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Deep Leaning Architectures and its Applications: A Survey

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***Abstract*—** In the field of Artificial Intelligence (AI), Deep Learning is a method falls in the wider family of Machine Learning algorithms that works on the principle of learning. Deep learning models basically works without human intervention and they are equivalent, and sometimes even, superior than humans. With the rise of emerging technology, deep learning draws an attention by many researchers and it is widely used in several areas including image, sound and text analysis. The paper discussed deep learning background, types of deep learning architectures and applications from different domains where researchers used deep learning models successfully.

***Keywords*—**Deep Learning, Convolutional Neural Network, Deep Belief Network, Recurrent Neural Network

I. INTRODUCTION

In the field of Artificial Intelligence (AI), Deep Learning is a method falls in the wider family of Machine Learning algorithms that works on the principle of learning. For learning, Supervised and Unsupervised, both of forms may use. In deep learning, a computerized model will perform specific set of classification or pattern analysis tasks based on previously learned data. For that, a model must be trained first with set of labeled data. Deep learning basically used to classify images, text or sounds. Deep learning models works without human intervention and they are equivalent, and sometimes even, superior than humans. Deep learning models are realized mostly through deep neural networks. It has been applied to several arenas that includes bioinformatics, image processing, Industrial automation, natural language processing, text and sound recognition and many more.

Artificial Intelligence consists a set of techniques that applied to develop computerized models that makes machines to act like human expert. Machine learning, a part of Artificial Intelligence paradigm, consists techniques that makes machines to learn by themselves based on experience. It makes enable machines improvised automatically over time. Deep learning is a part of machine learning and contains algorithms that makes machine "to learn" based on experience to perform the assigned task, mostly text, sound and image recognition. For that, it mainly uses an architecture of artificial neural network with higher number of hidden layers, called deep neural networks. In this paper, section II explained the deep learning background. Section III represented three well-known deep learning architectures with its applications from different domains and section IV discussed the conclusion.

II. BACKGROUND

The foundation of the concept of deep learning was based on artificial neural network research. The general example of the models work with deep architecture is a well-known feed-forward neural networks or multilayer perceptron that consists many hidden layers. In the arena of 1980, another algorithm for learning the weights of these networks is Back-propagation [1]. An artificial neural network constructs by consisting three layers of neurons: Input Layer, Output Layer and one or more Hidden Layers resides between Input and Output Layer. In Artificial Neural Network (ANN), a mathematical function is used to represent a neuron, an essential element of ANN. Neurons resides in each layer receives one or more values as an input, which are output of previous layers, except Input layer. A weight is usually assigns to each input and to calculate sum of these values, an activation function is used. In deep learning, a deep neural network is used that has more number of hidden layers and that makes a neural network "deep". These multiple layers are used for feature extraction and each layer uses output value of previous layer as an Input value.

Deep learning was basically introduced in 1980s but it gains tremendous popularity since 2006. As deep learning models require large number of hidden layers and huge amount of labeled training data, sustainable computational power is required. In last few years, machines with high performance GPUs are available in market. Also, cloud computing and parallel architectures gains huge popularity. Such high

performance machines equipped with advent technology makes easy to implement deep learning models. For different types of task, machine learning algorithms contains several methods to be used. Likewise, it is very much required to train deep learning models with vast amount of data. For these, machines with high computational power are required to make learning process faster. Therefore, it is desired to use deep learning models in the tasks where size of a dataset is very large and high computational powered machines are available.

