ARTIFICIAL INTELLIGENCE IN SOCIAL SCIENCE, HUMANITIES AND HEALTH

A PATH TOWARDS TRUSTWORTHY AI AND HUMAN-AI SYMBIOSIS



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Nicholas Vretos

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Artificial Intelligence in Social Science, Humanities and Health: A Path Towards Trustworthy AI and Human-AI Symbiosis

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FOREWORD

It is a real pleasure to introduce this volume, edited by Dr. Nicholas Vretos - a colleague and collaborator with whom I have had the privilege of working closely over the years.

Throughout our collaborations, Nicholas has consistently brought thoughtful insight, a balanced perspective, and a deep commitment to the responsible development of technology. These same qualities are clearly reflected in this book, titled "*Artificial Intelligence in Social Science, Humanities and Health: A Path Towards Trustworthy AI and Human-AI Symbiosis*".

At a time when Artificial Intelligence is rapidly reshaping our world, this volume offers an important and timely contribution. It brings together diverse voices around a shared vision: that AI should evolve not apart from human society, but alongside it, enhancing, rather than replacing, human creativity, values, and decision-making.

Nicholas's expertise, shaped through years of research, is evident in the thoughtful selection and organization of the contributions. The book navigates complex themes like trustworthy AI and human-AI symbiosis with clarity and care, making it accessible to a wide audience without sacrificing depth.

I believe readers will find in these pages both inspiration and practical insight — a resource that fosters not only technological innovation, but also critical reflection on the kind of future we wish to create.

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PREFACE

Artificial Intelligence (AI) continues to redefine the boundaries of knowledge creation, decision-making, and cultural interpretation across disciplines. Its expanding presence in fields such as healthcare, social sciences, and the humanities has generated transformative opportunities alongside urgent challenges. This edited volume, Artificial Intelligence in Social Science and Humanities and Health: A Path Towards Trustworthy AI and Human-AI Symbiosis, brings together a diverse, interdisciplinary collection of contributions that reflect the current landscape of AI in human-centered domains.

A key unifying theme throughout the book is the concept of Human-AI Symbiosis. Far from positioning AI as a replacement for human insight, the contributions here envision AI as a collaborative partner—a system designed to amplify human values, creativity, and capabilities. Symbiosis in this sense is a call for thoughtful co-evolution between technological design and social purpose, where machine intelligence is developed not in isolation but in continuous alignment with human needs and contexts.

Equally central is the goal of building Trustworthy AI. Across domains, the demand for AI systems that are transparent, fair, accountable, and robust has become a defining concern. The chapters in this volume collectively engage with this objective by showcasing applications and theoretical approaches that embody these principles.

Each chapter offers a distinct but interconnected contribution to this vision:

• AI-Driven Insights for Enhanced Healthcare: Leveraging Multimodal Data in eHealth Platforms presents integrated AI approaches for clinical decision support and personalized medicine.

• Current Trends, Innovations and Challenges in the Use of Artificial Intelligence in Microscopy explores how AI accelerates scientific discovery in the field of biomedical imaging.

• Data Science and Artificial Intelligence Under Ethics and Legal Perspectives discusses normative and legal frameworks essential to responsible AI deployment in society.

• AI-Promoted Protein-Protein Interaction Site Identification and Analysis: Recent Advances in Public-Private Innovations highlights collaborative research environments where AI bridges institutional boundaries in health and biotech.

• AI and Politics examines the role of AI in shaping political discourse, electoral influence, and democratic processes.

• Privacy-by-Design AI introduces architectural strategies for embedding data protection and transparency at the core of intelligent systems.

• Agent-Based Modelling (ABM) in Archaeology: A Useful Tool for Studying Past Human Societies demonstrates how simulation models offer new pathways for cultural and historical interpretation.

• Recent Advances in AI for Literature and Art investigates how AI technologies intersect with the creative process, reshaping the way we understand and produce literature and visual

culture.

Together, these chapters illuminate the complex, often reciprocal relationships between technological systems and human values. This book is intended for scholars, researchers, practitioners, and students engaged in AI, data science, healthcare, the humanities, and the social sciences. It aims to provide both theoretical depth and applied insight for those working toward responsible, human-centered innovation.

Acknowledgements

This volume would not have been possible without the dedication and intellectual generosity of the contributing authors. We also extend our appreciation to the reviewers who offered critical feedback and to the editorial and production teams who supported the realization of this project. Above all, we acknowledge the broader community of interdisciplinary researchers striving to ensure that AI evolves not only with technical excellence, but with ethical foresight and societal relevance.

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CHAPTER 1

Machine Learning and Deep Learning within the Context of Artificial Intelligence

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Abstract: This chapter provides an overview of the connections between Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL), offering a broader view of how ML and DL fit within the overall AI landscape. In this chapter, we explore the historical roots of AI in philosophy before discussing its eventual development into both mathematical constructs and programming. There remains considerable confusion regarding the definitions of AI, ML, and DL. While many refer to any recent ML or DL model as "AI," this is not entirely accurate. The primary branches of thought are symbolic representation (using logic-based rule sets), ML (data-driven learning), and DL (complex networked layers used for data processing). We briefly discuss algorithms and architecture and delve into the underlying mathematics. Using several domains such as CV, NLP, Healthcare, and Recommender Systems as examples, we illustrate how these ideas have transformed the way machines operate. However, we also emphasize the importance of fairness, interpretability, and ethics, as well as the need to understand how these systems operate. Finally, we conclude with a discussion of the future direction of AI, including Neurosymbolic AI, Explainable Models, and Edge Computing. We advocate that AI should continue to be grounded in human values and sensibility despite its growing complexity. The aim is to clarify the connections between AI, ML and DL. While complete clarity is difficult to achieve given the complexity of this area, we highlight the most important concepts to establish the key distinctions and similarities between AI, ML and DL.

Keywords: Artificial Intelligence, Deep learning, Machine learning, Neurosymbolic AI, Symbolic reasoning.

INTRODUCTION

Historical Roots of AI

The history of Artificial Intelligence (AI) extends far beyond the era of computers and binary code. It reaches back centuries, to early philosophers, mathematicians,

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and inventors who experimented with machines. For centuries, people have wondered whether thinking could be reduced to a step-by-step process, or whether logic could operate on its own. Philosophers in ancient Greece were already grappling with these questions.

It is commonly believed that Aristotle laid the foundations of formal logic, in which he envisioned reasoning as divided into patterns, similar to those of geometry. He created a rational system, the first of its kind, through which he sought to make thinking more organized and systematic. Even though it is impossible to imagine that Aristotle considered his system to be a mechanical process, his work laid the groundwork for later thinkers who believed that intelligence might be reduced to a system of rules that could be followed to reach a particular result. His syllogisms in particular gave subsequent philosophers and logicians a framework on which to build, shaping the way people reason.

In the Middle Ages, Ramon Llull constructed his unusual Ars Magna, a system of rotating disks of symbols intended to discover truth through mechanical combination. Though rudimentary by modern standards, it was one of several early origins of the algorithmic imagination. Then, in the 17th century, Leibniz envisioned a "universal calculus," a language that could express any line of reasoning and compute it as well. Leibniz even built a small mechanical machine, the Stepped Reckoner, which could add and subtract—small but significant steps toward what we would now call automation.

