New frontiers in Digital Libraries: The trajectory of Digital Humanities through a computational lens^{*}

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Abstract

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This study examines the influence of technological evolution on Digital Humanities, starting from Moore's Law formulated in 1965, which predicted the doubling of transistor density on a chip approximately every two years, thus exponentially increasing computing power at decreasing costs. We verify how this prediction has been confirmed in the evolution of microprocessors and their cost reductions. Subsequently, the paper explores Ray Kurzweil's theories, particularly his projection towards a "technological singularity" where Artificial Intelligence will match human intelligence, highlighting how these prospects have stimulated significant technological developments. Through an analysis of key moments, the work maps how such advancements have impacted Digital Humanities, investigating the evolution of computing capabilities and the growing role of Artificial Intelligence. The goal is to understand how Digital Humanities has responded and can respond to technological stimuli, adapting research methods and facilitating interdisciplinary integration. We conclude by reflecting on how Digital Humanities can actively shape its future in a context of rapid technological changes, proposing strategies for greater synergy between technology and the humanities.

Keywords

Digital Humanities, Technological Evolution, Artificial Intelligence, Moore's Law, Technological Singularity, Interdisciplinary Integration, Future Technological Trends.

1. Introduction

Digital Humanities (DH) represents an interdisciplinary field situated at the intersection of technological innovation and humanistic research [\[1\]](#page--1-0). Over the past decades, DH has increasingly leveraged digital technologies to transform how researchers analyze, interpret, and disseminate knowledge [\[2\]](#page--1-1). At the core of this transformation is the influence of key technological principles that have driven changes not only in computing hardware but also in conceptual approaches to Artificial Intelligence (AI) [\[3\]](#page--1-2) and interdisciplinary integration [\[4\]](#page--1-3).

This paper begins by exploring the evolution of microprocessors through the framework of Moore's Law (Section [2.1\)](#page--1-4), which predicted exponential growth in computing power alongside decreasing costs. The analysis demonstrates how these trends have significantly impacted DH, expanding the field's capacity to handle and process large datasets. Following this, the paper examines Ray Kurzweil's theory of technological singularity (Section [2.2\)](#page--1-5), which anticipates a future where AI will match and surpass human intelligence. The implications of this theory are considered in the context of both opportunities and ethical challenges for DH, particularly in the application of advanced AI models.

The paper then provides an overview of the historical intersections between AI and DH (Section [4\)](#page--1-6), tracing key milestones in the development of both fields. By analyzing these pivotal moments, we highlight how AI has enhanced research methods in DH, enabling more complex data analysis and new

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forms of interpretation in areas such as text analysis, pattern recognition, and digital reconstruction of cultural artifacts.

In addition, this work discusses the impact of AI-driven tools (Section [5\)](#page-7-0) that have revolutionized humanistic studies. These tools, which utilize natural language processing, machine learning, and image recognition, are reshaping how scholars engage with digital archives, historical texts, and cultural data.

By mapping the trajectory of technological advancements and their influence on DH, this paper aims to not only showcase the progress that has been made but also reflect on how DH can continue to evolve. As the field responds to rapid technological changes, it must foster stronger synergies between technology and the humanities, ensuring that future innovations enrich research practices and methodologies.

2. Technological evolution

The narrative of technological evolution in the DH is often grounded in two influential theories: Moore's Law [\[5\]](#page-9-0) and the Kurzweil Curve [\[6\]](#page-9-1). Both have provided critical insights into the accelerating pace of technological progress and its implications for the humanities.

2.1. Moore's Law and microprocessor trends

Formulated in 1965 by Gordon Moore, co-founder of Intel, this law postulates that the number of transistors on a microchip doubles approximately every two years, though the cost of computers is halved [\[5\]](#page-9-0). Moore's observation not only predicted the exponential increase in computing power, but also predicted the decreasing cost of technologies, facilitating widespread access to advanced computational tools [\[7\]](#page-9-2). This principle has underpinned the dramatic enhancements in processing speeds, storage capacity, and the efficiency of new algorithms, which in turn have had a profound impact on the capabilities available to scholars in the humanities [\[8\]](#page-9-3).

