Digital Processing and Deep Learning Techniques: A review of the Literature

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Abstract. This the first goal of digital image processing was to aid a human observer in intercepting certain events taking place through such images, yet we are more inclined to suppress the observer. We want to ask the computer to automatically analyze images in the same approach that a human observer might. Mathematical approaches are used to process images in image processing.Different approaches are done to the image in image processing to obtain a better image.The main goal of image enhancement is processing certain image so that the result is more appropriate for a specific application compared to original image. The first part of the presented study gives an overview regarding the approaches of digital image processing, while the second section introduces the concept of deep learning (DL) approaches and compares them.

Keywords: Digital image processing, Deep Learning (DL), Segmentation, Classification, Feature extraction, Convolutional Neural Networks (CNN).

1. Introduction

Antennas The Jet Propulsion Laboratory, Bell Labs, and MIT were among the first to create image processing, also known as digital image processing, in the 1960s[1]. It was created with satellite images, character recognition, medical imaging, and photo enhancement in mind. In the case when third-generation digital computers began to provide the storage and speed capacity needed for the practical implementation related to image processing algorithms. The field of digital image processing has exploded in popularity. Because of its low cost and versatility, digital image processing has become the most prevalent type of image processing in the 2000s, thanks to the development of fast computers and signal processors[2]. In addition, image processing can be defined as an approach for improving raw images acquired from sensors/cameras aboard satellites, aircrafts, and space probes, as well as images captured in everyday life, for a variety of purposes. This image processing discipline has greatly advanced in the past few years, extending to various technological and scientific fields [3]. The goal of image processing is divided into numerous categories [4].

1.1 Image retrieval: By using image processing, the user can just see the parts of the image that are relevant to them.

1.2 Image recognition: Mathematical approaches are used to process images in image processing.

1.3Image sharpening and restoration: Different approaches are done to the image in image processing to obtain a better image.

In digital image processing area, DL is used for solving challenging problems (such as image colorization, classification, detection and segmentation). DL approaches like Convolutional Neural Networks (CNNs) have pushed the boundaries of what can be achieved by the improvement of the prediction performance using big data and abundant computational resources. Problems which have been previously thought to be impossible to solve are currently being solved with a super-human accuracy. A good example of the is image classification. Since being reignited in 2012 [5] by Sutskever, Krizhevsky, and Hinton, DL has dominated the domain because of the significantly superior performance than previous approaches [6].

2. Analog Image Processing:

Electrical signals are used in this processing procedure to make any changes to the image that are needed. 2D analog signals are processed in analog processing. Images are altered in this method by altering the electrical signal. It is primarily used for hard copies, such as photography and printing [4].

3. Digital image processing:

The term "digital image processing" indicates the use of a digital computer for processing 2D image [7]. It refers to the digital processing of any 2D data in a larger context. An array of real numbers indicated via a finite number of bits is referred to as a digital image. The repeatability, versatility, and preservation of original data precision are the main benefits of digital image processing systems.
The different Image Processing methods are [8]:

- Image preprocessing
- Image enhancement
- Image comperssion
- Image segmentat
- classification
- Feater extraction

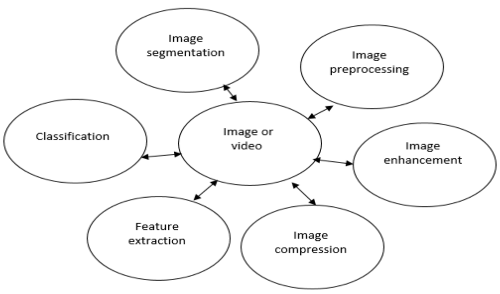

Figure 1: Image Processing methods

3.1. Image Preprocessing

Image data that had been obtained by sensors on a satellite is utilized for the prevention of errors that are associated with pixel geometry and brightness values in image preprocessing. Correcting such errors requires using proper mathematical models that may either be statistical or definite. Image enhancement can be defined as the process of improving the image's visual impact through adjusting the pixel brightness values. Also, image enhancement refers to a group of the methods for improving the visual look of an image or converting it into a format that is more suitable for machine or human interpretation. Due to the limits of imaging subsystems and illumination conditions while capturing images, images taken from satellites and conventional and digital cameras can lack brightness and contrast. Various sorts of noise can be found in images. The purpose of image enhancement is to highlight specific image features for further display or analysis [9]. Contrast and edge enhancement, noise filtering, pseudo-coloring, magnifying, and sharpening are some examples. Image analysis, feature extraction, and image display all benefit from image enhancement. The enhancement method itself has no effect on the data's inherent information content. It merely draws attention to particular aspects of an image. The majority of enhancement methods are interactive and application specific. The following are a few of the enhancement approaches: (Noise Filtering, Contrast Stretching, Histogram modification).

