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A Computational Model of Minimal Consciousness Functions

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***Abstract*—**Interest in Human Consciousness has been revived in the late 20th century from different scientific disciplines. Consciousness studies involve both its understanding and its application.

In this paper, a computational model of the minimum consciousness functions necessary in my point of view for Artificial Intelligence applications is presented with the aim of improving the way computations will be made in the future. In section I, human consciousness is briefly described according to the scope of this paper. In section II, a minimum set of consciousness functions is defined - based on the literature reviewed - to be modelled, and then a computational model of these functions is presented in section III. In section IV, an analysis of the model is carried out to describe its functioning in detail.

***Keywords*—**Consciousness, perception, attention.

I. INTRODUCTION

ALTHOUGH discussions about the soul go back to Plato and Pitagores times. It was the French philosopher and mathematician Rene Descarte who in 1633 first started the Mind-Body Dualism dilemma by posing the question of how and where does the mind interact with the body. Since then theories to solve the Cartesian impasse have been written throughout the centuries, yet up to today, no consciousness definition has been unanimously agreed upon by the scientific community [1].

Consciousness studies relate to different fields of science namely: philosophy, neurosciences, biology, cognitive sciences and psychology. This results in the concept of consciousness being defined differently in accordance to the scientific framework it is regarded within [3-10]. According to Weiskrantz[1] (1988):"Each of us will have his or her own idea of what, if anything, is meant by 'consciousness' and insisting upon a precise definition would be a mistake"[7].

Nevertheless it is important to have a clear definition of consciousness before trying to model it , this definition does not have to be universally accepted but should be complete and clear enough to conduct to the realization of its author's goal.

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[1] Lawrence Weiskrantz, Emeritus Professor of Psychology, Oxford University,book:Consciousness, lost and found, Neurospychology of Cognitive Function, Blindsight: A Case Study and Implications.

II. A HUMAN CONSCIOUSNESS DEFINITION

The difficulty in technically defining consciousness lies in the fact that scientists are actually trying to project human phenomena, which are themselves the origin of sciences, into the limited spectrum of science itself. With this in mind, the scope of this paper is limited to modeling only selected features of consciousness, which are to some extent scientifically perceivable to the human mind [11-12], [16-18].

In my point of view, human consciousness stands for the ability to continuously (as long as the person is awake) perceive both the external surrounding environment and the internal makeup of the body, set a goal to be reached with respect to the current situation, and decide on an action to be taken, then finally transform these perceptions, goals and actions into thoughts and concepts that evolve into an internal mechanism of Judgment and decision-making based on experience and memories.

The perceptions of the environment and the body status, along with the goal to be reached are inputs to the conscious mind. The judgment and decision-making mechanism is the consciousness means to recognize that a certain outcome of a specific action - that will be chosen as most appropriate with respect to given perceptions - is resulting into the maximum good i.e. giving most satisfaction to the person [21], [22].

The consciousness contents and mechanisms are constantly both adjustable and expandable as more concepts and thoughts are fed in [13].

III. MINIMAL CONSCIOUSNESS FUNCTIONS

As far as Artificial Intelligence applications are concerned, there is a minimal set of functions that are sufficient for an artifact to exhibit artificial consciousness. Henceforth, the model depicts the human consciousness information processing as follows:

First, Human information processing is using environmental and/or internal stimuli to bring a new thought into consciousness, second, information gets processed and reasoning takes place using ideas of which the person is immediately conscious and stored memories and experiences to reach a set goal, i.e. the centre of attention, at the same time the most adequate method is selected for processing taking into account the afore mentioned components. Third, these same new ideas are stored in the background until a new reasoning process requires them i.e Learning takes place. Fourth, the human consciousness orients attention towards high priority processes, resulting in a possible interruption of the processing taking place simultaneously. Fifth, conscious states are continuously broadcasted to all brain functional areas i.e. Consciousness is globally available [14]. Finally, expertise is acquired by repeated exposition to similar situations [2], [19], [15], [20].

