

# Use of a Dynamic Personality Filter in Discrete Event Simulation of Human Behavior Under Stress and Fatigue

Mamadou Seck, Claudia Frydman, Norbert Giambiasi<sup>1</sup>

Tuncer I. Ören<sup>2</sup>

Levent Yilmaz<sup>3</sup>

Université Paul Cézanne – Aix Marseille  
Marseille, France

[claudia.frydman,norbert.giambiasi}@univ-u-3mrs.fr](mailto:{claudia.frydman,norbert.giambiasi}@univ-u-3mrs.fr)

University of Ottawa  
Ottawa, ON, Canada

[oren@site.uottawa.ca](mailto:oren@site.uottawa.ca)

Auburn University  
Auburn, Alabama, USA

[yilmale@eng.auburn.edu](mailto:yilmale@eng.auburn.edu)

1. M&SNet: LSIS (Laboratoire des Sciences de l'Information et des Systèmes)
2. M&SNet: Ottawa Center of the MISS; School of Information Technology and Engineering (SITE)
3. M&SNet: AMSL (The Auburn Modeling and Simulation Laboratory)

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## ABSTRACT

Cognitive complexity is an important factor in decision making in problem solving. As a personality trait, openness is related with cognitive complexity. Hence, dynamic updates of openness corresponding to the changes in its facets can be used to update the values of cognitive complexity which in turn can affect the decision making abilities and performances of humans represented in simulation studies. The possibility to develop dynamic personality filters to affect human performances in human behavior simulation studies are pointed out.

## 1. Introduction

As a team, our interest in the study of human cognitive abilities is to understand and test the mechanisms of several aspects of cognition to be able to incorporate them in simulation studies. We foresee two types of use: (1) enhance simulation studies and contribute to the advancement of the methodology and technology of cognitive simulation and (2) use cognitive simulation to test hypotheses about human cognition. We also aim that the results should be applicable in human cognition in general and in the study and/or simulation of cognitive abilities relevant to human-computer interaction.

It is well accepted that stress and fatigue are important factors in cognitive abilities. While fatigue deteriorates performance, a minimum level of stress is needed for good performance. Too little and too much stress affects performance negatively. In an article [Seck, Frydman, and Giambiasi, 2004], we reported a discrete event simulation of human behavior under stress and fatigue. Personality representation –based on five traits– for human behavior simulation was reported by Ören and Ghasem-Aghaee [2003]. The dynamics of personality traits each based on six personality facets as well as use of fuzzy logic to represent this personality dynamics is reported by Ghasem-Aghaee and Ören [2003]. In yet another article [Ghasem-Aghaee and Ören, 2004], we elaborated on the effects of cognitive complexity in agent simulation. In that article, the following were reported:

- how cognitive complexity affects problem solving abilities of people,
- how cognitive complexity and one of the personality traits, i.e., “openness” are related,
- how one can recalculate (using fuzzy logic) “openness” as a personality factor, based on its six facets, i.e., fantasy, aesthetics, feelings, actions, ideas, and values, and
- how this personality dynamics can affect the cognitive complexity which affects the problem solving capability of humans.

In this article, we aim to combine the findings of the above cited articles to specify discrete event simulation of human behavior under stress and fatigue taking into account the human personality characteristics. Similar to digital filters in digital photography, personality characteristics can be conceived as a filter –a dynamic personality filter– in human behavior simulation. The dynamic aspect of the personality filter stems from the fact that the fuzzy values of a trait (openness in this application) can be recalculated based on the changes in the values of its six facets. The updated fuzzy value of the

corresponding trait (openness in this application) affects the cognitive complexity of the individual which in turn affects his/her ability to cope with complexity. And this ability may be related with human-computer interaction or any other task.

By modifying the values of personality facets and corresponding personality traits, one can use a same mechanism to represent different personalities. This has the following main applications:

- (1) Use the same mechanism to represent personalities and tailor the representation to a specific personality. In this way if the personality is represented as a class, different objects can be instantiated to represent different personalities.
- (2) For a given personality, the long-term modifications of some of the personality traits can easily be represented as different values of the personality filter. This possibility can be useful to represent and simulate the effects of training on the long-term modifications of personality.
- (3) Similarly, for a given personality, the short-term modifications of personality traits can easily be represented as different values of the personality filter. This possibility can represent for example, modifications of openness due to fatigue and/or stress.

