DEEP LEARNING FOR HEALTHCARE MANAGEMENT AND DIAGNOSIS

Arnon Bruno Ventrilho dos Santos, Deborah Ribeiro Carvalho
Pontifícia Universidade Católica do Paraná (PUC-PR)
E-mails: asantos.quantum@gmail.com, drdrcarvalho@gmail.com

Abstract: *Deep Learning is a sub-area of Machine Learning, which deals with the recognition, processing, interpretation and classification of images, text, speech, etc. It has been investigated and applied to the identification of faces in social networks, texts in manuscripts, oral communication for human-computer interaction and health. This article aims to present applications of Deep Learning in healthcare. To do this, a research for works using the following descriptors was performed: "Deep Learning", "Health", "Management", "Diagnostics", "Network", "Deep Learning". 14 papers were identified, highlighting especially the areas of computer science, health. As a result, it was identified that most studies suggest the use of Deep Learning for clinical diagnosis, due to its excellent accuracy in the interpretation and identification of patterns of disease in medical imaging. This work also indicates that the implementation of Deep Learning with back-propagation and CNN (convolutional neural networks) algorithms in classification tasks, while dealing with nonlinear problems, can achieve superior accuracy, even outperforming human agents. This conclusion is especially interesting for the medical field, which conducts the analysis and diagnostics based mainly on images. The potential of this technique not only assists in medical decisions and the accuracy of the diagnosis, but also assists the medical specialist to suggest treatment measures, consequently to speed the process and make the care of a medical specialist, known as being of high cost and difficult to access, viable to all people.*

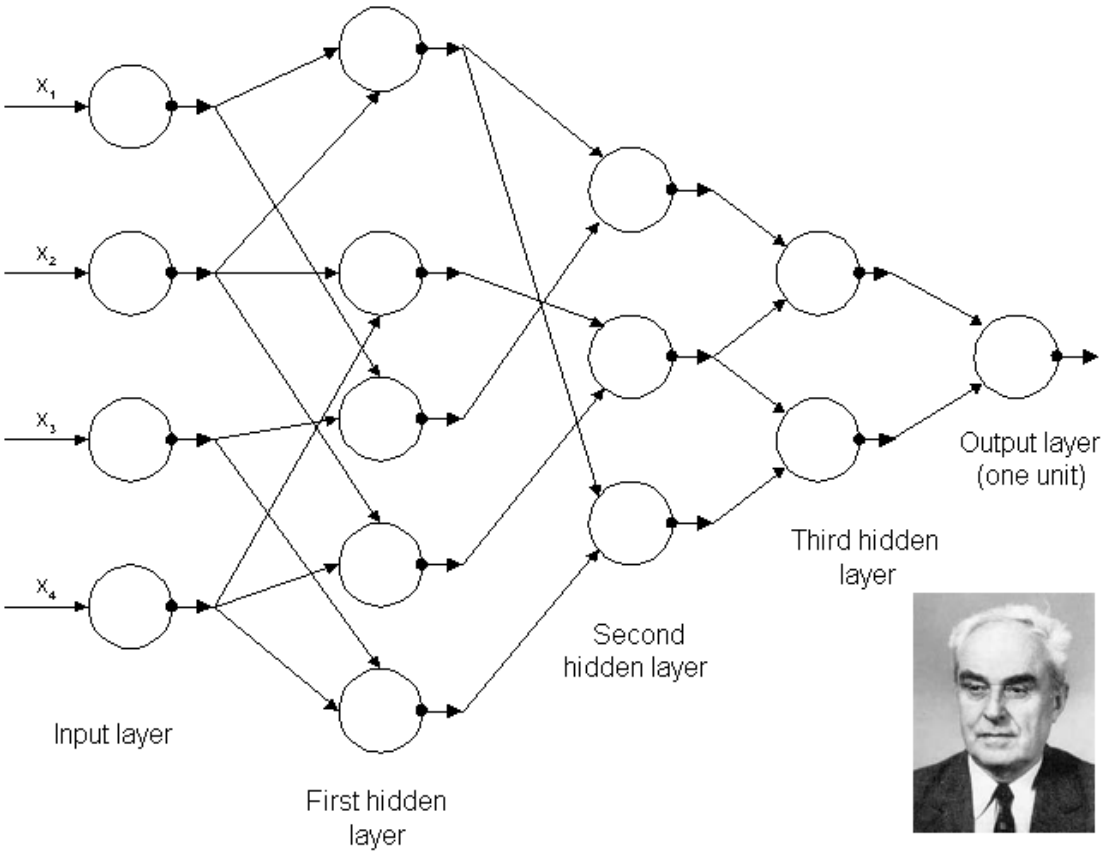
Keywords: Deep Learning, Algorithms, Diagnostics, Machine Learning, Convolutional Neural Networks, backpropagation.

