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Multilayer Agent-Based Model for Decision Support System Using Psychological Structure and Emotional states

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***Abstract*— Human decision in complex domains like management, medicine, environment… is stressed by the time and many emotional or psychological constraints that are seldom included in Decision Support Systems (DSS). In a previous article, we presented a Multi-Agent Decision Support System (MADSS) providing the integration of the different categories of knowledge representation. and bringing them to cooperate in elaborating the decision. However, in stressfull domains, for a more realistic system, we need to model as well the impact of emotion and the psychological structure of each actor making a decision. Our model includes a psychological structure layer, an emotion layer, a behavior layer and a decision layer. These layers are all influencing the ability of an agent to make or not an appropriate decision. The emotion equilibriums are represented by attributes. The psychological structure layer triggers tasks and behaviors according to the emotion states. Automata are designed to describe individuals typical behaviors, abilities or handicaps according to different psychisms and personalities. The behavior layer set a current goal, selects a strategy or a scenario to achieve it. The decision layer makes a decision if the agent is able to provide it.**

I. INTRODUCTION

Some Decision Support System (DSS) have been proposed to help workers during their job to cope with the steps of the decision making in complex domain like management, medicine and environment. These DSS are provided for enhancing the efficiency of the decisions in these domains. Therefore, this kind of DSSs is well suited to aid a user to solve a problem and take an appropriate decision according to available knowledge sources or stored experience[9][11].

However, these DSSs have no representation of each actor's ability to take appropriate decisions. Moreover, these DSS are not relevant when more or less emotional agent showing different psychological structure are interacting in the environment and are either making suitable or poor decision. The purpose of this work is to provide a Multi-Agent Decision Support System (MADSS) to model the emotion and the psychological structure of interacting actors making decisions in complex domains and stressfull contexts. This model will be used to build simulators of agent attitude in various situations such as emergency medicine, trading, education, environment and industrial catastrophes, military conflicts… In all these domains, modelling the emotional aspect and the psychological structure of the agents is essential. Many approaches were proposed to model the agent emotion for different purposes: providing more human, friendly user interface and facial animation [1][8], educational games and pupil metacognition [3] [5], military conflicts [13].

Firstly, different existing models of emotion are briefly reminded. Our main contribution is to introduce the representation of the individual's psychological structure which is closely interacting with the emotion level.

Thus, the section 2 describes a multilayer model composed of the psychological structure layer, the emotional state layer, the strategy and behavior layer, the decision making layer. A schema describes the interactions between these different layers and the decision process.

The section 3 describes the psychological structure layer. It firstly provides a generic model of typical neurotic tendencies and common personality structures. The model is then specialised to fit with different kinds of neurosis.

The section 4 presents the emotional state layer which relies on the well known Ortony, Clore and Collins' model (OCC model) [6][7]. The emotion state layer is composed of balance attributes defining the emotional state of each agent.

The section 5 shows how the emotion and the psychological structure are modelised and combined together to provide the agent strategie and behavior.

The section 6 describes the decision making layer defining the appropriate tasks to achieve a goal and the relationship with the strategies and behaviors layer. This latter determines if the agent emotional state allows the agent to really perform the required tasks provided by the decision making layer. At last our approach is compared with other similar works. The conclusion section summarizes the main contribution of our model and the perspectives of this work.

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II. A MULTILAYER MODEL OF MULTI-AGENT DECISION SUPPORT SYSTEM

Most available computationally models of emotion rely on the OCC model developed in 1988 [6]. The OCC model defines events, agents and objects. Events are considered to induce emotional consequences. Agents are able of actions that have effects on the environment. Objects have imputed properties. The OCC model represents emotions as valenced reactions to the perception of the world. That is: one can be pleased about the consequences of an event or not (pleased/ displeased); one can endorse or reject the actions of an agent (approve/disapprove) or one can like or not aspects of an object (like/dislike). Then, the events can have consequences for others or for oneself and on acting agents. Thus, the different emotional balances are depicted by couples of (positive/negative) reactions represented by variables. For short, we do not provide the specialization tree of the OCC model but we just summarize the couples of variables in table 1.

