

UNIVERSITY OF CRAIOVA

Programme: *Partnerships in Priority Domains, Applied research collaborative projects*

UEFISCDI Project code: PN-II-PT-PCCA-2013-4-0544

Title of the project: *Advanced control systems for bioprocesses in food industry (ADCOSBIO)*

Contract no.: 211/2014

Period: 01.07.2014-31.09.2017

## REPORT OF ACTIVITY

### - Synthesis -

#### Phase III / 2016

#### Process analysis and the design of advanced control techniques for bioprocesses in food industry and wastewater treatment

The project ADCOSBIO follows the recent research trends in order to apply the research results to bioprocesses in food industry, particularly to bread production and to related wastewater treatment processes. Bioprocess modelling and control can be successfully achieved using interdisciplinary approaches from control engineering, biochemistry, applied mathematics and information technology. The bioprocesses are complex nonlinear systems, characterized by modelling uncertainties, interconnections, delays, and lack of cheap and reliable instrumentation. In the project these interdisciplinary approaches will be used to develop advanced monitoring and control systems.

The main research objectives of ADCOSBIO project are as follows:

1. Analysis and modelling of processes in food industry;
2. Development of novel estimation and identification techniques for bioprocesses;
3. Design of advanced control techniques for three classes of bioprocesses;
4. Implementation of advanced control systems for processes in food industry.

***Within the third phase of the project (III/2016)***, several researches from the third objective and partially from the fourth one were accomplished. In accordance with the project plan, the following specific research activities were achieved:

#### **Activity III.1**

Design of neural networks based adaptive control techniques for fermentation bioprocesses and for wastewater activated sludge bioprocesses

#### *Obtained results:*

- Innovative techniques for the design of adaptive control algorithms by using dynamical neural networks. The neuro-adaptive algorithms were implemented and tested for two case studies: a micro-algae fermentation bioprocess and an activated sludge bioprocesses, both with applications to wastewater treatment processes. (Scientific Report)

### **Activity III.2**

Development and laboratory testing of hybrid intelligent techniques for bioprocesses

*Obtained results:*

- Hybrid intelligent control technique for wastewater treatment bioprocesses, obtained by combining the nonlinear model predictive control (NMPC) with the dynamical systems modelling by using neural networks (RBNN) and by solving the optimization problems with meta-heuristic algorithms – PSO (*Particle Swarm Optimization*). (Scientific Report)

### **Activity III.3**

Study and technical documentation for the wheat grinding process (at partner P1)

*Obtained results:*

- Studies, technical documentation and tests at the wheat grinding process located at partner P1 (Calafat Mill): general description and technological flow, technical description of the electrical equipment and of wheat grinding installation. A detailed technical documentation for the process analysis was prepared at partner P1.

### **Activity III.4**

Technical report for the flour processing (P1)

*Obtained results.* The analysis of flour processing at partner P1:

- Operational flow scheme of the process;
- Analysis of the physical and biochemical properties of the wheat and of the flour;
- Analysis and tests of the wheat quality.

### **Activity III.5**

Industrial process analysis for the bread production (P1)

*Obtained results.* Study and technical specifications of the bread production process:

- General description and technological flow at bread factory;
- Technical specifications of the primary equipment (oven, dough processing machines, etc.), including the control equipment;
- State feedback solutions and optimal solutions for drive control with applications in food industry;
- Modelling and control techniques for conveyers.

### **Activity III.6**

Study and technical documentation for the activated sludge wastewater treatment process

*Obtained results:*

- Description of the technological flow at the Wastewater treatment station Calafat (process general lines, mechanical and biological stages);
- Technical specifications: technological equipment and primary control loops.

### Activity III.7

Dissemination of research results

*Obtained results:*

- Publishing of two papers in ISI (WoS) indexed journals (under review the last year): *Combustion Science & Technology* (Taylor & Francis) [Rom16a], article awarded by UEFISCDI in 2016; *International Journal of Biomathematics* [Rom16b];
- A research stage at the Department of Automatic Control, CentraleSupélec, France, and two research stages at Department of Automation and Info-communication, University of Miskolc, Hungary;
- Participation with 8 papers at scientific conferences: ICC 2016 [Mar16] - Best paper award, ICSTCC 2016 [Şen16a], SACI 2016 [Alb16], [Stî16], SISY 2016 [Boj16], INDIN 2016 [Pre16] (all IEEE Xplore indexed), ICAT 2016 [Sel16], [Şen16b]; publication of a chapter in a Springer volume (LNCSI) in December 2015 [Şen15].

