Deep Learning and Its Applications: A Review

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Abstract

In the past few years, Deep Learning has becoming a trend. Since deep learning attempts to make a better analysis and can learn massive amounts of unlabeled data, deep learning has been applied to several of fields. Hence, this paper presents a review on deep learning and its applications over the years, with a goal of providing useful references to other researchers to get the idea for new application with deep learning in future research. There are seven applications that have been applied with deep learning were identified, namely automatic speech recognition, image recognition, natural language processing, drug discovery and toxicology, customer relationship management, recommendation systems and bioinformatics. For each of these, we discuss the results of the study and also point out the areas in need of further research.

Keywords: Deep Learning, Applications

1. Introduction

Deep Learning (DL) or more commonly known as deep structured learning or hierarchical learning is a division of Machine Learning (ML) which is based on a set of algorithms that attempt to model high-level abstractions in data, [1, 2]. Such algorithms develop a layered, hierarchical architecture of learning and representing data. This hierarchical learning architecture is inspired by artificial intelligence emulating the deep, layered learning process of the primary sensorial areas of the neocortex in human brain, which automatically extracts features and abstractions from underlying data [3, 4, 5]. Based on [6, 7], DL algorithms are useful when it comes to dealing with large amounts of unsupervised data and naturally learn data representations in a greedy layer-wise method.

In recent years, there are a number of researchers have applied DL algorithms to various different fields. Therefore, the purpose of this paper is to review and to discuss the applications that have been done over the years with DL algorithms. We will discuss further in Section 2, which may assists other researcher to study DL and its applications. Finally, the conclusion of this review is expressed in Section 3.

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2. The Applications of Deep Learning

This section describes the foundation of this review by discussing several of fields that have been applied with Deep Learning algorithm.

Automatic Speech Recognition (ASR)

Google has announced that Google voice search had taken a new turn by adopting Deep Neural Networks (DNN) as the core technology used to model the sounds of a language in 2012 [8]. DNN replaced Gaussian Mixture Model which has been in the industry for 30 years. DNN also has proved that it is better able to measure which sound a user is fabricating at every instant in time and with this they delivered prominently increased speech recognition accuracy.

In 2013, DL has gained full momentum in both ASR and ML [9]. DL is basically linked to the use of multiple layers of nonlinear transformations to derive speech features, while learning with shallow layers comprises the use of exemplar-based representations for speech features which have high dimensionality but typically vacant entries.

Image Recognition

Deep max-pooling convolutional neural networks is used to detect mitosis in breast histology images was presented in [10]. Mitosis detection is very hard. In fact, mitosis is a complex process during which a cell nucleus undergoes various transformations. In this approach, DNN as powerful pixel classifier which operates on raw pixel values and no human input is needed. Hence, DNN automatically learns a set of visual features from the training data. DNN is tested on a publicly available dataset and significantly outperforms all competing techniques, with manageable computational effort: processing a 4MPixel image requires few minutes on a standard laptop.

Large and deep convolutional neural network is trained to classify the 1.2 million high-resolution images in the ImageNet LSVRC-2010 contest into 1000 different classes [11]. On the test data, they achieved top-1 and top-5 error rates of 37.5% and 17.0% which is considerably better than the previous state-of-the-art. From all the experiments, the results can be improved simply by waiting for faster GPUs and bigger datasets to become available.

Natural Language Processing

Recently, deep learning methods have been successfully applied to a variety of language and information retrieval applications. By exploiting deep architectures, deep learning techniques are able to discover from training data the hidden structures and features at different levels of abstractions useful for the any tasks. In 2013, [12] proposed a series of Deep Structured Semantic Models (DSSM) for Web search. More specifically, they uses a DNN to rank a set of documents for a given query as follows. First, a non-linear projection is performed to map the query and the documents to a common semantic space. Then, the relevance of each document given the query is calculated as the cosine similarity between their vectors in that semantic space. The neural network models are discriminatively trained using the click-through data such that the conditional likelihood of the clicked document given the query is maximized. The new models are evaluated on a Web document ranking

task using a real-world data set. Results show that the proposed model significantly outperforms other latent semantic models, which were considered state-of-the-art in the performance prior to the work presented in [12].

