NiHA: A Conscious Agent

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***Abstract*— This paper reports ongoing work in the development of self-aware artificial general intelligence, called Nature-inspired Humanoid Cognitive Computing Platform for Self-aware and Conscious Agent (NiHA). It is based on a quantum and bio-inspired cognitive architecture for machine consciousness and artificial intelligence. So far, a number of different cognitive features have been implemented to help facilitate the realization of NiHA. These implemented features include imaginations, dreams, personal semantics, psycho-psychological based motivations and ethics. Apart from these, some industrial applications are also underway. The review of the results obtained from these applications is encouraging and supports the potential to achieve a certain level of consciousness.**

Keywords-machine consciousness; NiHA; cognitive machines

I. INTRODUCTION

Recent years have witnessed exceptional progress in the field of Artificial General Intelligence (AGI) and Machine Consciousness (MC). Considering the current pace of technological evolution, it is envisaged by some that in the future, machines will become self-aware and even potentially become part of a man-machine society. The idea of implementing consciousness in machines is thus not new [1]-[5]. It does, however, raise several philosophical and computational issues [5]-[7]. Addressing these issues requires the unification of different knowledge domains such as physical sciences, neuroscience, psychology, and computer sciences [8]. Consequently, it has resulted in the establishment of computational theories of the mind [8]-[11], and domains which include both bio-inspired [11] and quantum-inspired methods [8][12]-[17]. Various researchers have contributed to the construction of computational equivalent of the human mind/brain [7]-[8][18]-[24]. In this regard, several projects have been initiated which include the Blue Brain Project [25]; the Human Brain Project [26]; DARPA and the Brain Initiative [27]. In addition to these projects, there have been recent corporate efforts by the likes of Google [28]-[30], Facebook [31]-[34], and IBM [35].

A roadmap for addressing the challenges of bio-inspired modeling is shown in Figure 1. One of the most challenging of these is getting humans to accept them as co-workers (socio-cognitive agents) [11][36].

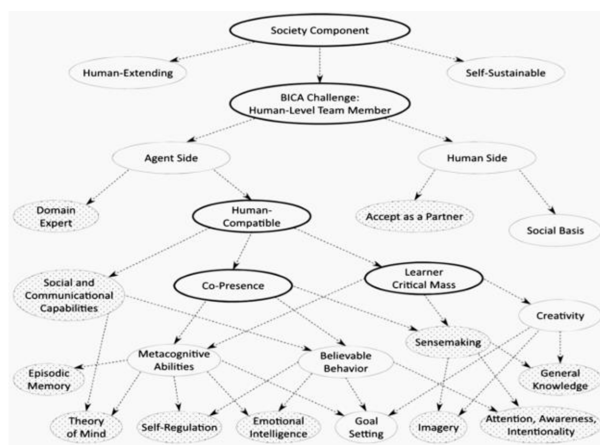

Figure 1 - Roadmap for the Bio-inspired Challenge [11]

From the roadmap, it can be seen that these socio-cognitive agents must be capable of producing believable conscious-like behavior and a sense of their presence in their human co-workers [11]. The benefit of such behavior is clear when considering socio-assistive robots, domestic robots, and personal robots. Examples of such machines acting as co-workers have long appeared in entertainment

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films (for example, 'Geminoid F' an actoroid, acted in the film 'Sayônara, 2015'), and more recently a robot named Sophia, was awarded citizenship by Saudi Arabia [37]. Moreover, significant work has been done in the form of cognitive computing which includes IDA [9], LIDA [38], WATSON [35], CLARION [39], SIRI [40] and CORTANA [41].

Although current progress is encouraging, there are still many issues that need to be addressed before reaching the point where it can be claimed that the presence of phenomenal consciousness [7] in machines has been achieved. Simply to achieve functional consciousness [7] the agent must demonstrate voluntary control of attention, intention, action selection, motivation, goal-setting abilities, emotional intelligence, and self-regulation along with communication capability utilizing the cognitive constructs listed earlier [11].

One of the critical factors to help facilitate the implementation of the aforementioned is the selection of an appropriate modeling technique. Current literature suggests that there are two approaches for such modeling. These are a hierarchical and non-hierarchical approach [42], where a hierarchical model treats consciousness as a single reality with different levels of depth and a non-hierarchical model treats consciousness as a self-organizing multiplicity of embodied states (this allows the emergence of intelligence which is greater than the sum of its information).

