Existing Research Topic 16

A Fatigue Assessment for Steel Bridges using Fiber Opti Sensors and Machine Learning

Appears to be quite a bit of recent published work (2020) in this area with regard to steel bridges + fiber optic sensors + machine learning.

RiP Database & TRID Database:

2019 (active) Sensor-assisted Condition Evaluation of Steel/Prestressed Concrete Girder Bridges Subjected to Fire – Phase III

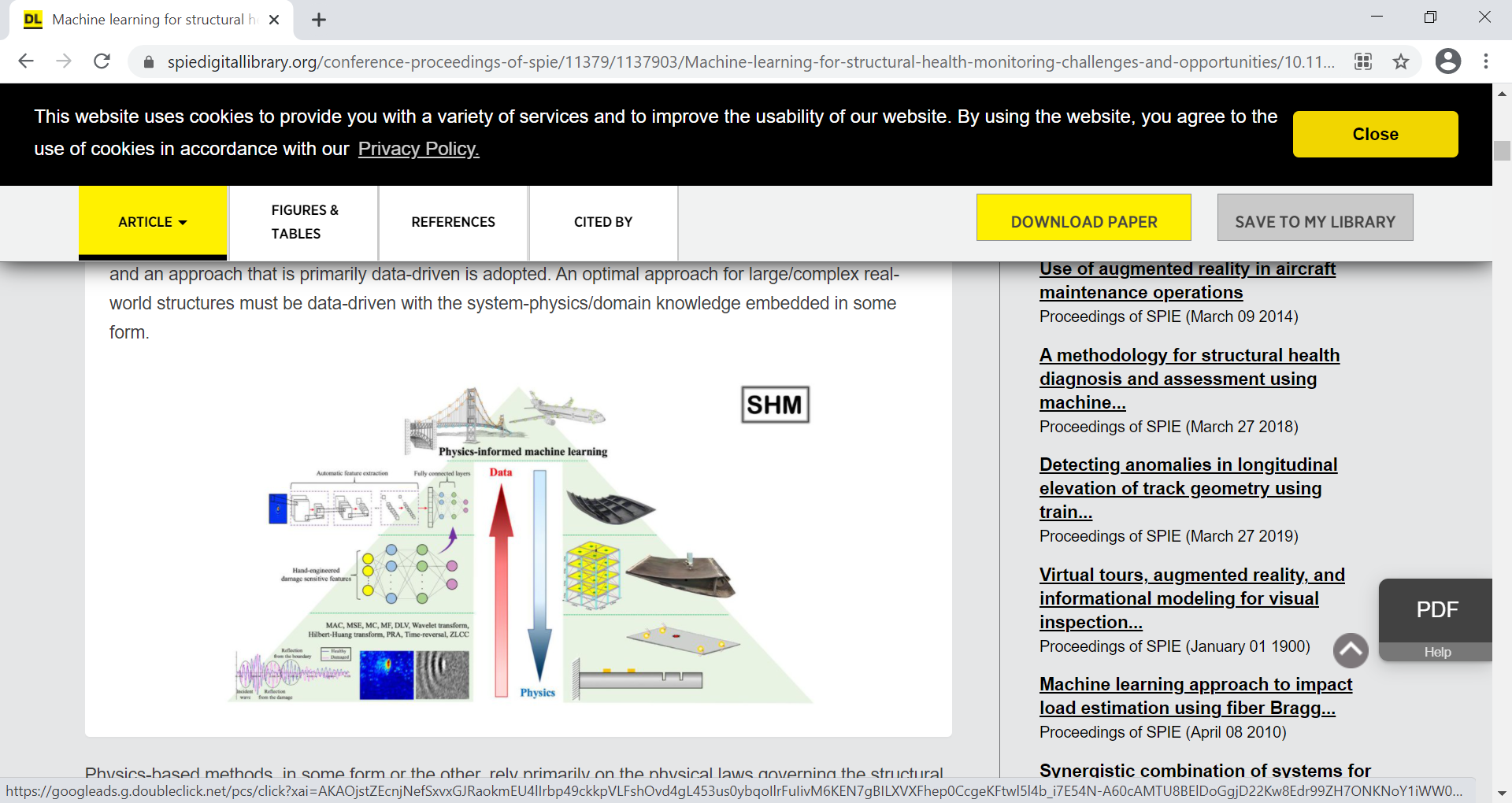
<https://trid.trb.org/Results?txtKeywords=fiber%20optic%20steel%20girder&txtTitle=&txtSerial=&ddlSubject=&txtReportNum=&ddlTrisfile=&txtIndex=&specificTerms=&txtAgency=&sourceagency=&txtAuthor=&ddlResultType=&chkFulltextOnly=&recordLanguage=&subjectLogic=or&dateStart=&dateEnd=&rangeType=emptyrange&sortBy=publisheddate&sortOrder=DESC&rpp=25#/View/1685055>

