Task Sheet 5

Universität Konstanz

Local sampling

Deadline 15.00, 06.06.2024

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

Lecturer: Prof. Dr.-Ing. Heiko Hamann

Tutor: Simay Atasoy, Till Aust

Objectives:

- ▷ implement a Buffons needle simulator
- ▷ measure performance in a swarm simulation

Task 5.1 Buffon's needle

Implement Buffon's needle for needle length $b = 0.7$ and line spacing $s = 1$. Note that you do not have to simulate the whole setting in a big 2-d plane. Instead you can reduce the situation to a single line segment of width s because the middle of the needle always ends up between two lines. What remains is simple geometry that determines whether the needle intersects with one of the two lines based on the needle's angle.

a) Use your simulation to determine the intersection probability P. Test your program by checking whether it estimates good approximations to π according to $\pi = 2b/(sP)$.

b) An experiment consists of n needles being thrown. Run experiments with $n \in \{10, 20, \dots, 990, 1000\}$ trials. For each setting of n, run the experiment 10,000 times (i.e., 10,000$\times n$) and calculate the standard deviation of the resulting set of intersection probabilities. Plot the standard deviation over the number of trials n.

c) For a maxium of $n = 100$ trials, plot the currently measured probability of many experiments over the trial number n along with the Binomial proportion 95%-confidence interval.[1]

d) Measure the ratio of experiments for which the true probability[2] is outside of the the 95%-confidence interval based on the measured probability. Plot this ratio over the number of trials n. Interpret your results.

Task 5.2 Local sampling in a swarm

We have a robot swarm of size N with the robots uniformly distributed over the unit square (robot positions (x, y) with $x \in [0, 1]$,$y \in [0, 1]$). Each robot is either black or white with equal probability. The local sampling is done in the following way. A particular robot perceives the color of all robots (including itself) in the neighborhood. The neighborhood is defined by the sensor range r. A robot belongs to the neighborhood of another robot if their distance is less than the sensor range r. From the local ratio of black robots the robot estimates the overall number of black robots in the swarm.

Implement this scenario. Do experiments for swarm sizes $N \in [2, 200]$ each with sensor ranges $r \in [0.02, 0.5]$. For each setting of N and r do 1000 independent experiments and calculate mean and standard deviation of the robot's estimate of black robots in the swarm. Plot mean and standard deviation for some interesting settings. Try to think of consequences that these measurements would have for an implementation of a robot swarm whose effectivity is directly dependent on these local samplings.

[1] from the lecture we know that the Binomial proportion 95%-confidence interval is defined by $\hat{P} \pm 1.96\sqrt{\frac{1}{n}\hat{P}(1-\hat{P})}$.

[2] from the lecture we know that the true probability is $P = 2b/(s\pi)$.