SensIT: Towards data-driven infrastructure management

Carlos Gil Berrocal
M.Sc., Ph.D., Postdoctoral researcher
Chalmers University of Technology / Thomas Concrete Group
412 96 Göteborg, Sweden
e-mail: carlos.gil@chalmers.se

Ignasi Fernandez
M.Sc., Ph.D., Associate professor
Chalmers University of Technology
412 96 Göteborg, Sweden
e-mail: ignasi.fernandez@chalmers.se

Rasmus Rempling
M.Sc., Ph.D., Associate professor
Chalmers University of Technology / NCC
412 96 Göteborg, Sweden
e-mail: rasmus.rempling@chalmers.se

ABSTRACT

The successful use of new technologies will enable novel management strategies, which will promote an upgrade of the current infrastructure network to a new generation of safer, more efficient and more sustainable smart infrastructure: the infrastructure 2.0. This paper summarizes the main core areas of a new asset management paradigm that has been developed within the SensIT project at Chalmers. Preliminary results and future work are presented and discussed.

Key words: Structural Health Monitoring, Fiber optic sensors, Cracking, Data visualisation.

1. INTRODUCTION

Maintaining the performance of the transport infrastructure is crucial to guarantee the users' safety and to ensure a country's positive economic growth. However, the advanced age of many structures added to existing degradation processes and the ever-increasing level of demands in terms of traffic loads, represent an enormous challenge for the effective management of the transport infrastructure. Current methods include labour-intensive inspections and disrupting maintenance operations, which often constitute a major part of the recurrent cost of infrastructure.

The SensIT project is a research initiative at Chalmers University of Technology together with a constellation of industry and public sector partners aiming at combining the recent technological advances in wireless sensing, cloud data services, AI and novel visualization tools to develop new management strategies that will enable an upgrade of the current infrastructure network through a new generation of smart structures. This paper presents some preliminary results of the project.

2 SENSIT: PROJECT DESCRIPTION AND PRELIMINARY RESULTS

The four main areas related to the manipulation of data, namely acquisition, management, analysis and visualisation, that comprise the core of the SensIT project and that have been identified [1] as the critical aspects for the development of an integrated system for infrastructure management decision support are illustrated in Fig. 1.

