Collaborative Negotiation System based on Argumentation

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Research Initiative

- Conflicts arise in Teamwork
  - Agents can access only local(not global) information
  - Agents' interpretation of the information differs
  - Agents may need to act despite missing information
- Negotiation based on Argumentation
  - Agents propose/counter-propose with arguments or justifications
- Motivation for Argumentation
  - Appropriate in collaborative settings
    - Not hide information from teammates
    - Increase the speed and likelihood of agreement
  - Negotiation over multiple criteria
    - Single numeric quantity may be inappropriate

CONSA: COllaborative Negotiation System based on Argumentation

- CONSA negotiation process
  - Initial phase
    - Detect conflict & jointly commit to resolving it;
  - Argumentation phase
    - One generates a proposal & the others evaluate the proposal;
    - If no conflict, accept the proposal, else continue argumentation;
  - Termination phase
    - Terminate if conflict resolved or resolution unachievable
  - Exploit STEAM† teamwork rules
- Real-time negotiation
  - Decision theoretic reasoning
  - To avoid extra communication, pruning inference tree of proposal

† M. Tambe, Towards flexible teamwork, JAIR, 7:83-124, 1997

CONSA example

- Implemented example
  - Helicopter pilot agents which negotiate battlefield positions(resource)
  - Using Soar with ModSAF simulator
- Firing position negotiation
  - Each firing position should be at least 1 kilometer apart from the others
  - Initial phase
    - Agents detect conflict (position interference)
    - jointly commit(establish joint goal) to resolve the conflict
  - Argumentation phase
    - One agent(A1) proposes [move, A1:500m, A2:500m] with justification {Desired distance: 1km, A1: <= 700m, A2: no restriction, Enemy: 5Km, ... }

CONSA example (continued)

- Argumentation phase (continued)
  - The other agent(A2) evaluates the proposal and rejects it with justification {A2: <= 400m}
  - A1 generates a new proposal [move, A1:600m, A2:400m] with updated justification
- Termination phase
  - Either A2 accepts the new proposal
  - Or conflict unachievable
    - A1 or A2 terminates negotiation with justification {Enemy: < 500m}

