Supplemental Materials

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This document provides supplemental materials for the manuscript entitled "Diffusion-Induced Barrier Coverage of Multi-Layer Robotic Sensing Networks with Adaptive Scheduling Strategy" by Pengyang Fan, Chao Zhai and Hehong Zhang, and it is composed of two parts. The first part discusses the effect of network size (number of agents) on the performance of multi-layer barrier coverage compared to the single-layer barrier coverage, and the second part provides experimental validation on the proposed barrier coverage approach in the robotic platform of Robotarium.

1 Effect of Network Size

Figure 1 presents a comparison of the detection probabilities for single-layer and multi-layer barrier coverage with different numbers of agents at the end of coverage process. It is observed that there is no significant difference in the detection probability between single-layer barrier coverage and multi-layer counterpart when the number of agents is small. As the number of agents increases, the detection probability of multi-layer barrier coverage becomes visibly higher than that of single layer counterpart, which indicates the superiority of multi-layer barrier coverage. When the number of agents reaches a certain value, it becomes futile for single layer barrier coverage and multi-layer counterpart to increase the number of agents further. For instance, when the number of agents reaches 50, the detection probability of single layer barrier coverage increases to 99.8%, whereas the detection probability of multi-layer barrier coverage is close to 100%.

2 Experimental Validation

Experimental validation aims to test the practical feasibility of proposed coverage control algorithm and investigate how control commands drive robots to coordinate their behaviors in practice. Compared with

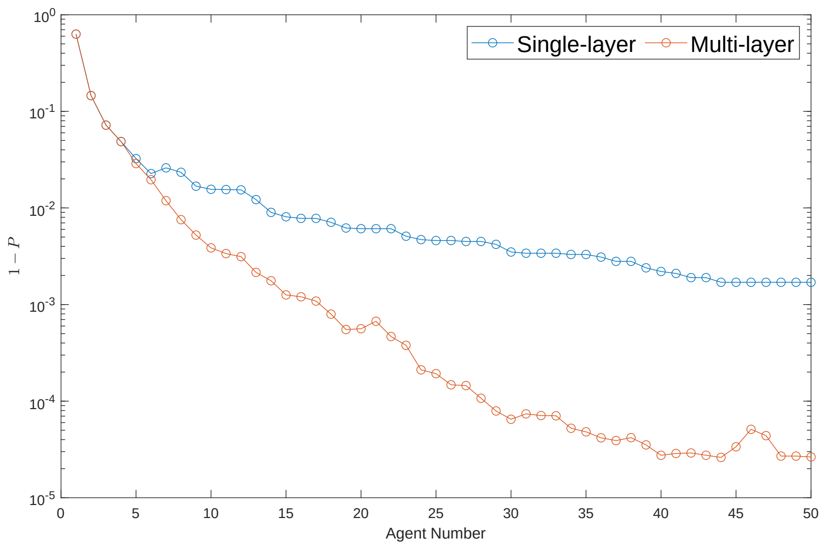

Figure 1: Invalid detection probability for single-layer barrier coverage and multi-layer counterpart with respect to the number of agents.

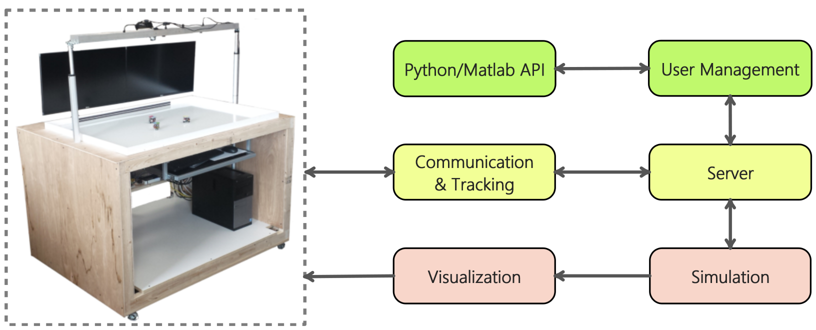

Figure 2: Experimental platform for multi-robot coverage optimization using Robotarium [1].

numerical simulations, real robots are adopted with non-holonomic constraints in the experiments, and obstacle avoidance is guaranteed through infrared distance sensing.

2.1 Experimental setup

The remote-access experiments are carried out on an open multi-robot platform of Robotarium to validate the proposed barrier coverage algorithm [1]. Figure 2 illustrates the experimental architecture of Robotarium, and the platform is composed of robot hardware (for motion tracking, wireless communication, and virtualization) and remote user machines (for user management, code verification and upload, etc). In the experiment, eight robotic vehicles move in the area of $3.2m \times 2m$. The initial position and ori-

