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EVALUATION OF HOW TO APPLY DEEP LEARNING IN BIOMEDICAL ENGINEERING

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Abstract

Recent developments in image processing have contributed to the advancement of rapidly developing technological systems. Studies on image processing, especially in the health field, have increased its popularity. Despite the success achieved on existing methods, whether it is medical images or images in other fields; the deep learning model is a model that contributes more in terms of time and performance compared to existing methods. While processing is done on single-layer images with existing methods, high-performance results can be obtained on multi-layer images with the deep learning model. The most important feature of deep learning is that it processes the operations on the image in a single go and can discover parameters that need to be entered manually. In addition, the fact that technology companies are turning to deep learning has increased their competitive power among themselves, and the methods they have built on deep learning in scientific terms have started to be preferred more than existing methods. In the biomedical field, which is one of the areas with limited dataset access, datasets have recently been obtained rapidly.

Keywords: *CNN, deep learning, image processing, biomedical, biomedical imaging*

Inroduction

In a world where digitalization is rapidly spreading, obtaining data has become quite simple. Deep learning models have achieved significant success with the increase in the amount of data. Each deep learning model is unique with its architecture and components. These models have minimized the errors received in many areas, thus leaving traditional methods behind. At the same time, it has been seen that higher successes are achieved by minimizing human influence. Creating models similar to the human nervous system has taken the field of artificial intelligence to an advanced level. Deep learning models have been used especially in areas such as image analysis, audio analysis, robotics, autonomous vehicles, gene analysis, cancer diagnosis and virtual reality, and have achieved excellent results compared to human performance.While used in the relevant field, attention has been paid to prevent time loss, improve memory and power usage, and avoid stacking layers on top of each other.

With the continuous development and advancement of deep learning technologies, new opportunities and challenges will arise. Designing more complex, automated decision-making systems, ensuring that systems learn, understand and make decisions better, understanding objects and events in data types such as images, videos, and text, developing more effective learning methods under limited data conditions, using knowledge learned in one field in another, understanding the ethical relationship between deep learning, and developing human-focused, fair artificial intelligence are inevitable areas to focus on in the future. Researchers and experts can expand the boundaries of deep learning and achieve new successes by working in these areas.

Image processing is a technology that obtains fast results with various interface software in a computer environment for the functions performed by the human eye. Various models have been developed in this technology and these models have also contributed to the scientific studies. Using image processing and clustering methods, many categories of analysis are performed on the image such as shape detection, labeled classification, shape separation, and structuring into subclasses (Zhang J., Y. Xia, Y. Xie, M. Fulham, and Feng D., 2017). The most preferred model in the results of these analyses is the deep learning model, which is a sub-branch of machine learning. Deep learning, which has a multi-layered structure according to the machine learning method and is inspired by the functioning of the human brain, has been attracting increasing interest recently (Koitka S. and Friedrich C. M. , 2016). Image processing experts and academicians at universities use machine learning in application areas such as analyzing videos, classifying images obtained as a result of analysis, learning natural language, etc.

In this process, machine learning uses "Graphics Processing Unit" (GPU) to achieve revolutionary fast and high-performance results. When GPUs are compared to "Central Processing Unit"s (CPU), GPUs are preferred because they have a performance superiority of 10 to 100 times in their applications. In particular, networks are deepened with hidden networks in the Artificial Neural Network (ANN) architecture. This means a lot of memory consumption. Excessive memory consumption can be met by having sufficient hardware in terms of both time and performance. That's why GPUs are preferred instead of CPUs. Deep Learning is the name of the system that can automatically extract features from training sets containing labeled images and allows the use of multi-layered neural networks together, unlike machine learning. It has begun to be used in many areas such as image and sound analysis, robot technology, remote sensing, genetic analysis, cancer and disease diagnosis, etc.

The reason why it is preferred so much is that it can provide fast and high results. This situation has sometimes exceeded human criteria. In these areas, especially large companies (Google, Facebook, Samsung, Microsoft, Intel etc.) continue their investments and studies intensively. Today, the increase in the number of cameras used in every field and the detection of objects in the images obtained from cameras, just like the human eye, has made the machines achieve incredible results with the deep learning model in image processing. In this way, thousands of image sets have shown very successful results with the deep learning model (https://keras.io/ Accessed: 12-Mar-2018).

