This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TAFFC.2020.3028512, IEEE Transactions on Affective Computing

Normative Emotional Agents: a Viewpoint Paper

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Abstract—Human social relationships imply conforming to the norms, behaviors and cultural values of the society, but also socialization of emotions, to learn how to interpret and show them. In multiagent systems, much progress has been made in the analysis and interpretation of both emotions and norms. Nonetheless, the relationship between emotions and norms has hardly been considered and most normative agents do not consider emotions, or vice-versa. In this article, we provide an overview of relevant aspects within the area of normative agents and emotional agents. First we focus on the concept of norm, the different types of norms, its life cycle and a review of multiagent normative systems. Secondly, we present the most relevant theories of emotions, the life cycle of an agent's emotions, and how emotions have been included through computational models in multiagent systems. Next, we present an analysis of proposals that integrate emotions and norms in multiagent systems. From this analysis, four relationships are detected between norms and emotions, which we analyze in detail and discuss how these relationships have been tackled in the reviewed proposals. Finally, we present a proposal for an abstract architecture of a Normative Emotional Agent that covers these four norm-emotion relationships.

Index Terms—Multiagent systems, intelligent agents, social agents, affective computing.

1 Introduction

Social interactions generate emotions that motivate and influence the perception of the environment, the social relations and the actions that people carry out. They are also present and play an important role in decision-making processes [46]. In these processes, people take into account not only the rules and consequences of their actions, but also the emotions that their actions will generate in themselves and in others. There is a growing interest in the analysis of the role of emotions in the area of Judgment and Decision Making [26]. Typically, decision alternatives and their consequences have associated emotions that guide the decision towards a specific path in complex multi-attribute environments. Several papers document this idea about the relevant role that emotions play for decisions and motivations to perform specific actions [77], [102].

On the other hand, as social beings, we humans use norms as a mechanism to regulate our interactions. And norms can be reinforced or supported by the emotions they are expected to generate [47]. For example, in the case of an individual who complies to a norm, this behavior may lead to social approval of the group or personal satisfaction of the individual. And in the case of non-compliance with a norm, this action may cause shame or disapproval on the individual or on part or rest of individuals who form part of the social context of the norm.

In the Artificial Intelligence field, to give more realism to agents that should be similar to humans in applications such as simulations of social systems, teams of simulated humans, agent-human teams, or virtual agents that interact with or assist humans among others, agents' reasoning and decision processes should resemble the human way of thinking and making decisions considering not only the rational process but also the influence of emotions. For this reason, agents should consider the interplay between norms and emotions taking into account the norms of the context in which they are as well as the emotional implications and consequences that compliance or non-compliance with these norms can generate.

For example, consider a virtual scenario where there is a set of agents within an organization of taxi drivers. The organization has established a set of rules and regulations. One of these rules implies that taxi drivers have to form a queue to pick up customers in taxi stations, so the last driver arriving must go to the end of the queue. If a taxi driver violates this norm, so when he arrives at a taxi station he goes to the beginning of the queue to be the first to pick up the clients, the agent might have achieved his objective of getting as many clients per day as possible. However, the violation of the rule might generally generate negative emotions. On the one hand, the other agents may generate emotions such as anger or reproach that could trigger other actions in the environment (e.g. social isolation to the non-complaint agent). On the other hand, the driver who violated the norm might generate, depending on his personality, negative emotions such as shame (for being punished or rejected by his colleagues), or positive emotions such as satisfaction (for achieving his goals) if he is an agent who prioritizes his own benefit over that of society.

In a previous paper [76], we made an initial analysis of the relationship of norms and emotions. In this current paper, we perform a deeper and updated review and analysis of the work done in the area of emotions and norms and how they relate to each other. For doing this, we first present a summary of the relevant works on norms in MultiAgent Systems (MAS), as well as for emotions in MAS. Next we provide an overview of works of Normative Emotional Agents, and from this review we extract four types of relationships between norms and emotions. Then, we classify the proposals with regard to these four relationships that we propose. Finally, according to these relationships and state of art, we define the architecture of a Normative Emotional Agent (NEA).

The contributions of this work are:

- Analysis of the relations between emotions and norms.

This work was supported by the Spanish Government project TIN2017-89156-R, the Generalitat Valenciana project PROMETEO/2018/002 and the Spanish Goverment PhD Grant PRE2018-084940. (Corresponding author: Estefanía Argente)

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This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TAFFC.2020.3028512, IEEE Transactions on Affective Computing

- Review of the state of the art of normative emotional agents.
- Proposal of a Normative Emotional Agent Architecture.

The article is structured as follows: in section 2, a brief review of the most important works on Normative Multiagent Systems is given. Section 3 focuses on emotions and Emotional Multiagent Systems. Section 4 describes the current state of multiagent systems that combine norms and emotions. In section 5 we propose four relationships between norms and emotions that we have detected from the state-of-art, and we discuss how current Normative Emotional Agent proposals include these four relationships. Next, in section 6, we propose an extension of BDI architecture for Normative Emotional Agents that integrates both normative, emotional and BDI components. Finally, sections 7 and 8 contain the discussion and conclusions of the work, respectively.

2 Norms in Multiagent Systems

In multiagent systems, norms have been mainly used to solve coordination and cooperation problems between agents, by regulating the behavior of software agents and their interactions. To this end, norms make it possible to describe the obligations of agents (what actions they must take in a given context), their prohibitions (what actions they must not take) and, where appropriate, the sanctions for violating the norms, or the rewards for complying with the established rules [23]. Formal specifications, such as deontic logics [62], [133], are generally used for the description of norms.

In this section, we will briefly review how the concept of norm has been treated in the field of multiagent systems. Thus, we will first enumerate the different types of norms that can be distinguished; then the life-cycle of norms will be detailed; and finally a summary of the most relevant approaches of normative multiagent systems will be given.

2.1 Norm Typology

Depending on who promulgates a norm and whom it affects, we can distinguish different types of norms. In fact, there are different classifications of norms, like those proposed by Tuomela [127], Dignum [37], Boella [15], Criado [29], Mahmoud [81] or Savarimuthu [109].

Nonetheless, four main types of norms can be distinguished from all these proposals (see Table 1): institutional norms, social norms, interaction norms and private norms.

Institutional norms [15], [29] or r-norms (rule norms) [127] are those that are promulgated by the authority of an organization or by the institution itself. They generally describe the ideal behavior of the system, indicating the obligations of the agents (i.e. actions to be performed in a given context, or within a specified time frame, since they are considered necessary for the global desirable properties that the system may exhibit [10]), the prohibitions (i.e. actions that agents should not perform in a given context, since they are considered to negatively interfere with the actions of other individuals [10]), and, where appropriate, the permissions or actions allowed in certain contexts (i.e. "what one may do") [15]. Generally, in multiagent systems, it is normally assumed that all those actions over which no prohibitions or obligations are established are permitted.

In human societies, institutional norms are equivalent to our laws [109]. As an example, taking into account the normative regulation for taxi drivers[1] an institutional norm would be: "When a person wishes to hire a taxi from any of the stances authorized by the Licensing Authority and there is more than one taxi in the stance, the first taxi shall have first option for the hire and the other driver or drivers must advise the hirer accordingly in the event of the hirer attempting to hire a taxi other that the first taxi in the line. Having done so, the driver or other drivers shall have fulfilled their obligation in respect of this condition and shall be free to accept the hire if the hirer so wishes. Failure to comply may lead to a fine and/or the suspension or loss of the license."

In a multiagent system, institutional norms are predefined (i.e. initially included in the knowledge of the agent when programming it) or they must be transmitted to any agent of the system. In addition, non-compliance with an institutional norm is usually associated with a sanction or punishment, so it can imply being severely penalized, for example with restrictions on the actions to be carried out, with economic sanctions or directly with the expulsion from the system. Institutional norms are especially important in open systems, where agents must work with other agents who probably do not have the same set of objectives [97]. If the behavior of agents were not controlled, agents would be concerned only with their own interests, and the common welfare of the system would not be achieved. The institutional norms are transmitted to the agents through the regulatory authorities, who in turn must be in charge of monitoring the system to detect unauthorized behavior and sanction if necessary. In other cases, such as in electronic institutions [44] like AMELI [45], there are institutional agents, named governors, devoted to mediating the participation of an external agent within the institution. There is one governor per participating agent. These governors know what the institutional norms are and, since each participating agent can only communicated with its governor, they inform agents about the actions that they can do, actions that are forbidden or are obliged to do, and they apply the corresponding sanctions and/or rewards to the agent.

Social norms [109], s-norms [127] or conventions evolve, in a bottom-up way, from interactions between members of a society, indicating established ways of doing things. Thus, unlike institutional norms, they are not promulgated by any authority representing the institution, but represent behaviors that arise from repeated interactions between individuals, such as the act of greeting when we see someone we know. If someone skipped that social norm, he would be considered by others as unsociable, disrespectful, etc., and could be penalized with similar behavior towards him by others. Therefore, it is important to acquire social norms, because their violation can have important consequences, such as being unpopular or even marginalized from a group. Taking again the example of the taxi drivers, we have previously seen that the institutional rule allows any taxi driver to accept an offer of a customer if he has previously informed the client that she should go for the taxi at the beginning of the line. However, among taxi drivers it is usually frowned upon to act in this way. Therefore, we could say that the following non-written social norm exists among them: "Do not accept clients if you are not the first in line", so that a violation of this social norm will result in rejection by the other taxi drivers (reflected by feelings of reproach, diminution of its reputation, or even social exclusion), and/or a feeling of guilt

[1]See as an example the regulations for taxi drivers in Scotland: https://www.falkirk.gov.uk/services/law-licensing/licensing/transport/docs/taxi-drivers-licence/2-guidance/Taxi%20Driver%20Conditions.pdf?v=201906271131

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Norm type	Promulgated by	Target	Enforcement	Description
Institutional	Institutional authority	Society	Sanctions/Rewards	YES (Deontic)
Social	Emerge from social relationships	Society	Social mechanisms (emotions)	NO
Interaction	Participants of the interaction	Participants of the interaction	Sanctions/Rewards	YES (Deontic)
Private	Individual agent	Individual	Moral, emotions	NO

TABLE 1: Norm classification.

in the taxi driver who infringes it, when he prioritizes his own economic benefit more than following the social norm.

In a multiagent system, non-compliance with a social norm may imply that the degree of trust or confidence that the group has with respect to the non-compliant agent is reduced, leaving the agent marginalized or even expelled from the group or the multi-agent system. The complexity of this type of rules lies in their nature, since they are emerging rules, which are generally not explicitly described in society, so that individuals, when analyzing their behavior and that of other agents and its consequences, must establish the socially accepted behavior patterns to be followed [117], [136]. Likewise, the mechanisms to ensure compliance with these “unwritten” norms are often based on social mechanisms such as ostracism, recrimination, etc., mechanisms that are directly related to the emotional aspects of individuals [29].

