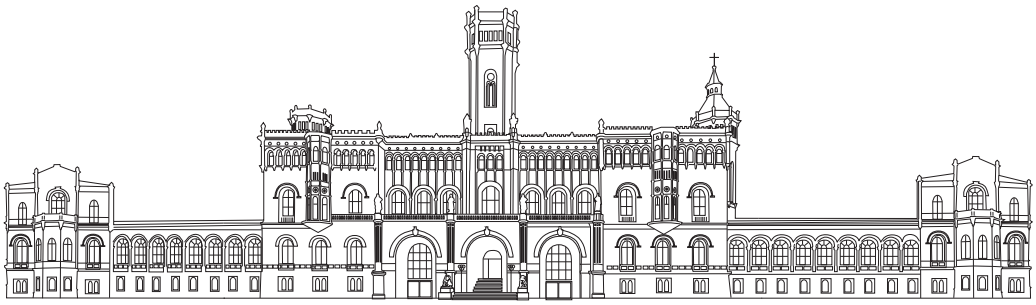

LEIBNIZ UNIVERSITÄT HANNOVER

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Aspect Based Sentiment Analysis with Convolutional Neural Networks

Masterarbeit

zur Erlangung des akademischen Grades „Master of Science (M. Sc.)“ im Studiengang Wirtschaftsingenieur der Fakultät für Elektrotechnik und Informatik, Fakultät für Maschinenbau und der Wirtschaftswissenschaftlichen Fakultät der Leibniz Universität Hannover

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Contents

1 Introduction

1.1 Motivation

"Information is not knowledge." — Albert Einstein

In times, where the usage of the internet for any purpose is on the rise, one knows that data is the "new oil". But data is nothing without being able to extract its meaning and the correlating inference. The internet has arrived in the mainstream for a while now, thus data is persistent in various forms and huge amounts. Besides graphical and audio content, data in form of human natural language represents an important part of the information available on the internet. But human language can hold more information than in the trivial case of short, unambiguous, and explicit statements. A piece of natural language can contain all kinds of less obvious information, expressed, for example, through rhetorical means, context or opinion terms.

About 80% of the worlds data is considered to be unstructured and appears not to be organized in a pre-defined and consistent manner [1]. Apparently, a large piece of this comes from text data like emails, social media, articles, reviews etc. that is usually difficult, time-consuming and expensive to analyze. There are two main types of textual information: facts and opinions (Liu et al., 2010). Facts are objective, verifiable statements, while opinions are the subjective expression of a person's thoughts. Sentiment analysis "is the field of study that analyzes people's opinions, sentiments, appraisals, attitudes, and emotions towards entities and their attributes expressed in written text" (Liu, 2015, p.1). The entity can either be an individual, an event or a topic. sentiment analysis aims to find efficient and effective means to extract contextual information about opinions in samples of human natural language in a standardized and automatic way. Leveraging the mentioned huge amount of opinionated data already available on the internet with means of sentiment analysis in large scale, offers huge potentials for many, be it companies, governments or the media (Zhang et al., 2018, p. 1). There is no more need for the costly conduction of surveys and opinion polls to gather public opinions because of the abundance of such information publicly available on the internet.

[1] https://www.ibm.com/blogs/watson/2016/05/biggest-data-challenges-might-not-even-know/

Sentiment analysis of opinions about products and services performs reasonably well in contrast to political texts (Liu, 2015). Product reviews provide the benefit, that they are highly focused and opinion rich, enabling to see different issues more clearly than in other forms of opinionated texts. In contrast, other opinionated online texts, like tweets for example, are short, use colloquial language and target many different topics. Therefore the focus in this paper will be on the sentiment analysis use-case of product review analysis.

In order to extract details about the different facets of an opinion about a product, a sentiment analysis on aspect level is performed, called aspect based sentiment analysis (short: **ABSA**). In the example “This phone has a very nice screen, but the battery life is disappointing”, the aspects or facets of the opinion about the phone would be "screen" and "battery life". The automated identification of these aspects, called aspect extraction, is one of the sub-tasks of ABSA and is “the most important and challenging task among them all and hence, studied by most of the researchers as compared to the other tasks” (Rana and Cheah, 2016, p. 3).

While the concept of deep neural networks is not new, deep learning (application of deep neural networks to machine learning tasks) is a recent development, enabled by the increased power of today’s computers in terms of speed and memory (Khan et al., 2018, p. 6). Since deep learning algorithms made impressive advances in fields as computer vision, natural language processing (short: **NLP**) researches are increasingly focusing on the means of new deep learning methods (Young et al., 2018, p. 1) like for example convolutional neural networks in aspect extraction for sentiment analysis (Poria et al., 2016a).

