Model of a Neuron Network in Human Brains for Learning Assistance in E-Learning Environments

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Keywords: E-Learning, E-Learning Environments, E-Learning Assistance, Cognition Simulation, Recommender Systems, Brain Neuron Model, UFO.

Abstract: It is typically known that brain neurons are responsible for a significant part of our knowledge adaption process. However, it is not yet fully understood how knowledge adaption works or what conscious intelligence is. The aim of this research is to investigate how an E-learning environment can automatically identify learning sequences to dynamically map them to specific learning types for suggesting course material, which makes learning more individual, flexible and faster. For the purpose of this research, a neural ontology is created. In this ontology, the characterization of one neural brain cell is meant to represent every neuron cell in our brain as a specific part of a neural network to get closer to the answer how a simulation of brain functions could be accomplished. This paper describes a neural network theory and how the conceptual model of a neural brain cell could be interpreted through the concept of cognitive pattern match in relation to intelligence. In conclusion, two fundamental hypotheses for effective knowledge adaption in E-learning environments are derived.

1 INTRODUCTION

Modeling reality is a common approach in the computer sciences. First of all, building models is not only a means of reducing costs; it also helps in understanding what is of yet currently unknown about the conception of ideas. Unified Foundation Ontologies (UFO) (Poli et al., 2010, pp.175), demonstrates how ontologies can be used as technology in building models which approximate reality. Many different brain models have been described by scientists in various fields. This paper diverges significantly from these other approaches, however, in that it offers an ontological focus on the functionalities and properties which a single neuron cell can have, and thus holds for all the different specializations of all types of neurons in the body. With this in mind, it is possible to acquire each type of neuron cell from a generalized neural axon entity, which all neurons possess. The focus lies on the creation of a neural network for conscious cognition through computer simulation. Ontological perspectives are used to create this brain neuron model which results in conceptual models that are closer to reality and applicable in E-Learning environments.

1.1 Related Work

The ontological simulation of neural brain functions has already been carried out. An example for bee swarm intelligence research can be found at (Mosteghanemi and Drias, 2012), however it was not focused on educational learning environments until now. Simulation research began investigating the use of ontology from the year 2000 onwards. In *Proceedings of the 2004 Winter Simulation Conference* (Fishwick and Miller, 2004, pp. 259) the authors describe both the RUBE project by providing an XML-based simulation modeling framework, as well as the DeMo project by supporting an ontology-driven discrete event simulation (Silver et al., 2009). Through high-level simulation language, the DeMo project supports the paradigms of 'state-oriented', 'event-oriented', 'activity-oriented' and 'process-oriented' simulation, although it was not based on a foundational ontology (Guizzardi and Wagner, 2010, p. 653).

1.2 Justification for the Research

The ontological model of a single neuron cell devel-

R. Kisch H. and L. R. Motta C..
Model of a Neuron Network in Human Brains for Learning Assistance in E-Learning Environments.
DOI: 10.5220/0005439904070415
In *Proceedings of the 7th International Conference on Computer Supported Education* (CSEDU-2015), pages 407-415
ISBN: 978-989-758-108-3
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oped in this research describes what a neuron is able to do, its relevant components from a computational point of view, and the events which a neuron is able to fire. These previous aspects were combined in order to build a neuron cell database with entities and relations. Keeping this in mind, the developed ontology in this research enables the creation of a neural network of databases up from a single neuron cell node. Therefore, each database in the neural network can store information, within the entity of a single neuron, all information concerning connections to other neurons, the definition of products, and the operations which were made in the neuron's connection states. This event-based approach can be viewed as the starting point for the simulation of the thinking processes. With this conceptual model, we could be able to map thinking and learning activities from their base (buttom up) instead of tracking behaviors and map them back to neural activities captured beforehand (top-down). An example of the complexity of the top-down approach in mapping and tracing the neurons in the brain of a bee into a common 3D reference system is illustrated by (Rybak et al., 2010). With tracking and mapping the expected thinking behavior in a E-learning environment, the learner can be supported with learning-suggestions based on predicted learning-paths of other learners whose learning maps has already been created.

