The Development Overview of Artificial Mind

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ABSTRACT
Artificial Intelligence (AI) has attracted much attention on both academic field and industry recently. The partial target of AI is to bring convenience to human life, even replace human force in complex and dangers work context. The final focus of AI is to behave as Natural Intelligence (NI) revealed by humans and other animals. In this paper we provide a review of the development of Artificial Mind (AM), including artificial perception, artificial emotion and artificial consciousness. We have investigated the above fields to figure out what points they have been advanced in contrast to NI. The results shown that with the popularity of AI research and progress, the AM has been pushed forward a lot. But there are still large gaps between AI and NI.

CCS Concepts
• **Computing methodologies→Artificial intelligence**.

Keywords
Artificial intelligence; artificial mind

1. INTRODUCTION
Artificial Intelligence is to design a machine system to think and act like human beings. It is realized on machine to artificially simulate and extend human intelligence, aiming at thinking and acting like human beings [1], AI is one of the largest cross-disciplinary fields in science and engineering. It contains several sub-fields and involves so many research fields.

Generally speaking, AI contains six subfields including machine learning, computer vision, natural language processing, knowledge and reasoning, robotics and finally game theory and ethics. In this paper, we walk the reader through AI development from Artificial Mind (AM) aspect. We provide an entire survey on Artificial Perception (AP), Artificial Emotion (AE) and Artificial Consciousness (AC). Our definitions of AP, AE and AC are in line with the definitions of previous work, but with a little difference which we will explain in following context [3–6].

Briefly speaking, AI development history can be divided into seven stages. First, in 1936, the mathematician Alan Mathison Turing proposed the famous Turing machine, a mathematical model of computation that defines an abstract machine which manipulates symbols on a strip of tape according to a table of rules [2]. After that computer system and related procedure languages were invented, bringing machine and architecture basis for AI. Hence, Turing is widely considered to be the father of theoretical computer science and artificial intelligence (AI). Second, from year 1956 to 1974, AI has been firstly proposed formally. In this stage, AI has experienced its first golden years. In 1957, Herbert Alexander Simon, et al. created the General Problem Solver (GPS) program and other related work, which are great achievement in information processing research.

Third, from year 1974 to 1980, after studying AI deeply, researchers have realized that difficulty of AI research is much greater than imagined. AI experienced the first winter stage. In 1977, Edward Albert Feigenbaum has published paper "The art of artificial intelligence: I. Themes and case studies of knowledge engineering", providing knowledge engineering and expert system.

Fourth, from year 1980 to the late 1980s, AI experience boom stage. The expert system was further advanced. Then, natural language processing and computer vision have been further developed into industry. The fifth stage is from year 1987 to 1993, in which AI has experienced another winter. The sixth stage is from year 1993 to 2001, in which intelligent agent was proposed. The seventh stage is from year 2000 to present, in which deep learning, big data and artificial general intelligence have enjoyed a prosperity due to large amounts of data and faster computer and machine learning techniques.

This paper takes attention to Artificial Mind (AM), including Artificial Perception (AP), Artificial Emotion (AE) and Artificial Consciousness (AC). We provide a review of AM including AP, AE and AC. We give a brief observation on Natural Mind (NM), which serves as a clue for distinguishing AM and NM. We briefly discuss the related-aspects in NM that have informed and inspired AM design. We describe three aspects in detail: (i) AP, including artificial sensation and perception; (ii) AE, including artificial emotion and affect; (iii) AC, including consciousness and cognitive processes. We briefly discuss the main differences existing between the NM and AM, after providing what status the three aspects of AM have been developed into, we give out our understanding of future directions of these researches.

2. NATURAL MIND
Everyone knows that the mind is the product of the brain. But the question is how the brain makes the mind? The answer to this question also gives the important clue for designing AM. There are psychological and neuroscience knowledge in this question, which are not the focus of this paper. Hence, we omit

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the details of psychological and neuroscience knowledge, and provides an abstract description of NM research.

The first aspect of NM is sensation, referring to the processing of senses by the sensory system. Sensation research is to study how we human beings are able to see, hear, taste, smell and feel touch or pain. Sensation is the detection of physical stimuli and transmission of that information to the brain [8]. From this definition, we see that the processing of senses can be divided into 4 stages: stimulus, sensation, sensory coding and perception. Stimulus is common to human, such as light, sound, smell, sweet taste and physical collision.