2.2. The Kurzweil Curve and the concept of singularity

Parallel to the implications of Moore's law, the provocative theory of technological singularity, popularised by the futurist Ray Kurzweil, posits that exponential growth of technologies will eventually lead AI to equal and then surpass human intellectual capacity. Kurzweil's vision of the singularity [\[6\]](#page-9-1) not only forecasts a future where human and machine intelligence merge, but also suggests a paradigm in which AI growth could autonomously accelerate beyond human control. This paradigm elucidates both compelling opportunities and significant ethical dilemmas for the field of DH, extending the boundaries of what can be actualized through computational methodologies.

Expanding on these technological foundations, this paper explores Kurzweil's singularity theory, which asserts that AI will reach human-level intelligence by a specific timeline. We present a critical analysis of this prediction, citing a recent study published in the *Proceedings of the National Academy of Sciences* in 2024, which examines the behavior of GPT-3 [\[9\]](#page-9-4) and GPT-4 [\[10\]](#page-9-5) through standardized personality tests and a series of behavioral games simulating real-world economic and moral decisions, such as financial investment management [\[11\]](#page-9-6). The study details the AI's performance in six distinct games designed to reveal traits like spite, trust, risk propensity, altruism, fairness, cooperation, and strategic reasoning. ChatGPT-4's responses, often indistinguishable from or superior to human behavior, suggest its potential to surpass the Turing test in specific contexts.

However, in contrast, ChatGPT-3's responses were frequently perceived as non-human, highlighting behavioral differences between the two AI versions. This analysis led to what was essentially an advanced Turing test pass for AI, demonstrating a propensity for generosity and fairness exceeding the average human player.

Researchers suggest that future studies should test more AI models across various behavioral tests to compare their personalities and traits. This emerging field, termed the "behavioral science of artificial intelligence", encourages interdisciplinary collaboration to investigate AI behavior, particularly its relationship with humans and societal impact. The findings suggest that knowing AI such as ChatGPT can exhibit more altruistic and cooperative behavior than the average human may increase our trust in using it for negotiation, dispute resolution, or assistance. This research aids in understanding when and how we can rely on AI, potentially shaping future interactions between humans and AI. In response to these technological advancements, this paper seeks to delineate the evolution of DH through the analytical lens of key milestones in the development of AI and computing power. Each milestone reflects a leap forward in technology that has enabled DH scholars to engage with complex datasets and perform nuanced interpretations of cultural artifacts at unprecedented scales.

As we trace the milestones in technological evolution, from Moore's Law to Kurzweil's singularity, this paper seeks to map the transformative impact of these advancements on DH. Each technological leap provides scholars with the ability to engage more deeply with complex cultural artifacts and datasets, enabling richer, more nuanced interpretations. In the following sections, we will explore these milestones in detail, examining how they have shaped current DH practices and will continue to drive the field towards a more technologically integrated future.

3. Historical intersections of Artificial Intelligence and Digital Humanities

Understanding the development of DH requires a historical perspective on its intersections with AI. This section traces key moments in both fields, from the early conceptualization of AI at the Dartmouth Conference to the emergence of DH projects like the Index Thomisticus. Through an analysis of these milestones, we explore how the convergence of computing and the humanities has transformed research methods and scholarly practices.

The figure [1](#page-12-0) presents a vertical timeline that juxtaposes the historical milestones in the development of DH and AI against the backdrop of two key technological growth predictions: Moore's Law, indicating the exponential growth of transistor count, and Kurzweil's Prediction of overall technological growth. The x-axis represents computational power on a logarithmic scale, highlighting the rapid increase in computational capabilities over time. The y-axis denotes the years from 1950 to 2030.

