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Image Processing Techniques and Neuro-computing Algorithms in Computer Vision

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Abstract: Computer vision is a multidisciplinary field that cannot be separated with image processing techniques and Neuro-Computing specifically Deep Learning (DL) algorithms, in recent time DL techniques enable computer vision to understand the content of an image, moreover, it is working hand in hand with image processing techniques because image preprocessing are essential components in digital image analysis. Therefore, the remarkable advancement recorded by computer vision today such as in remote sensing, security, medical imaging and robotics etc. The aim of this research work was to explored the technical and theoretical contributions of image processing techniques and DL algorithms to computer vision. A systematic method of literature review was adapted. Basic image processing techniques such as standardization, denoising, filtering, and segmentation are clearly explored, concept of DL algorithms are briefly discussed, recent reviewed articles (from 2018 to date) are obtained from top journals in computer vision thus; IEEE, Elsevier and ISPR and tabulated as a major source of information for this work. We have shown some of the software's used for the implementation of deep learning researches in computer vision. Finally we concludes and give recommendations based on our findings.

Keywords: Computer Vision, Deep Learning, Object Detection, Neuro-computing, Image Processing, Filtering

1. Introduction

Neuro-Computing techniques has achieved unprecedented progress in many areas of computer vision specifically Deep Learning (DL) ranging from object detection [1-10] images classification [11-17] image segmentation [18-20, 22, 23] and scene classification [24-30]. Moreover, in recent time the same techniques are also applied in remote sensing [31, 32], and [33]. It is noted in this work that most of the recent works in computer vision prefer to use the standard datasets for their analysis as in [34-36]. Despite the implementation of various DL techniques in the areas of computer vision many reviews and survey are also devoted to the exploration of DL algorithms in computer vision and are clearly discussed in the next section of this paper. The aim of this research work was to explore the recent contribution of image processing and Neuro-computing techniques in computer vision.

We have reviewed recent research articles and peer review papers from the top ranked journals of computer vision in the world such as ISPR Journal of photogrammetry and remote sensing, IEEE Geoscience and remote sensing magazine ETC. This is to indicate the quality of this review and its uniqueness. We have downloaded 120 research articles and 60 review and survey papers. Due to the nature of our survey we have extract 77 papers that are related to our work and discarded the rest.

The rest of this work is organized in sections, Section 2 we have discuss the concept of Image Processing techniques in relation to computer vision, Section 3 we have discuss the concept of convolutional neural network as a major technique for object detection in satellite images. Section 4 we have discussed and reviewed the application of deep learning techniques in computer vision. Section 5 we have reviewed recent survey researches that applied deep learning techniques in computer vision. Section 6 we have identify some of the software's available for the implementation of computer vision researches and finally we have concluded and recommend.

2. Image Processing Techniques

An image can be expressed as two- dimensional function $f(x, y)$ where $x \; and \; y$ represent the spatial coordinates and the altitude of f at any pair of coordinates (x, y) is known as the intensity or gray level of the image at that point. If x, y and the altitude values of f are all finite and discrete quantities the image is called digital image. The term gray level is used to describe the intensity of monochrome images. However colored image are formed by three colors Red, Green, and Blue (RGB). Digital images are mostly represented and store in a matrix form or in an array of numbers every digit in the matrix is located at a specific row and column every digit is used to represent a pixel in a two- dimensional picture element that is non-divisible element of digital image [37].

2.1. Image Standardization

One most important constraint that exists in some deep learning techniques, such as Convolutional Neural Network (CNN), is the need to resize the images in a dataset to a unified dimension. This implies that our satellite images must be cropped, resize and scaled to have identical widths and heights before fed to the learning algorithm for easy computation and avoid unnecessary errors. Especially the number of pixels values of the images must be the same.

2.2. Image Digitization

Generally images are converts into digital in two ways digitalization of the coordinate value or digitalization of the amplitude value, hence digital image are represented by M X N matrix.

2.3. Image Denoising

Image denoising is an important component in an image preprocessing because noise in digital images are inevitable in computer vision to preprocessed images they need to be denoised by using filters these includes;

1. Gaussian noise filters.
2. Mean filters of random noise removal.
3. Midpoint filter is seen to be a hybrid filter that combine statistical filter and averaging filter and which is good for denoising Gaussian noise and uniform noise.
4. Alpha-trimoned Mean Filter.
5. Contraharmonic filter.

