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COMPARATIVE STUDY OF CAPSULE NEURAL NETWORK IN VARIOUS APPLICATIONS

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Abstract: The advancement in the machine learning and the computer vision has caused several improvements and development in numerous of domains. Capsule neural networks are one such machine learning system that imitates the neural system and develops the structures based on the hierarchical relationships. It does the inverse operation of the computer graphic in representing an object by, segregating the object in the image into different part and viewing the in-existing relationship between the each parts to represent in order to preserve even the minute details related to the object, unlike CNN that losses major of the information's related to the spatial location of the object that are essential in the segmentation and the detection. So the paper presents the comparative study of the capsule neural network in various application, presenting the efficiency of the capsules networks over the convolutional neural networks.

Keywords: capsule neural network, convolutional neural network, computer vision, machine learning, applications,

1. Introduction

The capsule network neural architectures, is a type of artificial neural network that comes under the machine learning system. It is most prominent in modelling a hierarchical relationship and closely imitating the biological neural systems. The development of the capsules network lays back on the concept of expanding the convolution network to reuse the end results to discover more steady and advanced exemplification of the developing capsules. Being a novel architecture in the neural networks and an enhanced approach of the prevailing neural network model especially for the tasks in computer vision, the capsule network have been designed as an alternative for the convolutional neural networks, as the CNN shows few limitations in accomplishing the applications of the computer vision in spite of its efforts in managing the accuracy in the areas where it is applied.

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The convolutional neural networks described as the pedestal of the image processing in a deep learning aspect [2], initially was developed with the aim of classifying the images, utilizing the successive convolution layers and pooling layers. Despites its capability of managing to attain accuracy in the process, the convolution neural network caused few performance degradation due to the reduction in the data dimension for acquiring the spatial invariance, thus causing a loss in the information's (rotation, location, various attributes related to position and scale) that may be required in the process of segmentation, the object detection and proper localization of the objects. This the segmentation and the detection process worse. The alternative techniques, employing the end to end connected layer [14] and utilizing the reinforcement learning [15] developing advanced training and designing techniques for the convolutional neural network [16] to reduces the difficulties in the process of segmentation and detection, to gain accuracy in the classification of the images, were tedious but did not show up with any improvements, so the this lead to the devising of the new architecture of convolution neural network known as the capsule neural network [17] . This approach was proposed as an alternative to the short-comings of the convolutional neural network by the Geoffrey Hinton. The fig.1 below shows the traditional convolutional neural network

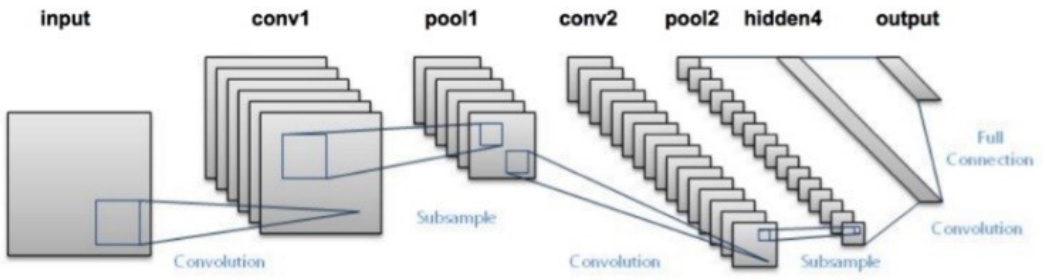

Fig .1 Conventional Convolutional Neural Network

The capsules in the approach represent the group of neurons that hold all the minute information about the spatial location of the object to reduce the adversities in the process of the segmentation and the detection. The capsule network engages the inverse steps of the computer graphics in representing the image. For e.g. in detecting an object the object is inwardly sub-divided into many parts and a relationship is developed between all the sub parts (hierarchical relationship) of the object, to represent the object. The fig.2 shows the architecture of the capsule neural network.

The capsule neural network architecture constitutes three main parts such as the input layer, hidden layer and the output layer , the hidden layer further constitutes , three more layers such as the convolutional layer, primary capsules (lower and high layer also known as digi-caps).