1. INTRODUCTION

"Deep Learning is a set of Neural Networks algorithms (branch of machine learning), it can learn multiple levels of representation and abstraction to aid in the interpretation of data. The higher-level abstractions are defined from the abstractions of lower levels, so that increasingly complex functions can be worked" Seeböck (2015, p. 1).

Although Rina Dechter, north-american Ph.d in Artificial Intelligence, was the first person to propose the term Deep Learning (Dechter, 1986, p. 178), the creation of an algorithms with this feature was introduced already in 1965 by the Ukrainian mathematician Alexey Grigorevich Ivakhnenko and his co-worker V.G. Lapa, who proposed a multi-layer neural network where higher level abstractions pass the lower layers of the network to the extent that the function parsed grows in complexity (Figure 1). (Ivakhnenko and Lapa, 1965).

Figure 1: architecture of the first network of Deep Learning, proposed by Ivakhnenko



Source: Blog NVIDIA[1]

Since Ivakhnenko, researches have been carried out on the development of techniques in the field of artificial Neural Networks. The first breakthrough came with the development of backpropagation algorithms, in 1986 by Hinton (Hinton et al., 1986, p. 533). This algorithm was the first computational model of multi-layered learning that was truly efficient, because it was able to solve not just linear problems (as the models developed before Hinton and Ivakhnenko), but also non-linear problems.
However, the high computational cost that learning tasks with this complexity required contributed to slow the development of these and possible new techniques of machine learning and neural networks training.
Deep Learning truly re-emerged only in mid-2011 with the use of this technique by part of a team of researchers at Google Inc. Since then the subject has been widely studied and applied, as will be seen throughout this work.
In 2013, the company "Enlitic", begins to develop solutions for automation in health, and is currently selling tools that use Deep Learning for the recognition of images, and provide great assistance to the diagnosis, treatment and medical management procedures.
Despite its potential for healthcare, the use of Deep Learning in this area is still starting to be explored, a fact that, in the course of this work was found to be due to the contemporaneity of this technique, as well as by the low availability of works to identify opportunities and benefits from the adoption of Deep Learning strategies.

[1] Available at: < https://devblogs.nvidia.com/parallelforall/deep-learning-nutshell-history-training/> Accessed on May. 2016.

This work, therefore, proposes to present the applications of Deep Learning for healthcare, comparing the different approaches, aiding in the visualization of advantages and vulnerabilities, enabling research and development of new techniques for the improvement of health services.

2. METHOD

This work was done following the recommendations of PRISMA (Statement for Reporting Systematic Reviews and Meta-Analyses of Studies). This is a list of 27 fundamental items that should be considered for clear communication of a systematic review.

Eligibility criteria

Observational and controlled studies were included in this study, and whose results could be confirmed by expert analysis in the health area and computer science, as seen along some of these studies.
Given the notoriety that Deep Learning acquired only recently and its "low-maturity", as claimed by (Najagabadi et. al, p. 18, 2015), there is a relatively small amount of published studies, so all relevant studies and also reviewed here refer to the years of 2013, 2014 and 2015, all published in the English language. These studies were selected because of their theoretical and practical importance for the area of Deep Learning applied to the diagnosis and medical management processes, therefore it was no basis for this research studies that involve Deep Learning in disciplines that nothing or little would contribute to the target area.
Were also added information about what is being broadcast in digital media on Deep Learning, as different opinions of specialists and practical results.