The timeline is color-coded to demarcate significant eras in computing history, such as the Early Computing Era, the advent of Personal Computing, the Internet Age, the convergence of AI & Big Data, the period of AI Everyday Integration, and the projected phase leading Towards Singularity.

Key milestones in the AI domain are marked by orange lines, while those in DH are indicated by blue lines. Milestones include seminal events such as the Dartmouth Conference [\[12\]](#page-9-7) marking the conceptual birth of AI in 1956 and the commencement of the Index Thomisticus project in 1949 [\[13\]](#page-9-8), considered the beginning of DH. Notable AI achievements, such as IBM's Deep Blue's victory [\[14\]](#page-9-9) over the world chess champion in 1997 and the introduction of GPT-3 in 2021 [\[9\]](#page-9-4), are plotted alongside DH advancements like the inauguration of the Digital Public Library of America in 2013 [\[15\]](#page-9-10).

Moore's Law and Kurzweil's Prediction are represented by lines with markers, where Moore's Law is displayed with a solid blue line and blue circular markers, and Kurzweil's Prediction is depicted by an orange dashed line with cross markers. The illustration clearly demonstrates the acceleration of technological progress, with Moore's Law closely tracking the actual milestones in AI and DH, and Kurzweil's Prediction suggesting a more generalized technological advancement.

The vertical orientation of the timeline provides a direct visual correlation between the passage of time and the escalation of computational power. Annotations for each milestone are placed adjacent to the year they occurred, with text labels providing a succinct description of each event. The period from 2010 onwards is highlighted in a shaded pink region, emphasizing a phase of rapid progress and the denser clustering of milestones, reflecting the increasing impact and integration of AI technologies in various domains.

Overall, the figure effectively conveys the symbiotic relationship between computational advances and milestone achievements in AI and DH, illustrating a clear trend towards more sophisticated and integrated technological applications as time progresses.

3.1. Milestones in Artificial Intelligence

The progression of AI has been characterized by numerous critical junctures, each facilitating significant advancements in machine learning, inferential reasoning, and decision-making algorithms. This section elucidates seminal milestones in the evolution of AI, tracing the development from primitive symbolic reasoning systems to sophisticated contemporary neural networks. These technological advancements have profoundly impacted the methodologies utilized by DH scholars in their engagement with computational tools.

1956 - Dartmouth Conference: Marked as the official birthplace of AI, the Dartmouth Conference brought together key thinkers like McCarthy, Minsky, and Shannon. They discussed the hypothesis that "every aspect of learning or any other feature of intelligence can, in principle, be so precisely described that a machine can be made to simulate it" [\[12\]](#page-9-7). This conceptualization of AI proposed the possibility that machines could not only compute but also think, reason, and adapt like humans. While the ambitions discussed at the conference were far-reaching, and progress was slower than expected due to technological and conceptual limitations at the time, the event established the foundational goals and broad expectations for the field of AI [\[16\]](#page-9-11). The Dartmouth Conference did not only serve as the birthplace of AI; it was the cradle for ideas that would evolve over the next decades, eventually giving rise to key areas like expert systems, neural networks, and modern machine learning.