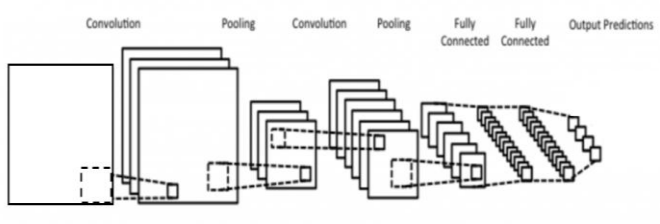
III. DEEP LEARNING ARCHITECTURES

There are two major considerations while working with the deep learning: Processing is multilayer non-linear and learning form can be supervised or unsupervised [2] The popular architectures used to create deep learning models and discussed in this paper are Convolution Neural Network, Deep Belief Network and Recurrent Neural Network. For general classification problems, Deep Belief Network is widely used. Convolution Neural Network is one of the most popular deep learning architecture used for classification of image, text and sound. Moreover, Recurrent Neural Network is used when data is more in the form of sequential.

a. CONVOLUTIONAL NEURAL NETWORK

Usually, deep neural networks are trained by using large amount of data and learn features directly from data without manual extraction of features. Convolutional Neural Network (CNN) is one of the most widespread deep neural network models that owns the capability of learning features automatically from input data. It is a special class of feed forward neural network and as it eliminates manual feature extraction, it is mostly used for image classification and makes the deep learning highly accurate. Unlike machine learning, manual extraction of features from images are not required and it is capable to perform an entire task like classification of images without manual intervention. [3]. Animal visual cortex is taken as a basis for learning process of CNN. Figure 1 illustrated an architecture of CNN that composed of convolutional layers, pooling layers and fully connected layers [4].

On input image, a set of filters are applied in Convolutional layer and the generated data is passed to the Pooling layer. At each convolution layer, Feature maps are obtained. It is gained through computing convolutions between local patches and weight vectors called filters. Feature maps are group of local weighted sums [5].



*F*igure 1. Architecture of Convolutional Neural Network

In order to improve the efficiency of training, filters are applied repeatedly. This process helps to reduce the number of parameters during learning process. Maximum or average subsampling of non-overlapping regions in feature maps is performed at each pooling layer. This process helps to handle more complex features [5]. At last, fully connected layers are working as a regular neural network. It is a final learning phase that maps the features to the predicted outputs. At present, CNN seems to be one of the most efficient deep learning architectures owing the capability of processing images, text and sounds.

One of the frequent use of CNN is in the field of medical imaging. Different types of images include X-rays, MRIs, CT scans, PET Scans and ultrasound are used for diagnostic process. CNN is applied to segment brain images efficiently by many researchers Zhang W, et al. [6], Moeskops P, et al. [7], Nie D et al. [8]. Moreover, MRI images are useful to identify tumor and CNN gives significantly better results for Tumor segmentation and identification as per results obtained by Chen, Lele et al. [9] and Raunaq Rewari et al. [10]. Researchers also applied CNN for recognition of Carotid Plaque Composition [11], analysis of Cardiac data [12], left ventricle segmentation [13] and identification of prostate cancer [14] from MRI images.

Convolutional Neural Network also applies to segment X-ray images. It has been applied for extraction of discriminative features [15] from X-ray images by M. Srinivas et al. and it delivered accurate diagnosis from chest X-ray images without any knowledge of previous domain as per the results discussed by Y. Dong et al. [16]. It has been provided more accurate and faster Tuberculosis diagnosis and achieved an 85.68% classification accuracy by C. Liu et al. [17]. It has also been useful to segment structure of bone to assist in further diagnosis process as mentioned by Cernazanu-Glavan, C et al.[18]. CNN was designed to analysis of CT scans that supported the screening of lung cancer [19], to segment anatomical structures [20] and to detect Thrombus [21] from CT images.

The another wide usage of CNN is for classification of sound data. Many researchers classified and identified different types of sounds automatically by using CNN architecture. Examples are classification of environmental sound [22],

Music classification from audio [23], Lung Sound classification [24], Heart and Lung Sound Classification [25]. It has been also shown that CNN reduces the error rate by 6%-10% and worked efficiently for speech recognition tasks [26]. In the field of natural language processing, analysis of sentimental data plays a crucial role. CNN model has been applied successfully and achieved test accuracy of 45.4% for analyse the sentimental data as shown by X. Ouyang, P. et al [27]. Also, sentimental analysis on Twitter data [28], Short Text [29] and Multimedia data [30] accomplished by constructing CNN. The Table 1 shows the several domains with research areas where researchers successfully applied CNN.

