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A MULTI-AGENT MODEL APPROACH TO FILL UP THE GAP BETWEEN EMOTION, PSYCHOLOGIC AND BRAIN COMPUTING

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KEYWORDS
Neurone ontology, Glia, Endocrine, Fuzzy vectorial Space, Fuzzy vector space, Object oriented model, Multi-agent system

Abstract

Deep learning and artificial neural networks are used to simulate synapses and recognition features of brain perception. However, they do not take into account, the dynamic, the plasticity and the diversity of the interneuron local communication: electrical, chemical and paracrine synapses. Moreover, these models do not implement the glia that conveys long distance hormonal messages that interact with neurons and make them available everywhere in the whole body at the same time. These internal hormonal messages strongly influence the state and the behavior of all the brain layers and nuclei (fear, emotions, sleeping and awakening). We have shown in our previous article that these hormonal messages are essential to consciousness and thinking. We know that the nervous system is always evolving and that this evolution is necessary to achieve long-term memory, cognitive, sensitive, motor and language tasks. We have also described the features of the object oriented subsymbolic perception pyramid and those of the object oriented linguistic pyramid. In this work we provide a junctions object ontology to implement the different type of synapses and hormonal messages and a multi-agent system that integrates and control them. The supervisor agent represents anatomical and connection constraints of the brain layer and nuclei and control the diffusion of hormones and neuromediators. The temporal fuzzy vector space (TFVS) is used to tune the composition of neuron objects in layers and nuclei objects and to implement the emergence of their states and features according to a holistic systemic approach. We present the necessary tools and TFVS object classes to implement the MAS subsymbolic perceptive and psychological layers. To illustrate the approach we propose a simulation of object perception and recognition, emotion tagging, indexation to store the cognitive experience corresponding to a set of threatening objects in the environment.

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INTRODUCTION

The FVSOOMM model described in previous works Colloc (2019) offers the necessary operators to implement decision support systems in medicine, psychology, management Colloc (2020b) and territorialisation Colloc et al. (2022). The model relies on our object model based on composition and extended with temporal fuzzy vector spaces (TFVS) where fuzzy vector space functions (FVS) describes the evolution of each attributes and component objects involved in the system. In this paper, we will use the connective approach of our object model Colloc et al. (1996) and show the modelling a prototype of a multi-agent system (MAS) that implements neuroendocrine, immune, peripheral nervous system interactions that are described in Colloc (2000a;b). This article follows the necessary steps shown in the FVSOOMM method to implement the Multi-Agent System (MAS) that simulates some functionalities of the layers and nuclei of the brain and particularly the artificial consciousness model which was proposed in the previous article (Colloc,2021). The section 2 presents the human nervous system and shows the main differences with artificial neural networks and deep learning. The section 3 shows the topology and the connection constraints of the nuclei and layers of the nervous system. This section presents also the emotion implementation and the psychological model. The section 4 recalls the different steps of the FVSOOMM model and method presented in a previous paper. Section 5 describes the MAS architecture and the relationships between the emotions and the psychological model. The section 6 concerns the future works and projects of this work and is followed by a conclusion.

CAPABILITIES OF NEURONS IN CONVENTIONAL ARTIFICIAL NEURAL NETWORKS AND DEEP LEARNING

In neural network models and more recently deep learning, artificial neurons are all of the same nature (they are undifferentiated), we can only distinguish the input and output layers on which they are arranged and connected. Artificial neural networks do not take into account:

1. The cell diversity (classification) Many types of

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neurons are found in the encephalon: Purkinje cells, pyramidal, reticulary cells...

2. The variety of neuromediators: acetylcholine, serotonin, γamino-butyric acid, noradrenalin, peptides;

3. The variety of transmission modes and messages including synapses (electrical, paracrine, chemical) and glia-related hormonal messages (Shepherd 2018);

4. The functional specialisation of known nuclei and brain layers identified by Neurophysiologists using the functional Magnetic Resonance Imaging fMRI that have mapped the cognitive functions in the brain Shepherd (1988).

