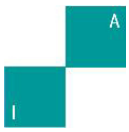
Inteligencia Artificial 50(2012), 30-45



INTELIGENCIA ARTIFICIAL

http://erevista.aepia.org/

Emotion-directed Argument Awareness for Autonomous Agent Reasoning

S. E. Fulladoza Dalibón[1,2], D. C. Martinez[1,2], G. R. Simari[1]
{sef,dcm,grs}@cs.uns.edu.ar

[1]Artificial Intelligence Research and Development Laboratory
Department of Computer Science and Engineering
Universidad Nacional del Sur - Alem 1253, (8000) Bahía Blanca, Buenos Aires

[2]Consejo Nacional de Investigaciones Científicas y Técnicas

Abstract Most of the work on reasoning and decision-making in virtual agents relates the choices with an exhaustive exploration, analysing every possible alternative and implication, and trying to maximize some utility measure in order to make the best decision. Humans, however, seem not to reason and make decisions naturally in this way. As authors such as Herbert A. Simon [21] have proposed, humans seem to develop a concept of bounded rationality, according to which human reasoning process and decision-making is bounded to a part of reality at a time as a focusing effect. According to some psychologists, focus of thought is one of the main purposes of emotions in humans. Using an abstract framework, in this work we propose an approach to consider emotions as an argument-selection heuristic towards the ability for an agent to reason and act in a believable manner. Influenced by emotions, the agent will produce a line of reasoning according to the evolution of its own emotional state.

Keywords: Believable Agent, Emotions, Argument Awareness, Abstract Argumentation Framework.

1 Introduction & Motivation

The study of emotions in Artificial Intelligence is a novel area of research with recently increased interest. Although emotions are often seen as being an obstacle to rational reasoning, when constructing agents that interact with humans the modelling of emotions plays a relevant role. In several scenarios, such as virtual simulations or interactive digital entertainment, a model of emotions may contribute to create *believable* agents, which is a kind of agent that provides the illusion of life, and thus permits the audience's suspension of disbelief [4]. Even more, psychological and neurological evidence suggests that emotions are relevant and necessary for rational behaviour [23], especially in social contexts [14].

We are interested in how emotions affect the behaviour of an agent, specially in the process of reasoning for decision making. In particular, in this paper the focus is put on the study of argumentation processes influenced by emotions. Argumentation is an important subject of research in Artificial Intelligence and it is also of interest for logicians, philosophers, communication theorists, and other researchers in several disciplines. A form of argumentation is present in many activities, most of them related to social interactions between humans, as in civil debates, legal reasoning or every day dialogues. In essence, the subject of study in this discipline is the use of *arguments* as a form of reasoning. An argument is a piece of reasoning that supports a claim from certain evidence. The central idea in Argumentation is that

ISSN: 1988-3064(on-line)

a proposition or claim will be accepted if there exists an argument that supports it, and this argument is regarded as acceptable with respect to an analysis performed considering all the available counterarguments. Therefore some of the arguments will be *acceptable* or *justified* or *warranted* arguments, while others will be not. Usually, a rational agent will examine its knowledge base in order to find arguments for and against the original claim, and for and against arguments found in the same process. This search is exhaustive, and the agent constructs a *dialectical tree* where arguments and counterarguments are analysed. In this tree, some arguments include information which is closely related to the original topic while others are challenging or defending information of minor topics in the overall discussion. When modelling a rational agent with intended believable behaviour, this exhaustive analysis is counter-productive.

In this work we propose an approach to consider emotions as an argument-selection heuristic towards the ability for an agent to reason and act in a believable manner. Being influenced by emotions, the agent will produce a line of reasoning according to the evolution of its own emotional state. This is a natural behaviour. Suppose a fearful person is in his house, and suddenly he realizes there is an increasing smoke from the kitchen. Although there may be several explanations for this, such as overcooked cake or curtains on fire, a fearful person may conclude the kitchen is on fire. There may be reasons to run away or to fight this fire with an extinguisher. However, a fearful person that experiments a strong increase of fear will find reasons to run away, no matter how sound other actions are. Arguments for running are highly selectable, because they are consistent with the emotion of fear. Even more, its emotional state is not static. As long as this person realizes that there is a fire in the house and it is possible to save his life by using an extinguisher, other thoughts may arise in his mind, as "Call insurance company" or "Review cooking times in recipe". As the consideration of pieces of information continues, the emotional state of the agent naturally flows. This pattern of thinking is interesting for modelling believable behaviour in virtual environments as simulations and entertainment software.

Several authors consider emotions as an input in reasoning and decision-making [24, 11, 20, 5, 16, 12, 13]. Moreover, the idea of using emotions as heuristics in decision making process, in contexts where it is not possible (or realistic) to consider all alternatives, has been discussed previously in [9]. In particular, we are not interested in establishing a strong causal relation between descriptions of situations (including emotions) and decisions, as many approaches do. We do not want to consider emotions just as an extra factor that the agent must take into account. Neither we want to establish a direct matching between emotion patterns and behaviours, as we do not know all the necessary variables to do so properly, and furthermore, there is not certainty about whether human behaviour is deterministic or not. Because of that, we try to keep the determinism at bay by introducing some dynamics in the relation between emotions and behaviours. Our model uses emotions as a mechanism causing the origination of some thoughts (those which are relevant to the set of the agent's emotions at the situation), and the concealment of other (those which are not relevant). The arisen thoughts have effects over the emotions felt by the agent, changing their values, and so the conditions to the emergence of the following thoughts. In this way, the chaining of originated thoughts leads to conclusions, and later to decisions, that are not only compatible with the explicit information about the situation (the typical situation descriptors), but also are (during the process) promoted by agent's internal information about the situation: its emotional context. So, we propose the use of emotions as a control mechanism over *what is thought* by an agent, in such a way there is an indirect control over its conclusions, i.e., over what it believes, what it decides, and then how it behaves.

We are not proposing a new theory of emotions, but a form of integration of emotion models with argumentation. In our framework, an emotional agent is equipped with an argumentation framework and an internal emotional context. Both elements are treated in an abstract level, without specifying how arguments are constructed nor what is the implemented emotional model. The emotional context may change as arguments are identified by the agent. Also, the relevance of arguments is influenced by the emotional context of the agent. If an agent experiences extreme fear, it may start *thinking* about arguments that deepens the fear emotion, which in turn leads to a blocking of more anti-fear arguments.

This paper is organized as follows: In section 2, we show a brief review on the work done over integration of emotions on virtual agents and make a short revision on abstract argumentation frameworks. In section 3, we present the formalism: the proposed argumentation framework, the emotional context. In section 4, we describe an Emotionally Influenced Agent, an agent that selects emotionally relevant arguments for thinking, presents some functions (additional to these in the framework) that help the agent

doing so, and we explain the process of argument selection (or awareness). Also we discuss some ideas about management over possible conflicts between aware arguments, and the influence of the resolution of such conflicts over the process of awareness. In section 5 we present a functional example showing the process of argument selection, and remark in the dynamics of emotions and its influence in argument awareness. Finally, we draw conclusions and mention future work.

2 Background

2.1 Emotions in Agents

The concept of emotion is somehow discussed, with little consensus on its formal meaning. There are, however, various approaches to emotion characterizations proposed by the affective computing community, such as the OCC model [18], which decomposes emotions according as reactions to the consequences of events, consequences of an agent's actions, and an agent's attitude towards certain objects. This approach, as well as these presented in [19] and [10] among others, are known as *appraisal theories of emotion*. According to the appraisal theories, the human emotions arise as result of cognitive evaluations over elements on the environment. The appraisal of such elements is made concerning some set of fixed variables (such as event desirability, relevance, controllability) that differ between particular theories. The OCC model is used in some agent architectures [22, 6] since it introduces a computationally tractable model of emotions. However, we are not only interested in the modelling of the emotions elicitation, but also in the influence of emotions over the process of thought, and then over decision-making and behaviour.

