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Reasoning: A capability of AI contributing to human-computer interaction design

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Abstract. Artificial Intelligence (AI) has gone through significant development in the past decade. During this period, the ability of AI for reasoning has improved as well. At the same time, the software and the interactive digital product have made great progress. Therefore, it would be reasonable if the reasoning ability of AI could be applied to Human-Computer Interaction (HCI) design, which could provide more efficient methods for advancing user experience and help designers create products that are more satisfying to users. In this paper, we introduce the current developing status of the reasoning ability of AI. Then, we propose four characteristics of HCI and explore how these features could correspond with the application of AI reasoning. Furthermore, we present the existing applications in this field. Finally, we show our insights on the future of this combination in replacing users' roles, interactive data analysis, user experience evaluation, and template production.

Keywords: artificial intelligence, reasoning, human-computer interaction, user experience.

1. Introduction

Since the term "Artificial Intelligence (AI)" was proposed in the early 1950s, its relative research has been continuing and there is a great development in this field. During this period, some researchers try to equip AI with the ability of reasoning, that is, allowing AI to imitate the human's thinking process. And much work has been done in this field, which covers multi-step reasoning (including solutions for the most popular reasoning task: Visual Question Answering) and relational reasoning. Until now, AI can perform some basic reasoning. At the same time, interaction design for a better user experience has been drawing more and more attention. Many companies and researchers have realized that it is of great importance that their products could offer a great experience for their users. One of the principles in interactive design is to make the software more human-like. Thus, some researchers have applied AI to enhance user experience and it turned out that this combination is quite satisfying. Wu et al. said that "Machine learning boosts the inferrability of multimedia through endowing it with the ability to reason [1]." Therefore, in this paper, we are going to explore the feasibility and excellence of applying the capability of AI for reasoning to Human-Computer Interaction Design. We summarize what has been done in AI for reasoning and present the results achieved so far. Furthermore, we point out how will this research evolve in the future.

2. Related work for AI reasoning

Reasoning is a symbol of an intelligent mind. It means the ability to infer the solution to the current question or situation by utilizing acquired knowledge. Reasoning is a breeze for all human beings, but

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not for artificial intelligence since the principle of the human brain is extremely complex. Fortunately, the rapid development of the neural network provides a promising way to realize this function. Plenty of work has been done and the neural network can solve some simple questions about reasoning, such as Visual Question Answering (VQA) [3]. There are two essential parts for neural networks to gain the ability of reasoning. The first would be multi-step reasoning, and the other would be relational reasoning.

Multi-Step Reasoning

In a natural neural network, reasoning is achieved by thinking multiple times. When we try to draw a conclusion about a question, we need to remind our learned knowledge and repeat a thinking procedure several times in our brain. And that would be the same for AI. An effective way has been proposed named Retrieval Neural Network (RNN) and several forms have been introduced. Drew A. Huston and Christopher D. Manning designed the MAC Network [2]. There is a recurrent network in MAC Network, which depends on many MAC cells. The MAC cell consists of a control unit, a read unit, and a write unit. The structure of the cell is shown in Fig. 1. What's more, when it comes to reasoning, there is a large amount of research focusing on Visual Question Answering (VQA) [3]. VQA is a method to determine whether AI is capable of knowledge-based reasoning and commonsense reasoning by offering a picture and a series of related questions. Example questions are presented in Fig. 2. Kan Chen et al. proposed a classic attention-based solution, which is the one-step solution capable of finding the objects in the image [4]. More recently, Wu et al. developed the chain of reasoning (CoR) [5], which can produce a multi-step reasoning method. The chain of reasoning is a breakthrough from the limitation that all the outputs of the VQA are based on original input. The structure of CoR is presented in Fig. 3. It could produce new results and relations. In addition, Cadene et al. adopted multimodal relational reasoning in VQA. They decided to model the interaction between different regions of an image in a vectorial representation [6].