Non-hierarchical methods can be used for modeling emergent artificial general intelligence [42], while hierarchical methods can be used for modeling a cognitive system comprised of multiple complex subsystems interacting together in synergy to generate conscious behaviors [42]. Both approaches have strengths and weaknesses. Keeping in mind the limitations of both methods, one of the successful methods for modeling is hybrid. The hybrid approach allows the modeling of higher abstraction in a hierarchical fashion. The functional level of these abstractions consists of subsystems that may operate according to the different paradigms. The hybrid approach seems to be the most promising as it ameliorates the deficiencies associated with the other methods.

Apart from bio-inspired modeling discussed above, this study also takes into account quantum inspiration. There are a number of school of thought associated with quantum inspiration explaining the functioning of brain/mind, consciousness, and intelligence. The reason for taking into account quantum inspiration is that the Universe is governed by the laws of nature [43]. The brain, mental processes along with other biological reactions, physical realities from quantum to classical world, computation, are all part of nature. If the Universe is quantum mechanical then mental processes can be described using quantum theories [43] and the mysteries of the brain, mental processes, and emergence of consciousness can be due to quantum processes or quantum computations [14][44]-[46].

Quantum mechanics is the study of subatomic particles that possess features such as superposition and entanglement, and the computation performed on them is referred to as quantum computation. Analysis of interpretations of quantum mechanics suggests that it has the computational/mathematical potential to model cognition/consciousness. There are different schools of thought on this issue, namely: (i) quantum mind/ consciousness, (ii) quantum cognition, (iii) quantum artificial intelligence.

Quantum consciousness assumes that the brain works on the principles of both neural and quantum computations [14][43][44][47]-[50]. Quantum cognition does not explicitly discuss the involvement of quantum mechanics in the function of the brain at the physical level [51]-[53]. Rather this paradigm acknowledges the mathematical and abstraction strength of quantum mechanics to model human memory, knowledge representation issues, perception, decision making and reasoning process. There are a number of useful references that expound this school of thought [15][16][54]-[58] which uses quantum inspired neural networks, quantum Bayes network and other quantum cognition algorithm to model complex human mental facilities. In contrast to quantum consciousness, quantum artificial intelligence is about transforming existing artificial intelligence algorithms to make them work on quantum computers [12][13].

The existence of consciousness in machines can be evaluated using both qualitative and quantitative methods. Qualitative analysis can be performed using Aleksander's axioms of conscious [59]. Qualitative analyses using Aleksander's Axiomatic postulates that an agent having depiction, imagination, attention, volition, and emotion may possess some kind of conscious activity [59]. Moreover, the quantitative analysis includes Quantum Mutual Information (QMI) and ConsScale method [60]-[63]. QMI is a method that was developed to determine the correlation between the subsystems of two quantum states where these states are not pure states [8]. ConsScale is a characterization mechanism for the evaluation of consciousness in an agent [61].

Moreno originally proposed ConsScale [61], a method that was later improved upon [62][63], as the reference method for analysis of the correlation between cognitive and conscious capability. ConsScale mainly evaluates an agent based on its behavior and architecture [62].

Following the legacy of the aforementioned studies, project NiHA (Nature-inspired Humanoid Cognitive Computing Platform for Self-aware and Conscious Agent) was initiated. In this paper, NiHA is introduced as an entity with a limited level of consciousness and general intelligence. The design and implementation strategy are also articulated and the results acquired so far presented. The results are encouraging and suggest that NiHA may possess a certain level of consciousness. This does not imply that NiHA is fully conscious or that it possesses human-level of phenomenology or general intelligence, neither do the authors intend to claim such. Indeed, NiHA is an attempt to explore the possibility of designing and implementing an artifact that falls under the domain of machine consciousness and artificial general intelligence.

In this paper, Section II details NiHA's architecture, Section III deals with its applications and functionality, Section IV describes the test of consciousness, and Section IV documents the results and discussion.

II. NATURE-INSPIRED HUMANOID COGNITIVE COMPUTING PLATFORM FOR SELF-AWARE AND CONSCIOUS AGENT (NIHA)

NiHA is based on previous work related to the unified theory of the mind, 'Quantum & Bio-inspired Intelligent & Consciousness Architecture (QuBIC)' (see Figure 2) and on the code-base of an agent called Johi [8].