Following this line of reasoning, the minimum consciousness functions to be modelled for artificial intelligence are listed below:

1. Internal and external Perception.
2. Adaptation and learning.
3. Prioritising and Attention Direction
4. Recruitment and Optimization
5. Acquisition of Expertise
6. Self Monitoring and Global Availability

IV. Computational Model for Selected Functions

A. Model:

The following design (Fig.1) is suggested to model the above-mentioned features:

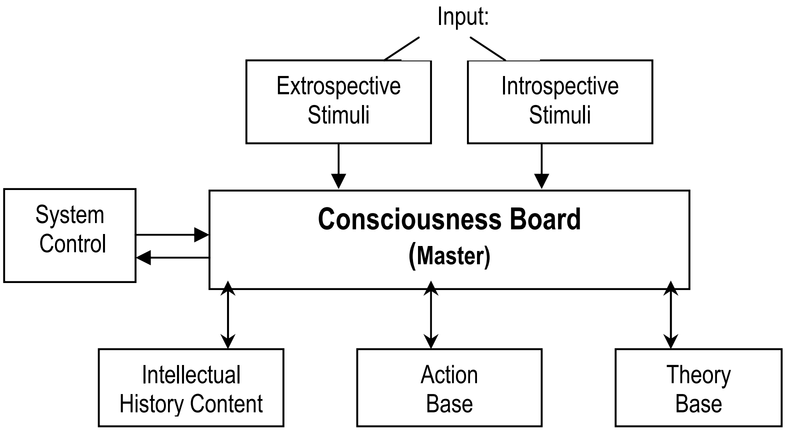


Fig. 1 Model of Selected Features of Consciousness

The stimuli receptors are divided into extrospective receiving environmental stimuli and introspective receiving system stimuli. The theory base contains fixed concepts and varying concepts with respect to the context. The action base contains all possible actions to be taken by either component of the system while the intellectual history content holds computational histoy.

The system control carries the lowest level tasks by actually performing physical actions as instructed by the consciousness board.

At the centre of the model is the consciousness board, which monitors all operations and takes decisions on actions to be taken for the other components of the model.

The Consciousness Board functions are listed below [24], [25], [26]:

1) Reportability of mental states and the ability to access those internal states [28].
2) Storage of past computational experience.
3) Maintenance of Global Availability of Conscious States to all other classes.
4) The ability to flexibly shift attention from focus to another [29].
5) Discrimination, categorization and Selection of Action Plan with regard to specific environmental stimuli and past computational Experiences [27].
6) Adaptation, Optimisation and learning [30]
7) Concept formation and Association by similarity of particular characteristics [32].

B. Internal Communication

Extrospective and Introspective are continuously fed in to the Consciousness board in a one way input flow. While the communication between the CB and its different classes is a 2-way flow (see Fig. 2).

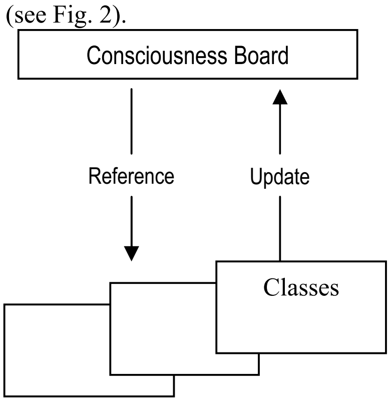


Fig. 2 CB-Classes Relationship

The communication between the CB and the system control is as well a 2-way flow (see Fig. 3)

