

LightScout: Statistical Benchmarking of Stochastic Illumination for Robust Particle Tracking

Master 2 internship project (with extension possible for fully funded PhD)

Host team

The Bioimage Mining group, led by Philippe Roudot at Institut Fresnel and CENTURI (Aix-Marseille University), develops computational methods for measuring molecular and cellular dynamics from microscopy data. Our research lies at the interface of statistical signal processing, computational imaging, optimization, and quantitative biology. We design acquisition strategies and estimation algorithms together to push the boundaries of what can be measured in living organisms.

Technological and computational challenge

We still know very little about the **nanometric machinery** that **drives** our physiology and **diseases**. While fluorescence enables visualization, tracking small fluorescent objects inside living tissues is difficult because signals are weak and background fluorescence is strong. Increasing illumination power improves visibility but can damage the sample.

Random Illumination Microscopy has emerged as a solution to obtain high-contrast images in scattering tissue by recovering information from the statistics of many independent illumination patterns. However, this sensitivity comes at a cost: a conventional reconstruction combines tens to hundreds of images. The sample must therefore remain effectively unchanged during acquisition, which restricts the method to fixed samples or sufficiently slow particle dynamics.

The central bottleneck tackled by LightScout is to bring this high sensitivity to moving objects. Rather than reconstructing an image first and tracking particles afterward, LightScout jointly estimates whether a particle exists and how it moves directly from the changing measurements. Occasional bright observations, called scouts, provide reliable evidence that a particle is present; a probabilistic motion model then tests and connects weaker observations before and after each scout. The internship will determine when this joint estimation of particle existence and motion can recover dynamic trajectories more accurately than conventional illumination for the same photon budget, and at what computational cost.

Internship objective

The student will design and implement a statistical benchmark of the LightScout principle in a single-particle or sparse-particle setting. A simulation framework will generate trajectories for which the true positions and motion parameters are known. It will reproduce the main sources of variability in fluorescence microscopy, including particle motion, photon and camera noise, background fluorescence, illumination fluctuations, false detections, missed detections, and temporary disappearances. A conventional tracking baseline will be compared with a LightScout-inspired estimator initialized from high-confidence scouts.

Perspective

The internship opens the door to an exciting PhD project within the EndoTrack Project, led by P. Roudot and C. Collinet (IBDM). The project is fully funded by the PEPR Math-Vives project and pioneers the quantification of molecular trafficking in living embryos through a random illumination method and a state-of-the-art hybrid estimator that combines stochastic frameworks and AI.

Candidate profile

We are looking for a Master 2 student in applied mathematics, signal processing, statistics, computer science, data science, or a related engineering field. We especially value a strong desire to learn, intellectual rigor, curiosity, and clear communication.

Research environment

The student will work in an interdisciplinary environment of the Phyti team at Fresnel Institute, combining signal processing, computational microscopy, imaging, and access to the quantitative biology community at CENTURI.

Application

Applicants should send a CV, a short cover letter describing their interest in the project, and, if available, examples of relevant academic or programming work to Philippe Roudot at philippe.roudot@univ-amu.fr.

Practical information : Level: Master 2 internship, Duration: approximately 5–6 months, Starting date: to be discussed

