Emotional Dynamics and Coping Mechanisms to Generate Human-Like Agent Behaviors

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ABSTRACT

Emotion mechanisms represent an important moderating factor of human behavior. Thus, they are necessary to produce realistic behavioral simulations. This work addresses this challenging issue by incorporating emotional processes into an agent model. We intend to show the potential of emotions and coping mechanisms to produce fast and human-like emotional behaviors, particularly, in emergency situations. We focus on the interplay of emotions and goals and its impact on agent behavior. Emotions constitute heuristics to agent decision making. They induce emotion-specific goals that orient agent goal adoption mechanisms and fasten its behavior selection.

Introduction

Several computational models of human emotions exist. However, they are still unable to address satisfactorily the integration of emotion generation and its effect in the context of cognitive processes (Miqueleiz and Martínez 2015). In fact, emotion mechanisms cover different processes. These include mainly the detection and appraisal of significant environmental cues to generate the convenient emotions. They also incorporate the decision about the convenient agent behavior to respond to the fact that caused the emotion called coping. The latter refers to the thoughts and behaviors people use to manage the internal and the external demands of stressful events (Lazarus and Folkman 1984). Although the coping process is greatly related to emotional mechanisms, this process is underestimated, and the emphasis is on the appraisal and experience phases of emotions (Lazarus 2006). Emotions can differ radically in the way in which they manifest themselves in behavior as a function of intensity (Ortony 2009); when emotions are of high intensity, goal directedness diminishes and behavior becomes more organized by action tendencies and readiness

(Roseman 2013). Emotional mechanisms are more relevant to decision making under uncertainty and high stakes (Belhaj, Kebair, and Ben Said 2015) such as in the case of emergency situations. These are stressful situations where there is no time to deliberation that assesses the advantages, disadvantages, and consequences of behaviors (Roseman 2008). Therefore, fast emotional behaviors are needed to adapt to such situations. Emotions can then directly trigger behaviors and evoke mechanisms to cope with these situations that are not used in more relaxed emotional conditions (Becker et al. 2006). The simulation of human behaviors influenced by emotions is particularly important to reproduce human-like behavioral simulations during emergency situations. These simulations are useful in training applications of rescuers. They also allow the study of different scenarios of an emergency situation evolution in order to establish intervention plans (Valentin et al. 2011).

In this work, we aim to study human emotional dynamics and their effects on agent behaviors. We particularly aim to study the interplay of emotions and goals and its consequences on behavior selection by integrating coping mechanisms into an emotional agent. The agent decision-making process is based on the Belief-Desire-Intention (BDI) paradigm (Rao and Georgeff 1991). The agent model makes use of a computational model of emotions to generate agent emotions that we have proposed in a previous work (Belhaj, Kebair, and Ben Said 2014a) and that is based on the appraisal mechanisms proposed in the OCC model of emotions (Ortony, Clore, and Collins 1988). We intend to study the impact of the triggered emotions on agent behavior. Particularly, coping mechanisms that are associated with these emotions constrain agent decision-making process and lead to the generation of the convenient emotional behavior. The proposed coping model builds on the recent psychological model of coping of Roseman (2013). The emotional agent model is implemented to create an emotional agent based simulator of human civilians in an emergency situation. The simulator is integrated into the RoboCupRescue Simulation System (RCRSS) (RobocupRescue 2013), which is an agent-based simulator of an emergency situation after an earthquake.

The following section presents the theoretical background necessary to comprehend emotion and coping mechanisms and the relationships that exist between emotions and goals. It also describes the psychological theory of coping on which we base the proposed coping model. After that, we outline related work from the literature (Section 3). Then, we describe the proposed emotional agent model (Section 4). Subsequently, we provide an application and an implementation of the model to create a realistic social simulation of civilians in emergency situations. We also present the integration of the simulator within the RCRSS and discuss experimentations that we have carried out. Finally, we draw a conclusion and present perspectives of the current work.

Theoretical background

Emotion, appraisal and coping

Roseman defines an emotion as "a coherent, integrated system of general-purpose coping strategies, guided by appraisal, for responding to situations of crisis and opportunity (when specific-purpose motivational systems may be less effective)" (Roseman 2013). The cognitive appraisal of what happens in the environment results in the experience of particular emotions with some intensity levels. Then, a coping process induces a decision about the convenient behavior to deal with the fact that caused the emotion. Thus, the coping process determines the response to the appraised significance of events. Therefore, it is an important aspect for creating human-like agents that have to handle different situations depending on their appraisal of the situation (Gratch and Marsella 2004). Existing computational models of coping are mainly based on the coping theory proposed by Lazarus and Folkman (1984). The theory distinguishes two forms of coping; problem-focused coping occurs when a human acts in the environment to deal with a stressful situation. It involves the selection and execution of actions that achieve a desired goal (Lim et al. 2012). However, emotion-focused coping aims at lowering the intensity of strong negative emotions by trying to change the human's interpretation of the causing event. Despite of the strength of this theory, the matching between emotions and particular coping strategies remains not straightforward. Besides, the theory does not present the effect of the coping strategy on the behavior in the case of emotion-focused coping after the intensity of the negative emotion has been lowered. The recent theory of coping proposed by Roseman (2013) does not make a distinction between categories of coping. Differently, it focuses on the behavioral manifestations of emotions in terms of action readiness that is particularly important for responding to highly emotive circumstances. Besides, Roseman's theory identifies coping strategies as responses characteristic of both negative and positive emotions and that shape agent goals, actions and behaviors. Moreover, Roseman conceptualizes emotions as an organized system of coping responses by establishing links between emotions, appraisals and consequent behavior patterns that are related to each of the emotions he defines in his "Emotion system." Therefore, we choose to study the behavioral manifestations of emotions according to Roseman's theory of coping.

