Journal of Information Technology and Digital World (ISSN: 2582-418X)
www.irojournals.com/itdw/

A Graph Neural Network based Fake Currency Recognition Approach

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Abstract

In general, fake currencies are being circulated around, for collapsing the country's economy. It is achieved by spreading the money to foreign tourist people and vision-impaired people. This proposed work aims to assist such people on detecting the genuineness of the currencies given to them. The work is designed using a customized Graph Neural Network (GNN) - based approach for estimations, and its performance is compared to the traditional Convolution Neural Network, K-Nearest Neighbor, and VGG16 network. This experimental study has been performed utilizing an openly available dataset called Indian currency notes from Kaggle website. The outcome of the study indicates that the suggested GNN model performs better than the existing approaches.

Keywords: Image detection, recognition, currency segmentation, feature extraction, currency validation

1. Introduction

Fake currencies were detected by the officials through the quality of the currency note with their figures. In some cases, a blind eye verification method was used to check the presence of secret codes included by the government. Later, such methods were not effective in verification due to the development on printing technology. The hackers are also trained to print even the micro letter secret codes in the original currencies, and it is very hard for human vision to recognize such micro letters. Table 1 indicates the primary vision based features that are used to detect the two thousand rupees Indian currency note. Therefore, computer and camera -based recognition systems were developed in the later years, and those are represented as image processing techniques [1]. The image processing techniques were structured to verify the color deviation of the currency note from the regular notes. For this, the color level of the original notes is included to the algorithm as a threshold range, and on

DOI: https://doi.org/10.36548/jitdw.2022.4.002
Received: 25.09.2022, received in revised form: 01.12.2022, accepted: 17.12.2022, published: 27.12.2022
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verification, the deviations are used for estimation and prediction. In the same way, the sizes of the pictures included in the currency note are also verified with a valid segmentation approach, and their length and circumference are compared with the threshold values for estimation [2].

Table 1. Major vision features of 2000 Rupees Indian currency note

S.No	Features
1	Latent image with denomination
2	Micro letters – (India)
3	Electrotype watermark of Mahatma Gandhi's portrait
S.No	**Special features for visually impaired**
1	Intaglio printing of Mahatma Gandhi at the center
2	Intaglio printing of Ahsoka pillar
3	Seven angular bleed lines on left and right side

The outcome of the image processing algorithms is comparatively better than the human vision but they are not done with an acceptable accuracy. Therefore, the recent year techniques are designed with a neural network -based architecture for making the computer machine to think and act like a human on prediction and estimation. However, the primary limitation of the neural network architectures is their training process. It requires a huge amount of sample for training the model [3]. The following section explores the list of image processing and neural network -based algorithms developed for fake currency detection process.

2. Literature Survey

A K-Nearest Neighbor (KNN) based technique was implemented in [4] to detect the fake currencies through preprocessing and feature selection techniques in banknote authentication dataset. The experimental work showed a satisfied result in terms of accuracy and precision. A multi-pixel level based analytic technique in [5] was performed to detect the fake currencies in MATLAB software package. It helped to detect various ranges of features available in the currency note as they are in different sizes [5]. An image processing -based fake curacy detection technique was implemented with image segmentation and feature observation on MATLAB software [6]. It observed the size, color, and text on the various places of the Indian currency note for evaluation.

A pattern recognition technique based fake currency detection approach was structured in OpenCV application in [7]. The test currency samples were segregated into multiple pieces of data for verifying their closeness to the training data given to the application. A deep learning -based technique was implemented in [8] with Mobilenetv2-FCD architecture on detecting the Indian fake currencies. It achieved an accuracy rate of 98% which was comparatively better than the Mobilenetv2 model's accuracy of 85%.

An Indian currency denomination detection technique was designed using Convolution Neural Network (CNN) algorithm on OpenCV platform [9]. Here the process was enhanced by having a canny edge detection technique for extracting the information on the region of interest. The work was also further enhanced with multi-scale template matching algorithm for attaining a best accuracy of 98.5% [9]. A hybrid method was framed in [10] by incorporating the recurrent CNN with reinforcement learning that included image processing steps like image enhancement and segmentation. The performance was compared over the traditional RNN and SVM and found satisfied with its maximum accuracy of 99%. A comparative analysis was performed among the various machine learning approaches through supervised learning method [11]. The work utilized the samples from UCI machine learning repository, and the experiment was performed in comparing to the ANN, SVM, KNN and Gradient boosting classifier. The experimental work reached the maximum accuracy of 99.8% at KNN algorithm with 0.992 f1score.

A deep CNN based approach was developed in [12] to detect the fakeness in the Indian currencies. The work methodology comprised of image preprocessing, transformation, edge detection, segmentation, and feature extraction before making the pattern comparison. The experimental work achieved a maximum accuracy of 96.6% in performing classification with various denominations of Indian notes [12]. An Indian currency recognition technique was designed to observe the fakeness from a video file [13]. The work was structured with ResNet V2 model, and that reached an accuracy of 87% in the self-made dataset. An ANN based technique was proposed in [14] to observe the features from the Indian currency notes from UV light condition. The UV light allowed the camera to capture the features in an efficient way. Therefore, the outcome of the proposed work as improved over the traditional methods [14].