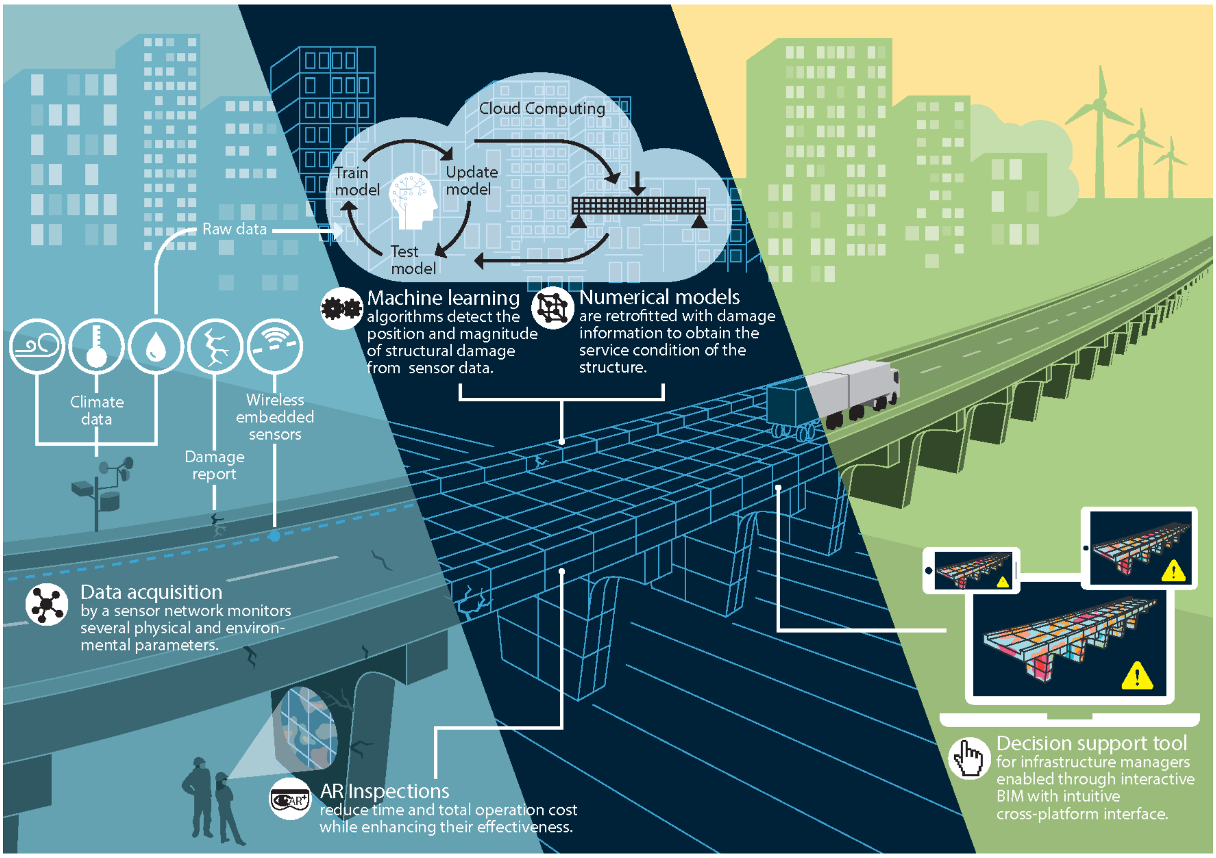

Figure 1 – Infographic illustrating the main areas of the SensIT project and their interrelation.

2.1 Data acquisition – remote distributed sensing

Sensors are critical elements in SHM systems, which must be chosen adequately to serve the intended purpose under the expected conditions and for a certain time span. Therefore, choosing robust and stable sensors which are not affected by external stimuli and which can surpass the service life of the host structure is crucial for the development of effective monitoring system.

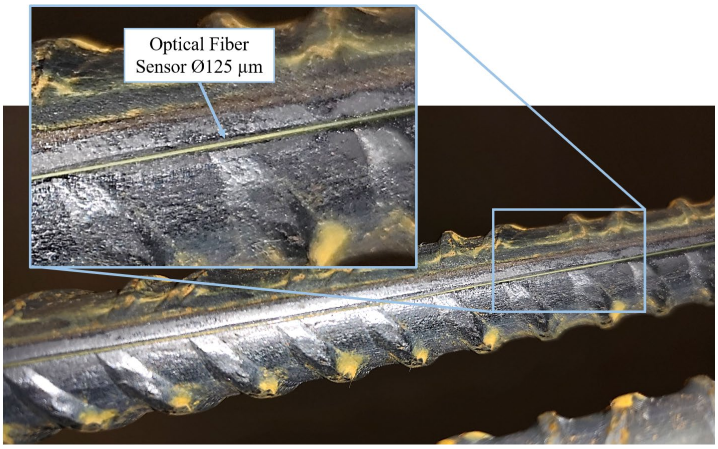

Figure 2 – Detail of an optical fiber sensor installed into a steel reinforcement bar.

Optical fibers have been regarded as excellent candidates due to their outstanding properties. Among others, they are non-intrusive thanks to their reduced dimensions, see Fig. 2, lightweight, chemically inert and corrosion resistant. They can operate over a wide range of temperatures and unlike electrically powered sensors, they are not affected by electromagnetic interference. In addition, a single optical fiber can accommodate multiple sensing points along its length, thereby saving tremendous amounts of time and money in wiring and installation. Moreover, recent studies on distributed optical fiber sensors (DOFS), see e.g. [2], have revealed the great potential of these kind of sensors for SHM in concrete structures.

