Chapter 3
An Overview of Swarm Robotics

Andrei George Florea
Politehnica University of Bucharest, Romania

Cătălin Buiu
Politehnica University of Bucharest, Romania

ABSTRACT

Robotic swarms represent the application target of the studies presented in this book and therefore required the reader to be acquainted with the main concepts behind this branch of robotics. The introduction of swarm robotics principles is done only after presenting multi-robot systems, in comparison with single robot systems. Among the concepts that are defined in this chapter we mention: swarm robotic system, stigmergy and neighborhoods. After this theoretical introduction, the chapter continues with a presentation of robotic platforms that can be used to validate swarm algorithms. Among the robots listed are the Kilobot, the e-puck and the Khepera. As swarm robotics generally requires a large number of individuals, the costs of running experiments on real robots can become high. For this reason, robot simulation platforms are also discussed at the end of this chapter.

INTRODUCTION

Swarm robotics is a recent and important paradigm which is based on the principles of swarm intelligence applied to large groups of simple robots. Robotics itself is a fast developing area in which theoretical scientifical advances have been backed by impressive technological developments. The International Federation of Robotics (IFR press release, n.d.) is releasing every year robot statistics and forecasts. For 2015, it was reported the largest number of industrial and service robots sold. More than 41,000 units of professional service robots were sold with a sales value over 4.6 billion USD. As for the personal and domestic use service robots, there were sold more than 5.4 million units with a sales value of over 2.2 billion USD. The projections for the period 2016-2019 indicate that more than 333,000 units of service robots for professional use and over 42 million units of service robots for personal and domestic use will be installed. The general industry has been the key sector leading the increasing demand for industrial robots which in 2015 increased by 15% with a global sales value of over 11.1 billion USD. At the end of

DOI: 10.4018/978-1-7998-1754-3.ch003

2015 there were 1.6 million operational industrial robots. Robot density is a key indicator when comparing the distribution of industrial robots in various countries. This indicator is defined as the number of multipurpose industrial robots per 10,000 persons employed in the manufacturing industry. The average robot density in 2015 was 69 (IFR press release, n.d.)

The *Robotics 2020 Multi-Annual Roadmap* issued by SPARC (Lafrenz, 2016) supports a Strategic Research Agenda in robotics. The roadmap provides an interesting and useful view of the robotics market with key market domains (manufacturing, healthcare, agriculture, consumer, civil, commercial, logistics and transport) and identifying key abilities for robots (Adaptability, Cognitive Ability, Configurability, Decisional Autonomy, Dependability, Interaction Ability, Manipulation Ability, Motion Ability and Perception Ability).

Swarm robotics is based on collective intelligence that arises from the interaction of many, simple robots. While most of the experiments in swarm robotics have been performed in simulation and to demonstrate key macroscopic behaviors, the real-world applications of swarm robotic systems are gaining momentum. The goal of this chapter is to provide an introduction to the principles of swarm robotics, key definitions, some examples of robots and software platforms that are commonly used in swarm robotics experiments.

SWARM ROBOTICS

Multi-Robot Systems: An Overview

Multi-robot systems (or collective robotic systems) are systems composed of multiple (autonomous) mobile robots and they offer important advantages as compared to single robot systems (Parker, 2008): (1) a task may be too complex for a single robot to achieve; (2) when the task by itself is distributed this requires the use of multiple robots to achieve it; (3) a single very complex robot might be more expensive to build than many simpler robots; (4) the inherent parallelism of a multi-robot system can help to solve the task quicker; (5) robustness is greatly improved when using multiple robots. There are different ways in which a multi-robot control architecture can be organized: centralized, hierarchical, decentralized, and hybrid.

Networked robots are a special case of multiple robot systems in that the coordination and cooperation between individual agents (robots) is achieved through networked communication. According to the IEEE RAS Technical Committee on Networked Robots (http://www-users.cs.umn.edu/~isler/tc/), networked robots are robotic devices connected to a communications network and can be divided into: (1) tele-operated robots (commands and feedback are exchanged through the network with human operators) and (2) autonomous networked robots (robots and sensors exchange data through the network).

Swarm robotics is an expanding research area in collective robotics that studies how emergent behaviors arise from direct local interactions between a large number of simple robots and through their indirect interaction via a shared environment. There is no central coordination of the robots, yet the swarm, as a whole, displays capabilities that are beyond those of individual robots. The main motivations for swarm robotics research are scalability (adding any number of additional robots would not change the group behavior as a whole), flexibility (the swarm is capable to operate with success in different environments while performing different tasks), and robustness (failure of single robots would not affect the behavior and performance of the swarms as a whole) (Şahin, 2005).