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Review Article

Integrating HCI Principles in AI: A Review of Human-Centered Artificial Intelligence Applications and Challenges

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Abstract: This review explores the integration of Human-Computer Interaction (HCI) principles in AI to advance Human-Centered Artificial Intelligence (HCAI). It highlights how these fields intersect to create user-friendly AI systems that enhance human capabilities and align with human values. Given the recent interest of HCI in user-centered design and AI in technical innovation, this paper bridges this divide by infusing principles from HCI into AI systems. Relevant peer-reviewed articles, conference papers, and case studies have been selected from leading databases like IEEE Xplore, ACM Digital Library, ScienceDirect, and Google Scholar, encompassing publications from 2017 to 2024. The inclusion criteria for the review focus on interdisciplinary approaches, real-world applications, and challenges of HCAI, while studies that do not have a clear methodology or lack relevance to HCAI were excluded. This paper identifies some of the key gaps, highlights the successful applications of HCAI across healthcare, education, and entertainment, and discusses various challenges that have arisen, such as bias, transparency, and balancing automation with human control. Findings reveal that iterative design and human-centered frameworks will lead to better usability and ethical fit for HCAI, but significant challenges remain. This study proposes an integrative framework for bringing HCI principles into AI design through interdisciplinary collaboration in developing systems that will enhance human capabilities while considering ethical aspects. Future directions include responsible AI, personalized healthcare, and effective human-AI collaboration.

Keywords: Artificial Intelligence; Human-AI Interaction; Human-Centered Artificial Intelligence; Human-Computer Interaction; User Experience of AI Design.

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1. Introduction

Human-Centered Artificial Intelligence (HCAI) has emerged as a critical research area incorporating the principles of Human-Computer Interaction and Artificial Intelligence to develop systems sensitive to human needs, ethics, and usability. Unlike earlier approaches that largely focused on mere technical achievements, HCAI explicitly focuses on building AI systems for augmenting human capabilities and building trust and transparency in human-AI interaction [1]–[3].

Many studies conducted in Human-centered AI have revolved around two main research questions: "How can we augment human needs with AI rather than replacing humans?" and "How can we design AI systems to provide sufficient human interaction while ensuring that users can easily intervene at any point through intuitive interfaces and clear usability?".

The earlier efforts in this arena have been largely isolated in nature between HCI and AI. For example, HCI research mainly focused on usability, accessibility, and human factors in interfaces [4], [5]. On the other hand, AI research focuses on complex algorithms with less concern for user experience[6]. While these laid the foundation in their respective fields, they

have many real challenges- for example, user adoption, bias, and opacity[6] [7]-resulting from a lack of integration between the two. However, new endeavors in combining these studies reveal the potential of HCAI to fill these voids [7], [8].

Despite these advances, some key challenges still need to be overcome, such as mitigating bias in AI systems, creating transparent "explainable AI," and striking a balance between automation and human intervention[9]. This paper contributes to adopting HCI principles in developing AI systems that ensure usability, ethics, and human-centered design.

The contributions of this review are as follows:

- Identification of critical gaps in the existing AI and HCI methodologies.
- Key applications of HCAI across various industries include healthcare, education, and entertainment.
- Propose a framework for embedding HCI principles into AI design to make it more user-centered.
- Future research directions will include ethics in AI development and personalized healthcare applications.

A systematic selection strategy was used to conduct the literature review. Peer-reviewed articles, conference papers, and case studies were sourced from academic databases such as IEEE Xplore, ACM Digital Library, Google Scholar, and Science Direct. The inclusion criteria were focused on studies published between 2017 and 2024 that emphasized interdisciplinary approaches to HCI and AI, applications of HCAI, real use cases of HCAI, and challenges like explainable AI and ethical considerations. More importantly, the papers had significant empirical findings or comprehensive frameworks selected, while others were excluded without clear methodologies or relevance to human-centered AI.

The sections in this review paper include the following: Section 2 discusses a literature review of human-computer interaction and artificial intelligence, with the main focus being where the two fields converge. Section 3 focuses on HCAI, describing its applications across many industries and highlighting some of the most successful application cases. The challenges facing HCAI at present are also addressed in this section. Section 4: Trend analysis - giving a detailed account of the findings of the research done by the author. Finally, Section 5 concludes by discussing the potential transformative impact of HCAI and proposing directions for future research.

