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Cognitive science and artificial intelligence: simulating the human mind and its complexity

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Abstract: This study encompassed around the interdisciplinary study of cognitive science in the field of artificial intelligence. Past as well as current areas of research have been highlighted such that better understating of the topic can be ensured. Furthermore, some of the present-day applications of cognitive science artificial intelligence have been discussed as these can be considered as the foundation for further improvement. Prior to discussion about future scopes, real-time complexities have been revealed.

1 Brief overview of cognitive science and artificial intelligence

The science of psychology came into focus since 1800s with several researchers searching for common yet specific human mind characteristics. Cognitive science has been first highlighted in the 1930s in context to psychology as this concept is considered to be an indicator of reaction to a given stimulus. With time, this topic was backed up with computer models that enabled simulation of levels of human thinking [1]. Cognitive science is now referred to as the study of every detail about mind and includes varieties of research science in the fields of philosophy, education, artificial intelligence (AI), neuroscience, linguistics and anthropology. Scientists associated with cognitive science study behaviour as well as intelligence, emphasising on ways the central nervous system process, transform and represent information. Aim of cognitive science is to understand principles of intelligence such that better comprehension of mind and learning can be facilitated. AI is moreover, the simulation of human intelligence, processed by computerised systems. This enabled acquisition of information and using applicable rules to come to a definite conclusion such that self-correction can be fostered [2].

1.1 AI within cognitive science

Initially, the branch of AI emphasised on cognitive behaviour of machines. However, technological advancements allowed AI to encapsulate concepts of cognitive science and focus on ways human or animal or machine store information. This led to the development of intelligent machines with which, speech or emotion recognition, learning and planning, problem-solving and reasoning have become possible [3]. It is also the fact that traditional AI techniques offered limited scopes, in terms of optimistic predictions, which with time became possible with invention of cognitive robots. According to the ideas of [4], robots with wide spectrum of cognitive powers are referred to as cognitive robots. It is possible for these robots to perform open-ended tasks without human help. Integration with a dedicated processing architecture enabled these robots to learn and accordingly respond to complex situations. Knowledge acquisition is however, yet to be explored due to widespread requirement of prediction systems like artificial neural network.

Symbolic modelling is a computer science paradigm which makes effective utilisation of knowledge-based systems and integrates such with the philosophical perspective. Investigation of human-like intelligence models started from early 1990s with use of SOAR. Sub-symbolic modelling on the contrary consists of neural network models and relies on the fact that the brain is an amalgamation of several simple nodes. Due to this, the problem-solving capacity is found to be derived from the connection between these nodes [3]. As a result, numerous approaches of structuring mind have been observed to be simulating, starting from creation of artificial neurons to depicting mind as a collection of symbols, rules and plans.

2 Past and current research in cognitive science and AI

Technological advancements and innovations have made it possible for scientists to stimulate human brain on computerised system with much more precision and accuracy. In other words, it is the cognitive science AI that has ensured effective utilisation of power of computers to supplement thinking ability of human beings. Computer simulation in AI can therefore, be termed as the reproduction of a system's behaviour such that simple as well as complex goals can be achieved [5]. However, there was a time when the ability of AI to model minds was questioned due to lack of revolutionary notion on use of computation as a formal modelling for language recognition. Moreover, there are several past researches works that contradicted with today's fact that AI are identical with cognitive science. This is because that era embarked AI for understanding intelligence in general and not for humans. Additionally, in order to gain better and depth insight about the nature of human mind, the foremost goal is eventual development of both machine and human-level intelligence. One of the significant challenges which emerged due to non-distinguishable intelligent agent and human intelligence is the Turing test [6]. Reason behind this is that these intelligent agents face multiple situations due to incomplete information.

As a result of this, encoding data for these situations has become a limited approach so as to simulate human intelligence. All these concepts together restricted past researchers and scientists to design pre-programmed intelligent agents with solutions that can simulate human intelligence and can also resolve associated problems. These in turn, made it a mandate for the intelligent agent to be equipped with the ability to make decisions depending on the available information [7]. At the same time, this revealed the requirement to re-evaluate past solutions such that future decision-making processes can be enhanced. Consequently, this leads to a more fundamental understanding about ways human mind would learn and solve problems. This in turn, facilitated the necessity to design intelligent systems that would have the same level of intelligence as that of the human mind.

However, as time went by, technological advancements have widened up scopes of AI to foster a natural interaction. Specifically, speech recognition and handwriting recognition are

the two most common areas of cognitive science AI which attracted the attention of researchers. For instance, the article, 'Speech Recognition and Cognitive Skills in Bimodal Cochlear Implant Users' emphasised on determination of the relation between speech recognition and cognitive skills. And for this, 17 users of cochlear implant have been chosen and the cognitive test was done. Aim behind this was to measure processing speed, working memory capacity and executive functioning of the users. All these settings led the researcher to reveal that speech recognition along with bimodal testing have enhanced their speech [8]. At the same time, it has been highlighted that processing of bimodal stimuli is related to different cognitive skills. It has also been analysed that 32% executives depict voice recognition to be the most widely used AI in their businesses.

