical Engineering, Galgotia College of Engineering and Technology, Greater Noida, Uttar Pradesh, India

CSN Koushik Department of Electrical and Computer Engineering, New York University, Tandon School of Engineering, New York, USA

Eesha Thakur Department of Computer Science and Engineering, Sreenidhi University, Hyderabad, Telangana, India

G. Aarushi Reddy Department of Computer Science and Engineering, Sreenidhi University, Hyderabad, Telangana, India

Hunny Gaur Department of Computer Science, IMS Engineering College, Ghaziabad, Uttar Pradesh, India

J. Samuel Manoharan Department of Electronics and Communication Engineering, M. Kumarasamy College of Engineering, Karur, Tamil Nadu, India

K. Harinadh School of Management Sciences, Sreenidhi Institute of Science and Technology, Hyderabad, Telangana, India

Nitesh Pandey Department of Computer Science and Engineering, Jaypee University of Engineering and Technology, Guna, Madhya Pradesh, India

Prateek Mishra Department of Electrical and Electronics Engineering, Baderia Global Institute of Engineering & Management, Jabalpur, Madhya Pradesh, India

Padmaja Grandhe Department of Computer Science and Engineering, Sreenidhi University, Hyderabad, Telangana, India

Pankaj Gupta Department of Mechanical Engineering, Jaypee University of Engineering and Technology, Guna, Madhya Pradesh, India

Pawan Kumar Arora Department of Mechanical Engineering, Galgotias College of Engineering and Technology, Greater Noida, Uttar Pradesh, India

Radha Raman Pandey Department of Computer Science, IMS Engineering College, Ghaziabad, Uttar Pradesh, India

Ranjan Mishra	Department of Computer Science and Engineering, Jaypee University of Engineering and Technology, Guna, Madhya Pradesh, India
Rashmi Rani Maheshwari	Department of Mechanical Engineering, Galgotias College of Engineering and Technology, Greater Noida, Uttar Pradesh, India
SPV Subba Rao	Department of Electronics and Communication Engineering, Sreenidhi Institute of Science & Technology, Hyderabad, Telangana, India
Shruti Bhargava Choubey	Department of Electronics and Communication Engineering, Sreenidhi Institute of Science & Technology, Hyderabad, Telangana, India
Saket Gumudavelli	College of Engineering, Northeastern University, Boston, Massachusetts, USA
Sri Silpa Padmanabhuni	Department of Computer Science and Engineering, PSCMR College of Engineering & Technology, Vijayawada, Andhra Pradesh, India
Swathi Buragadda	Department of Computer Science and Engineering, Lakireddy Balireddy College of Engineering, Mylavaram, Andhra Pradesh, India
Shambhavi Tamrakar	School of Management Sciences, Sreenidhi Institute of Science and Technology, Hyderabad, Telangana, India
T V Divya	Department of Computer Science and Engineering, Sreyas Institute of Engineering and Technology, Bandlaguda, Hyderabad, Telangana, India
Vivek Singh	Department of Mechanical Engineering, Galgotia College of Engineering and Technology, Greater Noida, Uttar Pradesh, India
Yaamini R	Department of Computer Science and Engineering, Sreenidhi University, Hyderabad, Telangana, India, India
Yogesh Shrivastava	Department of Mechanical Engineering, Galgotias College of Engineering and Technology, Greater Noida, Uttar Pradesh, India

CHAPTER 1

Data Mining and Knowledge Discovery in Pervasive Environments

Ashutosh Choubey[1,*] and **Prateek Mishra**[1]

[1] *Department of Electrical and Electronics Engineering, Baderia Global Institute of Engineering & Management, Jabalpur, Madhya Pradesh, India*

Abstract: Data mining and knowledge discovery are crucial in pervasive computing systems, which are distinguished by dynamic user behaviours, contextual variations, and different management requirements. Unlike classical data mining, which uses static databases or data warehouses, ubiquitous data mining works at the communication level, frequently in real time and on flowing data. Streaming data mining is supported by a variety of technologies, each with unique requirements imposed by the nature of pervasive data, such as variability, volume, and velocity. Data transmission time, contextual distinction, and processing accuracy are all important factors to consider. This study investigates the capabilities of current data streaming infrastructures and identifies issues particular to pervasive contexts. We demonstrate the limitations of current systems in handling real-time, adaptive mining activities using hypothetical application scenarios and instructive case studies. These examples demonstrate crucial gaps and growing opportunities, particularly in real-time decision making and adaptive intelligence. To summarise, pervasive data mining is a dynamic and expanding research subject with tremendous promise for transdisciplinary applications in social sciences, healthcare, transportation, and smart environments.

Keywords: AI ethics, Data mining, Emotion recognition, Emotional intelligence (EI), Empathy in AI.

INTRODUCTION TO PERVASIVE ENVIRONMENTS

One of the central research themes in the information society era is the advancement of pervasive environments. Pervasive computing envisions a world where computing technologies are seamlessly integrated into everyday objects, enabling them to communicate over the Internet.

[*] **Corresponding author Ashutosh Choubey:** Department of Electrical and Electronics Engineering, Baderia Global Institute of Engineering & Management, Jabalpur, Madhya Pradesh, India; E-mail: ashutoshchoubey14@gmail.com

Shruti Bhargava Choubey & Yogesh Shrivastava (Eds.)
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In such environments, physical objects become context-aware entities capable of sensing, processing, and exchanging information. This connectivity allows the environment to recognize these objects, interpret the data they hold, and autonomously interact with or respond to the external world.

In this context, pervasive environments are envisioned as spaces where technology is embedded as unobtrusively as possible into everyday physical objects, which are primarily devoted to daily life activities [1]. This paradigm fosters new modes of human interaction, where devices are not only interconnected but also endowed with intelligence, context-awareness, and communication capabilities. The aim is to enhance user experience by linking physical objects with relevant and meaningful digital information, thereby creating a seamless, intelligent, and responsive environment.

This ubiquitous computing framework is expected to become a defining characteristic of the information society. The pervasive integration of information chips into a wide range of settings, including homes, workplaces, and public spaces, transforms these environments into intelligent systems [2]. For example, refrigerators may suggest recipes based on their contents, washing machines could recommend optimal programs, and phones might automatically place calls based on user habits and context.

The conceptualization of pervasive environments is increasingly informed by the analysis of practical systems and real-world applications. While developing robust and dependable services often requires divergent technological approaches, there are also significant overlaps and shared characteristics that allow applications to be embedded across diverse environments. This interconnectivity results in networks of complex, often ubiquitous systems that span various domains.

The complexity and relevance of pervasive environments are further amplified in priority sectors such as healthcare, education, and entertainment, where emerging applications demand innovative solutions. The term pervasive denotes not only the physical distribution of technology but also an underlying modeling approach that captures the behavior and interactions of intelligent components within the environment. To systematically represent such systems, conceptual models may be developed in a three-phase approach: the first phase aims to characterize the dynamic nature of pervasive environments and define foundational modeling constructs.

Definition and Characteristics

Over the past years, there has been a growing interest in data mining and knowledge discovery in pervasive environments. This area covers the development, implementation, and evaluation of data processing methods and data-driven models in technologically enhanced pervasive real-world environments that have traditionally not been perceived as primarily data collection platforms. Such environments, pervasive environments, can be physical or virtual, and they should be able to host complex systems that actively process a huge amount of heterogeneous information in near real-time. Pervasive environments are assumed to be unique in terms of their users' behavior, content, data dynamics, and information processing. They are defined as complex physical or virtual spaces enriched with various electronic devices and displays, where information is seamlessly accessed, and a broad range of services is composed.

These environments are characterized by the ubiquity of various devices, suggesting that technological solutions are omnipresent and not objects of deliberate interest to inhabitants. In order to build and maintain such solutions, their components need to function according to the user's current needs and expectations. In other words, pervasive environments are a special class of applications where ICT systems are supposed to be able to adapt to and model their natural environment in order to enhance remote communication or interaction with such an environment. Hence, the notion of pervasive environments as objects of data processing can be particularly associated with the class of complex technology-augmented environments.

This part presents the definition and characteristic features of such environments. Furthermore, it explains how these environments enrich the user's involvement by providing just-in-time and just-in-situ information content. Subsections then discuss the implications of pervasive environments on data dynamics from both the generation of data and the user interaction perspective. At least it proffers a brief taxonomy that should facilitate identifying the key components in a pervasive environment data model. The taxonomy also covers the results of data exploratory analysis that can be later visualized as actionable forms, something that is imperative for further usability of the knowledge discovered.

Applications and Importance

In the last few decades, a variety of places in almost any location have become smart thanks to the incorporation of computer-based systems that can sense, interact, and autonomously act in the world, also known as ubiquitous or pervasive computing. The Internet-of-Things (IoT) paradigm has propelled this

CHAPTER 2

Exploring Human-Computer Interaction and Affective Computing

SPV Subba Rao[1,*], Shruti Bhargava Choubey[1] and **Abhishek Choubey[1]**

[1] *Department of Electronics and Communication Engineering, Sreenidhi Institute of Science & Technology, Hyderabad, Telangana, India*

Abstract: This study begins with the notion that Human-Computer Interaction (HCI) and affective computing have a common goal: understanding, capturing, and altering human affect and physiological states. However, well-established methods from psychology, communication, and media studies have received limited attention in HCI and affective computing. This presentation provides: (1) a rationale for incorporating insights from these disciplines into effective research; (2) an outline of methodological frameworks used in humanistic studies of affect; and (3) examples of how these methods might enhance and inspire new paths in HCI and affective computing. The paper finishes by discussing the benefits and limitations of interdisciplinary collaboration in this context.