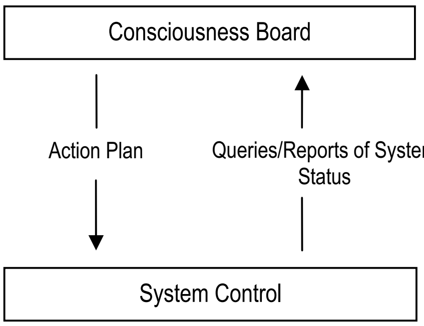


Fig. 3 CB-System Control Relationship

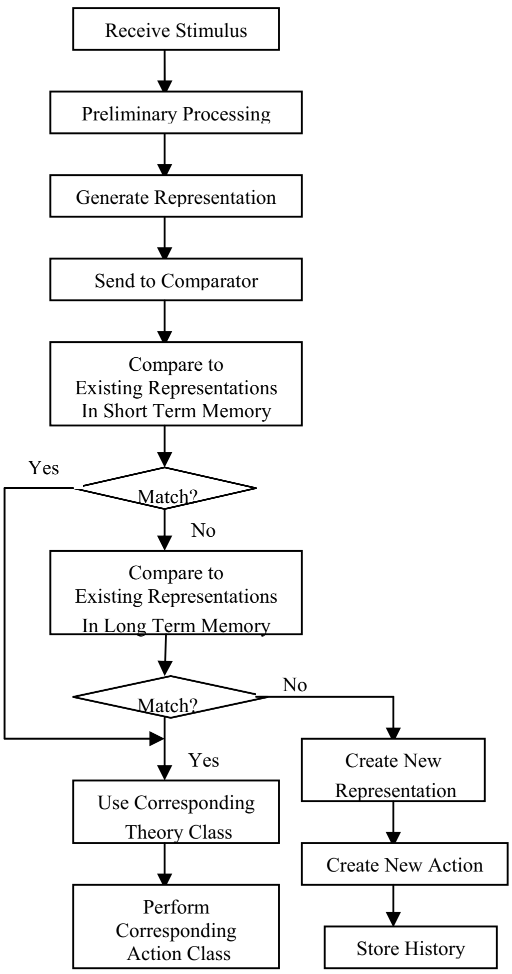
V. Model Analysis

A. Initial State

In the initial state, the action base and theory Base contain the basic elements necessary to allow the conscious board to start of. The intellectual history Content is empty because the system has never solved any problem before. While the extrospective stimuli and the introspective Stimuli sensors are in a LISTEN mode and the Consciousness Board is in a READY mode while the system control is in a RECEIVE mode.

B. Model Workflow

In this model, Stimuli are received from the extrospective and introspective stimuli sensors, they are then pre-processed by the C.B and a representation is generated, then sent to the comparator that classifies it as already existing or novel. Depending on this classification, the C.B either applies existing theories and actions or creates new ones to process the input representation. The model workflow is described in Fig. 4 below:



The consciousness board carries its main functions by communicating with its intellectual history, theory and action bases either through referencing them or updating them depending on the representations received from the stimuli censors.

C. Consciousness Board Functions

1. Learning, Adaptation and Concept Formation

The Properties space is initially populated with basic features including descriptive and contextual data; the features are then grouped into sets and subsets that define a class of objects (see Fig. 5).

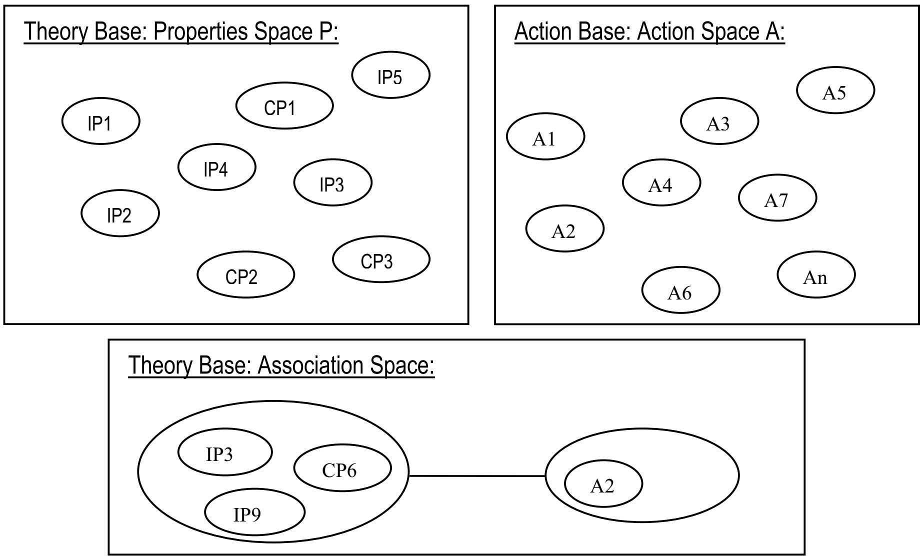


Fig. 5 Action and Theory Bases

After training the consciousness board with different basic features and the states they are in and the actions required, the consciousness board populates its theory base with a set of rules defining which actions to be taken for which set of features in which state, as the consciousness board is presented with more features, it learns how to create associations between representations and actions and stores what it learned in its theory base, at the same time it stores the steps it took before reaching the desired action in its intellectual history. The consciousness board learns to recognize these new features and decide what actions to take. In addition it learns new situational features.

