February 13, 2023

Prof. David N. Aurelio
Tufts University School of Engineering
419 Boston Ave.
Medford, MA 02155

Dear Professor Aurelio,

I hope this letter finds you well. Thank you for allowing me to research the applications of artificial intelligence in user interfaces. I am excited to inform you that I have completed the topic report which is attached.

In preparation for this report, I conducted sufficient background research on conventional user interfaces, AI technologies, and intelligent user interfaces to gain familiarity with the capabilities of current user interfaces and the opportunities for AI applications in user interfaces. This background research helped in narrowing down the focus of my research to two areas of potential AI implementation: how the user interacts with systems and how the system interprets and responds to them. Research into current AI tools allowed me to draw connections in how they supported these areas and make recommendations for how AI could be implemented into existing user interfaces.

Additionally, I have set a series of research goals designed to set a framework and guide how I approach synthesizing the data and presenting my findings. In the future, I hope to continue researching the applications of AI in user interfaces and how its applications can be used to create truly interactive intelligent user interfaces.

Thank you for taking the time to read and evaluate my report. I look forward to receiving your comments upon review. If you have any questions or concerns you can reach me through my email michael.yung@tufts.edu.

Sincerely,

Michael Yung

Tufts University Class of 2024
Medford, MA 02155

Topic Report:

Applications of Artificial Intelligence Technology to User Interfaces

Prepared by Michael Yung
Prepared for Prof. Aurelio

PSY 130, Tufts University
February 13, 2023

Introduction of Topic

User interface (UI) design is an integral aspect of Human Factors Engineering that creates a seamless connection in the ways users can interact with software, hardware, and computer-based interfaces. In this form of design, there is an emphasis on understanding users' needs and creating an interface that provides the means and support to facilitate those needs. Users tend to communicate with computers by directly manipulating a graphical or WIMP (windows, icons, menus, and pointing) interface (Moore, 2021). This results in a form of one-sided communication in which the user provides input that elicits a response from the computer.

With the advent of new artificial intelligence technologies, user interfaces are beginning to rapidly revolutionize the way users interact with them. Artificial intelligence tools like machine learning, language and speech generation, and virtual agents make communication between computers less like a one-sided conversation and more like an open dialogue. By applying AI tools to user interfaces, a new generation of interfaces centered around adapting to the user's specific needs has emerged, known as Intelligent User Interfaces or IUIs.

Unlike their traditional counterpart, IUIs focus on improving the efficiency and naturalness of human-computer interaction by reasoning and acting on existing models of users, domains, and tasks (Wahlster, 1998). Based on unique user preferences, an IUI might be able to interpret the information and create recommendations based on the user's interests or tendencies. This might arise in the form of product recommendations on sites like Amazon or adaptive technologies from virtual assistants like Alexa that can adjust their volume based on the surrounding environment.

A key idea to highlight is that IUIs emphasize interaction. By interpreting data from unique users, these interfaces can improve user interaction by providing benefits such as semi-automatic or automatic completion of tasks, the generation of coherent multimodal presentations, and comprehension of ambiguous or unclear communication (Wahlster, 1998). With such advancements in AI technologies and research into human-computer interaction, it raises the question of how we can integrate current AI into existing user interfaces to elevate them into IUIs that actively interact with users.

In this report, I conducted background research on user interfaces, the applications of AI technologies, and the benefits of IUIs. Using this information, I then isolated opportunities for AI application into user interfaces, namely in improving human-computer interaction and interpretation of inputs and outputs, and researched how existing AI tools can be used to supplement these interfaces. With this knowledge, I then sought to offer recommendations on developing IUIs.

Goals of Research

The goals of my research are to (1) discuss the importance of implementing AI tools into user interfaces, (2) identify what elements are necessary for an Intelligent User Interface, (3) outline the applications of specific AI tools, (4) offer recommendations on AI tool implementation to improve human-computer interaction, and (5) review the future developments of IUIs. The overall scope of this research is to evaluate where and how AI technologies can be applied to user interfaces and identify how existing AI tools can be used to improve these systems and convert them into interactive IUIs.

