Generative AI Meets Accessibility: Deformable Interfaces and Multimodal Solutions

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Abstract

Artificial intelligence (AI), especially large language models (LLMs), has evolved into one of the most influential technologies of our century. Yet, human interaction with AI is dominated by chat-based input windows. Although there have been some developments regarding wearable AI interfaces, the field remains largely unexplored. AI has the potential to revolutionize the way we approach accessibility by automating tasks that previously required human assistance. However, most AI tools are at least partly inaccessible to people who use assistive technologies to interact with computers. The goal of my Ph.D. research is to investigate how generative AI and LLMs can be made more accessible for people with disabilities and be utilized to create new accessibility tools through the use of multimodal interactions. I approach this problem using an iterative research through design (RTD) approach focused on close engagement with the target demographic.

CCS Concepts

• **Human-centered computing → Accessibility**.

Keywords

Accessibility, AI, Bio-Materials, Deformable Interfaces

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Figure 1: Abstract representation of an organic biofoam-like surface, created using Midjourney[1]

1 Introduction

Artificial intelligence (AI) has evolved to be arguably one of the most influential technologies of the century, with a global market size of over 184 billion USD in 2024 and an expected growth to over 826 billion USD by 2030 [29]. Especially generative AI and large language models (LLMs) have found their way into our daily lives through AI assistants such as ChatGPT[2] or Claude[3]. Despite this rapid growth, the interaction with AI assistants is still dominated by traditional input methods like chat-based input windows or GUI interfaces provided via common communication platforms like Discord[4]. While some companies like Rabbit[5] and Humane[6] have begun challenging these input methods by developing specialized hardware gadgets for users to engage with AI, much work remains to create solutions that are universally accessible and seamlessly integrated into everyday life. The interaction with LLMs remains very one-dimensional, and the current input modalities are not optimized for accessibility [19], making it hard for people with disabilities to interact with LLMs in an effective manner. At the same time, generative AI could also fundamentally change the way we approach accessibility in general: it is currently required to include dedicated accessibility features like alternative text for images, which could be replaced or enhanced by intelligent screen readers in the future [11], making huge portions of the internet accessible that do not include accessibility features. Services like *be my eyes*[7] that previously required a human agent to describe camera footage to visually impaired users can be automated by

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[1] https://www.midjourney.com
[2] https://chat.openai.com
[3] https://claude.ai
[4] https://discord.com
[5] https://rabbit.tech
[6] https://humane.com
[7] https://www.bemyeyes.com

introducing AI agents [31], making the service easier available and more efficient.

To diversify the range of possible input modalities, I want to use tangible artifacts such as deformable interfaces that offer various interaction types like bending or pulling. In my research, I want to explore the possibilities of making LLMs more accessible to people with disabilities while also utilizing generative AI to build novel accessibility tools. To ensure a user-centered development process, I will employ a research through design (RTD) [9, 36] approach.

2 Context and Motivation

Since before starting my master's program and way before I became an HCI researcher, I have been very interested in the maker community. I find it fascinating and empowering to build yourself a *toolkit* that enables you to create virtually anything by using 3D printing, laser cutting, microelectronics, programming, and other methods. Despite being a junior researcher in the early stages of my studies, I have extensive knowledge about rapid prototyping techniques and have also started teaching the course *Sketching With Hardware* at my university. I would like to provide my knowledge on prototyping and fabrication techniques to the graduate student consortium, establish collaboration contacts, and create a cross-disciplinary network with future partners and peers. As I plan to conduct research on tangible and deformable interfaces, I consider the TEI community as a valuable dissemination outlet.

3 Related Work

My research proposals consist of one primary and two secondary topics, as visualized in *Figure 2*. Primarily I will focus on how to make generative AI more accessible to people with disabilities and use it to build new accessibility tools. This topic is complemented by two secondary topics: deformable interfaces as an alternative input modality to interact with AI tools and bio-materials as an environmentally sustainable alternative for tangible interfaces.

