TEATIME: A Formal Model of Action Tendencies in Conversational Agents

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Abstract: This paper presents a formal model of socio-affective behaviour in a conversational agent based on the Action Tendency theory. This theory defines emotions as tendencies to perform an action. This theory allows us to implement a strong connection between emotions and speech acts during an agent-human interaction. Our model presents an agent architecture with beliefs, desires, ideals and capacities. It relies on 6 appraisal variables for the selection of different emotional strategies depending on the context of the dialogue. It also supports social regulation of emotions depending on social rules. We implemented this model in an agent architecture and we give an example of dialogue with a virtual insurance expert in the context of customer relationship management.

1 INTRODUCTION

Computer scientists are increasingly interested in adding an affective component to the human-agent interaction systems. Indeed, it has been validated that machines which express affective states enhance the user's satisfaction and commitment in the interaction (Prendinger and Ishizuka, 2005). Moreover, affects play a fundamental role in the decision-making process and rational behaviour (Coppin, 2009). They act as heuristics for decision making to ease the action selection process in context (Frijda, 1986). This role of affects is crucial for conversational agents that have to combine a rational answers with social behaviours. For instance, when the user expresses disappointment about a task done by the agent, a credible agent should be inclined to apologize rather than pursuing the task-oriented interaction. However, combining task-oriented answers with socio-affective behaviour in a dialogue is still challenging.

In order to achieve such a combination, one must better understand what are emotions and how they intervene in the decision process. The notion of "emotions" has been used initially to refer to the tendency to fight or to yell when you are angry against other, the tendency to run away when fear is triggered (McDougall, 1908) or the tendency to approach others (positive emotions). In contemporary theories (Lazarus, 1991), emotions are often defined as combination of numerous components such as 1) the appraisal component which evaluates the world changes in terms of goals, 2) the experience component which consists in labelling the feeling's change toward the stimulus with a common-sense word (fear, sadness, etc) and 3) the behavioural component which conveys physical actions, facial expression, and/or vocal output. Frijda in (Frijda, 2010) also stressed out 4) the motivational component which aims at changing the relation between the self and the stimulus and 5) the somatic component which prepares the organism for action.

The role of the motivational component, often referred as *action tendency* in some theories, is to give a direction to one's future actions. According to Frijda, this general direction overrides all other possible goals. Moreover, this component play an important role in behaviour regulation. Thus, the coping strategy, *i.e.* the agent's adaptation to the stimulus at the source of the emotion, cannot be chosen without this frame for possible actions. For this reason, we claim that implementing a proper decision mechanism in a conversational agent requires to incorporate the motivational component.

In this paper, we present a formal model of affect based on the action tendency theory which makes a connection between the appraisal process and the

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agent's verbal behaviour by modelling the motivational component. The agent interprets the user's utterances. It generates action tendencies and decides whether to perform an emotional reaction or to continue with the task-oriented dialogue.

In the following section, we discuss existing computational models of emotions and their relation of the motivational component of emotions. The third section explains the syntax and the semantics of our logical framework. The fourth section defines the appraisal and action selection process using those logics. In the fifth section, we illustrate the implementation of our model with a short interaction sample.

2 RELATED WORK

2.1 Action Tendency Theory

The Action Tendency theory is a part of the appraisal theories of emotions. The term *appraisal* refers to the continuous process of evaluating the stimuli encountered according to their relevance to well-being (Lazarus, 1991; Frijda, 1986). In other words, it describes the mechanism that makes an individual evaluate a situation, and later adapt to it. This adaptation is often referred-to as *coping*.

Several appraisal theorists argue that the evaluation process often occurs automatically, unconsciously and/or rapidly (Arnold, 1960; Frijda and Zeelenberg, 2001; Lazarus, 1991; Jenkins and Oatley, 1996). This is the reason why computer scientists are interested in the simulation of this process in virtual agents, so as to improve the spontaneity and the credibility of their reaction.

In all appraisal theories, the appraisal process results from the assignment of a value to a set of appraisal variables following the perception of a stimulus. For example: "is the stimulus good for me". Depending on the model, the output of this appraisal process can be either an emotional label (fear, joy, etc) for so-called *categorical models* such as OCC (Ortony et al., 1990), or a vector for so-called *dimensional models* such as PAD (Mehrabian, 1996).

However, it is important to understand that emotions cannot be reduced to a label or a vector: these are only a description of the state of the individual, in reaction to an affective stimulus, in order to adapt itself to the new situation. Frijda (Frijda, 1986) explains this aspect by saying that one of the goals of the appraisal process is to *prepare the individual for a reaction*. In this view, emotions can be seen as an heuristic mechanism to select the behaviours, which is the reason why Frijda refers to them as *action tendency*. In this model, the output of appraisal process is not a label or a vector but an action tendency (AT). It is defined as the will to establish, modify, or maintain a particular relationship between the person and a stimulus (Frijda, 2010; Frijda and Mesquita, 1998). This AT can then be turned into an emotion label as in categorical models (Roseman, 2011). It is important to note that action tendencies are not necessarily a preparation for physical action (Coombes et al., 2009). They may also be a mental action such as disengagement, disinterest, nostalgia, and so on.

Frijda also introduced another notion in his model: the *activation*. It has been defined in works prior to Frijda (Duffy, 1962) as a state of energy mobilization. Frijda used this term to refer to the state of readiness for action of a given organism (somatic or motor). The action tendency is said to be activated when it benefits from an energy concentration to reach the desired final state. In other words, the action tendency can be turned into a concrete behaviour or plan. On the contrary, the action tendency is said to be *inhibited* when it lacks energy concentration. The activation of physical behaviour resulting from a action tendency depends on several factors most of them are social rules (Frijda, 1986). The action of insulting, for instance, is a behaviour resulting from a state of anger. In some social groups, insulting is not acceptable. The tendency to insult is then inhibited. The way the individual adapts to the situation, taking into account social norms and self-capacity to deal with affects, is the coping strategy.

