SHM at The University of Campania: Flaw Detection by SHM with Static Sensors approach

Alberto D’Amore and Luigi Grassia
University of Campania “Luigi Vanvitelli”, Department of Engineering,
Via Roma 19, 81031 Aversa(CE), Italy

ABSTRACT

Structural Health Monitoring (SHM) is a technology aimed at monitoring the soundness of structures. Applications for aircraft structure are largely investigated. The goal oh SHM is to utilize the information acquired during the monitoring to save maintenance costs, improve flight safety, and design lighter structures. There are different issues investigated by SHM research, like load monitoring and impact detection. Damage detection is the most largely investigated issue, i.e. developing a system that utilizes sensors to detect the structure's damages. The damage detection can be performed utilizing dynamic sensors generating waves through the structures. Defects deviate and reflect the waves so that damage can be identified. On the other hand, damage detection based on static sensors utilizes sensors measuring the strain under loads, like strain gages or fiber optics. In this case, damage is detected by the strain modification concerning the pristine structure .

The University of Campania cooperates with Leonardo Aircraft in the CERVIA National research program on developing and validating software aimed to diagnose flaws (e.g. damages, debonding, delaminations) based on measurement of the strain field. First, the strain fields under load in pristine and damaged condition are compared; damages are identified by evaluating the change in the strain field. This work has investigated two different algorithms for damage detection, patented by Leonardo Aircraft; one is based on a reverse finite element model (f.e.m.) and the other on neural network. The algorithm concepts are described in the following.

LEONARDO’s SHM ALGORITHMS

The approach of the SHM algorithm based on reverse f.e.m. is outlined in fig. 1. A network of M static sensors is first established; among the M points, N points (with N<M) are selected to compare the measured and calculated strain; the remaining M-N points are utilized for reverse f.e.m. calculation. At a given time, t, when the structure is under load, the strains in the M points are read and recorded. Next, the loads corresponding to the measured values of the M-N values are calculated (e.g. by linear analysis), using the finite element model of the structure. Then, the differences between the measured values and the same values calculated with the outlined procedure, indicate a change of the mechanical behaviour of the structure, and allow the diagnosis of a damage. The analysis can be improved by mapping the differences; the presence of differences in points in the same zones can confirm the diagnosis.

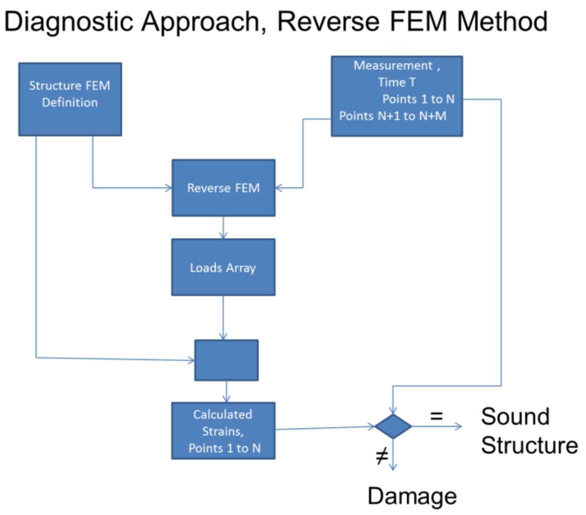

Fig.1 – Leonardo SHM algorithm based on f.e.m. approach

The described algorithm works on structures under load and requires the utilization of a f.e.m. of the structure. The quality of the obtained results is consequently dependent on the level of precision of the utilized model.

To this end, to overcome these issues, a further algorithm has been developed, based on neural network concepts. First, a network is established on a structure under load, so the strain in a point correlates with the surrounding points' strains. Then, applying a neural network software in each point allows to train the software using as input the strains of the surrounding points (slaves) and the strain in the central point (master) as output. After a sufficient number of iterations obtained in different load conditions, the neural network can foresee the value of the strain in each master point based on the strains in the slave points. In case of damage, differences between the measured strains and those foreseen by the neural network can be detected.

A typical neural network concept scheme is shown in fig. 2, showing a correlation between N input (slave) points and one output (master) point.

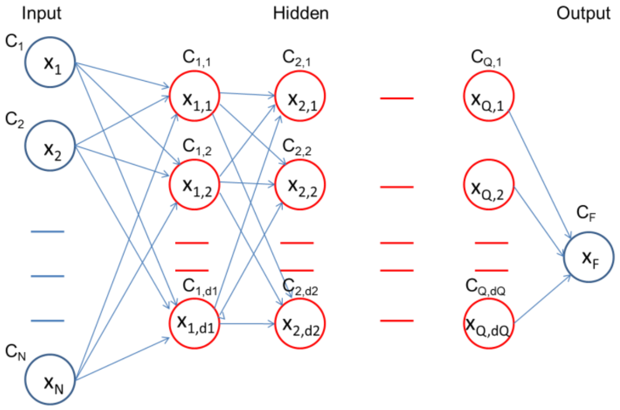

Fig.2 – Typical Neural Network correlation scheme

The logical scheme describing this approach is shown in fig. 3 (general approach) with the description of the single blocks reported in fig. 3.a (Data recording) , fig. 3.b (Neural network training) and 3.c (Structure soundness monitoring)