5. The neural layer topology is described with compositional and connection constraints at different levels of granularity.

These components of the central nervous system are not taken into account in artificial neural networks and in deep learning neural network. The purpose of these models is to implement learning features of signals and images. Our MAS model implements these different type of neurons, neuromediators, message types to simulate the functionalities of layers and nuclei of the brain. However, the experiences and works concerning artificial networks and deep learning are very useful to inspire some aspects of the MAS architecture.

Cell diversity

The brain is not only composed of neurons and their connections (axons and dendrites) but is also composed of astrocytes and oligodendrocytes that make up the glia (Gee et al. 2014). The glia provides the main interaction between the nervous system and humoral system that constitutes the mind-body integration as described by Francisco Varela in Varela (1989), Varela et al. (1993). During embryogenesis, the nervous system takes place from the ectodermal sheet of the embryo and finds its extensions in the skin that envelops the whole body. The neural tube and the neural crest gives rise of the different lines of the cells of the nervous system as described on figure 1. The embryogenesis of the nervous system is particularly well described in Alain Prochiantz's book where he shows the importance of time and homeotic hox genes Prochiantz (1995). According to our FVSOOMM method and figure 1, the ontology of embryogenesis of the nervous system is presented. The different cell lines depicted on figure 1 are specialized in the UML class diagram figure 2. The neurons are composed of different number of dendrites and on axone. The connection between neurons are shown figure 3.

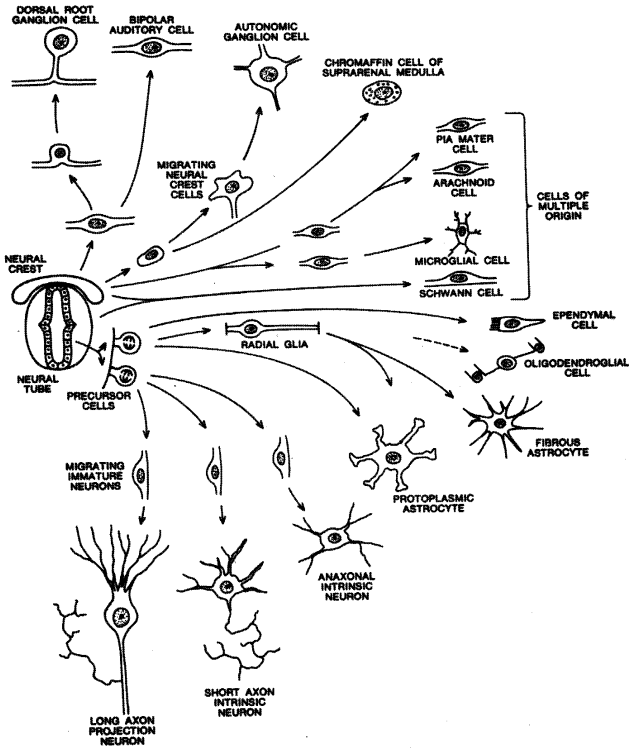

Figure 1: Nervous system embryogenesis Churchland and Sejnowski (1993), Shepherd (1988), Rakic (1981)