What this research will not cover are the specific details about the history of AI or how to design a good user interface incorporating AI, more so the applications of AI tools and how they can be leveraged. To narrow down my research, I intend on focusing on the application of AI specifically to user interfaces. This excludes any focus on AI being used for robotics, manufacturing, or healthcare. Additionally, this report will not cover the ethical considerations of AI.

Method of Researching Topic

To gain a full understanding of my topic and its applications, I reviewed a variety of interdisciplinary fields involved in IUIs, including human-computer interaction (HCI) and AI. When searching for relevant literature, I used resources such as Google Scholar and JumboSearch to search for keywords relating to these areas of research. Some of these keywords included, "intelligent user interfaces," "user interface user experience," "artificial intelligence," and "human-computer interaction." The types of literature I reviewed included a wide selection of peer-reviewed journal articles, expert publications, and news articles on the subject matter. Additionally, I conducted a significant amount of background research into AI and existing AI tools to understand how they could be applied to user interfaces.

Findings of Research

Background on AI and User Interfaces

User interfaces are the bridges that fill the gaps between human and computer interaction and allow us to communicate with our phones, change the channels on our TVs, and even drive our cars. They offer to the public the promise of easy-to-use and well-designed systems that actively meet real user needs (Lieberman, 2009). User interfaces must be well designed because they are the driving forces for many of the smooth interactions we have with hardware and computers in our daily lives; designing good user interfaces, therefore, results in a seamless user experience, increased productivity, and reduced frustration with systems. With rapid developments in AI technology, however, these tools are now being implemented into existing user interfaces to continue meeting users' evolving needs.

Typical user interfaces include graphical user interfaces and WIMP (windows, icons, menus, pointing) interfaces. Graphical user interfaces (GUIs) are the most common forms of user interfaces that allow users to interact with icons and graphics on a computer program or system using tools like a mouse or trackpad; rather than physically typing in commands for a computer to complete, you can navigate using a pointing device (Falk, 2014). WIMP interfaces operate under a similar premise in which users can interact with a variety of different graphics and widgets, like menus or pointers. Developing advancements in new computer modalities, however, not only supports improved user interactions but calls for the ever-increasing need for advancements in user interfaces to meet the user's needs. Modalities such as virtual reality, augmented reality, voice interactions, and now artificial intelligence issue the need to create new user interfaces that enable users to communicate with these systems.

Recall earlier, that the goal of user interfaces is to provide well-designed systems that improve user experience and productivity for the user. While conventional user interfaces are beneficial in achieving user needs, they could be significantly improved with the application of AI technology, otherwise the creation of an IUI. Artificial intelligence seeks to model human

thinking and implement these mechanisms into computer systems (Lieberman, 2009). While both AI and user interfaces have often gone through testing and application separately, when combined, they offer benefits that could significantly improve the user experience as a whole. AI systems do not have to solve all the user's problems alone and can rely on existing user interfaces for direct manipulation interaction when the user's goals are unknown. User interfaces, conversely, can rely on AI technology to implicitly understand user goals and streamline how they achieve those goals; rather than having explicit icons and menus for every user interaction, implicit user insights can be used to create shortcuts or improve efficiency based on user preferences (Lieberman, 2009). This could allow for the automation of certain rote tasks, personalization, and adaptive functionalities, all for the benefit of the user.

IUIs focus on incorporating automated and AI technology into existing user interfaces to improve the overall performance and usability of human-computer interaction. The use of AI allows user interfaces to leverage human skills and thinking and make interaction increasingly natural and effective. In terms of improved interaction, IUI systems offer capabilities such as human communication methods like speech and gesture and the capability to adapt to different interaction methods. The applications of AI also allow IUIs to support adaptive interfaces that adapt to the inferred capabilities of the user or multimodal systems that can enable natural forms of human input and output (Sonntag, 2015).