A. *Cognitive Architecture (QuBIC) of NiHA*

The cognitive architecture of NiHA is constructed in layers (see Figure 2). The first layer consists of physical components, while the second layer comprises of mental processes. The physical layer consists of sensors and actuators. The mental regime further consists of unconscious and conscious layers. . The unconscious layer consists of several cognitive units working together in order to regulate the involuntary and pre-programmed tasks that are essential requirements for the agent's self-regulation and optimum performance. The modules of the conscious layer are responsible for awareness, attention, intention and voluntary tasks. The conscious layer serves as the executive control of the mind and the functional description of the whole architecture is discussed in [8].

i. *Memory Units*

Unconscious components consist of several modules; these include memory systems, circadian clock, implicit behavior center, reflexes, decision action center, deed assessment module, seed knowledge, memory management, drives, and a synchronization unit.

a) *Sensory Memory*

Sensory Memory is responsible for the storage of sensory inputs coming from external and internal sensors. Sensed contents are collected in the implicit knowledge repository. Sensory processes apply basic filters to the sensory contents. The filters include those responsible for resizing the incoming image stream, encoding the stream as required and applying part-of-speech-tagger on the lingual contents. These sensory contents are then transferred to various unconscious modules as per the connections shown in Figure 2.

b) *Perceptual Associative Memory*

A copy of processed sensory contents is received by the Perceptual Associative Memory (PAM). PAM is responsible for the formation of an association between objects based on recognition, perception, and classification. Information is encoded for further processing, using structural and semantic analysis and collaboration between Short-Term Memory (STM) and Working Memory (WM). The percepts are then transferred to conscious memory system for further processing.

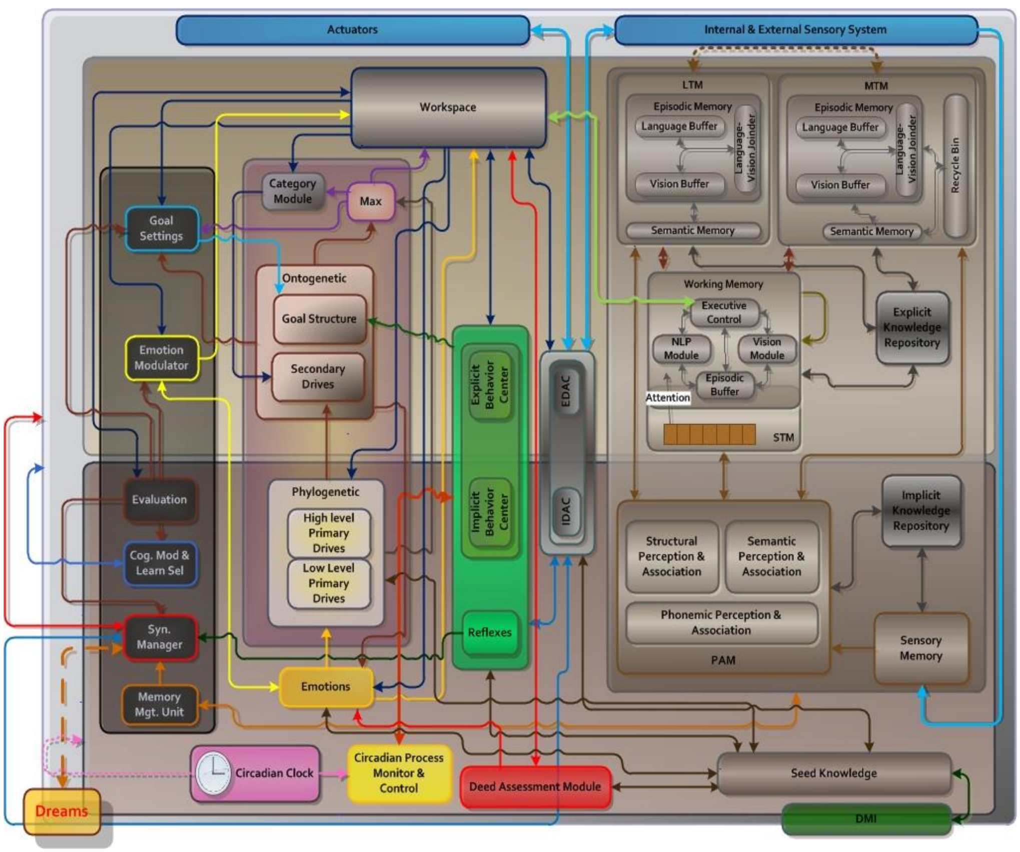

Figure 2 - NiHA's Cognitive Architecture (QuBIC) [8]