2. Literature Review

2.1. Human-Computer Interaction

Human-Computer Interaction (HCI) is an interdisciplinary field that bridges the gap between psychology/sociology and computer science/technology[4]. It is the study of human-to-technology communication and how to develop better interfaces, focusing on making technology more intuitive, efficient, and user-friendly[10]. The discipline of human-computer interaction has recently matured, and researchers have committed their energies to understanding how humans interact with technology.

Similarly, using the HCI principles has ensured the products are accessible and usable for all types of users, including people with disabilities. The authors[11] targeted perceptually rich sound interaction to create an increased intelligibility benefit for auditory interactions in mothers and children with Down syndrome (DS).

2.2. Artificial Intelligence

The term artificial intelligence has become ubiquitous in today's world. People have heard this term for almost a decade, and its capabilities still amaze us. Despite the many complexities, AI can be defined in a simple way, which is by making a model intelligent enough to understand what it received and then act upon that data as per the end goal. It's like teaching the machine to possibly think when solving problems independently as humans do[6].

2.3. How do AI and Human-Computer Interaction Intersect?

Different priorities and incentives direct the base of AI and Human-computer interaction. AI focuses more on developing AI algorithms, born in mathematics and engineering circles filled with very ambitious plans that took a long time to have expensive machinery[12]. In contrast, HCI was predominately around human psychology and how humans see things,

and it was more about evolving used hardware in a short time[7]. Despite these core differences, they both intersect in many ways.

Human-computer interaction goes hand-in-hand with the development of different AI products. HCI ensures that AI technologies are designed to focus on the users, considering their needs, abilities, and preferences. By incorporating principles and practices of human-computer interaction, AI engineers also can make more user-centered AI systems[13].

Many works presented the concept that, by marrying how we use computers- that is, human-computer interaction with artificial intelligence- or how computers can think like humans, great technology can be built that solves our needs. The authors [14] surveyed how collaboration in the field of HCI and AI benefits the disciplines by incorporating smart user interfaces, knowledge about comfort, and methodologies to represent data of AI systems.

Applying HCI principles in building AI applications has led to a seamless user experience and reduced errors, increasing user satisfaction[15]. Many papers address the difficulties and possibilities of AI systems being oriented toward people. The authors [16] underline the necessity of developing responsible artificial intelligence to get good results for humans. It has brought forth collaboration across different disciplines and has given guidelines for developing AI systems that will match the needs of humans and their values.

Not only are the AI industries booming, but we have barely scratched the surface of what such new technologies will allow us to do in our lives, from living and working with their help to playing games on them. So, to support this revolution and make AI applications and products user-friendly, many engineers and professors have used the term "Human-centered AI" to emphasize the importance of friendly collaboration and diversity of thought in AI development, highlighting the need for AI to serve humanity by incorporating insights from a wide range of fields, including humanities, social sciences, and technical disciplines [17].

3. Human-Centered AI

The idea of being overwhelmed by movies and video games where AI reigns over humanity and is no longer under the control of people and machines' rule is outdated. There is now a different approach, one full of computer devices that make human talents a thousand times stronger, enabling individuals to do amazing things while maintaining human control, "Human-centered Artificial Intelligence (HCAI)." The main function is to integrate human considerations into the design processes. This is achieved by incorporating some data about the targeted users and their needs/preferences into AI systems to ensure that these abide by human expectations and contribute towards enhancing user experiences [10]. It involves ensuring that particular AI systems respect human users regarding their needs, competencies, and desires; this idea is thus central to the design and development of any future AI system [18].

Another important concept is the incorporation of human-computer interaction principles and practices. This entails referring to dimensions such as ease of use, openness, and user assessment while designing AI products that are more convenient for navigation or interaction. Human-centered AI is a different way of thinking that respects the fact these are insanely intricate systems, and they induce real-world effects when deployed. This integration of human-computer interaction principles and techniques in artificial intelligence systems is known as HCI-AI or AI-HCI [8]. This can help developers promote more empathetic, human-centered AI systems that are aligned with our fundamental values and priorities. Human-centered AI is grounded in user research, iterative design processes, and user testing — techniques used to gather insights on human needs and behaviors that can feed into ideation to design an AI system[19].

