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Agents and Interactions

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Cooperative Design

- Interdependence of multiple actors
- Changing individual state changes state of others
- Interaction through changing state of common field
- Inherently distributed
- Semi-autonomous actors
- Different strategies, heuristics, goals, motives, …

- Sounds like agents to me!

Overview

- Agents
- Agent-based computing: state-of-the-art
- Application and deployment
- Technology timeline and agent design
- Challenge areas
- Opportunities

What is an agent?

- A computer system capable of flexible, autonomous (problem-solving) action, situated in dynamic, open, unpredictable and typically multi-agent domains.

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- control over internal state and over own behaviour

What is an agent?

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- experiences environment through sensors and acts through effectors

What is an agent?

- A computer system capable of flexible, autonomous (problem-solving) action, situated in dynamic, open, unpredictable and typically multi-agent domains.

- reactive: respond in timely fashion to environmental change
- proactive: act in anticipation of future goals

Multiple Agents

- In most cases, single agent is insufficient

- no such thing as a single agent system (!?)
- multiple agents are the norm, to represent:
  - natural decentralisation
  - multiple loci of control
  - multiple perspectives
  - competing interests

Agent Interactions

- Interaction between agents is inevitable
  - To achieve individual objectives, to manage inter-dependencies
- Conceptualised as taking place at knowledge-level
  - Which goals, at what time, by whom, what for
- Flexible run-time initiation and response
  - Contrasts with design-time, hard-wired nature of extant approaches

- Sloman's view of artificial intelligence and computer science
- Luck's view of agent-based systems and computer science

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State of the art

Views of Agents

- To support next generation computing through facilitating agent technologies
- As a metaphor for the design of complex, distributed computational systems
- As a source of technologies
- As simulation models of complex real-world systems, such as in biology and economics

Agents as Design

- Agent oriented software engineering
- Agent architectures
- Mobile agents
- Agent infrastructure
- Electronic institutions

Agent technologies

- Multi-agent planning
- Agent communication languages
- Coordination mechanisms
- Matchmaking architectures
- Information agents and basic ontologies
- Auction mechanism design
- Negotiation strategies
- Learning

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Application and Deployment

Applications and Deployers

- Assistant agents
- Multi-agent decision systems
- Multi-agent simulation systems

- IBM, HP, Siemens, Motorola, BT
- CapGemini
- Lost Wax, Agent Oriented Software, Whitestein, Living Systems, iSOCO

Agents in Manufacturing

- Shortening of incubation period from design to production
- Shortening of time from order to delivery
- Product lifecycles become shorter
- Product catalogue becomes larger
  - More products
  - More variations of product
- Requires flexibility and agility

