Learning to Cope with Critical Situations - A Simulation Model of Cognitive Processes using Multiagent Systems

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Abstract

How does someone react when he faces a critical situation in his life? We present in this paper a model for the simulation of people's behaviours in those particular situations. For this purpose, we use some coping strategies developed by researchers in the area of psychology. In our model we mainly consider the interactions between a person concerned and factors like his environment and his own abilities. We plan to implement our model by means of an holonian multi agent system approach, realized by distibuted knowledge based systems with a specific focus on cased-based reasoning technology.

1 Introduction

In our everyday life, we consistently face situations which pose more or less immense challenges. Examples can be the breakup with a partner, the loss of a job, an illness or even the death of a relative. As different as thoses challenges can be, the reactions of the persons who are facing the same kind of challenges can be very different as well. The problem consists in finding out, how someone reacts when he/she faces up a given challenge. The problem being a psychological one, there have been many reasearch groups in psychology working in that direction, beginning in the early 1980s. They developed psychological models and paradigms in order to represent and analyse people's behaviours.

In this paper, we present an agent-based approach for the representation and simulation of human behaviours in critical situations. In the next section, we will first present what has been done in the domain. It covers purely theoretical models from psychologists as well as some developed multiagent systems. We will then present our approach in Section 3 and explain how we intend to implement it. Finally in Section 4 we give a short outlook on relevant future work.

2 Related Work

As mentioned in the last chapter, many researchers in the domain of psychology have tried to find ways in order to understand human behaviour, particularly how a human being reacts when he faces any serious difficulties. They developed theories, software-based models, and simulation approaches for that purpose. As the human way to act is very complex and most of the time ambiguous, developing such software-based systems is not an easy task. It is very important to know first of all which (primary) factors influence human behaviour as well as which processes run during the respective moments and manipulate information. According to the psychologist Lewin, human behaviour can be defined as a function having the person and his environment as arguments (i.e., $B = f(P, U)$, see [Lewin, 1982]). The influence of the environment is thus a very important factor, according to Lewin.

The basis of a person's behaviour is determined by his so-called cognitive processes. Cognitive processes include skills like learning, perception, thinking, reasoning or resolving problems. There have been many approaches in the past in order to model and simulate those skills from a psychological point of view.

2.1 Cognitive Architectures

We will start by presenting some architectures which were developed in the area of social sciences. For a complete and universal definition of a congnitive theory, Newell proposed in [Newell, 1990] that the following mechanisms, which represent the abilities of a system, should be defined:

- Resolution of problems, decision finding
- Multi-purposing, learning, skills
- Perception, motor behaviour
- Language
- Motivation, emotion
- Dreaming, fantasize
- Etc.

However this list is not without controversy, since it is not easy to represent mechanisms like 'dreaming' even in psychology or social sciences. Furthermore, many other researchers are in doubt about the fact that 'dreaming' could really play a role when figuring out the behavioural processes.

In the following, we will particularly consider two types of cognitive architectures. The first type of architecture is called production systems. These systems consist of so-called productions. We can think of those productions as rules, which are used in order to transfer the actual state (of the person) into a goal state (i.e., achieve the solution of a problem). Some examples of such production systems are SOAR (State, Operator and Result) which is based on the "Physical Symbol Systems hypothesis" [Newell and Simon, 1961], ACT-R (Adaptive Control of Thought - Rational) based on the theory of Anderson [Anderson *et al.*, 2004] and EPIC [Kieras, 2004].

The second type of cognitive architecture, we would like to mention here, is the PSI theory [Dörner *et al.*, 2001]. The main difference between this architecture and the one above is the addition of emotional and social components.

It is actually conceivable that some of the behaviour in the architectures described above, up to a certain level of complexity, can be modelled (and thus implemented). Yet the models will not be quite realistic, not only because the human way of acting does not always follow a given guideline or a framework (due to the emotions and the social environment) but also because different situations most of the time imply different stress levels. Furthermore, it is not exactly defined in those architectures how a person will try to solve a problem in burdening situations. What we need here is a better definition of *coping* (resp. coping processes). In the next section we present some models and theories for that aim.