Search strategy

For this study, reasearches were conducted in the following electronic databases: virtual library of Cornell University, CIR (Computational Imaging Research Lab) at the University of Vienna, IJSR (Internation Journal of Science and Research), virtual library of the University of Maine, portal of the Faculty of information, knowledge and media of Toronto University and the Convolutional Neural Network portal for Visual Recognition of Stanford University using the strategy of searching for a combination of the following terms in English: "Deep Learning", "health", "management", "diagnostics", "Network", "Deep Learning".

In addition, searches were conducted on Google, seeking for what is being reported in digital media about the theme "Deep Learning". Therefore searches were carried out with the combination of the words "Deep Learning", "Deep Learning for health", "Deep Learning breakthrough", "Deep Learning systems".

Selection of the studies and extract of data

The selection of the studies was performed, initially, by the choice of articles through the relevance of the title, that is, if the article title brings some relationship to the study areas of this work. After this initial filter, a second filter took place, that was to review the proposal of the study by reading the introduction of each one of them and also if there was any relationship to the object of this research.

To manage which studies would be selected and used for this work, their respective names and authors were stored in a OneNote (Microsoft) document, which is a tool that manages notes and texts, synchronizing them with the cloud storage service OneDrive, also from Microsoft, without the need for file storage in the hard disk.

No additional filter was done by the author of this study because of the small amount of work in the area of interest.

Assessment of risk of bias

No method of assessing the risk of bias was used in this work, due to the fact that the studies aims to achieve different purposes.

3. RESULTS

A total of 145 articles were found through searches for terms related to the title and scope of this research, 103 in the virtual library being Cornell University, 1 in CIR, 30 in the Internation Journal of Science and Research, the University of Toronto 1, 9 in virtual library of the University of Maine and 1 in the Convolutional Neural Network portal for Visual Recognition of Stanford University.

After the first filter, a total of 21 works remained, being 13 from Cornell University, 1 from CIR at the University of Vienna, 3 from the Internation Journal of Science and Research, 2 from the University of Maine and 1 from the Convolutional Neural Network portal for Visual Recognition of Stanford University and 1 from the University of Toronto, the others one were rejected for failing to meet the target of this research area.

The second filter left a total of 14 articles that met the conditions necessary to serve as a basis for this research. 1 from the University of Toronto, 9 from Cornell University Library, 1 from CIR at the University of Vienna, 1 from Internation Journal of Science and Research, 1 from the University of Maine, 1 from Convolutional Neural Network portal for Visual Recognition of Stanford University, The remaining ones were rejected for not keeping relation with the object of this research (Deep-Learning for healthcare).

Najafabadi et al. (2015) describe Deep Learning as a series of algorithms that extract complex high-level abstractions as data representation through a hierarchical learning process. Complex abstractions are learned at a certain level based on simpler abstractions formulated in the previous hierarchy level.

As the subject achieved greater notoriety in recent years, LeCun et al. (2015) describes Deep Learning in a more didactic way for those who want to visualize it in examples of our day-by-day experience. According LeCun et al. (2015), Deep Learning can be defined as a set of techniques used by machine learning systems that identify objects in images, transcribe speech to text, make the identification and accurate combination of items according to the user's interest in shopping sites and selects relevant results in search engines on the internet.

Seeböck's (2015) definition, is similar to Najafabadi et al. (2015) idea by defining that "Deep Learning is a collection of machine learning algorithms, that can learn multiple levels of representation and abstraction to aid in data interpretation. Higher-level abstractions are defined from lower level abstractions, so that increasingly complex representations can be analyzed and learned "

