PJP/2011/FKEKK(41C)/S00973

MODELLING AND ANALYSIS OF BIT-COMMUNICATION BEHAVIOUR IN ARTIFICIAL SWARM

ANUAR BIN JAAFAR
MUHAMMAD NOORAZLAN SHAH ZAINUDIN
MOHD MUZAFAR ISMAIL

FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2013

PJP/2011/FKEKK(41C)/S00973

MODELLING AND ANALYSIS OF BIT-COMMUNICATION BEHAVIOUR IN ARTIFICIAL SWARM

ANUAR BIN JAAFAR
MUHAMMAD NOORAZLAN SHAH ZAINUDIN
MOHD MUZAFAR ISMAIL

RESEACH VOTE NO.:
PJP/2011/FKEKK(41C)/S00973

FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2013

ABSTRACT

MODELLING AND ANALYSIS OF BIT-COMMUNICATION BEHAVIOUR IN ARTIFICIAL SWARM

(Keywords: Swarm, Agent)

Bit communication in swarm agents is a communication process of transmitting data within a specific area. The data must be delivered to all agents in the area where such a communication process takes place and this process is also closely related to broadcasting through bit-communication as a way to spread out the data among all agents in the area. This research field needs an in-depth study of the behaviour of homogeneous agents by modelling and analysis of the reversing and non-reversing approaches. It also includes the investigation of the characteristic of data sender and receiver for random process of swarm. In this project, the swarm intelligence technique, which is useful for the bit-communication behaviour has been implemented. There are two approaches used for the transmitting and receiving process. In the reverse approach, the data can be sent back to the sender in the next cycle; when the agent randomly selects one-of its neighbours to transmit the data, while in the non-reversing approach, the data cannot be retransmitted back to the sender in the next cycle. The latter approach is shown to increase the system performance and efficiency up to 12%. By enhancing the number of bit used in bit-communication, the performance has a close approximation to cue based communication, which is an equivalent of the natural behaviour like the bees protecting their nest. As the conclusion, the bit-communication at higher bit order process can be used to produce a model like the cue based communication.

Key Researchers:

Anuar Jaafar
Muhammad Noorazlan Shah Zainudin
Mohd Muzafar Ismail

Email: anuarjaafar@utem.edu.my

Tel. No.: 06-5552025

Vote No.: PJP/2011/FKEKK(41C)/S00973

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

MODELLING AND ANALYSIS OF BIT-COMMUNICATION BEHAVIOUR IN ARTIFICIAL SWARMS

ABSTRACT

Bit communication in swarm agents is a communication process of transmitting data within a specific area. The data must be delivered to all agents in the area where such a communication process takes place and this process is also closely related to broadcasting through bit-communication as a way to spread out the data among all agents in the area. This research field needs an in-depth study of the behaviour of homogeneous agents by modelling and analysis of the reversing and non-reversing approaches. It also includes the investigation of the characteristic of data sender and receiver for random process of swarm. In this project, the swarm intelligence technique, which is useful for the bit-communication behaviour has been implemented. There are two approaches used for the transmitting and receiving process. In the reverse approach, the data can be sent back to the sender in the next cycle; when the agent randomly selects one-of its neighbours to transmit the data, while in the non-reversing approach, the data cannot be retransmitted back to the sender in the next cycle. The latter approach is shown to increase the system performance and efficiency up to 12%. By enhancing the number of bit used in bit-communication, the performance has a close approximation to cue based communication, which is an equivalent of the natural behaviour like the bees protecting their nest. As the conclusion, the bit-communication at higher bit order process can be used to produce a model like the cue based communication.

CHAPTER I

INTRODUCTION

1.1 PROJECT OVERVIEW

Communication is a process that has meaning between two or more living organisms. Basic communication must involve two variables which are sender and receiver. Sender will send the message to the receiver using some protocol or

language that can be understood by receiver. There are two types of communication which are wired and wireless communication. Wired communication involves physical connection for data transfer that connects directly or indirectly through communication nodes between sender and receiver. Telephone network, internet access, television cable and fibre-optic cable are some examples of the wired communication medium. On the contrary, the wireless communication does not have direct physical connection between sender and receiver. Wireless communication can be used to transfer data and information for short or long distance. TV remote control is a short distance device for wireless communication while cellular phone likes GSM, radios, and personal digital assistance (PDAs) are used for long distance in wireless communication. The most fundamental difference between the wireless and wired communication is actually the medium; the former uses radio waves whereas the latter uses cables.

