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Investigation into the Essence of Intelligence: The Theoretical Foundation and Design

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***Abstract*:** The development of artificial intelligent systems mainly based on and imitated from human intelligence. However, there is a deviation among scholars and practitioners in artificial intelligence, philosophy and psychology realms about the essence of human intelligence and human intelligent behaviors. This paper re-looks into the issues of deviation in intelligence and intelligent behaviors, and describes the theoretical foundation and the design set forth for a proposed study to re-investigate the essence of intelligence. In enabling a further investigation, the issues of intelligent theories, the quest of intelligence essence, the intelligent behavior and computation and the relationship between intelligent behaviors and artificial intelligence systems are addressed. The paper progresses to justify the investigation by discussing the nature of behavior with its respective issues that channel the discussion into intelligent processes and problem solving processes. Based on these justifications, the investigation embarks on Pragmaticism's scientific method - a philosophical thought for "a clear idea" promoted by C. S. Peirce 1839 – 1914.

***Keywords*:** intelligence, intelligent behavior, intelligent processes, problem solving processes, Pragmaticism's scientific method.

1. Introduction

The questions of "What is intelligence?" and "What are behaviors (abilities or attributes) that represent intelligence?" are frequently found in the studies of artificial intelligence (AI), philosophy and psychology. The effort of addressing these two simple connected questions is considerably vital due to the fact that they affect the development of artificial intelligent system that is capable of exhibiting and imitating full spectrum of human intelligent behaviors (IB).

The attempts to address the issue of intelligence and its representative behaviors with particular concern on understanding the essence of intelligence have been long discussed in the history. Scholars in the field of psychology have proposed a variety of theories such as the Two-Factor Theory [1], Multiple Intelligence [2] and Triarchic Theory [3] that ultimately offer a conceptual definition of intelligence. AI scholars have addressed such questions by developing intelligent systems following three main approaches or paradigms namely symbol processing, connectionism and New AI [4] that consequently proposes a theoretical definition for intelligence within their contextual tasks.

Various literatures have demonstrated the variety of IB repertoire [5-7] associated with intelligence and highlighted the so called "hallmark of behavior". In this sense, the hallmark is understood as a critical behavior in the repertoire. For example, *learning* is a hallmark of IB [8]. However, as for some studies [9-11], *action* is another hallmark. The variety of intelligent behaviors and its *hallmark* found in the discourses reflect the inconsistency of repertoire of IBs acknowledged by different scholars.

The issues of inconsistency of behaviors representing intelligence and the need of a further exploration are definitely matched the acknowledgement made by scholar [12] that "*determining intelligent behaviors is challenging*". It is assumed that the so called "challenge" is due to the study of behavior having been made contextual in that the identification of IB is "case based" and it is determined upon the abilities of the subject or agent being studied. In response to the challenge, scholar [13] stated that *"we discuss the diversity of views about what intelligence is because empirical studies often assume rather than explore the nature of the construct they are investigating, in this case, intelligence"*.

These excerpts clearly indicate the criticality to re-look into this issue. The exploration proposed in this paper is a continuous endeavor to revisit the conception of intelligence that refers to the scheme of inference that human follows when solving a problem.

The remaining of this paper is arranged to discuss the following parts. Section 2 justifies the IB and the development of artificial systems. The place of IB in the computational effort is briefly presented in section 3. Section 4 discusses the firm affinity between intelligence and IB in artificial system as intended by the pioneer of artificial intelligence. The motivation derived in section 4 leads to a proposal in exploring the nature of behavior whereby further discussion can be found in section 5. Section 6 highlights the intelligent behavior as an intelligent process. The enhancement of discourse on intelligent process into problem solving process and problem solving frameworks is presented in Section 7. Section 8 elaborates the insights discussed in Section 7 to include the discourse on Peircean Pragmaticism's scientific method. Finally, before the conclusive thought in section 10, section 9 outlines the design and the setting of the proposed study.

2. The Quest for the Essence of Intelligence

The attempts towards understanding intelligence have been long in existence in psychology and philosophy through special theories prescribed in Section 1. AI area has adopted

the cognitive science perspective in relation to the goal of understanding intelligence.

Various academic and industrial research initiatives have been conducted since the proposal of TT whereby they function as continuous efforts towards understanding intelligence. During this period of time, many grand initiatives have been conducted, including GPS [14-15], STRIPS [16], Mycin [17], AIXI framework [18], MDoI [19] and Machine Super Intelligence [20]. This study continues the quest for intelligence by focusing on the nature of intelligent behaviors.