Sensory coding is a processing where sensory systems translate the physical properties of stimuli into patterns of neural impulses. Obviously, the sensation processing starts from receptors (e.g., eye, ear, nose, mouth and skin), which indicates that designing an artificial sensation needs the devices that have similar functions with the receptors. The second aspect of NM is perception, which is the brain's further processing, organization and interpretation of sensory information. Obviously, perception is complex processing in brain. Different sensation processing types (e.g., vision, audition, gustation, olfaction, vestibular sensation and somatosensation) have different perception processing. Even in the same sensation type, different stimuli would get different perceptions.

To make the concepts of sensation and perception clearer, we provide a vision example of illustration in Fig. 1. When a person sees a picture. The light reflected by the picture is detected by specialized neurons in his/her eyes, and those neurons transmit signals to his/her brain. When the brain processes the resulting neural signals, he/she experiences the portrait and recognize the meaning of the face in the picture. Finally, he/she has perceived the picture and guessed the man in the picture.

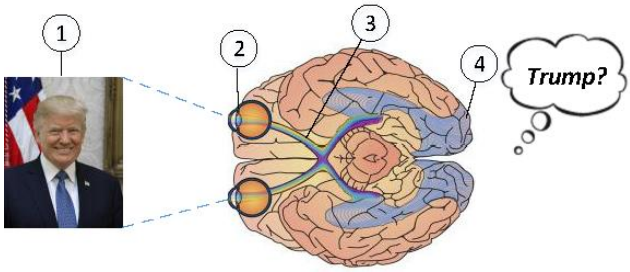

Figure 1. Vision example for sensation and perception.

1. Stimuli: A picture with lines and colors reflects light in the form of photons;
2. Sensation: Sensory receptors in eyes detect the stimuli;
3. Sensory Coding: The stimuli is transduced;
4. Perception: The brain processes the neural signals and constructs a representation of picture. The brain interprets the representation of the picture as Trump.

The third aspect is emotion, which is any conscious experience characterized by intense mental activity and a certain degree of pleasure or displeasure [11]–[15]. An emotion is an immediate, specific negative or positive response to environmental events or internal thoughts. Emotions have a physiological component. There are three major theories of emotion: JamesCLange, CannonCBard and Schachter-Singer Two-factor theory. In his 1884 article, William James argued that feelings and emotions were secondary to physiological phenomena [16]. Walter Bradford Cannon agreed that physiological responses played a crucial role in emotions, but did not believe that physiological responses alone could explain subjective emotional experiences [17]. Stanley Schachter formulated his theory on the earlier work of a Spanish physician, Gregorio Mara˜ nón, stating that emotion is based on two factors: physiological arousal and cognitive label. [18].

The fourth aspect is learning, which is a relatively enduring change in behavior, resulting from experience. It is a change in the state of a system produced by experience and reflected on behavior. Learning is a generic term of a diverse number of different cognitive processes [7], [8]. Learning makes animal benefit from experience to suit competitive environment. It also shapes animal's life style and behavior feature. The ability to learn is possessed by humans and animals to gain knowledge about the world. Psychological research provides the identification of four sorts of learning: non-associative, active, associative and observational learning. Non-associative learning refers to "a relatively permanent change in strength of response to a single stimulus due to repeated exposure to that stimulus" [9]. Non-associative learning can be divided into habituation and sensitization. Active learning occurs when a person takes control of his/her learning experience. Associative learning is the process by which a person or animal learns an association between two stimuli. Observational learning is learning that occurs through observing the behavior of others.

The fifth aspect is memory, which is closely related to learning. Memory is the faculty of the mind by which information is encoded, stored, and retrieved. It is a brain activity based on nervous system. Often memory is understood as an informational processing system with explicit and implicit functioning that is made up of a sensory processor, short-term (or working) memory, and long-term memory [10]. Hence, memory can be classified as sensory memory, short-term memory and long-term memory. Sensory memory holds sensory information less than one second after an item is perceived. Short-term memory is also known as working memory. Short-term memory allows recall for a period of several seconds to a minute without rehearsal. Long-term memory can store much larger quantities of information on potentially unlimited duration (sometimes a whole life span). Based on different types of memory, the objects of learning are also different.