Keywords: Affective computing, Human-computer interaction (HCI), Human affect, Interdisciplinary research, Methodological models.

INTRODUCTION TO HUMAN-COMPUTER INTERACTION

Technological advancements in the last few decades have led to the rapid development of many research areas. It has become clear that computers are no longer confined to laboratories, companies, and governmental organizations but have found their way into every part of everyday life. Satellites, televisions, and credit cards are widely used, and home computers, mobile phones, and the internet have all become household items. The social and economic impacts of such an infusion of technology are obvious in today's society. In recent years, it is believed that the next generation of technology should not only consider how fast it operates and how large its memory space is, but also give emphasis on how

[*] **Corresponding author SPV Subba Rao:** Department of Electronics and Communication Engineering, Sreenidhi Institute of Science & Technology, Hyderabad, Telangana, India; E-mail: subbarao.s@sreenidhi.edu.in

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easy it is to use. This belief has led researchers to debate the emphasis on performance and memory space to assist users in becoming more creative. One research area developed from such discussions is the field of Human-Computer Interaction (HCI) [1].

Important research questions in HCI include: How should interfaces be designed so that users can easily control computers? What system architecture and cognitive models best meet user needs?; Do visual icons better portray concepts for students as opposed to the written word?; and What are the usability advantages and disadvantages of using multimedia in an online tutorial? Simultaneously, the human interface with devices and computer games is also of great concern. Simple examples include pushing a button for the correct time on a watch, setting the temperature on a thermostat, and using a dizzying array of interaction devices for computer game consoles. The key issue here is that this new generation of devices is likely to stretch the traditional novel/homeowner interaction to the limits and present a research challenge beyond HCI. There are two cautions to be taken. Firstly, it is completely recognized that HCI is a broad church, with many researchers having disparate interests focusing on the common denominator of human use of computers. This study should be viewed not as a total description of the research area, but as an introduction to new research directions within HCI. Secondly, common threads are running throughout the paper; these being that models of HCI, in all its guises, should be "numerical" methods to allow discrimination about what works and what does not. This pre-testing, post-testing methodology espoused has much broader implications and is viewed as a significant advance in research methods and HCI practice [2].

Definition and Evolution of HCI

When addressing Human-Computer Interaction (HCI), it is essential to first define the relevant terms of the phrase itself. The term "human-computer" describes what is interacting, namely, human beings and computer systems. The term "interaction" is used to describe how people and computers work together, describing a set of practices, methods, and techniques that influence the way humans and computers communicate or work together. Therefore, "Human-Computer Interaction" can be seen as a mixture of arts, science, social disciplines, and many other fields that literally influence the use of technology and how users interact with technology.

Although the current practice of HCI is relatively new, its roots can be traced back to the early days of computing usage. HCI as we know it today originated as a term in the 1980s, emerging from technical and engineering-related discourse concerning man-machine systems, incorporating other fields such as cognitive

psychology. The first occurrences of the term were found in ACM publications in 1982, quickly adopted by commercial industries [3].

Since then, HCI has transformed into a burgeoning field with a much broader definition and scope, which goes beyond computing usability concerns. Interaction design focuses on user goals and needs, system constraints, the processes by which humans interact with these systems, and the outcome of this interaction. This tradition has expanded to address complex systems and activities while providing richer alternatives for user experience by considering the overall context of use. Instituted protocols ensure the potential design solution is usable by users, useful in terms of their needs, and can be transferred into effective IT products or systems. HCI has been subject to various design fashions and philosophies since the 1980s. From early cognitive man-machine systems thinking, it evolved to address a wider and deeper appreciation of user needs and behaviors [4]. This led to a focus on User-Centered Design (UCD) in the early 1990s. Over the past twenty-five years, these principles have been adopted pervasively in software and internet design. On the other hand, the 2010s witnessed the predominance of new design approaches like flat design and material design. However, central to all these different design epochs are the users themselves and their needs, goals, and behaviors. The development of computing and related technologies has been shaped by the different ways people interact with them. From complex command line instructions, the development of Graphical User Interfaces, the WWW, and, more recently, mobile technology, all these developments are, in one way or another, related to the discipline of HCI. Moreover, HCI is characterized by the somewhat eclectic mixture of disciplines in which it rests. On the one hand, it is informed by insights from cognitive science, enabling the design of technologies adapted to human cognition and other mental processes. On the other hand, it incorporates principles drawn from social psychology and communication to understand the emotional and social aspects of the user. At a broader level, interaction design engages in a broader conversation between the technological world and that of social sciences and the humanities, enabling forms of insights and innovations that otherwise would not have occurred. This study will explore Affective Computing as a specific part of this macrocosm. Focusing on the design of technologies that respond to the user's emotional inputs and states, it will cover advancements, applications, and, mostly, their implications in technology and society [5].

CHAPTER 3

Designing Empathy: The Role of Emotion in Human-Computer Collaboration

Anurag Agarwal[1], Radha Raman Pandey[2,*] and **Hunny Gaur[2]**

[1] *Department of MBA, IMS Engineering College, Ghaziabad, Uttar Pradesh, India*

[2] *Department of Computer Science, IMS Engineering College, Ghaziabad, Uttar Pradesh, India*

Abstract: Imagine a world in which computers understand not just our commands but also our emotions. This is the promise of incorporating empathy into human-computer communication as technology progresses; integrating Emotional Intelligence (EI) into robots becomes more possible. However, this trip is not without obstacles. People's belief in the power of emotions is what hinders the advancement of Artificial Intelligence (AI). AI emotions enhance human-machine cooperation, fostering empathy and trust. AI systems can handle emotional input by incorporating EI and empathy, affecting human-computer interaction. This section explains how to connect naturally with robots using their emotional model. The incorporation of EI and empathy in AI systems improves human-computer interaction and collaboration. This chapter explores the design and implementation of empathy in AI, namely the machines' ability to feel, grasp, and react to human emotions. This raises ethical concerns, such as the distinction between simulated emotion and actual human connections. This chapter highlights the importance of emotional intelligence systems in shaping the future of human-computer interaction and presents technologies with human-like thinking and emotions.

Keywords: AI ethics, Emotion recognition, Emotional intelligence (EI), Empathy in AI, Human-computer interaction (HCI).

INTRODUCTION

Breakthroughs in AI and HCI are occurring at a rapid pace, generating a new generation of human-machine teamwork. One needs empathy or the ability to connect with the feelings of another person in such alliances [1 - 3]. With the increasing presence of AI systems in our lives, such as virtual assistants, smart healthcare devices, *etc*., the book called ” Designing Empathy” examines the role of emotions in human-computer communication, and the way emotions can strengthen it through the virtue of empathy.

* **Corresponding author Radha Raman Pandey:** Department of Computer Science, IMS Engineering College, Ghaziabad, Uttar Pradesh, India; E-mail: radharamanp@gmail.com

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The creation of Emotional Intelligence (EI) in systems is an important area of research as machines increase their ability to make sense of and respond to human emotions [4 - 6]. This chapter examines the effects of emotions (human and machine) on collaborative relationships. The aim is to be aware of situations where emotionally conscious AI can contribute to more reflexive, attentive, and efficient exchanges.

AI is the ability of a machine to perform tasks like intelligent beings, particularly within computer systems. Among the subfields of AI are machine learning, computer vision, natural language processing, robotics, and expert systems. The capacity to carry out speech recognition, high-level data processing, decision-making, and communicate using language, amongst others, is no longer in the domain of human work; it is done by AI systems. The image shows how to develop an AI system, as shown in Fig. (**1**):

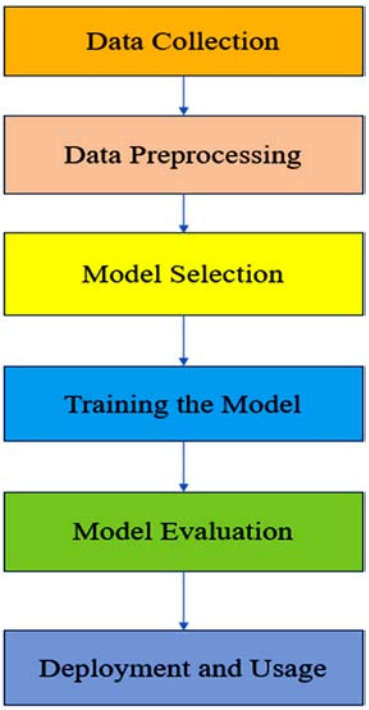

Fig. (1). Process of creating an AI system.

Emotional Intelligence (EI) is connected to the ability to recognize, read, and manage emotional expressions. This is an essential talent across various aspects of life, from personal relationships to career success. As reflected in Fig. (**2**), there are five important components of EI.

Fig. (2). Components/elements of EI.

1. Self-awareness: This is being aware of what you feel and how it can affect you. It is all about self-awareness of your strengths, weaknesses, and what drives you.
2. Self-Regulation: It involves managing feelings and behaviors. That consists of holding their own when under pressure and being adaptable to change.
3. Social Skills: This is applying your knowledge of feelings to establish and sustain good relations with others.
4. Motivation: When we are motivated, we are prompted to achieve goals and aspirations. It can be likened to a light that ignites a flame within us, giving us the energy to keep going even on a bad day.
5. Empathy: Empathy is a fundamental part of human engagement. It allows us to comprehend and share the emotions of others.