User Experience in Intelligent User Interface Design

User experience in regard to user interface design is largely defined by a system's usability and how well the user's end goals are met (Norman & Nielsen, 2022). IUIs are the next step to improving the user experience as they seek to further dissipate the line between human and computer interaction; they promise various benefits, most notably: more efficient interaction, more effective interaction, and more natural interaction. When considering how AI can be applied to user interfaces, the opportunities lie in two primary areas, how the user interacts with systems and how the system interprets and responds to them (Maybury, 1999). Investigating literature in these areas will help in identifying how current AI tools can actively be applied to user interfaces and used to improve the overall user experience.

Interactions

Whether you are asking Siri for directions to the nearest coffee shop, telling Alexa to turn off the lights, or opening Spotify to your daily curated playlist, these interactions are relatively one-sided. Currently, many interface systems rely on intermittent interactions; these interactions draw a clear line between human and computer communication in which the user is always the initiator of any interaction. This follows a turn-taking process in which the user offers a specified input and the computer offers a predefined response (Berkel et al., 2021). While intermittent interactions are most commonly used with user interfaces, it fails to address other forms of interactions that might not follow this specific turn-based process.

In order to keep up with advancing technology, user interfaces need to accommodate increasingly complex user interactions such as continuous and proactive interactions. In continuous interactions, computers actively listen and respond to continuous streams of user input. Similar to a conversation, a user can naturally provide a steady stream of inputs throughout an interaction and subsequently receive consistent outputs. Especially for simulation tasks, like driving a car or flying a plane, it is beneficial that the interaction is continuous and uninterrupted so that the user can consistently provide inputs without having to repeatedly issue

commands. We see common examples of continuous interaction through spell-checkers that correct consistent streams of user inputs from their keyboard (Berkel et al., 2021). Additionally, some forms of AI systems do not require any need for user input to complete certain actions. Proactive interaction occurs when AI systems can actively initiate and complete tasks based on accessible data and information from inputs like sensors; rather than the user, the system itself assesses the situation and chooses to initiate an interaction. This sort of interaction offers benefits in that simple user actions can be replaced by automated systems that seek to serve the user's goals (Berkel et al., 2021). For example, a user entering and opening the front door of their home might trigger an AI automated system to turn on the lights in certain areas to increase visibility. The goal of this form of interaction is to reduce the cognitive load on users and allow them to exert this energy on other tasks.

In all three of these interactions, it is important to note that the user can respond to the interfaces in distinct ways. While an intermittent interaction would result in a response by an AI system and subsequent interpretation by the user, a continuous interaction would involve consistent output from the AI system which a user might not need to consistently interpret. In the case of Microsoft Office's virtual assistant, Clippy, consistent suggestions while the user was performing highly concentrated tasks resulted in frustration with the system. Therefore, these systems should contain the option for users to ignore the system's suggestions and maintain their stream of input. In the case of proactive interactions, if certain interactions were not satisfactory to the user, they would have to actively react to the interaction and correct and adjust it themselves (Berkel et al., 2021).

Interpretation

With rapid advancements in the way we communicate with computers, user interfaces are beginning to evolve from singular modes of input and output to multimedia interfaces that use a combination of different media ranging from tactile inputs to audio and visual outputs. In traditional uses with GUIs, using a pointing device like a mouse to select an object might be more efficient than recognizing the spoken name of a word. Where GUIs were limited in their interaction capabilities, multimedia interfaces now go beyond the simple text-based search engines and employ a variety of modalities in order to best facilitate communication with the user (Sonntag, 2012). Multimedia interfaces now change how we interact with computers. Rather than binary inputs, interfaces are now challenged with interpreting ambiguous inputs that might result from audio and visual inputs.