2 MODEL EVOLUTION

This section will explain the evolution of the neuron cell model. The figures are meant to clarify how the syntax of UFO leads to models which become increasingly closer to reality. Each model's iteration was built in three steps. First, the iteration was checked for syntax using the Ontouml Lightweight Editor OLED (https://code.google.com/p/ontouml-lightweight-editor/), a case tool for ontological concept modeling. Second, the semantic relations between the entities were widely discussed for extension with many neural and biological scientists. Third, conceptual description was widely borrowed from the Systematic Approach for Building Ontologies (SABiO) (Falbo, 2004), which explains precisely how an ontology can be built step-by-step.

2.1 Identification of Ontological Objectives

During the first iteration, the focus was on competence questions, such as: "What is the central unit of a single neuron?". Based on different articles published in the scientific journal *Nature* e.g. (Grubb and Burrone, 2010), it was recognized that the axon of a brain neuron cell is the best starting point by which to begin modeling a neuron. Therefore, the axon entity was used as the main entry point for developing the model in each model iteration. The axon entity should also be used as the starting point for the interpretation of all models.

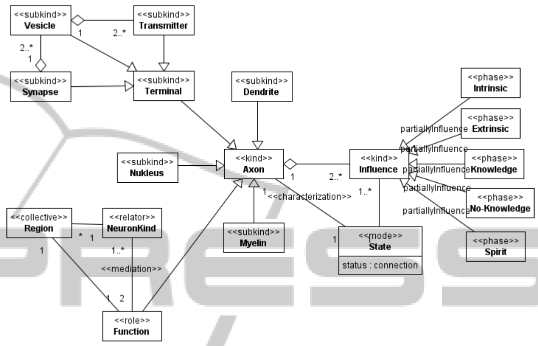

Figure 1: Neuron Node.

The model represented in figure 1 is the easiest to understand. The axon entity is located at the center and many other entities are specialized around it. A dendrite is a subkind of the axon, because it comes out of the axon and connects the axons, bodycells and dendrites of other neurons (http://www.human-memory.net/brain_neurons.html, 01/07/2014). In the top left corner of the model, the entities responsible for information retrieval between the axons can be seen. A terminal emerges from the axon on the opposite side of the dendrites. It has transmitters and synapses. Synapses contain many vesicles which are released by one or many transmitters. Properties and abilities such as the transmission ability of synapses, vesicles and transmitters are acquired from the terminal. At the bottom left, specialized functions that take place in specific types of neurons in particular brain regions can be seen. A *function* refers to the functional role which a neuron can have. The neuron is represented by its axon entity and so the functional role inherits all its abilities. A region is defined as a collection of particular neurons which are related to a specific function by mediation. Therefore, functions operate on the specific types of neurons in a region. On the right side of the model, many of the possible influences on the connection state of the axon can be seen. Axons can have three different states (connected, semi-connected and unconnected) (Sporns, 2011, p. 128). The given state of an axon is characterized through the many conditional influences which are part of other axon states. The myelin entity is an axon subkind which controls the velocity of the signals between neurons (Sanders, 1946). Following sections will refine this conceptual model by elaborating on many more aspects such as the storage function of the nucleus.

2.2 Capturing Ontology along Entities and Their Relations

The second iteration focused on the force-feedback ability of neuron cells. According to the Hebb-Rule (Hebb, 1949), the ”fired together - wired together” principal, one of the most important facts about neuron cells is that they influence one another. Hebb (1949) discovered that every neuron receives a feedback response after it has fired. Accordingly, for feedback about an actual axon state to be given, all of the neurons involved must be wired together. The axon state in this conception is considered to be of high importance in reconnecting neurons in the same constellation as they were before firing. Therefore, axon connection states for any specific moment need to be saved somewhere. As of yet, it still remains unknown to science where exactly information such as axon states is saved within the neuron. In a general manner, it appears that storage takes place in the nucleus of the neuron. The ”lastThought” entity is responsible for mediating the knowledge which is processed in one or many regions. The ”lastThought” entity is also responsible for the transformation of axon states according to the next conscious product from one thought to the next.