Representation of the performance of a person under fatigue and/or stress can systematically be represented by dynamic personality filters. Since this type of conception is rather new, the paradigm offered may represent a good possibility to study and test different hypotheses on the effect of fatigue and stress on performance of different types of people.

In discrete event simulation of human behavior, the study will take into account:

- (1) The stress and fatigue factors,
- (2) The cognitive complexity of an individual, and
- (3) The dynamics of the cognitive complexity by taking into account the updates in the six facets affecting openness trait of personality.

The results will be usable in cognitive discrete simulation in general, in testing hypotheses about human cognitive abilities in general and in human-computer interfaces in particular.

Section 2 of this paper will present theoretical aspects of stress from the physiology and psychology fields. In section 3 and 4, we elaborate on personality knowledge and cognitive complexity. Section 5 introduces the DEVS formalism. Then section 6 presents in more detail our DEVS based cognitive model.

## 2. Fatigue and Stress

Fatigue and stress are inevitable and they affect performance of humans. While fatigue deteriorates performance, the role of stress is different. For a human to be able to perform well, a stress above a threshold value should exist; similar to have a certain amount of tension on the strings of a violin. Too much tension would result by an inappropriate sound and later to the break of the string; similarly, too much stress may deteriorate the performance and can even be fatal.

### 2.1 Types of stressors

A synopsis of major types of stressors is given in Table 1 where physical and mental stressors are represented each in two groups:

- (1) Physical stressors consist of *environmental stressors* such as heat, cold; vibrations, noise, blast; hypoxia or lack of oxygen and *physiological stressors* such as lack of sleep, dehydration, and muscular fatigue.
- (2) Mental stressors consist of *cognitive stressors* such as too much or too little information, isolation, and hard judgment and *emotional stressors* such as threats, frustration, and boredom/inactivity/

**Table 1:** types of stressors.

Physical stressors	Mental stressors
<b>ENVIRONMENTAL</b> Heat, cold Vibrations, noise, blast Hypoxia (lack of oxygen)	<b>COGNITIVE</b> Information: too much or too little Isolation Hard judgment ...

PHYSIOLOGICAL	EMOTIONAL
Lack of sleep	Threats
Dehydration	Frustration
Muscular fatigue ...	Boredom/inactivity ...

## 2.2 Stress-performance relationship

As shown in Figure 1, Stress-performance relationship is represented by an inverted-U model.

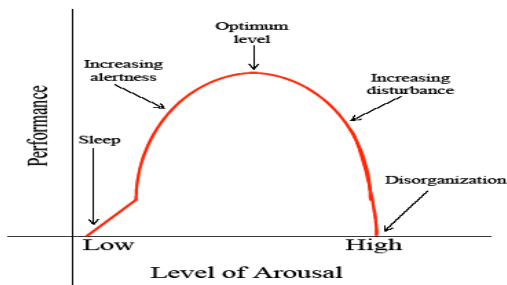


Fig. 1. The inverted-U hypothesis

it states that at low stress, performance is low; it improves until its highest point corresponding to the optimal level of stress or arousal. Then, performance level decreases when stress intensifies, leading to complete disorganization when stress level reaches panic.

## 3. Personality knowledge

From a simulationist point of view, representation of personality knowledge as well as representation of personality dynamics are summarized by Ören and Ghassem-Aghaee [2003] and by Ghassem-Aghaee and Ören [2003]. “A concise taxonomy of taxonomies of personalities is given at the site of personality project (Personality Project). In contemporary psychology, personality is specified as a function of thirty attributes –each of which called personality facet. The personality facets are clustered in five groups –each called a personality trait [or personality factor]. The five personality factors are also referred to as “the big five” [Costa and McCrae, 1992; Howard, 2000]. The value of each personality factor is determined by the values of its six facets. The five clusters of personality factors are also referred to by letter designation [Acton, 2001; Howard and Howard, 2001a, b]. Acton refers to them as the OCEAN model.

In the OCEAN model, the letters stands for the following meanings: O: Openness, culture, originality, or intellect; C: Conscientiousness, consolidation, or will to achieve; E: Extraversion; A: Agreeableness or accommodation; and N: Need for stability, negative emotionality, or neuroticism” [Ören and Ghassem-Aghaee, 2003].

