On the Need for Context Processing in Affective Computing

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Abstract: Research on Emotions within Artificial Intelligence and related fields has flourished rapidly through several years. Unfortunately, in much research the contextuality of emotions is disregarded. In this paper we argue, that recognizing emotions without recognizing their context is incomplete and cannot be sufficient for real-world applications. We present logical underpinnings of this claim and describe some consequences of disregarding the context of emotions. We also present our approach, in which the context of emotions is considered and describe some of the first experiments performed in this matter. The paper is finalized with a discussion on future development and applications of context processing within Affective Computing.

1. Introduction

Affective Computing (AC) [1] is a new field within Artificial Intelligence research. It is focused on developing machines capable to understand user emotions and adapt its behavior according to these emotions. Research on emotion recognition, the main stream in the field, has a nearly fifteen-year-long history of attempts to the task of recognizing emotions.

In the most popular methods the emotions are recognized from: facial expressions [2], voice [3], language [4] or biometric data [5]. Affective Computing have contributed greatly to the creation of more human-like interfaces and user-friendly systems [6,7,8]. However, in much research questions like "How to use the recognized information?" or "Is the expressed emotion appropriate for the context it appears in?" are often disregarded. Based only on behavioral approaches, methods for emotion recognition ignore the context of emotional expression. Therefore, although achieving good results in laboratory conditions, such methods are often inapplicable in real world tasks. For example, a system for recognition of emotions from facial expressions, assigning "sadness" when user is crying would be critically mistaken if the user was e.g. cutting an onion in the kitchen.

In this paper we will emphasize that recognizing emotions while disregarding their contexts causes methods to be insufficient for real-world applications. We will present the reasoning for this statement and describe some examples of how neglecting the context of emotion could cause a fallacy in system performance. We will also present our approach, where we focus both on the expression of emotion and the context it appears in. We will also briefly describe some of the first experiments performed in this matter. We will conclude this paper with a discussion on some future directions and applications of context processing to Affective Computing.

2. Emotions and Intentionality

View on emotion phenomena has evolved in time. In Middle Ages, emotions were considered as biological disturbances, passive states with no relation to rational thinking or cognition [9,10]. This approach has been proved wrong in neurobiology where it was showed that emotions and rationality are not separable entities but stem from each other as equally important processes in decision-making [11,12,13], and cognitive processes [14,15,16,17,18]. It was thus reassured that emotions are conscious and intentional mental phenomena [19,20]. Oxford English Dictionary defines intentionality as "the distinguishing property of mental phenomena of being necessarily directed upon an object, whether real or imaginary" [29]. In other words, intentional phenomena are always "about something".

As a property of emotional processes, the idea of intentionality implies that emotions necessarily need to be assigned a [formal/intentional] object [18,21,23]. The linguistic-pragmatic reality proves this. When people express emotions they often express them in terms of specifying their objects. For example, we are *afraid/proud* **of** something, or *happy* **about** something[1], etc. A function of all specific emotion objects forms a formal object of emotion. The formal objects of emotions have been defined as "axiological properties[2] which individuate emotions, make them intelligible and give them correctness conditions" [24,25,26]. Moreover, Solomon, in his theory of emotions as "engagements with the world" argues that emotions are not only intentional, but they are conscious choices and strategies by which people manage the world. The targets of those strategies are formal objects. Moreover, emotions and their formal objects are necessarily in a causal relation [27]. Formal objects, as sets of axioms defining the emotions, can be further reformulated as properties determining the context of emotions.

3. Emotions and Contextuality

The idea of contextuality with an application in logics, as proposed by Gershenson, assumes that "concepts are determined […] by the context they are used in." Gershenson gives a relative notion of a context as follows.

*"A **context** consists of the set of circumstances and conditions which surround and determine an idea, theory, proposition, or concept. These circumstances and conditions can be spatial, temporal, situational, personal, social, cultural, ecological, etc."*

Gershenson, 2002 [28]

[1] It has been argued that "moods" are not about anything specific and therefore are not intentional, which would introduce an inconsistency in the definition of emotion and emotion-related processes. Solomon solves this problem by noticing that the objects of moods are not unspecified, but rather moods take as their objects the whole world [21,22].

