Parallel and Distributed Simulation of Coalition Structure Generation in Cooperative Multi-agent Systems

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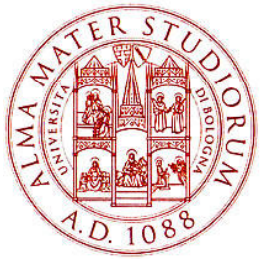

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Presentation outline

- Cooperative Multi-agent Systems
- Coalition Structure Generation (CSG)
  - real world examples
- Simulation of CSG
  - ARTÌS / GAIA+ / COALA
- Simplest simulated scenario
- Preliminary experimental evaluation
- Work in progress

Cooperative Multi-Agent Systems

- A **Multi-Agent System** (MAS) is a system composed of multiple interacting intelligent agents
- Some important characteristics of MAS are: the **autonomy** of agents and their **local view** (limited information sharing). Furthermore, the MAS are **decentralized**: there is any centralized control
- In this work, we consider **Cooperative Multi-Agent Systems**
- That is, the agents are inclined to work with each other in order to solve complex problems

Coalition Structure Generation (CSG)

- Given a set of agents, a **Coalition Structure** is partition of agents
- That is, a collection of disjoint coalitions or subsets of agents, called blocks, whose union yields the entire population
- A **Dynamic Characteristic Function** (DCF) or coalitional game, assigns a time-varying *worth* to each coalition
- The **worth of coalition structures** obtains as the sum of their blocks' worth
- Optimality attains where such a global worth is *maximal*
- Searching for optimal coalition structures is a NP-hard combinatorial optimization problem
- Therefore, an approach based on **heuristics** is necessary

Real-world examples

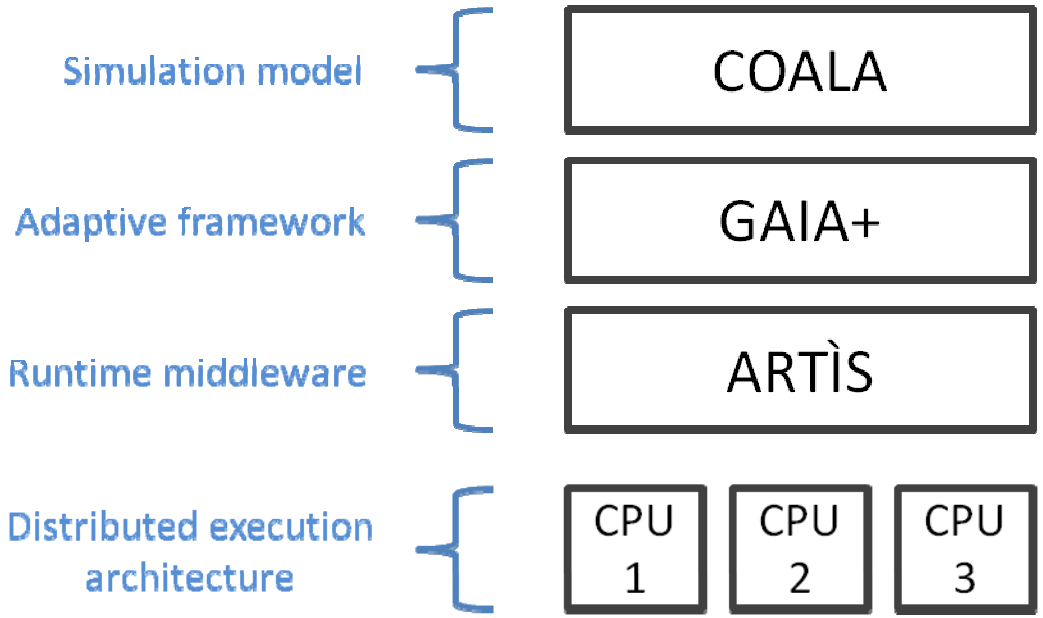
- In general, any optimal partitioning problem with **time-varying** and **imprecise** input (i.e. imprecise worth of blocks)
- For example:
  - what packages to sell in **e-commerce auction** mechanisms. What (optimal) combinations of goods to offer
  - **optimal clustering** with time-varying data sets (i.e. clustering in collaborative tagging systems)
  - coalition (**team**) structure generation in multi-skill organizations

Simulation of CSG

- The modeling and simulation of coalition structure generation in MAS is a complex task due to the intrinsic nature of the systems themselves, which are often:
  - **very volatile** in terms of interactions among agents
  - composed by **very large number** of agents
- The approach based on sequential monolithic simulation is unable to deal with such requirements mainly due to performance and scalability reasons
- Our approach is based on **parallel and distributed simulation**

Simulator design and implementation: logical structure

- Logical structure of the parallel / distributed simulator:



- The **Advanced RTI System** (**ARTÌS**) is a high performance distributed simulation middleware