In our everyday lives, we extensively rely on multimedia communication to converse with other individuals. The mere act of talking with someone involves a combination of gestures, spoken language, and even drawings. While humans are able to naturally interpret multiple inputs, computers are often limited to singular and unambiguous forms of input (Maybury, 1994). One of the benefits IUIs offer is multimedia input analysis to enable diverse forms of human-computer interaction. Multimedia input occurs when an interface supports a variety of different input methods and is subsequently more flexible in how it interprets the users' inputs. While traditional interfaces tend on using conventional input devices that provide definitive inputs like a computer mouse and keyboard, IUIs facilitate broader and more ambiguous forms of input (Maybury, 1999). Examples of these inputs include spoken language, writing, gesture, eye and body tracking, and facial expressions.

Multimedia input analysis is valuable to human-computer interaction because it has the potential of amplifying human abilities in a user interface. The use of multiple inputs offers the

potential for increased flow of information between humans and computers and additionally in how effectively information is interpreted (Maybury, 1994). Apple's Siri is a voice-speech input software that makes effective use of multimedia input to enable hands-free interaction. In cases where users might be occupied and unable to directly manipulate and interact with their smartphone, voice recognition and comprehensible voice outputs allow the system to effectively coordinate responses in audio and graphical outputs.

In addition to multimedia input analysis, IUIs offer the benefit of multimedia output in which system responses can be presented in a variety of different formats and media. While conventional user interfaces like GUIs respond to user input through predefined formats like menus and windows, IUIs are capable of interpreting user input and presenting outputs through a variety of different media in an integrated and coordinated manner. Examples of these outputs include typed or spoken language, graphics, and gestures (Maybury, 1999).

Applications of AI Tools

Understanding how AI can be used to improve user interaction and system interpretation is important for targeting AI tools that can be used to directly support these factors. User interface designers can use this information to understand the applications of AI tools and how they can be implemented into user interfaces. Examples of AI technology applicable to user interfaces include but are not limited to natural language processing (NLP), natural language generation (NLG), and machine learning (ML).

Natural Language Processing (NLP)

Natural language processing is a discipline within AI that uses a variety of computational methods to analyze naturally occurring texts and achieve human-like language processing. NLP systems rely on a variety of human language models to accurately interpret and break down ambiguous and complex meanings of individual words and sentences; levels of language processing include phonetics, syntax, and semantics to name a few. By naturally occurring texts, the system is able to interpret diverse languages, modes, and genres whether it be in written or oral form. The overall goal of most NLP-based information retrieval systems is to represent the true intentions of a user's query and express them in natural language as if they were speaking to a librarian (Liddy, 2001). Smart assistants like Alexa and Siri use NLP systems to interpret questions and sentences and provide useful responses based on context. Given the intricacies and complexities of human language, AI is becoming increasingly relevant in developing NLP systems that can accurately interpret and respond to our needs.

NLP offers applications in nearly any system that utilizes text including but not limited to: information extraction, question and answering, summarization, and dialogue systems. In information extraction, NLP can be used to recognize and extract information about distinct elements and develop structured representations. This has applications in queries in which systems can search and filter through extensive lengths of texts and find relevant information for users. On the same line, question and answering utilizes information extraction to provide single-answer responses or lists of relevant answer passages that would answer a user's query. Another application would be summarization in which the system is able to interpret and condense information from large passages into abbreviated formats. Dialogue systems would also allow humans to have intelligible conversations and increasingly natural interactions with computers (Liddy, 2001).

Natural Language Generation (NLG)

While NLP primarily focuses on the interpretation of human language, natural language generation focuses on the output of responses. Think of NLP as the listener in a conversation and NLG as the speaker (Liddy, 2001). The goal of NLG is to produce natural written or oral communication to users based on existing data that might have been recovered and interpreted by NLP. Given that computers and machines are often subject to the output of canned responses based on user inputs, NLG helps structure and respond in a comprehensible manner. NLG can be divided into a variety of different stages but pays particular focus on text planning, sentence planning, and the realization and correct use of grammar. Using existing models on text organization and sentence structure, NLG is able to generate coherent outputs based on accessible data and information (Cawsey et al., 1997). Complex examples include virtual assistants that provide personalized and adaptive responses to specific user needs while simpler cases might involve live chatbots that generate responses in a personal and easy-to-understand way.