Swarm is a collective behaviour by animals of similar size which aggregate together perhaps milling about the same spot or perhaps moving or migrating in some specific direction. Normally swarm is applicable to the insect's behaviour which has a special rule, behaviour or technique during their daily lives. There are several terms used in swarm such as flocking, herding, shoaling or schooling. Flocking is the behaviour of birds flying together in a group, while herding used by quadruped mammals and shoaling or schooling refers to swarm behaviour of fish.

In a real application, like in Penang area, where somebody sees the wave of tsunami at the beach, he wants to tell others about the danger that will occur. After that, he uses his mobile phone to share the data and information with others. Another example that can be used is during an earthquake. An earthquake can be felt because of the vibrations occur randomly in certain areas. Due to its sudden and random occurrence this initialization approach can be applied. The best way to describe the concept of bit-communication is like passing a baton from one to another in the area, which means that after the baton has been passed, the sender does not has the baton anymore. For 1-bit communication, there is only 1 baton exists in the arena.

For 2-bit and 3-bit communications, there are 2 and 3 batons respectively, which means that after the initialization, the sender has to transmit the data to two or three agents of its neighbours. The analogy is like, when an observer of an event wants to send a data or information, he will choose to send to many receivers that he has in his mobile phone, depending on the number of receivers he wants.

1.2 PROBLEM STATEMENT

A communication in swarm agents is a technique or method used for sending a data to all agents. This approach is used to study the effectiveness of communication that is based on behaviour exhibited by animals. In terms of communication, the communication using swarm of agents and current communication process like cellular phones has some differences because of different methodologies and approaches used. By modelling the bit communication in swarm agents, the comparison between the two methods can be analysed for the best performance in communication later on.

In bit-communication technique, an increase in the number of data being transmitted will increase the time taken for all data to be received by all agents. Furthermore the efficiency of the communication process for previous methods like cellular phones and swarm agent can be determined in terms of cost, quality, effort and error.

The purpose of study in bit-communication is to determine the complexity in bit-communication as to achieve same result as cue based behaviour. If the number of bit used is increased, the performance can be calculated.

1.3 PROJECT OBJECTIVES

The key research question for this research is "How can the swarm agent's behaviour be improved in bit-communication?"

The first objective of the project is to design one-bit communication for more than one agent in an area where reverse and non-reverse approaches are used for data transfer. The non-reverse behaviour does not allow the receiver to resend the packet of data back to the sender after one-cycle while the reverse method allows this.

The second objective is to design two-bit and three-bit communications for same area for reverse and non-reverse behaviour. The agents that have the data can send two or three packets of data simultaneously. Receiver agent the data packet can send two packets of data individually.

The third objective is to model the cue-based communication behaviour of honey bees protecting their nest as shown in nature. Ultimately, the goal is to study and understand the behaviour of all bit-communication that can improve performance in terms of cost, effectiveness and accuracy.

1.4 PROJECT SCOPE

In this project, communication among swarm agents is designed by using NetLogo 4.1.1 software. The design contributes to the study of the behaviour and characteristics of communication among swarm agents employing reverse and reverse approaches in data transfer. The behaviour and characteristics that are studied include the time taken to transfer data among all agents.

1.5 CHAPTER OVERVIEW

This thesis consists of five chapters. The following is an outline for Bit-Communication in Swarm Agents model. Chapter I discusses the project introduction that consists of project overview, project objectives, problem statement and project scope.

Chapter II discusses the literature review surrounding the project. The data and information collected from secondary sources such as books, and internet which are compared to determine the best solution to tackle the problem.

Chapter III describes the methodologies used to design the model of communication in Swarm Agents for transmitting and receiving data as well as indicating successful data transfer among agents. All these methodologies need to be followed to avoid any error and problem during the experiment.

Chapter IV presents and analyses the simulation data in tables and graphs as well as elaborates the results and findings for different number of bits used in communication.

Finally, in Chapter V, the conclusions are drawn and the future work are stated.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

The literature review included all those findings about swarms, multi-agents, wireless networking, broadcasting and all the relevant findings for this project.

2.2 Biological Foundation of Swarm Intelligence

Swarm intelligence is a modern artificial intelligence (AI) that focuses on the design of a system using multi-agent approach and has been applied in several applications such as for robotics and optimization application. The design method using swarm intelligence is different as compared with the traditional method like cellular phones.