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c) Decision Execution Center

The Decision Execution Center (DEC) consists of both conscious and unconscious components. It actually acts as a procedural memory. This unit consists of "how to perform a task" information which is needed mainly for motor actions.

d) Short-term Memory

Short-Term Memory (STM) receives and examines contents from PAM to determine what requires attention through a process called 'selective attention'. The content, which does not get attention, is forgotten when short-term memory overflow occurs or content's signal is decayed. This selective attention process acts as a gateway between unconscious and conscious layers, resulting in an awareness of sensory contents.

e) Working Memory

Working Memory (WM) is responsible for the manipulation and processing of information during the course of the cognitive process. WM consists of the central executive that is supported by visual memory (which process visual content) and spatial memory (contains the spatial maps and information about size and location of content).

ii. Long-term Memories

Long-Term Memory (LTM) holds the information for longer periods. LTM is composed of episodic and semantic memories. The episodic memory contains the information related to the agent's experience of particular events, while the semantic memory contains the record of meanings, facts, and knowledge related to objects.

iii. Circadian Clock, Monitoring and Control

The Circadian Clock (CC) triggers several high-level and low-level drives (and ensures the optimal performance of an agent), while the Circadian Monitoring and Control (CMC) units safeguard the activities by maintaining the threshold levels. CMC also protect various conscious and unconscious cognitive modules from malfunctioning.

iv. Seed Knowledge

One of the major challenges when modeling artificial general intelligence is to implement safe artificial intelligence. Seed knowledge acts as apriori knowledge implemented at design time. This provides ethical norms and a set of rules that try to ensure "safe" artificial intelligence. To date, a conceptual knowledge base has been designed but not yet implemented [64]. This knowledge-base contains information relating to ethical values, laws related to daily life, rules regarding social etiquette and an understanding of the difference between right and wrong. Seed knowledge has already been implemented in NiHA [8] [64].

v. Deed Assessment Module

The Deed Assessment Module (DAM) acts as the "inner self" and assesses performance with regard to the guidelines available as seed knowledge. Conscious and unconscious activities are regulated in the DAM based on predefined parameters and evolved knowledge.

vi. Emotions

The Emotion Module regulates and influences the rational decisions based on basic emotions [65]. The emotions are extracted from the facial expression of a human interacting with NiHA. The extracted expressions are then used for the regulation of decisions.

vii. Meta-cognition

Meta-cognition performs a regulatory role of managing several conscious and unconscious modules. These modules perform numerous tasks i.e. memory management, evaluation, emotion modulation, synchronization between conscious and unconscious modules, learning management and goal setting.

viii. Behavioral and Motivational System

The Behavioral System is responsible for generating implicit and explicit behaviors in the agent based on current context and experiences. The Motivational System [67], inspired by the work of Manzotti [66], generates motivations in an agent in the form of goals. These goals are then used to take desired actions, along with what and how the task will be done.

ix. Dreams

Dreams are the most important cognitive unit. It is responsible for memory consolidation, the evolution of ideas, and creativity through the manipulation of known objects. The first stage of Dreams (i.e. memory consolidation) has been implemented in NiHA [68], and is based on Quantum Neural Network and Quantum Genetic Algorithm.

x. Imagination

Imagination is the manifestation of scenarios that are not directly present to the sensors. The first stage of its implementation in NiHA had the goal of emulating the imagination of a young child. Studies suggest that young children only understand simple sentences. Imaginations implemented to date simulate psychological aspects comparable with that of a four-year-old child [69]-[70]. Further exploration in this area is in progress.

B. Design Rationale & Implementation Philosophy

The design and implementation principles that have been utilized are based on ConsScale guidelines [60][62][63]. According to these, every conscious agent must possesses mental processes and a physical or simulated body. The mental processes in NiHA are based on QuBIC. Currently, the mental processes have been interfaced with a simulated iCub robot [71]. The simulated iCub runs on a laptop mounted on an iCreate robot platform along with Microsoft Kinect sensor and is collectively known as NiHA's body. Moreover, the integration of the Allison humanoid robot with NiHA is underway.

