MAS-DisCoSim 4 PDP: a Testbed for Multi-Agent Solutions to PDPs

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ABSTRACT

This demo illustrates MAS-DisCoSim 4 PDP, a testbed environment for evaluating distributed multi-agent system solutions to pickup and delivery problems (PDPs). PDPs are well-studied problems in operational research, and provide a quite suitable context for testing and evaluating a wide variety of distributed solutions, using particular reasoning and/or coordination mechanisms. The testbed provides a reusable simulation framework, and a particular model for PDP environments.

The demo illustrates the testbed by showing two MAS-based solutions, one based on gradient field coordination, a second solution based on the coordination mechanism called 'delegate MAS'. The demo is interactive: a user can select any part of a map, downloaded from the OpenStreetMap website, can run various experiments, and can change - during simulation - various problem and solution characteristics and observe their effect.

Categories and Subject Descriptors

D.2 [**Software**]: Software Engineering

General Terms

Measurement, Design, Experimentation

Keywords

Distributed problem solving; Simulation techniques, tools and environments; Case studies and implemented systems

1. INTRODUCTION

Multi-agent systems are often studied as solutions to distributed coordination and control problems, i.e. problems in which a number of geographically distributed entities need to cooperate to achieve certain tasks. One example is the pickup and delivery problem or PDP [2]. In PDPs, agents control delivery vehicles driving in a road network, and need to accomplish tasks. Tasks are defined as picking up packages as they appear in the environment and delivering them to their destination. The agents need to coordinate the task allocation and potentially routing in order to have an effective and efficient overall solution. A PDP typically is a dynamic problem. The entities controlled by the agents, the delivery vehicles, are mobile and are affected by traffic. Because of the constant arrival of packages spread across the environment, the set of tasks to accomplish is changing continually.

Cite as: MAS-DisCoSim 4 PDP: a Testbed for Multi-Agent Solutions to PDPs, J. Van Gompel, B. Tuts, R. Claes, M. Cruz Torres, T. Holvoet, *Proc. of 9th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2010)*, van der Hoek, Kaminka, Lespérance, Luck and Sen (eds.), May, 10–14, 2010, Toronto, Canada, pp. 1639-1640

Various multi-agent-based solutions can be and are being studied for this application domain. Evaluating solutions is an essential research activity. The solutions have different performance characteristics and communication demands under various circumstances. This evaluation, unfortunately, is also very demanding as it requires developers to build detailed simulation models that capture the structure and dynamics of the traffic and PDP domain. To benchmark these multi-agent systems and evaluate the different coordination mechanisms under various circumstances we have developed a testbed for multi-agent systems in PDPs. This testbed is part of a larger effort to facilitate evaluation of multi-agent systems in both educational as well as research settings.

The MAS-DisCoSim (*MAS*-based *Dis*tributed *Co*ntrol *Sim*ulation) testbed offers a simulated environment in which both the PDP problem and the deployment infrastructure for agents is modeled. Environments can be instantiated using real world data, e.g. road network data from projects such as OpenStreetMap. This allows for the quick creation of repeatable experiments in which the performance of coordination mechanisms can be evaluated with respect to different road topologies, different communication capabilities and package arrival profiles.

A tutorial and video on the MAS-DisCoSim testbed can be found at `http://distrinet.cs.kuleuven.be/software/agentwise/mas-discosim/`.

2. LAYERED DESIGN OF THE TESTBED

The MAS-DisCoSim testbed has the following layers:

Core simulator This is the basic simulation engine. It offers a time-frame based simulation often used in traffic and multi-agent simulations.

Physical infrastructure model This layer models the road infrastructure and traffic dynamics. A microscopic model is used for the traffic situation - every vehicle is modeled and simulated individually. For this demo, the traffic model is augmented with the PDP concepts such as packages, pickup and drop off locations.