Mathematics and mechanics helped propel this line of thought. George Boole devised an algebraic logic that made reasoning resemble arithmetic, while both Babbage and Ada Lovelace considered the possibility of a machine capable of handling not only numbers but also ideas and symbols. In her notes, Lovelace suggested that one day machines might create music or art, but she believed they could never originate anything genuinely new on their own. This was, in effect, the beginning of artificial intelligence, though no one had yet named it. Alan Turing wrote a paper titled Computing Machinery and Intelligence, in which he posed a question that continues to be debated today: Can machines really think? He did not attempt to answer the question of what thought is, but invented the so-called Imitation Game, now known as the Turing Test. It assesses a machine's ability to hold a conversation with humans. It was an elegant way to sidestep an awkward question and turn it into something testable. Turing believed that intelligence might lie not in what something is, but in how it behaves. He wanted to know whether a machine could be intelligent even though we are not entirely certain what intelligence is. This represented a major departure: rather than attempting to define intelligence, it focused on what intelligence can accomplish.

The turning point came in 1956 with the Dartmouth Conference, where McCarthy, Minsky, Rochester, and Shannon met and formally coined the term Artificial Intelligence. Their ambitions were considerable: they believed that human-level intelligence could be recreated within a relatively short period, perhaps even within a single generation. It was a daring assertion, yet early programs such as the Logic Theorist were already showing promise, demonstrating that it was possible to encode reasoning into a machine, at least in some restricted domains of knowledge. These were the first steps that laid the foundation of the field of Artificial Intelligence and set the stage for the developments that would follow.

Computers of the 1960s could scarcely cope with the complexities of the real world. At the time, symbolic logic could not handle vague or missing information, and computers were slow and had limited memory. This led to the era known as the AI winter, when funding and enthusiasm for artificial intelligence largely dried up. Nevertheless, the pioneering work in AI was influential. It revealed the tension between logic and learning, between rules and data, and between the pursuit of ideal reasoning and adaptation to the real world. The history of AI is a long and winding one, marked by competing approaches that have each sought to emulate the human mind. From Aristotle's rational reasoning to the benchmark set by Turing's test, AI has sought to understand and reproduce human thought.

These developments, presented in Fig. (**1**), were significant milestones in artificial intelligence research. They identified some of the major differences between rationalist and empiricist thinking, between relying on logic or data to arrive at decisions, and between relying on symbols to reason and statistics to learn. When we consider the evolution of AI—from Aristotle's thoughts on logic to the Turing test—we can trace the convergence of philosophy, mathematics, and technology that helps us understand machine intelligence. This has been a long process in which many varied approaches have been tried. Nonetheless, it has helped establish a solid foundation for AI research.

Reasons to explain AI, ML, and DL

Although the past few decades have seen substantial progress, a lack of clarity persists in the discourse, as people still tend to conflate Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL). The popular media often reports any advancements in ML or DL as a breakthrough in AI, without specifying how these areas are hierarchically related to one another (LeCun *et al*., 2015). This distortion goes beyond semantics and points to ongoing issues in effectively conveying technological advancements to a general audience. AI is the broad scientific and engineering enterprise of creating intelligent systems.

CHAPTER 2

AI-Driven Insights for Enhanced Healthcare: Leveraging Multimodal Data Analysis in e-Health Platforms

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Abstract: AI-powered e-health systems are revolutionizing healthcare by enabling early identification of health problems, customizing treatment strategies, and improving patient care. These systems use data from sensors, wearables, electronic health records, and patient interactions. EU-funded initiatives ICT4Life and TeNDER demonstrate the capabilities of AI-powered e-health systems, focusing on chronic ailments like Parkinson's and Alzheimer's. These systems use multimodal data analysis, machine learning, and user-friendly interfaces to provide individualized care and improve health outcomes.

Keywords: Activity recognition, Assistive technology, Clinical decision support, Monitoring, Smart healthcare.

INTRODUCTION

In 2021, global health spending reached an astonishing $9.8 trillion, accounting for 10.3% of global GDP. Despite this investment, life expectancy has stagnated in many countries over the past decade, including the United States (US), which alone spends over $4 trillion annually on health (Sterlin, 2024). Meanwhile, healthcare systems worldwide are struggling to keep up with rising demands due to aging populations, an increasing burden of chronic diseases, and the growing prevalence of preventable Non-communicable Diseases (NCDs).

In Europe, the health and care systems face significant challenges, including shortages in the health workforce and the rising burden of diseases such as tobacco-related illnesses, neurodegenerative conditions, and obesity-related complications (European Commission, 2018). Additionally, the growing threat of

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infectious diseases, including antibiotic-resistant pathogens, poses a significant strain on public health systems. Furthermore, chronic diseases like dementia, Alzheimer's, and Parkinson's not only cause immense personal suffering but also place an economic burden on national health systems, costing the EU economy over EUR 196 billion annually, with global costs exceeding $1 trillion and projected to double by 2030.

As populations age, diseases such as Cardiovascular Disease (CVD), dementia, and Parkinson's have emerged as significant global health challenges. According to the WHO (Organisation, 2017), cardiovascular diseases accounted for 31% of all global deaths in 2016, making them the leading cause of premature death (37% of all deaths under 70) and disability. Similarly, dementia, including Alzheimer's disease, remains a critical public health issue, with an estimated 44 million people affected globally in 2018. This figure is expected to nearly double by 2030 and rise to 152 million by 2050 (International, 2018). Cognitive impairments associated with these diseases significantly affect Quality of Life (QoL), with symptoms like behavioral changes, mood swings, and planning difficulties frequently observed in individuals with Parkinson's.

Adding to these challenges is the strong desire among elderly individuals to remain independent in their homes. In Europe, only 3.3% of individuals over 65 reside in institutional centers, while 50% of those over 80 live alone, highlighting the importance of supporting independent living through effective health and care solutions. Remote healthcare solutions, particularly those enabled by advanced monitoring technologies, play a critical role in meeting these demands (Ponce *et al*., 2020). For instance, individuals with heart disease can benefit from Cardiac Rehabilitation (CR), which reduces mortality and morbidity, prolongs independence, and reduces strain on healthcare systems.

Over the past few decades, healthcare technology has undergone a profound transformation, driven by innovations in digital health solutions, data analytics, and Artificial Intelligence (AI) (Makade *et al*., 2024). Remote healthcare, which includes telemedicine, wearable devices, and mobile health applications, has become a cornerstone of modern healthcare systems. These technologies enable continuous care, facilitate proactive health management, and empower individuals to take charge of their health—whether managing chronic conditions or preventing future health issues—all from the comfort of their homes(Bertl *et al*., 2023). This shift is gradually moving healthcare away from traditional hospital-centric models toward more community-based, integrated care approaches.

Digital health solutions have emerged as transformative tools for addressing healthcare challenges (Malasinghe *et al*., 2019). Remote healthcare leverages

modern technologies to deliver care across geographic distances, using tools such as telemedicine, wearable devices, and mobile health applications (M. R. Islam *et al*., 2023). These innovations enable not only continuity of care but also proactive health management by empowering individuals to monitor their own health

(Alboksmaty *et al*., 2022). By bridging the gap between patients and providers, digital health has the potential to shift healthcare systems from hospital-centric to community-based, integrated care models. For example, remote monitoring technologies allow for real-time tracking of critical health metrics such as heart rate, blood pressure, and glucose levels. This approach not only facilitates early intervention but also enhances patient autonomy, enabling seniors and those with chronic conditions to maintain their independence while improving their quality of life.