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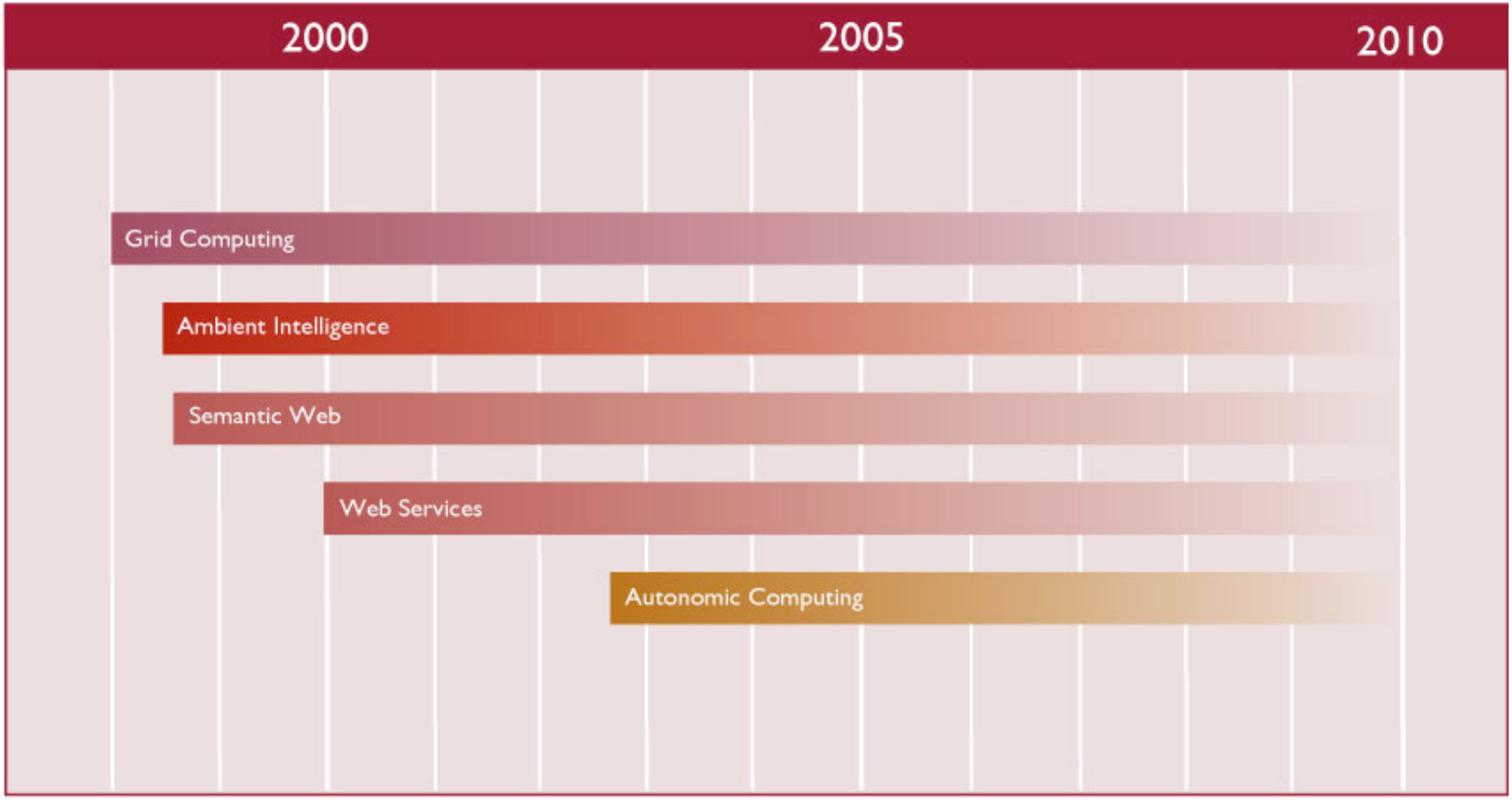
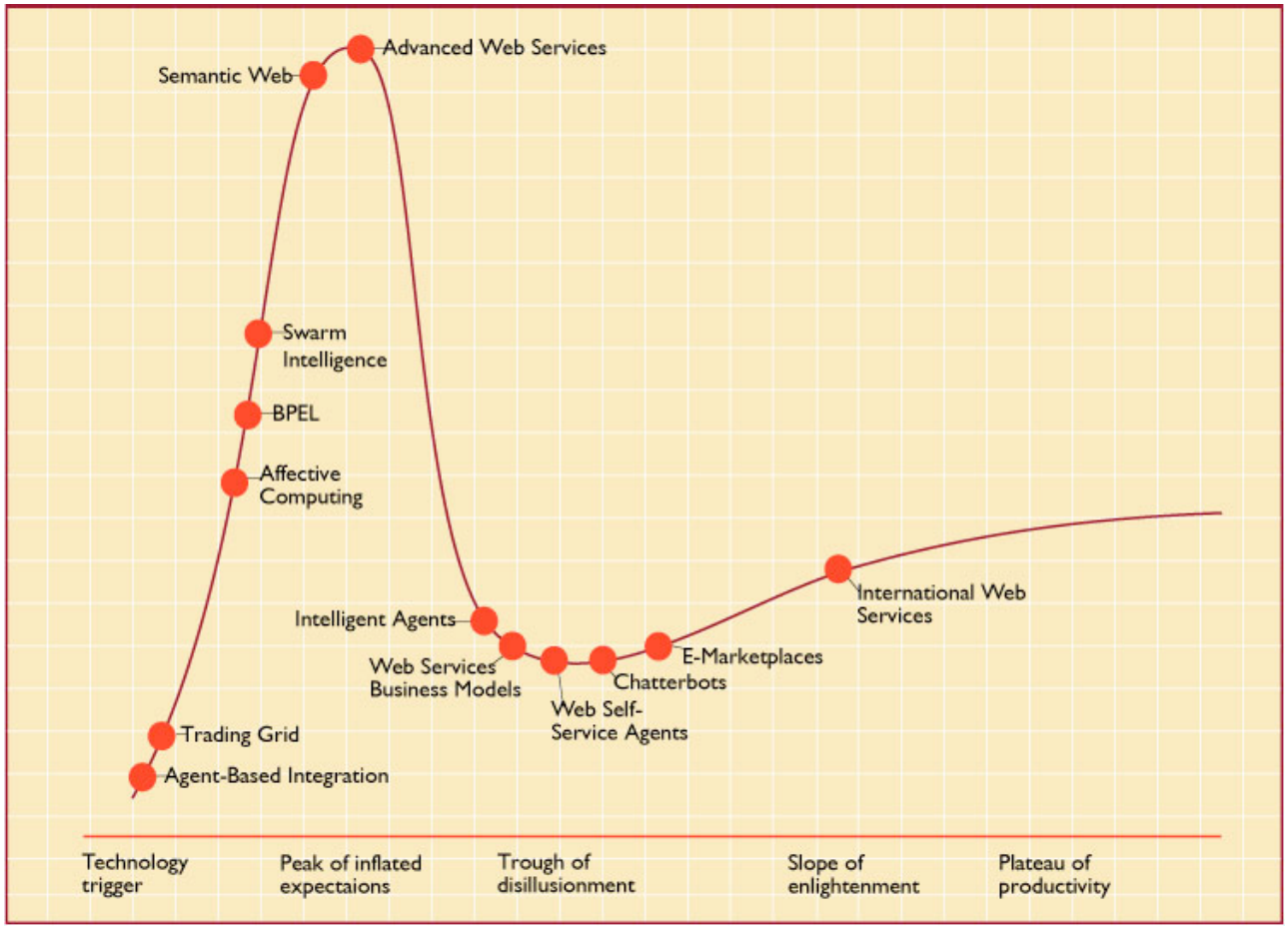
Technology Timeline