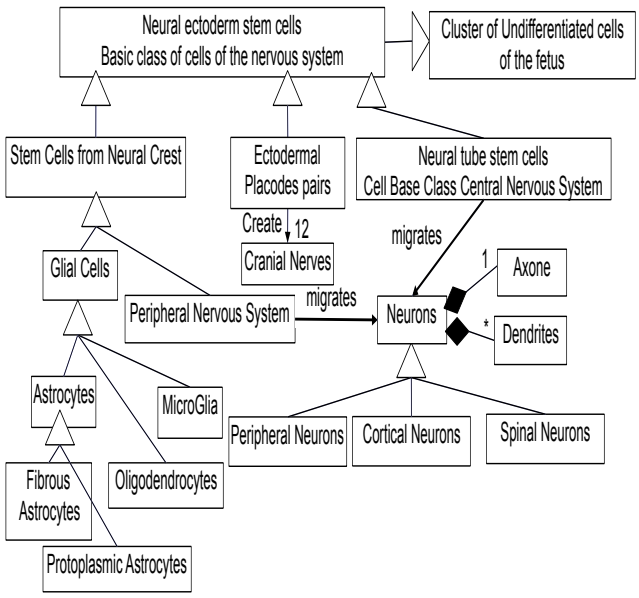

Figure 2: UML ontology of the nervous system of embryogenesis

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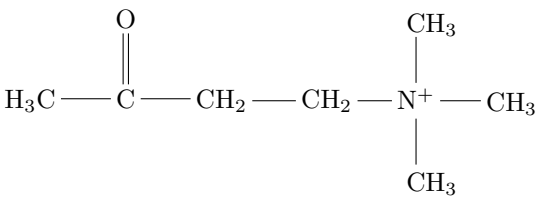
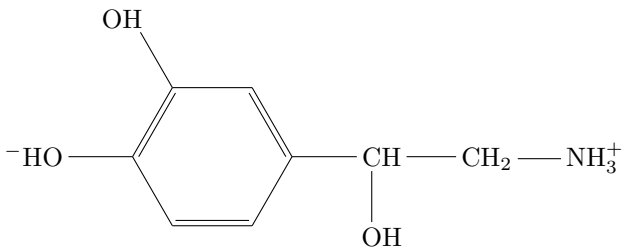
Neurotransmitters diversity

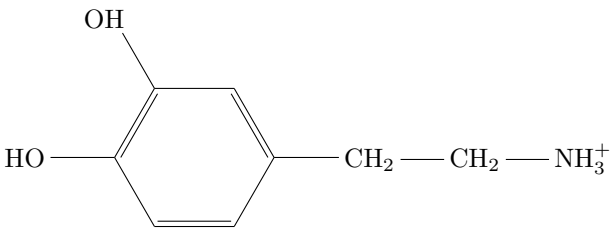
This subsection enumerates the main neurotransmitters that are found in the nervous system in synapses of neurons. Adrenaline is also an hormone produced by the surrenal glands and which has an effect on many neurons of the brain.

1. 

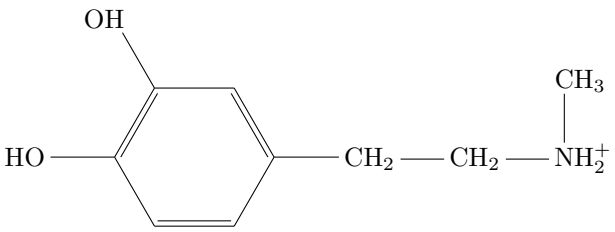
Acetylcholine

2. 

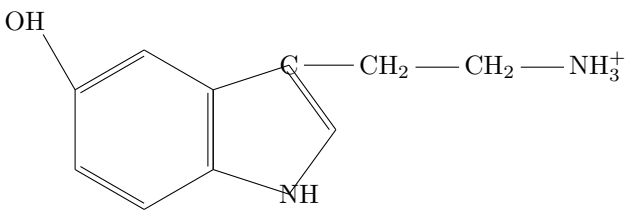
Noradrenaline

3. 

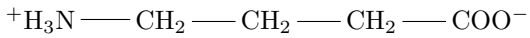
Dopamine

4. 

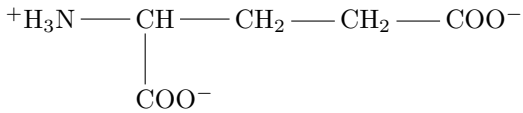
Adrenalin

5. 

Serotonin

6. 

γAmino Butyric Acid (GABA)

7. 

Glutamate

Transmission modes in the nervous system

The figure 3 shows the different types of connections between neurons, cells of the glia and endocrine cells. The table shows the type of relationship and junction for each type of message.