In this regard, a formalization of the action tendency using OCC model was presented in [23], introducing a mechanism for limiting and ordering options in an agent's action selection process. The EMA model [10, 17] is also a particularly interesting approach since, in addition to the arousal of emotions through the event appraisal, it presents different coping strategies [15] in order to model how the elicited emotions influence over other cognitive functions. In such work, the effect of appraised emotions over attention, believes, intentions, actions and even over future appraisals is considered. Similarly, in FAtiMA architecture [6] an OCC-based appraisal mechanism is combined with a continuous planner that implements problem-focused and emotion-focused coping.

Our proposal can be associated with the appraisal theories since, in our work, the relation between cognitive elements (represented through arguments) and the elicited emotions is made explicitly. Also, as in EMA model [17], in our framework the elicited emotions have effect on other cognitive functions. However, unlike in EMA and the other appraisal models, in which the focus of the appraisal is set in the elements of the environment (appraising strictly each one of these according to a fixed set of variables), in our framework the emergence of emotions is directed by what the agent thinks (which may include some current elements of the environment). We can also relate our framework with [23] in the sense of being a criteria for emotion-based selection. However, we are focused in the agent's inner process of reasoning through successive arguments awareness, instead of emotions directly linked to specific actions.

In the following section we recall elemental notions of classic abstract argumentation.

2.2 Argumentation frameworks

One of the main concerns in Argumentation Theory is the search for rationally based positions of acceptance in a given scenario of arguments and their relationships. This task requires some level of abstraction in order to study pure semantic notions. Abstract argumentation systems [7, 26] are formalisms for argumentation where some components remain unspecified, being the structure of an argument the main abstraction. In this kind of system, the emphasis is put on the semantic notion of finding the set of accepted arguments. Most of these systems are based on the concept of *attack* represented as an abstract relation, and extensions are defined as sets of possibly accepted arguments. For two arguments $\mathcal{A}$ and $\mathcal{B}$, if $(\mathcal{A}, \mathcal{B})$ is in the attack relation, then the acceptance of $\mathcal{B}$ is conditioned by the acceptance of $\mathcal{A}$, but not the other way around. It is said that argument $\mathcal{A}$ *attacks* $\mathcal{B}$, and it implies a priority between conflicting arguments.

The simplest abstract framework is defined by Dung in [7]. It only includes a set of abstract arguments and a binary relation of attack between arguments. Several semantics notions are defined and the Dung's argument extensions became the foundation of further research. Dung defines several argument extensions that are used as a reference for many authors. The formal definition of the classic argumentation framework follows.

Definition 1. *[7]* An argumentation framework is a pair $AF = \langle AR, attacks \rangle$ where AR is a set of arguments, and $attacks \subseteq AR \times AR$.

A set of accepted arguments is characterized in [7] using the concept of *acceptability*, which is a central notion in argumentation, formalized by Dung in the following definition.

Definition 2. *[7]* An argument $\mathcal{A} \in AR$ is *acceptable* with respect to a set of arguments S if and only if every argument $\mathcal{B}$ attacking $\mathcal{A}$ is attacked by an argument in S.

If an argument $\mathcal{A}$ is acceptable with respect to a set of arguments S then it is also said that S *defends* $\mathcal{A}$. Also, the attackers of the attackers of $\mathcal{A}$ are called *defenders* of $\mathcal{A}$. Acceptability is the main property of Dung's semantic notions, which are summarized in the following definition.

Definition 3. A set of arguments S is said to be
– *conflict-free* if there are no arguments $\mathcal{A}, \mathcal{B}$ in S such that $\mathcal{A}$ attacks $\mathcal{B}$.
– *admissible* if it is conflict-free and defends all its elements.
– a *preferred extension* if S is a maximal admissible set.
– a *complete extension* if S is admissible and it includes every acceptable argument w.r.t. S.
– a *grounded extension* if and only if it is the least complete extension.
– a *stable extension* if S is conflict-free and it attacks each argument not in S.

3 Combining Emotions and Arguments

As we have stated before while discussing believable behaviour, for any person in a given situation, not all the knowledge in its mind is equally relevant and present as a whole. Some thoughts arise which are compatible with the person's inner emotional context at the particular situation.

In order to model such an effect on thinking for believable agents, we have combined the arguments (the way in which we represent thoughts) and the emotions. In our model, basically, given an emotional context, there will be a subset of arguments from the universe of arguments -thoughts- that are consistent with it, and then these arguments will be available to arise as a thought in the agent's reasoning process. Also, when a thought arises, it has emotional consequences -as emotional side effects- that produce variations on the emotional context. In such a way, the environment in which the next thought arises is different from the previous one, and so a thought indirectly influences on what is thought next.

In this section, we present the components that integrates an agent that reasons by successively selecting arguments following an emotional criteria.

3.1 Emotional Context

One of the main elements on the formalism is a dynamic component, formed by a collection of all the emotions that the agent currently experiences and its current values. This collection is called the agent's *emotional context*. As stated before, we treat emotions in an abstract level and no references to a particular emotion model is made. A single emotion is represented as a positive literal and it is called here an *emotional factor*.

Definition 4. (Emotional Factor) An Emotional Factor EF is a positive literal in the form $ef\_name(p_1, \ldots, p_n)$, where the functor ef_name is the emotional factor name, and $p_1, \ldots, p_n$ are terms.

Examples of Emotional Factor can be *fear(fire)*, or *friendliness(kelly)*, the first representing the fear emotion toward the fire, and the second the attitude friendliness toward Kelly. Note that it is possible to

implement the OCC emotion model by representing each one of the 22 emotions by an emotional factor, but, as remarked before, it is not the intention of this paper.

An emotion is not a binary condition (to have fear or not). It can appear with different intensities at different times. A valued emotional factor is an emotional factor with a numerical graduation representing intensiveness.

Definition 5. (Valued Emotional Factor) A Valued Emotional Factor is a tuple $VEF = (EF, val)$ where EF is a Emotional Factor and $val \in \mathbb{Z}$ is a value representing the intensity of the Emotional Factor.

For example, a Valued Emotional Factor can be $(fear(fire), 5)$, representing that the emotion $fear$ toward the fire has an intensity of 5. The higher the value, the most intense is the emotion. We do not impose any numerical scale.

The emotional context of an agent is a collection of valued emotional factors, describing all the current emotions experienced by the agent and its intensities.

Definition 6. (Emotional Context) An Emotional Context EC is a finite set of Valued Emotional Factors. Given a Emotional Context EC, for each pair of Valued Emotional Factors $VEF_i = (EF_i, v_i)$, $VEF_j = (EF_j, v_j) \in EC$ if $VEF_i \neq VEF_j$, then $EF_i \neq EF_j$.

For instance, the set $EC = \{(fear(fire), 5), (friendliness(kelly), 3), (sad(alone), 7)\}$ is an emotional context.

3.2 Emotional Argumentation Framework

The second main element is an emotionally extended framework in which the arguments are related with emotions by means of functions establishing both the emotional conditions for availability of the arguments and emotional effects triggered by arguments.

