AI-assisted sensor-based road surface condition monitoring system

Dr. Xiang Wang*, Prof. Fumiya Iida (supervisor), Prof. Ioannis Brilakis (second supervisor)
* Email: xw438@cam.ac.uk

UNIVERSITY OF CAMBRIDGE

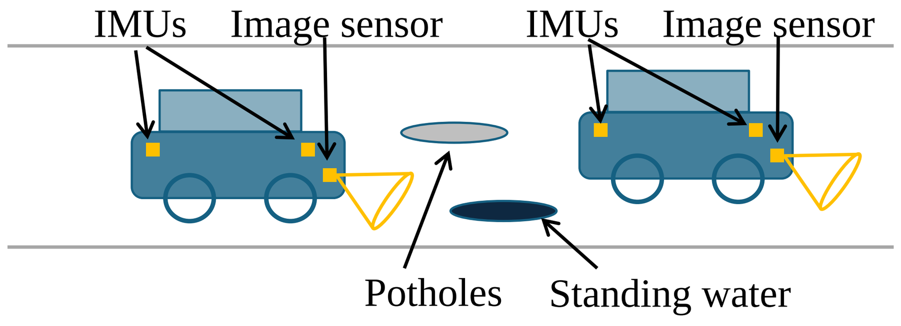
Introduction

Road transportation is an important component of transportation. Numerous roads to be monitored are a challenge for the management by the authorities. Untimely road maintenance endangers the safety of drivers and vehicles. Low-cost and high-efficiency Road Surface Monitoring (RSM) becomes an important target for future roads. Conventional RSM systems have the disadvantages of high costs and difficulty to be improved.

Motivations

In this research, the applicant wants to develop a real-time sensor-based road surface monitoring system to provide road surface information to the vehicles, drivers, and road management teams.

Two targets:
A) Sensor development
B) Algorithm development



A. Sensor Design

Idea: stress concentration regions (cracks) will be visualised by the sensor's colours.

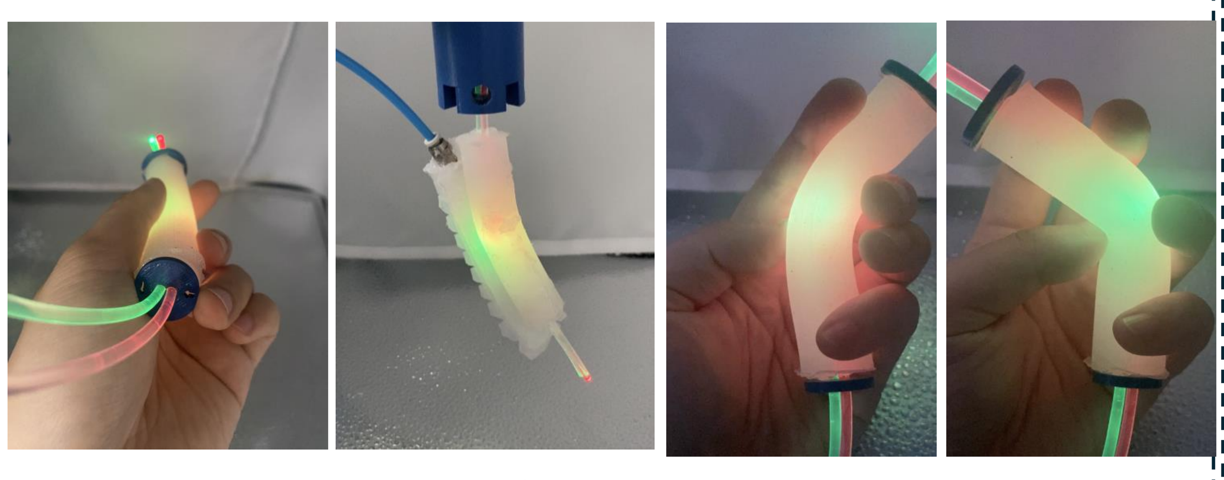


Fig. Designed soft continuum robot sensors with unlimited application potential

A universal soft strain sensor was designed as an indicator to show the local stress concentration regions (with colours) by being attached to the infrastructure (e.g. bridges or roads).

