Personality, Emotions and Physiology in a BDI agent architecture: the PEP → BDI model

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Abstract

Global security is a growing problematic nowadays. In particular, terrorist threats bring security actors to look for new training tools for major scale crisis.

In this context, simulation by multi-agent system enables the actors to observe the effects of their actions. In this article, we propose an extension of BDI architecture that consider physiology, emotion and personality: PEP → BDI, and show how it is used to model crisis situations.

1. Introduction

Since the terrorist attacks of September 11, crisis risks have become a growing challenge. Further difficulties arise about Nuclear, Radiological, Bacteriological and Chemical (NRBC) risks. In SAGECE (simulation for improvement of crisis management) the goal is to simulate an NRBC crisis in a virtual reality environment. Our involvement in this project is to model and control the behavior of implicated humans (civilian) with virtual autonomous humans / agents [1].

In this article, we introduce an agent architecture based on BDI that consider physiology, emotion and personality. Section 2 shows motivations of our work, section 3 presents the algorithm of our architecture named PEP → BDI. Section 4 describes modules and functions necessary to our representation. Then, we give an illustration of our architecture in section 5.

2. Motivation of our work

In cognitive modeling, BDI architecture [2], [3] is often used for its intuitive representation of agent reasoning. The reasoning is decomposed in modules for a clear structure. For these reasons, we decided to base our model on this architecture. However, in the original model, emotions, personality and physiology are not taken in account in the decision process. From this observation, Jiang and al. developped the eBDI architecture [4] that introduce emotion in a BDI architecture. However, this approach does not consider personality and physiology aspects.

In emotions modeling, several works have been proposed: Gratch [5] proposes the most accomplished current model for agent emotions representation. However, its formalism is complex and fully dedicated to emotions representation.

Silverman proposes a complete architecture [6] that considers agent emotions, physiology and personality. The functional separation of modules is static, in order to experiment unitary tests. This approach is complementary of ours.

DETT [1] agent architecture [7] deals with the link between personality and emotions in a straightforward way. It is based on properties defined in OCC model [8]. However, there are two limits to this approach: DETT is not explanatory, and it models only two emotions in relation with two personality aspects.

Personality is formed by parameters that indicate personality traits. The most known model is the big five (or OCEAN model[2]) [9]. In a crisis situation, only some prominent behavior elements are expressed. As a consequence, we use only personality traits relevant for the simulation.

Physiology represents the physical characteristics of agents. In litterature, modeling of physiology is mainly used in medical domain [10]. However, these mathematical models are often very complex and not adapted to an agent's body representation.

3. Algorithm for architecture PEP → BDI

Algorithm 1 details steps of perception to action cycle. Step 1 is agent initialization. Line 2 is the life cycle loop of an agent. Then the agent takes new information (perception, message and body) from the environment (line 3). This new information generates immediate emotions (4), and the agent changes its beliefs (5) in function of its emotions. Physiological informations are updated in the same way as beliefs (6). Then, the selection of desire and intentions (7-8) is similar to the classical BDI scheme except for emotion and physiology influence. Once intentions are selected, the

1. Disposition, Emotion, Trigger, Tendency
2. Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism

agent updates its emotions again (9-10). If new emotions are different (11), it updates again its beliefs, physiology, desires and intentions (12 to 15). Then, it plans its actions (16) and executes its new plan (17).

Algorithm 1 : PEP → BDI main loop

Inputs:
E_0 initial emotions, B_0 initial beliefs, I_0 initial intentions, Ph_0 initial physiology, Ph its physiological state, Pe_0 initial personality,Personality PeE for emotional tendencies, PeP for percept tendencies and for PeD action tendencies

1-$E \leftarrow E_0$, $B \leftarrow B_0$, $I \leftarrow I_0$, $Ph \leftarrow Ph_0$, $Pe \leftarrow Pe_0$
2-**While** *true* **do**:
3- $B_p \cup B_c \cup B_b \leftarrow Sense(Env, PeP) \cup Msg(Env, PeP) \cup Body(Env, PeP)$
4- $E \leftarrow primary\_emotion\_update(E, I, B_c, Ph, PeE)$
5- $B \leftarrow belief\_revision(B, E, I, B_c)$
6- $Ph \leftarrow physical\_state\_revision(B, E, I, B_c)$
7- $D \leftarrow options(B, I, Ph, PeD)$
8- $I \leftarrow filter(E, B, D, I, Ph)$
9- $E' \leftarrow E$
10- $E \leftarrow secondary\_emotion\_update(E, I, B, Pe)$
11- **If** $E' \neq E$ **then**
12- $B \leftarrow belief\_revision(B, E, I, B_c)$
13- $Ph \leftarrow physical\_state\_revision(B, E, I, B_c)$
14- $D \leftarrow options(B, I, Ph, PeD)$
15- $I \leftarrow filter(E, B, D, I, Ph)$
16- $\pi \leftarrow plan(I, actions)$
17- $execute(\pi)$

4. Main modules and functions

In this section, we present the main modules and functions of our architecture.

