Towards an ontology for describing emotions

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Abstract. The study of emotion in human beings has traditionally been a research interest area in disciplines such as psychology and sociology. The appearance of affective computing paradigm has made it possible to include findings from these disciplines in the development of affective interfaces. Still, there is a lack of applications that take emotion related aspects into account. This situation is mainly due to the great amount of proposed theoretical models and the complexity of human emotions. Besides, the importance that mobile computing area is acquiring has made necessary to bear context related aspects in mind. The proposal presented in this paper is based on 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 a formal model that can be easily computerized. Moreover, it is based on a standard, the Web Ontology Language (OWL), which also makes ontologies easily shareable and extensible. Once formalized as an ontology, the knowledge about emotions is used in order to make computers more accessible, personalised and adapted to user needs.

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. Consequently, emotions must be taken into account when implementing information systems in order to enable a more social and humanistic computing for our knowledge society. A new paradigm called affective computing works on the detection and response to user's emotions [1]. There is 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. In addition, 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 [1]. Therefore, emotion-aware applications should be designed in a flexible way if they are wanted to be used with a wider class of users. In this way, personalisation is necessary for more efficient interaction, and better tuning and acceptation of developed systems.

However, computer systems cannot be only user-centred. The rapid development of mobile computing implies that studying context is relevant in order to analyse user interaction with computer systems. In this sense, the great extent of situations involved in mobile computing has made context a critical factor to take into account when designing computer systems. In order to cope with elements that have influence in affective interactions between people and computers, several models have been developed. Some of them have been presented as ontologies. In any case, their main aim is to be computationally affordable.

It must be highlighted that there is a broad terminology related to affective states in human beings. There is a tendency to use the term "emotion" in a broad sense, especially in technological contexts [2]. Scherer [3] proposed a number of taxonomies for these affective states. This list was modified and defined in Douglas-Cowie et al. (2006).

This paper is focused specifically on Emergent emotion, instead of a global taxonomy of Affective states. This is made to reduce the complexity of proposed domain, due to space limitations in the paper. In [4], 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 – which may be in reality or in their mind". Besides, for the same reason, focus is mainly devoted to emotion detection and expression systems instead of modelling internal emotion processing in humans.

With the aim of solving presented problems and bearing proposed limitations in mind, we propose a generic approach to defining context-aware emotions taking different theoretical models into account. This approach can serve as a guide for flexible design of multimodal affective applications with independence of the starting model and the final way of implementation.

Next section of this paper presents several theories and concepts relevant for describing emotions. Afterwards, several topics related to ontologies and emotions are explained. Then, our conceptual model is highlighted before describing the ontology itself. Finally, some conclusions are shown and future works suggested.

2. Theories and relevant aspects for describing emotion

Emotion is a complex aspect 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 theoreti-

cal 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 [5], dimensional [6] and appraisal [7].

Lang [6] also proposed analysing of emotions according to three systems involved in the expressions of emotions: 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 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 [8]. 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 [9]. 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, [10] 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 [7] such as time-of-event were added in the context part of the proposed scheme. On the other hand, [11] proposed that context aware systems [12] are systems that adapt their behaviour according to context and that this context (location, time, activity, devices and person) includes also the user's affective state.

3. Ontologies and Emotions

Ontology has been a field of philosophy since Aristotle and from its beginnings, it has been characterised as a study of existence, a compendium of all there is in the world. Nowadays, it has evolved in great measure in the computer science and artificial intelligence fields. Currently, ontologies are viewed as a shared and common understanding of a domain that can be communicated between people and heterogeneous and distributed application systems. A detailed description is presented in Fig. 1.

Several ontologies for modelling affect have been proposed in literature. For instance, in text analysis area, Mathieu [13] 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, thanks to the work performed in its WordNetAffect extension [14]. With the support of ontology technologies, users can retrieve information in a semantic manner [15]. A primary course of ontology building is related to concept development. Focusing on speech, Galunov et al. [16] present an ontology for speech signal recognition and synthesis where emotion is taken into account. On the other hand, focusing on the context, Benta et al. [17] 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.

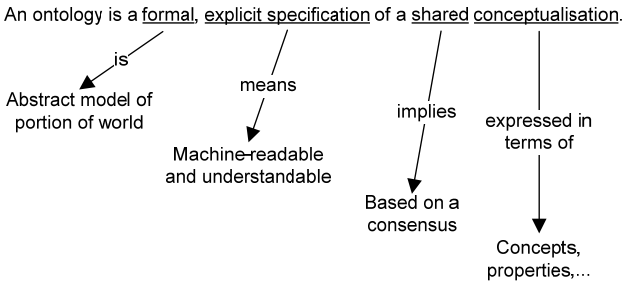

Fig. 1. Ontology definition [18]

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 et al. [19] describe an ontology based on emotional cues that uses media properties from different sources to model emotion. Apart from multimodality and user adaptation issues, technological evolution in mobile computing area has made necessary taking context into account in human-computer interaction situations. In this sense, Cearreta et al. [20] models user context by dividing it into several parts and focusing on emotion-related aspects in each part.

