International Journal of Scientific Research & Engineering Trends
Volume 7, Issue 2, March-April-2021, ISSN (Online): 2395-566X

Big Data Mining in Internet of Things Using Fusion of Deep Features

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***Abstract*-Today internet of things is employed in different fields such as security, protection and health care systems. This major attention causes huge amount of information transfer from different nodes in network. Recently, big data mining has become one of the most crucial challenges in IOT. In this paper, a novel method based on deep learning is proposed to mine images which is collected from IOT. The proposed method consists of two parts: 1) Features extraction, 2) classification. Features from a convolutional neural network called Alexnet is extracted to use in data mining process. In classification part, a couple of K Nearest Neighbor (KNN) is employed to process features. Also a majority voting approach is used to find the final result. We evaluated our method by pictures which was captured by MIT University. Experimental results proved that the proposed method has better accuracy and precision in comparison of KNN, SVM, Neural network and Bayesian classifiers.**

***Keywords*- Deep Learning, Internet of Things, Features, K-nearest neighbour.**

I.INTRODUCTION

The term Internet of things (IoT) is used to describe embedded devices (things) with Internet connectivity, allowing them to interact with each other, services and people on a global scale. IoT has been widely used in many applications such as industrial control, intelligent transportation and health care [1].

This growth causes huge amount of information to transfer through the network. In recent years, management and analysis of big data in IOT has become one of the most crucial subjects. Big data has complex and multimodal structure which makes processing difficult. So, an efficient method must be employed to mine collected data from IOT. Data mining in IOT improves decision making, energy management, sustainability and performance of the network.

Machine learning techniques have been found very effective and relevant to many real world applications in bioinformatics, network security, healthcare, banking and finance, and transportations [2].

Machine learning allows computers to evolve based on empirical data. A major focus of machine learning research is to automatically learn to recognize complex patterns and make intelligent decisions based on data. Deep learning is a novel method in machine learning that improved supervised and unsupervised classification [3]. One the most practical approaches of deep learning is convolutional neural network (CNN). CNN consists of convolutional, sampling and fully connected layers [4]. Figure 1 describes the structure of CNNs.

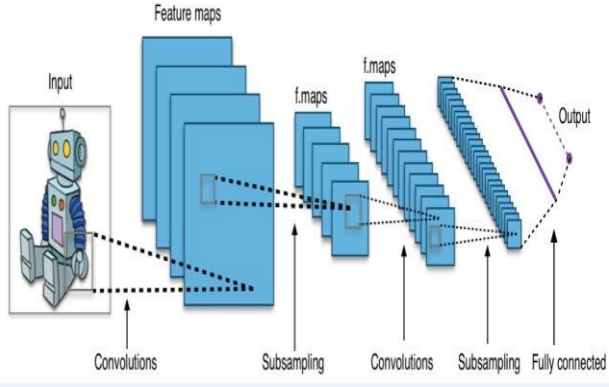

Fig 1. Structure of CNN.

Despite of numerous advantage of CNNs, it must be kept in mind that training of CNN on IOT's big data and its complex features is not an easy task. So, through recent years various deep learning models have been proposed. Bi-modal deep auto-encoder and multi-modal deep restricted Boltzmann machine [5-7] are such models that can be used in multi modal problems as well.

In this paper, we proposed a novel method that uses features of CNNs to mine big data in IOT. This paper is organized in 6 sections. Related work, deep neural network, proposed method, experimental results and conclusion are other five sections

II. RELATED WORK

The first multimodal deep learning model was presented for audio-video data feature learning [8]. This model first learns the features from each modality separately and then

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concatenates the learned features into a vector as the joint representation.

Srivastava and Salakhutdinov [9] employed a bimodal restricted Boltzmann machine for text-image data feature learning. In development of deep learning method, special attention must be paid for dealing with big data. For example, the large- scale stacked restricted Bolzmann machine [10] has millions of parameters for multimedia feature learning.

Ravi et al [11] proposed a methodology based on deep learning that uses extracted features from sensor data and classifies them in real-time fashion.