Table 1. Convolutional Neural Network (CNN) Research Areas

Domain	Input Data Type	Research Area(s)	References
Medical Imaging	MRI Images	Brain MRI images	[6][7][8]
		Tumor Segmentation	[9][10]
		Carotid Plaque Composition, Cardiac data Analysis	[11][12]
		Left Ventricle Segmentation, Identification of Prostate Cancer	[13][14]
	X-ray Images	Features Extraction	[15][16]
		Diagnosis of Tuberculosis	[17]
		Segmentation of Bone Structure	[18]
	CT Scans	Lung Cancer Screening	[19]
		Anatomical Structures Segmentation	[20]
		Detection of *Thrombus*	[21]
Sound Analysis	Audio Data	Classification of Environmental Sound Classification of Music, Classification of Heart and Lung Sounds	[22][23] [24][25]
		Speech Recognition	[26]
Text Analysis	Sentimental Data	Sentiment Analysis, Twitter Data Analysis, Short Text Sentimental Analysis, Multimedia Sentiment Analysis	[27][28] [29][30]

b. DEEP BELIEF NETWORK

Deep belief network (DBN) is made up with multiple layers of restricted Boltzmann machine (RBM) and represents as a graphical model. It contains many layers of hidden variables, having binary values and called hidden units or feature detectors [31], and typically represents as a stack of RBMs. There exists a symmetric connections between the top two layers and forms an associative memory. However, the lower layers consume top-down and directed connections [31]. Two distinct Neural Network types are contained by DBN. They are Belief Networks and RBM [32]. The training to the DBN occurs in two stages: unsupervised pretraining with unlabeled samples and then supervised fine-tuning with labeled samples [33]. Figure 2 displays the general architecture of DBN [34].

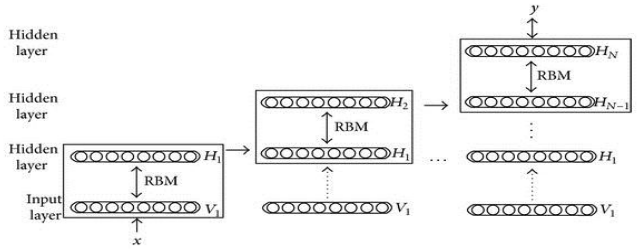


Figure 2. Architecture of Deep Belief Network

The noticeable use of Deep Belief Networks (DBN) is in the field of Natural Language Processing (NLP)[35]. It is complex task to process unstructured mass of text collected from Web. DBN has been applied for extracting attributes of entities with accuracy and with marginal manual interference [36]. In NLP, the information regarding word position plays an important role to analyse sentiment data. A novel approach used for text classification [38], incorporating positional information into Deep belief networks [37] and for categorisation of Biomedical Text [39] and gave better results. DBN has been also applied for classification of images by G. Liu et al.[40], S. Zhou et al. [41] and P. Zhong et al.[42] and they achieved good accuracy.

In the field of Medical Diagnosis, DBN was used to predict a cardiovascular risk by Kim J et al.[43] and Coronary Artery disease by ALTAN, Gökhan et al.[44]. Also, DBN applied as a classifier for ECG data with greater accuracy compare to the Neural Network by [44] and applied on multichannel EEG data to detect the likelihood of Seizure [45]. In medical diagnosis, CAD (computer assisted diagnosis) systems are designed that supports to reduce the probability of miss-

diagnosis, probably occurred due to fatigue, eyestrain, or lack of experience [46]. In such cases, accurate classifier is required and DBN was used as a classifier to diagnose the breast cancer by Mohamed abd el Zaher et al. [46] and for diagnosis of Syndrome by Guo-Ping Liu et al. [47]. In the area of speech recognition, the use of DBN was presented by [48][49][50] and observed that the usage of DBN makes the training process more robust and effective. The Table 2 illustrated the several domains with research areas where researchers successfully applied DBN.