The applications of NLG can largely be applied to the automation of tasks and the presentation of information in a comprehensible manner. Using a combination of language processing and generation, users can instruct computers to complete tasks and provide structured reports; it allows individuals to interact with computers more efficiently and proactively. Additionally, NLG also improves the accessibility of interactions by allowing for a more comprehensible generation of information through written and spoken language. In the case of health care, it is incredibly important that communication is clear. Among healthcare professionals and their patients, there is a strong need for the generation of textual reports and explanatory material from structured data. Improvements in NLG systems not only allow for flexible and efficient presentation of information but also contributes to better communication and fluency of output texts (Cawsey et al. 1997).

Machine Learning (ML)

Modern-day computer systems, in stark contrast to early interfaces, are increasingly more interactive and support frequent user input and multimodal communication. One of the key limitations of early computer systems was that they offered little flexibility and could not account for differences in user style, knowledge, and preferences. While some systems offered personalization, they required users to explicitly and manually input their preferences which were cumbersome and often not reflective of all their implicit behaviors. What machine learning technology offers, however, is the capability of automatic personalization of interactive systems. Machine learning is defined as a learning algorithm for a computer system used to improve its skill in a domain based on prior experience. By using existing datasets, the system is able to "learn" and create knowledge structures that help improve its performance on certain tasks. Additionally, ML involves a level of induction in which a system is required to make judgments based on its prior knowledge and experience; therefore the more amount of data it takes in, the greater its ability to create insights and predict results (Langley, 2006).

A potential application of ML is in constructing advisory systems that are able to provide recommendations to users based on their existing knowledge base. Given that the system is consistently taking in new inputs from the user via induction, it is able to effectively adapt the to unique preferences and behaviors of the user. Every user interaction adds to the existing knowledge base (Langley, 2006). With an ever-growing knowledge base, ML is beneficial in recognizing the goals of the user and developing plans and recommendations that assist them

(Lieberman, 2009). Interfaces that incorporate ML will contain a competitive advantage over those that do not as they provide users with a more personalized and efficient experience. Where this application of ML is limited, however, is in how much data is available for which to provide accurate and useful feedback, otherwise, how much time a user interacts with the system. This encourages faster learning methods that achieve high accuracy from small data sets rather than higher accuracy but slower learning (Langley, 2006).

IUIs in the Smart Home Industry

A growing industry in which the application of AI is becoming increasingly popular and successful is smart home systems. The concept of smart homes revolves around the idea of implementing technology into living environments in order to increase the habitual support of its inhabitants and therefore improve their overall well-being (Augusto & Nugent, 2006). The purpose and needs of this industry primarily focus on improving the quality of life for users, making the home environment more accessible, and reducing energy consumption (Guo et al., 2019). Smart homes are often equipped with a wide range of different technologies including sensors, wired and wireless networks, and intelligent systems. Given the interconnected nature of how users interact with smart home technology, it creates an expectation of an environment capable of actively reacting to and predicting the needs of the user, which naturally overlaps with the field of AI (Augusto & Nugent, 2006). As such, in recent years, significant advancements in AI technology have led to the implementation of these technologies into smart home products and systems, which has revolutionized how users interact with user interfaces.

While smart home systems offer convenient and economical solutions for turning on/off lights and heating systems based on the relative location of the user, they have more impactful uses in independent living. Especially for individuals struggling with physical or cognitive impairments, the introduction of AI systems can help support levels of independence, comfort, and security in their own homes (Augusto & Nugent, 2006). Individuals are now able to complete tasks that they would have otherwise has no control over and are able to continue living in their homes without the need for institutionalization. Therefore, the application of IUIs offers a competitive advantage in creating accessibility in interfaces and improving user experience.