Interaction norms [29] [37], [52] or group norms [10] are those Institutional norms defined within a subset of agents of a society. These norms are defined prior to the interaction between the members of this group of agents. They correspond to the concept of “legal contracts” or “formal agreements” of human societies.” They can be seen as those norms addressing collections of individuals and affecting their joint behaviors [10]. Their main feature is that they are explicitly created for a limited period of time, and describe which interactions are permitted, obligatory or restricted between a particular group of agents. Therefore, they would become norms with institutional character, but established between a reduced group of individuals, in order to regulate their interaction and establish their commitments of action. To this end, prior to the interaction to be carried out, the individuals of the group (or a representative) establish the rules of interaction or commitments [33], [82], based on obligations, prohibitions and permits. Interaction norms can also include sanctions to penalize the violation of rules, and rewards to encourage compliance.

In the taxi drivers example, although the taxi driver should drive to the destination by the shortest practicable route, he might decide with his clients a different route and stops, and this agreement might be represented as a formal agreement or interaction norm between the taxi driver and his current clients.

Finally, *private norms* [35], [37], [101], personal norms [127] or moral norms [10] represent the internal rules of the agent, which are self-imposed and ensure his autonomy. They represent regulations that, when followed, lead to behaviors that promote the agent’s own values [10]. These private norms are created within the mind of the agents as a result of the internalization of a social norm, or of the concretion of institutional norms and/or of interaction norms, and are accepted as principles [29]. Dechesne et al. [35] use this concept to represent the personal normative beliefs that a person has developed throughout his/her life. Therefore, they represent the norms of behavior that a person has for himself. In their work, different types of agent are established, depending on which type of norms (institutional, social or private) they give more importance to. Thus, “lawful” agents are those who always follow institutional norms; “social agents” give preference to social norms, so that they follow what most agents do; and “private agents” give preference to what they themselves judge to be correct.

In the taxi drivers example, if there is a taxi agent who continuously violates the social norm ”Do not accept clients if you are not the first in line”, if he is finally affected by the rejection of the others and, therefore, this negatively influences in his affective state, this could determine internalizing a private norm, such as ”being a norm-compliant”, in order to follow both institutional and social norms and to be able to obtain a positive response from the other agents. On the other hand, if a taxi agent who violates the social norm but obtains economic benefits that have a very positive impact on his affective state, he might internalize a private norm such as ”being proud of yourself”, ”being mainly rational”, so that he always puts himself (and his economical profits) before the rest of his professional colleagues.

2.2 Norm life-cycle

Frankz and Pigozzi reviewed in [53] all existing life cycle models of norms, and proposed a refined general norm life-cycle model comprising their systematic comparison of the life cycles of norms (see Figure 1). Accordingly, the life cycle of a norm begins with its creation (being created explicitly by an authority of the organization in which the agent is integrated, or previously included off-line in the agent’s code), or it can begin with the identification of the norm at run-time (for example, through observation of actions and (emotional) results of agents in the society). If the norm has been created by an authority, it must be transmitted to the agent for its subsequent identification or recognition. Once identified, the norm undergoes a complex internalization process, including conflict resolution and, where appropriate, acceptance. After internalization, the norm can be reinforced by internal operations of the agent itself, based on the application of motivational reinforcements or elicited emotions, or by the application of external actions (e.g. by other supervisory or controlling agents), which requires the transmission of the normative content, the identification and internalization of the norms by those other agents, etc. Finally, if the cyclical reinforcement of a given norm ceases, the norm loses its relevance and is gradually forgotten.

Regarding norm internalization, authors like Gintis [58] or Lorini [78] relate the internalization of norms to moral values or moral attitudes (ideals, standards) for discerning what is (morally) good from what is (morally) bad. Thus, they consider that the process of norm internalization implies that there are norms which, having a cultural and social origin, under certain conditions, are internalized by agents so that it is no longer necessary to apply external sanctions or rewards to ensure compliance with the rules. According to Gintis, ”an internal norm is a pattern of behavior that is intrinsically desired as a personal goal”. Thus, humans ”conform to an internal norm because so doing is an end to itself, and not

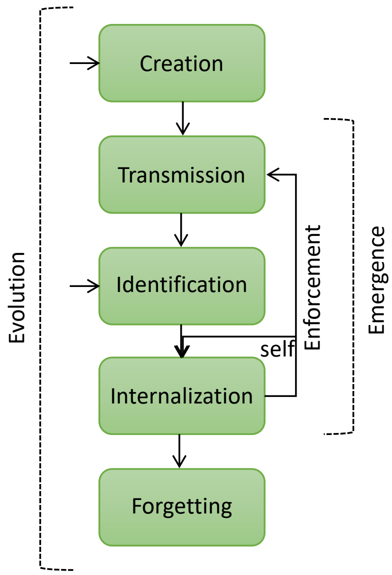

Fig. 1: General Norm Life Cycle, proposed by Frantz & Pigozzi [53].

merely because of the external social sanctions" [58]. Therefore, internalization is seen here as the process of generating the private norms of the agents.

2.3 Normative Multiagent Systems

Jones and Carmo defined the concept of a "normative multiagent system" as a set of (human or software) agents whose interactions are regulated through norms, so norms prescribe how agents should and should not behave in an ideal environment [24]. Boella and van der Torre [15] expanded this concept, defining Normative Multiagent Systems (NMAS) as "a multiagent system organized through mechanisms to represent, communicate, distribute, detect, create, modify and enforce norms, and to deliberate on norms and detect violation and compliance with them". Therefore, NMAS make use of the concept of norm as an "immaterial entity" that exists thanks to its acceptance by members of the society, and that allows avoiding conflicts and ensuring social order. Likewise, agents in NMAS must at least be able to represent and deliberate with norms in order to determine whether to comply with them (based on their objectives and the rewards and/or sanctions associated with the norms).

Comprehensive surveys on Normative Multiagent Systems include [16] [29], [98], [10] and [129]. Table 2 summarizes the most relevant, as well as the most recent approaches of Normative Multiagent Systems, ordered by year. Only for four approaches we could found the web reference of its related project, and the source-code or downloadable application. Most of the approaches are based on AgentSpeak programming language, proposing an extension of Jason with normative issues. Jason[2] is a well-known agent platform, well documented and easily downloadable from its website. Other approaches are based on 2APL[3] or ASP[4]. Recent approaches, such as NorJade [84] or JIA [2], propose extensions for the JADE [5] software platform. For example, JIA [2] includes Institutional Agents in the JADE platform that mediate interactions between client and provider businesses agents. These Institutional Agents are able to understand the semantics of FIPA speech acts, and they also know the norms of the business exchange and they are able to reason about concepts of norms, roles and powers, and to behave accordingly. This resembles the Electronic Institution framework [45], where there is an infrastructure to regulate the behavior of agents, with institutional agents who know the rules of the system that guide how agents should behave.

[2]http://jason.sourceforge.net/wp/
[3]http://apapl.sourceforge.net/
[4]ASP tools: https://potassco.org/
[5]https://jade.tilab.com/

3 Emotions in Multiagent Systems

There are several review articles that have analyzed contributions in the area of emotions and agents in different contexts such as simulation [21] or in emotion modeling in human-machine interaction systems [41], [65]. However, in this section, we aim to briefly review how the concept of emotion has been treated in the field of multiagent systems as basis for the proposal of the Normative Emotional Agent.

3.1 Emotion concept in Multiagent Systems

An emotion represents an affective state of consciousness in which, for example, one experiences joy, pain, fear, hatred, etc., which is distinguished from cognitive and voluntary states of consciousness[6]. Examples of emotions are: surprise, hope, joy, fear, sadness, anger, guilt, etc. Various studies have shown that emotions play a decisive role in many human processes, such as decision-making [31], learning, or even communication [105]. For instance, emotions can be seen as elements that intervene in the process of learning by reinforcement. When a positive or negative emotion is associated with an event, future similar events will consider the emotions in an anticipatory way to guide the decision [59], [118]. Emotions also influence how we evaluate our beliefs. For example, a positive state makes current beliefs more likely to be trusted. However, a negative state can cause beliefs to be questioned [75].

Research works in the area of multiagent systems have evolved to propose and develop agent models that allow to simulate human-like behavior in a realistic way. However, many of the proposals focus on the rational part of processes associated with human behavior, but the consideration of the influence of emotions or other affective characteristics, such as personality or mood, has been relatively sparse. Several works highlight the relevance of including affective features for social and cognitive functions, and for decision-making processes, which are considered essential characteristics for believable, coherent, and human-like agents [25], [87], [105].

Among the reasons to have believable agents, several works [1], [120] state that agents that interact with humans and that display emotions, recognize the human users' emotions, and respond to their emotions in an appropriate way, generate positive feelings in the humans during the interaction and improve their performance. Similarly, Ghafurian et al. [57] performed an experiment where the inclusion of emotions in virtual agents was perceived significantly more human-like when compared to random or emotionless agents and improved the cooperation and enjoyment of humans. In the context of multiagent teamwork [93], the use of believable agents that include emotions were

[6]WordReference Rando House Unabridge Dictionary of American English, 2017

Framework	Agent-oriented Programming Language	Web Reference
BOID (Broersen et al., 2001) [22]	Prolog	
AMELI (Esteva et al., 2004) [45]	ISLANDER	
NoA (Kollingbaum, 2005) [69]	NoA	
EMIL-A (Andrighetto, 2007) [8]	Not defined	
BIO (Governatori et al., 2008) [60]	Prop. deafeasible logic	
Normative AgentSpeak (Meneguzzi et al., 2009) [91]	AgentSpeak	https://github.com/meneguzzi/Iovis
NBDI (Neto et al.,2010) [40] [39]	AgentSpeak	
Oren et al. (2011) [95]	SWI-Prolog	
N-2APL (Alechina et al., 2012) [5]	2APL	
Panagiotidi et al. (2012) [99]	2APL	
MaNEA (Criado et al., 2013) [30]	Magentix2 (Supports AgentSpeak)	http://gti-ia.upv.es/sma/tools/magentix2/downloads.php
JaCaMo (Boissier et al., 2013) [17]	AgentSpeak	http://jacamo.sourceforge.net/
N-Jason (Lee et al., 2014) [73]	AgentSpeak	
v-BDI (Meneguzzi et al., 2015) [92]	AgentSpeak	
JSAN (Viana, 2015) [130]	AgentSpeak	
Shams et al. (2017) [119]	ASP	
JIA (Adam et. al, 2019) [2]	JADE	
NorJADE (Marir et al., 2019) [84]	JADE	https://github.com/MarirToufik/NorJADEFramework

TABLE 2: Summary of Frameworks for Normative Multiagent Systems.

beneficial to agents that have to come to a decision and act quickly, to communicate the current situation to the rest of the team, and collaborate with other members to compensate for certain situations. In simulation environments, several works have demonstrated that having believable agents facilitate the creation of more human-like behavior enhancing the realism of simulation [21]. In addition, previous studies in behavioral economics, psychology and neuroeconomics mention the relevance and necessity of emotions in the economic decision making process [131].

