Job title	**PhD Theory, model and approaches to the design of smart products/systems by using 4D printing technology and programmable materials**
Ref	2018-12-HERMES
Job type (PhD, Post-doc, Engineer)	**PhD**
Contract duration (months)	36 months
Qualifications (Master degree, PhD...)	Master degree
Job hours (full time/ part time)	Full time
Employer	UBFC – Université de Franche-Comté
Host Laboratory	ICB lab (Laboratoire Interdisciplinaire Carnot de Bourgogne) is a research unit of the Université de Technology de Belfort-Montbéliard (UTBM). In this institute, COMM department works on the following research issues: • Proactive design of mechanical systems by using the theory of spatiotemporal mereotopology, so as to provide a better integration, efficiency and flexibility in the product development process; • Additive manufacturing and the different underlying processes and the development of specific materials. Therefore, this PhD thesis proposal is part of a cross-sectoral theme (design of product-process-material interaction including intelligence), fully innovative regarding current scientific issues within the international community.
URL Host Laboratory	http://icb-comm.utbm.fr
Address Host Laboratory	UTBM, Rue du Château, 90010 Belfort Cedex
Job description	Over the last two decades, manufacturing industry has been progressively forced to increase product/system capabilities and compact its lifecycles by ensuring a certain level of flexibility and efficiency as competitive edges,

especially in the development phase where design activities and decisions have a great impact on downstream processes (i.e. manufacturing, assembly, etc.). This has been successfully achieved by considering (i) the capture and integration of lifecycle constraints and knowledge (e.g. design for X – DFX spectrum approaches, advanced Computer Aided Design – CAD) in mechanical product design so as to deliver lifecycle friendly products, (ii) the integration of other disciplines such as electronic in mechatronic product design and (iii) the integration of computing capability in the era of the Internet of Things for connected objects.

Such kinds of system have generated interesting and fruitful results in terms of theories, models, approaches and tools with a high level of maturity (from Levels 4 to 5). One promising and emerging trend consists in augmenting *systems/products responsiveness* and *smartness* once manufactured regarding user needs, and then increasing their lifetime by providing appropriate usage configuration in a specific use context and environment. Over the last five years, the emergence of *smart products/systems* (i.e. products/systems that are capable to adapt to their environment, self-assemble, repair themselves, able to sense their environment and react accordingly in a programmable manner, etc.) and *innovative additive manufacturing technologies* has required to deeply revise current well-established design and engineering approaches so as to deliver *dynamic product definitions* (i.e. product geometry embedding *functional material* and a *transformation logic*) at various levels of description (i.e. building, mechanical assembly, material, etc.). Such initiatives still remain ad-hoc from a maturity level point of view, and deserve to be intensively explored in the upcoming years.

This PhD proposal is part of a much larger project – called HERMES *(spatiotemporal semantics and logical knowledge description of mecHanical objEcts in the era of 4D pRinting and programmable Matter for nExt-generation of CAD systemS)* – which falls under the scientific issue "Advanced materials/processes and smart systems", and mainly focuses on the development of theory, model and approaches to the design of smart products/systems by using 4D printing technology and programmable materials. Nowadays, the concept of 4D printing technology is seen as an emerging and innovative way to build active/responsive and reversible mechanical structures by combining additive manufacturing capabilities and smart/functional materials, therefore providing an additional dimension to manufactured physical products/systems, time.

