Abstract

Unlocking information in the maps enables useful geospatial analysis, such as analyzing the evolvement of urban areas, the development of road networks. However, accurately converting information in maps into structured data is a challenge. In this paper, we focus on recognizing geographic objects on georeferenced raster maps. Popular and powerful Convolutional Neural Networks (CNN) shows promising recognition results processing scalable map sheets, but it still has misclassifications. In this paper, we propose to use semantic knowledge of geographic objects to improve the recognition results. We model the semantic relationships among geographic objects to remove some misclassifications. For example, our model automatically removes the recognized railroads which cross the wetlands, because the semantic relationship between railroads and wetlands is not across.

1 Introduction

Maps store valuable information that documents human activities and geographical features on Earth over a long period of time. For example, more than 200,000 map sheets in the USGS historical topographic map archive records the evolvement of railroad networks in the United States dating back to the 1900s. Such information is essential for the analysis that requires detailed historical geographic data. It is necessary to have a fully automatic method to precisely recognize map content in large numbers of maps and convert them into a structured format for further analysis.

The remarkable ability of Convolutional Neural Networks (CNNs) for image recognition makes it become a possible solution to recognize geographic objects on maps automatically. However, map recognition requires higher precision than other recognition tasks, such as human detection in the scenes. One pixel on the map represents some meters in reality, so one-pixel shifting in the recognition results lead to some meters shifting in reality. We want not only precise delineation of geographic objects on the maps but also as fewer misclassification as possible. The more precise the recognition results, the better for further analysis, for example, the researchers use the development of road networks to study the evolvement of urban areas. The poor recognition results have a negative effect on the analysis.

In this paper, we use the semantic knowledge as the prior knowledge to improve the recognition results from CNN. We model the semantic geographic location relationships among geographic objects as a knowledge graph. We use the knowledge graph to refine the recognition results in two ways. First, the knowledge graph helps us remove some misclassifications if the relationship between the recognition results and other objects conflicts with that defined in the knowledge graph. Second, if the recognition results have shifting problem, we can use the location of a geographic object of interest in the knowledge graph as the guidance to align them with the geographic object of interest on the maps.

The contribution in this paper is leveraging the prior knowledge to improve the recognition results. Our method models the semantic geographic location relationships among geographic objects on the maps as the prior knowledge to refine the recognition results in the post-processing step.

2 Related Work

Knowledge graph that encodes the prior knowledge can be used to refine the object detection. Rabinovich et al. [9] proposed a CRF model to maximize the consistency between the class labels and the semantics of objects. Another work by [4]
introduced a frequency based measure to quantify the relation between the concepts. They first compute the frequency of the occurrences of concepts, then calculate the Jaccard similarly between two frequencies to represent the consistency of two concepts. They also have a graph-based consistency measure that captures millions of concepts such that in-directed relations can be modeled. Some other works [7] [8] have shown graph neural network can be used to incorporate the knowledge about the visual world into the image classification problem. They construct the entity-relation graph and treat the graph as a special case of input. [7] used gated graph neural network and represented the relations as a sequential model. [8] formulate a graph search neural network where the features from the image are used to annotate the graph, and the output states of the concepts can be used to classify images.

Semantic knowledge as a kind of prior knowledge has broadly applied to facial expression recognition, speech recognition, and object detection to improve the results. Cheng et al. [2] proposed a semantic learning scheme to embed the high-level semantic knowledge to guide the low-level features for the facial expression recognition task. In the schema, they introduced a semantic-based learning algorithm to learn the weights for the low-level features according to the high-level semantic knowledge. Jeong et al. [6] innovatively corrected the errors in speech recognition using semantic knowledge as the postprocessing instead of lexical knowledge. Their new method can correct both semantic and lexical errors. Ruiz-Sarmiento et al. [10] proposed a novel approach to reduce the labor of collecting a large number of training data by taking advantage of semantic knowledge. They modeled objects geometrical properties and contextual relations as an ontology to help tune the model in the training process.

Semantic knowledge is also helpful for the geographic image recognition. Durand et al. [3] proposed a method to assign semantic labels to detected objects in remote sensing images by matching them with the concepts in the ontology. Andres et al. [1] modeled the experts’ knowledge as an ontology to help land cover classification in remote sensing images. They built the ontology based on spectral, pseudo-spectral and textural features to represent experts’ knowledge about land cover classification. Gu et al. [5] proposed a pipeline for the object-based semantic classification for high-resolution satellite imagery. The pipeline consists of three steps: ontology modeling, classification, and classification improved based on semantic rules.

References