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Learning multiple layers of knowledge representation for aspect based sentiment analysis

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ABSTRACT

Sentiment Analysis is the task of automatically discovering the exact sentimental ideas about a product (or service, social event, etc.) from customer textual comments (i.e. reviews) crawled from various social media resources. Recently, we can see the rising demand of aspect-based sentiment analysis, in which we need to determine sentiment ratings and importance degrees of product aspects. In this paper we propose a novel multi-layer architecture for representing customer reviews. We observe that the overall sentiment for a product is composed from sentiments of its aspects, and in turn each aspect has its sentiments expressed in related sentences which are also the compositions from their words. This observation motivates us to design a multiple layer architecture of knowledge representation for representing the different sentiment levels for an input text. This representation is then integrated into a neural network to form a model for prediction of product overall ratings. We will use the representation learning techniques including word embeddings and compositional vector models, and apply a back-propagation algorithm based on gradient descent to learn the model. This model consequently generates the aspect ratings as well as aspect weights (i.e. aspect importance degrees). Our experiment is conducted on a data set of reviews from hotel domain, and the obtained results show that our model outperforms the well-known methods in previous studies.

1. Introduction

The explosive growth of social media on the Internet has helped people not only receive information on the networks but also generate information to others. Online interaction is becoming more real. People can discuss and give information about anything on social networks, Twitter, forums, blogs, etc. There is a special kind of information that is about opinions, evaluations, feelings, and attitudes. This information comes from the customers when they talk about the services or products they have used, or about the social events in their lives. Online interaction also changes the traditional purchasing behaviors, as well as social studies. Customers often look for online reviews about a product or service that they intend to use. Authorities also go online to find information about people's comments about social events. With this trend, there are more studies on automatic analysis and synthesis of information from customer reviews collected from social media. Thanks to the useful information provided by these studies, manufacturers can improve their products, the authorities can adjust policies accordingly, as well as customers can choose the product best suited to their conditions.

The development of technology along with the demand of analyzing opinionated information has led to a new research topic in

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natural language processing and data mining named “opinion mining and sentiment analysis”. Studies on this problem started from the 2000s, addressing some problems including polarity classification [1,2], subjectivity classification [3–6], and opinion spam detection [7–9]. Early studies focused on the simple inputs which usually contain the opinion on one subject and the task is how to classify this opinion into the classes negative, neutral or positive [10–12]. Recent problems with more complicated inputs have attracted many researchers. A review often contains evaluations on different product aspects, or contain comparable opinions. Some problems of concern include detecting comparable sentences [13,14], determining aspects [15–17], rating aspects [18–20] or determining aspect weights [21–23]. Aspect-based sentiment analysis recently becomes an important problem, in which we need to give the synthesized sentiment on every product aspects. That is because in some cases, customers want to know not only the evaluation on the product but also on each of its aspects. Manufacturers may also want to know about the evaluation on each product aspect as well as its importance degree to customers. Some studies addressed this problem with the two assumptions of the input: the first one assumes each review is assigned with aspects' ratings; the second one assumes each review is assigned with the overall rating for the product but is not assigned with aspects' ratings. This paper follows the second one and the problem here is how to derive the aspect ratings as well as aspect weights from a set of reviews given overall ratings.

Some previous studies such as [24,25] have proposed a model called the Latent Rating Regression (LRR) which is a kind of Latent Dirichlet Allocation to analyze both aspect ratings and aspect weights, or [26] used the Maximum A Posterior (MAP) technique to tackle the aspect sparsity problem. However, these previous studies have had limitations with their methods. They developed classification methods in which they used a bag of words from the input text as the feature set. These models used directly the words as features and derived results with the independent hypothesis of those features. Recently models for generating word embeddings [27–29], in which the real-valued vectors represented for input words have been widely used in various models such as in [30,31]. Some deep learning techniques have been applied for aspect based sentiment analysis such as convolutional neural network [32], deep memory neural network [33], long short term memory [34]. In general, most of these studies focus on the tasks of aspect term extraction, aspect category detection, aspect level sentiment classification and they have not yet done for the task of analyzing aspect ratings as well as aspect weights.

Different from previous studies, in this paper we will discover a new approach of representation learning for the task of detecting aspect ratings and aspect weights. Our view focuses on how to utilize the representation learning methods and the deep learning mechanism to form the nature of sentiment representation from textual opinions. This is based on an observation that the overall ratings of a review is a composition of its aspect ratings, and in turn each aspect rating is generated from different textual pieces of the review through words to sentences. Therefore, we will develop a model that draws a multi-layer representation with objective to form a compositional sentiment (i.e. the overall rating). By this model we have formulated the problem as natural as it should be. We have used a general framework of feed forward neural network integrated with the representation learning techniques of word embeddings [28] and compositional vector models [35] for capturing semantic information as well as get richer knowledge in higher representations. The parameters of this model will be learned with the objective of reaching the target overall ratings given by the training data set. This result consequently returns the aspect ratings and aspect weights as the problem objectives.

Especially in the architecture of the proposed model we have designed a layer called “higher aspect representation” aiming for sharing information between aspects that leads to enrich knowledge for the model. It can also solve the problem of long range dependencies between each aspect and its sentiments. It is worth to emphasize that our model has a different architecture to all previous studies and that is based on the multiple layer representation for knowledge combination from the textual opinions to overall sentiment ratings.

We evaluate our proposed model on the data collected from Tripadvisor¹ and use the five aspects including *Value*, *Room*, *Location*, *Cleanliness*, and *Service*. This data set is also used by the related previous research [24,25]. The experimental result has shown the effectiveness of our model for multi-layer representation in comparison with other models of feature representation such as bag of word, word vector averaging, or paragraph vector.

The rest of this paper is organized as follows: Section 2 presents related works; Section 3 introduces basic models for representation learning which will be used for our model; Section 4 includes the definition and notations of the problem. Section 5 presents our proposed model with multi-layer representation. Section 6 presents our algorithm for learning the proposed model; Section 7 describes our experiments and results. Some conclusions are presented in the last section.

2. Related work

The task of aspect-based sentiment analysis can be divided into the sub-tasks as aspect term extraction, aspect category detection, aspect sentiment classification, aspect rating, and aspect weight determination. In general, a lot of studies have been solved these sub-tasks since the pioneering work of Hu et al. [15]. In this paper we just consider the works which is closed to our work that are aspect rating and aspect weight detection.

Aspect rating aims to assign a numeric rating (i.e $1 \sim 5$ stars) to each aspect in which a higher aspect rating means a more positive sentiment. Several studies also combine the tasks of determining overall ratings and aspect ratings into an account and learn the unified model. Snyder et al. [18] proposed the Good Grief Algorithm based on PRanking training algorithm for ranking aspects (i.e. rating aspects) using the dependencies among aspects. Titov et al. [19] used a topic based model and a regression model for extracting aspect terms as well as detecting aspect ratings.

¹ www.tripadvisor.com.

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