1960 - First AI Program: The development of The Logic Theorist in the late 1950s, and its public introduction in 1960 [\[17\]](#page-9-12), is considered a landmark event in the history of AI. Created by Allen Newell, Herbert A. Simon, and Cliff Shaw, this program was designed to emulate human problem-solving abilities, specifically in the realm of symbolic reasoning. The Logic Theorist was a groundbreaking step in demonstrating that a machine could perform tasks that required human-like thought processes, which was a core idea emerging from the 1956 Dartmouth Conference on AI. At its core, The Logic Theorist was an automated reasoning system. Its primary objective was to replicate the deductive reasoning process used in mathematics. The program's creators drew inspiration from their work in psychology and operations research, particularly from their interest in human problem-solving techniques. Newell, Simon, and Shaw believed that human cognitive processes could be formalized and modeled by machines, and The Logic Theorist was the first major experiment to test this hypothesis. The program was revolutionary for its ability to prove mathematical theorems. Specifically, it could generate proofs of theorems from Whitehead and Russell's famous work, Principia Mathematica. Out of 52 theorems in this highly formal and abstract work, The Logic Theorist successfully proved 38. Even more astonishing, the program found a more elegant proof for one of the theorems than the original authors had proposed, showcasing the potential of AI systems to not just replicate but enhance human intellectual processes[\[18\]](#page-9-13). The Logic Theorist's success marked the beginning of an era where machines were seen as capable of more than just simple calculations; they could engage in abstract reasoning and solve complex problems traditionally seen as requiring human intelligence. The work of Newell, Simon, and Shaw contributed to the birth of the cognitive revolution, an interdisciplinary movement that involved computer science, psychology, and philosophy. In addition, The Logic Theorist paved the way for future AI programs like the General Problem Solver (GPS) [\[19\]](#page-9-14), also developed by Newell and Simon, which attempted to generalize the methods used in The Logic Theorist to solve a broader range of problems.

1997 - Deep Blue Defeats Kasparov: In May 1997, IBM's Deep Blue made history by defeating the reigning world chess champion, Garry Kasparov, in a six-game match. This victory was not just a remarkable feat in the realm of chess but a watershed moment in the development of AI, as it showcased the capability of machines to rival and surpass human intellect in highly complex and strategic tasks. It was a landmark in AI research, demonstrating that computers could excel in specific domains that required deep strategic thinking and decision-making [\[14\]](#page-9-9).

2011 - Watson Wins Jeopardy: In February 2011, IBM's Watson marked another historic milestone for AI by defeating Ken Jennings and Brad Rutter, two of the most successful human contestants in the history of the Jeopardy! game show. Watson's victory was not just a triumph of AI in a game setting, but a clear demonstration of the evolving power of natural language processing (NLP) and machine

learning technologies. It showed that AI could handle not only structured tasks like chess but also the nuanced, context-driven complexity of human language [\[20\]](#page-9-15).

2012 - The 2016 victory of AlphaGo developed by Google DeepMind, over Lee Sedol, one of the top Go players in the world, was a defining moment in AI history. The game of Go, with its 19x19 grid and more possible positions than atoms in the observable universe, requires a combination of strategic depth, intuition, and abstract thinking—challenges that had made it a final frontier for AI. AlphaGo's success was built on its innovative use of deep learning and reinforcement learning. It combined two deep neural networks: a policy network to guide the AI toward likely moves and a value network to assess the board's strategic position. These networks, trained through millions of games of self-play, allowed AlphaGo to not only master the game but also outperform human intuition [\[21\]](#page-9-16). This triumph highlighted AI's ability to solve complex, unstructured problems and laid the foundation for future AI systems in areas requiring long-term planning and strategic thinking, such as medicine, finance, and logistics. It also raised philosophical questions about the nature of intelligence, as AlphaGo demonstrated the potential for AI to innovate and create solutions previously unseen in human play [\[22\]](#page-9-17).

2014 Generative Adversarial Networks (GANs): The introduction of Generative Adversarial Networks (GANs) by Ian Goodfellow in 2014 [\[23\]](#page-9-18) was another transformative moment in AI, particularly in the realm of generative models. GANs consist of two neural networks: a generator that creates new data and a discriminator that evaluates whether the data is real or generated. Through this adversarial process, GANs learn to produce highly realistic outputs. GANs revolutionized image generation, allowing AI to create stunningly lifelike pictures, videos, and even artworks. This innovation expanded the possibilities for creative AI applications in fields such as Art and Design (AI-generated artworks and visual effects are increasingly integrated into creative industries); Medical Imaging (GANs help generate synthetic medical data to improve diagnostic algorithms); Deepfakes (While controversial, GANs also enabled the creation of deepfake technology, raising important ethical discussions about the use of AI in media). The impact of GANs [\[24\]](#page-9-19) is widespread, driving advances in creative industries, gaming, virtual reality, and synthetic data generation, highlighting AI's role in augmenting human creativity.