The theory of action tendency highlights the strong connection between emotions and actions and proposes hint on how to integrate this connection in affective component for human-agent interaction systems such as conversational agents. In our work, we propose to enhance a simple task-oriented conversational agent with a computational model of action tendency so as to produce more spontaneous and relevant reactions. The action tendencies are expressed through speech acts since we are in the context of dialogue, but our model can be used for a more general purpose.

2.2 Affective Models in Literature

A great number of affective models for conversational agents have been proposed during the last two decades. Most of them are founded on one or more psychological theories so as to produce realistic behaviours for the virtual agents. For example, the ALMA model for controlling the non-verbal behaviour of a virtual agent (Gebhard, 2005) is

based on the PAD theory by Mehrabian (Mehrabian, 1996). It computes the emotion of a virtual agent at each time of the simulation based on external stimuli. In a different context, (Adam et al., 2009) propose a modal logic implementation of the OCC theory (Ortony et al., 1990) to compute the emotions, reason about them and build believable agents. However, these models of emotions do not cover the behavioural component: they do not explain how the agent should behave in reaction to the computed affects.

A few cognitive architectures have been proposed that implement both the appraisal component and the behavioural component. The most famous ones are EMA (Gratch and Marsella, 2004), based on Lazarus' theory (Lazarus, 1991) and FAtiMA (Dias and Paiva, 2005), based on the OCC theory. Both models rely on a specific list of variables to implement the appraisal and the experience components. Both models also support the description of coping behaviours. However, in these models, the emotion labelling (which corresponds to the experience component of emotions) makes a separation between the appraisal process and the behaviour selection. On the contrary, according to (Frijda, 1986), these processes cannot be separated: the behaviour is part of the experience itself.

Similarly, (Dastani and Lorini, 2012) proposed a formal model for both appraisal and coping. The action selection is defined through inference rules in the model itself: emotions directly affect the beliefs, desires and intentions of the agent. For instance, when an agent faces a fearful event, it will reduce its intention toward the action that produces this situation. However, this work has three limitations. First, it relies on emotion intensities, which are difficult to compute and justify from a psychological point of view, as explained by (Campano et al., 2013). Second, it only considers a limited subset of the OCC emotion categories for appraisal and the coping process only considers two negative emotions. Last, they do not consider the cause of the emotion, which is very important in social interaction since it impacts the action tendency as shown by (Roseman, 2011).

Other approaches consider the social dimension of the interaction. For example, the Psychsim cognitive architecture (Pynadath and Marsella, 2005) proposes an action selection mechanism based on a formal decision-theoretic approach: the agent selects actions based on beliefs and goals and can adopt social attitudes using reverse appraisal and theory of mind. However, the architecture does not consider affects in the action selection process. Our goal in the TEATIME model is to define how the affects intervene in the action section.

The model proposed by (Courgeon et al., 2009) in the MARC architecture proposes a direct connection between appraisal and action tendencies. This models is based on Scherer's theory (Scherer, 2005) and it connects the appraisal variables to action units for the facial animation of the virtual character. This model focuses only on non-verbal behaviour and does not consider the decision-making process (action selection or dialogue). For this reason, it is complementary with our approach: we focus on building a connection between appraisal and action tendencies for dialogue act selection in a conversational agent.

The formal model proposed by Steunebrink and Dastani (Steunebrink et al., 2009) also aims at taking into consideration action tendencies in the decision making process. The appraisal process is based on the OCC theory of emotions and the proposed coping mechanism is inspired by Frijda's theory of action tendencies. However, this model is not compliant with the theories of emotions in social science, because it makes a clear separation between the appraisal process and the coping processes. Action tendencies are simply coping strategies for social emotions (such as pity, resentment and gratitude) or re-evaluation of the situation to revise the agent's desires.

The problem with such an approach is that, when it comes to dialogue, actions cannot be separated from emotion expression. For instance, insulting the interlocutor is a dialogue act that conveys the anger emotion. For this reason, one cannot separate the emotion appraisal from the action performance. Actions tendencies are the theoretical bricks that connects the two and, to our knowledge, no complete computational model of action tendencies has been proposed in the literature.

Our goal in this paper is to propose a model of emotions in which action tendencies (*i.e.* the motivational component in Frijda's theory) directly connect the evaluation process with the action selection mechanism.

3 THE TEATIME LOGICS

The TEATIME model aims at offering a formal representation, using modal logics, of the affective process from appraisal to action selection in the context of dialogical interaction. TEATIME stands for Talking Experts with an Action TendencIes MEchanism. It is part of a more general virtual agent architecture that combines knowledge representation, dialogue management and agent's animation. This architecture is

used to build assistant agents in different industrial applications such as customer relationship management and online help.

The interaction relies on a strict turn-taking approach (as opposed to continuous interaction). The user utterances are interpreted as atomic stimuli for the decision process. The agent evaluates the stimuli with respect to a set of *appraisal variables*, depending on its beliefs, desires, ideals and capabilities. This may generate an *action tendency*, following the theory proposed by (Roseman, 2011). This model is illustrated on Figure 1. The appraisal process evaluates the stimulus's impact on the agent's goals. If it has a direct or indirect impact, the action tendency mechanism is used to select the answer. Otherwise, the agent follows classical task-based interaction rules (that will not be presented in this paper).

This section presents the syntax and semantics of the TEATIME logical model.

3.1 Syntax

3.1.1 Agents, Facts and Actions

Let $\mathcal{AGT} = \{i, j, ...\}$ be a finite set of agents, $\mathcal{F} = \{\varphi_1, \varphi_2, ...\}$ a finite set of atomic facts and $\mathcal{ACT} = \{a, b, ...\}$ a finite set of physical actions.