Academicians working on image processing have focused on image processing studies in the biomedical field in recent years and have increased their activities on deep learning as a model. Another important reason for the interest in deep learning models is that there is enough data to be trained and the physical infrastructure required for processing this data is ready. This article touched on the comparison of deep learning models supported by various companies with existing architectures in the biomedical field. The most important reasons for focusing on the biomedical field are:

The data sets obtained in this field can be obtained more easily and quickly compared to the past, and a new solution method has been found with the deep learning model compared to classical methods. In addition, the lack of past information on deep learning models in the biomedical field, the faster and higher detection of various diseases in image processing in a field that is important for human life such as health, can be listed as reasons. Before examining the studies in the biomedical field, it will be useful to give brief information about deep learning models and their related libraries.

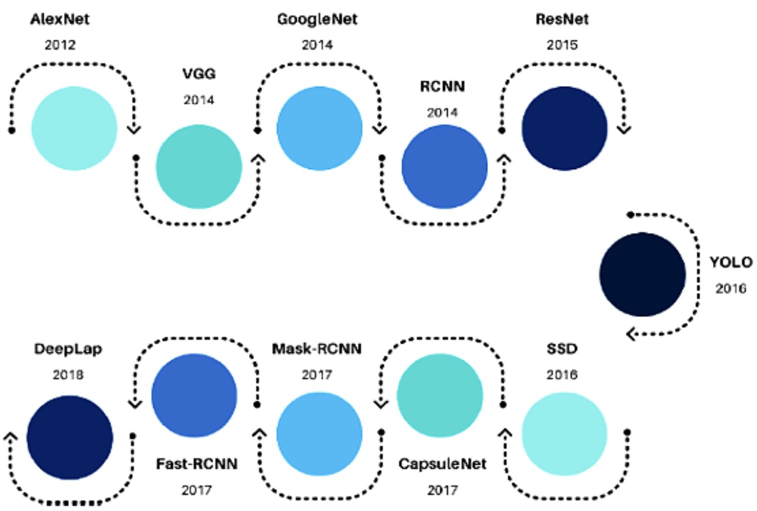
2. Deep Learning Libraries:

Deep learning has led to major breakthroughs in many areas. Of course, the most important factor that enables this is that there are many library files written in various programming languages (Java, C#, C++, Python, etc.) on deep learning. "TensorFlow, Lasagne, Keras, MXNet, Caffe, Torch, etc." are the most preferred libraries. These libraries support many deep learning models such as multilayer neural networks (MLNs), recurrent neural networks (RNNs), feed-forward networks. Caffe: It is a library written on deep learning and image processing. It can also be run on application languages such as Python and Matlab. The most important feature of the Caffe library is that it has pre-trained models (Y. Jia et al, Jun. 2014). Keras: It is a high-level deep learning library written on the Python programming language. Its most important feature is that it can also run on the Tensor Flow Library (https://keras.io/ (Accessed: 12-Mar-2018). TensorFlow: It is an open source deep learning library supported by Google. It makes it easier to build deep networks on GIUs. It is generally preferred for numerical calculations in image processing (https://www.tensorflow.org/ (Accessed: 12-Mar-2018). Torch: It is a library that simplifies even the most complex problems and prepares the algorithm for solving the problem in a fast and flexible structure. Torch can work on image processing, audio processing, video, image, etc. formats. The programming languages it supports are Lua and Python. MXNet: This library is known as a multi-language library because it is supported by programming languages such as R, Python, Scala, Julia. In this way, it is possible to compare the work done in different programming languages.

