NOVEL DEEP LEARNING AND GIS-BASED APPROACH FOR ROAD INVENTORY SURVEY

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ABSTRACT- The existing road inventory preparation methods are time-consuming, labor-intensive, inefficient, and there is no acceptable method for 3D urban visualisation. Accordingly, the study proposed a new cost-effective application to prepare road inventors & 3D urban visualiaation utilising deep learning technologies. The study comprised three main stages. In the first stage, the study conducted literature reviews. In the second stage, the study develops the application. Finally, the study validated the developed application by using Ranna as a case study. Further, the application recorded an accepted level of kappa accuracy. i.e., 92% & 90% for two models in the case study. transport planners and urban planners can employ the proposed application to prepare road inventors and 3D urban visualisation as the main contribution of this study.

Keywords: Road Inventory; Deep Learning; Open Data; Transport Planning; GIS

1. INTRODUCTION

Road inventory systems provide decision-makers and engineers with information and tools to evaluate diverse characteristics of the transportation system, such as road safety, level of service, passenger and vehicular demand, and quality of the transportation network, etc. [1]; [2]. Therefore, maintaining a road inventory system with fresh and up-to-date data causes efficient and sustainable transportation management. In terms of that, there have been ample techniques and studies to collect this road inventory data by diverse researchers. However, many of these technologies are expensive, labor-intensive, and incapable of keeping up with the rapid changes in transportation systems [2]. In recent years, convolution neural networks (CNN) have made great progress in image classification tasks[3];[4]. However, although CNN models distinguish better accuracy in capturing road inventory information, they still show some minor drawbacks and limitations due to the data methods used[1]. Therefore, this study introduces a novel framework to collect road inventory data in the aspects of road material, road type, and surrounding land use character of the road network using the state of the art of computer visioning technologies by overcoming the limitations of current methods. In contrast, road material, type, and land use character are divided into several major categories. It identified that asphalt, concrete, and aggregates are the common material types of urban road networks, while road types vary from single-lane road networks to very complex, multiple-lane road networks. In another way, land use characteristics are a distinguished variety of land use features besides the road network, such as commercial, residential, and mixed, etc.

2. MATERIALS AND METHODS

This study has three key sections. These are the literature survey, model development, application, and validation. Based on the literature, the performance of various image processing models in urban feature identification was investigated. Further, an expert discussion series was carried out to identify the Sri Lankan Road classification method, building use mapping approach, their field practices, and the pertinency of global technologies in the Sri Lankan context. Finally, a semi-automated framework was developed to overcome the above constraints. In that process, two main models were developed: the Road Category Model (RCM) and the 3D Urban Visualisation Model (3D UVM). Further, the RCM was trained to identify 6 road type categories and the 3D UVM was trained to identify 5 building categories.

The study used free data sources to develop the proposed framework, such as OSM data, Google Street View Images (GSV), Google Earth Images, and the Digital Elevation Model (DEM). Among the GSV, the major data sources used to identify the road and land-use features are The main tools that were used to develop this framework were QGIS, Open Layers Plugin, and threeJS plugin. And also, all the tools are free and open source. The image processing models were developed by using the "Keras" and "TensorFlow" libraries. Python was the programming language used. This study used the "transfer learning" technique for developing the model. Thus, it doesn't require a high number of training samples. IP models were trained by using categorized GSV images. The softmax activation function is used for the final layer, and "Relu" was used in the middle layers. The optimizer of this model was "adam". Further, both models were developed based on the same CNN architecture.

The selected case study area for framework application was Ranna. In that process, different roads were selected based on selection criteria. The model validation was performed by two methods. First, accuracy is discussed with the testing dataset after comparing the model predictions with the manual classification of the road categories and building categories. Finally, the kappa accuracy and confusion matrix are used to determine the model accuracy.

