Unveiling the Power of Graph Neural Network for Intelligent Analysis of Objects

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A fundamental and difficult problem in computer vision is object detection. Identifying the visible items in an image may aid in its description and understanding. The extracted data may also be useful for other tasks such as activity detection, content-based picture retrieval, and scene recognition. Every day, billions of people post photographs and videos to the internet as technology and internet access become more widespread. To effectively utilise this enormous amount of data, it is necessary to be able to swiftly and precisely extract information from these pictures. In recent years, substantial advances in object identification and classification have been made possible because of convolutional neural networks (CNN), but it neglects the relationship among objects. In order to enhance object detection performances, this work examined various object detection techniques and used a graph convolutional network (GCN) approach to take advantage of object co-occurrence in an image. Research indicates improved accuracy for object detection and classification.

Keywords: Object detection, Graph Convolutional Networks, Graph Attention Network).

in: *Advancements in Communication and Systems*. Ed. by Ashish Kumar Tripathi and Vivek Shrivastava. Computing and Intelligent Systems, SCRS, India., 2023, pp. 91–106. DOI: https://doi.org/10.56155/978-81-955020-7-3-8

1 Introduction

One of the most important tasks related to computer vision involves discovering instances of particular visual objects in digital pictures like photo or video frames, such as humans, animals, automobiles or buildings. Designing computational models for applications in computer vision is the aim of object detection.It gives the most fundamental data they require: “What things are where? ”. Object Detection serves as the foundation for many other computer vision jobs like object tracking, image captioning, image segmentation, and more. Object detection deals with the localization and classification of objects contained in an image or video. Object detection is two step process, Finding foreground entities based on features and then verify it with a classifier. Object detection is done with two approaches broadly. First approach is to identify object from images or video using image processing techniques whereas in another approach ,a sequence of images are used to recognize the object with which it detects obscured objects as well where first approach fails. A new era in computer vision (CV) has emerged as a result of deep learning-based techniques, in which algorithms may be trained to carry out a variety of tasks, from object recognition to position detection. There are numerous CNN-based object identification techniques that have produced excellent results for feature extraction on a single item region when looking for items, followed by object detection [1][2][3]. In other words, these techniques typically primarily focus on local information and disregard the relationships between the items and between objects and scenes. The suggested approach uses Graph Convolutional Network to recognise objects by identifying semantic relationships between them.

2 Graph Neural Network

Deep Neural Network that is appropriate for studying graph-structured data is the Graph Neural Network (GNN). A graph is a non-linear data structure made up of edges connecting a finite number of nodes, also known as vertices. Commonly used notation for vertices and edges are V and E, a graph is represented as G =(V,E), where a vertex $vi \in V$ and a directed edge between vi and vj is represented by an arrow as $i \longrightarrow j$, it forms an ordered pair of nodes $(vi,vj) \in V \times V$. Undirected edges are assumed to have equal weightage from both directions [48].

2.1 Graph Convolutional Network

Convolutional neural network that may deal directly with graphs and their structural information is the graph convolutional network (GCN). For a GCN model, it is needed to learn a function of features on a graph.The Object Detection using semantic relation graph techniques efficiently detect object from image and video data by finding semantic relationship using graph convolutional network. Graph convolutional network will infer relationship between objects and also object-scene association to increase accuracy. GCN applies a filter to a graph and looks

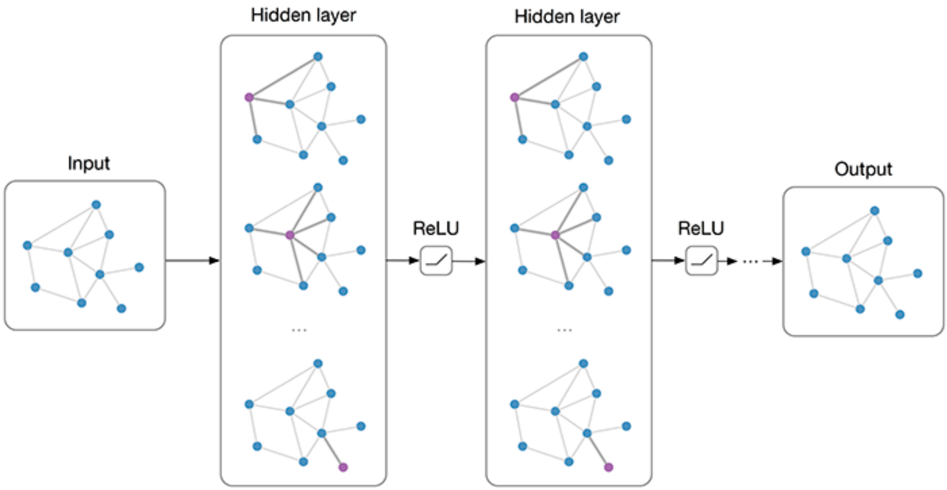


Figure 1: Multi-layer Graph Convolutional Network (Thomas Kipf)

for significant vertices and edges that can be used to categorise nodes within the graph, much how CNN extracts the most crucial information from an image to classify the image. GCNs can be broadly classified under two categories based on the algorithms used, 1) The Spectral Graph Convolutional Networks is based on signal preprocessing theory and 2) Spatial Graph Convolutional Networks analyses a node's attributes depending on its k local neighbours and operates on the local neighbourhood of nodes.

