Task Sheet 2

Universität Konstanz

Synchronization

Deadline 15.00, 02.05.2024

Lecture: *Collective Robotics and Scalability*, Summer Term 2024

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Objectives:

- investigate a method to synchronize an asynchronous swarm
- experience influence of swarm connectivity/swarm density

Task 2.1 Synchronization of a Swarm

Swarm systems are asynchronous systems. There is no central clock that could be accessed by everyone. If a swarm needs to act in synchrony it has to explicitly synchronize first. An example of a biological system that shows synchronization is a population of fireflies (see image). "Though most species of firefly are not generally known to synchronize in groups, there are some (for example, *Pteroptyx cribellata*, *Luciola pupilla*, and *Pteroptyx malaccae*) that have been observed to do so in certain settings."[1]

Figure 1: Synchronized flash of fireflies.

In the following we create a simple model of such a firefly population. The population is scattered randomly over a square of 1 by 1 (uniform distribution). We assume that fireflies are stationary and can only perceive local neighbors in their vicinity. We say two fireflies are within the vicinity of each other if the distance between them is smaller than r. Hence, there is a virtual disc centered at each firefly's position and every other firefly sitting on that disc is a neighbor. The fireflies flash in cycles. We define the cycle length by $L = 50$ time steps. We initialize the fireflies to uniformly randomly distributed clock cycles (i.e., not sycnhronized). The firefly flashes for $L/2$ steps followed by $L/2$ steps of not flashing. This holds except for those cases when the firefly tries to correct its cycle to synchronize. In the time step after it has started to flash it checks its neighbors and tests whether the majority of them is actually already flashing. If so, the firefly corrects its clock by adding 1, that is, it is decreasing the current flashing cycle from $L/2$ to $L/2 - 1$ steps and will consequently flash 1 step earlier next time.

a) Implement the model for swarm size $N = 150$ and cycle length $L = 50$. Calculate the average number of neighbors per firefly for vicinity distances $r \in \{0.05, 0.1, 0.5, 1.4\}$. Plot the number of currently flashing

[1] http://ccl.northwestern.edu/netlogo/models/Fireflies

fireflies over time for vicinity distances $r \in \{0.05, 0.1, 0.5, 1.4\}$ for 5000 time steps each. When plotting the number of currently flashing flies, make sure you plot the full interval of $[0, 150]$ for the vertical axis.

b) Extend your model to determine the minimum and maximum number of concurrently flashing fireflies during the very last cycle (last $L = 50$ time steps starting from $t = 4950$). By subtracting the minimum from the maximum you get double of the amplitude of the flash cycle. Average the measured amplitudes over 50 samples each (50 independent simulation runs with 5000 time steps each) and plot them over vicinities $r \in [0.025, 1.4]$ in steps of 0.025. What seems a good choice for the vicinity and the swarm density?