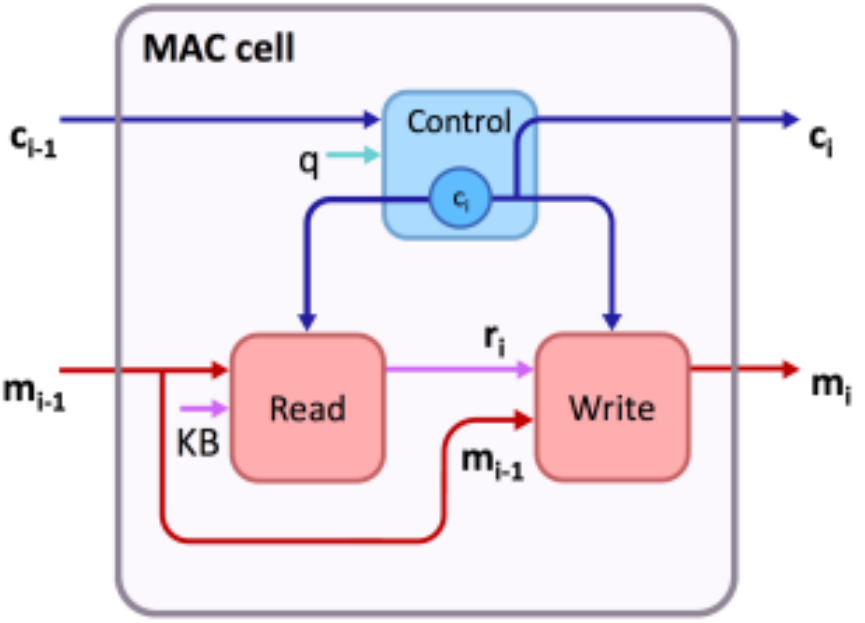

Figure 1. The control unit could develop the next control information based on the last control information and the information from the question. The read unit would utilize the last memory and figure, which enables it to read the new information. The write unit writes the new memory by using the new information and the last memory [2].

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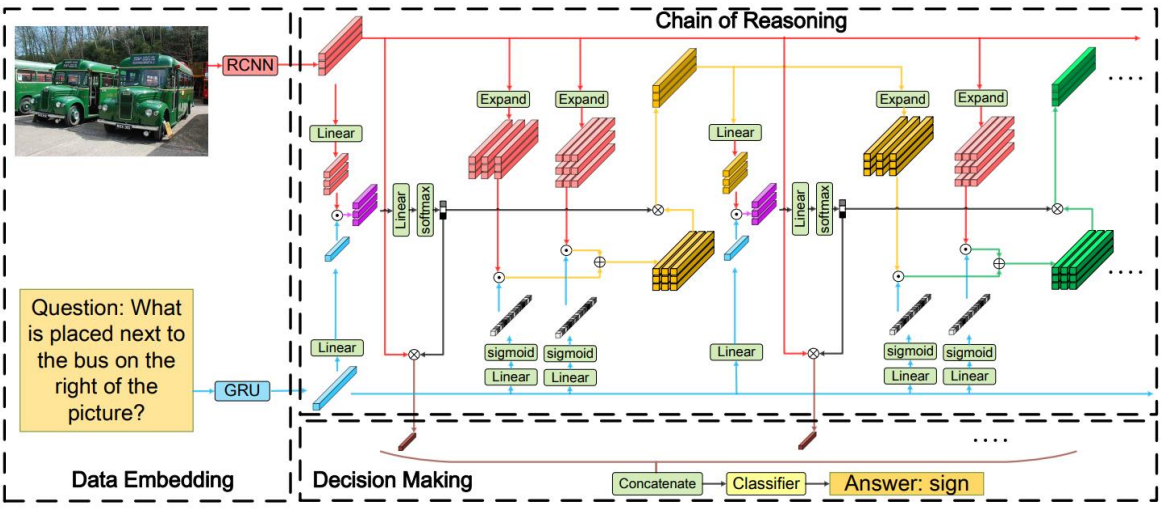

Figure 2. The structure of CoR. The picture shows the operating principle of CoR to solve the VQA questions [5].

Figure 3. Example questions for VQA. Here are some examples of free-form, open-ended questions collected for images via Amazon Mechanical Turk [3].