For example, in the context of interaction with a tourist assistant, $\mathcal{AGT} = \{agt, user\}$, we can consider the facts *chvr* (City Has Vegan Restaurant) and *vrb* (Vegan Restaurant Booked) and the action *bvr* (Book Vegan Restaurant): $\mathcal{F} = \{chvr, vrb, \ldots\}$ and $\mathcal{ACT} = \{bvr, \ldots\}$.

For a given agent $i \in \mathcal{AGT}$, we denote $\mathcal{ACT}_i \subseteq \mathcal{ACT}$ the set of actions that i can perform.

We also define two predicates *Ask* and $Inform$ as follow:

$\forall i, j \in \mathcal{AGT}, \forall a \in \mathcal{ACT}, \forall \varphi \in \mathcal{F}$:

$$Ask_{i,j}a \ , \ Inform_{i,j}\varphi \in \mathcal{F}$$

$Ask_{i,j}a$ describes the fact that the agent i asks the agent j to do the action a. $Inform_{i,j}\varphi$ denotes the fact that the agent i informs the agent j that φ is true.

3.1.2 Beliefs, Desires and Ideals

Following a BDI-based approach, we define a set of modalities for expressing propositions about facts. For a given agent $i \in \mathcal{AGT}$ and a given fact $\varphi \in \mathcal{F}$, $Bel_i\varphi$ describes a belief of agent i and should be read "the agent i believes that φ is true" ; $Des_i\varphi$ describes an appetitive desire that the agent aims at reaching. It should be read "the agent i desires φ". $Des_i\neg\varphi$ describes an aversive desire (*i.e.* a desire that the agent aims at avoiding). $Ideal_i\neg\varphi$ should be read as "The agent i has for ideal $\neg\varphi$" or simply "φ does not conform with the ideals of agent i".

3.1.3 Action Execution and Conditions

We also define classical predicates for action execution. For any agent $i \in \mathcal{AGT}$ and for any action $a \in \mathcal{ACT}_i$, $Done(a,i)$ represents the fact that agent i has achieved action a and $Exec(a,i)$ represents the fact that agent i can perform action a.

To compute the impact of a stimulus φ, it is necessary to know the list of actions that made the fact true. We denote $\mathcal{PL}^{\varphi} \subset \mathcal{ACT} \times \mathcal{AGT}$ the set of actions that explain the fact φ (the computation of this set is not part of this paper). For all couple $(a,i) \in \mathcal{PL}^{\varphi}$, the following formula holds:

$$\models \varphi \Rightarrow Done(a,i)$$

In the above example, the couple (bvr, agt) explains the fact *vrb*: $vrb \Rightarrow Done(bvr, agt)$.

Also note that facts can depend on each other. For instance, *vrb* depends on the fact *chvr* in the above example. This is represented in the logics by the formula: $vrb \Rightarrow chvr$. Conversely, if the vegan restaurant is closed (*vrc*), it cannot be booked. This is represented by: $vrc \Rightarrow \neg vrb$. Such inferences will be used in the appraisal process.

3.1.4 Action Tendencies and Emotional Strategies

Action tendency is defined by (Frijda, 1986) as a state of readiness to perform one or more action which aims at establishing or modifying or maintaining a particular relationship between the appraising person and the stimulus. As explained by (Roseman, 2011), action tendencies are a part of *emotional strategies* which correspond to high-level goals that a person wants to achieve regarding a stimulus: these emotional strategies are the primary result of the appraisal while action tendencies participate in the resolution of the strategy in a specific context.

For example, imagine that Bob insults Anna. This stimulus will be appraised into a general emotional strategy to *Move Against* the responsible of the situation (here Bob). This concept of "Move Against Bob" is an emotional strategy which Anna is attempted to reach by following an action tendency. Several speech actions can correspond to this strategy (e.g. Anna might insult Bob back or yell at him or criticize him).

Each emotional strategy coupled with the event cause corresponds to a set of actions : "Move Against Someone" could be expressed by yelling, fighting,

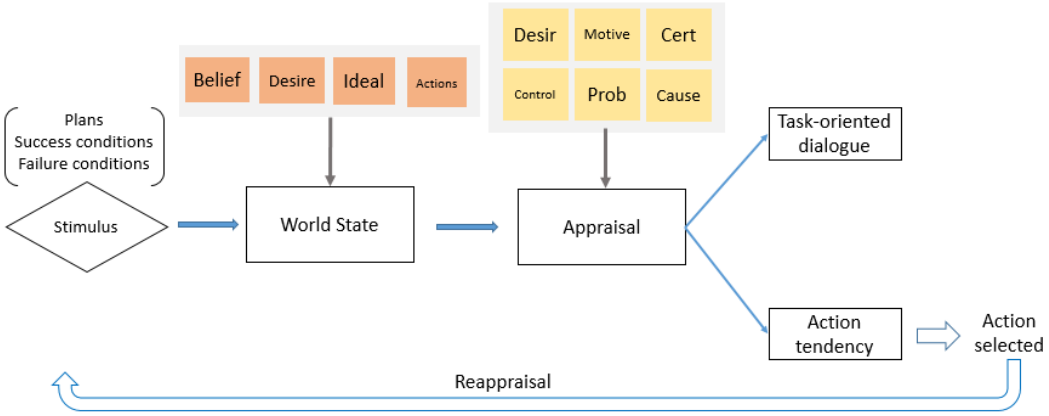

Figure 1: Overview of the TEATIME architecture.

hurting, etc. "Move Against Self" could be expressed by withdrawing, punishing self, submitting, etc. "Move Away from Circumstances" could be showed by leaving the conversation. Some examples were presented in (Roseman, 2011) and a more complete state-of-the-art of action tendencies in literature can be found in (Bossuyt, 2012).

The TEATIME model implements these two aspects of the motivational component of emotions. We consider the 8 emotional strategies proposed by Roseman:

- *Prepare To Move Toward It* (PMT)
- *Move Toward It* (MT)
- *Stop Moving Away From It* (SMA)
- *Prepare To Move Away From It* (PMA)
- *Move Against It* (MA)
- *Move It Away* (MIA)
- *Stop Moving Toward It* (SMT)
- *Move Away From It* (MAF)

Each strategy answers to a different kind of appraisal. However, at a given time of the interaction, these strategies are not mutually exclusive: several emotional responses can be generated for a single situation. This requires the agent to combine the strategies.