The first academic papers on Deep Learning for healthcare refers to the years 2013, 2014 and 2015 in works such as the one from Liu et. Al (2013), that proposed the use of Deep Learning to improve the accuracy of diagnosis of chronic gastritis. In this work, the author compares different algorithms for multi-layered learning modeling. They conclude that the use of DBN (Deep Belief Networks) models are better in terms of accuracy, while dealing with learning, recognizing and classifying different types of chronic gastritis sindromes, if compared to other methods. Li et. Al (2014), worked to improve the quality and accuracy in the diagnosis of brain diseases. According to their study, the combination of various modalities of brain data influence in a better diagnosis of diseases, however, these data are often incomplete, which makes their combination harder to perform. The author then makes use of Deep Learning with the use of CNN to classify the modalities of brain data in order to improve its completeness and also suggests the use of DBN by evaluating that the results of this model can be equally accurate. Nie et. Al (2015) who performed an interesting study implemented Deep Learning models able to infer what disease afflicts users seeking for online assistance. The model classifies the sparse set of responses from users and infers from it, what better disease relates to the symptoms presented. Kahou et al. (2015), which proposed the use of a technique to identify emotions from video records by implementing Deep Learning models with CNN and RNN (recurrent neural-networks). The authors however still evaluate to be hard making any conclusion given the complexity of this problem. Hochreiter et al (2015), who proposed the implementation of Deep Learning for prediction of toxicity of chemicals in food and medicines, using algorithms such as backpropagation. According to this study, Deep Learning have along with CNN and backpropagation algorithms proven itsel as being even more efficient in the evaluation of toxicity than the tools solely designed for this purpose.

I've noticed from these preliminary work a predominance of the use of Deep Learning for clinical diagnosis.

Also in this field, Schmidhuber (2015) asserts that the world spends more than 10% of all the money in health (> 6 trillion per year), mostly in medical diagnoses by experts and professionals of very high cost (which restricts its audience to those with more financial resources and with greater mobility). Partial automation can not only save a lot of resources, but also make the diagnosis of experts accessible to many who can't pay for it. The author believes, based on these observations, that Deep Learning can directly and indirectly act on saving lives.

Esteva et al. (2015) developed one of the most revealing works of Deep Learning on the medical diagnosis field.

They have developed a model that is able to identify and differentiate between potentially cancerous formations in early stages of this skin disease (cancerous formations follow a recognizable pattern) from other skin diseases.

Early identification of skin cancer formations produces a rate of 94% chance of survival for 10 years, while the final phase after the disease with metastases produces a 15 percent survival rate. Using the dataset of 23,000 images, the researchers trained the network based on CNN to perform the classification of these formations, restricting the problem to two classes-cancerous and non-cancerous. With a 90% accuracy rate in the standings, the result of Deep Learning approach outperformed both a dermatologist and a medical student that reached a precision of 46% and 52% respectively.

Li et al. (2014) have prepared an interesting work, proposing an improved diagnosis for brain diseases. The method takes the form of CNN, where the input and output are two volumetric modes. The network contains a large number of trainable parameters that capture the relationship between input and output modalities. When trained in individuals with all types, the network can

estimate the given output mode input mode – producing accurate diagnoses as well. Although fairly accurate, this approach demands a great computational cost. The authors of such work also suggests that the use of other Deep Learning modeling techniques should be tested in order to compare its accuracy.

When refering to different Deep Learning approaches, Seeböck (2015, p. 13-p. 29) brings an extensive analysis of some of the Deep Learning modeling methods during the classification task of computerized lungs tomography images (making use of the algorithms such as, K-Nearest Neighbors, K-Means clustering, neural networks, R2SVM), showing what are the theoretical differences of each of the approaches, assessing its learning time under a particular dataset and what factors influence to a greater accuracy of classification and prediction. The author concludes that R2SVM algorithm shows itself to be more effective and accurate than the other algorithms tested for classification tasks.

A particular interesting information that exemplifies the range of techniques for Deep Learning is what was presented in the biggest competition of images recognition in the world, at the sixth annual edition of "ImageNET Image Recognition Challenge at the beginning of 2015.

