Ontology Based Affective Context Representation

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Abstract

In this paper we propose an ontology based representation of the affective states for context aware applications that allows expressing the complex relations that are among the affective states and between these and the other context elements. This representation is open to map different affective spaces; basic and secondary states relation (using Fuzzy Logic), the relation between these states and other context elements as location, time, person, activity etc. The proposed affective context model is encoded in OWL. Due to difficulties in direct detection of the secondary affective states we propose a method to infer the characteristic values of these states from other context elements' values. The deduces states are used here to improve the behavior of a Context Aware Museum Guide in order to react more intuitively and more intelligent by taking into account the user's affective states.

Keywords: context awareness, affective computing, ontology, logical inference.

1. Introduction

The following scenario illustrates the relations between the affective states and other context elements when visiting an art museum, guided by a context aware system: "It's Friday evening and Victor decides to visit the Art Museum. Entering the museum he receives a context aware electronic guide, running on a smart phone or PDA, which explains to him about each painting he approaches. In the first room with low light and old dark color paintings he gets bored after watching a few items. As he moves slowly from one room to another and because of his boredom his electronic guide gives him a friendly warning regarding his time left for the visit (until closing). Now Victor becomes a little stressed and accelerates his walk. Reaching his preferred painter's room each painting presentation incites his curiosity and his guide empathizes with him alternating presentations with empathic phrases. […later in another room] A curator impassionedly presents some guest artifacts to a group of people. Victor is enthusiastic hearing him and having other art lovers around him. The context aware electronic guide is now mute and displays a sympathetic smile…"

One semantic relation is between Victor as *Person* and his *Affective State*: boredom. Another relation is between his state and its object (cause) - the room he is in, that is a *Location*. The moment of *Time* (the end of the working week and the evening) and the low light of the room induce the *Affective State* boredom to *Person* Victor.

The interest in affective computing [1] is increasing nowadays as computer systems tend to become more powerful facilitating real-time basic affective states detection. We see affective states as a part of user's every day life, of his context. So, we think more attention should be awarded to affect in context aware systems.

Context aware systems are systems that adapt their behavior according to context [2]. This context (location, time, activity, devices, person) includes also the user's affective state.

Semantic Web Ontology [3] was used lately in context modeling and reasoning allowing expressing the relations between the context elements and inferring new data (as described in section 4.1). But the existing ontological context modeling frameworks are not enough to solve specific problems related to ontological affect modeling analyzed in section 2.

From our perspective an ontological context aware framework is more then a context model using ontology on different context concepts as it allows reasoning in order to improve the model and using a triggering mechanism that bind the different ontological representations all together.

2. The problem

Affective models are originating from psychology and are further developed by different specialists [4]. We make a clear distinction here between the affective model and the representation of it in a computer system, as the later is the formalization of the former.

The existing affective models can be classified as the affective states are a part of a:

- vector (one dimension) containing five[5], seven [6], eight [7], twenty two [8] affective states (usually considered as basic states) or
- space (two [9] or three[10][11] dimensional) of states where the basic and secondary states (which are derived from the basic ones) are distributed.

A first problem when formalizing these models is that the representation should be as general and flexible as possible to allow all the models to be mapped to it.

The research on detecting affective state is getting good results when considering a limited set of basic states [12][13] but only a few papers concern the secondary ones [14]. A second problem is how to express the link between the basic and secondary states in order to infer the last ones from the former. In section 3.1 we describe the solution for the first two problems.

Even if we agree that someone can feel more than one emotion at a time [15], we may simplify and say that just one is dominant at a precise moment. A third problem is how to express the relation between the potential states and the current (dominant) state (see Section 3.2).

A fourth problem arises from the relation of the affective states with other context elements. This problem is detailed in 3.3. How can we express relations as:

- who is the owner of an affective state,
- what is the causal relation: affective state - object,
- what is the link between the affective state and the time?

