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Adaptive Control Algorithms of Gluconic Acid Production for Educational Purpuse

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Abstract

The development of interactive software systems is a modern approach to the training of biotechnologists. One such system that is currently being developed is InSEMCoBio. The purpose of this study is to derive modern algorithms for monitoring and control of Gluconic acid production process. When the algorithms will built-in the system will allow users to compare the results of the application of different controls to the same object. The GDM approach is used in deriving algorithms. This allows the synthesis of software sensors of immeasurable process variables. In this way the process is monitored and its adaptive control is realized. A scheme of the whole training system is proposed, clearly showing the place of the derived algorithms and their connections with the other functions of the system.

The system InSEMCoBio - main functions

In Fig. 1, the architecture scheme of the system is given. The algorithms for identification, monitoring and control are shown in yellow in the scheme. Three types of optimization algorithms for the purposes of model identification are already built-in the system. Some blocks shown in blue, are already realized. They are related to the **choice of**: process and corresponding experimental data, as well as the model's structure for the selected process and identification algorithm. The following functions are already realized and the results (in rose) are: set of optimal models for batch mode of cultivation; analysis of the models; choice of the best model. The best model is used instead the real process in simulations.

The algorithms for monitoring and adaptive control shown below will be built-in. A model for control is derived of the basis of the best model

For the purposes of education the user has the opportunity to get acquainted with the possibilities of bioprocess monitoring and control- by activating the corresponding blue block. For the control algorithm the user has the opportunity to choice either fed-batch or continuous modes of cultivation. In the considered case the controlled variable is carbon source glucose (*G*). Since only two of the variables are measured on-line glucose (*G)* and dissolved oxygen (O_2) in this process, the system allows monitoring of the dynamics of unmeasurable variables biomass (*X*)and Gluconic acid (*GA*) for which software sensors have been synthesized.

