Ph.D. in Information Technology
Thesis Defenses

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Raffaele Malvermi– XXXV Cycle

Advanced techniques for the mapping of acoustic sources

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Abstract:

A STATISTICAL APPROACH TO NON-DESTRUCTIVE TESTING IN STRINGED MUSICAL INSTRUMENTS
Non-Destructive Testing (NDT) denotes a class of methods that are able to assess the status of a material or a system component without the need of destroying the sample. Indeed, a prediction of the property of interest is obtained as the result of an indirect measurement, i.e. typically the acquisition of a prescribed physical quantity emitted from the surface of the object. The measured quantity is assumed to be related to the property to be inspected. Therefore, any change in the measured quantity can be attributed to a change in the status of the object, i.e. from “working” to “damaged”. Since its first formalization during the industrial revolution, the use of NDT in industry has grown steadily to attenuate the risk of flaws in manufacturing processes that are becoming increasingly complex and automated. In this sense, NDT can prevent from the risk of material wasting and be an important factor of sustainability.
The experience gained by our research group in the city of Cremona, known to give the birth to some of the most famous violin makers in history and where fine violin making still takes place nowadays, has revealed how greatly this kind of craftsmanship would benefit from the use of NDT. The choices made by the violin maker everyday, while designing and making a violin, can fatally affect the durability and the sound quality of the instrument once completed. Makers have to select the raw material by their own before envisioning the instrument, according to their experience, manual skills and empirical rules of thumb. Having a quantitative way to actually measure the elasticity of a tonewood specimen before the purchase would greatly support makers in their search. Makers design the shape of the instrument, according to some models shared by the community. The outline, arching and thickness profile of the violin soundbox, in fact, play an important role in the sound. However, the occurrence of any smearing while carving the plates may deviate the sound obtained for the complete instrument from the desired one. Therefore, it would be desirable to track the effect of each adjustment made by the maker, i.e. carving or repair, on the vibrational profile of the instrument component, even when only contactless measurements are allowed on the instrument, e.g. historical violins. In addition to his/her manual skills, a violin maker should be able to assess the quality of an instrument, e.g. to define its price. The judgment relies usually on the visual inspection of the instrument, together with the perceptual evaluation of its sound. Having a measurable and objective set of descriptors would offer to makers and musicians a common ground on which to base the evaluation of a violin. Given the challenges characterizing the maker’s daily activities, the introduction of NDT into violin making can help makers to make informed and sustainable choices. However, the available NDT techniques must be adapted before being employed inside a violin maker’s workshop, by ensuring cheap, portable and real-time implementations.

In this thesis, we propose to fulfill these requirements by following a statistical approach. In practice, the proposed framework relies on concepts and methods borrowed from Data Analysis and Machine Learning, thanks to which it is possible to approximate complex models without the need of analytical formulations or strong simplifications in the description of the involved physics, thus enabling fast estimations starting from a few measures. The proposed approach is used to formalize and solve each of the previously mentioned challenges in terms of an inverse problem. We believe that this thesis can be considered as a first step towards the development of portable and cost-effective technologies with the aim to extend the benefits of Non-Destructive Testing to a wider class of manufactures, that is, in the direction of a more sustainable way of designing and using everyday products.

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