Using Intelligent Self-Organizing Bioparticle Swarms for Uniform Occupancy of Arbitrary Dimensions

Anthony Abraham[1], Juan Lorenzo Hagad[2], Satoru Iwasaki[2], Takuya Obuchi[2], Jian Yang[2]

[1]Osaka University, Graduate School of Frontier Biosciences,
[2]Osaka University, Graduate School of Information Science and Technology

Introduction

Swarms

In nature, many organisms are known to exhibit complex collective behaviour and coordination. This can be seen in schools of fish, insect colonies, and certain species of bacteria[1]. This seemingly intelligent behaviour is a result of relatively simple interactions between individuals in the swarm; and their environment.

Coordinated behaviour in bird, fish and insect swarms

Following the growing popularity of micro-scale biomimetics; we aim in this study to investigate the applications of swarming algorithms towards micro-scale biological and pseudo-biological agents, with the goal of intelligent micro-scale swarms.

Specific Objectives

Intelligent Micro-scale Swarms

1. To find existing mechanisms for micro-organism swarming behaviours.
2. To define a communication and behaviour switching mechanism for simple bio-particle agents.
3. To define a formal, parametric swarming model for uniform filling of the multi-targeted area in a given region, Fig.1.
4. To test the robustness and efficiency of the final model as compared to simple swarming behaviours.

