Title: Biomolecular Control Systems (EE798N)

Offered in I Semester, 2023-2024

Instructor: Dr Abhilash Patel (apatel[at]iitk.ac.in)

Objective: The objective course is to introduce concepts of systems biology and synthetic biology from the perspective of control and systems engineering. The course will impart learning on modelling, analysis, and design of desired biological systems on a molecular scale.

Contents:

Topics

- Cell as a system
- Central dogma of molecular biology
- Deterministic modelling of chemical reactions
- Stochastic modelling of chemical reactions
- Modeling gene regulation, protein degradation
- Modeling signal transduction
- Modeling metabolic pathways
- Modeling enzymatic reactions
- Negative feedback in cells, time response, Repressilator, limit cycles
- Integral feedback in cells, Homeostasis and perfect adaptation
- PID realization in cells, differentiator
- Positive feedback in cells, cellular differentiation, toggle switch
- Multi-feedback in cells, excitability, relaxation oscillation
- Feedforward loops in cells, pulse, delay
- Recombinant DNA technology for realization
- Plasmid design, transformation
- Promoter engineering, operator, inducible promoters
- UTR design, RBS Strength, conformational change
- RNA regulation
- Design challenges
- Retroactivity, Modularity
- Resource constraint
- Host cell dynamics, Evolution
- Implementation in Bacterial vs mammalian cells
- Noise in cell
- Overview of spatial aspects, morphogenesis, consortia, quorum sensing

Recommended Textbooks:

1. Del Vecchio, D. and Murray, R.M., 2014. *Biomolecular Feedback Systems*. Princeton University Press. (web version: https://fbswiki.org/wiki/index.php/Biomolecular_Feedback_Systems)
2. Ingalls, B.P., 2013. *Mathematical modeling in systems biology: an introduction*. MIT press. (web version: https://www.math.uwaterloo.ca/~bingalls/MMSB/)
3. Klipp, E., Liebermeister, W., Wierling, C. and Kowald, A., 2016. *Systems biology: a textbook*. John Wiley & Sons.
4. Addgene, Plasmids 101: A Desktop Resource (3rd Edition), (https://info.addgene.org/download-addgenes-ebook-plasmids-101-3rd-edition)
5. Brown, T.A., 2020. *Gene cloning and DNA analysis: an introduction*. John Wiley & Sons.
6. Liljeruhm, J., Gullberg, E. and Forster, A.C., 2014. *Synthetic biology: a lab manual*. World Scientific