2.4. Image Restoration

Image restoration is the method of regaining the natural characteristic of the image that has been degraded. We already define the real image as $f(x, y)$ and the degraded image as $g(x, y)$ the connected relationship between f to g is called degradation model represented as

$$g(x, y) = H[f](x, y) + n(x, y) \tag{1}$$

Where H is the degradation operator and n is the noise.

2.5. Image Segmentation

Segmented image is a processed image without noise and sometime sharp which can be an input f and the output could be an image g or not even an image but would be an attribute set of point representing the edges of f boundaries of object but, segmentation is based on certain criteria such as similarity, color texture or region of interest or any set of predefined rules.

If we consider a differentiable function $(x, y) \rightarrow f(x, y)$ in two dimensions to let defined it gradient operator as being the vector of first order partial directives.

$$\Delta f(x, y) = \left(\frac{\partial f}{\partial x} \; (x, x) \frac{\partial f}{\partial y} \;\; (x, y) \right) \tag{2}$$

And the gradient magnitude as Euclidean norm of the vector Δf

$$|\Delta f|(x, y) = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2} \tag{3}$$

3. Convolution Neural Network (CNN)

Deep learning is a subset of Neuro-computing, CNN is also a subset of DL technique that are suitable for computer vision research. it consist of inputs layer and many of feature detection layer which perform convolution, pooling and Rectified linear Unit, at convolutional stage it apply convolutional filters to activate certain features in the image, at the pooling stage it reduce the number of pixel in the image by using non-linear down sampling or sub-sampling. The second to the last layer is called classification layer, it convert 2D feature map to 1D feature map vector, it is fully connected with N-dimension output where N is the number of objects to be classified and the final output will shows the probability that the input image belong to the class of object under review. The architecture of CNN utilize three major techniques local reception fields, tied weights and spatial sub-sampling [38].

3.1. Unsupervised Learning

Deep unsupervised learning these category of deep learning require no label data for training it learned from the significant feature of the data and relationship in the data but the major disadvantage of this technique is the inability to provide accurate concerning data sorting as well as the computational complexity of the dataset. Several techniques are available in this categories; Deep Boltzmann Machine (DBM) and auto encoder which are widely applied in clustering. Deep Boltzmann machine all the connections in this technique are undirected with multiple hidden layers it apply stochastic maximum likelihood during the training process and require no label in the training dataset. The advantage of this technique is the ability to optimize the parameters of all layers. Deep belief network in this technique two top layers form undirected graph and the lower layer form directed generative model [39].

3.2. Semi-Supervised Learning

Deep semi-supervised learning require semi-labeled dataset for training. They are widely applied for text document classification. This includes; generative adversarial network (GAN) the disadvantage of this technique is that unwanted features are learned from the input data and make wrong decision.

4. Deep Learning Applied in Computer Vision

The taxonomy of computer vision includes; object detection, image segmentation, scene classification, image retrieval, pattern recognition, target recognition and so on. In this section we have reviewed recent articles (from 2017 to date) that applied any of the DL techniques in computer vision.

Table 1. *Deep Learning Algorithms in Computer vision.*

Authors	Date	Network	Focus
1. Arshitha and Biju [39]	2020	CNN	Detection in satellite image
2. Scott *et al.,* [15]	2017	CNN	Land cover classification
3. Kadhim and Mohammed [40]	2020	CNN	Satellite image classification
4. Imamoglu *et al*. [41]	2018	CNN	Multi-spectral image classification
5. Deepthi, Sandeep and Suresh [42]	2021	CNN	Object detection in remote sensing
6. Deng *et al.,* [43]	2017	CNN	Object Recognition
7. Gao *et al.* [44]	2017	DCNN	Scene classification
8. Cheng, et al. [45]	2018	CNN	Scene classification
9. Boulleg and Farah [30]	2018	CNN	Image retrieval
10. Zhou, Newsam, Li and Shao [46]	2017	CNN	Object detection
11. Ye et al. [4]	2018	CNN	Land cover classification
12. Zhou, Deng and Shao, [48]	2018	RCNN	Urban land used classification
13. Zhang et al., [47]	2020	OCNN	Image classification and segmentation
14. Zhang et al., [48]	2018	CNN	Road extraction and building
15. Yu et al. [49]	2017	DCNN	Image classification
16. Mahdianpari et al., [50]	2018	CNN	Classification of land cover
17. Alshehhi et al. [51]	2017	DL	Land used classification
18. Kussul et al., [52]	2017	CNN	Semantic labelling of images
19. Volpi and Tuia, [53]	2017	RCNN	Oil and tank detector
20. Rene, He, Girshick and Sun [54]	2017	CNN	Detection of seal in satellite images
21. Muhammad et al., [55]	2018	DL	Object detection in aerial images
22. Geng, wang, Fan, and Ma [56]	2017	MLE	Object Classification
23. Qin, Guo and sun, [57]	2017	DBN	Target recognition
24. Li, wu, and Du [58]	2017	DRNN	Image classification
25. Mou, Ghamisi and Zhu [59]	2017	DL	Image classification
26. Santara et al [60]	2017	DSL	Image classification
27. Chen, lin, Zhao, Wang, and Gu [12]	2017	DL	Object detection

