The 1st International Project Competition for Structural Health Monitoring (IPC-SHM, 2020)

Sponsored by:

- **ANCRiSST**
- **Lab of Intelligent Civil Infrastructure, Harbin Institute of Technology, China**
- **Smart Structures Technology Laboratory, University of Illinois at Urbana-Champaign, USA**
- **CCCC Highway Consultants CO., Ltd.**
- **CCCC Civil Big Data Information Technology (Beijing) Co., Ltd.**
- **State Key Laboratory for Health and Safety of Bridge Structures, China Railway Bridge Science Research Institute, Ltd.**
- **State Key Laboratory on Safety and Health of In-service Long-span Bridges, JSTI Group, China**

Welcome

As the demands on our infrastructure continue to increase, while resources remain limited, research into structural health monitoring (SHM) has grown in importance throughout the world. The combination of artificial intelligence (AI) technology with SHM offers exciting research opportunities to better ensure that our infrastructure is safe and reliable.

To foster and encourage innovation in the SHM community, especially during this difficult time with the global COVID-19 crisis, this year we are initiating an international student project competition for SHM. The competition is organized by the Asia-Pacific Network of Centers for Research in Smart Structures Technology (ANCRiSST), Harbin Institute of Technology, the University of Illinois at Urbana-Champaign, and four other companies who are leaders in the application of SHM technologies. All interested students and young scholars are invited to participate in the competition.

The competition consists of three projects, each incorporating data drawn from a full-scale bridge. The three projects are: (1) image-based identification of fatigue cracks in bridge girders; (2) data anomaly detection for SHM; and (3) condition assessment of stay cables. Certificates and cash prizes (1st prize - $1000; 2nd prize - $500; 3rd prize - $300) will be awarded for each of the three project competitions. Participants may take part in one, two, or all three projects. We will be publishing the IPC-SHM 2020 proceedings online, which will include the papers and presentation videos from contest participants. Papers from winning entries will be recommended for publication in the Journal of Smart Structures and Systems, subject to the Journal's peer review process.

We warmly welcome you to the competition and wish you good luck in your efforts!

Prof. Hui Li
Chair of IPC-SHM, 2020
Changjiang Scholarship Professor
Professor of School of Civil Engineering
Harbin Institute of Technology, China

Prof. Billie F. Spencer Jr
Chair of IPC-SHM, 2020
Nathan M. and Anne M. Newmark Endowed Chair in Civil Engineering
University of Illinois at Urbana-Champaign, Urbana, IL, USA

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Yuequan Bao	Harbin Institute of Technology, China
Jian Li	University of Kansas, USA

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Jian Zhang	Southeast University, China
Dongyu Zhang	Harbin Institute of Technology, China

Rules

- Participants must be full-time undergraduate students, M.S. students, PhD students, or young scholars within three years after obtaining their PhD.
- Participation can be by individuals or by teams (each team can have no more than 5 persons).
- Participants can compete in one, two, or all three projects.
- Registration forms must be submitted to ipcshm@yahoo.com by June 21, 2020. A data download link will be opened after registration.
- Contest entries must include: (i) commented code that will reproduce your results (MATLAB code should be tested in MATLAB 2019b or 2020a; Python code should be tested and submitted as a Google Colab notebook. Corresponding dataset for reproduction should be submitted as a shareable file link on Google Drive), (ii) a ten-minute presentation video with both the slides and the speaker clearly visible and associated PowerPoint slides, and (iii) a 10-15 pages paper following the downloadable template on the IPC-SHM website.
- The papers and presentation videos will be included in the proceedings published on the IPC-SHM 2020 website.
- All submitted material should be in English.

Prizes

- Winners will be selected by the Awards Committee based on the identification accuracy, the video presentation of the results, and the submitted paper (see IPC-SHM Evaluation Metrics below).
- First prize (1000 USD cash), Second prize (500 USD cash) and Third prize (300 USD cash) will be awarded for each of the three project competitions.
- All participants will receive certificates.

Publications

- The IPC-SHM 2020 proceedings will be published online.
- The winning teams will be invited to contribute full papers for possible publication in a special issue of the Journal of Smart Structures and Systems. Other participants will have opportunity to contribute a paper to the special issue. All papers will be subject to rigorous review.

