Organizing Multi-Agent Systems

Presented by - The Nashtags

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Source

- Horling, B., & Lesser, V. (2004). A survey of multi-agent organizational paradigms. *The Knowledge Engineering Review, 19*(4), 281-316.

Outline

- Introduction
- Types of organizations
  - Description
  - Advantages and disadvantages
- Other organizational topics
- Discussion
- Conclusion
- Questions

Introduction – What is an organization in a MAS?

- The collection of roles relationships, and authority which govern its behavior
- Guide how agents interact with each other over the course of a particular goal
- No single type of organization works in all situations
- All organizational approaches have their own advantages and disadvantages

Introduction – Why have organizations in a MAS?

- Organizations in a MAS can:
  - Limit the scope of agent interactions
  - Provide strength in numbers
  - Reduce or manage uncertainty
  - Help groups of simple agents exhibit complex behavior
  - Help groups of sophisticated agents reduce the complexity of their decision-making

# Introduction – What are the downsides of an organization in a MAS?

- Organizations in a MAS can:
  - Adversely affect computation and communication overhead
  - Reduce the overall flexibility or reactivity of the system
  - Add an additional layer of complexity to the system
- Must carefully choose the appropriate type of organization for a MAS

Types of Organizations

- Hierarchies
- Holarchies
- Coalitions
- Teams
- Congregations
- Societies
- Federations
- Markets
- Matrix Organizations
- Compound Organizations

Hierarchies - Description

- Agents in a tree structure
- Agents higher in the tree have a more global view than agents below them
- Data produced by lower level agents travels upward
- Control flows downward, higher agents provide direction to those below
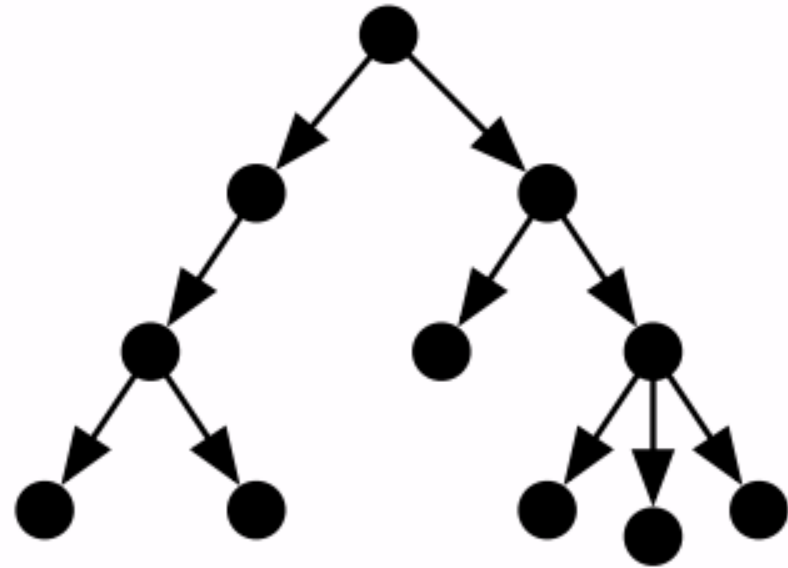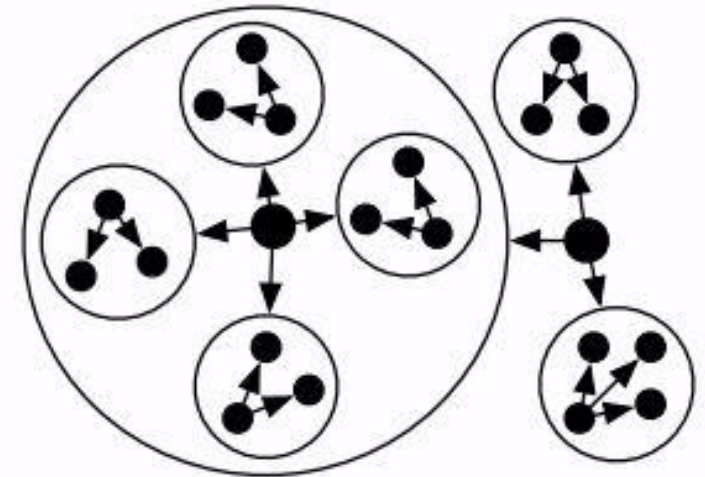
Hierarchies – Advantages and Disadvantages

- Advantages:
  - Good to use when tasks are easily decomposed into subtasks
  - Constrains the number of interactions between agents
- Disadvantages:
  - Can lead to a rigid or fragile organization susceptible to single-point failures
  - Prone to bottlenecks

