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EmotionsOnto: an Ontology for Developing Affective Applications

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Abstract: EmotionsOnto is a generic ontology for describing emotions and their detection and expression systems taking contextual and multimodal elements into account. The ontology is proposed as a way to develop an easily computerizable and flexible formal model. Moreover, it is based on the Web Ontology Language (OWL) standard, which also makes ontologies easily shareable and extensible. Once formalized as an ontology, the knowledge about emotions can be used in order to make computers more personalised and adapted to users' needs. The ontology has been validated and evaluated by means of an applications based on a emotions-aware Tangible User Interface (TUI). The TUI is guided by emotion knowledge previously gathered using the same TUI and modelled using EmotionsOnto.

Keywords: Design of affective interaction systems, emotions, ontologies, context, multimodality
Categories: H.5.2, I.2.4

1 Introduction

Human beings are eminently emotional, as their social interaction is based on the ability to communicate their emotions and to perceive the emotional states of others. Emotion is a complex aspect and findings of different areas, such as anthropology, psychology, and biology, have clearly something to say. In this sense, emotions must be taken into account when implementing computing systems in order to enable a more social and humanistic computing for our knowledge society.

Affective computing paradigm deals with detecting, interpreting and responding to user's emotions when developing systems and devices [Picard, 2000]. Interest in this area is driven by a wide spectrum of promising applications, such as virtual reality, smart surveillance or perceptual interfaces. Affective computing concerns multidisciplinary knowledge background such as psychology, physiology and computer science [Tao, 2005].

In affective computing area there are a great variety of theoretical models of emotions, which can frame the design of affective applications, and there are different

technologies that can be used for their implementation. Although there are many common properties, emotions are not universal: they are differently expressed in different cultures and languages, while many emotional properties are individual. There is rarely a one-size-fits-all solution for the growing variety of computer users and interactions [Obrenovic, 2005]. Therefore, emotion-aware applications should be designed in a flexible way so a wider class of users can use them. In this way, personalization is necessary for more efficient interaction, better tuning and acceptance of developed systems.

There is a broad terminology related to affective states in human beings. The term "emotion" tends to be used in a broad sense, especially in technological contexts. Scherer [Scherer, 2000] proposed a number of taxonomies for these affective states. The original list was later modified and redefined in [Douglas-Cowie, 2006]. This new list includes: Attitudes, Established emotion, Emergent Emotion (full-blown), Emergent Emotion (suppressed), Moods, Partial emotion (topic shifting), Partial emotion (simmering), Stance towards person, Stance towards object/situation, Interpersonal bonds, Altered state of arousal, Altered state of control, Altered state of seriousness and Emotionless.

This paper is focused specifically on Emergent Emotion (full-blown), instead of a global taxonomy of affective states. This is made to reduce the complexity of proposed domain so it is easier to deal with. Besides, for the same reason, focus is mainly devoted to emotion detection and expression systems instead of modelling internal emotion processing in humans. In [Douglas-Cowie, 2006], Emergent Emotion (full-blown) is defined as "states where the person's whole system is caught up in the way they react to a particular person or situation". It involves aspects such as:

- Distinctive positive or negative feelings about the people or situations involved.
- Impulses to act or express yourself in particular ways and avoid others
- Distinctive changes in your body, for instance in your heart rate or tendency to sweat
- Emotion does not last very long – it comes on quite quickly, and dies down reasonably soon (unless there is something very unusual happening)

Our contribution is to overcome the above mentioned limitations referring to the lack of flexibility when personalizing affective computing applications by providing a generic ontology for describing detection and expression systems related with emotions, while taking contextual and multimodal elements into account. The ontology is proposed as a way to develop an easily implementable formal model, as it is based on the Web Ontology Language (OWL) standard [W3C OWL Working Group, 2012]. However, the knowledge about emotions in the ontology can be used by affective computing applications with independence of the underlying technology.

The proposed ontology in this paper is based on a generic model geared towards capturing the entities that take part in the Emergent Emotion process [López, 2008]. The model is presented in Section 3 and it has been formalised as an ontology following a classical ontology engineering methodology [García, 2006]. The ontology has been developed to be as agnostic as possible regarding existing emotion theories. This way, developers of affective resources are not tied to a given theoretical

approach. In this sense, developers can use different theoretical approaches in the same ontological and technological framework. For instance, for the application based on Tangible User Interfaces described in Section 4.2, a categorical theory of emotions [Ekman, 1984] has been applied. However, other approaches have also been considered, like the dimensional [Lang, 1979] or appraisal [Scherer, 1999] approaches.

Consequently, the ontology can help implementing emotion-aware applications based on a wider range of theoretical approaches. This flexibility and wide applicability of EmotionsOnto is in great part due to the fact that it is capable of modelling contexts. In order to do that, the DOLCE upper ontology [Gangemi, 2002; Porello, 2014] is reused and extended, particularly the Description and Situation concepts. Descriptions correspond to the representations for the situations, which then trigger and are associated with emotions. Moreover, in order to cope with the enormous range of different situations that might need to be associated with emotions, they are modelled using the building blocks provided by FrameNet [Scheffczyk, 2008]. It is a big lexical database, with more than 10,000 word senses, structured following Frame Semantics [Fillmore, 2006]. Frames fit really well with situations modelling as they try to explain words meaning by building a description of a type of event, relation, or entity and the participants in it.