Table 2. Research Areas of Deep Belief Network (DBN)

Domain	Input Data Type	Research Area(s)	References
NLP	Text	Understanding of Natural Language	[35]
Text Processing	Text	Attribute extraction of Entities, Positional Information, Text Classification, Categorization of Biomedical Text	[36][37] [38][39]
Image Processing	Images	Image Classification	[40][41] [42]
Medical Diagnosis	Statistical, ECG and EEG Data	Prediction for Cardiovascular Risk, Coronary Artery Diseases Diagnosis, Seizure Detection	[43][44] [45]
	Breast Cancer Dataset, Clinical CG dataset	Diagnosis of Breast cancer, Syndrome Diagnosis of Chronic Gastritis	[46][47]
Sound Processing	Speech Data	Recognition of Speech	[48][49][50]

c. RECURRENT NEURAL NETWORK

Recurrent Neural Network (RNN) is an architecture of deep learning that is mostly used to process sequential data. Here, unidirectional cycle is formed between units and unlikely of traditional feed-forward neural network, shows better performance in the area of Natural Language Processing, text and speech recognition [51] RNN can be constructs as depth as the size of the input data series. RNN is capable to accumulate the past information as it possesses "memory" and the widely used type of RNN is LSTM (Long short-term memory) [52]. The figure 3 represented the architecture of RNN [53].

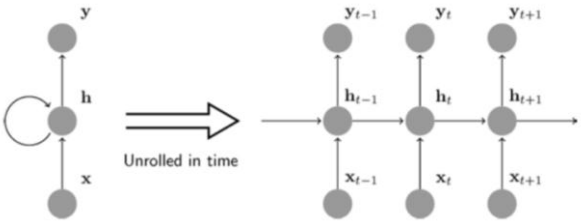


Figure 3. Architecture of Recurrent Neural Network

For a time sequence, Recurrent Neural Network (RNN) permits it to show vigorous temporal behaviour. A survey of applying RNN for statistical language modelling was presented by Wim De Mulder et al. [54]. Another researcher T. Ishitaki et al. [55] presented his work in the area of Network Security using RNN. They proposed an approach to design a model using RNN to detect the intrusion in The Onion Router (Tor) network [55]. Other distinct work has been presented by Malek Alaeddin [56] in the field of optimization problem. He showed the several applications of RNN to general optimization problems. In time series analysis, it predicts the future values of data from the detected sequential series of data values. B. Q. Huang et al.[57] applied multi-context RNN for applications that are based on time-series data. They measured the performance evaluation of this network against handwriting recognition and energy load forecasting which are real word applications. Given a dialogue context consisting of one or more utterances, the model must generate the next response in that dialogue. In the field of Natural Language Processing (NLP), Serban, I. et al.[58] came with a novel application of Multiresolution RNN to generate dialogue response. The proposed model generates the next response in the dialogue based on the given dialogue context consisting of one or more utterances [58]. The another noticeable use of RNN for handwriting recognition. Many researchers had worked in this area with the applications of RNN and got promising results as dropout improvisation in handwritten recognition by V. Pham et al. [59] and handwritten recognition for Arabic language by Graves A. [60]. In Indian context, Chakraborty, Bappaditya et al. [61] had applied RNN with Long Short Term Memory (LSTM) for recognition of online handwritten of Bangla language, that seems to the one of the difficult Indian scripts [61]. Also, the LSTM network model possesses "memory" that makes them capable to collect information for longer time presented by P. Voigtlaender et al. [62] and that helped them to use for handwriting recognition [62]. The several domains with research areas where researchers successfully applied RNN is depicted in Table 3.

Table 3. Research Areas of Recurrent Neural Network (RNN)

Domain	Input Data Type	Research Area(s)	References
Network Security	Data from Network Analyser	User Behaviour Prediction	[55]
Optimization	Mathematical	RNN for Optimization Problems	[56]
Time-Series Analysis	Temporal Data	RNN for Time Series Applications	[57]
NLP	Dialogue Context	Multiresolution RNN for Dialogue Response Generation	[58]
Handwriting Recognition	Handwritten Data	Handwriting Recognition with RNN, Use of LSTM for Handwriting Recognition	[59][60] [61] [62]

IV. Conclusion

The paper depicted the introduction and background of deep learning. The well-known deep learning architectures namely Convolutional Neural Network (CNN), Deep Belief Network (DBN) and Recurrent Neural Network (RNN) has been explained in the paper. Also, the paper surveyed the work of several researchers with their domain and research area in the field of deep learning. It helps researchers to explore and understand architectures and applications of deep learning.