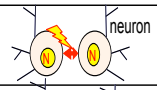
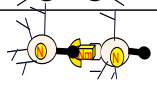
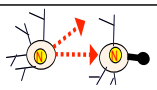
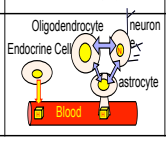
Type of Message	Image	Type of Relationship	Type of junction
(1) Electrical synapse		Neuron to neuron	1-1 tight bidirectional
(2) Chemical Message		neuron to neuron	1-1 tight monodirectional
(3) Paracrine Message		Neuron towards a nearby population of target neurons	n-m near
(4) Hormonal Message endocrine		Neuron or endocrine cell towards all distant neurons with appropriate receptors	n-m distance

Figure 3: Transmission modes in the nervous system

TOPOLOGY AND CONNECTION CONSTRAINTS

The different layers and nuclei are connected together at different levels of granularity. The neurons and the cells of the glia (astrocytes and oligodendrocytes) exchange messages with the different transmission modes (chemical synapses, paracrine and hormonal) figure 3. These relationships between the different layers are shown on the figure 4.

Functional specialisation of layers and nuclei in the brain

The cortex is composed of six layers and has rather the same structure everywhere on the surface of the brain Mountcastle (1978). However, the neuron layers and nuclei are specialized in the cortex and the connection

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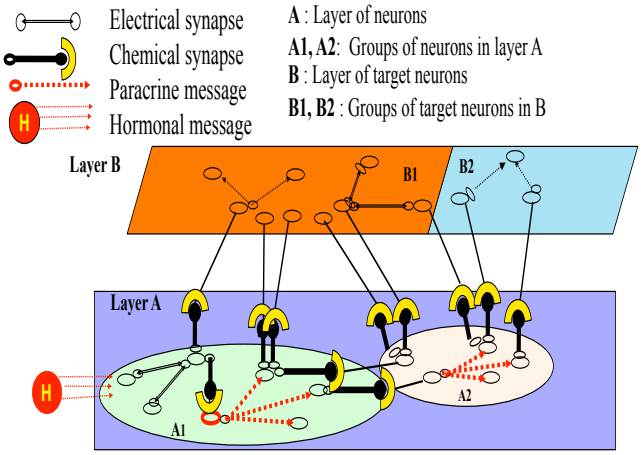

Figure 4: Interconnection between layers and nuclei of the nervous system (Colloc 2000a)

between them allows the emergence of the objects of the environment in each type of sensory perception (hearing, sight, touch, smell, taste) which are interconnected together Hawkins and Blakeslee (2005). Each layer controls that the flows of perception is coherent with the others by means of feedback loops figure 5. The agregation of subsymbolic levels provides the emergence of the object with all its characteristics.

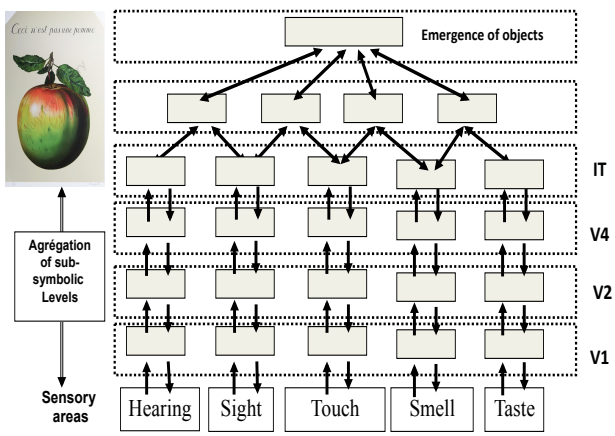

Figure 5: Sensory emergence of known objects

Emotion implementation

The emotion attributes are mainly represented with the use of the emotion labelling of flows of perception concerning the identified objects. The emotions of the MAS is described using the Ortony Clore and Collins model (OCC) Ortony et al. (1988) to define the relevant pairs of variables and design the emotions with vectors of our FVS object oriented model. The emotion labelling is done with the value of relevant OCC variables figure 6. Each variables of OCC and the different balances of sensitive objects are defined using the FVSOOM model Colloc et al. (2022). Each pair of variables is represented by a FVS function $F_1(Ev)$ *to* $F_{11}(Ev)$ where Ev is an event concerning a person P, myself or an object of the environment. These functions are further used to implement the Self and the This instances of the psychological model figure 7.