2.2 Coping Processes

We will list here some coping methods. These methods are very important for us, since that is what we need in order to predict the reaction (behaviour) of a person facing a critical situation. There already exist many coping theories. Yet most of them can only be applied for a specific area (e.g. coping strategies for people with a cancer disease, [Taubert, 2003]). Kast provides in her book [Kast, 1989] many definitions and strategies for crises, but they are not really formalized. As a consequence they are not appropriate for use in simulations. That is why we based on the theories and models below for our work.

The first theory was introduced by Richard Lazarus [Lazarus, 1984] and is called *transactional stress theory*. It is based on the assumption that the thoughts and behaviours of each person depend on the characteristics of the actual situation as well as those of the person himself. Examples of the characteristics of a person are his skills, beliefs and moral concepts, whereas some characteristics of a situation are requirements, limitations and resources. A given situation is stressful for a person if the characteristics of that situation overburden or threaten his characteristics. According to Lazarus, stress thus depends on how a person judges the correlation between his characteristics and those of the situation. For that estimation Lazarus differentiates between two types of assessments. The first one (*primary assessment*) is used to identify if a given situation is stressful or not. If a situation is stressful, the second type of assessment (*secondary assessment*) is used to identify which kinds of resources can be used in order to overcome the problem. This leads to the design of a coping strategy which can be divided into basic functions:

- problem-oriented coping and
- emotion-oriented coping.

The second modell is from Sigrun-Heide Filipp (see [Filipp, 1995]) and is based on Lazarus' theory. In Filipp's model, the person is not a passive factor which is influenced by the situation, but instead the active part of the person (e.g., concerning the perception and assessment of a situation) does play an important role. The analysis of a stressful situation is seen as a process flow along a time axis with the following units:

- precursory conditions,
- rival conditions in the person,
- rival conditions in the situation,
- characteristics of the stressful situation,
- analysis process and
- effects of the analysis.

Filipp provides with this list a good source of potential factors of influence.

The most recent theory on coping strategies is from Brandtstädter and Greve [Brandtstädter and Greve, 1994]. It is based on the fact that intentions are a key part of psychological theories of action. Except for knee-jerk or automated behaviours, human actions are motivated by intentions. When somebody faces a critical situation, his actual state strongly differs from his goal state (i.e., his intentions). In order to solve the problem, the person essentially can use one of the following three forms of coping processes:

- *Assimilative processes*: the strategy here is to solve the problem by working directly on the actual state. That is, it is an active art to work through a problem, in which the person uses the available resources in a problem oriented way. The available resources can be the person's own resources or external ones.
- *Accomodative processes*: this strategy is used when the person believes he can not change the actual state (i.e. solve the problem) by himself. He then tries to adapt his goal state such that the discrepancy to the actual state can be diminished.
- *Immunizing processes*: in this case, the person just ignores the discrepancy between the actual state and his goals. He can for example perform actions that disminisches the meaning of the discrepancy.

2.3 Agent-Based Simulation Approaches

Meanwhile there exist many multiagent systems that deal with the simulation of human behaviour. Yet most of them concentrate on the social behaviour between the agents. The most popular are EOS and Sugarscape.
EOS (Evolution of Organized Societies) was the first agent-based simulation system that dealt with the cognitive processes (see [Klügl, 2000]). Sugarscape is another popular rule-based (agent-based) system which focuses on social behaviour [Epstein and Axtell, 1996].
However, we cannot directly reuse both system approaches because they do not deal with coping.