A prominent example is AI in medical imaging, where deep learning algorithms analyze X-rays, MRIs, and CT scans with accuracy comparable to radiologists (Arora *et al*., 2025). These systems can detect early signs of conditions like cancer and neurological disorders, facilitating quicker diagnoses. AI decision support systems process patient data to recommend personalized treatments, shifting care from general to precision medicine—crucial in remote healthcare where access to specialists is limited.

AI also plays a key role in chronic disease management platforms like Livongo* for diabetes. This platform tracks glucose levels, provides real-time coaching, and recommends diet or medication adjustments based on AI insights. These tools improve patient adherence and quality of life by offering on-demand care.

At the heart of these technologies are sensors and smart devices, which play a pivotal role in enabling real-time data collection and analysis. Biosensors embedded in wearable devices, for instance, can measure biomarkers such as glucose, cortisol, and lactate levels, providing insights into both physical and mental health (Alvarez *et al*., 2017; Theodoridis *et al*., 2017). Similarly, accelerometers and gyroscopes are used to track movement patterns, aiding in rehabilitation or fall detection for elderly individuals. By integrating these sensors into larger healthcare ecosystems through the Internet of Things (IoT), healthcare providers can access a continuous stream of patient data, enabling predictive analytics and early interventions.

Sensors, smart devices, and AI are reshaping healthcare delivery, particularly in remote settings. Wearables and connected health applications monitor vital signs, transmitting data to cloud platforms for AI-driven analysis (Visconti *et al*., 2019). AI-powered devices, such as Continuous Glucose Monitors (CGMs), track glucose levels throughout the day, sending alerts when levels deviate from the

CHAPTER 3

Current Trends, Innovations and Challenges in Multi-Modal AI-Powered Assistants for Pathology

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Abstract: The rapid advancement of Artificial Intelligence (AI) has significantly impacted the healthcare sector, particularly through the development of multi-modal AI assistants. This book chapter examines the current state-of-the-art in the field of AI-based multi-modal assistants with a specific focus on pathology. Leveraging the convergence of large language models and computer vision techniques, these systems are designed to enhance diagnostic accuracy, streamline workflows, and improve patient outcomes in pathology. Multi-modal AI assistants integrate diverse data modalities, including histopathology scans and biomedical texts, to perform complex diagnostic tasks. The use of computer vision in analyzing histopathology images allows these models to detect subtle patterns and anomalies that may be missed by human pathologists. Concurrently, the integration of large language models enables the processing and interpretation of large volumes of biomedical literature, providing comprehensive insights and augmenting the diagnostic capabilities of these systems. This paper provides an in-depth analysis of the methodologies used to develop these multimodal AI systems, highlighting their ability to address challenges such as data scarcity and task specificity. By synthesizing current research and development efforts, we present a holistic view of how these technologies are being utilized to advance the field of pathology. We discuss the performance metrics, clinical applications, and potential future directions for multimodal AI assistants in healthcare. Ultimately, this survey aims to illuminate the transformative potential of AI in pathology, showcasing how the integration of computer vision and large language models can lead to more accurate diagnoses, efficient workflows, and better patient care.

Keywords: AI agents, Computational pathology, Computer vision, Large language models, Multimodal AI.

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INTRODUCTION

In recent years, Artificial Intelligence (AI) has made its mark on many fields, including medicine. AI algorithms can significantly influence various aspects of healthcare, from medical image processing in Computed Tomography (CT) scans (Afshar, 2021; Islam, 2022; Mukherjee, 2022; Kollias, 2024), Positron Emission Tomography (PET) scans (Sanaat, 2021; Xing, 2022; Guo, 2022) and also in Magnetic Resonance Imaging (MRI) (Montalt-Tordera, 2021; Kang, 2021; Billot, 2023; Cuocolo, 2020), X-ray images (Sharma, 2020; Rasheed, 2021; Saygılı, 1073) and ultrasound images (Wang, 2022; Kainz, 2021; Vadhiraj, 2021; Mishra, 2021; Gofer, 2022). AI-powered systems offer valuable support across domains, with many institutions integrating these algorithms into their infrastructure to assist clinicians and medical personnel in decision-making and workflow optimization. They can assist with screening and early detection of potential health issues, identifying risks before symptoms appear (Ma, 2023; Porras, 2021; Rykov, 2021), and aiding in diagnosis (Swanson, 2023; Myszczynska, 2020; Richens, 2020; Zoabi, 2021). By having access to patient history and lab results, they can help conclude or narrow down to a specific condition, prognosis; with the help of additional information, they can help predict the likely course or outcome of a disease based on diagnostic findings, and also treatment planning (McIntosh, 2021; Samarasinghe, 2021; Pattyam, 2021), provide additional information, and help develop personalized treatment protocols based on the patient's history.

AI also plays a crucial role in other imaging-based areas of pathology, which is essential for diagnosing and understanding diseases. Various types of microscopy slides, including histopathology, cytopathology, molecular pathology, and hematopathology, provide critical insights for disease identification and treatment planning. Histopathology, in particular, remains the gold standard for many medical diagnoses due to its detailed examination of tissue samples. Additionally, large databases like PubMed (PubMed official database, 1996) have enabled the development of data-driven AI models, significantly improving performance in pathology-related tasks.

Deep learning has enabled the processing of high-dimensional data, such as images and text, and can generate highly accurate predictions. For that reason, AI holds significant potential in pathology, particularly with the advent of advanced high-tech microscopes capable of producing highly detailed images, which serve as ideal inputs for deep learning algorithms. Furthermore, advancements in deep neural network architectures, combined with the availability of large-scale datasets, have established a robust foundation for applications across various subfields of pathology, utilizing diverse inputs, such as high-resolution

microscope images and extensive collections of physician notes documenting findings, diagnoses, and treatments. Convolutional Neural Networks (CNNs) (Lecun, 1998) and Vision Transformers (ViTs) (Dosovitskiy, 2010) have emerged as leading architectures for image-based tasks, while the advent of Large Language Models (LLMs) has opened new possibilities for analyzing unstructured textual data, including medical records, research literature, and diagnostic notes. The advent of LLMs has unlocked significant potential for analyzing unstructured textual information in pathology, enabling the extraction and synthesis of insights from medical records, diagnostic notes, pathology reports, and vast corpora of research literature. These models not only enhance the efficiency of text-based data interpretation but also support decision-making by uncovering patterns and relationships within complex medical narratives. Similarly, Vision-Language Models (VLMs) provide a transformative approach by bridging visual and textual data, allowing for the integration of image-based diagnostics with accompanying textual descriptions, such as annotations, clinical summaries, or histopathological findings. This capability to process and correlate multimodal data offers significant advances in areas such as automated reporting, comprehensive diagnostic systems, and education. With these powerful tools, network architectures, and datasets now available, AI is expected to overcome existing challenges and drive groundbreaking progress in pathology.