Early versions of smart home systems were limited to simple motion sensors and basic interactions that would detect inputs and provide outputs (Augusto & Nugent, 2006). The next generation of systems, however, is driven by intelligent virtual assistants like Alexa and Google home that use voice-driven technologies. Smart home systems have transitioned from relatively low-interaction systems to systems that are capable of intelligently communicating with humans. This transition has largely been a result of the advancements in NLP and NLG in which virtual assistants are able to utilize advanced voice recognition to more accurately interpret user inputs and then generate multimodal responses; it results in highly efficient and more natural human-computer interaction. The applications of IUIs in smart home systems are an example of how AI can successfully be used to elevate user interfaces. Incorporating the latest AI advancements into user interfaces has been and will continue to transform the way in which systems proactively help their inhabitants in an intelligent way (Augusto & Nugent, 2006).

AI Technology Implementation

As discussed previously, the application of AI into user interfaces is beneficial for improving human-computer interaction and overall user experience. When considering how to implement AI into existing user interfaces, designers must understand how AI can be selectively

applied as needed as part of a more complete product. AI should be thought more of as a way to amplify the user's ability in an existing user interface rather than an omniscient problem solver (Birnbaum et al., 1997).

A key idea to highlight in user interfaces is that they are often underconstrained and riddle the user with a variety of different options. Where AI is beneficial is that it can be used as an agent capable of helping intelligently make suggestions that guide the user to making a decision. The potential downside of this is that the reasoning and suggestions capabilities of AI would lead the user to view the system as more annoying than useful; therefore its usage should be thoroughly considered and sparingly applied. AI should be applied in a way that does not disturb the user and gives the user the option to ignore any suggestions (Birnbaum et al., 1997).

When considering whether AI should be implemented into a system, it is important to weigh the advantages of AI techniques over using traditional methods. Some interactions may be more successful with direct-user manipulation and therefore eliminate the need for AI techniques as a whole. Other downfalls of AI applications include being prone to making mistakes and clouding the user's mental model for how the computer is interpreting their input. Making mistakes can make verifying and correcting them restrictive to the user and lead to a lower sense of reliability with the system. In most cases, it is important to consider where AI is applied to the interface so that the benefits outweigh the problems. In other cases, traditional methods can be used to support the use of AI in the interface (Birnbaum et al., 1997). For example, when considering how a user can interact and provide inputs to an interface, it would be important to consider the use of NLP in order to more effectively interpret ambiguous user inputs via natural language or text. Depending on the purpose of the interface, AI may or may not be necessary for providing outputs to the user. If a user is completing a hands-off task, NLG through text-to-voice would be useful, otherwise, traditional text responses would also suffice.

Future Developments of IUIs

IUIs are the next step towards transforming the way users can interact with user interfaces. With exponential strides in AI technology, companies across the globe are now looking for ways to incorporate it into their technology. The recent introduction of ChatGPT by OpenAI in late 2022, has led to a rapidly growing interest and popularity of AI technology and the start of an AI arms race among some of the world's top companies like Google and Microsoft. For reference, ChatGPT is an AI natural language processing tool capable of providing exceptionally natural and useful responses to user inputs. It gained more than 30 million users two months after its debut and has made its mark as one of the fastest-growing software products (Roose, 2023b). Microsoft recently lined up a deal with OpenAI and now uses ChatGPT as a tool to intelligently power its search engine, Bing. The application of ChatGPT into Bing's interface allows for a blend between a search engine and a chatbot in which a user's question would be met by a natural response written in full sentences and annotated with links (Roose, 2023a). While its application in Bing is still prone to error, it still offers significant opportunities in improving the interaction between humans and computers. Its recent applications demonstrate its potential to transform human-computer interaction from a one-sided conversation, into a fully-interactive dialogue.