2. Storage of Past Computational Experiences

After completion of the Learning phase, the Consciousness Board is in Update mode where it is saving its new theory to the Theory Base, if there is a new action, it will be saved to the Action Base and in all cases, the intellectual history is saved.Reportability of Consciousness States The Consciousness Board level of activity defines the different states in which it is as follows:

3. Reportability of Consciousness States

The Consciousness Board level of activity defines the different states in which it is as follows:

1. Sleep (lowest activity in the presence of no internal or external stimulus),
2. Normal (Normal flow in the presence of non novel stimulus),
3. Alert (High activity in the presence of Novel stimulus),
4. High Alert (Highest level of activity in the presence of emergency stimulus)

Each State is associated with a different Mode the CB is on:

TABLE I
CONSCIOUSNESS STATES AND MODES

CONSCIOUSNESS STATE	CONSCIOUSNESS MODE
Sleep	Ready Mode
Normal	Process Mode
Alert	Learn Mode, Update Mode
High Alert	Optimized Process Mode, Update Mode

4. Perception

The consciousness board Perception takes place by identifying a representation of a stimulus. A representation is a set of features or properties P that are sufficient to define a unique object O in a particular state N, the properties are divided into Inherent Properties IP and Contextual Properties CP. These features and states are stored in the Theory Base that associate each representation i.e. a certain object in a certain state to an action in the Action Base.

The Extrospective Sensors and the Introspective Sensors perform the initial pre-processing by generating an initial set of features defined by the sensor's filters; these features involve both contextual and inherent properties. This initial representation is then fed to a comparator that performs the classification of Stimuli based on the stored representations (see Fig. 6).

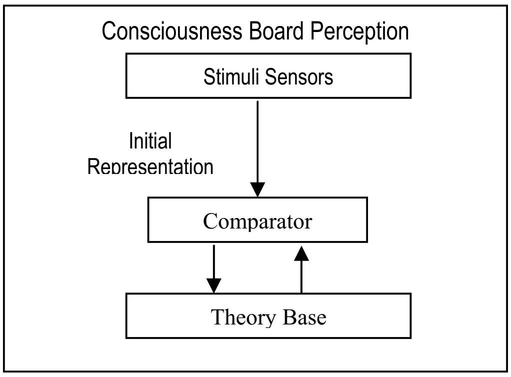


Fig. 6 Consciousness Board Perception

Long-Term Memory and Short-Term Memory are both subsets of the Theory Base. i.e. referring to memory is similar to referring to theory base. Short-term memory is the set of working representations that have been last used or created or that have close relationships to representations being processed while long-term memory is the rest of representations that have been stored.

If there is a match, i.e.: the stimulus falls into one of the theory base for which an action plan is already allocated and there is no need to store the intellectual history, then the stimulus is treated according to the stored plan of action (Association) for this specific representation, otherwise the stimulus requires further processing which entails training the Consciousness Board on new required actions.

5. Discrimination and Action Recruitment

There is a measure of Novelty involved in this comparison, the more features mismatch between a stimulus representation and existing feature sets in either memory, the higher is the novelty of the stimulus. A match does not have to be perfect, a threshold value is decided for acceptable matching percentage, a scoring function will run during comparison to get the highest scoring feature set, based on this score, the stimulus is tagged either: Novel, or Not Novel. The higher the percent match the stronger is the inhibition of the Conscious Board into a Sleep or Normal Mode, if the stimulus has sufficient new features to cause a mismatch (low percent mismatch) with existing representations then further evaluation of the representation is carried out which means The consciousness board is in a Learn mode.

In addition a % feature is set by giving a scaling number that would define a stimuli as being e.g. 60% property1, meaning that the same set of features can represent different a group of stimuli that are differentiated changing the weights.

6. Prioritising and Attention Direction

The consciousness board comparator carries a discrimination procedure that would direct attention by activity allocation to the stimuli depending on their importance.