… and design in agents

Trends and Drivers



Gartner's Hype Cycle



Predictions and Targets

	Short Term	Medium Term	Long Term
Industrial Strength software	Peer to peer Better development tools Agent UML Web Services	Generic Designs for Coordination Libraries for agent-oriented development	Best practice in agent systems design
Agreed Standards	FIPA ACL Peer to peer Better development tools Web Services Semantic description	Flexible business/trading languages Libraries of interaction protocols	Tools for evolutions of communications languages and protocols
Infrastructure for Open Communities	Web mining Semantic interaction Data integration and Semantic Web	Agent-enabled semantic web (services) Electronic institutions	Shared, improved ontologies Dynamic norms, roles, laws
Reasoning in Open Environments	Organisational views of agent systems	Enhanced understanding of agent society dynamics Theory and practice of argumentation strategies Norms and social structure Theory and practice of negotiation strategies	Automated eScience systems and other application domains
Learning Technologies	Adaptation Personalisation Hybrid technologies	Evolving Agents Self organisation Distributed learning	Run-time reconfiguration and re-design
Trust and Reputation	Security and verifiability for agents Reliability testing for agents Self-enforcing protocols	Norms and social structures Reputation mechanisms Formal methods for open agent systems Electronic contracts	Trust techniques for coping with malicious agents

Dimensions

- Sharing of knowledge and goals
- Design by same or diverse teams
- Languages and interaction protocols
- Scale of agents, users, complexity
- Design methodologies

Current situation

- One design team
- Agents sharing common goals
- Closed agent systems applied in specific environment
- Ad-hoc designs
- Predefined communications protocols and languages
- Scalability only in simulation

Short term

- Fewer common goals
- Use of semi-structured agent communication languages (such as FIPA ACL)
- Top-down design methodologies
- Scalability extended to predetermined and domain-specific environments

Medium term

- Design by different teams
- Use of agreed protocols and languages
- Standard, agent-specific design methodologies
- Open agent systems in specific domains (such as in bioinformatics and e-commerce)
- More general scalability, arbitrary numbers and diversity of agents in each such domain
- Bridging agents translating between domains

Long Term

- Design by diverse teams
- Truly-open and fully-scalable multi-agent systems
- Across domains
- Agents capable of learning appropriate communications protocols upon entry to a system
- Protocols emerging and evolving through actual agent interactions.