3.2 Image Enhancement

The main goal of image enhancement is processing certain image so that the result is more appropriate for a specific application compared to original image. It sharpens image features including boundaries, edges and contrast to improve the usability of a graphic display for analysis and display. The most difficult aspect of image enhancement is to quantify the enhancement criterion, which necessitates the use of a large variety of image enhancement approaches to achieve adequate results. Image enhancement approaches could be based on spatial or frequency domain approaches [10,11].

3.3 Image Compression

Image compression is a technique for reducing the size of digital images to save transmission time and storage space. Lossless compression is preferable for artificial images like icons, technical drawings as well as high-value content like medical imagery or archive image scans. Lossy techniques are best for natural images like photos, in which a small loss of fidelity is acceptable in exchange for a significant drop-in bit rate. Visually lossless compression is lossy compression which generates insignificant differences. Lossless image compression approaches include run-length encoding, Lempel Ziv encoding, and Huffman encoding. Lossy image compression could be achieved using transform coding techniques like DCT and Wavelet transforms, followed by quantization and symbol coding [12]. Figure 2 depicts a general compression model.

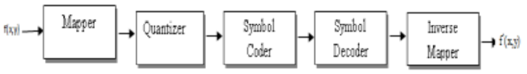

Figure 2: General Compression Model

3.4 Image Segmentation

The term "segmentation" refers to the partitioning of an image into multiple parts or regions. Image segmentation divides an image into subparts based on the problem to be solved and needs of the user [13]. Pixels are used to split the image. Image segmentation divides the image such that it becomes extremely accurate. This approach is mostly utilized in order to analyze substances, borders, and other records that are significant to processing [14]. Image segmentation produces a set of sections that cover the entire image or a group of contours that are removed from the image. The goal of segmentation is to make an image easy to evaluate and more significant by simplifying or changing the way it is displayed. It improves the image's appearance. Image segmentation is done for object recognition, image compression, and editing purposes. Image thresholding techniques are used for image segmentation. Furthermore, segmentation assigns a label to each one of the pixels in the image, allowing pixels with comparable labels to share definite characteristics [15]. Figure 3 represents the Image Segmentation Techniques.

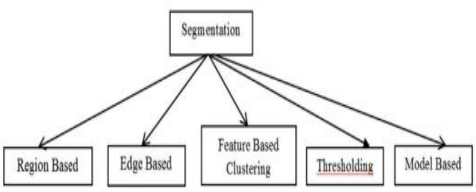

Figure 3: Image Segmentation Techniques

3.4.1 Threshold Based Segmentation:

Thresholding is the most straightforward way for segmentation. Those points are both below and over the definite threshold value. Edge detection is used for calculating the histogram's value. As a result, the threshold value is only accurate if the edges are correctly detected. In a complex environment, this method does not produce adequate results [16].

3.4.2 Edge Based Segmentation

The edge detection approach is another segmentation method. Edges are drawn to recognize pixel values, and such edges are compared to other pixels. There are a few gaps between the edges since they are not closed with each other. As a result, linking is done for filling the gaps between edges [17].

3.4.3 Clustering Based Segmentation

Clustering is the most significant unsupervised learning problem. Clustering is a different type of challenge that involves identifying a structure in a set of unlabeled data. Clustering is considered as the process of grouping objects into groups that are related in some way. As a result, a cluster is a collection of objects that are 'similar' to one another but 'dissimilar' to objects from other clusters. The Markov random field is used in this approach. Inbuilt region constraints are utilized for color segmentation. MRF is combined with edge detection for defining edge accuracy [18]. The relations between color components are included in this approach.

