THEORETICAL

Passing messages between images to improve particle tracking

Methods to extract information from the tracking of mobile objects or particles have applications for the physical and biological sciences. The general goal of tracking particles is to extract clues about their dynamics and to make inferences about the laws of motion and/or unknown modeling parameters.

Tracking techniques based on simple criteria of proximity in time-consecutive snapshots are useful to identify the trajectories of the particles. Ideal cases for tracking are those where the density and the mobility of particles are low and the acquisition rate of images is high. However, tracking becomes difficult as the motility and/or the density of the particles increases, causing uncertainties in the trajectories that particles followed during the images' acquisition time. Even with state-of-the-art cameras, there are often ambiguities in reconstructing the trajectories of particles in turbulent flow and birds in flocks.

Photo. Flock of birds.

Michael Chertkov ((Physics of Condensed Matter and Complex Systems, T-4 and the Center for Nonlinear Science, CNLS), Lenka Zdeborová (T-4), Lukas Kroc (Information Sciences, CCS-3), and collaborators Florent Krzakala (École Supérieure de Physique et de Chimie Industrielles ParisTech and Centre National de la Recherche Scientifique, France) and M. Vergassola (Centre National de la Recherche, France), developed an algorithm that extracts statistics of trajectories of moving particles from image sequences, which mathematical models can then use to determine a system's unknown parameters. The algorithm utilizes "Belief Propagation," a Bayesian statistical method that infers the properties of the system based on how the system has changed from one observation to the next. To approximate the most likely particle trajectories between successive images, the method calculates an object's probability of occupying a location, or node, by allowing other nodes to share information and fine-tune locations predicted by dynamical equations of motion. Thus the algorithm creates a probability distribution map of particle locations. The scientists' results compare favorably with Markov Chain Monte-Carlo models, which are widely used in object-tracking studies. However, the Belief Propagation algorithm can significantly decrease computation time by running concurrently on single or multiple computers. The scientists conclude that this method could be applied to track challenging phenomena, such as bacterial colony migration and particles in turbulent fluid flows. Reference: "Inference in Particle Tracking Experiments by Passing Messages between Images", ***Proceedings of the National Academy of Sciences USA*** (Early Edition); doi: 10.1073/pnas.0910994107. Laboratory Directed Research and Development (LDRD) supported the work.

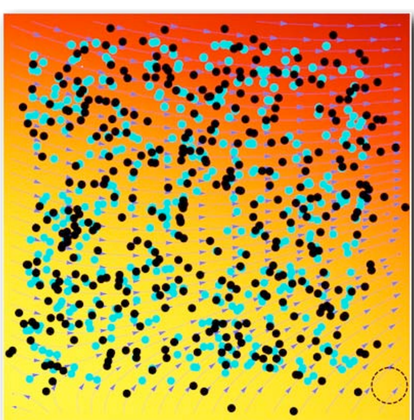

Figure 8. Arrows visualize flow inferred from a set of identical particles in two consecutive images. Black indicates the initial position of the particles, and blue indicates the final position. The circle in the right corner shows the strength of diffusion.