Multiagent Systems (SMA-UPC)

4. Multiagent Systems Design
Part 7:
Coordination (II)
Implicit Coordination and Organisational Structures

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SMA-UPC 2006

Multiagent Systems (SMA-UPC)

Explicit and Implicit Coordination

- Another way to cut the cake

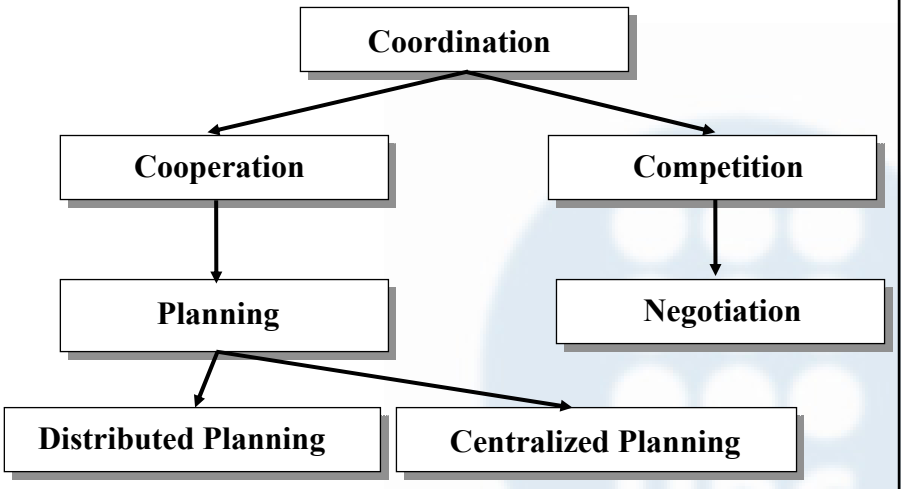
Coordination

Definitions

- **Coordination** could be defined as the process of managing dependencies between activities. By such process an agent reasons about its local actions and the foreseen actions that other agents may perform, with the aim to make the community to behave in a coherent manner.
- An **activity** is a set of potential operations an **actor** (enacing a role) can perform, with a given goal or set of goals.
- An **actor** can be an agent or an agent group
- A set of **activities** and an ordering among them is a **procedure**.

Coordination

Types of coordination



Coordination
Another Classification

- **Coordination** can also be divided along another dimension:
  - **Explicit Coordination**: agents communicate goals, plans, actions, state of the world with the explicit goal of acting coherently.
  - **Implicit Coordination**: no communication – the environment acts as the interaction mechanism

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Implicit Coordination for Coordination

- Reasons for Implicit Coordination
- Agent Modelling
- Social Structure
- Emergent Coordination
- Subsumption as Coordination

Reasons for Implicit Cooperation

When explicit coordination is not best...

- Why do you need something other than explicit coordination?
- In some cases it just cannot be applied:
  - **Speed**: it takes too long to communicate with others – by then the opportunities are missed (think of a football game – simple signals may work, but lengthy explanations don't...)
  - **Security**: not wanting others to know what your plans are.
  - **Complexity**: some agents may be too simple to deal with the complexity of generating and understanding messages.
  - **Lack of a communication channel**: there may actually be no way to communicate

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Agent Modelling

Thinking about others

- Even if you cannot talk to the other agents you may still want to reason about them.
- Several main methods:
  - **Recursive Modelling Methods** (Durfee, Vidal and Others): assume the others have a similar structure to you – and may have a model of you...
  - **Plan Recognition** (Tambe et. al.): rather than trying to model the "mind" of the other agents – try to understand what they are trying to achieve – this breaks down to trying to plan their *possible actions* and identifying the potential end goals of their actual actions.
  - **Game Playing / Game Tree Search**: modelling opponents – e.g. with Alpha-Beta Search.

Social Structure Based Methods

Thinking about Society

- Social structure based methods impose restrictions or norms on the behaviour of Agents in an environment.
- Common approaches include:
  - **Social Laws** (Shoham et. al.): global rules which agents follow and lead to "coherent behaviour", either instilled in the agent or communicated when entering the environment. (E.g. - "driving on the right hand side".)
  - **Social Power Relations** (Castelfranchi et. al.): a theory of dependence relations, in particular to model goal adoption. (E.g. carrying out work on behalf of a superior.)
  - **Social Structures, Norms / Electronic Institutions**: -> covered elsewhere in the course

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Emergent Coordination

Properties that arise spontaneously

- Coordination in cases where:
  - There is no communication between agents.
  - There is no mechanism for enforcing a-priori social rules / laws.
  - Agents have their own agenda/goals and do not care about others.
- The resulting coordination is emergent and cannot be said to be based on Joint intention
- Examples include:
  - Tidy Bots
  - WASP and ANT based paradigms – stymergy

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The Case of the Tidy Bots

Beckers and Deneubourg

- Challenge:
  - A randomly distributed number of pieces of rubbish on a 200x200 grid
  - Agents can detect rubbish and push it around
  - How do you collect all the rubbish into a single heap?