The sixth aspect is consciousness, which is the state or quality of awareness, or, of being aware of an external object or something within oneself [19]. Consciousness refers to moment-by-moment subjective experiences. There are many higher-order cognitive processes, including consciousness, perception, attention, awareness, thinking, reasoning, problem solving, decision making, understanding, judging and so on. It is possible to identify four forms of consciousness: Sensory experience, "the phenomenal sense that something exists in relation to, or has an impact on, a person". Practical consciousness, "knowing how to do things, knowing how to go on". Reflective consciousness, "the modality in which people reflect upon the first two forms. It is the stuff of ordinary philosophy and day-to-day thinking about what has been done and what is to be done". Reflexive consciousness, "reflecting on the basis of reflection, and interrogating the nature of knowing in the context of the constitutive conditions of being" [20].

The study of consciousness is always difficult because consciousness is coming from 'self' instead outside stimuli. It is difficult to determine what state of consciousness of a person is. Hence, the consciousness is still uncertain in a clear definition,

which continues to challenge scientific psychology. There are a large body of literature on consciousness, which we omitted for brevity.

3. THE CLASSIFICATION OF ARTIFICIAL MIND

We classify Artificial Mind (AM) into three types as shown in Fig. 2. The first type is Artificial Perception (AP), which corresponds to sensation and perception. The second type is Artificial Emotion (AE), which corresponds to emotion and affect in NM. The third type is Artificial Consciousness (AC), which corresponds to learning, memory and consciousness.

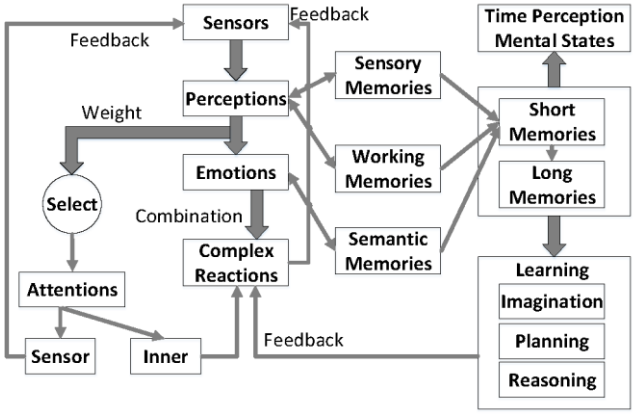

Figure 2. The view of Artificial Mind (AM). Artificial Consciousness (AC) goes through all the interactions among models.

We believe that the core of NM is Artificial Consciousness (AC). One reason is that it leads us to better understand human beings: How do us humans perceive the world, reason, think, make decision, solve problem, etc., and finally evolve? Another reason is AC will help people from many aspects, e.g., to help solve human problems and to explore the world with human together. In the following sections, we will detail the development and achievement of these three artificial things illustrated in Fig. 2.

4. ARTIFICIAL PERCEPTION

To realize artificial perception, we need artificial sensation first. In the broadest definition, a sensor is a device, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. A good sensor should be sensitive to the measured property, be insensitive to any other property likely to be encountered in its application, and it does not influence the measured property. The types of sensors are much more various than human sensors, such as sound, vibration, transportation, chemical, electric current, environment, fluid velocity, position, angle, optical, light, imaging, etc. These sensors would make artificial sensation much more accurate and complex.

Meanwhile, the methods of information transmission from sensor to artificial system are various. Take the Internet of Things (IoT) for example, IoT is the network of physical devices, vehicles, home appliances and other items embedded with electronics, software, sensors, actuators, and network connectivity which enables these objects to connect and exchange data [21]. The simple way of transmission is to directly link the sensor and artificial end point by physical lines.

The artificial perception is the process that allows the artificial system to access and interpret sensory information and introspect its own mental content [6]. According to the natural perception in Section 2, artificial perception can be classified as five types: visual, auditory, gustatory, olfactory, haptic and kinesthetic perception. A worth-noting thing is that perception is a top-down processing, leading to an artificial perception with a feedback loop. A suitable and novel technology for this perception is ASsociative Neural Network (ASNN) which represents a combination of an ensemble of feed-forward neural networks and the k-nearest neighbour technique. The method operates by simulating the short- and long-term memory of neural networks [23]. ASNN is able to incorporate new data cases of short-term memory and provides high generalization ability without retraining the neural network weights.