There is a parallel between representation of a large number of colors and the representation of different personalities. A vector of three elements can represent the values of Red, Green, and Blue, Depending on the resolution to represent each component color, one can have for example 256 values for each color. Similarly, there are five personality traits; hence, a vector of five elements can represent a personality. As explained by Ören and Ghassem-Aghaee [2003], if only two fuzzy values can be distinguished for each element,  $2^5 = 64$  types of personalities can be distinguished. This number can become 243 ( $= 2^3$ ) if each trait can be discriminated even having as values low, average, or high.

## 4. Cognitive complexity

As stated by Streufert and Swezey [1986], persons who are high in cognitive complexity are able to analyze (i.e., differentiate) a situation into many constituent elements, and then explore connections and potential relationships among the elements. Characteristics of high and low-cognitive complexity people are summarized from Streufert and Swezey [1986], in Table 2.

Table 2. Characteristics of high and low cognitive complexity individuals

Characteristics	High cognitive complexity people	Low cognitive complexity people
Information	More open to new information	opposite
Attraction	Attracted to high cognitive complexity people as well as to low cognitive complexity people	Attracted to low cognitive complexity people with similar attitude
Flexibility	More flexible in thinking More fluency of ideas in creativity	opposite
Social influence	Change attitude more easily	More stable in attitudes
Problem solving	Tend to search for more information	opposite
Strategic planning	Greater flexibility in considering alternatives	opposite
Communication	More effective at a communication dependent task	opposite
Creativity	Able to generate more novel ideas	opposite
Leadership	Show leadership	

Figure 2 represents the relationship of level of processed information and situational complexity [Athey 1976]. Based on Athey's work [Athey 1976], Ören [1978] elaborated on the importance of increasing cognitive complexity of an individual to increase his/her effectiveness in coping with complex situations. "However, for each individual there is a critical point beyond which the level of processed information, hence the individual's information processing effectiveness is decreased. After the critical point, an increase in the situational complexity may worsen the individual's ability to cope with complexity, by causing a decrease in his/her level of information processing" [Ghassem-Aghaee and Ören, 2004].

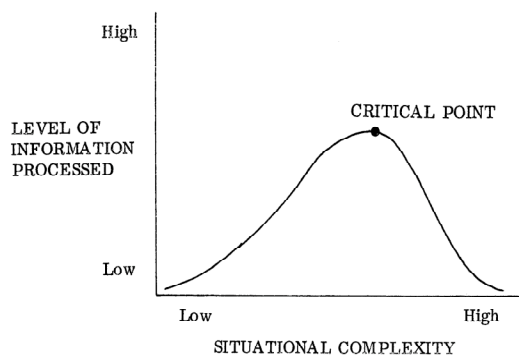


Figure 2: Different levels of information processing of an individual depending on the situational complexity

Figure 3 shows a comparison of information processing curves of two types of individuals, i.e., high and low cognitive complexity individuals "where two important points are shown: First,  $c_h$ , the critical point of high cognitive complexity individual is higher than  $c_l$ , critical point of low cognitive complexity individual. Thus increasing the cognitive complexity of an individual –within the applicable limits of course– may increase the range of situational complexity within which he/she can perform effectively. Or depending on the task, it may be advisable to assign an individual with cognitive complexity commensurate with the task. Second, for a given situational complexity, the level of information processed by a high cognitive

complexity individual  $i_h$  is greater than  $i_l$  which corresponds to a low cognitive complexity individual” [Ghassem-Aghaee and Ören, 2004]. Taken into consideration the fact that fatigue and stress can affect openness of an individual brings other possibilities for the study of human performance. A given individual may have his/her performance affected by fatigue and stress. The modification of the openness can be represented as an update of the personality filter and can be used in a simulation study.