The interplay of emotions and goals

Emotion effect on behavior emerges from its effect on decision making. Decision making consists in evaluating perceptions and choosing the adequate action to carry out. This evaluation depends on the physical properties

of what was perceived from the environment and on the properties of the perceiving person: intelligence, experience, current goals and plans and emotional state (Kasap and Magnenat-Thalmann 2007). In this work, we intend to study the interplay of emotions and goals and their potential to direct agent decision-making process. Miceli, De Rosis, and Poggi (2006) identify three possible relationships between goals and emotions. First, emotions monitor and signal the (possible) achievement or thwarting of goal. In fact, assessing whether a situation is relevant to one's well-being depends on its relevance to one's goals. Thus, if no goal is at stake, there will be no emotion (Lazarus 2006). Second, emotions may generate goals as a behavioral response to the fact that caused the emotion that implies the production of some goal. Finally, emotions may become goals since one may perform or avoid an action in order to experience or avoid the experience of the associated expected emotion. This work intends to show the impact of agent emotions on subsequent goal adoption and behavior selection. Thus, we focus on the first and second categories of emotion-goals relationship. In fact, the first category concerns the emotion generation process where goal-based emotions may arise from appraising events according to their impact on goals. However, the second reflects the behavioral manifestation of emotions. The latter elicits new goals to respond to the fact that caused them.

The coping theory of Roseman

Roseman's (2013) coping theory postulates that each emotion is associated with a coping strategy that is manifested when the emotion is experienced. The strategy of each emotion constitutes the way to cope with opportunities and crises that people face when they are pursuing their individual general purpose goals. Roseman (2013) considers that emotions give rise to emotion-specific goals called "Emotivational goals" that motivate agent actions. These "Emotivational goals reduce response time by increasing focus on a particular general purpose goal" (Roseman 2008). He also suggests particular actions that may take place when the emotion is experienced. In Table 1, we summarize the coping response defined for each emotion represented by the presumed effect of emotions on actions and the emotivational goals they may elicit as defined by Roseman (2013).

The theory also assumes that positive emotions that are elicited by events that are consistent with current goals (motive-relevant events) are associated with the tendency to preserve the current state. However, negative emotions appear to be associated with a tendency to overcome the situation that elicited them. Moreover, actions that minimize harm are relatively high priority compared to actions that maximize reward that are relatively low priority. Finally, motive-relevant events are considered to be caused either by self, by others or by impersonal circumstances. Therefore, responding to

Table 1. Emotivational and behavioral components of an emotion and the associated coping strategy.

Emotion	Emotivational component (goal)	Behavioral component (action)	Response/coping strategy
Joy	Sustain	Jump up, celebrate	Move toward it
Distress	Terminate, get away	Move around, leave	Move away from
Hope	Make happen	Anticipate, approach	Prepare to move toward or to stop moving away from it
Fear	Get to safety, prevent	Vigilance, inhibition or flight (run)	Prepare to move away from or to stop moving toward it
Pride	Recognition, dominance	Touch, hold	Move toward self
Shame	Get self out of sight	Decrease attention to	Move self away
Love/ Like	Connect	Exhibit, assert	Move toward other
Dislike	Dissociate	Withdraw, conceal, submit	Move away from other
Guilt	Redress	Reproach, punish self	Move against self

these causes my need self-control strategies, interpersonal actions or actions in the physical space, respectively.

Related work

Different computational models of emotions exist. These may be classified into two main categories: logical models of emotions (using mainly BDI logics) and quantitative models of emotions. Here, we only consider the approaches that have included coping mechanisms in their models.

Models of emotions based on BDI logics

This category of approaches to modeling emotions formalizes emotions triggering conditions and coping strategies using logical rules. Emotion mechanisms are specified by establishing some relationships between high-level cognitive mental states such as beliefs, desires, intentions, emotions and motivation. The approach presented in Carole and Longin (2007) includes emotion-focused coping strategies for the regulation of a subset of negative emotions of the OCC model. The authors define coping strategies to modify agent beliefs or desires and intentions toward ignoring the facts that caused that negative emotions and to generate new intentions that trigger new positive emotions (Carole and Longin 2007). The approach does not consider the quantitative aspects of emotions. This makes unclear how the defined coping strategies can alleviate the experience of negative emotions and make the situation after applying these strategies better than before (Steunebrink, Dastani, and Meyer 2009). Steunebrink, Dastani, and Meyer (2009) integrate the notion of action

tendencies that arise with respect to particular emotions in order to model coping mechanisms. The model gives only a logical analysis of the action tendency concept and only considers negative emotions. Steunebrink, Dastani, and Meyer (2010) formalize the eliciting conditions of four emotions: Joy, Distress, Hope and Fear. They also specify emotion-inspired constraints to restrict the preferences to choose among possible plans. Logical BDI-based rules are presented to show how the four specified emotions can be used to constrain agent deliberation.

