DIGITAL FUTURES IN HUMAN-COMPUTER INTERACTION

Design Thinking for Digital Transformation

Edited by **Zhiyong Fu, Anna Barbara and Peter Scupelli**

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Digital Futures in Human-Computer Interaction

The application of futures thinking in Human-Computer Interaction (HCI) has become increasingly important in recent years. Integrating speculative thinking with future design approaches has allowed HCI researchers to explore the potential impacts of technology on digital society. However, the implementation and application of futures thinking in HCI research is an emerging area. *Digital Futures in Human-Computer Interaction: Design Thinking for Digital Transformation* fills this gap by systematically analyzing HCI's innovation trends in the digital era.

This book explores the dialogue between digital transformation and futures thinking for alternative visions of HCI research. The book highlights significant trends and advancements in futures thinking related to HCI. Case studies illustrate the role of futures thinking, offering readers a broad overview of the subject while detailing the competencies and practices that can lead to successful futures design.

This engaging and informative reference will appeal to students, academics, and researchers interested in various design aspects related to HCI. These aspects include service design, sustainable design, product design, space design, visual communication, design education, futures studies, and social innovation.

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Foreword

In the 1980s, a group of futurists (James Dator, Lestor Cingcade, Wayne Yasutomi, and myself) explored the futures of robotics/artificial intelligence (AI). As we were working with the Hawaii Judiciary (Cingcade himself was the Administrative Director), we imagined a future where lawyers and judges would first increasingly use AI for minor judicial decision-making (administrative tasks such as parking fines) and eventually adopt it for more complex judicial decision-making. We then asked, what would be the conditions where AI/robotics would become so ubiquitous that robots would have legal rights. Certainly, most judicial leaders could not see the relevance of our speculations. However, they did understand that institutions needed futures literacy to stay relevant to the changing needs of citizens. Thinking of the unthinkable – robotic rights – distances us from the present, allowing us to see the present as not only remarkable, but designable. It spurs creativity and ensures that the outlier is embraced.

Futures literacy is not only about seeing the new possibilities in emerging innovation but also using the future to redesign the present. To think, feel, and act differently. To do this, futurists first challenge the used future – current institutional practices that no longer work but continue because we have always done it that way. Once this used future is challenged, we then anticipate and create alternative futures.

This novel book will help in this task. It explores how the future of human-computer interaction is likely to change and what policies – frameworks, ethical guidelines, narratives – are needed to guide this change. Evolution is moving from random to co-designed: humans with nature with technologies. In this process, merely living the programmed futures of others will not suffice. We need to innovate and co-design with actors and networks, human and non-human to create a transformative future. This book can help us in this process.

Sohail Inayatullah
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Preface

In an era marked by rapid technological advancements, digital transformation has become a cornerstone of innovation across industries. Human-Computer Interaction (HCI), as a field where technology and human interaction intersect, is at the forefront of this transformation, facing unprecedented opportunities and challenges. Within this fast-evolving landscape, futures thinking has emerged as an essential tool to drive innovation in HCI, providing a new way of thinking that empowers us to transcend the present, envision, and shape future technological ecosystems and societal structures. Futurescaping, a central concept in futures thinking, is not merely a tool for prediction but a design philosophy. By leveraging imagination, fiction, and extrapolation, the HCI field is poised to explore new possibilities and break through the limitations of current technological and social paradigms.

This book delves into the dynamic relationship between digital transformation and futures thinking, providing a comprehensive analysis of future trends, futures literacy, and practical applications. It aims to illuminate how these strategies can help shape preferable futures in the HCI domain, involving not only technological innovation but also deep reflection on societal impacts. As HCI evolves, there is a growing responsibility to ensure that the technologies we create contribute to a sustainable and human-centered future.

The book is structured to offer both theoretical insights and practical tools for those interested in the future of HCI. Section I establishes the foundation by examining future trends in HCI. It opens with an analysis of the effects of digital transformation on industries such as finance, healthcare, and education, and then explores emerging technologies in areas like care services and museums. Section II delves into futures literacy, examining methodologies for futures thinking, exploring pedagogical approaches for entertainment technology, and emphasizing long-term thinking in digital product-service systems, especially for small and medium-sized enterprises (SMEs). Section III shifts focus to practical applications and competencies, covering current methods in design futures, AI empathy in the metaverse, speculative design artifacts, interactive narratives, and affective evaluation strategies in human-AI interactions. Section IV concludes with a discussion of the broader societal implications of these emerging trends. It explores sustainability-oriented design futures methods, ecological thinking in HCI, the societal impacts of third-wave HCI research, and the influence of digital technology on personal well-being and quality of life.

Throughout the book, a careful balance is struck between theoretical exploration and practical application. By focusing on both technological innovation and human-centered design, it addresses the evolving challenges in HCI while anticipating future possibilities. Case studies and real-world examples enrich the discussion, providing a comprehensive understanding of how futures thinking can guide HCI research and practice.

As digital transformation continues to accelerate, HCI will face increasingly complex challenges and opportunities. Futures thinking offers the critical framework

needed to guide technological development toward more sustainable and ethically responsible outcomes. By encouraging reflection on current practices and thoughtful projection into the future, we can shape a more inclusive and balanced technological future. In particular, areas such as artificial intelligence and the metaverse present significant opportunities, but they also require careful consideration of their long-term social and ecological impacts.

This book is a valuable resource for anyone seeking to explore the intersection of technology, design, and the futures that lie ahead. It invites readers from diverse design disciplines—including service design, product design, and social innovation—to harness the power of futures thinking in shaping a better tomorrow, where technology and humanity evolve together in harmony.

Zhiyong Fu, Anna Barbara, and Peter Scupelli
Co-founders of Global Design Futures Network (GDFN)

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Zhiyong Fu is a tenured associate professor and doctoral supervisor at the Department of Information Art and Design, Academy of Arts and Design, Tsinghua University. He serves as the Director of the Art and Technology Innovation Base at Tsinghua University, Deputy Director of the China Innovation and Entrepreneurship Education Research Center, Secretary-General of the Information and Interaction Design Committee of the China Industrial Design Association (IIDC) President of the International Chinese Association of Human-computer Interaction (ICACHI). He is Co-founder of the Global Design Futures Network (GDFN), the member of the Second Global Important Agricultural Heritage Systems Expert Committee of the Ministry of Agriculture and Rural Affairs and a Director of the China-Europe Alliance for Arts and Humanities Education.

His teaching responsibilities include undergraduate and graduate courses in interaction design, service design, design thinking, and innovation and entrepreneurship. His research interests encompass intelligent product and service design, smart cities and design futures. He is the leader for multiple national and international research projects and published papers in key international conferences/journal in HCI and design. Fu was a recipient of the Ministry of Education's New Century Excellent Talents Support Program in 2006 and was a visiting scholar at the University of Tsukuba, Japan, in 1998, and Carnegie Mellon University, USA, in 2008. He played a key role in planning and organizing the China-U.S. Young Maker Competition under the Ministry of Education from 2014 to 2023 and he currently co-leads GDFN, a future-oriented global creative community that is preparing future-thinking innovators to tackle sustainability challenges with the design futures methodology.

Anna Barbara is Associate Professor in Architecture and Interior Design at the Design Department, Politecnico di Milano; President of POLI.design; Member of the Board of Directors of the World Design Organisation; Co-founder of the Global Design Futures Network; Scientific coordinator (with Venere Ferraro) of the D\Tank, Design Department, Politecnico di Milano; Italian Design Ambassador (2020, 2021, Kuwait; 2022, Sudan). Graduated in Architecture at Politecnico di Milano, she is teaching as visiting at Tsinghua University, Academy of Art and Design, Beijing (2019, 2024, China); at Kookmin University, School of Architecture, Interior Design and at Master Brain 21 (1999, South Korea). She was Canon Foundation Fellow at Hosei University (2000, Japan), Special Mention of Borromini Prize (2001), Selected by Archmarathon (2018), Selected ADI-Index 2019, 2023, Special Mention Fedrigoni Top Award – Large Format Communication, 2023; Eccellenze della Lombardia 2019, 2023; Exhibited t Biennale di Venezia (2010, 2022), Triennale di Milano (2003, 2016). Author of Storie di Architettura attraverso i sensi (2000, 2020), Invisible Architectures. Experiencing places through the senses of smell with Anthony Perliss (2006, 2023); Sensi, tempo e architettura (2012), Sensefulness, new paradigms for Spatial Design (2019), Extended Store. How digitalization affects the retail space

design with Yuemei Ma (2021). She designed international sensorial projects for companies in Japan, China, USA, Europe, UAE, and UK as founder of Senselab.