2.1 SOAR architecture

This cognitive programming-based system has been developed at the University of Michigan in order to simulate the human brain. This system can be referred to as an alternative approach due to the fact that SOAR system stores and retrieve information from working memory [7]. Reinforcement learning that tunes values of rules and altogether, helps in creating numeric preferences is also supported by this cognitive system. In order to enhance flexibility, a structure within the working memory is created which considers rewards. SOAR has also enabled stimulation of virtual humans that supports face-to-face collaboration and dialogues [9]. In spite of the fact that this application has integrated capabilities of natural language understanding, emotion, action and body control however, it is criticised as it is suitable only for the virtual world. Whether aspects of psychology need to be minimised such that better approximation of the knowledge level of symbol processing can be acquired is still under question. This is because SOAR architecture attempts to replicate the evolutionary design process in order to result in better symbol system.

2.2 ACT-R (adaptive control of thought-rational)

ACT-R is a computer simulation or cognitive architecture that aims at defining basic and irreducible perceptual and cognitive operations. As inspired from psychological theories, every task that a human performs is a combination or series of discrete operations. ACT-R can therefore be considered a method to specify ways in which a human brain can be organised so as to process modules of cognition production [10]. Like SOAR, this cognitive architecture relies on computational implementation of special code language. It would be required by the researcher to download the ACRT-R code and load it into a Common Lisp distribution for obtaining access as an ACT-R interpreter. Doing so, would enable specifying of human cognition which would, however, be in the form of an ACT-R language-based script. On successfully executing this entire process, one is likely to produce automatic step-by-step simulation of human behaviour. Additionally, it is possible to take cognitive operations like memory encoding, mental imagery manipulation besides visual and auditory encoding into account. Its declarative memory system has been designed in a way to model human memory. At the same time, this architecture has allowed modelling of understanding and production of natural language. Complex tasks like capturing of how people are able to solve algebraic equations have also been possible with the use of ACT-R [11].

2.3 Stimulating creativity

Most of the current papers related to simulation of human level intelligence within the process of decision making have been witnessed to be emphasising on significance of imitating creativity. It is the fact that past experiences and knowledge is the foundation of decision making and also to suggest for changes. However, creativity is depicted to be a gifted ability of human beings with which, it is possible to solve problems, think, interfere and develop. Creativity is of three types namely, concrete, abstract and artistic [12]. Creativity in the field of engineering applications is however, mainly concrete as this type is about the generation of innovative, new and unique solutions in an environment full of conditions and restrictions.

Time has succeeded in achieving these concepts which were once just an assumption. For instance, AI enabled informed creative decisions, not to recreate the human mind, rather to interact with humans and to inspire creativity. Increasing use of AI for augmenting human capabilities has assured super creativity and assisted human mind in a way where achievement of better results in a short period of time has become possible. This era of man versus machine has now become the reality with everyday human-centric processes are now done automatically, without the need of human beings. For instance, giving presentation of clients or conduction of interviews no more requires physical presence of human beings [13].

3 Applications and importance of cognitive science AI

Considering the discussions made above, it can be added that there are a wide range of importance along with numerous applications of cognitive science AI. It is the fact that the concept of cognitive science AI has underwent massive transformations with time, resulting in an era where it has become possible to develop software that would consider cognitive abilities to solve complex reasoning problems. EvBrain is an example of brain simulation software that is designed to develop artificial brain models. Therefore, with use of this software, artificial animals with brains can be created that would successfully survive in the predator-prey environment. Advanced level of intelligence is, therefore, essential to consider large amounts of information and also to solve complex logic problems in a short time span [10]. Along with this, development of human level intelligent agents has provided a replica of the human mind with which, it is comparatively easier to study about the human brain. Reason behind acquiring depth understanding and knowledge about realistic simulations of human cognition is to draw theories that would showcase human nature, considering cognitive limitations.

It is moreover, assumed that key goals of cognitive science, especially the ways in which intelligence and creativity develops in brain would be known to all [14]. Past literature works have also suggested that better understanding of the learning process of human brain including retrieval of information might lead to improved learning methods. This human progress therefore, has opportunities to be implemented in schools where mind or brains of students are on the verge of learning new things. Similarly, doing so would bring in desirable changes in existing theories and would prioritises development of medical solutions for individuals, dealing with brain trauma. Some of the significant applications of cognitive science AI are as follows.

3.1 Speech-to-text and text-to-speech

Integration of AI with cognitive science has led to the development of speech to text services which in turn have offered human beings with a diverse range of capabilities. For instance, utilisation of these services would support several transcription scenarios like speech or conversation transcription and custom speech transcription. The first type has been designed to convert spoken audio into text. And for this, one is only required to call for the API for recognising the source of the audio, followed by real-time streaming [15]. The second type of application is suitable for in-person meetings as one can capture speeches in real time with its use. Not only this, rather this advancement has fostered smooth recording of discussions, identification of the speaker, time and also follow-up.