O'Leary [12] examined relationship between big data, internet of things and internet of signs. The main question in this paper is in which ways big data and signs can be generated in IOT.

Li et al [13] presented a deep convolutional computation model that learns hierarchical features of big data by using the tensor representation model. To make full use of the local features and topologies contained in the big data, a tensor convolution operation is defined to prevent over fitting and improve the training efficiency.

III. DEEP NEURAL NETWORK

Deep neural network (DNN) is a new type of neural network that have multiple hidden layers between input and output layers [14]. DNNs have capabilities of modeling the non-linear and complex structure of data and also extract hierarchical representation from it. Structure of DNNs consists of a series of modules that each one gains its input from last module's output. Each module is called layer. Layers connect with each other through weighted edges and bias values. Figure 1 demonstrates structure of DNN.

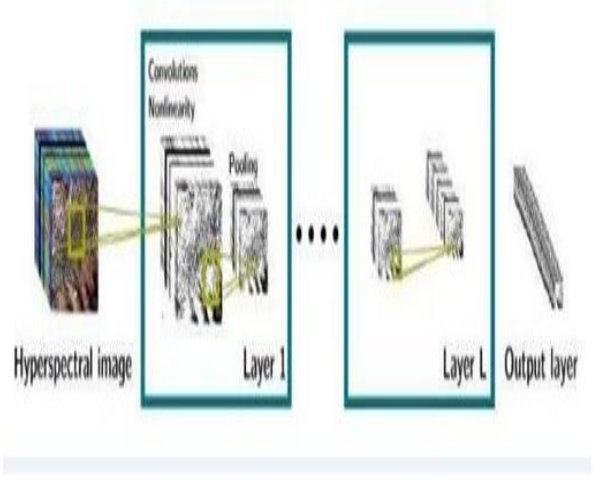

Fig 2. Deep Neural Network.

DNNs have feed-forward structure in a way that input layer is connect to output one without loop. The difference between DNNs and neural network is depicted in figure 2. There are various types of DNNs that each one is specified for certain kind of problem. For instance, recurrent neural network is mostly used in natural language processing and convolutional neural networks are developed for machine vision problems.

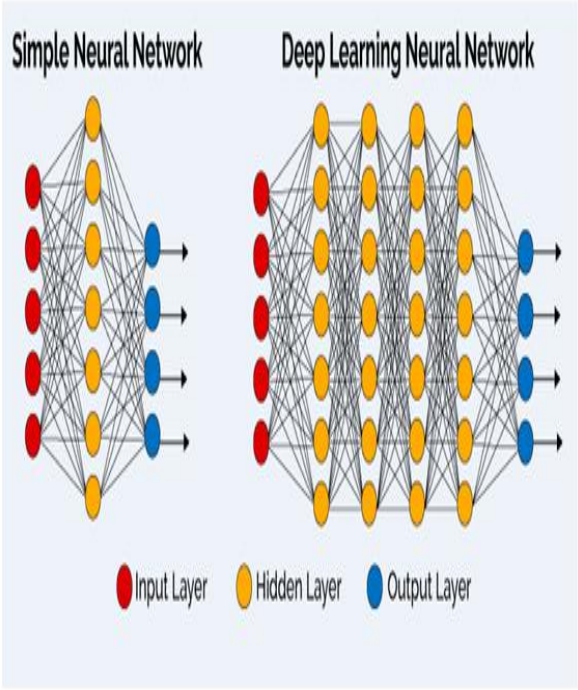

Fig 3. The difference between simple neural network and deep learning neural network.

IV. PROPOSED ALGORITHM

The proposed method is based on a convolutional neural network called Alexnet that is trained and evaluated on images which is captured by cameras in IOT. Cameras were set in urban areas, buildings, outdoor and indoor environments. Figure 2 shows sample images of dataset. Alexnet architecture was published in [15], achieved significant improvement over the other non-deep learning methods for ImageNet Large Scale Visual Recognition Challenge (ILSVRC) 2012.