Drug Discovery and Toxicology

Quantitative Structure Analysis/Prediction Studies (QSAR/QSPR) attempt to build mathematical models relating physical and chemical properties of compounds to their chemical structure. In [13], multi-task learning is applied to QSAR using various neural network models. They used an artificial neural network to learn a function that predicts activities of compounds for multiple assays at the same time. The method is compared with alternative methods and reported that the neural nets with multi-tasking can lead to significantly improved results over baselines generated with random forests.

In 2015, AtomNet has been introduced as first structure-based, deep convolutional neural network which designed to predict the bioactivity of small molecules for drug discovery applications [14]. This paper also demonstrates how to apply the convolutional concepts of feature locality and hierarchical composition to the modeling of bioactivity and chemical interactions. AtomNet outperforms previous docking approaches on a diverse set of benchmarks by a large margin, achieving an AUC greater than 0.9 on 57.8% of the targets in the DUDE benchmark.

Customer Relationship Management

A framework for autonomous control of a customer relationship management system been charted by [15].First, a modified version of the widely accepted Recency-Frequency-Monetary Value system of metrics can be used to define the state space of clients or donors is explored. Second, a procedure to determine the optimal direct marketing action in discrete and continuous action space for the given individual, based on his position in the state space is described. The procedure involves the use of model-free Q-learning to train a deep neural network that relates a client's position in the state space to rewards associated with possible marketing activities. The estimated value function over the client state space can be interpreted as customer lifetime value (CLV), and thus allows for a quick plug-in estimation of CLV for a given client. Experimental results are presented, based on Knowledge Discovery and Data Mining Tools Competition, mailing dataset of donation solicitations.

Recommendation Systems

Automatic music recommendation has become an increasingly relevant problem in recent years, since a lot of music is now sold and consumed digitally. Most recommender systems rely on collaborative filtering. In 2013, [16] proposed to use a latent factor model for recommendation, and predict the latent factors from music audio when they cannot be obtained from usage data. Traditional approach is compared using a bag-of-words representation of the audio signals with deep convolutional neural networks, and the predictions is evaluated by quantitatively and qualitatively on the Million Song Dataset. The result shows that the recent advances in DL translate very well to the music recommendation setting, with deep convolutional neural networks significantly outperforming the traditional approach.

Recent online services rely heavily on automatic personalization to recommend relevant content to a large number of users. This requires systems to scale promptly to accommodate the stream of new users visiting the online services for the first time. Work by [17] in 2015 proposed a content-based recommendation system to address both the recommendation quality and the system scalability. They also proposed to use a rich feature set to represent users, according to their web browsing history and search queries. They use a DL approach to map users and items to a latent space where the similarity between users and their preferred items is maximized. Scalability analysis show that the multi-view DNN model can easily scale to encompass millions of users and billions of item entries.

Bioinformatics

The annotation of genomic information is a major challenge in biology and bioinformatics. Existing databases of known gene functions are incomplete and prone to errors, and the bimolecular experiments needed to improve these databases are slow and costly. While computational methods are not a substitute for experimental verification, they can help in two ways: algorithms can aid in the curation of gene annotations by automatically suggesting inaccuracies, and they can predict previously-unidentified gene functions, accelerating the rate of gene function discovery. In this work [18], an algorithm that achieves both goals using deep auto encoder neural networks is developed. With experiments on gene annotation data from the Gene Ontology project, it shows that deep auto encoder networks achieve better performance than other standard machine learning methods, including the popular truncated singular value decomposition.

3. Conclusion

Based on Section 2, there are seven applications that have been applied with Deep Learning were identified. The applications are:

a) Automatic Speech Recognition
b) Image Recognition
c) Natural Language Processing
d) Drug Discovery and Toxicology
e) Customer Relationship Management
f) Recommendation Systems
g) Bioinformatics

Deep Learning is a fast-moving and proliferating discipline. It is not easy to form a well-balanced and well-informed summary view of the newest developments in this field. Thus, it is still harder to have a vision of its future applications.

