Single Target Tracking in Bionanosensor Networks: Preliminary Simulation Results

Yutaka Okaie
Graduate School of
Information Science and
Technology, Osaka University
1-5 Yamadaoka, Suita, Osaka
565-0871, Japan
okaie.yutaka@
ist.osaka-u.ac.jp

Tadashi Nakano
Graduate School of
Frontier Biosciences,
Osaka University
1-3 Yamadaoka, Suita, Osaka
565-0871, Japan
tadasi.nakano@
fbs.osaka-u.ac.jp

Takahiro Hara
Graduate School of
Information Science and
Technology, Osaka University
1-5 Yamadaoka, Suita, Osaka
565-0871, Japan
hara@ist.osaka-u.ac.jp

Shojiro Nishio
Graduate School of
Information Science and
Technology, Osaka University
1-5 Yamadaoka, Suita, Osaka
565-0871, Japan
nishio@ist.osaka-u.ac.jp

ABSTRACT

In this short paper, we consider a mobile bionanosensor network for tracking a moving target. Two types of interactions are introduced for a group of sensors to collectively perform target tracking: one type of interaction to allow a group of sensors to move toward the target and another type to distribute over the environment. Preliminary results are provided to demonstrate that a group of sensors collectively track a moving target.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous; D.3.4 [**Systems and Software**]: Information Networks

General Terms

Design

Keywords

Target tracking, mobile sensor network, molecular communication, nanonetwork, collective behavior

1. INTRODUCTION

In bionanosensor networks, biological nanomachines are distributed in an aqueous environment to perform various tasks for applications [1, 2, 3, 6]. Nanomachines are made of biological materials and capable of interacting with chemical signals in the environment. Examples of nanomachines are synthetic molecular complexes, artificial cells, and genetically engineered cells. Since nanomachines are made of biological materials and operate based on chemical energy, applications in biomedical and environmental areas are anticipated.

In this paper, we consider a mobile bionanosensor network for target tracking. The mobile bionanosensor network consists of biological nanomachines, simply referred to as sensors in the rest of the paper. Sensors are capable of releasing and reacting to molecular signals and moving about the environment of interest (e.g., within a human body). A target is also a mobile biological object (e.g., a pathogen, infectious micro-organism, or artificial biological device) and its presence is assumed to be a potential threat to the environment.

One challenge of the mobile bionanosensor network is to design a method of signaling by which a group of sensors collectively perform target tracking. Signaling through molecules, namely, molecular communication is a key mechanism for a group of sensors to cooperate. In this paper, we introduce two types of signaling molecules for molecular communication: *repellent* and *attractant*. The repellent is regularly secreted from a sensor and the attractant only from a sensor that detects a target. Both types of signaling molecules form a concentration gradient in the environment that impacts the mobility of a sensor. A sensor tends to move toward a higher concentration of the attractant and therefore move toward the target. A sensor also tends to move toward a lower concentration of the repellent and therefore move away from each other to distribute over the environment.

In the area of wireless sensor networks, mobile sensors are used for target tracking. In [5], for example, artificial potential fields are introduced to compute virtual forces among sensor nodes, and a case study is presented to demonstrate that a group of sensor nodes is capable of chasing a moving

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target based on virtual forces. In the area of bio-nanosensor networks, target tracking is not yet investigated; however, there are relevant works on collective behavior. [4] describes collective behavior of a group of bacteria to achieve a high spatial occupancy of a biological environment (e.g., inside a human body) for medical applications.

2. PRELIMINARY RESULTS

In our simulation, a group of 50 sensors are initially placed at random locations in a 10×10 cm^2 bounded space. A chemotaxis model of a bacterium is applied to simulate the movement of a sensor, and the capability of a group of sensors to track a moving target is evaluated in terms of how the average distance between a sensor and the moving target changes over time.

The tracking capability of a group of sensors is affected by the methods of cooperation among sensors, and preliminary experiments are run to examine the following four cases: (1) *no cooperation*, in which sensors do not interact with attractant and repellent, (2) *cooperation with repellent*, in which sensors interact with repellent only (3) *cooperation with attractant*, in which sensors interact with attractant only, and (4) *cooperation with repellent and attractant*, in which sensors interact with both repellent and attractant.

Fig. 1 shows the cumulative probability of the distance between a sensor and the target for the four cases described above. In cases (1) no cooperation and (2) cooperation with repellent, only 14% of sensors are found near the target ($<$ 1.8 cm). This is because they move independently from the target location. In cases (3) cooperation with attractant and (4) cooperation with attractant and repellent, 27% of sensors are found near the target ($<$ 1.8 cm), indicating that sensors are able to collectively chase the moving target (e.g., by surrounding the moving target). The distributions of sensors in the two cases (3) and (4) are different in that sensors in (4) are more widely distributed in the area that is distant from the target ($>$ 1.8 cm).

Fig. 2 shows the average distance to the target as a function of the moving velocity of the target. The figure shows that a group of sensors that cooperate through attractant (i.e., (3) and (4)) is able to achieve a short distance to the target, but the distance to the target increases as the moving velocity increases. The average distance in other two cases are not impacted by the moving velocity, since sensors move independently from the target in these two cases.

3. CONCLUSION

This paper presented our preliminary results on mobile bio-nanosensor networks. Our current and future work includes further design, simulation, and mathematical analysis for mobile bionanosensor networks. Wet-lab experiments are also an important future work to demonstrate the feasibility of a bacterium-based bionanosensor network.

4. ACKNOWLEDGMENTS

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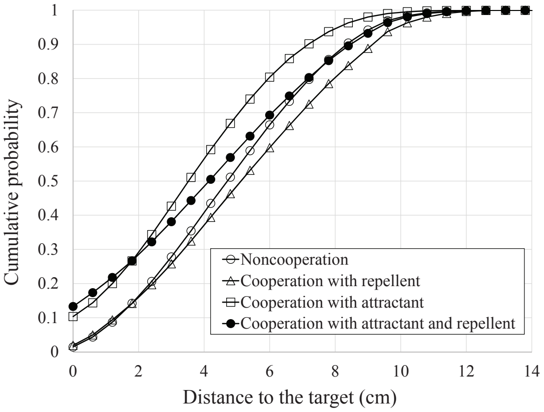

Figure 1: Distribution of distances to the target. A sensor moves at $5.0{\times}10^{-3}$ (cm/s) and the target at 2.0×10^{-2} (cm/s).

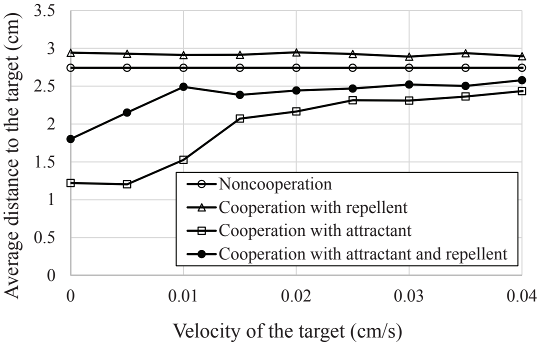

Figure 2: The average distance to the target as a function of the moving velocity of the target.

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