Peter Scupelli is Associate Professor of Design, and Director of the Learning Environments Lab. He was Visiting Professor at Politecnico di Milano (2022-2024) and the Nierenberg Professor at Carnegie Mellon University (2019-2022). Peter's current research focus is on learning environments and sustainable design futures. Peter is co-founder of the Global Design Futures Network (GDFN). Peter was an executive co-chair for the International Conference for Design Futures (ICDF) from 2020 to 2023. He holds a Ph.D. in Human-Computer Interaction, M.S. in HCI, M.Des. in Interaction Design, and an undergraduate Architecture degree. Peter has published over fifty-seven peer-reviewed papers at international conferences and journals. His research has been funded by the National Science Foundation and Institutes of Educational Science.

Peter teaches undergraduate, masters, and doctoral students. His teaching and research focus on three fundamental topics necessary to bring aspects of Transition Design to design practice: (a) aligning short-term design action and long-term vision goals, (b) embedding values into design processes, and (c) creating sustainable futures-oriented design methods. In *Dexign Futures*, students learn to combine Design Thinking with Futures Thinking to align short- and long-term time horizons. In *Design for Zero-Carbon Lifestyles*, he teaches how to live a zero-carbon lifestyle and create zero-carbon organizations. In *Design Your Futures*, students learn to design their life.

His work with Gruppo A12 was exhibited in the Architecture Biennale of Venice; PS1-MOMA, New York; the São Paulo Contemporary Art Biennial; the ZKM Museum of Karlsruhe, Germany, and many other places.

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Section I

Future Trends in HCI

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1 Digital Transformation and Future HCI

Zhiyong Fu and Jiawei Li

INTRODUCTION

Digitalization and Digital Transformation: An Analysis Framed by Actor-Network Theory

Background of Digital Transformation

In the 21st century's wave of digitization, digital transformation has become the engine driving profound changes in the global economy and society. This transformation not only involves the comprehensive reshaping of enterprise operating models and work modes but also touches upon various aspects of people's daily lives. The pervasive nature of digital transformation is evident not only in reshaping business ecosystems and market landscapes but also in exerting profound influences on cultural forms and social interactions. For example, the rise of digital media and social platforms has massively altered the ways people acquire information and engage in communication, while the widespread application of big data and artificial intelligence (AI) technologies is gradually redefining operational standards and productivity boundaries across various industries.

Tratkowska's (2019)'s paper analyzes the critical role of the VUCA (Volatility, Uncertainty, Complexity, and Ambiguity) environment in digital transformation and explores strategies to address these challenges. In the VUCA era full of volatility, uncertainty, complexity, and ambiguity, organizational digital transformation has become a necessary step to gain competitive advantage and ensure survival (Mukhlisah, 2023). Digital transformation serves not only as a potent driving force for the development of organizations worldwide but also plays a pivotal role in strategic formulation, operational efficiency enhancement, business model innovation, and employee capability improvement (Çebi & Gözlü, 2023). Thus, it further suggests that digital transformation significantly affects the ability to alleviate financing constraints, enhance the identification, and capture of innovation opportunities, thereby helping reduce the risk of enterprise innovation investment and improving the level of investment volatility management. Under the impetus of the digital wave, organizations can not only better adapt to changes in the external environment but also achieve more precise market positioning, more efficient resource allocation, and more flexible business model innovations through the exploration and utilization of data resources. For organizations, thoroughly understanding and seizing the opportunities and challenges of digital transformation and actively responding to the uncertainty brought by the VUCA environment will be crucial to future development. By formulating scientific digital transformation strategies, optimizing organizational

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structures and processes, and enhancing employee digital literacy, organizations can establish themselves firmly in the digital age and achieve sustainable development.

The theoretical background of digital transformation is extensive and in-depth, covering multiple key areas. Bonanomi points out in his research that multidisciplinary design firms, when promoting digital transformation, need to consider multiple dimensions such as collaboration, iteration, platform, and network paradigms (Bonanomi & Bonanomi, 2019). These paradigms not only integrate considerations at the process and organizational levels but are also influenced by the unique characteristics of the company and its environment. In addition, Xu, Hou, and Wang delve into the frontier research of digital transformation and construct a comprehensive and systematic theoretical framework (Xu et al., 2022), aiming to provide strong support for management practices and guide future theoretical explorations and empirical studies in this field. In the domain of digital workplaces, Weritz emphasizes the importance of key elements such as entrepreneurial mindset, digital responsibility thinking, digital literacy, and change skills (Weritz, 2022). He believes that these capabilities are essential for individuals' development and growth in the digital age, including skills in communication, community management, data analysis, and web development. Markus and Rowe point out in their research that in order to fully utilize diverse theoretical representations of digital transformation, the information systems field needs to clearly distinguish and accurately label various phenomena (Markus & Rowe, 2023). Finally, the research by Hanelt, Bohnsack, Marz, and Antunes further reveals the impact of digital transformation on organizational design (Hanelt et al., 2021) They point out that digital transformation endows organizational design with plasticity, enabling it to continuously adapt to changing environments. This process is driven by digital business ecosystems and is to some extent covered by traditional organizational change frameworks.

Digital transformation is not only a technological innovation but also a profound change in business and organizational models. Kamila Tratkowska's definition in the journal "Management Sciences." reveals its essence: digital transformation is far more than mere technological applications; it touches the very foundation of business models, including value creation, customer interaction, and the reshaping of internal processes (Tratkowska, 2019). At the core of this transformation is the use of digital technology to drive these deep-seated changes, thereby enhancing efficiency, improving customer experience, and exploring new market opportunities. This also provides diverse paths and strategic choices for numerous organizations in pursuit of digital goals, highlighting the complexity and multidimensionality of digital transformation. With the deepening of digital transformation, its impact has permeated various industries, from automotive, energy, and manufacturing to healthcare, banking, tourism, and education, all undergoing profound changes (Haktanır et al., 2022). In the public sector, digital transformation can bring about experimental, inclusive, and anticipatory governments, promoting innovation and creating public value (Kaivo-oja et al., 2022). It is worth noting that some "digital-native" companies such as Alibaba, Uber, and Airbnb, propelled by the winds of digital transformation, have reshaped traditional industry landscapes through innovative business models. By leveraging digital transformation, they break through the boundaries and limitations of traditional industries, providing consumers with more convenient, efficient,

and personalized service experiences. The successful practices of these enterprises not only offer valuable experiences and insights for other businesses but also further demonstrate the important role of digital transformation in driving industry innovation and development.

Meanwhile, the rapid development of digital technologies such as robotics, AI, and virtual reality has deeply integrated into our daily lives, altering our perceptions and modes of interaction (Cinque & Vincent, 2022). In this context, digital twin technology has emerged, bringing new possibilities to organizations, production, and life matrices. The application of digital twin technology in the organizational, production, and life matrices can span multiple dimensions of this matrix. Digital twins are a technology for creating virtual replicas of physical entities, allowing real-time simulation and analysis of the state and behavior of entities. At the organizational level, digital twins can be used to optimize operations, enhance decision-making, and improve efficiency.

Actor-Network Theory

Actor-network theory (ANT) is a theoretical framework for studying the interaction between society and technology, first proposed by Bruno Latour and others in the 1980s (Latour, 2007). The idea originated from the early 1980s at the Centre de Sociologie de l'Innovation (CSI) of the École des Mines in Paris, developed by Michel Callon, Bruno Latour, and John Law, reflecting a post-structuralist concern with non-foundationalism and the multiplicity of material-semiotic relations. At its core, ANT posits that society is composed not only of human actors but also includes non-human actors (such as technologies, objects, concepts, etc.) playing crucial roles within networks. This theory emphasizes the relationships between actors and the process of network construction, suggesting that the formation and development of socio-technical systems occur through ongoing interactions and negotiations among actors. It provides a method for understanding and analyzing the complex interactions within systems, particularly suitable for examining phenomena like digital transformation that are multidimensional and cross-disciplinary. ANT can be viewed as an analytical framework for studying the interactions among science, technology, and society, aiding in understanding processes of technological development and knowledge creation. This approach challenges purely social or technological explanations, emphasizing the relationships between social and technical elements, whether human or non-human (Wikipedia contributors, n.d.) Characterized by its relational, processual, and constructivist nature, ANT can be employed to investigate scientific practices and technological developments. The theory has been widely applied across various disciplines and fields, often serving as implicit background knowledge rather than an explicit theoretical or methodological paradigm.

Within the context of digital transformation explored in this chapter, ANT offers a unique perspective by conceptualizing digital transformation as a network of actors including technologies, human users, developers, regulatory bodies, as well as social norms and practices. It underscores the agency of non-human actors, such as software and algorithms, which is crucial for understanding advancements in human-computer interaction (HCI). Moreover, the concepts

of translation and negotiation within ANT are essential for understanding the interactions among various stakeholders involved in digital transformation. Additionally, ANT's perspective of heterogeneous engineering aids in comprehending the design and development of digital platforms that integrate diverse user needs and technological possibilities. Through this theoretical framework, this chapter explores how "key actors" in digital transformation, such as technologies, humans, organizations, etc., interact and how these interactions form networks that either facilitate or impede transformation. By analyzing trends in HCI development and technological innovation cases in key industries such as finance, retail, healthcare, education, and manufacturing, it demonstrates how the integration of design thinking, future thinking, and AI technology is driving rapid advancements in the HCI field.