3.4.4 Region Based Segmentation

This approach [19] groups together specific segmentation objects. This approach employs a region-based segmentation method. The region as a whole should work together. It's also referred to as similarly based segmentation. After applying the procedure, the image's texture and color are changed, and a vector is formed from the edge flow. The edges are after that subjected to additional processing [20].

3.4.5 Feature Based Clustering

Clustering is the most significant unsupervised learning problem. Clustering is a different type of problem that involves identifying a structure in a set of unlabeled data. Clustering is the process of grouping objects into groups that are related in some way. As a result, a cluster is a collection of objects that are 'similar' to one another but 'dissimilar' to objects from other clusters.

3.5 Classification

Image classification is utilized for the extraction of information from images, such as the pixels and labels. For the purpose of performing the classification process, several images of one objects are needed. A suitable method of classification and a sufficient number of the training samples are fundamental for the effective categorization. Fundamentally, the system of classification is deliberately dependent upon the requirements of the users. There is a high number of the methods of classification are accessible like the ANNs, fuzzy logic, expert systems, and others. Different classification algorithm types, such as the sub pixel, per field and per pixel. The per-pixel classification is the one that is utilized most often. The sub-pixel methods compact with varied pixel problem. Those resent higher precision levels. For the fine 3-D resolution data per field classification can be considered as the optimal choice. The methods of classification are either unsupervised or supervised. In the supervised classification approaches, the spectral signatures obtained from the samples of training are utilized for the image classification. The signature file can be created easily from given samples of training, additionally, using the multi-variate tools of classification, the image is classified. In the unsupervised methods, the output is dependent upon the machine with no user interaction. In those approaches, the pixels that belong to one category will be grouped under one class. The diagram below represents the processes of the supervised and the unsupervised methods of classification. In the supervised classification, the samples are initially collected, after that, they will be assessed. Then, signature file will be created. After creating the signature file, different methods of classification are applied on signature file for classifying the image. The unsupervised method deals with the principle of the clustering, where no samples are gathered for additional processing. All of the work is performed by the device, using different algorithms. There can be a number of the factors that are associated with the classification, and those are highly significant for getting successful outcomes. Those factors are high quality sensed data, valid classification technique, the analyst's experience and skills. A suitable approach of classification as well as an adequate number of the training samples are pre-requisites for the effective classification [21]. Figure 4 shows the classification techniques.

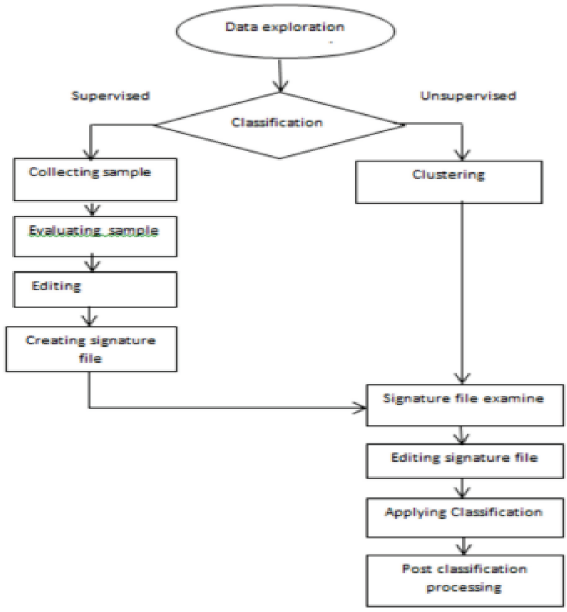

Figure 4: Classification Techniques

3.6 Feature Extraction

The methods of feature extraction have been developed for the extraction of the features in the synthetic aperture radar images. This approach performs the extraction of the high-level features that are required for the purpose of performing target classifications. The features can be described as the items uniquely describing a target, like the shape, size, location, composition, and so on. The approaches of segmentation are utilized for the isolation of desired objects from the scene in order to make it possible for performing subsequent measurements on it[22]. The quantitative measurements of the object features provide the ability for image classification and description. In a case where preprocessing and desired segmentation level was accomplished, some methods of feature extraction are implemented on segments for the purpose of obtaining the features, and it is succeeded by applications of the methods of classification and post processing. There is a high importance in focusing upon the phase of feature extraction, due to its observable impacts upon the recognition system's efficiency. The process of feature selection of the feature extraction approach represents the single most significant factor in the achievement of the high efficiency of the recognition. The process of feature extraction was defined as "the extraction from raw data information which is most suited for the purposes of the classification, at the same time as decreasing intra-class pattern variability and increasing the inter-class pattern variabilities". Which is why, selecting a proper method of feature extraction based on the input that is to be applied requires being performed with maximum care[23]. Considering all of those factors, it will be important to look at the different available approaches for the feature extraction in certain domain, covering a wide range of case possibilities. Different feature extraction approaches have been listed inTable 1 [24].