EmotionsOnto has passed through an ontology validation and evaluation process. This process is based on some common ontology measure types and evaluation methods. In order to perform a complete evaluation of the ontology, measures should be complemented with ontology evaluation methods [Gangemi, 2006]. We have performed a task-oriented evaluation by putting the ontology into practice. This experience has shown that the ontology is capable of accommodating concrete emotion theories and put them into practice in the context of an emotion-aware application.

The resulting ontology, EmotionsOnto, is validated in a use case, a real-world applications that manages affective information, which proves the validity of the proposed approach in emotion-aware application based on Tangible User Interfaces [TUIs) called Emoti-Picture Frame (EPF) [Neyem, 2007], as detailed in Section 4. A TUI has been selected in order to better explore how interaction with physical objects and the direct feedback they provide drives affective engagement [Cuijpers, 2011; Nguyen, 2009]. The ontology structures and contextualizes the knowledge managed by the application controlling the TUI.

The TUI features some sensors: a microphone, a camera and some buttons that help users directly communicate their emotional state to the TUI. The emotion concept has been concretized into joy, acceptance, fear, submission, sadness, disgust, anger, and anticipation [Plutchik, 1980]. Some of these emotions have been then associated to the emotional buttons and the application learns to associate the situations it perceives to emotional states. It also then tries, guided by predefined rules, to influence the user emotional state by playing music or showing pictures.

The rest of the paper is structured as follows. The next section presents several theories and concepts relevant for describing emotions, together with several topics related to ontologies and emotions. Then, the conceptual model underlying the proposed EmotionsOnto is introduced in Section 3. The use cases that is helping

validate and evaluate the ontology is presented in Section 4. Finally, conclusions and future work conclude this paper in Section 5.

2 Related Work

Emotion is a complex topic and findings of different areas, such as anthropology, psychology, and biology, are included in its wide-ranging discussion. In the field of psychology, definitions of emotion have been proposed with different theoretical orientations. In this sense, theories of emotions proposed by cognitive psychology are a useful starting point in order to describe emotion. Although several cognitive models of emotions exist, the most commonly ones used in affective computing area are the categorical [Ekman, 1984], dimensional [Lang, 1979] and appraisal [Scherer, 1999].

Lang [Lang, 1979] also proposed analysing emotions according to three systems involved in their expression and detection: Subjective or verbal information (i.e. reports about perceived emotions described by users), Behavioural (i.e. facial and postural expressions, speech paralinguistic parameters), and Psychophysiological answers (such as heart rate, galvanic skin response –GSR– and electroencephalographic response).

The subjective, behavioural and physiological correlates of emotions should be taken into account when possible. The correlations among the three systems could help computers to interpret ambiguous emotions. In that sense, more specific models or classifications that describe the components of each system of expression can be found in the literature and selected according to the particular case. These examples include acoustic correlates of speech [Scherer, 1986], verbal [Bradley, 1997] or facial expressions [Lang, 1979].

The emotional memory arisen from the experience of the individual and the cultural surroundings [also called socialized emotion) also has an influence on affective states in humans as well. Sociology of emotions has typically examined how affect arises, linking emotions to particular types of interactions [Goffman, 1956]. Besides, as the emotional answer is often socialized, it does not necessarily correspond to a pure emotional answer and it can mask real affective states.

It is noteworthy that, generally speaking, research has paid little attention to context in affective computing area [Douglas-Cowie, 2005]. Context is inescapably linked to modality, and emotion is strongly multimodal as emotional cues may appear in various different channels. However, not all types of emotional cues tend to be available together, as context can affect relevant or accessible emotional cues.

For instance, Devillers [Devillers, 2005] explained that emotional behaviour models require representing multiple levels involved in emotional processes: the emotional context, the emotion itself and associated multimodal behaviours. In that work, some appraisal descriptors derived from the appraisal model (Scherer, 1999] such as time-of-event were added in the context part of the proposed scheme.

On the other hand, [Baldauf, 2007] proposed that context aware systems are those that adapt their behaviour according to context and that this context [location, time, activity, devices and person) also includes user's affective state. Regarding the use of emergent emotion in real world applications, Lim [Lim, 2009] describe a novel

emergent emotion model for a context-aware guide with emotions and personality that accompanies visitors touring an outdoor attraction.

2.1 Ontologies related with emotion modelling

Different ontologies have been proposed in literature with the aim of modelling emotion and affect related issues. These ontologies are normally focused on analysing concrete areas. For instance, in text analysis area, Mathieu [Mathieu, 2005] presented a semantic lexicon in the field of feelings and emotions. This lexicon is described with an ontology. Words in the lexicon are emotionally labelled as positive, negative and neutral.

Emotional annotation has also been used in WordNet ontology [Fellbaum, 1998], producing the WordNetAffect extension [Strapparava, 2004]. With the support of ontology technologies, users can retrieve information in a semantic manner [Chi, 2007]. A primary course of ontology building is related to concept development. Focusing on speech, Galunov [Galunov, 2004] present an ontology for speech signal recognition and synthesis where emotion is taken into account. On the other hand, focusing on the context, Benta [Benta, 2007] present an ontology based representation of the affective states for context aware applications which allows expressing the complex relations that are among the affective states and between these and the other context elements.