In summary, ANT provides robust theoretical support for understanding and guiding the development of digital transformation and future HCI. By revealing the complex interactions among technology, users, and society, ANT helps us better understand how to design and implement more effective and user-centric HCI systems.

An ANT Perspective on Digital Transformation and HCI

To gain a deeper understanding of how digital transformation influences and shapes HCI development, we can employ the perspective of ANT. ANT emphasizes the interactions between human and non-human actors, as well as the importance of translation and negotiation processes in shaping network evolution. Figure 1.1 illustrates a network diagram based on ANT theory, demonstrating key actors and their interactions in digital transformation.

In this network, human actors and non-human actors (such as technologies, business processes, organizational structures, etc.) are intertwined, collectively driving the process of digital transformation. Human actors influence non-human actors through technological innovation, changes in business models, and restructuring of organizational patterns, while non-human actors shape the decisions and behaviors of human actors through empowerment and constraints. This bi-directional interaction reflects the mutual shaping relationships among actors in ANT theory. Various elements of digital transformation, such as technological innovations like AI, big data analytics, cloud computing, Internet of Things (IoT), as well as business and organizational changes like value creation, customer interactions, internal process optimization, and employee skill enhancement, all interact through translation and negotiation processes, ultimately shaping the direction of HCI development. Simultaneously, factors within the field of HCI, such as design thinking, future thinking, and social impacts, also interact with various elements of digital transformation through translation and negotiation processes, influencing the outputs and outcomes of HCI, such as user insights, rapid iterative development, seamless interaction experiences, personalized services, and social responsibility considerations. By presenting a complex interaction network between digital transformation and HCI based on ANT theory, this chapter highlights the critical roles of both human and non-human actors in translation and negotiation processes, as well as how these processes collectively drive the development and evolution of HCI. This offers a new perspective for comprehensively understanding the impact of digital transformation

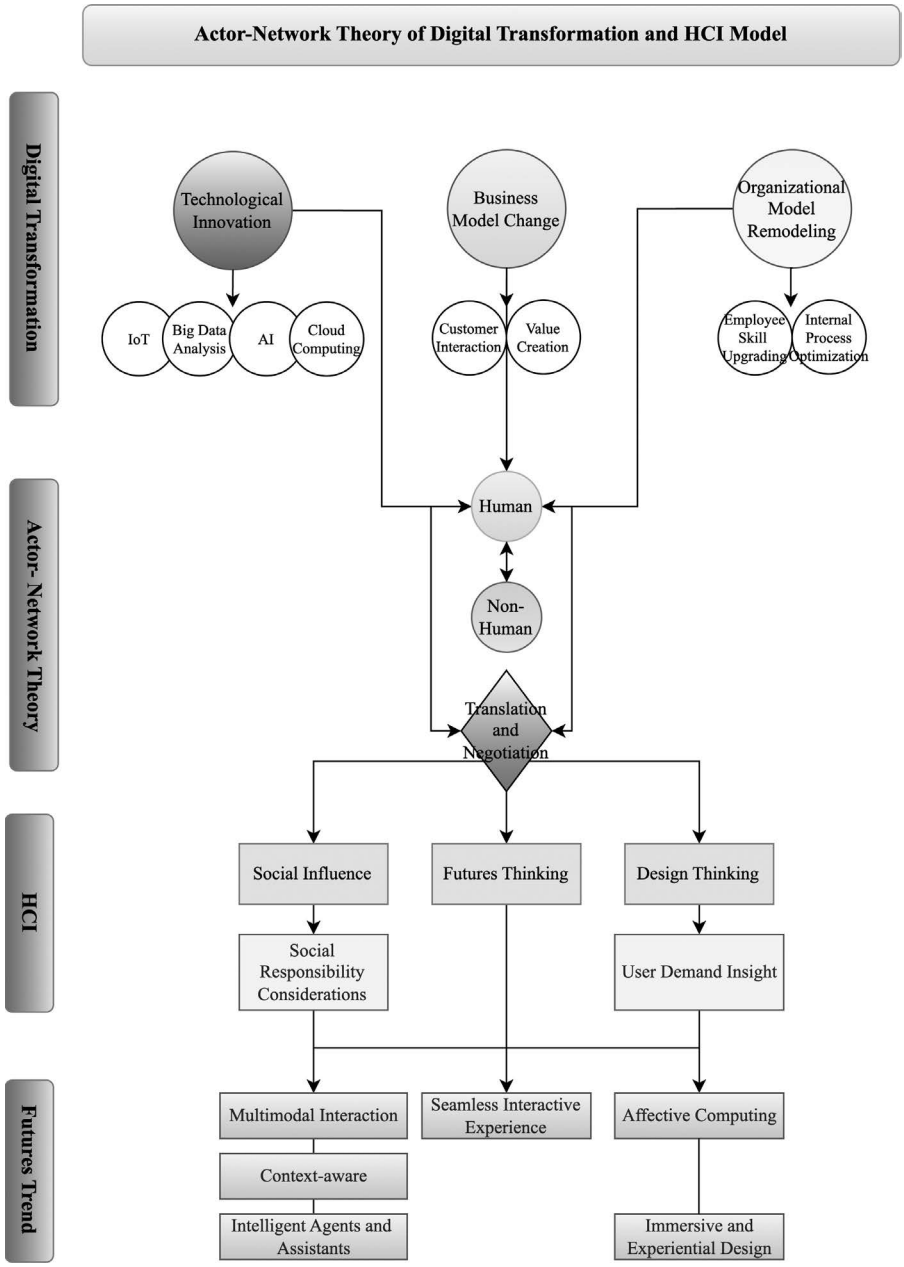

FIGURE 1.1 An ANT Network of Digital Transformation and HCI

on HCI and considering multiple factors, such as technology, business, organization, and society, when designing future HCI systems.

To further elucidate and analyze the relationship between digital transformation and HCI, the authors introduces the concepts of "human actors" and "non-human actors" from ANT theory and represents their interactions in digital transformation using subgraphs. Emphasizing the bi-directional influence between human and non-human actors, this approach underscores the interactions and mutual shaping among actors in ANT theory. In the section on HCI, the author introduces the "translation and negotiation" processes, linking factors such as design thinking, future thinking, and social impacts, demonstrating how they collectively influence the development of HCI through translation and negotiation. The outputs of HCI, including user insights, rapid iterative development, seamless interaction experiences, personalized services, and social responsibility considerations, are all formed through translation and negotiation processes between human and non-human actors, further highlighting the core concepts of ANT theory, such as the interaction between human and non-human actors, translation and negotiation processes, and how these processes collectively shape the development of digital transformation and HCI. Additionally, it illustrates the close connection between digital transformation and HCI and how various factors influence HCI outputs and outcomes through complex interactions.

Factors Driving Digital Transformation and ANT Analysis

Digital transformation represents a critical challenge and opportunity for contemporary societies and organizations. It involves leveraging digital technologies to reimagine and redesign business models, products, and services in response to rapidly changing market demands and societal expectations (Vial, 2021). Applying ANT to analyze digital transformation can unveil the intricate networks of actors involved. In this process, ANT provides a robust analytical framework for understanding how technology, humans, and organizations interact within the socio-technical networks shaping and propelling digital transformation (Latour, 2005a). Technology is no longer merely a tool or medium for change but can actively participate as an actor in the construction of socio-technical systems. For instance, cloud computing platforms, as non-human actors, interact with enterprises (human actors) and market strategies (conceptual actors), jointly driving innovation and evolution in business models. Enterprises, by adopting cloud platforms, gain more flexible access to, storage of, and processing of large volumes of data, which may have been previously unattainable due to cost and technological constraints. This adoption not only alters the IT infrastructure of enterprises but also facilitates the emergence of new work patterns and service models. Within this new socio-technical structure, the interaction between cloud platforms and enterprises fosters process optimization, improved collaboration efficiency, and the creation of new services. Similarly, cloud platforms are closely linked with conceptual actors like market strategies. With intensified market competition, enterprises need to respond more flexibly and agilely to market changes, and the elasticity and scalability of cloud platforms meet this demand. Enterprises utilize cloud platforms to deploy applications and services rapidly, achieving personalization and customization, thereby better attracting and

retaining customers. Additionally, cloud platforms interact with regulatory bodies in the form of government regulations and standards. With the strengthening of data security and privacy regulations, cloud service providers must ensure compliance with legal requirements. This may influence the design and management of cloud services, thereby impacting how enterprises utilize these services to support their operations. Ultimately, consumer behavior also acts as a significant actor influencing the application and development of cloud platforms. As user expectations for internet services continue to rise, they increasingly favor services that offer seamless, instantaneous, and personalized experiences. Cloud platforms enable enterprises to meet these expectations, launching more attractive products and services, thereby shaping consumer usage habits and preferences. In this complex network comprised of diverse actors, cloud platforms symbolize not only technological innovation but also crucial participants driving socio-economic transformation and innovation in the digital age. Through interactions with other actors, cloud platforms continuously reshape the business landscape of the digital era, demonstrating their significant role in contemporary socio-technical change.