Important Dates

- June 21, 2020 – Registration, please send the registration form to *ipcshm@yahoo.com*.
- August 31, 2020 – Submit the following items to *ipcshm@yahoo.com* for each project in which your team is competing:
  - Commented code that will reproduce your results (MATLAB code should be tested in MATLAB 2019b or 2020a; Python code should be tested and submitted as a Google Colab notebook. A corresponding dataset for reproduction should be submitted as a shareable file link on Google Drive),
  - A ten-minute video presentation, with both the slides and the speaker clearly visible, and associated PowerPoint slides (participants can use Google Drive, Baidu cloud, or other file sharing tools to upload the video presentation and share the downloadable link to the organizing committee), and
  - A 10-15 pages paper following the IPC-SHM paper template.
- September 30, 2020 – Announcement of competition winners.

Contact

- **Website:** http://www.schm.org.cn, http://sstl.cee.illinois.edu/ipc-shm2020/
- **E-mail:** ipcshm@yahoo.com

Project 1: Image-based Identification of Fatigue Cracks in Bridge Girders

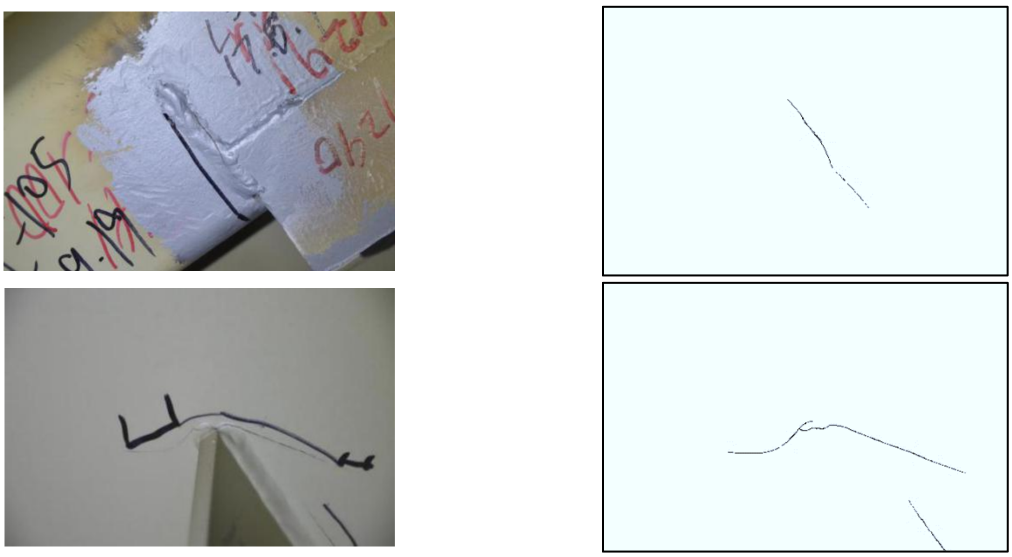
Background

In the spirit of several well-known image recognition competitions that have been organized in the field of computer vision, this first project involves an image recognition challenge for identifying fatigue cracks. We release an image dataset of fatigue cracks found in steel box girders of an in-service long-span bridge in China.

Orthotropic steel bridge decks and steel box girders are key components of long-span bridges. Due to coupled factors of initial material flaws and dynamic vehicle loads, cracks often occur at the bridge connection details, especially around welding joints. At present, the detection of fatigue cracks in steel box girders is performed by visual inspectors, which heavily relies on subjective experience and is inevitably labor and time intensive. The development of image-based fatigue crack identification methods will significantly assist the autonomous inspection of steel box girders for long-span bridges.

Data Description

The dataset includes two folders: Images (*.PNG) and Labels (*.PNG) as shown in Figure 1.1. The Images folder includes 200 original fatigue crack images with resolutions of 4928*3264 and 5152*3864. Except for 120 image-label pairs, 80 additional original images are also provided to assist the training process. The images have been obtained by different bridge inspectors and captured with a variety of internal and external camera parameters. The released image dataset is recommended to be included in the training process, while participants are also allowed to use other images to assist the training procedure. In the labeled images folder, cracks are annotated as black pixels.