Source	Target	$F_i(x)$	(+)	(-)
Consequence of an event **Ev**	Concerning another person	F_1(Ev)	Happy for	Resentment
		F_2(Ev)	Gloating	Pity
	For myself	F_3(Ev)	Hope	Fear
		F_4(Ev)	Joy	Distress
Emotion felt concerning **Ef**	Myself	F_5(Er)	Pride	Shame
		F_6(Er)	Gratification	Remorse
		F_7(Er)	Gratitude	Anger
	Another Person	F_8(Er)	Admiration	Reproach
		F_9(Er)	Gratification	Remorse
		F_{10}(Er)	Gratitude	Anger
Emotion concerning an object **O**		F_{11}(O)	Love	Hate

Figure 6: OCC Emotion FVS functions

Psychological model

The psychological model integrates different layers Environement, Conscious, Preconscious, Unconscious and the psychological concepts described by Sigmund Freud: the Ego ("das Ich"), the super-ego ("das über Ich") and the Id ("das Es"). The figure 7 shows the representation of the objects and the persons of the environment in these different instances which are storing these object perceptions according to the emotions felt.

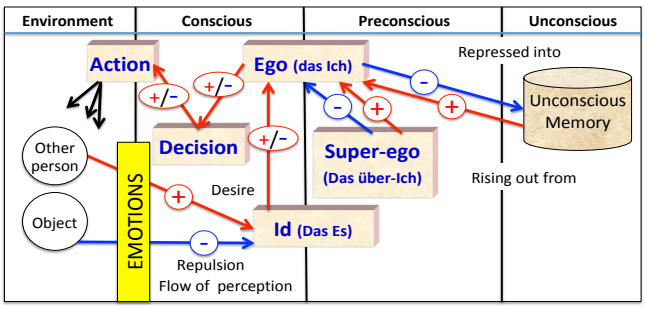

Figure 7: The psychological model

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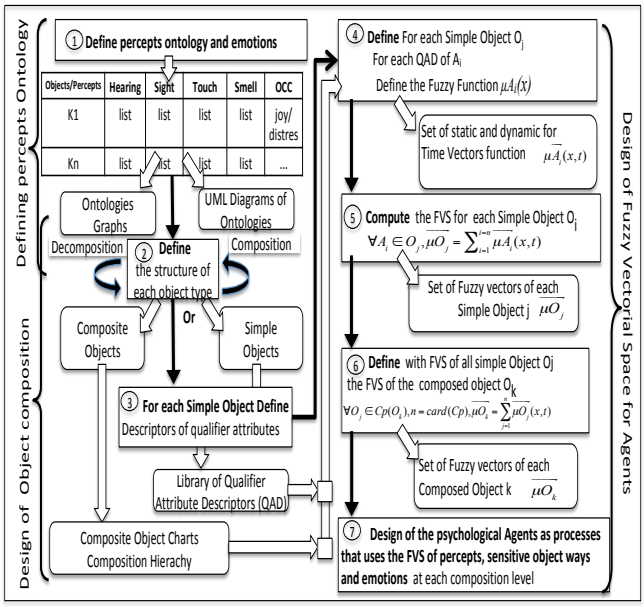

Figure 8: The FVSOOMM Method to design the MAS

The FVSOOMM Model and Method

The figure 8 shows the necessary steps of the FVSOOMM method to implement the agents, with the fuzzy vector space object oriented mode that describe the percepts, signs and composite sensitive objects of the MAS, according to figures 5 and 9.