Definition 7. (Emotional Argumentation Framework) An Emotional Argumentation Framework is a tuple $\Phi = (Args, Attacks, EFs, AS, ES, ESE)$ where

- $Args$ is a finite set of Arguments,
- $Attacks \subseteq Args \times Args$,
- EFs is a finite set of Emotional Factors,
- AS is an Activation Stimuli Function $AS : Args \to \mathbb{Z}$.
- ES is an Emotional Stimuli Function $ES : Args \times EFs \to \mathbb{Z}$,
- ESE is a Emotional Side Effect Function $ESE : Args \times EFs \to \mathbb{Z}$,

The arguments in $Args$ are not always available to be used. The main idea for capturing believable behaviour is that an argument has to satisfy a requirement, i.e., it has to reach some *stimuli*, to become interesting. Then the argument is said to be *activated*. The amount of stimuli required for the activation of a particular argument A is determined by the Activation Stimuli Function. For an EAF $\Phi = (Args, Attacks, EFs, AS, ES, ESE)$, the Activation Stimuli Function AS for an argument $A \in Args$ is such that $AS(A)$ is the minimum amount of stimuli required by A in order to be activated.

We have already displayed a way to know how much stimuli is required by a particular argument to be activated. However we have not said anything yet about the way in which an argument obtain that required stimuli to be activated. For that, various elements are involved: These are the *emotional stimuli*, the *contextual value*, and the *stimuli score* functions.

The *Emotional Stimuli Function* indicates the effect (influence) that each internal factor has over the stimuli of each particular argument. In other words, for an argument A and for an emotional factor EF_i, the function returns the amount in which the current value of EF_i (in the EC) increases/decreases the stimuli of the argument. For an EAF $\Phi = (Args, Attacks, EFs, AS, ES, ESE)$, for each Emotional Factor $EF \in EFs$ and each argument $A \in Args$, the Emotional Stimuli Function ES is such that $ES(A, EF) = i$, where the value i represents that EF increases/decreases the stimuli of A i times the current value of EF.

Example 1. *Suppose an argument A = "there is a fire, I should run away", and the emotional factor $fear(fire)$. Suppose that $ES(A, fear(fire)) = 3$, and $(fear(fire), 2)$ is a valued emotional factor in the emotional context. Then, the consideration of the argument A is stimulated by the $fear(fire)$ emotion in the amount of* 3 *times the current value of $fear(fire)$, obtained from the corresponding valued emotional factor in the current emotional context (in this case* 2*). So, the argument A is stimulated by the $fear(fire)$ emotional factor in $(3*2) = 6$ points. The more intense the emotion of $fear(fire)$ felt by the agent in the situation, the more stimuli obtains the argument A. Now, suppose the emotion* sadness*, and suppose that $ES(A, sadness) = 0$. Despite the agent may be very sad, the emotion* sadness *is in this case irrelevant to the stimulation of argument A, and then it does not provide any stimuli to this argument. There are emotional factors that are highly relevant to some argument stimuli (i.e., to the emergence of a thought), while other factors are less relevant, or not relevant at all. Through the ES function, we can represent which factors are relevant to which arguments, and how relevant they are.*

As we can see from the previous function, it is necessary to recover the current value of the emotional factor in order to calculate the real amount of stimuli provided by an emotional factor to the argument. To this end, we define the *Contextual Value Function* that returns the current value of a given emotional factor if it is present in the emotional context, zero otherwise.

Definition 8. (Contextual Value Function) Let EF be an Emotional Factor and $EC = (VEF_1, VEF_2, \ldots, VEF_n)$ an Emotional Context, where $VEF_i = (EF_i, val_i)$. The Contextual Value Function $CV : EFs \times EC \rightarrow \mathbb{Z}$ is such that $CV(EF, EC) = val_i$, if $\exists VEF_i \in EC$ such that $EF_i = EF$, otherwise $CV(EF, EC) = 0$.

Finally, the *Stimuli Score Function* computes the overall stimuli of the argument (how relevant this argument is in the given context), by considering the stimuli provided by all the emotional factors affecting the argument. This is not a fixed part of the framework, so we present the following implementation, but others may be used.

Definition 9. (Stimuli Score Function) Let $\Phi = (Args, Attacks, EFs, AS, ES, ESE)$ be an EAF, where $EFs = \{EF_1, EF_2, \ldots, EF_n\}$, let $A \in Args$ be an argument and let EC be an Emotional Context. The Stimuli Score Function $SSc_\Phi : Args \times EC \rightarrow \mathbb{Z}$ is such that $SSc_\Phi(A, EC) = \sum_{i=1}^{n} CV(EF_i, EC) * ES(A, EF_i)$.

Example 2. *Consider the emotional factors $\{fear, sadness, anger, happiness, ...\} \in EFs$, the emotional context EC = ((fear,3), (sadness,2), (anger,4), (happiness,1), ...), an argument $A \in Args$, and suppose that $ES(A, fear) = 2$, $ES(A, sadness) = 2$, $ES(A, anger) = 1$, $ES(A, happiness) = 0$, and for all other emotional factor EF_* is $ES(A, EF_*) = 0$ (i.e., these do not influence A's stimuli). Then, $SSc(A, EC) = 3 * 2 + 2 * 2 + 4 * 1 + 1 * 0 + CV(EF_k, EC) * 0 + \cdots + CV(EF_n, EC) * 0 = 14$. This means that, in the emotional context EC, the argument A has a stimuli of* 14 *points. Note that the stimuli of the argument would be different under another emotional context. But, what does that particular value implies? Without a context, it is just a number. To become more meaningful it should be analysed in relation to the stimuli of another arguments. Suppose a context in which such stimuli (*14*) is one of the highest argument's stimuli. Then, in such context, A is an interesting argument to be considered against other less stimulated arguments. In the other hand, if it is the case of a context in which there are many arguments much more emotionally stimulated than it, then A is not interesting at all.*

As we stated before, as well as the emotions influence the availability of arguments, the consideration of arguments have influence over emotions. Such influence provides in our framework the dynamic nature that the emotional context has. The *Emotional Side Effect Function* indicates which is the emotional effect of each argument over each emotional factor, and thus, how each argument impacts over the current emotional context. For an EAF $\Phi = (Args, Attacks, EFs, AS, ES, ESE)$, the Emotional Side Effect Function ESE of an argument $A \in Args$ over an Emotional Factor $EF \in EFs$ is such that $ESE(A, EF) = \Delta i$, meaning that the dialectical use of A increments/decreases on Δi the value of EF on EC. The Emotional Side Effect Function determines the variation over the current value of EF in the EC caused by the use of an argument A. Δi represents the amount in which the Emotional Factor EF is increased or decreased.

Example 3. *Consider an EC containing a VEF* $(fear, 3)$*, an argument A, and suppose that* $ESE(A, fear) = -2$*. If argument A is used in the dialectical process, then the value of fear in the EC will be decreased by* 2*, so the actualized EC will contain the VEF* $(fear, 1)$ *instead of* $(fear, 3)$*.*

In the following section we present the notion of *Emotionally Influenced Agent* which uses an *Emotional Argumentation Framework* as just defined.

4 Emotionally Influenced Agent

An Emotionally Influenced Agent is defined by the two previous elements: an *emotional argumentation framework* and an *emotional context*. The emotional argumentation framework, as we present in the previous section, represents the set of available arguments, their attacks, the conditions for the arguments activation defined over the emotional context, and the variations caused by the arguments to the emotional context. The emotional context represents the set of all current emotional factors, and current values, that the agent experiences.