Table 1. Overview of feature extraction methods

Grey scale subimage	Binary		Vector (skelton)
	Solid character	Outer contour	
Template matching	Template matching		Template matching
Deformable templates			Deformable templates
Unitary Transforms	Unitary Transforms		Graph description
	Projection Histogram	Contour profiles	Discrete features
Zoning	Zoning	Zoning	Zoning
Geometric moments	Geometric moments	Spline curve	
Zernike moments	Zernike moments	Fourier descriptors	Fourier descriptors

4. History of the Deep Learning:

The models of DL may be also known as the NN with the deep structures. The NN's history is dated back to the 1940's, and main aim has been the simulation of human brain systems for the purpose of solving the general problems of learning in principled ways. It has gained a great deal popularity in 1980's and 1990's after proposing backpropagation concept by Hinton *etal*. None-the-less, as a result of training over-fitting, lack in training data of large scale, limited computational powers and insignificance in the performance in comparison to other tools of ML, the NN have fallen out of fashion in the beginning of the 2000's. The DL became popular in 2006 with the advancement in the speech recognition [25]. DL recovery may be a result of the factors below.

• Appearance of the large scale annotated training data, like the ImageNet, for the full exhibition of its very broad capacity of learning;

• Significant improvements in the network structure design and strategies of training;

• Fast development of the high performance systems of parallel computing, like the GPU clusters.

With the unsupervised and layer-wise pre-training that is driven by the Auto-Encoder (AE) or the Restricted Boltzmann Machine (RBM), a good initialization has been presented. With the drop-out and data augmentation, the problem of the overfitting in the training was relieved [26]. With the batch normalization (BN), training very deep NN has become rather sufficient. In the meantime, different network structures, like the Overfeat, AlexNet [27], ResNet, VGG and GoogLeNet [28], were researched in detail for the purpose of improving performance. What has prompted the DL to have massive impacts upon the whole academic community? It could be a result of Hinton's group contribution, whose massive effort had shown that the DL would result in bringing revolutionary break-through on the grand challenges instead of only obvious enhancement on the small data-sets. Their success has resulted from the training of large CNNs on 1.20 million labeled images together with some approaches (such as ReLU operation [29] and 'drop-out' regularization).

5. Deep Learning techniques:

DL techniques that implement the deep NNs have gained popularity as a result of increasing the high-performance computing facility. DL can achieve more flexibility and power as a results of the fact that it is capable of processing large numbers of the features in the case of dealing with the unstructured data. DL passes data over multiple layers; every one of the layers has the ability to progressively extract the features and passing them to the following layer. The initial layers perform the extraction of the low-level features, and subsequent layers combine the features for the formation of complete representation [30].

The 1st ANN Generation has been composed of the perceptrons in the neural layers that have been limited in the computations. The 2nd generation performed the calculation of error rate and back-propagated error. The RBM could overcome back-propagation's limitations, which has resulted in simplifying learning. After that, other networks eventually evolved [31]. Figure1 depicts a timeline that shows the deep models' evolution along with conventional model. The efficiency of the classifiers utilizing DL enhances on large scales with the increase in the data amount in comparison with conventional approaches of learning. Figure2 illustrates performance of the conventional algorithms of ML and algorithms of DL [32]. The efficiency of the conventional ML approaches becomes stable in the case of reaching training data threshold while DL upturns its efficiency with the increase in the data amount. Nowadays, DL is utilized in quite many applications like Amazon and Netflix's engines of recommendation, Google's image and voice recognition, Apple's Siri, automatic text and e-mail replies, chat-bots, and so on. Figures 5,6

Respectively shows evolution of deep models and Why Deep Learning .