2.2 Object Detection using Graph Convolutonanal Network

Issues concerning non-Euclidean spatial data are typically tackled with GCN. The relationship between entities is modelled and the relationship between data is retrieved by encoding structure information of the non-Euclidean spatial data[1].

Authors [8] proposed a method to Transformed images into graph where patches are considered as nodes, build isotropic and pyramid architecture and experiments performed on image net and COCO dataset and observed that Pyramid architecture is effective in visual task. Authors have suggested that in order to solve the problem of object detection as a graph networking problem, one must first extract the semantic relationship between objects and scenes. Graph attention network (GAT) is used to find hidden data concerning the relationship between objects' semantic contexts[9]. This technique can significantly increase object detection accuracy, but it needs a lot of labeled data to train the network. The PASCAL VOC dataset was used for experiments. Authors [10] provided different taxonomy for grouping of GNNs into categories,and future direction in terms of No. of convolution layers, scalability heterogeneous graphs and dynamicity. GCN exhibits a substantial development in feature learning[9].Devised method to concurrently identify and locate objects in an image and segment the image into pixel-wise semantic regions and shows that the cooperatively trained Base model outperforms the model that independently trained [11]. This study indicates that node features can be learned by exploiting the information from the graph itself and node representation can be transferred to the classification task for improving model performance. The spatial relationships method uses a geometric model among features, geometric model parameters are estimated, and then by calculating the distance between features and spatial information, false matches are removed, this method is used when the detected features are ambiguous [23]. This study conducted a thorough analysis of the literature on graph convolutional networks and organised it into two simple taxonomies based on the various graph filtering operations and the application domains [4].The observations are GCN in practice only uses two layers and using more graph convolution layers may reduce the performance,More work is required for dynamic network [34]. Analyze methods of existing object detection models and describe reference data sets. It provides a comprehensive overview of many methods of systematic object detection, including single-stage and two-stage detectors. This survey summarizes different object detection methods,datasets, and applications[33]. Object detection is a key field in Computer Vision, allowing computer systems to see their environments by detecting objects in visual images or videos.

2.3 Graph Attention Network

GAT offers an attention mechanism throughout the propagation stage. The attention layer's goal is to make it possible to determine the attention coefficient of node pairs (i, j) based on various neighbour node attributes.It addresses the drawback that the weight value of edges is fixed when utilising the GCN model[50].

3 Approach

The idea is proposed for object detection based on identifying semantic relationship between objects and between object and scene. Fig 2 presents proposed sys-

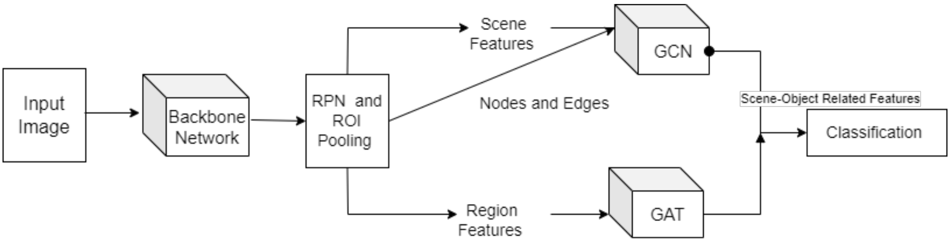


Figure 2: Proposed Architecture

tem. The Region Proposal network receives the features from backbone network extracted from input image and generates regions from it.The features are extracted using a graph convolutional network. With the ROI Pooling interested regions are extracted.To extract object to object features graph is used which is modeled as object properties as nodes and co-occurrence with other objects as edges.The classifier/regression uses additional information to precisely identify the object. GCN's main approach is to apply convolution on a graph.Typically, neural networks (NNs) use an input of x to forecast an output of z. The input to the NN of a GCN (Graph Convolutional Network) is a graph. Additionally, it infers the value zi for each node i in the graph rather than just one z. Additionally, GCN uses Xi and its surrounding nodes in the calculation to produce predictions for Zi.Instead of having a single node for the first layer in GCN, X now has an array of nodes. The features of a node are contained in each row of the matrix in which X will be encoded. This shows that a node's output in a hidden layer depends on both the node and its neighbouring nodes. Propagation rules used is [50].