Also note that these strategies are independent from the application domain. The target of the emotional strategy, referred to as "It" in the definitions, is important: it directly impacts the list of possible action tendencies. For example, Move Toward the interlocutor can be done in approaching her, connecting to her, whereas Move Toward oneself consists in exhibiting pride. Following Roseman's proposal, we consider three possible directions in our model: $self$ represents the appraising agent, $other$ the interlocutor in the dialogue and $circ$ any external cause. Action tendencies refers to sets of possible actions in answer to a given emotional strategy and target.

More formally, let $\mathcal{ES}$ be the set of 8 emotional strategies and $\mathcal{IT} = \{self, other, circ\}$ be the set of possible target. For any agent $i \in \mathcal{AGT}$, possible action $a \in \mathcal{ACT}_i$, emotional strategy $e \in \mathcal{ES}$ and target $t \in \mathcal{IT}$, the proposition $Tend(i,a,e,t)$ represents the action tendency to perform the action a to achieve the strategy e toward the target t.

In the example above, the tendency to yell could be activated in Anna toward Bob:

$$\models Tend(anna, yell, MA, other)$$

The first role of the TEATIME component in the conversational agent is to select the relevant emotional strategy based on appraisal variables. The list of appraisal variables is presented in the following section. The second role is to select actions based on the action tendencies and the agent's ideals. This will be presented in section 4.

3.1.5 Appraisal Variables

There is no consensus about the number and the meaning of appraisal variables needed to generate an emotional response in appraisal theories. In our model, we chose to use Roseman's list of appraisal variables. We define 6 appraisal variables: causality, desirability, controllability, motive, nature of the problem and certainty.

Formally, we define 6 predicates. Let $i \in \mathcal{AGT}$, $\varphi \in \mathcal{F}$, $t \in \mathcal{IT}$, $v \in \{-,0,+\}$ and $nat \in \{intri, instru\}$:

$Cause(i,\varphi,t)$ represents the fact that agent i considers that t (self, other or circ) is the cause of stimulus φ.

$Desir(i,\varphi,v)$ states that agent i considers φ as desirable (+), undesirable (-) or is indifferent to φ (0).

$Control(i,\varphi)$ represents the fact that agent i has control over an undesirable stimulus φ, *i.e.* it is capable of executing an action toward the cause of the stimulus.

$Motive(i,\varphi,v)$ represents the nature of the desire impacted by the stimulus (appetitive or aversive).

$Cert(i,\varphi)$ expresses the fact that the stimulus φ is certain.

$Prob(i,\varphi,nat)$ expresses the nature of problem for an undesirable stimulus (intrinsic or instrumental).

Section 4 explains how these predicates are computed at runtime, depending on beliefs and desires.

3.1.6 TEATIME Valid Formulaes

A proposition p in the TEATIME logics is defined using the following Backus-Naur form, in which $\varphi \in \mathcal{F}$, $i \in \mathcal{AGT}$, $a \in \mathcal{ACT}*$, $e \in \mathcal{ES}$, $t \in I\mathcal{T}$, $v \in \{-,0,+\}$ and $nat \in \{intri, instru\}$:

$$\begin{aligned} prop \quad ::= \quad & \varphi \mid Exec(a,i) \mid Done(a,i) \mid Tend(i,a,e,t) \mid \\ & Cause(i,\varphi,t) \mid Desir(i,\varphi,v) \mid Control(i,\varphi) \mid \\ & Motive(i,\varphi,v) \mid Prob(i,\varphi,nat) \mid Cert(i,\varphi) \end{aligned}$$

and a formula f is defined as:

$$\begin{aligned} f \ ::= \ & prop \mid \neg f \mid f \wedge f' \mid \\ & Bel_i\varphi \mid Des_i\neg\varphi \mid Des_i\varphi \mid Ideal_i\neg\varphi \end{aligned}$$

3.2 Semantics

The TEATIME semantics is based on possible worlds (Kripke semantics). Let us consider the universe $\Omega = \{\mathcal{AGT}, \mathcal{F}, \mathcal{ACT}*, \mathcal{ES}\}$ and $\mathcal{M}_\Omega = \{\Omega, \mathcal{W}, \mathcal{V}, \mathcal{B}, \mathcal{D}, I\}$ with:

- $\mathcal{W}$: the non-empty set of possible worlds,
- $\mathcal{V} : \mathcal{W} \rightarrow 2^{Prop}$ the valuation function for all propositions (facts and predicates *Exec*, *Done*, *Tend*, *Cause*, *Desir*, *Control*, *Motive*, *Prob* and *Cert*).
- $\mathcal{B}, \mathcal{D}, I$ transition functions from $\mathcal{AGT} \times \mathcal{W}$ to $2^{\mathcal{W}}$ which associate for each $w \in \mathcal{W}$ the set of possible worlds accessible by the agent's beliefs $Bel_i(w)$, desires $Des_i(w)$ and ideals $Ideal_i(w)$ (respectively).

For a formula f, a model $M \in \mathcal{M}$ and a world $w \in W$, $M,w \models f$ read as φ is true at (M,w)

The rules defining the truth conditions of formulas are:

- $M,w \models p$ iff $p \in \mathcal{V}(w)$
- $M,w \models \neg f$ iff $\mathcal{M},w \not\models f$
- $M,w \models f \wedge f'$ iff $\mathcal{M},w \models f$ and $M,w \models f'$
- $M,w \models Bel_i\varphi$ iff $\forall v \in \mathcal{B}(i,w), M,v \models \varphi$
- $M,w \models Des_i\varphi$ iff $\forall v \in \mathcal{D}(i,w), M,v \models \varphi$
- $M,w \models Ideal_i\neg\varphi$ iff $\forall v \in I(i,w), M,v \models \neg\varphi$

with p a proposition, i and agent and f a formula.

