On a class of sigmoidal growth models induced by reaction networks

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We formulate and study a class of sigmoidal growth models induced by catalytic reaction network via the mass action law. The proposed reaction network, called pre-logistic, is based on the autocatalytic logistic reaction inducing the familiar logistic growth model. The pre-logistic reaction network consists of two catalytic reactions. We show that the dynamics of the pre-logistic network is close to the dynamics of either the logistic, or the first-order saturation reaction depending on the ratio of the rate constants. In particular we show that the autocatalytic logistic reaction can be obtained as a limit case of the pre-logistic reaction network whenever one of the rate constants tends to infinity while the other is kept fixed. Hence the pre-logistic reaction can be considered as a generalization of both the logistic and the saturation reactions and thus can be used in a number of real-world situations when modeling growth processes in life sciences. A generalization of the pre-logistic network involving more intermediate steps is also discussed. The proposed growth models possess clear physic-chemical mechanisms and are suitable for fitting a variety of measurement data. Numerical examples of the proposed growth models using experimental measurement data from the field of microbial cultivation are presented and graphically visualized.

References

[1] Anguelov R., Borisov M., Iliev A., Kyurkchiev N., Markov S., *On the chemical meaning of some growth models possessing Gompertzian-type property*, Math Meth Appl Sci. 2017;12 https://doi.org/10.1002/mma.4539

[2] Iliev A., Kyurkchiev N., Markov S., *On the Approximation of the step function by some sigmoid functions*, Mathematics and Computers in Simulation 2017; 133:223–234.

[3] Lente G. *Deterministic Kinetics in Chemistry and Systems Biology*, Briefs in Molecular Science, Springer 2016.

[4] Chellaboina V., Bhat P., Haddat M., Bernstein S., *Modeling and Analysis of Mass-Action Kinetics*, IEEE Control Systems Magazine 2009; 60–78.