3. Ontology Based Affect Representation

3.1. General Affective Model

There is a gap between the two main types of affective models (vector or space of affective states) as there is no mechanism to quantify the continuous affective space into a discrete set of affective states and vice versa. T. Yanaru [16] proposed in 1995 a method to deduce a secondary state as a linear combination of the (eight) basic affective states. Inspired by his work we take into consideration the activation-evaluation model [17] and we propose that each secondary state should have a membership degree value for each of the basic state considered. Moreover the membership degree will be expressed for each of the two following axes: valence (how positive, negative or neutral the state is) and activation (how dynamic the state is). The third axis will measure the intensity of the state as in [11] using values as low, medium, high.

In figure 1 we define a class *State* in SOCAM [18] with three subclasses: *Affective, Mental* and *Physiological.* The *Affective* class has three subclasses: *Basic*, *Secondary* and *Current*. *Affective* has attributes that define the region occupied by each state on each of the three axes:

- minValence, maxValence $\in [-1,1]$
- minActivation, maxActivation $\in [-1,1]$
- intensity $\in [0,1]$.

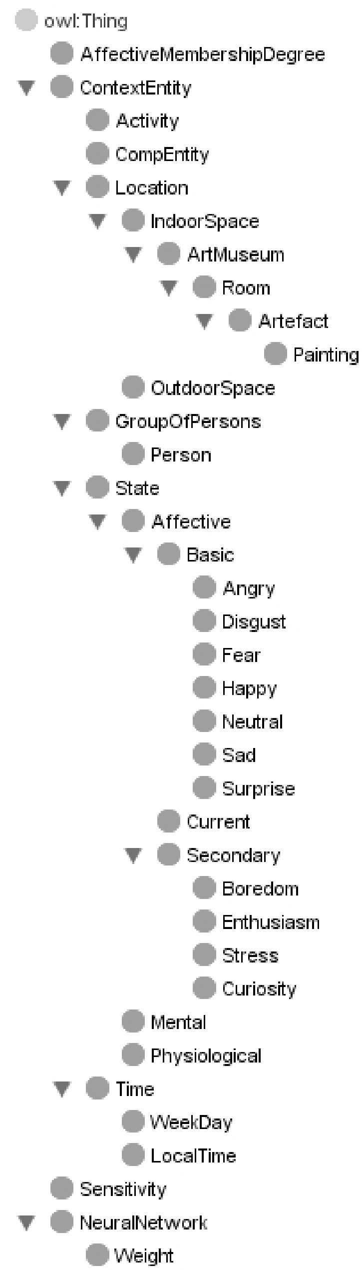

Figure 1. Our proposal for the affective extension to SOCAM [18] described in Protégé

The *Basic* has subclasses depending on the affective model used. We propose the one with seven states: anger, neutral, happy, sad, surprise, disgust and fear.

The *Secondary* has as subclasses a number of items that application-specific. In the presented scenario we only define: relaxed and stressed (represented by a dotted line heart shape). The *Current* class will be described in the next section.

3.2. Current Affective State Representation

The current state $\Psi_{current}$ should be the one that is the most powerful at that particular moment for the user. That is the maximum of the all products intensity of the state Ψ_i and the triggering φ_i sensibility of state 'i':

$$\Psi_{current}=\max(\Psi_i*\varphi_i), \quad (1)$$

where i=1,n and n is the number of all the existing states (basic or secondary) as it is depicted in figure 2:

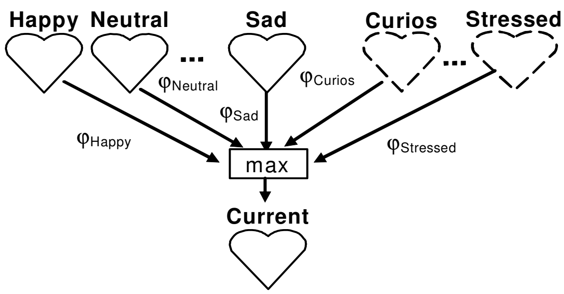

Figure 2. An exemple on how we propose to determine the current (dominant) affective state

Sensibility is seen here as the predisposition of a person to react with an affective state triggered by a stimulus (event or object) and is expressed as floating numbers between 0 and 1.

3.3. Affect in Relation to Other Contexts

We propose to represent the relations between the affective states and the other context elements as properties of the affective states class: owl:ObjectProperty for the ownership and the affective state-object causal relations. For expressing the affective state's time attributes we decided to use owl:datatypeProperty.