2018 - 2024: In recent years, AI has moved from experimental systems to technologies that shape everyday life [\[25\]](#page-9-20), achieving critical milestones that underscore its real-world impact [\[26\]](#page-9-21).

In 2018, AI systems like Google's BERT (Bidirectional Encoder Representations from Transformers) [\[27\]](#page-9-22) began surpassing human benchmarks in reading comprehension tasks. These models could understand and respond to questions about a text with greater accuracy than humans in some cases[\[28\]](#page-10-0). This marked a significant leap in NLP and contributed to improvements in:

- Search engines and virtual assistants, like Google Assistant and Alexa, which could better understand and respond to complex queries.
- Document analysis in fields like law and finance, where AI helps parse through vast amounts of text to extract relevant information.
- This breakthrough in NLP has fundamentally improved human-AI interaction, enabling more intuitive and effective communication with machines.

During the COVID-19 pandemic, AI played a critical role in accelerating the vaccine development process [\[29\]](#page-10-1). Using AI-driven algorithms to analyze vast amounts of biomedical data, scientists were able to identify potential vaccine candidates more rapidly; optimize vaccine designs using predictive models that evaluated the immune responses of different formulations; accelerate clinical trials by using AI to monitor and analyze trial data in real-time. Companies like Moderna used AI to design their mRNA vaccines, reducing the development timeline from years to mere months [\[30\]](#page-10-2). AI's contributions during the pandemic demonstrated its potential to solve global health challenges and highlighted its value in fields such as drug discovery and epidemiology.

From 2018 to 2024, artificial intelligence made remarkable progress in the field of autonomous vehicles, greatly advancing the areas of navigation, perception, and decision-making. Companies such as Waymo, a subsidiary of Alphabet, have been leading the way in testing and deploying self-driving cars in urban settings [\[31\]](#page-10-3). These advancements have been fueled by key developments in several areas. First, computer vision has improved significantly, allowing AI systems to more accurately identify and interpret objects in the environment, making autonomous navigation more reliable [\[32\]](#page-10-4). Second, the integration of sensor fusion has enabled AI to merge data from various sources, such as LiDAR, cameras, and radar, to form a comprehensive understanding of the vehicle's surroundings, improving safety and efficiency [\[33\]](#page-10-5). Third, reinforcement learning has played a critical role in allowing AI systems to learn how to navigate complex traffic scenarios, making real-time decisions to ensure safe and efficient driving [\[34\]](#page-10-6). As a result of these technological strides, autonomous vehicles are now closer to becoming a widespread reality. AI has demonstrated increasing reliability in practical applications such as urban driving, delivery services, and even autonomous trucking. Nevertheless, challenges remain, particularly in terms of regulatory approval and ethical considerations, as these systems continue to evolve [\[35\]](#page-10-7).

These milestones from 2016 to 2024 illustrate AI's rapidly expanding capabilities, from mastering ancient games to solving global challenges like vaccine development. With continued advancements in machine learning, deep learning, and reinforcement learning, AI is becoming an integral part of solving complex, real-world problems and shaping the future of human technology interaction [\[36\]](#page-10-8).

3.2. Milestones in Digital Humanities

Parallel to the advancements in AI, the domain of DH has progressed from initial endeavors in computational text analysis to the extensive implementation of AI-driven methodologies. This section delineates pivotal milestones in the evolution of DH, underscoring the transformative impact of computational techniques on conventional humanities disciplines and the emergence of novel forms of scholarly inquiry.

1949 - Index Thomisticus by Father Busa: The Index Thomisticus, created by Father Roberto Busa, is widely considered the first major project in DH. Busa sought to use computational methods to analyze the works of Thomas Aquinas, a massive corpus of medieval theological and philosophical writings. Busa collaborated with IBM to develop a computational indexing system, which enabled the analysis of word frequencies and structures across Aquinas' texts [\[13\]](#page-9-8).