Simulator design and implementation: GAIA+ and COALA

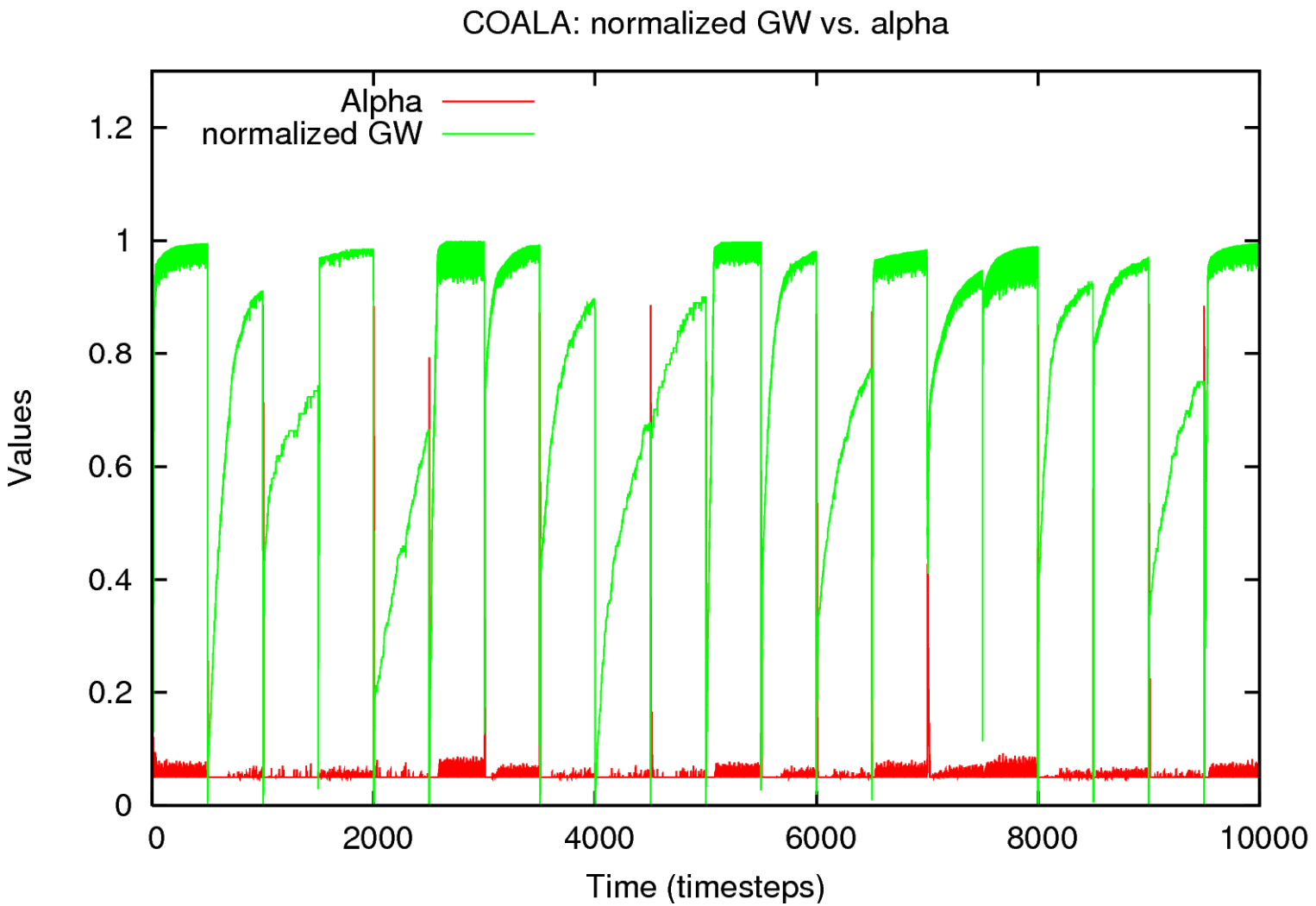
- The **Generic Adaptive Interaction Architecture** (**GAIA+**) is a load balancing framework for parallel and distributed simulation that is based on *dynamic reallocation of simulated model entities*. GAIA+ is in charge of the dynamic and adaptive *load-balancing* of computation and communication in the distributed execution architecture
- **COALA** (**COAlitions Learn and Adapt**) is a new simulation tool for the study of massively populated MAS, specifically designed for the modeling of coalition structure generation
- For details: http://pads.cs.unibo.it

Simplest simulated scenario

The simplest simulated scenario:

- **Merge-and-split heuristic**: constant (random) re-configuration towards coarser and finer partitions
- **Dynamic Characteristic Function** (DCF) varying every 500 simulated time-steps
- **Symmetric DCF**, that is the worth of coalitions depends only on their cardinality (a very simple DCF)
- **Population** of 10.000 simulated agents

Preliminary experimental evaluation



GW normalized Global Worth of the coalition structure (higher is better)

Alpha normalized exploration parameter of the heuristic

Work in progress

- **More challenging scenarios:**
  - more complex Dynamic Characteristic Functions (DCF)
  - non-symmetric DCFs
  - larger populations
- **Under the simulator point of view:**
  - exploiting the GAIA+ clustering and load-balancing features to speed-up the simulation runs
  - simulation cloning techniques to satisfy the requirement of examining alternative scenarios concurrently

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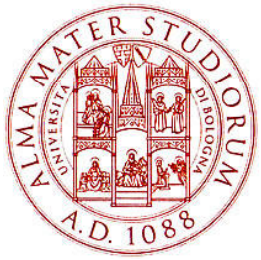

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