		+	-
Consequences of events	For others	Happy for	Resentment
		Gloating	Pity
	For self	Hope	Fear
		Joy	Distress
Actions of Agents	Self Agent	Pride	Shame
		Gratification	Remorse
		Gratitude	Anger
	Other Agent	Admiration	Reproach
		Gratification	Remorse
		Gratitude	Anger
Aspects of Objects		Love	Hate

Table 1 Couples of (positive/negative) emotion variables according to the OCC model

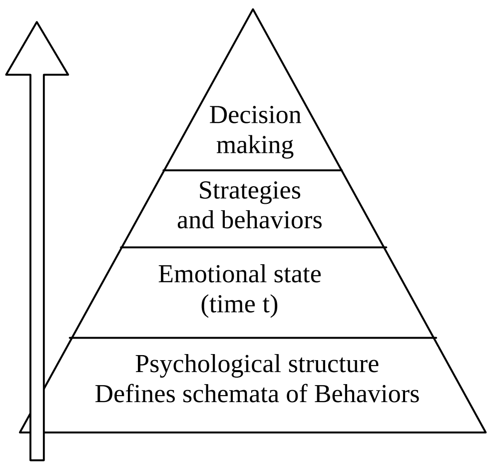

Fig. 1 A multilayer model of decision

A complete description of the OCC model is available in [6] and computational applications in [7][4][1].

The aim of our proposition about model of decision is to use a multilayer description with 4 layers which will be explained in the following paragraphs. Note that the base of this model is the psychological structure as described in figure 1.

III. THE PSYCHOLOGICAL STRUCTURE LAYER

First, we describe the psychological structure which are able to act on the decision making behavior which is influence by emotional aspects. In figure 2, we present how and where the psychological structure intervene in the emotional learning loop.

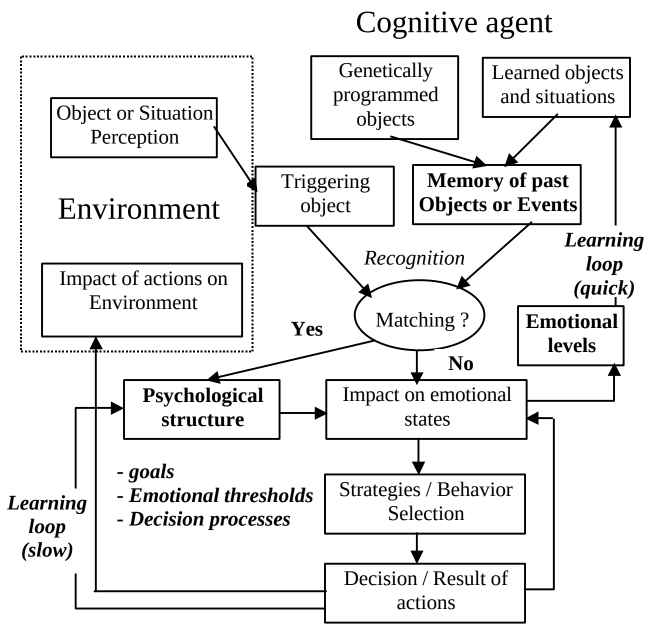

Fig. 2 . The emotion learning loop and psychological learning loop

Psychological structure can be studied through neurotic aspects of the considered personality. We show in the table 2, a description of such personality, while table 3 shows a neurosis classification.

A neurotic personality		
- A list of anxiogeneous events		
	- An anxiogeneous event is :	
	Or	- The perception of a triggering object(s) having specific characteristics (eg. fear of mice)
		- The perception of situation(s) or scenario(s) defining specific contexts (eg. agoraphobia)
- A list of emotional effects		
	- An emotional effect is :	

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	And	- The increase or a decrease of emotional parameters
		- The Emotional states should trigger defence behaviors
- A list of defence behaviors		
	And	- The agent sets a goal (most of the time : the elimination of the unpleasing situation or of the object causing the disagreeable emotional state
		- The agent elaborates a defence strategy. Each strategy is a set of connected actions executed to achieve the goal (destroy the object, flight, avoid, prevent…).
	Or	- The agent may show inappropriate behaviors caused by the pathological neurotic personality