Definition 10. (Emotionally Influenced Agent) An Emotionally Influenced Agent is a tuple $Ag = (\Phi, EC)$, where Φ is an Emotional Argumentation Framework and EC is the agent's Emotional Context.

An agent reasons by a progressive consideration of arguments, under an evolutive emotional context. The arguments represents the possible thoughts of the agent, and the emotional context influences over which of these thoughts (arguments) are emotionally relevant for the situation. An argument emotionally relevant to a situation is said to be *activated* in such situation. In order to discover which arguments are currently activated, the agent uses the *arousal function*, that returns the subset of activated arguments from the universe of possible arguments. An argument is activated for a situation with an emotional context EC if its stimuli score according to EC reaches its activation stimuli.

Definition 11. (Arousal Function)
Let $\Phi = (Args, Attacks, EFs, AS, ES, ESE)$ be an EAS. Let EC be an Emotional Context. The Arousal Function $AF_\Phi : EC \rightarrow Args$ is such that $AF_\Phi(EC) = \{A \in Args \text{ such that } SSc_\Phi(A, EC) \geq AS(A)\}$

When an argument is considered, its associated *emotional side effects* are triggered, producing changes over the current emotional context, according to the Emotional Context Update Function.

Definition 12. (Emotional Context Update Function) Let $Ag = (\Phi, EC)$ be an Emotionally Influenced Agent, where $\Phi = (Args, Attacks, EFs, AS, ES, ESE)$, $EC = (VEF_1, \ldots, VEF_n)$ is an Emotional Context with $VEF_i = (EF_i, val_i)$, and let $A \in Args$ be an argument. The Emotional Context Update Function $ECV : ECs \times Args \rightarrow ECs$ is such that $ECV(EC, A) = EC'$, with $EC' = (VEF'_1, \ldots, VEF'_n)$ and $VEF'_i = (EF_i, val'_i)$, where for each $VEF'_i \in EC'$ is $val'_i = val_i + ESE(A, EF_i)$.

Each time a new argument is considered, the emotional context variates as consequence. The sequence of arguments leading to an emotional context is called an *emotional argumentation stage*. It is represented by such sequence and the concluding emotional context. This is formalized in the following definitions.

Definition 13. (Argumentation Sequence) An Argumentation Sequence $ASeq$ is a sequence $[A_0, \ldots, A_n]$ such that $\forall i A_i \in Args$.

Definition 14. (Emotional Argumentation Stage) An Emotional Argumentation Stage ST is a pair $(ASeq, EC)$ where $ASeq$ is an Argumentation Sequence and EC is an Emotional Context. For an Emotional Argumentation Stage ST_i, we call ST_i^s to its Argumentation Sequence and ST_i^e to its Emotional Context.

An agent starts from an initial Emotional Context EC_0 and an empty Argumentation Sequence $[\,]$, which configures the initial emotional argumentation stage ST_0, and it reasons through successive transitions between emotional argumentation stages. It is possible to move from a stage ST_A to another ST_B through a Stage Transition, according to which an argument $X \in Args$ is selected and attached to the end of ST_A^s into the new Argumentation Sequence ST_B^s and the Emotion Context ST_B^e is obtained by applying the emotional side effects of the argument X over ST_A^e. Remember that not every argument in $Args$ is plausible to be considered for a transition from ST_A to another stage. Only activated arguments (the relevant ones in the actual context) are considered, i.e., the arguments in $AS(ST_A^e)$.

Definition 15. (Stage Transition) Given the Emotional Argumentation Stages ST_A, ST_B and the argument $X \in AS(ST_A^e)$, the Stage Transition $ST_A \xrightarrow{X} ST_B$ is such that $ST_B = ([ST_A, X], ECV(ST_A^e, X))$.

In the following section, we present a more refined transition between Emotional Argumentation Stages, in wich only the most stimulated arguments are selected.

4.1 Focused Selection

We have established so far the condition that an argument, in order to be considered in an emotional argumentation stage, must be activated according to the previous stage's emotional context. However, since the emotional context variates dynamically as a result of the considered arguments, and thus that variation changes the conditions under which an argument is selected to be considered into the next stage, the order in which the arguments are introduced are very relevant to the final set of considered arguments. We propose then, as an extra condition, that for an argument to be selected in an emotional argumentation stage, in addition to be activated in that stage, it must be contextually preferred over all other available (activated) but not yet used argument according the stage's emotional context. An argument A is contextually preferred to another argument B according to an emotional context EC if the stimuli for A is at least as much as the stimuli for B.

Definition 16. (Contextual Preference) Given an Emotional Context EC_i and two arguments $A, B \in AF(EC_i)$, we say A is preferred over EC_i with respect to B if and only if $SSc(A, EC_i) \geq SSc(B, EC_i)$.

Proposition 1. *Given the Arguments $A, B \in AF(EC_i)$, if $SSc(A, EC_i) = SSc(B, EC_i)$ then both A is preferred over EC_i to B and B is preferred over EC_i to A.*

The contextually preferred set for an emotional argumentation stage is the set of all arguments that are not present in the argumentation sequence of that stage and are contextually preferred to every other argument that is not in the argumentation sequence of the stage.

Definition 17. (Contextually Preferred Set) Given an Emotional Argumentation Stage ST_i and the $EAF\ \Phi = (Args, Attacks, AS, ES, ESE)$, the Contextually Preferred Set $CPS_\Phi : ST \rightarrow Args$ is such that $CPS_\Phi(ST_i^e) = \{A \in Args - ST_i^s$ if A is preferred over ST_i^e to every Argument $B \in Args - ST_i^s\}$.

Since we want the emotional relevance to be preserved through the reasoning process, we state that every Stage Transition must be a Focused Stage Transition.

Definition 18. (Focused Stage Transition) Given an EAF Φ, a Stage Transition $ST_A \xrightarrow{X} ST_B$ is a Focused Stage Transition if and only if $X \in CPS_\Phi(ST_A)$.

Example 4. *Suppose that the agent is in the stage $ST_2 = ([A_0, A_1], EC)$, and it has the arguments $\{A_0, A_1, A_2, A_3, A_4, A_5\}$ with $AS(A_0) = 3$, $AS(A_1) = 2$, $AS(A_2) = 5$, $AS(A_3) = 7$, $AS(A_4) = 4$, $AS(A_5) = 9$, $SSc(A_0, EC) = 11$, $SSc(A_1, EC) = 10$, $SSc(A_2, EC) = 5$, $SSc(A_3, EC) = 8$, $SSc(A_4, EC) = 8$, and $SSc(A_5, EC) = 5$. Although arguments A_0 and A_1 are activated, transitions $([A_0, A_1], EC) \xrightarrow{A_0} ([A_0, A_1, A_0], EC')$ and $([A_0, A_1], EC) \xrightarrow{A_1} ([A_0, A_1, A_1], EC')$ are not possible since A_0 and A_1 are already on the base sequence. A_5 is not activated, since $AS(A_5) > SSc(A_5, ST_2)$. Both A_2, A_3 and A_4 are activated, but only transitions $([A_0, A_1], EC) \xrightarrow{A_3} ([A_0, A_1, A_3], EC')$ and $([A_0, A_1], EC) \xrightarrow{A_4} ([A_0, A_1, A_4], EC')$ are Focused Stage Transitions since $A_3, A_4 \in CPS_\Phi(EC)$ because $SSc(A_3) = SSc(A_4) > SSc(A_2)$.*

Example 5. *To consider the concept in a less abstract situation, suppose an agent in a stage where the last selected argument is argument A, concluding that the kitchen is on fire and the argument, and has the argument B, concluding to run away, as a possible argument to be selected in the following transition. Suppose there are another possible arguments concluding alternatives to run away, such as to extinguish the fire, to call to the fire department, to put aside some important things, and so on. In order to be a focused stage transition, the stage transition $([..., A], EC) \xrightarrow{B} ([..., A, B], EC')$ must be such that B (the argument for run away) is a contextually preferred argument over EC (the emotional context that results*

from the evaluation of the argument A concluding that the kitchen is on fire). That is to say that the argument for run away must be, according to the emotional context EC, at least as good (emotionally stimulated) as the alternative arguments.