This chapter addresses the interplay of emotion and technology, highlighting public receptiveness to incorporating EI into HCI to promote more naturalistic, meaningful, and productive collaboration.

The key idea of this study is to build AI systems that are not only effective but also capable of establishing rapport and trust with humans [7 - 10]. EI includes recognizing, interpreting, and responding appropriately to emotional cues. In this chapter, we focus on the role of emotions in decision-making, communication, and problem-solving processes in human-computer interaction, identifying how they can be used to improve experience and increase collaboration and creativity in AI systems.

This chapter expands on some theoretical concepts, algorithms, and a conceptual framework diagram to demonstrate the remarkable power of emotionally intelligent AI and what this means for the future of human-computer interaction.

CHAPTER 4

Multi-Agent Reinforcement Learning-Based IoT Sensor Network for Energy-Efficient, Secure, and Scalable Routing Optimization

A. Sathiya[1,*], **A. Sridevi**[1], **J. Samuel Manoharan**[1] and **A. Sangeetha**[1]

[1] *Department of Electronics and Communication Engineering, M. Kumarasamy College of Engineering, Karur, Tamil Nadu, India*

Abstract: Modern IoT sensor networks are complicated, and intelligent decision-making is critical for energy efficiency, communication costs, and network flexibility. Traditional rule-based and centralised systems have substantial limits due to the long computing delays needed in such large-scale deployments, as well as the volume of data generated. As a result, Multi-Agent Reinforcement Learning (MARL) appears to be the best solution: the sensor nodes can function as autonomous agents, learning and adapting to changing environmental conditions through decentralised decision making. This chapter explores the use of MARL to improve packet transmission, network longevity, and power consumption in sensor networks. Cite the efficacy of several MARL architectures, including Centralised Training-Decentralized Execution (CTDE), Fully Decentralised Learning, and Hierarchical MARL, in terms of sensor coordination. An experimental framework is built on OpenAI Gym, TensorFlow, and NS3 and used to develop MARL-based sensor nodes that dynamically change their transmission power and task scheduling. The performance indicators (*e.g.*, Packet Delivery Ratio (PDR), energy usage, and network efficiency) are examined, demonstrating that MARL outperforms conventional optimisation methods. It is also discussed in the context of real-world applications such as smart cities, healthcare monitoring, environmental sensing, and industrial IoT (IIoT). Finally, the chapter provides insights into scaling problems, integration with new technologies such as 6G and quantum computing, and security enhancement *via* blockchain. This study also incorporates recent works such as: [Chebyshev Polynomial Based Emergency Conditions with Authentication Scheme for 5G-Assisted Vehicular Fog Computing], [ANAA-Fog: A Novel Anonymous Authentication Scheme for 5G-Enabled Vehicular Fog Computing], [Password-Guessing Attack-Aware Authentication Scheme Based on Chinese Remainder Theorem for 5G-Enabled Vehicular Networks], [ECA-VFog: An Efficient Certificateless Authentication Scheme for 5G-Assisted Vehicular Fog Computing], [CM-CPPA: Chaotic Map-Based Conditional Privacy-Preserving Authentication Scheme in 5G-Enabled Vehicular Networks], [Provably Secure with Efficient Data Sharing Scheme for Fifth-Generation (5G)-Enabled Vehicular Networks without RSU].

[*] **Corresponding author A. Sathiya:** Department of Electronics and Communication Engineering, M. Kumarasamy College of Engineering, Karur, Tamil Nadu, India; E-mail: sathyaayyadurai@gmail.com

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Keywords: Decentralized learning, Energy efficiency optimization, Hierarchical MARL, IoT sensor networks, Multi-agent reinforcement learning (MARL), Packet delivery ratio (PDR), Reinforcement learning in edge devices, Smart sensing systems.

INTRODUCTION

Since the Internet of Things (IoT) and sensor networks are considered basic building blocks of current modern intelligent systems, they can collect, process, and decide on real-time data. Such networks are important to a variety of applications, including smart cities, healthcare, industrial automation, and environmental monitoring. Nevertheless, there are unsolved scalability, energy efficiency, and network adaptability issues with deploying IoT. Due to the dynamic nature of the environments, traditional optimization techniques are not able to handle the environment, and thus, advanced learning-based techniques such as Multi-Agent Reinforcement Learning (MARL) are required. In MARL, multiple sensor nodes are treated as intelligent agents that are allowed to learn from the environment to achieve a desired performance and optimize it without central control. Unlike the traditional rule-based approaches, which are preceded by predetermined conditions, MARL promotes adaptive decision making, which results in energy efficiency, data transmission optimization, and real-time fault management [1 - 3]. This is due to its capability to dynamically allocate resources on the network while at the same time minimizing computational overhead, making it a perfect choice for the deployment of large-scale IoT. This chapter discusses how MARL can be integrated into IoT sensor networks by providing a structured overview of MARL fundamentals, architectures, implementation strategies, evaluation performance, and real-world applications. The discussion demonstrates the use of MARL for decentralizing control, dynamic resource management, and intelligent adaptation in IoT systems. MARL is further validated in experimental frameworks and networked case studies in real-world case studies in modern IoT sensor networks that overcome scalability, adaptability, and efficiency [4 - 6].

THE EVOLUTION OF IOT SENSOR NETWORKS

It can be seen that Internet of Things (IoT) technology has advanced very fast, and sensor networks have gone from being basic data acquisition systems into ultra complex, self-optimizing intelligent systems in the blink of an eye [7, 8]. An IoT-based sensor network is a collection of interconnected devices that are continuously monitoring, collecting, and transmitting data to a centralized or distributed processing unit, as shown in Fig. (**1**).

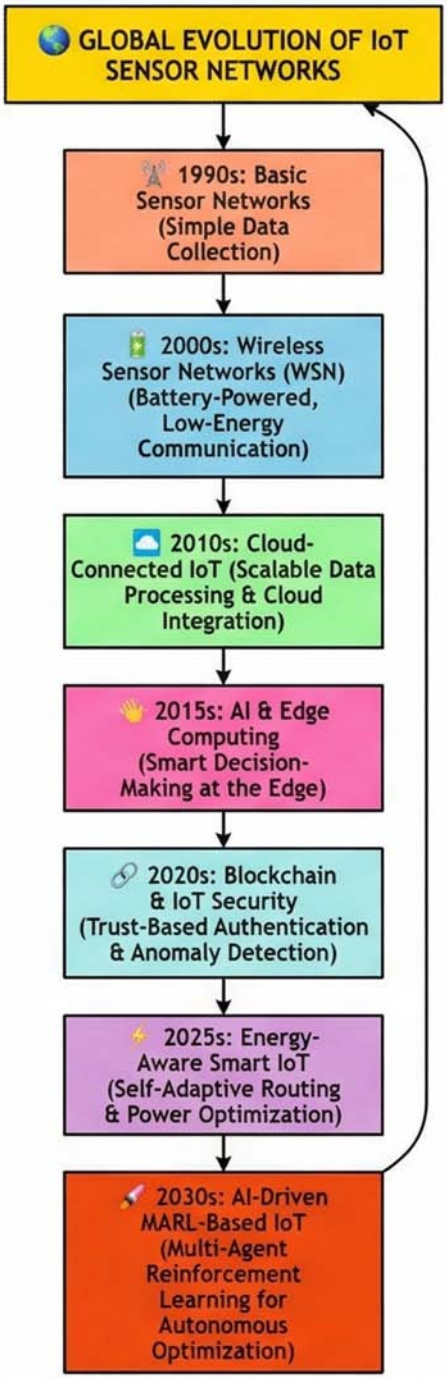

Fig. (1). Evolution of IoT sensor networks.

CHAPTER 5

Next-Generation Product Development through Pervasive Intelligence: Evolutionary Computation and Optimization Techniques

Saket Gumudavelli[1,*]

[1] *College of Engineering, Northeastern University, Boston, Massachusetts, USA*

Abstract: In recent years, the growth of "smart" products, those that integrate several technologies and are equipped with a variety of sensors and cameras, has become more prevalent. The software contained in these products is becoming more complicated, demanding effective support systems to speed up and improve the product development process. As a result, developing next-generation systems and product development technologies that not only improve everyday living but also promote industrial growth has become a major problem. One interesting option is the development of open platforms infused with developing intelligence, which will allow developers to successfully address a wide range of technological difficulties. These platforms should be branded and offered as unique industry solutions. This chapter examines a number of attempts in applied evolutionary computation and optimisation. These innovative approaches play an important part in the development of modern industrial products. In addition, current subjects such as ant colony optimisation and other social intelligence paradigms are investigated. The chapter's title concisely expresses the key goals and significance of the underlying study.

Keywords: Analytical framework, Chapter generation, Content outline, Contextual relevance, Core ideas, Essential terms, Key concepts, Subject matter, Summarization, Thematic elements.

INTRODUCTION

The increasing need to succeed in a changing landscape of computational intelligence and technology necessitates new perspectives and revolutionary methods for the development of next-generation products [1 - 5]. The pursuit of ubiquitous technologies gets traction in improving the potential of smart products.

[*] **Corresponding author Saket Gumudavelli:** College of Engineering, Northeastern University, Boston, Massachusetts, USA; E-mail: Saketgumudavelli28@gmail.com

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The product development domain stands to profit substantially from a pervasive intelligence infusion of intelligent systems and methodologies.

