TECHNISCHE UNIVERSITÄT DARMSTADT

Effects of asymmetry in gene expression noise on functionality of small gene networks

Fachbereich 18
Elektrotechnik und Informationstechnik
Bioinspirierte Kommunikationssysteme

Department 18
Electrical Engineering and Information Technology
Bioinspired Communication Systems

Prof. Dr. Heinz Koeppl
Head of lab

Sofia Startceva
Project supervisor

Rundeturmstraße 12
64283 Darmstadt

sofia.startceva@bcs.tu-darmstadt.de
https://www.bcs.tu-darmstadt.de

September 2020

Gene expression is an inherently stochastic process. Nevertheless, gene networks successfully govern functioning of living cells, exhibiting the ability to sense environmental changes and react accordingly (i.e., sensitivity), as well as the ability to withstand a certain degree of potentially disruptive perturbations (i.e., robustness). Further, noise in gene expression is not merely a nuisance but an important component that enables existing functionality of gene networks [1, 2].

Noise in gene expression can be observed from distributions of molecular numbers in a cell population or from distributions of time intervals between RNA production events. These distributions are often asymmetric and are well-modelled by a negative binomial distribution [3]. A recent study of *in vivo* gene expression has demonstrated that it is possible to regulate asymmetry of these distributions while not altering their coefficient of variation, suggesting that this asymmetry could have a significant role in functionality of gene networks [4].

This project will investigate the effects of asymmetry in gene expression noise on robustness and sensitivity of common gene network motifs, such as self-regulating genes, gene switches and oscillators [5]. The student will learn about stochastic models of gene expression and small gene networks and will perform analytical analysis as well as stochastic simulations. This starting goal can be expanded based on the interests of the student. For example, the project can be further developed by introducing extrinsic noise sources such as cell growth and division, by considering alternative models of gene expression and gene networks, or by building a software for automatic analysis of functionality of small gene networks based on the shape of gene expression noise, which would be of interest in the context of synthetic gene network design.

Skills and knowledge in the following areas will be helpful when working on this project: programming, probability theory, stochastic modelling.

For further information, please contact Sofia Startceva.

References

[1] Arjun Raj and Alexander van Oudenaarden. Nature, nurture, or chance: Stochastic gene expression and its consequences. *Cell*, 135(2):216–226, 2008.

[2] Avigdor Eldar and Michael B. Elowitz. Functional roles for noise in genetic circuits. *Nature*, 467(7312):167–173, 2010.

[3] Zhixing Cao and Ramon Grima. Analytical distributions for detailed models of stochastic gene expression in eukaryotic cells. *Proceedings of the National Academy of Sciences*, 117(9):4682–4692, 2020.

[4] Sofia Startceva, Vinodh K. Kandavalli, Ari Visa, and Andre S. Ribeiro. Regulation of asymmetries in the kinetics and protein numbers of bacterial gene expression. *Biochimica et Biophysica Acta (BBA) - Gene Regulatory Mechanisms*, 1862(2):119–128, 2019.

[5] Uri Alon. Network motifs: theory and experimental approaches. *Nature Reviews Genetics*, 8(6):450–461, 2007.