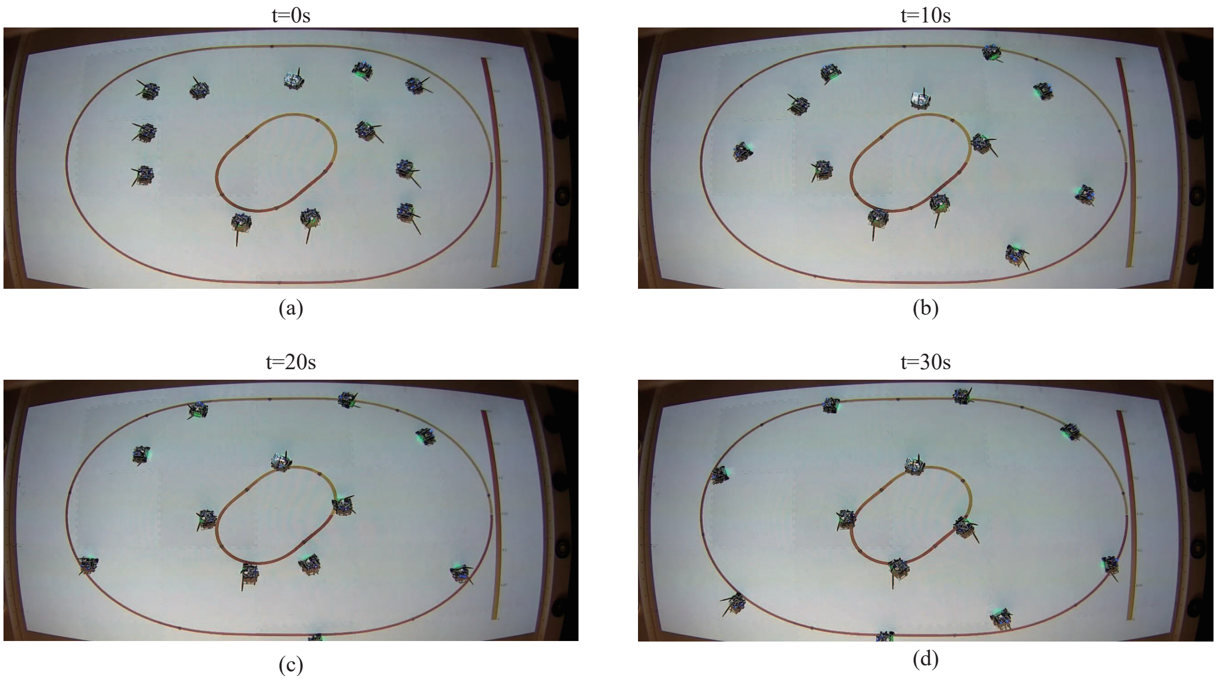

Figure 3: Experimental snapshots for two-layer barrier coverage.

entation of mobile robots and phase angles of partition points are assigned at random. The corresponding experimental video has been uploaded onto the website [2], and each trial lasts for 30s.

2.2 Discussions

Experiments are conducted on the Robotarium platform, and there are two layers in the robotic sensing network composed of 12 robots to monitor the external intruders. The polar equations of the two layers are given by

$$\begin{cases} R_1(\theta) = 0.65 + 0.15\sin(2\theta), \\ R_2(\theta) = 2.3 + 0.5\cos(2\theta). \end{cases}$$

The invasion probability is the same as that in the simulation, and it is described by the function $f(d) = \exp(-d^2)$. The experiment video is recorded and shared on the website [2]. Figure 3 presents four snapshots of multi-robot experiment to illustrate the process of barrier coverage. At the beginning of the experiment, all robots move towards the inner layer. Once the inner layer is filled with robots, they head for the outer layer. Eventually, all the robots are working on two layers, with four robots staying on the first layer and eight agents located on the second one. The time evolution of detection probability for the barrier coverage is displayed in Fig. 4. It is evident that the detection probability of the second layer is not as desirable as that of the first layer, as the first layer is prioritized to ensure a higher detection probability

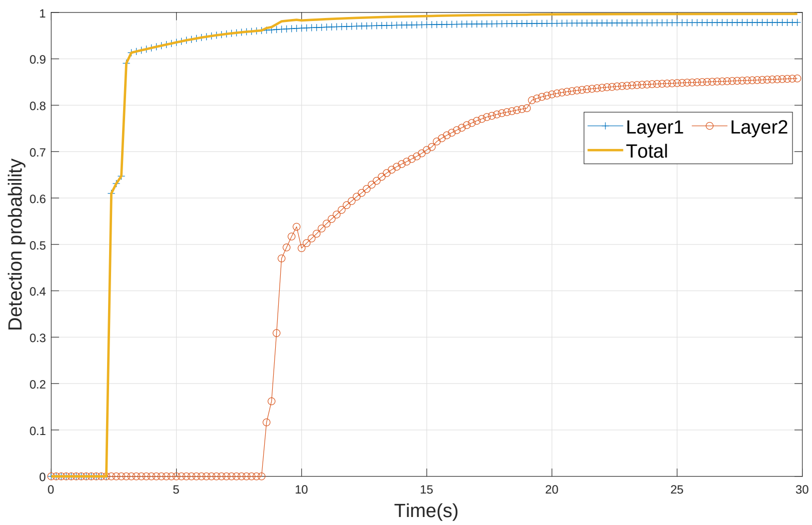

Figure 4: Detection probability of each layer and entire sensing network in the experiment.

when the number of robots is insufficient. It is worth pointing out that the detection probability of entire sensing network is greatly improved by assigning robots on the second layer.

References

[1] D. Pickem, E. Squires, and M. Egerstedt, The Robotarium: An open, remote-access, multi-robot laboratory, 2016.

[2] Experimental video at https://youtu.be/qol7xeealda.