3.1. Applications of Human-centered AI

There are many applications of HCAI, and all the applications have one goal in common: making the user experience seamless and valuing users' needs as a top priority. There are many different sectors in which HCAI has contributed significantly. Some of the noteworthy sectors are listed below.

3.1.1. Healthcare sector

HCI-AI has been widely implemented in healthcare sectors where the designed systems are intended to support healthcare workers by providing decision assistance, improving diagnostic accuracy, and personalizing patient treatment[20]. We can take the example of Babylon Health, where AI extensions are already in place to deliver medical consultations and health assessments in an accessible format[2].

Babylon Health is an example of an application in the healthcare sector that integrates with health tech and combines virtual clinical appointments with AI. Web and mobile apps of this healthcare AI allow patients to connect with healthcare professionals seeking medical advice, referrals, prescriptions, and convenience in access to health services [21]. Babylon Health has implemented HCAI principles to ensure a user-centric vision for an easy-to-use, intuitive medical tool that enables users to understand their health. Interactive and detail-oriented, the Digital Twin visualizes health organ by organ for better understanding. The application also accords with the principles of HCI by making 24/7 access to general practitioners possible, which speaks volumes about its usability and accessibility[22].

3.1.2. Education Sector

One of the sectors where we can undoubtedly say that AI has influenced the most is our education. By being AI-driven and using HCAI principles, the students can now understand how you learn best and at a faster pace than others. This also enables the systems to help teachers identify a student's strengths and areas for improvement so that specific interventions can be done [23].

For example, Grammarly is an AI-powered writing assistant that helps users improve their writing by catching errors and making contextually relevant suggestions. This tool eases the editing process in education, extending learning by underlining mistakes and allowing for quick correction. Its ease of use helps students build good writing habits and work their way around writer's block[24].

3.1.3. Workplaces

The arising of intelligent AI products using HCAI has made the lives of working professionals easier. One of the popular companies, IBM Watson, offers different AI solutions that increase workplace productivity in some major corporate functions, such as customer service and data analysis. This ensures productivity is improved without causing harm to or alienating human workers[25].

For example, IBM Watson uses a mix of AI techniques, including machine learning, natural language processing (NLP), computer vision, automatic speech recognition, knowledge representation, and more. IBM Watson combines different products (Companies using IBM Watson, 2024). It offers a simple interface for building, training, and deploying machine learning models and helps extract useful information smarter from the big pile of articles or web pages. Watson products have shifted the system style from traditional UI to user-centered design[26].

3.1.4. Accessibility

The world is not just black and white. There are many gray areas in it. The number of people with disabilities has been increasing day by day. Applying HCAI to the designed AI products to augment the needs of disabled people has been one of the major applications of HCAI. For instance, natural language processing and speech recognition offer more user-friendly communication systems[27].

Google has applied generative AI to enhance the smart search experience via content generation, inferring users' productivity and delivering more relevant search results[28].

Also, Google Search Generative Experience (SGE) anticipates users' needs and wants with the help of generative AI which reduces the users' cognitive load[29].

3.1.5. Entertainment Sector

AI is used in many different entertainment areas, such as games and videos. Music etc. One of the notable applications is a music application named Spotify. This application helps to identify music preferences based on understanding and customization using AI algorithms, thus enhancing the user experience[25].

Spotify uses Natural Language Processing (NLP) with HCI principles in its mobile and web-based applications, which aim to create exciting and conversational experiences that are easy to use by any age group by implementing voice interfaces[30]. They mainly focus on

human connections and empathy along with the users' emotional and logical needs, which is the epitome of using design thinking and implementing HCI principles[31].

3.2. Challenges of Human-centered AI

There exist many challenges on the road to Human-Centered AI. Some have already motivated some solutions and implementations, while others are hard to overcome. A few of those are short-listed below.