2.3 Knowledge Processing - Pattern Match

The entity rolemixin ”lastThought” can be specialized as additional information, the production of new knowledge, or the declination of previous cognitive definitions. These three entities represent the concept of the specific influences by which the axon states can be modified. Created knowledge mediates a neurotropic influence on the frequency which in turn creates the collective ”Motif” entities (cf.) (Sporns, 2011). These operations take place to create new knowledge. The mixin ”Neurotropic” consists of entities which are not relevant for the conceptual model illustrated here and therefore requires no further explanation. These specialized entities were excluded from the model in the last iteration for complexity reasons. Based on the neuron’s feedback process, three mayor abilities were discovered in the following conceptual model iteration, as illustrated in figure 3:

- **Collection.** On the upper left area of the model, collection is refined by a material derivation where chemical information is retrieved from the vesicle entities and transfered to the synapses. The collection itself is understood as the beginning of the thinking process where relevant knowledge fragments are collected from memory.

- **Association.** On the left side, the model illustrates how the collected knowledge fragments are chemically retrieved from the soma entity, and are then electrically combined in a frequency which allows the axon state of neurons to create a collective association between themselves. This association, called collective ”Motif”, has a specific function and operates on specific neuron types which have specialized themselves in visual movement calculation for example.

- **Definition.** A motif is created by connections between neurons. These connections are established over the axon states of associated neurons. The connected neurons operate on information. Each operation generates knowledge which can be either stored or transformed further. The definition of further transformation is mediated by the rolemixin ”lastThought” entity and can be specialized into three further role entities. The transformation which takes place through the role ”Transformation”, however, leads to a new collection by which the circle is closed.

2.4 Motif Refinement

The next important iteration (figure 4) takes a closer look on part-whole relations. Part-whole relations are especially important for the motifs because each motif is controlled by a higher instance collective, called collective ”Controller”. The exact manner in which this controlling occurs is not well-known (Nan-Jie Xu et al., 2011), but fortunately, this does not make a difference for the conceptual model. What is important for a computational model is the relationship between thought and states of connection. In this model, we go further by describing the relationship between the controller and the motif as being transitive and extensional in nature. This is done because each thought is seen as a whole in its own right which can be refined into more specific thoughts, and each of these thoughts can in turn be extended with further information. A thought is non-shareable in that it has a particular relation to a context. A conclusion based on a thought is always reached according to the environment in which the thought was processed. The same

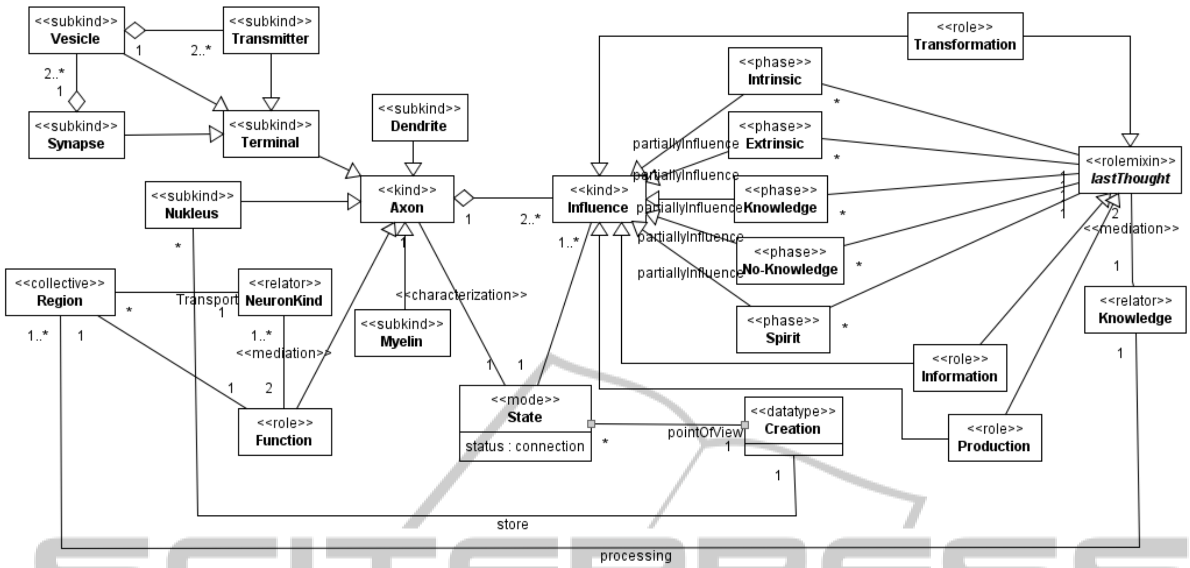

Figure 2: Force-Feedback.