Widespread demand of AI has tended scientists and researchers to integrate text to speech or speech to text with the Android platform. Two common examples of both types include Android's native Text-to-Speech feature, Voice Aloud Reader and Google Assistant and OneNote, respectively. The first example automatically works with Google apps that offer read aloud feature. Additionally, one can adjust the pitch, speech rate and are available at different languages. Foremost example of speech to text on the

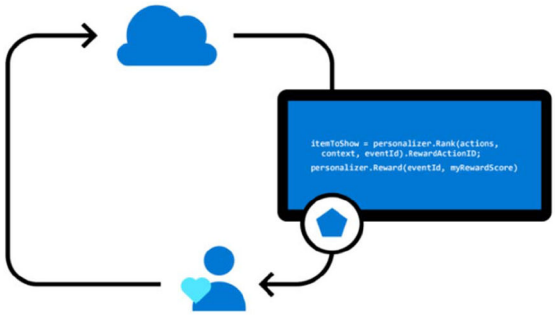

Fig. 1 *Reinforcement learning loop of personaliser of Microsoft Azure (source [16])*

contrary, allowed conversion of audio to text by making use of neural network models. This application moreover, comes with location-based reminder, podcast player and managing of diary [16].

3.2 Personalise

Use of personalised interactions is the outcome of cognitive science AI thereby allowing individuals to rely on and create rich and personalised experiences for users. To be more specific, this modern application lets an organisation to prioritise contents as these are the medium to improve the experience of users. The more relevant the content is, the more satisfied users are. Cognitive services as offered by Microsoft Azure include Personaliser Preview wherein, reinforcement learning-based capability is delivered. Inspired from the findings of a number of studies in this field, reinforcement learning is a technique that allows AI to optimise goals, based on individualised configuration [16].

Fig. 1 can also be referred to as personaliser reinforcement-learning cycle. Reason behind this is that this cycle tends an individual to achieve business goals by learning from real-time interaction with end users.

4 Complexity associated with achieving brain simulation

It has now become the reality for the learning process to become more intelligent with brain-simulation software that mimics neural networks of the human brain. At the same time, it is also the fact that investigation of functioning of brain with computational modelling is complex. This is because of extreme precision, efficiency and accuracy required to model millions and millions of neurons present in a human brain [17]. Achieving the desired level of brain simulation is limited as most of the cognitive operations within a human brain depend on analogue transactions, whereas a computerised system is fully digital. As a result of this, simulation of operations like neurotransmitter concentration, spike frequencies, potential of membrane and metabolic gradients are lagging behind. In other words, present day brain simulation with use of AI requires including of parameters like extracellular interactions of a brain and receptor binding. However, these are still not taken into account as determination of extracellular interaction of the human brain is related to consideration of ways by which stiffness of extracellular matrix and pH so as to influence interaction between receptors and matrix ligands [18]. However, there is lack of evidences regarding measuring of pH in a computerised system. This therefore, requires generation of algorithms that would be based on the working principle of brain.

This has moreover, facilitated the requirement of studying functional integration to acquire knowledge about how different regions of brain work altogether to process information. However, unavailability of top-down and bottom-up models have restricted casting of brain thereby minimising scopes of hypothesis-testing systems and proceeding with typical simulations, respectively [19]. Additionally, there is a lack of evidence regarding passing the Turing Test with AI allowing fully simulation of brain. Another imitation of computerised simulation of intelligence that is worth mentioning is related to speed and capacity of hardware required for performing computation. Reason behind this is that there are no technologies that would tend to fasten running of large-scale simulations than real time. Co-evolution of human mind and intelligent systems has encountered huge challenge due to availability of artificial bots [13]. These bots attracted the attention of a large number of human and left them with the dilemma whether they are even interacting with other humans.

5 Future trends or scopes in simulating the human brain

Considering continuous improvements and technological innovation, it can be mentioned that it would be exciting for AI researchers in the next 20 years. This is because the human mind has an excellent capability to perform diversified mental as well as physical tasks, without giving much stress on the brain. The advent of nanotechnology which aimed at increasing speed and memory of computational hardware is estimated to be the future of human brain simulation. Not only this, but modern cognitive science AI theories are analysed to be fostering better understanding of mind and brain [16]. Advancements in the fields of cognitive and psychological science enabled diverse understanding of human behaviour thereby making scopes for intelligent agents. In context to the perspective of cognitive science, it can be added that there is a wide range of scopes to proceed with large-scale cognitive simulation, which is referred to as macro-modelling. Most of the cognitive simulations of today's world emphasises on only process only. Inputs to these simulations are hand generated whereas outputs are hand evaluated. As a result of this, it becomes problematic for human beings to deal with large heaps of data [9]. Emergence of macro-modelling is therefore assumed to be helpful in capturing a broader perspective or dimension of human behaviour.

6 Concluding remarks

It can therefore, be concluded that AI is a useful tool in the research area of cognitive science as this technological innovation facilitated better understanding of human mind. Useful insights about human recognition have been made possible with AI-based applications like speech to text, text to speech, natural language understanding and personaliser. It is furthermore, estimated for intelligence agents to enhance the ability of human brain simulation. However, there are certain complexities that might end up in limiting scopes of brain simulation for which improvements like nanotechnology and cognitive science AI theories are desired. These theories would specifically, enable full understanding of human mind besides taking complex problems into account.

7 References

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