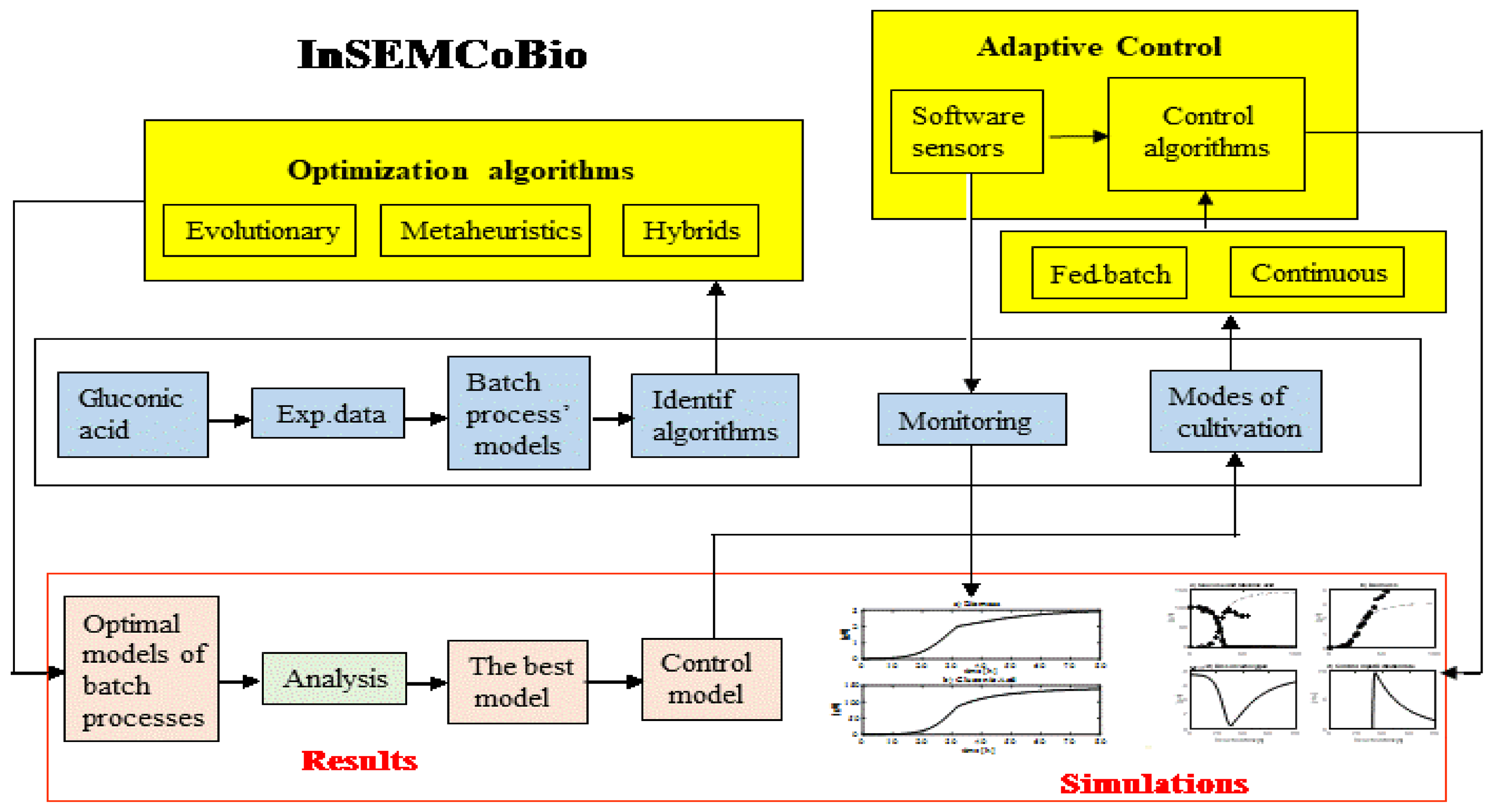

Fig.1

Results

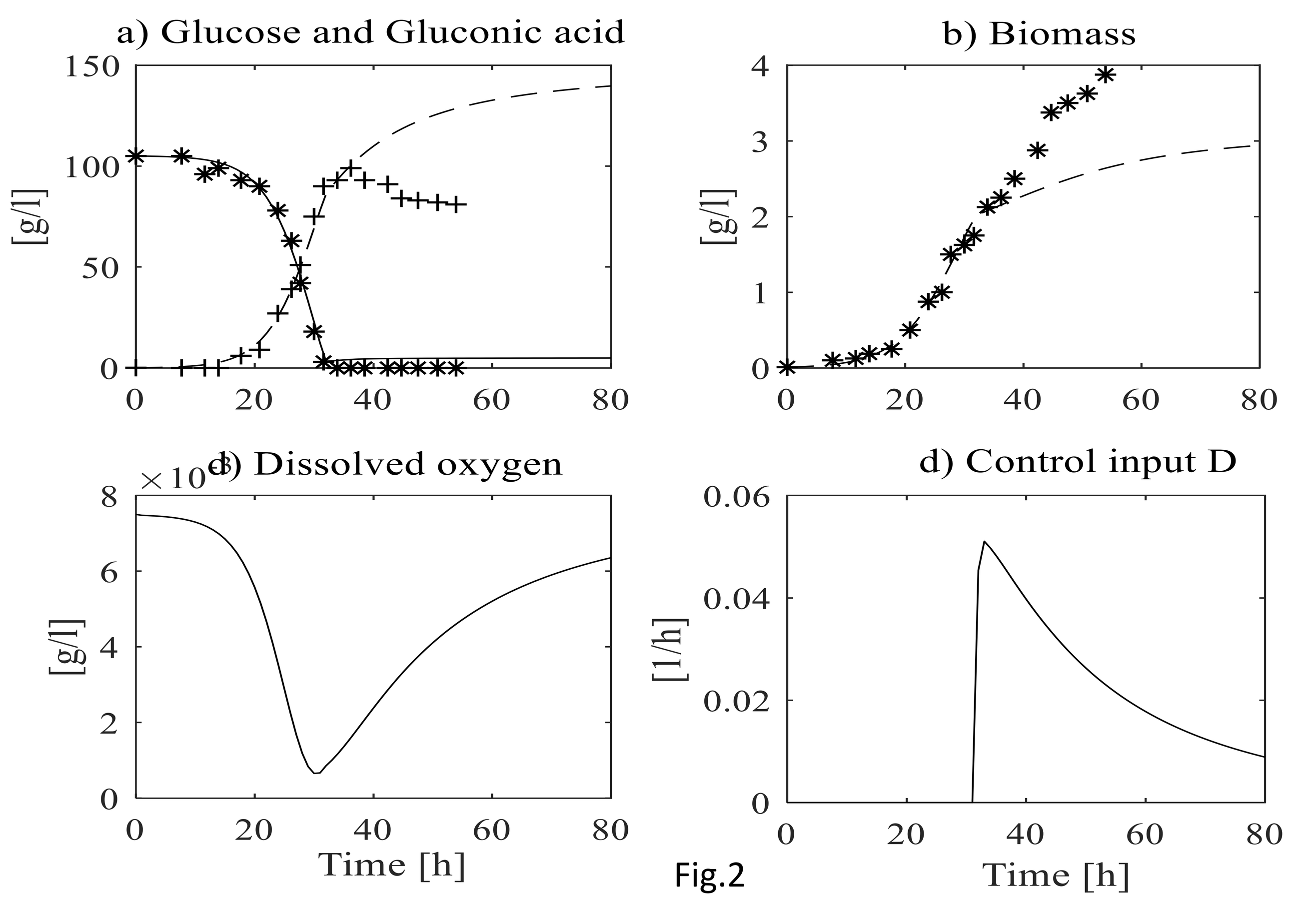

Fig.2

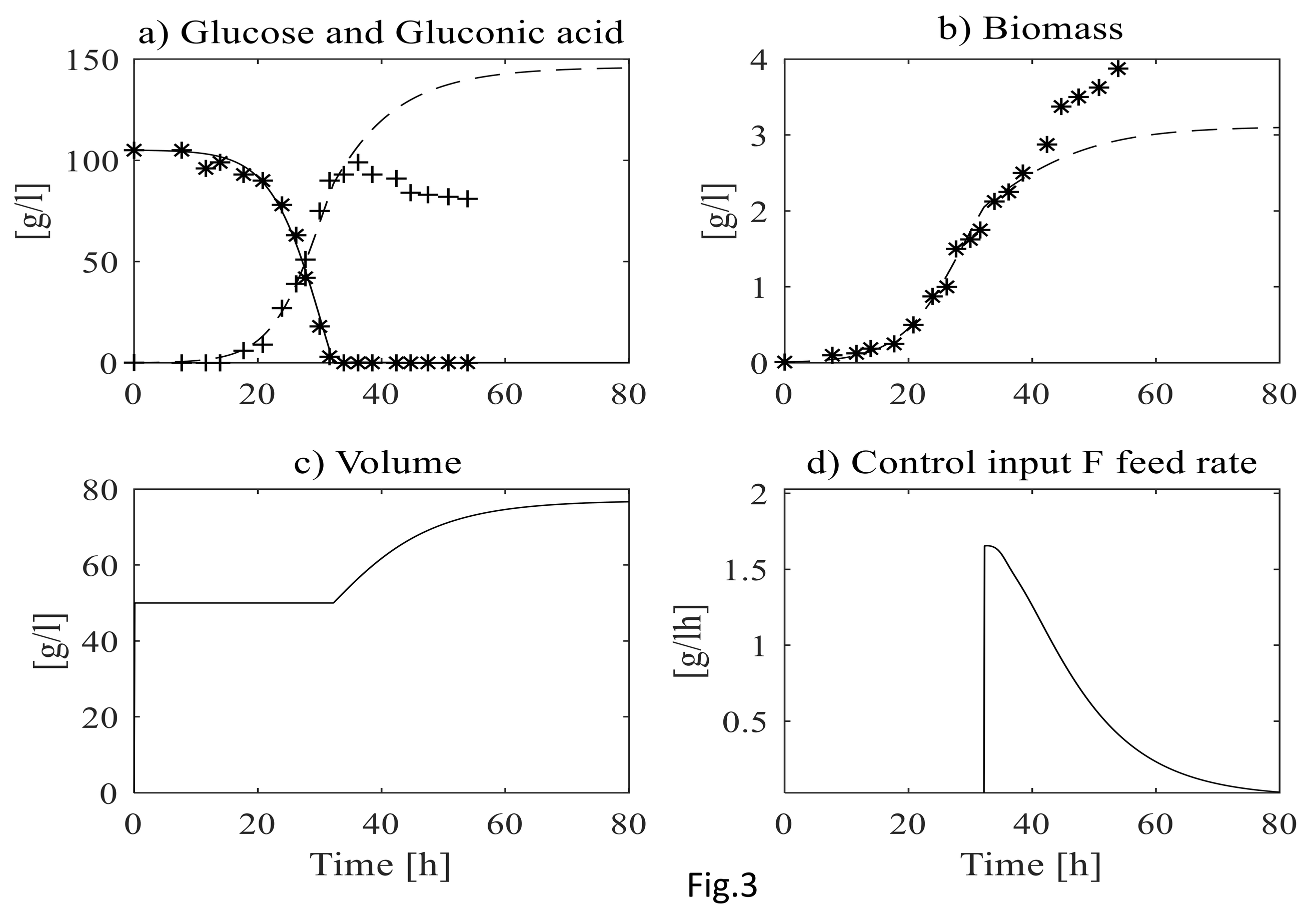

Fig.3

Derivation of Continuous Control of Glucose Concentration

First step $\frac{dG}{dt} = -X_e G\theta_2 - GO_2\theta_3 - D(G - G_{in}))$

Second step $\lambda(G^* - G) = dG/dt$

Third step $D = \frac{-\lambda(G^*-G) - X_e G\theta_2 - GO_2\theta_3}{G - G_{in}}$

Derivation of Fed-Batch Control of Glucose concentration

First step $\frac{dG}{dt} = -X_e G\theta_2 - GO_2\theta_3 - \frac{F}{V}(G - G_{in})$

Second step $\lambda(G^* - G) = dG/dt$

Third step $F = \frac{\mathbf{G_{in}}(-\lambda(G^*-G) - X_e G\theta_2 - GO_2\theta_3)}{G - G_{in}}$

$dV/dt = F$

Discussions

The simulations are realized under following conditions: The initial values of process variables are *X(0)*= 0.1[g/l]; *G(0)*= 0.01[g/l]; $O_2(0)$= 0.0075[g/l]; *GA(0)*= 0.01[g/l]. The value of glucose concentration in the feed, G_{in}, is equal to 200 [g/l]. This value is chosen from expert's point of view. For initial values of biomass and gluconic acid estimators are taken as the initial values of experimental data because these values are known at the begging of the fermentation. The simulation investigation of the control algorithms are