Quantitative models of emotions

The second category includes quantitative computational models of emotions that consider quantitative aspects of emotions such as intensity. Marsella and Gratch (2009) present Emotion and Adaptation (EMA), a computational model of emotions that includes mainly emotion-focused coping strategies. The implemented agent behaviors are believable, according to the study. However, agent mental states are represented by complex structures including appraisal frames and inspired from planning (Carole and Longin 2007). EMA explains both the rapid dynamics of emotional reactions and slower deliberative responses in a single and automatic parallel appraisal process. FearNot model (Aylett et al. 2005) is an interesting BDI-based approach that implements emotion-focused and problem-focused coping mechanisms. FAtiMA (Dias, Mascarenhas, and Paiva 2014) represents a modularized version of the FearNot model that includes different components related to emotions generation, reactive and deliberative behaviors influenced by emotions among others. The main challenge in FAtiMA is that it requires XML definitions of goals importance, emotional reactions and actions tendencies for different characters (Lim et al. 2012).

The aforementioned approaches adopt Lazarus's theory of coping to integrate coping processes in their computational models of emotions. Inspired by existing coping models, we propose our modeling of coping mechanisms. We adopt a quantitative approach that incorporates emotion generation and coping mechanisms to study the impact of an agent emotional dynamics in its action selection process. However, unlike these approaches, we adopt Roseman's theory of coping to model coping mechanisms with positive and negative emotions. Moreover, we integrate coping strategies with emotions through the new notion of emotivational goals. The latter are emotion-specific high-level goals that enable the definition of constraints to agent behavior selection since they can interrupt, sustain or make happen agent individual goals. We also integrate coping mechanisms with Standard-based (or Attribution) emotions and with Attitude-based emotions, generally absent from the described coping models.

Emotional agent model

The emotional agent model involves three main components: A Perception module, An Appraisal module and a Behaviur module (Figure 1). The Perception module allows the agent to update its beliefs by processing and categorizing its perceptions into five categories of perceptual data. These categories include Events (Self-Related Events [SRE], Prospected Events [PE] and Other-related Events [ORE]), Actions and Objects of the environment.

Each category of perceptions is appraised by an appraiser in the Appraisal module. The appraisal of the SRE, the PE and the ORE results on three categories of Goal-based emotions that are the Well-Being Emotions (WBE), the Prospect-Based Emotions (PBE) and the Empathetic Emotions (EE), respectively. The appraisal of agent actions gives rise to Attribution Emotions (AE). Finally, the appraisal of object aspects triggers Attitude-Based Emotions (ABE). The different appraisers use specific dimensions (appraisal variables of the OCC model) to generate emotions and compute their intensities. The intensity of an emotion I_e is calculated using specific Appraisal variables A_i that have some Weights w_i. Equation 1 presents a general form of the formula used to compute the intensity of an emotion (Details about the computational model of emotions and the formula it uses to compute particular emotions intensities are provided in (Belhaj, Kebair, and Ben Said 2014b)). The resulting emotions are used to update the emotional state of the agent. The output of the appraisal process is an emotional state that affects the agent goals and orients its behavior.

$$Ie = \left| \prod_{i=1}^{n} wiAi \right| \tag{1}$$
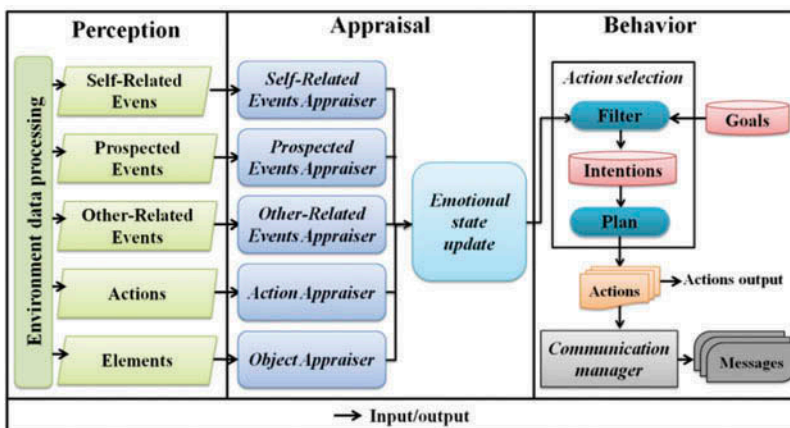

Figure 1. The emotional agent model.

In our modeling, we aim to cover the individual aspect of emotions (effects on individual goals), their social aspect (relation with others) and their moral aspect (through Standard-based or moral emotions).

Mental states formalization

The emotional BDI agent behavior is directed by four mental sates that are Beliefs B, Desires or Goals G, Intentions I and Emotional state E. Following the approach presented in (Battaglino, Damiano, and Lesmo 2013), we add another mental state to represent agent Standards S necessary to evaluate actions and generate Standard-based emotions. Therefore, an agent a can be represented by the tuple $a(B, G, I, E, S)$. As detailed above, agent beliefs include information about the agent itself (SRE), its prospects (PE), other agents (ORE), actions and environment elements. We consider a set of individual general purpose goals G_I and a set of Standard-based goals G_S (represented to model agent cognitive evaluation of actions to be consistent or inconsistent with its standards). In addition to these categories, we add the emotivational goals associated with emotions G_E (necessary to include coping strategies with agent emotions). We adopt the general formalization of goals proposed by Van Riemsdijk, Dastani, and Winikoff (2008) to represent individual goals G_I . An individual goal g is represented by the tuple g $(S_c,$ $A_c, D_c, S_g, \Pi)$. S_c, A_c and D_c represent the suspension, activation and dropping conditions of a goal and S_g represents its state (Active, Suspended or Dropped). In fact, an agent has a set of suspended goals (Desires). When a goal is adopted by the agent (Active), it corresponds to the desire the agent has committed to (Intention). An agent has a set of plans Π that can be executed to achieve its current intention. Each plan $\Pi_i \in \Pi$ is associated with the achievement of an individual goal $gi \in G_I$. In this work, our aim is to study the interplay of emotions and goals. Therefore, we abstract from the representation of agent plans. Thus, a plan Π_i could be a BDI plan set, a single action, a sequence of actions or even a program. If different action plans are possible to choose to achieve one goal, these are assigned some priorities. Thus, if the plan with the highest priority fails to achieve the goal, the next plan (if any) could be selected for execution (if the agent is still committed to that goal). Emotivational goals G_E and Standard-based goals G_S are not goals that the agent pursue but, rather, cognitive goals that promote or inhibit individual general purpose goals adoption. Thus, we represent them by the tuples g_e (A_c, D_c, S_e) and $g_s(A_c, D_c, S_s)$, where S_e and S_s represent these goals states (Active, Dropped). Emotivational goals are activated (dropped) when the corresponding emotion is (is no more) the strongest emotion of an agent. However, Standard-based goals are activated (dropped) when an agent standard is considered (no more considered) as violated. We define an agent emotion e by a vector that contains the Name N, the