Each property in the representations either inherent or contextual carries an emergency level tag; a representation would be tagged with emergency if the sum of its properties emergency levels is beyond a set limit (it is possible that a single property emergency level is higher that the set limit). This measure of importance is the second rating that decides the level of activity. E.g. a usual stimulus, which requires habitual actions, will have the highest priority if it carries a Contextual Property with highest emergency level.

If the stimulus is tagged emergency then full attention is directed to servicing it while any lower emergency stimulus occurring at the same time would be inhibited and queued based on its emergency level.

Any activity would be interrupted and its state saved until control returns to it at a defined pointer.

In addition, Repetition of a non-changing stimulus leads to an acceptable level habituation of response. The representations have a frequency counter which defines a representation as habitual if it has a high frequency or non habitual if it is rarely happening or novel.

Therefore the threshold definition contains three different Limits: Novelty Rating Limit (Limit1), the Emergency Limit (Limit2) and the Frequency Limit (Limit3). (See Fig.7)

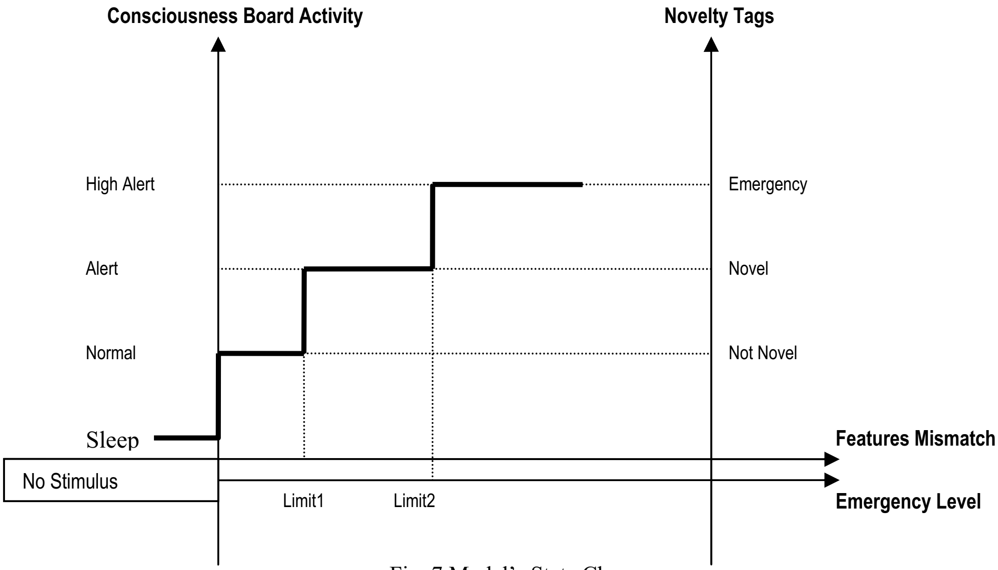


Fig. 7 Model's State Changes

Note: These thresholds could be subject to change as a measure of the Consciousness Board maturity.

The above graph is a 3-Dimensional Graph following the conditions listed in Table II:

TABLE II
CONSCIOUS BOARD STATES

	NO STIMULUS	Mismatch>=Limit1	Mismatch<=limit1
Emergency Level >= Limit2	Sleep	High Alert	High Alert
Emergency Level <= Limit2	Sleep	Alert	Normal

Where: Emergency Level =

$$\sum_{PI0}^{PIn} EmergencyLevels + \sum_{PC0}^{PCn} EmergencyLevels \quad (1)$$

And:

Mismatch =

$$Min(\delta(Existing\,Representation, Stimulus\,Representation)) \quad (2).$$

δ is an error calculated as the distance between the existing representations and the stimulus representation.