This chapter provides a comprehensive overview of the role of AI-powered assistants in pathology, highlighting advancements in computer vision, LLMs, and multimodal AI systems. It explores state-of-the-art methodologies for image classification, segmentation, and diagnosis, as well as the integration of VLMs to enhance interpretability and support decision-making. Additionally, this chapter examines the impact of AI on pathology workflows, discussing key datasets, training strategies, and emerging trends. By synthesizing recent research and evaluating current challenges, we aim to provide a thorough understanding of how AI-driven pathology assistants are shaping the future of digital pathology and clinical practice.

LITERATURE RESEARCH

To ensure a complete and thorough selection of papers for analysis, the PRISMA guidelines were followed to conduct a systematic literature search. Articles were retrieved in September 2024 from the following academic databases: Scopus, CVF, IEEEXplore, and ScienceDirect. As this study investigates the impact of AI-powered agents in pathology, the search focused on topics related to vision, natural language processing, and language models. The specific search conditions are depicted in Fig. (**1**).

CHAPTER 4

Data Science and Artificial Intelligence Under Ethics and Legal Perspectives for the Detection of Chronic Respiratory Diseases

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Abstract: Science has evolved through successive paradigms over many centuries, while all of these were founded on postulated hypotheses for exploring the behavior of natural phenomena and their driving processes. These are subsequently validated through experimental methods with observation and measurements. As a result, theories were formulated not only to quantify these processes but also to predict them across multimodal and multidimensional contexts. Through this process, humanity progressed along long journeys of scientific discovery, uncovering explainable phenomena and processes. Specifically, we have encountered four science paradigms, of which the first one specialized in *empirical* e*vidence*, followed by the one based on *Theories and Mathematical Formalisms* for explaining natural processes, while the third paradigm specialized in *Computational Modelling*, using machines. The current fourth paradigm under which science is evolving now covers *Data Intensive Computing and Artificial Intelligence*, also known as Data Science and Artificial Intelligence. Our study falls within the current scientific paradigm, in which observational data and patient measurements from patients with Chronic Obstructive Pulmonary Disease (COPD) are intelligently analyzed using machine learning techniques. The performance of the classifiers is based on machine learning and testing for detecting COPD conditions. Our approaches are embedded within the GDPR's ethical and legal perspectives on AI and the advancement of care for COPD patients in the years to come.

Keywords: AI in medicine, Artificial intelligence, COPD, Ethics, Law, GDPR, Machine learning, Science paradigms.

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INTRODUCTION

The accelerated deployment of Artificial Intelligence (AI) across multiple application domains in the health sector has been phenomenal over the last two decades of the 21st Century. This was undoubtedly due to the convergence of affordable technologies such as smart wireless sensing, big data processing and storage, and cloud computing technologies, to name but a few. This has indeed generated great interest in transforming how modern healthcare is delivered, both now and in the coming years. Nevertheless, it is important to bridge the gaps between the successfully developed AI classifiers and predictive algorithms for health diagnosis, and to adapt them for practical operational use in clinical environments. Although great progress has been made in developing highly trained, high-performing AI algorithms for detecting various health conditions, significant challenges remain in interpreting their outputs and enabling scalable deployment for clinical care and decision support (Emanuel, 2019). Therefore, it is of paramount importance to understand and communicate the complexity of care delivery in the health sector, enabling AI experts to grasp it in depth and incorporate it into their scientific research and discoveries. Within collaborative, multidisciplinary AI and clinical care research teams, machine learning and classifier outputs must be translated into well-articulated, clinically meaningful interpretations. This challenge is not unique to AI and its application in health but extends to many other scientific disciplines.

For example, when atomic physics was born with the discovery of radioactivity in 1896 and the electron a year later in 1897, it took decades for societies to confidently accept the safe use of radioactivity for medical diagnosis and care (Allisy, 1996; Robotti, 1997). In fact, the United Kingdom pioneered a legislative framework for radiological safety through Parliament, under the Radioactive Substances Act 1948. This established a sound ethical and legal framework for organisations to implement stringent processes and controls when involved in the use of radioactive substances and irradiation machines for medical treatments and care (Binks, 1949; Windeyer, 1963).

In light of the above, we see a parallel in the emergence of AI as a new method for advancing medical care this century (Svensson, 2023). While AI is increasingly becoming a new accelerator for scientific discovery, it is equally becoming an enabler for accelerating problem-solving of issues in medical diagnosis and care. However, these issues are of a highly challenging nature. They are encountered, for example, in the treatment of cancers, chronic respiratory conditions, neurodegenerative diseases, and more. These diseases are experimentally observed through the collection of large volumes of observational

data, while the most effective pharmacological and other therapeutic approaches for their early and efficient treatment remain to be fully established.

The generation of biobanks of observational data concerning these diseases has given AI an opportunity to become a leading approach for accelerating scientific discovery and problem-solving. The aim is to develop high-performing machine learning algorithms that use biobanks of data for the intelligent classification and understanding of medical conditions. Furthermore, AI will help us understand the evolutionary stages and behaviour of such diseases, potentially guiding us to find appropriate cures soon (Gromiha, 2024). Also, note that AI methods, together with affordable big data technologies, are available for enable scientific discoveries. These have the potential to generate new mathematical theories for explain and validate phenomena and processes (Vervoort, 2023). Again, the parallel holds with AI and atomic physics. The latter accelerated cancer treatments and care, while at the same time advancing fundamental physics during the 20th century, such as quantum mechanics and elementary particle physics, through the formulation of unified quantum field theories (Sia, 2021; Close, 1979).

With all of this in mind, science went through four paradigms over time. These all contributed to accelerating scientific discoveries at their own specific pace. Nevertheless, each required the establishment of ethical and legal perspectives appropriate to the context of their respective epochs. The fourth paradigm, which we have reached, is uniquely entangled with big data and AI. It is also viewed through the lens of ethical and legal frameworks to be put in place for its secure, safe, and socially acceptable use in modern problem-solving.

In the following sections, we shed light on the progressive evolution of the four science paradigms (Tansley, 2009) and on the General Data Protection Regulation (GDPR) perspectives for using research data (Hoofnagle, 2019; Rumbold, 2017; Dove, 2018).

THE FOUR SCIENCE PARADIGMS

Science, which was historically known as “Natural philosophy”, has undergone various stages of development over many centuries. While these stages were limited by experimental observations of natural phenomena and processes of interest, their progress in formulating hypotheses and validating them for understanding, together with the approval of scientific peers, remained slow and socially challenging. The stages of scientific development have gone through specific key paradigms over time. The leap through these paradigms was often aided by major progress in mathematical theories and/or technical approaches for enabling better designs of field experiments for scientific discovery and validation. So far, we have been through three science paradigms before we

CHAPTER 5

AI-Promoted Protein-Protein Interaction Site Identification as a Powerful Tool for the Development of Personalized Therapies: A Survey on Recent Advances

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Abstract: Protein–Protein Interactions (PPIs) are crucial for numerous biological processes. Understanding the mechanisms that affect PPIs offers significant opportunities to expand the druggable proteome and therapeutically tackle various chronic diseases, including cancer. Conventional biological experiments for identifying protein-protein binding sites are costly and time-consuming. Therefore, numerous computational approaches have been developed to predict PPI sites. Traditional computational methods typically exploit global or local features of protein sequences for PPI site prediction; however, their accuracy is relatively limited given the problem's complexity. Recently, a new perspective on bioinformatics has emerged through Artificial Intelligence (AI), particularly in the field of Deep Learning (DL). DL techniques exploit the availability of extensive, labeled datasets and, through an automated, iterative learning process using multilayered neural networks, analyze and extract the underlying patterns that eventually correlate the data with their assigned labels. This study will provide a thorough analysis of AI-promoted PPI site identification methodologies, detailing the basic steps of the process. The most recent advances in this field and the most representative approaches will also be presented. Emphasis will be put on the interactions of the B-cell Receptors (BcR) with antigens, which is a special case of PPI with additional challenges. Finally, a case study for

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in-silico prediction of BcR-Antigen Interactions in B-cell lymphomas (Chronic Lymphocytic Leukemia – CLL) are discussed to exemplify the potentiality of AI towards the development of personalized cancer treatment. The main technical challenges of the above computational approaches are highlighted, and research directions are proposed.

