UNIVERSITY OF CRAIOVA

Programme: ***Partenerships in Priority Domains, Applied research collaborative projects***
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Title of the project: ***Advanced control systems for bioprocesses in food industry (ADCOSBIO)***
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REPORT OF ACTIVITY
- Synthesis -

Phase II / 2015
Identification, on-line estimation and validation via real-life experiments of bioprocess models

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 second phase of the project (II/2015), several researches from the first and second objectives and partially from the third one were achieved, by means of specific research activities, in accordance with the project plan.

Activity II.1

Validation of proposed models through laboratory experiments, by using the available pilot bioreactors and related equipments

Obtained results:

- Experimental models of the bioprocesses. Fermentation processes models were experimentally validated by using two laboratory bioreactors (Biostat A plus - Sartorius and New Brunswick BioFlo115 - Eppendorf). Also, models of wastewater treatment processes were validated by using a pilot station and a SIMBA simulator (for an urban wastewater treatment station).

Activity II.2

Data collection, analysis, tests and comparisons for the industrial processes implemented at partner P1

Obtained results:

- Technical documentation concerning the process analysis – wheat grinding, flour processing and bread production process, and for the wastewater process, at partner P1 (Scientific report).

Activity II.3

Novel distribution-based identification techniques and artificial intelligence identification approaches for fermentation bioprocesses and activated sludge wastewater treatment processes

Obtained results. Set of novel identification algorithms for bioprocesses:

- Distribution-based multi-level off-line identification algorithm for bioprocess parameters;
- PSO (*Particle Swarm Optimization*) identification algorithm for bioprocess parameters.

Activity II.4

Analysis and comparisons concerning the state observers for bioprocesses

Obtained results. Set of novel on-line estimation procedures for bioprocesses:

- Design procedure of state exponential observers;
- Design procedure of asymptotic observers;
- Novel design procedure for on-line estimation by using interval observers;
- Design procedure of Sliding Mode Observers for linearized bioprocesses.

Activity II.5

Synthesis and implementation of combined and hybrid estimation algorithms for bioprocesses in food industry

Obtained results:

- Combined and hybrid estimation techniques: combined estimation of yield coefficients and of reaction rates; solutions for hybrid estimation of reaction rates and state variables, with applicability to yeast fermentation and wastewater treatment bioprocesses (Scientific report).

Activity II.6

Experiment-based iterative tuning and evolutionary optimization-based tuning of controllers for control loops in food industry

Obtained results. Intelligent tuning algorithms for controllers (Scientific report):

- Controller design for time delay systems by using the shape coefficients method;
- Intelligent tuning of controllers in structures with many freedom degrees, intelligent PID control and optimal control;
- Experiment-based iterative tuning of controllers;
- Operating modes of digital controllers used in food and biotechnological plants.

Activity II.7

Dissemination of research results

Obtained results:

- Publishing of five papers in ISI (WoS) indexed journals, some of them under review the last year: *Asian Journal of Control* (Wiley) [Pet15], *BioMed Research International* [Sel15], *Computers in Industry* (Elsevier) [Răd15], *Combustion Science and Technology* (Taylor & Francis) [Rom15b] (accepted), *International Journal of Biomathematics* (under review) [Rom15c];

- Participation with 10 papers at scientific conferences: INISTA 2015 [Stî15], ICSTCC 2015 [Luc15], [Mar15b], ICCC 2015 [Mar15a], [Șen15a], SACI 2015 [Sga15], [Voi15] (all IEEE Xplore indexed), ICAT 2015 [Rom15a], [Șen15b] (selected for publication in journals), CNIC 2015 [Rom15d], plus a paper from 2014, extended to a Springer chapter (in press) [Șen16].

Publications

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[Mar15a] Marin C., Selişteanu D., "Finite time response control of affine systems", *Proc. of 16th Int. Carpathian Control Conf. (ICCC'15)*, Hungary, pp. 304-309, 2015.

[Mar15b] Marin C., Selişteanu D., Popescu D., Roman M., "Adaptive optimal control of a continuous stirred tank bioreactor", *Proc. of 19th Int. Conf. System Theory, Control and Computing (ICSTCC'15)*, Romania, pp. 49-54, 2015.