3.2 Theories of Emotion

The study area of Affective Computing aims to integrate emotions into intelligent systems, thus giving them the ability to recognize, feel, infer and interpret human emotions, defining for this purpose computational models of emotions. In the field of Multiagent Systems, it is equally important to provide the agents with a Computational Model of Emotions (CMEs), so that emotions can also form part of their decision-making process and communication with the other agents of the system [103]. CMES [105] provide autonomous agents with appropriate mechanisms for processing emotional information, obtaining synthetic emotions and generating emotional behaviors, so then agents can be able to recognize the emotions of human users and/or artificial agents and to simulate and express emotional feelings. These models are based on theories of emotions, which we briefly detail next.

The most relevant theories of emotion are: appraisal theories, dimensional theories and hierarchical theories. The difference between these theories is how they represent emotions. Appraisal theories focus on the cognitive determination of emotions and on their adaptive function. Emotions are considered as processes rather than states [1]. However, dimensional theories just classify and represent the emotional state in a dimensional space without explaining how they arise [71]. Hierarchical theories consider a set of basic emotions where each emotion acts as a discrete category rather than an individual emotional state [42]. Next, we briefly describe each theory.

Appraisal theories of emotion state that emotions are generated from individuals' interpretations and explanations of their circumstances, i.e., how individuals relate to their environment [55], [96], [106]. In this way, emotions arise from the evaluation of objects, situations, and other agents existing in the environment that directly or indirectly impact the individual's beliefs, objectives and plans [105]. Among the most relevant models of this theory, it is worth mentioning the OCC, Fridja, Lazarus, and Scherer models. The OCC appraisal theory is one of the most widely used in CMEs [64], [74], [85] because its elements correspond to notions commonly used in agent models. The OCC model takes into account 22 emotions that are obtained from the aspects of *objects* (hate, love), actions performed by *agents* (admiration, shame, pride, reproach), and the effects of *events* generated by agents' actions (happy-for, disappointment, hope, satisfaction, relief, joy, fear, pity, distress, resentment, gloating, fears-confirmed). Furthermore, these emotions are combined to give rise to a set of compound emotions, i.e. emotions concerning the effects of events caused by the actions of the agents (gratification, anger, remorse, gratitude). The model proposed by Frijda [55] considers emotions as experiences of forms of appraisal and as states of preparation for action. This model defines three different stages: (i) the evaluation of the internal state and the environment for the satisfaction or obstruction of concerns (i.e., individual needs, values, goals, and beliefs); (ii) the impulse or inducement of an action tendency; and (iii) the generation of actions, for example, expressive behaviors such as facial expressions.

Lazarus [51] considers a primary and a secondary appraisal. The primary appraisal refers to the evaluation of a stimulus to determine if it helps or threatens one of the individual's goals. The secondary appraisal refers to evaluating the available capabilities and resources to cope with the stimulus. These two kinds of appraisal can be executed in any order. Lazarus considers that emotions generate actions that cause physiological modifications in order to help the individual adapting to his/her environment.

Scherer [112], [113] proposed a cognitive component process model of appraisal where, unlike the Lazarus model, appraisal consists of a well-defined sequence of "stimulus evaluation steps". The sequence of this process consists on the evaluation of the novelty and unexpectedness of a stimulus, its intrinsic pleasantness, its coherence with the individual's goals, the coping possibilities, and its compatibility with shared norms (i.e., evaluate the significance of a particular action in terms of its social consequences).

Dimensional theories of emotion consider emotions from a structural perspective, differentiating on the basis of two or more fundamental dimensions, such as excitation and valence [105]. In these models a specific affective state is represented as a point with dimensional coordinates. These models are easy to process and interpret by computer systems and their mathematical representation is used in the analysis and synthesis of emotions for simulation purposes [71]. Examples of dimensional theories are Russell's two-dimensional framework [107], Russell and Mehrabian's three-dimensional framework (PAD model) [108], and MicroPsi [9]. Russell's work [107] considers a variety of affective phenomena such as emotions, moods, and feelings that are characterized by pleasantness (disgust/pleasure) and activation (non-arousal/arousal). Mehrabian and Russell introduced the PAD model, a three independent emotional dimensions to describe people's state of feeling (Pleasure, Arousal and Dominance). The D part of PAD (submissiveness/dominance) is related to temperament and was re-conceptualized as part of the appraisal process in an emotional episode (a cold cognitive assessment of the situation eliciting the emotion). This PAD model has also been used to describe personality types and represent temperament scales [90]. Schimmack and Grob state that the most common models of affect structure include two or three dimensions and the choice of one model could be influenced by cultural and/or linguistic factors [114]. The MicroPsi [9] uses the parameters that determine the behavior of the agent, i.e., arousal, resolution level, dominance of the leading motive, the level of background checks (the rate of the securing behavior), the level of goal-directed behavior, and valence to describe emotions implicitly. For instance, if we follow the MicroPsi theory, the emotion of anger originates from failure to reach a goal and is characterized by a low level of resolution, which can lead to limited problem-solving ability. Also, the failure increases the sense of urgency leading to impulsive actions, and a narrower examination of the environment.

Finally, in the *hierarchical theories* of emotions, there is a reduced set of basic, primary or fundamental emotions, which have an evolutionary basis and are innate and instinctive, and which have been extensively researched and identified. These basic emotions (e.g. anger, surprise, happiness, disgust, sadness and fear) are considered as basic elements that allow the construction of more complex emotions, such as shame, empathy, guilt and embarrassment. The most accepted group of basic emotions was established by Ekman [42], who presented the six basic emotions listed above, which are common in the world regardless of cultural differences.

3.3 Emotions Operating life-cycle

Based on the models proposed in [7], [94], [105], and unifying the ideas presented in them, we propose a generic model that describes the main processes of the operating life-cycle of emotions (see Figure 2): appraisal (emotional evaluation stimuli), elicitation of emotions, and coping (generation of emotionally driven responses).

The *appraisal* process consists of the subjective evaluation (automatic and unconscious or controlled and deliberate) of external and internal stimuli perceived by the agent [113]. The agent should evaluate the relevance of each stimulus since not all them may be relevant from an emotional point of view. Several parameters can be used in order to perform this appraisal phase such as agents beliefs, desires, intentions, concerns, memories, and internal/external events.

Elicitation of emotions process takes place based on previous information and the agent's mental state (i.e., beliefs about the world, desires and intentions), the previous affective state and the agent's personality. In this second phase, the agent determines coherent emotions, their intensity and his current affective state. The affective state can be represented either as a set of emotion categories, appraisal variables, or mood dimensions [7].

By varying the affective state of the agent, the *coping* process determines whether some action is required to return the affective state to the "desired state" or to take some reactive action (e.g., facial expressions [135], body language [34], or changes in the speech [68]). According to Lazarus & Folkman [51], a "desired state" is a state where the negative emotional responses associated with stress (i.e., stimulus as a response characterized by physiological arousal and negative affect [51]) are reduced and it is closely related to personality. According to [72] there are two approaches to coping. One is problem-focused and usually occurs when there is a problem that modifies the affective state. In this case, a behavior is generated to deal with the problem. The other approach is emotion-focused, which usually takes place when there is not any solution for a problem and hence, the behavior is oriented to control the emotional response. Dastani and Lorini [32] also considered three types of coping strategies which deal with emotions: (i) by forming or revising intentions, (ii) by changing the agent's believes (more precisely, agent's belief strength) and (iii) by changing the agent's goal strength.

After the *coping* process, the *appraisal* process can be triggered again (re-appraisal), even when there is not an event to be processed [113]. In this process, there is a re-evaluation of circumstances that corresponds with the rational or cognitive dimension of emotions [88]. To do this, it is relevant to take into account the circumstances and intentions. Appropriate emotional responses are subject to a correct interpretation of reality that is in turn valuable in terms of publicly accessible standards of judgment.

In addition, emotions have a strong social component, which can influence interactions and be transmitted to other group members through emotion contagion [19]. In this process, one group member influences the emotions of another group member (and vice versa) by conscious or unconsciously inducing moods [116]. A collective emotion can be generated from individual emotions. There are studies that establish that the transmission of positive emotions encourages the construction of personal resources, such as social-emotional and intellectual skills, contributing to improve broad-minded-coping, increase the positive effect over time, and create an upward spiral towards an emotional well-being of the individual [54]. However, negative emotions shrink individuals' thought-action repertoires. For instance, Bosse et al. [19] propose a spiral model to simulate emotion contagion in MAS. Other approaches analyze the dynamics of emotions in groups based on the dynamic Newton Law [104]. This model allows to calculate the emotional attraction between entities, establish the resulting emotion of the attraction, and the emotional propagation velocity.

3.4 Emotional Multiagent Systems

As explained above, emotions have been integrated into multiagent systems using Computational Models of Emotions [105], which provide autonomous agents with the appropriate mechanisms to process emotional information, obtain synthetic emotions and generate emotional behaviors, so that the agents may be able to recognize the emotions of humans and/or artificial agents and to simulate and express emotional feelings.

A significant number of CMEs have been designed on the basis of appraisal theories, such as EMotion and Adaptation (EMA)

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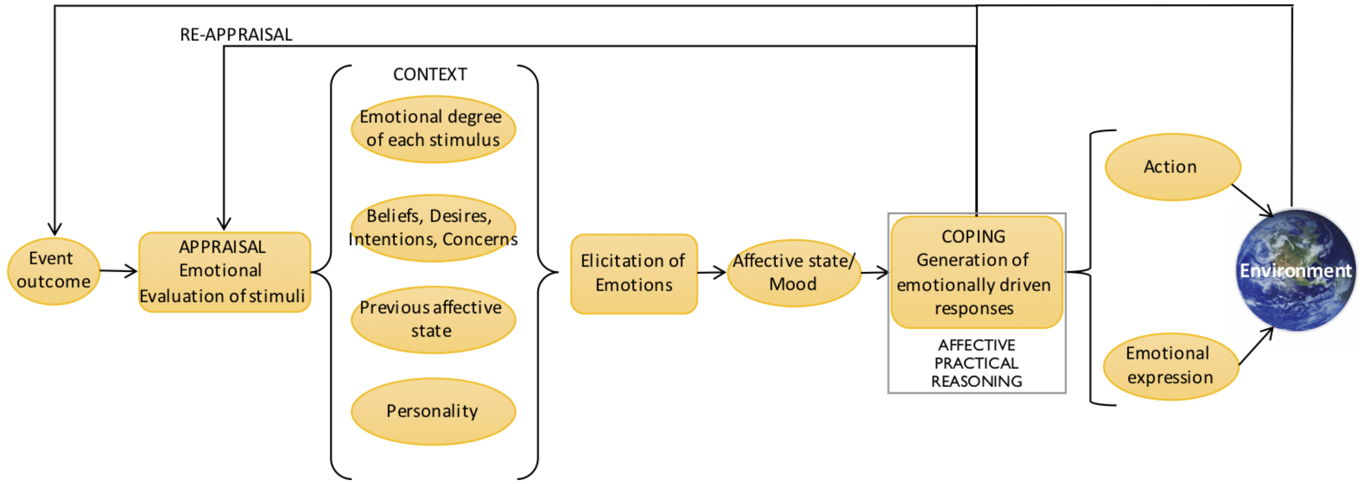

Fig. 2: Emotions operating life-cycle in an agent. Squares represent processes and circles represent input/output elements.