Keywords: BcR-antigen interactions, Deep learning, *In-silico* prediction, Mutations, Protein-Protein Interactions (PPIs).

INTRODUCTION

Protein-Protein Interactions (PPIs) are vital to every biological process, as they enable proteins to interact and form complex networks essential for cellular function. These interactions govern many cellular activities, including signal transduction, gene expression, immune responses, and the formation of cellular structural components (Lu, 2020). As proteins rarely function independently, the regulation of PPIs ensures proper coordination of biological pathways, maintaining homeostasis and allowing organisms to adapt to environmental changes. Emphasizing their central role in normal physiology, dysregulation of PPIs is closely linked to the development of various diseases, rendering them critical targets for therapeutic intervention (Kenanova, 2023).

Structural and Functional Significance of PPIs in Health and Disease

At the molecular level, PPIs occur when two or more proteins bind together through non-covalent forces, such as hydrogen bonds, van der Waalsinteractions, and hydrophobic interactions (Slater, 2020). The specificity of these interactions is driven by the structural complementarity of the protein surfaces, often involving highly conserved residues known as “hot spots” that contribute disproportionately to binding energy. PPIs can be transient or stable, with transient interactions typically facilitating dynamic processes such as signal transduction (Nooren, 2003), whereas stable interactions contribute to the assembly of multi-protein complexes, such as the ribosome or proteasome. Given their fundamental role in cellular function, the dysregulation of PPIs is often associated with the development of various diseases, including cancer, neurodegenerative disorders, and infectious diseases (Cheng, 2021). Mutations or alterations in proteins can disrupt their normal interactions, leading to aberrant cellular behavior and disease progression.

Therapeutic Targeting of PPIs

The central role of PPIs in disease has made them attractive targets for therapeutic development. However, targeting PPIs poses unique challenges because protein

interaction surfaces are often large, flat, and lack the well-defined pockets typical of enzyme or receptor active sites. Despite these challenges, significant progress has been achieved in developing therapies that modulate PPIs, including small molecules, peptides, and biologics such as monoclonal antibodies.

PPIs are fundamental to nearly all biological processes, playing a key role in cellular communication, molecular assembly, and the regulation of critical pathways. Advances in experimental and computational methods continue to improve our understanding of PPIs and open new avenues for drug development. By targeting these interactions, researchers are developing novel therapies with the potential to treat previously intractable diseases, offering new hope for patients worldwide.

AI's Role in PPI Research

The integration of AI in PPI research offers transformative benefits, particularly for advancing precision medicine and accelerating biomedical discoveries. AI, especially through DL, enables the analysis of complex datasets and the extraction of patterns that would be challenging to uncover using traditional methods. By training on large datasets, AI models can predict PPI sites with high accuracy, providing valuable insights that help bioscientists better understand cellular processes and disease mechanisms. For instance, AlphaFold (Jumper, 2021), an AI model developed by DeepMind, has led groundbreaking advances in predicting protein structures, contributing to PPI research by providing structural data previously unavailable for many proteins. These advancements allow researchers to identify potential drug targets more efficiently and design personalized therapies, as AI can reveal patient-specific PPI profiles that may inform treatment strategies. Overall, AI enhances the capabilities of scientists and clinicians by reducing the time, cost, and complexity of PPI site identification, making it a crucial tool for advancing personalized therapies and understanding disease.

PROBLEM FORMULATION

Given the Three-Dimensional (3D) structures of two biomolecules (such as proteins, DNA, and small ligands), the objective of PPI site prediction is to identify the binding residues on the first molecule (which is usually called the receptor) that interact with the second molecule (which is usually called the ligand). The 3D structures are usually obtained from the Protein Data Bank (PDB), where each PDB file provides detailed atomic coordinates and metadata, enabling molecular modeling and interaction analysis with tools such as PyMOL (DeLano, 2002) or ChimeraX (Pettersen, 2021). If a PDB file is unavailable and

CHAPTER 6

AI and Politics

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Abstract: Artificial Intelligence (AI) can be effectively employed to benefit political science in multiple ways, through the emerging field of 'computational politics'. Initially, this field is defined as the use of data analytics, AI and, to a lesser extent, systems theory (cybernetics) in political science. It includes public opinion monitoring, the study of political information propagation (*e.g.*, echo chambers) and computational propaganda, given that social media platforms can be hijacked to propagate hate speech, disinformation, *etc.* The field also examines political activism *via* social media, forms of e-enabled participation, as well as the impact of AI and ICT methods on political structures and democratic processes (*e.g.*, e-direct democracy, increasingly-smaller-world phenomenon, rich-get-richer effect in social media resulting in 'messiahs'/influencers, *etc.*). This discussion sets the stage for presenting concrete examples of computational politics methods, illustrated by two specific case studies. The first one involves a computational analysis of electoral results from Greek elections between 1974 and 2019. This approach is applicable to any country and political period, offering meaningful qualitative insights. The second case study focuses on public opinion prediction through mass-scale semantic analysis of social media posts to gauge aggregate support for various political parties. This analysis can be correlated with conventional polls to predict election outcomes more accurately. Finally, conclusions are drawn, and future directions are suggested based on the preceding discussion.

Keywords: Computational politics, Digital propaganda, Dimensionality reduction, Election prediction, Political analysis, Social media analysis, Sentiment analysis.

INTRODUCTION

Politics has existed since humans formed societies. Democracy, derived from the Greek words 'demos' (people) and 'kratos' (rule), first emerged in ancient Greek city-states as direct democracy (Ober, 2008). In this system, citizens directly participate in decision-making by voting in popular assemblies. However, demo-

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cracy largely declined during the Hellenistic period, though elements of participatory governance persisted locally (Cartledge, 2009) and did not re-emerge in a significant form until the Enlightenment, which, along with the American and French Revolutions, laid the groundwork for the modern, hierarchical system of representative democracy (Hobsbawm, 1962). This system, where periodically elected representatives govern professionally on behalf of the people, also has roots in the pre-Imperial political structures of the Roman Republic and the self-governing Italian city-states of the Middle Ages, though these systems varied in their democratic practices (Ober, 2008). Today, representative democracy is globally dominant and, in most cases, adheres to liberal ideals of constitutionally guaranteed individual freedoms, as well as to Montesquieu's principle of separating executive, legislative, and judicial powers in state institutions. However, in practice, these branches occasionally intersect in ways that may diminish the effectiveness of established checks and balances, as seen in instances of executive overreach.