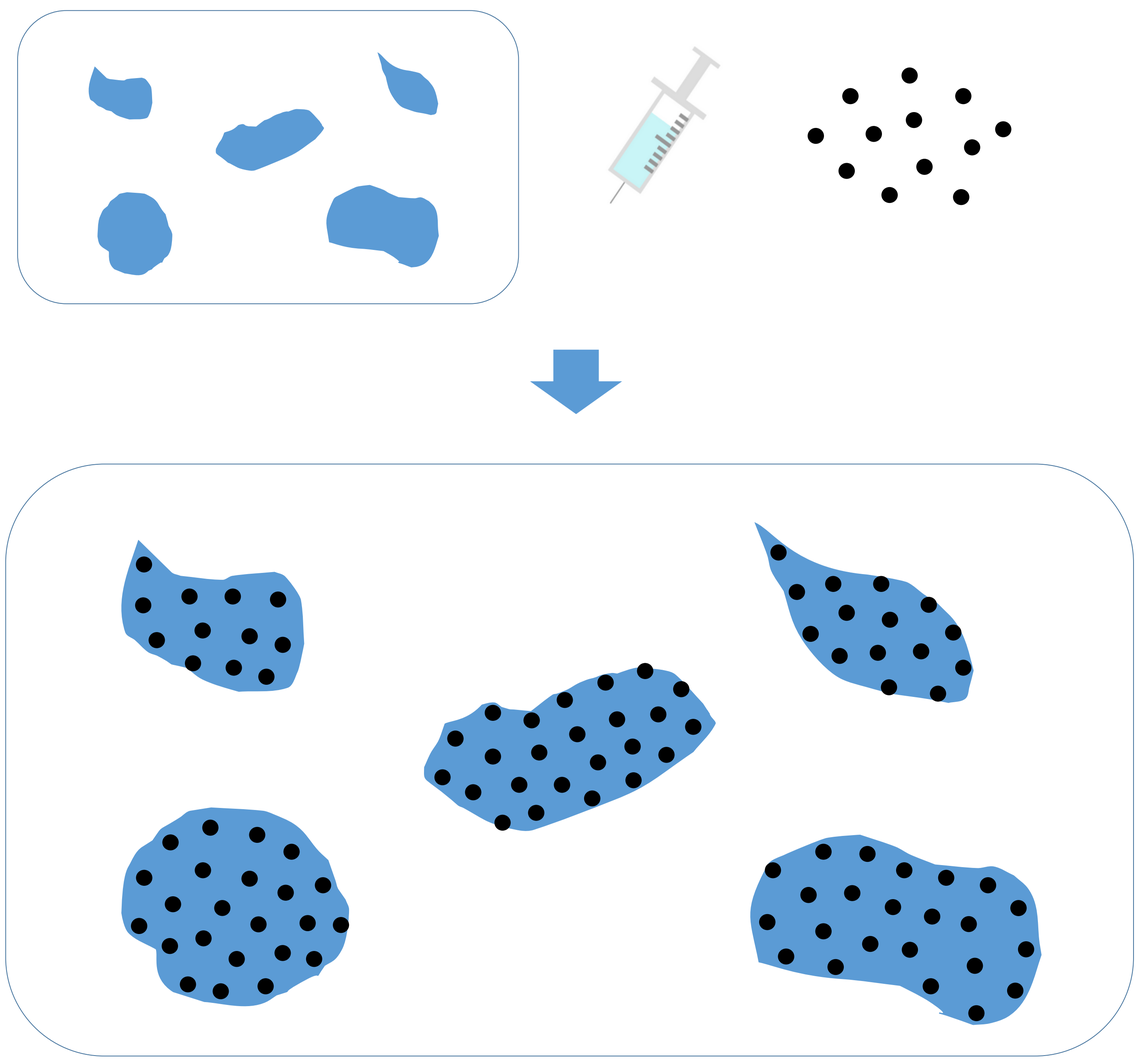


Fig.1. Uniform filling of the multi-targeted region in an area.

Mathematical Model

Imitation of chemotaxis of bacteria

In order to describe the motion of bio-particle agents ,we refer to Chemotaxis of Bacteria. We think that their motion follows the equation;

$$\frac{\partial C_b}{\partial t} = D_b \Delta C_b - \left(\frac{\partial (f_a - f_r) C_b}{\partial x} + \frac{\partial (f_a - f_r) C_b}{\partial y} \right)$$

C_b : Concentration of bio-particle agents
D_b : Diffusion coefficient of bio-particle agents
$(f_a - f_r)$: Velocity of advections

One of our goals is mathematical analysis of this equation. Different behaviors appear by varying parameters.

Underlying Work

Uniform Occupancy of Unitargeted Area

The whole work is divided into several parts, including:
1. A swarming model for uniform filling of an area.
2. A swarming model for searching and navigation for multi-targeted areas.
3. To do the analysis and verification with contrasting the agent-oriented model with corresponding mathematical model.
4. The bio-engineering implement of the swarm.

Analogy of Chemotaxis of Bacteria

Through concentration-adaptive regulation in tumbling angle, bacteria move in different ways.

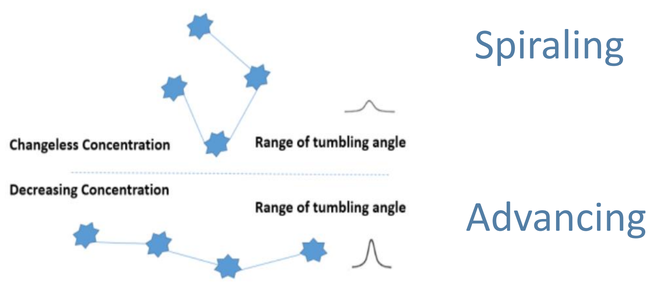
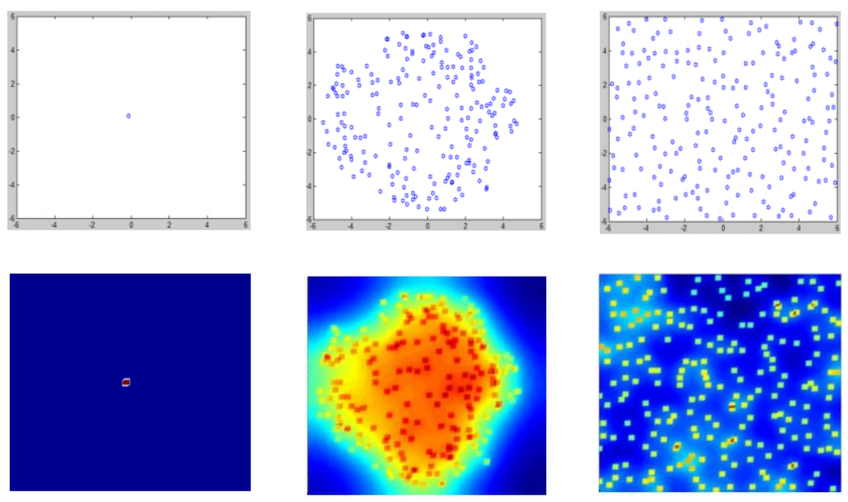


Fig.2. Bacteria's behaviour in different concentration conditions[2].



(A) Initialization Phase (B) Distribution Phase (C) Halt Phase

Fig.3. Uniform filling of one area.

Reference

[1] 1. Shklarsh, A., Ariel, G., Schneidman, E. & Ben-Jacob, E. Smart swarms of bacteria-inspired agents with performance adaptable interactions. PLoS ComputBiol.7,e1002177(2011).
[2] Waters, C. M. & Bassler, B. L. Quorum sensing: cell-to-cell communication in bacteria. Annu. Rev. Cell Dev. Biol. 21, 319–46(2005).