[86] or PEACTIDM [83]. Modal logics are particularly well-suited to represent agents' mental attitudes and to reason about them. Steunebrink et al. [123] proposed a computational model, similar to EMA, based on a logical specification language to formalize the "OCC theory". They formalize emotions in terms of objects, actions, and events keeping in mind its implementability in a multiagent system. Adam et al. [1] aim to formalize twenty emotions from OCC theory through a modal logic to consider the relationships between agents' emotions and their actions. First, they consider the influence of emotions on the agent's behavior by formalizing in a BDI framework some coping strategies. Then, they implement a logical model of both appraisal and coping in a BDI agent. Lorini & Castelfranchi [79] present a conceptual and formal clarification of two main types of surprise: mismatch-based surprise (surprise due to a recognized inconsistency between an expectation and a perceived fact) and astonishment (surprise due to the recognition of implausibility of the perceived fact). They also propose a method to integrate surprise in a formal model of belief change.

Among the CMEs based on dimensional theories we can find WASABI [14], Alma [56] and GENIA3 [6], [125]. This last work also provides an extension to Jason [18] for defining personality traits for agents, rationality, and different affective categories, based on the PAD model.

Finally, examples of CMEs based on hierarchical theories are Cathexis [128] and WASABI (which combines dimensional theories with hierarchical theories).

4 Overview of Normative Emotional Agents

In this section we review the works that have integrated emotions and norms within agents, named here as Normative Emotional Agents. Table 3 shows an analysis of these works. The first column contains the first author of the article where the proposal is described, as well as its reference. The second column is the year of the publication. The two following columns describe the emotional theory used in the proposal and the emotional architecture employed. The fifth column indicates the agent architecture used for the multiagent system. The sixth column indicates the formalism used for norm representation. The seventh column describes the scenarios where these works were applied. And finally, last column indicates the name of the final proposed architecture.

Staller and Petta [122] proposed TABASCO$_{JAM}$, which is an agent-based architecture that combines the emotional-agent TABASCO (a **T**ractable **A**ppraisal-**B**ased **A**rchitecture for **S**ituated **Co**gnizers) architecture [121] and the JAM [63] BDI architecture. The TABASCO$_{JAM}$ architecture captures the main components of the emotion process (appraisal, impulse and cognitive actions), detailed by Fridja appraisal theory [55]; and the five components of the JAM agent (a World Model, a Plan Library, an Interpreter, and Intention Structure and an Observer). The basic steps of TABASCO$_{JAM}$ architecture are: (i) the *Observer* component perceives the world and updates the *World Model* (a database representing the beliefs of the agent); (ii) the *Appraisal* component maps beliefs of the *World Model* to the appraisal outcome and calculates an intensity value, which (iii) the *Impulse* component uses for adding a goal to the *Intention Structure*; (iv) the plans in the *Plan Library* applicable to the goals published by the *Impulse* component include the actions to be performed; and (v) a regulatory process at the *Appraisal* component determines whether the execution of a plan instance generates a norm violation, and the meta-level plan uses the appraisal outcome and the intensity value for determining whether to obey or violate the norm (see Figure 3). Norms are implemented here as a general behavior regulation by means of *If-then-else* rules hard-coded in the agents. Authors used the "Aggression control" scenario [27] to evaluate their proposal.

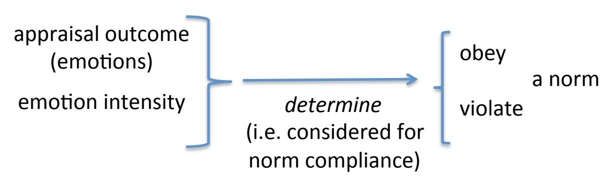

Fig. 3: Emotion usage for the normative reasoning process in Staller and Petta's work.

Bazzan et al. [13] defined a framework for simulating agents with emotions, also based on the "aggression control" scenario, in which normative and non-normative strategies in the control of aggression among agents are used. In the emotional part of their framework, the authors translated the OCC theory into a rule-based system that generates cognitive-related emotions in an

Proposals	Year	Emotion Theory	Emotional Architecture	Agent Architecture	Norm Representation	Scenario	Final Architecture
Staller [122]	2001	Frijda's	TABASCO	JAM (BDI)	If-then-else rules	Aggression control	TABASCO_{JAM}
Bazzan [13]	2003	OCC	OCC translation in Rule-Based system	Not specified	If-then-else rules	Aggression control	
von Scheve [132]	2006	Elster's	MULAN	SONAR	Petri Nets		MULAN + SONAR
Ahmad [4]	2012	OCC	OCC translation in Rule-Based system	OP-RND (BDI)	Normative Goals	EPMP	OP-NRD-E
Ferreira [48]	2013	OCC	FAtiMA	BDI	Deontic logic	Smoking	
Schaat [110], [111]	2015, 2017	Russell's	Sima-C	Not specified	Internalized norms	Green electricity	
Kollmann [70]	2016	Combination appraisal & dimensional models	SiMA	JADE	Episodes	Building automation	ECABA
Bourgais [20]	2019	OCC	BEN	BDI	Deontic logic	Nightclub Evacuation	GAMA + BEN

TABLE 3: Normative Emotional Agents State of Art.

agent. These *If-then-else* rules test either the desirability (of a consequence of an event), the praiseworthiness (of an agent's action) or the appealingness (of an object). The rule determines the potential for generating an emotional state accordingly. For simplicity, they have only focused on four main emotions: anger, joy, resentment and pity. Moreover, similarly to Staller and Petta's work, norms are here directly implemented in the agents as part of these *If-then-else* rules.

Von Scheve et al. [132] [50] based their approach on Elster's analysis of emotions, who determined that emotions are both the result of mechanisms and can trigger mechanisms [43]. Elster argues that imposing sanctions on the norm violator is driven by emotions such as contempt, disdain or disgust, that would entail negative emotions (e.g. shame, guilt, embarrassment) in the violator. Von Scheve et al. proposed a Petri-net based model that combines SONAR (a socionic multiagent architecture) and MULAN (a multiagent architecture) to model social entities formed by different layers. They used MULAN for implementing key concepts like autonomy, mobility, cooperation and adaptation; and the SONAR architecture to model the internal representations of an entity (acknowledgment, observation and actions). In their approach, agents can observe the behavior of others and perceive norm transgression. If so, social emotions of contempt, disdain or disgust are elicited and their expression constitutes the sanctioning of a norm violator which gives rise to negative emotions in the violator and induces states of shame, guilt or embarrassment (see Figure 4). Although dealing with social norms, this proposal lacks of an explicitly representation of norms (e.g. by using deontic logic); and their Petri Net modeling implies reference nets (with recursive nets that are tokens of nets again) that might make the modeling of emotions and norms rather complex.

Ahmad et al. [4] presented the OP-RND-E framework, based on the OP-RND normative framework [3], where norms are modeled as obligations to perform a specific action within a time constraint. The emotional model they propose is based on the OCC theory and it only considers the emotions "joy", "pride", "distress" and "shame" to represent the two types of categories of emotions: positive and negative. Events are represented by the occurrence of goals, which can be normative goals, mandatory personal goals and discretionary personal goals. Therefore, norms are modeled as normative goals that specify the actions to be

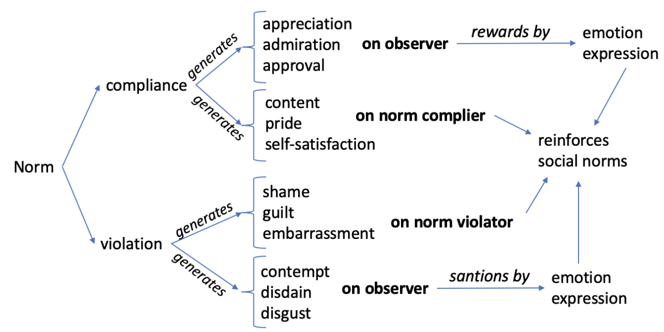

Fig. 4: Norms and emotions relation in von Scheve et al. proposal.

performed within a given time. Emotions appear when events occur, and the agent needs to use its resources to complete the tasks necessary to achieve the normative goal (see Figure 5). For instance, a positive emotion (joy) is generated by gaining extra time to reach the normative goal, and "pride" is generated by the ability to perform the action on time; whereas a negative emotion (distress) is generated by wasting time to reach the normative goal, and another negative emotion (shame) is generated for not being able to perform the action on time. Therefore, changes in events provoke positive or negative emotions, which influence the convenience of the agent. If the provoked emotion is negative, the agent will re-evaluate his plans. Hence, emotions cause an agent to consider alternative actions to achieve the normative goal. In order to validate their proposal, the authors considered the "Examination Paper preparation and Moderation Process" (EPMP).

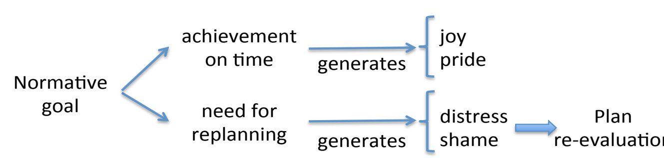

Fig. 5: Generation of emotions according to Ahmad et al. proposal.