Table 2. *Survey Researches.*

Author	Year	Network	Focus	Limitation
1. Ball, Anderson and Chan., [61]	2019	Deep learning	Comprehensive survey	No Image Pre-processing
2. Song, Gao, Zhu And Ma [62]	2019	CNN	Survey	No Image Pre-processing
3. Hyedari and Mountrakis [63]	2019	DNN	Meta-analysis	No Image Pre-processing
4. Zhang, Zhang And Du [64]	2020	Deep learning	Technical tutorial	No Image Pre-processing
5. Lu, Sun, and Zhang [65]	2019	CNN	Feature aggregation	No Image Pre-processing
6. Paoletti, Haut and Plaz [66]	2019	Deep learning	Review	No Image Pre-processing
7. Parikh, Patel and Patel, [67]	2020	Deep learning	Review	No image Pre-processing
8. Li *et al.,* [68]	2019	Deep learning	Overview	No Image Pre-processing
9. Pashae, Kamangir, Starck And Tissot,[69]	2020	Deep learning	Review	No Image Pre-processing
10. Liu *et al*., [70]	2018	Deep learning	Advances and Feature	No Image Pre-processing
11. Laith *et al*., [71]	2018	DL	Survey	No Image Pre-processing
12. Xiangwei, Doyen and Steven [72]	2019	DL	Recent advances	No Image Pre-processing
13. Lincheng et al., [73]	2019	DL	Survey	No Image Pre-processing
14. Payal *et al*., [74]	2020	DL	Survey	No Image Pre-processing
15. Jiao *et al*. [75]	2019	DL	Survey	No Image Pre-processing
16. Abhishek et al. [3]	2021	DL	Survey	No Image Pre-processing
17. Vipul and Roohie, [76]	2020	DL	Review	No Image Pre-processing

5. Recent Survey Articles

In this section we have centered our search to recent survey articles (from 2018 to date) that applied deep learning techniques in computer vision in addition to see limitations and build on that however, it comes to our noticed that all reviews are subjected to deep learning only not dwelling into the aspect of image processing which is an important part in computer vision because image preprocessing is one of the building blocks of datasets for computer vision. Table 2 summarized the recent survey articles.

6. Image Processing and Deep Learning Software

Image Preprocessing softwares for deep learning algorithms are available for the implementation of computer vision research but the common once are MatconvNet (MATLAB), Tensorflow (C++ and python), R, Caffe (C++), Torch (C and Lua), Keras (python), Deeplearning4j (Java), MxNet, Theano (Python), Gluon (C++), OpeenDeep (Python), NTK (C++) and ConvnetJs. Some of these softwares are open source and some are not [77].

7. Conclusion

In this work we conducted a thorough reviw in the application of deep learning techniques in computer vision. We have subjected our serch towards various categories of deep learning algoriths together with their associated architectures that are applied in computer vision researches, we have used systematic format of literature reviw and explored critically the state-of the-art in all aspect of computer vision and also explored survey and review researches in the state-of-art. furthermore, we have summarized the major softwares and toolboxes use for the implementation of computer vision researches.

8. Recommendations

Based on the findings of this review work the following recommendatons has been made;

1. Several issues in the area of DL in relation to image processing are still on silent mode they need to be explored.
2. There is need to explored more on datasets issues in regard to DL.

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