Deployment infrastructure model This layer models the deployment infrastructure. Every entity in the physical layer can be equipped with a computation device

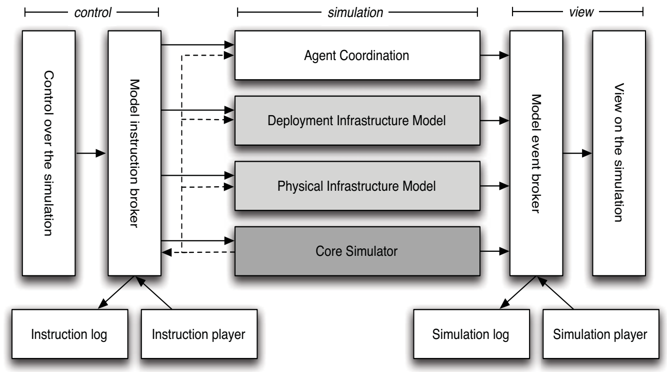

Figure 1: Layered structure of the testbed.

capable of communicating with other devices. This computation device is assumed to control the physical entity it is deployed on. Bandwidth, delay and communication range of mobile entities are modeled and can be altered at runtime.

Agent coordination layer This layer is to be used for implementing a multi-agent solution. The MAS can be implemented in plain Java or specialized agent programming languages (APLs). Agents are conceptually deployed on the computation devices defined in the deployment infrastructure layer. Communication between different agents is modeled in the deployment infrastructure layer. The physical entity under control of the agent, such as a delivery vehicle, is modeled in the physical infrastructure layer. Instructing a physical entity is done through the computation device in the deployment infrastructure layer.

The layered design offers flexibility for implementing multi-agent solutions as well as for setting up experiments with dynamics for each layer.

3. THE TESTBED AS AN EVALUATION TOOL

We highlight several key features that make the testbed suitable for evaluating multi-agent-based solutions.

The testbed allows for repeatable experiments. Events that occur in the models, such as the introduction of additional delivery vehicles, changes in the arrival rate of packages or changes in the communication parameters can be recorded for later use. This allows the evaluation of various solutions for the exact same problem.

Events resulting from agents actions are also recorded. These events can be used to analyze the performance of the multi-agent systems, either at runtime (showing performance figures on-line) or offline. To facilitate offline analysis, events can be recorded in various formats suitable for analysis and graphing in tools such as R or Excel.

To evaluate the multi-agent systems in realistic settings, the physical model of the testbed can use OpenStreetMap data to model real-world road networks. The explicit modeling of inter-agent communication allows evaluating the communication overhead imposed by the coordination mechanisms and the influence of degrading communication on the efficiency of the multi-agent system.

4. ILLUSTRATION OF TWO SOLUTIONS

To illustrate the testbed, we have implemented two solutions using distinct coordination mechanisms. As mentioned in section 2, this entailed implementing the coordination mechanisms and relevant agent behavior in the top *agent coordination layer*, where we could use the functionality offered by the other layers.

The first coordination mechanism uses gradient fields [3] to govern the agent's actions. By emitting repulsive fields, agents tend to distribute themselves across the simulated environment. This has a positive effect on the *time-to-pickup* metric. Pickup locations emit attractive fields, pulling agents in the vicinity towards the package in need of a pickup. This helps the allocation of deliveries to nearby delivery vehicles.

The second coordination mechanism uses delegate multi-agent systems [1], to allocate and route the delivery vehicles. Agents in control of delivery vehicles emit smaller, ant-like agents that explore a virtual environment in search of packages that need to be picked up. From these pickup points, the ant-like agents start looking for possible routes to the package drop-off point. When an ant-like agent finds a package and a possible route to the destination, it reports this information back to the agent in charge of the delivery vehicle. This agent can choose between different possibilities presented by different ant-like agents.

The testbed allows parameters of both the coordination mechanism and the simulation models to be changed at runtime. In our demo the communication range of the agents can be modified using the graphical user interface. The results of these changes are visible in the map view and, eventually, also in the performance metrics graphs.

5. CONCLUSION

In this demo we illustrate the MAS-DisCoSim testbed as a platform for evaluating multi-agent systems and coordination mechanisms in solving complex distributed problems. Two solutions, that is, a gradient field approach and an approach based on delegate MAS are shown in the interactive demo. The testbed is used within the DistriNet labs for research purposes, and will be used in the master course on multi-agent systems.

We believe that with the development of the MAS-DisCoSim testbed, the evaluation of multi-agent systems will be facilitated. By offering a common platform and reference point, it could stimulate the evaluation and comparison of coordination mechanisms by the research community. Today, that is before the first release of the testbed, three academic institutions have shown great interest in using the testbed.

6. REFERENCES

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