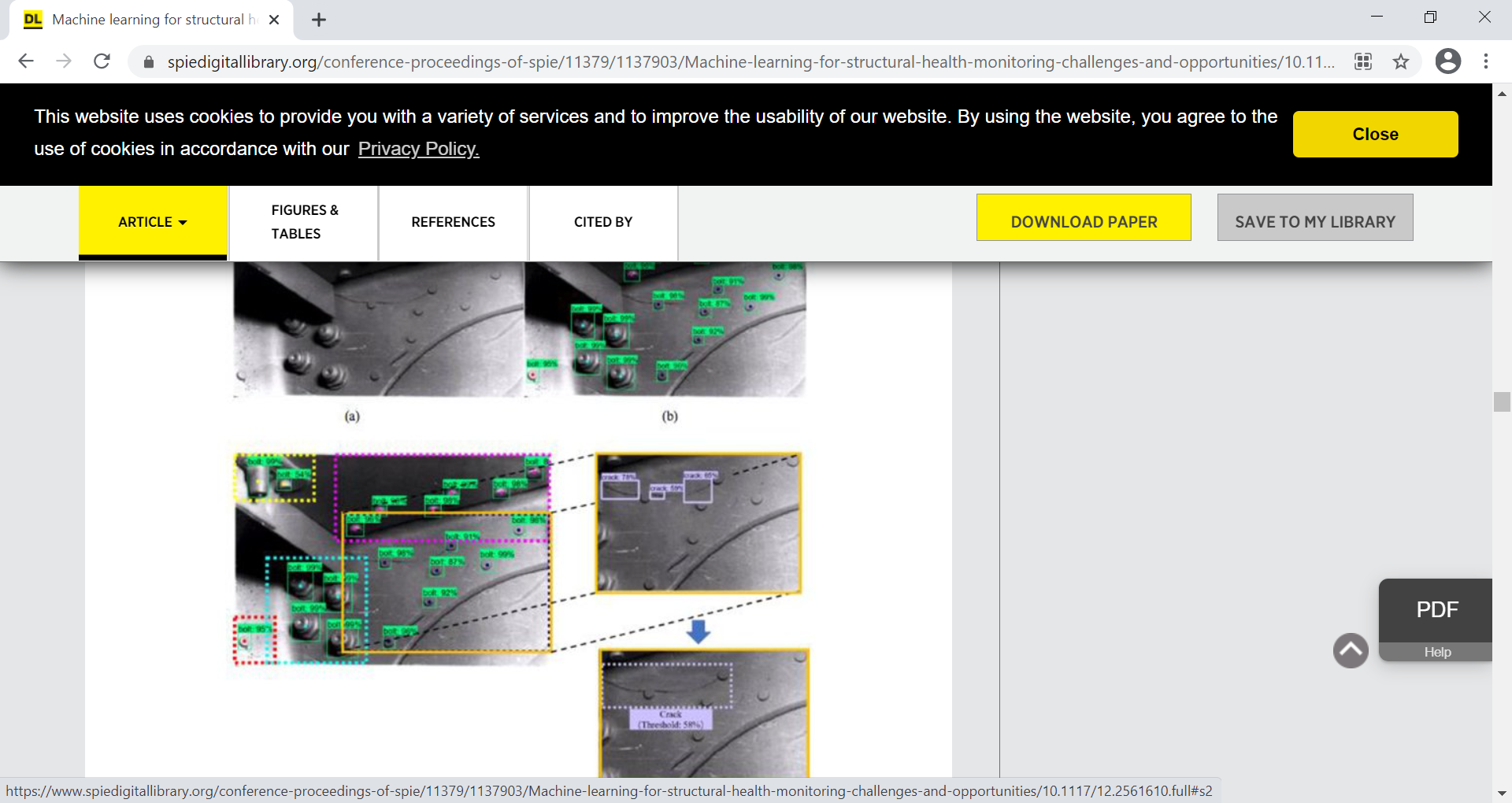
The overarching goal of this multi-phase study is to develop and validate a post-fire condition evaluation method for steel- and prestressed concrete-girder bridges (overpasses or viaducts) based on material and structural data, a fire scenario (e.g., a fuel tank on highway), and environmental factors (e.g., moisture and wind). The proposed method involves fire dynamics simulation underneath a bridge, thermomechanical analysis of the structure, and structural condition assessment against material strengths. One of the key challenges to achieve this goal is to measure strains in steel members on fire and detect concrete cracks to validate various computational models. Phases I and II of this study aimed to understand and validate the performance of distributed fiber optic sensors based on Brilliouin optical time domain analysis (BOTDA) for temperature and strain measurements in reinforced concrete (RC) bridges, and develop and validate a fire dynamics simulator and a thermomechanical model with measured data. In particular, the deployment scheme and data quality of distributed sensors embedded in concrete and attached on steel members are evaluated. The effects of multiple steel girders on the aerodynamics and heat distribution of a fire are investigated through fire dynamics and thermomechanical analysis. Phase III of this study aims to understand the performance and behavior of prestressed concrete girders under a fire and quantify the prestress loss over time using distributed fiber optic sensors such as BOTDA. Due to uncertain bonding between an optical fiber and concrete, strain measurements based on the transfer of strain from concrete to the optical fiber are less reliable particularly to determine the loss of prestress in tendon. Therefore, a new distributed fiber optic acoustic sensing system will be used to detect cracks developed in proximity of the concrete-tendon interface.