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Technological Challenges

an Organisational Perspective

Technological Challenges

- Reasoning capabilities for agents in open environments
- Negotiation and argumentation
- Trust negotiation and management
- Virtual organisations
- Electronic institutions
- Self organisation and emergence

Reasoning in Open Environments

- Cannot handle issues inherent in open multi-agent systems
  - Heterogeneity
  - Trust and accountability
  - Failure handling and recovery
  - Societal change
- Coalition formation
- Demanded by emerging computational infrastructures
  - Grid
  - Web Services
  - eBusiness workflow systems

Negotiation and Argumentation

- Some existing work but currently in infancy
- Point solutions
- Algorithms and negotiation protocols
  - Which bidding or negotiation algorithms are most effective
- Interplay of different negotiation algorithms
- Effective strategies and protocols
- Languages for expressing service agreements
- Mechanisms for negotiating, enforcing and reasoning about agreements

Trust negotiation and Management

- Currently techniques for authentication, verification, validation
- Sophisticated distributed systems involve action in absence of strong existing trust relationships
- Need to address problems of establishing, monitoring and managing trust
- Enable interaction in dynamic and open environments
- Trust of agents in agents
  - Norms
  - Reputation
  - Contracts

Virtual Organisations

- Virtual organisations as the means to release the power of the Grid
- Well-defined procedures to determine when to form new virtual organisations
- How to manage them
- When to disband them