In Figure 1, we show a general schema about a transition from an emotional argumentation stage to another, making visible the relations between the main previous concepts. In that schema we can see that:

1. From the stage ST_4 and by the help of AS and SSc functions, the sets of activated ($AF(Args, EC_4)$) and contextually preferred ($CPS(ST_4)$) arguments are obtained.
2. An argument (A_4) is selected from the set of *contextually preferred* ones. There are not restrictions on which of these must be selected.
3. Argument A_4 is added to the argumentation sequence in the stage ST_5.
4. The emotional side effects of A_4 (defined by the ESE function) are triggered. Thus, the new emotional context EC_5 is generated from the application of the emotional side effects over the previous emotional context EC_4.

In items 1 and 2 it is shown how the argument that will lead to the transition is selected. In items 3 and 4 it is shown the effect of the transition in the reasoning process. The new emotional argumentation stage ST_5 will configure the starting point for the next stage transition.

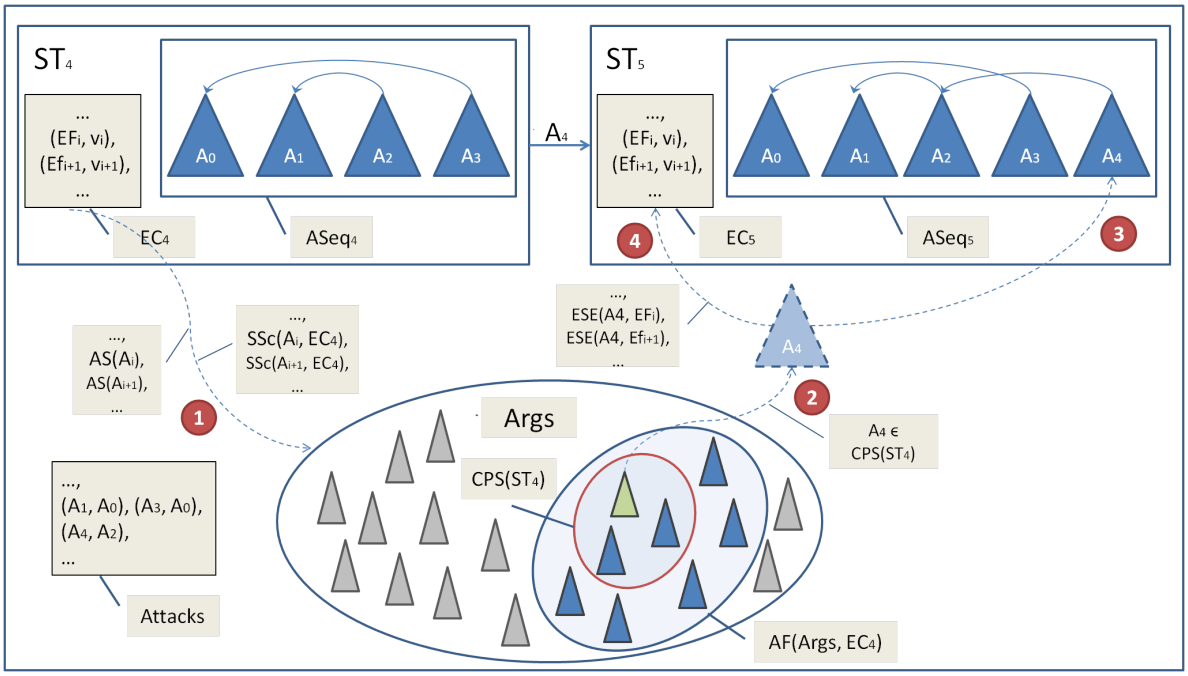


Figure 1: Transition between emotional argumentation stages

As a final analysis, consider jointly the interactions between the components: from a set of available arguments, the emotional side effects may differ from an argument to another. Thus, depending on which stage transition is selected by an agent from a stage (i.e., which is the selected argument), it may result on different emotional contexts for the next stage. Since the activated and the contextually preferred sets of arguments depends directly on the emotional context, the selected argument for a transition depends on the activation and contextual preference, and the emotional context depends on the selected argument again, then the argument selection in a stage transition influences indirectly on the argument selection on following stages transitions. In such a way, configuring correctly both the emotions triggered by the consideration of the arguments, and the emotional conditions for their emergence (i.e, the AS, ES and

ESE functions in the framework), we think it is possible for an emotionally influenced agent to follow a coherent reasoning sequence based on emotions.

4.2 Conflicts in an emotional argumentation stage

Given an emotional argumentation stage ST_n, note that the set of arguments in ST_n^S is a subset of $Args$, and the attacks among arguments in ST_n^S are a subset of $Attacks$. As it may exist contradictions among the arguments in ST_n^S (and then there may be contradictory conclusions), it may be required to decide what to believe in the stage. In order to obtain a consistent set of arguments, it can be used any Dung's extension [7] over the set of arguments on ST_n^S. However, since we maintain useful emotional information at each stage, we believe that we can develop a more suitable method that takes advantage of it so the agent can decide among contradictory arguments. Emotions could be used, alone or in combination with some other factors, as a measure of the arguments strength, and then induces an order of preference between arguments. Note that, since emotion values change dynamically, it would be a dynamic order, and would depend in the current emotional context. According to this, a *Preference-Based Argumentation Framework* [1, 3, 2] could be built from any argumentation stage ST_n. The current stimuli ($SSc(A_*, ST_n^e)$) of each argument in ST_n^s would be used as the value to establish the preference order between arguments, in such a way that a more stimulated argument would be preferred to a less stimulated argument. Hence, refined extensions, where the most stimulated arguments prevail, can be obtained. As we stated before, due to the variation in the emotional context and in arguments among emotional argumentation stages, refined extensions will vary from a stage to another. Synergistic more complex approaches where, for instance, arguments can ally in joint attacks against stronger ones (see accrual of arguments [25]), can also be related to Emotional Argumentation Frameworks.

In addition to this, the interaction between arguments in a stage ST_n should impact in emotions, since as our thoughts modify our emotional context, decisions also do. Then, in the case of deciding between two conflicting argument A and B, the emotional context resulting from the agent opting for argument A would be different to the emotional context resulting from the agent opting for B, and this variability may originate different thoughts in response. Such an effect would enrich the dynamic of the reasoning process, making it more realistic.

In the following section, we present an example showing the process of argument selection in an Emotionally Influenced Agent.

5 A functional example

In this section, we introduce a reduced example. Here we show the way in which under a given emotional context some arguments become activated and others do not. Also we show that when one of these arguments is selected (this means that the agent has such thought), the emotional context variates as consequence, and then may happen that some arguments that were not activated in the past scenario become activated now, and some others that were activated are now non-activated. This causes that, possibly, different thoughts are available to be brought to mind depending on the current dynamically changing emotional context.