Although these kinds of unimodal approaches have relevance in their respective fields, they lack properly expressing the multimodal nature of human emotions. In this sense, multimodal ontologies for describing emotion have been proposed. For instance, Obrenovic [Obrenovic, 2005] describes an ontology based on emotional cues that uses media properties from different sources to model emotion.

3 Contribution

The proposed ontology in this paper is based on a generic model geared towards capturing the entities that take part in the Emergent Emotion process. The model is summarised in Figure 1. This model has been formalised as an ontology following a classical ontology engineering methodology [García, 2006]. The ontology, and the model it is based on, tries to be as emotions-theory agnostic as possible. The objective is to develop an ontology flexible enough to accommodate existing emotions theories, such as the ones presented in the literature review.

The underlying Emergent Emotion model is formalised using Semantic Web tools [Lytras, 2008], more concretely the Web Ontology Language (OWL) [W3C OWL Working Group, 2012]. OWL makes it possible to attain a great level of expressivity while producing a web ontology that can be easily shared through the web and thus be opened to third party extensions.

The different parts of the model have been developed using the primitives provided by OWL. The main building blocks are classes, which represent concepts in the model, and properties, which represent the relations among the concepts. The first step has been to model all the ovals in Figure 1 as OWL classes.

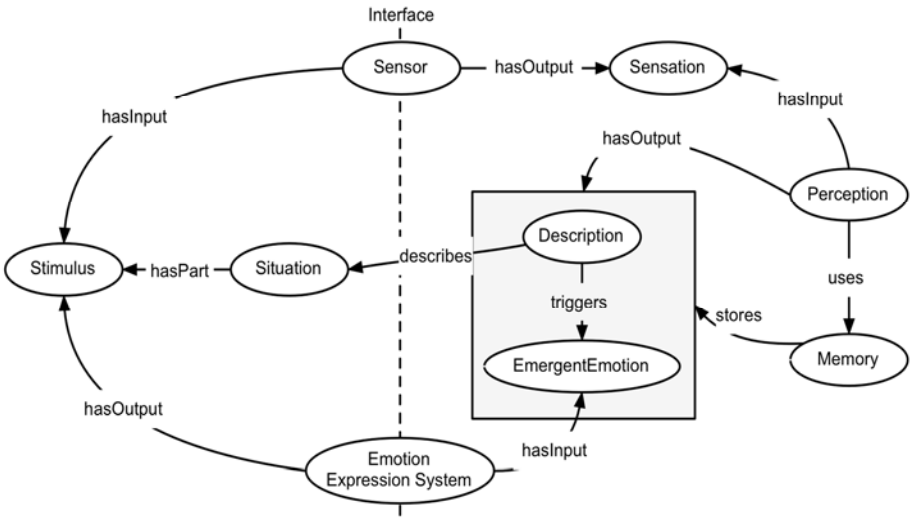

Figure 1: Emergent Emotion and human information processing systems

The main classes in the model are organised in three groups:

- **External world**: this corresponds to the "external world" that the modelled agent sensors perceive and where the agent emotion expression systems actuate. This might range from the real world where human agents or robots actuate to virtual worlds where virtual agents operate. In Figure 1 this corresponds to the left of the vertical dotted line labelled "Interface". It includes the concepts:
  - **Situation**: an arrangement of element of the "external world" as recognised and contextualised by an agent on the basis of a Description the agent makes. More details about Descriptions below.
  - **Stimulus**: they constitute the input gathered by sensors. They are produced by "external world" objects including agents' Emotion Expression Systems.
- **Interface**: this is the barrier between the "external world" and the conceptual models generated "inside" agents. The interface includes the following concepts:
  - **Sensor**: both artificial and biological sensors. They capture Stimulus from the "external world" and convert them into Sensations, internal representations of the stimulus.
  - **Emotion Expression System**: this is an agent system that allows the agent to communicate to other agents, as stimulus, its emotional state.
- **Internal world**: this corresponds to conceptual world of representations built "inside" agents. It is structured by the following concepts:

- **Sensation**: the representation of stimulus generated by sensors.
- **Perception**: the mechanism through which sensations are gathered and organised, in combination and guided by previous experiences, to generate descriptions of situations perceived in the real world.
- **Description**: the representation of an "external world" situation used by the agent in order to guide its behaviour, including its emotional responses.
- **Emergent Emotion**: states where the agent's whole emotional system is caught up in the way they react to a particular situation [Douglas-Cowie et al., 2006], which is "internally" represented using a description.
- **Memory**: part of the agent where previous experiences are stored, i.e. descriptions based on sensations together with links to other descriptions and emergent emotions.

The ontology is completed with some properties that relate all these concepts 8hasInput, hasOutput, hasPart, describes, triggers, stores and uses) and some axioms that restrict the kind of things that these properties can link to and from. In OWL, these axioms are called OWL Restrictions and, in the context of a class, they specify to objects of what class does that property link to when applied to objects of the source class.

For instance, the ontology contains a restriction that specifies that the triggers property when applied to the class Description points to objects of type EmergentEmotion. The specification of the ontology (EmotionsOnto henceforth) in OWL format is available online1.

The previous formalisation of the Emergent Emotion model helps building an ontology that facilitates computerised emotions management. However, it provides little semantics apart from those explicitly present in the model. For instance, the ontology provides just some information about what a Sensor is. In order to enrich the ontology, we have taken existing upper ontologies into account.