ANT challenges traditional technological determinism and social constructivist perspectives, proposing that technology and society are co-constituted through interactions within networks. This perspective is particularly useful for analyzing digital transformation as it necessitates researchers to consider a wide range of actors, including users, developers, policymakers, and the technology itself, and how they collaborate and compete within evolving networks. Furthermore, digital transformation is also regarded as a key driver of social and economic development. Kallinikos, Aaltonen, and Marton explore how digital technologies reshape modes of information processing, communication, and organizational collaboration, thereby influencing social structures and individual behaviors (Kallinikos et al., 2013). These changes not only reflect technological advancements but also embody a reimagination of how people live and work. Finally, as digital transformation deepens, considerations for ethics and privacy become increasingly important. The data collection and processing activities spurred by digital transformation exacerbate concerns regarding individual privacy protection and data security (Zuboff, 2019). Within the analytical framework of ANT, these concerns are viewed as actors within the network, whose voices and rights need to be fully considered and protected throughout the digitization process. By applying the core concepts of ANT to analyze digital transformation, we can gain a deeper understanding of how various actors interact and how these interactions shape and reshape the trajectory and outcomes of digital transformation. The author believes that ANT provides a robust framework for exploring and analyzing the complexity and dynamism of digital transformation, emphasizing the roles of both human and non-human actors in shaping and developing digital networks (Table 1.1).

KEY INDUSTRY EXAMPLES OF DIGITAL TRANSFORMATION

Digital transformation has brought revolutionary changes to traditional industries such as finance, retail, healthcare, and education by introducing digital technologies like mobile applications, online platforms, and AI, significantly enhancing

TABLE 1.1
ANT Core Concept Explanation and Application in Digital Transformation

Core Concepts of ANT	Conceptual Explanation	Application in Digital Transformation
Actor	Actors can be individuals, groups, organizations, or any non-human entities capable of influencing the network. In ANT, actors have equal status, whether human or non-human.	In digital transformation, actors include employees, management, IT systems, smart devices, and so on. For example, smart devices (such as IoT devices) act as actors by collecting and analyzing data, influencing business decisions and operations.
Network	The network is a relational structure formed by interactions among actors. These relationships define how actors influence each other and the behavior and development of the entire network.	The networks involved in digital transformation encompass various interconnected elements such as technological infrastructure, organizational structure, and business processes. For instance, cloud computing platforms connect different business applications and data storage, forming networks that support digital businesses.
Translation	Translation refers to the process of interaction among actors, through which actors translate their intentions, needs, or goals into actions and relationships within the network.	Translation occurs during the process of transforming organizational goals into specific technical solutions. For example, the digital strategy of a company (the intent of the actors) is translated into concrete technology deployments and business process transformations.
Mediator	Mediators in ANT refer to entities that, during the process of transmission, can change, transform, or reconstruct the content they transmit. Mediators cause changes in relationships and actions within the network.	In digital transformation, software tools and platforms serve as mediators; they not only transmit information but also can change work methods and business models. For example, data analytics software can transform raw data into insights, thereby altering the decision-making process.

operational efficiency and user experience, and driving service modernization. The author discusses digital banking and digital e-commerce as key examples.

In the financial sector, Singapore's DBS Bank has successfully transformed into a leading digital bank through its "digital banking" strategy, introducing mobile banking apps, online trading platforms, and AI customer service, greatly optimizing traditional banking service models (Garg et al., 2021). In its digital transformation process, DBS adopted a "comprehensive and progressive" strategy. On the one hand, it vigorously embraced emerging digital technologies, continuously innovating digital products and services through a combination of internal development and external collaboration. On the other hand, it emphasized integration with traditional businesses, striving for seamless integration of online and offline, and old and new

systems. Specifically, DBS invested heavily in digital infrastructure construction, building a cloud-native modern IT architecture, significantly improving system flexibility and response speed. It also redesigned the entire digital operation and service process, improving front-end service efficiency and reducing back-end operating costs. In terms of customer experience, DBS is committed to providing users with simple, intelligent, and seamless experiences. By analyzing customer behavior preferences through big data, it launches personalized products and services. Leveraging technologies such as AI and machine learning (ML), it provides value-added services such as intelligent risk control and intelligent investment advice. Meanwhile, DBS Bank's integrated approach, combining its mobile app, online banking, and physical branches, offers customers a consistent cross-channel experience. Additionally, DBS actively embraces the concept of open banking, collaborating with fintech companies, e-commerce platforms, and social media to innovate financial scenarios continuously, expanding user touchpoints. For instance, it introduced the PayLah! e-wallet, integrating into daily life payment scenarios, and partnered with Taobao to launch the Tao Silver service, among others. These digital initiatives helped DBS Bank achieve low-cost, high-efficiency operations while providing customers with unprecedented premium experiences, facilitating its successful transformation into a leading digital bank.

In the retail industry, e-commerce giants Alibaba and Amazon have reshaped the shopping experience and supply chain management through digital platforms. Alibaba's "new retail" strategy, in particular, integrates online and offline scenes through an O2O model, delivering a seamless shopping experience to consumers and fundamentally changing traditional retail formats. Specifically, Alibaba, through its platforms such as Tmall and Taobao, has built an efficient digital trading scene for consumers and merchants. Consumers can purchase and pay online, enjoying convenient shopping experiences, while merchants utilize the platform for precise marketing and channel expansion. Alibaba also built an intelligent logistics system to improve delivery efficiency (Kim, 2018). Moreover, Alibaba's "new retail" strategy further integrates online and offline businesses, upgrading physical store operations through digital means to provide consumers with a seamless experience. On the other hand, Amazon's success stems from its advanced digital supply chain system and customer-centric philosophy. Through big data analysis, Amazon can accurately predict customer demands and achieve efficient inventory management. Its core lies in providing rich, low-cost, and efficient products and services. Additionally, Amazon has vigorously developed its self-operated logistics and AI technologies to continuously enhance operational efficiency. The digital practices of these two e-commerce giants greatly enrich consumers' shopping scenarios, bring new business growth opportunities to merchants, and drive the entire retail format toward digitization and intelligence.

During the pandemic, telemedicine has become an important means to ensure public health through digital means such as mobile applications, video consultations, and AI assistance, providing convenient medical services to patients at their doorsteps (Smith et al., 2020). In the education sector, online education platforms such as Coursera, Khan Academy, and edX have emerged, breaking geographical and time constraints, making high-quality educational resources accessible, and meeting

the needs of personalized and flexible learning for students. It is evident that digital transformation empowers traditional industries comprehensively, driving efficiency improvements and service optimization, bringing unprecedented convenience and intelligent experiences to people's production and life.

THE DEVELOPMENT TRENDS OF HUMAN-COMPUTER INTERACTION: STARTING FROM THE ANT PERSPECTIVE

HCI is a discipline that studies the interaction between humans and computer systems, aiming to design more user-friendly, efficient, and humane technological products and services. With the deepening of digital transformation, the HCI field faces unprecedented challenges and opportunities. Combining the characteristics of ANT mentioned earlier provides a useful analytical perspective for understanding and deciphering the intricate interactions between technology and human actors in HCI.

First, ANT emphasizes that HCI involves not only direct interactions between humans and machines but also the roles of various non-human actors such as the environment, society, and culture. The work of Norman emphasizes the importance of design in optimizing HCI, proposing that design principles should fully consider human needs and limitations (Norman, 2013). Through the theoretical framework of ANT, we can further expand this viewpoint, viewing the design process as an interaction and negotiation among human and non-human actors such as machines, environments, societies, and cultures. Suchman, through case studies of HCI, proposed the concept of "situated action," emphasizing the situational and interactive nature of the interaction process (Suchman, 1987). By applying ANT theory, this insight can be extended to a broader social-technical network, thus understanding how HCI is a dynamically constructed process involving multiple actors. On the other hand, with the continuous evolution of technology, the HCI field is exploring more complex interaction methods, such as communication with computer systems through touch, sound, brain signals, etc. Kaptelinin and Nardi discussed the application of activity theory in HCI design, emphasizing the interactive relationship between human activity practices and technology (Kaptelinin & Nardi, 2012). Combining activity theory with ANT provides an integrated theoretical framework for analyzing and designing complex HCI systems. Looking back to the present, the rise of AI and ML technologies has brought new changes to HCI. Oulasvirta and Hornbæk studied the role of AI in HCI design, particularly how AI is used to predict and adapt to user needs and behaviors (Oulasvirta & Hornbæk, 2016). From the perspective of ANT, the progress of such technology reflects not only the evolution of technology itself but also the redefinition of the roles and relationships between human and machine actors in the constantly changing social-technical network. Overall, with the continuous advancement of digital technology, ANT will undoubtedly open up new theoretical perspectives and practical paths for HCI research. ANT provides a social-technical integrative analysis perspective, helping to comprehensively understand the interactions among various actors in the HCI process and the relationship between technology and human activity practices, thus supporting the design of more humane and situational interaction experiences.

