The Role of Metacognition Application for Creating Self-studying Type Artificial Intelligence System

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Abstract

The major difference between humans and other species is our ability of non-conscious control. Similarly, artificial intelligencean be considered a unique species which is distinguished from human beings because of its lack of cognition regulation, self-regulation, self-assessment and self-diagnosis abilities. Applying these capabilities on AI will revolutionize autonomous systems and provide a new perspective on artificial intelligence. This paper defines the structures and methodologies required to provide Metacognition capabilities to AI systems. We will primarily introduce the AI Meta-reasoning System Model created by Schmill MD & Oates T (2008) and Multifaceted and Multilevel Model of Metacognition created by Efklides (2008) as a theoretical framework, then we'll develop an AI's metacognition system model based on these two models. Then, under the subject "how to make AI react differently based on recognizing a person's current mood," we will discuss the feasibility of applying metacognition theories on AI to enable it to self-adjust, self-assess, self-control and regulate its cognition.

Statement of the Problem

In today's society, AI technologies are smarter, more complex and more innovative. However, they sometimes cannot provide people their desired service. For example, a Google Home[1] can easily play a music list under people's instruction, but it cannot play an appropriate list of music based on people's current mood. Additionally, unlike humans, the knowledge storage of artificial intelligence cannot be improved with its experience, because it doesn't have memory track to store the information it just experienced with. Therefore, machines are unable to alter their responses to changing environments. For instance, the robot Sophia[2] cannot answer a question which is excluded by her inner algorithms. Based on those problems mentioned above, metacognition provides an Artificial Intelligence system with a sense of Self-Analysis, or Introspection, allowing the system to "think about what it thinks", thus self-controlling its reaction to humans.

Purpose of the Study

The purpose of this study is to analyze metacognition application on AI systems by implementing AI's current abilities including face detection, speech recognition, invariant recognition, object detection and so on, to provide a more accurate perspective on how to create a self-analysis type AI system. Our ultimate goal is to provide scientists a feasible

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[1] Google Home is a brand of smart speakers developed by Google. Speakers enable users to speak voice commands to interact with services through Google's intelligent personal assistant. A large number of services, both in-house and third-party, are integrated, allowing users to listen to music, control playback of videos or photos, or receive news updates entirely by voice.

[2] Sophia is a social humanoid robot developed by Hong Kong-based company Hanson Robotics.

and actual inspiration to develop a humanitarian-flexible AI system which can capture and utilize emergent behavior, derive concepts, preserve its own attention, and avoid interruption and distraction during the analytical process.

Research Question

For the purpose of this study, the following questions were addressed:

1. Based on the metacognition model created by Efklides (2008), can the metacognitive process occur in AI as it occurred in human's brains?
2. If the metacognition process is applicable for AI, what is the logic of its operating process? Will it be the same or different with human's metacognitive process?
3. When comparing the metacognitive process of humans with AI, what are the advantages and drawbacks of AI metacognition?

As part of this study, the investigation will include two research hypotheses:

1. The model of human being's metacognitive process is also applicable on AI.
2. By implementing metacognitive processes, AI can achieve self-analysis and introspection.

Definition of Terms

1. *Artificial Intelligence* — is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans and other animals. In computer science AI research is defined as the study of "intelligent agents": any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals. Colloquially, the term "artificial intelligence" is applied when a

machine mimics "cognitive" functions that humans associate with other human minds, such as "learning" and "problem solving". See glossary of artificial intelligence.

2. *Metacognition*－Knowledge of Cognition. Refers to what a system knows about its own cognition or about cognition in general. In short, it describes the system's techniques to think to think about how and what it thinks. It includes three different kinds of metacognitive awareness: declarative, procedural, and conditional knowledge.

- **Metacognitive Knowledge** (also called Metacognitive awareness) is what the system knows about itself as a cognitive processor
- **Metacognitive Regulation** is the regulation of cognition and learning experiences through a set of activities that help people control their learning.
- **Metacognitive Experiences** are those experiences that have something to do with the current, on-going cognitive endeavors (current mission).

3. *Machine Learning*－A field of computer science that gives computer systems the ability to "learn" (i.e. progressively improve performance on a specific task) with data, without being explicitly programmed.

