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PARALLEL AND DISTRIBUTED SIMULATION OF COALITION STRUCTURE GENERATION IN COOPERATIVE MULTI-AGENT SYSTEMS

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Multi-Agent Systems (MAS) consist of autonomous agents that interact to solve interrelated problems. If agents collaborate to optimize the overall outcome, then the system is cooperative. In this setting, a great deal of attention has been paid to coalition structure generation, where outcomes are partitions of agents, that is, collections of disjoint coalitions or subsets of agents, called blocks, whose union yields the entire population. Given a function that assigns a worth to each coalition (i.e. a coalitional game), the worth of coalition structures obtains as the sum of their blocks' worth, and optimality attains where such a global worth is maximal. Searching for optimal coalition structures is a NP-hard combinatorial optimization problem, requiring to experiment heuristics-based search methods. As an example, this problem arises in combinatorial auctions, where agents are to be interpreted as goods to sell and the coalitional game gets determined by the available bids, so that maximizing the revenue amounts to optimally partition the goods and sell the blocks. Our concern is with coalition structure generation in dynamic settings, where the worth of coalitions varies over time in an unknown and unpredictable fashion.

Modeling and simulating coalition structure generation in MAS is a complex task due to the intrinsic nature of the systems themselves, which are often: (1) very volatile in terms of interactions among agents, and (2) composed by very large numbers of agents. The approach based on sequential monolithic simulation is unable to deal with such requirements, mainly due to performance and scalability reasons. On the other hand, the aggregation of computational resources following a parallel or distributed simulation approach is very promising. In this case, it is possible to deal with highly populated models, simulating complex agents' behaviors and interaction patterns among the agents. The main drawback of this approach is the communication overhead due to synchronization and data distribution in the distributed architecture. Without specifically designed and implemented techniques, the overhead could reduce or overcome the gain obtained with the aggregation of computational resources, and therefore slow down the execution speed of the simulation to an unacceptable level.

We designed COALA, a new simulation tool for the study of massively populated MAS and specifically for the modeling of coalition structure generation. The COALA implementation is based on the Advanced RTI System (ARTÌS) distributed simulation middleware and takes advantage of a new load balancing framework for distributed simulation, the Generic Adaptive Interaction Architecture (GAIA+). GAIA+ is a framework based on dynamic reallocation of simulated model entities which, in turn, is implemented on top of ARTÌS. The main task of GAIA+ is the dynamic and adaptive load balancing of computation and communication in parallel and distributed simulation environments. Dynamic coalition structure generation constitutes a novel complex setting where to work with such tools.

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