3.2.1. Ethics in AI Development

The challenge is how AI systems will strive toward ethics in the light of fairness, accountability, and benefit to society. That is, creating transparent, accountable AI that reflects human values. It also covers developing AI that understands human-like signals and responses to emotional states and fosters fairness without discrimination[32].

Recent case studies in AI development have focused on ethics. One of the notable examples is Google DeepMind's AlphaFold system. AlphaFold predicted the structure of proteins, but there was a link to ethical issues related to misuse in developing biological weapons. DeepMind hastened to introduce an AI Ethics Board and brought in guidelines concerning transparency, making AlphaFold's data openly available to the scientific community worldwide. They developed an ethical framework that strictly controlled access to the data, adding regulations about medical collaboration. DeepMind collaborates with ethicists and biotechnologists to use their AI tools responsibly and embed fairness and accountability in future projects[33].

3.2.2. Bias and Privacy Concerns

AI systems may get biased toward certain groups due to biased data, discrimination, and poor outcomes. Hence, diversified data and algorithm tuning have to be considered. Another important aspect is data privacy; most AI technologies require personal data, which is a huge privacy concern[34].

Management of AI systems requires careful design to prevent biases. For instance, Amazon's recruitment tool initially favored male candidates due to biased data, leading to its discontinuation and public backlash. Amazon has since focused on using balanced data, conducting regular audits to correct biases, and collaborating with external experts to promote fairness[35].

Similarly, Apple was criticized for sending data to its servers regarding user data. Then, it implemented various differential privacy methods that allowed AI to learn data in aggregate and not individual identities. Apple continues to take steps to enhance privacy, such as encryption and publically voicing support for stronger privacy regulations, and it puts user privacy at the heart of its brand identity[36].

3.2.3. Combining Automation with Human Control

As AI systems become more autonomous, ensuring that humans can still intervene when necessary is crucial. The balancing between automation and human control will involve the design of cooperative human-machine systems in which both entities share the authority, ability, responsibility, and control so that advances in automation make life easier, safer, and more enjoyable than harder and miserable[37].

Overconfidence in automation results in accidents, such as Tesla's Autopilot car crashes, where the computer driver failed at that place under the circumstances that called for human assistance. A Tesla running on Autopilot mode crashed in 2016 because it could not discern a white truck against a bright sky. After public outcry and increased regulatory scrutiny, Tesla introduced changes that added more safeguards to Autopilot and prodded drivers to stay engaged and confirm their attentiveness. Currently, Tesla is rewriting its self-driving technology to focus on safety by having a feature that always prompts the driver to take over [38].

3.2.4. Collaborating Human and AI

Designing AI systems that interact with humans respectfully and ethically is essential. These systems must respect human cognitive abilities and avoid overwhelming or misleading users[39].

For example, a case study on Boeing's MCAS aimed to prevent stalls but failed to communicate effectively with pilots, leading to twice fatal accidents. In turn, Boeing grounded the fleet, redesigning MCAS for multiple sensors and improving pilot communications to include manual overrides. Boeing is now improving the development of AI and automation systems

with enhanced safeguards and working with regulators on enhanced certification processes for new AI-driven aircraft systems[40].

Making AI genuinely human-centered demands crucial steps in ethics, bias, and privacy, striking a balance between automation, human control, and much more. Companies like Amazon, Apple, Tesla, and Boeing illustrate the importance of ethical development, diverse data use, and effective communication in AI systems. By prioritizing these aspects, we can harness AI's potential while ensuring it aligns with our ethical standards and serves the public good.

4. Analysis

4.1. Trend Analysis

The term HCAI began gaining significant popularity around 2019. One of the fundamental roles was the establishment of Stanford's Human-Centered AI Institute, which officially formalized the term HCAI[3].

Even though there were a lot of different terms to define HCAI before 2019, the importance of involving humans while designing AI applications was researched before that [41]. This concept was discussed much before the coining of the term HCAI. Discussions and publications on ethical concerns, human values, and user-centric designs in AI systems were popular in research circles[9].

In this trend analysis, the publications from 2017-2024 have been analyzed where we can see significant changes and growth within industrial and academic sectors, see Table 1.

Table 1. Trend analysis of HCAI from 2017-2024.