Relational Reasoning

Except for multi-step reasoning, relational reasoning is another way to imitate the human thinking process. Algorithms could utilize relational knowledge and information to acquire the ability of reasoning as well. Scarselli et al. propose Graph Neural Network (GNN), which has become prevailing in relational reasoning [7]. Most research uses graph neural networks to accomplish tasks such as object detection, object tracking, and VQA by integrating basic features and then creating senior features. Yu et al. use a general Layout-Graph Reasoning (LGR) to show structural relations

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among clothing landmarks [8]. Zhu et al. apply generated parameters into the graph neural network, which enables relational message-passing [9]. The overall structure of [9] is presented in Fig. 4. In addition, Zhou et al. present many kinds of new forms of the graph neural network [10] such as graph convolutional network (GCN), graph attention network (GAT), and graph recurrent network (GRN). These variants performed well in many tasks.

Besides, some research also adopts Relation Network to achieve this goal. Santoro et al. solve various problems about relational reasoning by using RN-augmented networks [11]. We could know the model in Fig. 5. Zhou et al. introduce the Temporal Relation Network (TRN) to capture temporal relations among video frames [12].

The capability of AI for reasoning has evolved to the point where it has become a state-of-art technology. And if we utilize this ability in human-computer interaction, the interaction design and relative technologies will reach a new level. Nonetheless, there is still a lot of room for the development of AI reasoning, since the human brain is so sophisticated that it is hard for the neural network to simulate it. We are looking forward to seeing the emergence of new technologies and more applications

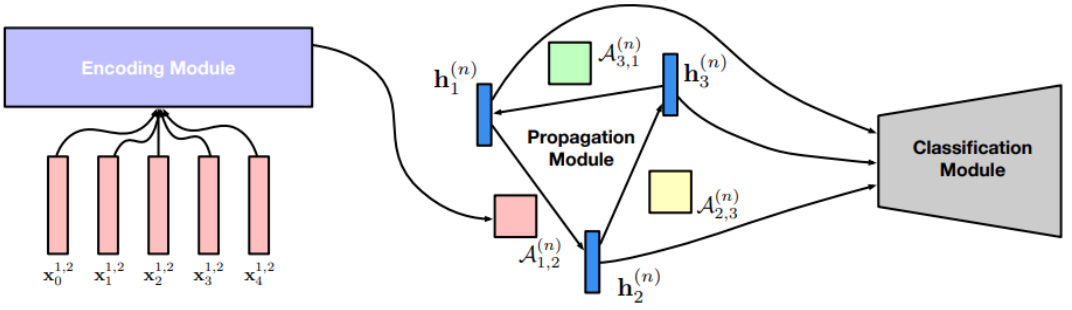

Figure 4. The overall structure of Graph Neural Network with Generated Parameters [9].

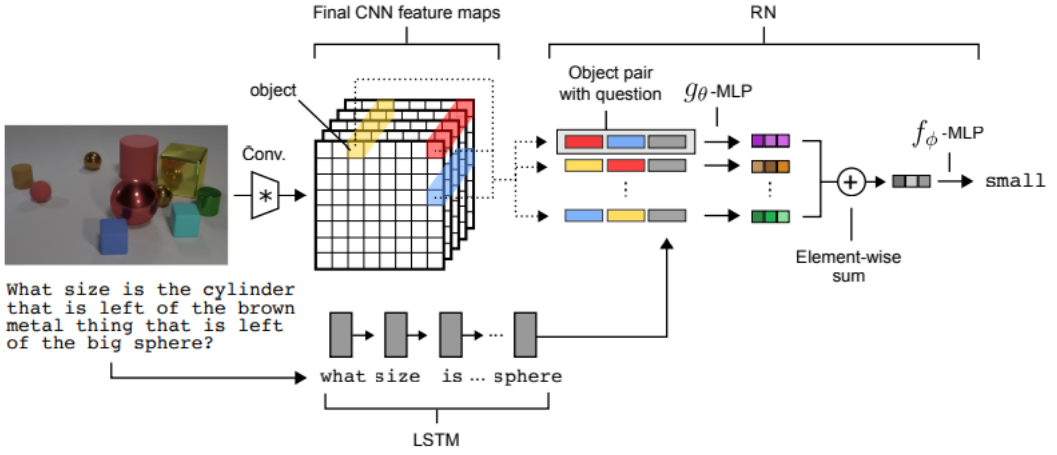

Figure 5. The model of Relational Network with VQA [11].