This chapter investigates the transformative potential of pervasive intelligence to pique interest and encourage further integrations of paradigm-shifting systems and methodologies in the area of product development. A special emphasis is also made on the potential synergy of pervasive intelligence, evolutionary computation, and optimisation techniques to better handle existing difficulties while improving development efficiency and innovation.

Product development has long been a top priority for competitive organisations in this extremely complicated and dynamic technology era. It is a comprehensive process that necessitates significant resources to support several interdependent activities, such as idea conceptualisation, design creation, prototype construction, efficacy evaluations, testing, analysis, and refining, to mention a few. A plethora of multifunctional and departmental requirements inevitably apply to such sophisticated and intricate processes, making efficient and timely development difficult, especially given the restrictions of time and resources [6 - 10].

An increase in attempts to pioneer cognitive and smart systems and technology has triggered a tsunami of change in the knowledge-driven and Internet-oriented paradise. In this era of ubiquitous intelligence, it only makes sense to consider and celebrate the demands and potential of incorporating intelligence-driven and intelligently enhanced systems and methods into the product creation environment. This manuscript is a mixture of such ideas and diligent research efforts aimed at determining the possibilities for improved creation of next-generation products. The goal of this project is to inspire and encourage enquiries and considerations about the widespread possibilities of intelligent and smart systems and processes in the field of product creation [11 - 15]. It is conceivable to see the changing prospects and possibilities, as well as the future problems and directions for such insightful displays. More importantly, as the integration of intelligent technology continues to take root in the field of product development, it is desired to better identify and appraise the collection of intelligent systems and methodologies that are enabling such an emerging paradigm. Last but not least, the goal of this study is to highlight the potential future development and synergistic attainment of pervasive intelligence, evolutionary computation, and optimisation techniques, as well as to strengthen the capability to overcome existing challenges and improve the development efficiency and innovation of smart products.

Background and Significance

The rise of pervasive intelligence has revolutionized how products come into existence and how consumer requirements are managed. With ever-increasing pressures to deliver increasingly complex and intelligent products to market, a variety of evolutionary computation or optimization techniques have begun to be employed in the development of next-generation products [16 - 20]. This research evaluates the integration and use of pervasive intelligence optimization techniques within product development ecosystems as a strategy to create and converge toward smarter solutions. It then goes on to highlight its application in the context of two use-case examples for the development of an automotive and information communication technology product. Together, recommendations and future strategic pathways are derived to support manufacturers and developers when applying pervasive intelligence techniques within the product innovation process to identify a smarter node within an ever-evolving smarter product sphere [21 - 25]. With the increasing emergence and convergence of technologies and a rapidly shrinking footprint tendency, it is critical to provide methods and tools to improve development workflow, especially for more constrained, but highly varying DSPs like those used in hearables.

The use of pervasive intelligence within product development ecosystems has developed into an essential area of research and innovation focus. With the rise of newer connected technologies, the demand to turn ideas and concepts into products has increased ever more rapidly. A variety of evolutionary computation and optimization techniques have been developed and employed to assist in generating and optimizing products. In the realms of pervasive intelligence, these techniques can be used to capitalize on meaningful IoT-generated data from all aspects of a product development environment, including the development of raw technologies, to make the best decisions. On that account, so far, the successful demonstration and use of such systems have not been found.

Research Objectives

The major objectives of the research presented in this report include developing a comprehensive understanding of the role and capabilities of pervasive intelligence with respect to next-generation product development. It also examines how pervasive intelligence can be effectively integrated within relevant concepts, methods, tools, and systems for contemporary product development activities. In this context, the specific goals are to investigate how pervasive intelligence can be effectively and efficiently embedded within product and environment systems for personalised and innovative design and production, and how it can be applied to enhance strategic and operational performance in terms of responsiveness,

CHAPTER 6

Synergy of Pervasive Intelligence with Evolutionary Computation and Optimization Techniques

CSN Koushik[1,*]

[1] *Department of Electrical and Computer Engineering, New York University, Tandon School of Engineering, New York, USA*

Abstract: This study investigates the interaction of pervasive intelligence with evolutionary computation and optimisation techniques. Pervasive intelligence is one aspect of pervasive technology, which includes wireless communication, wearable computing, and context-aware computing. Evolutionary algorithms and optimisation techniques are quickly gaining popularity for handling a wide range of real-world challenges. The purpose of this work is to support the concept of included pervasive intelligence systems with automatic parameter tuning procedures through the use of ubiquitous technology. The existing pervasive intelligence systems' limitations are projected to be greatly decreased by improving their adaptability and plug-and-play capacity. It is assumed that such innovative systems will benefit not only system designers but also end users.

Keywords: AI, Deep learning, Pervasive intelligence, Wireless communication.

INTRODUCTION

With the increasing complexity of modern sectors such as healthcare, urban development, and manufacturing, as well as ongoing concerns about environmental stress, cognitive workload, and hygiene risks, the importance of technological advancements such as pervasive intelligence, evolutionary computation, and optimisation is becoming clear [1].

The purpose is to provide a full overview of these technologies while emphasising the relevance of their upcoming accompaniment and interactivity, resulting in a synergistic approach.

[*] **Corresponding author CSN Koushik:** Department of Electrical and Computer Engineering, New York University, Tandon School of Engineering, New York, USA; E-mail: koushikcsn@gmail.com

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The current issue establishes the basis for evolving technology as a scientific chapter poised to form a classic industrial background [2 - 5]. While pervasiveness will deal with the increasing level of physical complexity, evolutionary and swarm solutions will deal with informational and organismal complexity.

This chapter intends to provide insight into how pervasive intelligence and evolutionary computation can be approached and collaborated upon using research approaches. The chapter has six sections in total. Following this introduction, the second and third sections will cover the theoretical foundations and interrelationships of pervasive intelligence, evolutionary computation, and optimisation. While the first two parts will discuss mutual enhancement and comparative criticism of these scientific concerns, the third will focus on how pervasive intelligence can primarily improve evolutionary algorithms. Following a preface regarding the importance of an indicative and durable solution in such an arbitrary setting, the transitional connection will be discussed in the following section.

FUNDAMENTALS OF PERVASIVE INTELLIGENCE

Pervasive Intelligence is a rapidly growing topic that encompasses the ability to incorporate artificial intelligence, smart management, and efficient data collecting and processing into daily items and situations. Widely deployed sensors, smartly coupled devices, extensive data analytics, and deliberate actions are only a few of the basic criteria for enabling such intelligence. Pervasive Intelligence's analytic focus must be on the numerous prospects for breakthrough technologies and personalised responses that will arise from merging and regulating other pervasive technologies [6 - 10]. Pervasive intelligence was only made possible by the widespread deployment of sensors in physical things, buildings, and urban components to collect and analyse the necessary data. As a result, the implementation of the IoT boosts Pervasive Intelligence by allowing any physical thing to detect and act, as well as interact with users. Ultra-fast, scalable, and energy-efficient data analytics are also required to support Pervasive Intelligence processing, which is based on vast data collected offline and in real time. Given all of these tremendous requirements, a user-centric management architecture is required to construct ubiquitous systems that provide end users with pervasive capabilities. To increase user-centric design, agent-oriented intelligent systems can be used, along with widely acknowledged technology-based stores and a flexible, open point of view. The user is at the centre of Pervasive Intelligence; hence, emphasis is placed on system relevance, connected services, fixed computations, and decision-making within client terminals. Communication

performance and device utility should be updated in rapidly changing environments. Aside from the fixed contact between the user and the client terminal, context-aware technologies, which rely on online and real-time data analysis of the surrounding environment, improve the user's surroundings and the user experience, thanks to the rapid growth of sensors and IoT. By the end of the twentieth century, computer technology had advanced dramatically, ushering in a new era [11 - 15]. The interaction of the computer and the user made digital systems more accessible and easier. Over time, more and more systems with multiple functions have been implemented in homes, hospitals, telecom networks, shops, and enterprises. Pressing the decommissioning of workflow built for specific devices generated through the advanced sharing of information occurs between the process and management parameters. New quantum advances in data collection techniques and uncovering the hidden meanings of a wide range of interconnected and independent data are envisaged. The transfer of methodologies and techniques from various information flows into integrated applications will have a significant impact on the emerging cross-fertilization society.

Definition and Concept

Pervasive intelligence refers to agents' smooth and direct contact with their living environments, which are often invisible microprocessors. Pervasive intelligence is essentially the inconspicuous acceptance and control of the intelligent world that surrounds us. This is claimed to mean that people are continually working in, encountering, and accepting the benefits of the smart environment's intelligence in their daily lives, more or less subconsciously and usually. It presents a vision of increased focus on making entities around people exponentially smarter than they are today, as well as references to work linked with components of this vision, particularly those that naturally incorporate Evolutionary Computation [16 - 20]. Pervasive intelligence should be seen as equivalent to “ubiquitous” intelligence. Although this concept has been coined before, the first implementation that demonstrated the word occurred at a workshop. Since then, this concept has been applied in a variety of dense, context-aware settings.