Holarchies - Description

- A self-similar organization
- Made up of *holons*—discrete groups in the system

- Each holon is composed of one or more subordinate holons

Holarchies – Advantages and Disadvantages
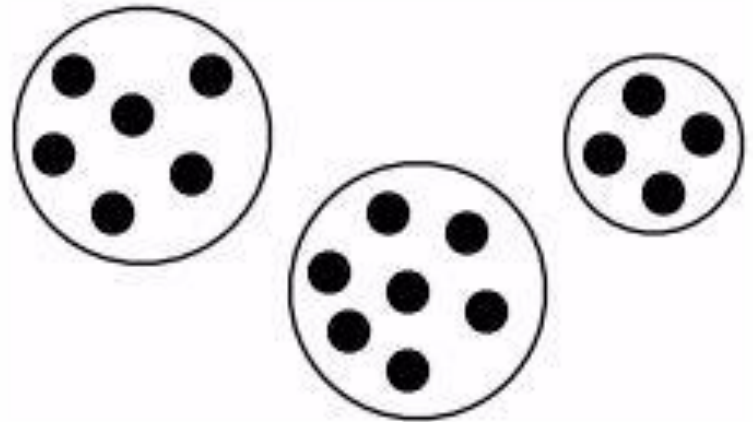
- Advantages
  - Good when goals/tasks can be recursively decomposed into subtasks
  - Holons are autonomous enough to determine how to best satisfy requests they receive
- Disadvantage
  - A relatively complex organizational structure

Coalitions - Description

- Subsets of an agent population
- Goal-directed and short lived
- Formed with a specific purpose in mind
- Dissolve when goal is achieved
- Agents are interested in maximizing their individual utility, not the group's

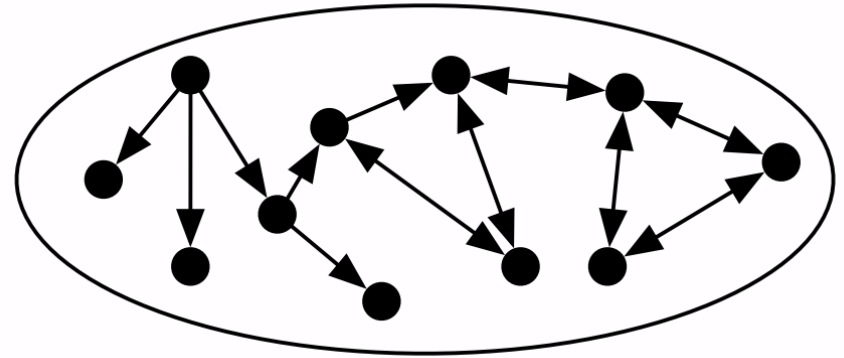# Coalitions – Advantages and Disadvantages

- Advantages
  - Coalitions may be treated as a single atomic entity after formation
  - Allows agent to increase their utility by working in groups rather than working alone
- Disadvantages
  - Agents must share the "winnings" after a coalition has achieved its goal

Teams - Description

- Grouping of agents share a common goal

- Agents coordinate in some fashion

- Underlying structure of interactions is arbitrary

- Agents seek to maximize the utility of the team, not their individual utility

Teams - Advantages and Disadvantages
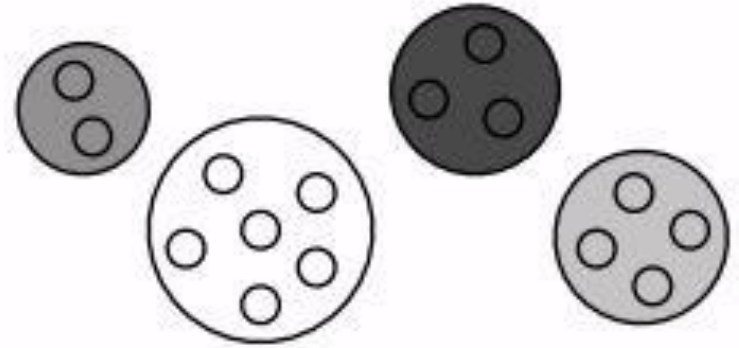
- Advantages
  - Teams can address larger problems than agents can on their own
  - Redundancy
  - Economies of scale
- Disadvantages
  - Increased communication overhead

Congregations - Description

- Groups of agents who have banded together to derive additional benefits
- Not formed with a single purpose in mind
- Assumed to be long-lived groupings
- Agents seek to maximize their individual utility, not the group's utility
- Formed among agents with similar or complementary characteristics