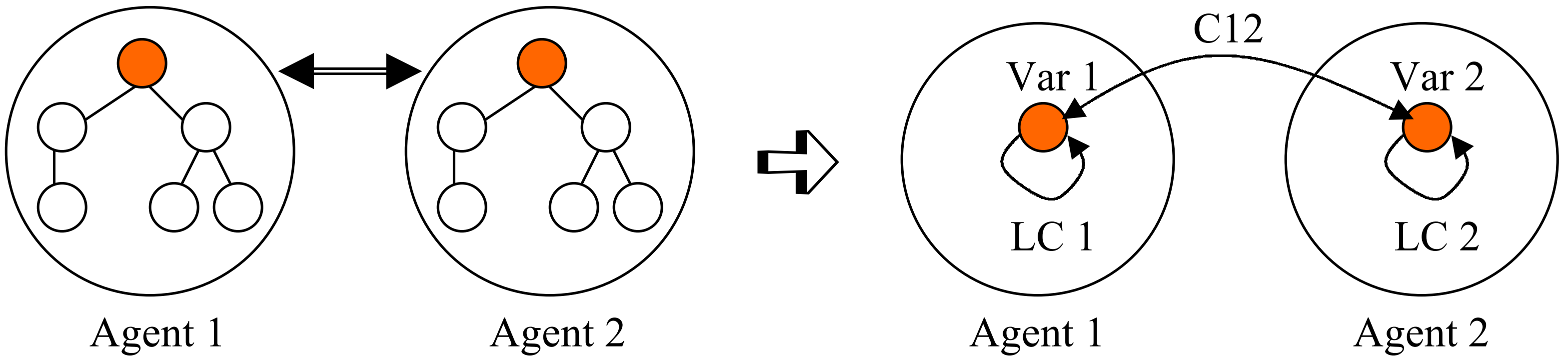
Computational Model for Argumentation

- Questions for argumentation (especially in large scale)
  - Performance of different argumentation strategy?
  - Impacts on convergence in conflict resolution?
  - Anytime, approximate results in real-time?
  - Overhead of argumentation?
- Need for computational model
  - Formulate argumentation with Distributed Constraint Satisfaction Problem(DCSP)
  - DCSP provides a good abstraction
  - Good DCSP algorithms are available: e.g. Yokoo's multi-AWC(Asynchronous Weak Commitment) algorithm†
- **Part of DYNAMITE(http://www.isi.edu/dynamite) with Wei-min Shen, Weixiong Zhang**

†M. Yokoo, K. Hirayama, Distributed constraint satisfaction algorithm for complex local problems, ICMAS '98

Mapping argumentation into DCSP

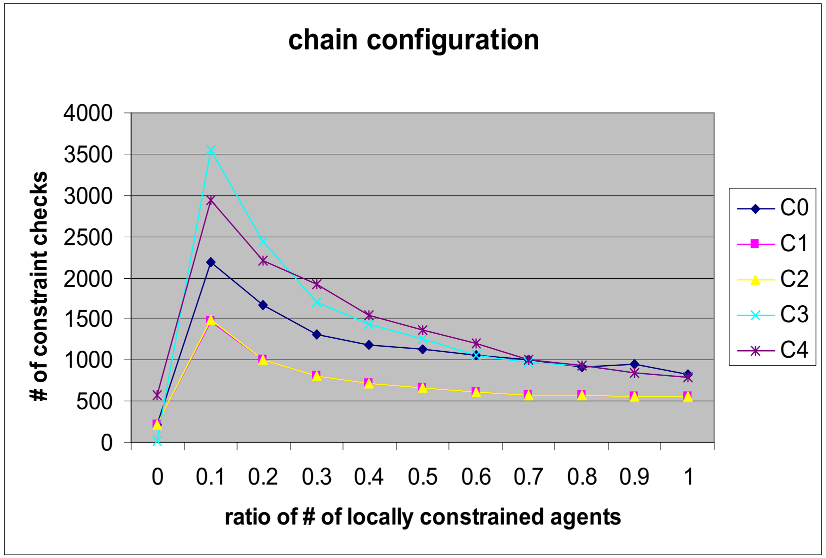
- Multi-AWC concerns with variable ordering(prioritization) and value ordering(min-conflict)
- Argument is a constraint propagation
- Our approach
  - Agents communicate their "local constraints (justifications for proposals)" to their neighbors
  - Interleave constraint propagation with value selection

