**Call for PhD candidates**

## 1. PhD thesis description

### PhD Title

> Generative design of structures integrating digital materials based on artificial intelligence and robotic systems programming for 4D printing

### Keywords

Design; 4D printing; Smart materials; Additive manufacturing; Robotic; Artificial Intelligence

### Presentation of the research team

The ICB UMR 6303 CNRS lab at Univ. Bourgogne Franche-Comté / Belfort-Montbeliard University of Technology 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 currently 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 – led by **Prof. Frédéric Demoly** – has recently been emerged in order to address the design, modeling and optimization 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 and University of Colorado.

### Description of the PhD subject

Based on these current technological advances, the path of multi-material 4D printing can be understood as a disruptive and interdisciplinary risk-taking. This scientific orientation breaks voluntarily with the work of the key actors of the 4D printing field. Indeed, the innovative work of the ICB UMR 6303 CNRS laboratory opens up promising prospects for the creation of a start-up company in the medium term, claiming advanced design/simulation methodologies, software tools coupled with artificial intelligence (AI) and a hybrid 4D additive manufacturing system using poly-articulated robots.

These first technological bricks require user feedback, essential for continuous improvement and adoption, but especially scientific and technological reinforcements. Thus, the proposed thesis topic concerns the generative design of AI-based multi-material structures for 4D printing. The originality lies, on the numerical level, in designing objects capable of changing shape by exploiting different representations (geometric skeletons, solids and voxels). These representations are essential to integrate business knowledge and constraints, but also to apply qualitative (symbolic AI) and quantitative (connectionist AI) reasoning. The representation of 3D/4D objects based on voxels, exploiting digital materials, raises the greatest number of scientific issues regarding the need for reasoning on how to distribute properties and materials in the design space, but also for the control of the manufacturing phase. The manufacturing of 4D composite objects (multi-materials), involves multiple strategies to investigate.

### Supervisors

**Prof. Frédéric Demoly**
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## Candidate skills

Mechanical design and modeling, materials science, robotics, open-mindedness, autonomy, programming skills, motivation for entrepreneurship.

## Application

Applicant must send CV, motivation letter, and transcripts to frederic.demoly@utbm.fr by 05/15/2022.

## 2. References related to the PhD thesis

[1]  Sossou G., Demoly F., Montavon G., Gomes S., Design for 4D printing: rapidly exploring the design space around smart materials. *Procedia CIRP*, 2018, 70, 120-125.

[2]  Ge Q., Qi H.J., Dunn M.L., Active materials by four-dimension printing, Applied Physics Letters, 2013, 103(13), 131901.

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[4]  Sossou G., Demoly F., Belkebir H., Qi H.J., Gomes S., Montavon G., Design for 4D printing: A voxel-based modeling and simulation of smart materials, Materials and Design, 2019.

[5]  Hamel C., Roach D., Long K., Demoly F., Dunn M., H.J. Qi, Machine-learning based design of active composite structures for 4D printing, Smart Materials and Structures, 2019, Accepted.

[6]  André J.-C., From additive manufacturing to 3D/4D printing 1 – From Concepts to Achievements. ISTE Wiley, November 2017, 354p.

[7]  Sossou G., Demoly F., Belkebir H., Qi H.J., Montavon G., Gomes S. Design for 4D printing : A voxel-based modeling and simulation of smart materials. Materials & Design, 2019, 175, 107798.

[8]  Sossou G., Demoly F., Belkebir H., Qi H.J., Montavon G., Gomes S. Design for 4D printing : Modeling and computation of smart materials distributions. Materials & Design, 2019, 181, 108074.

[9]  Sun X., Yue L., Yu L., Shao H., Peng X., Zhou K., Demoly F., Zhao R., Qi H.J., Machine Learning-Evolutionary Algorithm Enabled Design for 4D-Printed Active Composite Structures. Advanced Functional Materials, 2022, 32 (10), 2109805.

[10] Demoly F., Dunn M.L., Wood K.L., Qi H.J., André J.-C., The status, barriers, challenges, and future in design for 4D printing. Materials & Design, 2021, 212, 110193.

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