3 SIMOCOSTS

3.1 The Model

We present here our model SIMOCOSTS (SImulation MOdel for COping STrategy Selection) for the simulation of process-based problem solving [Müller, 2006]. The model is based on the psychologycal theories developed by Filipp, Lazarus, Brandstädter and Greve.
One main difference between our simulation approach and other ones consists in the fact fact that all the other view the respective persons as normal agents. However we think that the distinct abilities of the individuals should affect each other. This implies the need of an internal communication between these abilities. Furthermore the quality of the abilities should change (e.g. decrease) in respect with

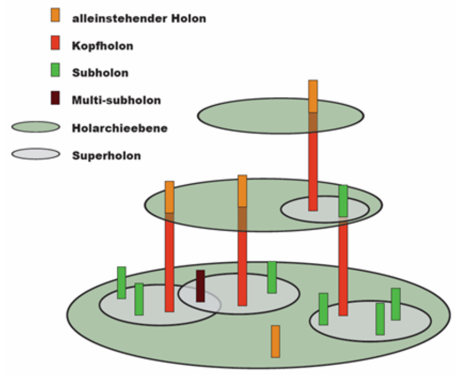

Figure 1: Representation of holons from [Glückselig, 2005].

the time elapsed since its last use in order to be able to represent obivion for example. This leads to the fact that we think the abilities inside an individual should be modelled as agents.
In addition, we also want the individual as a whole to be seen as an agent. That is why we resorted to the 'holonian agent systems'. Holons[1] are agents, which can in turn consists of further agents. With that concept we have some kind of 'recursion', where an agent that is a part of superordinate agent is called a subholon and the superordinate one is called superholon. Some of the advantages of the use of holons are:

- high flexibility,
- good scalability,
- better modelling and
- distinct level(s) of abstraction.

Figure 1 shows a view of holons by [Glückselig, 2005].

For our system, the superholon is the environment and everthing else is an agent or a subholon in it. We then consider conflicts in that environment as specific situations. The environment has some functional units (see Figure 2):

- the context generator,
- the situation generator,
- the communicator and
- the individuals.

The main purpose of the communicator is the communcation between the individuals as well as between individuals and the other components (units). It also has a timer available whose purpose will be explained later.
As our simulation is about human behaviours in critical situations, the modelling of the individual is in our case very important. Each of them has the following subholons, which represent the characteristics of the person:

- Person characteristics,
- Environment characteristics,
- Interface,
- Interpretation and
- Problem solving.

[1]The current (modern) meaning of the term 'holon' was first used by the author Arthur Koestler in some of his many books (e.g., The Ghost in the Machine, 1967)

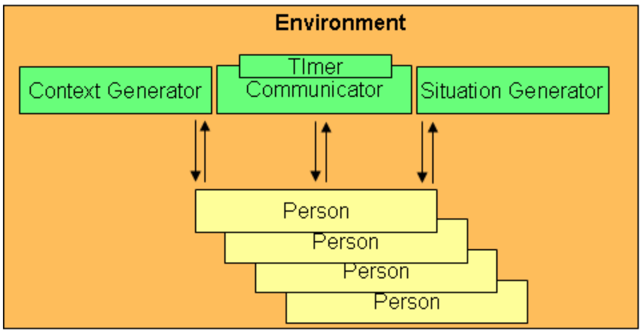

Figure 2: Environment of SIMOCOSTS

Some person characteristics are:

- The physiological situation, which is important while choosing the (coping) strategy,
- General knowledge, whose modelling can be very complex,
- Skills,
- Goals,
- etc.

The environment characteristics consists of subholons representing the way the persons represents his environment:

- The social environment,
- the material environment and
- the societal environment

The interface between the individual and his environment is composed of two components, an input and an output. The input, also called *affector*, receive messages sent from other individuals or the environment (e.g. sensors). The output (called *effector*) then plays the role of the sender of messages.

The holon 'interpretation' is used to know if a given situation is critical for the individual. It is modelled according to Lazarus' stress theory mentioned in Section 2.2 (i.e. the situation is analyzed in two phases: the primary and secondary assessment).

The problem solving part is the most important part of our simulation, since it comes into operation when a critical situation was detected. It is made up of three subholons

- *Mastering* is used when a problem was analysed that can be simply solved with the person's characteristics,
- *Coping* (strategies) are employed when a critical situation cannot be directly solved by the individual. The strategies used here are from [Brandtstädter and Greve, 1994] and were discussed in Section 2.2.
- *Decompensation*: this represents the last possibilities in the case that the problem could not be solved.

In Figure 3, we can see a detailed representation of our SIMOCOSTS model with focus on the indvidual.