- Step 1 of figure 8 defines the boundaries of the MAS, describes the actors (internal and external actors) and the objects of the MAS, and builds a dictionary of their attributes and relationships to be described in Step 2. The expert user of the system (EXPU) designs the components of the MAS. At the moment, there is no end-user because the prototype of the system is not yet completed and need further experimentations. During this first step, the necessary objects and attributes of the different modules of the MAS are designed according to the figure 9. The exchanges between the modules of the system are defined by the psychological model .

- Step 2 of figure 8 covers the design of the ontology that defines all the object classes, their composition hierarchy (is-part-of) relationships and all the relevant qualifier attributes attached to the objects of each class. Classes described in the ontology figure 2, the emotion variables figure 6 and the psychological model 7 can be mapped in one or several UML class diagrams.

- Step 3 of figure 8 concerns the modelling of the MAS with a fuzzy vector space. It relies on the composition relationship and the qualifier attribute descriptors (QADs) to describe the relevant attributes of the objects of the MAS (neuron agents, glia cells, layers, nuclei) instances (either simple or composite) of the sensory hierachy figure 5 and the psychological model figure 7.

- Step 4 of Figure 8 defines the fuzzy functions. For each necessary simple object O_j of the MAS, choose the QADs of each relevant attribute $O_j.a_i$ in the list of previously defined QAD. Several iterations of Steps 3 and 4 are used in turn to define necessary objects Object Type Descriptors (OTDs) and attributes (QADs).

- Step 5 of Figure 8 computes the resultant FVS of simple objects. For each simple object O_j, the resultant time function vector of the object is calculated from their attribute's function vectors.

- Step 6 of Figure 8 defines the FVS of composite objects. For each composite (composed) object O_k, its resultant time function vector is computed from all of its component objects O_j and attributes $O_k.a_i$.

- Step 7 of Figure 8 implements the pattern-matching algorithms that uses the vectors of the composite objects to recognize the objects at each level of the sensitive flows described figure 5 and in the figure that describes the MAS figure 9. Emotions and psychological objects figure 6 and 7 are implemented at a more macroscopic level and allows to compare object states described by their resultant vectors and taking into account time.

MAS architecture

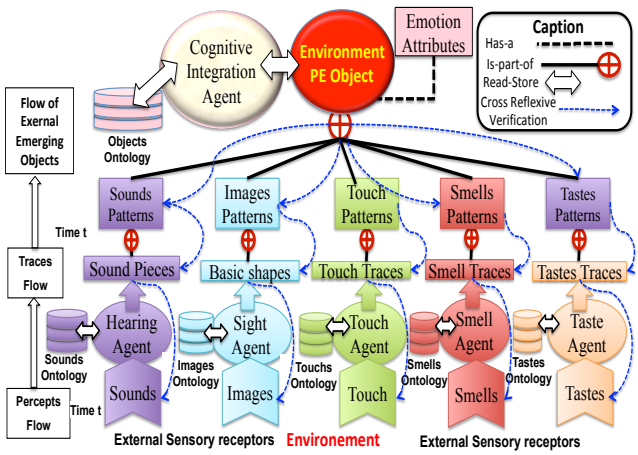

Figure 9: MAS for Subsymbolic Perception of Environemental External Object

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Figure 9 describes the multi-agent system (MAS) that deals with the perception of the objects in the environement: (OE) in figure 9. The proposed architecture is similar to the layers of the cortex organisation shown figure 5. The MAS involves agents specialised by the flows of input percepts and compute them according to the sensory receptors. The agents compare the inputs with the respective sensory ontologies that stored the history of passed percepts components and their relationships and they output tagged shapes, pieces and traces object that are components of existing objects. As in the cerebral cortex, the agents can verify at each level that the comparison remains relevant and they detect mismatches upward and backward in the different flow of sensory ways. This is possible because the MAS is multithreaded. The Cognitive External Integration Agent is a supervisor agent that integrates the entire sensory object flows that compose the emerging objects of the environement (OE). The supervising agent plays the role of the hippocampus the top object of figure 5 that ensures the multisensory associative memory of perceived objects. This MAS represents the conscious part of the Id (Das ES) of the psychological model depicted on figure 7 and the emotion balances (Desire/repulsion) provided by the environement objects and actors and events. The emotions modelled with the OCC model tagged the OE objects presented on figure 6.