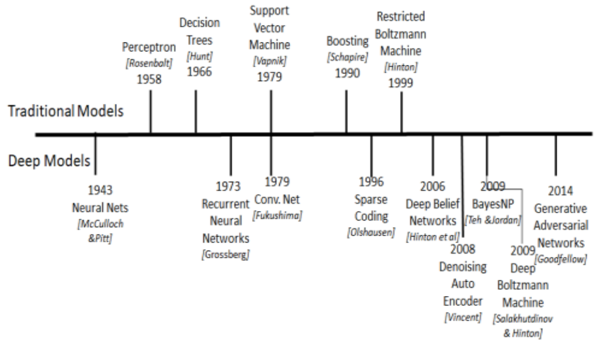

Figure 5: Evolution of Deep Models

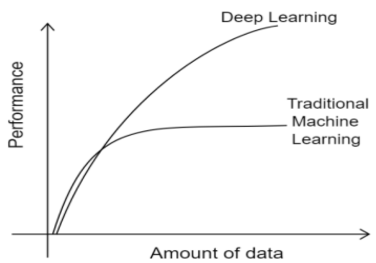

Figure 6: Why Deep Learning?

6. DL Approaches:

Deep neural networks can be described as successful tools for the area of supervised, Reinforcement, unsupervised, and hybrid learning methods.

6.1 Supervised Learning:

In this type of the learning, input variables that are denoted as X, are mapped to the output variables that are represented as Y with the use of an algorithm for the learning of mapping function f.

$$Y = f(X) \qquad ....(1)$$

The objectives of learning algorithm is the approximation of mapping function for the prediction of output (Y) for new input (X). The error from predictions that has been made throughout the process of the training may be utilized for the output correction. The process of the learning may be terminated in the case where all inputs have been trained for obtaining the target outputs. The regression for solving the problems of regression [33], SVMs are utilized for the classification, RF is utilized for the problems of regression and classification [34].

6.2 Unsupervised Learning:

In the process of the unsupervised learning, only input data is available without any corresponding outputs to map. Such strategy of learning is aimed at learning about the data through the modelling of data distribution. The algorithms may have the ability for discovering the exciting structure that is present in data. The problems of clustering and association utilize the unsupervised learning, like K-means for clustering problems [35], the Apriori algorithm has been utilized in the association problems A. Mathew *etal*.

6.3 Reinforcement Learning:

The reinforcement learning utilizes a reward and punishment system for the training of the algorithm, in other words, an agent or algorithm learns from the environment. The agent gains the rewards for the correct performance and punishment for the incorrect performance. For instance, considering a self-driving car case, the agent is rewarded for safely driving to the destination and punishment in case of going off-the-road. In a similar way, if a program is playing chess, the state of the reward could be winning the game and the punishment is getting check-mate. The agent attempts at maximizing rewards and minimizing penalties. In this type of the learning, the algorithm isn't given any information about the way of performing the process of the learning; none-the-less, it operates through the problem on independently [36].

6.4 Hybrid Learning:

Hybrid learning can be defined as the architectures which take advantage of the discriminative (i.e. supervised) and generative (i.e. unsupervised) components. The combination of a variety of the architectures may be utilized for designing a hybrid deep NN. They're utilized for the human action recognition with the use of the action bank characteristics, and they're expected to be producing considerably better results [37].

7. Deep learning (DL) approaches:

Some powerful methods which may be implemented in the algorithms of DL for the reduction of training durations and optimization of the model will be explained in the sections below. The pros and cons of every one of the methods have been listed in detail in Table1

Back propagation: whereas solving a problem of optimization utilized gradient based approach, back-propagation may be utilized for the calculation of function gradient for every one of the iterations [38].

Stochastic Gradient Descent: utilizing convex function in the algorithms of gradient descent guarantees the finding of optimal minimal value without being entrapped in the local minimum. According to function values and rate of learning or size of the step, it could reach the optimal value in a variety of the manners and paths [39].

Learning Rate Decay: the adjustment of the rate of learning results in increasing performance as well as reducing training duration of the algorithms of the stochastic gradient descent. The commonly utilized approach is gradually reducing the rate of learning, where one can make large changes at first, followed by the gradual reduction of the rate of learning in the process of training. Which can allow the fine-tuning of weights in subsequent steps [40].