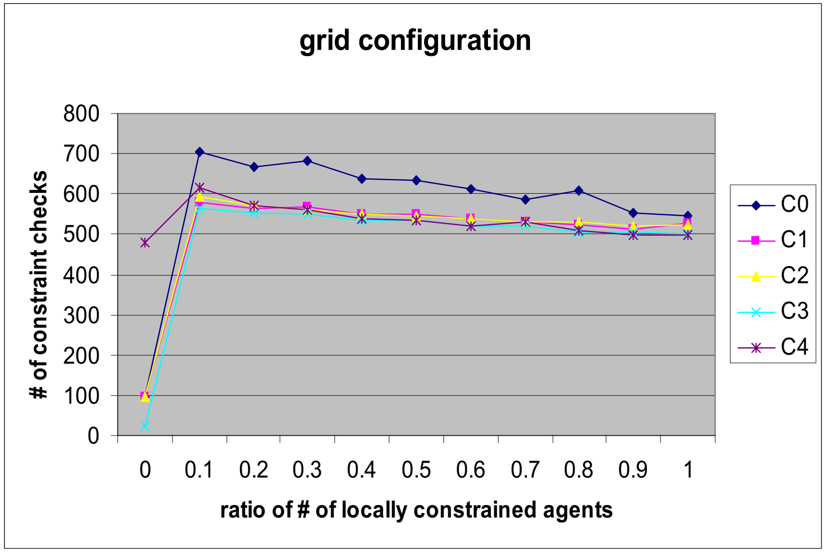


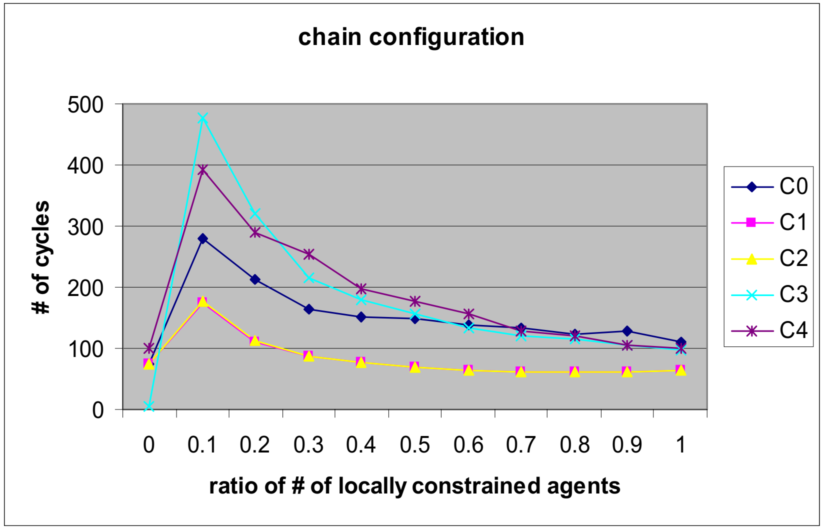
Cooperative negotiation strategies

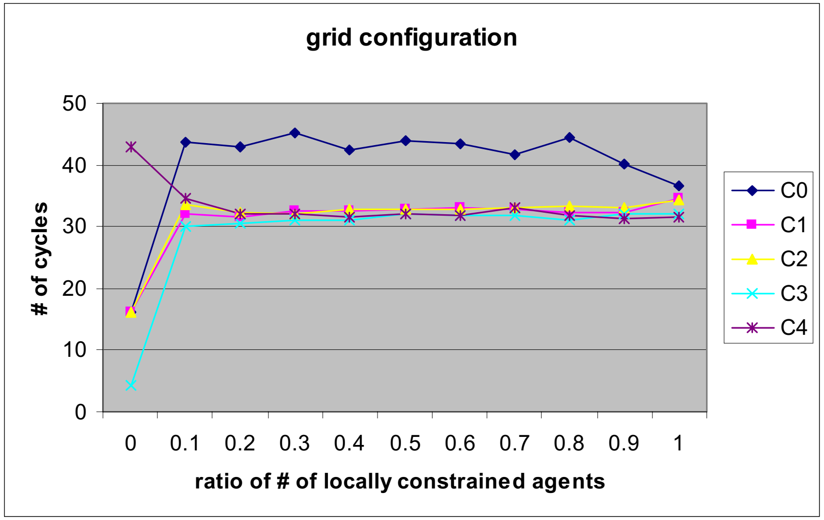
- Cooperativeness of an agent
  - When selecting a value, how much flexibility(# of consistent values/# of domain values) is given to neighbor agents
- Different levels of cooperativeness
  - C0: original multi-AWC
  - C1: in good, same as C0; in nogood, best value for higher agents
  - C2: same as C1 except that, in nogood, cooperative to lower agents in some degree
  - C3: in good & nogood, best value for higher agents
  - C4: same as C3 except that, in good, cooperative to lower agents in some degree
- More *cooperativeness*, better *performance*(less *time*)?
- Evaluation with a mapping of firing position example
  - Criteria: # of constraint checks, # of cycles, distribution of efforts, ...
  - With different configurations: chain, ring, tree, and grid

Strategies evaluation









- C3 & C4 are not superior to the other strategies!

Conclusion

- Objective:
  - Negotiation for conflict resolution
- Collaborative negotiation via argumentation
- Real-time negotiation
- Modeled in DCSP & experimental results