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Simulating robot groups with elements of a social structure using KVORUM

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Abstract

This paper describes the architecture of KVORUM, the agent-based modeling environment developed by the authors to explore certain design decisions and facilitate simulation usage in the field of group robotics, specifically for research of robotic systems with elements of a social structure. KVORUM is a prototype of a simulation system that should adequately abstract away complexities of a physical system while providing convenient interfaces and library modules for modeling groups of mobile land robots and individual agent's intrinsic structures. It was built from the ground up as a modular, highly extensible system focused on speed of calculations that is to be achieved by using proper simplification of physical and other effects, and by the ability to perform simulations using parallel computing. In KVORUM the developed abstractions and limitations of a parallel architecture are tested without fully adhering to parallel computing requirements. It is shown that the proposed method of simulating such systems is applicable to a wide variety of problems from the field of group robotics with elements of a social structure (and swarm robotics in general). Some features of the architecture and models used in KVORUM allow for it to be extended in next iterations to fully support simulations on parallel computing systems.

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1. Introduction

The main task of group robotics is the construction of such a system that would give new qualities and improved characteristics due to the interaction of many individual agents possessing relatively simple rules. The main method of studying these systems is simulation and agent modeling, for which researchers use different environments and libraries.

The term “agent” means anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors [17] and Autonomous agents are computational systems that inhabit some complex, dynamic environment, sense and act autonomously in this environment, and by doing so realize a set of goals or tasks for which they are designed[12].

One of the areas of research in group robotics is the study of biological systems in order to apply the principles of their organization to build a team of robots, as they demonstrate many desirable qualities, such as resistance to external perturbations, ability to work in unknown environments and efficiency. A new and very promising direction in this area is the approach based on social behavior and the various mechanisms associated with it [6]. We will further refer to artificial groups that have these mechanisms as “groups with elements of a social structure”.

The review of various existing simulation systems as well as analysis of the common problems in this field allowed to obtain a set of requirements and showed that no existing system fully satisfies them. First of all, let us briefly not some characteristic modeling systems, as well as their features in connection with the problem under consideration

Gazebo[10]is a program and a set of libraries that allows one to simulate the behavior of robots with regard to physical effects. Capabilities of the simulation system can be expanded using readily available plugins or by writing new plugins, for example, by adding infrared rangefinders, a video camera or physical effects of movement through a liquid. However, Gazebo is poorly suited for simulating systems with a large number of agents because of the rather high computational cost (it is difficult to model more than 1000 agents).

AnyLogic [3] and Repast[1]provide very versatile tools for agent-based (and other types in the case of AnyLogic) modeling. Both systems are undoubtedly powerful and advanced modeling tools, but they are aimed at a greater range of tasks than simulating robotic systems with social structure elements, and as a result, as far as we know, they do not provide any special libraries for modeling systems in this field.

Unlike systems that support detailed modeling of physical processes, or the universal agent-based and simulation modeling systems, there are simulations and modeling libraries made explicitly for social systems. The examples are NetLogo[19], Myrmedrome [4] and AntMe! [18]. NetLogo, despite the power of the language itself, has very limited functionality for modeling robotic systems with elements of social structure, and the other two programs are not modeling libraries, but they rather illustrate and simulate some elements of behavior of ants.

Myrmedrome [4] is an agent-based ant colony simulator, built on the principle of ants' reaction exclusively to local events. Ants interact with each other using chemical signals (Fig. 1a, white lines – pheromones’ paths). Agent control algorithms are nondeterministic: at every step, when all the parameters of the ants are updated, there is a possibility that the selected action will not be performed. This makes the system flexible to unforeseen situations. Myrmedrome imitates the life of an ant’s colony in a restricted area of the environment. The social organization is based on a caste system, in which there are workers and soldiers. The first perform basic functions to find food, which they store in joint stomachs (and which are shared with other ants). Workers will try to kill prey upon encountering it and will consider ants from other colonies a threat and announce their presence using pheromones. Soldiers defending the nest will find a source of danger and seek to destroy it. The program provides the user with the ability to manipulate the environment and ants: add food, move ants, change the parameters of pheromone, the number of ants and some other (Fig. 1a). It is an anthill simulation but not a library for modeling, and the source code of this program is not open for modification.

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