Table 2. A generic model of the neurotic personality

Neurosis	Triggering object	Anxiogeneous events	Emotional effects	Defence behavior
Obsessional neurosis	Lack of objects Lack of misdoing	Anxiety of loosing an object. Anxiety of not achieving appropriate tasks	Severe inner struggle Fear and anxiety	Ritual and necessity to carry out actions again and again Compulsive need to verify
Phobia neurosis	Animals Crowd Closed places	Abnormally intense dread of certain objets or specific situations	Dread Fear	Flight Avoiding Prevent
Hysterical neurosis	Herself or himself image Others' sight	Anxiety of offending or displeasing	Anxiety Halluci-nations	Repression Flight Avoiding indifference Versatility Theatrical behavior

Table 3. A simplified neurosis classification

IV THE EMOTIONAL STATE LAYER

In this section, we describe the emotional state layer of the model. This layer relies on the Ortony Clore Collins (OCC) model of appraisal which is the most widely accepted. The OCC model defines a set of 22 emotion parameters representing a certain positive and negative intensity of 11 items. The emotion quickly changes over time.

We use a sigmoid fuzzy logic function to describe each couple of parameters of the OCC model table1. The figure 3 depicts the example of Joy/distress concerning the effect of an event k evaluated by a score [-1,1] that is considered as desirable when is near to 1 or undesirable when it is near to -1, neutral when it is near 0. All other couples of variables of the OCC classification table 1 are represented in a similar way. The item k could represent the consequences of an event, the impact of agent actions for self or others and the aspects of an object.

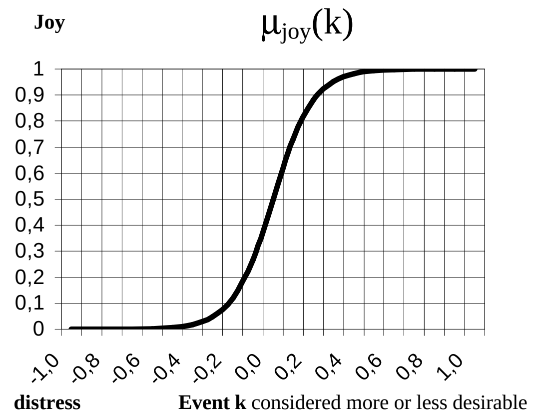

fig. 3 A fuzzy logic membership function μjoy(k)

V THE STRATEGIES AND BEHAVIORS LAYER

Formalism proposed

This layer has to manage previous layers, psychological level and emotional states and to define behaviors taking into account them.

The formalism proposed is based on finite-state automata composed of:

- a set of internal states characterizing mental situation, for example;
- transitions which describe the way going from one state to another. In the following, the event k evaluated by the score in the interval [-1,1] is the shutter release of the transitions.

We proposed to complete this formalism allowing us to introduce stochastic aspects in behavior descriptors. For this, each transition has to output a probability which indicates the chance that the transition was really done. To achieve this aspect, we base our model on automata with multiplicities or probabilistic automata as a sub-class of them.

Thus, the mathematical formalism for the behavior representation at each time t is a probabilistic automata $A(t)$ as the following 5-uple (Σ, Q, I, J, d):

- Q is the finite set of internal behavior states;

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- Σ is the set of perceived event k. As previously indicated, each event k is evaluated by the score in the interval [-1,1]
- I and J are respectively the set of initial and final states from whom a behavior (or specific strategy, for example) can start and finish respectively.
- d is a mapping from $Q \times \Sigma \times Q$ to [0,1] which describe all transitions associated to a couple of states and a event in input. The output of the mapping is a stochastic value.

Behavior, emotional state and psychologic structure bounding

We explain now, how the mapping d is linked with emotional states as following:

1. For each transition j and each event k, we define
$$I_j = \arg \bigotimes_{i \in [1,N]} a_{j,i}(t) m_i(k)$$
Where N is the number of different emotion parameters (in OCC model, this corresponds to the numerical value: 22), $a_{j,i}(t)$ are relative importances between all emotional parameters at time t for the transition j, the operator $\otimes$ corresponds to one of the two classical operators, $\wedge$ or $\vee$, that is in fact the minimum or the maximum value. As usual, the operator arg$\otimes$ return the index corresponding to the min or max value .
2. We consider then the fuzzy logic function associated to the previous computed index I_j :
$$E_j(k) = m_{I_j}(k)$$
3. We defined a random variable associated to two values u and v which respectively correspond to the fact the transition is crossed or not.
$$X : \begin{cases} [0,1] \to \{u, v\} \\ if \ x \le E_j(k) \ then \ X = u \\ else \ X = v \end{cases}$$
4. Finally, the probability computed as output of the transition j, associated to an event k is:
$$P_j = P_j(\{X = u\}) = E_j(k)$$