Upper ontologies are very generic ontologies, about concepts like object or process, that settle down the ontological foundations about what is there in the world [Sowa, 1999]. Consequently, they provide very basic and fundamental semantics about the kind of things that a more specialised ontology, like the one proposed in this work, can deal with. Building an upper ontology is a very complex process and thus it is recommended to reuse existing upper ontologies instead of elaborating a full conceptualisation for the concepts in a specialised ontology.

In order to do so, DOLCE [Gangemi, 2002] has been chosen, that stands for Descriptive Ontology for Linguistic and Cognitive Engineering, because it fits really well with the underlying considered cognitive aspects. In fact, the Description and Situation concepts in this ontology have been reused from DOLCE and extended. These concepts provide a framework for representing contexts, which are the entities associated to EmergentEmotions in our model.

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[1] Emergent Emotion Ontology (EmotionsOnto),
http://rhizomik.net/ontologies/emotionsonto/

DOLCE also provides generic concepts that have been used in order to contextualise those in EmotionsOnto. First of all, there is Event that generalises any occurring thing in our model. There are some concretisations, i.e. Process, an event considered in its evolution, and Action, an event with at least one agent that participates in it.

On the other hand, there are objects. PhysicalObject has been used in order to contextualise concepts like Sensor, which we have detailed further in the ontology with artificial and biological sensors, and more specifically with human-like senses. SocialObject is the generalisation for Description and Situation, but also for Verbal, a kind of EmotionExpressionSystem together with Behavioural systems that have been specified as Actions.

All these relationships between EmotionsOnto and DOLCE concepts are shown in Figure 2, where DOLCE concepts are coloured in grey. Moreover, the figure also shows additional concepts, apart from those shown in the model, that concretise concepts like EmotionExpressionSystem or Sensor. Additionally, the ontology also includes the different kinds of Context identified during the conceptualisation process. SocialContext and EnvironmentalContext are modelled using Situation. On the other hand, PersonalContext is based on the Interface concept that includes both the EmotionExpressionSystem and the Sensor concepts.

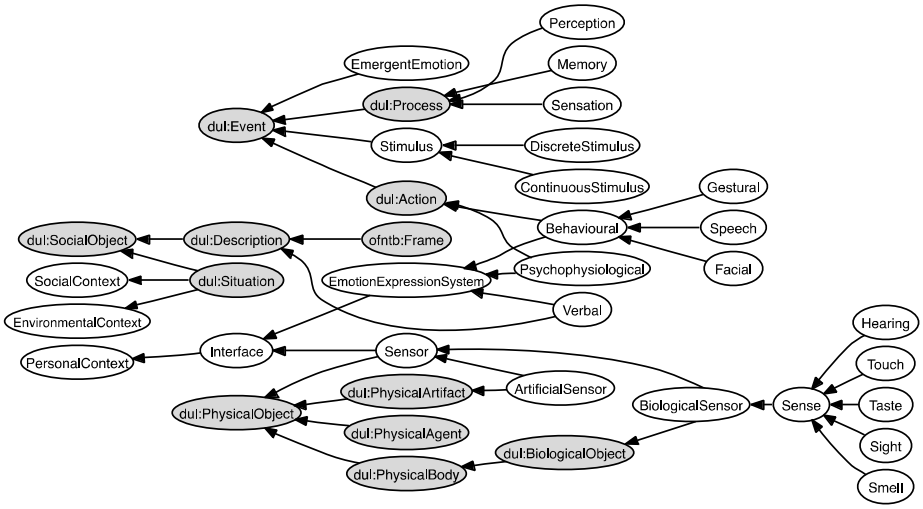

Figure 2: EmotionsOnto core in the context of the DOLCE upper ontology

Although DOLCE provides the building block for modelling context, i.e. Description and Situation, concrete means that allow modelling the descriptions for the situations that trigger and are associated with emotions are necessary. However, to develop an ontology capable of dealing with the huge range of situations that might be associated with emotions is out of the scope of the ontology. Consequently, we have selected an existing ontology that provides such a wide scope called FrameNet [Scheffczyk, 2008].

FrameNet has been selected because it is better suited for modelling context as situations. FrameNet is based on the frame-modelling paradigm. A frame is a schematic representation of a typical situation (e.g. eating, removing, classifying, etc.) together with a list of the kinds of participants, properties and other conceptual roles that are seen as components of that situation2. Moreover, it can be easily connected with DOLCE, as it can be noted in Figure 2, where the concept Frame appears as a subclass of Description. Consequently, we can accomplish a smooth integration of DOLCE and FrameNet in the context of EmotionsOnto.

For instance, in order to model the situation "John enters the room" using FrameNet, it is possible to use the "enter.v" lexical unit, which belongs to the "Arriving" frame. This frame defines a set of Frame Elements (FEs) and some of them might be used in order to model the participants and properties of this situation. The Frame Element "Theme" is associated with the object that moves, in this case "John". On the other hand, the FE "Goal" is associated with where the Theme ends up as a result of the motion, in this case “the room”.

4 Evaluation using Tangible User Interfaces

The EmotionsOnto has been evaluated using the Emoti-Picture Frame (EPF) [Collazos, 2007], a picture frame that features a Tangible User Interface (TUI). This TUI makes it possible to establish emotional communications among users because it allows anyone with Internet access to transmit their feelings by displaying them on a TUI or a GUI interface (see Figure 3, left). Moreover, it can learn from this interaction and then use this knowledge to influence users’ emotional states when they are not communicating. The learning process is based on modelling situations using the EmotionsOnto and then associate the corresponding descriptions to emotional states as provided by the user using the TUI or GUI interface buttons.

