INTERUNIVERSITY PH.D. PROGRAM BETWEEN

POLITECNICO DI BARI AND UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

IN INDUSTRY 4.0

ADDITIVE MANUFACTURING FOR ELECTRICAL ACTUATION SYSTEMS AND SENSING

PhD candidate

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Cycle

XXXVII

Tutors

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Description of the research program

Additive Manufacturing (AM) processes allow the creation of three-dimensional (3D) parts directly from CAD models, with geometric complexity and in unconventional materials. In this direction AM has been applied in the field of implementation and robotics, entering the key enabling technologies (KET) of industry 4.0, radically transforming the "smart" industrial sector. In fact, in the last decade 3D printing has made it possible to create unconventional actuators, opening up numerous lines of research, ranging from classic industrial actuators (linear, rotary, etc...) to models that imitate the movements in nature, like animals and vegetables. These are called soft robotics.

The aim of the three-year research is to create innovative actuators with fluid channels, modeled according to specific electromagnetic properties (based on the Lorentz Force), in which it is possible to insert conductive materials (or semiconductors) unconventional, surpassing the classic copper windings. Innovative actuator solutions will also be sought both in shape and in electromagnetic operation: complex geometries both hard and soft robotics that exploit different types of printable materials will be studied, designed, manufactured and tested (PLA, ABS, TPU, CNT...), different AM technologies (Fused Filament Fabrication (FFF), Stereolithography (SLA)...) and different types of power supply.

The research activity is divided into two macro areas of study:

1. Actuators. Study of new possible application frontiers of the various printing technologies and materials, applying them to electromagnetic implementation to study forms and geometries in terms of tribology, sliding, surfaces, materials and orientation on the printing surface. The objective is to research and realize a series of "unconventional" actuations for both hard and soft robotics (linear actuators, particular geometries, natural shapes etc...). These will be applied in areas ranging from industrial to biomedical, through wearable devices and sensors

2. Automation of 3D printing processes of fluid channels and conductive materials. The "internal" geometries of the actuator will be studied in order to create fluidic and microfluidic channels able to guarantee the insertion of conductive/semiconductor material in the same, moving towards a miniaturization of the channels in the first place and then of the actuators. Up to now, there is no real technology that can automate the process of creating the actuators in its mechanical and electrical parts; in this direction the goal will be to study, design and implement a fully automated process that leads to a reduction in costs and manufacturing time.

The entire activity involves the continuous improvement of the printing process parameters to optimize the geometric and tribological properties of the parts, pursuing the reduction of time and costs and having as fundamental paradigms those of process automation, miniaturization and modularization of parts.

In addition, arrangements will be made to test the sensing applied to the field of AM, using both the implementation and the sensor made by 3D printing. Also in this case, different technologies and innovative materials will be used for three-dimensional printing.

Schedule of the research activities

First academic year (planned)

	Description	Period	Activity abroad
1.1 Literature searches	State of the art literature research on the implementation of Additive Manufacturing (AM) by gallium.	1-3	NO
1.2 FFF application	Study, design, implementation and testing of AM linear actuators with Deposition technology, Fused Filament Fabrication (FFF).	3-6	NO
1.3 SLA application (miniaturization)	Study, design, implementation and testing of linear AM actuators using resin technology, Stereolithography (SLA).	6-9	NO
1.4 Comparison of design	Comparison tests of designs in activities 1.2 and 1.3. Tribological, electromagnetic and process parameters study.	9-12	NO

Second academic year (planned)

	Description	Period	Activity abroad
2.1 Literature searches	State of the art literature research on unconventional implementation in additive manufacturing (AM) and electromagnetic excitation (EM).	1-3	NO
2.2 Non-linear actuator	Study, design, implementation and testing of non-linear/soft implementation forms by different AM and electromagnetic excitation technologies.	3-9	NO
2.3 Literature searches	State of the art literature research of multi-material plastic/conductive printers (macro automation area).	6-9	NO
2.4 Innovative 3D printer realization for automizzation process	Study, design, realization of a possible 3D printer customized for application needs (conductive material in fluidic microchannels). Actuator realization.	9-12	NO