This capability offers information storage, computation and transformation in shape and/or material property. One important challenge consists in tackling the lack of support to ensure shape/material programmability in the early design stages as well as physical capabilities in fabrication. In other words, new design tools are needed to fully take advantage of the complex dynamics, multi-material programmability, self-assembly and self-reconfiguration behaviors, and domain-specific knowledge. In such a way, the fact of designing and manufacturing programmable products/systems – able to evolve in different contexts (e.g. state transformation, kinematic, form, etc.) to provide an appropriate service to the final user – will require engineering and manufacturing research efforts at different levels, such as product/system level (mechanical structure to smart systems), process level (traditional

	manufacturing to additive manufacturing) and material level (traditional material to smart ones).
	The definition of physical objects and their relationships over space and time requires a **common sense engineering approach**, also called **transdisciplinary approach**, that concerns and governs many disciplines in a top-down fashion. Indeed, this crucial issue is currently tackled from various perspectives in the domains of geomatics, computer science, engineering and materials science to name a few, but a harmonization is needed to fully embrace 4D printing and programmable matter capabilities. Actually both promising technologies address the spatial change (i.e. configuration, shape and physical properties) of physical objects over time but with specific approaches, which need to be aligned and adopted from a semantic and logical point of view for further computational issues in design of smart products/systems.
	4D printing is based upon the interaction of additive manufacturing and smart materials so as to build active/living objects with external stimuli (e.g. temperature, pH, light, electricity, mechanical force, magnetic force, etc.). As for programmable material, matter has the ability to change its physical properties (e.g. shape, density, optical properties, etc.) in a planned manner based on autonomous sensing. Such promising concepts tackle a common issue but at different hierarchical levels (i.e. building, physical object, material, etc.). Therefore, it becomes vital to establish a concrete semantic and logical foundation, on which several stakeholders from various research fields can refer to.
	Therefore, this PhD proposal aims at elaborating (i) a strong foundational theory enough suitable for covering the semantic and logical description of dynamical phenomena knowledge at various scales (i.e. territory/building, mechanical assembly, material, etc.), (ii) a multi-layer ontology for semantic and logical reasoning, on which (iii) computational mechanisms will be developed in order to deliver dynamical CAD models ready for 4D printing.
	This PhD will be supervised by three representative and complementary actors with key competencies in the Bourgogne Franche-Comté (BFC) region, leading cutting edges research efforts in: (i) the description of dynamical phenomena over time in geospatial environment (UB-Le2i) and (ii) the spatiotemporal mereotopology-based theory for describing the evolution of engineering entities and their relationships over space and time for mechanical assemblies and 4D printing applications (UTBM-ICB). Such supervision team will provide a great opportunity to share interest and develop transdisciplinary knowledge research to computational challenges on increasing smartness of system at various physical levels.
Supervisor(s)	**Dr. Frédéric DEMOLY** Head of Product design and development branch Deputy Director of S-mart Franche-Comté academic society ICB UMR 6303, CNRS Mechanical Engineering and Design Department Univ. Bourgogne Franche-Comté, UTBM Tél.: +33 (0) 3 84 58 39 55 F-90010 BELFORT Cedex, France frederic.demoly@utbm.fr

	Dr. Christophe CRUZ Head of Smart Environment department Laboratoire LE2I – FRE 2005 IUT Dijon-Auxerre, Départ. Informatique, UBFC christophe.cruz@ubfc.fr **Prof. Samuel GOMES** Head of ICB-COMM department Head of Mechanical Engineering and Design department ICB UMR 6303, CNRS Univ. Bourgogne Franche-Comté, UTBM samuel.gomes@utbm.fr
Candidate profile	
Keywords	Mereotopology, Ontology, Semantics, Product design, Smart materials, Additive manufacturing, 4D printing, Computer-Aided Design
Application deadline	25th of June, 2018
Starting Date	September 1, 2018
Application	**PhD Position** Please send the following documents (all in one PDF file) by e-mail to job-application@ubfc.fr: 1) For EU candidates: Copy of your national ID card or of your passport page where your photo is printed. For non-EU candidates: Copy of your passport page where your photo is printed. 2) Curriculum Vitae (1 page). 3) Letter of motivation relatively to the position (1 page). 4) Copy of your Master degree and/or Engineer degree if already available. 5) Copy of your final marks and ranks. 6) Coordinates of reference persons (maximum 3, at least your master thesis supervisor): Title, Name, organization, e-mail. If you have questions regarding the application, please contact the supervisors.