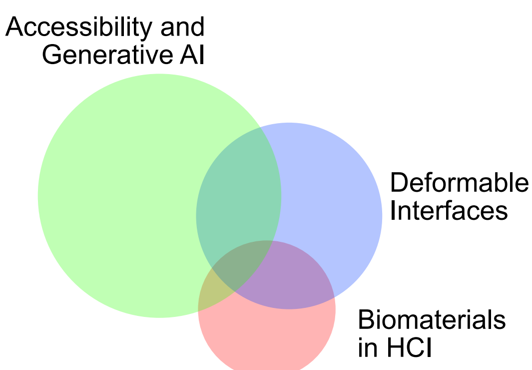

Figure 2: Venn diagram of the primary and secondary topics of my research

3.1 Accessibility and Generative AI

As previously mentioned, the interaction with generative AI is still dominated by chat-based input methods and little has been done to challenge this status quo. In a recent review McMahon [19] rated the accessibility of different AI chatbots and found one of the most popular chatbots, ChatGPT, to be very inaccessible:

- "To have the screen reader read the text that ChatGPT generates, a user needs to bring the focus to the top of the window and then have the screen reader read the whole page from the top down. There is no way to specify which part of the conversation to read, which makes it hard for a user to easily navigate a long conversation within ChatGPT's interface." [19]
- "The buttons have no labels. It is impossible to know which buttons are the copy, edit, and rating buttons on ChatGPT." [19]

As outlined by Alshaigy and Grande [1] different types of disabilities bring their own challenges when interacting with generative AI tools, clearly showing the importance of a paradigm shift in the field. While Vanderheiden and Marte [30] state in their recent work that the introduction of generative AI as an accessibility tool should not replace conventional accessibility features, generative AI has the potential to automate many tasks. This includes the creation of alternative texts [27], adaptive screen readers that can interpret images based on the context of a website [11], and systems that describe the real world to visually impaired people through the interpretation of a camera input [31]. Even though there have been recent developments in the field of accessibility through AI, the field remains largely unexplored due to the novelty of generative AI in everyday life.

3.2 Deformable Interfaces

Traditionally, interfaces consist of rigid materials, however, so-called *deformable interfaces* made of soft/flexible materials are gaining attention in the scientific community. Deformable Interfaces have the potential to offer more interaction possibilities compared to rigid interfaces, by allowing the user to alter the shape of the interface through bending [7, 15, 26], stretching [23, 32], squeezing/pinching [25, 34], twisting [15] and pulling [24]. An interface may also consist of soft/flexible materials without their malleable properties being used as distinct input modalities as mentioned above. However, for this to work, new fabrication techniques need to be applied like bendable breadboards that enable rapid prototyping on curved and organic surfaces [16].

Using soft/flexible materials in interfaces also introduces new challenges for the electronic components that are being used, as they need to conform to the shape-changing properties of the flexible material. While in some cases it might be viable to use traditional components embedded into the material (e.G. *StringTouch* [24]), other cases might call for the use of flexible electronics [3] like microprocessors [4] or touch sensors [33].

In this vein, inspiration can be drawn from the field of electronic textiles (eTextiles) which deals with highly deformable and flexible surfaces and often makes use of conductive string elements when integrating circuits into textiles [6, 18].

3.3 Bio-Materials in HCI

Because the fabrication of eTextiles often involves processes that make electronics inseparable from the fabric they are attached to [12], a lot of research has been done on the usage of bio-materials for eTextiles. Among these, carbon-based materials are the most prominent, followed by cellulose [12]. In their recent work *EcoThreads*, Zhu et al. [35] explored the option to create fabrics out of sustainable and biodegradable threads that can be woven into eTextiles. This has the advantage that the integrated electronic components can be detached and reused, while the fabric itself, including the conductive threads, can be disposed of without causing environmental harm [35].