Third academic year (planned)

	Description	Period	Activity abroad
3.1 Literature searches	State of the art literature research on actuation and sensing by electromagnetic excitation through direct ink writing (DIW).	1-3	YES (Karlsruhe institute of technology (KIT), Germany)

3.2 3D printing of DIW actuators	Study, design, implementation and testing of linear/non-linear/soft implementation forms using different DIW technologies and electromagnetic excitation (automatic process) and sensing devices.	2-6	YES (Karlsruhe institute of technology (KIT), Germany)
3.3 Literature searches	State of the art literature research of devices manufactured in AM (soft, electromagnetic, etc.) for sensing.	6-8	NO
3.4 3D printing sensing devices	Study, design, implementation and testing of devices exclusively for sensing made using different AM technologies.	8-12	NO

Provisional training and research activities plan

First academic year (planned)

	Description	**Period**	**Duration**	**CFU**
PhD courses	Multidisciplinary Research Applications of 3D Printing	3-9		2
	Implementation and application of Design of Experiment techniques to experimental and numerical campaign	3-9		2
	Flexible and Stretchable Electronics	6-11	20 hours	2
Master's degree courses	Tecnologia meccanica II	6-12	6 months	6
Participation to seminars and international congresses or workshops	Polibathon "sostenibilità" (Associazione ADI Politecnico di Bari)	2	3days	3
	AITEM Academy di base "L'innovazione in ambito tecnologie e sistemi di lavorazione manifatturieri", Politecnico di Milano	3	3 days	4
Presentation of research products at international congresses or workshops	CIRP-BIOM: V cirp conference on biomanufacturing	9	3days	5
	TOTAL OF CFU FOR TRAINING ACTIVITIES			
Individual research activity	Bibliographic research, study and design of artifacts, realization of artifacts, laboratory tests, use of printers for AM.	1-12	12 months	27
Students' supervision	Supervision in lab activities and thesis for students	6-12	6 months	3
Integrative didactive activities				
Preparation of manuscripts for conferences or journals	Research articles for Cirp, AM magazines on linear implementation through AM and EM.	3-12	9 months	6

	TOTAL OF CFU FOR RESEARCH ACTIVITIES	
	TOTAL OF CFU FOR YEAR I	**60**

Second academic year (planned)

	Description	**Period**	**Duration**	**CFU**
PhD courses	. Human-based Smart Manufacturing Systems	1-6	20 hours	2
Master's degree courses	Electrical drives for industrial applications (frequenza)	6-12	6 months	3
	Meccanica applicate alle machine II	4-12	6 months	6
Participation to seminars and international congresses or workshops				
Presentation of research products at international congresses or workshops				
	TOTAL OF CFU FOR TRAINING ACTIVITIES			
Individual research activity	Bibliographic research, study and design of artifacts, realization of artifacts, laboratory tests, use of printers for AM, realization custom printer.	1-12	12 months	33
Students' supervision	Supervision in lab activities and thesis for students	1-12	12 months	6
Integrative didactive activities				
Preparation of manuscripts for conferences or journals	Research articles for AM magazines on innovative implementation through AM and EM; on open custom printer implementation.	4-12	8 months	10
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			
	TOTAL OF CFU FOR YEAR II			**60**

Third academic year (planned)

	Description	**Period**	**Duration**	**CFU**
PhD courses	New Frontiers Of Scientific Research Based On 3d Printing In Structural And Building Engineering	1-6		2

Master's degree courses				
Participation to seminars and international congresses or workshops				
Presentation of research products at international congresses or workshops				
	TOTAL OF CFU FOR TRAINING ACTIVITIES			
Individual research activity	Bibliographic research, study and design of artifacts, realization of artifacts, laboratory tests, use of printers for AM and DIW.			46
Students' supervision				
Integrative didactive activities				
Preparation of manuscripts for conferences or journals	Research articles for AM magazines on implementation and innovative sensors through AM and EM.			12
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			
	TOTAL OF CFU FOR YEAR III			**60**
	TOTAL OF CFU FOR THE WHOLE PHD COURSE			**180**