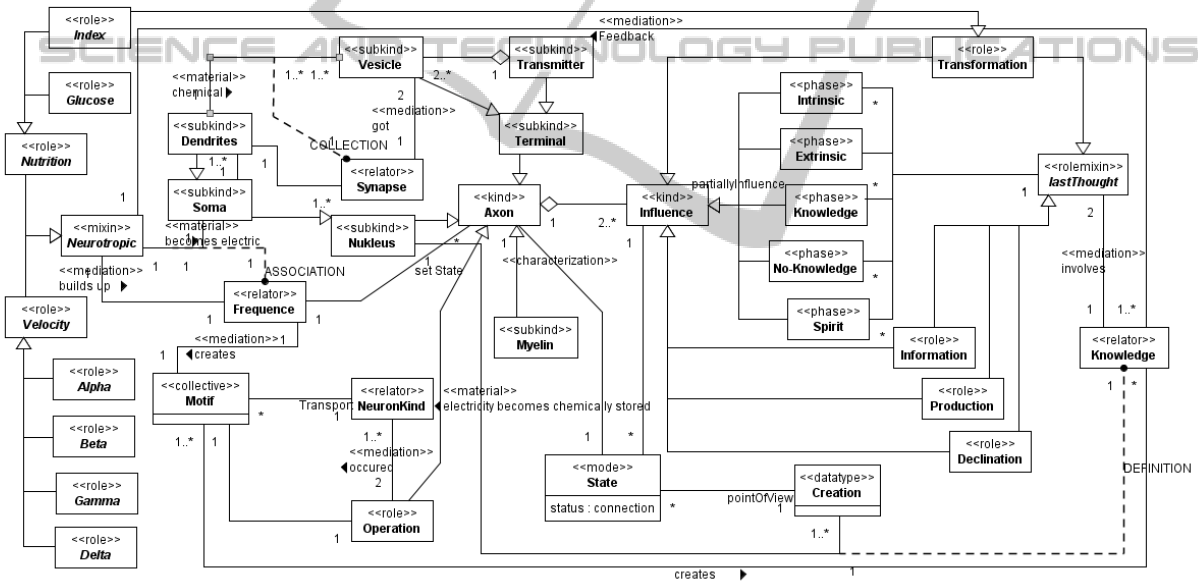

Figure 3: Knowledge Processing.

thought, while correct in the environment in which the thought was processed, could be wrong in a different environment. The environment is always essential for a conclusion, otherwise the conclusion (cognitive definition) would cease to be reliable. All thought relies on the axon state of the wired neurons. Therefore we can say that all thoughts are homeomerous to each other.

Furthermore, a motif is understood as a functionally separate part of the whole brain, while a neuron cell is seen as a functionally seperate but substantially related individual of the whole sub-motif. The neuron does not lose its function if the whole (sub-motif) ceases to exist. Instead, the specialized abilities of neurons are used by another motif, which is most probably the motif which surrounded the sub-motif, thus automatically becoming related to a new whole. All the functions of one neuron cell are applied to a brain impact-function, and thus a brain operation will only have the expected (better procedural promised) impact on the motif to which the neuron cell applies.

2.5 Dynamification using UFO-B

In general UFO-B is an UFO-A increment related to perdurants (Guizzardi, 2005, p. 382). UFO-B is very