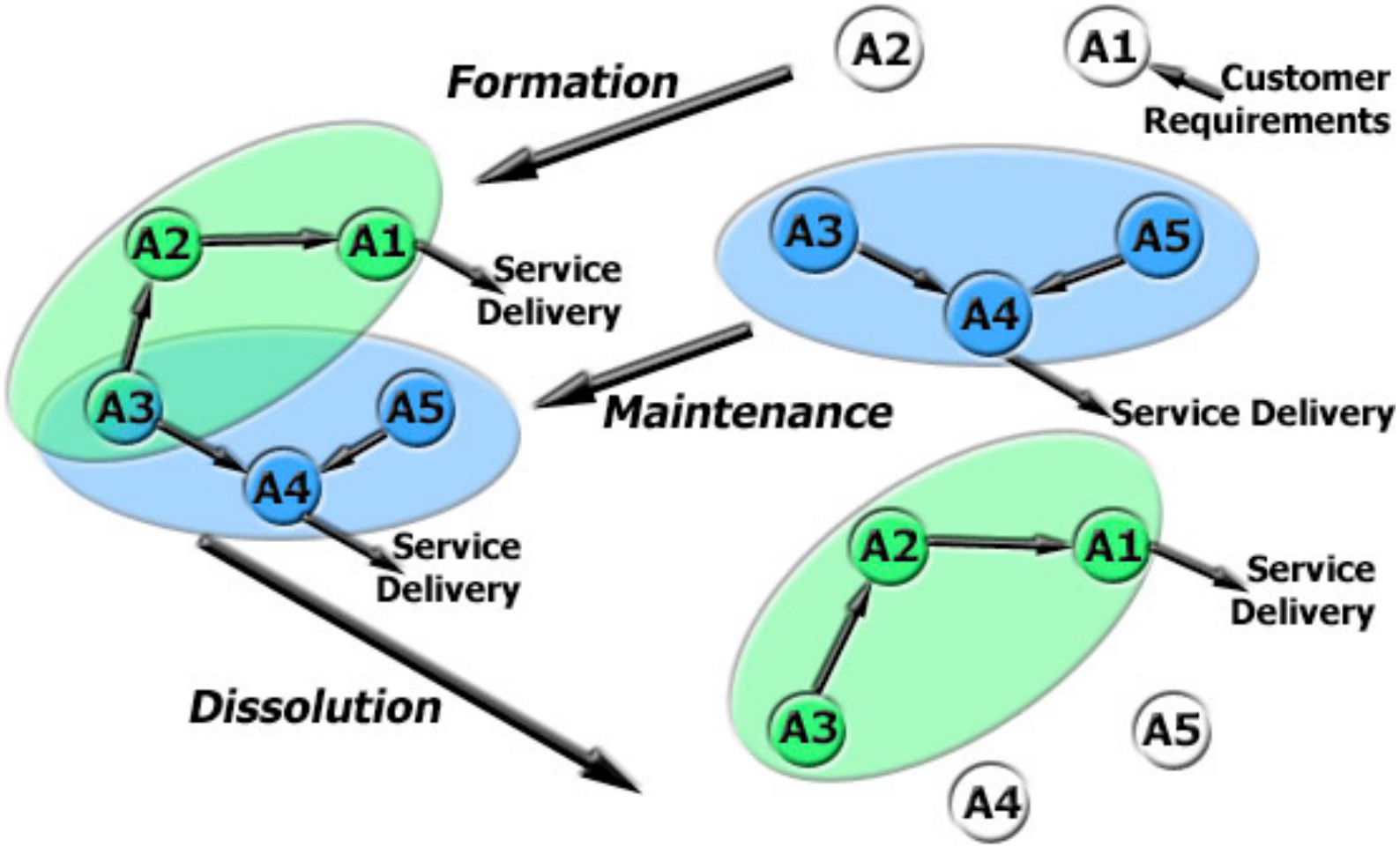
Example: CONOISE

- Work with BT, Aberdeen, Cardiff

- Virtual Organisations
- Decision to Form a VO
- Deciding Whether/What to Offer
- Accounting for Quality Expectations
- Deciding What to Accept

- Continues in CONOISE-G, Grid-enabled CONOISE

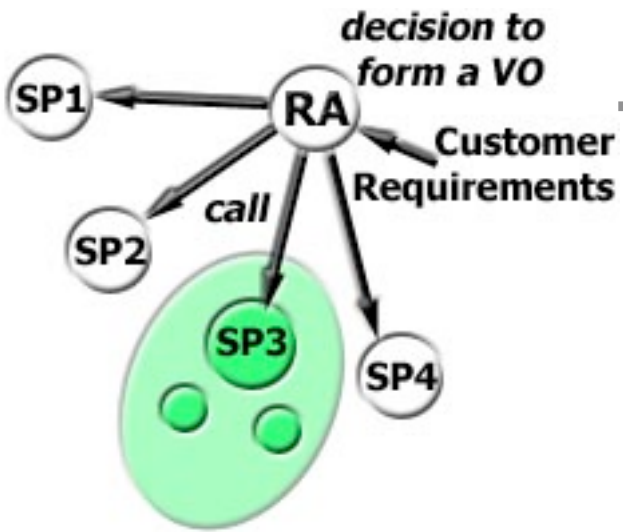
Virtual Organisations



VO Management

- *Agents identify potential service providers (responding to customer requirements or perceived market niche)*
- *Negotiate to form consortia, which bid for contracts to meet user requirements*
- Adapt consortia in response to changes in the market.
- Disband consortia if there is no longer any need for the service(s) offered

Decision to Form a VO



- Package required by customer:
  - Movie subscription
  - News service
  - >50 free text messages per month
  - ≥30 free phone minutes per month

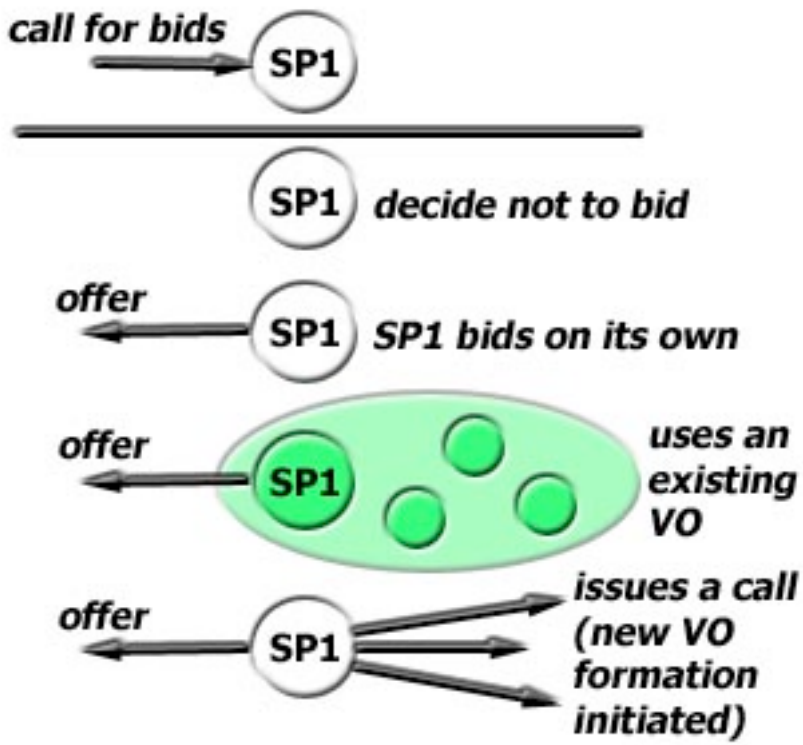
- RA responds to customer requirements by attempting to form a VO
- Identifies potential suppliers (through yellow pages)
- Issues call for proposals

