Chapter 2
Towards Application of Collective Robotics in Industrial Environment

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ABSTRACT

The chapter is concerned with a significant area of modern robotics, i.e. multiple robots working as one group, team, swarm or organism. The notion of taxonomy is introduced and an overview of cooperative, networked, swarm and nano-robotics is given. The chapter also analyzes reconfigurable robotics as a tool for improving granularity and adaptive functionality. The development of symbiotic self-reconfigurable systems is discussed and a survey of artificial self-organization is provided. Advantages provided by robots working in collective ways are demonstrated, such as: advanced flexibility and adaptivity; possibilities to evolve behaviours, functions and structures; extended reliability of swarm and symbiotic systems; economic considerations related to agility of enterprises. Finally, emphasis is given paid to a more "difficult issue" which artificial self-organization. It is indicated that technical collective systems may have self-organizing phenomena, despite the fact that they are artificially designed.

INTRODUCTION

Modern robotics (Siciliano & Khatib, 2008) trends not only to be reliable, cheap, autonomous, but also cognitive, adaptive, safe and friendly for users (Dodd, 2007). New generation of robot systems is capable of self-configuration (Shen at al., 2006), self-diagnostics and self-healing (Mokhtar et. al., 2008), possesses enough sensing features and computational intelligence on board not only to sense environment, but also to adapt to changes (Kernbach et al., 2008). Application of such robot systems in industrial environments makes possible new types of manufacturing (Westkaemper, 2008): smart, reconfigurable on demand, scalable from micro- to macro- dimensions, transparent for workflow- and management- processes.

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Industrial robotics (Colestock, 2008) in general follows this trend: lightweight robots (KUKA, 2006) are developed, classical robot arms receive more on-boards sensors with pre-cognitive capabilities (ABB, 2007), new industrial application fields with a demand on cooperative actuation appeared (EURON, 2005). In the research are automatic guided vehicles (AGV) with an attempt of making them more intelligent and autonomous (Watanabe et al., 2001), cooperative assembling in automotive industry - so-called "RoboTeams" (Vasilash, 2006), cooperative process handling (Appelqvist et al., 1997) and process planning (Kornienko, 2004), and others.

Cooperative aspects of sensing and actuation are massively used by collective robotics (Kornienko, 2005). In contrast to classical robotics, dealing only with a few complex robots, collective robot systems consist of many more simple interacting autonomous elements, denoted commonly as agents. In industrial environment these agents are robots, manipulators, manufacturing cells, AGV, functionalized micro- and nano- particles (Schmid, 2004) or particles in colloidal systems (Fujita & Yamaguchi, 2009). Depending on requirements, collective systems have different coordination mechanisms, reflected in cooperative, networked and swarm robotics correspondingly. Another difference to classical robotics consists in functionality. Functionality of a large robot is in the same time a function of the whole robot system, whereas a functionality of the whole collective system emerges as a result of many interacting individual behaviors. In this way collective systems are able to demonstrate much more diverse functionality than mono-functional robotics.

The concept of "working together" provides several essential advantages (Kernbach, 2008). First of all, systems, consisting of many independent autonomous agents, are very reliable. When some agents are destroyed or malfunctioned, other agents take their place. Secondly, collective systems have many degrees of freedoms and are much more flexible than centralized ones. This flexibility, or in other words - hardware plasticity, can be used in developmental processes (Lungarella et al., 2003) as well as for adaptation (Kornienko, 2004). Finally, due to decentralized control, collective systems are scalable in a wide range of structural, diversity or dynamic loads (Constantinescu et al., 2004).

Lately, the research in collective systems becomes imbedded into domains of reconfigurable, evolutionary and social robotics. As mentioned, elements of collective systems behave independently so that a common functionality emerges as a cooperative behavioral pattern. In new developments, small individual robots can self-assemble into one large artificial symbiotic organism (Kornienko et al., 2007), (Kernbach, 2008). In this way collective systems can emerge a mono-functional behavior, however agents still remain independent from each other, so that a high flexibility is ensured. The symbiotic robotics combines advantages of collective systems, such as a high reliability and adaptivity, with advantages of mono-functional systems, such as uniform actuations.

Collective systems possess very interesting macroscopic properties. The interacting system can be considered on two different levels (Haken, 1977). On the microscopic level, we observe a behavior of all agents. On this level there is no central instance in charge of coordination, therefore the system is reliable, but difficult to control. Considering the system on the macroscopic level, we can derive several low-complex mechanisms, which are in charge of controlling and self-regulation. Using these mechanisms, the designer can create a purposeful collective behavior without limiting degrees of freedom. This is one of the ways of making the self-organization in artificial collective systems controllable, self-regulating and technically purposeful (Kernbach, 2008).

In the following sections these points will be considered more in detail. First, we introduce taxonomy of collective systems in Section "*Overview of Collective Robotics*" and give a brief overview of cooperative, networked, swarm and nanorobotics. Section "Advantage of collective robotics" is devoted

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