[2] Or "properties derived from axioms [= here, specific objects of emotions]".

Gershenson gives the following general example: "the concept 'cat' will be determined by the context in which it is used. It can be a context of veterinary medicine, naughty pets, violent cartoons, cute animals, Broadway musicals, etc. The way we refer to 'cat' will change considerably depending on the specific context that we are using." [28]. He formalizes this idea as follows: "Every proposition P can only have a truth value (or vector) **in dependence** of a context C. This truth value is **relative to** the context C." Gershenson argues further that, since people learn concepts socially, incongruencies within context of any concept are verified by experience.

All the above, when expanded to the emotion phenomena provides a set of conditions for an emotion to take place.

- Emotion *E*, takes form of an expression *e* and has an object O_E;
- *E* is in causal relation with O_E ($O_E \rightarrow E$);
- Emotion object O_E defines (partially) *E*, and
- Gives the [correctness/truth] condition to E;
- O_E (or set of O_E's) makes up a context C_E for *E*, and
- $O_E \in C_E$;
- General C_E is formulated through collecting experiences *X*, and
- Value of *E* changes with the change of C_E;

With this set of conditions we can propose a simplified statement that emotion is a function of *expression* appearing within *context*, where *context*, learned by *experience*, is constituted by *object(s)*. As we can see, the function is solvable only when a certain expression appears within a matching context. The function is not solvable when the context either does not match the expression or is not given, or computed. Below we present a set of examples of situations, where [not providing/providing false] context for an expression ends in error in computation.

3.1 Consequences of Ignoring Emotion Context

Generally perceived emotion recognition can be defined as "using some (behavioral[3]) assumptions to determine emotional state (of a human)". The assumption that emotions can be sufficiently analyzed looking only at the behavior comes from William James [10,30]. James gives an example of what happens when people see a bear. When one sees a bear, hair on one's head stand up, he feels shivers, opens his eyes wide and runs. In James's interpretation the mind perceives the behavior (adrenaline, fast heartbeat, eyes open wide) as the emotion (fear). Although this theory has been proved wrong (see for example Ellsworth in [31]), in emotion recognition it is still a usual approach. In examples below, we show how looking only at the behavior/expression and not taking into consideration the context/object of emotion might cause critical errors in emotion recognition.

Example 1: Recognition of emotion from facial expressions
Expression: User is crying (presence of tears and facial expression);
Assumption: User is sad (?);
Context: The user is cutting an onion in the kitchen;
We can easily see that a system based on the assumption that, when the user is crying, he must be sad, will be critically wrong when not processing the context of this behavior.

Example 2: Recognition of emotion from speech signals
Expression: User speaks with a loud voice;
Assumption: User is angry (?);
Context: The user is listening to the music with his headphones on and cannot hear well.

Example 3: Recognition of emotion from gestures
Expression: User waving hands above his head;
Assumption: User is angry (?);
Context: The user has won a lottery or is in trouble and is waving for help;
In the worst scenario, a robot designed to draw back when the user is angry will not help the user eventually causing the user's death.

Example 4: Recognition of emotion from physiological signals
Expression: User has a high blood pressure;
Assumption: User is excited (?);
Context: The user has a hypertension or arrhythmia.
Not knowing the context that the user has a hypertension might bring serious consequences. In the worst scenario we can imagine a grotesque situation when a robot, designed to familiarize with a user, starts showing an expression of excitement, while the actual need is to give the user a medicine

Example 5a: Recognition of emotion from language
Expression: User has used vulgar language, such as "f*ck";
Assumption: User is irritated (?);
Context: The user is actually saying it like "Oh, f*ck, yeah!" (positively excited).

Example 5b: Recognition of emotion from language
Expression: User has used the word "happy";
Assumption: User is happy (?);
Context: The user might be actually saying: "I'm **not** happy", or "I'm so happy that bastard was hit by a car!"

