Computer-Aided Teaching of Process Engineering

VI - Studies on Bioprocess Identification and Control through a Process Simulator

E. Ferreira[1], F. Oliveira[2], P. Pimenta[3], R. Oliveira[3], S. Feyo de Azevedo[3*]

[1]Universidade do Minho, Engenharia Biológica, Largo do Paço, 4700 Braga PORTUGAL
[2]Universidade do Minho, Electrónica Industrial, Largo do Paço, 4700 Braga PORTUGAL
[3]Departamento de Engenharia Química, Faculdade de Engenharia da Universidade do Porto, Rua dos Bragas, 4099 Porto Codex, PORTUGAL

Abstract

In this paper we present a simple computer-based laboratory set-up for experiments concerning real-time system identification. The set-up is constituted by a 'Process Simulator' computer and a 'Control' computer, communicating via serial RS-232 protocol. The former can simulate multivariable non-linear systems in real-time, in this specific experiment the fed-batch fermentation of baker's yeast. The latter performs the tasks of system identification and control, viz - (i) identification is performed employing a methodology based on a general non-linear deterministic model representation of fed-batch fermentations; (ii) control is performed employing an adaptive linearizing scheme.

Scope

The vast majority of processes in the chemical, biochemical and food industry are of a non-linear nature and exhibit multiple inputs and multiple outputs. Their dynamics and control are difficult to study both for theoretical and practical reasons. In many instances experiments with real industrial processes even at pilot scale are not carried out for reasons of economy and safety. Often on-line measurements are not available or simply they are too expensive.

A number of methodologies have emerged over the past ten years which make explicit use of stochastic and deterministic model structures for process state estimation and control. Of particular interest are those theories proposed by Bastin and Dochain (1990), addressing the on-line estimation and adaptive control of bioreactors, based on a general non-linear deterministic model representation of such systems. Post-graduate students should be exposed to these methodologies, particularly to the concepts of on-line analysis, software sensors and adaptive strategies.

We have applied the approach in reference to the study of baker's yeast fermentation in fed-batch regime and for that purpose developed a 'computer-based laboratory experiment'.

The set-up employed is represented in fig. 1. It is constituted by a 'process' computer and by a 'control' computer communicating via the serial RS232 ports.

In the 'process' computer we run the application to the biological system on the environment of the 'general simulator of non-linear multiple-input-multiple-output systems' developed in our group (Pimenta and Feyo de Azevedo, 1993).

In the 'observer and control' computer we run the theoretical approach for state and parameter estimation and for control. The identification algorithms receive, optionally in 'real time', in synchronized 'scaled time' or in simulation time, the 'measured' state variables generated by the

process simulator. The adaptive control scheme utilizes the 'observed' state to compute the control action.

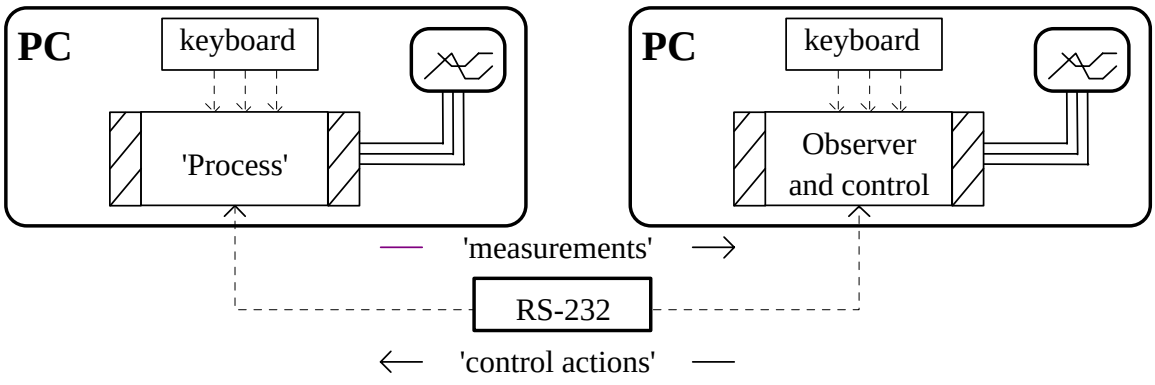

Fig. 1. Laboratory set-up for experiment on bioreactor control.

Communications are performed under a protocol which is specific of the process simulator.

With this experiment and the underlying theory students will be able to -

(i) learn about the role of modelling and interactive simulation in process analysis;
(ii) learn about baker's yeast fermentation, by running it in open-loop and manipulating on-line process inputs and process parameters;
(iii) understand the concept of software sensors;
(iv) to study the identification theory and sense its robustness to model uncertainties, to time varying parameters and to noisy measurements;
(v) to sense the importance of sampling rates in process control and to assess the performance of the adaptive linearizing scheme proposed.

Conclusions and Significance

We have presented a laboratory set-up which is adequate for postgraduate student training in real-time system identification and control of bioreactor performance, where the approach implemented is based on a general non-linear deterministic model of such processes. The setup employed is easily transportable since it only requires standard personal computer technology.

Poster and Software Demo

The work is presented in the meeting as a poster and through software demos.

References

Bastin, G.; Dochain, D. (1990) 'On-line Estimation and Adaptive Control of Bioreactors', Elsevier, Amsterdam.

Pimenta, P.; Feyo de Azevedo, S. (1993) 'A Real-time Process Simulator for Non-linear MIMO Systems', European Symposium on Computer Aided Process Engineering 2, Computers and Chem. Engng., 17 suppl., pp. S343-348.

Acknowledgements *- This work was partially supported by JNICT, under contract n. B/D 224/90-IF.*