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Weighted high-order hidden Markov models for compound emotions recognition in text

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ABSTRACT

Emotion recognition in text has attracted a great deal of attention recently due to many practical applications and challenging research problems. In this paper, we explore an efficient identification of compound emotions in sentences using hidden Markov models (HMMs). In this problem, emotion has temporal structure and can be encoded as a sequence of spectral vectors spanning an article range. The major contributions of the research include the (i) proposal of weighted high-order HMMs to determine the most likely sequence of sentence emotions in an article. The weighted high-order HMMs take into account the impact degree of context emotions with different lengths of history; (ii) introduction of a representation of compound emotions by a sequence of binary digits, namely emotion code; (iii) development of an architecture that uses the emotions of simple sentences as part of known states in the weighted high-order hidden Markov emotion models for further recognizing more unknown sentence emotions. The experimental results show that the proposed weighted high-order HMMs is quite powerful in identifying sentence emotions compared with several state-of-the-art machine learning algorithms and the standard *n*-order hidden Markov emotion models. And the use of emotion of simple sentences as part of known states is able to improve the performance of the weighted *n*-order hidden Markov emotion models significantly.

1. Introduction

Inspired by the unavoidable link between emotions and human intelligence, rational decision making, social interaction, and more, the field of Affective Computing (AC) emerged in order to narrow the communicative gap between the human and computers by developing more human-like computational systems. Affect systems are being developed for various applications, including distance education systems, improving drivers' safety, finding depressed writers, and affect-sensitive interfaces. The basic principle behind most AC systems is that automatically recognizing a user's affective states can enhance the quality of the interaction, thereby making an AC application more usable and effective.

Recently, a considerable amount of effort is being put forward to textual emotion recognition due to the ever increasing affective text available in the forms of blog, chat, online news, and twitter. The dominant techniques in textual emotion recognition generally fall under three broad categories: emotional keyword spotting [15,23,27], machine learning methods [31,48,51], and concept base methods [21,33].

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Emotional keyword spotting methods rely on the presence of obvious emotional words. It is straightforward and easy to implement. The weakness of this approach is the poor recognition of affect when negation is involved.

Machine learning methods generally follow traditional text classification approaches, where an input text is represented by a bag of words, and then feature extraction techniques like emotional keywords spotting and negation identification are applied to mapping the text into a feature vector, after that machine learning methods such as support vector machines [48], conditional random fields [52] are applied to determine which emotion category should the input text belong to. However, state-of-the-art methods in text classification achieved only modest performance in this domain [31]. The main reason should be that traditional text classification approaches failed at capturing emotional information beyond the input text itself.

Concept based methods use Web ontologies or semantic networks to accomplish semantic text analysis [11]. Concept base methods are considered superior to purely syntactical techniques because they can analyze multi-word expressions that don't explicitly convey emotion, but are related to concepts that convey emotion. The performance of concept based methods relies heavily on the semantic knowledge bases. In order to semantically and affectively analyze natural language text, an affective lexical resource, SentiWordNet [4] has been developed for supporting sentiment classification applications. SentiWordNet is the result of the automatic annotation of all the synsets of WordNet [19] according to the notions of "positivity", "negativity", and "neutrality". Each synset is associated to three numerical scores which indicate how "positive", "negative", and "objective" (i.e., neutral) are the terms contained in the synset. Using SentiWordNet, Berardi et al. proposed to assign a sentiment score to each term in the chunk for detecting the sentimental valence (or "polarity") of a given hyperlink [8]. By creating a word-level dictionary from SentiWordNet, Baccianella et al. developed a software system, called StarTrack, that automatically rated a product review according to how positive it is (a number of "stars") [5].

Inspired by SentiWordNet, SenticNet [9] has been constructed for exploring polarity information for common-sense knowledge concepts such as "accomplish goal", "bad feeling", "celebrate special occasion", "lose temper", or "be on cloud nine", which are usually found in natural language text to express positive and negative viewpoints. In [12], the largest existing taxonomy of common knowledge was blended with a natural-language-based semantic network of common-sense knowledge, and multi-dimensional scaling was applied on the resulting knowledge base for open-domain sentiment analysis.

In this domain, new models and methods are constantly emerging, such as sentiment topic models for social emotion mining [[41],[53]]; unsupervised feature extraction for feature-oriented opinion determination [38], ensemble of feature sets and classification algorithms [51]; combination of active learning and self-training for cross-lingual sentiment classification [22]; the application of sentence features for subjectivity and polarity classification [14]; the combination of features-based coreferencing and memory-based learning to improve opinion retrieval in social media [3]. New and emerging applications also help prompt the development of new techniques, such as analyzing stock markets by evaluating sentiments [28], stream-based active learning for sentiment analysis in the financial domain [45]; augmented Z-numbers for machine-subjectivity representation [6]. More comprehensive surveys on sentiment analysis can be found in [10,11,18,34,44].

Although various textual affective features and methods have been studied extensively, most previous work ignored an efficient way of using context emotion clues for emotion recognition in text. An analysis on a blog emotion corpus has shown that there are some statistical rules of emotion transfer in a blog article [36]. For example, in an article, a sentence emotion of "angry" is more likely to transfer to "hate" instead of "joy" in the next sentence. And thus, context emotion clues are essential attributes for text emotion recognition. In addition, previous work mostly focused on recognizing single emotion for an input text while ignoring that quite a few sentences contain multiple compound emotions, which are indispensable for expressing complex feelings in the use of language. Inspired by these observations, we therefore propose weighted high-order hidden Markov models for compound emotions recognition in text. This work applies categorization model [15] for emotion recognition in sentences. The weighted high-order hidden Markov Models (HMMs) take into account the impact degree of context emotions with different lengths of history. We design emotion code to represent compound emotions as a sequence of binary digits such that the weighted high-order hidden Markov emotion models can be easily extended to compound emotions recognition. And then we combine machine learning algorithms under bag-of-words model to get the emotions of simple emotional sentences as part of known states for further improving the performance of the weighted n-order hidden Markov emotion models.

The remainder of this paper is organized as follows. Section 2 presents the principle of the weighted high-order HMMs for compound emotions recognition in text. In Section 3, the architecture of the proposed approach is presented. Section 4 describes the method of decoding using part of known states in hidden Markov emotion models. Section 5 presents experimental results and discussion. Section 6 draws conclusions and outlines directions for future work.

2. The principle of the weighted high-order HMMs for compound emotions recognition in text

HMMs provide a good statistical framework for solving a wide range of time-series problems, and have been successfully applied to many pattern recognition and classification problems, such as speech recognition [17,30,46,49], computational biology [2,16,29,47], and metadata extraction [24,32,35].

In our previous work of constructing a blog emotion corpus [36], a statistical analysis on emotion transfer revealed some statistical rules of emotion transfer contained in a blog article. This work therefore is partly motivated by this observation. The emotion transfer analysis in blogs shows emotion continuity in adjacent contexts. Consequently the sequence of sentence emotions in an article has a typical time-ordering even if some random variations are possible. Left-right HMMs [40] are particularly well suited to model stochastic transient processes which have a particular temporal signature. In this work, we propose weighted high-order HMMs for emotion recognition in text. In the problem of sentence emotion recognition, sentence emotion