An Accelerated Resource Utilization in Autonomous Stochastic Mobile Multi-Agents

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ABSTRACT

This paper describes how to coordinate autonomous mobile multi-agents, whose agents stochastically move over a finite resource consisting of cells in accordance with transition probabilities. We assume there are interactions or coordination among agents such that (1) each agent cannot move to a destination cell occupied by agents more than the agents of a current cell and (2) their agents have time-lag. Then it is ideal that every cell is always occupied by agents, because of the efficient use of resources, and it is desirable to be the fewest expected number of cells not occupied by agents. The first result shows that the resource utilization of accelerated mobile multi-agents with appropriate average moving speed becomes higher than the resource utilization of mobile multi-agents without average moving speed. Then the resource utilization can be accelerated to maximum by giving appropriate moving speed. The second result shows that there are the best moving speed of system-specific optimum to utilize the resources of autonomous stochastic mobile multi-agents.

Keywords: Autonomous Stochastic Mobile Multi-Agents, Coordinated Multi-Agent Systems, Mobile Multi-Agents, Resource Utilization, Transition Probabilities

1. INTRODUCTION

This paper describes a new accelerated resource allocation of autonomous mobile multi-agents, whose agents stochastically move on the cells arranged over a finite resource, i.e. a straight line, according to transition probabilities with time-lag (or time-delay) and average moving speed (also called simply speed, or velocity) in synchronization. The moving of each agent is restricted, and it depends on the number of agents over destination cells within a specific ranged window, so that there is coordination among agents. The first analysis and experiments show that the resource utilization of mobile multi-agents becomes higher than the resource utilization of mobile multi-agents without average moving speed, i.e. the resource utilization can be accelerated to maximum by giving appropriate moving speed. The second result shows that the maximum utilization of the resources are analyzed, and we present the optimal moving speed concerning a system-specific inertia or viscosity.

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In our real world, there are a lot of unusual beings with unexpected phenomena that are beyond human understanding. In fact, a mobile multi-agent behavior is one of them, while it is quite difficult to analyze the behavior of multi-agent systems, because there are interactions or coordination among agents.

We are in need of a simple model being no fat in mobile multi-agents, KISS: Keep It Simple Stupid (Axelrod, 1984). Fortunately, Sen et al.’s (1996) proposed a basic simple model of mobile multi-agents, and Rustogi et al. (1999) presented the fundamental results in mobile multi-agent models. Ishiduka et al. (2003) also introduced a time-lag and showed the relationship between time lag and stability in mobile multi-agents. These models are intended to clarify how fast the mobile multi-agents fall into a complete stable state, i.e. a hole state in absorbing Markov chain (Grinstead & Snell, 1997), thus the goal is how to design a coordinative system which falls into a stable hole in shorter passage time as soon as possible.

On the other hand, Toyabe et al. (2010) experimentally demonstrated that information-to-energy conversion is possible in an autonomous single stochastic mobile agent. The idea is that when an agent goes up the spiral stairs during stochastic movements, it sets the stopper on the stairs so that the agent does not come down. This approach needs an explicit control that the agents do not come down the spiral stairs. Our ultimate goal is to extract energy from stochastic mobile multi-agents.

Our model which is called MATMS (Multi-Agent with Time-lag and Moving Speed) is based on Sen et al.’s (1996) and the developed model with time-lag proposed by Rustogi and Singh (1999). We note that our purpose is different from Sen et al. (1996), Rustogi et al. (1999) and Ishiduka el al. (2003) works which try to clarify the relationships between time-lag and stability in multi-agent systems. In other words, their papers try to find or design the multi-agent configurations satisfying autonomous uniform resource allocation in a shortest passage time. On the other hand, our multi-agents initially start from the state at a highest resource utilization, every agents on resources stochastically move over cells, and it just likes atoms in a liquid. They never stop. In addition, we extend their models to have average moving speed. Our model satisfies Markov condition and irreducible so that the behavior after infinite time does not depend on the initial configuration of the multi-agents, and our problem is to find higher resource utilization of multi-agent configurations accompanying agent movements. It just likes as a molecule has an energy so that it is always moving, and it depends on the manner of substances. Shioya and Miura (2012) discovered a new stable behavior of mobile multi-agents with appropriate moving speed. In this paper, we show that the resource utilization of stochastic mobile multi-agent systems, whose agents move as a whole in average, becomes higher than other ones not having average moving speed, analytically and experimentally.

Our model MATMS is a kind of stochastic mobile cellular automata, SMCA (Wolfram, 2002), and they are both in finite state Markov mobile model. An MATMS can translate to an SMCA, and the obtained SMCA becomes a complicated SMCA with many cell neighborhoods compared to SMCAs with five or nine cell neighborhoods or more. Another similar model is Random Walk (Blom et al., 1994). An essential distinction from above two is that MATMSs have an acceleration and time-lag of stochastic moving cells like atoms or particles in gas.

To view the results of our works might brings us the following question. How to give a moving speed of mobile multi-agents? The moving speed is naturally caused by stochastic mobile multi-agent behavior, if individual objects in nature are governed by the minimum entropy production principle (also see the paper: Shioya and Miura 2012). But, we note that, for a given multi-agent, the speed for efficient use of the resources does not exactly match the speed for more stable behavior by comparing this paper and the previous paper (Shioya & Miura, 2012).
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