Robust multi-target tracking

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Background: Multi-target tracking refers to the problem of estimating the state of an unknown number of dynamical objects from noisy and partial observations. Challenges arise from the fact that (i) it is not generally known which observation originates from which object, (ii) not all objects produce observations at each observation time (false negative) and (iii) some observations are simply originated from noise or from other objects in the background that are not of interest (false positive). The observations can come from an imaging device such as illustrated in Figure 1 where multiple moving proteins are imaged on the surface of a cell using a microscope. In the context of Figure 1, estimating the motion and the potential interactions of the proteins with the cell is key for understanding how the underlying biological systems behave from a dynamic viewpoint. The Bio-imaging example considered here is just one of the many applications in which multi-target tracking is an important component; other application areas can be considered such as Robotics, Surveillance or Defence. Existing solutions to the general multi-target tracking problem include Bayesian approaches based on spatial point processes [1,2] where both the objects and the observations are modelled using Poisson point processes, hence representing the uncertainty in both the number and the respective states of objects. However, when applying multi-target tracking algorithms to real data, there is an inherent difficulty in setting all the parameters required to model the diverse sources of uncertainty affecting the objects and their observation. Indeed, it is not usually possible to learn all these parameters, especially when they can be different for each object and evolving in time, e.g., the probability of detection.

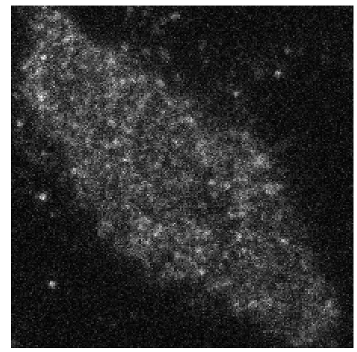

Figure 1: Image of proteins at the surface of a live cell obtained using fluorescence microscopy.

Aims and scope: The general objective of this project is to apply some recent results [3] suggesting to use an alternative representation of uncertainty to model the fact that some of the parameters of the multi-target tracking problem are only partially known, e.g., only a lower bound on the probability of detection might be available. There are several challenges in applying this new methodology:

- C.1 The implementation details of the recursion proposed in [3], as an alternative to [1], have to be determined; which includes deriving adapted simplification procedures and extracting the relevant information.
- C.2 The assumed robustness provided by the approach has to be demonstrated on simulated data.
- C.3 Several versions of the algorithm as well as extensions of it can be derived under different assumptions about which parameters are known and which are not.

MSc and PhD Project: The MSc project will focus on Challenge C.1 and will aim at proposing an implementation of the algorithm. Some preliminary results regarding the robustness, mentioned in C.2, will also be sought. There is an existing simplified version of the algorithm in Python, but Matlab or R can also be used. The extension of this MSc project toward a PhD will cover all aspects C.1–C.3 with some potential for a demonstration of effectiveness on real data.

Applications: Considering the large spectrum of applications where multi-target tracking is a required component, any improvement in terms of robustness would have a significant impact on the availability of easily applicable algorithms.

References: **[1]** R. Mahler. *Multitarget Bayes filtering via first-order multitarget moments.* IEEE Transactions on Aerospace and Electronic systems, 39(4), 1152-1178, 2003. **[2]** F. Caron, P. Del Moral, A. Doucet and M. Pace. *On the conditional distributions of spatial point processes.* Advances in Applied Probability, 43(2), 301-307, 2011. **[3]** J. Houssineau. Detection and estimation of partially-observed dynamical systems: an outer-measure approach. arXiv preprint arXiv:1801.00571, 2018.