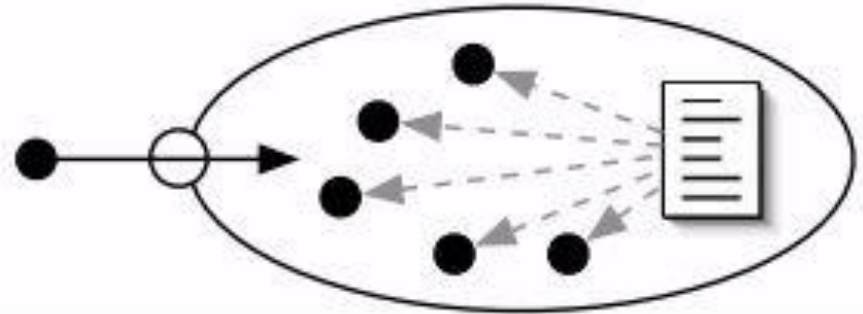# Congregations – Advantages and Disadvantages

- Advantages
  - Facilitates the discovery of agent partners by reducing the population that must be searched
  - Reduces complexity of searches and limits the number of interactions between agents
- Disadvantages
  - Congregations may not contain the optimal agents to interact with

Societies - Description

- A long-lived social construct
- Open systems

- Impose constraints on agent behavior in the form of laws, norms, and conventions
- Act as environment through which agents meet and interact

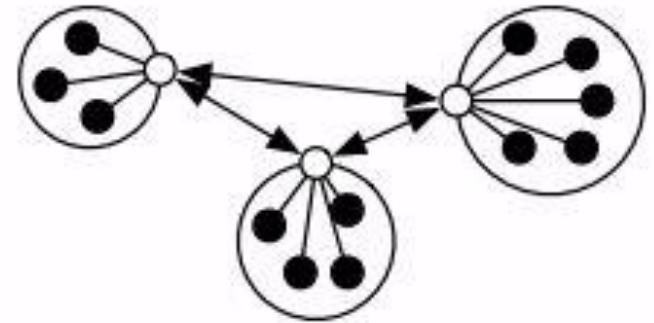# Societies – Advantages and Disadvantages

- Advantages
  - Allows for more complex inter-agent behaviors by allowing agents to make simplifying assumptions about the behavior of other agents
  - Imposes structure and order but allows specific arrangements of interactions to be flexible
- Disadvantages
  - Laws must balance between system coherence and agent autonomy

Federations - Description

- A group of agents cede some amount of autonomy to a single delegate to represent the group

- Group members interact only with this delegate which acts an intermediary between the group and the outside world

- The intermediate then interacts with the delegates from other groups

- Each group is known as a *federate*

Federations – Advantages and Disadvantages

- Advantages
  - Reduces the number interactions in the system
  - Non-delegate agents only have to interact with the agents in their own federate
  - Reduces communication complexity and messaging burden
- Disadvantages:
  - Agents must cede some of their autonomy

Markets

- Agents may place bids for or sell items such as shared resources or tasks
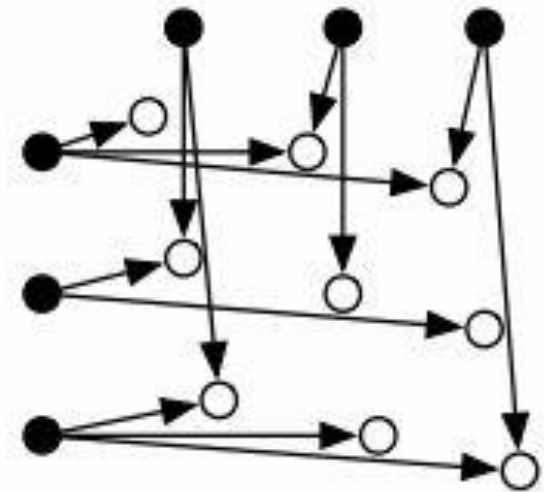- Agents are competitive
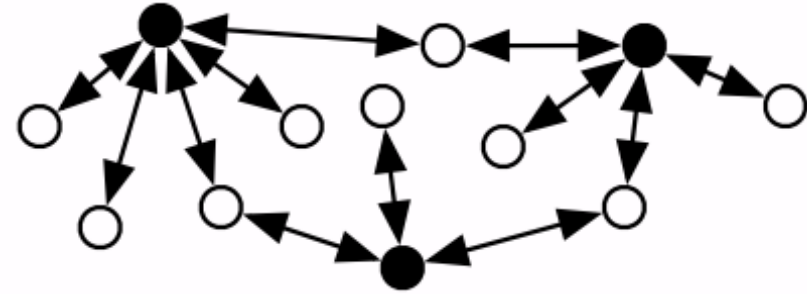
Advantages
- Excel at resource allocation
- Has strong theoretical foundation from research on human economies