Category C, the Valence V (positive (p) or negative (n)), the Intensity I_e and the Target T (Self, Other or Object) (e (N, C, V, I_e, T)). Finally, a standard is represented by the tuple s (I_s, M_C, V_C) where I_s, M_C and V_C correspond to the standard importance, its maintenance and violation conditions.

A decision-making process influenced by emotions

The decision-making process of the proposed agent architecture extends the BDI paradigm with emotions. A BDI agent model tries to emulate the human practical reasoning process. It follows a sense-think-act loop. The significant changes in the environment are perceived during the sense phase. The beliefs are than updated. The second phase decides about agent behavior. It comprises the deliberation phase that reasons about the different goals and beliefs of the agent in order to commit to one of the possible options (intention selection). It also constructs the convenient plan to achieve the chosen intention. The third phase consists in acting in the environment by executing the convenient action plan. In the current work, we focus on the impact of emotions on goal adoption mechanisms. Therefore, coping mechanisms with agent emotions are integrated into the agent deliberation process. Emotions induce emotivational goals. The latter orient the agent deliberation process toward maintaining, suspending or revising the agent current intention. That way, coping mechanisms enable the agent deliberation process to initiate a relevant individual general purpose goal g_i to deal with the situation that caused the emotion. Actually, we consider that the emotion with the highest intensity is the one considered that affects the agent behavior and activates the corresponding emotivational goal (Table 1). An individual goal may be activated when its *activation conditions* A_c meet the agent new beliefs about itself, other agents and about its environment. The agent active goal and the appropriate action plan that allows its achievement are maintained until the goal is achieved, or recognized as unachievable (*dropped*) or until a new emotion, that is most intense than the current emotion, is experienced by the agent. In the case that two emotions have the same intensity level, we consider that a negative emotion has a higher priority than a positive emotion.

Integration of coping mechanisms in the agent deliberation process

Our modeling effort of the coping mechanisms with emotions covers the different emotions listed in Table 1, augmented with the empathetic emotion Sorry-for (pity). Although this emotion is not considered in Roseman's theory of coping, we consider this emotion because it is necessary to model agent actions and interactions in our application domain that is studying human behavior in emergencies.

Coping with goal-based emotions

- *Joy*: the *Joy* emotion may be elicited when a desirable SRE (an event that is consistent with agent goals) is appraised *e (Joy, WBE, p, I$_{Joy}$, Self)*. If *Joy* is the strongest emotion of the agent, then the corresponding emotivational goal g$_{Joy}$, that is to *"Sustain"* the current individual goal, is *activated* (see Table1). In fact, feeling the *Joy* emotion indicates that a positive *SRE* event that promotes the realization of the agent current individual goal g$_i$ has taken place. Therefore, the *Joy* emotion is associated with the coping strategy to *"Move toward"* the fact that caused that positive emotion and then with a goal keeping strategy. Thus, the agent continues the execution of the current action plan Π$_i$ associated with the *active* goal g$_i$.

- *Distress*: the *Distress* emotion results from the appraisal of an undesirable event for self (i.e., an event that has a negative impact on agent current goal), *e (Distress, WBE, n, I$_{Distress}$, Self)*. When *Distress* is the agent strongest emotion, it gives rise to the emotivational goal g$_{Distress}$ that is to *"Terminate"* the new situation and the coping strategy to *"Move away from"* the stimulus that caused the emotion. Therefore, the emotion *Distress* is associated with a goal revision strategy where the current intention g$_i$ and the current plan Π$_i$, being executed to accomplish it, are no more consistent with the new situation. Thus, the agent enters a new deliberation cycle and a new individual goal g$_j$ is activated, and one of its corresponding plans Π$_j$ is adopted for execution.

- *Hope*: the *Hope* emotion may arise when a positive PE is appraised *e (Hope, PBE, p, I$_{Hope}$, Self)*. It is associated with the emotivational goal g$_{Hope}$. The latter corresponds to wanting to *"Make happen"* a positive prospected situation. Depending on the agent coping potential, it tries to attain the positive prospected state. Therefore, if the current general purpose goal g$_i$ is consistent with its prospects, it tries to achieve it. Elsewhere, a new individual goal g$_i$ that enables the agent to make true its prospects (if there is one) is activated and pursued.