"He must be a dull man who can examine the exquisite structure of a comb so beautifully adapted to its end, without enthusiastic admiration." (Darwin, C. 1872. In author Blum, and Merkle, 2008). 5000 years ago, the Egyptians kept the honeybees and were amazed by the beauty of bees' comb. However, the real beauty of the bees' comb is in the logical thinking about how the bees can build the hexagonal cells perfectly? It was suggested that the shape of hexagon can hold the most honey,. However, a French physicist R.A.F. de Réaumur calculated that the amount of material and wax needed to build the equality of hexagon. Normally to create a perfect hexagon shape, all the six angles need to be set to 120°. However for bees, the colony did not learn that because bees were "blindly using the highest mathematics by divine guidance and command" (Ball 1999). The theory said that bees need a divine guidance to build hexagonal cell cannot be accepted because it was natural for bees to build hexagonal cell.

It was exactly such 'Darwinian fables' that inspired the biologist and mathematician D'Arcy Wentworth Thompson to write his book *On Growth and Form* (Thompson 1917). Previously Thompson argued about the hexagonal cell, built by the bees, is a simple example that show the pattern formed to all layers of bubbles to the space. The wax of the Bees' is a soft wax that simply pulls a perfect hexagonal cell in array form by physical forces techniques. Hence the pattern formed spontaneously and no natural selection or divine interference needs to be invoked (Ball 1999).

Autocatalytic reaction-diffusion systems will lead to Turing patterns (think stripes on tiger) in both chemical and biological mediums (Kondo and Asai 1995; Ball 1999), and minerals form patterns that have even been mistaken for extra-terrestrial fossils (McKay *et al.* 1996). According to the behaviour of swarm, it shows physical forces and the arrangement of the cell can explain the pattern formation for every swarm found in our environment. So it is not a surprising thing that the patterns are inspirations for many people either they are scientist or not. Lately the hexagonal pattern of Bees' in their honeycombs is not unique anymore. By using some chemical reaction, the pattern can be formed as same as the hexagonal shapes.

In fact, the growth of bacterial colonies has proven to be an important playground for testing idea on non-living branching systems (Ball 1999). As it

turns out, many branching patterns found across nature can be explained by same process, knows as diffusion-limited aggregation, resulting from the interactions of the particles, be they molecules or individual bacteria (Ball 1999). All these similarities are illustrated on pattern formation of bacteria colonies for their working principles. Each bacterium manipulated the amount of food to another bacteria and resistance of a liquid to shear forces of their medium. Ball found many branches pattern and formation in the bacteria nature of lives. The honeybee's comb is not just amazing because of the perfect form of hexagonal cells but also because bees also can fill every cell with their eggs for the next populations. The egg will turn to larvae, pupae and finally be a new bee in the colony. In addition, the bees' also can fill the cell with pollen, which is to feed the egg, and nectar that will convert to honey in a characteristic pattern. The pattern can be differentiated into three parts; for egg (new population), honey and pollen as shown in Figure 2.1. When the behaviour of bees is studied further, the egg and pollen must be closer to each other because the egg needs food to live before it can be transformed to a new bee. After the new bees are produced, it needs to work to find food and honey for their colonies. This process continues until the bees can produce eggs. The beauty of the Bees' working environment is that they are working in macroscopic entities that are very small to see by the normal eye. Honeybees are suitable for observation and study, because the population or colonies of bees can experimented in a small house or area as shown in Figure 2.1. For a deeper observation, all bees can be marked with numbers to see the movement and interaction among them. The best way to mark all bees is by putting the

number on their head. However, as to observe all of these populations, the bees must be put in their environment, for the population ecosystem not to be interrupted. Furthermore, bees without any number pasted on them can determine the new bees. By observation also, the behaviour of bees can be distinguished for the different three parts; for food, egg and honey. All these three parts are allocated clearly in several pattern for the process or working of the bees at any time.

Figure 2.1: A snapshot for the colonies of Bees' *(reproduced with permission from Richard Underhill, Peace Bee Farm, Proctor, Arkansas, USA)*

As it turns out, bees do have a clear preference when they remove pollen or honey from cells (Blum and Merkle, 2008). Figure 2.2 shows the structure pattern of bees' colonies. The hexagonal with grey, white and black colours indicates the honey, pollen and brood respectively. There are more locations of eggs compared to pollen or brood in the hexagonal cells. 54.49%