2020 Machine learning for structural health monitoring: challenges and opportunities

<https://www.spiedigitallibrary.org/conference-proceedings-of-spie/11379/1137903/Machine-learning-for-structural-health-monitoring-challenges-and-opportunities/10.1117/12.2561610.full?SSO=1>

Abstract A physics-based approach to structural health monitoring (SHM) has practical shortcomings which restrict its suitability to simple structures under well controlled environments. With the advances in information and sensing technology (sensors and sensor networks), it has become feasible to monitor large/diverse number of parameters in complex real-world structures either continuously or intermittently by employing large in-situ (wireless) sensor networks. The availability of this historical data has engendered a lot of interest in a data-driven approach as a natural and more viable option for realizing the goal of SHM in such structures. However, the lack of sensor data corresponding to different damage scenarios continues to remain a challenge. Most of the supervised machine-learning/deep-learning techniques, when trained using this inherently limited data, lack robustness and generalizability. Physics-informed learning, which involves the integration of domain knowledge into the learning process, is presented here as a potential remedy to this challenge. As a step towards the goal of automated damage detection (mathematically an inverse problem), preliminary results are presented from dynamic modelling of beam structures using physics-informed artificial neural networks. Forward and inverse problems involving partial differential equations are solved and comparisons reveal a clear superiority of physics-informed approach over one that is purely datadriven vis-à-vis overfitting/generalization. Other ways of incorporating domain knowledge into the machine learning pipeline are then presented through case-studies on various aspects of NDI/SHM (visual inspection, impact diagnosis). Lastly, as the final attribute of an optimal SHM approach, a sensing paradigm for non-contact full-field measurements for damage diagnosis is presented.