This method is trained with ImageNet dataset that contains 1.2 million 256*256 images belonging to 1000 categories. Alexnet has five convolutional layers, three pooling layers and two fully-connected layers which results in 60 million free parameter. Convolutional layers are responsible for extracting local features and pooling layers gathers all local features in order to reduce computation costs. Also, there are Rectified Linear Units (ReLU) and NORM layers between every convolutional and pooling layers.

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Fig 4. Sample image of dataset that is employed for training and evaluation of proposed method.

ReLU models the behavior of neurons in network. Standard mathematical formula to model neuron's output as function of its input (x) is f(x) = tanh(x) or f(x) = (1+e-x)-1. Also, deep convolutional neural networks with ReLUs are trained faster as well.

Using NORM layers causes top-1 error to decrease by 1.4%. Structure of Alexnet is depicted in figure 3.

Reported results from ILSVRC 2012 shows that Alexnet has top-5 error of 15% which is better than other non-deep learning methods. Based on these experimental results, we decided to employ Alexnet for our data mining method. In this paper, parallel processing on GPU is used for training of Alexnet. Table 1 defines main parameters of training process.

Table 1.defines main parameters of training process.

Parameter	Value
Maximum iteration	420000
Gamma	0.1
Momentum	0.9
Weight decay	0.0005
Error	Softmax With Loss

Fig 5. Structure of Alexnet.

Places [] and imagenet [] are used for training of Alexnet. Each one has more than 2.5 million images. Alexnet that is trained by places is called places-Alexnet and the other one is called Hybrid-CNN.

The proposed method consists of two main layers: 1) Feature extraction and 2) classification. In first layer, Feature of these two network are extracted and applied in fusion process. There are various techniques to fuse extracted features from different descriptors such as:

Feature-level fusion is to learn an optimal feature subspace for clustering or classification tasks. This type of methods can exploit the joint benefits of varying modalities, thus it often largely improves the performance of learning algorithms.
Model-level fusion tends to explore the inner relevance among different modalities in the model construction. Decision level fusion uses diverse learning algorithms (e.g. classifiers) to evaluate multimodal data and score each modality by its influence on learning performance

In this paper, decision level technique is used to fuse places-Alexnet and Hybrid-CNN features. In second layer, combined features are employed to train classifiers. The overall structure of proposed method is shown in Fig.4. Three classifiers are considered in second layer in order to analyze and process features. These classifiers are trained with extracted features and according to their accuracy, a weight will be assigned to each one.

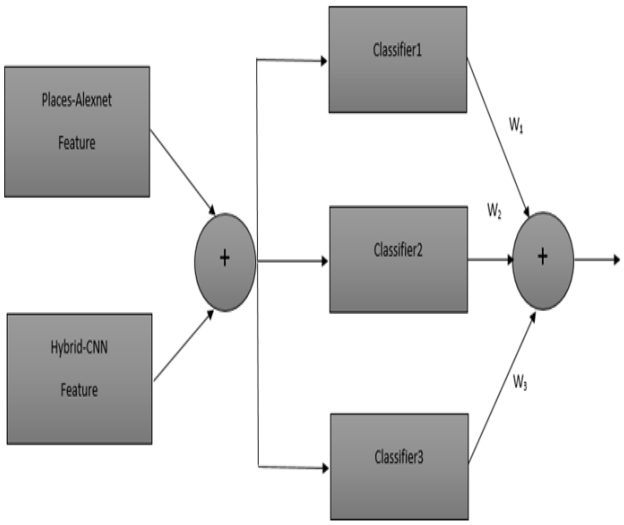

Fig 6. Overall structure of proposed method.

Equation 1 defines how each weights will be assigned to each classifier:

$$W_i = \frac{Acc_i}{Acc_1 + Acc_2 + \cdots + Acc_N} \quad (1)$$

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Acci is accuracy of classifier (i) and N is total number of classifiers (N=3). The sum of all weights is equal to one. The classifier that has higher training accuracy, will have higher weight as well.

