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Multi-purpose bridge strain data fusion for BWIM and structural monitoring

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EXTENDED ABSTRACT

KEY WORDS: BWIM, Weight in motion, SHM, structural health monitoring

1 INTRODUCTION

This work presents some results obtained using bridge strain data relevant to the Society of Civil Structural Health Monitoring (SCSHM) bridge benchmark [1]. Data has been processed to obtain information on both bridge behavior and on the features of vehicles passing through the bridge. Namely, the processing of data from sensors located at different sections of the bridge enables to retrieve information relevant to a) the dynamic and static bridge characteristics and b) to the passing vehicle characteristics such as speed, weight, length and number of axles (see Figure 1). Furthermore, in this work it is shown how data fusion techniques permit to improve the quality of the estimation of relevant information extracted from multiple sensors, for both Bridge Weight-in-motion (BWIM) and structural monitoring in the SCSHM bridge benchmark.

2 METHODOLOGY

The proposed methodology, tested on the SCSHM benchmark, allows to extract data from multiple strain sensors positioned at different locations of the bridge. The use of multiple strain sensors enables the detection of time-related features, such as the velocity of the vehicle. Furthermore, each sensor enables the retrieval of diverse information. For instance, sensors closer to the road surface are more suitable for capturing the local response to the passage of single axles, while sensors located on the beams capture the global bridge response in terms of deflection. If the bridge has several lanes, sensors located under each lane will be more sensitive to vehicles passing over that specific lane.

Each step of the methodology is here described. Concerning the bridge – related data, it is possible to use all the sensors to extract parameters that describe the dynamic behavior of the bridge, for example frequencies and modal shapes. This can be done either by processing the response of the during the passage of a vehicle, (for instance by taking an interval of 10 seconds centered on the strain peak during the transit), or by processing a longer signal obtained concatenating all the responses measured by the same sensor at a given location.

Vehicle-related information is also extracted from strain measurements. Vehicle velocity and direction are identified based on the time lag between the peak strains at two bridge cross sections. The gross vehicle weight is estimated using the area method, as presented in [2]. The length of each vehicle is calculated by dividing its speed by the duration of the strain history recorded at midspan. Since this strain history represents the measured influence line for strain at midspan in the time domain, it remains non-zero for a period longer than the actual time the vehicle spends crossing the midspan. To account for this discrepancy a calibrated fictitious length is subtracted from the initially estimated length.

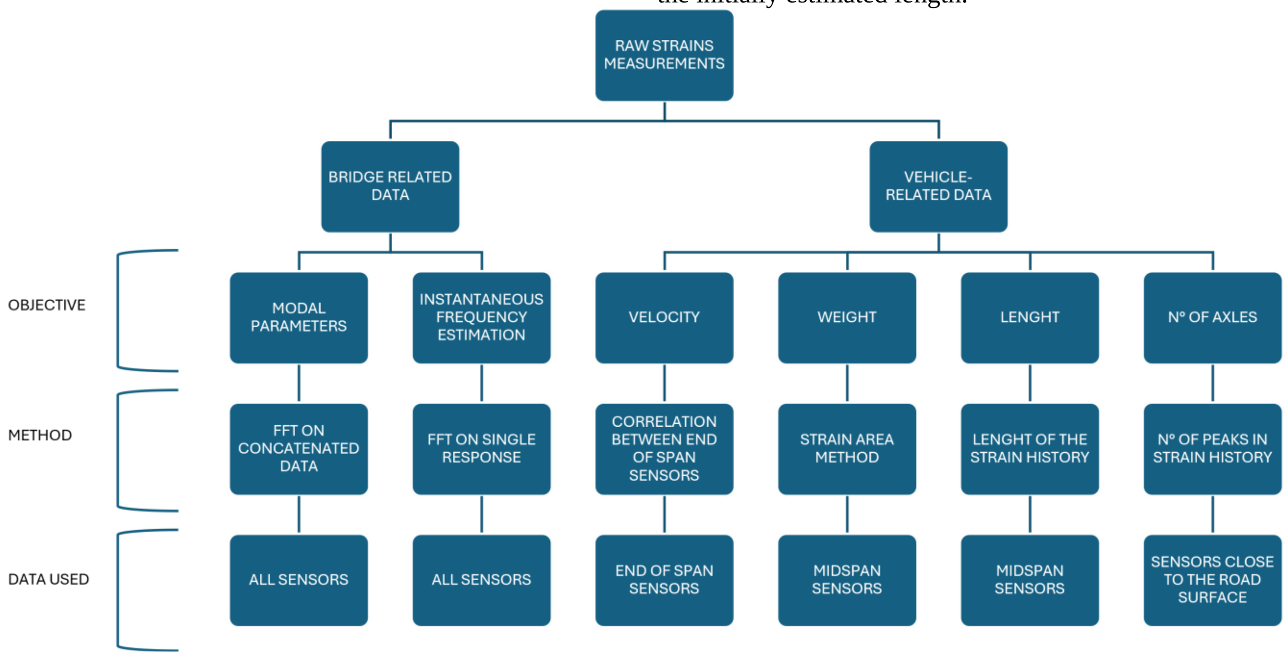

Figure 1. Flowchart of the proposed methodology.