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References

[1] Hinton, G. E., Osindero, S., & Teh, Y. W. (2006). A fast learning algorithm for deep belief nets. *Neural computation*, 18(7), 1527-1554.

[2] Bengio, Y. (2009). Learning deep architectures for AI. *Foundations and trends® in Machine Learning*, 2(1), 1-127.

[3] Bengio, Y., & LeCun, Y. (2007). Scaling learning algorithms towards AI. *Large-scale kernel machines*, 34(5).

[4] Bengio, Y., Courville, A., & Vincent, P. (2013). Representation learning: A review and new perspectives. *IEEE transactions on pattern analysis and machine intelligence*, 35(8), 1798-1828.

[5] Arel, I., Rose, D. C., & Karnowski, T. P. (2010). Deep machine learning-a new frontier in artificial intelligence research [research frontier]. *IEEE Computational Intelligence Magazine*, 5(4), 13-18.

[6] Hinton, G. E., Osindero, S., & Teh, Y. W. (2006). A fast learning algorithm for deep belief nets. *Neural computation*, 18(7), 1527-1554.

[7] Bengio, Y., Lamblin, P., Popovici, D., & Larochelle, H. (2007). Greedy layer-wise training of deep networks. *Advances in neural information processing systems*, 19, 153.

[8] Hasim Sak, Andrew Senior, Kanishka Rao, Françoise Beaufays and Johan Schalkwyk (September 2015): *Google voice search: faster and more accurate*.

[9] Deng, L., & Li, X. (2013). Machine learning paradigms for speech recognition: An overview. *IEEE Transactions on Audio, Speech, and Language Processing*, 21(5), 1060-1089.

[10] Ciresan, D. C., Giusti, A., Gambardella, L. M., & Schmidhuber, J. (2013, September). Mitosis detection in breast cancer histology images with deep neural networks. *In International Conference on Medical Image Computing and Computer-assisted Intervention* (pp. 411-418). Springer Berlin Heidelberg.

[11] Krizhevsky, A., Sutskever, I., & Hinton, G. E. (2012). Imagenet classification with deep convolutional neural networks. *In Advances in neural information processing systems* (pp. 1097-1105).

[12] Huang, P. S., He, X., Gao, J., Deng, L., Acero, A., & Heck, L. (2013, October). Learning deep structured semantic models for web search using clickthrough data. *In Proceedings of the 22nd ACM international conference on Conference on information & knowledge management* (pp. 2333-2338). ACM.

[13] Dahl, G. E., Jaitly, N., & Salakhutdinov, R. (2014). Multi-task neural networks for QSAR predictions. *arXiv preprint arXiv*:1406.1231.

[14] Wallach, I., Dzamba, M., & Heifets, A. (2015). AtomNet: A Deep Convolutional Neural Network for Bioactivity Prediction in Structure-based Drug Discovery. a*rXiv preprint arXiv*:1510.02855.

[15] Tkachenko, Y. (2015). Autonomous CRM Control via CLV Approximation with Deep Reinforcement Learning in Discrete and Continuous Action Space. *arXiv preprint arXiv*:1504.01840.

[16] Van den Oord, A., Dieleman, S., & Schrauwen, B. (2013). Deep content-based music recommendation. *In Advances in Neural Information Processing Systems* (pp. 2643-2651).

[17] Elkahky, A. M., Song, Y., & He, X. (2015, May). A multi-view deep learning approach for cross domain user modeling in recommendation systems. *In Proceedings of the 24th International Conference on World Wide Web* (pp. 278-288). ACM.

[18] Chicco, D., Sadowski, P., & Baldi, P. (2014, September). Deep autoencoder neural networks for gene ontology annotation predictions. *In Proceedings of the 5th ACM Conference on Bioinformatics, Computational Biology, and Health Informatics* (pp. 533-540). ACM.