The challenge was to classify correctly 100,000 different photographs from "Flickr" and delivers them correctly in 1000 categories (e.g. iPod, modem, tablet etc). The winning algorithm based on Convolutional Neural Networks (CNN), designed by researchers at Microsoft Research (DEEP LEARNING FOR RESIDUAL IMAGE RECOGNITION, He at al., 2015), reached the excellent accuracy rate of 96.5% in the task classyfing these images. According to Microsoft itself, this accuracy rate surpasses the rate of a human being, which is about 94.9% (DELVING DEEP INTO RECTIFIERS: SURPASSING HUMAN-LEVEL PERFORMANCE ON IMAGENET CLASSIFICATION, He et al., 2015).

Seeböck (2015, p. 1) describes some of the possibilities for Deep Learning, this time also in the area of diagnostic medicine, establishing that "machine learning techniques can be used in the field of medical imaging, including computerized Diagnostics, image fusion, image-guided therapy, and image retrieval in databases. Deep Learning methods, therefore, are a collection of Machine Learning algorithms that try to automatically learn multiple levels of representation and abstraction that contribute to the understanding of the data"

Najafabadi et al. (2015) suggests that Deep Learning can also be used for process improvement in Big Data. According to him, Deep Learning can draw abstract representations of a large volume of raw data, through the use of a multi-level hierarchical learning approach, where at a higher level more abstract and complex representations are based on the concepts learnt less abstract representations of the lower levels of the hierarchy. This approach is useful when you want to rightly sort and format a large amount of data with no defined format.

The author believes that more studies on the adaptation of Deep Learning in Big Data are necessary for considering limitations on issues that have not been treated by him as the dimensionality of the data, scalability of deep learning models, semanticgrammatical, indexing information retrieval etc. Although this is a preliminary study, this work is an interesting starting point for researches linking Deep Learning to Big Data.

As can be seen, the different references of this work propose Deep Learning approaches that meet different purposes, especially those dealing specifically with healthcare. However, it was noted a certain predominance of works relating the use of Deep Learning with diagnostic medicine. The following table is intended to synthesize the applicability of the mentioned papers by defining its respective area on the health are and (or) in which field the referred works are linked to.

Table 1-health area where the works analyzed focus or they find greater applicability:

Reference (year)	Clinical Diagnosis	Clinical Management
He et al. (2015)	X	X
Esteva et. al (2015)	X	
Le Cun et. al (2015)	N/A	N/A
Seeböck (2015)	X	
Najafabadi et. al (2015)		X
Schmidhuber (2015)	X	X
Li et. al (2014)	X	
Liu et. al (2013)	X	
Kahou et. al (2015)	X	
Hochreiter et al. (2015)	X	

N/A-not available or not enough information to cooperate with this description.

The one table below attempts to synthesize which Deep Learning methods are used by some of the references in their work during classification, since all of them use Deep Learning for this task. When applicable, the table tries to compare the accuracy between Deep Learning apporaches and a human agent.

One can easily notice a predominance of CNN and backpropagation algorithms, which can mean that they are far more efficient and accurate than the other known algorithms for classfication tasks, mainly due to the fact that they can easily work with non-linear problems, which is the problem of correctly classifying images. These facts can be easily checked from the results in He et. al (2015) and Esteva et. al (2015) researches.

Table 2 – classification methods used in Deep Learning-according to some of the studied references

	Classification model used along with Deep Learning						**% accuracy in classification**
Reference (year)	**K-Means**	**K-NN**	**Deep Beleif Network**	**Back-Propagation**	**Convolutional Neural Network**	**Deep Learning**	**Human**
He et al. (2015)					X	96,5%	90%
Esteva et. al (2015)					X	94,9%	52% e 46%
Le Cun et. al (2015)					X	N/C	N/C
Seeböck (2015)	X	X		X		N/C	N/C
Najafabadi et. al (2015)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Schmidhuber (2015)						N/C	N/C
Li et. al (2014)					X	N/C	N/C
Liu et. al (2013)			X			N/C	N/C
Kahou et. al (2015)					X	N/C	N/C
Hochreiter et al. (2015)				X		N/C	N/C

(The above table shows a summary of the approaches used by the references of this work)

N/A-not included enough information to cooperate with this description.