Beliefs. Belief is a conviction of the truth of a proposition. Beliefs can be obtained via perception, communication or via the body of the agent itself. In PEP → BDI architecture, beliefs are influenced by emotions and personality.

Desires. Desires are the options (opportunities) available for an agent. Usually, they are obtained thanks to its current beliefs and intentions.

Intentions. Intentions are options selected by the agent. Intentions influence emotions: once an agent adopts an intention, it will plan the consequence of its intention and it can influence its emotions which can influence beliefs and reasoning. Intentions are not definitive in our model.

Emotion. Agent emotions evolve according to its environment, actions, perceptions, personality and physiology. Emotions work by pair, we take into account emotions relevant to a crisis simulation: fear/hope, anger/gratefulness, shame/proud and reproach/trust.

Personality. Personality is a set of characteristics that makes an agent psychologically, mentally and ethically different from an other one. In our representation, there is no update function for personality Pe because personality does not evolve in the simulation duration.Personality traits relevant to the simulation are: empathy, altruism, docility, curiosity, cautiousness, leadership, stressability, bravery, nervosity, affective link and normativity.

Physiology. Agents physiology can be directly affected by the simulation environment, or time dynamics can modify agent's health. Parameters important in this simulation are the following: stress, hunger/thirst, tiredness, temperature, injury and contamination.

We now formally define PEP → BDI functions. Let us define: Pe the set of all possible personalities, E the set of all possible emotions, Ph the set of all possible physiologic state, B the set of all possible beliefs, D the set of all possible desires and I the set of all possible intentions.

Perception Functions. New information can be obtained by perception (sight, hearing, smelling, . . .), communication (messages) and by the agent himself (injury, tiredness, . . .). As a consequence, we define three perception functions based on these three ways to get new information:

- Perception function based on new percepts:

$$Sense : Env \times PeP \rightarrow B_p$$

  with Env the environment, PeP perception inclinations and B_p the set of possible belief candidates from perception. Naturally, the calculation of $Sense$ is based on the environment.
- Perception function based on communication:

$$Msg : Env \times PeP \rightarrow B_m$$

  with B_m the set of possible belief candidates from communication. The messages are dispatched by the environment.
- Perception function based on agent sensation:

$$Body : Env \times PeP \rightarrow B_b$$

  with B_b the set of possible belief candidates from the body agent itself. A part of the information comes from the environment (injury by fire, contamination, . . .) and the other part comes directly from the agent (tiredness, . . .).

Emotion Update Functions. As in eBDI model [4], we have two different update functions in order to take into account primary emotions and secondary ones. Primary emotions are a direct reaction to a percept.

Primary emotion update peu is evaluated such as:

$$peu : E \times I \times Ph \times PeE \times (B_m \cup B_p \cup B_c) \rightarrow E$$

Secondary emotions come after primary emotions, they can be a direct consequence of primary emotion and/or be a result of some complex reasoning. Secondary emotion update seu is calculated as:

$$seu : E \times I \times B \times PeE \rightarrow E$$

Secondary emotion update considers the new belief base B computed by function Brf. Only the elements that have evolved are considered: emotions E, intentions I and beliefs B.

Belief Revision Functions. The belief revision function takes as input the three ways of obtaining new informations:

$$Brf : E \times Pe \times I \times (B_p \cup B_c \cup B_b) \rightarrow B$$

In our representation, emotions E and personality Pe have an impact on the way the new beliefs are interpreted.

Physiology update. Physiology update pu manages the perceptions results B_b because the agent state can be impacted by the environment. We consider emotions E because stress is a physiological parameter. We give the following physiology update:

$$pu : B_b \times E \times I \rightarrow Ph$$

Options (Desires) update. This function is similar to the one in BDI model but takes into account Personality Pe and Physiology Ph parameters:

$$options : B \times I \times Pe \times Ph \rightarrow D$$

Filter for selection of options. This function is similar to the one in BDI model but takes into account physiology Ph and emotion E parameters. The function $filter$ choses the best option (the intention I) between the different options and is defined as:

$$filter : E \times B \times D \times I \times Ph \rightarrow I$$

Plan function. When the intention of the agent is selected, the agent has to plan which actions he will do to achieve its intention. Hence, it will select a set of actions π. We define function $plan$ as:

$$plan : I \times actions \rightarrow \pi$$

where $actions$ is the set of possible actions for a given intention I.