[Pet15] Petre E., Tebbani S., Selişteanu D., "Robust-adaptive control strategies for a time delay bioelectrochemical process using interval observers", *Asian Journal of Control*, Wiley, 17, (5), pp. 1767-1778, 2015, [Impact factor IF = 1.556].

[Răd15] Rădac M.B., Precup R.E., "Optimal behaviour prediction using a primitive-based data-driven model-free iterative learning control approach", *Computers in Industry*, Elsevier, 74, pp. 95-109, 2015. [IF = 1.287].

[Rom15a] Roman M., Selişteanu D., Petre E., Şendrescu D., "Modelling and adaptive control of a yeast fermentation process inside a fed-batch bioreactor", *Proc. of Int. Conf. on Advanced Technology & Sciences (ICAT'15)*, Turkey, pp. 171-177, 2015.

[Rom15b] Roman M., Selişteanu D., "Modeling of fast reactions mechanisms for biomass conversion processes", *Combustion Science and Technology*, Taylor and Francis, in press, 2015, [IF = 0.991].

[Rom15c] Roman M., Selişteanu D., "Modelling of microbial growth bioprocesses: Equlibria and stability analysis", *International Journal of Biomathematics*, under review, 2015, [IF = 0.805].

[Rom15d] Roman M., Selişteanu D., "Modelling of biochemical processes for efficient enzymes production", *16th International Scientific Congress (CNIC'15)*, Cuba, EIN-P-025, 2015.

[Sel15] Selişteanu D., Şendrescu D., Georgeanu V., Roman M., "Mammalian cell culture process for monoclonal antibody production: nonlinear modelling and parameter estimation", *BioMed Research International*, ID 598721, 2015, [IF = 1.579].

[Sga15] Sgaverdea S., Bojan-Dragoş C.A., Precup R.E., Preitl S., Stînean A.I., "Model Predictive Controllers for magnetic levitation systems", *Proc. of 10th Jubilee IEEE Int. Symposium on Applied Computational Intelligence and Informatics (SACI'15)*, Romania, pp. 171-176, 2015.

[Stî15] Stînean A.I., Bojan-Dragoş C.A., Precup R.E., Preitl S., Petriu E.M., "Takagi-Sugeno PD+I fuzzy control of processes with variable moment of inertia", *Proc. of Int. Symposium on INnovations in Intelligent SysTems and Applications (INISTA'15)*, Spain, pp. 335-342, 2015.

[Şen15a] Şendrescu D., Selişteanu D., "Modelling of bacterial growth bioprocesses based on heuristic optimization techniques", *Proc. of 16th Int. Carpathian Control Conf. (ICCC'15)*, Hungary, pp. 470-474, 2015.

[Şen15b] Şendrescu D., Selişteanu D., Ionete C., "PID controller tuning for bacterial growth bioprocesses control", *Proc. of Int. Conf. on Advanced Technology & Sciences (ICAT'15)*, Turkey, pp. 254-258, 2015.

[Şen16] Șendrescu D., Tebbani S., Selișteanu D., Bioprocesses Parameter Estimation by Heuristic Optimization Techniques, in S. Olaru *et al.* (eds.), Developments in Model-Based Optimization and Control, Chapter 11, 22 p., *Lecture Notes in Control and Information Sciences* 464, doi 10.1007/978-3-319-26687-9_11, Springer, 2016.

[Voi15] Voişan E.I., Paulis B., Precup R.E., Drăgan F., "ROS-based robot navigation and human interaction in indoor environment", *Proc. of 10th Jubilee IEEE Int. Symposium on Applied Computational Intelligence and Informatics (SACI'15)*, Romania, pp. 31-36, 2015.

Conclusions

The research objectives of the second phase of the project were achieved. The research results consist of: experimental validation of bioprocess models, data analysis form industrial processes, novel identification algorithms and on-line estimation techniques for bioprocesses, achievement of combined and hybrid estimation techniques, and intelligent tuning algorithms for digital controllers. Scientific reports were completed and the research results were disseminated via the publication of scientific papers (five in ISI indexed journals and 10 presented at conferences). By using the results of the first two phases, in the next year advanced control techniques for bioprocesses will be developed, in different control system structures. These techniques will be implemented, tested and validated on processes in food industry.