3. Intelligent Behaviors and the Computational Effort

IB serves as a fundamental reference of AI in order to explain various categories of intelligence in computation [21]. IB is taught as "outcome of simulation and replication of human intelligent behavior through machines" [22-23]. As for scholar [24], IB *"is behavior the consequences of which are judged to be intelligent"*. Earlier, scholar [25] explained that IB *"includes behavior based on the a - ability to cope in a systematic fashion with a range of problems of varying structures, b - ability to build, describe, interpret, compare, modify and use complex structures, including symbolic structures like sentences, pictures and maps, and c - plans for action"*. These excerpts indicated the role of IB and its applications into computation and have served the motivation for exploring the intelligent behaviors aiming at understanding the essence of intelligence.

4. The Affinity between Intelligence and Intelligent Behavior in Artificial System

The Turing Test (TT) [26] suggests that intelligence of an artificial agent is measurable from its capability to properly mimic human behaviors with some resisted [27-30] and some others accepted aspects [31-33]. The TT stands as a fundamental reason for studying the affinity between intelligence and behaviors. This paper based on its core idea from the view put forward by A. Turing, wherein intelligence is attributed by behavior.

The interdependency between intelligence and behaviors is postulated by scholar [34] in that *"although sampling human attitudes is rejected as a method of answering the question 'Can a machine think?' in the first paragraph of Computing Machinery and Intelligence, we can read the entire paper as primarily concerned with human attitudes*. The "human attitudes" in this sense refers to behavior, specifically an enormous variety of human conducts.

Following the TT, in order for an agent i.e. human, machine or robot to be intelligent, it must be capable of thinking. While thinking can be considered as the ultimate property for intelligence, other properties also play a critical role in describing this quality. The scholar [35] states *"when we study intelligence, what we actually observe is intelligent behaviors or conducts, not intelligence itself"*. Furthermore, scholar [36] claims that *"we must refer to intelligent behaviors, not subjective statements about human do when they think a guideline to determine intelligent behaviors in machine"*. These statements indicate that a variety of behaviors are descriptions for intelligence in an agent, while thinking is one of the behavioral patterns. From this, it is learnt that studying intelligence cannot be separated from the study of behaviors.

5. Re-Exploring the Nature of Behavior

The term "behavior" includes *all actions* of organisms [37] and refers to any observable and measurable response or act [38] that a human performs. Consecutively, scholar [39] insists that behavior relates with "*anything we do – talking, sleeping, blinking, or reading*". Meanwhile, scholar [40] considered the cognitive aspect of the conception of behavior. This is due to the fact that cognition serves as a conduit for the observable behavior to occur. The insight derived from some studies [37-38, 40] implies that behavior includes both cognitive and non-cognitive dimensions and it appears from the processes. This implication leads to the insight that studying intelligence must consider and integrate the element of process in its foundation.

5.1 Behavior is/as Process

In further explaining the behavior as a process, scholar [41] clarifies the concept of cause and movement. Figure 1 and 2 illustrate the morphology of cause and movement to explain the process as behavior.

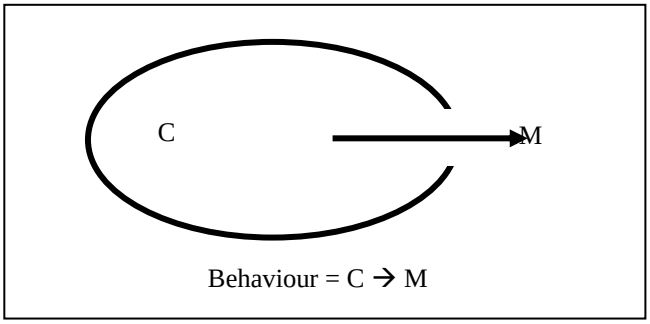

Figure1: The morphology of cause and movement

In Figure 1, the morphology states that cause → movement C → M where C refers to causal events and M indicates things humans do whereby behavior is therefore acknowledged. The 'C' in this figure can be interpreted as causal processes that eventually yield M, *i.e.* $C_1 \rightarrow C_2 \rightarrow C_3 \rightarrow M$. The scholars' [41] idea that behavior acts as a process is further supported by scholar [42] in the study of methodology for control architecture.