Suppose the following situation: An agent is in his house, watching T.V. quietly over his sofa. His pet is rounding the room. Suddenly it hits a rack next to the T.V. and a candle falls over the carpet, and it ignites rapidly. The fire extends in direction to the curtains and the table, and soon also the tablecloth is burning. Our agent must react, but it can reason in very different ways. As an example, consider the following arguments as possible agent's thoughts:

$$\left\{\begin{array}{c} A_0 : \text{“There is a fire in the room”} \\ A_1 : \text{“The house is on fire, I must go away as soon as I can”} \\ A_2 : \text{“There is a fire, I must extinct the fire before it grows”} \\ A_3 : \text{“It's all on fire! I going to die!”} \\ A_4 : \text{“The fire will burn my possessions, I must rescue what I can”} \\ A_5 : \text{“The fire will burn my possessions, I going to lost all what I have”} \\ A_6 : \text{“The fire will burn my possessions, but if I stop the fire my goods will be safe”} \\ A_7 : \text{“The fire will burn my possessions, but the insurance} \\ \text{company will cover all my losses”} \end{array}\right\} \subset Args$$

and the emotional factors $\{e_{fd}$: fear(die), e_{co}: courage(), e_{ca}: calm(), e_{fp}: fear(loss_possessions)$\} \subset EFs$.

Now, we describe the ES, AS, ESE functions, and the initial emotional context EC_0. To model different agents (i.e., agents who perform different personalities, have different backgrounds, etc, and so behave differently) we can set different configurations over the ES, AS and ESE functions. In the framework, we do not impose any range for values of functions. The configuration of the functions is particular to each implementation, and then implementers are free and responsible for the preservation of the equilibrium in the agent's criteria. Since the implementer configures both the emotional variations (through the ESE function) and the semantic of the emotions (through the AS and ES functions), he can use any scale he want to use, but being consistent on it, according to the effect he desires to show.

For instance, to naively model a fearful agent, we can follow the guideline below:

- Make the AS function to have lower values for fear-consistent arguments (such as A_1, A_3), for these thoughts to become less restrictive to arise. This way, this kind of thoughts will be more “usual” in such kind of agents.
- Make the ES function to reflect higher influence of fear-like emotional factors over fear-consistent arguments, for these thoughts to become more stimulated by such emotions. This way, lower values of fear-like EFs promote in this kind of agents thoughts that in more “normal” agents would require higher values of fear-like EFs.
- Make the ESE function to include fear-like EFs as a side effect on a greater diversity of arguments, and in higher intensity. For example, an agent who is highly afraid of snakes, may feel quite high increase of fear when considering arguments about snakes, even if the argument is not about a snake near the agent.

For the current example, we model a slightly valiant and a little materialistic agent. The agent is not very prone to fear, but tends to protect its possessions. It becomes it a little disturbed when its possessions are in risk. The ES, AS, and ESE functions for the agent are described as follow:

$$A_0 : \left\{\begin{array}{l} AS(A_0) = -15 \\ \hline ES(A_0, e_{fd}) = 4; ES(A_0, e_{co}) = 0 \\ ES(A_0, e_{ca}) = -1; ES(A_0, e_{fp}) = 3 \\ \hline ESE(A_0, e_{fd}) = 2; ESE(A_0, e_{co}) = -1 \\ ESE(A_0, e_{ca}) = -4; ESE(A_0, e_{fp}) = 4 \end{array}\right. \quad A_1 : \left\{\begin{array}{l} AS(A_1) = 10 \\ \hline ES(A_1, e_{fd}) = 5; ES(A_1, e_{co}) = -3 \\ ES(A_1, e_{ca}) = -2; ES(A_1, e_{fp}) = 0 \\ \hline ESE(A_1, e_{fd}) = 1; ESE(A_1, e_{co}) = -2 \\ ESE(A_1, e_{ca}) = -3; ESE(A_1, e_{fp}) = 0 \end{array}\right.$$

$$A_2 : \left\{\begin{array}{l} AS(A_2) = 35 \\ \hline ES(A_2, e_{fd}) = -2; ES(A_2, e_{co}) = 4 \\ ES(A_2, e_{ca}) = 1; ES(A_2, e_{fp}) = 1 \\ \hline ESE(A_2, e_{fd}) = 0; ESE(A_2, e_{co}) = 3 \\ ESE(A_2, e_{ca}) = 1; ESE(A_2, e_{fp}) = 0 \end{array}\right. \quad A_3 : \left\{\begin{array}{l} AS(A_3) = 50 \\ \hline ES(A_3, e_{fd}) = 4; ES(A_3, e_{co}) = -4 \\ ES(A_3, e_{ca}) = -5; ES(A_3, e_{fp}) = 0 \\ \hline ESE(A_3, e_{fd}) = 4; ESE(A_3, e_{co}) = -3 \\ ESE(A_3, e_{ca}) = -5; ESE(A_3, e_{fp}) = 0 \end{array}\right.$$

$$A_4 : \left\{\begin{array}{l} AS(A_4) = 20 \\ \hline ES(A_4, e_{fd}) = -1; ES(A_4, e_{co}) = 3 \\ ES(A_4, e_{ca}) = 1; ES(A_4, e_{fp}) = 4 \\ \hline ESE(A_4, e_{fd}) = -1; ESE(A_4, e_{co}) = 2 \\ ESE(A_4, e_{ca}) = 0; ESE(A_4, e_{fp}) = 0 \end{array}\right. \quad A_5 : \left\{\begin{array}{l} AS(A_5) = 5 \\ \hline ES(A_5, e_{fd}) = 0; ES(A_5, e_{co}) = 0 \\ ES(A_5, e_{ca}) = -2; ES(A_5, e_{fp}) = 4 \\ \hline ESE(A_5, e_{fd}) = -1; ESE(A_5, e_{co}) = 4 \\ ESE(A_5, e_{ca}) = -2; ESE(A_5, e_{fp}) = 4 \end{array}\right.$$

$$A_6 : \begin{cases} AS(A_6) = 30 \\ \hline ES(A_6, e_{fd}) = -2; ES(A_6, e_{co}) = 3 \\ ES(A_6, e_{ca}) = 1; ES(A_6, e_{fp}) = 5 \\ \hline ESE(A_6, e_{fd}) = -1; ESE(A_6, e_{co}) = 2 \\ ESE(A_6, e_{ca}) = 0; ESE(A_6, e_{fp}) = 0 \end{cases} \quad A_7 : \begin{cases} AS(A_7) = 38 \\ \hline ES(A_7, e_{fd}) = 2; ES(A_7, e_{co}) = -2 \\ ES(A_7, e_{ca}) = 4; ES(A_7, e_{fp}) = 3 \\ \hline ESE(A_7, e_{fd}) = 0; ESE(A_7, e_{co}) = -1 \\ ESE(A_7, e_{ca}) = 2; ESE(A_7, e_{fp}) = -2 \end{cases}$$

According to what we have stated in the guideline, the presented configuration has some particularities:

- Argument A_0 is a very "cheap" argument, in the sense that it need very few stimuli to be activated. The emotions stimulating the argument are $fear(die)$ and $fear(loss\_possessions)$, meaning that the relevance of thinking about the fire grows with the increase of agent's fear to die (which is usual in most people) and with the fear to loss possessions (because of its possession protection tendency). Since it has a low AS value, it would be easily activated, unless the case of very high values of calm (rare values) that could cause disinterest about the event.