3. Deep Learning Models

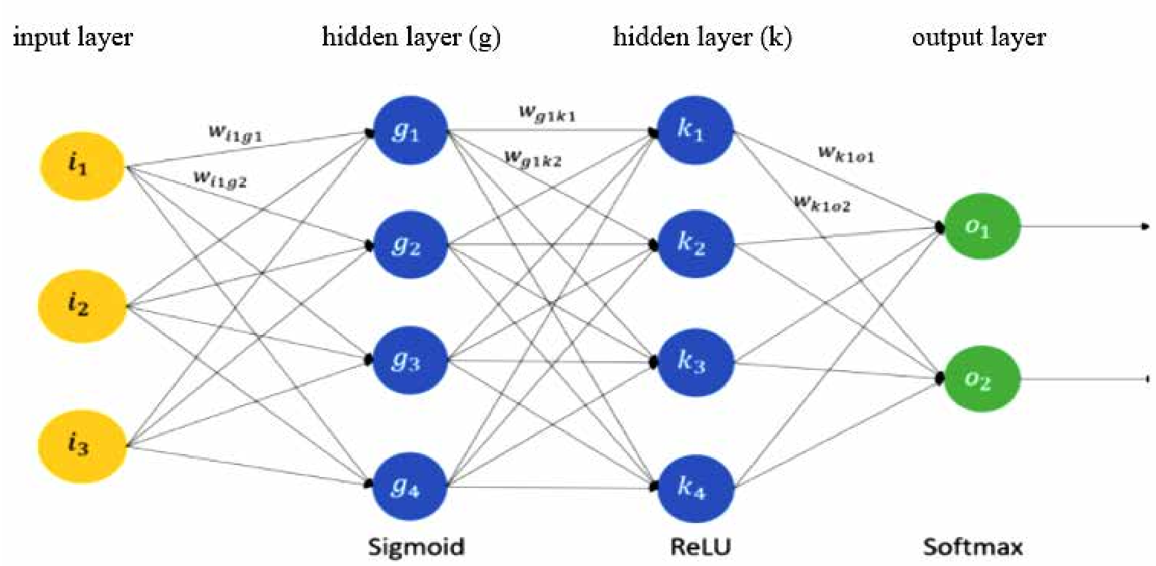
As a result of the digitalization of today's age, the amount of data is rapidly increasing exponentially. This situation has contributed to the developments and successes in the field by increasing the amount of data that the algorithms of methods such as deep learning need to be successful. Deep networks perform the learning process on raw data by obtaining the necessary data from the representations in the relevant layer. Each model built on its architecture is of particular importance. Alex Net, ZF Net, GoogLeNet, Microsoft RestNet, R-CNN, Fast R-CNN and Faster R-CNN models can be listed among the models considered important. In these models, logics such as preventing time loss, improving memory and power usage, and creating a structure that does not stack layers on top of each other have been adopted. Figure 1 shows the development of models developed with the deep learning method over time.

Figure 1. *Methods developed with deep learning architectures (Saleem vd., 2019)*



The Alex Net model, developed on the deep learning architecture in 2012, proved once again how valuable the deep learning approach is by winning the ImageNet competition. While the error rate of computerized object identification was 26.2%, the error rate was reduced to 3.6% with Microsoft RestNet as a result of the continuous development of the architectures. The success of deep learning models has ensured high success in many areas where the architecture is used. The successes it has achieved have enabled the development of many practical applications of machine learning, the expansion of the field of artificial intelligence and its popularity. Deep learning is formed by the combination of artificial neural networks, layers, activation functions, weights and backpropagation algorithm components. It is a learning process in which multilayer neural networks are used to produce output from input data. In order to explain the terms more clearly, it is possible to make the following explanation: ANNs are mathematical models inspired by the biological nervous system. The network structure of the ANNs in Figure 2 can be examined. ANNs are formed by connecting nerve cells (neurons) with a network structure. Neurons, which are processing units, receive input data, perform calculations using weights and activation functions, and transmit the results to other neurons. Deep learning ANNs use this modeling approach.

Figure 2. *Schematic representation of multilayer artificial neural network*



Activation functions are used to calculate the outputs of neurons and represent the non-linear properties of neurons in signal transmission. It can be said that activation functions such as Sigmoid, ReLU (Rectified Linear Unit), and Tanh are widely used. In deep learning networks, the concept of weight is used for the connection between input data and output data, and the concept of bias is used to adjust the activation threshold of cells. These parameters are learned and updated during the training of the network. The training process in question is carried out with the backpropagation algorithm. This algorithm calculates the amount of error between the outputs of the network and the real values backwards and updates the weights with this error information. In this way, the network can learn the relationships between input data and outputs and make more accurate predictions. The selection of such algorithms directly affects deep learning performance. Another factor affecting performance is the design of the deep learning architecture and the layer arrangement. Deep learning architectures will be examined in detail under a separate heading. Deep learning networks process data through layers, each layer forming a specific group of operations. It can be said that it is responsible for the operations on data and the flow of information. With the development of ANNs and the increase in the number of hidden layers, the ESA architecture, which is referred to as a deepening network, has entered an incredible rise. The main difference that distinguishes this architecture from ANNs is that it prevents memorization during the training phase of the network structure. ESA is a deep learning model that can automatically extract the features of images and perform complex tasks. ESAs consist of more than one layer and complete the training process by processing the input data layer by layer. The layers used in the ESA architecture include the convolution layer, the smoothed linear unit layer (ReLU), the pooling layer, the fully connected layer, the Dropout layer and the classification layer. The convolution layer creates activation maps by applying filters to the input image.

The flattened linear unit layer breaks the linear structure of the network and pulls the negative values to zero. The pooling layer is used to reduce the input size and reduces the size by taking the maximum values or averages on the data coming from the convolution layer. The fully connected layer is connected to all fields of the previous layer and calculates the weight matrix. The Drop Out layer closes random nodes to prevent the network from memorizing and increases the diversity of the network. The classification layer performs the classification process and predicts objects in deep learning architectures. These layers form the basis of deep learning models and are used together to perform the learning process. The convolution layer extracts features in the image, while the ReLU layer breaks the linear structure. The pooling layer reduces the size, while the fully connected layer calculates the connections. The DropOut layer prevents memorization, while the classification layer predicts the results. The combination of these layers is used to increase the performance of deep learning models and perform various tasks.