Difficulties of Conducting Research

Given that I had no prior knowledge of the concepts of user interface design, AI, and IUIs, it was initially difficult to filter through academic literature in order to find relevant information. My research was interdisciplinary in nature and required me to delve into a variety of different fields including human-computer interaction, adaptive user interfaces, and various different AI tools and technologies. As such, there were conflicting definitions and applications of certain AI tools to a variety of different user interfaces.

While there was an overwhelming amount of literature on individual topics including machine learning, user interface applications, and human-computer interaction, there was significantly less on IUIs. Given that IUIs are a niche domain, it was difficult finding information that created relevant connections between my areas of research. Additionally, much of the literature I found was slightly outdated and described very early applications of AI in user interfaces. Therefore, I spent more time researching modern literature and drawing connections and comparisons between sources.

Remedies of Difficulties

In order to improve and develop my understanding of AI and user interfaces, I conducted background research on conventional user interfaces, their goals and purpose, and how AI could be used to supplement those goals. Additionally, I reviewed the literature on IUIs to establish a definition, purpose, and understand their applications to a variety of fields. Given that the general principles of IUIs and AI were similar across different literature, my next goal was to narrow down the scope of my research so that I could effectively establish relevant connections between AI tools and user interfaces. As a remedy, I identified two primary opportunities in which AI could be applied to user interfaces: how the user interacts with systems and how the system interprets and responds to them. This allowed me to research these specific opportunities across different domains and identify AI tools that could actively be used to support them. In terms of making relevant and up-to-date connections, I drew upon studies that explored the active application of AI in modern-day user interfaces and made comparisons with the older literature. This allowed me to further understand the impact and benefits AI had on improving the user experience.

The remedies listed above ultimately allowed me to culminate my research into this final report which highlights the key opportunities for the implementation of AI tools, specific AI technology that can support those opportunities, and recommendations for how AI might be implemented into existing systems.

Discussion of Findings

The findings of this literature draw interdisciplinary connections between domains of AI technologies and applications, user interfaces, and human-computer interaction in order to develop an understanding of the opportunities of AI and how it could be effectively implemented into existing user interfaces to develop interactive IUIs. Overall, I found the early literature on these topics to be widely applicable and relevant to how AI is currently being applied to systems. Though much of the literature written in the early 2000s was speculative in nature for the eventual applications of AI toward creating more efficient and natural interactions, its current applications have in fact reaffirmed these findings. AI techniques are increasingly being used as agents and tools to better understand and interpret user inputs and provide increasingly natural

and accessible responses through the use of multimodal interfaces, NLP, and NLG. The use of additional AI tools like machine learning has also allowed for improved interactions between users as they allow for increased personalization and adaptation to the user's needs.

Although the literature about IUIs was more difficult to come across by, I was able to draw relevant connections between the purpose and goals of IUIs and how they would guide the application of AI into user interfaces. Much of the literature emphasized that IUIs focused on improving the efficiency and naturalness of human-computer interaction by reasoning and acting on existing models of users, domains, and tasks (Wahlster, 1998). Based on the factors of "efficiency" and "naturalness," I sought to focus on understanding how AI could be specifically applied in these areas. This narrowed my research to how the user interacts with the system and how the system interprets and responds to them, given that improved interactions would result in greater efficiency and improved interpretation would result in increased naturalness of communication. Further research into the application of specific AI technologies in these areas and examples of successful implementation in industries like smart homes supported my findings on the benefits and future potential for IUIs. In line with the goals of IUIs, AI tools are improving human-computer interaction by enabling interfaces to interpret and respond through multimedia output and by providing personalized and intelligent recommendations that help guide users.

Based on recent developments by OpenAI and the implementation of AI tools like ChatGPT into various systems, I strongly believe that the use of AI techniques not just limited to NLP, NLG, and machine learning will be instrumental in revolutionizing how users interact with interfaces; IUIs will be the next stepping point in the evolution of user interfaces.