Four Waves of HCI

HCI is a multidisciplinary field focused on understanding and designing interactions between humans and computers. It integrates theories and methods from various disciplines such as anthropology, sociology, cognitive science, and psychology. The scope of HCI technology covers various aspects, from ethnography and participatory design to usability testing and controlled experiments. Over the years, HCI has evolved to involve various aspects of people's lives, including spirituality, global crises, disabilities, as well as emerging technologies such as wearable devices, robots, and virtual reality. The future prospects of HCI research include gamified interactions, self-tracking and behavior change technologies, conversational agents, among others (Seaborn & Fels, 2015; Kersten-van Dijk et al., 2017; Weger & Yeazitzis, 2023). The development of HCI can be divided into four stages or waves: the first wave of HCI focused on cognitive science and human factors, employing strict guidelines, formal methods, and systematic testing; the second wave shifted toward interactions within work environments and practice communities, introducing concepts such as context and adopting active methods like participatory design workshops and contextual inquiry (Bødker, 2015); the third wave emphasized the contextual nature of HCI, recognizing that interactions are embedded in complex and constantly changing environments, and emphasized the staged nature of language communication (Borin & Edlund, 2018). Some scholars advocate for embracing the fourth wave of HCI, prioritizing politics, values, and ethics, driving true institutional change, and incorporating political activism into mainstream HCI (Rydenfält & Persson, 2020). Additionally, feminist theories of science, technology, and society are used to examine normative cultures in computer science, revealing gender differences and power relations in the field (Ashby et al., 2019).

What Are the Challenges and Opportunities for HCI in the Next Wave?

Currently, HCI is in a new era full of opportunities and challenges. With the rapid development of emerging technologies such as AI, the IoT, and virtual reality, HCI needs continuous innovation and adaptation to meet the growing needs and expectations of people. In this process, HCI faces many challenges but also contains enormous opportunities.

First, the emergence of human-computer hybrid systems poses new challenges to HCI. In these systems, humans and machines need to collaborate seamlessly to complete tasks. However, how to ensure effective communication and coordination between humans and machines, and how to manage and optimize the accuracy of language interactions are urgent issues to be addressed (Dove et al., 2022). Additionally, creating and conveying personalized interaction experiences in dialogue systems is also a topic worthy of in-depth exploration (Pinhanez, 2020). At the same time, mastering the appropriate timing of interactions, knowing when to initiate dialogue actively and when to listen silently, is crucial for enhancing user experience (Frauenberger, 2019). Despite the many challenges, HCI also faces numerous opportunities in the next wave of development. With the popularity of the IoT, supporting interactive skill sharing and autonomous learning becomes possible. Users can share their skills with

other users or smart devices in the IoT environment, or learn new skills autonomously by observing and imitating (Jones et al., 2023). This new interaction mode is expected to greatly enhance user creativity and productivity. Another opportunity is the development of Entanglement HCI. This emerging field focuses on the performance relationship between humans and technology, reconstructing the process of knowledge generation, tracking accountability and ethical issues, exploring design and material practices, etc. By integrating humanities and social sciences with engineering technology, Entanglement HCI is expected to reveal the deep-seated rules of HCI, and promote HCI toward a more humane, intelligent, and trustworthy direction. In addition, HCI education also faces opportunities for change and innovation. By studying the interaction modes between students and users, exploring reflective teaching methods, we can cultivate more HCI talents with interdisciplinary perspectives and innovative capabilities (Roldan et al., 2020). These talents not only master technology but also have profound humanistic literacy and social responsibility, able to think and design from the perspective of users, promoting HCI to better serve the development of human society.

The author believes that HCI is both facing challenges and full of opportunities in the next wave of development. As researchers or practitioners in HCI, we should base ourselves on the present, look to the future, bravely face challenges, seize opportunities, continuously innovate, and promote the continuous advancement of this dynamic and promising field of HCI. Only in this way can we better utilize HCI technology, let technology truly serve people, and benefit human society.

The Interaction between Digital Transformation and HCI

In the wave of digital transformation, HCI plays a crucial role. As a bridge connecting technology and users, the development of HCI not only drives digital transformation but also is deeply influenced by it. From the perspective of ANT, digital transformation and HCI constitute a complex network composed of various actors, including technology, users, organizations, and social environments. In this network, each actor interacts and influences each other continuously, shaping the trajectory of digital transformation and HCI development collectively.

On the one hand, digital transformation provides new opportunities and challenges for HCI development. The emergence of emerging technologies such as AI, virtual reality/augmented reality (AR), and the IoT has opened up new possibilities for HCI design. These technologies not only change the way people interact with digital systems but also challenge traditional HCI design principles and methods. For instance, the development of AI technology enables more natural and intelligent HCI, but it also raises new issues regarding privacy, security, and ethics. On the other hand, the development of HCI also provides essential support and guidance for digital transformation. Well-designed HCI systems can significantly enhance the effectiveness of digital transformation, promote the adoption and application of new technologies. The research results in the HCI field, such as user experience design, ergonomics, and human-computer collaboration, provide important theoretical guidance and methodological support for the practice of digital transformation. For example, user-centered design concepts help ensure that digital transformation initiatives truly meet user

needs, thereby enhancing user acceptance and participation. The interaction between digital transformation and HCI is fully reflected in various industries. In finance, retail, healthcare, education, manufacturing, and other fields, digital transformation initiatives have introduced cutting-edge HCI technologies and design concepts, bringing innovation to business models and user experiences. Conversely, the digital transformation practices in these industries also provide rich application scenarios and empirical cases for HCI research, promoting further development of HCI theories and methods.

Successful HCI cases, such as intelligent assistants and wearable devices, demonstrate the interaction between technology, users, and social environments in the process of digital transformation, driving the evolution of HCI design. Take intelligent assistants as an example; their design not only reflects the progress of AI technology but also embodies the changes in user needs and society's expectations for convenience and intelligent services. In various industries' digital transformation processes, HCI plays a key role. For example, in the financial industry, the application of virtual customer service representatives and chatbots is becoming increasingly popular. These AI-based systems can provide 24/7 services, answer customer inquiries, process transactions, and even provide personalized financial advice. For instance, Bank of America's "Erica" virtual assistant uses AI and predictive analytics to help customers manage their finances (Bank of America, n.d.). In the retail industry, AR technology brings more interaction and fun to the shopping experience. IKEA's "IKEA Place" app allows users to virtually place furniture in their homes, helping them make wiser purchasing decisions while reducing returns due to size or style mismatch (IKEA, 2017). In the healthcare industry, wearable technology benefits from the push of digital transformation. Devices like Fitbit and Apple Watch can monitor users' health indicators in real-time, provide personalized health reports and advice through synchronization with smartphones, and even predict the risk of certain health issues (Patel et al., 2012). In the education field, VR and AR technologies are creating immersive learning experiences (Google, 2017a). Google Expeditions allow students and teachers to visit remote geographic locations or historical scenes through VR, providing a new interactive and participatory learning mode. In manufacturing, collaborative robots (Cobots) play an important role in the digital transformation of the manufacturing industry. These robots are designed to work safely with human workers, performing tasks such as assembly, polishing, and painting. Companies like General Electric and BMW have successfully deployed Cobots on their production lines, improving flexibility and efficiency (Liu et al., 2024).

With the continuous deepening of digital transformation, HCI plays an important role not only in the above-mentioned industries but also in a wider range of fields, and the boundaries of HCI are constantly expanding. The emergence of the "More-than-human HCI" concept marks the transition of HCI from a human-centered approach to a more ecological and diversified development stage. This trend is highly consistent with the sustainable development goals of digital transformation, emphasizing the full consideration of the interests and well-being of non-human actors (such as animals, plants, and the environment) in the digital transformation process, promoting harmonious coexistence between humans and nature. The interaction between digital transformation and HCI is complex and close. As an important part of digital

transformation, the development of HCI is not only driven and influenced by digital transformation but also provides crucial support for the successful implementation of digital transformation. From the perspective of ANT, examining the interaction between the two, we can more comprehensively grasp the opportunities and challenges of digital transformation and explore a more inclusive and sustainable development path. With the emergence of new concepts such as "More-than-human HCI," the interaction between digital transformation and HCI will enter a new stage that is more ecological, intelligent, and human-centric, contributing wisdom and strength to the sustainable development of human society and the Earth's home.