In addition, a set of inference rules has to be defined in the TEATIME engine. For instance, a fact cannot be simultaneously an appetitive and an aversive desire:

$$\models Des_i\varphi \Rightarrow \neg Des_i\neg\varphi$$

The next section only presents the rules that define the emotional process.

4 DYNAMIC APPRAISAL AND ACTION SELECTION

The execution of the TEATIME model is composed of a phase of appraisal followed by a phase of emotional response, as explained in the previous section. The first phase selects the emotional strategy based on appraisal variables. The second phase selects the agent's response to the stimulus.

4.1 Computation of Appraisal Variables

This subsection presents the computation of the appraisal variables. It explains how we have implemented the principles from (Roseman, 2011) using modal logics.

There is no consensus about the number and the definition of appraisal variable through literature. In our model, we had to simplify some definitions of appraisal variables in order to build a computational model easy to understand and implement.

We consider only two participants in the interaction: $i \in \mathcal{AGT}$ is an agent and $i' \in \mathcal{AGT}$ its interlocutor. In the following, $M \in \mathcal{M}$ is the current model and $\varphi \in \mathcal{F}$ is the fact to be appraised.

4.1.1 Causality

Causality is a complex topic and understanding the causes and consequences of actions and facts requires complex models (Pearl, 2009). We chose to simplify the causality definition in the TEATIME model in order to facilitate the implementation. In our model, indirect contribution to a fact is not taken into account and all direct contributions to an action achievement have the same value. We thus make the supposition that all actions are equally important and voluntarily achieved.

The causality of φ is evaluated according to the set of actions $\mathcal{PL}^{\varphi}$ that explains this fact and the agents that performed these actions. We want $Cause(i,\varphi,self)$ to be true when the agent i has at least done one action in $\mathcal{PL}^{\varphi}$. Similarly, we want $Cause(i,\varphi,other)$ to be true when at least one action is done by the agent's interlocutor. If none are responsible for all actions in $\mathcal{PL}^{\varphi}$, or if there is no such action (φ is true a priori), the agent must consider that the fact is caused by "the circumstances" and $Cause(i,\varphi,circ)$ shall be true.

Concretely, we have the following rules in the TEATIME inference engine:

- $M \models Cause(i,\varphi,circ)$ iff $\forall(a,j) \in \mathcal{PL}^{\varphi}$ such that $M \models Done(a,j)$, $j \neq i$ and $j \neq i'$
- $M \models Cause(i,\varphi,self)$ iff $\exists(a,i) \in \mathcal{PL}^{\varphi}$ such that $M \models Done(a,i)$
- $M \models Cause(i,\varphi,other)$ iff $\exists(a,i') \in \mathcal{PL}^{\varphi}$ such that $M \models Done(a,i')$

Note that a single stimulus can have multiple causes. In this case, we can have up to three actions tendencies that can be generated.

4.1.2 Desirability

In the TEATIME model, the stimulus φ is desirable in three situations: if it is an appetitive desire of the agent; if it contributes to an appetitive desire of the agent; or if it prevents an aversive desire of the agent. Formally, $M \models Desir(i,\varphi,+)$ iff

- $M \models Des_i\varphi$ or
- $\exists\psi, M \models Des_i\psi \wedge \psi \Rightarrow \varphi$ or
- $\exists\psi, M \models Des_i\neg\psi \wedge \varphi \Rightarrow \neg\psi$.

Similarly, $M \models Desir(i,\varphi,-)$ iff $M \models Des_i\neg\varphi$ or $\exists\psi, M \models Des_i\neg\psi \wedge \psi \Rightarrow \varphi$ or $\exists\psi, M \models Des_i\psi \wedge \varphi \Rightarrow \neg\psi$: φ is undesirable if it is related to an aversive desire or if it prevents an appetitive desire.

In all other situations, we cannot determine the desirability of φ: $M \models Desir(i,\varphi,0)$.

4.1.3 Motive

The motivational variable (represented by the predicate *Motive* in our model) is strongly related to the desirability, as explained by (Roseman, 2011). Indeed, it specifies the nature of the desire that the stimulus φ has impacted. It is positive if the stimulus impacted an appetitive desire and negative if it impacted an aversive desire. Formally, $M \models Motive(i,\varphi,+)$ iff

- $M \models \neg Desir(i,\varphi,0)$ and
- $M \models Des_i\varphi$ or $\exists\psi, M \models Des_i\psi \wedge \psi \Rightarrow \varphi$ or $\exists\psi, M \models Des_i\psi \wedge \varphi \Rightarrow \neg\psi$.

For example, if the agent has the appetitive desire to book a vegan restaurant but it receives the stimulus "the restaurant is closed", it will appraise $Desire(i,vrc,-)$ but $Motive(i,vrc,+)$.

Similarly, $Motive(i,\varphi,-)$ is true when the fact (desirable or un-desirable) is related to aversive goals. Note that *Motive* will have no value if the stimulus' desirability is evaluated to 0.

4.1.4 Controllability

This cognitive evaluation variable defines whether the agent is capable of acting or adapting to a fact φ. It is relevant only when the stimulus is undesirable. The controllability is positive if agent is capable of performing an action towards the cause of the stimulus. This reaction is necessarily the result of an action tendency and, according to (Roseman, 2011), it occurs only in two particular emotional strategies: move against (MA) that modifies the stimulus and move it away from you (MIA) that alters the perception of the stimuly. If there exists an action doable by the agent that satisfies one of these strategies toward the cause, the controllability is positive. Otherwise it is negative.

Formally, $M \models Control(i,\varphi)$ iff

- $M \models Desir(i,\varphi,-)$ and $\exists t,a$ such that:
- $M \models Cause(i,\varphi,t) \wedge Exec(a,i)$ and
- $M \models Tend(i,a,MA,t) \vee Tend(i,a,MIA,t)$.