REFERENCES

[1] Deng, Li. Three classes of deep learning architectures and their applications: a tutorial survey, APSIPA transactions on signal and information processing, 2012

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

[3] What Is Deep Learning?, retrieved from https://in.mathworks.com/discovery/deep-learning.html on May 20, 2018

[4] Convolutional Neural Networks Tutorial in TensorFlow, retrieved from http://adventuresinmachinelearning.com/convolutional-neural-networks-tutorial-tensorflow/ on May 20, 2018

[5] Min, Seonwoo & Lee, Byunghan & Yoon, Sungroh, Deep Learning in Bioinformatics. Briefings in Bioinformatics, 2016, 18. 10.1093/bib/bbw068

[6] Zhang W, et al., Deep convolutional neural networks for multi-modality isointense infant brain image segmentation, Neuroimage, 108, 214–224, 2015, doi: 10.1016/j.neuroimage.2014.12.061

[7] Moeskops P, et al., Automatic segmentation of MR brain images with a convolutional neural network, IEEE Trans. Med. Imaging, 35(5), 1252–1261, 2016, doi: 10.1109/TMI.2016.2548501

[8] Nie D, Dong N, Li W, Yaozong G, Dinggang S, Fully convolutional networks for multi-modality isointense infant brain image segmentation, in 2016 I.E. 13th International Symposium on Biomedical Imaging (ISBI), 2016

[9] Chen, Lele & Wu, Yue & Dsouza, Adora & Z. Abidin, Anas & Xu, Chenliang & Wismüller, Axel, MRI tumor segmentation with densely connected 3D CNN, 2018, 10.1117/12.2293394

[10] Raunaq Rewari, Automatic Tumor Segmentation from MRI scans, http://cs231n.stanford.edu/reports/2016/pdfs/328_Report.pdf

[11] Y. Dong, Y. Pan, X. Zhao, R. Li, C. Yuan and W. Xu, Identifying Carotid Plaque Composition in MRI with Convolutional Neural Networks, 2017 IEEE International Conference on Smart Computing (SMARTCOMP), Hong Kong, pp. 1-8, 2017

[12] Margeta, J., Criminisi, A., Cabrera Lozoya, R., Lee, D.C., Ayache, N., Fine-tuned convolutional neural nets for cardiac MRI acquisition plane recognition, Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization, Taylor & Francis, pp. 339 – 349, 2017

[13] Vázquez Romaguera, Liset, Costa, Marly Guimarães Fernandes, Romero, Francisco Perdigón, Costa Filho, Cicero Ferreira Fernandes, Left ventricle segmentation in cardiac MRI images using fully convolutional neural networks, Proceedings of the SPIE, Volume 10134, id. 101342Z 11 pp. 2017

[14] Wang, Xinggang & Yang, Wei & Weinreb, Jeffrey & Han, Juan & Li, Qiubai & Kong, Xiangchuang & Yan, Yongluan & Ke, Zan & Luo, Bo & Liu, Tao & Wang, Liang, Searching for prostate cancer by fully automated magnetic resonance imaging classification: Deep learning versus non-deep learning. Scientific Reports, 7, 2017, 10.1038/s41598-017-15720-y.

[15] M. Srinivas, D. Roy and C. K. Mohan, Discriminative feature extraction from X-ray images using deep convolutional neural networks, 2016 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Shanghai, 2016, pp. 917-921

[16] Y. Dong, Y. Pan, J. Zhang and W. Xu, Learning to Read Chest X-Ray Images from 16000+ Examples Using CNN, 2017 IEEE/ACM International Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE), Philadelphia, PA, 2017, pp. 51-57.