2.2 Data analysis – deep learning

Individual data values need to be contextualised, relativized to other parameters and combined with a certain set of assumptions to obtain meaningful information. This information must then be placed within a theoretical background and used in conjunction with a model to obtain knowledge. An example of the data-information-knowledge transition is shown in Fig. 3 where DOFS raw data is analysed to determine the number and position of cracks in a RC beam subjected to 3-point loading. Knowledge can eventually be turned into expertise, i.e. the key aspects for decision making, by the analysis of experienced and trained operators. However, this could change through the implementation of AI, i.e. deep learning algorithms, which could not just become a decision support tool for engineers but also unlock the path towards predictive structural assessment [3].

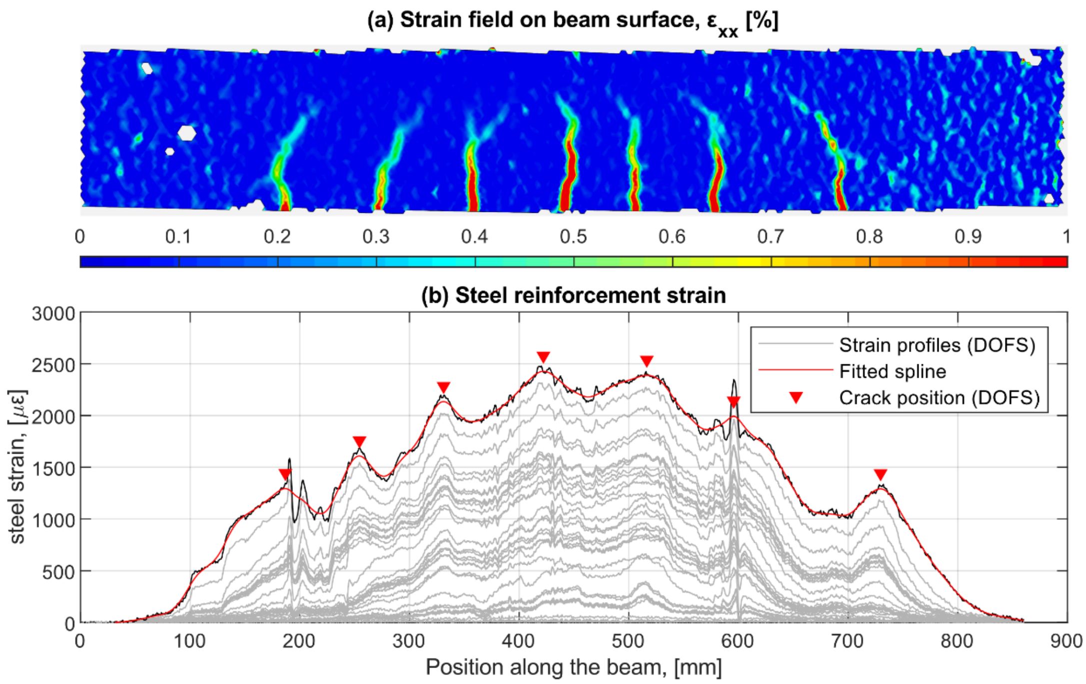

Figure 3 – (a) strain field of RC beam under 3PBT from DIC; (b) Identification of the crack locations through analysis of strain profiles obtained by distributed optical fiber sensors.

2.3 Data visualisation

Information, whether it is raw data or a sophisticated damage index, needs to be conveyed in a clear, efficient and intuitive way to the relevant actors. Building Information Modelling (BIM), combining 3D computer-aided design visualization with integrated data, offers a perfect platform for data visualisation. Moreover, thanks to modern graphic libraries, 3D models can be rendered in the browser, thus removing the need of proprietary software. An example of this is shown in

Fig. 4, where the 3D model of a RC beam is displayed in the SensIT web application. Moreover, augmented Reality (AR) also possesses a great potential for the visualization of data on-site, which could represent a giant leap in the efficiency of structural inspections. By visualizing structural condition information as an overlay displayed on the actual structure, the time and extent of the inspection and subsequently the cost and disruption to the infrastructure users could be significantly reduced.

