Ph.D. in Information Technology
Thesis Defense

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Francesca RATTI – XXXIV Cycle

Engineering information transfer in living systems via molecular communication

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Abstract:

Molecular Communication (MC) is an emerging field directly inspired by natural communication between cells in biology. In MC, the information is encoded into and decoded from molecules rather than electromagnetic waves, thus exploiting biological materials to enable communication among biological nanomachines, which are existing or artificially synthesized small-scale devices. Some examples of nanomachines are genetically engineered cells, molecular motors, biological and artificial cells, synthetic molecules, and bio-silicon hybrid devices. The study of MC has applications in several fields. One of the most prominent is biomedical research, e.g., to address the problem of smart drug delivery, detect pathologies, and model the spreading of infections.
This is an interdisciplinary thesis that focuses on applying communication and information theory concepts to the field of MC. Indeed, even though MC systems are fundamentally different from their traditional communication counterparts, the latter can provide key tools and theoretical foundations for their analysis. This research focuses on the objectives stemming from the design of synthetic biological circuits to exploit, control, and enhance the performance of MC systems. The main goal of our investigation is to understand how to maximize the reliable information exchange in MC circuits. In general, information transfer in such systems is hindered by the intrinsic stochasticity of natural biological processes, e.g., the non-deterministic occurrence of chemical reactions, the diffusion of molecules in the extracellular environment.
In this work, we face this challenge both from a data-driven and an analytical perspective, investigating novel techniques to quantify and optimize information transfer. This thesis includes a fundamental and application-agnostic standpoint, focusing on molecular circuits in cells and biochemical signaling systems. Additionally, it also includes applications and results in different fields, ranging from biological cells communication to genomic systems. A common thread of this research is the application and adaptation of traditional concepts of information theory, such as mutual information, channel capacity, and sampling theorem, to biological circuits. Overall, results show that the information theory-based theoretical framework represents an essential resource to analyze and improve MC systems, despite the evident differences with classical electronic circuits.

PhD Committee

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