Figure 3 illustrates, in an ontological graph, the evolution of the current state in time determined by activities, locations, and persons. We may see that an affective state may have different context elements as objects.

***Person* is in an affective state**

As described in the scenario, Victor is passing from boredom to enthusiasm. Each of these secondary states may be induced by some other context elements; in this case only boredom is illustrated. For each individual of *Person* will be a *isInTheState* owl:ObjectProperty specific relation with individuals of the *Current*. The current affective state can be either basic or secondary.

Affective state – object relation

Victor is in the Room1 when he gets bored, so the object of his boredom is this room.

For each *Current* (affective state) we propose an owl:ObjectProperty names *isInducedBy* that indicates the object of that state in that particular moment.

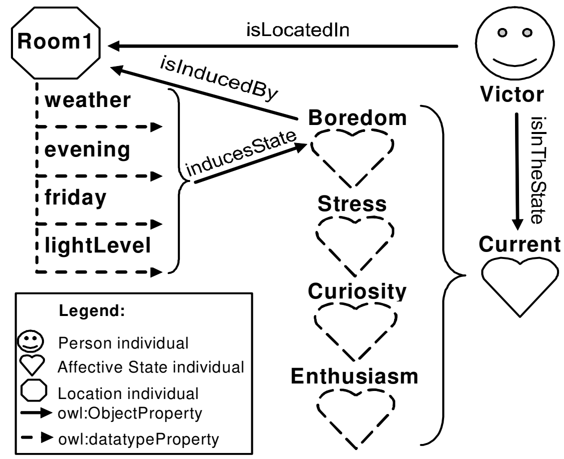

Figure 3. The ontological graph for the presented scenario

Representation of time for an affective state

The affective states are permanently changing. The timestamp will allow an automatic system to understand these successions in time. Affective detectors sense the basic states and some of the secondary. They may add this time information to the corresponding states. As a consequence the parent class *Affective* will have the following owl:datatypeProperty instances: *start*, *stop*, *duration*.

The first two (*start* and *stop*) are self-explained. The *duration* is the value of time initially estimated by the sensor that indicated the time to live of that affective state.

Time may have another use then that of a timestamp when it's duration means something for the user like in: "It's weekend, I feel relaxed…" or "It's the 8 o'clock humor TV show". In this case the time is the object (cause) of the state and we will represent it as discussed in the above paragraph.

4. Extending SOCAM to Include Affect

In the last years the growing interest on semantic web inspired the context aware researchers to develop ontological frameworks to deal with the complex problem of context representation and reasoning. A good overview paper that compares the most important context aware (ontological and not) frameworks is [2]. Although there is a need for a more specific up-to-date study on ontological context aware frameworks this is beyond the purpose of this paper.

SOCAM(CONON) [18] and CoBrA(SOUPA) [19] are two of the most complete frameworks. SOCAM allows expressing the causal relation between classes (dependency) and classification of the context elements (as sensed, deduces and defined), even if SOUPA is more general and easier to integrate among already existing ontologies (i.e. FOAF, DAML-Time).

4.1. How to represent Fuzzy Logic in OWL

We proposed in section 3.1. to express the relation between secondary and basic states as membership degree. SOCAM does not offer explicit support for this representation. In the work of A. Ranganathan et al [20] they mention about using Fuzzy Logic but the formalization is predicate-based. Our approach following the one presented in [18] is OWL based, as OWL became standard for W3C Semantic Web [3].