1966 - Humanities Computing: In 1966, the term "Humanities Computing" was first coined to describe the growing field of computational methods applied to humanities research [\[37\]](#page-10-9). This early stage of DH was characterized by the use of computers for text analysis, data storage, and the creation of digital editions of literary and historical texts. The introduction of this term signaled the emergence of a new academic area, as scholars began to recognize the potential of computing technology to transform humanities research.

1980 - Quantitative Analysis in History: Historian Charles Tilly revolutionized the field of historical research by introducing quantitative analysis. His work showed how statistical methods could be used to analyze historical events and social movements, marking a shift toward data-driven approaches in the humanities [\[38\]](#page-10-10).

1990 - First DH Conferences: The establishment of a community through these early conferences created a foundation of shared practices and promoted collaborative projects at the intersection of digital technology and the humanities, fostering innovation in the field [\[39\]](#page-10-11). These conferences played a key role in building a community around DH, offering a platform for exchanging ideas and methodologies. They promoted interdisciplinary collaboration, with scholars from fields like history, literature, linguistics, and computer science contributing insights on using digital tools in research. This environment of collaboration and innovation led to the development of new tools and frameworks that would shape DH for years to come.

2000 - Formation of ADHO: The establishment of the Association of DH Organisations provided crucial institutional support and sustained the efforts and initiatives in DH on a global scale [\[40\]](#page-10-12).

2010 - DH Becomes a Common Term: The term "DH" was universally recognised, representing its establishment as a significant academic field. This recognition was instrumental in securing funding and institutional support for DH projects [\[41\]](#page-10-13).

2013 - Digital Public Library of America: The Digital Public Library of America (DPLA) was launched in 2013 with the mission of providing access to the cultural heritage and historical records of the United States in digital form. The DPLA aggregates materials from libraries, museums, and archives, making them freely available to the public. [\[15\]](#page-9-10).

2020 - AI Integration in DH: By 2020, AI tools had become an integral part of DH, enabling scholars to analyze large datasets with unprecedented precision [\[42\]](#page-10-14). AI's role in DH encompasses various areas, such as NLP techniques that allow researchers to analyze and interpret vast amounts of text, image recognition algorithms that assist historians in examining visual data like historical photographs or artwork, and machine learning models that detect patterns in large corpora of texts or historical data.

2022 - Widespread Adoption of Machine Learning in DH: By 2022, machine learning (ML) techniques had become widely adopted in DH, enabling scholars to conduct more advanced analyses and uncover deeper insights from large datasets. Applications of ML in DH have included text classification and topic modeling [\[43\]](#page-10-15) to identify themes in extensive textual datasets, predictive modeling to forecast historical trends or analyze patterns in human behavior, and network analysis to map relationships between historical figures, organizations, or cultural movements.

2024 - Generative AI in Digital Humanities: By 2024, generative AI had gained significant traction within DH, with tools like GPT-4 [\[44\]](#page-10-16) and beyond being used to generate text, translations, and even creative works that emulate historical writing styles. Researchers have begun using generative models not only for text production but also for re-imagining lost literary works or hypothesizing alternate historical narratives. This advancement has sparked new debates on the role of AI as a creative partner in humanistic inquiry and its ethical implications in rewriting history [\[45\]](#page-10-17).

These milestones highlight the growing integration of computational methods with humanities research, reflecting the transformation of the field into a data-driven discipline that leverages digital tools to uncover new knowledge. From the early innovations of Father Busa to the modern-day use of AI and machine learning, the DH continue to evolve, opening up new possibilities for scholarly inquiry and knowledge production.

4. AI's influence on Digital Humanities

Artificial Intelligence (AI) has had a transformative impact on DH, extending far beyond methodological improvements. AI has fundamentally reshaped how researchers interpret, visualize, and engage with complex datasets, opening new avenues for scholarship. This section explores the specific contributions AI has made to DH, including advancements in research methodologies, pattern recognition, and the interpretation of visual data. We also address the challenges and opportunities that arise from the growing integration of AI within DH workflows [\[46\]](#page-10-18).