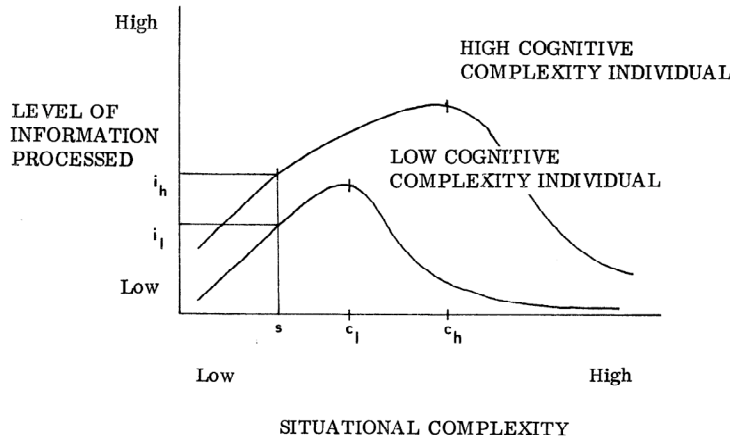


Figure 3: Comparisons of information processing curves of two types of individuals, i.e., high and low cognitive complexity individuals

#### 4.1 Cognitive complexity and openness

“In Chapter 12 of the handbook of emotional intelligence, it is indicated that “openness has also been associated with other cognitive or quasi-cognitive variables, including moral reasoning, cognitive complexity and wisdom” [McCrae, 2000]. The relationship of cognitive complexity and openness as a personality trait inspires applicability of personality update concept of dynamic personality to cognitive complexity. The personality facets which affect openness are: fantasy, aesthetics, feelings, ideas, and values. The dominant facet, i.e., the one having the largest weighted value determines openness. Any value change in any of the personality facets affecting openness may induce a personality update and change in the value of openness to affect the cognitive complexity of the individual” [Ghassem-Aghaee and Ören, 2004].

### 5. DEVS (discrete event simulation) formalism

DEVS (Zeigler, B., 1984) is a modular formalism for deterministic and causal systems’ modelling. It allows for behavioural description of systems. A DEVS model may contain two kinds of DEVS components: Atomic DEVS and Coupled DEVS.

#### 5.1 Formal specification of an atomic DEVS model

AtomicDEVS =  $\langle S, ta, \square_{int}, X, \square_{ext}, Y, \square \rangle$

- The time base is continuous and not explicitly mentioned :  $T = \mathbb{R}$
  - $S$  represents the set of sequential states: The dynamics consist in an ordered sequence of states in  $S$ .
  - $ta(s)$  is the lifetime function of a state in the model.
  - $\square_{int}$  is internal transition function, allowing the system to go from one state to another autonomously.
  - $Y$  is the set of outputs of the model.
  - $X$  is the set of (external) inputs of the model. They interrupt its autonomous behaviour by the activation of the external transition function  $\square_{ext}$ .
- The system’s reaction to an external event depends on its current state, the input and the elapsed time.

#### 5.2 Formal specification of a coupled DEVS model

The coupled DEVS formalism describes a discrete events system in terms of a network of coupled components.

CoupledDEVS =  $\langle X_{self}, Y_{self}, D, \{M_i\}, \{I_i\}, \{Z_{i,j}\}, select \rangle$

*Self* stands for the model itself.

-  $X_{self}$  is the set of possible inputs of the coupled model.

-  $Y_{self}$  is the set of possible outputs of the coupled model.

- D is a set of names associated to the model's components, self is not in D.

-  $\{M_i\}$  is the set of the coupled model's components, with i being in D. These components are either atomic DEVS or coupled DEVS.

-  $\{I_i\}$  is the set of l'ensemble des influencees of a component. That is what defines the coupling structure.

-  $\{Z_{i,j}\}$  defines the model's behaviour, transforming a component's output into another component's input within the coupled model.

As concurrent components can be coupled, many state transitions can have to occur at the same simulation time. A selection mechanism then becomes necessary, in order to choose which transition is to be executed first. So is the role of the "select" function.

## 6. DEVS models

This part of the research is being conducted principally in the context of the PIOVRA project (Bruzzone A.G., 2002), aiming at the creation of a new generation of CGFs.

Essentially based on the DEVS formalism (Zeigler, B., 1984), the cognitive model that we are designing consists of various layers, each of which has a specific role, from the detection, appraisal of events and situations, to actions taken by the synthetic agent to attain goals.

External events are sensed by the agents depending on their current attentional focus (yet to be modeled) and are appraised in the appraisal component of the framework. That appraisal is achieved by taking account of the nature of the event, its intensity, the type of mission that is being done and the possible interference of such an event or situation with the outcome of the current task (does it threaten the achievement of a goal?). After that analysis, a mapping with stressor intensities is done. Of course, one can easily accept that different persons, depending on their dominant personality trait, principally Neuroticism, will react differently, and experience varying stressor intensities in such a context. The evaluation of the new stress level is done in the stress component based on the inverted U-hypothesis. Then those stress values are transmitted to the behavioral model and may cause a difference in the agent's behavior. That behavior is in humans materialized by information processing, decision making and a given action on the environment. One may suspect that different persons, depending on their personality may react differently.