4. DISCUSSION

It doesn't matter if one wants to seek out the most didactic or the most technical definition, the potential that Deep Learning systems can provide for different areas of knowledge is remarkable, including medicine, where the relationship between accurate diagnosis, treatment, cost and speed are keys to the success.

The definition of LeCun (2015) about the use of techniques of Deep Learning in day-by-day finds support in everyday life, when we see, for example, shopping suggestions we received while we browse through sites such as Amazon.com, Facebook etc.

In the medical field, Vinod Khosla (entrepreneur, visionary and co-founder of Sun Microsystems), who believes that Deep Learning technologies will replace 80% of the work that the doctor does nowadays, implying directly into substantial improvements in diagnostic medicine and quality of resources management.

This statement generated controversy among the medical profession that although, in a way, reluctantly acknowledges that much of their efforts can, in the present or in the future, be replaced by expert systems to the extent that the area of Deep Learning advances in the recognition of images, texts and talks.

Specialities such as Radiology (criticized for allegedly causing the high cost of healthcare) and pathology (gateway to more specific specialty) that can be severe and positively impacted by advances of Deep Learning in image recognition. It isn't hard to conceive though that Deep Learning algorithms may be able to perform these tasks more quickly and with greater accuracy than human doctors currently do. This has been addressed throughout our work and many authors analyzed here indirectly suggest the same for the near future.

In addition to researchers, several start-ups and large companies are developing or investing in the development of Deep Learning solutions for the diagnosis of clinical pictures. IBM, for example, began the testing of its software of digital diagnostic, "Avicenna", able to identify patterns and abnormalities in medical imaging, such as CT scans and also relies on text and other data from patient records to suggest possible diagnoses and treatments.

In addition to IBM, other companies such as Alterlnics and Enlitic invest resources in research and development of Deep Learning based systems to diagnose medical conditions. They already commercialize some tools that deal with medical diagnosis in friendly and intuitive way.

Although specific applications of Deep Learning for health management are not observable with the same ease that KDD applications in healthcare does, there are initial approaches, like the one from Najafabadi et al. (2015), which deals with Deep Learning as a tool to support other areas that develop solutions for management, such as Big Data.

5. CONCLUSIONS

The study and research of Deep Learning, especially with convolucionais neural networks and back-propagation, made this technique reach a precision superior to human precision for recognition and classification of images and text (which is confirmed in experiments of Li etal. (2015), Esteva et. al (2015) and He et al. (2015)), however, this area still has room for improvement and expansion, especially in the development of new approaches and medical tools aimed at not only the identification of images, but the precise diagnosis in various specialties of diagnostic medicine, indirectly aiding more effective management also features in the area of health.

Based on the studies analyzed, it was identified the predominance of studies using Deep Learning for diagnostic medicine. This is mainly due to the fact that experiments with this technique have shown

to be capable of better identification and classification of patterns in images, if compared to a human agent. Another crucial factor is that many companies (such as Microsoft, Google, Facebook) are investing huge amounts of resources on research to improve the identification of patterns in images with Deep Learning.

In healthcare management, we identified that there are no studies directly related to this area. The studies that more closely match Deep Learning to methods for management in health are as well linked at applications that produce diagnostics, since these tools can, through the models of Deep Learning, be capable of infer whether the given treatment is as effective as another treatment of higher cost, as part of what was implicitly suggested by Schmidhuber (2015). Certainly the amount of technical and financial resources devoted to the improvement of Deep Learning in image recognition, what is of extreme interest to diagnostic medicine, end up overshadowing the development of techniques focused on health management. Unfortunately no studies were found that explicitly support this idea, mainly because of the precocity and recent notoriety that Deep Learning acquired. Therefore, the use of Deep Learning for management models in healthcare are an excellent and promising research opportunity.

Another promising area for future research, due to the potential of Deep Learning for identification and classification of images (in addition to the widely cited "diagnostic medicine") is to use it the identification of feelings from video images or sounds. This could be of singular interest for psychology, for business and for law. Based on what was checked throughout this study, it is obvious that Deep Learning can provide significant improvements for these segments and initial studies about its effectiveness are still not conclusive.