Visual perception is the ability to interpret the surrounding environment using light in the visible spectrum reflected by the objects of the environment. Artificial visual perception not only uses digital camera to capture the picture from environment, but also to 'feel' the target of other perceptions such as auditory and gustatory perceptions. Artificial visual perception contains visual preprocessing, visual attention, gaze direction, visual memory and object recognition. Visual preprocessing is to capture the image by camera or sensor from outside environment and generate data information for further processing. Theories and observations of visual perception have been the main source of inspiration for computer vision.

Auditory perception has the following steps to perceive sound: separate sounds perception, sound pattern recognition, sound direction perception and auditory motion sensing. Separate sounds perception means that the artificial system is able to extract sounds suitable to perceive. Sound pattern recognition is to obtain the sound pattern from a mix sound information from sensor. Sound direction perception is to help capture the target sound from an unknown direction. Auditory motion sensing is to suit the sound motion in a dynamic environment.

Gustatory perception or taste and olfactory perception have been studied for the last two decades mainly from the point of view of the features of gustatory and olfactory neuron receptor fields. Generally speaking, chemical sensors with overlapping selectivity patterns could be used to discriminate among different tastes and odors. The combinatorial signals pattern emerging form the ensemble of receptors is the key of taste and odor classification, identification and recognition [24].

Haptic perception gives information by touching object. Haptic sensor should get the information of touched object, such as hardness, surface feature, temperature, pressure etc. The information can be classified as two parts. The touched part and untouched part of sensor. Meanwhile, haptic perception has long-term memories to store position data of object. Kinesthetic perception gives position, motion and tension of object. This perception is important when artificial system has to identify what position and situation it is in. These two perceptions covered various applications such as prosthetic, teleoperation and especially advanced robotics [25].

The high-level perception process of computer technology can be viewed as pattern recognition, a branch of machine learning that focuses on the recognition of patterns and regularities in data, although it is in some cases considered to be nearly synonymous with machine learning [22].

5. ARTIFICIAL EMOTION

Emotion is one of the most significant features of human, which makes a person feel good, bad, pleasure and pain. There are some robots that can make the facial expression of emotion while they did not have real emotion progress in their system. And researchers start to implement the emotional artificial robot like human.

The simple way to generate emotion is to use the perceptions described in the above Section 4. A taste sensor that senses a sweet taste would give the artificial emotion a pleasure feeling. A sensor that is damaged would give a pain signal to artificial emotion system. A pleasure signal makes the system more 'exited' or 'positive' or 'optimistic' while a pain signal makes the system more 'negative' or 'slow'. A 'positive' action includes focused attention, continuable working attitude, prompt response, etc. A 'negative' action includes delayed response, pessimistic attitude, error-prone operations, etc.

It is advised that pleasure is a process that some conditions are matched in artificial system while pain is a process that some conditions are mismatched in artificial system. Meanwhile, the reactions invoked by these feelings would further promote the development of emotion. The emotion expressing is a feedback system both in and outside the artificial system itself. The emotion also can rise from memory in artificial system. The key problem is how to determine what the feelings are in current artificial system. The ideas are to determine feelings according previous experiences or memories and current situation in and outside the system.

The artificial reaction to emotion is proposed as two modes: representational and non-representational modes [26]. In representational mode, artificial emotion system perceives accurate sensor information and makes basic decision on emotion results. In non-representational mode, artificial emotion system should self-talk about what the feelings it has in current situation. After both modes of emotion decision, the reaction to decision would be evoked and put on sensor processing. The different basic sensations would generate different reactions. Meanwhile, the combination of different reactions would generate complex emotion.

Further emotions will inspire artificial system to evolve. An artificial system with emotion will have feelings about its environment, leading to further interactions between it and its environment. For instance, a pleasure talk would make system more likely to continue the talk, and even generate other emotions such as curiosity to understanding the talked person. The further emotion may be desire for something or willing to learning something. Similarly, pain emotion gives the artificial system a stop signal or an experience memory. An idle system would have a boring emotion, and chose an action from its memory to relieve the boring feeling.