Originally, democracy did not address social issues comprehensively. Equality was limited to peers, excluding enslaved people, and marginalized groups. Aristocratic medieval Italian republics generally served the interests of local nobility and privileged groups, while modern representative democracies were developed to serve the bourgeois class, with institutionalized slavery and suffrage restrictions, based on income, property ownership, gender, race, and/or ancestry criteria, persisting well into the 19th and 20th centuries. Universal suffrage only became widespread post-World War I (Mazower, 2009), with struggles continuing in cases like South Africa under Apartheid. Broader social equality demands did not gain prominence until the 1960s, under pressure from the American Civil Rights Movement and the French May 1968 events, in the context of the post-WWII social democratic consensus in the West (particularly in Europe) (Mazower, 2009).

Despite successes in stability and progress, democracy has often struggled to address crises effectively, as seen in the collapse of democratic regimes (*e.g.*, Weimar Germany) and the erosion of democratic institutions by strong figures such as Napoleon or Hitler. One factor contributing to this is that the economy significantly influences democracy, although the latter is not a formal, constitutionally recognized power, like the legislative, executive, or judiciary. Economic power concentrated among elites contrasts with democracy's egalitarian ideals (Piketty, 2014). There is evidence that capitalist systems can allow private market entities to exert a significant influence on democratic processes through mechanisms such as lobbying and political donations, perpetuating financial inequality despite democratic principles. Moreover, the media, termed the 'fourth estate', profoundly impacts democracy but lacks formal recognition (Piketty,

2014). While traditional media faced regulation, the rise of unregulated social media has transformed the flow of information and political discourse.

Modern representative democracy operates through elected parliamentary deputies aligned along the right-center-left spectrum, rooted in the French Revolution. Traditional political mappings occasionally fail to capture the complexity of contemporary issues, such as immigration and environmental policies, which often transcend ideological lines. Nowadays, computational linguistics and Artificial Intelligence (AI) offer powerful tools to objectively map political concepts, analyze hidden relations, and enable richer scientific visualizations of the political spectrum. Such methods can, *e.g.*, explain whether an odd political coalition is purely opportunistic or a child of necessity, or whether it has deeper roots.

AI has the potential to contribute significantly to political science in various ways. This chapter discusses this potential by mainly focusing on the multifaceted field of *computational politics* that has emerged in recent years. It represents a groundbreaking integration of data analytics, AI, and systems theory, providing new tools to analyze and influence political phenomena. It is an interdisciplinary field that seeks to understand political systems as dynamic, interconnected networks, in which individuals (nodes) and their interactions (edges) create complex systems of influence and power.

Unlike traditional political science, which often relies on historical analysis or qualitative methods, computational politics employs quantitative modeling, real-time data analytics, and advanced machine learning techniques to analyze societal dynamics. Applications range from public opinion monitoring and election forecasting to exploring how disinformation and computational propaganda shape political landscapes. It also examines novel forms of e-participation and digital activism, assessing their impact on governance and democracy.

The scope of computational politics extends beyond analysis to include predictive tools and decision-making aids. However, the risks of misuse – whether through manipulation of public opinion or the amplification of extremist narratives – underscore the ethical challenges of this field. This chapter provides an in-depth exploration of its key components, applications, and challenges, grounding the discussion in both theoretical frameworks and real-world examples. An initial essay on these ideas can be found in Kondyli, (2022).

The remainder of this chapter is structured as follows. Initially, computational politics is defined and introduced as an area of study covering a wide range of topics related to the use of AI and ICT in political science. The chapter discusses digital tools and relevant issues surrounding public opinion monitoring, election

CHAPTER 7

Privacy-by-Design AI

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Abstract: In this chapter, we present the Privacy-by-Design Artificial Intelligence (PBD-AI) framework, which consists of the relevant AI methods and tools that automatically handle, process, and store private/sensitive/personal data, by incorporating terminology and definitions related to privacy protection in their optimization options/terms. We begin the chapter by defining what might consist of private/personal data, such as facial/human images, medical images and data records, surveillance/inspection (*e.g.*, aerial) data, and videos capturing private properties. Moreover, we formally define privacy protection problems such as data de-identification and data de-detection, in accordance with the European General Data Protection Regulation (GDPR) and other relevant legal frameworks. Next, we delve into state-of-the-art methodologies based on machine learning that have been applied for personal image data protection while maintaining relevance to other modalities as well (*e.g.*, personal data voice recordings). Methodologies that estimate (universal) data transformations in order to hinder automatic face/person detection and/or disable automatic face/person recognition/re-identification are described in detail, where their main objective is to optimize the transformation for balancing between private data protection (achieving maximum de-identification performance) and data utility, such as introducing less noise to the private data and/or achieving aesthetically pleasing de-identification. In addition, a section is dedicated to the problem of reversible privacy protection, *i.e.*, the problem of learning reversible privacy data transformations, either linear or non-linear, that must be unique for each data sample so that it is (almost) impossible to reverse engineer the transformation by using pairs of private data samples and their de-identified versions. This property enables protecting and restoring the private data upon request while eliminating the need to maintain double copies of the private/sensitive personal data. Finally, we conclude the chapter with an overview of the private data market, including valorization opportunities for the privacy protection methods.

Keywords: De-detection, De-identification, Private data market, Privacy-by-design AI, Reversible privacy protection.

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INTRODUCTION

In the age of digital transformation, the protection of personal data is increasingly becoming a priority in both research and application development. In the past few years, personal, sensitive, and private data have proliferated. Examples of such data include videos captured by publicly installed surveillance cameras, videos collected by personal mobile phones and drones, which are commonly uploaded to social media, medical images and records collected for personal health purposes, or even personal sensor data that are collected for research purposes. This almost unconstrained personal data collection has increased the risk of unauthorized processing, including automated processing by Artificial Intelligence (AI) systems.

This phenomenon has created a need for frameworks that ensure that personal data is handled and stored in a privacy-preserving manner. This chapter introduces the Privacy-By-Design Artificial Intelligence (PBD-AI) framework, which provides a set of AI methods and tools for automatically preprocessing private data with built-in privacy protection mechanisms. The framework integrates privacy-preserving techniques directly into AI models by incorporating privacy-related terminology and definitions into their optimization objectives. The goal is to make privacy an inherent feature of AI systems rather than an afterthought, thereby complying with international regulations such as the General Data Protection Regulation (GDPR).

Privacy-preserving AI has been a growing area of research, with various approaches emerging to address the need for robust privacy protection mechanisms. Techniques such as data de-detection and data de-identification have been proposed to protect sensitive personal information, especially in the context of personal data used in AI applications, including facial recognition and medical imaging. A significant body of work has focused on machine learning-based methods to prevent the misuse of sensitive data, with notable advancements in algorithms for automatic facial recognition obfuscation, voice data protection, and de-identification of other personal information. These approaches generally aim to balance between privacy protection and data utility, ensuring that personal information remains protected while maintaining enough data quality for AI systems to function effectively. The integration of privacy protection directly into AI models is a critical next step in this field, and various methods have been explored to optimize privacy-preserving transformations.

