Preface

Swarm robotics can be defined as the study of how a swarm of relatively simple physically embodied agents can be constructed to collectively accomplish tasks that are beyond the capabilities of a single one. Different from other studies on multi-robot systems, swarm robotics emphasizes self-organization and emergence while keeping in mind the issues of scalability and robustness. These emphases promote the use of relatively simple robots, equipped with localized sensing abilities, scalable communication mechanisms and the exploration of decentralized control strategies.

With the recent technological advances, the study of robotic swarms is becoming more and more feasible. There are already a number of ongoing projects that aim to develop and/or control large numbers of physically embodied agents. In Europe, the CEC (Commission of the European Communities) has been funding swarm robotics studies through its FET (Future and Emerging Technologies) program. In USA, DARPA (Defense Advanced Research Projects Agency) has funded swarm robotics projects through its SDR (Software for Distributed Robotics) program.

Within this context, we set out to organize a meeting to bring together researchers in swarm robotics to review the ongoing studies, and to discuss and identify the research directions. Despite being the first meeting on the topic, our proposal to organize the workshop as part of the SAB 2004 (From Animals to Animats: Simulation of Adaptive Behavior) conference was enthusiastically accepted by the organizers, and Alfred Hofmann of Springer kindly agreed to publish the proceedings as a State-of-the-Art Survey in their LNCS (Lecture Notes in Computer Science) series. The Swarm Robotics Workshop was held on July 17, 2004, Santa Monica, CA, USA, after the SAB 2004 conference. We can confidently say that most of the prominent research tracks on swarm robotics were represented, and the workshop achieved the goals it set forth.

This volume contains 13 articles that were presented during the workshop which, we believe, provide a good review of the current state-of-the-art in swarm robotics studies. The first article is contributed by Gerardo Beni, who had coined the term *swarm intelligence* 15 years ago. In this article, Beni tells the story of how, and in what context, the term was conceived. He then describes the evolution of the term "swarm" applied to different domains, setting the stage for the term "swarm robotics." In a complementary follow-up to Beni's article, Şahin, in his article, proposes a definition for the term swarm robotics and puts forward a set of criteria that can be used to distinguish swarm robotics studies from the many other flavors of multirobot research. Balch's article reviews some of his early work on multirobot systems that are very relevant to swarm robotics approaches.

Dorigo et al.'s article provides a nice review of the SWARM-BOTS project, funded by CEC within FET. As part of this project, a mobile robot platform with the ability to connect to each other, called an *s-bot*, is developed. This platform and its physics-based simulations were then used to study self-organization and self-assembling behaviors, inspired from those observed in social insects. Payton et al.'s article reviews another project, funded by DARPA within SDR, describing their vision behind the "virtual pheromone" approach. They describe how a swarm of *pherobots* (mobile robots that can locally communicate with each other through directional infrared messaging) can be used to find survivors in disaster areas and guide the user towards them. Rothermich et al.'s article presents a review of another project, funded by the same source, on how a swarm of *swarmbots*[1] (mobile robots that can localize each other through "line-of-sight infrared communication") can perform collaborative localization in an unknown environment. Seyfried et al.'s article presents the vision of the I-SWARM project, funded by the CEC within the FET (Future and Emerging Technologies) program, which started in 2004. The I-SWARM project has a goal of designing a micro-robot of size $2 \times 2 \times 1$ mm that can be mass produced in thousands. The challenges of building micro-robots of that size are discussed.

Spears et al.'s article describes the "physicomimetics" framework, which relies on local control rules derived from physics, rather than ethology, and illustrates how this approach can be used to create solid formations for distributed sensing, liquids for obstacle avoidance, and gases for surveillance tasks. One advantage of this approach is the use of standard physics analysis techniques that allows the reliable control of the emergent behaviors by establishing correct parameter settings from theoretical first principles.

Martinson et al.'s article also focuses on the task of distributed sensing, and illustrates that, by exploiting a common reference orientation, orthogonal control rules can be developed that reduce the occurrence of local minima in the formation of lattices. Their control rules are a blend of ethological and physicomimetics-inspired behaviors. A nice aspect of their work is an illustration of robustness in the face of sensor noise.

Bayazıt et al.'s article reviews how roadmap methods can be integrated with simple flocking methods to generate guided behaviors such as exploring and shepherding. Winfield et al., in their article, introduce a new concept called "swarm engineering" to study how swarm intelligence-based systems (like swarm robotic systems) can be "assured of dependability." Lerman et al. review their work on the mathematical modeling of swarm robotic systems and discuss how such modeling would be of help in their analysis and design. The last article of the volume is another from Gerardo Beni. In his paper, Beni proves that "swarms with partial random synchronicity can converge in cases where synchronous or sequentially updated schemes do not." We believe that this result is very powerful, since it provides a rigorous support to the view that the swarm robotic approach has advantages over traditional centralized control approaches.

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[1] The swarmbots have no relation with the SWARM-BOTS project described above.

conference; Alfred Hofmann of Springer for accepting to publish the post-proceedings of the workshop as a State-of-the-Art Survey in the Lecture Notes in Computer Science series; all the authors for submitting their papers; and the program committee members for providing timely and objective reviews which improved the quality of the articles in this volume. The program committee consisted of: Tucker Balch, O. Burçhan Bayazıt, Gerardo Beni, Marco Dorigo, Paolo Gaudiano, Alcherio Martinoli, David Payton, Cem Ünsal, Alan F.T. Winfield, and Joerg Seyfried.

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Finally, we would like to take this opportunity to announce the web site http://swarm-robotics.org. The idea of building a web site had emerged during the workshop, and we believe that it will be essential to build a swarm robotics community. The web site already hosts the presentations and movies of the papers included in this volume, and BibTeX entries for swarm robotics literature. We invite all interested researchers to visit the web site and join this newly forming community.

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