Quality Expectations

- A customer specifies the services required:
  - Movies, news, phone and text messaging
- But will also have certain quality expectations w.r.t. service delivery:
  - An integral part of the customer's requirements
- These expectations will be used to bias the decision of which service provider(s) to use

Deciding Whether/What to Offer

- SP1 manages the provision of a set of resources over time
- Maintains a schedule of resource use
- Schedule represented by constraints on resource use (commitments)
- Used to determine what it *can* offer



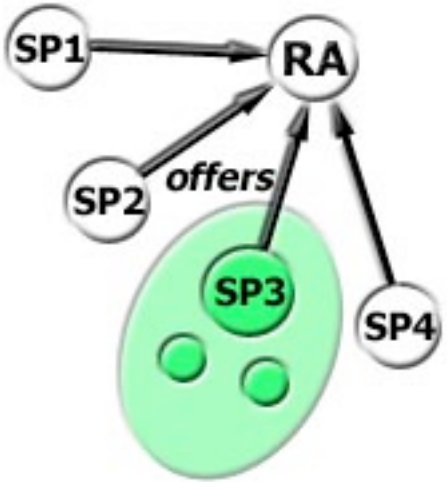
Weighing up Alternatives

- It may be worth breaking a prior commitment to make an offer on a lucrative contract
- How does the agent represent and weigh up its alternatives?
- Constraint reification can be used to ask "what if …?" questions
- Allows the agent to prioritise its commitments

Deciding What to Accept

- Offers received from potential service providers
- Various alternatives may be offered and constraints placed on them
  - E.g. SP3 specifies that text and phone must be taken as a package

Service Provider	Movies (pcm)	News (daily)	Text (#free)	Phone (#free)
SP1	10	24		
SP2		72		
SP3			120	30mins
SP4	5			30mins