$M \models \neg Control(i,\varphi,-)$ in all other situations (including when controllability is not a relevant question).

4.1.5 Certainty

In our model, the certainty of the stimulus is simply the coherence of this stimulus with the agent's beliefs. Formally, $Cert(i,\varphi) \equiv_{def} Bel_i(\varphi)$.

4.1.6 Problem Nature

The nature of the problem is only relevant when the stimulus is undesirable. The problem is *instrumental* if the stimulus participates in the failure or success of a desire. On the contrary, it is *intrinsic* if the stimulus itself is a desire.

Formally:

- $M \models Prob(i,\varphi,intri)$ iff $M \models Desir(i,\varphi,-) \wedge Des_i\neg\varphi$
- $M \models Prob(i,\varphi,instru)$ iff $M \models Desir(i,\varphi,-) \wedge \neg Des_i\varphi \wedge \neg Des_i\neg\varphi$

4.2 Computation of the Emotional Strategy

Table 1 describes the computation of the emotional strategy depending on the different appraisal vari-

ables. A star means that any value is acceptable for the predicate. The last column gives the resulting emotional strategy. This table is extracted from (Roseman, 2011). The only difference is that we did not consider the surprise and its associated appraisal variable "expectedness" in our model.

Table 1: Computation of the Emotional Strategy.

Desir	Caus	Control	Prob	Cert	Motive	ES
-	Self/Other	-	*	*	*	MAF
		+	Intri	*	*	MIA
			Instru	*	*	MA
	Circ	-	*	-	*	PMA
					-	MAF
				+	+	SMT
		+	Intri	*	*	MIA
			Instru	*	*	MA
+	Self/Other	*	*	*	*	MT
	Circ	*	*	-	*	PMT
				+	-	SMA
					+	MT

4.3 Action Selection

Based on the emotional strategy, the TEATIME engine selects an action according to the possible action tendencies, as defined by the *Tend* predicate (see section 3.1.4). Several verbal and non-verbal actions can participate in the same emotional strategy. The fact of smiling, looking at avidly, saying sweet words are different actions for showing love to someone. The selection of one action among others depends on the context.

In TEATIME, the context that defines the choice of action corresponds to the rules of social interaction, which are implemented in the "ideals". Thus, when an action tendency is generated from the appraisal process, the coherence of actions belonging to that tendency with social norms is computed. If no action satisfies the ideals, the agent simply drops the tendency and the system falls back to the task-oriented interaction rules. If one or several actions conform with the ideals and can be directed toward the cause of the emotional strategy, the agent selects one that is addressed to the cause of the event (self, other, circ) and performs it.

Formally, let M be the current model of the world and e and t be the emotional strategy and the target appraised by agent i. We compute the set A^* of actions compatible with the ideals:

$$A^* = \{\ a \in \mathcal{ACT}_i \mid \quad M \models Tend(i,a,e,t)\ \wedge \\ (\forall \phi \in \mathcal{F}, M \models (Done(a,i) \Rightarrow \phi) \Rightarrow \neg Ideal_i \neg \phi)\ \}$$

The agent selects one action in A^* and performs it. In the next dialogue turn, the appraisal process should produce a different emotional strategy and target. If this is not the case, the agent will not select the same action again. This corresponds to the re-appraisal process as described by Frijda (Frijda, 1986).

5 IMPLEMENTATION EXAMPLE

The TEATIME formal model has been implemented in Java and integrated within a virtual agents and chatbot architecture for Customer Relationship Service. To overcome complexity issues that arise with modal logics inference engine (SAT modal logics is NEXP-time complete), we implemented the TEATIME rules as Java methods that manipulate the stimuli. Facts and actions are represented by Java objects and the appraisal variables are computed by methods. The selection of the emotional strategy is computed in linear time.

In this section, we illustrate how the TEATIME model works during a small interaction. We took an insurance application example where the user can ask questions about her contract and evaluate the help given by the agent. It is important to note that our work does not concern Natural Language Processing (NLP). We use a professional engine developed by the French company DAVI to identify which fact has been invoked by the user.

The (domain specific) knowledge base of the agent is represented into an ontology which regroups the insurance expertise and dependencies between facts and actions. The NLP engine identifies the general intention of the user's utterance and turns it into a stimulus (i.e, a fact φ) as shown on figure 3. It uses a set of pattern-matching rules coupled with the domain ontology. This determines which fact has been said by the user and which task-oriented answer should be chosen.

Each fact in the ontology is also associated with beliefs, desires and ideals of the agent, so that the TEATIME formal model can be applied to generate affective responses.

When the NLP engine fails to detect a domain-related intention in the ontology, the agent express an action tendency to "Stop moving toward" which corresponds to the emotional label "Sadness". Indeed, misunderstanding the user utterance is considered to be an in undesirable, uncontrollable, certain fact with an appetitive motive.

Interactions need to be dynamically managed by rules and related to a domain-specific knowledge base.