V. EXPERIMENTAL RESULT

In this section, Experimental results of the proposed method will be reported. Implementation of Alexnet is done in Caffe [16]. Caffe is an open source deep learning framework that is developed at UC Berkeley with C++ and Python programming language. Caffe is applied in various computer science problems such as image processing, video processing, data mining and etc. Numerous deep learning methods (RCNN [17], CNN [18] and LSTM [19]) are included in Caffe for easy programming and development. Also, Caffe provides GPU parallel processing for training of CNNs which makes training phase faster.

Implementation of classification layer is done MATLAB. MATLAB is a programming language and interface that contains vast range of toolboxes. In this paper, machine learning toolbox is used to implement classification layer. An image dataset which was collected by MIT University was applied to evaluate accuracy and precision of the proposed data mining method. This dataset contains images from indoor and outdoor places such as offices, pavement, streets and corridors [20].

To each image, a label will be assigned based on whether it shows outdoor or indoor environment. So, the main question that the propose data mining method is searching for is which image is capture in indoor places or outdoor ones.

FC7 layer was chosen for features extraction in both places-Alexnet and Hybrid-CNN. This layer is well-known for its reach and compact information.

In classification part, K-nearest neighbors (KNN) method is employed as classifier to separate indoor images from the outdoor ones. KNN is a non-parametric method used for classification and regression [21].

In this method, label of data is assigned based on labels of its k nearest neighbors. KNN method was chosen because of its simplicity and accuracy which helps us find out whether Alexnet features are informative or not.Accuracy and precision parameter are used to measure performance of the proposed method. Equation 2, 3 show how these two parameters are calculated:

$$Accuracy = \frac{Correct}{Total} \quad (2)$$

$$Precision = \frac{Correct}{Instances} \quad (3)$$

Correct is the number of correct samples which are classified correctly, Total is total number of images in evaluation dataset and instances are total number of images in same category.

We have implemented the proposed method on a Core i7 PC with 8 Giga Byte RAM and NVIDIA 1060 6 Giga Byte graphic card. A comparison is made between the proposed datamining method and four classifiers (SVM, Neural Network, KNN, Bayesian) in table 2. As you can see, the proposed method outperforms the other classifiers.

Table 2.comparison between datamining method accuracy.

Method	Accuracy(%)
ProposedMethod	100
SVM	91
NeuralNetwork	73
KNN	87
Bayesian	65

Table 3.comparison between datamining method precision.

Method	Precision(%)
ProposedMethod	100
SVM	88
NeuralNetwork	81
KNN	84
Bayesian	76

Another comparison is made in table 3 which is based on precision parameter. Precision demonstrates how accurate a classifier is data in same category. This parameter helps to find out whether the proposed method has better performance in indoor or outdoor images. Experimental results proves that the proposed method has better accuracy and precision value than SVM, Neural Network , KNN and Bayesian classifiers.

VI. CONCLUSION

In this paper, a novel data mining method for internet of things is proposed. Input data is collection of images which is captured by cameras in indoor and outdoor environments. The proposed method is based on a convolutional neural network called Alexnet and has two main layers: 1) feature extraction and 2) classification. In first layer, features of places-Alexnet and Hybrid-CNN are extracted and fused using decision level technique. Then, three KNNs will be trained by extracted features. Based on

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training accuracy, different weights will be assigned to each classifier. Classifier with higher accuracy has higher weights as well.

We employed Caffe and MATLAB in order to implement the proposed data mining method. Training and feature extraction is done in Caffe with advantage of using GPU parallel processing. MATLAB' machine learning toolbox is used in implementation of classification layer.

A dataset which was gathered by MIT University was used for evaluation of the proposed method. Experimental results proved that our data mining method has better accuracy and precision than SVM, KNN. Neural Network and Bayesian classifiers.

VII. FUTURE WORKS

In this paper, we only studied one CNN (Alexnet). Alexnet was the first CNN which could be used in complex problems. But for further works, it is strongly suggested that other convolutional neural network such as Caffenet, Cifar and NIN will be evaluated as well.

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