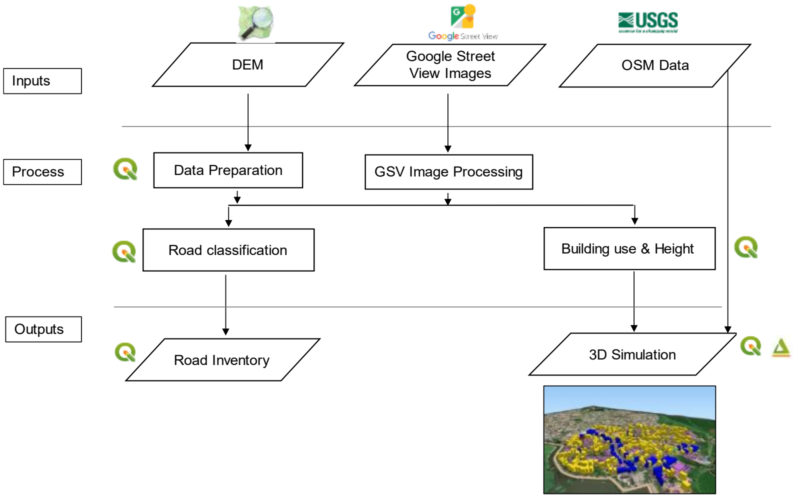

Figure 1. Proposed Framework Structure

3. RESULTS AND DISCUSSION

First, trained models were tested by using a testing image set. Both models were fine-tuned by testing data results, expected for significant accuracy. Both models showed greater than 90% accuracy with the training dataset. According to the RCM results, "one-lane asphalt," "two lanes demarcated asphalt," and "two lanes do not demarcate asphalt" show significant accuracy. Most importantly, all the road categories are showing greater than 80% accuracy. Kappa's accuracy of the RCM is 92%. According to the 3D UVM results, the highest accuracy is shown in the residential one-story category, which is 97%.

And the overall kappa accuracy is 90%. The result validates the 3D UVM and RCM and is significant for road type classification and building category/height identification in the SL context.

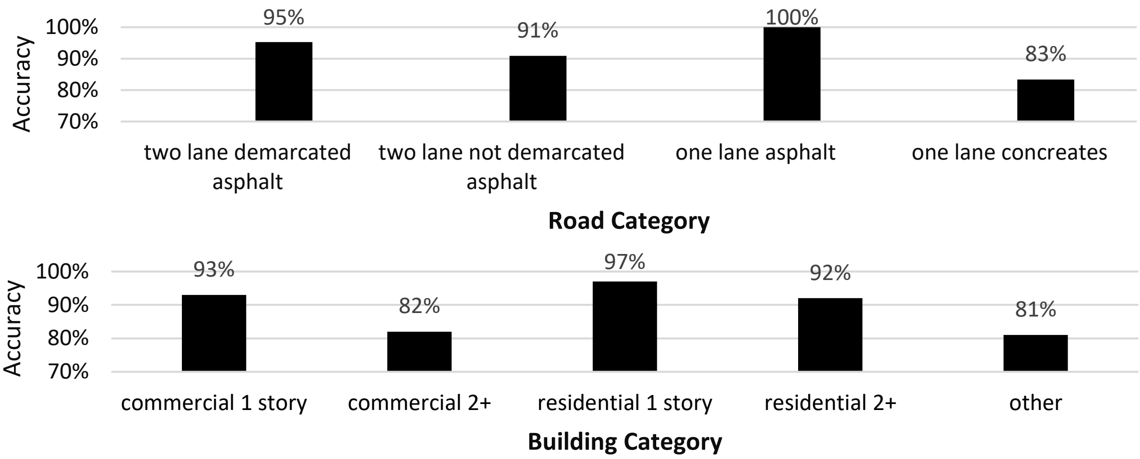

Figure 2. RCM & 3D UVM Accuracy

4. CONCLUSION

The study developed a new approach to collect road inventory and map building uses and their height in urban areas: based on deep learning knowledge while conquering the limitations stated in the present practices. The image processing models recorded an accepted level of kappa accuracy. i.e. 92% and 90%, Ranna case study. Further, the results revealed that the proposed framework is highly applicable for developing countries like Sri Lanka. Accordingly, the main contribution of this study is developing an efficient, financially affordable, labor-effective, accurate, and efficient framework to collect road inventory and urban visualisation. However, there are some limitations in this study, such as framework applicability depends on the coverage of the GSV image availability. Secondly, some areas do not have updated GSV images, so output information will not be updated. Since this study has promising applicability in streetscape images to map building uses and collect road data, it can be used manually collect images for high accuracy.

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