Disadvantages
- Increased complexity since markets mostly deal with auctions

Matrix Organizations - Description

- Allows many managers or peers to influence the activities of an agent through goals, direction and feed back

  - Contrasts to a hierarchy where agents report to a single manager
  - Forms a mixed initiative environment

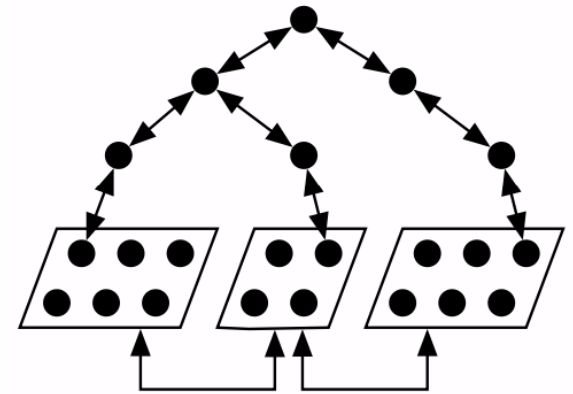# Matrix Organizations – Advantages and Disadvantages

- Advantages
  - Allows an agent's capabilities to be shared so that their functionalities may be shared to the benefit of all
  - Good for when agents are viewed as functional, limited resources
- Disadvantages
  - Actions of agents may become dysfunctional if it is pulled in too many directions at once

Compound Organizations - Description

- "Hybrid" organizational structures.
- Contain characteristics of several different organizational styles

- Some organizational structures pair better than others
  - Within teams, a hierarchy can be created
  - Societies may support an internal organizational structure within the larger context of the society
  - Hierarchies can be combined with a set of coalitions

Compound Organizations – Advantages and Disadvantages

- Advantages
  - Can use the most effective structure for the particular goal without limiting options that might be used elsewhere in the system
  - Allows system to be more flexible and responsive
- Disadvantages
  - More complexity
  - Agents may need to take on different roles in the different organizational structures in the system

Other Organizational Topics

- How do you generate an organization in a MAS?
  - Scripted techniques
  - Controlled techniques
  - Emergent techniques
- Organizational adaptation
- Coordination and negotiation
- Autonomy
- Agent diversity

Discussion

- No single approach is better than all others in all situations
- Hierarchies, teams, coalitions, and markets are the most researched structures
- Provide the most flexibility and offer positive results fairly easily
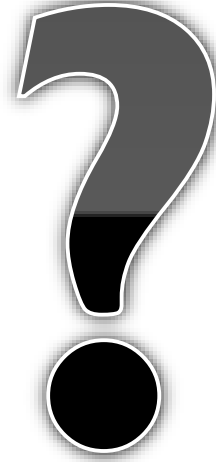- Distinction between structures is blurred in practice

Recap

Paradigm	Key Characteristic	Benefits	Drawbacks
Hierarchy	Decomposition	Maps to many common domains; handles scale well	Potentially brittle; can lead to bottlenecks or delays
Holarchy	Decomposition with autonomy	Exploit autonomy of functional units	Must organize holons; lack of predictable performance
Coalition	Dynamic, goal-directed	Exploit strength in numbers	Short term benefits may not outweigh organization construction costs
Team	Group level cohesion	Address larger grained problems; task-centric	Increased communication
Congregation	Long-lived, utility-directed	Facilitates agent discovery	Sets may be overly restrictive
Society	Open system	Public services; well defined conventions	Potentially complex, agents may require additional society-related capabilities
Federation	Middle-agents	Matchmaking, brokering, translation services; facilitates dynamic agent pool	Intermediaries become bottlenecks
Market	Competition through pricing	Good at allocation; increased utility through centralization; increased fairness through bidding	Potential for collusion, malicious behavior; allocation decision complexity can be high
Matrix	Multiple managers	Resource sharing; multiply-influenced agents	Potential for conflicts; need for increased agent sophistication
Compound	Concurrent organizations	Exploit benefits of several organizational styles	Increased sophistication; drawbacks of several organizational styles

Conclusion

- Organizational structure in a MAS can have significant impact on the system's performance
- The choice of organizational structure depends on the particular system
- Must weigh the pros and cons of each type of organizational structure

Questions?

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Thank You!