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The number of axles is calculated by counting the number of peaks in the strain histories for sensors close to the road surface, where each peak corresponds to consecutive axles (e.g. when two axles or three axles are very close to each other, as in the case of a semitrailer, only one peak is counted).

Finally, the joint analysis of data recorded by several sensors can provide enhanced information about the bridge condition and performance. For instance, the comparison of vehicle weight and number of axles may be useful for identifying overloaded vehicles. Furthermore, it is of interest to combine vehicle-related with bridge related data, for instance to investigate the dynamic response of the bridge in relation to different vehicle typologies and speed.

3 APPLICATION ON THE SCSHM BENCHMARK

The proposed methodology is applied to the study of the SCSHM bridge benchmark [1]. The investigated structure is a simply supported span, with a length of 22.71 m, carrying two lanes. The span is instrumented with 32 electric resistive strain gages to monitor strains and six thermocouples to monitor air/structure temperature under the deck. Strain gages are placed at several cross-sections (end of spans, midspan and ¾ of the span) and at different locations within each section. The dataset contains data recorded during passages of more than 3000 vehicles, namely strains time histories from the 32 sensors, environmental temperature, and photos of the vehicles. The following results emerge from the analysis of data.

- The dynamic response is affected by the type and speed of the transiting vehicle and by temperature. The correlation between temperature and natural frequencies is shown in Figure 2 where results obtained from data relevant to the passage of more than 3000 vehicles are reported. Results highlight that an increase in temperature leads to a decrease in frequency. The decrease is more relevant where temperatures are below 0°C, due to the stiffening effect of ice, consistently with findings from other case studies [3].

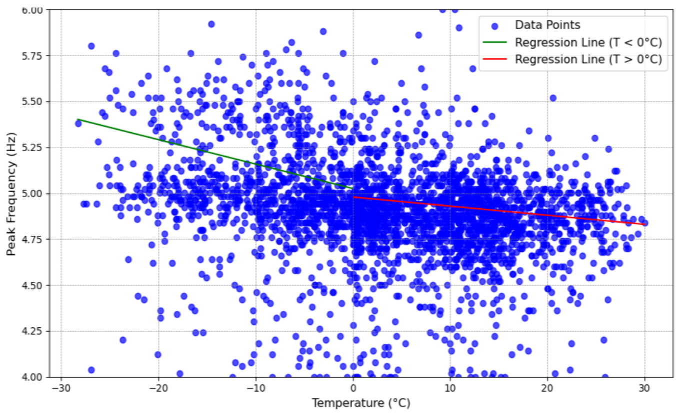

Figure 2. Scatter plot Temperature-Frequency for single vehicles passing through the bridge.

- The traffic composition in the two directions can be retrieved from the analysis of the velocity, direction and weight of each vehicle. Results suggest that the number of vehicles crossing the bridge in one direction is almost twice the number in the opposite direction. Furthermore, the weight distribution is slightly different in the two directions.
- From the combined analysis of vehicle weights and the estimated number of axles (see Figure 3), it is possible to infer if the vehicle is loaded or not. The estimate might be improved by detecting each single axle instead of groups of axles.
- The integration of vehicle-related data into bridge-related data will contribute to improving the quality of the information. For instance, the vehicle weight can be better estimated by accounting for bridge stiffness correction due to environmental temperature than can be appraised from the relationship between frequencies and temperature.

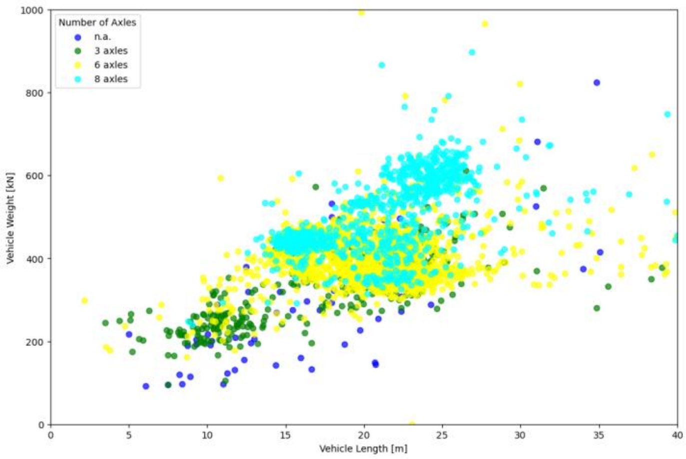

Figure 3. Scatter plot comparing vehicle length, vehicle weight and number of axles.

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