The fundamental concept underpinning pervasive intelligence and virtual reality is very closely connected. In general, intelligent systems should be designed to give highly personalised services to their users based on a variety of factors, including personal goals, emotions, spontaneous acts, and preferences. The entire interactive approach must shift from the user questioning an otherwise passive and reactive environment to the environment surrounding this person, actively and adapting actively to the user's needs (*e.g.*, predicting them) to promote exceptional levels of safety: safe from a medical perspective and in the sense of socially agreeable

CHAPTER 7

Adaptive Firefly Algorithm to Find the Optimal Number of Features in IIOT Data in Detection of Cyber Security Attacks

Sri Silpa Padmanabhuni[1], Padmaja Grandhe[2,*], Swathi Buragadda[3] and **T V Divya[4]**

[1] *Department of Computer Science and Engineering, PSCMR College of Engineering & Technology, Vijayawada, Andhra Pradesh, India*

[2] *Department of Computer Science and Engineering, Sreenidhi University, Hyderabad, Telangana, India*

[3] *Department of Computer Science and Engineering, Lakireddy Balireddy College of Engineering, Mylavaram, Andhra Pradesh, India*

[4] *Department of Computer Science and Engineering, Sreyas Institute of Engineering and Technology, Bandlaguda, Hyderabad, Telangana, India*

Abstract: Many machine learning researchers believe that poor prediction results from a model are caused by either noisy data or creating a model with the incorrect method, but the reality is that the ideal parameters necessary are selected based on the dataset. So, rather than standard methodologies, the proposed research focuses on feature selection using genetic algorithms. Optimisation is the concept of determining the best values for the parameters connected with the learning process. During the optimisation process, the algorithm takes some initial values and continuously updates the position, velocity, and other parameters. Firefly is a metaheuristic algorithm that computes the fly's attraction using the Euclidean distance. The attractiveness of the suggested algorithm, the adaptive firefly algorithm, is computed using the KNN algorithm, with K as one of the objective functions and the second objective function being to reduce the number of features. The firefly algorithm's key components are light intensity and brightness, both of which are exponential.

Keywords: Adaptive firefly, Bio-inspired, Correlation, KNN, Objective function, Random search, RFE.

* **Corresponding author Padmaja Grandhe:** Department of Computer Science and Engineering, Sreenidhi University, Hyderabad, Telangana, India; E-mail: padmaja.g@suh.edu.in

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INTRODUCTION

The IoT SCADA dataset is a well-known dataset for cybersecurity research. To begin, the fundamental component of supervised machine learning is 'features'. The data analysis shows that a few attributes have no impact on the target variable [1]. Traditionally, researchers employed correlation or PCA analysis to discover key traits [2]. Performing correlation analysis on the IIoT dataset yields 23 attributes. Table **1** displays the most relevant qualities based on the association.

Table 1. Correlation analysis.

S.No	Feature Name	Correlation
1	StartTime	0.356
2	SrcAddr	0.4671
3	Mean	0.45
4	Sport	0.51
5	Dport	0.26
6	SrcLoad	0.56
7	Load	0.55
8	SrcRate	0.56
9	Rate	0.56
10	pLoss	0.57
11	SlntPkt	0.37
12	Dur	0.3
13	TcpRtt	0.28
14	Sum	0.46
15	Min	0.46
16	Max	0.37
17	sTtl	0.37
18	dTtl	0.83
19	dlpId	0.39
20	RunTime	0.46
21	SrcJitAct	0.46
22	Traffic	0.99
23	Target	1

Similarly, existing techniques such as RFE have 24 properties; nevertheless, the number of attributes required could be lowered further [3]. So, the suggested

study employs a genetic algorithm to optimise the number of characteristics. In an optimisation algorithm, the model must first construct an objective function before determining the set of input variables that meet the specified function and checking for constraint satisfaction. In general, the genetic algorithm can do global optimisation or local optimisation. Since the proposed research wants to find the best parameter based on the given dataset, it chooses "local optimisation" [4]. The bio-inspired algorithms are categorised into three types, which are shown in Fig. (**1**).

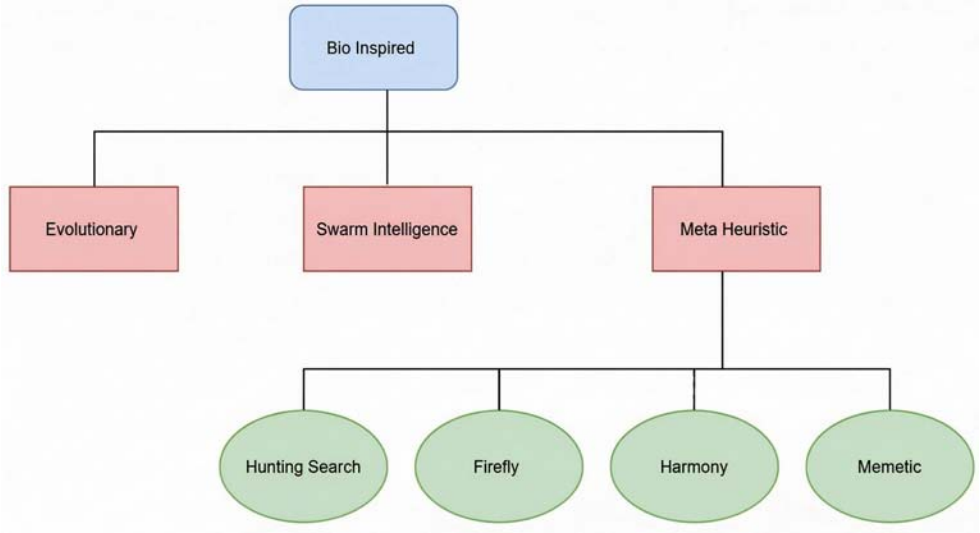

Fig. (1). Classification of bio-inspired algorithms.

The firefly algorithm is known for its randomized local search based on the attractiveness of other flies. Because of their unique flashing property, they can attract their species as well as other species. The attractiveness is proportional to the distance between the files [5].

LITERATURE REVIEW

Sadeem Dheyaa Shamsi *et al*. [1] reported that the dataset focuses on Secondary Users (SUs) operating in a cognitive radio network that perform real-time spectrum detection and routing operations. HCSS is a routing protocol designed specifically for CRAHN networks, bringing forward adaptive and efficient routing solutions. This technique combines fundamental aspects of the Spectrum-Aware SSR protocol with SARP capabilities. The network starts by enabling spectrum sensing in all nodes. The network distribution enables neighbouring

CHAPTER 8

Artificial Intelligence and Machine Learning: Transforming the Future of Technology

Brijesh Verma[1,*], **A.K. Richharia**[1] and **Vivek Singh**[1]

[1] *Department of Mechanical Engineering, Galgotia College of Engineering and Technology, Greater Noida, Uttar Pradesh, India*

Abstract: AI and machine learning are transforming the way we solve problems in our data-driven environment. AI allows machines to perform tasks that need human intelligence, such as comprehending language and making decisions. ML enables systems to learn from data and improve on their own. In recent years, advances in computing, massive data, and deep learning have propelled AI and ML into critical domains such as health, finance, transportation, and entertainment. Computer vision, language processing, and neural networks are all powered by cutting-edge technology that is used to detect fraud, run medical tests, and even drive self-driving cars. While AI and ML hold significant promise, they also raise concerns about justice, privacy, job loss, and environmental harm. Strong standards, clear explanations, and global collaboration to investigate how AI is evolving are effective ways to address these issues. New trends include AI that makes things, individuals working with AI computing on the edge, and AI assisting with climate issues. Combining AI and quantum computing might lead to significant advances in the discovery of new pharmaceuticals and materials, while a new method of learning ensures that data remains private. AI will also help to address major global issues such as poverty and disaster response. To summarise, AI and ML are transforming industries and solving complex problems, but we must be cautious about how they influence people and society. We can use these technologies to build a more intelligent, egalitarian, and sustainable future. Recent works also highlight AI–5G integration and VANET authentication schemes such as CLA-FC5G, FCA-VBN, and D-BlockAuth.

Keywords: Artificial intelligence, Deep learning, Ethical challenge, Future trends, Machine learning.

INTRODUCTION

AI and ML have transformed our approach to addressing data-driven concerns. AI refers to machines that can do functions typically associated with human

[*] **Corresponding author Brijesh Verma:** Department of Mechanical Engineering, Galgotia College of Engineering and Technology, Greater Noida, Uttar Pradesh, India; E-mail: brijesh.verma@galgotiacollege.edu

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intelligence, such as comprehending natural language, recognizing patterns, and solving problems [1 - 5].

A subset of AI Machine learning allows systems to automatically learn from data and improve performance over time without programming. Recent advances in AI and ML have altered areas such as healthcare, finance, transportation, education, and entertainment. This article explores the history, components, applications, ethical concerns, and potential developments of this remarkable technology.

HISTORICAL EVOLUTION OF AI AND ML

Artificial Intelligence (AI) and Machine Learning (ML) development spans over fifty years and has been affected by advancements in computing technology, as well as mathematical and data science achievements [6 - 10]. AI originated in the 1940s, when early researchers such as Alan Turing proposed robots capable of replicating human thought processes. The Dartmouth Conference in 1956 formalised "Artificial Intelligence" as an academic domain. Early AI research focused mostly on symbolic thinking and rule-based systems, which needed explicit programming of logical rules to solve issues in computers. As the study proceeded, researchers recognised that creating rules to meet every circumstance was unfeasible, particularly in complex systems. Machine Learning emerged in response to the requirement for AI systems capable of automatically detecting patterns and making data-driven decisions. The original creation of neural networks and decision trees happened in the 1980s, but their capabilities were limited due to a lack of computer capacity. The development of massive data and faster hardware, such as GPUs, in the 2000s, enabled deep learning approaches to thrive. AI and machine learning technologies are at the vanguard of technological growth, improving important sectors such as healthcare and finance, while autonomous systems and natural language processing define technological and societal futures [11 - 15]. Table **1** presents the history of artificial intelligence.