- *Fear*: The *Fear* emotion is triggered as a result of the appraisal of a negative PE, *e (Fear, PBE, n, I$_{Fear}$, Self)*. It is considered as an emergency emotion associated with a threat to one's safety. Therefore, the emotivational goal associated with this emotion (g$_{Fear}$) is to *"Get to Safety."* Safety is the highest priority for humans. Therefore, when the agent physical well-being is endangered, any goal that is not consistent with the new situation is suspended. Thus, in threatening situations, the agent deliberation process is reinitialized, and a new goal g$_j$ that is associated with the preservation of its safety is activated and pursued.

- *SorryFor*: SorryFor is an Empathetic Emotion that may be elicited when a negative event that happens to others is appraised *e (SorryFor, EE, n, I$_{SorryFor}$, Other)*. We presume that when an agent feels *SorryFor* another

agent because of a matter that happened to this other agent, it copes with that negative emotion by trying to provide it with support. In fact, the emotion SorryFor (pity) causes the motivation to help. Thus, pity induces activation of an emotivational goal ($g_{SorryFor}$) that we name "Support." The latter results in the suspension of the agent current intention and its commitment to a goal oriented toward providing others with instrumental or moral support.

Coping with standard-based emotions

Standard-based emotions are triggered as a result of action appraisal. An action is considered as praiseworthy (blameworthy) if the agent considers it as consistent (inconsistent) with one of its standards s ∈ S.

- *Pride: Pride* arises with some intensity I_{Pride} if the agent performs a praiseworthy action *e (Pride, AE, p, I_{Pride}, Self)*. Thus, the performed action meets one of maintenance conditions M_C of one of the agent standards *S*. The coping response associated with *Pride* is to "Move toward self." This can be translated into an increase in the corresponding standard importance value I_s.
- *Shame and Guilt*: These emotions are triggered when the agent performs a blameworthy action, *e (Shame, AE, n, I_{Shame}, Self)* or *e (Guilt, AE, n, I_{Guilt}, Self)*. The difference between *Shame* and *Guilt* resides in the nature of the fact or (the problem) that elicited them. *Shame* arises if the agent violates the standard with the inability and incompetence to maintain it. However, *Guilt* is associated with negative power. In fact, it could be able to avoid the standard violation (Turrini, Meyer, and Castelfranchi 2010). Thus, these emotions are experienced when the performed action meets one of *violation conditions* V_C of one of the agent standards *S*. The emotion *Shame* is associated with the emotivational goal "Get self out of sight." Conversely, *Guilt* gives rise to the emotivational goal "Redress." Thus, if one of these emotions corresponds to the agent's strongest emotion, it may lower the standard importance I_s or try to lower the intensity of the experienced emotion by beginning other activities.

Coping with attitude-based emotions

- *Like*: Like is elicited by appraising positively attractive object in the environment *e (Like, ABE, p, I_{Like}, Object)*. The *Like* emotion gives rise to the "*Connect*" emotivational goal (g_{Like}). Therefore, the agent copes with that emotion by displaying the "*Move toward it*" coping strategy. Consequently, the agent tries to attain the attractive object.

- *Dislike*: The *Dislike* emotion is elicited as a result of observing a negative aspect of an object in the environment e *(Dislike, ABE, n, $I_{Dislike}$, Object)*. It is associated with the emotivational goal "Dissociate" ($g_{Dislike}$). Therefore, the agent tries to decrease its attention to the object by diminishing the intensity of the *Dislike* emotion and trying to move away from it.

Case study: Emotion and coping in an emergency situation

Emotion generation process

The agent perceives its environment in order to detect significant changes in the sates of the world, the states of other agents and its own states. It classifies its perceptions into the perceptions categories defined in the agent model. Then, it appraises the categorized perceptual data to generate the convenient emotions. In Table 2, we provide a summary of the perceptual data categories appraised by each appraiser and the emotion(s) of the OCC model they may trigger as defined in (Belhaj, Kebair, and Ben Said 2014a).

Coping behavior

Agent goals and standards

In the context of emergency situations, an agent is assigned four individual general purpose goals. The latter are "Find a refuge," "Escape a risk," "Get saved" and "Help a person." As suggested in the agent model, the

Table 2. Perceptual data categories and potential resulting emotions.

Appraiser	Perceptual data category	Perceptual data	Elicited emotion	Emotion category
Self-related events Appraiser	Self-Related Events	Safe (self) InRefuge (self)	Joy	Well-being emotions (WBE)
		Injury (self) InDanger (self) HealthStateDown (self)	Distress	
Prospected events appraiser	Prospected Events	ProspectRescue (self)	Hope	Prospect-based emotions (PBE)
		Prospect Injury (self) ProspectDeath (self)	Fear	
Other-related events Appraiser	Other-Related Events	Injury (other) InDanger (other) HealthStateDown (other) Death (other)	SorryFor	Empathetic emotions (EE)
Action appraiser	Actions	Agent Self action	Pride Shame/ Guilt	Attribution emotions (AE)
Object appraiser	Elements of the environment	Refuge Blockade, building	Like Dislike	Attitude-based emotions (ABE)

achievement of an agent intention is performed through an action plan. The objective of the current work is not to study planning mechanisms but rather to study the interplay of emotions and goals and its impact on behavior. Thus, according to this focus, we reduce agent plans to single actions. The actions that are associated with each goal are provided in Table 3. The latter also includes the activation, dropping and suspension condition(s) of these goals that correspond to particular agent beliefs. In emergencies, we actually consider only one standard that is "Helping a person in need is an action that conforms to standards."