A light-weight CNN architecture was designed to make a web and mobile application for detecting the fake currency notes in [15]. The work was performed with a self-made dataset, and its performance was compared over the different types of CNN architectures.

The experimental work reached a maximum accuracy of 98.4% that was comparatively better than the accuracy of xception model 66.86% [15]. A deep learning based mobile application was developed to assist the blind persons on detecting the denominations of the currency notes. The experiment was performed with the CNN model, and the training and testing process was conducted with both private and public clouds. The conducted experiment attained a maximum accuracy of 98% in the private cloud [16].

3. Proposed Method

The literature section indicates that there are few techniques developed to detect the fake currencies just by using the image enhancement and segmentation steps. Later, some methodologies were designed to make algorithms with deep learning -based architectures. However, such deep learning based algorithms were incorporated with several image processing steps like preprocessing and pattern extraction. In the recent years, the advancement of neural network architectures does not require any preprocessing step for enhancing the image quality. Therefore, the proposed work is implemented to detect the fake currencies from the original currencies by the help of Graph Neural Network (GNN).

3.1 Graph Neural Network

In general, a graph represents the relativeness between any two parameters of factors. It is also used to estimate the closeness and connections over the conducted things. The GNN is structured to organize its network through a graph data. The graph data of an image comprises of its information on various locations, and it is technically specified as nodes in GNN model. The algorithm finds the similarity of the nodes available in training and testing data for estimating its prediction. The architectural overview of a general GNN is shown in figure 1. Basically, the nodes of GNN are represented as v, and its feature and ground truth values are labelled as x_v and t_v respectively. The ground truth label of a graph is used to estimate the labels of the unlabeled images. It is generated by making a dimensional vector h_v that includes the information of the nearby pixels.

$$h_v = f\ (x_v, x_{co[v]}, h_{ne\ [v]}, x_{ne\ [v]})$$

Where,

$x_{co[v]}$ = edge features connected with the basic node

$h_{ne\ [v]}$= embedding values of the basic node

$x_{ne\,[v]}$ = features of the nearby node from the basic node

f = transition function on dimensional space

Therefore, the above equation is expressed as,

$$H^{t+1} = F\,(H^t, X)$$

Where,

H and X = Concatenation of all h and x

Hence, the outcome of the GNN o_v is represented as follows on passing the h_v and x_v.

$$o_v = g(x_v, h_v)$$

As the GNN is an fully connected feed forward network, its loss function can be represented as,

$$loss = \sum_{i=1}^{p} (t_i - o_i)$$

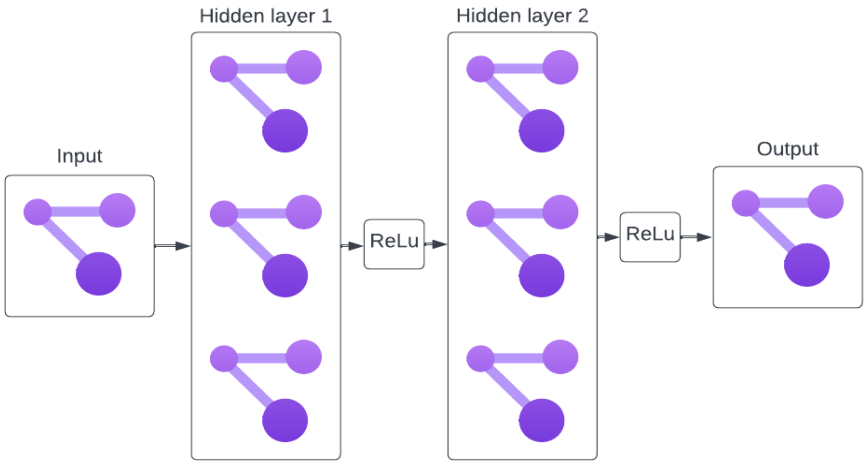

Figure 1. Architecture of a GNN

3.2 Methodology

The performance of the proposed GNN model is compared with the traditional KNN, CNN, and VGG 16 networks as they are widely used in the previous techniques. The work utilizes the Kaggle dataset [17] on Indian currency note 2020 dataset. The dataset contains 4002 images of various Indian currency denominations that were collected from internet and mobile phone camera. The work also utilizes a set of fake currency images on each

denomination that was collected from online and offline resources. Therefore, 4932 images are considered in the work, and a dataset split-up ratio of 75:25 is considered for the training and testing process. The experimental work is performed in the Google Colab system and its workflow is shown in figure 2.