1.2 Relevance

Sentiment analysis opens the opportunity to efficiently capture the opinion of the general public about social and political topics, company strategies or product preferences. Therefore it raised interest of both the scientific community (because of the open challenges) and the business world (because of the great potential for application in marketing and finance). Sentiment analysis systems allow companies to make sense of their sea of unstructured text data, for example emails, social media contributions or product reviews, which is why there is a good number of small and large companies, that focus on opinion mining (sentiment analysis and opinion mining are interchangeable terms (Medhat et al., 2014)) as part of their mission (Poria et al., 2016a). Large companies in the information technology sector, like Google and Facebook have realized this massive potential and established big research labs regarding NLP, of which sen-

timent analysis is a sub-task. In fact sentiment analysis has grown to one of the most active research areas in NLP and has spread from computer science to management and social sciences like marketing, finance, politics communications, health science and even history (Zhang et al., 2018, p. 1).

The more opinions are collected, the higher is the need for some form of summary (Hu and Liu, 2004). The manual analysis of all online product reviews of just one single popular product for example, would require a lot of effort and time and furthermore, some of these reviews might already be outdated. Considering additionally, that different people only agree around 60-65% of the times when judging the sentiment for a particular piece of text (Hassan Saif et al., 2013), manual analysis does not appear as a reasonable alternative (Zhang et al., 2018, p. 1). Sentiment analysis aims to solve these problems all at once by enabling scalability, real-time analysis and consistent criteria. Huge amounts of data are to be analyzed immediately with steady criteria, which helps managers, officials and decision makers to judge the impact of their product (Rana and Cheah, 2016, p. 2).

With respect to the high complexity of the natural human language and the proliferation of diverse topics and sites, it is pretty hard to reach a certain level of accuracy in aspect extraction for sentiment analysis (Zhang et al., 2018, p. 1). At the same time, an accuracy, that is at least close to a human level accuracy is a crucial requirement for the operationality. The recent success of neural networks and deep learning in NLP has also sparked the hope for a drastic increase in performance in sentiment analysis (Young et al., 2018). Researching the application of deep learning methods like convolutional neural networks on the task aspect extraction therefore promises great progress for aspect-based sentiment analysis.

1.3 Research Question

Aspect based sentiment analysis, as the most fine-grained level of sentiment analysis, offers the most detailed insights about a piece of opinionated text and therefore contemplates for many applications, of which customer review analysis is one. “Aspect extraction is the most vital and extensively explored phase of sentiment analysis”, and the foundation to carry out the subsequent classification of sentiments regarding their polarity in precise manners (Rana and Cheah, 2016, p. 1). Before the work of Poria et al. (2016a), most of the research on aspect extraction, focused on unsupervised and semi-supervised learning, while the benefits of supervised learning were not perceived to be sufficient to compensate the laborious and time consuming task of creating and labeling the data set (Rana and Cheah, 2016, p. 17). Supervised techniques

were not outperforming unsupervised approaches but required more effort for data preparation, hence proving the significance of unsupervised approaches. All kinds of shallow machine learning methods have been leveraged (Zhang et al., 2018) but despite some remarkable results, Rana and Cheah (2016) agreed upon the existence of several problems, that need to be identified and solved and leave aspect extraction for sentiment analysis imperfect and with potential for improvement.

Since about a decade ago, deep learning approaches have emerged as a powerful alternative solution to a range of tasks in the research area of NLP (Goodfellow et al., 2016). Modeling the semantic relatedness between the target of an opinion and its attributes is difficult (Zhang et al., 2018, p. 14), resulting in the mentioned weaknesses of many existing models and emphasizing the potential of leveraging the more extensive learning power of deep learning models. Poria et al. (2016a) were the first to introduce the application of deep learning onto the task of aspect extraction and set new benchmarks by outperforming other state-of-the-art non deep learning methods with their approach. Apart from the higher effort to create a labeled training set, they radically reduced the endeavor of handcrafted feature engineering and development of linguistic patterns (short: **LP**), which previous approaches leveraged heavily (Poria et al., 2016a, p. 43). They use a deep convolutional neural network that is trained on a large text corpora and additionally put in an ensemble with a set of simple linguistic rules. Besides from challenging the performance of state-of-the-art methods, their approach proves to be more efficient than existing approaches (Poria et al., 2016a, p. 43).

The deep learning approach for aspect extraction by Poria et al. (2016a) rapidly gained attention (more than 200 citations in 2 years) beyond the scientific community of sentiment analysis into the whole NLP field (Young et al., 2018). This was thanks to its outstanding performance and the fact that convolutional neural networks were primarily seen in computer vision applications previously. But not only the proven performance of such deep learning methods led to their increased prevalence in NLP, but also their capability to harness large amount of computation and data with little engineering by hand (LeCun et al., 2015). Poria et al. (2016a) claim to have proved their convolutional neural network based deep learning model to be a suitable method for the task of aspect extraction. Since this would offer vast new opportunities in the field of ABSA, the validation of this claim and further development of such models is leading to the following research question (RQ):

RQ: *How to design a topology of convolutional neural networks to perform aspect extraction for aspect based sentiment analysis? And how well does it perform?*