As AI systems expand across industries such as healthcare, security, and retail, the ethical and legal implications of using personal data are becoming increasingly pronounced. The challenge lies in ensuring that AI systems do not compromise

individuals' privacy while still extracting meaningful insights from the data. The motivation for developing the PBD-AI framework is to create AI systems that inherently respect privacy rights by integrating privacy preservation. In particular, the increasing use of AI technologies in surveillance and health-related fields calls for an efficient and legally compliant way to handle personal data. Privacy protection in these applications needs to go beyond traditional techniques, offering robust mechanisms that not only anonymize but also safeguard the utility of data for ongoing AI learning and analysis. This chapter aims to address these concerns by introducing methodologies that ensure data protection without compromising data value.

This chapter contributes to the growing body of knowledge on privacy-preserving AI by presenting a comprehensive framework for Privacy-By-Design AI (PBD-AI). The framework focuses on addressing critical privacy protection challenges, such as data de-identification and data de-detection, by incorporating them directly into AI algorithms. We explore advanced machine learning techniques that optimize data transformations to prevent automatic face detection, recognition, and re-identification, while minimizing noise introduction and maintaining data utility. Additionally, we examine the concept of reversible privacy protection, where privacy-preserving transformations are reversible, allowing for data restoration upon request without the need for double data storage. The rest of the chapter is structured as follows:

Section 2 includes definitions of what might constitute private/personal data, such as facial/human images, medical images and data records, surveillance/inspection (*e.g.*, aerial) data, and videos capturing private properties. Moreover, it provides an overview of the definitions of lawful data processing under the European General Data Protection Regulation (GDPR) and other relevant legal frameworks.

Section 3 details the problem formulation and the components of the privacy- by-design AI framework. The privacy-by-design AI framework is designed to ensure that personal data is anonymized from the very beginning of the data collection process, in compliance with privacy regulations like the GDPR. The importance of defining who is authorized to process the anonymized data is highlighted, with different de-identification techniques, such as pixelation or adversarial attacks, being more appropriate depending on whether the data is stored in physical or digital form. The framework centers on two key concepts: de-identification, which prevents data from being linked to specific individuals, and de-detection, which ensures that no personal data can be detected in the first place.

Section 4 performs a deep dive into state-of-the-art methodologies based on machine learning that have been applied for personal image data protection, while

CHAPTER 8

Agent-Based Modelling (ABM) in Archaeology: A Classical Vision

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Abstract: Agent-based modelling has been introduced into archaeology over the last three decades, on a variety of chrono-cultural systems and issues. The archaeological application of ABM is among the earliest AI applications in the human sciences. Even if the current practice of archaeology does not feel the impact of ABM in its daily practice, the influence of agent-based modelling approaches is by no means negligible. Through a critical, non-exhaustive assessment of this thirty-year experience, this chapter aims to raise questions about the limited application of ABM in Mediterranean archaeology of the first millennium B.C. and to stimulate future discussion of possible fields that could be the subject of modelling of this type.

Keywords: Agent-Based Modelling (ABM), Archaeology, Agentic Artificial Intelligence, Ancient historical archaeology, Mediterranean archaeology.

INTRODUCTION

Artificial Intelligence (AI), recognized for its transformative potential, is infiltrating all areas of society, including research. Regarded as one of the most innovative technologies with the greatest impact in the years to come, AI is moving into ever wider fields. The human and social sciences are no exception. Indeed, many questions need to be asked to develop ethical and responsible technology, but also to avoid making AI "out of soil". But the encounter between the human sciences and AI opens up new perspectives: the possibility of answering fundamental research questions and making new discoveries by analyzing vast quantities of data and extracting unprecedented knowledge. AI is gradually transforming the social practice of science, raising new epistemic, methodological and ethical challenges (Müller, 2020; Nyholm, 2023). More specifically, for some time now, research in the human sciences has also been undergoing the transition from automation to AI. This transition has triggered epistemological changes in the human sciences, whether through the advent of

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linguistic and textual data corpora, iconographic and visual data corpora, the use of automatic processes or, in a broader sense, the digital humanities. The epistemological impact on the human sciences has grown in importance, even if some of it is still invisible. Indeed, this is apparent in the growing importance of computation and data — for example, with the democratization of database software, which now offers high-level capabilities at no cost.

At the same time, the new possibilities are making databases, information storage, and processing all the way to the results more complex. In this way, the paradigms of all disciplines are being affected, first by digitization, then by decision-making, or at least the suggestion of decision-making, by the machine recognized as intelligent (Burenhult, 2002).

It is now technical and epistemological in nature given that AI, in particular through the management of large corpora, will be able to intervene in the diversity of methods and research objects specific to the human sciences. Over and above the ethical and methodological issues at stake, this is a reality that the human sciences will have to take into account and integrate AI into their approaches and practices to improve performance and broaden their scope of intervention in a constantly changing world.

Archaeology is a human science with its own object, which is the study of the human past based on material remains (all kinds of vestiges, objects, traces, *etc*.) that bear witness to the presence and functioning of past human cultures and societies. In parallel with its specific object, archaeology operates on the same terrain as its related disciplines, from anthropology to sociology, and in between history, ethnology, art history, philology, human geography, *etc*. At the same time, archaeology is in constant dialogue with more "scientific" disciplines, including paleontology, geology, geochemistry, geomorphology, geophysics, biology, zoology, *etc*. (Renfrew *et al*., 2024). But above all, archaeology is practiced in scientific laboratories, alongside field and artefact collections. From this point of view, it is located at the crossroads of the human sciences and the sciences (Trigger, 2006; Ed., 2020). Today, a specialised branch of archaeology deals with the application of AI in everyday archaeological research (for example, the International Conference Archaeo-Informatics, the last at DAI Istanbul, "Use and Challenges of AI in Archaeology", 2024, 25-26 November).

The use of the complex systems paradigm and multi-agent systems modeling in archaeology, in other words, with Agent-Based Modeling (ABM) and Agent-Based Simulation (ABS), as a dynamic approach in archaeological applications, allows researchers to simulate complex systems by modeling individual agents and their interactions. Its various methods are particularly useful for

understanding social processes and dynamic phenomena based on archaeological contexts and assemblages. ABM is expanding rapidly from 2000 onwards, as evidenced by the growing number of articles and books devoted to this type of work (*e.g*. (Kohler *et al*., 2007; Wurzer *et al*., 2015; Lake, 2020; Romanowska *et al*., 2021) *etc*.), specific PhD projects (*e.g*. (Chliaoutakis, 2020; Ourednik, 2010; Schmitt, 2014; Zanotti, 2016), *etc*.) and even the publication of specialized journals such as JASSS (Journal of Artificial Societies and Social Simulation). Indeed, the multi-agent approach is proving to be a very powerful tool for characterizing and understanding complex socio-geographical systems. Simulating the interactions between the elementary entities of a system is a method used to summarize and illustrate facts established by specialists (archaeologists, geographers, sociologists, *etc*.) or to test the plausibility of more general hypotheses on socio-environmental dynamics (Sanders, 2007). ABM is at the crossroads of various fields, of which AI is undoubtedly the most decisive.

ABM has several applications in archaeology, of which three are particularly important. Social simulation can be modeled by interactions among multiple agents in order to explore social structures and relationships in ancient societies and communities. Cultural dynamics can be simulated through the spread of cultural practices and technologies, providing insights into how these elements evolved over time. Resource management multi-agent systems can be programmed to represent different resource management strategies, allowing for the analysis of sustainability and decision-making in historical contexts. Simulation, with its representation and explanation, is at the heart of the different approaches.

