A Survey of Multi-robot Simulators *

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Abstract

This report presents a survey of existing simulation packages for multiple robot research.

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1 Introduction

One of USC Robotics Research Lab's recent projects involves the development and implementation of intelligent, taskable robot colonies with learning capabilities to support small unit operations. Consisting of two air and four ground vehicles, the group's main purpose would be assistance in the reconnaissance and securing of a certain terrain. Given that computer simulation of multi robot systems provide a strong testbed, especially for the Artificial Intelligence (AI) aspects of such cooperative tasks, our first attempt was to summarize currently available simulation tools for similar systems.

In this report we compare and contrast several simulation packages developed to study multiple robot systems. The interdisciplinary nature of this research area has led to a variety of software tools as well as abstraction levels, ranging from populations of cellular-automata-alike entities to highly distributed, realistic simulation environments. This relatively broad range is due to the interaction among the fields of Multi-Agent Systems, Artificial Life [4], Distributed AI and Autonomous Mobile Robotics.

In doing this survey, our main goal has been to identify different design approaches followed by the research community so far, besides software issues such as portability and extendability.

2 Descriptions

2.1 Distributed Interactive Simulation

Distributed Interactive Simulation (DIS) was originally developed by DARPA as an extension of the Simulation Network (SIMNET) program, allowing multiple simulators to share a virtual environment and interact. As a long-term goal, the U.S. Military plans to bring together various tactical simulators using the DIS protocol [8], which is also available as an IEEE Standard [5], [6] since 1994.

In DIS, information exchange is accomplished using Protocol Data Units (PDU's), which are pre-defined for a number of interaction types. The principle PDU type is the Entity State PDU, encapsulating the position, linear and angular velocities as well as accelerations of an entity at a given time. In addition, message-PDU's provide a powerful means of extending the current set of PDU's.

The U.S. Military and a number of private technology companies such as Carmel Applied Technologies, TASC-Primark and Distributed Simulation Technology have been using the DIS approach. Brutzman's work [1] on Autonomous Underwater Vehicle (AUV) simulations is one of the well-documented DIS implementations.

WWW sites : http://dis.pica.army.mil/ and http://siso.sc.ist.ucf.edu/dis/index.htm

2.2 Mission Lab

MissionLab is a set of software tools developed by Prof. Arkin's research group at Georgia Tech under a DARPA contract, with the aim of designing and testing behaviours for single robots and robot teams [2], [3]. Supporting both 2D-simulated and real robots (built by Denning Mobile Robotics and Nomadic Technologies), MissionLab also encompasses a command language interpreter which is capable of translating high-level mission statements into a series of commands for individual robots of a team. These robots, in turn, embody behaviour-based control architectures.

Contact person : Prof. Ronald Arkin (arkin@cc.gatech.edu)
WWW site : http://www.cc.gatech.edu/ai/robot-lab/research/MissionLab/

2.3 Swarm

Swarm is a simulation package for multi-agent systems, developed at The Santa Fe Institute. The basic unit of simulation is the swarm, a collection of agents executing a schedule of actions and interacting via discrete events.

Contact person : Chris Langton (cgl@santafe.edu)
WWW site : http://www.santafe.edu/projects/swarm/

2.4 Khepera Simulator

Khepera Simulator is a freeware package developed by Olivier Michel, allowing to develop controllers for the mobile robot Khepera. It includes an environment editor and a graphical user interface.

Contact person : Olivier Michel (Olivier.Michel@di.epfl.ch)
WWW site : http://diwww.epfl.ch/lami/team/michel/khep-sim/

2.5 VirtualRobots Simulator

VirtualRobots software package was developed as a tool in the research of mobile robots at the Department of Computer Science, University of Essex, England. It is basically a 2D simulation of a mobile robot environment.

Contact person : John Standeven (stanj@essex.ac.uk)

2.6 SIEME

SIEME has been developed by Magnin Laurent, a former graduate student at the LAFORIA Lab in France. This simulation platform allows the user to create, test and modify the behaviors of the robots in an environment defined using the Sieme syntax. It has been mainly used to study team behavior for soccer playing robots [7].

Contact person : Magnin Laurent (Laurent.Magnin@laforia.ibp.fr)
WWW site : http://www-laforia.ibp.fr/ magnin/these/sieme.html

3 Requirements

Simulator	*Platform*	*Prog. Lang.*	*Library*	*Documentation*
MissionLab	Solaris 1.x/RedHat Linux 4.0	C	IPT, CThreads	User Manual
Swarm	Solaris and Linux	Objective C	-	Web site
Khepera	UNIX	C	X11	User Manual
SIEME	PC	Smalltalk80	-	-
VirtualRobots	UNIX	C	PVM	-

Table 1: Software Requirements of the Simulators

4 Features

Simulator	*Domain*	*World model*	*Dynamics*	*Communications*
MissionLab	military	2D	none	yes
Swarm	multi-agent	mostly grid 2D	implementable	yes
Khepera	mobile robots	2D	none	-
SIEME	soccer	2D	-	-
VirtualRobots	mobile robots	2D	none	-

Table 2: Features of the Simulators

5 Conclusion

As a result of this survey, we realized that none of the currently available simulation tools suited well to our purposes. Since our project involves both aerial and ground-based robots, a considerable amount of dynamics have to be integrated into the simulations to achieve realistic physical behaviors.

A possible approach seems to develop a new 2D simulator, encompassing reasonable robot dynamics together with sensor and noise models. For inter-robot communications, UNIX-based socket programming could be chosen.

References

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[2] Ronald C. Arkin Douglas C. MacKenzie and Jonathan M. Cameron. Multiagent mission specification and execution. *Autonomous Robots*, 1999.

[3] Tucker Balch Douglas C. MacKenzie, Khaled S. Ali. *MissionLab User's Manual V.2.0.* Georgia Institute of Technology, College of Computing, Atlanta GA 30332, February 1997.

[4] Howard Gutowitz. Artificial-life simulators and their applications. Technical report, The Santa Fe Institute, January 1995.

[5] IEEE. Standard for distributed interactive simulation–application protocols, 1278.1, 1995.

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[7] Laurent Magnin. *Modélisation et simulation de l'environnement dans les systèmes multi-agents. Application aux robots footballeurs.* PhD thesis, Université de Paris VI, Novembre 1996.

[8] U.S. Army Training and Doctrine Command. The battle labs brochure. Web Site, 1996.