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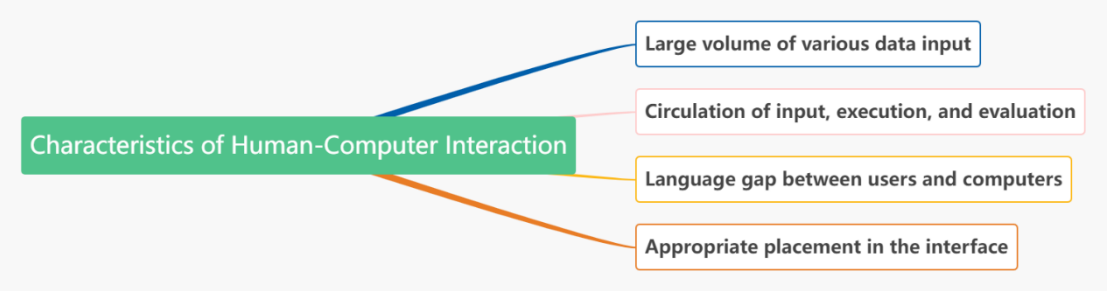

Figure 6. The characteristics of HCI. Firstly, the input data is of different kinds and the volume is large. In addition, there is an "input-execute-evaluate" cycle in almost every interaction. Also, there is a gap between natural and machine languages, and appropriate placement is essential in interaction design.

3. Application of reasoning ability from Artificial Intelligence in Human-Computer Interaction

Characteristics of Human-Computer Interaction

There are several characteristics of Human-Computer Interaction that would be helpful in our goal. Characteristics are all presented in Fig. 6. We will discuss these characteristics in detail in this section, especially how these features will correspond with the reasoning ability of Artificial Intelligence.

A) Large volume of various data input

Since the concept of Human-Computer Interaction has been introduced, the volume of data that could enter or be obtained from a system has been dramatically increasing, and there are more and more different types of data as well. To deal with various kinds of data or other forms of information from users, a reasonable way is to utilize the reasoning ability of Artificial Intelligence, which enables researchers to analyze and understand all the relationships among data. By doing this, it would be easier to process a large amount of data. Furthermore, designers would provide a better user experience by designing a more appropriate interactive method that depends on the correlations between data.

b) Circulation of input, execution, and evaluation

The interaction starts with inputs, such as the data, the goal, or both. Then, the inputs will be executed by the computer. Finally, the user will evaluate the output provided by the computer. These three operations from the user and the computer form the basic loop in interaction. From this cycle, we could know that the user would evaluate the output, which includes the behavior of reasoning. Therefore, if we could apply the feature of reasoning in the execution part of computers, the user would receive a more satisfying result.

c) Language gap between users and computers

It's universally acknowledged that computers use machine language, such as binary, numeral data, etc., which is contrasting with human's natural language. To deal with this problem, the concept of Natural Language Processing (NLP) has been introduced, which aims at processing natural language with the computer, or more precisely, Artificial Intelligence. The necessity of understanding users' goals or desires enables Artificial Intelligence to process the inputs from users and achieve further analysis. That way, users are able to enter whatever they want, which is the symbol of a better user experience.

d) Appropriate placement in the interface

Appropriate placement is the prerequisite for users to successfully accomplish their tasks. Nonetheless, it is difficult to specify every user's task correctly since everyone has their own goal when using the computer. Thus, it would be effective if we employ Artificial Intelligence to learn from the user's behavior. Then, based on the analysis, designers are able to provide interfaces satisfying users' needs.

