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Investigation of Deep Learning Framework to Accelerate AI for Image Processing Applications

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Abstract
Organizations and society at large face a significant challenge as a result of the projected increase in data generation, consumption, and storage, which is predicted to surpass 180 zettabytes by 2025. The increasing size and complexity of datasets creates new computational and theoretical challenges. Over the past 20 years, data science tools have grown in popularity in tandem with this progress due to their numerous applications in managing complicated data, high accuracy, exceptional adaptability, and flexible customisation. Data analysis is more difficult when it comes to images because the amount of data that needs to be processed grows along with the desired image quality. Despite the fact that traditional machine learning (ML) methods are still widely used in a variety of academic sectors and industries, the scientific community has shown a significant amount of interest in the development of new artificial intelligence approaches. The development of neural networks has led to notable advancements in fields like image processing and comprehension. In this study, aa comprehensive research into the most recent advancements in artificial intelligence (AI) design and the optimisation methodologies that have been proposed to handle picture processing challenges was carried out by us. In spite of the fact that there have been encouraging results, there are still a great deal of challenges to be conquered in this area of research. In this study, we focus on image processing applications and discussed the key and more recent improvements, applications, and advancements that have occurred in this field. In addition to this, we offer some suggestions for potential future research in this rapidly developing topic.

Keywords: Deep learning, artificial intelligence, and image processing, reinforcement learning

INTRODUCTION

One of the most significant ways that society communicates is through images, which are packed with vital information. The ability of the human visual system to naturally extract significant and occasionally subtle information makes it possible to perform a variety of tasks, from the most basic, like object identification, to the most sophisticated, like knowledge generation and integration. This system is typically the first to come into contact with media. The visible component of the electromagnetic spectrum is the only part of the spectrum that this technology can access. Thus, the extraction of pertinent and essential information for performing various tasks in various settings and application domains is a core function of image processing through computer systems. The processing of lunar surface photos marked the beginning of image processing in 1964. picture processing, to put it simply, is a subfield of signal processing that focusses on developing computer techniques for digital picture

analysis, enhancement, compression, restoration, and information extraction. Image processing has garnered a lot of attention from the scientific community and industry due to its numerous applications. Together with the development of computer technology and the need for systems that function at ever-higher levels of accuracy and dependability, this curiosity, and processing speed, has made it possible for image processing techniques to advance significantly from the usage of non-learning-based approaches to the implementation of ML techniques.

Building computers and computational systems that can carry out tasks like speech recognition, image recognition, and natural language understanding is the focus of the computer science discipline known as artificial intelligence. —ideally automatically—ML first emerged in the middle of the 20th century [1]. When providing innovative methods for creating AI models, Multidimensional arrays are computational data structures for encoding vectors, matrices, and tensors of a higher order, and linear algebra operations on them are frequently used in ML and other scientific computing applications [2].
Machine learning is a data analysis method that automates the creation of computer algorithms and analytical models to predict future information. These models are especially helpful for assessing data and identifying possible trends, and they may be used with a variety of data formats [3]. Over the past ten years, this set of methods has become so popular and a hot research issue that practically everyone uses modern AI models on a daily basis [4].
Many aspects of technology have been transformed by AI, especially machine learning. In the realm of image processing, the importance of these methods is especially clear. Complex image processing tasks including facial identification, object detection and classification, synthetic image synthesis, semantic segmentation, picture restoration, and image retrieval have been made possible by the advancement of computers and algorithms. There are numerous benefits to using machine learning techniques in image processing that have an impact on every aspect of society. This technology can increase the precision of data analysis, streamline procedures, and open up new opportunities in a variety of fields [5][6]
High-precision picture analysis and interpretation are achievable with machine learning algorithms. Neural network technology advancements in recent years have made it possible to precisely recognise things, recognise patterns, and do intricate visual analysis. In fields like medicine, where a precise diagnosis can change a patient's life, pursuing ever-increasing precision is crucial.[7]

METHODOLOGY

In order to perform this assessment, we reviewed a significant number of ML-related scientific publications, particularly those that addressed image processing techniques that used DL and RL techniques to practical problems. [8][9]