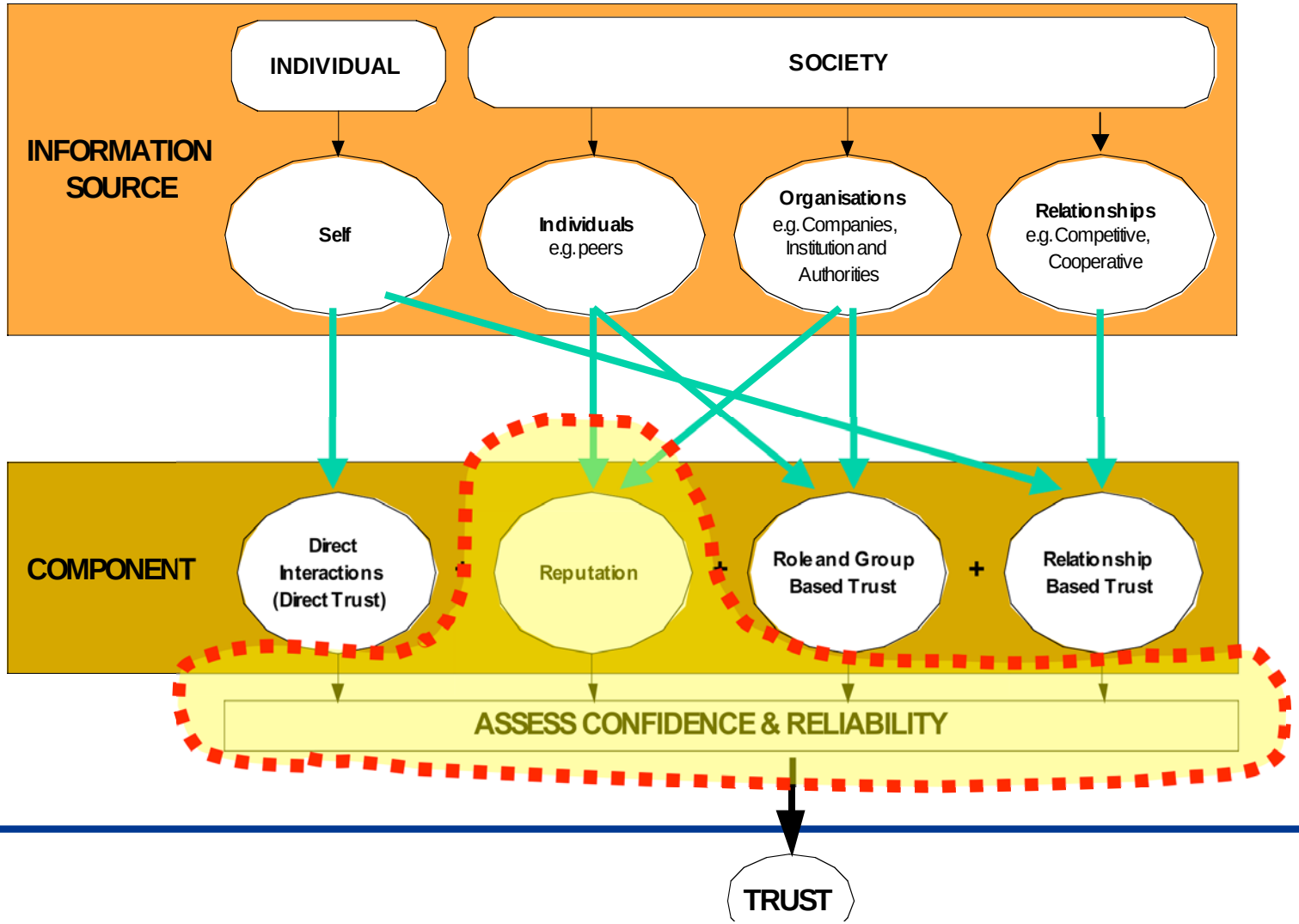


Selecting the Right Coalition

- The information available for selecting a coalition consists of:
  - Supply offers with their associated utilities
  - Demand information from the customer
- The most suitable set of partners must be selected; i.e. highest utility (lowest cost and best match to quality expectations)
- This selection must be made in a computationally feasible time frame

- Trust and reputation information used (CONOISE-G)

Sources Of Trust

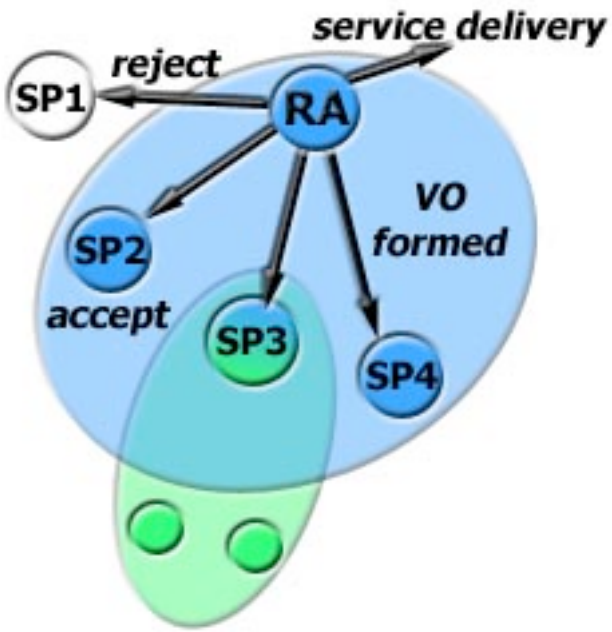


The Use of Auction Mechanisms

- Auctions are an efficient method of allocating goods/services in dynamic situations to the agents that value them most highly
- Traditional auctions provide a simple means for the sale of single items
- In combinatorial reverse auctions, however, bidders (SPs) may bid for arbitrary combinations of items (this is the case in CONOISE)

Confirmation of Coalition

- Coalition formed:
- News service from SP2 (72 updates per day)
- Text and phone (must be taken together) services from SP3 (120 free text msgs & 30 phone mins – wanted >50 text & ≥30 phone)
- Movies from SP4



CONOISE VO Summary

- Customer requirements identified (services required and quality of service)
- Potential partners identified and asked to bid
- Nature of bid determined through constraint-based representation of prior commitments
- Offers combined with quality expectations
- Polynomial time market clearing algorithm used to identify a good coalition
- Coalition formed…

