Using Machine-Learning for tracking individual neurons in the small cnidarian Hydra

The small cnidarian Hydra possesses one of the simplest "brain" of the animal kingdom. Therefore, the tracking of all his individual neurons is possible and might lead to the first entire decoding of a brain (i.e. the understanding of how interacting neurons can integrate the environment's cues, compute the animal's state and trigger appropriate behaviors).
This project will aim at developing single-particle tracking that will integrate machine-learning for finding the optimal associations between moving particles.

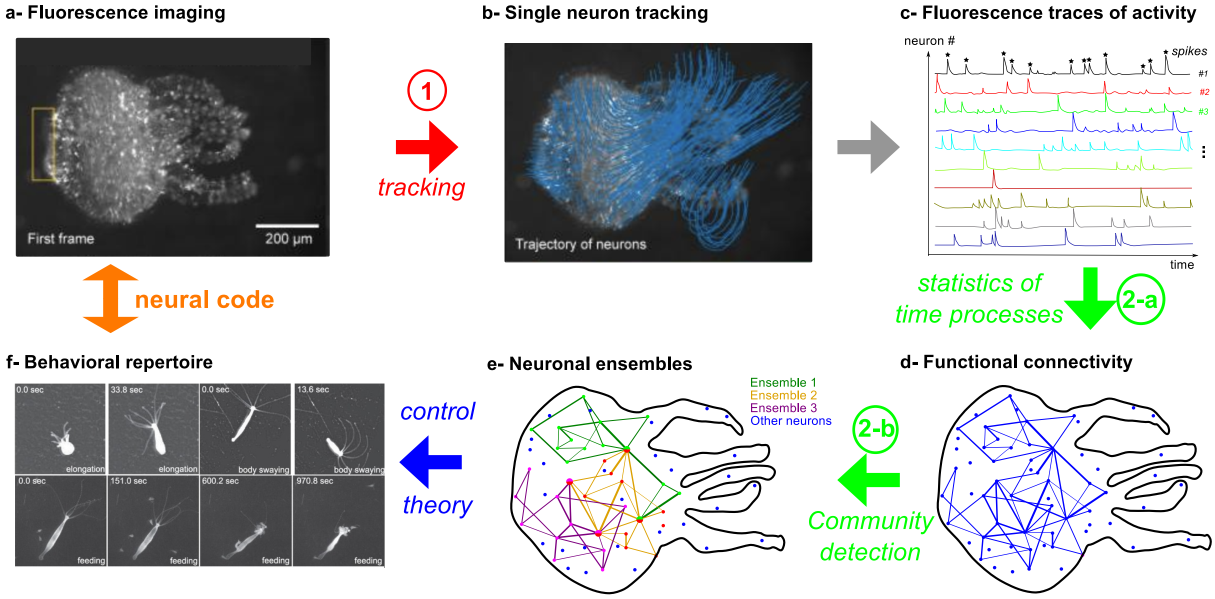

Figure 1: *Breaking* the neural code of Hydra consists in relating the sequential activity of neurons or ensemble of neurons, observed with fluorescence imaging (**a**) to each specific action of the animal (**f**), as they document significant relations of causality between the time series of individual neurons' activities. Our multi-step approach consists in (**b**) long-term, single particle tracking of $\approx 1000 - 2000$ neurons in freely-behaving and deforming animal (manual tracking over only 200 frames (20 s) is shown here (adapted from [3]), (**c**) extraction of individual fluorescence traces and spikes (highlighted with black stars for neuron #1), (**d**) statistical inference of neurons' functional connectivity (line thickness indicate connection weights) and, (**e**) clustering into significant neuronal ensembles. Finally, recasting the activity and functional connectivity of individual neurons in an optimal control theory framework will help to understand how the coordinated activity of hundreds to thousands neurons control the animal's state (**f**). Methodological developments (aims 1&2) are highlighted in red and green.