Deep Learning has started to attract more attention, especially with the competitions organized by ImageNet since 2012, and deep learning models have started to be preferred in image classification in the competitions. To give some preliminary information about these popular models:

Alex Net, which made its name in the 2012 ImageNet competition, was trained with approximately one million images and is a deep learning model with a very high success rate in classifying images. This model was modeled to classify a thousand objects (Krizhevsky A., I. Sutskever, and Hinton G. E., 2012).

ZF Net: This model was designed inspired by the AlexNet model and better results were obtained compared to AlexNet. It won first place in the ImageNet competition in 2013. The difference compared to AlexNet is that the filter size is 7×7 and the number of steps is 2. In addition, it used the "Cross Entropy", "Probabilistic Gradient Descent" and "ReLu" algorithms in its own architecture. The ZF Net architecture consists of 7 layers (Zeiler M. D. and Fergus R., 2014).

Goog LeNet won first place in the ImageNet 2014 image classification competition. In the ImageNet competition it entered in 2012, it increased its success rate from 89.06% to 93.33% in 2014. The GoogLeNet architectural structure consists of 22 layers, and this architecture has proven that increasing the number of layers increases the performance of the classification process when the dataset is too large. In order to prevent overloading of large-sized images, it filters images of various sizes such as "1 × 1, 3 × 3, 5 × 5" in the same time frame.

Microsoft ResNet: The RestNet architecture contains more layers than other architectural structures and has 152 layers in its structure. The number of layers contains almost 7 times more layer parameters than the GoogLeNet architecture. RestNet came first in the ImageNet image classification competition held in 2015. While the human error rate is accepted as 5–10%, RestNet reduced this rate to 3.57% in the competition held in 2015 (Wu S., S. Zhong, and Liu Y., 2017).

Res NeXt model: This model is a model that classifies images with deep learning developed by the Facebook software company. It adopts the strategy of "dividing, transforming and merging" image inputs with several special filter methods (1×1, 3×3, 5×5 etc.); It has a homogeneous multi-branch architectural structure. The ResNeXt model is inspired by ResNet and VGG models.

R-KSA model: The purpose of this model, known as regional KSA, is to correctly detect objects on the image. This architecture is the architecture that detects objects on images taken from different angles or at different times of the same environment and gives us the relationships between objects. It analyzes the image from different sized windows for each image by performing a region selection search and classifies pixels according to their color, texture and density for each object definition (Girshick R., J. Donahue, T. Darrell, and Malik J., 2014).

The most important shortcoming of the B-KSA model is that it spends a lot of time while training the dataset. To overcome this deficiency, the "Faster B-KSA" model was developed. With this model, instead of running thousands of times for each image; one image is run and the other images are accepted without running the values of the image that was run (Girshick Ö. R. , J. Donahue, T. Darrell, and Malik J., 2014).

4. Deep Learning in Biomedical Field:

Recently, especially studies conducted with deep learning models have achieved successful results in various fields, while activities in the biomedical field have also increased rapidly. With the access to large-scale data sets in this field, the intensity of deep learning studies on biomedical has started to increase rapidly. This section mentions academic studies on deep learning in the biomedical field. One of the studies conducted in the classification of biomedical images: The use of the fine-tuned KSA method in the classification process. With the fine-tuning method, the existing KSA model is trained with ready data sets and the weight updates of the model are obtained. Later, when different data sets ARE left to be trained in the model, the feature and classification process are faster since the weight updates are made in advance.

5. Discussion and Conclusion

Deep learning is a branch of artificial intelligence. The aim is to extract features faster, more efficiently and most importantly automatically in image processing and reflect them in the result. In traditional methods, this function is entered manually. Perhaps the best feature of deep learning models is that they allow the use of many designed models and many traditional methods in the classification of an image. When we compare deep learning models with each other, the most important disadvantage is that they consist of a large number of layers and parameters. Most of the deep learning architectures work in a stacked manner, that is, in order. Although some of the layers operate in parallel in their own structures, this situation can be seen as a disadvantage in the deep learning model. The complexity of the architectures can also negatively affect the performance obtained. As a result, in this article we have compiled, brief information was presented about the recent studies in the biomedical field related to deep learning. Deep learning models and libraries were mentioned at a basic level for those who want to work in the biomedical field, and the use of these models with traditional methods and their effects on the performance results obtained were mentioned.

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