- Because of its materialistic tendency, argument A_5 to think about the possible lost of possessions is also easy to arise (even more than the argument to run away to be safe). It has quite low stimuli requirements. Emotional context on which the agent experience some fear to loss its possessions, and even more if the agent is not calm down would be appropriate to arise such thought. As side effect to think about it, the agent is encouraged, also decreasing non-related emotions (such as fear to die) and focusing in emotions related to the possible loss of possessions.

- Even both arguments A_2 and A_6 are for extinct the fire, they are different in its motivations. Then, argument A_6 benefits of the fear to loss possessions, and is, for this agent, more prone to arise.

- Both A_4 and A_6 are arguments for rescue its goods from the fire. However, the action proposed by A_4 is perceived as a less risky and less effective action by the agent. Because of that, even it is less expensive (and less disadvantaged by the fear to die), it is also less stimulated by the fear to loss its possessions.

- Argument A_3 requires a lot of stimuli to arise. This is because the agent is not so fearful to have such a thought in normal emotional conditions. But if the agent gets overwhelmed by circumstances (with high negative values in calm, and a great fear to die), then it could fall in this kind of hopeless thoughts.

- Although argument A_7 could be a pretty good solution to the fire problem in a fully rational system (the agent would minimize risks, recover losses, reduce stress), it is not easy to arise in our approach under the current situation, since the argument activation requires the agent being in a calm state to be able to think in this less instinctive solution.

We state the following initial Emotional Context for the agent: ST_0^e ={(fear(die),1), (courage(),1), (calm(),3), (fear(loss_possessions),1)}

From this starting emotional context, the SSc is calculated, then SSc and AS values are compared for each argument. We illustrate in Figure 2 the set of arguments, each one with a bar, where the horizontal line in the bar represents the AS value, i.e., the stimuli requirements, and the fullness level indicates the SSc value, i.e the amount of stimuli acquired by the argument. The arguments whose SSc value overcome the AS value (painted in green - dark grey for printed versions) are the activated arguments, i.e., the subset returned by the Arousal Function ($AF(ST_0^e)$), while the arguments in light grey with grey borders, whose SSc value do not reach the AS value, are the non-activated arguments.

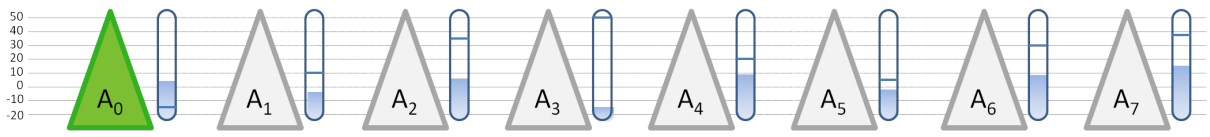


Figure 2: Args activation on ST_0^e

The most stimulated argument, according ST_0^e, is A_0. The argument is then selected in the starting emotional argumentation stage and its side effects are triggered, modifying the emotional context. The thought about the fire in the room introduces some fear to die, a major fear to loss its possessions, reduces the calm and decreases a bit the agent's courage.

The new emotional argumentation stage is composed by the argumentation sequence $ST_1^s = [A_0]$ and the resulting emotional context $ST_1^e = \{$(fear(die),3), (courage(),0), (calm(),-1), (fear(loss_possessions),4)$\}$.

Once obtained the emotional argumentation stage ST_1, the AF function is applied again, but using the new emotional context ST_1^e. We show in Figure 3 the arguments activation under such context.

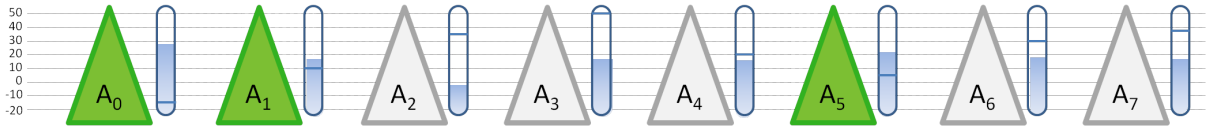


Figure 3: Args activation on ST_1^e

The activated arguments in this stage are A_0, A_1 and A_5. Argument A_0 has been selected in the previous stage, so it is not available now. The other activated argument (to run away) is also likely to be selected, but it is overcomed in stimuli by A_5, and then it is shelved by such prioritary thought. The other arguments are not even activated, so these have no possibility to arise: despite the increase on the EF $fear(loss\_possessions)$, resulting emotional context (ST_1^e) is not sufficient to activate arguments for face the fire and rescue as many goods as it can, nor for extinct the fire in order to safe its goods. Then, the chosen argument is A_5. The agent just bewails its potential losses. However, this selected thought leads the agent (through its side effects) to high increase on feelings of fear upon the idea of losing all what it has, and a decrease in its calm. The courage is pretty increased by the thought, as a mechanism to be able to cope with it. Also, there is a slight decrease in $fear(die)$ as a soft defocusing effect.

In result, the new stage is defined as follows: $ST_2^s = [A_0, A_5]$ and $ST_2^e = \{$(fear(die),2), (courage,4), (calm(),-3), (fear(loss_possessions),9)$\}$. The new activation for ST_2^e is shown in Figure 4.

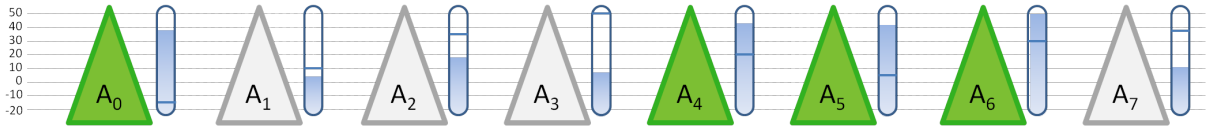


Figure 4: Args activation on ST_2^e

In the new stage, arguments for extinct the fire to keep its goods safe (A_6) and for rescue what it can from its possessions (A_4) are activated due the newly increase on $fear(loss\_possessions)$ and the growth in $courage()$ before mentioned. However, argument A_7, which is also stimulated by fear to loss possessions, does not become activated. If the agent were more calm down maybe such argument would be highly relevant, but due to its current state, its negative value in $calm()$ decreases the stimuli of such argument.

In this instance, the agent selects the argument A_6 for extinct the fire in order to save its goods. Note how the dynamic of the framework is, that the argument now selected was not even activated in stage ST_0 nor stage ST_1, but due to the successive thoughts of the agent, it has turned the most relevant thought in stage ST_2. Also, argument A_1 which was a pretty good candidate in stage ST_1, becomes not activated in stage ST_2 mostly due to the increment on courage (now that the agent is more emboldened, it is less prone to flight thoughts). The stage ST_3 is defined by: $ST_3^s = [A_0, A_5, A_6]$ and $ST_3^e = \{$(fear(die),1), (courage,6), (calm(),-3), (fear(loss_possessions),9)$\}$.

The arguments selected trough the stages are not what the agent finally decides, but just thoughts that the agent has and that work as a guide to its final decision. Note that, at a given stage ST_n, the agent will not have to consider all the possible arguments, just these already selected. Then, as the set of available arguments at a moment is restricted, the agent's decision is focused.

Note from the example that, despite argument A_0 had been selected in stage ST_0, this argument increased its stimuli in stage ST_1, making it then even more preferable than when it was originally selected. In our model, we have established a restriction stating that already selected arguments cannot be selected again. However, this kind of phenomena (high increase or decrease on arguments already selected) should have some impact on the reasoning dynamics, as increasing/decreasing stimuli on related arguments (a plus on focusing), or providing/subtracting strength to the argument in the case of a conflict (as discussed in section 4.2).

