Embedded algorithms for detection and location by **elastic guided waves** of controlled **delamination-type damages** in laser-impacted composite plates

sponsor: CEA-List

Prize: The team selected by the jury on this subject will win a **3 k€ prize** offered by CEA-List

1. Context

Elastic guided waves, emitted and received by a sparse network of piezoelectric transducers, represent a promising solution for Structural Health Monitoring (SHM). Numerous research teams worldwide have developed various strategies and algorithms to process guided wave signals for detecting, locating, and characterizing potential defects in diverse structures and operational contexts.

The objective of this study is to benchmark different approaches under the constraint of embedded system execution. It features an advanced motherboard, “Orchestra”, see below), with enhanced computational and memory capabilities.

Algorithms proposed by participating teams will be evaluated on a standardized structure: a composite plate equipped with eight piezoelectric transducers. A realistic delamination will be induced using the Laser Shock Wave Technique (LSWT)[1], leveraging facilities available at ENSAM (Figure 1).

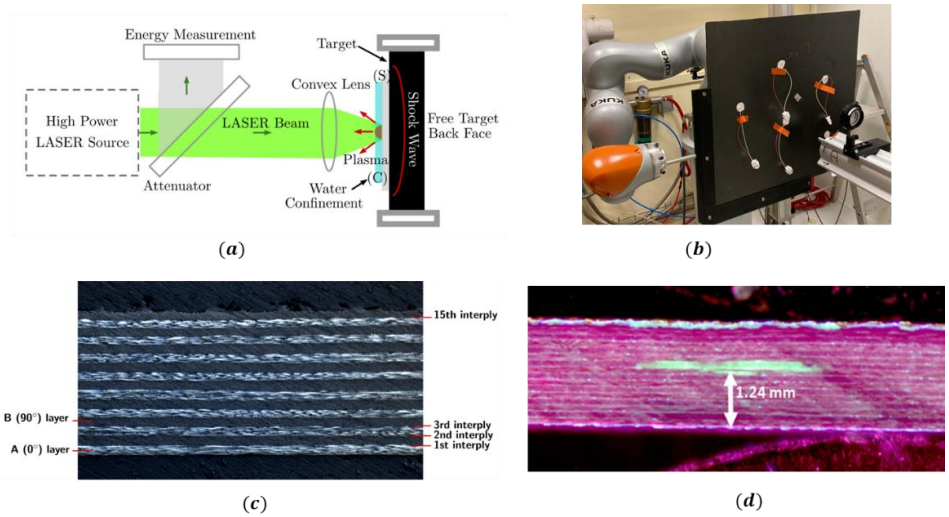

Figure 1 : The laser shock process for generating controlled damage: (a) the laser principle, (b) the automated setup, (c) a pristine 8-ply composite structure, (d) visualization of delamination controlled in size and depth.

[1] https://sam.ensam.eu/handle/10985/12394?locale-attribute=en

2. Objectives of this subject

Each team is expected to propose an algorithm to process guided wave signals captured on a quasi-isotropic composite plate of 600x600 mm² and 3 mm thickness equipped with eight piezoelectric transducers. Signals will be collected over several weeks in an uncontrolled environment. Impact damage will be introduced at an unknown time following the acquisition of a significant database of pristine signals and artificial defects (added mass) at various locations. Participants will also have access to a CIVA SHM module license to generate synthetic signals for algorithm testing and training.

The algorithms must:

- Detect the first signal after damage creation.
- Estimate the location and size of the defect.

Signals will be provided periodically by the organizers. Algorithms must run on the Orchestra motherboard and will be executed live during the EWSHM conference challenge session for performance evaluation. While AI usage is optional, any AI-based solution must be deployed using the Aidge framework, dedicated to embedded AI and available on Orchestra.

3. Tools

CIVA SHM Module: A specialized module of the CIVA software (developed by CEA and commercialized by Extende) for simulating SHM via ultrasonic guided waves. It can generate datasets with varying damage positions and sizes. Full specifications are available here.

Orchestra Motherboard: An embedded processing board for monitoring applications, developed by CEA. It will be used to run and evaluate team-developed algorithms. Full specifications are available here.

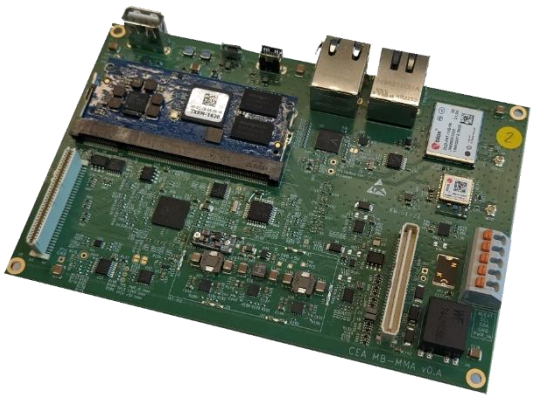

Figure 2: CEA Orchestra motherboard

Aidge: Aidge, is an open-source and collaborative platform hosted by the Eclipse Foundation, that facilitates the design of efficient deep neural networks tailored to constrained environments. Details are available here. Aidge can be downloaded on a computer to generate source code optimized to be executed on Orchestra motherboards.

The teams will receive:

- A temporary licence for CIVA SHM
- Example of configuration files for CIVA SHM + a training for the use of CIVA
- Nominal material parameters of the composite plate
- Location and type of the 8 piezoelectric transducers
- Four experimental datasets collected in an unmonitored environment over approximately two weeks
- An Orchestra board (or web-based access if the number of teams exceeds hardware availability)
- A tutorial on Aidge for deployment on Orchestra

4. Steps

- February 15st: Description of the configuration, access to CIVA SHM module and example files
- Beginning of March: Remote meetings gathering organizers and all teams on subject 2 (select emission signals and exchange about subject 2)
- March 15th: First experimental dataset of labelled pristine signals (D1)
- April 1st: 2nd dataset with labelled pristine signals (D2) + labelled artificial defect signals (D3)
- May 1st: dataset with unlabelled laser impact damage signals (D4)
- July 1st: deadline for submitting a two-page methodology and results summary
- July 7th: availability of Orchestra boards for test (if not sent to teams before)
- July 9th: presentation of results and live demonstration during a plenary session

5. Expected results

The teams are expected to develop an algorithm to process guided waves signals for damage detection, location and sizing. The algorithm must run on Orchestra board.

The teams should also propose metrics to evaluate the performances of their algorithm.

The evaluation criteria are the following:

- 40 %: Quality of the scientific approach, clarity and effectiveness of the presentation, quality of the discussions with the jury
- 40 %: Quality of the results obtained (including quality of the code published) and presented / demonstrated during the special session
- 20 %: Innovation and expected impact in the field

The teams are encouraged to share code/data under open-source licenses and to publish their results after the conference. However, this is not mandatory and the organizers and other teams will not have access to proprietary code, even if executed via a web server.

6. Organizers: CEA-List and ENSAM-PIMM

Contacts:

- Clément Fisher clement.fisher@cea.fr
- Nazih Mechbal nazih.mechbal@ensam.eu
- Bastien Chapuis bastien.chapuis@cea.fr

More info about Aidge:

https://eclipse.dev/aidge/