Ferreira et al. [48] [49] focused on how to increase the believability of agents with virtual character representation by generating emotions not only from the events that affect a character's goals, but also from other sources, such as norms and

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standards. Therefore, they proposed a model for the generation of emotions based on the appraisal of actions associated with norm-related events, such as the compliance or violation of a norm. Their model includes social aspects such as normative context, in-group and out-group relations, social roles and the socially acceptable behaviors prescribed by the social norms that are active in a given context to infer the emotional state. The emotions are the result from the appraisal of actions that conform or deviate social norms. The emotions (i.e., pride, shame, admiration and reproach) are triggered based on appraisal variables: praiseworthiness/blameworthiness (i.e., how socially acceptable or reprehensible that action was), expectation-deviation (i.e., how unexpected the action was) and cognitive unit strength (i.e., similarity between users' attributes and social relation). The authors considered a smoking scenario to validate their proposal. They used the Fearnot AffecTIve Mind Architecture (FAtiMA) [36], a BDI architecture that gives agents the ability to react emotionally to events. This architecture uses the OCC theory but has no explicit notion of norms. Thus, they complemented this architecture with a normative model, in which the norms are composed of the following elements: targets (agents expected to comply with the norm), activation/expiration conditions (causing activation/expiration of the norm), normative conditions (prescriptions for the behavior of the targeted agents) and relevance (importance of the norm). The emotions "pride" and "shame" are generated when the agent considers its own actions as laudable (when it complies with the norm) or reprehensible (when it does not comply with it), respectively. "Admiration" and "reproach" are generated by valuing the actions of other agents as laudable or reprehensible (see Figure 6). In this proposal, agents are constantly checking whether a norm activates or expires. When an agent perceives a new event, it checks whether it is an action by an agent that triggers compliance with or violation of a norm. When compliance is detected, the agent evaluates the event and calculates its praise and deviation from expectations to determine the intensity of the resulting emotion.

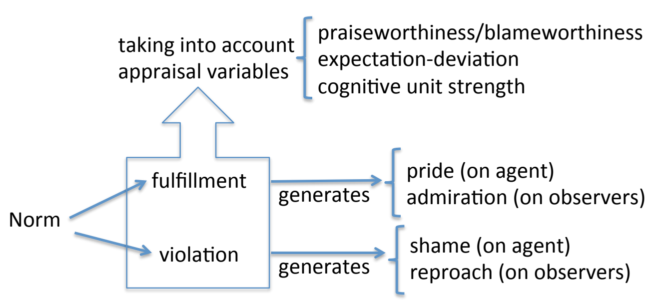

Fig. 6: Generation of emotions according to Ferreira et al. proposal.

Schaat et al. [111] developed a sociocognitive agent to examine the psychological and sociological factors that influence consumer decision-making. The authors propose a decision model that integrates motivation, emotion, and normative mechanisms using a unified activation and valuation framework. The model adapts agent's decision taking into account bodily needs, internalized norms, and external situations. Emotions are the mechanism to integrate these different demands. Every demand generates unpleasure/pleasure emotion. In case of an unpleasure emotion, this activates positively valuated actions to reduce the unpleasure. If an activated action would prevent the fulfillment of a demand, this may generate an unpleasant emotion and conflict may arise. This model has been integrated in MASON simulation environment to analyze users' behavior when they decide whether a user switches to green electricity or not. This is mainly a theoretical model that has only been tested on an agent simulation environment, but it does not have any support of agent platforms nor emotional architectures. This proposal is enhanced in [110] where authors apply norms and emotions to a broader set of scenarios.

Kollmann et al. [70] proposes a multiagent approach to develop a distributed cognitive architecture based on the cognitive architecture SiMA (Simulation of the Mental Apparatus and Applications [134]) that includes emotions. The proposed architecture is called ECABA and provides a primary process that deals with reactive behavior and a secondary process that controls deliberative behavior to cope with long-term goals. In the secondary process, social rules and rewards can be defined to specify the desired behavior of the system. Moreover, emotions are included in the internal evaluation mechanism of the system following the pleasure principle of psychoanalysis. System makes choices with the expectation of increasing pleasure and minimizing unpleasure. The proposed architecture was applied to a typical building automation use-case. As a result, we can consider that emotions, in their proposal, serve as a kind of utility function for determining which goals to follow and, in some sense, which social norms should be followed, since social norms represent here desired behavior of the system (see Figure 7).

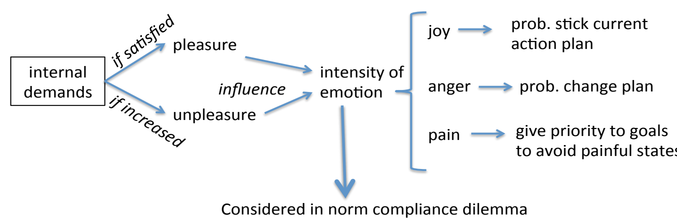

Fig. 7: Usage of emotions according to Kollman al. proposal.

Finally, Bourgais et al. [20] included emotions and norms into the GAMA[7] modeling and simulation development environment, by means of the BEN (Behavior with Emotions and Norms) agent architecture, which provides social agents with cognition, emotions, emotional contagion, personality (using the OCEAN model [89], also named as big five factors model), social relations, and norms. The definition of emotions in GAMA is based on the OCC theory of emotions. Twenty emotions can be created within the BEN architecture: eight emotions related to events, four emotions related to other agents and eight emotions related to actions [21]. In this work, social relations, such as liking for another agent, dominance, solidarity and familiarity, are also taken into account. These social relations of an agent are updated according to its cognitive and emotive states. For example, the degree of liking between two agents depends on the valence (positive or negative) of the emotions induced by the corresponding agent. In the BEN architecture, an agent follows these four steps: (i) first the agent perceives from the environment, which allows her to create new believes, new social relations, apply the emotion contagion (updating her emotions according to the emotions of other agents perceived, based on the charisma of who transmits and the receptivity on the infected), and execute

[7] https://github.com/gama-platform/gama/wiki

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sanctions on others (by updating the social relation links with the violator agents); (ii) next the agent generates emotions based on her knowledge, applying the OCC theory, and updates her social relations with others; (iii) then she makes decisions, applying both the cognitive BDI engine and the normative engine, in which obligations relate with desires and norms with plans; and (iv) finally temporal dynamics are applied, degrading the cognitive mental state, the emotion intensity and the norm status.

As we have seen, state of art proposals have mainly used the appraisal theory as the basis for their emotional model. As agent architectures, they are chiefly based on BDI approaches, in which they incorporate norms, mainly as *if-then-else* rules (hard-wired in the deliberative process); or explicitly represented and managed by normative components.

Apart from the works presented above, there are other interesting approaches that, although still being very preliminary and mainly theoretical, we would like to refer. For example, Virginia Dignum, claiming that there is a need for novel agent architectures that integrate different socio-cognitive elements such as emotions, social norms and personality, presented MaaS (Mind as a Service) architecture, a framework to develop social intelligent systems, based on the composition of different cognitive modules, or services such as emotions, social norms and personality [38]. Inspired by Service-oriented architectures, she proposes a 'Deliberation Bus' that enables to design agent deliberation processes as a composition of services. Formal models of socio-cognitive functions are the basis for the meta-models which can then be used to generate generic service models. Through the Deliberation Bus, these services are composed into an operational MaaS that can be embedded in social intelligent artifacts that interact with people, such as Embodied Virtual Agents (EVAs) or other avatars or cognitive robots. Another interesting example is the work of Thompson et al. [126], who describe a narrative world where characters (i.e., agents) follow a set of social norms. Agents are given sets of permitted actions and obligations to fulfill based on the current situation of a story. The authors propose to consider the emotional state of agents for their action choice. Before carrying out a change in the story plan, each agent asks to the audience for encouragement. Based on the audience response (i.e., cheers or boos) the emotional state (based on Russell's model) of the agent is influenced. The emotion changes the agents' motivation to select a certain permitted action to carry out as part of its plan.

Regarding case studies, some research works have based their experiments on the aggression control scenario proposed by Conte and Castelfranchy [27]. In this scenario, agents perform a set of basic actions (e.g., moving, eating, attacking an edible agent) to survive in a food shortage situation. Each agent is characterized by a force, which increases when eating and decreases when moving and attacking. Each agent has a food items and all agents follow a normative strategy to control aggression: they do not attack agents who eat their own food (this is the institutional norm, called the "finder-keeper" norm). In addition, agents follow a utilitarian strategy to control aggression: they do not attack agents whose strength is greater than their own. The result of this case study showed that the normative strategy reduced aggression (i.e., the number of attacks) much more than the utilitarian strategy [27].

Staller et al. [122] propose a case study based on [27] and consider the assessment of the concern, i.e., that the optimal feeding status is considered a basic concern for the agents, i.e., as long as this concern is not satisfied, the foods are considered relevant. Therefore, "normative emotional agents" decide whether or not to obey the institutional norm (i.e., finder-keeper norm), based on the strength of their concerns about optimal feeding status and compliance with the norm. In [13] they carried out a similar experiment, but emotions were used to characterize different types of agents: happy, resentful, painful or angry agents. Experiments showed that normative emotional agents in a normative social system are more efficient than a simple normative social agent, since the former ended up with higher levels of force and lower attack rate, and therefore performed better than simple "normative agents". In [4], the authors validate their OP-RND-E framework with an "Examination Paper preparation and Moderation Process" (EPMP) case study, in which rational normative agents were compared with emotional normative agents. This case study attempts to determine the actions and emotions of a lecturer in the execution of the process of preparation and submission of the examination paper to the Examinations Committee.

Ferreira et al. proposal [48] [49] was validated in a scenario that considers the existing no-smoking law in bars and restaurants, which is present in many European countries. In this scenario, the user's avatar is seated with other characters inside a bar where the "No smoking inside bars" rule is activated. After an initial conversation, indicating which agents are friends and which are completely unknown, one of the agents starts smoking (because he considers his goal of smoking to be more important than the norm), and the remaining agents react emotionally to that violation of the norm. Authors evaluated different versions of this scenario, varying the importance of the norm and different configurations of group members (i.e., friends or strangers). The proposed model was able to generate emotions in synthetic characters similar to those felt by humans in analogous situations.

Schaat et al. have applied norms and emotions to a consumer decision scenario [111]. They simulated how social media influences in the decision of switching to green energy. In this scenario, they analyzed the interplay of motivation, emotion, and social norms in the final decision.

Thompson et al. [126] proposed the use of agents, norms and emotions to simulate a narrative world. Agents had a set of permitted actions and norms to comply with. However, agents had the final decision about conforming the expectations or not. The decision was influenced by their emotional state, which was determined by the feedback of the audience.

Finally Bourgais et al. [20] simulated in GAMA the evacuation of the Kiss Nightclub in Santa Maria, Brazil, which was set in fire. They reproduced the behavior of the people caught in this tragedy, with statistical results similar to the real life case.

5 Norms and Emotions: Relationship

Based on the review of the state of t he art on Normative Emotional Agents as well as on the life cycle of norms and emotions, see in the previous sections, we can define four types of relationships or connections between emotions and norms (see Figure 8): (1) emotions are taken into account in the process of normative reasoning; (2) compliance with or violation of a norm generates emotions in the agent who performs the action regimented by the norm, or in the observers of this action; (3) emotions are used as a way to enforce social norms; and (4) emotions allow the norms to be internalized, so that certain behaviors accepted by society and/or which positively influence the affective state of the agent, may end up being considered as private norms, seen as principles or concerns of the agent himself.