The motivation behind this study is to address a number of philosophical and design issues not taken into account previously. These issues are associated with quantum-inspired modeling, synchronization of autonomous functions through the circadian clock, imaginations, dreams, personal semantics, and psychophysiological regulation of drives through the modeling of insulin and glucose interplay, seed knowledge including deed assessments. Further details on these features are documented in [8][70] The quantum inspiration is based on methods from quantum cognition and quantum artificial intelligence.

The aforementioned features are complex systems and depended on one another as shown in Figure 1. Therefore, modeling of such systems requires the implementation of the cognitive architectural framework, together with a set of cognitive processes, cognitive cycles, and representation schemes [72]. The cognitive processes and cycles are inspired from pandemonium theory [1], feature-integration theory [73], unified theory of an artificial mind, global workspace theory [74] and QuBIC architectural model [8]. The neural correlates of the architectural model are summarized in [75]. These features were implemented separately due to computational and design complexity and are yet to be integrated into the architectural framework (moreover, some are still at the conceptual stage). The overall design and implementation was service oriented. These modules are implemented using different programming languages and run on Windows and Ubuntu platforms. Further details are provided in the 'languages and tools' section.

C. Cognitive Processes and Codelets

The pandemonium theory suggests the presence of demons (mini-agents) in the mind, working in synergy to perform various cognitive tasks in parallel [1]. These cognitive tasks may range from simple identification of objects to learning and to execution of complex sensory motor controls. Generally, these demons are called codelets in cognitive computing domain [2][76][77]. According to the pandemonium theory, these codelets are an independent set of programs working in parallel to process incoming signals. Therefore, each of these codelets has well-defined responsibility and executes continuously and cyclically. Further details on codelets and their standard implementation and guidelines are available in [2][76][77].

In NiHA, the codelets were implemented as proxies to the actual implementation of the code in QuBIC architectural framework. The actual implementations are either in the form of C#'s tasks from 'Task Parallel Library' (TPL) [78] or services implemented running as nodes on the network. Implementation of these codelets as TPL-tasks or services was determined based on response time and the programming language in which they were coded. Cognitive processes with short running time and programmed using C# were developed as TPL-tasks. Cognitive tasks, which were implemented on different platforms or had large execution time, for example learning codelets, were implemented as services. This division is simply a rule of thumb, and in order to keep cognitive optimization, variations can be made as per requirement and future need. Table 1 summarizes the list of codelets in NiHA.

TABLE I - CODELETS OF NiHA

Codelets	Working
Sensory-Motor	A codelet converts internal planning to motor actions
Learning	A codelet responsible for configuration of learning algorithms for a different type of streams.
Vision	A codelet work in collaboration with detection and recognition codelet to assign meaning to visual streams.
Language & Understanding	Language codelet works with several other codelets for the understanding of text and speech processes.
Perceptual	A codelet train system to assign meanings to sensory signals.
Drives and Motivation	Based on a high level and low drives, codelet formulate motivation for an agent to do specific tasks.
Attention and Awareness	Attention codelet bring sensory contents into the conscious part. A codelet that attempts to train attention on some particular kind of information. Examples: Expectation codelet, intention codelet
Emotions	A codelet that regulate the internal representations based on emotions detected from the external environment.
Dream	A codelet work in synergy with memory consolidation codelet to generate dreams and restructure memory blocks.
Circadian	Circadian is just like clock used to check the mode of NiHA every few minutes.
Memory Consolidation	A codelet accountable for the restructuring of associated memory constructs.
Imaginations	Imagination codelet works on storytelling technique. It makes visualization based on internal representations and current scenarios.
Deed Assessment	Deed assessment codelets evaluate agent on the basis of ethical knowledge stored in seed knowledge.
Signaling and Synchronization	Codelet responsible for the interaction and synchronization of numerous signals of the cognitive stream.

Conceptually, each codelet is a part of the codelet eco-system running on top of a cognitive module. As shown in Figure 3, a set of codelets are working on the contents of workspace module. These codelets are pre-programmed for specific tasks, for example, the conversational codelet generates a potential response after processing the lingual contents from the workspace. In parallel to this, the tagging codelet tags the current mental state with the prevailing positive and negative emotions. Responses from various codelets are compiled together by the underlying modules as chunks. These chunks are then broadcasted to relevant modules for further processing.