The system was developed using phidgets3, a set of plug and play building blocks for low cost USB sensing and control from Personal Computers (Figure 3, right). The EPF interface is composed by two main parts (Figure 3, left): corresponding a Picture Area, where is stored a picture of the sending-user, and a Feeling Area which allows the perception of the sending-user current emotional state. The feeling area is composed by different features as coloured emotional buttons, a Heart-Emotional Indicator and a set of history-emotional buttons.

The emotion concept was originally concretised into the categorical emotions defined by (Plutchik, 1980]: joy, acceptance, fear, submission, sadness, disgust, anger, and anticipation. These emotions have been then associated to the emotional buttons in the interface of the TUI.

On the other hand, the TUI features a small screen for digital picture display, speakers and an emotional indicator shaped as a heart that can display different colours. These output channels are used by the TUI in order to communicate with the user. The objective of the current TUI implementation is to try to make the user experience, for instance while the user works at the office, more pleasant. In order to

[2] FrameNet, http://framenet.icsi.berkeley.edu

[3] Phidgets, http://www.phidgtes.com

do that, the TUI is capable of generating visual and audio stimuli by showing pictures or playing songs.

The TUI mimics user behaviour and recreates simple descriptions for the situations arising from these stimuli. Basically, there are two kinds of situation, "playing a given song" and "displaying a given picture". Both kinds are modelled using frames. The TUI then tries to recognize the user emotional response to these situations using its sensors (emotion detection in speech or face features) and/or receives direct input from the user through the emotional buttons.

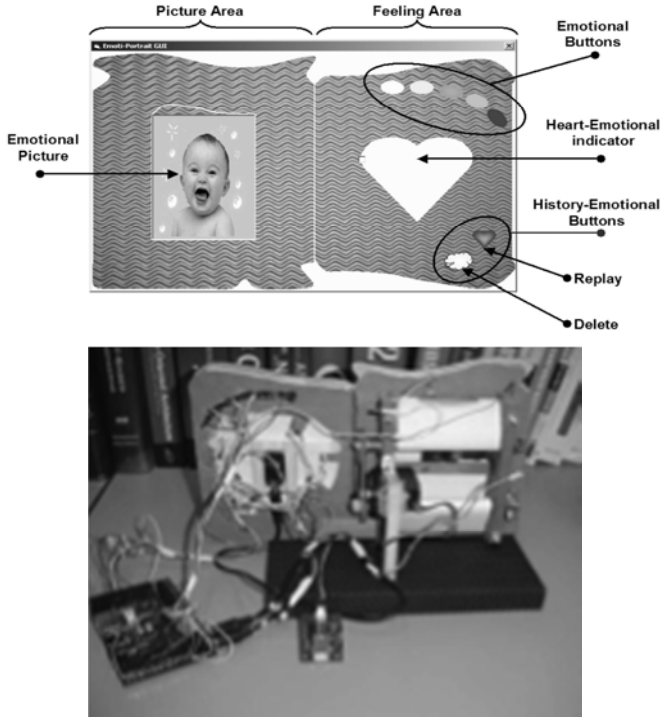

Figure 3: Picture frame enhanced with emotion sensors and expression systems (front and rear views)

Then, the TUI associates situations and the emotions it observes in order to drive some simple rules that implement its behaviour. These rules are based on concepts defined in EmotionsOnto. Basically, the initial behaviour is to randomly play songs and display pictures from user's favourites. This process helps the TUI learn user's emotional responses. When some associations have been learnt, the TUI is then capable of responding to user emotional changes. For instance, if it detects sadness, it responds by playing songs and/or displaying images that have been associated to a happy user response, as shown in Figure 4.