The examples above show that determining only the expression for an emotion does not yet provide a sufficient conditions for the computation to take place and the need for considering the context is clearly visible.

4. Processing the Context of Emotions

It has been argued that the semantic and pragmatic diversity of emotions is best conveyed in language [21,22]. As language is a strictly contextual entity, we decided to focus on natural language processing methods for emotion recognition (also referred to as Affect Analysis).

4.1 Contextual Valence Shifters

One of the common problems in the keyword-based systems for affect analysis is confusing the valence of emotion types, since the emotive expression keywords are extracted without their grammatical context. An idea aiming to solve this problem is the idea of Contextual Valence Shifters (CVS). Contextual Valence Shifters as an application in Sentiment Analysis was first proposed by Polanyi and Zaenen [38]. They distinguished two kinds of CVS: negations and intensifiers. The group of

[3] We use "behavioral" in a wide meaning, including body or face movements (bodily behavior), physiological processes (inner behavior of human body as a system), speech signals and language (language behavior).

Table 1 Distribution of number of emotion objects and semantic categories among emotion types.

Emotion type (No. of expressions)	Number of extracted: emotion objects	semantic categories
joy (224)	6123947	120068119
relief (106)	3321795	66605209
dislike (532)	2957596	59136703
fondness (197)	2441865	45816845
fear (147)	1184952	23490755
excitement (269)	1104998	23102117
sadness (232)	930698	18911960
surprise (129)	898138	18164806
anger (199)	292500	5966179
shame (65)	202678	4006378
ρ	0.24848	0.24848

negations contains words and phrases like "not", "never", and "not quite", which change the valence polarity of the semantic orientation of an evaluative word they are attached to. The group of intensifiers contains words like "very", "very much", and "deeply", which intensify the semantic orientation of an evaluative word. So far the idea of CVS analysis was successfully applied to the field of Sentiment Analysis of texts in English [39]. A few attempts of applying CVS to the analysis of the Japanese language [40] show that it is also applicable for the Japanese language.

As the first step towards contextual processing of emotions we applied CVS as a supporting procedure for affect analysis system for Japanese [41]. As a result, we noticed a slight improvement the affect analysis system. Although CVS phrases did not appear very often in our test sets, not considering them in a research on emotions could cause significant misunderstandings in the interpretation of user emotions.

4.2 Contextual Appropriateness of Emotion

As another realization of the statement of this paper we have developed a method making use of the wider context the emotion is expressed in [32,33,34,35]. The method determines, whether the expressed emotion is appropriate for its context. The method introduces an idea of Contextual Appropriateness of Emotions to Affective Computing research. This idea adds a new dimension in emotion recognition, since it assumes that both positive and negative emotions can be appropriate, or inappropriate, depending on their contexts (see the examples below).

1. I'm so happy I passed the exam! `[happiness/positive: appropriate]`
2. I'm so happy that bastard was hit by a car! `[happiness/positive: inappropriate]`
3. I'm so depressed since my girlfriend left me... `[depression/negative: appropriate]`
4. I'm so depressed for the Easter is coming... `[depression/negative: inappropriate]`

The structure of these particular examples consists of: expression of emotion (here: the beginning of the sentence, like "I'm so happy", or "I'm so depressed"), and its context (the latter part of the sentence), bound with a causality morpheme/phrase (since, for). Our method takes advantage of this type of sentences. Firstly it uses affect analysis system ML-Ask [36] to recognize

```
<emotion type: haji [shame] (202678 EmObj;
   4006378 SemCat)>
   <emotive expression: sekimen [turn red/feel
   ashamed] (2316 EmObj for this EmoExp)>
      Sentence<20 Japanese characters>:
      "Chakku wo shimeru no wasureta to ki ga
      tsuitara sekimen shita..."
      ["I turned all red when I noticed I
      had a fly open..."]
        EmObj: <Chakku shimeru no wasureta
           to ki ga tsuita> [Notice to
           have a fly open]
        CausInf: <tara> [because]
        EmoExp: <turn red/feel ashamed>
   ...
<emotion type: yorokobi [joy] (6123947 EmObj;
   120068119 SemCat)>
   <emotive expression: ureshii [happy]
   (1078312 EmObj)>
      ...
   <emotive expression: ureshimi [joyfulness]
   (5 EmObj)>
      ...
   ...
...
```