Theoretical Framework

Meta-reasoning system model, which was defined by Schmill MD & Oates T (2008). Cited that an AI system capable of reasoning about its own capabilities is said possess the ability of meta-reasoning. The logic of AI metacognitive process is similar to meta-reasoning model. Figure 1 is a typical meta-reasoner model. consisting of a sensorimotor subsystem, shown in the figure as the *ground level* and responsible for sensing and

effecting changes in an environment, a reasoning subsystem, shown as the *object level* and responsible for processing sensory information and organizing actions at the ground level, and a meta-reasoning component, shown as the *meta level* and responsible for monitoring and controlling the application of components at the object level.

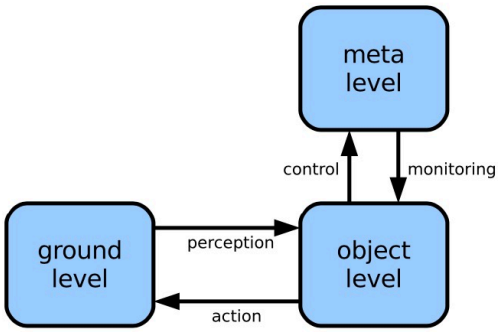

Figure 1: An overview of a typical meta-reasoning system

Multifaceted and Multilevel Model of Metacognition is created by Efklides (2008), which discussed three issues that depart from the early conceptions of metacognition: The faces of metacognition, the conscious / non-conscious character of it, and its relations with the self-regulation process as well as co-regulation and other regulation process. The model has been showed in Figure 2.

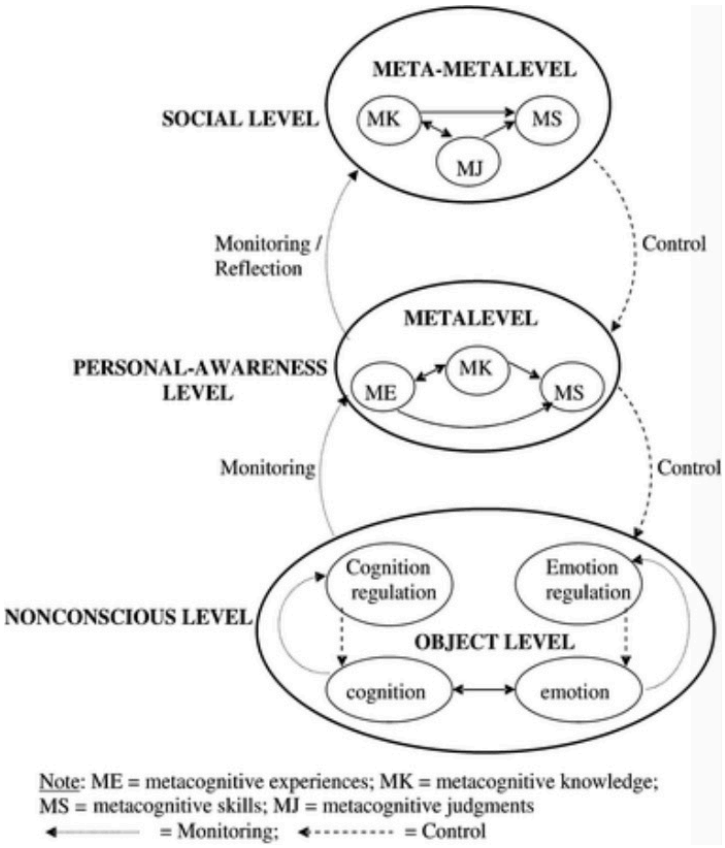

Figure 2. A Multifaceted and Multilevel Model of Metacognition.

Metacognitive Process of Artificial Intelligence. Based on the models of Schmill MD & Oates T (2008) and Efklides (2008), we presented an architecture called Metacognitive Process of Artificial Intelligence, depicted in Figure 3. For the specific functions of each level, please see Research Design part.