[17] C. Liu et al., TX-CNN: Detecting tuberculosis in chest X-ray images using convolutional neural network, 2017 IEEE International Conference on Image Processing (ICIP), Beijing, 2017, pp. 2314-2318. doi: 10.1109/ICIP.2017.8296695

[18] Cernazanu-Glavan, C & Stefan, Holban, Segmentation of Bone Structure in X-ray Images using Convolutional Neural Network. Advances in Electrical and Computer Engineering. 13. 87-94, 2013, 10.4316/aece.2013.01015

[19] P. Rao, N. A. Pereira and R. Srinivasan, Convolutional neural networks for lung cancer screening in computed tomography (CT) scans, 2016 2nd International Conference on Contemporary Computing and Informatics (IC3I), Noida, 2016, pp. 489-493

[20] Xiangrong Zhou, Ryosuke Takayama, Song Wang; Xinxin Zhou, Takeshi Hara, Hiroshi Fujita, Automated segmentation of 3D anatomical structures on CT images by using a deep convolutional network based on end-to-end learning approach, Proc. SPIE 10133, Medical Imaging 2017: Image Processing, 1013324 (24 February 2017); doi: 10.1117/12.2254201

[21] Lisowska, Aneta & Beveridge, Erin & Muir, Keith & Poole, Ian, Thrombus Detection in CT Brain Scans using a Convolutional Neural Network. 24-33, 2017, 10.5220/0006114600240033.

[22] K. J. Piczak, Environmental sound classification with convolutional neural networks, 2015 IEEE 25th International Workshop on Machine Learning for Signal Processing (MLSP), Boston, MA, 2015, pp. 1-6. doi: 10.1109/MLSP.2015.7324337

[23] S. Dieleman, P. Brakel, B. Schrauwen, Audio-based music classification with a pretrained convolutional network,