### Publications

- [Alb16] Albu A. Logical inference modeled by Petri nets, *11th IEEE Int. Symp. Applied Comput. Intelligence & Informatics (SACI 2016)*, Timișoara, Romania, pp. 137-140, 2016.
- [Boj16] Bojan-Dragoș C.-A., Preitl S., Precup R.-E., Hergane S., Hughiet E.G., Szedlak-Stînean A.-I. State feedback and Proportional-Integral-Derivative control of a magnetic levitation system, *IEEE 14th Int. Symp. Intelligent Systems & Informatics (SISY 2016)*, Subotica, Serbia, pp. 111-116, 2016.
- [Mar16] Marin C., Popescu D., Petre E., Selișteanu D. Mathematical modelling of systems with state dependent delays. Applications for conveyor belt plants, *17th Int. Carpathian Control Conf. (ICCC 2016)*, Slovak Rep., pp. 479-484, 2016.
- [Pre16] Precup R.-E., Rădac M.-B., Petriu E.M., Roman R.-C., Teban T.-A., Szedlak-Stînean A.-I. Evolving fuzzy models for the position control of twin rotor aerodynamic systems, *IEEE 14th Int. Conf. Industrial Informatics (INDIN 2016)*, Poitiers, France, pp. 237-242, 2016.
- [Rom16a] Roman M., Selișteanu D. Modeling of fast reactions mechanisms for biomass conversion processes, *Combustion Science and Technology*, Taylor and Francis, 188(2), pp. 290-305, 2016. [Impact Factor IF = 1.193]
- [Rom16b] Roman M., Selișteanu D. Modelling of microbial growth bioprocesses: Equilibria and stability analysis, *International Journal of Biomathematics*, 9(5), Art. no. 1650067, 21 p., 2016. [IF = 0.938]
- [Sel16] Selișteanu D., Roman M., Popa D.A., Petre E. Nonlinear adaptive control of a fermentation fed batch process, *4th Int. Conf. Advanced Technology & Sciences (ICAT 2016)*, Rome, Italy, 6 p., 2016.

- [Stî16] Szedlak-Stînean A.-I., Preitl S., Precup R.-E., Bojan-Dragoş C.-A. An adaptable feedback control solution for a drive system with variable parameters, *11th Int. Symp. Applied Comput. Intel. & Informatics (SACI 2016)*, pp. 209-215, 2016.
- [Şen15] Şendrescu D., Tebbani S., Selişteanu D. *Bioprocesses Parameter Estimation by Heuristic Optimization Techniques*, in S. Olaru, A. Grancharova, F.L. Pereira (Eds.), *Developments in Model-Based Optimization and Control*, Chapter 11, pp. 237-254, *Lecture Notes in Control and Information Sciences 464*, Springer, dec. 2015.
- [Şen16a] Şendrescu D., Petre E., Bobaşu E., Roman M. Parameter estimation of bioprocesses via parallel Particle Swarm Optimization, *20th Int. Conf. System Theory, Control & Computing ICSTCC (ICSTCC 2016)*, pp. 336-441, 2016.
- [Şen16b] Şendrescu D., Selişteanu D., Popa B. Modelling of biotechnological systems using parallel computing, *4th Int. Conf. Advanced Technology & Sciences (ICAT 2016)*, Rome, Italy, 6 p., 2016.

## Conclusions

The research objectives of the third phase of the project were achieved. The research results consist of: design of adaptive, neural and hybrid control algorithms with applicability to bioprocesses; studies, documentations and technical reports for the industrial processes of wheat grinding, bread production and wastewater treatment processes. Scientific reports were completed, research stages were achieved and the research results were disseminated via the publication of scientific papers (2 in ISI indexed journals and 8 presented at conferences, 1 chapter in a Springer volume). By using the results of the first three phases, in the next year advanced control techniques for bioprocesses will be implemented, in different control system structures.