(a) Original fatigue crack image (b) Pixel-level binary ground-truth label

Figure 1.1. Examples of the steel box girder fatigue crack image dataset.

Goal & Evaluation

The goal of the first project is to train a model for the semantic segmentation of fatigue crack pixels from original image data; this model should be submitted to the organizing committee for evaluation. A blind dataset consisting of 80 images with verified pixel-level labels will be used to evaluate the performance of the code submitted by each team. The performance will be assessed using the average mIoU (Intersection-over-Union) between the ground-truth and predicted cracks for all the test images.

Project 2: Data Anomaly Detection for SHM

Background

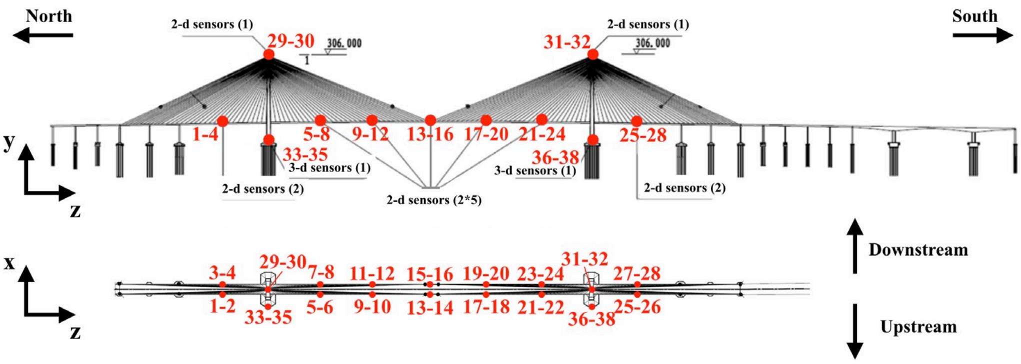
The widespread application of sophisticated SHM systems in civil infrastructure produces a large volume of data. However, the harsh environmental conditions of civil structures cause the data measured by SHM systems to be affected by multiple anomalies. These anomalies pose a significant barrier for automatic warning for damage or accidents. The identification and removal of data anomalies due to environmental variations is thus an important preprocessing step in a successful warning system.

Data Description

In this project, a dataset that consists of one-month of acceleration data for a long-span cable-stayed bridge in China is provided. There are 38 sensors, whose locations are illustrated in Figure 2.1. The sampling frequency is 20Hz. Table 2.1 describes the characteristics of the normal data and the six classes of anomalies. Figure 2.2 gives an example for each data pattern. The data structure is shown in Figure 2.3. Additionally, a dataset with labels for the time series by hour is provided by the file label.mat. For the one-month (31 days) of data for 38 sensors, the dimension of the labeled dataset is 744*38.

Goal & Evaluation

Participants should implement anomaly detection for the dataset using a method of their choice. Note that participants are not required to use image classification. The six data anomaly patterns (No. 2-7) shown in Table 2.1 should be considered, and the occurrence time and type of abnormal data should be identified. The committee will evaluate the performance in identifying these six patterns (occurrence time and type) by the submitted codes using a blind dataset.



x-direction:	2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 29, 31, 33, 36	y-direction:	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 35, 38	z-direction:	30, 32, 34, 37

Figure 2.1 The bridge and placement of accelerometers on the deck and towers.

Table 2.1 Description of each data pattern.