shown in figures 2 and 3. Model simulations are given with lines. The result of the gluconic acid and biomass control for all cases are shown with dashed lines. Experimental points of batch phase are given with stars '*' for glucose and biomass and with plus "+' for gluconic acid. In both subfigures *a* the curves of glucose and gluconic acid are shown. In both subfigures *b* the biomass is given. In subfigure 2c concerning continuous processes, the dissolved oxygen is shown. In subfigure 3c concerning fed-batch processes, the volume is shown. In both subfigures *d* the control input – dilution rate or feed rate is given. Both control laws are derived in three steps. The first one is a choice of the input/output model of the closed-loop system. The second step is to select a stable reference model of the tracking error of controlled variable, where λ is control tuning parameter. The third step is a substitution of the input/output model in the corresponding reference one. This algorithm is shown above for each of the cases. In both cases the control variable is maintain at some low value of the substrate (G) in the culture medium (0 or 3 g / l). These two approaches are implemented through continuous (Fig. 2) and fed-batch control (Fig. 3).

Comparing the results obtained up to 80 hours of fermentation in sub-figures 2a and 3a, it was found that a fed-batch control (3a) achieves a higher concentration of the target product compared to the continuous control (2a). It should be noted that the fed- batch control process must be stopped when the volume reaches the maximum working volume (80 l), while during continuous mode the process may take longer. This does not give grounds for a definite conclusion under which cultivation regime will accumulate a larger amount of target product.

Conclusion

The algorithms developed in this study will be integrated into the system together with similar algorithms, developed for other food production processes. The choice of a process as well as the activation of the functions related to the identification, monitoring and control will be realized by the users through simple actions. In this way, users will be able to get acquainted with the results of modern algorithms without being familiar with the theory of their development, as well as with the software of their implementation. What has been said so far gives grounds to define the system under developing InSEMCoBio as interactive and user-friendly.

Acknowledgements

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