This research also reinforces what is alleged by (Najagabadi et. al, p. 18, 2015): Deep Learning is an area not yet mature. Meaning that this technique is very recent and still has only a few studies showing its potentialities. What is even more visible in healthcare, because Deep Learning as suggested by Schmidhuber (2015), provides importante automation in the medical field and could not only save huge amounts of money, but also make the attendance of an expert doctor accessible for all the people.

One can finally say that Deep Learning, being a branch of machine learning, try to approach this area of one of its original goals: Artificial Intelligence and Artificial Intelligence through Deep Learning applied to health shows itself capable of brilliant results.

REFERENCES

BENGIO, Y; HINTON, G.; LeCUN. Y. **Deep Learning**, USES, Nature Magazine, VOL. 521. 2015 p. 436-p. 444

CHUA, T-S; NIE, L; ZHANG, B; ZHANG, L; WANG, M; YAN, n. **Disease Inference from Health-Related Questions via Sparse Deep Learning**, IEEE Transactions on Knowledge and Data Engineering, Volume 27, Issue 8, School of Computing, National University of Singapore, Singapore, 2015. p. 2107-2119

DECHTER, Rina, **Learning While Searching In Constraint-Satisfaction-Problems**, Association for the Advancement of Artificial Intelligence, Computer Science Department, University of California, Los Angeles, CA, 1986. p. 178

ESTEVA, A; KUPREL, B; THREN, n. **Deep Networks for Early Stage Skin Disease and Skin Cancer Classification**, Stanford, CA, 20115. 8 p.

HO, K; REN, S; SUN, J; ZHANG, x. **Delving Deep into Rectifiers: Surpassing Human-Level Performance on ImageNet Classification**, Microsoft Research, USA, 2015. 11 p.

HO, K; REN, S; SUN, J; ZHANG, x. **Deep Learning for Residual Image Recognition**, Microsoft Research, USA, 2015. 12 p.

HINTON, g. e., **Learning Distributed Representations of Concepts**, Proceedings of the eighth annual conference of the cognitive science society, Amherst, MA, 1986. p. 1-12

HOLLYWOOD, S; KLAMBAUER, G; MAYR, A; UNTERHINER, t. **Toxicity Prediction using Deep Learning**, Institute of Bioinformatics, Johannes Kepler University Linz, 2015. p. 1-8

IVAKHNENKO, A.G., **Group Method of Data Handling**, Soviet Automatic Control, 1966, 31, p. 43-71

JI, S; LI, R; LI, J; SHEN, D; SUK, H; WANG, l. **Deep Learning Based Imaging Data Completion for Improved Brain Disease Diagnosis**, Medical Image Computing and Computer-Assisted Intervention-MICCAI, Department of Computer Science, Old Dominion University, Norfolk, VA, 2014. p. 305-312

KAHOU, S.; KONDA, K; MICHALSKI, V; MEMISEVIC, R; PAL, c. **Recurrent Neural Networks for Emotion Recognition in Video**, University of Montreal, Montreal, 2015. p. 1-7

KHOSHGOFTAAR, T. M; MUHAREMAGIC, AND; NAJABADI, M; SELIYA, N; WALD, r. **Deep learning applications and challenges in big data analytics**, Florida Atlantic University, Journal of Big Data, 2015. p. 1-21

LIU, G-P; LU, X; QIAN, P; ZHENG, W; ZHONG, T; WANG, Y-Q. **Deep Learning Based Syndrome Diagnosis of Chronic Gastritis**, Computational and Mathematical Methods in Medicine, 2014 Volume, Shanghai University of Traditional Chinese Medicine, Shanghai, 2014.

SEEBÖCK, Phillip, **Deep Learning in Medical Image Analysis**, Vienna, 2015. 161 p.

SCHMIDHUBER, Jürgen**, Deep Learning in Neural Networks: An Overview**, Istituto Dalle Molle di Studi Sull ' Intelligenza Artificialis, University of Lugano, SWz, 2014. 75 p.