While 3D-printable bio-plastics [2] are commercially available for standard 3D printers, bio-foams have yet to be thoroughly explored. Bio-foams (see *Figure 1*), are made by adding gas into liquid bio-plastics, are soft and deformable, and can even be 3D printed as showcased by Palcova [22]. In their work *Biohybrid Devices*, Nicolae et al. [21] used cellulose-based bio-materials and showcased different fabrication types (growing material around the electronic components, layering, laser engraving, etc.) that enable the embedding of electronics into them.

Combining these fabrication methods with recent advances in deformable interfaces and flexible electronics as discussed in *subsection 3.2*, has the potential to create tangible interfaces that are more ecologically friendly.

4 Research Question

In my research, I am designing and evaluating techniques for new types of accessible AI interactions. Based on the related work presented above, I will address the following research questions (RQs):

- **RQ1:** How can generative AI be made more accessible for people with disabilities using alternative interaction methods like deformable interfaces?
- **RQ2:** How can generative AI be utilized to create new accessibility tools that support multimodal interactions?

5 Research Activities and Methodology

I plan to utilize the RTD approach [9, 36], which can be defined as "the process of iteratively designing artifacts as a creative way of investigating what a potential future might be" [36]. I will include the following methods and research activities to address the research question outlined in the previous section.

5.1 Systematic Literature Review

I will critically review the existing literature in the field of accessibility and AI using the PRISMA [20] approach, to get an overview of the current state of the art and see what has already been done. I plan to focus on the following questions:

(1) How have tangible and other multimodal interfaces been used to facilitate interaction with AI?
(2) In what ways has AI been applied to enhance accessibility?

5.2 Expert Interviews

I plan to work closely with experts on the topic, including caregivers and researchers, to gain in-depth insights into accessibility problems with chat-based input windows and uncover opportunities for AI to increase accessibility. As this is a highly regulated field, it is imperative to ensure ethical correctness and stick to previously established standards.

5.3 User-Centered Design Workshops

I will organize workshops with people with impairments and caregivers to co-create and ideate on the design and functionality of generative AI interfaces, ensuring the solutions are deeply rooted in user needs and preferences and solve problems. The user is involved in the design process as early as possible to identify problems with the current interaction methods and design effective alternatives.

5.4 Rapid Prototyping and Early Ideation

I will employ an ideation loop that includes the development of prototypes at the early stages of research and testing them with users to ensure a user-centered focus. This approach allows for early adjustments to the prototype, ensuring it aligns more closely with user needs throughout the development process.

5.5 User Testing and Evaluation

I will test the created experience prototypes in realistic conditions in the form of field studies, to assess the effectiveness of the research approach. This includes long-term studies over the span of multiple days with interviews at the end, as well as shorter, observational studies.

6 Data Collection and Analysis

Because of the user-centered design approach, my research will mostly rely on qualitative data collected from studies and interviews with the user group, which will be analyzed using affinity diagramming [13]. I will also collect qualitative data in the form of questionnaires like the system usability score (SUS) [5], the affinity technology interaction scale (ATI) [8], the user experience questionnaire (UEQ) [17] and the task load index (NASA-TLX) [14] to complement the data from the interviews. Moreover, I plan to collect quantitative data that arises from the interaction with physical prototypes, like the frequency of use of certain features, the speed of interaction, or physiological measurements like stress.

7 Timeline

I am currently in the first month of my PhD studies at the HCI Group at LMU Munich under the supervision of Alexander Wiethoff, and I plan to complete my studies over the span of three years. I have been involved in several publications: a demo paper as first author [28], a full paper as second author [10], and I am currently in the process of publishing the results of my master's thesis as second author. Over the coming months, I plan to get an overview of the current state of accessibility in combination with generative AI by reviewing existing literature and starting collaborations with institutes for impaired people to get early insights into problem areas. Later, I plan to work closely with material scientists to further explore the space of deformable (sustainable) interfaces.

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