No.	Anomaly patterns	Description
1	Normal	The time response is normal oscillation curve; frequency response is peak-like (may differ between bridges)
2	Missing	Most/all of the time response is missing, which makes the time and frequency response zero
3	Minor	Relative to normal sensor data, the amplitude is very small in the time domain
4	Outlier	One or more outliers appear in the time response
5	Square	The time response is like a square wave
6	Trend	The data has an obvious trend in the time domain and has an obvious peak value in the frequency domain
7	Drift	The vibration response is non-stationary, with random drift

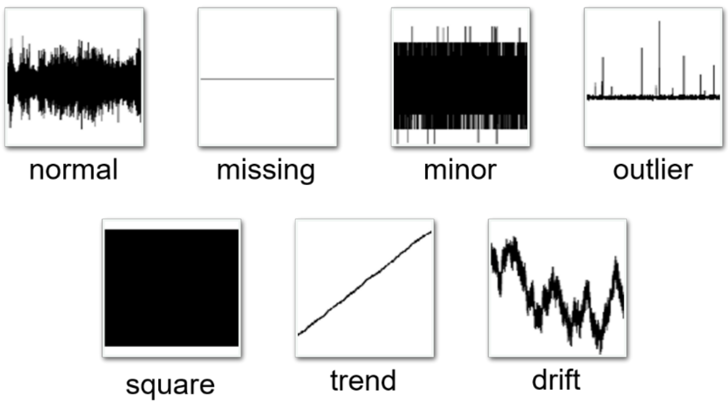


Figure 2.2 The example for each data pattern (duration of each time series: 3600s).

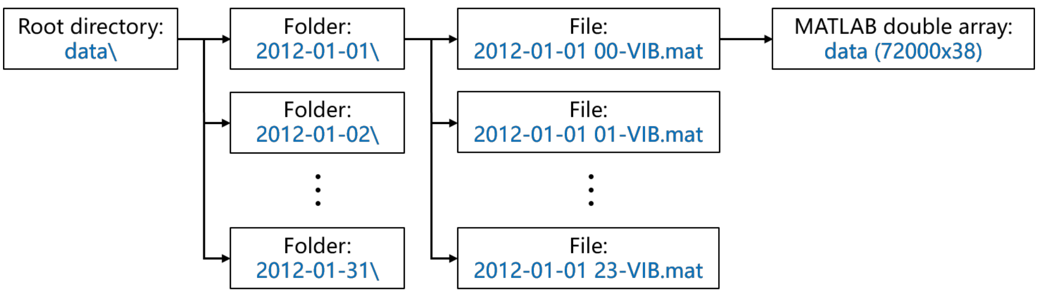


Figure 2.3 Data structure of the provided dataset.

Project 3: Condition Assessment of Stay Cables

Background

Stay cables, one of the most critical components in cable-stayed bridges, are often subject to harsh environments resulting in corrosion. Condition assessment of stay cables has long been a key topic in the SHM field. Cable tension is the most direct condition indicator of stay cables, and several vibration-based cable tension identification methods have been proposed for time-varying cable tension identification. However, cable tension response is influenced by a number of factors, including the dead load, environmental effects, vehicle loads, and cable tension redistribution due to damage; determining the condition of stay cables directly from only the total cable tension is difficult. Further research is needed.

Here we release a cable tension dataset monitored from an in-service cable-stayed bridge in China (Figure 3.1), which is a double-tower and double-cable-plane cable-stayed bridge that consists of 168 stay cables (84 pairs). Cable pairs are numbered from 01 to 21 on the tower side to the riverside/bank side (Figure 3.1). ‘S/N’ stands for cables on south tower side and north tower side respectively, and ‘A/J’ stands for cables on the bank side and riverside, respectively. For example, SJ17 represents the No. 17 cable pair on the riverside anchored on the south tower. In each pair, ‘S/X’ stands for cables on the upstream side and downstream side, respectively, e.g., SJS17 and SJX17.

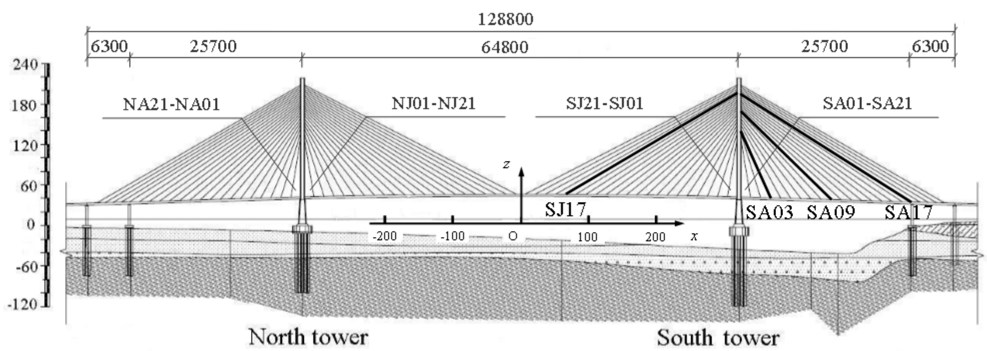


Figure 3.1 The investigated cable-stayed bridge (unit: mm).