Application of reasoning technology from Artificial Intelligence in Human-Computer Interaction Design

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Currently, machine learning methods are being applied to promote user experience in some fields or products. One spectacular way is to assist users to achieve their goals when using computers or other electronic devices. Other methods including generating interactive templates and users' behavior analysis are also being used. Although the reasoning parts of Artificial Intelligence are far from being human-like, it is possible to utilize what we have now to improve user experience. We will summarize the progress made in this application from the three methods mentioned above, hoping to provide a comprehensive view of the development in this field.

a) User-assisting

When we learn that the reasoning ability of AI is a way to simulate the human thinking process, what comes to mind easily is that we could utilize this ability in user-assisting activities. This assistance would be significantly effective when users are trying to accomplish creative works, painting, for example, and some researchers have already come up with some innovative ideas in this application. Changhoon et al. proposed an original form called "Duet Draw" [13]. This is an AI-embedded interface based on CNN and Sketch RNN, which enables the user and the AI agent to draw together. This research has created a new paradigm of human-computer interaction and provided a great user experience for users. We could know the process of "Duet Draw" in Fig. 7.

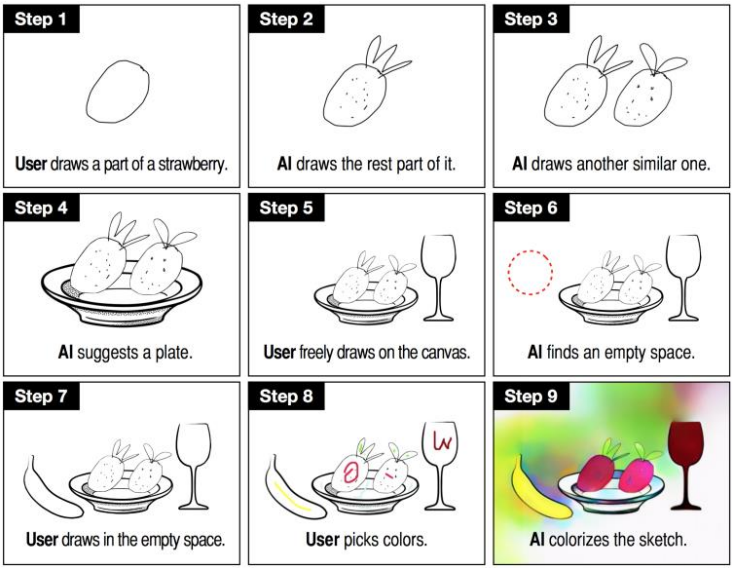

Figure 7. Procedure of Duet Draw. AI and users could collaborate to finish a painting [13].

b) Interactive Template Generating

Not just for the users, AI reasoning could also be applied to the creative works produced by designers who aim at delivering a good user experience. That means, AI could generate works that have the value of user experience based on the reasoning ability and the samples learned. Sara et al. presented a Creative Artificial Intelligence System (CAIS), which could automatically produce creative works of aesthetic and emotional quality [14]. In their research, they proved the feasibility of their idea and claimed that it would have user experience applications. This technology provides a brand-new way for designers to create works, which brings both conveniences for designers and satisfaction for users.

c) User Experience Evaluation

Besides collaborating with users, AI could also assist researchers and designers to observe and analyze users' behavioral preferences. A simple way to do this is mouse-tracking, that is, to record users' mouse trajectories to achieve user experience evaluation. Recent UX evaluation studies have been based on mouse tracking, but relatively few have applied AI inference algorithms to achieve this. Kennedy et al. introduced an interaction monitoring application titled Artificial Intelligence and Mouse Tracking-based User eXperience Tool (AIMT-UXT) [15], which is proved to be more

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comprehensive and effective. We could see the architecture of this tool in Fig. 8. Maxim et al. utilized the Artificial Neural Networks (ANNs) to assess the user-subjective web interface similarity [16].

4. Development Prospects

Since the reasoning ability of AI is still in the early stage of development, more and more research will be done and advanced methods will merge to deliver a better user experience. In this section, we would explore future development models of AI reasoning algorithms and how these models would serve as the basis for enhancing user experience.