Table 1. History of artificial intelligence.

Period	Focus/Development
1950s	The Turing Test proposed by Alan Turing
1950s-1970s	Symbolic AI and logic-based reasoning
1980s	Expert systems with rules programmed by domain experts
1990s	Shift to data-driven learning models.
2000s-present	Deep learning, neural networks, and data-driven AI

KEY CONCEPTS IN AI AND ML

Artificial Intelligence Overview

Artificial Intelligence (AI) is the imitation of human intelligence processes by technology, specifically computer systems. These processes include learning (acquiring data and rules for using it), reasoning (using rules to conclude), and self-correction. AI systems can analyse data, identify patterns, make judgements, and communicate with humans. Different types of artificial intelligence. AI is divided into numerous kinds [16 - 20]:

- Narrow AI (Weak AI):
  - Focused on performing a specific task.
  - Most AI we use today falls under this category.

Examples: Chatbots, virtual assistants (Siri, Alexa), recommendation systems (Netflix, YouTube), image recognition tools.

- General AI (Strong AI):
  - This refers to AI that can understand, learn, and apply intelligence across a wide range of tasks, just like a human.
  - It does not exist yet, but it remains a goal in AI research.
  - A General AI would be able to perform any intellectual task that a human can do.
- Super AI:
  - This represents a theoretical future stage of Artificial Intelligence (AI) that exceeds human intellect across all cognitive, creative, and social dimensions. Prospective research should prioritize Post-Quantum AI (PQAI) security, Federated Learning (FL) integration, and the development of Trustworthy AI (TAI) within critical infrastructure.
  - Such systems possess the potential to transcend human capabilities in every sphere, ranging from rigorous scientific discovery to complex social dynamics.
  - Currently, it’s purely speculative.

Machine Learning Overview

Machine Learning (ML) is a subfield of Artificial Intelligence (AI) that focuses on creating algorithms that enable computers to learn patterns from data and make judgments or predictions without being explicitly programmed, instead of adhering to hard-coded rules. ML systems grow over time through experience

CHAPTER 9

AgriConnect: AI's Touch, Farmer's Growth

Padmaja Grandhe[1,*], Eesha Thakur[1], G. Aarushi Reddy[1] and **Yaamini R[1]**

[1] *Department of Computer Science and Engineering, Sreenidhi University, Hyderabad, Telangana, India*

Abstract: Climate variability, inefficient resource management, and a lack of real-time data are among the issues facing agriculture today. Many rural farmers deal with smartphone inaccessibility and inadequate digital literacy, making it difficult to gain critical agricultural insights. To address these difficulties, we offer an AI-powered Smart Board, which is a solar-powered, offline-compatible device equipped with IoT sensors (soil moisture, temperature, humidity, and pH sensors), drones, and real-time data processing capabilities. It sends voice-based alerts in local languages with climate change warnings, crop care suggestions, and real-time government updates (minimum support price, subsidies, and market trends). It also collects crop data and recommends pest-prevention and irrigation management strategies. A voice-enabled query system enables farmers to ask questions and receive AI-powered responses, while radio integration provides emergency alerts and expert views. This technology, which features a simple touch interface and an AI-powered hotline, empowers farmers, boosts productivity, and supports sustainable agriculture, ensuring a wiser, data-driven future.

Keywords: AI-powered drones, IoT sensors, Radio alerts, Real-time MSP updates, Smart irrigation, Touchscreen dashboard, Voice-based AI assistant.

INTRODUCTION

Currently, agriculture is overwhelmed with difficulties caused by unpredictable weather patterns, lack of water, irrigation systems, and pest attacks, which are a major cause of huge losses in the agricultural field [1 - 5]. What makes the situation worse is that most farmers lack access to modern digital technology due to low smartphone penetration and unstable connections in rural areas with poor infrastructure. The majority of existing AI-powered farming solutions rely extensively on cloud computing and phones, which makes them either broken or unusable in such underserved communities [6 - 10]. To address these short-comings, we are presenting AgriConnect: an AI-powered Smart Board, which is a

* **Corresponding author Padmaja Grandhe:** Department of Computer Science and Engineering, Sreenidhi University, Hyderabad, Telangana, India; E-mail: padmaja.g@suh.edu.in

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solar-run, offline-compatible system containing sensors through IoT, drones, and AI-based analytics. The company introduced an innovative platform that helps farmers receive voice alerts, market trend analysis, and real-time notification of the government schemes, which will help farmers make the right decisions to make farming sustainable and profitable.

LITERATURE REVIEW

In the article on crop management systems with the help of artificial intelligence. Anmol Giri [11] considered the possibilities of artificial intelligence in implementing the principles of crop management through pest control and yield prediction. The manual drone image interpretation dependency, however, delays the processing, implementation, and the system has a dependency on cloud connectivity, making it inefficient in remote areas. Dr. Neeraj Mittal [12], in his article, "Revolutionising Agriculture: The Digital Transformation of Farming," wrote about climate and pest monitoring tools that, although they have a certain value, are not detailed enough on the field level, and (last but not least) do not integrate with government services. In an article titled, Farmer Touch: Harnessing Technologies to Increase Crop Production [13], authored by Mohana Siri Vasamsetty, they suggested the use of AI chatbots and soil health monitoring, but this sort of thing requires smartphones and internet, which is something most rural farmers do not own. In the article, AI-Based Yield Prediction and Smart Irrigation [14], Deepak Sinwar promoted the application of CNNs, drones, and IoT sensors to predict yield and identify diseases, though the system is dependent on the cloud as its key component. In the article by Lalbaksh Albulushi and Zubair Shahdost [15], named Drone-Assisted Farming, the authors concentrated on autonomous drones devoted to spraying pesticides and checking crops to increase the effectiveness of the crop, but the solution also assumed the technological maturity of the sector. In part, Apeksha R. Gawande [16], in "Analysis of Crop Diseases Using IoT and Machine Learning Approaches," suggested early disease identification through IoT and ML, which would require less amount of pesticides, though, in this case, it would presuppose connectivity as well. Finally, Ranveer Chandra [17] presented the FarmBeats platform based on precision agriculture with support using cloud analytics. Although the model holds promise, it uses expensive hardware and needs constant access to the internet, which limits its scalability in low-resource settings.

All these works make it clear that technological progress in the field of farming AI exists, but there is a gap in accessibility. AgriConnect will help to overcome this gap because it provides AI features and does not require smartphones and continuous connections, hence it is more inclusive and farmer-friendly.

PROBLEM IDENTIFICATION

Existing AI-based solutions in agriculture have the following limitations:

- The dependence on the internet and cloud computing makes them impractical for rural farmers.
- Delayed pest detection leads to crop losses.
- High costs and reliance on smartphones limit accessibility.

Fig. (**1**) shows several consequences faced by the farmers. To solve these issues, the AI-powered Smart Board provides an offline, real-time solution that integrates AI, IoT, and drone-based monitoring for precise and cost-effective farming.

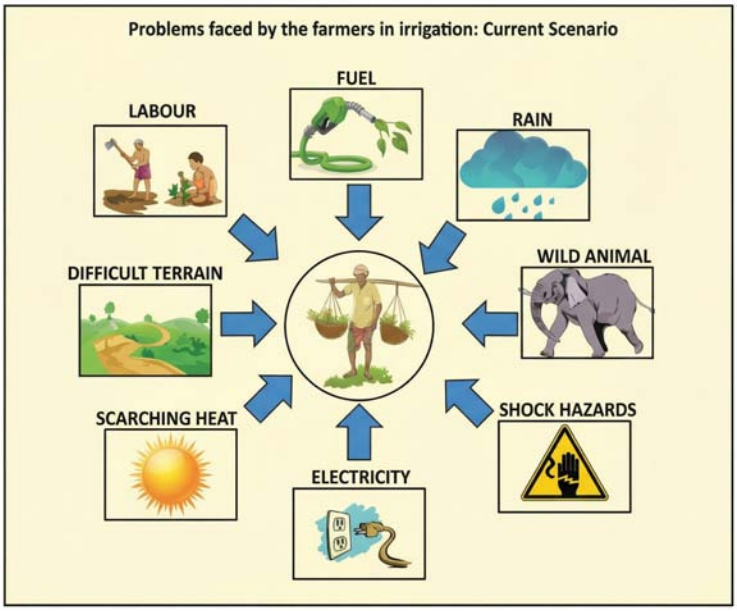

Fig. (1). Consequences faced by farmers.

CASE STUDIES

i. AI-Powered Pest Detection (Punjab, India)

Problem: Late pest detection led to 30% wheat loss.

Solution: Drones scan fields, AI detects infestations, and farmers get real-time voice alerts.