Technological Innovation and User Experience

In the wave of digital transformation, the field of HCI is undergoing unprecedented changes. Technological innovation and user experience, as two core elements of HCI development, are increasingly receiving attention from both academia and industry for their interaction and influence. From the perspective of ANT, the enhancement of technological innovation and user experience depends not only on the efforts of individual actors but also on the result of the collaborative actions of the entire actor-network.

Technological innovation serves as a significant engine driving HCI development. The emergence of new technologies such as AI, virtual reality/AR, and the IoT has opened up new possibilities for HCI design. Take haptic feedback technology as an example; its development has significantly improved the immersion and interactivity of virtual reality systems, providing users with a more realistic and natural experience (Pacchierotti et al., 2017). However, ANT theory reminds us that the success of technological innovation depends not only on the advancement of technology itself but also on its alignment with factors such as user needs and sociocultural environments. Only when new technologies can effectively meet users' real needs and are widely accepted and used in specific sociocultural contexts can their value be truly realized (Latour, 2005b).

User experience is a crucial indicator for measuring the success of HCI design. Digital transformation not only changes the way users interact with technology but also raises higher requirements for user experience. From the ANT perspective, the formation of user experience is not only influenced by technical factors but also closely related to users' cognition, emotions, and behaviors (Hassenzahl, 2013). To enhance user experience, HCI designers need to deeply understand users' needs and expectations and closely integrate them with the technological innovation process. Moreover, different sociocultural environments also have significant impacts on user experience. Cross-cultural studies indicate significant differences in user preferences and acceptance of interaction design across different cultural backgrounds (Reinecke & Bernstein, 2013). Therefore, HCI design needs to fully consider cultural diversity and provide user experience solutions that meet localization needs.

At the organizational level, digital transformation is reshaping the operation mode and value creation logic of traditional organizations. Traditional organizations are mostly centered around the physical world, emphasizing physical resources and offline operations, while digital organizations pay more attention to the development

and utilization of the virtual world. They reconstruct and optimize business models, organizational structures, and value chains through digital technology and innovative thinking (Vial, 2021). This transformation is not only reflected in the digitization and automation of internal processes but also in the fundamental change in the interaction mode between organizations and the external environment. Digital organizations are more open, agile, and flexible, capable of rapidly sensing and responding to market changes, and collaborating deeply with customers, partners, and other stakeholders through digital platforms and ecosystems (Vial, 2021).

In the production field, digital transformation is driving the transition from traditional manufacturing to smart manufacturing and personalized customization. Traditional production models primarily rely on the physical world, relying on large-scale, standardized production lines to achieve economies of scale. Digital production fully leverages the advantages of the virtual world, realizing intelligent design, simulation optimization, and rapid iteration of products through technologies such as digital twins and additive manufacturing (Tao et al., 2019). This production model is more flexible and efficient, capable of meeting the increasingly diverse and personalized needs of users. At the same time, the deep integration of the virtual world and the physical world also provides strong support for real-time monitoring, predictive maintenance, and other aspects of the production process, contributing to the improvement of production efficiency and product quality (Kusiak, 2018).

In summary, the interaction between technological innovation and user experience in digital transformation can be summarized in the following aspects (Table 1.2).

These transformations reflect the profound impact of digital transformation on the HCI field, while also indicating new directions and possibilities for HCI research and practice. As digital transformation continues to deepen, the synergistic development of technological innovation and user experience will become an important proposition in the HCI field.

TABLE 1.2
The Interaction between Technological Innovation and User Experience in Digital Transformation

Dimensions	Traditional Models	Digital Transformation
HCI Design	Technology-Centric	User-Centric, emphasizing alignment between technology and user needs, as well as societal and cultural contexts.
Organizational Operations	Physical World-Centric, emphasizing physical resources and offline operations.	Virtual World-Centric, restructuring business models and organizational structures through digital technologies and innovative thinking.
Production Models	Primarily relying on the physical world, leveraging large-scale, standardized production lines.	Primarily leveraging the virtual world, implementing intelligent design and personalized customization through digital twins, additive manufacturing, etc.

When exploring the impact of digital transformation on HCI, it may be beneficial to approach it from a scenario construction perspective. Analyzing the impact of digital transformation on HCI can help us to comprehensively and systematically understand this complex and dynamic process (Bishop et al., 2007). By identifying key uncertainties and exploring multiple possible future scenarios, decision-making and strategic planning can be facilitated. In the context of digital transformation, the dimensions of physical world/virtual world and traditional/digital represent crucial uncertainties shaping the future development of HCI. By constructing a 2×2 matrix based on these dimensions and utilizing relevant future research methods such as Futures Triangle (Inayatullah, 2008), Futures Signals (Hiltunen, 2008), Futures Signs (Saritas & Smith, 2011), and Futures Wheel (Glenn, 2009), a more comprehensive analysis of the impact of digital transformation on HCI can be achieved. Additionally, employing the causal layered analysis (CLA) method (Inayatullah, 1998), allows for the exploration of the deeper factors influencing how digital transformation affects HCI, such as worldviews, values, and institutions. From the perspective of the experience triangle, the future development of HCI needs to comprehensively consider the dimensions of product, audience, and context (Hassenzahl, 2018).

On the other hand, analyzing the internal and external influences of human-driven and technology-driven factors is crucial for understanding the motives, processes, and outcomes of digital transformation. Human-driven factors emphasize a people-centric approach, focusing on the impact of digital transformation on individuals, organizations, and society, and emphasizing the harmony between technological development and human values. Technology-driven factors, on the other hand, focus on driving business growth and efficiency improvement through technological innovation, emphasizing the leading role of technology in digital transformation (Vial, 2021). The impact of digital transformation on HCI can be examined from the perspectives of the Anthropocene and Metamodernism. In this context, human-driven approaches need to consider the ecological effects and social ethical impacts of technology, while technology-driven approaches need to balance technological humanistic connotations and social responsibilities, considering the shaping role of technology on deep-seated factors such as user emotions and identity. The concept of the Anthropocene emphasizes the profound impact of human activities on the Earth's ecosystem, prompting us to reflect on the relationship between technological development and sustainability (Latour, 2017). In this context, human-driven digital transformation needs to pay more attention to the ecological effects of technology, ensuring the coordination and unity of the digital process with environmental protection. At the same time, human-driven digital transformation also needs to consider the impact of technology on social ethics and human values, avoiding the negative externalities of technology. Metamodernism represents a cultural trend of reconstructing meaning and value after the deconstruction of postmodernity (Vermeulen & Van den Akker, 2010). In the context of metamodernism, technology-driven digital transformation not only seeks efficiency and functionality improvement but also considers the humanistic connotations and social responsibilities of technology. This implies that HCI design should not only meet users' functional needs but also consider the shaping role of technology on deep-seated factors such as user emotions and identity (Table 1.3).

TABLE 1.3
The Shaping Role of Underlying Factors

Analytical Dimensions	Internal Influences	External Influences
Human-driven	Emphasize the ecological impact of technology to ensure the coordination and harmony between digitalization processes and environmental conservation.	Pay attention to the impact of technology on social ethics and human values, avoiding negative externalities of technology.
Technology-driven	Pursue efficiency and functionality enhancement while also considering the humanistic implications and social responsibilities of technology.	Consider the role of technology in shaping deep-seated factors such as user emotions and identity.

DESIGN THINKING AND FUTURES THINKING: SHAPING THE DIGITAL FUTURE

Integration of Design Thinking and Futures Thinking

In the digital age, the integration of design thinking and futures thinking has opened up new perspectives for HCI design. Design thinking emphasizes innovative approaches that are human-centered, technically feasible, and commercially viable (Brown, 2009), focusing on the process of innovative problem-solving and employing user-centered design methods and iterative experimentation. Futures thinking, on the other hand, focuses on exploring and predicting possible future scenarios, forming forward-looking innovative solutions based on this exploration. As mentioned earlier, the six pillars of futures thinking—mapping, predicting, timing, deepening, creating alternative futures, and transforming—provide HCI designers with a methodology to consider long-term social trends and technological developments during the design process, ensuring that design outcomes meet the needs and expectations of future users (Inayatullah, 2008).

The integration of design thinking and futures thinking not only enhances the foresight and capability to address complex problems but also encourages interdisciplinary collaboration. Sanders and Stappers emphasized the importance of co-creation, where designers, researchers, users, and other stakeholders participate in the design process, exploring and defining possible future scenarios and solutions through the integration of different perspectives and knowledge (Sanders & Stappers, 2014). Dubberly and Pangaro demonstrated how systems thinking can be applied in the design process, emphasizing the importance of considering interactions between systems when designing complex interactive systems (Dubberly & Pangaro, 2009). By combining systems thinking with design thinking and futures thinking, HCI designers can gain a more comprehensive understanding and design HCI systems that meet future user needs and technological trends.