Modelling the emotions of the psychological model with FVSOOMM

The pairs of variables of the OCC model figure 6 are used to compute FVS functions that assess the events concerning the actors and objects perceived in the environment and that constitutes the *This* instance of the psychological model of the consciousness MAS figure 10 and of the *Self* instance figure 11. The FVS functions are time functions that show the evolution of the state of the Self F_4 *to* F_7 and the This instance according to the events that occurs concerning other persons F_1, F_2 *and* F_8, F_9, F_{10} and the objects: F_{11}. This evolution constitutes the history of the MAS perception. The temporal modelling of FVSOOMM is described in Colloc et al. (2022).

Action decision according to emotion

The decision to take an action concerning a situation or an event is modelling with a finite state automaton (FSA) and transitions that are assessed by the probability of each relevant action according to the emotions provoked by the object, person or event involved in the situation.

1. For each transition $u \rightarrow v$ and each event K_i, we define the probability of the transition $P(K_i, t)$ according to the vector $F_{11}(O, t) \in [-1, 1]$ that describes the emotion concerning object, person, event, situation provoked by the object O at time t.

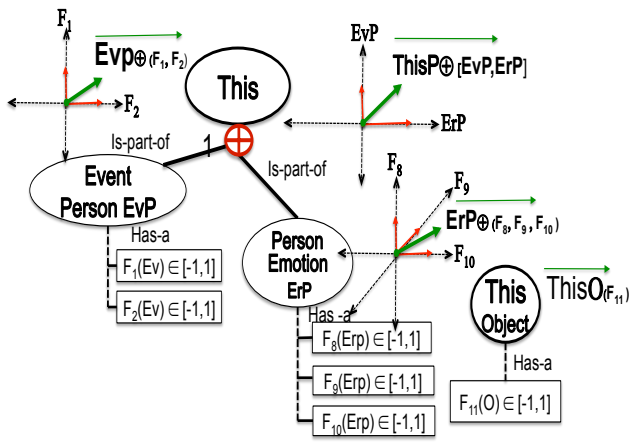

Figure 10: Emotion FVS components of the This instance

2. A random variable X, which is the value of a dice, is associated with the two values: v the transition is crossed, v the transition is not crossed figure 12.

3. A numeric dice is thrown to know which transition is crossed according to the probabilities computed for this event of meeting the object O (a rose or a snake) figure 13.

4. The corresponding decision is taken and applied. Some people like snakes and others are allergic to roses.

Future works

However, this MAS is a prototype based on the psychological model and a lot of work is remaining to implement the necessary modules of the system to provide the features of the nervous system and to fill up the gap between the cell level and the nuclei and layers of the brain and their functionalities. The implementation of the subsymbolic perception of internal body MAS which is described in the previous paper Colloc (2020a) is not presented in this article and will be the subject of future works. We are currently using FVSOOMM to develop the flow of perception of the subsymbolic level for each perceptual agent from external sensory receptors. This work will propose a new type of neural networks that are based on our FVSOOMM model.

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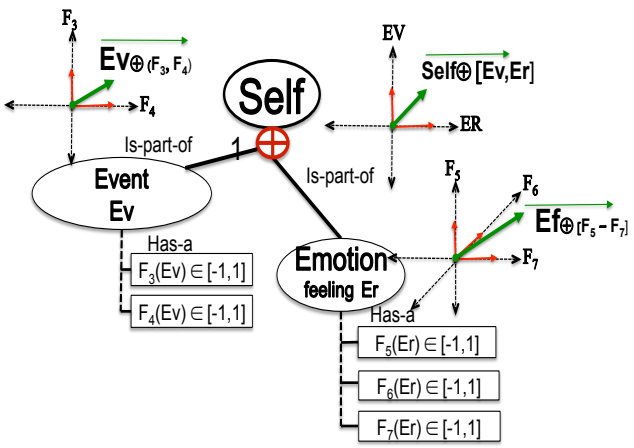