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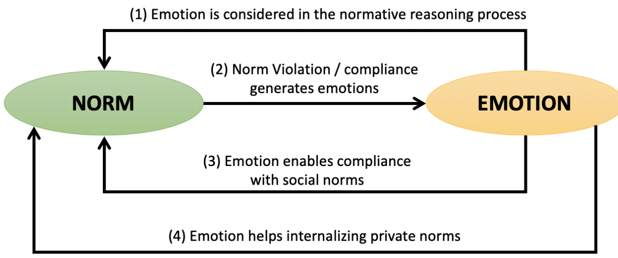

Fig. 8: Emotions and Norms relationship.

5.1 Emotions are considered in the normative reasoning process

As Criado et al. argue [29], decisions about whether or not to comply with a norm should not only be based on rational decisions (which is usually the case), but should also take into account emotions, in order to provide a more realistic and complex solution to the decision-making problem. Therefore, in the process of normative reasoning that determines whether or not to comply with the active norm, one must consider the expected usefulness of this decision in terms of the effect on the agent's objectives, the coherence of this decision with respect to the agent's cognition, and the agent's emotions with respect to the action and its consequences.

In the example of the taxi drivers, the emotions of the taxi driver agent (his emotional state), as well as the emotions or states of mind that compliance/ noncompliance with the norm is expected to produce individually or socially, will be taken into account by the taxi driver when he must evaluate whether or not to comply with his norms.

5.2 Norm violation/compliance generates emotions

Compliance with or violation of a norm by an agent can provoke positive or negative emotions in the agent himself and in the agents who have observed such action [132] [48]. Thus, for example, an agent who performs an action to achieve a goal by following a norm can give rise to feelings of gratification by the agent himself who is proud of respecting a norm and happy of reaching a goal and approval in the observers; while the performance of an action that violates a norm and prevents or hinders the achievement of the observers' goals could give rise to the feeling of anger in the observers. In [48], "the appraisals focused on how actions conform or not with internalized standards will trigger Attribution Emotions (pride, shame, admiration and reproach). Pride and shame occur when the agent is appraising its own actions as praiseworthy or blameworthy, respectively, while admiration and reproach arises from appraising the actions of others as praiseworthy or blameworthy. Thus, actions that cause the fulfilment of a norm are considered praiseworthy while actions that violate norms are blameworthy".

In the example of taxi drivers, if a taxi driver picks up customers without being the first in line, with the rational intention of making money (they could be his only customers for the whole day), this action will in himself provoke positive or negative feelings, based on his emotional state (personality and concerns). In addition, in the rest of society, this behavior could provoke negative feelings in the other taxi drivers in the line when they see that the social norm has not been respected.

5.3 Emotions enable compliance with social norms

Emotions can also be used as a mechanism to enforce social norms. For example, the violation of a social norm can trigger negative emotions such as shame or guilt in the violator of the norm, even if no one observes that the norm has been violated [122]. Thus, emotions arise as negative internal consequences of the violation of a social norm (or positive consequences for the compliance with the social norm) and can therefore serve as mechanisms for enforcing social norms, apart from the use of other types of sanctions or rewards. Furthermore, these resulting emotions may also differ depending on who is violating the social norm. For example, an agent may feel shame or guilt for violating a social norm himself, but will feel contempt or anger when it is another agent who violates the social norm. Staller and Petta [122] believe that people will feel embarrassed and isolated when they do not follow social norm. For example, when someone is the only one wearing jeans at a gala dinner, she may feel ashamed and try not to relate to others because she feels that she has not followed the established social norm. If other actors also feel contempt for someone who has not followed that social norm of dress protocol, emotion acts as a mechanism to reinforce the social norm.

For their part, Adam et. al [1] carry out an analysis of social cohesion based on three factors: emotions, social norms and mutual knowledge. The social emotions (shame, guilt, pride, admiration) felt towards a group come from respecting or violating the moral and cultural values shared by the group. These emotions influence the cohesion of the group by pushing towards respect for rules so that individuals can continue to be accepted by the group.

Emotions can also promote specific cooperative behaviors. For instance, the work of Joffily et al. [66] discusses the relationship between emotions, sanctions and cooperation, with emotions being involved in cooperation and punishment decisions. Both positive and negative emotional reinforcement, along with the availability of sanctions, encourage cooperation. Their work shows that emotions derived in the agent himself and in other agents, as a consequence of the decision taken by the agent, will affect his behavior, so that the agent will be more willing to cooperate. Therefore, emotions influence the application of norms, the agent's behavior and, ultimately, his or her social relations.

In the example of taxi drivers, since the taxi driver knows that the social norm "It is frowned upon to accept clients if you are not the first in line" can provoke emotions in society and lead to his exclusion from society if he does not follow that norm, the taxi driver should take these emotions into account in his normative reasoning process. Compliance with the rule thus reinforces social cohesion.

5.4 Emotions help to internalize the norms

There is work in the social sciences that argues that the anticipation of emotions (i.e., the anticipation of the state of mind that will result from compliance with a norm) promotes internalization and compliance with the norms [43]. For example, the work described in [50] models the application of social norms in societies of agents based on emotions. In this approach, society controls compliance with the norm and generates social emotions such as contempt or disgust in case of violation of the norm, and admiration or appreciation in case of compliance with the norm. Similarly, agents observe the expression of these emotions and are able to generate emotions such as shame or satisfaction as a response. If the agent knows that a norm is being violated by his

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action, associations between negative emotion and transgression of the norm "encourage the (re)internalization of social norms and, at the same time, update the corresponding internal representation of the norm" [50]. Likewise, "compliance situations are associated and internalized together with positive emotions, motivating the agent to look for situations in which compliance with the internal (updated) representation of a norm leads to intrinsically gratifying positive emotions".

On the other hand, following Scherer's model of appraisal theory [113], the evaluation of the meaning of an action of an agent and the analysis of the affective states observed in other agents (coping), in terms of their social consequences, allows the agent to infer social norms and to foresee that if he complies with them society will be satisfied by that fact.

Therefore, the observation of the emotions of other agents of the environment can serve as a complementary mechanism for the inference of social norms. Thus, if an agent observes that, before a certain action carried out by himself or by another agent, other agents of the environment express negative emotions in that regard, he will be able to determine that such action is not well seen by society, thus inferring a social norm in that regard. Moreover, a repetitive observation of the group's emotional expressions associated with compliance or violation of the norms, combined with its emotional state and concerns, will lead the agent to establish "what is right" and "what is wrong", that is, it will allow him to infer his own private norms, associated with the agent's morality.

For example, for a novice taxi driver, who is not familiar with the social norms of the group, observing the negative emotions of other taxi drivers when he picks up customers without being the first in line may help him determine that "that action is not well seen. As he advances in his interaction with other members of society, and based on his emotional state, principles and personality, the agent may come to infer private norms of the type "be a norm complier" or "be admired by other taxi drivers", for example.

5.5 Discussion

All these types of relationships between norms and emotions are fundamental in virtual environments where agents should resemble human beings, societies, groups, organizations and/or human communities (i.e., simulations of social systems, teams of simulated human beings, teams of human agents or virtual agents interacting with or assisting human beings). In these environments, it is essential that the agents show emotional reactions related to the importance of the norms being observed or violated, in order to increase the realism of these agents. For intelligent agents to be realistic they should respect and follow the rules (institutional norms and/or conventions and/or group norms) established in the virtual social environment. Therefore, the expected states of mind of other members of society and/or of oneself should condition, together with other parameters (i.e., beliefs, goals, concerns, personality, etc.), his/her future decisions on whether or not to follow a certain norm. The emotional reactions of the agents are not only the result of the satisfaction of their objectives, but also of the actions carried out in the social environment, such as the violation of an important social norm, even if that action has contributed to the success of a personal objective [49].

These four relationships are rather dependent between them in human societies. As Gintis states [58], "the uniquely human capacity to internalize norms strengths the cultural transmission (which includes social norms), and moreover, "human beings have prosocial emotions, including shame, guilt, and empathy, that equip the individual with rewards for altruistic behavior and penalties for self-regarding behavior". Therefore, when we humans take into account emotions when determining whether or not we follow a norm, this can also influence us to internalize that norm (assuming it as a principle or concern of our own). The emotions we feel when violating or following the norm can also serve as reinforcement for future behaviors. Thus, emotions act internally as sanctions or rewards on oneself, thus helping us to follow social norms.

In societies of artificial agents, however, as we have seen in our state of the art, norms and emotions have been related in a more simplified way, normally considering independently one or two of these relationships at most. For example, in a multi-agent system, agents can be designed to consider only their own current emotions as part of their normative reasoning process; or agents can be designed to show feelings of rejection (as a form of social expression) when faced with a violation of norms.

Reviewing the state of the art of Normative Emotional Agents (explained in section 4), we can see that, as described on table 4, the proposals of Staller and Petta [122], Bazzan et al. [13] and Kollman et al. [70] only make use of emotions in the normative reasoning process – corresponding to our relationship (1) – mainly to help agents decide whether or not they comply with a norm, basing this decision not only on reasoning based on utility, but also on the intensity of the emotions valued. Moreover, Ahmad [4], Ferreira [48] and Schaat [110], [111] focus on the generation of emotions when agents comply or violate the norms, that is, on the generation of emotions in the agent himself and in the observers of the action, corresponding to our relationship (2).

The socionic multi-agent architecture SONAR proposed by von Scheve et al. [50] allows to represent, with Petri Nets, the sanctioning of non-conforming behavior through social emotions. When an agent observes the behavior of another and perceives the transgression of a norm, this provokes social emotions of contempt, disdain or disgust and the expression of these emotions constitutes the sanctioning of the violator of the norm, giving rise to negative emotions in the violator himself and inducing in him states of shame, guilt or embarrassment. Furthermore, as certain negative emotions can normally be associated with a situation of violation of a norm, the occurrence of a similar event will automatically induce the associated emotions. The association between the negative emotion and the transgression of the norm thus promotes the internalization and reinforcement of social norms and their internal representation. Therefore, this architecture takes into account the relationships (2) and (3) between norms and emotions that we have defined, as well as the relationship (4) in the sense of allowing the inference of social norms (although in this architecture private norms are not contemplated).