Maturity of Research Topic

In my research, an abundance of literature on relevant fields of human-computer interaction and the applications of AI in user interfaces demonstrate maturity for the topic. While the topic of IUIs and AI has long been studied and has extensive research into their applications, recent developments in AI technology like ChatGPT have significantly less literature and research given its inception within the past few months. Given that research on the implementation of these recent topics has still yet to mature, I predict that the implementation of AI technologies into user interfaces will become increasingly studied as more companies begin to adopt AI into their systems.

Future Direction of Research Topic

A future direction of this research would be to continue exploring different approaches to implementing AI into user interfaces. While my research was concerned with important considerations such as limiting the implementation of AI to only where the benefits outweigh the drawbacks, additional research can be done on user interface design and how AI can be physically applied. In using design heuristics, it would be beneficial to understand how the AI tools should be presented on the user interfaces and how they are able to interact with the user in a way that does not disrupt their actions. Conducting a cross-analysis between successful conventional user interfaces and IUIs would be important in creating guidelines for AI implementation. Additionally, with the landmark introduction of ChatGPT, given the recency and rapid expansion of how AI tools are being applied to a variety

of systems, more research can be conducted on how AI is being integrated into systems and its future applications.

Conclusion

In a period where user interface design is at the forefront of all computers and software, users are more than ever expecting higher levels of convenience and turning towards AI tools like virtual assistants for personalized and immediate assistance. Significant improvements in how AI tools can generate natural language and conversation, interpret information, and respond to users have encouraged the evolution of traditional user interfaces into highly adaptive ones. While traditional user interfaces prioritize anticipating the user's needs and responding to their direct inputs, IUIs use AI tools to interpret information from the user and respond to their immediate needs. It improves the user experience by offering an efficient and natural interaction that encourages an open dialogue between both parties. IUIs can also offer benefits such as the comprehension of ambiguous or unclear communication and semi-automatic or automatic completion of tasks, which offers to streamline and improve overall productivity and efficiency.

Two primary areas of opportunities for AI applications in user interfaces include improving how users interact with user interfaces and how systems can interpret and respond to their inputs. The use of more complex user interactions beyond intermittent ones like continuous and proactive interactions enables flexible communication and improved efficiency from the automation of tasks or the interpretation of continuous streams of input. Additionally, AI tools also have the potential in enabling diverse forms of human-computer interactions through the use of multimedia inputs and outputs; systems are able to interpret ambiguous inputs and construct structured outputs that suit the needs of the user. Given that the field of AI seeks to model human thinking, various AI tools and techniques would be beneficial in supporting these areas and developing more natural communication, thereby improving the efficiency of interactions (Lieberman, 2009).

With the use of NLP, NLG, and machine learning, several industries involved in smart home products have already seen successful applications of these AI tools in user interfaces. Virtual assistants like Alexa can utilize advanced voice recognition to more accurately interpret user inputs and then generate multimodal responses; it results in highly efficient and more natural human-computer interaction that improves the user's overall experience. The benefits of IUIs, however, are not only limited to smart homes as their recent uses in search engines and digital applications are continuing to improve existing user interactions.

Implementing AI tools into existing user interfaces is the next step towards revolutionizing how we approach user interface design. With the recent and rapid application of AI technology into user interfaces, the field of IUIs is being increasingly relevant and important in developing natural and interactive user interfaces. It is important to continue researching this area to further understand opportunities for AI and techniques for seamlessly integrating them into existing user interfaces. To summarize, research in this report conducts a thorough review of opportunities for AI tool implementation and how current tools are being used to elevate existing user interfaces. The goals of this research are to (1) discuss the importance of implementing AI tools into user interfaces, (2) identify what elements are necessary for an Intelligent User Interface, (3) outline the applications of specific AI tools, (4) offer recommendations on AI tool implementation to improve human-computer interaction, and (5) review the future developments of IUIs.

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