A. Methods of Search and Information Sources

The information sources, which were regarded as respectable university repositories and published periodicals, were examined to ensure the papers' dependability. In order to give a broad and comprehensive picture of how image processing research has evolved and can be applied, we made an effort to incorporate studies from a variety of fields and subjects into the chosen sources. However, some regions seem to have become more interested in some of the previously discussed ML techniques. Using a collection of phrases that were closely associated with image processing, a search was conducted on well-known scientific search engines such as Springer Science Direct and Core. These search engines were chosen because they enabled us to conduct comparison searches, target specific terms, and filter

results according to the research field where we were conducting our investigation. For the purpose of ensuring that the themes were relevant to data science and/or artificial intelligence across a wide variety of topics and journals, we simply utilised the search filter that was required. [10]

The prompt "image processing AI" as of February 2023 yields publications primarily pertaining including "computer science," "medicine," together with "engineering." In actuality, the results of the searches conducted in the three distinct research aggregators remained reasonably constant. Figure 1 presents an overview of the outcomes that were achieved. The situations listed above may possibly be more common than others since there is more research available on some subjects.[11]

B. Selection Criteria for Articles: Inclusion and Exclusion

Numerous research works were proposed by various writers as a result of the research conducted in the various repositories. Given the volume of research conducted and the ongoing advancements in this field, we decided to concentrate mostly on studies conducted within the last five years. The research sources that offered innovative and/or captivating uses of machine learning in image processing were examined and chosen. The goal was to give a comprehensive overview of current developments in machine learning research while presenting the data in a more manageable style.[12]

CONTEXUAL FRAMEWORK

Digital photos have become widely available because to the increasing usage of social networks and the internet in general. Being privileged allows one to discuss information and express feelings, which opens up a wide range of uses. One of the first steps in identifying and interpreting an image is figuring out what aspects of a scene are fascinating. We will present a general technical background study of machine learning and image processing in order to assist the reader in comprehending how the various strategies are utilised to process images and extract their features. Additionally, we will explain the primary concepts and technicalities of the several forms of artificial intelligence models currently in existence. This will guide the reader through the subjects discussed and continue to provide pertinent context for the review's scope.

IMAGE PROCESSING

An aesthetic and impactful configuration of areas and objects is what humans perceive as an image. Recent advancements in image processing methods, such as noise reduction, enhancement, and compression, are useful in a range of everyday situations, both at work and as citizens. In order to do classification tasks, an image can be reduced to millions of pixels, which makes the processing of data extremely challenging. Not only does accuracy have an impact on the results of the segmentation process, but it also has an impact on the outcomes of future activities that are either directly or indirectly dependent on it.. Segmentation is a difficult and complex image processing task that is employed in many disciplines, including automated image systems. The goal of segmentation is to divide a picture into its regions of interest (ROI), or representative body portions (or objects), without overlapping. A global image descriptor (GIST), a histogram of orientated gradients (HOG), and a number of feature descriptors, such as texture, colour, and edges, can be used to do this. The human visual system instinctively segments images without any further effort, Nevertheless, segmentation is one of the areas of image processing and computer vision that presents the greatest amount of difficulty.

Object detection has garnered a significant amount of interest from the scientific community due to the fact that it has a wide range of applications. and significance. Detecting items that are significantly larger

than the image in which they are situated or detecting many objects of varying sizes may be required, depending on the goal. Depending on the image's dimensions, object detection yields different results, with larger objects typically yielding better results [13]. The most varied fields find use for image processing methods and algorithms. Picture processing has expanded in a variety of fields in the field of medicine, encompassing machine learning, picture mining, pattern recognition, and computer vision.