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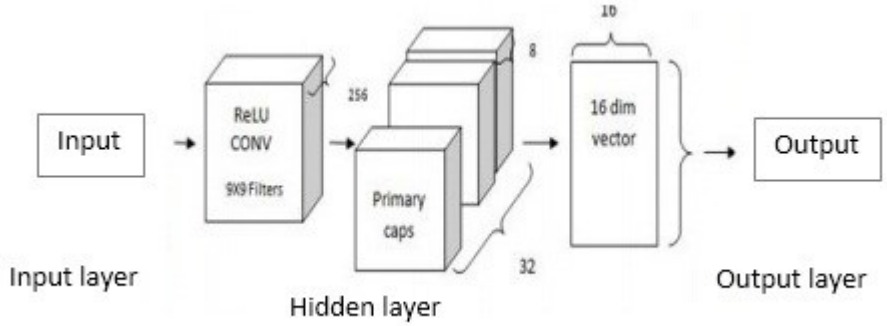

Fig.2 Capsule Neural Network Architecture

The paper gives the comparative study of the capsule neural network architectures employed in various applications overcoming the draw backs of the convolutional neural network.

The paper is organized in the remaining with 2 literature survey holding the various applications that engage the capsule neural network replacing the convolutional neural network, 3. The efficiencies of the capsule neural network over the CNN 4. Conclusion.

2. Literature Survey

Sreelakshmi, K., et al [2] proposes the capsule neural network in separating the plastic and the non-plastic wastes, replacing the convolutional neural network, the sorting out of waste becoming a very prominent problem nowadays is handled by employing the capsule neural network, by gathering the two types of data sets, collecting the images from the websites and from the real time. The images gathered are utilized in training the model and further the testing is done and the proposed method utilizing the capsule networks over the convolutional neural network shows considerable improvement with an accuracy of 95.7% for both the dataset, .972 precision, .954 recall and .963 F1-score. The fig. 3 shows the ROC curve of the capsule and the CNN that holds the efficiency of the Capsnet.

Teto, et al [21] gives the study that compares the operation of the c-capsule-net and the convolutional neural networks in automatically identifying the animals in the wilderness, employs the convolutional capsule neural network architecture for the proposed work, and discuss the learning efforts of the capsules from the convolutional

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layer and the capability of the capsule to rebuilt the image of any size and any resolution reaching an accuracy of the 96.48% the fig.4 below shows the convolutional capsule neural network architecture

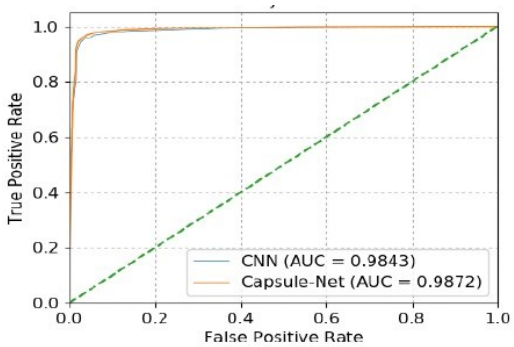

Fig .3 ROC curve [2]

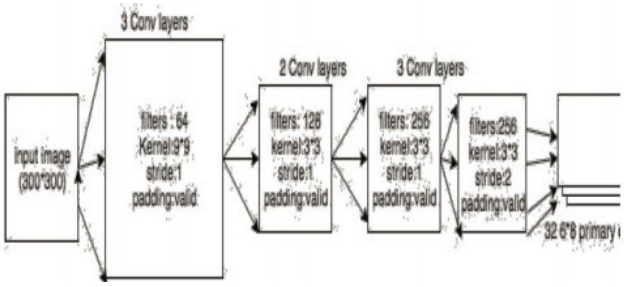

Fig .4 Convolutional Capsule Neural Network Architecture [21]

Wang et al [4] the author utilizes the capsule neural network in intelligent fault diagnosis (IFD), replacing the traditional fully connected CNN that degrade the performance by ignoring the location relationship of features. The capsule network employed in the fault diagnosis enhances the accuracy of the classification in IFD. The fault time frequency graphs are collected by the WTFA and the frequency obtained are used in training, and the parameters showing much alteration are chastened with the cost function, the dynamic routing is done and the length of the capsule is utilized identifying the fault in the diagnosis. The fig .5 shows the three layer capsule neural network architecture for the fault diagnosis.