The implementation of ABM in archaeological research depends on a number of factors, including the scale of the project, the statistical sufficiency of the elements to be processed, and the extent of the data characterising the agents. To effectively involve ABM in archaeological research, all that needs to be done is to follow the usual methodological steps: define the research question by precisely defining the objectives of the use of ABM, develop the model in order to create a precise definition of the agents in terms of their behaviours in a given environment, run various simulations applying the model following different versions to observe all possible responses and possibilities in the results, and finally analyse results by evaluating the data generated by the simulations to draw conclusions with the aim of interpreting the archaeological context.

The modeling work takes place in the final phases of global research development, in particular to contribute to the validation and sensitivity analysis of two multi-agent submodels currently under construction. This is the research phase, during which several scientific disciplines are involved: Mathematics

CHAPTER 9

Recent Advances in AI for Literature and Art

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Abstract: In recent years, there has been substantial progress made in LLMs and Generative AI. Neural text and images have become easily accessible, with a significant impact on literature and art. Diffusion algorithms can create realistic images through user-guided text prompts, and LLMs such as ChatGPT have been able to create any kind of text or code based on user instructions. In this study, we create a taxonomy of the most popular and important uses of AI in literature and the arts. We focus on recent algorithms for each subcategory to map current directions in academic research and potential use cases.

Keywords: Art restoration, Artificial Intelligence, Generative AI, Literary studies, Machine translation.

INTRODUCTION

Literature and art are personal, human endeavors. We do not think of a machine writing a story or creating a painting, at least until very recently. Advanced AI models such as Dall-E 2 (Ramesh *et al*., 2022), Midjourney and ChatGPT have been made widely accessible and have exhibited many applications in economics, education, healthcare, banking, programming, and, of course, literature and art.

Neural image and text generation is a rapidly growing field of research that extends naturally to the arts. Our goal is to map existing neural technologies and methods in the literature and the arts, and to identify possible applications that have not yet been formally implemented.

In the first section, we showcase applications of AI algorithms in literature, especially in creative writing, literary analysis, automated text editing, translation, and accessibility. In the second section, we present a number of image and art generative algorithms, along with techniques for restoration of visual information

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and art. Lastly, we present some interesting AI adaptations created in collaboration with human artists, paving the way for a more deliberate use. Fig. (**1**) presents the applications of AI in literature and art that we will explore.

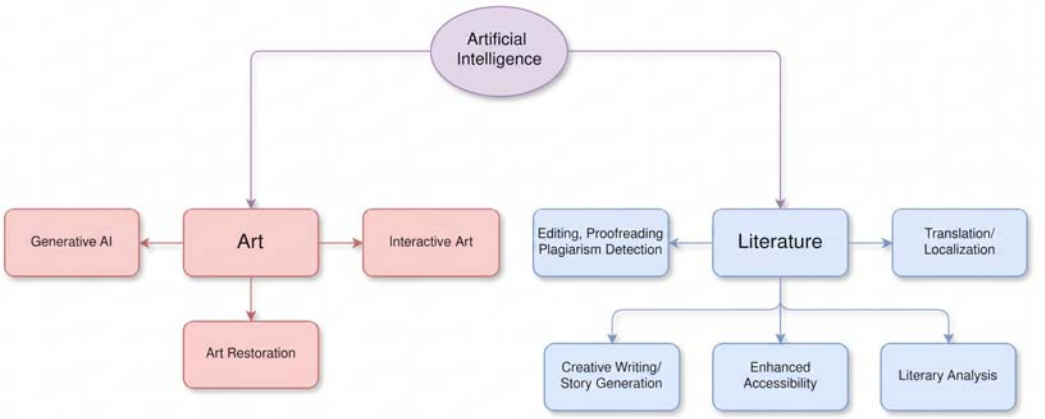


Fig. (1). This study is concerned with applications of AI in the fields of literature and art. This diagram shows the topics discussed in each section.

We do not claim that the provided categories are exhaustive or that they present the complete picture, given that AI and its applications are growing rapidly. However, this study functions as a snapshot of the field and may serve as inspiration for more innovative and thoughtful creations in the future.

APPLICATIONS IN LITERATURE

Recent advances in NLP and LLMs have enabled algorithms to generate stories, poems, dialogues, scripts, and more. Large models such as ChatGPT, Claude, Llama (Touvron *et al*., 2023), and Gemini (Team *et al*., 2023) have come to dominate text generation and are widely used both for creation and processing (style/tone change, translation, editing, *etc*.). Nevertheless, the field continues to produce innovative research that offers promising avenues for application in literature and literary studies.

Creative Writing and Story Generation

Large neural language models have proven capable of creating virtually any text the user requires, from professional emails or official documents to code in any programming language.

However, they have also been applied to cultural endeavors, such as creating plays (Magee *et al*., 2024), where a framework using multiple LLM agents is introduced, functioning as a "Drama Machine". Unlike other methodologies,

where characters are created and then iteratively changed in a one-dimensional structure (Qin *et al*., 2024), this framework allowed the authors to simulate dynamic character development and adaptive narratives by employing two roles, Ego and Superego. Ego handles external interactions, and Superego acts as an internal moderator, with both implemented through models such as Llama 3 (Dubey *et al*., 2024), Claude, or GPT-4o.

Testing involved two scenarios: a simple interview, in the genre of social realism, and a plot-driven detective drama, each exploring character behavior with and without Superego influence. The Superego modified responses through strategies such as prompt rewriting, user input reinterpretation, and response critique, enabling more nuanced character arcs than those produced without it. The Director, another LLM, is responsible for the external observer role and creates the settings and plot in which the characters act.

A classical Chinese poetry generator, based on a token-free LLM called Char-Poet (Yu *et al*., 2024), can craft poems with controllable format and content, as well as narratives and stories. Because the model is token-free, it can produce one character at a time, giving the user greater control, which is especially important for the structure of a classical poem.

Chatbots can provide useful tools for writers by assisting with the creation of a rough draft. In a study, Chakrabarty *et al*., (2023) created a collaborative framework for creativity support for writers grounded in the cognitive process theory of writing, based on GPT-3.5. Findings from a user study of 30 participants indicate that writers find LLMs most helpful for translation (*e.g*., targeted rewriting) and reviewing (*e.g*., draft feedback). Given that current models exhibit limitations such as reliance on clichés, lack of nuance, and difficulty addressing complex or darker topics, the authors emphasize the model's importance as a rewriting and feedback tool rather than an original idea generator.

One of the most notable applications of AI, and specifically LLMs, in neural text generation is text summarization (H. Jin *et al*., 2024). With the advent of ChatGPT and other large models, some researchers consider the task essentially solved, as in the study by Pu *et al*., (2023), where the authors argue that human evaluators prefer summaries generated by LLMs and contain fewer factual errors and hallucinations.

However, text summarization still has room for improvement (Subbiah *et al*., 2024). When it comes to short stories and narrative summarization, current LLMs have problems with specificity and the interpretation of subtext. The models evaluated are GPT-4 (Achiam *et al*., 2023), Claude-2.1, and LLama-2-70B. Among the study's findings is that "unreliable narrators are a challenge for LLMs"

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