In order to swiftly extract relevant information from the data, it is frequently required to limit the quantity of data inputs when image processing issues arise. This is done in order to apply some machine learning models. By reducing the image into a reduced set of characteristics, an operation that picks and measures the sample data attributes in a reduced form and imitates the high-level properties of the source can be of assistance with this process. Because of this, the original data can be recreated in some sense. There are several classic machine learning methods that can be utilised to improve the results of photo interpretation, despite the fact that deep neural networks are often used for this purpose. The dimensionality of the picture data that a deep convolutional neural network was able to retrieve was reduced by Zeng et al., for instance, by the utilisation of principal component analysis. [14]

OVERVIEW OF MACHINE LEARNING

Machine learning (ML) is driven by a conceptual knowledge of how the human brain functions. It focusses on certain activities that frequently need pattern recognition, such as image processing, direct marketing, directing business decisions, or spotting irregularities in business processes. ML is motivated by this understanding. Because of its remarkable versatility, high precision, and adaptability, it has proven to be helpful in a wide range of other industries. Within the field of environmental research. and engineering fields, it has become increasingly widespread during the past few years. Deep learning systems learn from data to recognize and categorize patterns, enabling them to make judgments with little assistance from humans.[15]

In many study domains and industries, classical techniques are still widely used, especially when dealing with datasets that are unsuitable for modern deep learning architectures and methods. As some data scientists like to point out, selecting the appropriate model depends on the problem being solved, and that no single machine learning technique fits all data. Observing data as instances is the foundation of the learning process in diagnostic modelling using the concept of classification. In these cases, the model is built by using the data and its annotated labels to learn.

Even though ML models are a crucial component of data handling, there are other preparation processes that must be completed, such as data collection, method selection, model training, and model validation. One of the most important requirements for creating an effective classifier is choosing pertinent features, which enables strong and targeted learning models.

The primary difference between the two primary categories of machine learning techniques—supervised and unsupervised learning—is the presence of labels in the datasets.

- Labelled training datasets are utilised in the process of supervised learning for the purpose of identifying predictive functions. It is imperative that every instance of a data item contains both an input for the values and the predicted labels or output values. For the purpose of developing a predictive model that can forecast the result based solely on the relevant input data, this family of algorithms searches for correlations between the values that are input and those that are output into the system. A wide range of algorithms, including linear regression, KNN, decision trees, ANN,

random forest, SVM and others, can benefit from supervised learning techniques, which are appropriate for regression and data classification.

- Using unlabelled training datasets, unsupervised learning is commonly employed to address a number of pattern recognition issues. Based primarily on clustering algorithms [16], unsupervised learning algorithms can categorize training data into distinct groups based on their unique characteristics [17]. Since the number of categories and their meanings are unknown, unsupervised learning is typically utilized for association mining and classification problems DT-classifiers, SVM, and K-means are a few often utilised algorithms. Before attempting to cluster a collection of data, it is frequently necessary to require data processing tools such as principal component analysis (PCA), which is utilised for dimensionality reduction.

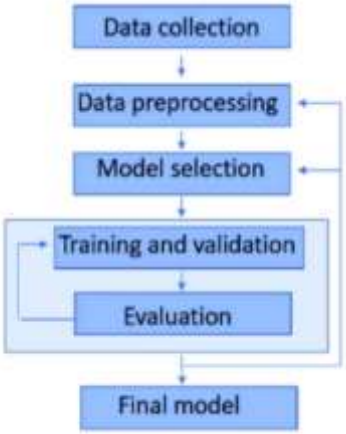

Fig.1. ML flowchart

Recent years have seen a number of advancements in AI research due to the return of neural network techniques, which have sparked innovations in fields such as natural language processing and picture comprehension. Based on this viewpoint, deep reinforcement learning (DRL), which is a combination of reinforcement learning (RL) methodologies and neural network modelling, appears to be an especially promising area of artificial intelligence research. In the past five years, this technique has become one of the most intense fields of artificial intelligence research. It has shown very promising results in terms of imitating human-level performance in activities such as playing video games, playing poker, playing multiplayer games, and playing difficult board games like as Go and Chess. Due to the fact that its learning principles were partially influenced by research on animal training and are believed to be closely related to neurological mechanisms for reward-based learning that centre on serotonin in the brain, DRL may be of special interest for studies in the fields of psychology and neuroscience. Apart from its inherent significance as an AI topic, DRL may also be of particular interest for artificial intelligence research.