Data Description

The published dataset in MATLAB ‘.mat’ format contains the monitored cable tension data of a group of cables (14 cables of SJS08 to SJS14 and SJX08 to SJX14) for 10 days (2006-05-13 to 2006-05-19, 2007-12-14, 2009-05-05, and 2011-11-01), and monitoring data in each day is saved in a separate mat file. Each mat file contains a 1x1 structured dataset with 2 fields named as ‘CF’, in which ‘CF.Data’ is the time-varying cable tension data and ‘CF.Sensor’ denotes the cable number. The sampling frequency is 2 Hz. Figure 3.2 illustrates a classical time-varying cable tension measured by load cell incorporated between cable and anchorage of SJS10 in 2006-05-15, in which red solid line is the trend item (dead load effects and environmental effects) and the blue peaks are the vehicle-induced cable tension.

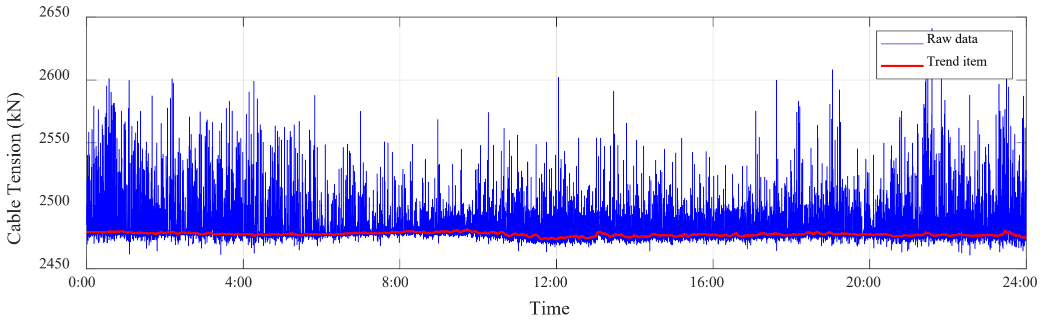


Figure 3.2 Time varying cable tension of SJS10 in 2006-05-15.

Goal & Evaluation

One out of the 14 cables was found damaged (the damage is rupture of wires) in the year 2011. Participants are required to identify which cable is damaged based on the published dataset. Details on the data preprocessing, the feature extraction, and the statistical model should be included in the submitted paper and will be evaluated together with the identification results.

IPC-SHM Evaluation Metrics

The work submitted by participants will be evaluated by the committee according to **“Identification Accuracy”, “Video Presentation”**, and **“Submitted Paper”**. The weights associated with these three parts are shown in Table 1. There will be two stages in the evaluation. The first stage is the preliminary evaluation by the organizing committee. The second stage is the final evaluation by the awards committee.

Table 1. Evaluation Metrics.

Item	Descriptions	Weighting
Identification Accuracy	The model accuracy score will be determined as follows: (1) For Project 1, a top-down ranking order of submitted models by participants will be given based on the average mIoU for the blind-test images. (2) For Project 2, the identification accuracy of the occurrence time and patterns of abnormal data will be evaluated on blind-test data. (3) For Project 3, the identification results will be evaluated based on the ground truth knowledge of all the cables.	35%
Video Presentation	The presentation will be evaluated based on: (i) originality and creativity, (ii) organization of content, (iii) oral delivery, (iv) understanding of research methodology, and (v) clarity of artwork (charts, graphs, slides).	25%
Submitted Paper	The paper will be evaluated based on: (i) adequacy of literature review, (ii) organization of content, (iii) innovation and creativity, (iv) research methodology, (v) clarity of figures and tables, (vi) technical conclusions, and (vii) language usage.	40%