Dropout: The problem of the overfitting in the deep NNs may be solved with the use of dropout approach, which is implemented through the random dropping of the units as well as their connections throughout the process of the training [9]. The Drop-out presents a sufficient approach of regularization for the reduction of the over-fitting and improvement of the generalization errors. This method can also give a better performance on the tasks of supervised learning in the areas of computational biology, computer vision, speech recognition and document classification [41].

Max-Pooling: In this approach, a filter is pre-defined, which is applied then across non-overlapping sub-areas of input, taking the maximal value within the window as output. The dimensionality, in addition to computational costs for learning multiple parameters, may be decreased with the use of max-pooling [42].

Batch Normalization: this approach decreases the covariate shift, thus resulting in the acceleration of the deep NN. It result in normalizing inputs to the layer, for every one of the mini-batches, in the case of updating weights throughout training. The normalization results in stabilizing learning as well as reducing training epochs. The NN's stability may be increased through the normalization of output from preceding layer of activation [43].

Skip-gram: the word embedding approaches may be modelled with the use of this approach. In this model, 2 terms of vocabulary share similar context; then, these terms are quite similar. For instance, sentences like "dogs are mammals" and "cats are mammals" are considered meaningful, as they share one meaning, which is "are mammals." The skip-gram may be carried out through the consideration of context window the contains n terms and train NN through skipping one of those terms and after that, utilized the model for the prediction of the skipped term [44].

Transfer learning: In this approach, the model that has been trained on some certain task is utilized on a different associated task. The knowledge that has been obtained throughout solving a certain issue may be transferred to some other network that will be trained on an associated problem. Which has allowed for the rapid progression and improved efficiency throughout solving the 2nd problem. The Comparison of Deep learning methods have been listed in Table 2 [45].

Table 2. Comparison of Deep learning methods

Method	Description	Merits	Demerits
Back propagation	Used in Optimization problem	For calculation of gradient	Sensitive to noisy data
Stochastic Gradient Descent	To find optimal minimum in optimization problems	Avoids trapping in local minimum	Longer convergence time, computationally expensive
Learning Rate Decay	Reduce learning rate gradually	Increases performance, Reduces training time	Computationally expensive
Dropout	Dropsout units/ connection during training	Avoids overfitting	Increases number of iterations required to converge
Max-Pooling	Applies a max filter	Reduces dimension and computational cost	Considers only the maximum element which may lead to unacceptable result in some cases
Batch Normalization	Batch-wise normalization of input to a layer	Reduces covariant shift, Increases stability of the network, Network trains faster, Allows higher learning rates	Computational overhead during training
Skip-gram	Used in word embedding algorithms	Can work on any raw text, Requires less memory	Softmax function is computationally expensive, Training Time is high
Transfer learning	Knowledge of first model is transferred to second problem	Enhances performance, Rapid progress in training of second problem	Works with similar problems only

8. Result and discussion:

The digital image processing always represents one of the interesting fields, due to the fact that it provides enhanced pictorial knowledge for the human interpretation as well as the processing of the image data for the transmission, storage, and representation for the machine vision.

Digital Image processing is utilized for the enhancement of image quality, which is obtained from a variety of the sources. The present study includes a discussion of a variety of the approaches of image processing, like image preprocessing, compression, segmentation, feature extraction, and image enhancement. Those approaches have been utilized in several fields. The selected approach is depends on the field of application. Each one of those techniques with their own advantages and drawbacks.

The approaches of deep learning (DL) outperform the current approaches of ML. It provides the computational models with the ability for progressively learning the features from the data at a number of the levels. DL popularity, which has been amplified as amount of available data has been increased in addition to advancements of the hardware providing powerful computer devices.

The approaches of DL, implementing deep NN has become popular as a result of increasing high-performance computing facilities. DL can achieve higher flexibility and power because of its capability in processing numerous features when dealing with the unstructured types of the data.

9. Future Scope:

There is a high number of the approaches that were created up until nowadays for the enhancement however, there remains more need for the improvement that could be carried out through the AI systems for the optimization, which could result in the generation of sufficient results. In the future, effective approaches of image enhancement utilizing AI will be established, so that the results of the improvement could be accomplished in a balanced way, which could result in providing better optimization results.

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