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Synchronous Robots vs Asynchronous Lights-Enhanced Robots on Graphs [1]

Mattia D'Emidio[2]

Gran Sasso Science Institute (GSSI), Viale Francesco Crispi, I–67100, L'Aquila, Italy.
Department of Information Engineering, Computer Science and Mathematics, University of L'Aquila, Via Vetoio, I–67100, L'Aquila, Italy.

Daniele Frigioni[3]

Department of Information Engineering, Computer Science and Mathematics, University of L'Aquila, Via Vetoio, I–67100, L'Aquila, Italy.

Alfredo Navarra[4]

Department of Mathematics and Computer Science, University of Perugia, Via Vanvitelli, 1, I-06123, Perugia, Italy.

Abstract

In this paper, we consider the distributed setting of computational mobile entities, called robots, that have to perform tasks without global coordination. Depending on the environment as well as on the robots' capabilities, tasks might be accomplished or not.
In particular, we focus on the well-known scenario where the robots reside on the nodes of a graph and operate in Look-Compute-Move cycles. In one cycle, a robot perceives the current configuration in terms of robots positions (Look), decides whether to move toward some edge of the graph (Compute), and in the positive case it performs an instantaneous move along the computed edge (Move).
We then compare two basic models: in the first model robots are *fully synchronous*, while in the second one robots are *asynchronous* and *lights-enhanced*, that is, each robot is equipped with a constant number of lights visible to all other robots. The question whether one model is more powerful than the other in terms of computable tasks has been considered in [Das et al., *Int.'l Conf. on Distributed Computing Systems, 2012*] but for robots moving on the Euclidean plane rather than on a graph.
We provide two different tasks, and show that on graphs one task can be solved in the fully synchronous model but not in the asynchronous lights-enhanced model, while for the other task the converse holds. Hence we can assert that the fully synchronous model and the asynchronous lights-enhanced model are incomparable on graphs. This opens challenging directions in order to understand which peculiarities make the models so different.

Keywords: Distributed algorithm, Synchronicity, Mobile Robots, Luminous Robots

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1 Introduction

In the last few years a considerably large amount of research, in the area of distributed computing, has been devoted to the study of models and algorithmic approaches for the so-called *robot-based computing systems*, due to their importance in a wide range of real-world applications. In this kind of systems a set of mobile entities, usually referred as *robots*, have either to perform tasks and/or to achieve goals under a variety of assumptions that depend on the considered scenario [6,14].

Particular efforts have been dedicated to models where robots are *autonomous*, i.e. they act without a central control, and operate in a *Look-Compute-Move* (LCM) operational mode (see [1,2,3,19,22] and references therein). In such a model, which has become a prominent one in the area of distributed algorithms for robot-based computing systems, robots operate in so-called *LCM cycles*. During each cycle, a robot acquires a snapshot of the surrounding environment (*Look* phase), then executes an appropriate algorithm, which is the same for all robots, by using the obtained snapshot as input (*Compute* phase), and finally moves toward a desired destination, if any (*Move* phase).

Several modeling assumptions have been also considered that can affect the computational power of the robots. In particular, in some cases, robots may have distinct identities, i.e. each robot is associated with a different identifier that can be used during the Compute phase. If robots are without identifiers, they are said to be *anonymous*. In some other cases, robots may have a finite but *persistent* memory device whose content is preserved from one LCM cycle to the next; robots are said to be *oblivious* if they do not, which means that they start each cycle without any information about what happened in the past.

In this research area, many different problems and tasks have been studied: robots might be asked to gather in certain specific locations [20] (also known as the *Gathering* problem), to form a desired geometric pattern [21] (also known as the *Pattern Formation* problem), or to explore an unknown area [17] (also known as the *Exploration* problem). In addition, several different settings have been investigated. Robots can move on a Euclidean plane [16], or they are constrained to move on a given input graph, which can either be known in advance [9] or not [4]. Robots can be able to communicate, e.g. by means of tokens as in [15], or not [18]. Finally, there might exist or not an objective function to be optimized, associated with the problem (see [3,11,12,13] and references there in). For instance, one may ask for the minimum number robots, the minimum number of steps performed by all the robots, or the minimization of the maximum number of steps performed by a single robot, to achieve a certain goal.

Look-Compute-Move cycles might be subject to different temporal constraints

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[2] Email: mattia.demidio@univaq.it

[3] Email: daniele.frigioni@univaq.it

[4] Email: alfredo.navarra@unipg.it