We have proposed a computable formalism (automata-based) for modeling the behavior in respect of the emotional aspect. One of the major aspects in this operating automata description is the introduction of the coefficients $a_{j,i}(t)$ for each transition j, each emotion parameter I at the instant t. These coefficients are obtained from the psychological structure and a database knowledge about them. So, via these parameters, the psychological structure acts on the behavior model, taking into account nevrotic personality, for example. Another aspect of the efficiency of these parameters is based on the fact that they can evolve, using genetic processus. This aspect can confer to the behavior some adaptive aspects.

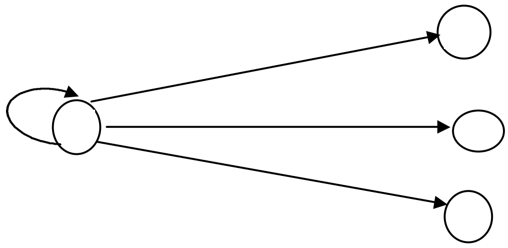

fig. 4 A probabilist automaton for modelling the emotion / behavior relationship in a specific psychological structure

Illustrative sample

Let us take a simple situation: “buying an object”, eg. a computer. In this general type of problems, one can summarize different choice criteria according different aspects : the knowledge concerning the object (the features, capabilities, price …), the feeling for the object and the personality which is built according to the life experience. Thus, the first part of the decision process is supported by reasoning on the available information concerning the object to buy. The second part is purely driven by the emotion and feeling of the object: the good or bad perception (shape, color, smell,…) and moreover, the relation with pleasant or unpleasant past events or perceptions previously stored in the memory. The third part is defined by the psychological structure and the corresponding decision schema which are evolving during each individual’s life. Therefore, our model is composed of three so called closely interelated layers: psychological, emotional state, decision making.

The psychological layer is defined by a library of general behavior and strategies automata. These automata define meta-schema according to the current psychological knowledge. They are driving the agent general behavior and strategy.

The emotional state layer is composed of a set of valanced emotional state variables determining the issues of transitions of behavior and strategies automata in the previous layer.

The decision making layer is represented by a library of knowledge automata defining the correct decision process to solve a specific problem. The stored knowledge represents the appropriate solving method and the relevant data sources concerning a class of problems. Even if the relevant knowledge is available, this layer don’t take into account the agent emotional or psychological ability to actually solve the problem at the moment. The following table summarizes the necessary steps to buy the object. Figure 5. represents the transition according two different psychological structure: optimistic or obsessionnal.

Tasks to choose and buy an object	
1	Set a list of wished object properties : preferences
2	Select a set of objects showing some relevant properties in a group of available objects
3	Get the specific features of selected objects
4	Compare the features of the selected objects with the required properties
5	Rank the selected object according to the preferences
6	Verify the properties of the best ranked objects
7	Decide to buy or reject an object
8	Pay for the object

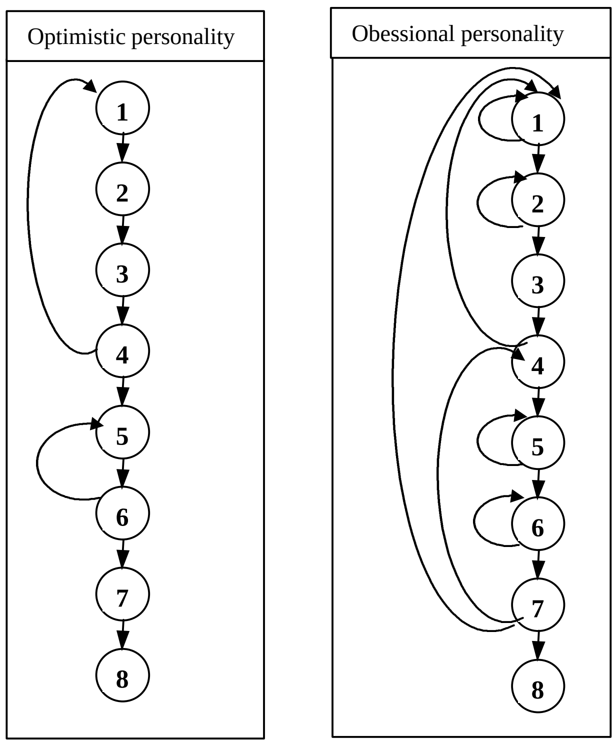

Fig. 5 Automata of two psychological structures during the same buying process

VI THE DECISION MAKING LAYER

This layer is mainly described in a previous article [10]. We briefly summarize the architecture of a Multi-Agent Decision System which provide the necessary knowledge sources to take appropriate decisions but don't take into account the emotion and the psychological structure of the decision-maker.