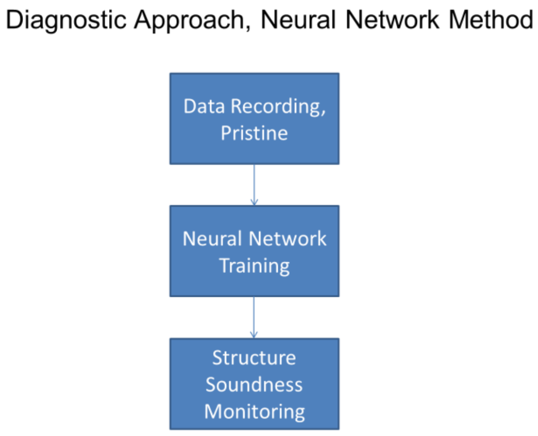

Fig.3 – Leonardo SHM algorithm based on neural network approach – general scheme

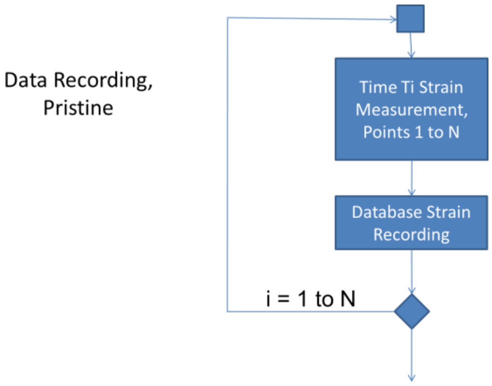

Fig.3.a – Leonardo SHM algorithm based on neural network approach – Data Recording scheme

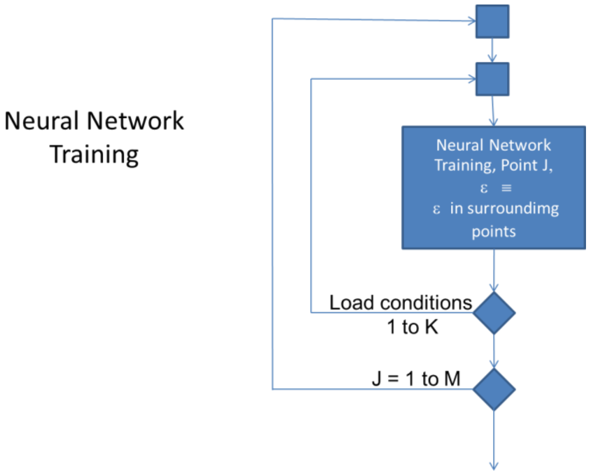

Fig.3.b – Leonardo SHM algorithm based on neural network approach – Neural Network training scheme for K condition and M points

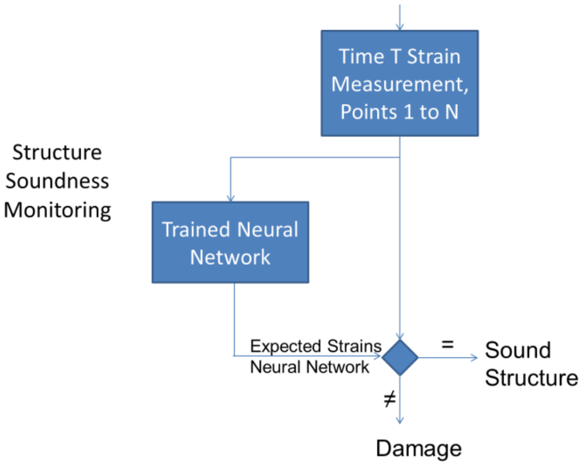

Fig.3.c – Leonardo SHM algorithm based on neural network approach – Structure Soundness monitoring scheme for N points

The above algorithm is conceived to work on structures under load but, differently from the first one, doesn't require the utilization of a f.e.m. of the structure, but is only based on data recordinga. Similarly to the first algorithm the analysis can be improved by mapping the differences; the presence of differences in points in the same zones can confirm the diagnosis. Also, comparing the results in different load conditions can be used to check the result, evaluating whether the differences between foreseen and measured strain are occasional or confirmed under different loads.

The described algorithms have been validated both virtually and experimentally. Part of the theoretical and experimental results deriving from the modeling approach developed by the University of Campania (research group in Materials Science and Technology) is reported in the following bibliographical references.

REFERENCES

[1] T.Dong, N.H.Kim, Reviews of Structural Health Monitoring Technologies in Airplane Maintenance Perspective, 2018 AIA/AHS Adaptive Structure Conference

[2] Grassia Luigi, Iannone Michele, Califano America, D'Amore Alberto "*Strain based method for monitoring the health state of composite structures"* Composites Part B: EngineeringVolume 1761 November 2019 Article number 107253

[3] M. Iannone - European Patent (granted) 2281224 "Procedure for prognostic of a structure submitted to loads" published on the European Patent Bulletin of 1/2/2012; US Patent (granted) 8,706,447dated 22/4/2014

[4] M. Iannone - European Patent (granted) "Procedure for diagnosis of a structure under loads" published on the European Patent Bulletin of 20/12/2017; US Patent (granted) 9,969,507 dated 15/5/2018

[5] M. Iannone – Italian Patent (filed) n° 102018000006499 "Procedimento per la diagnostica di una struttura sottoposta a carichi basato sulla misura di spostamenti, e sistema per l'attuazione di detto procedimento" dated 20.06.2018.

[6] Califano America, Chandarana Nehab, Grassia Luigi, D'Amore Alberto, Soutis Constantinos, *Damage Detection in Composites By Artificial Neural Networks Trained By Using in Situ Distributed Strains* Applied Composite Materials Open *Access* Volume 27, Issue 5, Pages 657 - 6711 October 2020