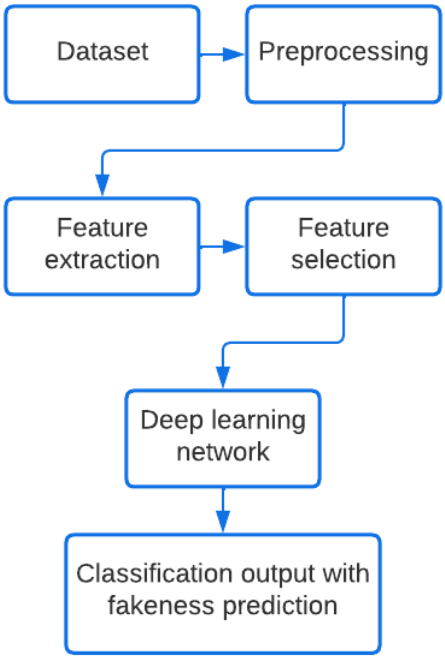

Figure 2. Workflow of the proposed method

3.2.1 Preprocessing

The preprocessing step resizes the images into a specific size (100x200) and format, for creating uniformity in the training and testing process. Apart from resizing, the work does not involve any image enhancement kind of application. The pixel values of the images are also not varied in the work, and that helps to predict a best classifier for its operation on various lighting conditions.

3.2.2 Feature extraction and selection

The feature extraction work includes the operation of collecting color, pattern and shape information from the given training image. Based on the given threshold value, the predicted information is forwarded to the classifier network for analysis.

3.2.3 Deep learning network

The deep learning networks are structured with neural network -based connection for storing the learnt information in its hidden layer. The data that are stored in the hidden layers

will get updated time to time, by sending a new sample for its training process. The trained network is finally considered for the classification process. There it compares the collected features with the stored features on the hidden layer and makes the decision.

4. Result Analysis

The performance of the conducted experiment is verified in terms of accuracy, sensitivity and specificity. The accuracy represents the total percentage of correctly detected samples from the given total samples. The sensitivity is also represented as recall, where the analysis gives an idea over the correctly detected positive samples ratio. In the same way, the specificity determines the values of the negative samples. Table 2 represents the performances of the verified algorithms over the proposed, and the same has been projected as a comparative chart in figure 3.

Table 2. Performance of the conducted experiment

Performance Metrics	Algorithm			
	CNN	KNN	VGG16	GNN
Accuracy	64.8	73.1	68.1	81.01
Sensitivity	65.3	73..8	68.9	82.3
Specificity	63.1	72.9	66	80.9

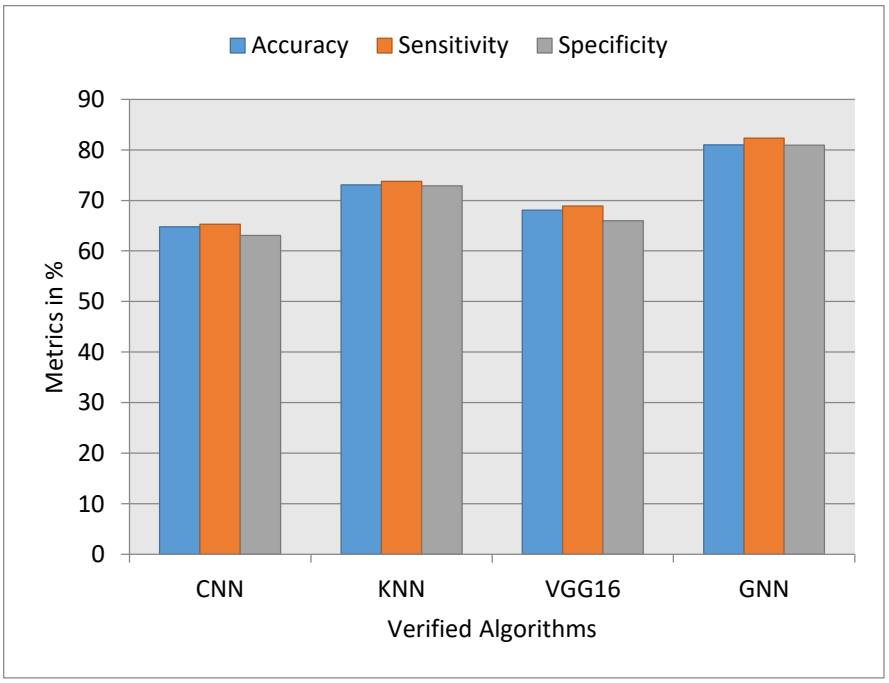

Figure 3. Comparative analysis of the verified algorithms

The experimental projection indicates that the performance of the GNN is comparatively higher over the regular CNN, KNN and VGG16 networks. The GNN achieves a maximum accuracy of 81.01% and that is comparatively 16% better than the CNN network. In the same way, the sensitivity and specificity of the GNN are also far better than the other network architectures. The performance of the GNN can also be improved when it is implemented with preprocessed data with image enhancement in the training process.

5. Conclusion

A deep neural network -based fake currency recognition approach using GNN model has been proposed in this work. The work is organized without any image enhancement technique on the database and the self-made data samples, and with those images the GNN network performs better over the previous popular techniques. However, the accuracy observations are not enough to meet the application requirement on real-time implementation. Therefore, the GNN model can be trained with an enhanced image dataset in its training process, and that can be tested with a non-processed data sample.

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