# CSC Program 2020

## 1 TITLE

Artificial intelligence based generative design for 4D printing

## 2 KEYWORDS

Machine learning, artificial intelligence, generative design, smart material, simulation, voxel modeling, 4D printing, additive manufacturing.

## 3 PRESENTATION OF THE RESEARCH TEAM

The ICB UMR 6303 CNRS lab is composed of six research departments in which COMM department leads research efforts on design, modeling and optimization of mechanical systems. In such a department, three issues are addressed :

1) Mechanical modeling and optimization;
2) Manufacturing processes and techniques optimization;
3) Advanced design of mechanical systems.

Among these research works, a cross research theme has recently been emerged in order to address the artificial intelligence based generative engineering for 4D printing of transformable systems. Therefore, this PhD thesis proposal is part of this aforementioned theme, fully innovative regarding current scientific issues in France or even within the international community, more specifically at Georgia Institute of Technology. The applicant will be also associate to the Laboratory for Mechanics of Soft Materials and 3D Printing, in which Prof. H. Jerry Qi is leading a team focused on 3D printing of soft active materials (like shape memory polymers, light activated polymers, etc.) to enable 4D printing methods, and also on a wide spectrum of 3D printing capability including multi-material inkjet 3D printing, Digital Light Processing 3D printing, Direct Ink Writing, and Fused Deposition Modeling.

## 4 DESCRIPTION OF THE PHD SUBJECT

This PhD proposal falls under the scientific calls “Engineering Science – New theory and technology of manufacturing” and “Science of materials and new materials – Calculation of materials and simulation for design”, and focuses on generative design methodology for transformable products by considering 4D printing technology, the emerging technology combining additive manufacturing techniques and stimulus-responsive materials. Nowadays one can definitively state that the products of the future must be sustainable, modular, transformable and/or adaptable to the human being and context that surrounds it. This is true for both manufactured products that require continuous evolutionary processes. New development strategies consequently become urgent and crucial to define and produce augmented solutions that are able to evolve in order to deliver the appropriate functionality at the right time and in the right context. Essential to this trend is to understand the progress of product capabilities, intelligent materials and manufacturing technologies in industry over the last decades. Starting from mechanical solutions, then mechatronics systems to recently towards connected objects, and again more recently to smart products, industry – falling under the umbrella of industry 4.0 initiative – have successfully shift over these first three kinds of product. However, a major gap still exists to become mature with the development of smart products (i.e. products with the ability to transform in order to perform different functionalities or enhanced functionality), especially those produced by combining additive manufacturing technologies and active materials (i.e. stimulus-responsive materials allowing products to sense and react accordingly to their environment).

This first industrial barrier is actually due to the maturity level of advanced additive manufacturing techniques associated to multi-material printing capabilities and the lack of knowledge on smart materials behavior and distribution to be considered and defined from the conceptual design stage where the functional aspect of the product is committed. This also coincide with the instinctive intent to develop products that makes sense and naturally biologically-inspired solutions in order to build "living" objects once manufactured and stimulated. In such emerging research area, one major research issue consists in designing 4D printing friendly solutions as soon as possible in the conceptual design. Here the main objective of this PhD proposal is to combine Artificial intelligence-based computational simulation (machine learning, digital morphogenesis, etc.), digital manufacturing technologies and multi-physics concurrent consideration in design. Such efforts will reinforce ongoing research works on design for 4D printing and extend current computational mechanisms and 4D printing knowledge. The student could explore computational mechanisms and innovative modeling techniques via Rhinoceros 3D (including plug-ins like Grasshopper, Kangaroo, etc.) in order to model and simulate dynamic design solutions. From a physical point of view, the student could customize do it yourself 3D printers with increased capabilities so as to cover 4D printing advantages, and also use commercial advanced multi-materials 3D printers. The PhD student will collaboratively work with other PhD students working on related research issues, especially addressing design for 4D printing issue applied to transformable products, at UTBM (France) and Georgia Institute of Technology (USA).

## 5 SUPERVISORS

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