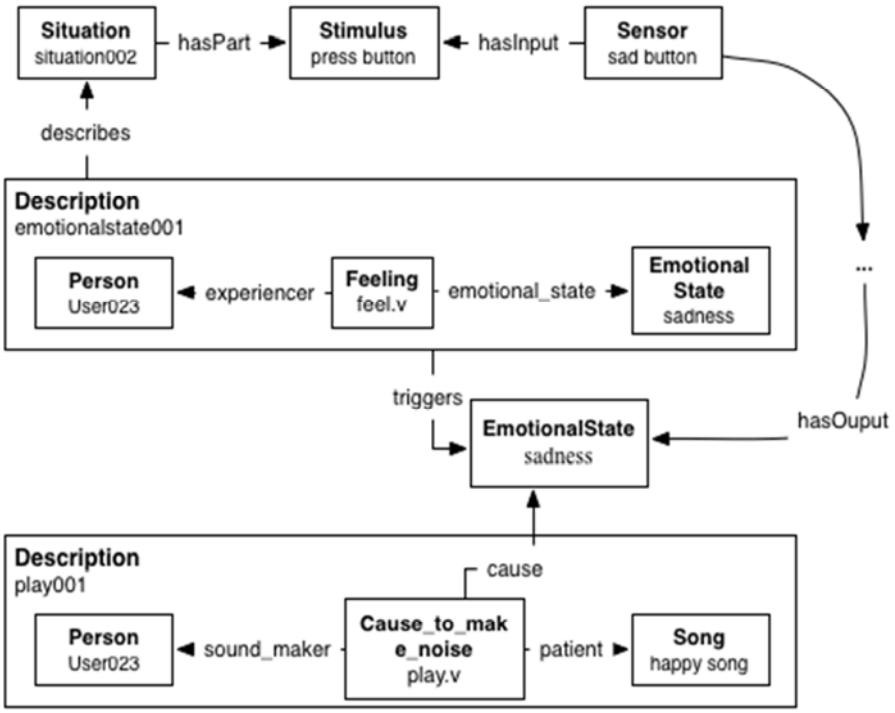

Figure 4: Representations based on EmotionsOnto for the TUI scenario

It is important to note that the ontology does not help the system recognise the emotional responses, but to model the emotions and associate them to descriptions of situations and other parts of the Emergent Emotion Model. However, though this can be learnt from user interaction, our experience shows that the system requires some bootstrapping emotional knowledge that makes it useful and thus motivates user to continue using it.

4.1 Empirical study

Thanks to the emotional input previously gathered using the TUI, specially the emotional input gathered through TUI buttons when pictures were displayed to the user, it was possible to set an initial experiment where the EPF was evaluated using the PrEmo [Desmet, 2003] methodology, as described in the next subsection. The objective of this empirical study was to test how a group of users reacted to the emotional stimuli of the EPF.

4.1.1 Participants

The test was performed to 14 computer science students at University of Cauca, Colombia. Seven of them were women and the other half men.

4.1.2 Material and Instruments

The instrument we used for evaluating the EPF was PrEmo [Desmet, 2003]. It is a non-verbal self-report instrument that measures 14 emotions that are often elicited by product design. Of these 14 emotions, seven are pleasant (i.e. desire, pleasant surprise, inspiration, amusement, admiration, satisfaction, fascination), and seven are unpleasant (i.e. indignation, contempt, disgust, unpleasant surprise, dissatisfaction, disappointment, and boredom). They are shown in Figure 5.

4.1.3 Procedure

The users turned the EPF on. They were asked to use the system freely during 30 minutes. After they used it, they had to report their experience using a questionnaire based on the PrEmo emotions. Instead of relying on the use of words, respondents had to report their emotions with the use of expressive cartoon animations. In the instrument, each of the 14 measured emotions is portrayed by an animation by means of dynamic facial, bodily, and vocal expressions.

Of these 14 emotions, seven are pleasant (i.e. desire, pleasant surprise, inspiration, amusement, admiration, satisfaction, fascination), and seven are unpleasant (i.e. indignation, contempt, disgust, unpleasant surprise, dissatisfaction, disappointment, and boredom). Each user had to label his/her experience using the EPF with just one of the emotions.

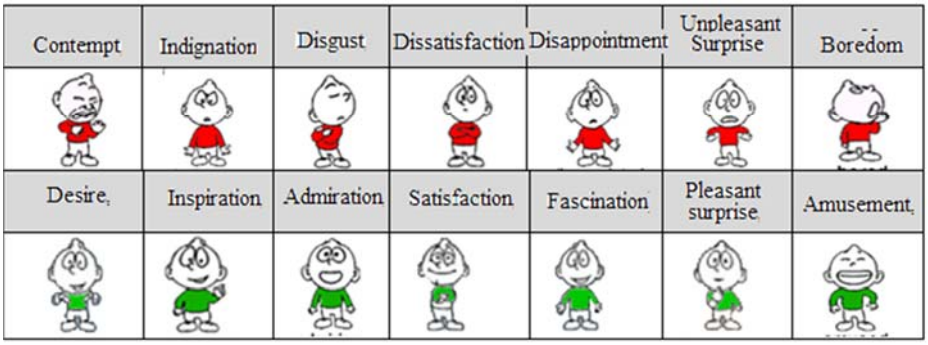

Figure 5: Portraits of the emotions in PrEmo

4.1.4 Results

The participants showed the highest scores for the following emotions: admiration, satisfaction, and fascination. As it can be observed in Table 1, all them correspond to positive emotions. In this sense, results show that the product and interacting with it was perceived as positive by all users.

Contempt	Indignation	Disgust	Dissatisfaction	Disappointment	Unpleasant Surprise	Boredom
0	0	0	0	0	0	0
Desire	Inspiration	Admiration	Satisfaction	Fascination	Pleasant Surprise	Amusement
0	0	**6**	4	4	0	0

Table 1: Results for the PrEmo-based evaluation of the Emoti-Picture Frame (EPF) based on the questionnaire based on Figure 5

5 Conclusions and Future Work

Affectivity in human beings is a very complex term where a lot of multidisciplinary research has been performed from different fields. Providing a computerized basis to perform a knowledge base that allows dealing with affective related concepts such as emotions requires a ground. Performed work tries to provide such ground. In this paper we present a generic model for describing emotions and their detection and expression systems taking contextual and multimodal elements into account. The model is formalised as an easily computerised ontology.

The ontology has been developed to be as totally agnostic as possible regarding existing emotion theories. Although this fact can seem to be surprising, it is justified because if allows independence from theoretical approaches, so developers of affective resources are not tied to a given theoretical approach. In this sense, different theoretical approaches can be used by developers. Thus, it makes the ontology valid for a wide range of proposed theoretical approaches. It is remarkable that context has received little attention regarding emotion-aware application development. This work takes this concept into consideration as a necessary component for modelling emotion. In this sense, proposed ontology is based on the definition of relevant contextual elements.