Proceedings of the 12th International Society for Music Information Retrieval (ISMIR) conference, pp. 669-674, 2011.
[24] Aykanat, M., Kılıç, Ö., Kurt, B. et al. J Image Video Proc. (2017) 2017: 65. https://doi.org/10.1186/s13640-017-0213-2
[25] Q. Chen, W. Zhang, X. Tian, X. Zhang, S. Chen and W. Lei, "Automatic heart and lung sounds classification using convolutional neural networks," 2016 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA), Jeju, 2016, pp. 1-4.
[26] O. Abdel-Hamid, A. r. Mohamed, H. Jiang, L. Deng, G. Penn and D. Yu, "Convolutional Neural Networks for Speech Recognition," in IEEE/ACM Transactions on Audio, Speech, and Language Processing, vol. 22, no. 10, pp. 1533-1545, Oct. 2014..
[27] X. Ouyang, P. Zhou, C. H. Li and L. Liu, "Sentiment Analysis Using Convolutional Neural Network," 2015 IEEE International Conference on Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing, Liverpool, 2015, pp. 2359-2364.
[28] Stojanovski, Dario & Strezoski, Gjorgji & Madjarov, Gjorgji & Dimitrovski, Ivica. (2015). Twitter Sentiment Analysis Using Deep Convolutional Neural Network. Lecture Notes in Artificial Intelligence (Subseries of Lecture Notes in Computer Science). 9121. 10.1007/978-3-319-19644-2_60.
[29] A. Hassan and A. Mahmood, "Deep Learning approach for sentiment analysis of short texts," 2017 3rd International Conference on Control, Automation and Robotics (ICCAR), Nagoya, 2017, pp. 705-710. doi: 10.1109/ICCAR.2017.7942788
[30] Cai G., Xia B. (2015) Convolutional Neural Networks for Multimedia Sentiment Analysis. In: Li J., Ji H., Zhao D., Feng Y. (eds) Natural Language Processing and Chinese Computing. Lecture Notes in Computer Science, vol 9362. Springer, Cham
[31] Geoffrey E. Hinton (2009), Deep belief networks, Scholarpedia, 4(5):5947.
[32] HussamHebbo, Jae Won Kim, Classification with Deep Belief Networks, https://www.ki.tu-berlin.de/fileadmin/fg135/publikationen/Hebbo_2013_CDB.pdf
[33] M. Tim Jones, Deep learning architectures, https://www.ibm.com/developerworks/library/cc-machine-learning-deep-learning-architectures/index.html
[34] Wang, Hai & Cai, Yingfeng & Chen, Long. (2014). A Vehicle Detection Algorithm Based on Deep Belief Network. The Scientific World Journal. 2014. 647380. 10.1155/2014/647380
[35] R. Sarikaya, G. E. Hinton and A. Deoras, "Application of Deep Belief Networks for Natural Language Understanding," in IEEE/ACM Transactions on Audio, Speech, and Language Processing, vol. 22, no. 4, pp. 778-784, April 2014. doi: 10.1109/TASLP.2014.2303296
[36] Bei Zhong, Jin Liu, Yuanda Du, Yunlu Liaozheng and Jiachen Pu, Extracting Attributes of Named Entity from Unstructured Text with Deep Belief Network, International Journal of Database Theory and Application Vol.9, No.5 (2016), pp.187-196
[37] Jin Y., Zhang H., Du D. (2017) Incorporating Positional Information into Deep Belief Networks for Sentiment Classification. In: Perner P. (eds) Advances in Data Mining. Applications and Theoretical Aspects. ICDM 2017. Lecture Notes in Computer Science, vol 10357. Springer, Cham
[38] Liu T. (2010) A Novel Text Classification Approach Based on Deep Belief Network. In: Wong K.W., Mendis B.S.U., Bouzerdoum A. (eds) Neural Information Processing. Theory and Algorithms. ICONIP 2010. Lecture Notes in Computer Science, vol 6443. Springer, Berlin, Heidelberg
[39] A. J. Yepes, A. MacKinlay, J. Bedo, R. Garnavi, and Q. Chen. Deep belief networks and biomedical text categorisation. In Proceedings of the Twelfth Annual Workshop of the Australasia Language Technology Association, page 123, 2014.
[40] G. Liu, L. Xiao and C. Xiong, "Image Classification with Deep Belief Networks and Improved Gradient Descent," 2017 IEEE International Conference on Computational Science and Engineering (CSE) and IEEE International Conference on Embedded and Ubiquitous Computing (EUC), Guangzhou, 2017, pp. 375-380.
[41] S. Zhou, Q. Chen and X. Wang, "Discriminative Deep Belief Networks for image classification," 2010 IEEE International Conference on Image Processing, Hong Kong, 2010, pp. 1561-1564. doi: 10.1109/ICIP.2010.5649922
[42] P. Zhong, Z. Gong, S. Li and C. B. Schönlieb, "Learning to Diversify Deep Belief Networks for Hyperspectral Image Classification," in IEEE Transactions on Geoscience and Remote Sensing, vol. 55, no. 6, pp. 3516-3530, June 2017. doi: 10.1109/TGRS.2017.2675902
[43] Kim J, Kang U, Lee Y. Statistics and Deep Belief Network-Based Cardiovascular Risk Prediction. Healthc Inform Res. 2017 Jul;23(3):169-175.
[44] ALTAN, Gökhan & Allahverdi, Novruz & Kutlu, Yakup. (2017). Diagnosis of Coronary Artery Disease Using Deep Belief Networks. European Journal of Engineering and Natural Sciences. 2. 29-36.
[45] Turner, J.T. & Page, Adam & Mohsenin, Tinoosh & Oates, Tim. (2014). Deep Belief Networks used on High Resolution Multichannel Electroencephalography Data for Seizure Detection. 75-81.
[46] Mohamed abd el Zaher, Ahmed allah & Eldeib, Ayman. (2015). Breast cancer classification using deep belief networks. Expert Systems with Applications. 46. 139-144. 10.1016/j.eswa.2015.10.015.
[47] Guo-Ping Liu, Jian-Jun Yan, Yi-Qin Wang, et al., "Deep Learning Based Syndrome Diagnosis of Chronic Gastritis," Computational and Mathematical Methods in Medicine, vol. 2014, Article ID 938350, 8 pages, 2014. https://doi.org/10.1155/2014/938350.
[48] M. D. Prasetio, T. Hayashida, I. Nishizaki and S. Sekizaki, "Deep belief network optimization in speech recognition," 2017 International Conference on Sustainable Information Engineering and Technology (SIET), Malang, 2017, pp. 138-143.
[49] Zulkarneev M., Grigoryan R., Shamraev N. (2013) Acoustic Modeling with Deep Belief Networks for Russian Speech Recognition. In: Železný M., Habernal I., Ronzhin A. (eds) Speech and Computer. SPECOM 2013. Lecture Notes in Computer Science, vol 8113. Springer, Cham
[50] Farahat, Mahboubeh & Halavati, Ramin. (2016). Noise Robust Speech Recognition Using Deep Belief Networks. International Journal of Computational Intelligence and Applications. 15. 1650005. 10.1142/S146902681650005X.
[51] Lee JG, Jun S, Cho YW, Lee H, Kim GB, Seo JB, Kim N., Deep Learning in Medical Imaging: General Overview. Korean J Radiol. 2017 Jul-Aug;18(4):570-584
[52] Recurrent Neural Networks Tutorial, Part 1 – Introduction to RNNs, http://www.wildml.com/2015/09/recurrent-neural-networks-tutorial-part-1-introduction-to-rnns/
[53] Min, Seonwoo & Lee, Byunghan & Yoon, Sungroh. (2016). Deep Learning in Bioinformatics. Briefings in Bioinformatics. 18. 10.1093/bib/bbw068.
[54] Wim De Mulder, Steven Bethard, Marie-Francine Moens, A survey on the application of recurrent neural networks to statistical language modeling, Computer Speech & Language, Volume 30, Issue 1, 2015, Pages 61-98
[55] T. Ishitaki, R. Obukata, T. Oda and L. Barolli, "Application of Deep Recurrent Neural Networks for Prediction of User Behavior in Tor Networks," 2017 31st International Conference on