Manufacturing of the sensor:

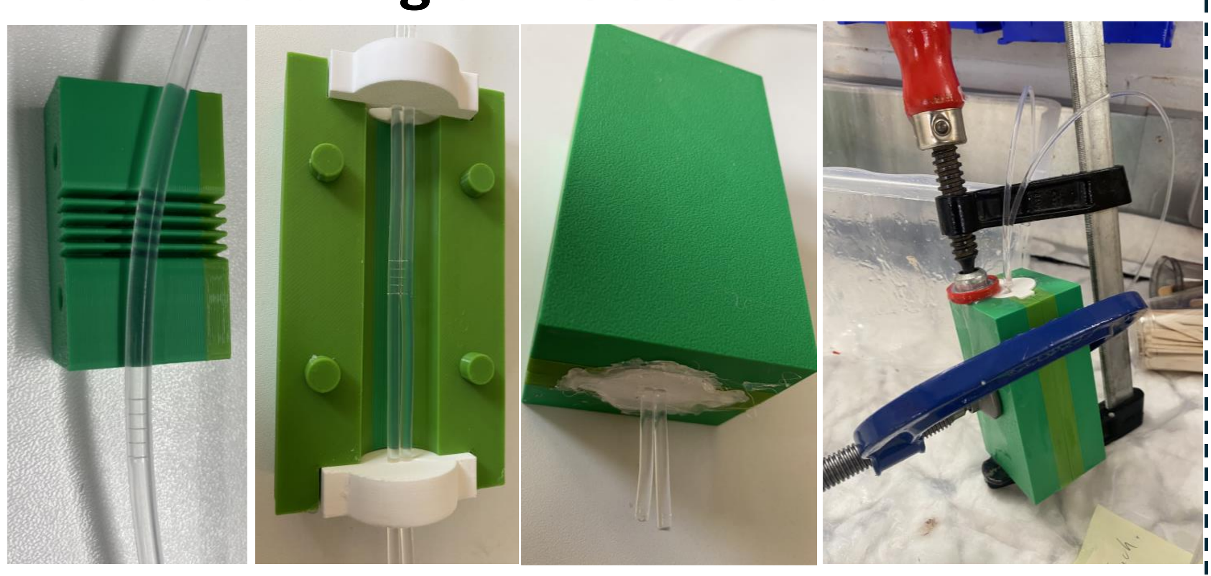


Fig. Soft continuum robot sensor manufacturing process

The sensor was manufactured in a mound. From left to right, the figures show the micro-structures of the designed sensor, the optical fibre sensor alignment in a mould, and the curing processes of silicone rubber (Ecoflex-20).

Principle of the sensor:

Optical fibre sensors are designed in the soft continuum robot's body. The shape-changing of the soft robot shows different colours by mixing the light dissipation in the opaque silicone rubber.