Coping behaviors in emergency situations

- *Joy*: Humans may have positive cognitions and emotions even after facing traumatic events (Vázquez et al. 2005). In fact, the *Joy* emotion was felt at having survived unharmed (Valent 1984). Humans may also feel happy when they are in the refugees (Vázquez et al. 2005). Therefore, we associated the *Joy* emotion with the appraisal of the SRE events *Safe (self)* and *InRefuge (Self)* (Table 2). Safe agents are agents that are able to adopt the intention to "Find a refuge." This intention is maintained by the "Sustain" emotivational goal induced when the agent strongest emotion is *Joy*. The agents that are trying to find a refuge may achieve their intention by performing the *"Walk"* action, in the crisis environment, corresponding to that intention (Table 3). Agents may also experience *Joy* when they are in refuges (*InRefuge (self)* event). In that case, their purpose to attain a refuge is achieved. Therefore, they may choose the *"Rest"* action to remain in these refuges. Safe agents are able to move in the environment. Thus, they may perceive other agents states. The latter may induce the *SorryFor* emotion. Consequently, they may engage in rescuing activities.
- *Distress*: We assume that the events that may be the cause of *Distress*, during emergency situations, are the *InDanger (self)*, *Injury (self)* or *HealtStateDown (self)* SRE (Table 2). These are undesirable events that happen to the agent itself accompanied with a negative impact on agent current intention. Therefore, an agent whose most intense emotion is

Table 3. Agent goals, their activation, dropping and suspension conditions and the actions for their achievement.

Agent goal	Activation condition(s)	Dropping condition(s)	Suspension condition(s)	Actions
Find a refuge	Safe(self)	InRefuge(self)	InDanger(self), Injury(self), Injury (other)	Walk, rest
Escape a risk	InDanger(self)	Safe(self)	Injury(self)	RandomWalk
Get saved	Injury(self), *HealtStateDown (self)*)	Death(self)	InRefuge (self)	AskForHep
Help a person	Safe(self), Injury(other)	InRefuge (other), Injury(self)	InDanger(self)	HelpOther

Distress activates its corresponding "Terminate" emotivational goal (Table 1). The agent then revises its current intention and activates a new goal that is consistent with the new state. In the case of a danger (*InDanger (self)* event), if the agent is still safe and able to avoid the danger, the "Escape a risk" goal may be adopted as new intention. Here, a fast action in the physical space is needed to move away from the danger ("RandomWalk" action). The *Distress* emotion is also elicited if the agent, after facing a danger, was not able to escape it. In that case, the agent could be injured or having its health state being worse (*Injury (self) or HealtStateDown (self)*). Here, the agent will try to "Get saved" and to "Terminate" the current state by asking for help ("AskForHelpSelf" action, Table 3).

- *Hope*: We suppose that in the emergency context, the agent may prospect the positive event to be rescued (*ProspectRescue (self)* event). The *Hope* emotion may be triggered as a result from the appraisal of that event (Table 2). When *Hope* is the strongest emotion of the agent, the associated emotivational goal is to try to "Make happen" the positive expected situation (Table 1). Therefore, a goal permitting the agent to make true its prospects is activated and maintained until being achieved. The agent may be facing a danger and still safe and able to move. Thus, its intention could be the "Escape a risk" goal, and the action selected for its achievement is to try to escape the danger ("RandomWalk" action, Table 3). Elsewhere (i.e., the agent is injured and unable to overcome the distressing situation by itself), the agent will aim to *"Get saved."* Thus, it tries to make true its prospects to be rescued by asking for help ("AskForHelpSelf" action, Table3).

- *Fear*: In emergencies, the appraisal of a negative prospected event (*ProspectInjury (self)* or *ProspectDeath (self)*) triggers the emotion *Fear* (Table 2). When the agent's most intense emotion is *Fear*, the corresponding "Get to safety" emotivational goal is elicited. Thus, the agent suspends its current intention and activates one of the goals that permit it to preserve its safety. An agent that experiences a strong feeling of *Fear* when acting in a crisis environment tries to flight if it has the ability to do so. Therefore, fearful safe agents run away by executing the "RandomWalk" action. The latter is adopted when the agent intention is to "Escape a risk." However, agents that are unable to change their states by themselves try to obtain social support by asking for help. The corresponding intention is then to "Get saved" accomplished by performing the "AskForHelpSelf" action.

- *SorryFor*: The events considered to trigger the *SorryFor* emotion when evaluated, in emergency situations, are the negative ORE; *Injury (other), InDanger (other), HealthStateDown (other)* and *Death(other)* events (Table 2). A safe agent in an emergency situation, whose most intense

emotion is the *SorryFor* emotion, copes with it by suspending its current intention and trying to provide others with help. The "Support" emotivational goal is induced by the empathetic emotion SorryFor. The agent tries then to help the agent in need by activating the "Help a person" goal. Thus, the corresponding "HelpOther" action is then adopted for execution.

- *Pride*: During emergencies, after having the *SorryFor* emotion triggered by the appraisal of a negative event that happens to others or after perceiving or hearing a person that is asking for help, the agent may either provide the person in need with help or prefer to continue pursuing its current intention. The emotion *Pride* arises if the agent performs an action that it considers as consistent with its Standards. The coping response associated with *Pride* is to "Move toward self." Thus, this is translated into an increase in the standard importance for the agent.