Figure 2 depicts the segment of causal chain; the process in which (3) is brought about by events like (1) and (2). The process in this sense is the bringing about or the causing or the production, of a terminal condition, state, or object. The reflection of all these processes, or when seen, the term behavior is used to explain the process. These two illustrations satisfactorily justify the idea that behavior is a process in its essence. The cause – movement (clearly seen) and digestion (cannot be seen) are bodily processes that humans do. The bodily processes (both seen and unseen) in both figures above are termed behaviors that are observable from human bodily conducts.

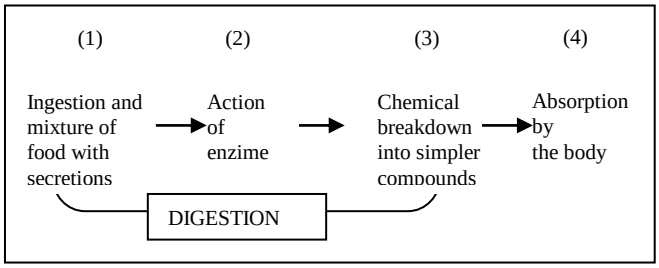

Figure 2: Sequence of digestion process

5.2 Intelligent Behavior as Intelligent Process

In daily life, human performs many activities and therefore exhibited many behaviors. However, not all human activities or behaviors can be considered as intelligent. The behaviors such as eating, seeing, walking, sleeping, talking etc. are not behaviors of intelligent associated with human. Literature suggested that intelligent in human lies behind the cognitive abilities such as reasoning, thinking, comprehending, planning and learning.

By considering the behavior as a process as described in 5.1, it further leads to the notion that intelligent behaviors are indeed "intelligent processes". Intelligent processes are then referred to the thinking processes that are based on deeper and more general laws which are common to all thinking organisms [43-44] especially human. Therefore, based on this understanding, any form of behaviors e.g. consciousness, reasoning, planning and learning is in fact an intelligent process in its essence.

6. The Intelligent Processes

While the bond between the behavior and process is certain, there is an issue of which intelligent processes considerably and appropriately represent intelligence behavior. One could enquire whether the scheme of perception – reasoning – action [5, 21] could be the reflection of intelligent processes. Or, one also may perceive the group of processes that include reasoning, planning, solving problems, thinking abstractly, comprehending and learning [45] as satisfactorily represent the whole idea of intelligent processes. Alternately, it is a wonder whether the more extensive collection of intelligent processes such as problem-solving, planning, learning, knowledge representation, natural language processing, perception, robotics, abstraction, and abduction [46-47] can sufficiently characterize intelligence.

Therefore, it is argued that the quest for the appropriate intelligent processes capable of representing intelligence is found to be compromised of the problem solving activities and problem solving frameworks. These problem solving activities and problem solving frameworks are then acknowledged to be the key for the intelligence [2, 14, 48].

7. Intelligent Process, Problem Solving Process and Problem Solving Frameworks

The essential part of intelligence being characterized by a problem-solving capability has been realized. However, some essential parts of intelligence require different attention due to the different intelligent processes involved in.

The exploration of processes that are considerably representing intelligence has led to several considerations of the problem solving processes. This is due to characteristics of problem-solving set forth by scholars [49] and [50] in that:

- Problem-solving is cognitive but can be inferred from behavior,
- Problem-solving results in behavior that leads to a solution, and
- Problem-solving is a process that involves manipulation of operations based on previous knowledge.

Table 1 tabulates the solving problems frameworks of [51-53] that indicate the intelligent processes.

Table 1: Examples of frameworks of intelligent processes

Frameworks of Intelligent Processes		
Framework [51]	**Framework [52]**	**Framework [53]**
Understanding the problem	Intelligence	Orienting
Devising a plan	Design	Planning
Carrying out plan	Choice	Executing
Looking back	Implementation	Checking

The three problem solving models tabulated in Table 1 are used in different setting. The frameworks [51, 53] are widely used in solving mathematical problems while the framework [52] is commonly used in management and business. Regardless the areas where the frameworks are applied to, the problems faced can be effectively addressed following the predetermined processes in the frameworks. This capability implies that problem solving frameworks work as the ultimate source for intelligent processes identification.

Up to this point, the three models exemplified in Table 1 address the issues of the study namely;

a) problem-solving involves processes,
b) problem-solving processes are intelligent processes
c) intelligent processes that reflect intelligent behaviors.