Execution of the plan. The goal of this function is to execute the plan that has been chosen by the $plan$ function. The execution of a plan has a direct influence on the environment Env:

$$execute : \pi \rightarrow Env$$

In practice, the actions are transmitted to the *ad hoc* module of the environment.

5. Algorithm execution example

In order to illustrate the decision process, let us decompose our algorithm for the agent scenario described above:

- E_0 initial emotions of this agent are neutral. We suppose that the agent starts with a standard emotional state.
- B_0 initial beliefs. Our agent knows that it had to wait in the queue and that it has just finished its precedent plan: escape from the incident place. $B_0 = \{wait\_in\_queue, escaped\_fire\}$
- Ph_0 initial physiology. The agent has not yet realized that it has been hurt. It is stressed by the evacuation. $Ph_0 = \{stress = low\}$.
- Pe_0 initial personality. Agent has a personality defined by: $Pe_0 = \{coward, normative\}$

Algorithm execution.

- Line 1: E, B, I, Ph and Pe are respectively initialized with E_0, B_0, I_0, Ph_0 and Pe_0.
- Line 2: agent is ready to start its life.
- Line 3: perception functions. Agent acquires new informations : $B_p \cup B_c \cup B_b =$

$$\begin{aligned} &= Sense(Env, PeP) \cup Msg(Env, PeP) \\ &\quad \cup Body(Env, PeP) \\ &= \{contam\_people\_near, time\_to\_wait\} \\ &\quad \cup\{agent\_complaining\} \\ &\quad \cup\{not\_contam\_itself, hurt\} \\ &= \{contam\_people\_near, time\_to\_wait, \\ &\quad agent\_complaining, not\_contam\_itself, \\ &\quad hurt\} \end{aligned}$$

- Line 4: primary emotion update peu is done at this phase. Because of new beliefs $\{contam\_people\_near, time\_to\_wait\}$, agent feels fear: $E = peu(E, I, B_c, Ph, PeE) = \{fear\}$
- Line 5: belief revision Brf is done. New beliefs $\{contam\_people\_near, time\_to\_wait\}$ and emotion $\{fear\}$ generate new beliefs $B = Brf(B, E, I, B_c) = \{risk(queue, high), time\_to\_wait\}$
- Line 6: because of new belief $B_b = \{hurt\}$ and beliefs $B = \{risk(queue, high), time\_to\_wait\}$ and emotion

$E = \{fear\}$, physical update pu function will generate two new informations $Ph = pu(B, E, I, B_b) = \{hurt, average\_stress\}$

- Line 7: new beliefs $B = \{risk(queue, high), time\_to\_wait\}$, new physiological informations $Ph = \{hurt, average\_stress\}$ and $Pe = \{coward, normative\}$ will generate new options $D = options(B, I, Ph, PeD) = \{wait\_in\_queue, find\_escape\}$
- Line 8: The agent has to select between two options to select its intention I:
  - To wait in the queue: this option has not a big activation level because the agent do not feel shame and is afraid to stay there.
  - To find an other escape by himself: contrary to first option, this option is selected because of agent's fear.

  $I = filter(E, B, D, I, Ph) = \{find\_escape\}$
- Line 9: Emotional state E is stored in E'.
- Line 10: The second emotion update seu is done. Our agent has a new conflicting intention $find\_escape$ that will increase its shame because of its personality $Pe = \{normative\}$. $E = seu(E, I, B, Pe) = \{fear, shame\}$
- Line 11: Emotions E are different after seu : $E' = \{fear\} \neq E = \{fear, shame\}$
- Line 12: The new belief revision will change belief B will still generate two beliefs $B = Brf(B, E, I, B_c) = \{risk(queue, high), time\_to\_wait\}$
- Line 13: New physical revision will lead to an increase of agent's stress because of its shame: $Ph = pu(B, E, I, B_b) = \{hurt, important\_stress\}$
- Line 14: There are still two options for the agent. $D = \{wait\_in\_queue, find\_escape\}$
- Line 15: Selection of options will be different because now agent has a high shame level in its emotions. $I = filter(E, B, D, I, Ph) = \{wait\_in\_queue\}$
- Line 16-17: Thanks to its intention, the agent plans his actions in order to wait in the queue and it executes its plan.

This example shows some prominent features of the PEP $\rightarrow$ BDI model, and particularly how it integrates emotion, personality and physiology in the decision process.

6. Conclusion

Simulation of human behavior, in particular in a crisis situation, needs to consider physiology, personality and emotion in order to obtain plausible behavior. For these reasons, we have proposed a new architecture: PEP $\rightarrow$ BDI.

This work can be improved in two directions. First, it is necessary to build an ontology of agent activities considering these 3 factors. Second, a validation of simulated behavior must be done at a global level and at individual level. This work of calibration will need psychology study and users experiments to improve our agents behaviors.

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