A MADSS is using four agent categories that are specialized from a generic type (GCAT) described in [10]. A first specialization provides *Knowledge Model Agent Types* (KMAT), which are specific according to the knowledge model (rules, evaluation functions, Case-Based Reasoning…) but independent to the application purpose. The second specialization supplies *Domain Specific Agent Types* (DSAT), which inherit reasoning and knowledge model capabilities from the appropriate KMAT and apply them to the specific domain e.g. in medicine: (infectious disease diagnosis, poisoning prognosis, epilepsy therapy, patient and treatment follow-up, previous clinical case retrieval…)… Then, Task Specialized Agents (TSA) are instantiated from DSAT and commit to tasks elected by the supervisor agent that coordinates the whole decision process. The TSAs access the domain relevant bases containing knowledge and data (represented with the appropriate model) when necessary.

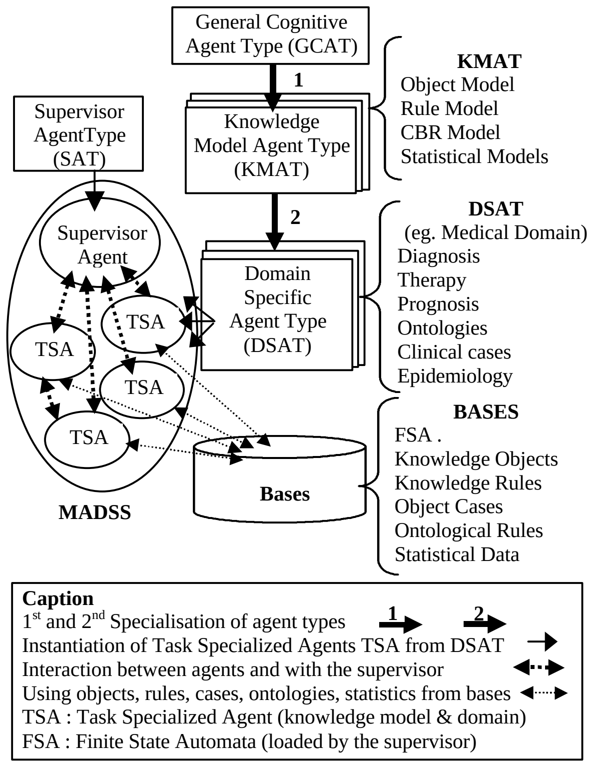

Fig. 6 : Specialisation of agents involved in a Multi-Agent Decision Support System (MADSS)

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The ontological agent type is a DSAT, which formalizes the terminology, and the entity definitions used during the information transaction between agents [16] [17].

The supervisor agent type provides a unique instance named *the supervisor agent* that make an intensive use of finite state automata which define the necessary tasks to build the appropriate decision. The decision-making layer is consistent with the other layers of the model defining the emotion and the psychological structure of the decision-maker.

Thus, the model both represents the necessary decision steps, the psychological and emotional ability of the decision-maker to actually take the appropriate decision. Such a model is much more suited to realistically simulate the agent attitude and behavior in stressful situations or when the agent's personality hinders to take a decision.

VII. CONCLUSION

We have proposed an approach of multi-agent decision support systems able to deal with the emotion and the pychological structure of the agents.

The main contribution of this work is to provide a general multilayer framework of interacting agent emotion and psychological structure. This model relies on the OCC model, and fuzzy logic membership functions defining a mental state. According to the value of the mental state, the agent’s behavior is driven by the transitions of a probabilistic automaton. Therefore, the transitions define if the emotion state is compatible or not with the execution of an action and they express the probability for the agent to actually carry out this action. Thus, the automaton represents the agent’s psychological structure of his behavior according to the emotion state which itself modified by the occurrence of pleasant or unpleasant events.

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