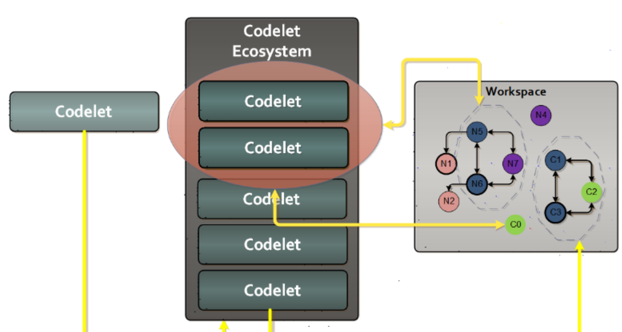

Figure 3 - Codelets in NiHA working in Synergy

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D. Tools and Languages used for Implementation

The following programming languages were used: C#, Java, Python, and C++. The high-level abstraction of NiHA's design is shown in Figure 4. The cognitive structure (QuBIC architectural framework) is written in C# using service-oriented programming. The service orientation is done using Apache Thrift, ROS.NET and YARP.NET. Apache thrift was used as the primary tool for implementing network computing between various services in the framework. ROS.NET is used where communication between modules written in C# and Robotic Operating System (ROS) is required.

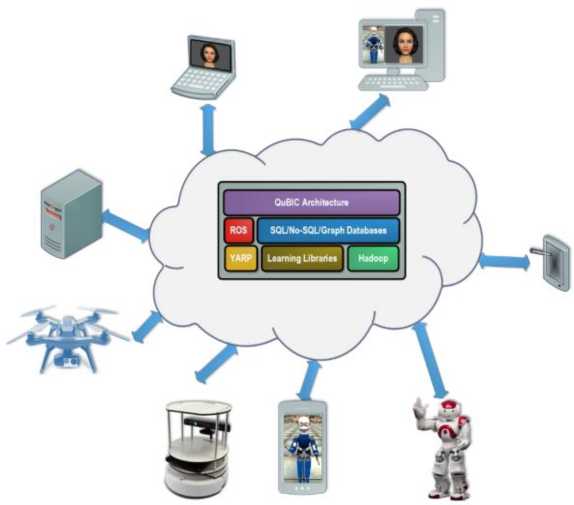

Figure 4 - Proposed NiHA Cloud

The software framework (YARP) for the iCub robot is written in C++ and YARP.NET is a wrapper/binder to interface YARP with C# code, which was acquired after compiling the YARP C++ code using SWIG. Python is used for natural language processing. Accord.NET and EmguCV are used for computer vision support and Accord.NET for audio processing. The conversation module was implemented using the Artificial Intelligence Markup Language (AIML). Weka.NET is used for machine learning support and MaryTTS for text to speech processing. Neo4j is a graph database used for the implementation of episodic and semantic structures. Moreover, quantum computations are performed using an in-house developed quantum computing library written in C# (see download section of the official NiHA website [79]).

E. Application and Functioning of NiHA

The current implementation allows NiHA to have general communication with a human operator. Moreover, it can play the popular paper-scissor-rock game. It can also construct an artistic work through storytelling processing utilizing imagination codelets. Moreover, it can construct short dreams using annotated images placed in the memory system. Details of the implementation of these applications and functioning will be published in the future but related video demonstrations are already available to be reviewed [79].

III. TEST FOR CONSCIOUSNESS

The objective of this paper is to report on progress to date on constructing NiHA, an agent that currently has limited consciousness and general intelligence. The presence of a certain amount of consciousness in an agent can be evaluated using qualitative and quantitative analyses. Qualitative methods include Aleksander's Axioms [59] and the quantitative methods, Quantum Mutual Information (QMI) [8] and ConsScale [63].