2017-2018	2019-2020	2021-2022	2023-2024
Beginning of the popularity of AI	The term HCAI was coined.	Ethics-based AI was popular.	Advancements in Human-AI Collaboration.
Researchers began to consider the ethical concerns of AI	A human-centered AI framework was developed[42].	Researchers began to focus on the safety and reliability of AI systems[43].	AI has become increasingly pervasive, resulting in debates in academic and research areas about its regulatory influence [44].
The necessity of AI transparency was emphasized[33].	Techniques aimed at improving user trust in AI systems emerged [45].	"Collaborative AI Model" was introduced, which focused on developing human capabilities with the help of AI[46].	Maturing of AI tools made for human-AI collaboration.
Emphasized the necessity for AI to work under human guidance[47].	Implementation of human-centered design methodologies for a wide array of user requirements.	Usability became an issue of growing importance [48].	Copilots in healthcare, education, and creative industries were developed to support human judgment but not to supplement it[49].
"Human in the loop" or "Explainable AI" was used to define HCAI [9],[41].	Research on explainable AI has focused on human-centric design principles to minimize discrimination[50].	User-centered interaction was prioritized while developing AI systems.	Articulated interest in personal and adaptive AI systems that can meet the unique needs of different users[51].

4.2. Author's Analysis

People in development industries have recently realized the importance of applying HCI principles to AI products. Many researchers have emphasized the need for a human-centered approach in AI development to ensure beneficial and value-aligned artificial intelligence technologies. During the research for this paper, the goal was to explore how AI systems were developed in previous years and how their development has evolved over time, using HCI principles as a framework for designing AI systems. AI systems are powerful and can be complicated to develop, so focusing on the product's user experience is crucial. This is why

developers are inclined to develop AI systems that behave according to human requirements and are not treated as technically complex systems as they were before.

After reviewing existing works of literature, research articles, journals, and existing AI systems, I could highlight that HCI principles have an important role in making AI interfaces easy to use, fast, and adaptable to user preferences. There was much evidence present that the collaboration of two fields known as HCAI is beneficial in resulting in more intuitive, adaptable, user-friendly, and accessible AI systems. We can analyze that many fields, such as psychology, sociology, design, etc., must collaborate to develop the AI system ethically and intuitively.

However, there should be an equal balance between how much we allow humans to intervene and how much AI should automate the work. The authors[52] state the importance of allowing the users to intervene and handle situations of any automation failure. Balancing human roles and AI is important in the growing era of automation and artificial intelligence. We must understand the trade-offs between human and AI performance, such as accuracy, speed, cost, and reliability, and how to allocate tasks accordingly. Engineers need to design AI systems that can collaborate, coordinate, and communicate with human users and other AI systems that can adapt to changing contexts and goals. The main challenge that engineers and researchers of AI will face is developing systems that enhance and support human capabilities, not surpass them.

5. Conclusions

This paper has discussed the need to implement and integrate HCI principles into the development of AI for systems to be user-friendly, effective, and according to human values and needs. A well-balanced approach was suggested wherein AI enhances human capability without overpowering the same and also brings into light ethical considerations such as bias, privacy, and transparency in AI systems. The paper has also discussed some of the AI products that have already integrated the principles of HCI into their products for better usability, thus creating more user engagement. In the future, there is a need to continue the research on the relationship between HCI and AI, addressing ethical concerns and designing systems that enhance human capability without surpassing it. After all, our objective should be to develop AI systems that will collaborate with humans and augment human capabilities while enhancing human experiences. Many other research areas in this field need in-depth research by the researchers. Some of the future research areas include:

Ethical AI Development: Another area in which researchers may seek methods to ensure AI systems are handled responsibly and with consideration for societal consequences.

Human-AI Collaboration: Although much research has been conducted in this area, there is still more room to research how to design AI systems capable of effective collaboration, coordination, and communication with human users.

Personalized health care: As the health sector is developing daily, AI can help automate the usual time-consuming tasks that health professionals should do; this will help them focus on personalized and more patient-centered care.

Interdisciplinary Approaches: There are many sectors of AI where collaboration with HCI principles will enhance that field. So, more focus can be given to those areas by the researchers.

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