4. Conceptual Model

Our model has been created with independence of the psychological theory used. When expressing emotions, the three systems proposed by Lang [6] are used. Besides, it is considered that senses are used by humans and sensors by computers in order to receive affective information. Multimodality of emotions is related to sensors and expression systems.

As it is mentioned before, emotion has a strong dependence on contextual elements. Therefore, it is necessary to define the model taking the whole context that

surrounds the user into account. It includes the personal part of the user and his/her affective state, which are also considered as parts of the context. Moreover, the model also includes environmental data, such as topics related to the place where user is. Finally, social aspects related to personal context are also described.

We start our model from emergent emotions because they are easier to detect and can serve as a basis to understand what it is involved in human affectivity. Then, we generalise our model in order to treat emergent emotions, as it can be seen in Fig. 2.

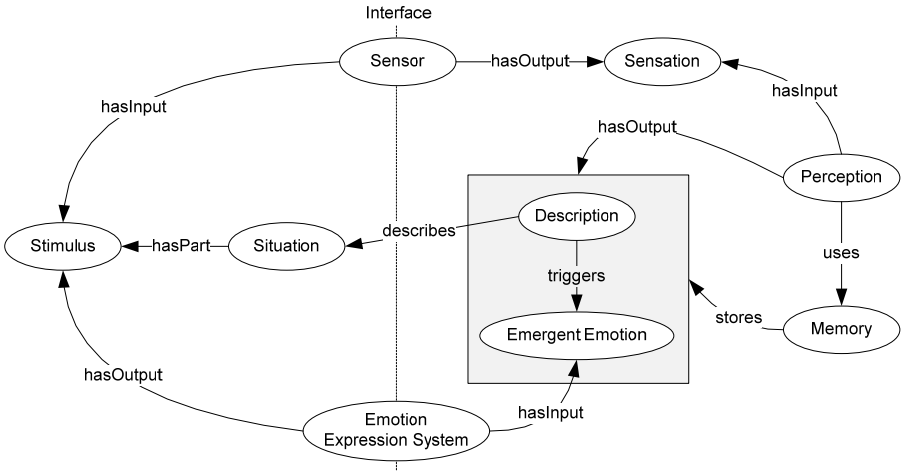

Fig. 2. Emergent emotion relationships with human information processing systems

Two main parts can be identified in Fig. 2, which are defined by the Interface line. This line groups the Sensor and Emotion Expression systems, which interface between the “physical world” on the left and the “mental world” on the right. In the physical world the model identifies arrangements called Situations that are constituted by a set of Stimuli. Stimuli are the input for Sensors, which have Sensations as output in the mental world. Sensations are the input for the Perception process, which uses memory in order to give meaning to Sensations and produces Descriptions, the mental representations for the Situations that describe them. Descriptions are associated to Emergent Emotions as they trigger them and both are stored in the Memory, from where they might influence the operation of future perceptions. Finally, Emergent Emotions constitute the output for the Emotion Expression System that reflects emotions in the real world by generating new Stimuli. In our model, we detail involved affective processes. The model is not trying to interpret emotions, because this depends on the used affective theory. In the same way, the "trigger" process in Fig. 2 is not detailed, because describing and interpreting emergent emotions also depends on affective theories. This model is detailed in the next section, formalised as an ontology. A detailed description of sensors and emotion expression systems is also provided.

5. Ontology for describing emotions

From the previous generic model, and following a classical ontology engineering methodology [21], a formalisation as an emotions ontology is developed. The ontology follows the modelling principles of the previous section and tries to be as emotions theory agnostic as possible. The objective is to develop an ontology flexible enough to accommodate existing emotions theories, like the ones presented in the literature review.

The first step has been to formalise the emotion model presented in the previous section. Semantic Web tools [22] have been chosen, more concretely the Web Ontology Language (OWL) [23]. 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 modelled 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 Fig. 2 as OWL classes. Therefore, there are classes such as *EmergentEmotion*, *Description*, *Memory*, *Perception*, *Sensor*, etc. For the relations among these concepts in the model, OWL object properties have been generated, i.e. *hasInput*, *hasOutput*, *triggers*, etc.

The ontology is completed with some axioms that restrict the kind of things that these properties can link. 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 full specification of the Emotions Ontology in OWL format is available on-line[1].

5.1. Rooting the Model on Upper Ontologies

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 little 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. Consequently, they provide very basic and fundamental semantics about the kind of things that a more specialised ontology, like the Emotions Ontology,

[1] Emotions Ontology, http://rhizomik.net/ontologies/2008/05/emotionsonto.owl

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.