4.1. Enhanced research methods

AI technologies, particularly in natural language processing (NLP) and machine learning, have revolutionized the way DH scholars conduct research. Since 2011, tools like IBM's Watson and Google's AlphaGo have enabled large-scale analyses of textual data, significantly improving the efficiency and accuracy of tasks such as text classification, sentiment analysis, and thematic extraction [\[47,](#page-10-19) [48\]](#page-10-20). These advancements allow researchers to manage extensive datasets that were previously too cumbersome for traditional analysis, enhancing both the scope and depth of humanities research.

4.2. Pattern recognition and data analysis

The introduction of Generative Adversarial Networks (GANs) in 2016, along with subsequent AI models, has empowered DH researchers to identify patterns in vast datasets with unprecedented precision. This capability is particularly impactful in historical studies, where detecting hidden relationships and trends within large corpora of texts or archival materials was once difficult or impossible [\[23\]](#page-9-18). AI's pattern

recognition abilities have led to groundbreaking discoveries in fields such as literary analysis, historical trend prediction, and cultural studies, offering new perspectives on age-old questions.

4.3. Visual data interpretation

Advances in AI, particularly in image recognition and processing through techniques like Residual Neural Networks (RNNs) since 2015, have had a profound effect on the analysis of visual and cultural artifacts [\[49\]](#page-10-21). These technologies enable the digital reconstruction of historical sites, artwork, and manuscripts, offering new insights for disciplines like archaeology and art history. AI-driven image analysis tools can recognize and restore damaged artifacts, contributing to the preservation of cultural heritage and enhancing our understanding of historical contexts.

4.4. Challenges and opportunities in AI integration

While the integration of AI into DH has introduced numerous opportunities, it also presents several challenges. One significant barrier is the complexity and opacity of advanced AI models, which can create a gap in understanding for humanities scholars. The "black box" nature of many AI systems can make it difficult to interpret their outputs, potentially leading to skepticism or misuse of the technology [\[50\]](#page-10-22). Additionally, there is a risk that AI may oversimplify complex humanistic inquiries, leading to reductive conclusions that overlook the nuances of cultural and historical data.

Nevertheless, the hypothesis is that as AI technologies become more interpretable and user-friendly, their adoption within DH will continue to grow. Increased transparency in AI systems, coupled with improved interdisciplinary collaboration, will allow for more nuanced interpretations and richer analyses. The future of AI in DH may even see AI systems not just as analytical tools but as creative collaborators, contributing to the generation of new knowledge in the humanities.

4.5. Future directions and hypotheses

As AI continues to evolve, its potential to further transform DH is immense. One promising direction is the development of increasingly sophisticated interpretive models that can personalize and adapt to the specific needs of researchers. AI's ability to create virtual historical environments and interactive simulations could revolutionize how we experience and understand the past, making cultural heritage more accessible and engaging to both scholars and the public. This integration holds the promise of transforming the humanities, making research more immersive, insightful, and interconnected [\[51\]](#page-10-23).

5. Tools enhancing humanistic studies through AI

As AI technology continues to evolve, its integration with DH is expected to deepen. Future advances in AI could lead to more sophisticated interpretative models and even more personalised and adaptive ways to engage with historical and cultural content. Furthermore, the potential for AI to help create virtual historical environments could revolutionise the field, offering immersive and interactive ways to experience and understand the past. Following we details several AI-powered tools that have revolutionized humanistic studies.