The statistical information is also taken care of as shown in Table III:

TABLE III
CONSCIOUS BOARD HABITUATION LEVELS

FREQUENCY	*Representation Tag*
Frequency Level >= Limit3	Habitual
Frequency Level <= Limit3	Non-Habitual

The workflow in Fig. 8 illustrates the Discrimination and Attention Direction Processes:

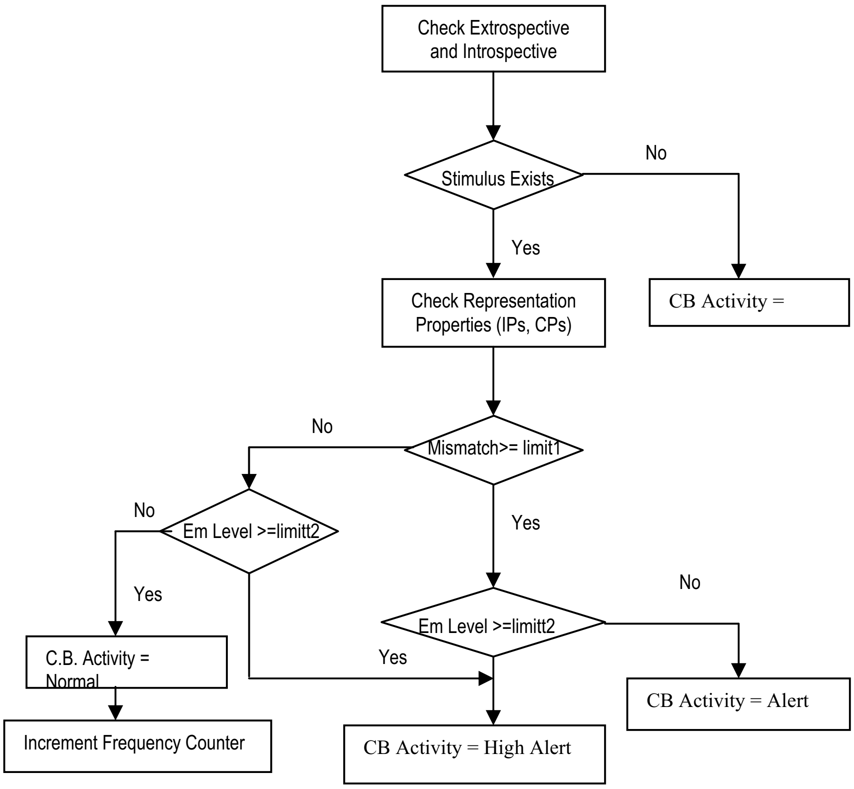


Fig. 8 Model's Workflow (Where Em = Emergency)

7. Global Availability

The exchange of information (the neural substrate) is done through a net of interconnected links that have their central node at the Consciousness Board. The Feature extraction at the extrospective stimulus sensors is different from that at the introspective stimulus receptor, a stimulus when internal is filtered on the state of the whole system components while an external stimulus is filtered on the Problem Context.

The consciousness Board can process 2 stimuli if their actions required are mutually exclusive, given the fact that a minimum percentage of processing power is allocated permanently to monitoring the global activity i.e.:

1. Activity allocation
2. Prioritizing
3. Optimization
4. System Control Communication
5. Extrospective and Introspective Sensors Communication.

The system control is the medium through which the actions would reach the end target be it a monitor or a control station and through which communication with the Consciousness Board is carried out. Each successful or failure Action is reported to the Consciousness Board.

In addition the Extrospective and Introspective Censors are continuously sending their status to the Consciousness Board.

VI. Conclusion

The realization of this model is being researched to constitute a sequel to this paper. The model described above could make use of many Artificial Intelligence tools to realise it. Namely the family the family of models in the Adaptive Resonance Theory developed by Carpenter and Grossberg. On the one hand, artificial neural networks are especially useful for classification and pattern recognition problems where training data is widely available, therefore could implement the learning process of the Consciousness Board. On the other hand, expert systems are based on the theory that creating propositions and performing logical transformations upon those propositions can model human experience and expertise. Expert systems are comprised of a knowledge base, a set of algorithms, which define how to infer knowledge, and an inference engine. New facts or answers are derived when the knowledge is fed through the inference engine and is processed according to the algorithmic rules. Therefore theory bases and property bases can make use of expert systems concepts. In addition, data mining techniques could be used for expertise acquisition. This model could be used in different applications such as humanoids development and control systems. Depending on the application area, adequate feature extractors are used to filter the important characteristics related to the specific artificial intelligence problem and complementary artificial intelligence tools [33] are chosen for the consciousness board functions.

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