Proposed ontology does also have implications regarding emotion-aware applications development. On the one hand, it allows integrating emotion-related context and multimedia elements. On the other hand, defining sensors in the way performed allows making use of them as user interface elements for inputs (such as text through the keyboard, utterances through the microphone) and outputs (such as emotional pictures in user interfaces, text output on the screen or embodied avatars). They can be linked with emotion expression and recognition systems. This approach has proven to be very useful for describing how emotion-aware applications work. Finally, it must be highlighted that being performed ontology developed using standards like OWL, it is also valid for a wide range of software development technologies and environments and thus can be used as a basis to engineer emotion-aware applications.

The ontology has been put into practice in the context of an emotion-aware application based on Tangible User Interfaces (TUIs) called Emoti-Picture Frame

(EPF). The EPF is an emotional awareness device that allows anyone with Internet access to transmit their feelings by displaying them on a TUI or a GUI interface. Emotion detection is based on explicit user input provided through TUI or GUI buttons while its expression system is based on the TUI or GUI screen.

An interesting future work lays on extending the ontology beyond Emergent Emotion. The first extension considered is to model affective states in humans in order to make the ontology capable of modelling more complex aspects of human affectivity. This will make possible to model users bearing above-mentioned affective states in mind. These enriched user models enable including aspects related with user disabilities and developing applications even more adapted to their needs. Finally, the inclusion of social context in the ontology allows exploring emotion in computerised social environments such as social networks.

Acknowledgements

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References

[Baldauf, 2007] Baldauf, M., Dustdar, S. Rosenberg, F.: A Survey on Context-Aware systems. International Journal of Ad Hoc and Ubiquitous Computing, 2(4), 263-277, 2007.

[Benta, 2007] Benta, K. L., Rarău, A., & Cremene, M.: Ontology Based Affective Context Representation. In Proceedings of the 2007 Euro American conference on Telematics and information systems (EATIS'07). Faro, Portugal, 2007.

[Bradley, 1997] Bradley M.M., Lang P.J., Cuthbert N.B.: Affective Norms for English Words (ANEW). NIMH Center for the Study of Emotion and Attention, University of Florida, 1997.

[Chi, 2007] Chi, Y-L., Peng, S-Y., &Yang, C-C.: Creating Kansei Engineering-Based Ontology for Annotating and Archiving Photos Database J. Jacko (Ed.): Human-Computer Interaction, Part I, HCII 2007, LNCS 4550, pp. 701-710. Berlin Heidelberg: Springer, 2007.

[Collazos, 2007] Collazos, C., Gonzalez, M.P., Neyem, A., Sturm, C., Guidelines to Develop Emotional Awareness Devices from a Cultural-Perspective: A Latin American Example. N. Aykin (Ed.): Usability and Internationalization, Part II, HCII 2007, LNCS 4560, pp. 314–323, 2007, Springer-Verlag Berlin Heidelberg 2007

[Cowie, 2005] Cowie, R., Douglas-Cowie, E., Cox, C.: Beyond emotion archetypes: databases for emotion modelling using neural networks. Neural Networks, 18, 371-388, 2005.

[Cuijpers, 2011] Cuijpers, R. H., Bruna, M. T., Ham, J. R. C., Torta, E.: Attitude towards robots depends on interaction but not on anticipatory behavior. In Proceedings of the International Conference on Social Robotics, 2011.

[Desmet, 2003] Desmet, D.M.A., Hekkert, P., Hillen, M.G.: Values and emotions; an empirical investigation in the relationship between emotional responses to products and human values. Proceedings of the 5th European Academy of Design Conference, Barcelona, Spain, 2003.

[Devillers, 2005] Devillers, L., Abrilian, S., Martin, J.: Representing real life emotions in audiovisual data with non basic emotional patterns and context features. Proc. 1st International Conference on Affective Computing and Intelligent Interaction (ACII'2005). Beijing, China, 2005.

[Douglas-Cowie, 2006] Douglas-Cowie, E., et al.: HUMAINE deliverable D5g: Mid Term Report on Database Exemplar Progress, 2006,
http://emotion-research.net/deliverables/D5g%20final.pdf

[Ekman, 1984] Ekman P.: Expression and nature of emotion. In K. Scherer and P. Ekman (Eds.): Approaches to emotion. Hillsdale, New Jersey: Erlbaum, 1984.

[Fellbaum, 1998] Fellbaum, C.: WordNet: An Electronic Lexical Database. Cambridge, MA: MIT Press, 1998.

[Fillmore, 2006] Fillmore, C.J.: Frame semantics. Cognitive Linguistics: Basic Readings, 34, 373-400, 2006.

[Galunov, 2004] Galunov, V.I., Lobanov, B.M., & Zagoruiko, N.G.: Ontology of the Subject Domain. In Proceedings of the Speech Signals Recognition and Synthesis, SPECOM'04. 9th Conference Speech and Computer. Saint-Petersburg, Russia. 20-22, 2004.

