The application of black-box modeling in long-term tunnel deformation monitoring

Kristof Maes, Stijn François

Department of Civil Engineering, KU Leuven, Leuven, Belgium

Wim Salens, Gerrit Feremans

SBE Engineering Consultants, Slachthuisstraat 71, 9100 Sint-Niklaas, Belgium.

Koen Segher

De Vlaamse Waterweg, Lange Kievitstraat 111-113, 2018 Antwerp, Belgium.

Contact: kristof.maes@kuleuven.be

Abstract

Tunnel closures related to maintenance and reconstruction works can lead to large economical costs and should therefore be avoided. This paper explores the use of novelty detection algorithms for long-term tunnel monitoring. The aim is to detect tunnel damage in an early stage, as such providing a tool to support the asset management. The proposed strategy is applied to the monitoring of the Waasland tunnel in Antwerp, where the deformations and temperatures have been monitored over a period of 14 months. The case demonstrates that novelty detection by means of principal component analysis enables the identification of minor changes in the tunnel response, and can therefore be embedded in an early detection warning system.

Keywords: Tunnel monitoring, novelty detection, pattern recognition, black-box modeling

1 Introduction

Tunnels are important elements of our integrated infrastructure system. Both road and rail tunnels are commonly used for the crossing of rivers, other roads and railway lines, or even entire cities. Their continuous operation is of paramount importance to avoid congestion and other large economical costs related to tunnel closures.

Although tunnels have been constructed for many decades, their structural integrity is often characterized by large uncertainty, which is mostly related to incomplete knowledge of the subsoil conditions. In addition, the tunnel response over its lifetime is influenced by uncertain factors such as thermal loading and underground water fluctuations, possibly leading to ageing problems.

Over the years, inspection, assessment and maintenance procedures have been developed by asset managers, in view of structural reliability, maintainability and availability of the infrastructure. So far, the majority of tunnel assessments is performed by expert operators and is limited to visual inspection. However, this classical approach is time consuming and prone to biased human error, which in the end may result in poor inspection quality.

Recently, a lot of research has been devoted to the use of sensors for the assessment of the tunnel state/response [1]. As an alternative to visual inspection, Montero et al. proposed robotic inspection [2]. Developments in measurements and sensor technology have also led to a wide availability of different measurement methods for

https://doi.org/10.2749/ghent.2021.0580
Distributed by structurae