ANALYZE THE VISUAL QUALITY OF ROADS UTILIZING DEEP LEARNING ALGORITHMS AND STREET VIEW IMAGES

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ABSTRACT - Visual quality of roads is one of very important factor in road design. However, in current practice objective analysis and judgment is lacking and mostly utilized subjective judgment to evaluate the visual quality of road. Therefore, this study attempts to develop a data driven framework to quantify the visual quality of roads. For that purpose, the study utilized deep learning algorithms and street view images. The study comprised of four-staged. The study developed two main models to quantify the quality of streets and conducted a validity assessment consisting of both internal and external validation to test the effectiveness of the proposed framework. The proposed framework achieved 90.51% internal validation accuracy using the tenfold cross validation technique and 86.7% external validation accuracy. Further, the framework recorded an accepted level of kappa accuracy of 80%. Accordingly, the study concludes that proposed framework and models would be effective tools for transport planners and street designers to objectively measure and map the visual quality of roads and proposed street designs.

Keywords: Visual Quality; Semantic Image Segmentation; Deep Learning; Street Design; Transport & Urban Planning

1. INTRODUCTION

The roads define the city image and act as its backbone of the city structure. The roads are used for a variety of activities such as eating, sleeping, strolling, gathering, shopping, celebrating, and worshipping (Kost & Nohn, 2011). Therefore, quantifiable measurements of design components in streetscapes and their impact on road quality are very important in street designing in the fields of transport planning and urban design. This study identified significant research gaps in relation to this field of study. Most of studies are usually done on manually obtained, small-scale datasets employing time-consuming methodologies that cannot support future study effectively (Ye, Zeng, Shen, Zhang, & Lu, 2019); assessing the quality of roads based on objective criteria methods are absent; present research on evaluating the quality of roads concentrates on the construction of the index system, data collecting, and processing, with no testing of the measurement results' dependability or the measurement model's validity (Wan, Lu, & Sun, 2022). Accordingly, the study proposed a new quantitative framework to analyze the visual quality of roads utilizing deep learning algorithms and street view images.

2. MATERIALS AND METHODS

There are four key phases in research design as given in Figure 1. The first step consists of two major components: a literature review and an expert opinion survey. The second step is model development. Two main models have been developed in this study: the convolutional neural network (CNN) model and the feed forward neural network (FFNN) model. As the third stage, a python-based program developed to load the trained the model with weights and get the outputs for testing. The final stage

is validation of the developed models. Both internal and external validation were conducted to identify the most suitable model for measuring the visual quality of roads.