[Gangemi, 2006] Gangemi, A., Catenacci, C., Ciaramita, M., Lehmann, J.: Modelling Ontology Evaluation and Validation. In The Semantic Web: Research and Applications, Lecture Notes in Computer Science, Vol. 4011 (pp. 140-154). Heidelberg, DE: Springer, 2006.

[Gangemi, 2002] Gangemi, A., Guarino, N., Masolo, C., Oltramari, A., & Schneider, L.: Sweetening Ontologies with DOLCE. In A. Gomez-Perez & V. R. Benjamins (Eds.), Proceedings of the 13th International Conference on Knowledge Engineering and Knowledge Management. Ontologies and the Semantic Web (EKAW'02), Lecture Notes in Computer Science (Vol. 2473, pp. 166–181). Heidelberg, DE: Springer, 2002.

[García, 2010] García, R.: Methodology. In: A Semantic Web Approach to Digital Rights Management (pp. 116-120). Saarbrücken, DE: VDM Verlag Dr. Müller, 2010.

[Goffman, 1956] Goffman, E.: Embarrassment and Social Organization. American Journal of Sociology 62:264-274, 1956.

[Lang, 1979] Lang P. J.: A bio-informational theory of emotional imagery. Psychophysiology, 16, 495-512, 1979.

[Lim, 2009] Lim, M.Y. & Aylett, R.: An Emergent Emotion Model For An Affective Mobile Guide With Attitude. Applied Artificial Intelligence, 23(9), 835-854, 2009.

[López, 2008] López J.M., Gil R., García R., Cearreta I., Garay N.: Towards an Ontology for Describing Emotions. In Proceedings of the 1st World Summit on the Knowledge Society. LNCS/LNAI Vol. 5288, Springer, pp. 96-104, 2008.

[Lytras, 2008] Lytras, M., García, R.: Semantic Web Applications: A framework for industry and business exploitation - What is needed for the adoption of the Semantic Web from the market and industry. International Journal of Knowledge and Learning, 4(1), 93-108, 2008.

[Mathieu, 2005] Mathieu, Y.: Annotation of Emotions and Feelings in Texts. In: Tao J., Tan T. and Picard R. W. (Eds.) Proceedings of ACII 2005, LNCS 3784, pp. 350-357. Heidelberg: Springer, 2005.

[Nguyen, 2009] Nguyen, H., Masthoff, J.: Designing empathic computers: the effect of multimodal empathic feedback using animated agent. In Proceedings of the 4th International Conference on Persuasive Technology, Claremont, CA, USA, ACM, 2009.

[Obrenovic, 2005] Obrenovic, Z., Garay, N., López, J. M., Fajardo, I., Cearreta, I.: An ontology for description of emotional cues. In: Tao J., Tan T. and Picard R. W. (Eds.) LNCS 3784, pp. 505-512, 2005.

[Picard, 2000] Picard, R.: Perceptual user interfaces: affective perception, Communications of the ACM, Vol. 43, No. 3, pp. 50-51, 2000.

[Plutchik, 1980] Plutchik, R.: A general psychoevolutionary theory of emotion. In R. Plutchik & H. Kellerman (Eds.), Emotion: Theory, research, and experience: Vol. 1. Theories of emotion (pp. 3-33). New York: Academia, 1980.

[Porello, 2014] Porello, D., Setti, F., Ferrario, R., & Cristani, M. Multiagent Socio-Technical Systems: An Ontological Approach. In Coordination, Organizations, Institutions, and Norms in Agent Systems IX (pp. 42-62). Chicago, USA: Springer International Publishing, 2014.

[Scheffczyk, 2008] Scheffczyk, J., Baker, C. F., Narayanan, S.: Ontology-Based Reasoning about Lexical Resources. In N. Calzolari, A. Gangemi, A. Lenci, A. Oltramari, & L. Prévot (Eds.), Ontologies and Lexical Resources for Natural Language Processing. Cambridge, MA: Cambridge University Press, 2008.

[Scherer, 1986] Scherer K.R.: Vocal affect expression: A review and a model for future research. Psychological Bulletin, 99, 143-165, 1986.

[Scherer, 1999] Scherer, K.R.: Appraisal theory. In: T. Dalgleish and M.J. Power, Editors, Handbook of cognition and emotion, Wiley, New York, pp. 637–663, 1999.

[Scherer, 2000] Scherer, K.R.: Psychological models of emotion. In Joan C. Borod (Ed.): The Neuropsychology of Emotion, pp. 137-162. New York: Oxford University Press, 2000.

[Sowa, 1999] Sowa, J. F.: Knowledge Representation. Logical, philosophical and computational foundations. Pacific Grove, CA, USA: Brooks Cole Publishing Co, 1999.

[Strapparava, 2004] Strapparava, C. & Valitutti, A.: WordNet-Affect: an affective extension of WordNet. In Proceedings of 4th International Conference on Language Resources and Evaluation (LREC 2004), pp. 1083-1086, Lisbon, 2004.

[Tao, 2005] Tao, J., & Tan, T.: Affective computing: A review. In J. Tao, T. Tan, & R. W. Picard (Eds.), Proceedings of the First International Conference on Affective Computing & Intelligent Interaction (ACII'05; pp. 981–995). Beijing, China: Springer, 2005.

[W3C OWL Working Group, 2012] W3C OWL Working Group: OWL 2 Web Ontology Language Document Overview, W3C Recommendation. December 2012, http://www.w3.org/TR/owl2-overview