- *Shame and Guilt*: The emotions *Shame* and *Guilt* arise if the agent does not or was not able to provide the agent in need with help respectively. In these cases, the agent lowers the standard importance and engages in other activities in order to cope with these negative emotions.

- *Like*: In a crisis environment, the agent may perceive a positively attractive object, such as a refuge (Table 2). Thus, when an agent is attracted to such an object, it may experience the *Like* emotion. The latter elicits the emotivational goal to "Connect" to it. Therefore, the agent adopts the corresponding coping strategy to "Move toward it." Thus, the agent starts walking toward the element of the environment that attracts it.

- *Dislike*: We suppose that blocked roads and collapsed buildings are the most important negatively attractive objects to the agent in a crisis environment (Table 2). The appraisal of such objects may elicit the *Dislike* emotion. The latter induces the "Dissociate" emotivational goal. Thus, the agent copes with the *Dislike* emotion in a way that decreases attention to the object by applying the coping strategy to "Move away from it."

An emotional agent based simulator to enhance civilians simulation in the RoboCupRescue simulation system

We implemented the agent model applied to the emergency situations context to simulate civilian agents in the RCRSS. The latter is an agent-based urban disaster simulation platform of an emergency situation after an earthquake. The perception module of an emotional agent filters the perceptual data that come from the RoboCupRescue simulation environment in order to extract significant events. The desirability (appraisal variable) of the events is thereafter computed. Each of the appraised events triggers a particular emotion. The strongest emotion gives rise to an emotivational goal that may alter agent intention commitment. The agent deliberation may be reinitiated when
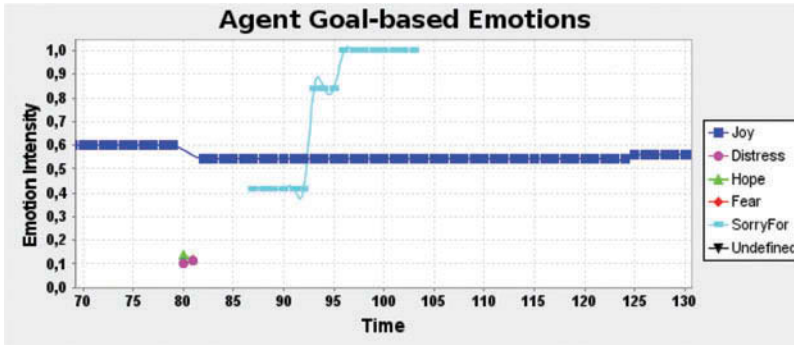
Figure 2. Evolution of Goal-based emotions of an agent.

new emotions are experienced. In the following paragraphs, we illustrate this mechanism, by showing the state evolution of an experimented emotional civilian agent in the RCRSS environment. We first show the emotion generation process of the agent. After that, we illustrate the impact of the agent strongest emotions on its intention adoption process and the subsequent selected behavior.

Figure 2 and Figure 3 are provided to illustrate the strong relationship between agent perceptions and their emotions. The former displays the goal-based emotions evolution of the agent. However, the latter shows the events that may elicit them when appraised.

We note that the events that an agent perceives trigger the convenient emotions when appraised as specified in Table 2. For example, being safe (Figure 3) elicits the emotion *Joy* (Figure 2). However, the agent experiences the *SorryFor* emotion (Figure 2) when it perceives and appraises a negative event that happens to another agent (Negative ORE, Figure 3).

Figure 4 illustrates the emotivational goals elicited by the agent strongest emotions and their impact on agent goals adoption and the actions selected to achieve the committed goal. We can notice that the agent choices of
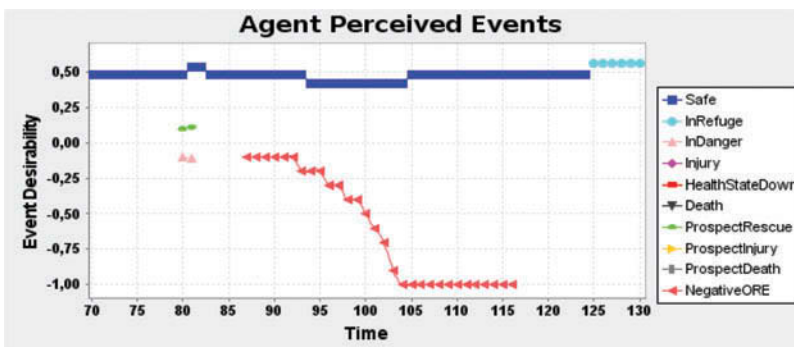

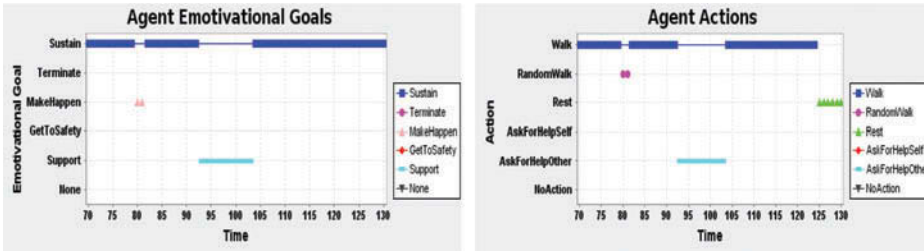**Figure 3.** Evolution of events desirability of an agent.