CHAPTER 10

AI-driven Robotic Arms in Industry 4.0: Harnessing IoT and Robotics for Smart Automation Simulation

Nitesh Pandey[1,*], **Ranjan Mishra**[1] and **Pankaj Gupta**[2]

[1] *Department of Computer Science and Engineering, Jaypee University of Engineering and Technology, Guna, Madhya Pradesh, India*

[2] *Department of Mechanical Engineering, Jaypee University of Engineering and Technology, Guna, Madhya Pradesh, India*

Abstract: Industry 4.0 is transforming automation by integrating IoT, robots, and artificial intelligence, resulting in intelligent and autonomous systems for industrial applications. With the growing demand for automation in industrial settings, robotic arms are critical for precision-based operations, including manufacturing, assembling, and material handling. The development of robotic arms for industrial automation requires precise modelling, control, and validation. This work advances industrial automation by improving the integration of robotic arms into smart manufacturing and autonomous operations. The study describes a design using Autodesk Fusion 360, simulation with the ROS framework, and validation with hardware integration and an object detection model on a robotic arm. To validate the design, FEA and generative design analysis for mass and volume optimisation are done on the model, revealing that steel and CFRP are the optimal materials for the desired strength. Furthermore, the designs' kinematics and perception are tested on Gazebo and RViz, while the final trained model for object identification using YOLO V8s is tested on the KSR10 robotic arm. The findings highlight the importance of simulation-driven research in improving robotic arm performance and guaranteeing seamless integration into new Industry 4.0 automation environments.

Keywords: Artificial intelligence (AI), Industry 4.0, Internet of Things (IOT), Robotics.

INTRODUCTION

The advent of Industry 4.0 has revolutionized manufacturing and automation through the integration of intelligent tools, including the Internet of Things (IoT), Artificial Intelligence (AI), and Robotics [1 - 5].

[*] **Corresponding author Nitesh Pandey:** Department of Computer Science and Engineering, Jaypee University of Engineering and Technology, Guna, Madhya Pradesh, India; E-mail: niteshpandey46974@gmail.com

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Nevertheless, the traditional manufacturing systems have resisted the challenges of precise, efficient, and versatile manufacturing that rendered them associated with increased manufacturing expenditures and diminishing production [6 - 10]. Among the strongest drawbacks, the need to employ human power in routine and dangerous processes should be pointed out, as this aspect contributes to the occurrence of mistakes, exhaustion, and safety issues. A new solution to these complications is proposed by robotized arms with modern algorithms and devices of the Internet of Things [11 - 15]. Artificially intelligent arms started to be used in the manufacturing business in 1937, when the so-called Bill Griffith P. Taylor created the crane-like robot [16].

Conventional robots cannot have strong visual recognition capabilities, and it is nearly impossible to adapt in real-time to an anomalous environment. This inflexibility costs them in the contemporary manufacturing arena. Recent studies were carried out to develop a more adaptive and cost-effective robotic system [17 - 20]. By constructing a cheap object-sorting robotic arm using a Raspberry Pi, Pereira *et al*. showed that it was possible to find cost-effective systems of automation [21 - 23]. On the same note, Chandramohan *et al*. demonstrated the cost-saving effectiveness of open-source systems by unleashing the development of an object identification and sorting robot (using a Raspberry Pi) at a comparatively small cost [24].

Machine vision is being implemented in robotic systems by scientists and researchers to enhance effectiveness and acceptance. Kachare has also stressed the role played by vision systems in enhancing the capabilities of robots by showing how an object sorting robot can use image processing technology [25]. Nandi *et al*. applied visual processing to design an automatic maturity prediction system to sort harvested mango [26]. The development of new materials and the design of robotic arms in the recent past has also resulted in flexibility in operations. Muramatsu *et al*. demonstrated a mobile quad-arm robot that could perform wheeled-legged tripodal locomotion and quad-arm manipulation as loco-manipulation, which presented the possibility of versatile robotic systems [27]. Bionic-inspired optimisation was used by Yang *et al*. to create a very biomimetic shoulder with successful advancement in human-like motion replication in a robot [28].

These works show the increased popularisation of adaptive production, smart, and cheap to produce the robotic system. Open-source frameworks, including the Robot Operating System (ros), need to be merged with computer vision skills to come up with cost-effective automation solutions. Moreover, it is unlikely that the robots can carry out numerous tasks and functions in various industrial environments because of the improvement of their robotic arm design, which is

more versatile. This study addresses these issues by proposing an integrated system comprising a mechanical robotic arm, a Raspberry Pi CPU, computational capacity, and OpenCV-based visual processing. By employing complex computer algorithms, frameworks, and readily accessible hardware tools, the system maintains cost-effectiveness while leveraging the accuracy of modern robotics [29, 30].

Moreover, generative Design Analysis (GDA) and Finite Element Analysis (FEA) were finally employed to test the design. The modular architecture of this system enables it to perform more tasks as operational needs expand, as it can integrate task-specific IoT devices. Such flexibility will enable the firms to gradually increase their level of automation, hence allowing them to safeguard their initial investment, but still have the capability of future expansion. This study will facilitate more use of cutting-edge automation technology through integrating computer vision, embedded computing, and mechanical robots with each other in a new mode. The given technique will address the three key issues of cost, flexibility, and scale, which is why it can be considered a viable choice for businesses that want to modernise their activities in an appropriate way, starting with the preservation of performance and stability.

METHODOLOGY

The major aim of this project is to design and test a modular robotic system that can perform functions like object detection, classification, and pick-and-place activities with the use of the KSR10 robotic arm, motor drivers, a Raspberry Pi, and a camera module. Some of the most important steps in the procedure of the technique, as indicated in Fig. (**1**), involve system design, kinematic studies, hardware and software development, and validation by simulations and manufacturing trials as discussed in the subsequent segments.

System Design

The system consists of a Raspberry Pi and Raspberry Pi Camera Module v3, motor drivers, and the KSR10 robotic arm. The KSR 10 robotic arm has 5 Degrees of Freedom (DOF) that enable it to move and manipulate objects in a precise position. The system has its main manipulator, the KSR10 Robotic Arm, which has five joints that include base, shoulder, elbow, wrist, and gripper. The motors are driven individually on different joints (L298N). As shown in Fig. (**2**), the Raspberry Pi serves as the main controller for the system. It solves the communication with the motor drivers, kinematics calculations, and image processing.

CHAPTER 11

The Role of Pervasive Intelligence in Fostering Business Growth for Startups

Shambhavi Tamrakar[1] and **K. Harinadh**[1,*]

[1] *School of Management Sciences, Sreenidhi Institute of Science and Technology, Hyderabad, Telangana, India*

Abstract: Pervasive intelligence, powered by data-driven decision-making, automation, and improved user experiences, is transforming the startup ecosystem via Artificial Intelligence (AI), the Internet of Things (IoT), and big data analytics. The chapter discusses the impact of pervasive intelligence on operational efficiency, market adaptation, and innovation, as well as how it might help startups improve their decision-making processes and expand. Startups can acquire a long-term competitive advantage by leveraging intelligent technologies to foresee market trends, manage resource allocation, and personalize consumer interactions. Pervasive intelligence also increases agility, allowing startups to scale efficiently and respond swiftly to changing market conditions. The study also identifies potential challenges, such as the need for qualified workers, complex technology integration, and data breaches. It identifies potential hurdles, such as data privacy problems, technology integration complexities, and a need for specialised labour. Through case studies and empirical analysis, this chapter explains how companies can strategically use pervasive intelligence to accelerate growth, improve consumer engagement, and build a footing in competitive markets. However, it also provides tremendous opportunities for entrepreneurs to innovate, develop quickly, and establish a competitive edge in an increasingly digital economy. This chapter examines real-world applications and case studies to show how companies can strategically harness pervasive intelligence while navigating its hurdles to generate long-term growth.

Keywords: Artificial intelligence (AI), Big data analytics, Decision-making process, Internet of Things (IoT), Pervasive intelligence, Startups.

INTRODUCTION TO PERVASIVE INTELLIGENCE

Nowadays, the concept of pervasive intelligence appears in three major fields: mobile telecommunications, the internet, and emerging fields related to large bandwidth and processing, as well as the global proliferation of sensors covering

* **Corresponding author K. Harinadh:** School of Management Sciences, Sreenidhi Institute of Science and Technology, Hyderabad, Telangana, India; E-mail: harinadh.k@sreenidhi.edu.in

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vast areas of industry, automotive, health, and human activity. Each moving object has dozens of sensors, and their data can provide tremendous value when examined [1 - 5]. They can, for example, result in less environmental damage, self-healing architecture, better service quality, more energy efficiency, and so on.

Pervasive Intelligence (PI) combines a variety of research and application technologies, including ubiquitous or pervasive computing, data mining and machine learning, artificial intelligence, data fusions, large-scale simulation, and chaotic systems analysis, as well as advanced wireless communications linked to mapped sensor fields in health, environmental, and transportation problems. Networked sensors must be intelligent, not just for data collection, but also for analysing local data, fusing it, and distributing important information over broad networks [6 - 10]. The primary function of networks in communication is the conveyance of raw data and information. Furthermore, smart or intelligent network nodes and systems can provide what is required of them [11 - 15]. This can take the form of assessing resources, providing services, or conducting computations. Connectionist logic is proposed as a method for the homogeneous design of networked communicating objects with embedded intelligence, generating local knowledge that, when transferred, will make the pervasive network of large area systems more intelligent, timely, and efficient, with less load on the networked and interested systems. As proof and the foundation of the technology, a specific sensor network to monitor CO_2 levels in the environment was devised, developed, and industrialised. Modelled data is compared to measured data, and the PI prediction capabilities are evaluated.