CONCEPTS OF DEEP LEARNING

A framework for heuristic learning, deep learning (DL) makes use of neural networks that contain several nodes of artificial neurones that are referred to as perceptron's. and subfield of machine learning, to discover patterns in data structures. Similar to a biological neuron, artificial neurons may process several inputs and operate based on mathematical calculations, producing a output. A single-layer perceptron, the

most basic type of neural network, consists of a processor, at least one input, and one output. CNN, recurrent neural networks (RNNs), and multi-layered perceptron's (MLPs) with many hidden layers are the three categories of DL algorithms that can be distinguished.

It is essential to take into account the fact that generic neural networks are learning systems that have an exceptionally low level of bias. According to the bias–variance trade-off, neural networks in the most popular form that were used in the early DRL models are sample-inefficient and require a significant quantity of data in order to be trained. A small selection of hypotheses can speed up learning if the learner's particular biases align with the content to be learnt or if the hypothesis is correct [18]. Numerous algorithm and model suggestions have surfaced, some of which—like CNNs, autoencoders, and multilayer feedback RNNs—have been widely applied in various situations.

To optimize system performance, several network models must be used for datasets containing text, audio, graphics, and more [19]. Because DL models perform better when handling some of the more conventional ML issues, they are frequently utilized for image feature extraction and recognition.

There are some significant differences between DL approaches and classical ML.

- In order to train a DNN, a loss function must be defined. This function is in charge of determining the process error, which is indicated by the discrepancy between the expected and actual output values. The mean squared error (MSE) is one of the most often utilized loss functions in regression situations [20]. Effectively obtaining analytical answers is impossible during the training phase because the weight vector that minimizes the loss function is altered. Gradient descent is the often employed loss function minimizing technique.
- Activation functions are essential for both learning neural network models and deciphering intricate nonlinear functions. No matter how many layers the model had, it would not be able to address and over one linear function without the addition of nonlinear features from the activation function. The most popular activation function in the early phases of neural network research is the Sigmoid function.
- Overfitting scenarios are more likely to happen in DL models because of their higher learning and data-adjusting capacity compared to typical ML models. For this reason, one of the most important and successful sets of methods for lowering generalization errors in machine learning is regularization. Additional tactics that can assist in achieving this objective include expanding the training dataset, ending the training phase prematurely or rejecting a part of the neurones' output during the training phase are both examples of termination strategies.
- Optimisers are utilised in deep learning algorithms to enhance stability and decrease the amount of time required for convergence. which also allows for increased efficiency in the hyperparameter modification process.

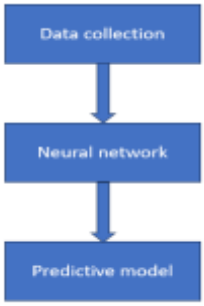

Fig.2. DL flowchart

Three primary mathematical approaches have been researched for picture modelling and representation in recent decades, mostly due to their shown modelling flexibility and adaptability. These techniques are those that rely on partial differential equations, wavelet analysis, and probability statistics. Sometimes reducing the amount of input data is required in image processing methods. For tasks like classifications, an image can be converted into millions of pixels, so record keeping would make processing extremely challenging. Some challenges can be addressed by reducing the image to a smaller collection of features, choosing and measuring a few relevant attributes of the raw input data in a more condensed format. DL advancements are very appropriate for image processing and segmentation applications [21] because the data attributes of tagged data can be automatically mined and analysed. A collection of unsupervised algorithms called autoencoders is used in a number of methods for feature selection and data dimensionality reduction.

CNNs, one of the many DL models, have been applied extensively to image processing capacity issues and have demonstrated more image than conventional algorithms. Like any other neural network, a CNN has many hidden layers, an input layer, and an output layer. A CNN with a single hidden layer usually comprises a normalization layer, a fully connected layer [22], a pooling layer, and a convolutional layer.