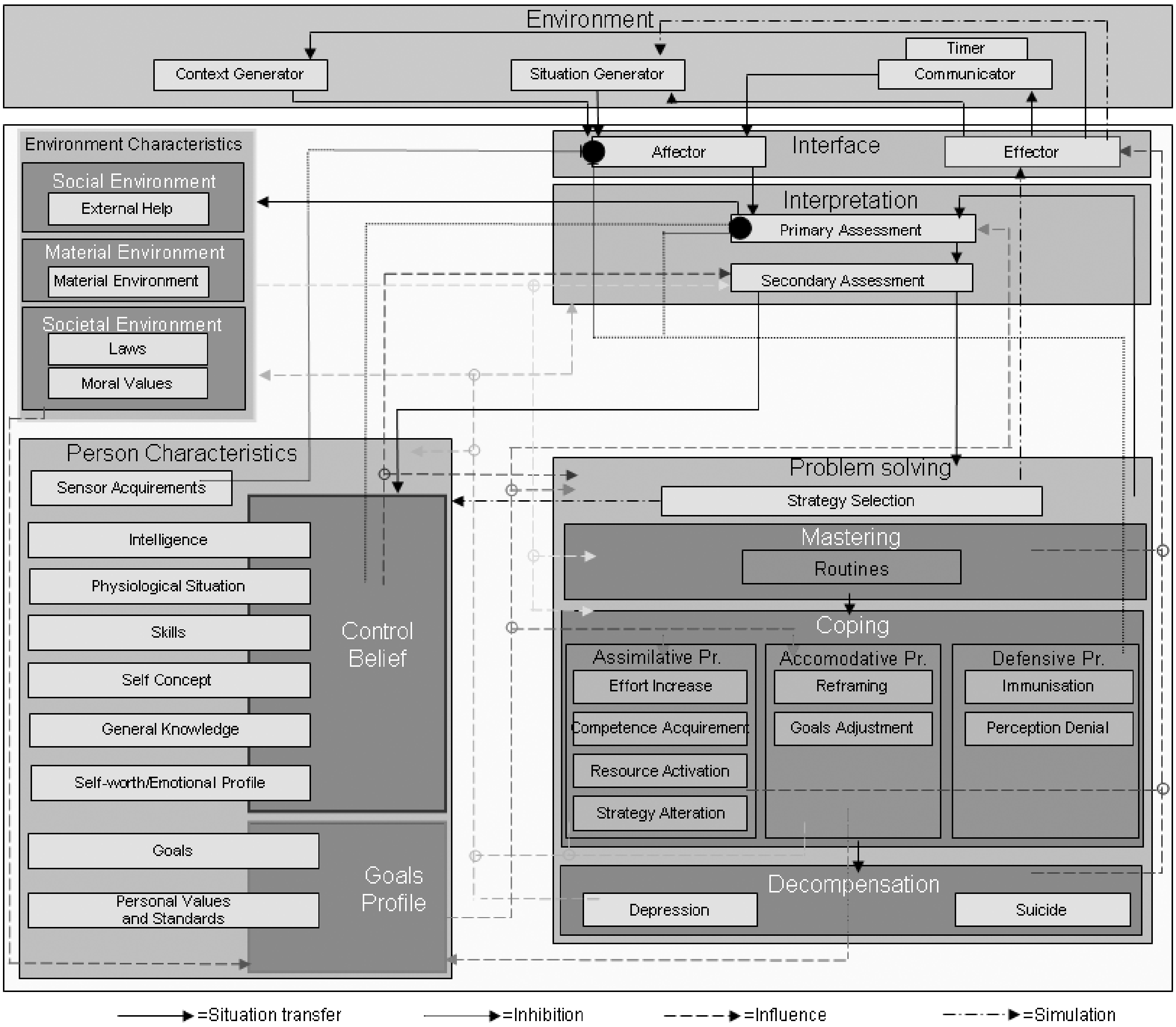

Figure 3: SIMOCOSTS model

3.2 Functionality of the Model

In order to illustrate how our model should work, we present an example here. The critical situation for the person in our example will be the breakup of a partner.