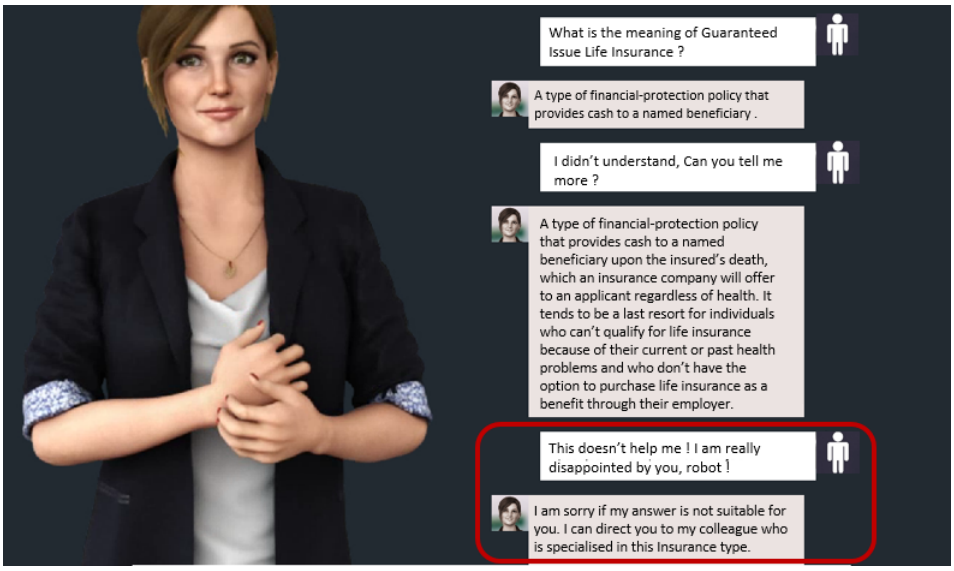

Figure 2: Implementation of Teatime in Insurance expert example.

Interaction Rules

For the example on figure 2, we applied three rules to manage the interaction dynamics :

1. When the agent i asks the agent j to perform an action a, and the action a is executable by the agent j, the agent j performs the action a. This rule is applied to the first and second utterance in the dialogue 2 where the user asks the agent to give information. In our model, it written this way :

   $Ask_{i,j}a \wedge Exec(a,j) \overset{def}{\Rightarrow} Do(a,j)$

2. When the agent i informs the agent j that φ is true, $Bel_j\varphi$ turns true. This rule is applied to the third utterance on figure 2 where the user informs the agent that he is disappointed. We write it this way :

   $Inform_{i,j}\varphi \overset{def}{\Rightarrow} Bel_j\varphi$

3. When the agent i beliefs that φ is true, that is undesirable, certain, uncontrollable related to an intrinsic problem and caused by self, it leads to an emotional strategy MAF. This rule is one of the appraisal rules defined in TEATIME model. It is applied to the third user utterance.

   $Bel_i\varphi \wedge Desir(i,\neg\varphi,+) \wedge Cert(i,\varphi) \wedge Control(i,\varphi) \wedge Prob(i,\varphi) \wedge Caus(\varphi,self) \overset{def}{\Rightarrow} Tend(i,a,MAF,self)$

Facts, Actions and Agents

For the insurance example, we defined a knowledge base containing three actions (a_1 = give-information, a_2 = give-details, a_3 = correct-mistake), three facts(φ_1 = information-given , φ_2 = details-given, φ_3 = customer-disappointment), two agents (*user* = human user, *agent* = virtual insurance expert)and relations between them($(a_1,agent) \in \mathcal{PL}^{\varphi_1}$, $(a_2,agent) \in \mathcal{PL}^{\varphi_2}$)

Interaction Dynamics

Here we describe formally the conversation flow illustrated on figure2:

1. $Ask_{user,agent}a_1$
2. $Ask_{user,agent}a_1 \wedge Exec(a_1,agent) \overset{def}{\Rightarrow} Do(a_1,agent)$
3. $Ask_{user,agent}a_2$
4. $Ask_{user,agent}a_2 \wedge Exec(a_2,agent) \overset{def}{\Rightarrow} Do(a_2,agent)$
5. $Inform_{user,agent}\varphi_3 \overset{def}{\Rightarrow} Bel_{agent}\varphi_3$
6. $Bel_{agent}\varphi_3 \wedge Desir(agent,\neg\varphi_3,+) \wedge Cert(agent,\varphi_3) \wedge \neg Control(agent,\varphi_3) \wedge Prob(agent,\varphi_3,intri) \wedge Caus(\varphi_3,self) \overset{def}{\Rightarrow} Tend(agent,a_3,MAF,self)$

In the example illustrated on figure 2, in the two first user utterance, the appraisal output is null as the facts have no link with agent's desires or ideals. The third one is undesirable for the agent. The whole appraisal process is then done. It is appraised by the agent as an undesirable, certain and uncontrollable, related to an intrinsic problem and caused by "*Self*" (the agent). Following the rules presented in section 4, it leads to an emotional strategy "Move Away From self" and the action tendency to correct the mistake and express regret. In this example, only the

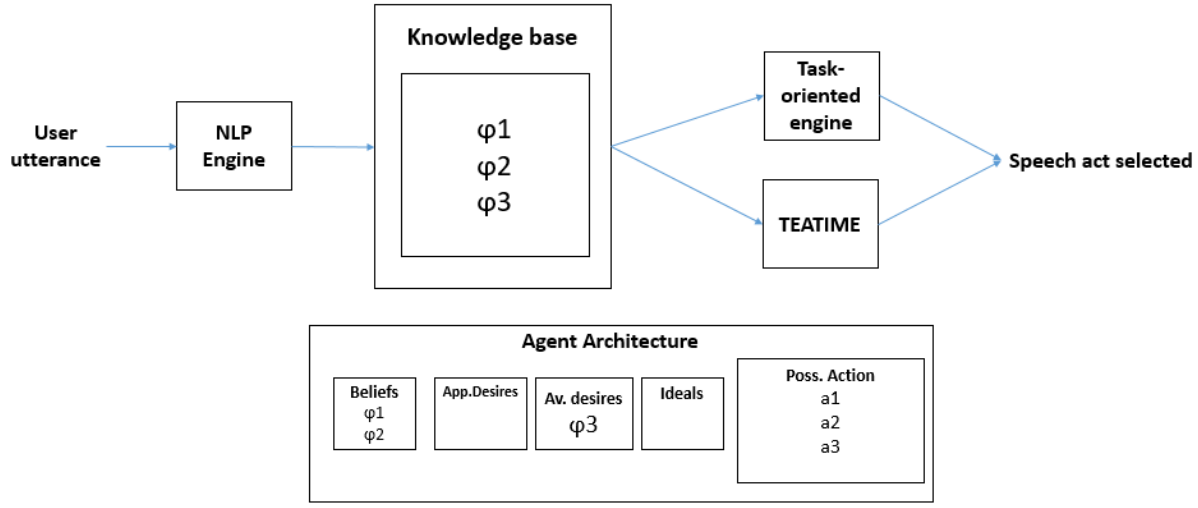

Figure 3: Dialog Process where TEATIME is implemented.

verbal output is impacted by TEATIME (the gesture visible on the screen capture is not controlled by our model, for now).