We propose that *AffectiveMembershipDegree* to have two owl:DatatypeProperty: *valenceDegree* and *activationDegree*. The relation between the Secondary and the *Basic* states we have represented by the owl:ObjectProperty *hasAffectiveMembershipDegree* and *isAFuzzyMemberOf, respectively*:

```
<owl:Class rdf:ID="AffectiveMembershipDegree">
   <owl:disjointWith rdf:resource="#ContextEntity"/>
</owl:Class>
<owl:ObjectProperty
rdf:ID="hasAffectiveMembershipDegree">
    <rdfs:domain rdf:resource="#Secondary"/>
    <rdfs:range rdf:resource="#AffectiveMembershipDegree"/>
 </owl:ObjectProperty>
 <owl:ObjectProperty rdf:ID="isAFuzzyMemberOf">
    <rdfs:domain
rdf:resource="#AffectiveMembershipDegree"/>
    <rdfs:range rdf:resource="#Basic"/>
 </owl:ObjectProperty>
<owl:DatatypeProperty rdf:ID="activationDegree">
    <rdfs:domain
rdf:resource="#AffectiveMembershipDegree"/>
    <rdfs:range rdf:resource="&xsd;float"/>
 </owl:DatatypeProperty>
<owl:DatatypeProperty rdf:ID="valanceDegree">
    <rdfs:domain
rdf:resource="#AffectiveMembershipDegree"/>
    <rdfs:range rdf:resource="&xsd;float"/>
 </owl:DatatypeProperty>
```

The values for the *activationDegree* and *valenceDegree* can be experimental determined.

4.2. Expressing the dominant relation in OWL

OWL does not allow for an ObjectProperty to have attributes. We use the class *Sensitivity* to store the value φ (*sensitive*) for each of the potential current states. Similar to the *AffectiveMembershipDegree* class the relations between *Current* and *Basic* and *Secondary* is an owl:ObjectProperty as you may see below:

```
<owl:ObjectProperty rdf:ID="hasSensitivity">
      <rdfs:domain>
         <owl:Class>
            <owl:unionOf rdf:parseType="Collection">
               <owl:Class rdf:about="#Basic"/>
               <owl:Class rdf:about="#Secondary"/>
            </owl:unionOf>
         </owl:Class>
      </rdfs:domain>
   <rdfs:range rdf:resource="#Sensitivity"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:ID="isOwnedBy">
   <rdfs:domain rdf:resource="#Sensitivity"/>
   <rdfs:range rdf:resource="#Person"/>
</owl:ObjectProperty>
<owl:DatatypeProperty rdf:ID="sensitive">
   <rdfs:range rdf:resource="&xsd;float"/>
</owl:DatatypeProperty>
```

Moreover each S*ensitivity* individual is specific for a particular person (i.e. a choleric is angry prone, φ_{Anger}=0.9) and *isOwnedBy* represents this relation.

The values for *sensitive* are obtained by experiments. A rule for a reasoning engine has to be written in order to determine the dominant current state of a user.

5. Related Work

We already mentioned that the existing affective state detectors can classify between the basic affective states, by using different classification methods. This is the reason why the representation of the affective state was usually only a matter of attribute-value pairs. With the development of embodied characters the need for a more detailed representation increased. VHML-EML (Virtual Human Markup Language-Emotion Markup Language) [21], APML (Affective Presentation Markup Language) [22], and MPML2.0.e (Multimodal Presentation Markup Language) [23] are examples of presentation language that are dedicated or include affective representation. These are all XML-based.

There are some ontological oriented representations that, compared to XML, has the advantage of allowing expressing relations among different elements. However they include only partially the affect like in GUMO (General User Model and Context Ontology) [24] or are focused on the actions that an animated character should do when a particular affective state is to be shown [25].

GUMO [24] style description of an affective state includes attributes as label, id, expiry, privacy, image, website and it may be a simple emotion or one of the five basic emotions.

The Affective Model that we propose in this paper is ontological based and is more detailed than GUMO in explaining the relations between the secondary and basic states and between the last two and the current affective state. Even if some other ontological model including affect could define relations with other context elements we extended an existing context aware framework SOCAM to improve the reuse of the general context aware application in affective rich environments.

We are preparing a test bed in an art museum taking into account specific affective states: curiosity, calmness, happiness, relaxation, interest, enthusiasm induced by factors as paintings content, the presence of people and weather conditions. The pilot tests are encouraging and we plan to publish the results in an extended paper.

6. Conclusion

We proposed an extension to the existing ontological context aware frameworks to represent in more detail affective states and the relations among them and other context elements. This representation also allows mapping different affective models thus unifying the different perspectives on affect modeling.

As future work we will focus on affective context reasoning that is going to be useful for deducing the attributes of the current affective state, the activities induces by the different states and solving conflicts between sensed, deduces and declared affective states.

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