AI-Driven Road Condition Monitoring across Multiple Nations

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Abstract

The doctoral work summarized here applies Artificial Intelligence (AI) for social good. The successful implementation would contribute towards low-cost, faster monitoring of road conditions across different nations, resulting in safer roads for everyone. Additionally, the study provides recommendations for re-using the road image data and the Deep Learning models released by any country for detecting road damage in other countries.

Introduction

The road infrastructure holds critical socio-economic importance for providing vital transportation services to people and commodities worldwide. It has a direct and substantial impact on people's lives, and thus it needs to be maintained regularly and monitored exhaustively from time to time. The accustomed methods for road condition assessment involve a labor-intensive physical inspection of road surfaces. These methods fail to meet the present requirements due to the vast area of road networks to be inspected in a limited time (Arya, Ghosh, and Toshniwal. 2019). The problem is intensified as the number of specialists who can evaluate such road damages and allocate optimal resources for pavement reparation is limited. Additionally, the monetary shortage restricts many local administrations from conducting the requisite inspections on time. Some metropolises automate road damage detection using high-performance sensors. Yet, the sensors are often costly and unaffordable for many local governments.

In this regard, the low-cost smartphone-based methods introduced by Maeda et al. (2018) for monitoring road conditions in Japan provide an affordable and deployable solution for multiple municipalities. Developing smartphone-based applications allows the general public to contribute towards road condition monitoring. With the app, anyone, not necessarily the field expert, can record the road damage with their Smartphone and upload it directly to the cloud servers. The presented doctoral work builds upon these methods and

utilizes Deep Learning models targeting the applicability for various countries.

Research Questions

The proposed work aims at utilizing AI for automating the monitoring of road conditions. Our article (Arya et al. 2021c) provides an extensive survey of the related research work. Considering that some municipalities in the world have already proposed AI-driven solutions, the proposed work addresses the requirement of municipalities/countries that are still struggling to find an operational solution. The following questions are considered to offer apt recommendations for the readers:

(i) What can one expect for their country when another country releases the data and models for automatic detection of road damage in that country?

(ii) For instance, Japan published the data and models in 2018 (Maeda et al. 2018). So the proposed research intends to provide the readers from other countries with the following information:

    a. Can they utilize the Japanese data and the models for detecting road damages in their country? Does it affect the performance of the model?

    b. Do they need to collect images from their country as well?

    c. If yes, what effect would these images have on the performance?

    d. Should they mix the images collected from their country with those published by Japan (or any other country, in general) or train a model using only the local data?

In addition, the work aims to propose new AI-driven models capable of detecting, classifying, and providing information related to the severity of road damage.

Anticipated Contributions, Proposed Research Plan, and the Timeline

The thesis intends to contribute to the three aspects: Data, Models, and Research Analysis to provide requisite recommendations, as elaborated below.

Data

The study proposes a large-scale, diverse road damage dataset comprising more than 26000 images collected from multiple countries (India, Japan, and the Czech Republic) using Smartphones in collaboration with researchers from Japan and Europe. It has been made freely available for supporting future research in this direction. Our data article (Arya et al. 2021d) provides the complete details.

Analysis & Recommendations

Our article (Arya et al. 2021c) addresses the research questions mentioned above. It presents an analysis assessing the applicability of Japanese data and models to develop models for India and the Czech Republic.

The quantitative analysis carried out in the work governed the visual observations. It indicated that utilizing data available from other countries helps in significantly improving the accuracy and generalizing ability of the road damage detection models. The experiments revealed that the models trained using a mixture of Indian and Japanese data outperformed the models considering data from one. Overall, the work acts as a prototype for developing models that could be applied globally or to a set of countries with similar road conditions.

New AI-Driven Models for Multiple Countries

The performance analysis carried out in our work revealed the poor performance of Japanese road damage detection models for detecting road damages in India and the Czech Republic. Hence, the current work proposes new models trained using different combinations of datasets from India, Japan, and the Czech Republic.

To this aim, the Global Road Damage Detection Challenge (GRDDC) was proposed and organized in collaboration with colleagues from the University of Tokyo, Japan. The challenge invited solutions for designing a single model capable of detecting and classifying road damages for all three countries.

The GRDDC was organized as an IEEE Big Data Cup, associated with IEEE International Conference on Big Data'2020, Atlanta, GA, USA. The participants were provided access to the proposed Road Damage Dataset and a preprint of the study's research analysis (Arya et al. 2020a).

The Big Data Cup gained wide attention, and over 100 teams registered for it worldwide. Our article (Arya et al. 2020b) provides complete details of the event and the top 12 solutions proposed by the GRDDC participants. These solutions illustrate the state-of-the-art Deep Learning models targeted for road damage detection and classification.

Remaining Work and Future Scope

The thesis further aims at providing an optimized model which would also provide information for severity analysis of the road damage. Apropos, segmentation-based approaches (Arya, Ghosh, and Toshniwal, 2021a and 2021b) are being explored to complement the already proposed object-level techniques and provide pixel-level information.

References

Maeda, H.; Sekimoto, Y.; Seto, T.; Kashiyama, T; and Omata, H., 2018. Road damage detection and classification using deep neural networks with smartphone images. Computer-Aided Civil and Infrastructure Engineering, 33(12), pp.1127-1141. doi: https://doi.org/10.1111/mice.12387.

Arya, D.; Ghosh, S. K.; Toshniwal, D. 2019. Machine Learning-based Road Condition Assessment using Remote Sensing Data. Paper presented at 2019 International Conference on Arasufest – Sequences, Codes and Designs, Kalamata, Greece. August 1-4.

Arya, D.; Maeda, H.; Ghosh, S. K.; Toshniwal, D.; Mraz, A.; Kashiyama, T.; & Sekimoto, Y. 2020a. Transfer learning-based road damage detection for multiple countries. arXiv preprint arXiv:2008.13101.

Arya, D.; Maeda, H.; Ghosh, S. K.; Toshniwal, D.; Omata, H.; Kashiyama, T.; & Sekimoto, Y. 2020b. Global Road Damage Detection: State-of-the-art Solutions. IEEE International Conference on Big Data (Big Data), Atlanta, GA, USA, pp. 5533-5539, doi: 10.1109/BigData50022.2020.9377790.

Arya, D.; Ghosh, S. K.; Toshniwal, D. 2021a. An approach for Automatic Recognition of Road Cracks using Image Processing and Machine Learning, International Conference on Machine Intelligence and Signal Processing, Arunachal Pradesh, India. Sept 23-25.

Arya, D.; Ghosh, S. K.; Toshniwal, D. 2021b. Image-based Automatic Recognition of Road Cracks for an Intelligent Pavement Maintenance Management System. Paper presented at 14th International Conference of Eastern Asia Society for Transportation Studies (EASTS), Hiroshima, Japan, September 12-14.

Arya, D.; Maeda, H.; Ghosh, S. K.; Toshniwal, D.; Mraz, A.; Kashiyama, T.; & Sekimoto, Y. 2021c. Deep learning-based road damage detection and classification for multiple countries. Automation in Construction, 132, 103935. doi: 10.1016/j.autcon.2021.103935.

Arya, D.; Maeda, H.; Ghosh, S. K.; Toshniwal, D.; & Sekimoto, Y. 2021d. RDD2020: An annotated image dataset for automatic road damage detection using deep learning. Data in Brief, 36, doi: 107133. 10.1016/j.dib.2021.107133.