The strength of the TEATIME model is to offer a general mechanism that can be used to select domain-specific actions sorted by emotional strategy. In the example, the designer needs to specify that:

$$\models Tend(agent, a_3, MAF, self)$$

where a_3 is the action that produces the last textbox and:

$$\models Des_{agent} \neg \varphi_3$$

where φ_3 corresponds to user disappointment (detected by the NLP engine).

6 CONCLUSION

We have presented a formal model of affects which integrates an appraisal process and an action selection mechanism based on the Action Tendency theory. Six appraisal variables are computed according to the agent beliefs, desires, ideals and capacities. The result of this appraisal is an emotional strategy that leads to actions tendency for the conversational agent.

One originality of the TEATIME model is to provide a formal description of the motivational component of emotions, which plays an important role in action selection. The model also conveys social rules of interaction using "ideals".

This model has been implemented but our evaluation is still work-in-progress. We are interested in evaluating the perception of emotions through speech acts produced by the agent. It is also interesting to evaluate the importance of social inhibition during an interaction. An agent without any regulation process would be perceived as non-credible. We are currently defining experimental protocol to support an empirical study on this impact. In order to assess the whole emotional response during the experimental interaction, we also want to extend the TEATIME model to the non-verbal expression of action tendencies through facial expressions, gesture and speech.

REFERENCES

Adam, C., Herzig, A., and Longin, D. (2009). A logical formalization of the occ theory of emotions. *Synthese*, 168(2):201–248.

Arnold, M. B. (1960). Emotion and personality.

Bossuyt, E. (2012). *Experimental studies on the influence of appraisal on emotional action tendencies and associated feelings*. PhD thesis, Ghent University.

Campano, S., Sabouret, N., De Sevin, E., and Corruble, V. (2013). An evaluation of the cor-e computational model for affective behaviors. In *Proceedings of the 2013 international conference on Autonomous agents and multi-agent systems*, pages 745–752. International Foundation for Autonomous Agents and Multiagent Systems.

Coombes, S. A., Tandonnet, C., Fujiyama, H., Janelle, C. M., Cauraugh, J. H., and Summers, J. J. (2009). Emotion and motor preparation: a transcranial magnetic stimulation study of corticospinal motor tract excitability. *Cognitive, Affective, & Behavioral Neuroscience*, 9(4):380–388.

Coppin, G. (2009). Emotion, personality and decision-making. *Revue d'intelligence artificielle*, 23(4):417–432.

Courgeon, M., Clavel, C., and Martin, J.-C. (2009). Appraising emotional events during a real-time interactive game. In *Proceedings of the International Work-*

shop on Affective-Aware Virtual Agents and Social Robots, page 7. ACM.

Dastani, M. and Lorini, E. (2012). A logic of emotions: from appraisal to coping. In *Proceedings of the 11th International Conference on Autonomous Agents and Multiagent Systems-Volume 2*, pages 1133–1140. International Foundation for Autonomous Agents and Multiagent Systems.

Dias, J. and Paiva, A. (2005). Feeling and reasoning: A computational model for emotional characters. In *Portuguese Conference on Artificial Intelligence*, pages 127–140. Springer.

Duffy, E. (1962). Activation and behavior.

Frijda, N. H. (1986). The emotions: Studies in emotion and social interaction. *Paris: Maison de Sciences de l'Homme*.

Frijda, N. H. (2010). Impulsive action and motivation. *Biological psychology*, 84(3):570–579.

Frijda, N. H. and Mesquita, B. (1998). The analysis of emotions. *What develops in emotional development*, page 273œ295.

Frijda, N. H. and Zeelenberg, M. (2001). Appraisal: What is the dependent?

Gebhard, P. (2005). Alma: a layered model of affect. In *Proceedings of the fourth international joint conference on Autonomous agents and multiagent systems*, pages 29–36. ACM.

Gratch, J. and Marsella, S. (2004). A domain-independent framework for modeling emotion. *Cognitive Systems Research*, 5(4):269–306.

Jenkins, J. M. and Oatley, K. (1996). Emotional episodes and emotionality through the life span.

Lazarus, R. S. (1991). Cognition and motivation in emotion. *American psychologist*, 46(4):352.

McDougall, W. (1908). The gregarious instinct.

Mehrabian, A. (1996). Pleasure-arousal-dominance: A general framework for describing and measuring individual differences in temperament. *Current Psychology*, 14(4):261–292.

Ortony, A., Clore, G. L., and Collins, A. (1990). *The cognitive structure of emotions*. Cambridge university press.

Pearl, J. (2009). *Causality*. Cambridge university press.

Prendinger, H. and Ishizuka, M. (2005). The empathic companion: A character-based interface that addresses users'affective states. *Applied Artificial Intelligence*, 19(3-4):267–285.

Pynadath, D. V. and Marsella, S. C. (2005). Psychsim: Modeling theory of mind with decision-theoretic agents. In *IJCAI*, volume 5, pages 1181–1186.

Roseman, I. J. (2011). Emotional behaviors, emotivational goals, emotion strategies: Multiple levels of organization integrate variable and consistent responses. *Emotion Review*, 3(4):434–443.

Scherer, K. R. (2005). What are emotions? and how can they be measured? *Social science information*, 44(4):695–729.

Steunebrink, B. R., Dastani, M., and Meyer, J.-J. C. (2009). A formal model of emotion-based action tendency for intelligent agents. In *Portuguese Conference on Artificial Intelligence*, pages 174–186. Springer.