Impact of Integrated Thinking on HCI

The combination of design thinking and futures thinking has profound implications for the future development of HCI. It encourages designers to not only focus on the application of current technology and immediate user needs but also anticipate the impact of future technological changes and societal shifts on user experience. This approach leads to a series of innovative HCI patterns, such as more natural language interaction, more efficient user interface design, and more personalized services. Furthermore, this integration also encourages interdisciplinary collaboration, allowing knowledge and theories from fields such as psychology, cognitive science, and sociology to be incorporated into HCI design, resulting in more comprehensive and in-depth design solutions.

As design thinking and futures thinking become more deeply integrated, the design principles of HCI are evolving. Designers are increasingly concerned with how to use technological innovation to address social issues, how to consider sustainability in design, and how to ensure that technological progress benefits all demographics. This evolution not only drives technological and methodological innovation in the HCI field but also promotes a sense of social responsibility and ethical awareness in design practice. By applying design thinking and futures thinking to HCI design, we can better understand the interactions between humans, technology, and society, contributing to the creation of a more humane, inclusive, and sustainable digital future.

Innovative Case Analysis

With the widespread application of design thinking and futures thinking in the HCI field, we have seen many impressive innovative cases. These cases not only showcase the latest advances in current technology but, more importantly, demonstrate how designers shape the future through forward-thinking and user-centered design methods.

Smart home control systems like Google Nest represent the application of design thinking and futures thinking in daily life (Google, 2020). By learning user preferences and automatically adjusting the home environment, these systems provide a more personalized and intelligent living experience. This design not only considers the current needs of users but also anticipates future expectations for home automation and energy efficiency. Similarly, wearable devices like Fitbit and Apple Watch demonstrate how design thinking and futures thinking are applied in the field of health management (Patel et al., 2015). These devices help users develop healthy habits through continuous monitoring and personalized feedback, reflecting designers' considerations for future health management models. In the customer service field, Alibaba's "Xiaomi" robot represents the innovative application of AI technology in HCI (Zeng, 2018). Through natural language processing and ML, "Xiaomi" can understand customer intentions and provide precise answers, greatly improving service efficiency and user satisfaction. This case demonstrates the development trend of future HCI, namely, using AI technology to create more natural and efficient interaction experiences. The application of virtual reality technology in education

and training fields, such as Google Expeditions, demonstrates the potential of design thinking and futures thinking in reshaping learning methods (Google, 2017b). Through immersive experiences, students can learn knowledge in a more intuitive and interactive way, improving learning interest and effectiveness. This innovation not only addresses current pain points in education but is also based on thinking and exploration of future learning models. In the transportation field, Tesla's Autopilot autonomous driving technology demonstrates the application of design thinking and futures thinking in addressing urban traffic issues. By integrating advanced sensors and AI analysis, this technology can optimize traffic flow, improve road safety, and provide ideas for the construction of future smart cities (Tesla, Inc., n.d.).

These innovative cases demonstrate the application of design thinking and futures thinking in various fields and their tremendous potential in shaping the future of HCI. By being user-centered and based on insights into future technological and social trends, designers can create more intelligent, efficient, and personalized interaction experiences, bringing substantial improvements to people's lives. At the same time, these cases also inspire us that design thinking and futures thinking are not just methodologies but also a shift in mindset. It requires designers to break free from current limitations, think about future possibilities with an open and innovative mindset, and use interdisciplinary knowledge and skills to turn visions into reality. Only by embracing change and designing the future with foresight can we create HCI experiences that truly meet people's needs and drive social progress.

THE FUTURE OF HUMAN-COMPUTER INTERACTION: THE ROLE OF ARTIFICIAL INTELLIGENCE

The Impact of Artificial Intelligence on HCI

The rapid advancement of AI technology is profoundly shaping the future of the HCI field, becoming a key driver for innovation in interaction design. The introduction of AI not only enhances the intelligence level of devices but also enhances the personalization and adaptability of user experiences, while opening up new interaction patterns and application scenarios. The progress in NLP technology enables voice assistants to more accurately understand and respond to user voice commands, making interactions more intuitive and natural. ML algorithms, on the other hand, can continuously learn from user behavior and preferences to provide more customized services and recommendations. The application of these AI technologies greatly improves HCI design, providing users with smarter, more efficient, and insightful experiences. However, we also need to recognize the challenges AI application in HCI faces. Amershi, Cakmak, Knox, and Kulesza pointed out the crucial importance of ensuring the usability and accessibility of AI systems, as it relates to users' ability to effectively understand and control these systems (Amershi et al., 2014). Shneiderman criticized the risks of excessive reliance on AI, particularly in neglecting user control and transparency. He advocates for the adoption of "Human-in-the-Loop" design principles to ensure that the application of AI technology does not undermine human decision-making autonomy and agency (Shneiderman, 2020). These viewpoints indicate that when integrating AI into HCI design, we must

carefully weigh its pros and cons and prioritize human-centeredness to ensure that technology always serves human needs.

To better anticipate the future impact of AI on HCI, we need to gain insights into technological trends and user expectations. Horvitz explored the intersection of AI and HCI, particularly in the application of AI for predicting user intents and needs. He introduced the concept of "mixed heuristics" to guide AI system design for better supporting human decision-making processes and enhancing the efficiency and effectiveness of human-computer collaboration (Horvitz, 2007). Research by Wang, Yang, Abdul, and Lim showcased the potential applications of AI in affective computing and user emotion recognition (Wang et al., 2019). These advancements indicate that future AI technologies will be able to create more sensitive and empathetic interaction systems, significantly improving user experiences.

Applications of AI in HCI: Case Studies

The author believes that foreseeing the development trends of AI in the HCI field is crucial for designing future-oriented HCI systems. By understanding the potential and limitations of AI, grasping user expectations and values, we can better guide technological innovation to shape a more intelligent, humane, and inclusive digital future. This requires HCI researchers and practitioners to maintain a forward-thinking mindset, actively embrace change, and uphold human-centered principles to ensure that AI technology always serves the goal of improving human life and societal well-being. Therefore, from the perspective of technological progress, such as the continuous development and integration of technologies such as AI, robotics, and the IoT, will drive innovation and breakthroughs in these fields. Second, in terms of user demand, people's expectations for smarter, more personalized, and efficient services and experiences are constantly increasing, which will drive the deepening application of AI in HCI. Furthermore, contemporary societal challenges, such as population aging, environmental degradation, and resource scarcity, highlight the potential key role of AI technology in addressing these challenges. Finally, in terms of value orientation, people's values toward technology are changing, placing more emphasis on human-centeredness, inclusivity, and sustainability, which will influence the development direction of AI technology. By analyzing multiple factors such as technology, demand, society, and values, we can foresee that AI will trigger extensive and profound changes in the future HCI field, creating a more intelligent, humane, and sustainable HCI ecosystem (Table 1.4).

FUTURE OPPORTUNITIES AND CHALLENGES

With the rapid advancement of AI technology, its application in the HCI field brings numerous opportunities for future interaction design while also facing several challenges. On the one hand, the introduction of AI technology is expected to significantly enhance the intelligence level of HCI and improve user experiences by opening up new interaction modes and application scenarios. On the other hand, ensuring the human-centric nature of interaction design, safeguarding user privacy and security, and balancing human-machine decision-making authority pose

TABLE 1.4
Anticipating the Changes AI Will Trigger in the Future HCI Field

Domain	Concept	Present	Near Future (5–10 years)	Far Future (10–20 years or beyond)
Embodied Intelligence	Combining AI with robotics to achieve higher levels of autonomy and adaptability to the environment, facilitating human-robot collaboration.	Preliminary AI robotic applications, such as smart home robots, industrial robots, etc.	Highly autonomous robotic systems capable of flexibly adapting to complex environments and seamlessly collaborating with humans.	Anthropomorphic AI robotic assistants with human-like cognitive, interactive, and learning capabilities, becoming partners to humans.
Empathetic Agents	Emphasizing the connection between AI and human emotions, improving human-computer communication through accurate emotion recognition and response.	Initial applications of affective computing, such as sentiment analysis, facial recognition.	More advanced empathetic AI systems capable of understanding complex emotional states and providing personalized emotional support.	AI assistants with genuine empathy, able to engage in emotional communication like humans, becoming emotional supporters and listeners.
Collaborative Networks	Highlighting the integration of AI with social systems, such as smart cities and social governance, showcasing AI's potential in improving resource efficiency and social participation.	Preliminary smart city applications, such as traffic management, energy optimization.	More comprehensive social collaborative networks, utilizing AI to optimize resource allocation and promote public participation in decision-making.	Highly intelligent, adaptive social systems with AI and humans collaboratively governing to achieve sustainable development and social equity.
Symbiotic Ecosystems	Exploring the harmonious coexistence of AI and the natural environment, emphasizing AI's crucial role in environmental monitoring, ecological protection, and sustainable development.	Initial AI environmental applications, such as wildlife monitoring, pollution prediction.	Broader AI ecosystems capable of real-time monitoring of environmental health, optimizing resource utilization, and promoting harmony between humans and nature.	Highly intelligent Earth ecosystem management systems, with AI becoming a key force in maintaining Earth's health and protecting biodiversity.

higher demands for the future development of HCI. As pointed out by Shneiderman, overreliance on AI technology may neglect user control and transparency, thereby weakening human decision-making authority and autonomy (Shneiderman, 2020). To address this challenge, future HCI design needs to adopt the "Human-in-the-Loop" principle, ensuring that AI technology operates under human supervision and control rather than replacing human judgment. This requires HCI researchers and designers to fully consider human needs and values when developing AI-driven interaction systems and to design modes of human-machine collaboration that enhance human capabilities rather than replace them.

