

University Politehnica of Bucharest
Department of Quality Engineering and Industrial Technologies
Faculty of Industrial Engineering and Robotics

HABILITATION THESIS

Theoretical and experimental scientific contributions to
Industry 4.0
(Intelligent automation, additive manufacturing, augmented reality)

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Bucharest, 2019

Abstract

The habilitation thesis is a synthesis of the scientific activity carried out from the completion of the doctoral thesis (June 2002) until July 2019. Thus, it contains the author's scientific contributions in the implementation of industry 4.0 concepts. It is largely based on the results of several research projects in the field of using informational techniques to optimize industrial processing: additive manufacturing, augmented reality, image processing and non-destructive control. In the research projects that were awarded as grants through national or international competition, the author was either the project manager, project responsible, a member in the scientific research team, or a member of the target group (as in the case of the postdoctoral research project):

- POSDRU/89/1.5/S/62557, Excelență în cercetare prin programe postdoctorale în domenii prioritare ale societății bazate pe cunoaștere (EXCEL), **postdoc researcher**, 2011-2013
- “FabLab cu tehnologie integrată de fabricație folosind realitate augmentată și imprimare 3D pentru echipamente de inspecție nedistructivă cu ultrasunete” - RA3DCND, PN-III-P2-2.1-BG-2016-0036, Contract 35BG/2016, 2016-2018, **project manager**
- „Sistem și metoda de imprimare 3D folosind materiale maleabile (P3DM)”, Grant intern Universitatea Politehnică din București, ID 263, 2016-2017, **project manager**
- Metoda de inspecție a lipiturilor de plexiglass, Contract „Cecuri de inovare” nr. 30CI/11.06.2012, **project manager**, 2012
- PN-III-P2-2.1-CI-2018-0987 166CI din 04/07/2018 Imprimare 3D pentru industria de tehnică de calcul – P3DIT finanțat prin programul PNIII, P2, Cecuri de Inovare, **project manager**, 2018
- FabLab 3D pentru industria de încălțăminte – 3DFI Fonduri PNIII, PN-III-P2-2.1-CI-2017-0490 27CI/2017, 2017, **project manager**
- „Augmented Reality and 3D Printing for technical entrepreneurs” (ARTE-3DP), Finanțat prin Mecanismul Financiar SEE 2009-2014, 16-SEE-PCB-RO BUCURES11/01, Proiecte de Cooperare Inter-Instituțională, Programul SEE RO15, 2016, **project manager**
- Global Digital Manufacturing – Industry 4.0 Joint Curriculum and Research, EEA GRANTS 2014-2021, Cooperation projects in higher education area, Strategic Partnerships, EY-COP-0001, **project manager**, 2018-2020
- „Augmented Reality for Technical Entrepreneurs” (ARTE), Finanțat prin Mecanismul Financiar SEE 2009-2014, EEA Grants, Proiecte de Cooperare Inter-Instituțională, 14-SEE-PC-RO BUCURES11, 01.06.2014-31.05.2016, **project manager**
- Platforma Online Inteligentă Colaborativă Pentru Proiectarea și Fabricarea Ghidajelor Personalizate în Chirurgia Ortopedică, PN-II-PT-PCCA-2013-4-0251, **researcher**, 2014-2016

- Sistem integrat de printare 3D a unor piese interconectate, UPB-GEX nr IM 21-17-05, 2017, **researcher**

The constant interest of the author lies in the implementation of IT techniques in industrial processes, including for their optimization. In this context the author mentions the use of artificial intelligence in industrial image processing for quality inspection on the manufacturing line. Moreover, as one can see from the list of implemented projects, author contributions were also in the field of rapid prototyping, or more specific to what nowadays is called additive manufacturing (noting the differences on those two terms in the context of literature review). The author has a special interest in improving an existing digital manufacturing technology – FDM (Fused Deposition Modelling), also known as MED3DP Material Extrusion 3D Printing. In the present, this technology can produce excellent results with minimum costs and without the need of expensive equipments.

Almost all of the author's scientific research interests are gravitating around the basic concepts of what it is known today as Industry 4.0 (a combination of physical and cybernetic systems used to develop autonomous integrated production processes).

As a direct consequence, the habilitation thesis is organised as follows:

- **Chapter 1 – Introduction to Industry 4.0** – depicts a small introduction of the basic concepts that are now integrated into Industry 4.0 in order to put into the right context the scientific research results presented in the next chapters;
- **Chapter 2 – Contributions regarding intelligent automation of production processes. Automated inspection of industrial products** – presents the scientific contributions regarding the automation of inspection processes of industrial products; these include the design and implementation of a prototype intelligent automated system for non-destructive testing of industrial products using liquid penetrant method and an installation for inspection of Plexiglas illuminated sign boxes; the intelligent system designed and realised within the Faculty of Industrial Engineering and Robotics, University Politehnica of Bucharest (formerly IMST) is based on applying artificial intelligence techniques for industrial image processing (applying Competitive Hopfield Neural Network in conjunction with fuzzy logic in order to determine whether a product corresponds to the expected manufacturing quality); such a system comprises a unit for image acquisition from the product that needs to be inspected, a unit for image processing based on artificial intelligence techniques and a unit that automatically detects from the results provided by the image processing unit the presence of defects in the inspected product;
- **Chapter 3 – Contributions to the field of additive manufacturing** – depicts the author contributions in the field of additive manufacturing; the author presents the design and implementation of a prototype system for 3D printing with maleable materials (such as clay, plasticine, gels, etc.) in conjunction with the polymers; one of the unique capabilities of additive manufacturing over classical manufacturing methods is the possibility to create interlocking parts without the need of assembly, thus leading to the creation of rotational and translational joints in demonstrative or functional 3D models; the scientific contributions lie in analysing the process parameters which need

to be considered when fabricating parts with cylindrical or spherical rotating joints using material extrusion 3D printing (joint tolerance and clearance, surface finish requirements, surface shape and dimensions or surface precision and trueness as they result from the converting ideal CAD files to the common file formats used in additive manufacturing)

- **Chapter 4 – The use of augmented reality in the support activities of industrial processes** – presents how one can use novel technologies such augmented reality in training activities for the industry, but also the use of such technology in the medical field;
- **Chapter 5 – Plans and objectives in the development of the future career** – this chapter depicts the authors main research directions