$$H^l + 1 = \sigma(D - (1/2)A(1/2)H^lW^l). \tag{8.1}$$

where Hl, Hl+1 represents the node matrices of layer l and layer l +1 respectively,D represents the diagonal node degree matrix of ˆA, where A represents adjacency matrix and ˆA = A +I. Wl is a weight matrix for the lth neural network layer and σ(·) is a non linear activation function like the ReLU. GAT mechanism is used for more accurate results The following formula is used to determine the coefficient of node pair (i, j) in the attention mechanism [50].

$$\alpha_i j = \frac{exp(LeakyReLU(aT[Whi \parallel Whj]))}{\sum_{k \epsilon Ni} exp(LeakyReLU(aT[Whi \parallel Whj])} \tag{8.2}$$

Here,α_{ij} is the attention coefficient from node j to i, Ni represents the neighbor node of node i. The node input characteristics are h = {h1, h2,..., hN}, hi ∈ RF, where N shows number of nodes and F represents characteristic dimension [50]. Issues concerning non-Euclidean spatial data are typically tackled with GCN. The relationship between entities is modelled and the relationship between data is retrieved by encoding structure information of the non-Euclidean spatial data. Convolutional neural network has Weak variance and even with the change in brightness it affects the final output,graph overcomes this effect [3]. Graph attention network (GAT) is used to find hidden data concerning the relationship between objects' semantic contexts [9] By exploiting the data in the network itself, node features may be learned, and node representation can be transferred to the classification task to enhance model performance [7].

4 Results

Existing methods are tested on COCO dataset.Faster RCNN was the most accurate object detection model as shown in the studies and proposed approach is based on faster RCNN and uses pretrained Resnet 50 model. Experiment were performed on COCO dataset, Faster RCNN goes through 3 layers, first features are extracted by training filters with fully convolution layers and then passed through RPN to get the region proposals and then again apply fully convolutional layer to classify object and bounding boxes. It correctly classifies the object. Few experiments based on GCN were performed for node classification and graph classification to check how well GCN model performs. These experiments were performed on well known dataset Cora and Pubmed. The figures below shows Fig.4(a) and Fig.4(b) shows 3 classes of pubmed dataset with GCN classification. Classes are denoted as nodes. Fig.6 shows the GAT evaluation on Pubmed dataset. Cora dataset has 7 classes and its GCN test accuracy and GAT test accuracy is shown in Fig. 5 and Fig. 6 respectively similar experiment is performed on citeseer dataset.

Table 1 shows performance of GCN and GAT.

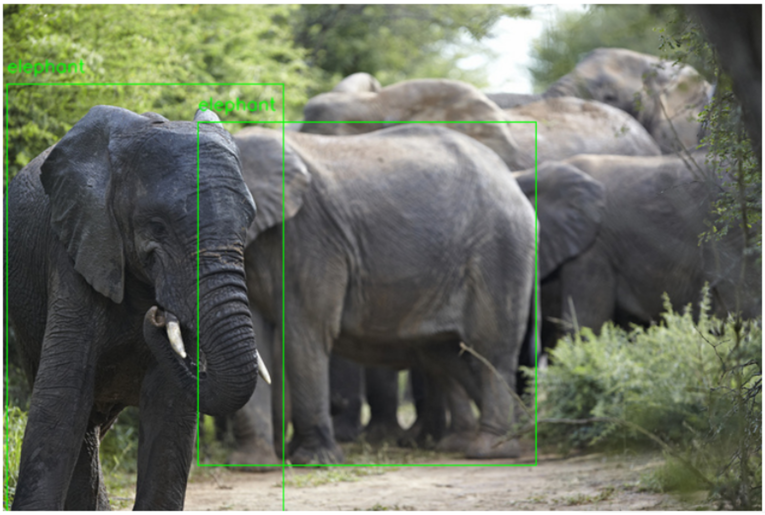


Figure 3: Object detection with GCN

Table 1: Accuracy of GCN and GAT

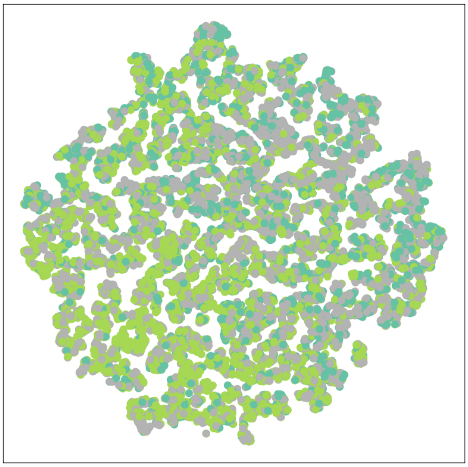
Name		
Dataset	GCN Test Accuracy	GAT Test Accuracy
Pubmed	0.79	0.7850
Cora	0.81	0.814
Citeseer	0.68	0.79