Virtual User

Interaction design should focus most on users. It is users who would use the product instead of who design it. Thus, communication with existing and potential users is of great importance. Several traditional methods have been employed for relatively a long time. Laugwitz et al. introduced an end-user questionnaire to assess user experience [17]. Simple and quickly as it is, the questionnaire is time-consuming and hard to acquire an inclusive estimation of all users. Another way is interviewing, which has the same drawback as the questionnaire and the result is probably inaccurate since there are always some unavoidable objective factors such as psychological or environmental factors.

Nowadays, AI is capable of doing basic reasoning, as we have mentioned above. And in the future, AI is likely to be able to roughly imitate the human thinking process. This means, they will not only deal with simple problems like VQA, but they will also be able to make judgments about their surroundings and do reasoning based on their knowledge acquired. Therefore, we introduce the term "Virtual User", which means the allowance for AI to replace traditional users' role for designers to evaluate users' habits and interests. AI can first learn some good design cases as reference. Then, once a designer has completed a piece, AI can use its reasoning capabilities to evaluate it and provide feedback to help the designer improve his or her work. In this process, AI replaces the role of users to provide a more convenient way for designers to determine whether their products could satisfy users' needs. This cycle is shown in Fig. 9. When the reasoning is explainable and advanced enough that it could provide a reasonable estimation of the software interface, "Virtual User" would be qualified enough to collaborate with designers to yield products that make users feel enjoyable and content.

Precise Interaction Data Analysis

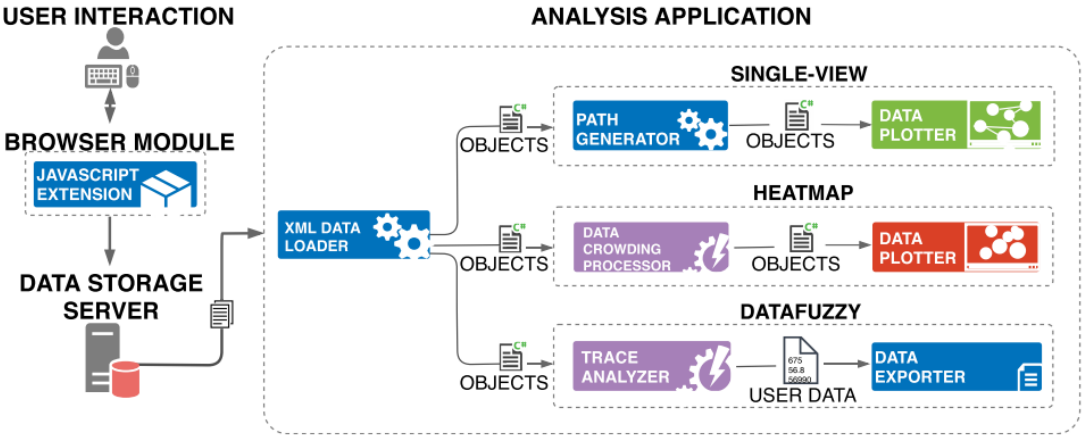

Figure 8. The architecture of the AIMT-UXT tool [15].

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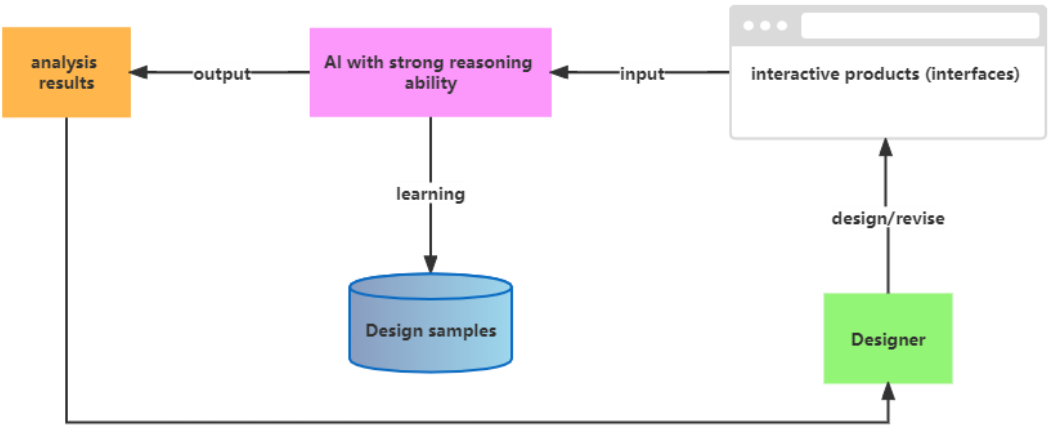

Figure 9. The working process of “Virtual User”. This is a cycle about how “Virtual User” works..