2020 Applying Deep Learning to Continuous Bridge Deflection Detected by Fiber Optic Gyroscope for Damage Detection

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7038955/>

Abstract Improving the accuracy and efficiency of bridge structure damage detection is one of the main challenges in engineering practice. This paper aims to address this issue by monitoring the continuous bridge deflection based on the fiber optic gyroscope and applying the deep-learning algorithm to perform structural damage detection. With a scale-down bridge model, three types of damage scenarios and an intact benchmark were simulated. A supervised learning model based on the deep convolutional neural networks was proposed. After the training process under ten-fold cross-validation, the model accuracy can reach 96.9% and significantly outperform that of other four traditional machine learning methods (random forest, support vector machine, k-nearest neighbor, and decision tree) used for comparison. Further, the proposed model illustrated its decent ability in distinguishing damage from structurally symmetrical locations. \*used scaled down cable-stayed bridge, not steel girder\*

2020 Recent Progress of Fiber-Optic Sensors for the Structural Health Monitoring of Civil Infrastructure

<https://www.mdpi.com/1424-8220/20/16/4517/htm>

Abstract In recent years, with the development of materials science and architectural art, ensuring the safety of modern buildings is the top priority while they are developing toward higher, lighter, and more unique trends. Structural health monitoring (SHM) is currently an extremely effective and vital safeguard measure. Because of the fiber-optic sensor’s (FOS) inherent distinctive advantages (such as small size, lightweight, immunity to electromagnetic interference (EMI) and corrosion, and embedding capability), a significant number of innovative sensing systems have been exploited in the civil engineering for SHM used in projects (including buildings, bridges, tunnels, etc.). The purpose of this review article is devoted to presenting a summary of the basic principles of various fiber-optic sensors, classification and principles of FOS, typical and functional fiber-optic sensors (FOSs), and the practical application status of the FOS technology in SHM of civil infrastructure.

2020 Strain monitoring of composite steel girder bridge using distributed optical fibre sensor system

<https://www.researchgate.net/publication/251716612_Strain_monitoring_of_composite_steel_girder_bridge_using_distributed_optical_fibre_sensor_system>

An I type steel girder was assembled with a concrete upper plate and then placed on two roller supports. Four vertical load

actuators were laid on the upper plate to add the vertical load. A single mode optical fiber was attached on the surface of the

lower flange of a composite steel girder bridge with a length of 39 m. Longitudinal strain distribution of a composite steel girder bridge is monitored directly using optical fibre sensor system based on Brillouin frequency shift dependency of the strain applied on the optical fiber. Brillouin scattering signal is generated through the Brillouin optical correlation domain analysis at a selected location. Strain data were acquired at 195 points with the interval of 20 cm over the full range. From the strain data over the entire length of the composite steel girder bridge, the strain distribution shape was shown when the vertical load was added on the bridge.

2020 (deep learning for fiber optic sensor, no steel girder ref) A machine learning method for inclinometer lateral deflection calculation based on distributed strain sensing technology

<https://link.springer.com/article/10.1007/s10064-020-01749-3>

Abstract Due to its unique advantages, the distributed fiber optical sensing (DFOS) technology has been used to study the performance of inclinometer so as to monitor landslide deformation. Strain distribution of inclinometer can be obtained by distributed strain sensing (DSS) cables, and the strain-deflection relationship can be established by using the widely accepted methods (e.g., the quadratic integral method and classical conjugate beam method). However, the application of quadratic integral method and classical conjugate beam method are based on many assumptions, and there will be remarkable deviation between calculated deflection and actual displacement with the increase of integral length. Given this, a new deflection calculation method based on machine learning is proposed. Through learning on the monitoring data, an implicit function model between depth, strain, and measured displacement is established by using the BP (back propagation) neural network algorithm. The efficiency of the proposed model has been verified against measured displacement, which demonstrates the capability of this method for landslide deformation prediction. Compared with the traditional integral method, the lateral deflection curve of inclinometer calculated by the proposed method is closer to the actual measured displacement both in trend and values. The proposed model shows great potential in the application of deflection calculation in engineering.