Advanced Information Networking and Applications Workshops (WAINA), Taipei, 2017, pp. 238-243.
[56] Malek, Alaeddin. (2008). Applications of Recurrent Neural Networks to Optimization Problems. 10.5772/5556.
[57] B. Q. Huang, Tarik Rashid and M-T. Kechadi, Multi-Context Recurrent Neural Network for Time Series Applications, World Academy of Science, Engineering and Technology International Journal of Computer and Information Engineering Vol:1, No:10, 2007
[58] Serban, I. V., Klinger, T., Tesauro, G., Talamadupula, K., Zhou, B., Bengio, Y., & Courville, A. C. (2017, February). Multiresolution Recurrent Neural Networks: An Application to Dialogue Response Generation. In AAAI (pp. 3288-3294).
[59] V. Pham, T. Bluche, C. Kermorvant and J. Louradour, "Dropout Improves Recurrent Neural Networks for Handwriting Recognition," 2014 14th International Conference on Frontiers in Handwriting Recognition, Heraklion, 2014, pp. 285-290.
[60] Graves A. (2012) Offline Arabic Handwriting Recognition with Multidimensional Recurrent Neural Networks. In: Märgner V., El Abed H. (eds) Guide to OCR for Arabic Scripts. Springer, London
[61] Chakraborty, Bappaditya & Sarathi Mukherjee, Partha & Bhattacharya, Ujjwal. (2016). Bangla online handwriting recognition using recurrent neural network architecture. 1-8. 10.1145/3009977.3010072.
[62] P. Voigtlaender, P. Doetsch and H. Ney, "Handwriting Recognition with Large Multidimensional Long Short-Term Memory Recurrent Neural Networks," 2016 15th International Conference on Frontiers in Handwriting Recognition (ICFHR), Shenzhen, 2016, pp. 228-233

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