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The Case of the Tidy Bots

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- Challenge:
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- Simple:
  - Robots don't need to talk to each other
  - Each implements a rule “push rubbish close to other rubbish”
- Emergent clustering of rubbish into heaps
- [Some planning can speed up the process though]

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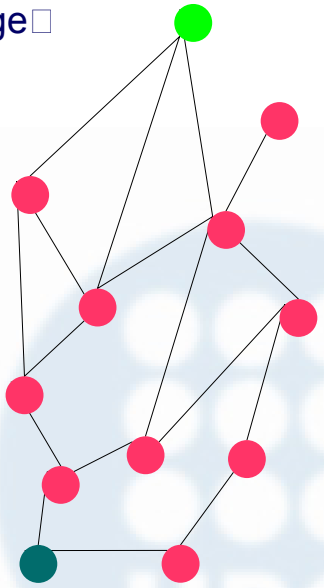
Network Routing Challenge

Appleby and Steward

- Network Routing problems are challenging. Solutions need to be:
  - Dynamic
  - Robust
- Network of N nodes ***n***, L links ***l***. Traffic flows as packets traverse the network.
- RIP/OSPF (or something similar) carries out cumulative shortest path measures



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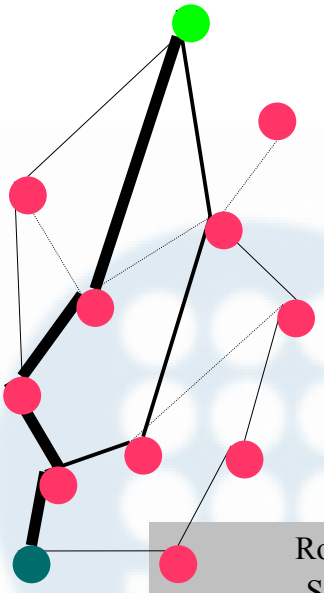
Network Ants II

Appleby and Steward

- Ants randomly explore the network
  - until they find a specific (or random) node
  - noting the time it took them to get there they return on their outward path marking with "pheromone"
- Ants seeking destinations follow trails
- Pheromones degrade over time.



Robust
Stable
Gradual Change

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Important Factors

- **Agents**:
  - Don't need to know about each other
  - Don't have special roles
  - Loosing a few doesn't matter
- **Environment**:
  - Acts as a communication mechanism
  - Is affected by the actions of all individuals
  - Cumulative effect significant

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Subsumption as Coordination

Robotics as a Multi-Agent System

- Brooks Subsumption Architecture:
  - Layers of controllers
  - Each of which creates a competence
  - Higher Layers suppress lower layers
- Can be seen as coordination
  - Is it Implicit or Explicit?
  - How would you model subsequent coordination of mutliple robots – each of which is based on subsumption?

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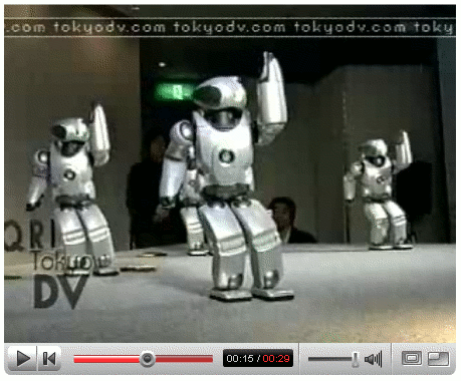
Robot Coordination (Inter and Intra)



Sony Quiro / YouTube

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Summary of Implicit Coordination Mechanisms

- Approaches:
  - *Do not allow direct agent-agent communication*
  - In some cases Agents:
    - Think about **each other**
    - Think about **society**
    - Think about the **environment**
  - The result is surprisingly coherent group (coordinated) action.
- Techniques can be combined with explicit coordination by:
  - Using explicit methods to agree high level goals
  - Using implicit methods to manage low level interactions

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Sugarland and the Mountains

- Grid Map
  - Food sources, Mountains
  - Water, Randomly moving population of agents
- Rules:
  - I have friends and people i am neutral to
  - If i meet a neutral – 20% to become a friend, 20% kill them, 60% do nothing
  - If i meet a friend, 50% i will tell them about a food source
  - If i meet a friend of a friend – 50% they become my friend.

Discuss the Dynamics..

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Sugarland and the Mountains

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- Resulted in Crazy population dynamics:
  - Rise and Crash
  - near extinctions
- A small change:
  - %chance Agents can make a mistake and make friends with a mountain

Discuss the Dynamics..

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Organisation & Meta Coordination for Coordination

- **Organisational Structures**
- **Organisation as a context for coordination**
- **Views on Organisations**
- **Organisational Design**
- **Some examples**

When one Coordination mechanism is not enough!

- Two main dimensions of meta-coordination:
  - **Choosing between multiple coordination mechanisms**: some might be more appropriate for some types of problems
  - **Using multiple levels of abstraction**: for example – using two types of multi-agent planning.
- Plus there are individual considerations:
  - **Choosing between lone and joint action**: what's best for me? for the team?
  - **Dynamic Commitment Reconsideration**: when do I pull out of team action?