**Figure 4.** Evolution of the Emotivational Goals and actions of an agent.

intentions and actions stem from its most intense emotions. In fact, when the agent perceives and appraises a fact in its environment, the result is the emotional experience (Figure 2). The latter elicits the coping mechanism associated with the most intense triggered emotions. The coping strategies induced by these emotions orient the agent intention adoption mechanism. Thus, they allow the agent to respond conveniently and rapidly to the facts that caused its emotions. That way, the agent decision-making process is constrained by the emotivational goals of the agent. The latter orients the agent goal commitment process toward the goals that permit it to adapt efficiently to the rapid changes in the dynamic crisis environment.

In the illustrative example, when *Joy* is the agent most intense emotion, it gives rise to the "Sustain" emotivational goal (Table 1). The latter corresponds to a goal keeping coping strategy. Thus, the agent adopts and maintains the "Find a refuge" goal. However, this intention is suspended when the agent perceives and appraises a negative event that happens to another agent (NegativeORE, Figure 3). In fact, this triggers the *SorryFor* emotion in the agent (Figure 2). This emotion induces the "Support" emotivational goal when it becomes the most intense emotion. The agent decision-making process is then oriented toward helping the person in need. Thus, the "Help a person" intention is then selected and achieved by performing the "AskForHelpOther" action (Figure 4). Note that, in RCRSS, only ambulance agents are able to rescue civilians. Therefore, we enable civilian agents to help each other through the "AskForHelpOther" action. The latter corresponds to sending a message held by the communication manager sub-module of the proposed emotional agent model.

In the following, we show the effect of modeling the *SorryFor* empathetic emotion on the behavior of civilian agents in RCRSS. The following illustrations represent the evolution of the number of civilian agents' strongest emotions and their actions. First, we consider agent emotions and actions without appraising what happens to others (i.e., without generating the *SorryFor* emotion). After that we integrate the simulation of the *SorryFor* emotion and represent its effects on agent actions (see Figure 5). The illustrations show the decrease of the number of agents having a *Joy* emotion
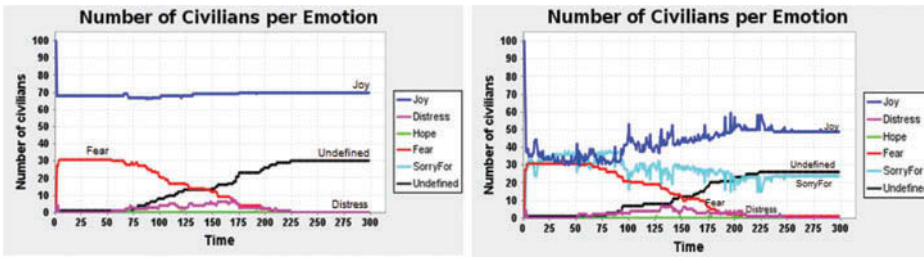
Figure 5. Evolution of the number of civilians per emotion without/with the consideration of the SorryFor emotion.
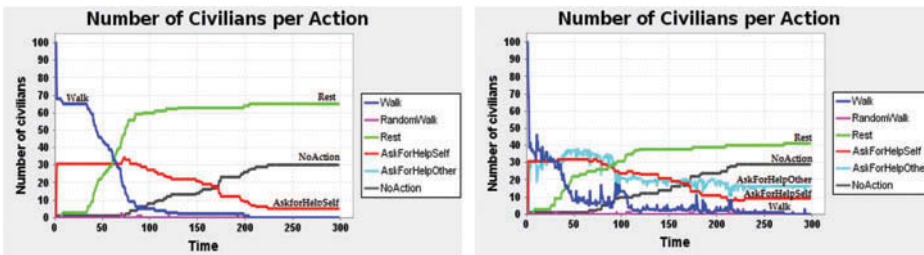
Figure 6. Evolution of the number of civilians per action without/with the consideration of the SorryFor emotion.

(those are safe agents that may move in the environment, help other agents or attain refuges by their own) during the simulation when considering the *SorryFor* emotion compared with those not having a *SorryFor* emotion (48 civilians vs 71 civilians, see Figure 5). The difference corresponds to agents that experienced *SorryFor* emotions.

Experimentations have proved that the agent actions are influenced by agent empathetic emotions. In fact, the number of emotional civilian agents that are walking in the crisis environment decreases when considering the SorryFor emotion (70 vs. 40 in at time t = 20, see Figure 6) since agents stop walking when they are trying to help other agents (*AskForHelpOther* action). Besides, this influences the number of civilians that attain refuges by the end of the simulation (66 vs. 41 agents having a *"Rest"* action, see Figure 6).

Conclusion and future work

In this paper, we introduced an agent model that includes emotions and coping mechanisms. The model emphasizes the influence of emotions on the agent decision making and action selection processes. In our proposal, emotions represent mechanisms for rapid adaptation to what happens in the agent environment. In fact, emotions represent shortcuts to fasten agent deliberation by considering emotion as a motivation to action.

This induces fast human-like mechanisms for action selection supported by the notion of emotivational goals particularly relevant to model and simulate human behavioral dynamics in emergency situations. The latter are situations where there is the time constraint to agent deliberation. The implementation of the coping mechanisms with different emotions shows the impact of the agent strongest emotions on its behavior and on generating a realistic social simulation of civilians during an emergency situation. In fact, agents are aware of their context, are able to manage their states and to respond emotionally and behaviorally to the requirements of the environment and other agents. An aspect that may need a more profound study is the empathy phenomenon that is induced by agent empathetic emotions. The latter has the potential to produce pro-social behaviors. Personality represents another moderating factor of human behavior that may be added to both emotions and coping models. In fact, personality influences emotions intensities, experience and display. It also shapes action tendencies.

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