Additionally, the application of AI technology in HCI also faces ethical and sociocultural challenges. For example, AI systems may amplify inherent biases in data, leading to unfair or discriminatory interaction design (Springer & Whittaker, 2019). Therefore, HCI designers need to adopt a more comprehensive perspective, focusing not only on technological performance but also on ethical and moral standards and social impact. This requires interdisciplinary collaboration, incorporating knowledge and insights from fields such as ethics, sociology, and psychology to jointly promote the development of responsible and inclusive AI technology (Wang et al., 2019).

Digital transformation also has a significant impact on the future development of HCI. The progress of emerging technologies such as virtual/AR and wearable devices provides more possibilities for innovative interaction design (Ashtari et al., 2020; Khakurel et al., 2020). At the same time, digital transformation requires HCI to adopt a more user-centric design philosophy, focusing on end-to-end user experience and integrating usability with business objectives (Sheng et al., 2021). HCI professionals are expected to play a more critical role in this transformation, driving organizational cultural change, promoting interdisciplinary collaboration, and translating research findings into practical applications (Bannon et al., 2018).

In conclusion, AI and digital transformation bring both vast opportunities and formidable challenges to the future development of HCI. To address these challenges and seize opportunities, the HCI field needs to adopt a more comprehensive, multidisciplinary, and human-centric research and practice paradigm. This requires us to uphold the values of human-centeredness, inclusivity, and responsible innovation while embracing technological innovations. Through human-machine collaboration, we can continuously explore and optimize HCI, ultimately realizing the vision of technology benefiting humanity and enhancing social welfare.

CONCLUSION

This chapter delves into the close relationship between digital transformation and future HCI, focusing on the impact of design thinking, future thinking, and AI technology on HCI development. In today's rapidly evolving digital age, understanding and guiding the progress of HCI are not only crucial for improving user experience but also key drivers of social and technological innovation. This study employs methods such as literature review, case analysis, and ANT to explore how digital transformation shapes the evolution of future HCI. By analyzing HCI development trends and technological innovations in different industries, the research

reveals that the integration of design thinking, future thinking, and AI technology is becoming the core driving force behind HCI field development. The findings confirm that through the application of these methodologies and technologies, we can effectively address the challenges brought by digital transformation and promote the design and implementation of more efficient and human-centered HCI systems.

The main contribution of this chapter lies in the systematic analysis of the roles of design thinking, future thinking, and AI technology in promoting HCI development. Especially through the perspective of ANT, this study reveals the interactions and influences of multiple actors such as technology, users, and social environment in HCI development. Additionally, through multiple industry cases, the chapter demonstrates the practical application of the aforementioned theories and technologies, further promoting HCI innovation and evolution. These findings not only enrich the theoretical foundation of digital transformation and HCI but also provide valuable guidance and inspiration for practitioners. The work of this chapter not only answers the questions raised in the introduction but also provides new perspectives and methods for understanding and guiding the future development of HCI in the digital age. By emphasizing the integration of design thinking, future thinking, and AI technology, this study is of great significance for improving user experience and promoting technological innovation while laying a solid theoretical and practical foundation for building a more interconnected, intelligent, and human-centric digital world. In the future, HCI researchers and practitioners should continue to uphold the principles of human-centeredness, inclusivity, and responsible innovation, delve deeper into the integration of design thinking, future thinking, and AI technology, and continuously explore and optimize HCI through human-machine collaboration to ultimately realize the vision of technology benefiting humanity and enhancing social welfare.

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Futures Thinking and Futures Literacy

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Relation to Chapter: Provides insights into how various governments within the Asia-Pacific region utilize Foresight and Futures Thinking in policy-making, relevant to the chapter's section on practical applications of these concepts in governance.

Arthur C. Clarke, writer, futurist, and inventor envisions the Future | Horizon | Past Predictions | BBC Archive. (1964). https://www.youtube.com/watch?v=YwELr8ir9qM&t=131s

García-Cruz, J. C. , et al. (2023). Myriad applications of bacteriophages beyond phage therapy. PeerJ, *11* , e15272. https://doi.org/10.7717/peerj.15272

Relation to Chapter: Cited to discuss the potential of bacteriophages in technology and HCI, relevant to the chapter's sections on biotechnological integration.

Harari, Y. N. (2016). Homo Deus: A brief history of tomorrow. Harvill Secker.

Relation to Chapter: Provides the futuristic context discussed in the concluding section of the chapter, especially regarding AI and biotechnology's impact on society.

Inayatullah, S. (2023) paper titled “Causal Layered Analysis: Poststructuralism as method” examines the application of poststructuralism in causal layered analysis. Metafuture: https://www.metafuture.org/2023/04/28/causal-layered-analysis-poststructuralism-as-method/

Relation to Chapter: This seminal paper by Sohail Inayatullah introduces CLA, which is utilized in the chapter to discuss how HCI can benefit from deeper Foresight methodologies.

Jorion, P. (2021). Humanism and its discontents: The rise of transhumanism and posthumanism. Palgrave Macmillan.

Relation to Chapter: Paul Jorion delves into the evolving relationship between humans and technology within the context of HCI's future through discussions on Humanism, Transhumanism, and Posthumanism relevant to the chapter's sections on Philosophical Perspectives.

Miller, R. (2021). Report of The Futures Literacy Lab-Novelty Online, Egyptian Youth Rethink the Future of Wellbeing in 2050. UNESCO's Library.

Relation to Chapter: This report offers a detailed example of a Futures Literacy Lab application, supporting the chapter's focus on UNESCO's methodologies for applying Futures Literacy.

OECD (2019) document on “AI Principles” outlines guidelines for ethical AI development and implementation. https://www.oecd.ai/en/ai-principles

Relation to Chapter: Cited in the ethical considerations section, outlining the principles for AI that promote transparency, accountability, and fairness, which are advocated for in the HCI practices discussed.

UNESCO (2018) “Transforming the Future: Anticipation in the 21st Century” explores the role of anticipation in shaping future outcomes. Paris: UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000264644

Relation to Chapter: This book, edited by Riel Miller, is one of the primary sources for the discussions on a central theme of this chapter Futures Literacy.

UNESCO . (2023). Futures literacy & foresight: Using futures to prepare, plan, and innovate (SHS/2023/PI/H/6). UNESCO. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000386511

Relation to Chapter: This source elaborates on the theoretical and practical applications of Futures Literacy as advocated by UNESCO, aligning with the methodologies discussed in the chapter.

UNESCO (2021). Recommendation on the Ethics of Artificial Intelligence. https://www.unesco.org/en/articles/recommendation-ethics-artificial-intelligence

UNESCO, & Prince Mohammad bin Fahd University (Saudi Arabia), Center for Futuristic Studies . (2023). Futures literacy laboratory playbook: An essential guide for co-designing a lab to explore how and why we anticipate. UNESCO. https://doi.org/10.54678/KSWO4445

Relation to Chapter: This document is used to back the discussions on the ethical considerations necessary in the development of HCI technologies, as mentioned in the chapter.

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Relation to Chapter: Supports the chapter's exploration of emerging technologies such as neural microelectrodes and their implications for the future of HCI.
Zhu, L. , Chao, C. , & Fu, Z. (2024). How HCI integrates speculative thinking to envision futures. Journal of Futures Studies, *28* (4). https://jfsdigital.org/how-hci-integrates-speculative-thinking-to-envision-futures/
Relation to Chapter: Directly correlates with the chapter's discussions on integrating speculative thinking within HCI, providing a case study and theoretical background.
I originally composed the poems “Yes, You Can Imagine,” “Imagination,” and “Wonder” in my native Urdu language. I translated them into English for their relevance to the theme of this chapter.
Relation to Chapter: Each poem celebrates the potency of imagination, creativity, critical thinking, empathy, intuition, and wonder aligning closely with themes such as Futures Thinking, Futures Literacy, HCI futures, Speculative Design, and Design Fiction methodologies.

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