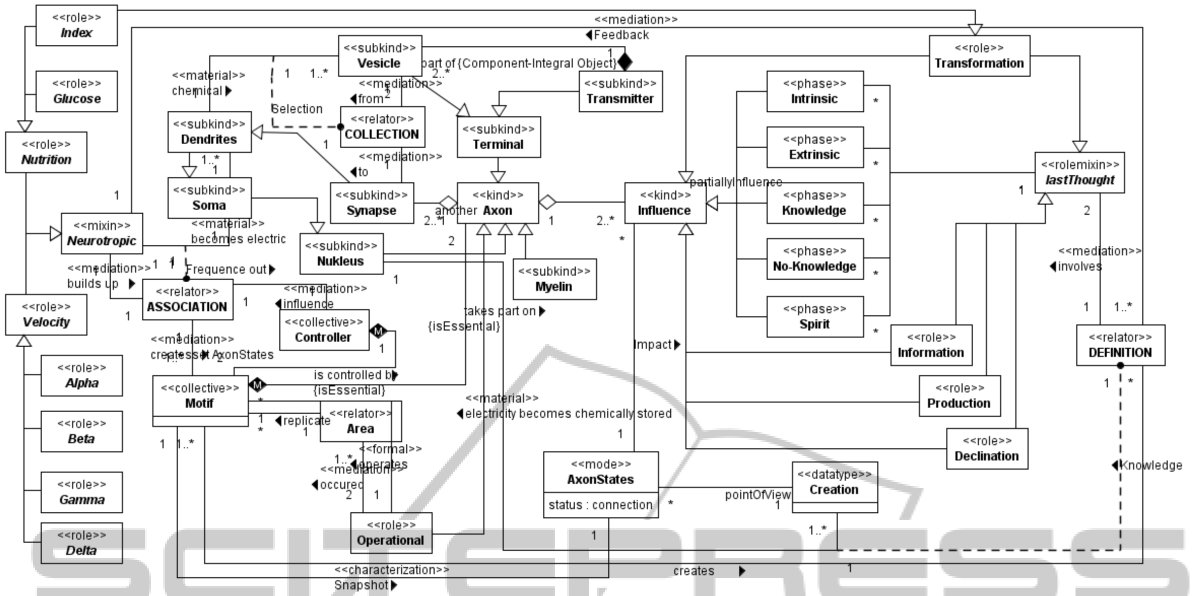

Figure 4: Wholes and parts.

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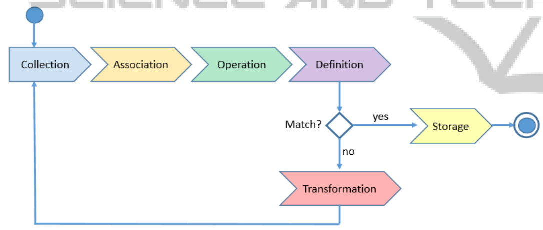

Figure 5: Event execution process.

useful for modeling events which have dynamical aspects and which occur in quantifiable time-space or in a defined situation. A situation is mostly construed as being changed by an event to fit a specific preposition. In figure 6, it can be seen that each event is marked with a specific color. There are six different colors which stand for six different events. Each event in turn has four related entities which define the situation. One of the entities is marked with three different colors which means that this entity is shared by three different events. This also indicates that these three different events are fired in an uninterrupted sequence. Figure 5 illustrates the execution of the colored events for a single though process.

Figure 7, derived from (Guizzardi and Wagner, 2010, p. 657), generally illustrates the higher level ontology concept of each event. The whole event execution process, which can be seen in figure 5, is an instance of the entity ‘Complex Event’. The ‘UFO-A::Object’ entity is defined through its near representation of the complete neuron cell model as shown in figure 6. Each ‘Object Participation Event’ will be defined in the following subsections. The ‘Agent’ entity, which every illustration represents, generalizes all the participation entities that a single event has (the pre-situation and post-situation being excluded).

Collection - Event (blue). The soma situation (subkind ”Soma-Situation”) satisfies the influence preposition (subkind ”Infl-Preposition”). The influence preposition can either be changed by a previous definition-event and/or a transformation-event. In the case of a transformation-event, the role ”Index-Collector” inherits most of the information which should be collected by the role ”Transformation”. In case of a definition, the index inherits most of the information from the mixin ”Neurotropic”. In both cases, these information entities (Transformation, Neurotropic) are used to create an information index for the role ”Index-Controller” which collects the indexed axon states stored in the nucleus of all neuron cells involved. When all of the chemically stored axon states have been collected, the index controller allows the mode ”Collected” condition, simplified in figure 8, which then enables the association-event.