Figure 2 A structure of the emotion object database with an example.

user emotions. ML-Ask, based on a linguistic approach to emotions, first separates emotive utterances from the non-emotive ones using on a set of emotive linguistic features. Then, it seeks for the specific expressions of emotion in the emotive utterances using an existing emotive lexicon. After specifying the emotions, a Web mining technique is used to verify their contextual appropriateness in four steps: **1)** extracting context phrases from an utterance; **2)** adding causality information to the phrases; **3)** cross-referencing the modified phrases on the Web with the emotive lexicon; and **4)** extracting lists of emotive associations for the context phrases. Emotions expressed by the user not appearing on the association list are perceived as inappropriate.

The method is based on the assumption that the Internet can be considered as a database of experiences people describe on their homepages or weblogs. Since context of emotions is formulated through collecting experiences (see section **3**), these experiences could be as well "borrowed" from the Internet [37].

The baseline method achieved an accuracy of 45%-50% [32]. However, after improving ML-Ask with Contextual Valence Shifters [33] and limiting the search in the Web-mining technique to blog contents [34], the accuracy was improved up to 60%-70%.

4.3 Database of Emotion Objects

One problem with the Web mining procedure was that it was time consuming. Processing of one context phrase was taking up to several minutes. To solve this problem we have gathered a large database of emotion objects. From a blog corpus containing over 350 million of sentences we extracted and implemented a robust ontology-type database of emotion objects - INFOE (*I kNow Formal Objects of Emotions*), containing 19,459,167 of unique emotion objects. Their distribution among emotion types is shown in Table 1. A structure of the database including some examples is described in Figure 1. The Spearman's correlation coefficient (ρ [rho]) calculated between the number of expressions in Nakamura's lexicon and the number of emotion objects

extracted for each emotion type was low (approximately 0.25), which means that the statistics does not depend on the number of seed phrases, and therefore is reliable.

5. Conclusions

In this paper we presented our approach to the analysis of emotions. We claimed that emotions are inseparable from their contexts and therefore analysis not considering the context cannot be fully applicable in real world applications. We presented logical reasoning for this statement and described some examples depicting how neglecting the context of emotion could cause a fallacy in the performance of a system for emotion recognition. We also briefly described the methods we developed for processing emotions within their contexts.

6. Future Work

As for the future works, we plan to focus on deepening the understanding of emotions by bootstrapping the context phrases. For example, in a sentence "I'm so depressed since my girlfriend left me..." the context phrase would be "girlfriend left". The Web mining procedure provides for such phrases a list of appropriate emotions. However, using similar Web mining procedure we plan to go further and find out the reason for an emotion object to happen. For example, to find out "why girls leave their boyfriends?". An answer for this question, found in the Internet, could be, e.g., "because boys are not sporty enough", or "because boys have no money". Next asked question could be, e.g., "why boys have no money?", etc. Sufficient accuracy in such bootstrapping method would provide a deeper knowledge about the causality of experiences. When applied in a companion agent this would help providing hint about probable undesirable consequences of user activities.

Processing the context of emotions, or Contextual Affect Analysis [35], is a newly recognized field. During its fifteen years of history Affective Computing was in great part focused on recognizing user emotions. However, little research addressed the need for computing the context of the expressed emotions. As we believe, in the age of information explosion, with an easy access to very large sources of data (such as Internet), the time has come to finally address this burning need. Our research is focused on only one type of emotion processing, affect analysis of text. The future challenge will be to develop methods for processing the context in more general meaning, making the machines aware of the sophisticated environment humans live in. We proved that contextual affect analysis is a feasible task and believe much research will be done in this matter in the near future.

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