A. Aleksander and Dunmall (ADM) Axioms

Aleksander and Dunmall, based on neuroscience studies, articulated the necessary properties for an agent to have indications of its own existence [59]. In this section, NiHA is assessed to determine its level of consciousness.

i. Depiction

Depiction is the mechanism of bringing the perceptual experiences into awareness. NiHA is able to formulate meaning from sensory information. The visual and auditory cues generate selective awareness about the existence and movement of the object(s) in an environment. Similarly, the acoustic cue in NiHA reacts by generating appropriate replies. According to Gamez [23], the integration of various perceptual signals give the sensation of something, that is *out there* and consequently, qualify the possibility of the depiction of an agent. The depiction is achieved in NiHA via the collaborative work of numerous codelets.

ii. Imagination

As mentioned earlier, in NiHA imagination is implemented in the form of the collaborative work of several codelets. So, NiHA can be credited with the existence of imagination in its primary form. Aspects of storytelling have been chosen for its initial development [69][70]. Moreover, NiHA is able to generate sensations and future aspects of known and unknown objects in the absence of any sensory information.

iii. Attention

The bottom-up and top-down attention mechanism is implemented in NiHA. The recall represents the top-down attention when signals are generated in working memory from long-term or medium-term memory, whereas signals coming from perceptual memory represent bottom-up attention.

iv. Volition

NiHA plans and simulates its actions before applying them to the environment and regulates them by means of its emotional state.

v. Emotions

Emotions play a vital role in manipulating the generation of goals and motivations. The Emotional Block, in NiHA,

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influences the effects of drives, decision-making, and planning. This block consists of six basic emotions [65]. Axiomatic analysis advocates the possibility of consciousness in NiHA. Moreover, the axioms suggest that the consciousness can be measured by evaluation of minimum mutual information exchange between cognitive blocks.

B. Quantum Mutual Information

Quantum Mutual Information (QMI) is used to measure the correlation between several sub-systems where the quantum states are not pure. Cognitive blocks can be represented as quantum states. This correlation represents the level of consciousness. For experimental analysis, the selected states are Working Memory (WM) and Perceptual Associative Memory (PAM).

i. Analysis 1

Signals were transmitted from the Sensory Memory block to the Perceptual Associative Memory block, the NiHA was supposed to get the awareness of conscious stream between various unconscious blocks.

ii. Analysis 2

Signals were transmitted from unconscious block (Perceptual Associative Memory) to conscious clock (Working Memory and Medium-term Memory) where NiHA was expected to get the attention of the memory contents.

iii. Analysis 3

Signals were transmitted from Working Memory to the Workspace and Medium-term Memory, where NiHA was supposed to get aware of the memory contents.

C. ConsScale

ConsScale was proposed by Moreno [61] and later matured [62][63] for the characterization of consciousness in an agent. The correlation between cognitive and conscious skills are being measured on the basis of Cumulative Levels Score (CLS) and ConsScale Quantitative Score (CQS). The levels of consciousness in ConsScales range from 0 to 11, from disembodied to super-human. The evaluation is mainly based on its architectural framework and behavior.

IV. RESULTS & DISCUSSION

The experiments have been performed on NiHA to analyze its conscious activity. In this regard, using signals transmitted from the unconscious region to the conscious region, signal analysis to determine level of consciousness were carried out using Quantum Mutual Information (QMI) sharing. Measuring of mutual information sharing is an established practice [23].

i. Analysis 1

NiHA did not show any conscious activity between unconscious blocks.

ii. Analysis 2

The analysis was performed on the contents being shared between Perceptual Associate Memory (PAM) and Medium-term Memory (MTM), similarly between PAM and Working Memory (WM). This resulted in conscious activity (see Figure 5). These results were recorded for 1,000 circadian clock cycles against 25 sample streams. The level of mutual information sharing shown in Figure 5 represents the level of consciousness recorded at different data sample points. The x-axis represents the sample number and the y-axis represents the level of consciousness in terms of mutual information sharing.

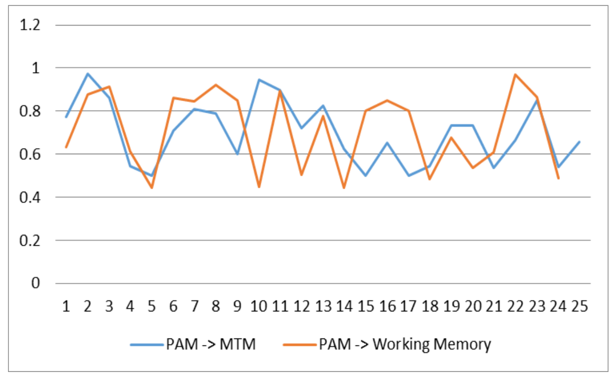

Figure 5 - Conscious activity between Perceptual Associative Memory and Working Memory [8]. The x-axis represents the sample number and Y-axis represents the conscious level in that sample.

iii. Analysis 3

The analysis was performed between conscious modules. These modules were Working Memory, Workspace, and Medium-term Memory. The consciousness level obtained between these modules is shown in Figure 6.