First of all, it is really important to define the situations, goals, and strategies such that they can easily communicate with each other. That means, we should also define the goals such that the properties of a goal can be compared to those of a situation. For the moment, we will define goals as well as situations as a list of weighted facts (with a weight between 1 and 10). Here, we will use natural language to represent these facts. Though we plan to use ontologies later for this purpose. In our example, the original goals of the person are shown in Table 1.

Table 1: Example for the original goals of the person.

Goals		
Goals	**Value**	**Weight**
Start a family	+	7
Self-worth	+	8
Free time	+	3

A situation is rated as burdening, if there exists some kind of discrepancy between its characteristics and those of the given goals. The critial situation that the person faces in our example (generated by the situation generator holon) can be seen in Table 2.

Table 2: Example for the critical situation of the person.

Situation: "Partner wants to break up"		
Affected characteristics/goals	**Value**	**Weight**
Start a family	-	10
Self-worth	-	6
Free time	+	6
To be single	+	10

We see from the table that the value of characteristic "start a family" for example collides with that of a goal. Now, we want to know, with the use of the primary assessment holon, whether the situation is critical or not. In Table 3, we show how the discrepancy is calculated.

The negative value of the discrepancy tells us that the situation is actually critical for the person. The secondary assessment holon should thus try to find out which strategy can be used as a remedy.

The formulation of assimilative strategies is quite complex, because it involves some of the person's characteristics like skills, self concept and general knowledge. With this kind of strategy, the person would for instance do something in

Table 3: Primary Assessment for the example.

Primary Assessment: "Partner wants to break up"	
Affected characteristics/goals	**Discrepancy**
Start a family	-10 * +7 = -70
Self-worth	-6 * +8 = -48
Free time	+6 * +3 = +18
Total discrepancy	**-100**

order to convince the partner not to break up.
With an accommodative strategy, the person would try to adapt to the current situation. Using goals adjustment in our example, the person may say that he/she currently does not want to start a family and that life is much better as a single. We show in Table 4 which goals are adjusted.

Table 4: Adjusted goals.

Strategy: Goals adjustments		
Application area: "Partner wants to break up"		
Intention: A Family has many disadvantages, it is more comfortable to be single		
Goal	**Value**	**Weight**
Start a family	+-	0
To be single	+	3
Free Time	+	5

We then recalculate in Table 5 the new discrepancy.

Table 5: Recalculation of the discrepancy after "goals adjustments" for the example.

Recalculation: "Partner wants to break up"	
Affected characteristics/goals	**Discrepancy**
Start a family	-10 * 0 = 0
Self-worth	-6 * +8 = -48
To be single	+10 * +3 = +30
Free time	+6 * +5 = +30
Total discrepancy	**+12**

The used statregy leads to a better value of the discrepancy. The situation is thus no longer burdening, but even positive.
Defensive Strategies inhibit the perception of the actual situation by affecting the affector and the primary assessment agent.

3.3 Implementation Idea

Having presented the model, we now shortly explain how we intend to implement it. The main idea consists in implementing each agent/holon of our model as an expert system (knowledge based system). Thus, the realization will be based on a distributed knowledge-based system architecture (see also [Althoff *et al.*, 2007]). Currently we intend to use the Information Access Suite of empolis for this purpose. As abilities like strategy selection need besides general knowledge also a lot experience in order to work properly, case-based reasoning will be on core technique used (among other inference techniques).

4 Outlook

One important aspect of the research shortly described in this paper is that it is interdisciplinary. Thus, we have to identify the necessary psychological knowledge to build the system and in addition, we need appropriate knowledge representation and processing techniques. In principle we plan for each agent/holon a full-sized knowledge-based system, because the tasks to handled are very challenging. As a consequence, in a first step we will concentrate on the realization of specific subparts of the model. Since we plan to implement the overall model as distributed system we hope that it becomes easier also to involve further domain experts if appropriate. Another idea we want to follow is to use cases available from life coaching situations to detail our model (e.g., Veeser 2001).

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