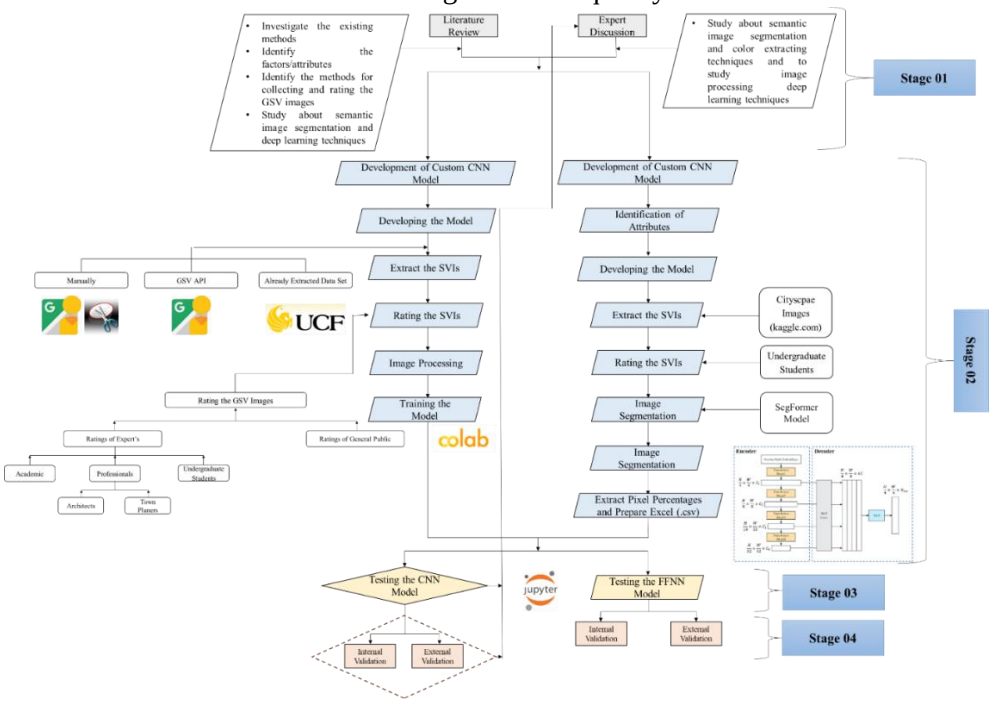


Figure 1. Methodology of the research

2.1. Development of Models

To assess the visual quality of roads, two separate models were developed: a CNN model and an FFNN model. The CNN model was developed using the transfer learning method and the image augmentation technique. The FFNN model was developed considering five main attributes: greenery, sky view, building frontage, motorization, and pedestrian space, each of which has an influence on the visual quality of roads.

2.2. Data Collection and Rating Images

This study's main source of data is Google Street View images. Manually, the google street view (GSV) API, and Cityscape datasets were used to extract 2684 street view images. The extracted images were rated on a Likert scale from low to high visual quality by an expert panel and the general public to train the developed modes.

2.3. Validation

Both internal and external validation were used for the accuracy assessments of developed models. Tenfold cross validation technique and accuracy metric in Keras was used for internal accuracy assessment. Kappa accuracy was calculated developing confusion metrices considering the actual and predicted ratings for the SVIs as the external validation.

3. RESULTS AND DISCUSSION

A quantitative framework is proposed to measure the visual quality of roads, where the X-axis represents accuracy, and the Y-axis represents the number of epochs. The accuracy metric validation of the CNN model in stage 05 yielded 90.51% internal and 86.7% external validation accuracy. The kappa accuracy was 80%. The results of the accuracy assessments are as follows.

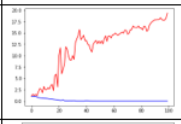
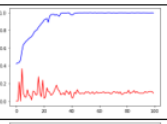
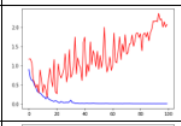
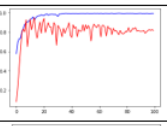
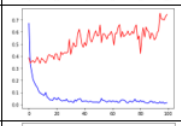
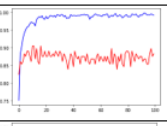
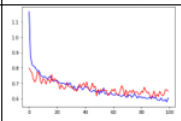
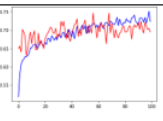
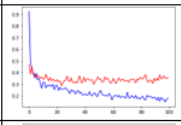
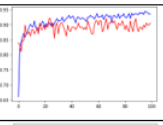
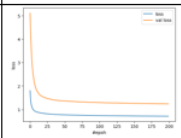
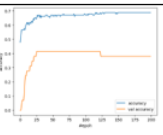
Model	Internal Accuracy		External Accuracy				Kappa Accuracy
	Loss Curve	Accuracy Curve	Low Quality	Moderate Quality	High Quality	Overall Quality	
Custom CNN model stage 01			84.6%	37.8%	30.4%	54.1%	27%
Custom CNN model stage 02			88.5%	89.2%	84.7%	87.4%	81%
Custom CNN model stage 03			86.5%	83.7%	86.9%	85.9%	80%
Custom CNN model stage 04			76.9%	78.4%	73.9%	76.3%	77%
Custom CNN model stage 05			84.6%	89.2%	86.9%	86.7%	80%
Custom FFNN model			51.9%	100%	67.4%	62.9%	46.6%

Figure 2. Accuracy assessments of developed models

4. CONCLUSION

The study developed a framework to analyze the visual quality of roads through street view images utilizing deep learning algorithms while overcoming the constraints noted in the existing practices. Transport planners and engineers can use this framework to make informed decisions on road design, construction, and maintenance. By understanding the visual quality of a road, they can identify areas where improvements can be made to enhance the overall user experience, such as adding greenery or improving pedestrian and cyclist infrastructure. Therefore, the assessment of visual quality of roads is a crucial component of transportation planning and engineering. It can provide valuable insights that can help in creating safer, more functional, and aesthetically pleasing road infrastructure.

REFERENCES

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