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Organisation as a Context for Coordination

Providing structure to dynamic worlds

- "**Organisation is Institutionalised Coordination**" (unkown quote):
  - Organisational structures capture relationships between agents
  - Some of those relationships may drive coordination under certain circumstances
- Example: A firefighting team
  - Through all drills and practices they stick to roles.
  - When an incident arises they "apply" this plan to the problem as it unfolds.
  - But dynamism may be needed at "run time".

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Streams of Research on Organisations

Different Problems to solve

- Different approaches:
  - **Characterisation**: what are they? what types are there?
  - **Formalisations**: how do we model them?
  - **Design**: how do we design the organisations that we need?
- More detail in other lectures, but organisations often fall into broad types:
  - **Peer-to-Peer systems**
  - **Markets**
  - **Strict Hierachies**
  - **Multi-Hierachies**

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Views of Organisation

Fox and Gasser

- **Fox**: discussion of why organisations are needed by also need to change – introducing "**transactional dis-economies**" and the need to deal with:
  - **Complexity**: using abstraction and ommission to streamline interactions.
  - **Uncertainty**: identifying the structures which cope best with the challenges the environment might throw up.
- **Gasser et. al.**
  - Settled and Unsettled questions (routines and ad-hoc coordination)
  - Webs of commitments, expectation of defaults

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Views of Organisation

Shoham, Werner, Castelfranchi, Jennings

- **Shoham et. al.**
  - Social Laws decrease the variability in the world
  - Laws can be applied to control relationships (boss – worker) to form organisations
- **Werner**
  - Characterises organisations in terms of roles and relations annotated by social rules
- **Castelfranchi and Jennings**
  - "Commitments to Commit" (meta-commitments)

Organisational Design (Off-line)

Picking the right structure

- So we can characterise and formalise organisations – how would you build one?!
- A range of methods for Off-line design:
  - **Classification based** (Malone et. al.): picking the right structure
  - **Automated approaches** (Crowstone et. al.): genetic algorithms and expert systems
  - **Agent Oriented Methodologies**: ADEPT, DESIRE, AALAADIN.

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Organisational Self-Design (On-Line)

Changing in the face of the environment

- The right organisation depends on the environment – which is constantly changing – so you can change it at runtime.
- Main Methods:
  - **Organisational Self Design** (Ishida et. al.): allowing processes to add more capacity to reasoning for rule based (or CSP) applications.
  - **Decomposition** / **Recomposition** (Guichard et. al.): merge and split agents
  - **Role Re-allocation** (Corkill, Lesser et. al): changes in structure based on roles and agents filling roles

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A Familiar Sequence?

ORD Cycle

- Durfee, So et. al. - four steps to organisational re-design (c.f. Wooldridge and Jennings).
  - **Monitor**: check performance against expectations (e.g. how well are individual acts of coordination going).
  - **Design**: new organisational arrangements
  - **Evaluate**: whether these will be successful
  - **Implement**: apply the changes
- Spot the familiar problems also:
  - Interdependence between steps?
  - How do you evaluate?
  - How do you implement?

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Example

Adaptive Network Capacity Management

- Routing of VPN connections in large-capacity Internet (MPLS/ATM) backbones is complex
  - Centralised approaches are too slow and prone to failures
- Standards define a hierarchical approach
- It turned out there was an “ideal” organisational structure derivable from resource state
  - But how to implement it?!
  - Centralised recalculation was impossible

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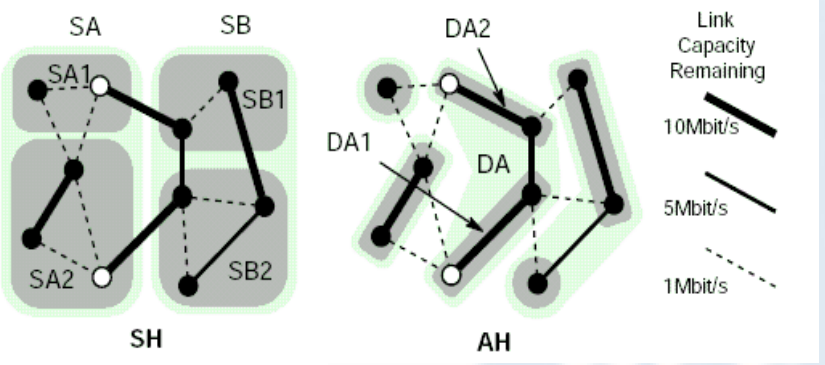
Example

Adaptive Network Capacity Management

- Solution:
  - Local adaptation rules – provably converging to the optimum
- Don't need “global redesign”



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(Partial) Summary of Organisations

- There will be more (detail and methods) in other parts of the course.
- For now Approaches:
  - *Focus on a structure / context for coordination*
  - Look at different types of structures:
    - Peer systems
    - Markets
    - Hierarchies etc.
  - Are concerned with streamlining or “hard-wiring” certain patterns which help coordination in instances of tasks arising in the execution world.

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Locating Material

- Slides are online on the course page
- Related Materials:
  - http://www.lsi.upc.edu/~steve/download/sma/biblio.ps
  - http://www.lsi.upc.edu/~steve/download/sma/coord.ps
  - [Note that - the bibliography is not only Coordination]