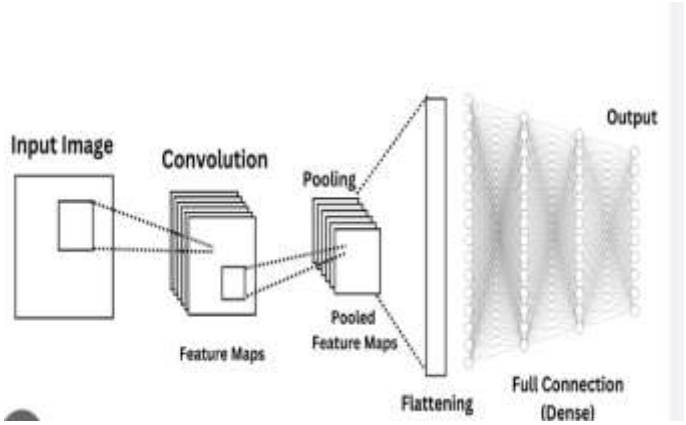

Fig.3. Architecture of CNN

DL models have demonstrated strong performance in natural language processing problems and are commonly employed in image segmentation and classification difficulties, object recognition, and image segmentation. For instance, face recognition software has been widely utilized in a variety of real-world contexts, including mobile phone features and security and surveillance systems at banks and airports.

Techniques for image processing can be used in a variety of ways. CCTV cameras and other surveillance systems have advanced quickly, making it more challenging for a human operator to see and analyze footage. After twenty to thirty minutes to of intense monitoring, human operators may overlook a significant amount of the screen motion, according to several studies [23]. Indeed, within the past ten years, object detection has emerged as a challenging research area. New computer vision-based detection has been made possible by the widespread use of powerful computers and high-speed internet. Examples of its applications include weapon detection, pedestrian identification, naval surveillance, and human activity recognition.

One alternate method for applying machine learning (ML) to image processing issues is image super-resolution (SR), which refers to a collection of technologies that include the process of recovering a super-resolved image from a single image or from a collection of photographs that depict the same

situation. Due to the fact that they are able to produce a high-resolution image from a single low-resolution input, machine learning applications have emerged as the most intriguing subject in the field of single-image SR. The computing load and the calibre of the training data remain the two main obstacles in this method. [24]

IMAGE PREOCESSING DEVELOPMENT

Applications of machine learning have been researched in a wide range of fields that need data processing and acquisition. Taking into account current publications from the previous seven years (2017–2023), we can observe that several research have been generated that deal with various issues and propose a wide variety of models. Specifically, we discovered a sizable number of academic articles expressing interest in applying DL in biology, engineering, and medicine. Considering the amount of research that has been done, there has been a noticeable rise in the number of published studies that focus on image processing and deep learning in recent decades. The results of a search for "image processing deep learning" in Springer link, only review and research papers were considered in this analysis, which suggested an increase from 1309 articles in 2005 to 30,905 articles in 2022.

CONCLUSION

We examined some of the most recent ML research in this review, specifically utilizing DL and RL techniques or their mixtures. It is becoming more and more clear that image processing systems are used in a wide range of settings and have produced ever-more-impressive outcomes as techniques have advanced. It is not surprising that some of the trends that have been discovered seem to suggest that some methodologies are more common in particular study fields. Among these patterns, we noticed:

Over the past few years, interest in image-processing systems that use DL techniques has skyrocketed. Engineering, computer science, and medicine are the fields that do image processing and artificial intelligence research the most frequently. In domains such as disease detection and prediction and computational biology, or to assist with particular tasks when paired with other more advanced methods, traditional machine learning techniques are still very useful today. Due to their capacity to get around some of the issues that more conventional approaches encounter, deep learning techniques have gained special attention in a variety of image processing difficulties. Researchers appear to be quite interested in enhancing model performance, cutting down on time and processing resources, and broadening the use of ML models to address specific real-world issues. Research employing a variety of classes and approaches to learning algorithms appears to have gained particular attention in the medical field. Medical exam analysis and other imaging applications have benefited from the usage of DL image processing. Additionally, certain fields continue to have success using more conventional ML techniques. Autonomous driving and driver profiling seem to be another area of interest, perhaps driven by the greater availability of information for both drivers and cars. In actuality, It is already common for current driver assistance systems to include functions such as (a) lane finding, (b) discovering free driving spaces, (c) identifying and detecting traffic signs, (d) detecting and recognising traffic lights, and (e) detecting and monitoring road objects. There is no question that this field of study will be the subject of several additional investigations in the near future.

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