5 Discussion

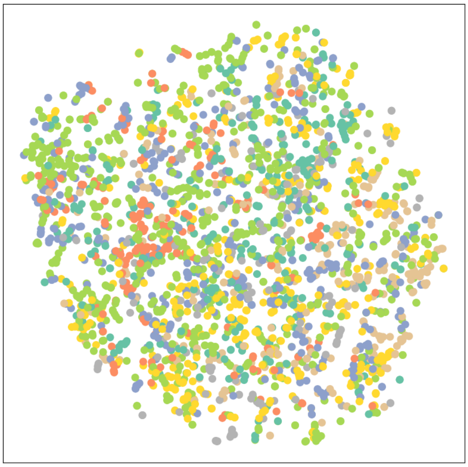
5.1 Challenges and Applications

For correct identification of the multiple objects in an image, it is crucial to accurately record the correlations between object labels and investigate these label correlations to boost classification accuracy. With the help of the graph convolution network, the relationships between objects may be modelled, but there are several difficulties, such as the large-scale graph's scalability, handling imprecise and noisy graph data, and developing efficient architectures for quicker preparation and analysis.

Applications of identifying specific objects include counting people, detecting pedestrians, detecting animals, detecting vehicles, detecting text, detecting poses,

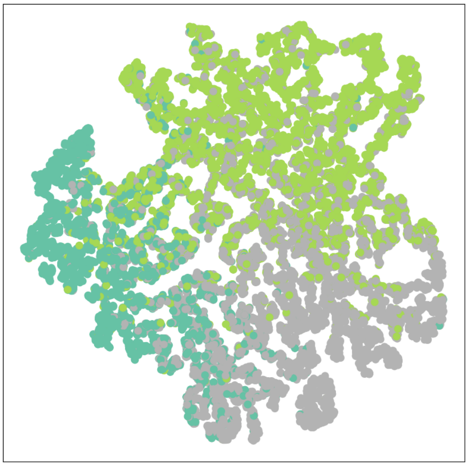


(a) Pubmed with 3 classes

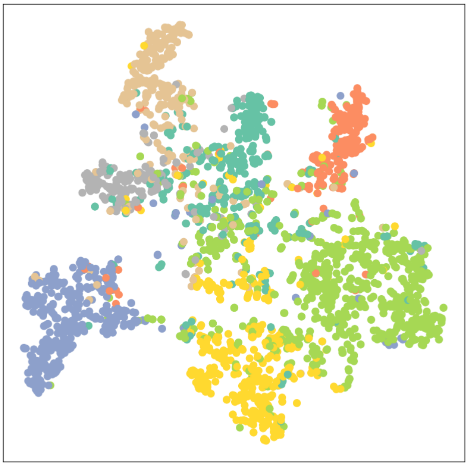


(b) Cora with 7 classes

Figure 4: Different Graph datasets

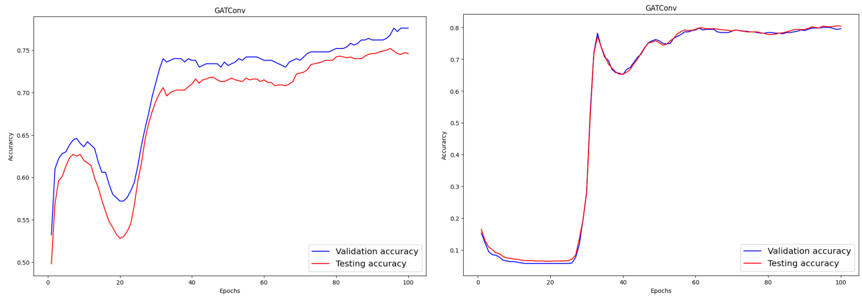


(a) Pubmed



(b) Cora

Figure 5: GCN Evaluation on different datasets



(a) Pubmed (b) Cora

Figure 6: GAT Evaluation on different datasets

and recognising licence plates.Object identification enables numerous more applications, including intelligent healthcare tracking, autonomous driving, advanced video surveillance, anomaly detection, and robot vision.

5.2 Experimental Study

The experiments are carried out on well known datasets .The experiments are performed on citation. Experimental results shows that accuracy improves with semantic mapping of objects. Further this approach will be used For the purpose of improving precise object detection ,and the implementation of object scene mapping will be carried out, which is suitable in the aforementioned range of application areas.

6 Conclusion

With the reviewed literature it is observed that Faster RCNN gives more promising results for object detection but lacks in identifying relation among objects. With the GCN, Object detection will be more accurate when object co-occurance and object scene association is considered for feature matching. To check for semantic annotation accuracy evaluation metric used will be Precision and recall, Intersection over Union, Average Precision, Mean Average Precision. With the stated approach it is possible to accurately detect semantically related objects which can be applicable in various areas like video surveillance systems, sports production, security, biomedical etc.

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