2020 Comparative Analysis on the Deployment of Machine Learning Algorithms in the Distributed Brillouin

Optical Time Domain Analysis (BOTDA) Fiber Sensor

This paper demonstrates a comparative analysis of five machine learning (ML) algorithms for improving the signal processing time and temperature prediction accuracy in Brillouin optical time domain analysis (BOTDA) fiber sensor. The algorithms analyzed were generalized linear model (GLM), deep learning (DL), random forest (RF), gradient boosted trees (GBT), and support vector machine (SVM). In this proof-of-concept experiment, the performance of each algorithm was investigated by pairing Brillouin gain spectrum (BGS) with its corresponding temperature reading in the training dataset. It was found that all of the ML algorithms have significantly reduced the signal processing time to be between 3.5 and 655 times faster than the conventional Lorentzian curve fitting (LCF) method. Furthermore, the temperature prediction accuracy and temperature measurement precision made by some algorithms were comparable, and some were even better than the conventional LCF method. The results obtained from the experiments would provide some general idea in deploying ML algorithm for characterizing the Brillouin-based fiber sensor signals.

2011 Crack detection of steel girders using Brillouin optical time domain analysis

<https://link.springer.com/article/10.1007/s13349-011-0006-8>

Abstract This article presents the results from an experimental program designed to evaluate the performance of a system consisting of a readout unit and a ribbon type Fiber Optic Sensor (FOS) based on Brillouin Optical Time Domain Analysis (BOTDA). The system is intended for the detection of cracks as well as the monitoring of long-term performance for steel bridge girders. The program consisted of introducing a crack at the center of a 3-m-long steel beam and monitoring its progression using static loading tests performed at ambient and sub-zero temperatures. For sensor lengths similar to those used in the field, the resonant frequency shifts per unit increase in crack width were found to decrease from 114 MHz/mm at ambient temperature (~25°C) to 65 MHz/mm at −10°C. Results also revealed nonlinearity and variability, which can be attributed to an incompatibility between the settings of the laser pump in the readout unit and the sensor length. Significant losses were detected along the bonded segments of the sensor and were attributed to the presence of ripples along the sensor. These undulations worsen with a reduction in temperature and are induced by the bonding procedure as well as the slack provided in the plastic sleeves containing the splices.

2008 Distributed Strain Measurement in Steel Bridge with Fiber Optic Sensors: Validation through Diagnostic Load Test

<http://worldcat.org/issn/08873828>

Fiber optic sensing technologies are emerging as valid alternatives for the health monitoring of civil structures. Distributed sensors based on Brillouin scattering add the unique capability of measuring strain and temperature profiles along optical fibers. Measurement is performed by establishing the correlation between fiber strain and temperature, and the frequency shift of the Brillouin backscattered light induced by a monochromatic light pulse. The technology holds potential for use on large structures and integrated transportation infrastructure. Its effectiveness has been assessed through scaled laboratory experiments, whereas field validation is limited to very few demonstration projects conducted to date. This paper presents a pilot application of Brillouin optical time domain reflectometry to measure strain profiles along the steel girders of a continuous slab-on-girder bridge subjected to diagnostic load testing. One of the exterior continuous girders required heat-straightening after falling during construction due to wind. The significance of applying a distributed measurement technique lies in the potential to assess the global girder response, which would be impractical and uneconomical using discrete measurement techniques. A 1.16 km long sensing circuit was installed onto the web of 4 girders. The circuit comprises bare optical fiber sensors, and a novel adhesively bonded fiberglass tape with embedded sensing fibers for strain measurement and thermal compensation. The strain profiles were first converted into deflection profiles and validated against discrete deflection measurements performed with a high-precision total station system. Structural assessment based on comparison of the strain profiles with the results of 3-D finite-element analysis of the bridge superstructure, and with specification mandated criteria, indicated that the response of the girder under investigation was within the design limits, and did not pose serviceability concerns. Factors that may affect measurement accuracy are discussed on the basis of the experimental and numerical results.

RNS Database: zero results for “fiber optic” + “machine learning” + “deep learning” + “steel girder”