To answer this research question, a convolutional neural network architecture for aspect extraction is being developed, following the approach of Poria et al. (2016a), including data pre-processing as well as model training algorithms. It will be equipped with a state-of-the-art database of pre-trained 300-dimensional word-vector representations, and in the following trained and evaluated with available aspect labeled customer review data sets. This thesis aims to challenge and reassess the achieved results on the task of aspect extraction presented by Poria et al. (2016a) regarding performance and generalization power through developing a comparable model, and evaluating the influence of configuration modifications. In order to asses the model in an exhaustive way, a profound error analysis is performed along with the execution of a self developed robustness test. Supposed outcomes are to reveal weaknesses in such architectures on the one hand and to validate its performance and thereby the claim to be well suited for the task of aspect extraction on the other hand. Since the deep learning approach is fairly new in ABSA and the remarks about the details of convolutional neural network application in publications like Poria et al. (2016a) are of rather sparse nature, this work also has an informative and enlightening character as additional contribution to the state of research.

In the following chapter (2) a brief overview about the basic theoretical background will be given and a short literature review that summarizes related previous work will be conducted. The most important concepts and definitions in NLP will be explained, along with the theoretical foundations of neural networks and convolutional neural networks. Evaluation measures will be introduced as well.

Chapter 3 describes the research strategy used for this work, the design science approach. Chapter 4 will go into detail about model development, network topology and describe how certain NLP-tools have been integrated into the algorithm. The fifth chapter (5) exemplifies specifications like the language corpora and data sets used, describes the performed error analysis and showcases the results in comparison to other state-of-the-art methods along with an extensive error analysis and a model generalization robustness test.

In the sixth chapter (6), the results are being discussed, limitations exposed and concluding recommendations are given. Chapter (7) provides conclusion and outlook.

7 Conclusion and Outlook

This thesis develops and examines a deep learning model for aspect based sentiment analysis. In this regard, it presents a fully developed convolutional neural network based explicit aspect extraction model as the first step of three in an aspect based sentiment analysis system. Since capturing the public opinion has always been of interest for various groups within governments, media and economy, there has always been a real world need for such a system. This demand can now be satisfied in a drastically more efficient and exhaustive way with the means of aspect based sentiment analysis and deep learning, enabled by the availability of sufficient amounts of data thanks to the world wide web and by the increasing computing power.

This thesis aims to develop and evaluate a convolutional neural network model for the task of aspect extraction and thereby to substantiate the claim, that convolutional neural networks are well suited for aspect based sentiment analysis, posed by the work of Poria et al. (2016a). Therefore, the topic's relevance and the exact research objective was stated in the introductory chapter 1. The second chapter (2) highlights important theoretical aspects in the fields of sentiment analysis and deep learning along with a short overview of the state-of-research on aspect extraction. The literature review revealed, that the deep learning approach is the most emerging method within aspect based sentiment analysis, despite its comparably young age. Chapter 3 presents the research approach used (Design Science Approach), while chapter 4 describes and illustrates the developed model and the used specialized training algorithm in detail. The performance of the developed model is documented in chapter 5 and shows that the size of the text corpus and the training architecture of the used word embeddings have a great influence on the performance, and that additional hand-crafted rule based algorithms can be dispensed when using a better embeddings set. The fact that the results were competitive or even outperformed the closely related work of Poria et al. (2016a), strongly emphasizes, that convolutional neural networks are well suited for the task of aspect extraction. Subsequently, the model's weaknesses are exposed by an in-depth error analysis of the wrongly predicted tokens. Further, its actual performance apart from the laboratory conditions of a scientifically developed training corpus is examined in a robustness test. The model performed well on the unseen data in this test, supposing a good generalization power of the model and thereby qualifying this approach for further employment in theory and practice. The work is completed with an exhaustive discus-

sion about model architecture, results and limitations along with recommendations for further research in chapter 6.

While being revolutionized by deep learning methods, natural language processing is wielding to the tipping point of a more advanced stadium, which could be rather described as natural language *understanding* instead of just *processing*. Its sub-disciplines, of which aspect based sentiment analysis is one, are experiencing shifts in performance and new available opportunities to a similar extend. This momentum is potentially leading to more advanced and more general applicable sentiment analysis systems, which could then be applied in a wide range of fields and use cases, far beyond the presented case of customer review analysis. Especially in politics and media, a better understanding of the general public could be deducted as well as the citizens needs and opinions, leading to better political decisions. Of course, a very conscientious analysis of the potential risks and possibilities of misuse is always to prioritize.

Further research can be separated into three broad promising perspectives. First the further analysis and development of improved aspect extraction systems in their core mechanisms and architecture with the objective to reach the missing percents in performance. This must be achieved under the restriction to limit the demand of labeled training data directly or to provide measures to label data automatically. Second, the maturation of the models concerning generalization regarding domains and languages. Third, the co-adaption with other models, that handle specific issues individually (e.g. implicit aspect finding) and the integration of the resulting outright aspect extraction ensemble algorithm into a holistic aspect based sentiment analysis system, comprising aspect classification and summarization as well.