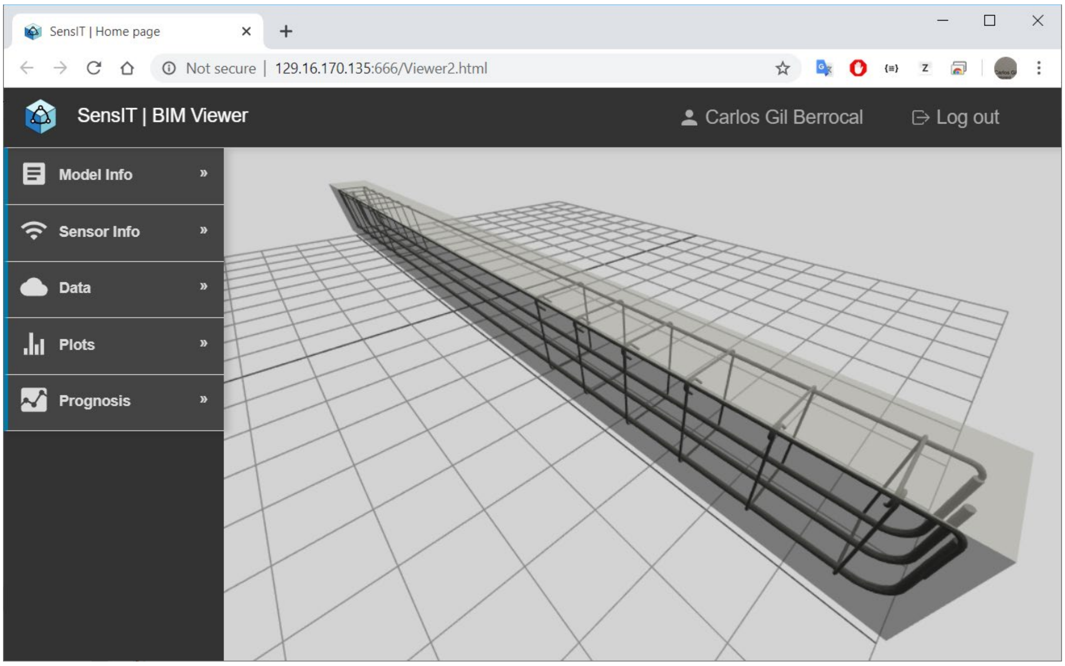

Figure 4 – Screen capture of a 3D RC beam model visualised in the SensIT web application.

3 CONSIDERATIONS AND FUTURE DIRECTIONS

A novel infrastructure management strategy has been presented leveraging the power of recent technological advances for the construction sector. The use of distributed optical fibers has revealed enormous potential for the monitoring of concrete structures, although more data is required to create a database that can be used to train and validate deep learning algorithms for automatic crack detection and predictive assessment. Moreover, numerical models should be developed to support the training of such algorithms. Further work requires the seamless integration of data visualisation in the SensIT web application. A first demonstration project is planned to showcase the capabilities of the system under laboratory conditions in real-time.

REFERENCES

[1] Berrocal, C.G., Fernandez, I. & Rempling, R. (2018). The road to sensor-driven cloud-based infrastructure management. In Proceedings: "SynerCrete'18: Interdisciplinary Approaches for Cement-based Materials and Structural Concrete: Synergizing Expertise and Bridging Scales of Space and Time", 823-828.

[2] Brault, A., & Hoult, N. (2019). Monitoring reinforced concrete serviceability performance using fiber-optic sensors. ACI Structural Journal, 116(1), 57–70

[3] Karypidis, D., Berrocal, C.G., Rempling, R., Granath, M. & Simonsson, P. (2019). Structural Health Monitoring of RC structures using optic fiber strain measurements: a deep learning approach. In Proceedings: "2019 IABSE Congress New York City – The Evolving Metropolis".