A sophisticated **tool for the recognition of symbols** in ancient manuscripts, utilizing state-of-the-art computer vision techniques [\[52\]](#page-10-24), accessible via this link: [https://symboldetection.streamlit.app.](https://symboldetection.streamlit.app) This tool employs advanced algorithms to automatically identify and classify symbols within digitized manuscripts, thereby facilitating more efficient analysis of historical documents. By leveraging deep learning models trained on extensive datasets of ancient scripts, it is capable of recognizing intricate and degraded symbols that are often challenging for human visual discernment. This significantly expedites the transcription and interpretation of ancient texts, a process that has traditionally been arduous and time-consuming, necessitating considerable manual effort. The tool's interface facilitates the uploading of manuscript images, subsequent to which the system employs advanced image processing algorithms to identify and classify the symbols present. The tool generates an output replete with suggested symbol classifications, which can be further refined by scholars through the adjustment of recognition parameters or manual correction of any inaccuracies. This capability renders the tool highly versatile and compatible with a diverse array of historical manuscript traditions and periods.The deployment of this tool signifies a substantial progression within the DH sphere, particularly impacting the disciplines of paleography, epigraphy, and the comprehensive examination of ancient texts. It efficaciously diminishes the extensive manual labor associated with transcription, simultaneously inaugurating novel methodologies for large-scale analysis of symbol patterns, intertextual linkages, and the linguistic evolution of historical documents.

A **platform for exploring a knowledge graph of world literature** [\[53\]](#page-11-0), which highlights the application of knowledge graphs, linked data, and natural language processing to enhance DH research [\[54\]](#page-11-1), accessible through this link: [https://literaturegraph.di.unito.it.](https://literaturegraph.di.unito.it) AI plays a central role in the platform by driving the construction, analysis, and visualization of the knowledge graph. Through the integration of AI techniques, the platform automatically extracts and processes vast amounts of unstructured literary data, uncovering relationships and patterns that would be difficult or impossible to detect manually.The core AI functionality of the platform involves advanced NLP algorithms that analyze textual data from a variety of sources, such as books, literary criticism, and historical records. These NLP models are trained to identify key entities (e.g., authors, works, places, themes) and their relationships, which are then mapped onto the knowledge graph. By leveraging AI, the platform can sift through large corpora of text to detect subtle connections, similarities, or contextual linkages that may have been overlooked in traditional research. Additionally, the AI employs entity recognition and semantic analysis to categorize literary elements and group related entities based on thematic, temporal, or geographic commonalities. This allows the platform to build a comprehensive and richly connected representation of world literature, where complex interrelationships between different works, authors, and concepts are highlighted.

A **system for extracting and analyzing topic trends** from a corpus of texts, using large language models (LLMs), NLP, and topic modeling techniques to present data visually through trend clouds and intertopic distance maps [\[55\]](#page-11-2). In this system, AI plays a critical role in automating the extraction of meaningful insights from vast corpora of texts, enabling researchers to uncover trends, themes, and relationships that would otherwise remain hidden.

6. Conclusion

This paper elucidates the significant influence of technological advancements, particularly in AI and computing, on the domain of DH. Examining the seminal impact of Moore's Law on computational power, as well as Ray Kurzweil's conjectures on technological singularity, it is evident that these developments have profoundly transformed the tools and methodologies available to humanities scholars. The incorporation of AI has considerably augmented the analytical capacities within DH, facilitating more advanced data analysis, pattern recognition, and visualization techniques.

As computational capabilities advance and AI becomes increasingly sophisticated, the scope of possibilities within DH will likewise expand. Nonetheless, these prospects are accompanied by significant challenges, such as the potential for oversimplifying intricate humanistic inquiries and the imperative for enhanced interpretability of AI models. Addressing these issues requires sustained collaboration between technologists and humanists to ensure that future innovations align with the ethical and intellectual imperatives of the humanities.

Moreover, the confluence of AI and DH possesses substantial potential to redefine the methodologies employed in the analysis and interaction with cultural and historical materials. By promoting interdisciplinary synthesis and the adoption of AI advancements, DH can not only respond to accelerated technological evolution but also influence the trajectory of its own progression. Consequently, DH will continually pioneer novel avenues for scholarly inquiry, safeguarding the intricate tapestry of human knowledge while harnessing the capabilities of contemporary technology.

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Figure 1: Timeline of technological advancements and milestones in Digital Humanities and Artificial Intelligence.