However, literature revealed too many problem solving frameworks in practice in numerous domains. This creates the issue of which framework has to be chosen as point of reference. Therefore, instead of relying on specific framework in practice, this paper opted to look into philosophical thought dealing with problem solving i.e. the Pragmaticism's scientific method of Charles Sander Peirce (1839-1914).

8. Intelligent Process and Pragmaticism's Scientific Method

Alongside the constraint of choosing appropriate point of reference to determine the intelligent processes described earlier, the revision into Pragmaticism's scientific method has also been motivated by suggestion of scholar [54] that reads "*we have to say goodbye to a notion of intelligence which mainly focuses on the cognitive capacities and human-like properties of a machine and to put our attention to a new concept of intelligence which focuses on the problem-solving capacities of computer systems".*

The phrase "*to put our attention to a new concept of intelligence which focuses on the problem-solving capacities*

of computer systems" in [54] clearly and definitely justifies the proposed study reported in this paper. It affirms the need for looking into problem solving model and formulating the intelligent processes in the models into computation.

Furthermore, the adoption of Pragmaticism's theory of inquiry in the quest for the origin of behavior-based problem-solving is not a weird idea. Earlier, scholar [52] observed Pragmaticism's scientific method as meaningful instrument in the area of problem-solving when he writes "*[The problem-solving] is a process of selective trial and error, using heuristic rules derived from previous experience, that is sometimes successful in discovering means that are more or less efficacious in attaining some end. If we want a name for it, we can appropriately use the name coined by Peirce and revived recently by Norwood Hanson it is a retroductive process.*

This excerpt acknowledges that Peircean scientific method as a mechanism is used for "*attaining some end"* which indicates the solution. In this way Peircean is problem solving model rooted in the philosophy for a clear idea. The Peircean scientific method or theory of inquiry has been acknowledged by many prominent researchers [55-59] through their academic research works. Thus, the applicability of this method as a source of reference for intelligent process that is expected to explain the essence of intelligence should not be an issue.

9. The Design of the Framework for the Proposed Study

All the issues addressed in section 2 to 8 serve the theoretical foundation for the proposed study. The foundation set forth herein leads to a design of the study reported in this paper and depicted through the Figure 3. It depicts the two ways of hierarchical connections between the investigated components. This design is unique since it roots from Peircean scientific method. It drives the problem solving processes. Problem solving processes reflect the intelligent processes and decision processes construct intelligent behaviors. Finally, the ultimate aim intended in the study i.e. the essence of intelligence, can be attributed from the intelligent processes of problem solving in Peircean inquiry.

10. Conclusion

This paper outlines the theoretical foundation and the design of the study on intelligence and intelligent behaviors in human for embodiment in machines and artificial systems. As a preliminary matter, this paper revisits and traces the underlying principle of behavior, which was found to be the process or intelligent processes in more specific context. The Peircean scientific method has been proposed in this research as the referential point for identifying the intelligent problem solving processes. Hence, this study is proposed and the framework of intelligence processes based on Peircean scientific method will be refined and presented [60].

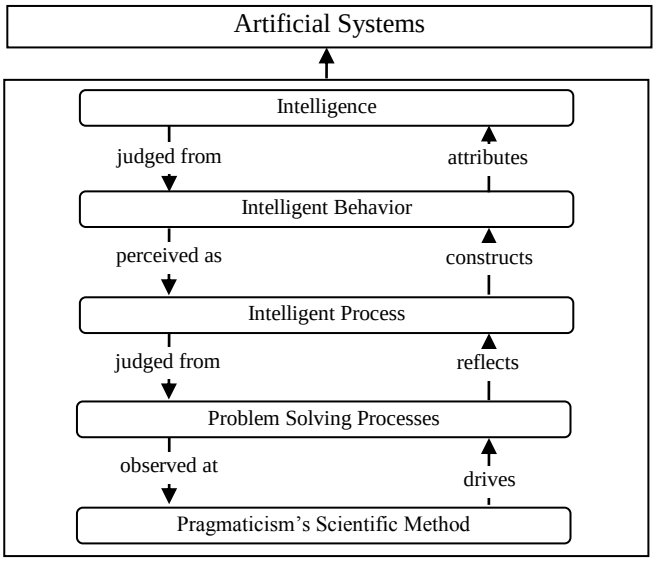

Figure 3: The design of the quest for intelligence

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