Association - Event (orange). The ”Neurotropic-Situation” created by collection from the previous event serves to satisfy the last thought preposition (”lT-Preposition”) which is the rolemixin ”lastThought” specialization. The role ”Associator” acquires all the information needed from the previous collective ”Motif”, and then formally uses the information from the collective ”Controller” to prepare the

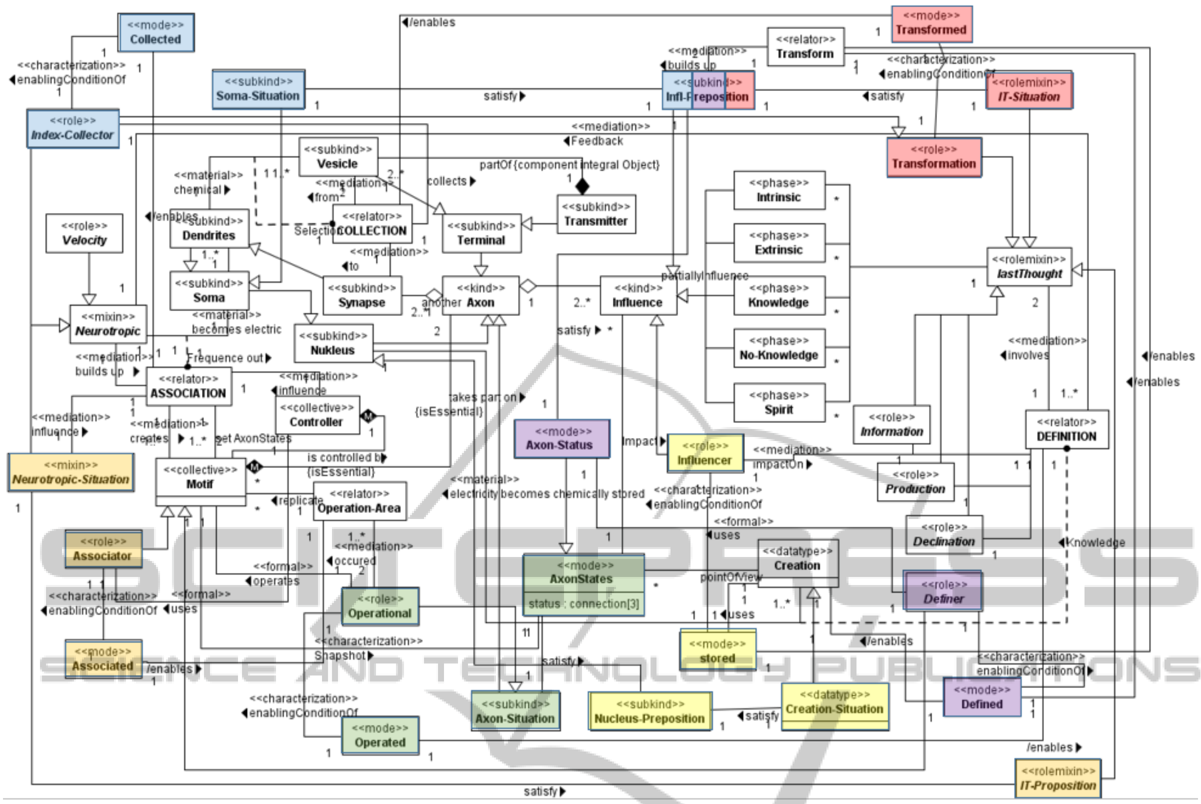

Figure 6: Parallel processing events.

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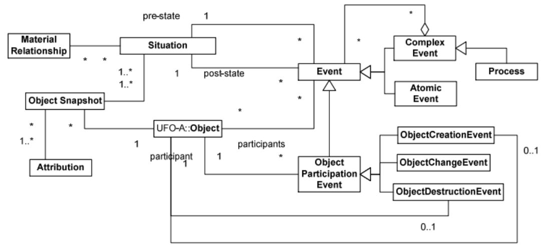

Figure 7: Event ontology.