In the BEN architecture of Bourgois et al. [21], agents are capable, through the perception of what the rest of the agents are doing, of establishing a complex system of social relations between them. When an agent perceives that one of his peers has violated or fulfilled a norm, he proceeds to sanction or reward that peer. Once the sanction or reward is applied, the agent updates his relationship with the other agent and updates his emotions accordingly and, therefore, it can be said that, indirectly, the BEN architecture allows the generation of emotions through norms. Moreover, emotions are also taken into account when, during

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Relationship	Staller	Bazan	von Scheve	Ahmad	Ferreira	Schaat	Kollman	Bourgais
(1) Emotion is considered in the normative reasoning process	YES	YES	NO	NO	NO	NO	YES	YES
(2) Norm violation/compliance generates emotions	NO	NO	YES	YES	YES	YES	NO	YES
(3) Emotions enforce social norms	NO	NO	YES	NO	NO	NO	NO	NO
(4) Emotions help internalizing private norms	NO	NO	NO	NO	NO	NO	NO	NO

TABLE 4: Analysis of how current Normative Emotional Agent proposals consider norm-emotion relationships.

the normative reasoning process, the agent tries to choose and activate one of his plans. However, although there is a certain degree of relationship between the norms and the emotions, they are not directly correlated. Social relations are used instead of emotions when describing a norm, so social norms (described here as intentions that do not come from an obligation, that can be disobeyed) are not inferred or reinforced through emotions, but through social relations. This architecture, in turn, does not model the concept of private norm. All the agent's norms are defined by the programmer and there are no mechanisms for inferring new norms. We can conclude, therefore, that in this architecture the relations (1) and (2) between norms-emotions have been mainly considered, and indirectly the relation (3).

In general, none of the proposals analyzed manages to represent the four relationships between norms and emotions established in this paper, hence the need for a new proposal for agent architecture, which we detail in the following section.

6 Normative Emotional Agent Abstract Architecture

We propose here an extension of the BDI architecture for a *Normative Emotional Agent* (NEA) that integrates both the emotional and the normative models (see Figure 9) and covers the four relationships between norms and emotions that we have described in the previous section.

The **Normative Component**, based on Frantz's normative life cycle [53] (explained in section 2.2) contains these processes:

- *Identification* process, in which the norm is recognized as such by the agent based on his perceptions (Brf-perceptions) or on the messages received from other agents (Brf-msg). All the identified norms are included into the agent's Normative Base, i.e., the representation of the normative knowledge. This Normative Base also contains the predefined norms, i.e., the norms programmed in the agent itself prior to its execution. In the proposed architecture, the norms of the Normative Base contain a description of their deontic operator (obligation, prohibition), their context, as well as the corresponding sanction and/or reward. Likewise, we associate to a norm what is here called "expected mood", which describes how compliance/ non compliance with the norm influences the mood of the agent or society (i.e., the mood or state of mind of other agents in its environment). In addition, we associate with the norm what we call "elicited emotions", which indicate what emotional event will be triggered in the agent associated with compliance/ noncompliance with a norm. This concept is related to the attribution emotions defined in [80], which arise when an individual attributes to himself or another person responsibility for a morally deplorable action (guilt) or a morally admirable action (praise). Therefore, the identification process will proceed to determine, for each norm, what the expected mood is and what the elicited emotions are related to that norm. For this, it will be taken into account both the emotional state, as well as the personality and concerns of the agent.
- *Internalization* process, in which agents decide whether or not to add a newly identified norm to their normative base. In this process, the agent reasons about the adoption of a certain norm by considering whether it conflicts with its own goals or with other existing norms, as described in Criado et al. [28].
- *Instantiation* process, which selects, from the Normative Base, which specific norms currently affect the agent, i.e. the set of *Active Norms*. In addition, based on the elicited emotions and the affective state of the agent, the agent's concerns are updated. One concern, according to GENIA3 [6], [125], expresses the desirability of a situation, i.e. a way of assessing how "good" the state of affairs is. For example, "to be admired by others", "to be proud of oneself", or "to be a norm-complier".
- *Normative Reasoning* process, which, according to the current intentions, beliefs and active norms, as well as the current affective state of the agent, decides whether the active norms are fulfilled or violated. This decision will also depend, if specified, on how the compliance/non-compliance with the norm influences the mood of the agent or the society, i.e. the so-called "expected mood". This decision is stored as a *Normative Decision State*, and also generates an intention.
  Emotions, represented here in the current affective state of the agent, can be seen as one more factor to be taken into account in the agent's utility function when selecting an action, as it is normally done in economic theories of emotion and decision including regret theory [124] and theories of interpersonal guilt [11] [12].
- *Norm fulfillment process*, which, based on the selected final actions, updates the *Normative Decision State* to indicate if the active norms have been finally fulfilled or violated, according to what has been previously decided. For example, it could be the case that the normative reasoning process proposes to violate a norm, but this intention is not finally selected in the action process. In the case that the norm has an associated "elicited emotion", the compliance/ non compliance with the norm will trigger the event specified in that "elicited emotion", which will reach the appraisal

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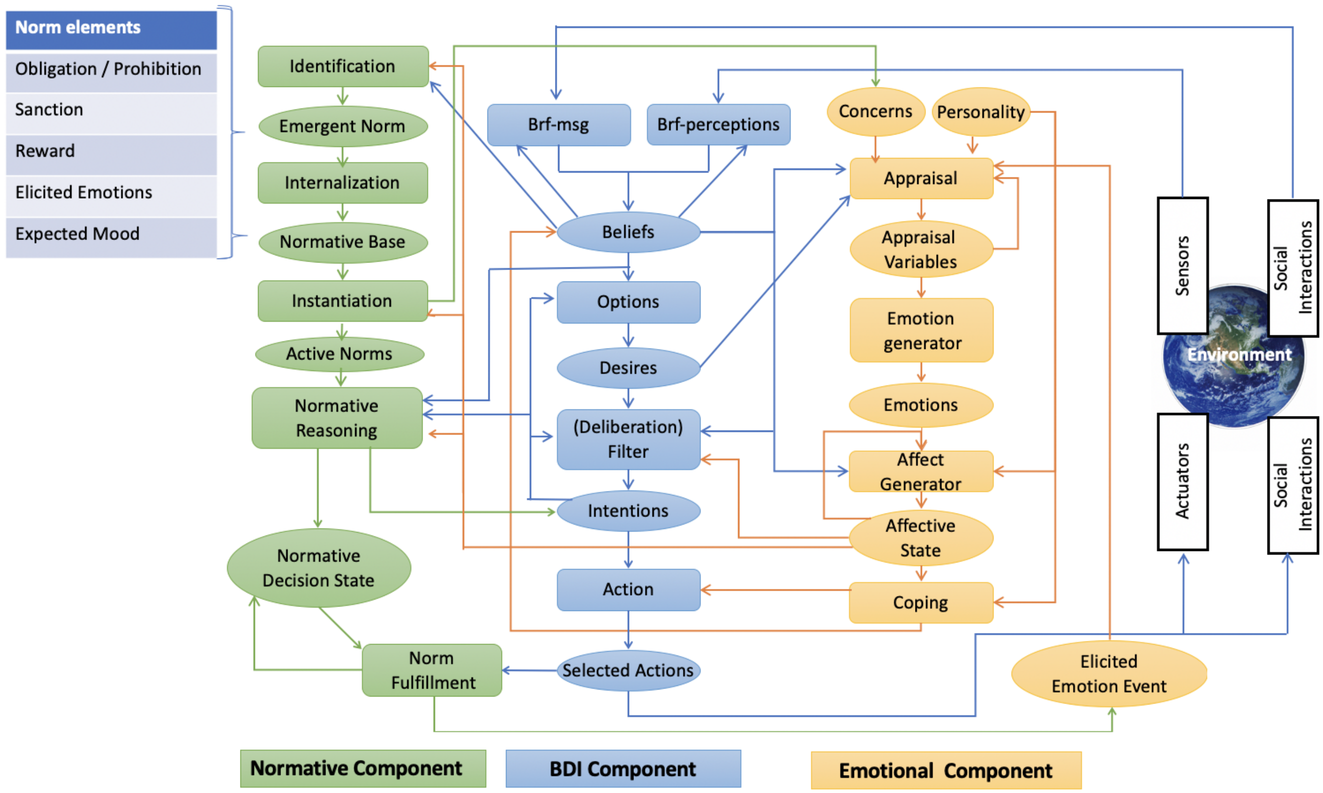

Fig. 9: Proposed NEA abstract Architecture. Squares represent processes, circles represent data elements and arrows represent flow of information (from processes to data elements or vice-versa). Orange arrows represent flow of information from the Emotional Component; Green arrows represent flow of information from the Normative component; and Blue arrows represent flow of information from the BDI component.

module of the emotional component.

The *Emotional Component*, based on [7] and the life cycle of emotions (explained in section 3.1), comprises the following processes:

- *Appraisal* function, which carries out the emotional assessment of the stimuli, according to the current state of the world (Beliefs), the *concerns* of the agent (i.e., interests, motivations, ideals, values or private norms), the desires of the agent and the events triggered in the "Norm fulfillment" process specified in the corresponding "elicited emotion". As a result, it computes the *appraisal variables* (desirability, praiseworthiness, appealingness).
- *Emotion generator* function, which generates the *emotions* consistent with the appraisal variables.
- *Affect generator* function, which performs the final obtaining of emotions, and is in charge of generating and updating the agent's *affective state* using current beliefs, the agent's personality, current emotions and current affective state (also known as mood).
- *Coping* function, which generates the responses driven by emotions (for example, emotional expressions). It is closely linked to the personality of the agent, as this process determines whether some responses of the agent or some reactive behavior should be generated, and what these responses or reactive behavior should be. This coping process may involve the generation of new intentions, as well as modifications in the agent's beliefs.

Finally, the *BDI Component* contains the typical elements and processes of any BDI architecture, which are now connected to both the emotional and the normative components, as follows:

- *Belief revision perception* function (Brf-perceptions), which uses a perceptual input together with the current beliefs to determine the new beliefs of the agent from the perceptions of the environment.
- *Belief revision message* function (Brf-msg), which uses a social interaction input along with current beliefs to determine the agent's new social beliefs from the agent's communicative acts.
- *Options* generation function, which generates desires based on the agent's current beliefs and intentions. These options or desires represent the means by which the agent can achieve its intentions.
- *Deliberation Filter* function, which determines what to do when generating the agent's intentions (e.g., increase profits). To do this, a deliberation process is carried out in which the intentions that were previously held, the current beliefs and desires and the current affective state of the agent are considered.
- *Action* selection function, which uses current intentions (including intentions generated in the Normative reasoning

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process) to determine the next selected action (plan) to be executed.

As we have seen, the description of a norm now includes both "expected mood" and "elicited emotion". The *expected moods* describe how the compliance/ non compliance with the rule influences the mood of the agent or society; while the *elicited emotions* describe what emotional event will trigger in the agent associated with the compliance/ non compliance with a rule.

