Bio-inspired Communication for Self-regulated Multi-robot Systems (MRS)

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Abstract

In this book chapter, we intend to present a timely analysis on various direct communication strategies of multi-robot systems (MRS) along with our case study of implementing communication systems for a large MRS with 40 robots. Both centralized and local communication strategies are explored within the context of self-regulated multi-robot task allocation (MRTA). For this purpose, we have used our collaborative trans-disciplinary model of division of labour called as attractive field model (AFM) (Arcaute et al. 2008). We also present an analysis of the scale-freeness of our implementation using experimental evidence from varying robot group size (8-40), experimental area (2-10 m^2) and number of tasks (2-10).

In order to illustrate the suitable mechanisms for communication in MRS, we have put our work in the context of a self-regulated phenomena, i.e., division of labour or MRTA. As a part of a collaborative project, we have studied the behaviour of ants, humans and robots and have developed AFM, a common formal model of division of labour in social systems. We introduce AFM formally by describing its general characteristics and underlying mathematical model. However, scientific models can not gain wider acceptance without validating those models by experiments with real systems. In our case, AFM has been originated from the study of ants, robots and humans and systematically tested through computer simulations and its validation is well under-way by putting it in human social systems and real robotic systems. We present the validation of AFM that brings self-regulated task allocation in our large MRS through a set of generic rules derived from the study of biological, human and artificial social systems (Sarker & Dahl 2010*b*).

Communication is the essence of any social interaction among individuals and their environments. Since biological studies of communications of various social insects and other animals become one the major inspirations for designing scalable communication system for large MRS. Particularly, a branch of MRS called swarm robotics (SR) has been solely established by following the natural mechanisms of self-organizations in various social insects and other biological species (Bonabeau et al. 1999). These self-regulated social systems provide

us with living examples of scalable and flexible social communication systems that effectively serve their various social needs. In biological literature, animal communication has been broadly classified into two classes: direct or explicit communication and indirect or implicit communication (e.g., stigmergy of ants through pheromone trails) (Balch & Arkin 1994, Labella 2007). In this article, we review various biological communication systems in terms of communication modalities, information flow, group size, productivity and so forth. We also review the state-of-the art of communication in multi-robot systems. AFM relies on the presence of a system-wide continuous flow of information. Our implementation shows that an interdisciplinary generic model of division of labour like AFM can not be realized effectively in a MRS without a suitable communication system. In this book chapter, the inclusion of our comparative results of self-regulated MRTA using both centralized and local communication systems can illustrate this fact more vividly (Sarker & Dahl 2010*a*).

We also analyse the scale-freeness of our MRS using experimental evidence from a number of experiments with parameter values, i.e., number of robots, tasks and area size, that vary systematically so that their ratio or characteristic scale remains constant. The issue of scale freeness in MRS is not widely studied, with a few exceptionsd(Gustafson & Gustafson 2006)). Our study fills that gap, particularly with a large number of real robots (up to 40).

This chapter is organized as follows. After an introduction in Section 1, Section 2 presents the attractive field model (AFM). Section 3 describes the validation of AFM for MRS. Section 4 reviews the various communication strategies found in biological and robotic systems. Section 5 describes results of our centralized and local communication experiments. Section 6 analyses the scale-freeness of our system. Section 7 presents related work and section 8 includes discussions and conclusions.

References

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