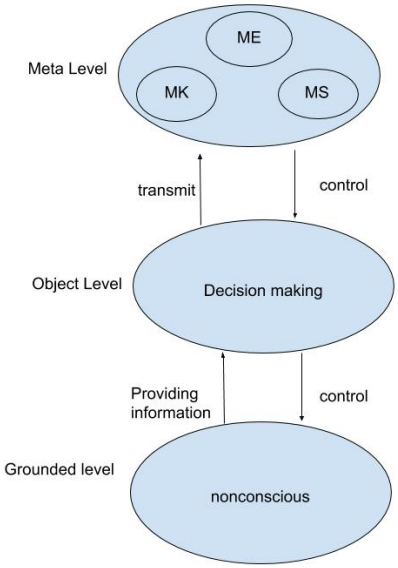

Figure 3. AI's metacognition model

Research Design

Subject Selection

Our design aims to develop a smart metacognition-based music box which can react differently based on recognizing a person's current mood, it can also consistently self-study by experiencing unexpected events. Firstly, our music box's metacognitive process will start at non-conscious grounded level, when the music box recognizes a person's instruction like "Please play a song for me" by using its speech recognition ability, the grounded level will have no idea about what kind of music should be played, therefore, it will provide information to object level, which will be responsible for making decisions on what kind of music will be played based on this person's personal interest, current mood (by using face detection technology). The meta level will be responsible for judging wether the object level "knows" about this person's personal interest, which refers to

metamemory[3] ability. When the object level doesn't know this person's interests, or be informed that the music they're playing does not match the person's personal interests, the meta level will guide the object level to us another methods to play the person's desired songs. For example, the meta level will provide object level another methods like analyzing what kind of music do males/females like, or figuring out what's the most recently popular music. When object level received guides from meta level, it will try these methods until it played the person's desired song, after which the object will record the data of this person's favorite and recall this data in the next time when meet this person. Interestingly, the meta level of our music box also has self-studying and self-analyzing ability. For example, when the object level recognized that most of teachers like piano music by using big data method, it will then take profession into consideration, hence, when the object level is confronting with a problem, meta level will inform it to consider a person's profession.

[3] Metamemory is a concept of an Artificial Intelligence system's memory capabilities and strategies that can aid in memory representation, retention, mining, retrieval, as well as the processes involved in memory Self-Monitoring. Metamemory constructs for an Artificially Intelligent system has important implications about how the system learns and uses memory. For example, the system can make a judgment on whether it has enough information to complete a mission, known as "judgments of learning."