The proposed NEA architecture reflects the four relationships between norms and emotions proposed in this work. In this way (see Figure 10):

1) *Emotions are considered in the normative reasoning process*. The agent's current emotional state and the *expected mood* associated with the norm are taken into account in the Normative Reasoning process, so that decisions about compliance with a norm are also based on emotional reasons.
2) *Compliance/Violation of a norm generates emotions*. To this end, the *elicited emotions* associated with the agent's norms are determined in the internalization process. Later, the Norm fulfillment process checks if the selected action matches the normative reasoning decision (i.e. the compliance or violation of an active norm), and if so, this compliance/violation generates an *elicited emotion event* that will be taken into account in the Appraisal function. This function, also based on the concerns of the agent and the appraisal variables and current beliefs, initiates the updating of the agent's current emotional state.
3) *Emotions enforce social norms*. Social norms should have *expected moods* associated with them to represent, alternatively, their sanctions or rewards. This *expected mood* is determined in the process of identifying the norm.
4) *Emotions help to internalize private norms*. In the process of instantiation, the correlation between the agent's affective state and the *elicited emotions* associated with the agent's normative base allow concerns to be updated, for example by generating new concerns of the type "to be compliant with norms", or "to do what the majority does", which in our proposal we associate with the agent's private norms.

7 Discussion

In this work, as a starting point, previous proposals in the field of normative agents and emotional agents have been analyzed. Thus, its most relevant components have been highlighted, such as the types of norms, the normative cycle, the different theories of emotion and the life cycle of emotions. The works proposed in both areas, although focused on norms or emotions, are closely linked. This link can be seen well in the works on the so-called Emotional Normative Agents, which try to integrate these two fundamental perspectives for the generation of agents in the most realistic way possible. Likewise, four types of relationships have been identified that we consider relevant between norms and emotions: (1) emotions influence the process of normative reasoning; (2) compliance/violation of a norm generates emotions; (3) emotions can be considered as mechanisms that facilitate compliance with social norms and social cohesion; and (4) emotions can be used as a mechanism to internalize private norms. These would be, according to our analysis, the highest level relationships between emotions and norms. Within these, other relationships could be considered.

As a result of the review of the state of the art of the so-called emotional normative agents, we have detected that most of the proposals work with the OCC theory of emotions, they use an architecture of BDI agents, the norms are generally already predefined in the agents (that is, they are not perceived by the environment, but they are already part of their initial knowledge), and in most of the proposals the approach adopted focuses on the relationships (1) and (2) between norms and emotions, i.e. on using the emotional state of the agent as another piece of the agent's normative reasoning, as well as on generating emotions in the agent himself and/or in the agents in his environment, as a result of the actions derived from compliance or non-compliance with the norm that governs his behavior.

To provide a more realistic and complex solution to the problem of decision-making, emotions must also be taken into account. At present, there is still a need for mechanisms that use both an explicit representation of emotions and an explicit representation of norms, to consider phenomena such as shame, honor, gratitude, etc. in the decision-making processes of any type of norms. Therefore, taking into account the revision of the normative emotional agents, we have proposed an agent architecture based on the BDI model that integrates norms and emotions and that allows the representation of the four most relevant relationships that we detect between norms and emotions. The proposed architecture considers in the agent's normative reasoning process, in addition to the typical utility-based reasoning, not only the affective state (mood), which integrates the current emotions assessed from previous events in the environment, but also considers the expected or elicited emotions (expected mood), which are supposed to be triggered in the agent himself or in the other agents in the environment, when the agent fulfills or violates the norm on which he performs his normative reasoning process.

It is relevant to mention that our proposal distinguishes between personality, mood and emotions. Personality refers to the set of individual traits that make people different from each other [61] [67]. The *affective state* or mood can be considered as a temporary state of mind or feeling, that is, it has a persistence. Mood is generally more stable than a particular emotion, although both are certainly involved [115]. When emotions are taken into account, the personality of the agent is also directly involved. Finally, emotions allow flexibility in the interpretation of events and the response according to the personality given to the agent.

As for the social norms that arise from the interactions of the agents, we need mechanisms that allow the agents to infer these social norms, for example by observing (through the environment) the rest of the agents, their responses and their interactions. Precisely, the emotional reactions of agents to social interactions can serve as a mechanism for an agent to infer or deduce a social norm. This could also imply the need to infer the emotions of other agents before a specific event, for example, paying attention to the response given by other agents who are familiar with the social context and determining the emotions that are evaluated. In the proposed abstract architecture of NEA, the "Identification" process within the normative component allows new norms to be inferred from the beliefs generated from social interactions (Brf-msg) and perceptions (Brf-perceptions), by observing the emotional reactions of other agents (caused by their respective coping processes).

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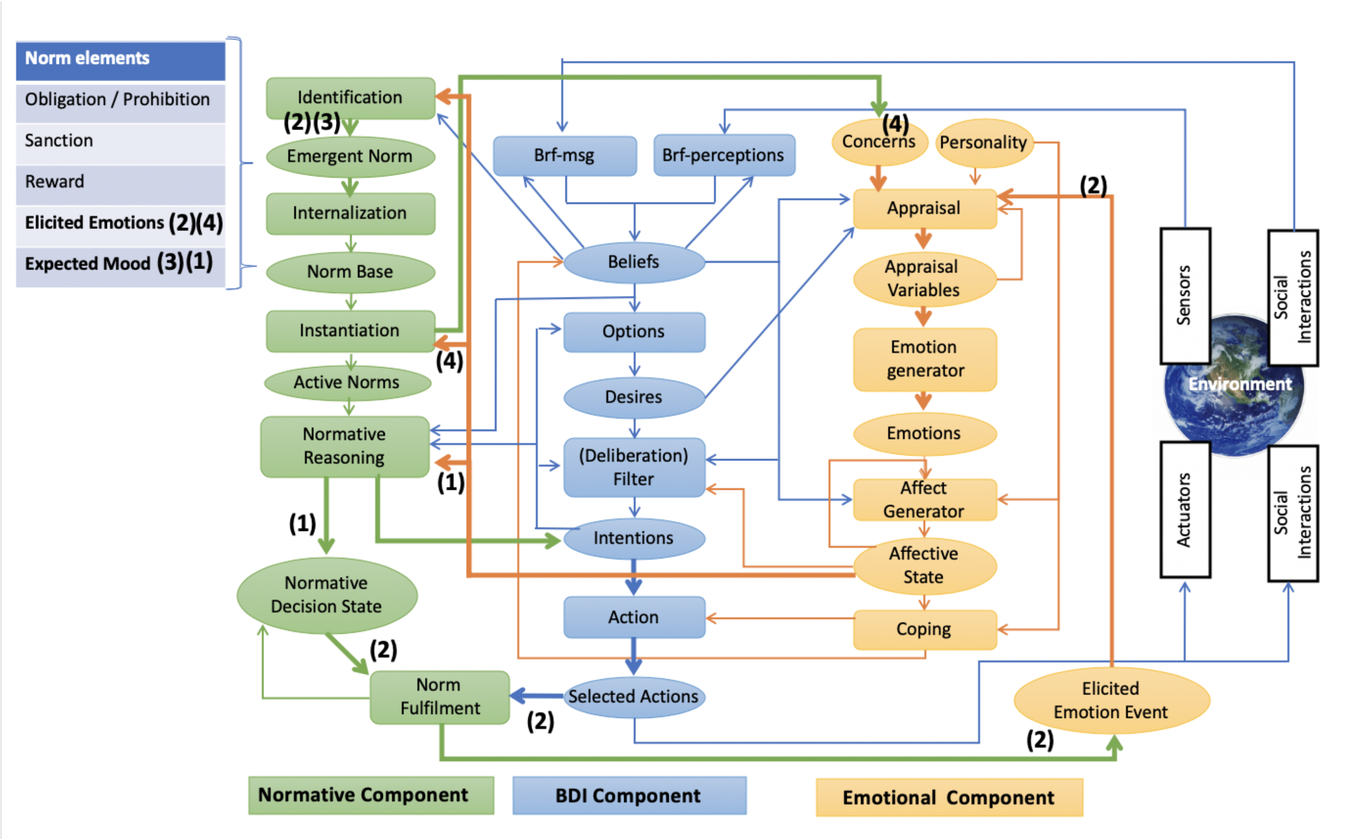

Fig. 10: Norms and emotions relations in NEA abstract architecture, where: (1) Normative reasoning process; (2) Emotion generation; (3) Norm enforcement; and (4) Norm inference relationships. Bold lines of arrows represent the relevant flows of information for each norm-emotion relationship, and the number in brackets indicates the corresponding relationship.

The proposed architecture allows the agents to be proactive and, through analysis of the environment, to infer social norms, as well as to internalize their values or private norms, represented here as *concerns*. When private norms are combined with emotions, then they can be considered as norms of morality [100].

Another interesting point to note is self-control of norms. Normative multi-agent systems usually enforce norms through one of these mechanisms [29]: second-party entities, in which agents directly participating in an interaction are in charge of monitoring and taking coercive measures on other participants in that interaction; or third-party entities (e.g. controllers of the system), in charge of applying sanctions in case of violation of the norm. However, little consideration has been given to self-monitoring, i.e. the possibility of applying sanctions/rewards on oneself, without the need of other actors to observe the action taken. In the proposed architecture, emotions could be used as an adequate mechanisms of self-control to comply with the norms, since this mechanism is based on the agent's own personal judgment, modeled through his own emotions and concerns.

8 Conclusions

This article focuses on the relationship between norms and emotions in the field of multi-agent systems. Firstly, we have briefly analyzed the treatment of norms in MAS, reviewing their typology, life cycle and normative MAS proposals. Secondly, we have reviewed the concept of emotion, from its use in the field of multiagent systems, detailing the main types of theories of emotions, their life cycle and the proposals of emotional MAS. Thirdly, we have carried out an exhaustive review of the proposals of existing multi-agent systems that integrate both norms and emotions in the agents, so that these systems contemplate that an agent is not only capable of representing the norms, recognizing them and determining whether to follow or violate them, but also represents, recognizes and includes the emotions within its normative reasoning process. Based on this review of the state of the art, we have proposed four relationships between norms and emotions, which also determine what a Normative Emotional Agent (NEA) should offer. Finally, we have proposed a new abstract architecture of the NEA, as an extension of the BDI architecture that combines both the normative and the emotional components and that integrates these four relationships between norms and emotions: (i) the consideration of emotions in the normative reasoning process; (ii) the generation of emotions (in the individual himself or in the observers) by the compliance/violation of a norm; (iii) the use of emotions as a support mechanism and recognition of social norms; and (iv) emotions as a trigger to allow the internalization of private norms.

As future work, we plan to develop mechanisms that allow us to infer social norms, for example, by analysing the actions and/or interactions of other agents in society and the emotional responses that such actions produce. These mechanisms could make use of the logical models of collective responsibility and collective guilt defined in [80], in order to determine behaviors that are collectively viewed as either commendable or worthy of rejection.

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This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TAFFC.2020.3028512, IEEE Transactions on Affective Computing

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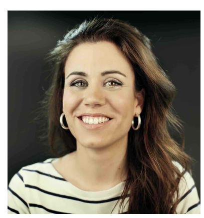

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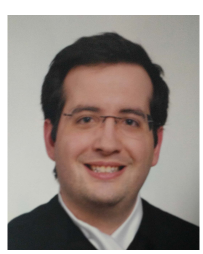

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