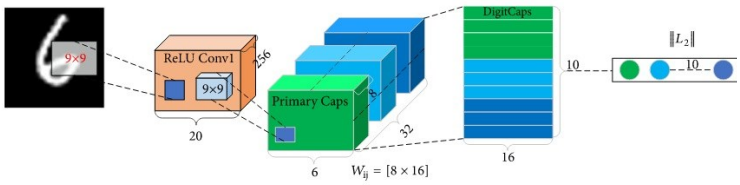

Fig .5 Three Layer Capsule Neural Network Architecture [4]

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Vesperini et al [5] the author engages the CapsNet in the image processing, for overcoming the limitations of the convolutional neural network, in the robustness of the affine transformation, and the identification of the images that are overlapped, the capsule neural network employed in the polyphonic sound event detection, improves the learning the learning rate and enhances the detection performances. The fig .6 shows the CapsNet used in sound event detection.

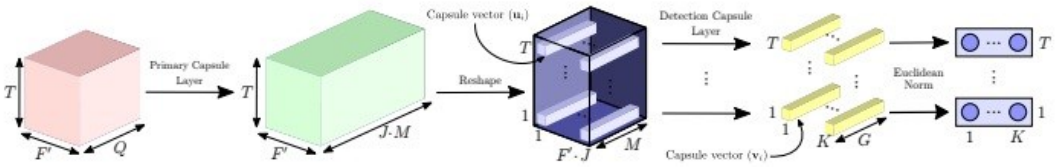

Fig.6 CapsNet in Polyphonic Sound Event Detection [5]

Figueroa et al [9] model for the structural damage localization and quantification based on the capsule neural network, locates and quantifies the structural damage utilizing the dual classification and the regression task. The proposed model is based on the CapsNet since the CNN is incapable of perceiving the movement in the images and the existence of the hierarchies within the images. The fig .7 shows the CapsNet architecture utilized in the structural damage location and quantification.

Jaiswal, et al [11] the generative adversarial network replaces the conventional convolutional neural network with the capsule neural network as a discriminator, during the designing of the image data. The generative adversarial network utilizing the capsule neural network in the modelling image data distribution, excels the performance of the convolution neural network. The table.1 showing the error rate of the Convolutional neural network and the capsule neural network shows the proficiency of the capsule neural network over the convolutional neural network. The table presents the error rate obtained for the CNN and the CapsNet based on the MNIST dataset, it displays the results for the semi-supervised classification based on the MNIST dataset.

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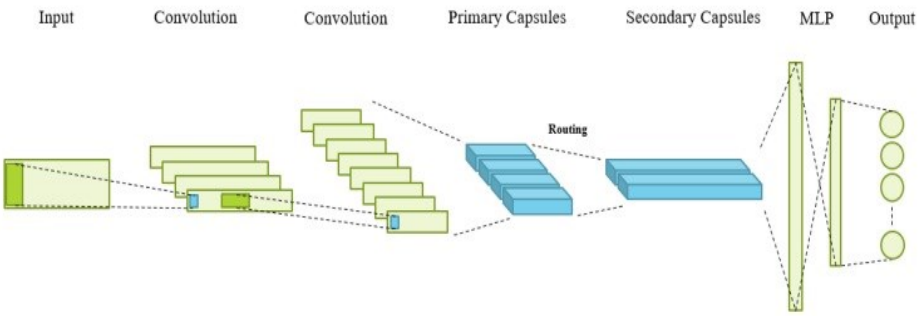

Fig .7 Structural Damage localization and quantification using CapsNet [9]

Model	Error Rate		
	n = 100	n = 1,000	n = 10,000
Convolutional GAN	0.2900	0.1539	0.0702
CapsuleGAN	**0.2724**	**0.1142**	**0.0531**

Table .1 semi- supervised classification –MNIST [11]

Zhang et al [12] for efficacious modelling utilizing the semantic hierarchy, the capsule networks are engaged for the slot filling and intent detecting through the dynamic routing by the agreement schemes, enabling the capturing of the high-level features to be actively participate in the dynamic routing engaged between the word capsules and the slot capsules enhancing the slot filling performance. The words, slots and the intent are framed as capsules and the hierarchical relationship between each capsules is sorted. The Capsnet for the process of joint slot filling and the intent identification proves an outrun performance compared to the Convolutional Neural Network.

