DIPARTIMENTO DI INGEGNERIA
CORSO DI DOTTORATO IN INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE -
PHD COURSE IN INDUSTRIAL AND INFORMATION ENGINEERING - 37TH CYCLE

Title of the research activity:	3D-printed smart structures for dynamic measurement.
State of the Art:	Smart structures, i.e. structures able of self-monitoring some physical quantities without the need of external sensors [1] are rapidly spreading in several engineering sectors such as aerospace [2,3], automotive [4] and bioengineering [5,6]. Additive manufacturing, due to the several advantages in terms of geometric complexity and of low production cost, is the most widely used manufacturing technique for the realization of structures with embedded sensors [7,8,9]. At the moment there are two possibilities for the realization of smart structures through additive manufacturing: an hybrid approach, where the sensing element is manually inserted during the printing process [7,8], or a multi-material technique in which the structure and the sensor are printed in a single process [7,8,11]. The recent possibilities of additive manufacturing allow, by exploiting the piezoresistive effect, realizing efficiently embedded 3D-printed sensors such as accelerometers and strain gauges [12-19]. Given the well-known feasibility of 3D-printed sensors, in recent years the research has moved towards their optimization, trying to increase both their static and dynamic performances. A set of printing parameters, that guarantee the maximum sensitivity of the instrument, is the actual research point [12,20-26]. However few research activities, about the optimization of the shape and positioning of the sensor within the structures, have been made. These last two aspects are however of considerable importance when dealing with the fabrication of smart structures for three main reasons: • Both the shape and the position of the 3D-printed sensor may contribute to a possible increase of the sensor performances. • Particular locations may introduce geometrical imperfections in the base structure, thus decreasing the structural strength of the components to external excitations. • If the sensor failed due to external loads, is it still able to monitor the phisycal quanty for which it was realized for? Since additive manufactured smart structures are frequently replacing components fabricated with conventional techniques, the previous questions must be necessarily answered. Only in this way, it would be possible to define a general procedure for the realization of 3D printed smart structures that guarantees high performance of the 3D-printed sensors, reliable smart structures and high structural strength capabilities of the component.

Short description and objectives of the research activity:

The purpose of the proposed research project is to design 3D-printed smart structures, trying to optimize (through numerical simulation, machine learning and advance approaches) the shape and the position of the 3D-printed sensor within the base structure. The main targets will be to maximize the sensor's perfomances and its ability to monitor physical quantites under whichever stress condition, trying to maintain good structural strength properties of the base structure. The results initially obtained will be experimentally validated on simple structures, with ad-hoc tests, in order to certify their accuracy. Once satisfactory results will be obtained, the 3D-printed sensors will be inserted into real mechanical components or systems, existing and/or newly produced, with applications ranging from aerospace, automotive to the agricultural sector. Since smart structures are of general applicability, many engineering disciplines will be addressed having to face problems related to structural strength, piezoresistivity and thermal effects.

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