Based on the discussion above, we know that the data generated during the interaction process is large and varied. And there is a language difference between the user and the computer. It can be imagined that when AI is powerful enough to reason like the human brain, the data-processing task could be assigned to AI. The addition of AI can make large amounts of complex and diverse data simpler. For example, to deal with the quantity, it is possible to infer and summarize the relevance of data, which is similar to the association analysis in data mining. That way, when the computer tries to execute the data, it would receive data sets, which are smaller in number and regular, instead of disorganized masses of data. What’s more, during the interaction process, many messages will be generated in the form of graphics or audio. The existence and application of AI inference capabilities will make it possible to transform these images or audio into text data. It will recognize them, reason about them, and finally produce results corresponding to them. In this way, the variety of data will be greatly reduced, bringing convenience to the computer to process it.

According to the speculation above, the amount and type of data to be processed will be minimized. Admittedly, whether this can be achieved depends on the future trend of AI and whether the data arising from the interaction process will evolve.

User Experience Evaluation

In the previous section, we only present a small number of techniques that combine user experience evaluation and AI. In fact, there are a lot of means to achieve this such as cardiac monitoring, mouse tracking, eye tracking [18], fixation of attention, etc. The reason why these methods are not being proposed in the paper is that they all have made little or no use of AI. Therefore, applying AI reasoning algorithms to these evaluative methods is of great importance for future studies. We will explore how to use AI to do innovation according to the existing technology.

Visualization is one of the state-of-art technologies in computer science. It is a technology that converts data into graphics or images to be displayed on the screen and then processed interactively. Therefore, applying visualization and reasoning algorithms to tracking and monitoring in user experience is a key ingredient for promoting user experience. It would be effective to utilize visualization to transfer data from monitoring and tracking activities into graphics and infer users’ usage trends by AI.

Another field waiting to be explored is the attention map, which is beneficial for the fixation of attention in user experience evaluation. Attention maps can provide researchers with a clear picture of users' behavioral preferences during interactions, and AI can infer from the attention map to do the assessment.

What’s more, object detection based on GNN could be used to monitor users’ movement when interacting. It will focus on the whole person instead of a certain part. AI can reason whether an

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interactive product is convenient for him or her and whether he or she is comfortable and content in the process of using it, which makes the evaluation more comprehensive.

In summary, when AI reasoning capability is further developed, researchers will have more ways to evaluate user experience, and the reasoning ability of AI will play

Design Templates

The main application area of AI reasoning algorithms is images. From the assistance of AI reasoning in creative works we have presented before, we could reasonably predict that it is possible for AI to produce creative works on its own. For enhancing user experience, the specific methods are as follows. First, AI will be provided with some excellent design examples to learn. Then, researchers will input some parameters, AI will produce an interface template based on what it learned and the data inputs. Finally, designers could come up with an interface that is able to offer a good user experience only by modifying the template. The key to this process is whether the AI can produce a reasonable product that delivers a good user experience, which depends on the development of reasoning ability of AI in the future. For now, some research has shown the potential of AI to generate creative works such as [14], but the use of higher-tech AI to produce better work is still expected. If it happens, it would benefit both designers and users.

5. Conclusions

In this paper, we explore the potential of applying the capability of AI for reasoning to Human-Computer Interaction Design. We do a summary review of the current development of AI and the characteristics of human-computer interaction. Based on these characteristics, we explored how to apply the reasoning ability of AI as a way to improve it. After that, we summarize the current applications in related fields, which mainly focus on creative works and user experience evaluation. Last but not least, we provide an outlook on future development from four dimensions, which are based on the characteristics of human-computer interaction.

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