### 6.1 DEVS Appraisal model

Our construct is being designed in such a way to be able to model individuals and groups at the same time, therefore it must be able to represent interactions between individuals like communication or emotional relations (Seck, Frydman, & Giambiasi, 2005).

The appraisal component is where events from the environment are appraised as stressors. The most influential models of psychological stress argue that the stimuli from the environment are appraised as threatening (challenge, harm or loss) or benign and depending on the degree of threat will result or not in a given stress reaction (Lazarus S., 1999). But the appraisal is not only based on the event, it depends also on the goal and maybe subgoals of the current mission. During a mission consisting in reaching a distant point in enemy zone, such a typology of events could be made, in terms of intensity:

- Suspect noises, blasts, ...
- Shots, losses in our camps, ...
- Loss of a team member, wounds, ...

And those threat intensities result in various stressor intensities. An expert is certainly able to establish a more precise hierarchy of events in a given context, considering goals and subgoals such as success of the mission, necessity of staying alive.

To add more realism to the appraisal phase, adding fuzzy variables representing personality may be an interesting idea. In the five factor personality model, the "Negative Emotionality" trait can be used to

represent the susceptibility to stress for an individual. Then we could have for example three types of soldiers with the following personality types when it comes to appraising events:

- Resilient (Rational, impervious)
- Responsive (Unable to maintain calmness for a long period of time)
- Reactive (Susceptibility to negative emotions)

On the following figure, we consider a given set of events to be appraised by an individual in a given context. The individual may be either Resilient (R-), Responsive (R), or Reactive (R+). Negative events X, Y, or Z may occur with varying intensities (1, 2, 3.) or positive events A, B, or C.

The initial state is APPR. When a Responsive (R) individual receives an event, he/she appraises it normally and generates the appropriate stressor output (when such an individual receives a x1 event, it goes to state Te1 and a Te!1 value is sent to the stress model.

When a Resilient (R-) individual receives an event, he/she appraises it as lower threat than it is, (when such an individual receives a X2, Y2, or Z2 event, it goes to state Te1 and a Te!1 value is sent to the stress model.

When a Reactive (R+) individual receives an event, he/she appraises it as higher threat than it is, (when such an individual receives a X2, Y2, or Z2 event, it goes to state Te3 and a Te!3 value is sent to the stress model.

When an individual of any type receives a A, B, or C event, it goes to state Te4, and a Te!4 value is sent to the stress model, which will be interpreted as an element that reduces stress.

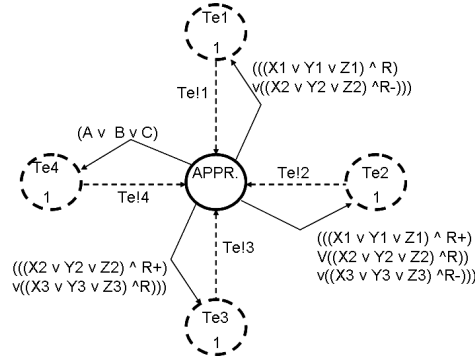


Figure 4: DEVS appraisal model

## 6.2 DEVS stress model with a personality filter

The understanding of the processes underlying stress has evolved recently, yet leaving numerous uncertainties. We consider a stressor as any event or situation (physical or mental) requiring a change in adaptation or behaviour of an individual (FM-22-51, 1994). It represents a threat to their welfare or survival. It can have positive or negative effects. A stressor implies physiological reflexes that prepare to tackle a situation or to flee it.

An optimal level of stress is useful for task performance. When stress is too low, it implies distraction and tasks are done haphazardly. An intense level of stress may cause poor motor coordination or even choking.

Many models try to link stress to performance. One of the most cited is the Yerkes-Dodson law, also referred to as the inverted-U hypothesis. It states that at low stress, performance is low; it improves until its highest point corresponding to the optimal level of stress or arousal. Then, performance level decreases when stress intensifies, leading to complete disorganization when stress level reaches panic (Lyle E. Bourne, Jr. & Rita A. Yaroush, 2003). Hancock's extended-U model, while focussing on attention, relates stress level to physiological and psychological adaptability (Hancock, P.A., & Warm, J.S. 1989). He defines various zones of the curve corresponding to physical and mental states depending on stress level.