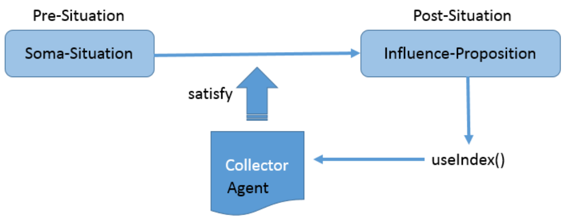

Figure 8: Collection Agent.

axon states of the needed motifs. In order to create new motifs and to establish novel connections between them, newly collected chemical material is derived from the subkind "Soma" (body cell) and converted to an electric impulse which travels at a specific frequency and sets the new axon states. When all the

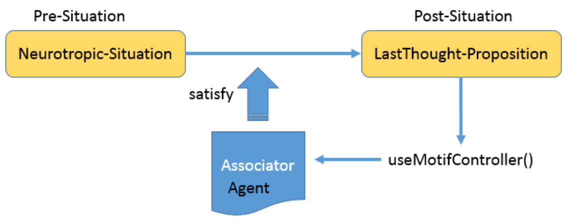

Figure 9: Association Agent.

motifs needed have been prepared, the accociation is then complete and the role "Accociator" enables the condition of the mode "Associated" (simplified in figure 9) which in turn enables the operation-event.

Operation - Event (green). The present "Axon-Situation" created by the role "Associator" serves to satisfy a previous snapshot mode "AxonStates", as prepositioned by the role "Operationial" beforehead. The role "Operational" entity, which is created as a specialization from the "Axon-Situation", mediates one or more "Operation-Area" relations by replicating considerable information into the associated collective "Motif". With this information, the role "Operational" formally operates on different motifs, enabling the condition of mode "Operated", and it is at this moment that all the operations needed are completed. It is at this time that the mode ”Operated”, simplified in figure 10, enables the definition event.

Definition - Event (purple). The mode ”Axon-Status”, which was operated upon earlier, is the situation which satisfies the subkind ”Infl-Preposition” (influence preposition) of the previous thought. The role ”Definer”, specialized from the current collective ”Motif”, formally uses the specialized ”Axon-States” to define whether or not something should be stored (role ”Production”) or transformed again (role ”Declination” and/or role ”Information”). The roles ”Production”, ”Declination” and ”Information” are specializations of rolemixin ”lastThought”. They are used as specification components for the definition event. In case of the definition that current axon states should be stored, the mode ”Defined”, simplified in figure 11, enables the storage event.

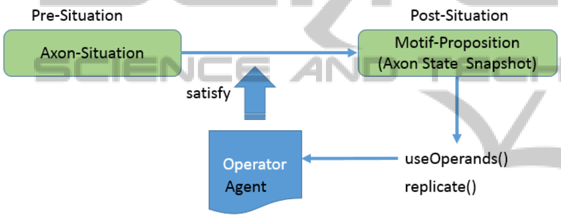

Figure 10: Operation Agent.

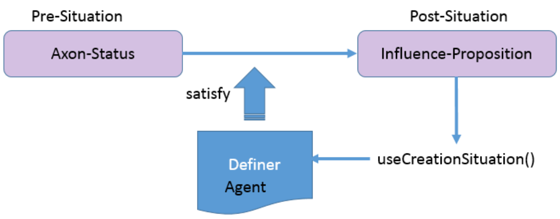

Figure 11: Definition Agent.

Storage - Event (yellow). The datatype ”Creation-Situation” acquires the datatype ”Creation” and presents a situation which needs to satisfy the subkind ”Nucleus-Preposition”. The ”Nucleus-Preposition” is a specialization of the subkind ”Nukleus” which indicates whether storage is performed or not. At this time, the point of view (the data type extracted from the axon states) is stored by the role ”Influencer”. This mediated role is acquired from the kind ”Influence” and enables the mode ”stored” condition. It is the mode ”stored” condition, simplified in figure 12, which in turn enables the transformation event.

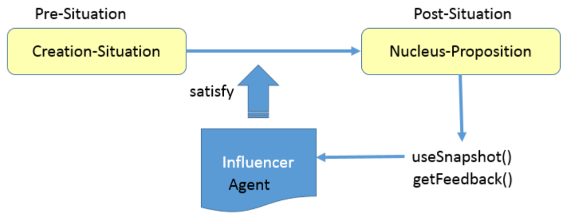

Figure 12: Storage Agent.

Transformation - Event (red). The relator ”Transform” builds the subkind ”Infl-Preposition” (influence preposition) through mediation which satisfies the rolemixin ”lT-Situation” (last thought situation). The ”lT-Situation” is a rolemixin ”lastThought” specialization and represents the actual state of the last thought. The role ”Transformation” is also a rolemixin ”lastThought” specialization which enables the mode ”Transformed” condition. The mode ”Transformed” condition represents the time at which all definitions are performed, and the role ”Index-Collector” (the collection of transformation information) is mediated by the relator ”Definition”. Then the mode ”Transformed”, simplified in figure 13, enables the collection event where a new iteration of the thinking process begins.