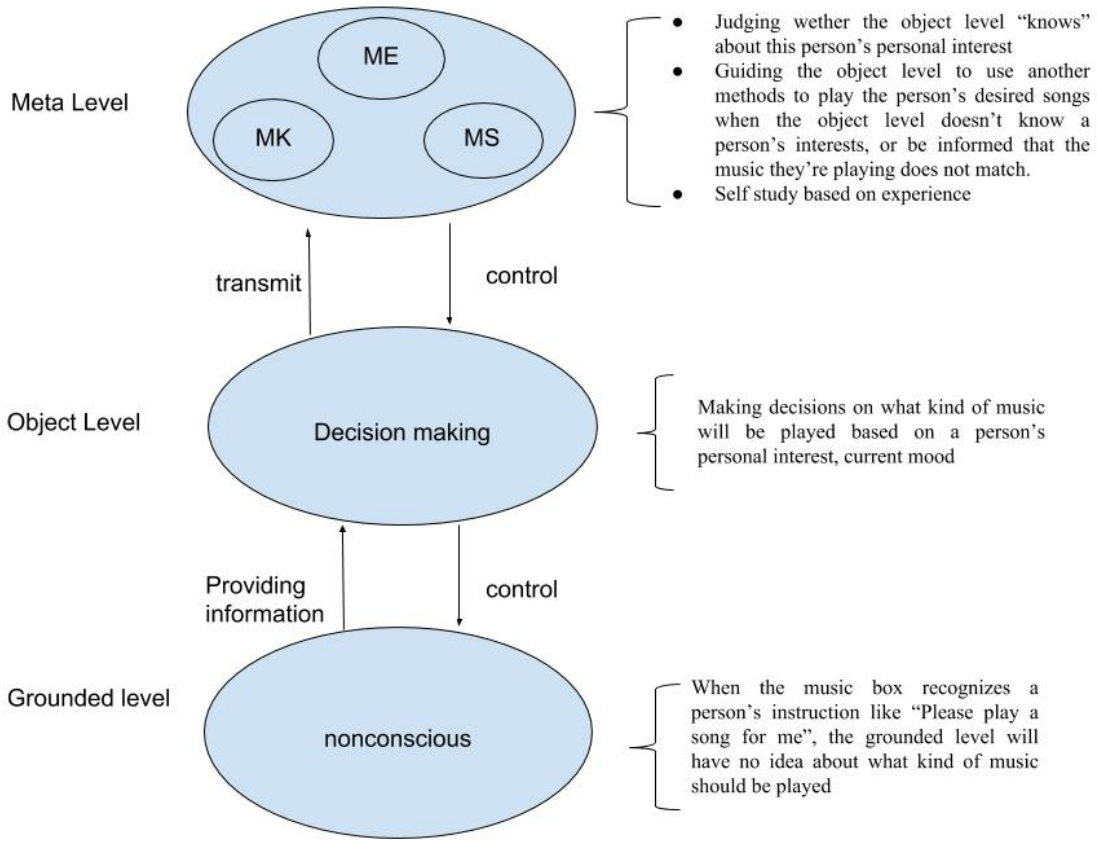

Figure 4. The Metacognitive Process

Measuring Instrumentation

Survey

We will randomly select 30 participants for our research. Then we will randomly divide them into 3 groups (Group A, B, C), each 10 participants will be asked to use our metacognition-based music box for a week, there will be 5 rounds, each round will take three weeks. For example, Group A will firstly use our music box for one week, after which group B will start using it, then Group C will follow, after this round, Group A will use our music box again, then the Group B and C will follow. After each round, all participants

will be required to complete a survey which determines wether our metacognition-based music box played their desired music.

Data Collection and Analysis Procedures

There will be two types of data. The first one will be derived from our music box's analysis about each participant's music interests. For each round we will review the data that this box has analyzed, then we will figure out the updating data to analyze AI's metacognitive process. The second one will be derived from participants' user experience feedback about our music box, to analyze what goals our music have achieved and what goals haven't achieved.

Anticipated Results

Each round's data is expected to be updated because consistently updating knowledge will show that AI has self-studying ability. Furthermore, after each round, our music box is expected to have deeper understanding about a person's music interest than last round. However, in order to find out the drawbacks of the metacognition application on AI, we will still look forward participants' negative feedbacks.

Implications for Practice

The metacognition application presented here constitute the beginnings of a framework to allow real autonomous AI systems that can think, reason, adapt, evolve, and provide self-awareness and self- assessment within the AI cognitive framework. The artificial cognitive neural framework described provides analysis, reasoning and reporting capabilities (cognitive intelligence). Providing Metacognitive and Metamemory structures

and processes within an autonomous AI system have the potential, I believe, to revolutionize AI and will allow full autonomy to be achieved.

Bibliography

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Ames A. Crowder, Shelli Friess. 2011. Metacognition and Metamemory Concepts for AI Systems. *International Conference on Artificial Intelligence*.

Anastasia Efklides. 2008. Aristotle University of Thessaloniki. Metacognition: Defining Its Facets and Levels of Functioning in Relation to Self-Regulation and Co-regulation. *European Psychologist* 13(4):277-287 · January 2008.

Detailed Budget

A. Personnel

This project requires both technical researchers and academic researchers to contribute. The programmer will be responsible for our music box's algorithm design. The AI designer will be responsible for designing the logic structure of our music box by applying Artificial Intelligence knowledge. The product designer will be responsible for designing the appearance of the music box.

Position	Computation	Cost
Programmer (CU student)	*($1,000 x 100%)*	*$1,000*
AI Designer(CU student)	*($1,000 x 100%)*	*$1,000*
Product Designer(CU student)	*($500 x 100%)*	*$500*
	TOTAL $2,500	

B. Other Costs

We will recruit 30 participants for our measurement part so the publishing costs for recruitment will be required. Since the measurement period will take 15 weeks, each participant will earn $15 for rewards.

Description	Computation	Cost
Participants Recruit x30	*($15 x 100% x30)*	*$450*
Printing / Reproduction	*($50 x 100%)*	*$50*
	TOTAL $500	

Detailed Schedule for Planned Work

Timeline	Task
2018	
April 15- April 30	*Technical Researcher Recruitment*
May 1- May 15	*Music Box Draft Design*
May 15- July 31	*Music Box Creation*
August 1-August 30	*Bug Testing and Improvement*
September 1- September 15	*Participants Recruit*
September 20- October 11	*Round 1Measruing*
October 12- November 2	*Round 2 Measuring*
November 3- November 24	*Round 3 Measuring*
November 24- November 30	*Data Collection*
December 1 -December 30	*Data Analysis*
2019	
January 1- March 31	*Research Paper Writing*
April 1- May 1	*Research Paper Correcting*
May	*Research Paper Presentation*