We had the idea of considering discrete states of stress, associating each one with a typical behaviour, and from the physiology and psychology literature, try to model how one goes from one stress state to another.

Based on that, we have proposed a model of stress in the DEVS formalism. It consists in a representation of discrete states of stress. Depending on their nature, external events make the stress level evolve from one state to another. Those events are sorted according to their seriousness or intensity by the appraisal function

presented in the previous section. Five discrete stress levels are considered, each representing a given zone of the inverted U.

Here also, personality may play a prominent role in defining the duration in which the individual stays in a non optimal state of stress, the Resilient and the Responsive tend to return to the optimum stress level through coping, while the Reactive, who is more subject to negative emotions, has a harder time coping with such situations. The lifetime function of the DEVS states ( $x$ 's on figure 6) can thus be calculated as a function of the personality fuzzy variable.

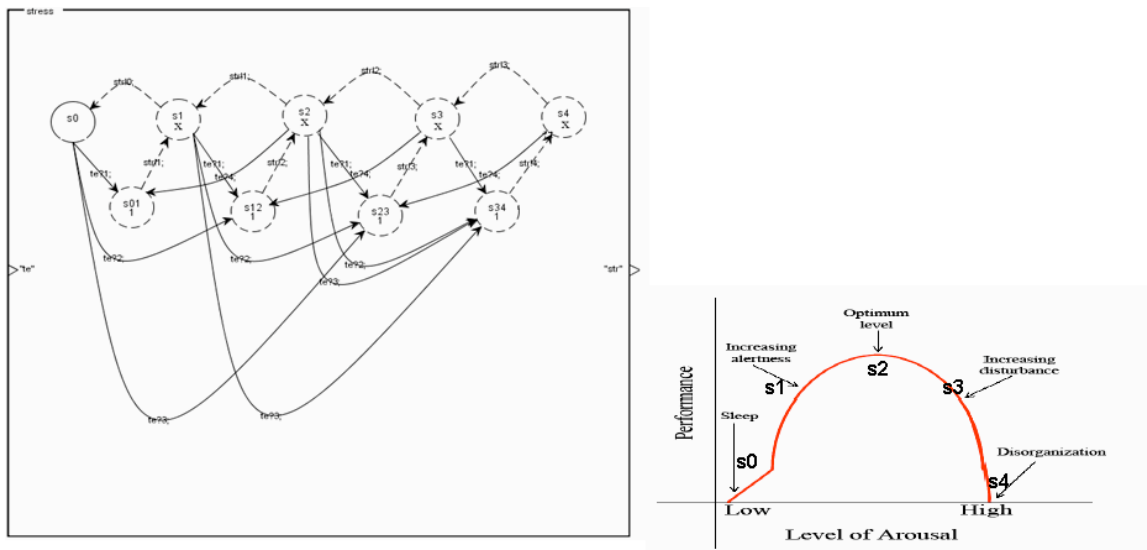
### 6.3 Modeling fatigue in DEVS

Following [5], transitions of a DEVS model can be conditioned by thresholds of a continuous function. We can model tiredness by a polynomial function of task durations multiplied the task's constant of difficulty. The rate of efficiency of a task in the behavioural model can be conditioned by the computed value of tiredness. The possibility for an agent to start or complete a physically demanding task can also be conditioned by such a function. The values of thresholds and of the constants of difficulty will be defined by experts and refined during validation phases.

### 6.4 DEVS behavioral model with a personality filter

A behavioural atomic model represents a set of tasks and transitions between tasks that belong to the same sub-mission with a set of distinct sub-goals that permit to appraise events in that given context. When the mission is fulfilled or when another mission is given with a higher priority, the behavioural model and the appraisal models are replaced with the relevant ones. That can be considered as an application of the sequential multi-model concept [Yilmaz, L. and Ören, T.I., 2004].

The current task of the agent is represented by a state. Events that induce a change in behaviour activate transitions that can be conditioned by values of state variables representing stress, tiredness or environmental information...