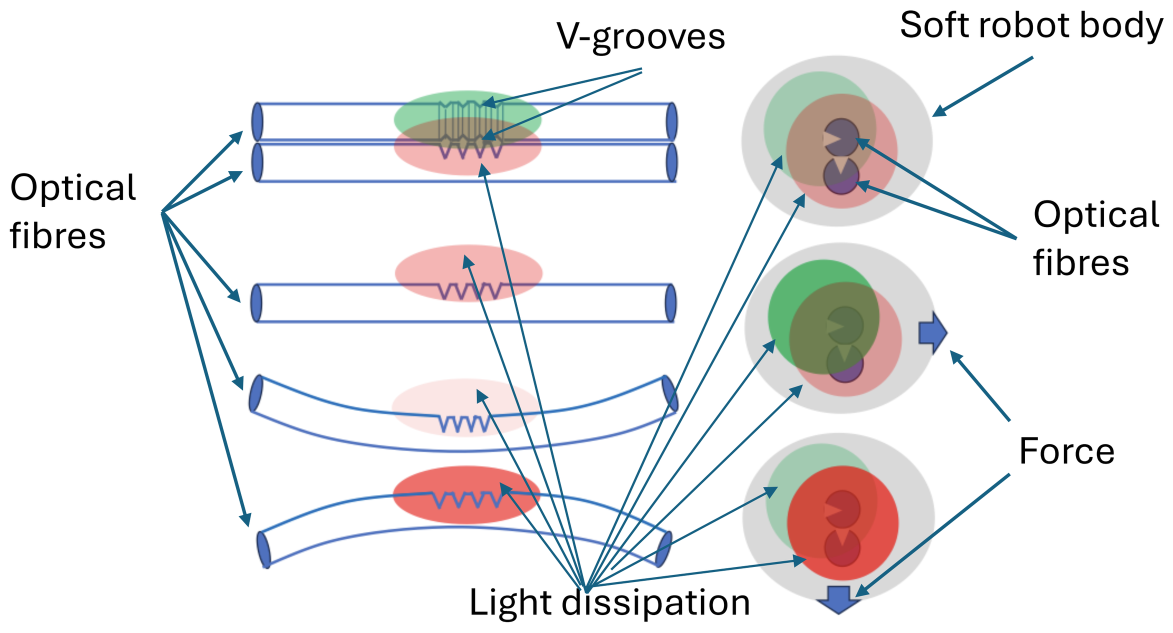


Fig. The principle of colour mixing in a soft continuum robot

B. Algorithm Design

Idea: road surface monitoring with optical computing methods based on acceleration data from civilian vehicles.

A simplified diagram of optical computing for road surface monitoring is shown below (the blue circle in the middle represents an optical fibre)

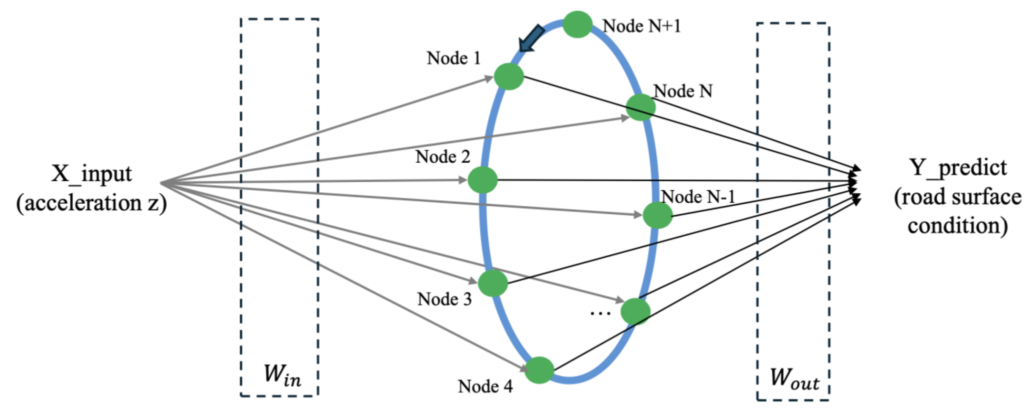


Fig. Optical computing with an optical fibre

Road condition prediction results:

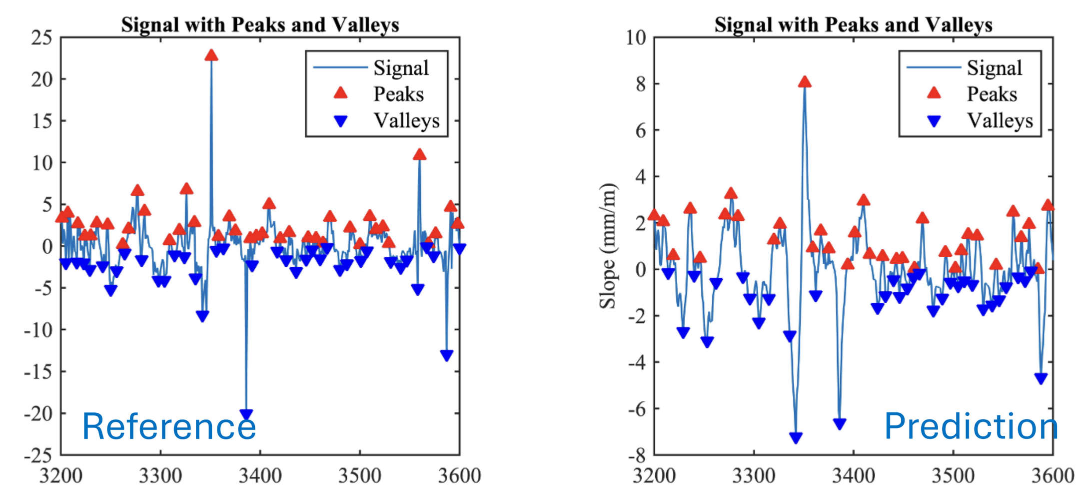


Fig. Road surface slope peaks and valleys prediction

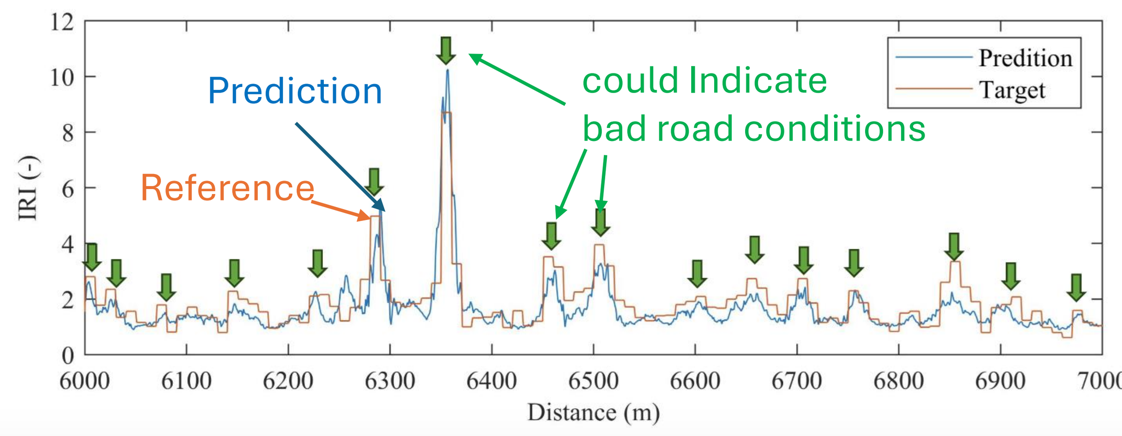


Fig. International roughness index prediction

About **90%** of road surface fluctuation peaks and valleys were predicted.
The accuracies of international roughness index prediction for 100 m and for 10 m were about **86%** and **73%**.

Advantages: it is a physical computing structure with fast-speed calculation.

This project:
1.Alignment with SDG:
SDG Target 3.6 - halve the number of global deaths and injuries from road traffic accidents by 2030
2.The starting and expected end TRL levels:
TRL Level 1 (Starting): Basic Technology Research
TRL Level 3 (Expected): Analytical and experimental proof-of-concept
3.Industry secondment needs:
Actively looking for secondment opportunities
4.Acknowledgement of dataset:
No dataset used from Future Roads

What next?

Continue research on road surface condition monitoring with conventional and unconventional sensors.

- Pavement monitoring (international roughness index)
- Pavement monitoring (friction)
- Developing sensors (including tyre sensors) for road condition monitoring

Acknowledgements

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References

- Review of multimodal data and their applications for road maintenance, Smart Construction,2024(2), pp. 1-39.

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