6 Conclusions and future work

In this work we have presented a framework for emotionally influenced argument awareness through the use of arguments enriched with emotional conditions and emotional effects. We have introduced the functions through which emotions and arguments are related. Next, we have defined an emotionally influenced agent, that is an agent with an emotional context and an emotional argumentation framework, in such a way it reasons by selecting arguments with the higher emotional stimuli, and being emotionally influenced by the use of the arguments. We state the necessary conditions under which an argument can be selected for passing from an emotional argumentation stage (an step on the reasoning process) to another.

We have presented an example where the dynamics of the emotional context and their effects over the argument selection is shown. We think it is an interesting approach to make the reasoning process of an agent more focused, each time avoiding arguments that are not emotionally-relevant for the agent, simplifying the amount of information that an agent uses in reasoning. We have also discussed about how to manage conflicts between arguments in a given emotional argumentation stage, and some ideas about possible effects of the interactions between already selected arguments over the dynamic of the argument selection process.

For future work, we propose to formally define an emotion-based semantic for decisions over the set of arguments selected across the successive emotional argumentation stages, taking into account the ideas discussed in this paper.

We also propose to integrate this formalism with the DeLP argumentation system [8]. In such integration, the emotions could be related to logical rules instead of arguments (i.e., a rule should reach some emotional interest to be used, and it would trigger some emotional changes as a result of using it). Thus, an activated argument could be formed by the chaining of activated rules, and a contextually preferred argument could be formed by the chaining of most emotionally-relevant rules.

In the present model, we calculate the stimuli score of an argument over a given emotional context as the summation of the current values of the emotional factors weighted by the importance of each one in the activation of the argument, as can be observed from the definition of SSc function. We are convinced that a synergy among the EF values is necessary to determine the stimuli of the arguments, but we are not sure that such summation is the right one. We also are going to work on an improved stimuli calculation mechanism that better reflects the effect of the combination of multiple emotions for argument's stimulation.

References

[1] Leila Amgoud, Yannis Dimopoulos, and Pavlos Moraitis. Making decisions through preference-based argumentation. In *KR*, pages 113–123, 2008.

[2] Leila Amgoud and Srdjan Vesic. A new approach for preference-based argumentation frameworks. *Ann. Math. Artif. Intell.*, 63(2):149–183, 2011. doi: 10.1007/s10472-011-9271-9.

[3] Leila Amgoud and Srdjan Vesic. Two roles of preferences in argumentation frameworks. In *ECSQARU*, pages 86–97, Berlin, Heidelberg, 2011. Springer-Verlag. doi: 10.1007/978-3-642-22152-18.

[4] Joseph Bates. The role of emotion in believable agents. *Commun. ACM*, 37(7):122–125, July 1994. doi: 10.1145/176789.176803.

[5] Lola Dolores Cañamero. Designing emotions for activity selection in autonomous agents. In R. Trappl, P. Petta, and S. Payr, editors, *Emotions in Humans and Artifacts*, pages 115–148. The MIT Press, Cambridge, MA, 2003.

[6] João Dias and Ana Paiva. Feeling and reasoning: A computational model for emotional characters. In *Progress in Artificial Intelligence*, volume 3808 of *Lecture Notes in Computer Science*, pages 127–140. Springer Berlin / Heidelberg, 2005. doi: 10.1007/11595014 13.

[7] P. M. Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artificial Intelligence*, 77:321–357, 1995. doi: 10.1016/0004-3702(94)00041-X.

[8] Alejandro J. García and Guillermo R. Simari. Defeasible logic programming an argumentative approach. *TPLP*, pages 95–138, 2004. doi: 10.1017/S1471068403001674.

[9] H. Geffner. Heuristics, planning, and cognition. In J. Halpern R. Dechter, H. Geffner, editor, *Heuristics, Probability and Causality: A Tribute to Judea Pearl*. College Publications, 2010.

[10] Jonathan Gratch and Stacy Marsella. A domain-independent framework for modeling emotion. *Journal of Cognitive Systems Research*, 5:269–306, 2004. doi: 10.1016/j.cogsys.2004.02.002.

[11] Amy E. Henninger, Randolph M. Jones, and Eric Chown. Behaviors that emerge from emotion and cognition: implementation and evaluation of a symbolic-connectionist architecture. In *Proceedings of the second international joint conference on Autonomous agents and multiagent systems*, AAMAS '03, pages 321–328, New York, NY, USA, 2003. ACM. doi: 10.1145/860575.860627.

[12] Eva Hudlicka. Beyond cognition: Modeling emotion in cognitive architectures. In *ICCM*, pages 118–123, 2004.

[13] Anja Johansson and Pierangelo Dell'Acqua. Emotional behavior trees. In *IEEE Conference on Computational Intelligence and Games (CIG'12) (to appear)*, 2012.

[14] Martyn Lloyd-Kelly, Katie Atkinson, and Trevor J. M. Bench-Capon. Emotion as an enabler of co-operation. In *ICAART (2)*, pages 164–169, 2012.

[15] Stacy Marsella. Modeling coping behavior in virtual humans: Dont worry, be happy. In *In AAMAS 2003*, pages 313–320. ACM Press, 2003. doi: 10.1145/860575.860626.

[16] Stacy Marsella and Jonathan Gratch. A step toward irrationality: using emotion to change belief. In *Proceedings of the first international joint conference on Autonomous agents and multiagent systems: part 1*, AAMAS '02, pages 334–341, New York, NY, USA, 2002. ACM. doi: 10.1145/544741.544821.

[17] Stacy C. Marsella and Jonathan Gratch. Ema: A process model of appraisal dynamics. *Cognitive Systems Research*, 10(1):70–90, 2009. doi: 10.1016/j.cogsys.2008.03.005.

[18] Andrew Ortony, Gerald L. Clore, and Allan Collins. *The Cognitive Structure of Emotions*. Cambridge University Press, July 1988.

[19] Klaus R. Scherer. Appraisal theory. In *Handbook of Cognition and Emotion*, pages 637–663. John Wiley & Sons, Ltd, 2005. doi: 10.1002/0470013494.ch30.

[20] Matthias Scheutz. Affective action selection and behavior arbitration for autonomous robots. In *IC-AI*, pages 334–340, 2002.

[21] Herbert A. Simon. *Reason in human affairs / Herbert A. Simon*. Stanford University Press, Stanford, 1983.

[22] Bas R. Steunebrink, Mehdi Dastani, and John-Jules Ch. Meyer. A formal model of emotions: Integrating qualitative and quantitative aspects. In *Proceedings of the 2008 conference on ECAI 2008: 18th European Conference on Artificial Intelligence*, pages 256–260, Amsterdam, The Netherlands, The Netherlands, 2008. IOS Press.

[23] Bas R. Steunebrink, Mehdi Dastani, and John-Jules Ch. Meyer. A formal model of emotion-based action tendency for intelligent agents. In *EPIA*, pages 174–186, 2009. doi: 10.1007/978-3-642-04686-5 15.

[24] J. Velàsquez. Modeling emotion-based decision-making. In *AAAI Fall Symposium. Emotional and Intelligent: The Tangled Knot of Cognition (Technical Report FS-98-03)*, pages 164–169, 1998.

[25] Bart Verheij. Accrual of arguments in defeasible argumentation. In *In Proceedings of the Second Dutch/German Workshop on Nonmonotonic Reasoning*, pages 217–224, 1995.

[26] Gerard A. W. Vreeswijk. Abstract argumentation systems. *Artificial Intelligence*, 90(1–2):225–279, 1997. doi: 10.1016/S0004-3702(96)00041-0.