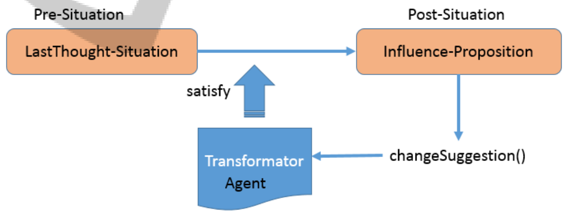

Figure 13: Transformation Agent.

2.6 Formalization of the Captured Ontologies

In the following subsections, the entities and their semantical objectives will be formalized.

Quantity of Thoughts. If a thought is a container categorized by its environment, then there are a quantity (q) of particular thoughts (A,B,C) about how a neural network in the brain could look (quantity A, short qA). There exists a quantity of thoughts in qA concerning one specific motif M of neuron cells (qB), and within these thoughts about a particular thought, there are a quantity of thoughts about the manner in which the components of a neuron cell (qC) could operate (O) recursively together in their environment E of neural axon states (S) within a collective (C). It could be said for example:

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$$\forall C(M) \rightarrow O(E^S) = M(qA) \subset (M(qB) \cup M(qC)) \quad (1)$$

From this perspective of thoughts concerning a neural network in the human brain, each neuron has the exact same functions, attributes and components for reaching mathematical and mereonymic operability. Additionally, the life-span (essential and separable cognitive products of a thought as the result of operatios on neural axon states of created motifs) of the relationship between first-thought, next-thought (thought and *SubQuantity* of thoughts as individual wholes), and a single motif (neural axon states which turn a substantial neuron into a particular thought) all correspond to Guizzardi's description of inseparable parts. Axon-states and thoughts are essential and seperable; they are highly dependent on one another other due to the fact that life-span of individual sub-quantities of thoughts are wholes in their own right, and thus do not loose their existence when they loose their whole. A quantity of thoughts must be as *infinitely diversible* (homeomerous) as the neural axon-states (motif) for the creation of sub-quantities of further though (thinking fractals). This is exactly what could be key in the production of the infinitely diverse intuitive cognitive products of creativity, which could in turn be the most important factor in measuring consciousness.

Transitivity Problem. All compositions need to be transitive as to assure that the operations of the whole have the correct impact on each of its parts. Transitivity holds true between *component functional complexes* when the parts share a similar essential parthood relationship which also applies to the whole (cf.) (Guizzardi, 2005, pp. 187). If the relationship between the parts is not the same as that between the wholes, the applicability of operations to the whole needs to be validated in order to assure that the operations between the parts of the whole have the correct impact. A formalized solution to isolate the scope of transitivity of functional part-whole relations can be found in (Guizzardi, 2009). However, all neurons must have the same kind of relationship within their sub-collections, and all sub-collections should also share the same type of relation as the neuron cells share with one another. The ideal situation would be that of a *subQuantityOf* and *subCollectionOf* relationships (corresponding to node-weight which equals the quantity of connections in neural networks) (Sporns, 2011, p. 8).

3 CONCLUSION

This paper describes the development of an ontology with the aim to answer many questions for consciousness in an automated way. This ontology has identified the most important factor in consciousness as being the creation of infinitely diversible cognitive products of creativity based on cognitive pattern-matching between particular collections of thoughts. Furthermore, three mayor neural brain cell abilities (described in section 6) were discovered as being of high importance for further researches in the field of cognitive product generation. Transitivity was introduced to be essential in the correct application of function impacts within particular thoughts. In conclusion to the created theory, two hypothesis can be derived:

Hypothesis 1. With the simulation of pattern matches between mapped thought collectives a learning environment is able to construct cognition automatically by observing learning behavior during course accomplishment.

Hypothesis 2. By observing learning behavior, a learning environment is able to adapt, create and differ learning fractals individually to support the learner with suggestions in order to understand materials better and faster.

Further research is needed to sequentially map and process patterns for cognition detection in E-learning environments. This knowledge answer the question how cognition relates to consciousness on a fundamental ontological basis.

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