6. ARTIFICIAL CONSCIOUSNESS

An artificial system is able to focus on a specialized object instead of all the objects around it because it can only process one object at one time [6]. This focus is reflected by sensor attention and inner attention. Sensor attention makes the corresponding sensor to sense specified object. Take visual sensation for example, the main sensor area is the high-resolution centra area of sensor, which determines visual attention. Another example is auditory sensation, the main sensor area is the high-sensitive centra area of sensor, which determines auditory attention. In addition, a perception of one type of sensation is able to impact other types of sensation. For example, a sudden lightening would turn the auditory attention to where the lightening occurs. Inner attention makes the artificial system to process a task at one time, which is more efficient than process more than one tasks.

Short-term and long-term memories are like retrieval information process. Short-term memories store the recent status of system itself and environment. For example, 'what has I done in this afternoon? Short-term and long-term memories are always related to time points and location and sensation. Hence, the construction of artificial short-term and long-term memories should use time point as main key and location as second key in memories and be related to sensory memories. The combination of keys would be used to search target event in memories. The match and mismatch signal will be returned if the target is found or not found. Short-term memories will fade away with time flows, and recent and new memories will be pushed into short-term memories. Obviously, the repeatedly evoked short-term memories should be stored in long-term memories. Similarly, the impressive or important or great events would be captured into long-term memories.

Based on memories, an artificial system can be deployed with high-level psychology behaviors such as imagination, planning, reasoning and finally learning. First, imagination is to call for perception information which comes from artificial memories instead of artificial sensation. Second, schedule or plan is based on imagination, because the effect of configured condition can be imagined. This gives the artificial system ability to predict a general result in future. Third, reasoning is based on memories. Obviously, this ability is feasible to be deployed in artificial systems because the machine learning technologies is naturally able to learn to reason rules from experiences. Lastly, based on artificial emotion, memories, imagination and reasoning, the system is able to learn new things for outside stimuli and inner reasoning.

So far, we have described artificial sensation, perception, emotion, memories and learning. The next target is to construct an artificial cognitive system. Obviously, the cognitive system should sensor outside world, perceive information by both sensor and inner memories, and finally process the meaning deduced from these actions and information. A cognitive system should be self-motivated and make suitable response to the outside environment.

Last but not least, artificial consciousness is the final target to develop a conscious system. The two theories of consciousness are dualism and monism. In science research, people prefer to explain materialism from monism. Most researchers reckon that consciousness is based on human neurons and neural processes. Technically speaking, artificial consciousness should be able to perceive and process the information on the world and be self-motivated. The artificial consciousness in science research is closely related to perception, attention and inner interaction. Artificial consciousness should focus on an object, making artificial attention inevitable. Artificial consciousness is closely related to perception.

According to the different construction thought, the model of artificial consciousness can be categorized into 5 types. One proposal is global workspace [27]. Global workspace model views the human brain as an organized network of specific automatic processors, providing a global information processing

in the brain. Intelligent Distributed Agent (IDA) is directly motivated by global workspace models [27]. IDA is a multi-agent system consisting of Java processes working in parallel.

The second proposal views consciousness as information processing and integration [28]. The basic thought is that the shared information among brain regions enables them to interact in a constructive fashion. The third model is self-model that an intelligent agent has an internal model encompassing not just the external world, but also including a model of itself [29]. One suggestion is that self-models could lead to "self-reference" whereby an artificial agent reasoning on itself can reason on its reasoning process on itself, resulting in a "self-referring loop" [30].

The fourth viewpoint is higher-level representations which argue that the level of representation determines the degree of consciousness and unconsciousness [31]. The representation is the pattern of information that denotes something. The fifth proposal is attention mechanisms [32]. This mechanism makes artificial system to select what it attends to actively, enabling the system to focus on behaviorally important aspects of sensory information.

7. CONCLUSION

This paper provides an overview of Artificial Mind (AM), including Artificial Perception (AP), Artificial Emotion (AE) and Artificial Consciousness (AC). By investigating these works, we found that AM is an ongoing work with a key difficult on consciousness definitions. Most works chose to simulate consciousness instead of making clear what consciousness is. The philosophical discussion and conscience questiones are proposed with AM designing. Although the AM work is facing these difficulties, the creation of consciousness remains a possibility. AM research will continue to provide helpful clues for understanding human consciousness

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