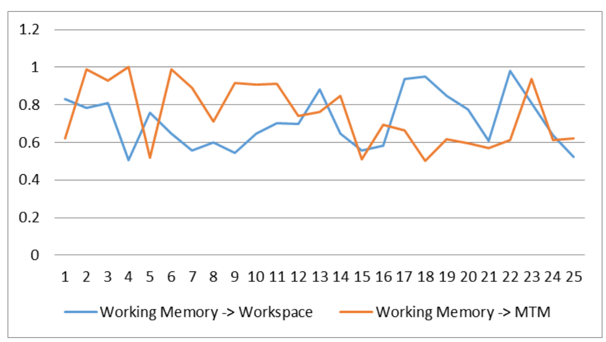

Figure 6 - Conscious activity between Working Memory and Workspace [8]. The x-axis represents the sample number and Y-axis represents the conscious level in that sample.

iv. ConsScale based Evaluation of NiHA

ConsScale was also applied in order to further clarify the class of consciousness which NiHA possess, given the current state of its implementation. A Cumulative Levels Score (CLS) of 1.27 and a ConsScale Quantitative Score (CQS) of 2.94 were obtained.

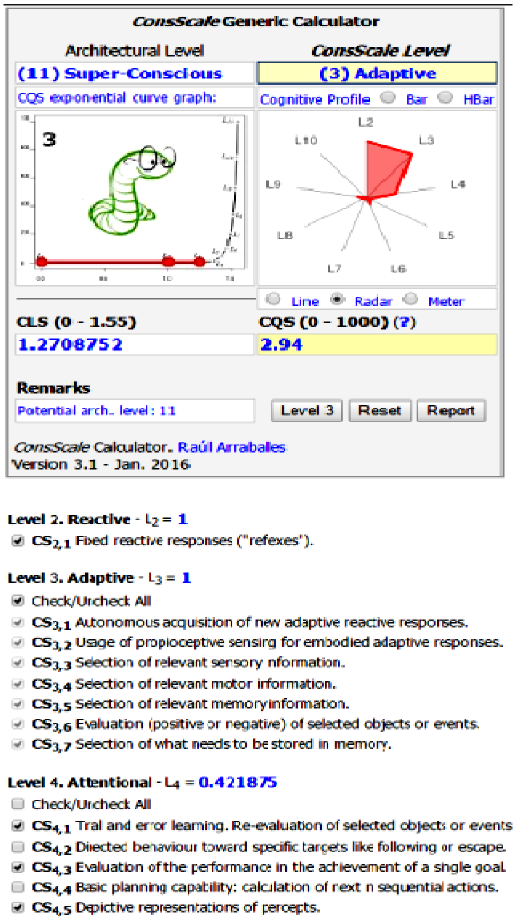

Figure 7 - ConsScale Evaluation Method for NiHA

The ConsScale result is summarized in Figure 7. It suggests that NiHA achieves a 3 on the 11 levels scale. It further proposes that by design NiHA is computationally equivalent to adaptive species, and therefore it still requires a lot of developmental work before anywhere close to achieving human level of consciousness.

V. CONCLUSION

The study reports an ongoing work in the development of NiHA which is based on the QuBIC architecture. NiHA is composed of several success stories, cognitive memories, dreams, imagination, machine ethics and socio-cognitive capabilities and other blackboard-like projects. Results obtained from various isolated studies imply that NiHA (as the extension of Johi) has a certain degree consciousness. The qualitative analyses suggest that all necessary conceptual and theoretical ingredients required to model a conscious agent are present. The quantitative analyses using quantum mutual information sharing suggests that at certain points in the signal stream, conscious activity was registered. This indeed supports the presence of a minimum level of consciousness. Furthermore, analysis using ConsScale suggested that this presence of consciousness can be classified as computationally equivalent to level 3 species.

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