As for the properties of the DEVS formalism, we can represent a reactive behaviour i.e. the agent reacts to external events with constraints expressed by state variables. The decision process is done by actions inside states, decision rules are represented by the transition alternatives. Phases' durations are either set to a static value or defined by a function (of the nature of the task, ability of the performer, stress and fatigue levels...)

Transitions may be internal, subject to the task's duration, or external, when a relevant event occurs.

Stress and fatigue interfere with behaviour through the coupling property of the DEVS formalism, i.e. any time the stress level changes, or any time the fatigue level exceeds a threshold, a message is transmitted to the behavioural model, and if necessary, the behaviour is updated.

The stress states we defined earlier have the following behavioural feature:

- S0: Sleep, inactivity
- S1: Slow reactions, average precision
- S2: Optimal level
- S3: Risk taking, bad choices
- S4: Bad precision, choking, panic.

The coupling property is also very interesting as it allows us to model communication between individuals like orders, or even the possible stress effect of the injury or death of a team member (considered as external events and appraised by the individual). It also may help us fulfil our necessity of aggregation and disaggregation capability.

Stress and fatigue can interfere dynamically on behaviour in performance and decision making (both variables can change within the course of a task). [Seck, M., Frydman, C., and Giambiasi, N. 2005]

We are now considering the effect of personality as performance moderator (does not change within the course of a task). Openness in the five factor personality model is related to cognitive complexity [Ghasem-Aghae & Ören, 2004]. Based on Athey's work [Athey 1976], Ören elaborated on the importance of increasing cognitive complexity of an individual to increase his/her effectiveness in coping with complex situations [Ören, 1978]. Based on that, we can distinguish on certain tasks, the performance difference between high cognitive complexity people and low cognitive complexity people. A first distinction might be done concerning the time necessary to finish successfully a cognitive task; a second one can be made concerning decision making as high cognitive complexity people are known to be more fluent in idea and more creative thus generally find best solution. To do so, each task of the DEVS atomic behavioural model will contain a variable representing the task's cognitive complexity. Different individuals with different personalities, the openness trait in particular, will have different performances in terms of both time and decision making.

Figure 6 is an example from a DEVS atomic behavioral model. As we stated earlier, states represent tasks, external events or the time advance function determine transitions. An individual whose cognitive complexity is low (ICC == low), by means of an event, is confronted with a mob of armed individuals of average aggressivity. That event triggers a transition to a decision task; the duration of that task is computed by comparing the task's cognitive complexity (TCC) and the individual's cognitive complexity (ICC). Then, she/he chooses to shoot or to negotiate. The decision here depends on the stress level of the individual.

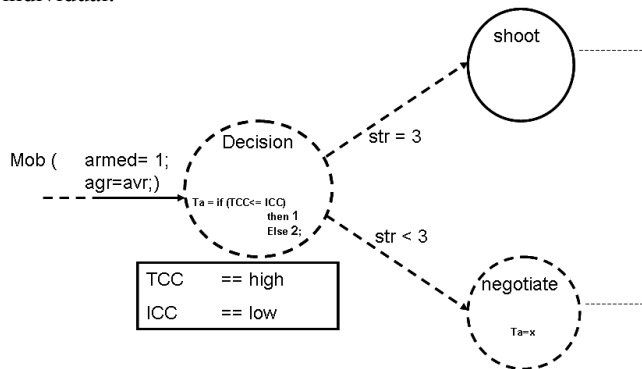


Figure 6: part of a DEVS behavioral model

## Conclusion

With all of the above, we see that a dynamic personality filter may be of great help towards the realism of human behaviour simulation, particularly in CGFs. The concept of that filter is a number personality variables representing, at coarse or fine grain, elements of human personality as defined in the five factor model. That filter will be instantiated every time a new agent is to be created. As we noted throughout this presentation, that filter will have effects all over the cognitive process, on the appraisal of events, on the coping with stress and also on the actions of agents. It allows us to obtain more believable models of human behaviour.

Realistic models of human behavior require representation of the effects of fatigue and stress. This part has already been possible for simulationists. See for example, [Seck, Frydman, and Giambiasi, 2004]. Recent advances of the representation of personality traits and relationship of the personality trait openness to fatigue and stress inspires us to represent personality as a dynamically updateable filter that can be used in the simulation studies of human performance. In this article we report the possibilities. We are planning to report simulation results in a sequel article.

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