Hasso Plattner Institut

Systemanalyse und Modellierung
Prof. Dr. Holger Giese
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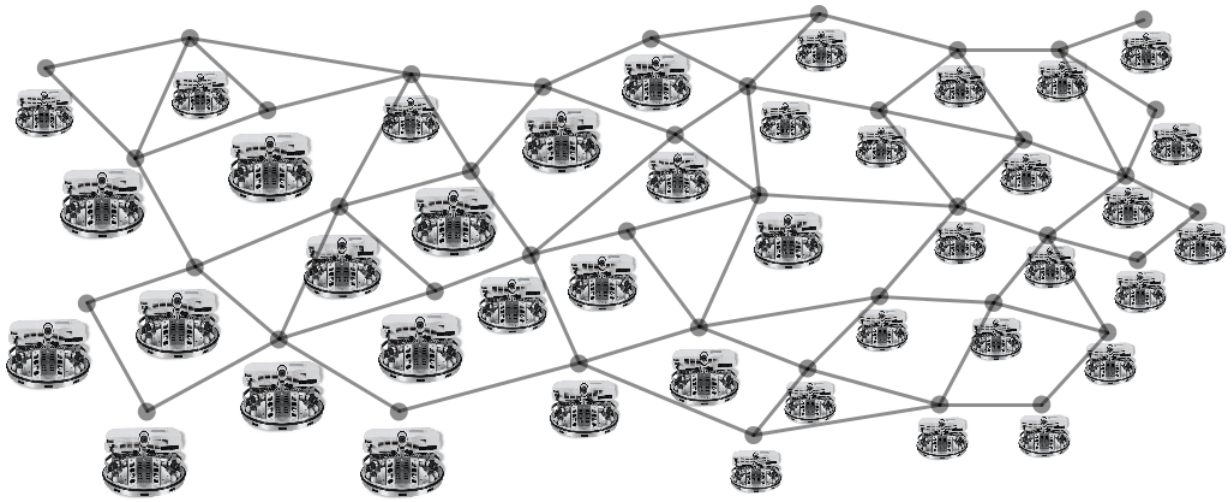
An Extensible Simulation Environment for Large-Scale Federations of Autonomous Mobile Systems

Background and Motivation

Cyber-Physical Systems (CPS) have started to emerge as a consequence of the general trend toward the integration of beforehand isolated systems into *large-scale* federations of distributed systems comprising software and physical entities. Moreover, each system as part of such a federation is *autonomous* in the sense that it is developed, operated, evolved, and governed independently from the other systems. However, they all interact with each other in a dynamic and open world, which causes individual systems to dynamically join or leave the federation over time, the federation architecture to dynamically vary, and emergent behavior of the overall federation.



An example for such a CPS is a large-scale federation of autonomous robots as shown in the figure above. In contrast to our CPS lab[1], in which three robots are available, this project should consider large-scale federations with hundreds or even thousands of robots. Though the robots may act autonomously and therefore independently from each other, they may also interact to jointly perform a task such as collaboratively exploring an unknown territory. Thereby, the robot may sense their environment, store important information in a context model and share that information with other autonomous robots in the system. This is illustrated in the figure by links connecting individual robots such that the whole federation can be described by a graph with robots as nodes and interactions between robots as links between the nodes.

This requires scalable means to test and validate such systems through simulation that makes use of the graph structure of such federations. For instance, while an individual autonomous robot can be rather easily simulated in isolation, the federation behavior that emerges when thousands of robots collaborate can only be effectively simulated with a scalable solution.

[1] `http://www.cpslab.de`

Description

The goal of the project is to design and develop an extensible simulation environment that enables the validation of types of systems such as a large-scale federation of autonomous robots. Thereby, the focus is set on a scalable and resource-efficient kernel of this environment that is able to simulate the collaboration of thousands of autonomous systems (robots) following a graph-transformation based approach. Scalability should be addressed by leveraging concurrency in simulating federations of autonomous systems on modern multi-core hardware.

This simulator kernel should allow the developer to analyze traces of the simulation, for instance, by logging the simulated behavior of individual autonomous systems and of the whole federation, and to monitor properties during the simulation, such as the convergence of the behavior of all robots toward a joint goal. Moreover, a visualization of the simulated behavior should be developed that supports focusing on the individual behavior of a single autonomous system and on the emergent behavior of the overall federation.

Finally, the simulator kernel should be extensible with respect to further requirements of CPS. Examples for such requirements are timing aspects such as real-time constraints for embedded systems (robots) controlling physical entities or probability aspects such as uncertainties of the reliability concerning the autonomous systems (robots) and the communication among them.

Contact

The project is supervised by Prof. Dr. Holger Giese (`Holger.Giese@hpi.de`) together with Joachim Hänsel (`Joachim.Haensel@hpi.de`), Thomas Vogel (`thomas.vogel@hpi.de`), and Sebastian Wätzoldt (`sebastian.waetzoldt@hpi.de`). If you have any question about this project, please contact one of them or just come around our research group.