The fig .8 gives the CapsNet in the joint slot filing and intent detection. Thus the literatures provides a study that compares the capsule neural network with the convolutional neural network, showing the proficiency of the capsules over the convolutional neural network.

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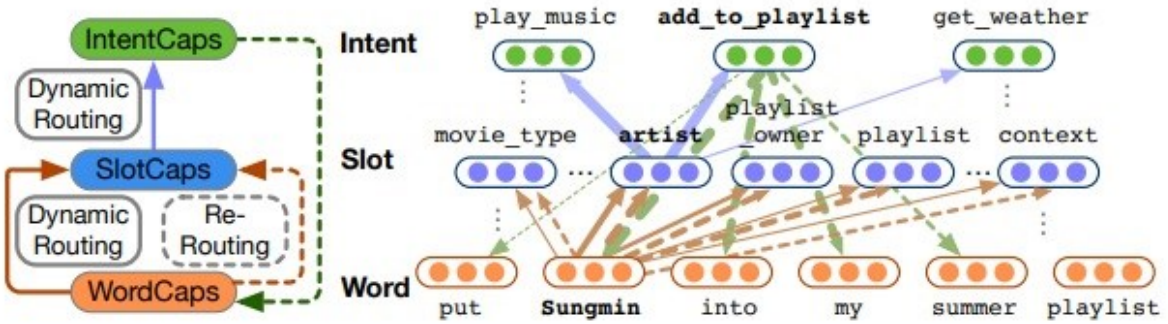

Fig .8 CapsNet in the joint slot filing and intent detection [12]

3. Efficiencies of the Capsule Neural Network

The capsule in the present in the capsule neural network, resemble the human brain in apprehending the required information's [2], it is equipped with huge potential of recognizing even objects that are complex from images captured with the very low quality, they learn better compared to the CNN by dividing the total images into sub – parts and hierarchical relating them and represents the picture with even better resolution than the CNN [21], the pooling layer in the CNN ignores the location relationship in the features leading to the degradation in the performance ,but the capsule shows effective feature extraction thus enhancing the classification accuracy[4]. The CapsNet causes prominent improvement in the performance of detecting the overlapped images and the sound compared to the convolution neural network [5]. The capsule neural networks surpasses the performance of the convolutional network in detection and the quantization of the structural damages as the convolutional neural network are impotent of realizing the rotations of the objects and the presence of the scaling within the objects [9]. The capsule network function as the capable alternative for the convolutional neural network in developing of the discriminator structures and other modules for the generative adversarial network [11]. Unlike the convolutional neural network the, Capsule neural network preserves the location of the object within the object. It works contentedly and effectively with the limited dataset available, preserving the positional information of the input provided. From the study presented it is understood that the routing agreements used perform well with the images as well as the sound that are overlapped. It is also understood that the capsule neural network does an automatic

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calculation for extracting the hierarchical relationship of the in the given objects. The activation vectors in the capsule network are interpretable, and outperforms the CNN by reaching a highest accuracy in classification using the MNIST dataset. Despites its advantages from the stud it was also understood that the capsules are not compatible with the huge dataset and handling complex problems, the literatures also showed that the power required for the capsule as well as the CNN classification are high.

4. Conclusion

The paper presenting the study comparing the proficiency of the capsule neural networks with the convolutional neural networks, shows, has shown the application that utilize the capsule neural network for, segregating, analysing, detecting, localizing and quantifying in place of the convolutional neural network. Since the capsule networks outperforms the convolutional neural network by enhancing the performance of classification. The capsule networks unlike the convolutional networks incurs a better learning process, that paves way for the improvement in the performance, further its ability to preserve the spatial location details and the automatically enumerate the existing relationships between the input objects, are the added advantages of the capsule neural network that makes it more popular. Similar to the convolutional neural network the capsule networks also faces the same problem of high power consumption. So in future the paper is to proceed with the analysis of the methods combined with the capsule networks to reduce the energy consumption in them.

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