Definition and Conceptual Framework

Definition of Pervasive Intelligence

In a world flooded with IoT devices, 'smart' technologies and platforms are producing massive amounts of data about our social infrastructure, metropolitan spaces, and personal daily lives [16 - 20]. With the rise of the 'big data' revolution, the availability of data can give new insights and chances for action. Pervasive intelligence extends beyond data to insight, beyond simple reactive or algorithmic responses to rich data inputs, to include a wider variety of potential user behaviours and the creation of more sophisticated technology. At the heart of ubiquitous intelligence is a person interacting in an environment comprised of (smart) technology that generates and responds to data, with those actions frequently feeding into the development of new data [21 - 25]. In this dynamic environment, data-driven insights can be used to structure and educate a wide

range of user behaviours, including day-to-day interactions as well as larger decisions like political engagement, lifestyle choices, and company investments.

Conceptual Framework

Pervasive intelligence is mostly built on technology, which converts raw data into useful data, collects relevant data, and displays it elegantly for easy comprehension. Underpinning the user-facing or outward technologies are more background technologies that are less visible to the user, yet manage data, analytics, and assist in driving user behaviour. These technologies provide the backbone of ubiquitous intelligence. Individual technologies can play different functions across the three layers, and the interaction of these three layers, technology, data analytics, and user behaviour, is what allows ubiquitous intelligence to function.

IMPORTANCE OF PERVASIVE INTELLIGENCE IN STARTUPS

Smart technologies have accelerated a paradigm shift away from traditional and digital intelligence and towards ubiquitous and pervasive intelligence. This unique approach has the potential to greatly influence product development and market concentration tactics, as well as manage value co-creation and customer experience. In a modern world where things are becoming more intelligent, the importance of pervasive intelligence for the natural existence and sustainability of a corporation cannot be overstated. More so for start-ups with limited operational viability, owing to insufficient sustainable resources. On a corporate level, ubiquitous intelligence is primarily concerned with a start-up's market dominance. To keep up with the competition and gain an advantage, indispensable options must be developed. Pervasive intelligence, which involves gathering and monitoring all forms of data, can help make timely decisions targeted at saving the company's life. The meticulous collection of primary data to monitor a target market ecosystem would provide crucial insight for wise decisions by top management.

The start-up's management team must consider investing in critical technology systems while harnessing ubiquitous intelligence to strengthen the company's market position. Each of these important technologies may have its own set of words, but the complete system might function perfectly in tandem. The main advantage would be the ability to track changes in the target market using advanced analytics and deep machine learning in real time. Furthermore, the appearance of innovative ideas would most likely represent a high level of interest in the area. This will enable flexible, rapid market renewal decisions based on

CHAPTER 12

The Evolution of AI-based Additive Manufacturing: From Rapid Prototyping to Mass Production

Rashmi Rani Maheshwari[1], Yogesh Shrivastava[1,*] and **Pawan Kumar Arora[1]**

[1] *Department of Mechanical Engineering, Galgotias College of Engineering and Technology, Greater Noida, Uttar Pradesh, India*

Abstract: Additive manufacturing's original goal of producing prototypes quickly has led to significant advancements, which have caused it to move toward large-scale precision manufacture. One of the primary drivers of this change is the implementation of Artificial Intelligence (AI) mechanisms, which enhance design skills and optimize manufacturing and quality management techniques. The presented review follows the development of AI-based AM since the first introduction of using AI to accelerate the process of creating prototypes, to its recent potential to deploy intelligent autonomous manufacturing systems. This study explains three fundamental technologies of AI used in AM, and how the technologies are applied towards the manufacturing process, with the resulting outcomes of such an application. Upon identifying the existing problems with standardized data systems, the research presents tactical ways of developing adaptive AI-AM systems that are sustainable. The introduction of AM and AI technology has already started transforming the standards of manufacturing in many industries.

Keywords: Additive manufacturing, Artificial intelligence, Process optimization, Rapid prototyping, Smart manufacturing.

INTRODUCTION

Brief Overview of Additive Manufacturing (AM)

3D printing through Additive Manufacturing (AM) manufactures using computerized digital graphics of objects [1]. Whereas subtractive manufacturing involves the removal of solid blocks of material to produce complex structures to

* **Corresponding author Yogesh Shrivastava:** Department of Mechanical Engineering, Galgotias College of Engineering and Technology, Greater Noida, Uttar Pradesh, India; E-mail: yogeshshrivastava90@gmail.com

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form objects and objects on demand with little or no wastage. Additive manufacturing involves making products in progressive layers based on drawings.

Some technologies in the AM family are called Direct Metal Laser Sintering (DMLS). Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), and Stereolithography (SLA) require specific types of materials and tasks. Due to its pace and flexibility, Additive Manufacturing (AM) was originally primarily used in rapid prototyping. However, manufacturers are now using AM to produce useful parts for the aerospace, biomedical, automotive, and consumer product industries [2].

Role of Artificial Intelligence (AI) in Revolutionizing AM

AI has emerged as a game-changing technology that solves the problems with traditional AM and opens the door to intelligent production. As a result, AI intervention may be included in nearly every facet of AM, from design and slicing to process monitoring, which occurs in real time, and post-processing, which occurs after the process is finished [3].

Its application in generative modeling and topology optimization in design, enhancement, and invention produces laced-out, lightweight structures that are otherwise impossible to achieve with traditional CAD tools [4]. Throughout the fabrication process, real-time sensor monitoring aids the machine learning algorithm in detecting flaws and probable failures and adjusting parameters as needed to increase efficiency and save expenses. In addition, artificial intelligence improves other real-time monitoring and control techniques, such as the use of computer vision systems during the manufacturing process, which is crucial for avoiding variation in large-scale production.

Predictive maintenance, intelligent material selection, and production planning are thus supported by AI, which makes AM a good fit with the goals of Industry 4.0, which include smart, connected, and autonomous manufacturing. Because of this, AI not only maximizes AM's performance but also reimagines its potential and strives for adaptable, competitive, and useful manufacturing solutions for a range of sectors.

Purpose and Scope of the Review

This article aims to provide readers with a brief but informative overview of the relationship between AM and IT, with a focus on how IT has helped to move AM from a prototype tool to a production approach. In order to increase knowledge of

the areas of research that will characterize future AI-AM advancements, this study examines AI design technologies in conjunction with process control and production management.

It discusses AM's history and disadvantages, looks at how various AI technologies might be combined, and provides examples and application cases from various industries. Finally, it examines some of the future scope and direction for expanding ISAMM and the path towards obtaining fully autonomous intelligent systems. It also presents important difficulties of the present time, such as data limitations and integrating systems. The scope is purposefully kept small to give readers information on how AI can be used to help researchers, engineers, and practitioners improve the effectiveness, caliber, and scalability of AM technology.

HISTORICAL PERSPECTIVE

Early Applications of AM: Rapid Prototyping in the 1980s–2000s

AM's origins date back to the 1980s, when Charles Hull created stereolithography, a technique that creates models by layering small slices of digital models. AM was used almost exclusively in rapid prototyping during the 1990s and early 2000s. This was a revolutionary technique that made it possible to create real components from CAD data in a matter of hours or days at most.

This feature was particularly intriguing since it had an impact on PDLC, particularly in the industrial sectors of automobiles and airplanes, where the process required numerous iterations. In order to save time and money during development, AM was used for more than only design validation, ergonomic testing, and early marketing. It also created functional and visual prototypes. The primary contribution in the field is displayed in Table **1**.

Table 1. Key contributions in the AM field.

Author(s)/Inventor	Year	Contribution	Impact on the AM Field
Charles W. Hull [5]	1984	Invented stereolithography (SLA) and founded 3D Systems	Pioneered the concept of layer-by-layer fabrication; foundational to all AM technologies
Scott Crump (Stratasys) [6]	1989	Developed Fused Deposition Modeling (FDM)	Enabled more accessible, cost-effective prototyping; laid the groundwork for desktop AM.
Carl Deckard (UT Austin) [7]	Late 1980s	Co-developed Selective Laser Sintering (SLS)	Introduced AM with powder-based materials, expanding material possibilities

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Shruti Bhargava Choubey

Dr. Shruti Bhargava Choubey received a BE with honors (2007) from RGPV Bhopal and an M. Tech. degree in Digital Communication Engineering (2010) from RGPV Bhopal. Subsequently, she carried out her research at Dr. K.N. Modi University, Banasthali, Rajasthan, and was awarded a Ph.D. in 2015. Presently, she is working as an Associate Professor & Dean of Innovation in the Department of Electronics and Communication at Sreenidhi Institute of Science and Technology, Hyderabad. She has published more than 100 papers (15 SCI, 71 Scopus) of national and International repute. She has been a member of many selection committees for the recruitment of staff and faculty. Her research areas include signal processing, Image processing, and Biomedical Engineering. She has produced 17 M.Tech degrees & amp; guided more than 70 B.Tech Project. She is a Senior member of IEEE, a member of IETE, New Delhi, and the International Association of Engineers (IAENG). She worked in different positions like Dean academic & HOD with numerous capacities. She was awarded the MP Young Scientist Fellowship 2015 & Received MP council fellowship in 2014 for her contribution to Research.

Yogesh Shrivastava

Dr. Shrivastava has a result-oriented profile with more than 75 research articles in various journals of repute. Dr. Shrivastava completed his Ph.D. in 2019 with a specialization in manufacturing technology and has research interests in Mechanical Systems and associated signal processing techniques. He has published several research articles based on the application of Artificial Intelligence. He has served as a guest editor in several reputed SCI and Scopus indexed Journals and conference proceedings. He has given several expert lectures sponsored by TEQIP-III and MHRD. Currently, he is working as an Assistant Professor in the Mechanical Engineering Department at Galgotias College of Engineering and Technology, Greater Noida, Uttar Pradesh, India.