We have chosen DOLCE [24], that stands for Descriptive Ontology for Linguistic and Cognitive Engineering, because it fits really well with the underlying cognitive aspects that we have considered in order to build the conceptual model. In fact, the *Description* and *Situation* concepts in the Emotions Ontology have been reused from DOLCE.

These concepts provide a framework for representing contexts. *Situation* stands for a unitarian entity out of a "state of affairs". The unity criterion is provided by a *Description*, an entity that partly represents it and that can be "conceived" by an agent: either human, collective, social or artificial.

Apart from these two concepts, DOLCE provides many other generic concepts that have been used in order to contextualise those in the Emotions Ontology. First of all, there is *Event* that generalises all 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 Emotions 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 *Action*s.

All these relationships among Emotions Ontology and DOLCE concepts are shown in Fig. 3, 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.

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 enormous range of situations that might be associated with emotions is out of the scope of an Emotions Ontology. Consequently, we have selected an existing ontology that provides such a wide scope called FrameNet [25].

We have selected FrameNet 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, spying, removing, classifying, etc.) together with a list of the kinds of participants, properties and other

conceptual roles that are seen as components of that situation[2]. Moreover, it is already connected with DOLCE, as it can be noted in Fig.3, where the concept *Frame* appears as a subclass of *Description*. Consequently, we can accomplish a smooth integration among the Emotions Ontology, DOLCE and FrameNet.

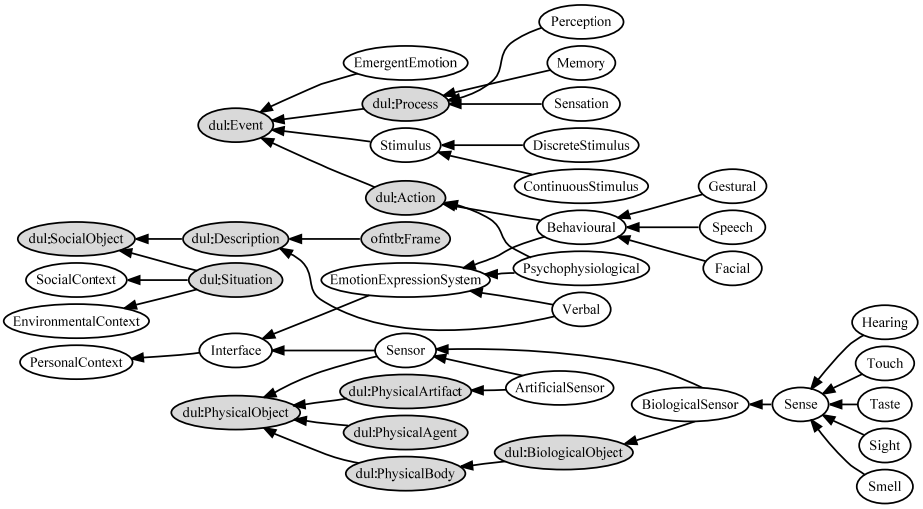

Fig. 3. The emotions ontology core in the context of the DOLCE upper ontology

For instance, in order to model the situation "Torres scored a winning goal in the last minute" using FrameNet, it is possible to use the "score.v" lexical unit, which belongs to the "Getting" 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 "Recipient" is associated with "Torres", the FE "Theme" is linked to "goal", "Result" is filled with "winning" and "Time" points to "in the last minute".

6. Conclusions and Future Work

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 ontology that can be easily computerised.

It is remarkable that context has received little attention regarding emotion-aware application development. This work takes this concept into consideration as

[2] FrameNet. Retrieved June 4th 2008 from http://framenet.icsi.berkeley.edu

a necessary component for modelling emotion. In this sense, proposed ontology is based on the definition of relevant contextual elements.

The ontology is based on the Web Ontology Language (OWL) standard, which makes ontologies easily shareable and extensible. This approach makes possible to reuse parts of DOLCE and FrameNet, two generic ontologies that help modelling descriptions and situations (D&S). D&S correspond to the only theoretical commitment that has been incorporated into the ontology, based on a cognitive interpretation of emotions. Apart from this, the ontology is totally agnostic regarding emotion theories. Existing semantic web technologies have proven to be valid and provide an adequate environment for modelling aspects related to human emotion.

The ontology can be used to develop applications that make computers more accessible, personalised and adapted to user needs. For instance, the ontology is being applied in an emotion-aware application based on Tangible User Interfaces (TUI) [26]. These TUIs are geared towards emotions-based human-computer interaction. The ontology structures and contextualizes the knowledge managed by the application, so it is been extended in order to deal with this concrete scenario.

Other 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 abovementioned affective states in mind. These enriched user models enable including aspects related with users disabilities and developing applications 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.

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