AURECON — Autonomous Dynamic Reconfiguration in Multi-agent Problem Solving

[Research Statement]

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Introduction

A well-known trade-off is that central systems usually achieve good results in controlling business processes but also violate social competency, efficiency and scalability demands. Multi-agent systems (MAS) can cope with these demands but often entail high communication overhead and suboptimal results due to their restricted overview. Our hypothesis is that real improvements in coordination and communication effort between technical artefacts can only be achieved by allowing a redefinition of competencies on the level of the individual problem solvers. Hence, our research target is to investigate such theoretical and practical concepts for autonomous dynamic reconfiguration in MAS within the AURECON project.

Merits and Pitfalls of Multi-agent Problem Solving

Social structures, such as in enterprises or in supply networks of different enterprises, create heterogeneous fields of competencies and influences. Few executives of organizational units accept transferring all their process data to other organizational units for global control. Even in the case that a monolithic problem solver could be theoretically applicable, problems of real-world size tend to be too complex to be solved by such a global system. Monolithic systems often scale poorly in the size of the problem. Partitioning the problem and searching for a solution composed from the solutions of detached subproblems is a promising approach to cope with this complexity.

Despite the named advantages, multi-agent problem solving also has major disadvantages. The complexity that has been saved within the several solvers is transfered to the coordination process. Due to this fact, investigations on todays distributed solver systems often report poor optimization results or vast communication overhead. Since global problem solving promises the higher quality solutions to the common problem but may be infeasible due to social, technical or security restrictions, we are facing a well-known trade-off between a global and a distributed design. Therefore, the design of the distribution is itself an optimization problem.

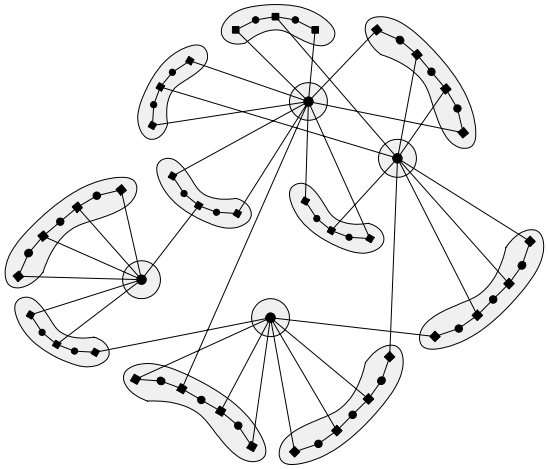

Figure 1: Fine-grained distribution

Autonomous Dynamic Reconfiguration

Since the distribution of agents is often not fully specified by the natural distribution of the problem, a typical engineering task in multi-agent problem solving is the design of the distribution. It has to be decided what part of the problem should be assigned to a certain agent.

The traditional approach to multi-agent problem solving is to design the distribution aspects off-line by statically assigning certain roles and competences to a fixed set of specific agents. The disadvantages of this fine-grained approach are strikingly shown by Figure 1 that shows ten requesting agents negotiating with four providing agents. Every arc between agents marks the need for external problem solving and such extensive communication.

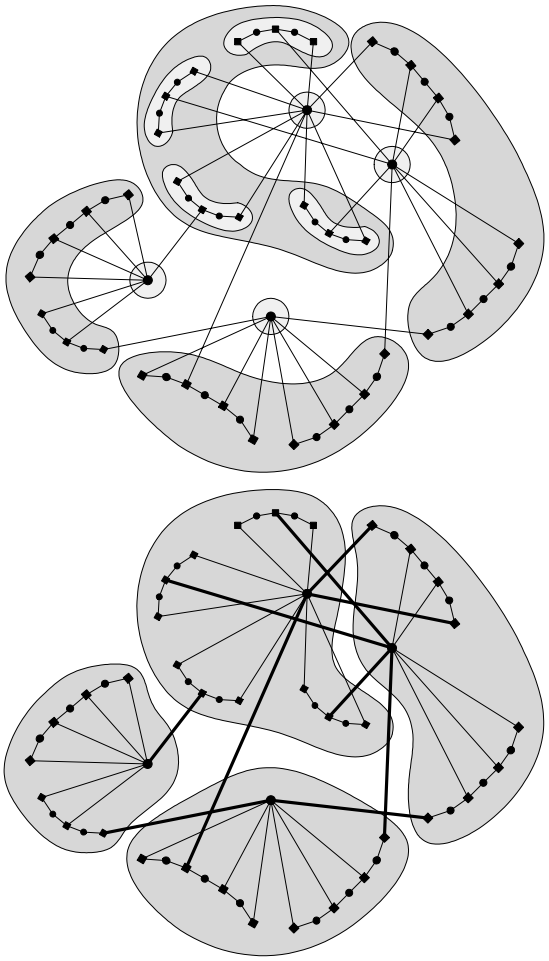

Figure 2: Several steps of agent melting

The main idea of AURECON is to define two local operators: *agent melting* and *agent splitting*. Agent melting joins two or more agents to a single new agent by transferring all subproblem knowledge, goals and solving skills of the former agents to the new one. Agent splitting splits an agent into two or more agents and distributes its problem knowledge and so on to the new agents. These operators can be applied autonomously by the agents themselves accompanying the problem-solving process.

It has been formally proven that combinations of agent melting and agent splitting operations are sufficient to systematically create all possible distributions of subproblems to agents. Such, the multi-agent system can dynamically adapt to the given problem structure, decreasing communication effort by melting strongly connected agents and decreasing internal complexity by splitting overloaded agents. Figure 2 illustrates the effect of applying agent melting to the situation in Figure 1.

The concepts underlying AURECON are theoretically founded on distributed constraint satisfaction and local dynamic graph partitioning and are almost fully implemented following a case study in medical appointment scheduling. We have also implemented tools to visualize and interact with different distributions of subproblems to agents. Figure 3 shows such a graph-based tool that visualizes the responsiblity relations between ten providing units, ten requesting units and their agents as well as the communication lines. Analytic and empiric evaluation results in the AURECON project are soon to come.

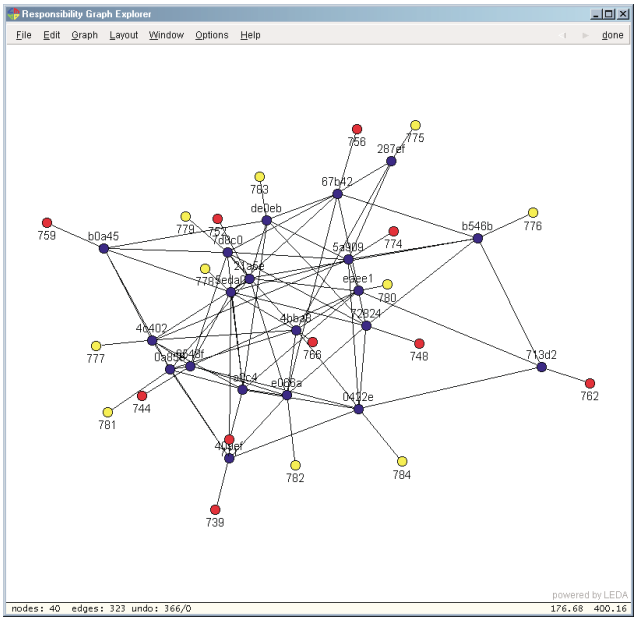

Figure 3: Visualization tool of AURECON

Acknowledgements

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