Figure 11: The emotion FVS components of the Self in the psychological model

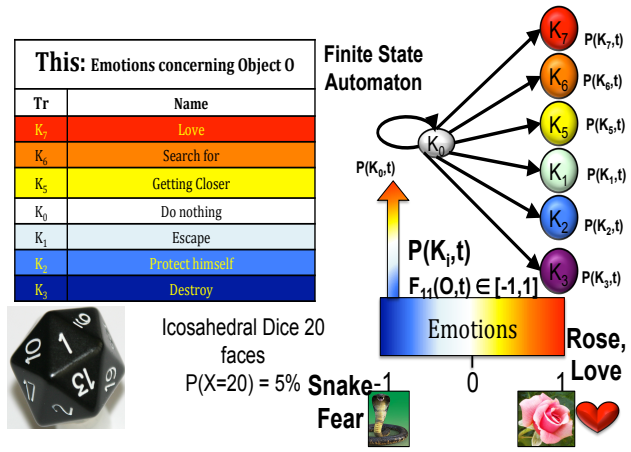

Figure 12: Modelling the decision according to the emotion provoked by an object

Conclusion

The paper shows the actual work in progress to build a MAS able to simulate some features of the brain with our dynamic object oriented plateform FVSOOMM based on fuzzy vector spaces. This pivot model allows to develop specific agents and to integrate them in the layers of the system. FVSOOMM allows time modelling of fuzzyness of composition and connection relationships between the continuous flow of components modelled in the system and particularly the emotion that must tagged affect each objects that are emerging in the system and that constitutes the experiences of memories of past objects and events.

This : Transition object O : Probabilities, Corresponding Dice					
	Action	O = Rose		O = Snake	
Tr	Name	$F_{11}(O,t) \geq 0$ $P(K_i,t)$	Dice : X $F_{11}(O,t) \geq 0$	$F_{11}(O) < 0$ $P(K_i,t)$	Dice : X $F_{11}(O,t) \leq 0$
K_7	Love	45 %	1 to 9	0 %	None
K_6	Search for	20 %	10 to 13	5 %	20
K_5	Getting Closer	15 %	14 to 16	5 %	19
K_0	Do nothing	10 %	17 or 18	10 %	17 or 18
K_1	Escape	5 %	19	15 %	14 to 16
K_2	Protect himself	5 %	20	20 %	10 to 13
K_3	Destroy	0 %	None	45 %	1 to 9

Figure 13: Dice of the object O (Snake, Rose) $F_{11}(O,t)$

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Joël Colloc earned his M.D. at the medical faculty of Lyon and a specialty degree of forensic medicine with a degree of clinical toxicology. He received a MSc. degree of IT from the Business School of Lyon (IAE) and a MSc. degree of computer sciences from the engineering school INSA of Lyon. He served as forensic physician at the Edouard Herriot Hospital in the neurological emergency department to cure drug addicted people, medical ethics and developed drug and addiction database. He went on to earn his Ph.D. in computer sciences at the INSA of Lyon. As Hospital assistant at the laboratory of medical computer science and he taught IT at the medical faculty. He was elected as associate professor in computer sciences at IAE of Lyon and he earned his accreditation to supervise researches in sciences at the Lyon 1. He is a Le Havre Normandy University professor in computer sciences since 2003. His main research topics concern e-health and particularly: fuzzy vectorial spaces (FVS), multi-agent clinical decision support systems (MADSS) and knowledge bases, Case Based Reasoning, ontologies, nervous system modelling and cognitive sciences and AI applications in medicine and human sciences. His human sciences researches try to conciliate the ethics of using Big Data in epidemiological studies, autonomous systems and robots and keeping ethics use of AI in order to improve clinical decision in medicine while preserving the patient-caregiver relationship, the privacy and the freewill choice of the patients.

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