- Trust and reputation
- Policing
- Quality of Service

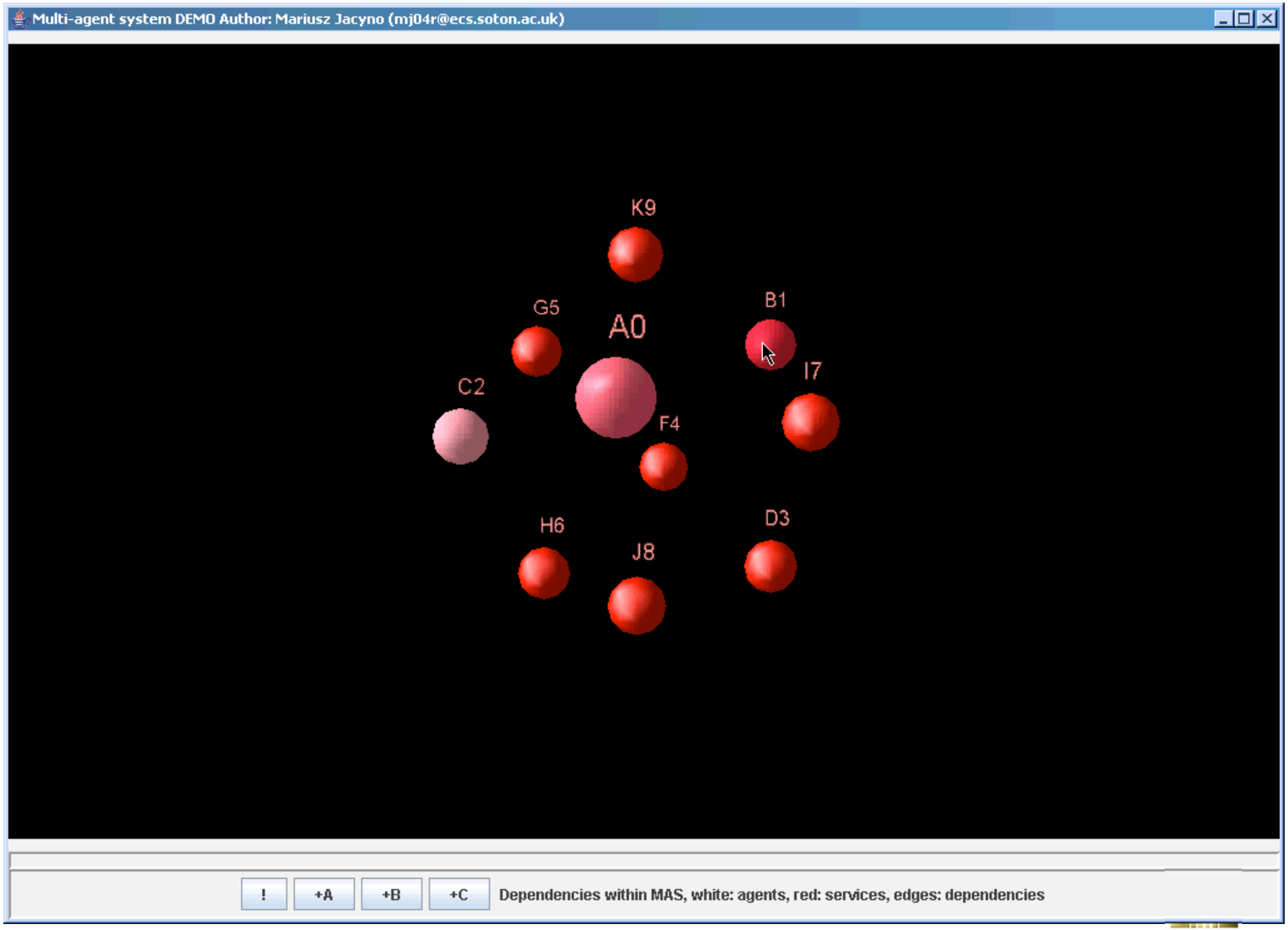
Self organisation and emergence

- IT underpins modern activities at all levels
  - Manufacturing, logistics, retail, finance, entertainment, healthcare, government, education, …
- It is increasingly a joined up world
- Traditional engineering techniques may not be suitable for interconnected networks of thousands of nodes
- Can IT systems remain usable as complexity increases?
- How to configure or optimise the organisation of complex systems?
- How to recover from failure?

- Biologically inspired self organisation processes

Example: Economic markets

- Emergent behaviour emerges from a system's low-level atomic interactions in a non-trivial manner
- In economic markets, the actions and interactions of individual traders can be characterised in simple terms
- Yet overall market dynamics that arise from trader interactions can be subtle and sophisticated
- In commodity markets traders collectively discover the best transaction prices without central control, and with each acting through self-interest


Multi-agent system DEMO Author: Mariusz Jacyno (mj04r@ecs.soton.ac.uk)
K9
G5
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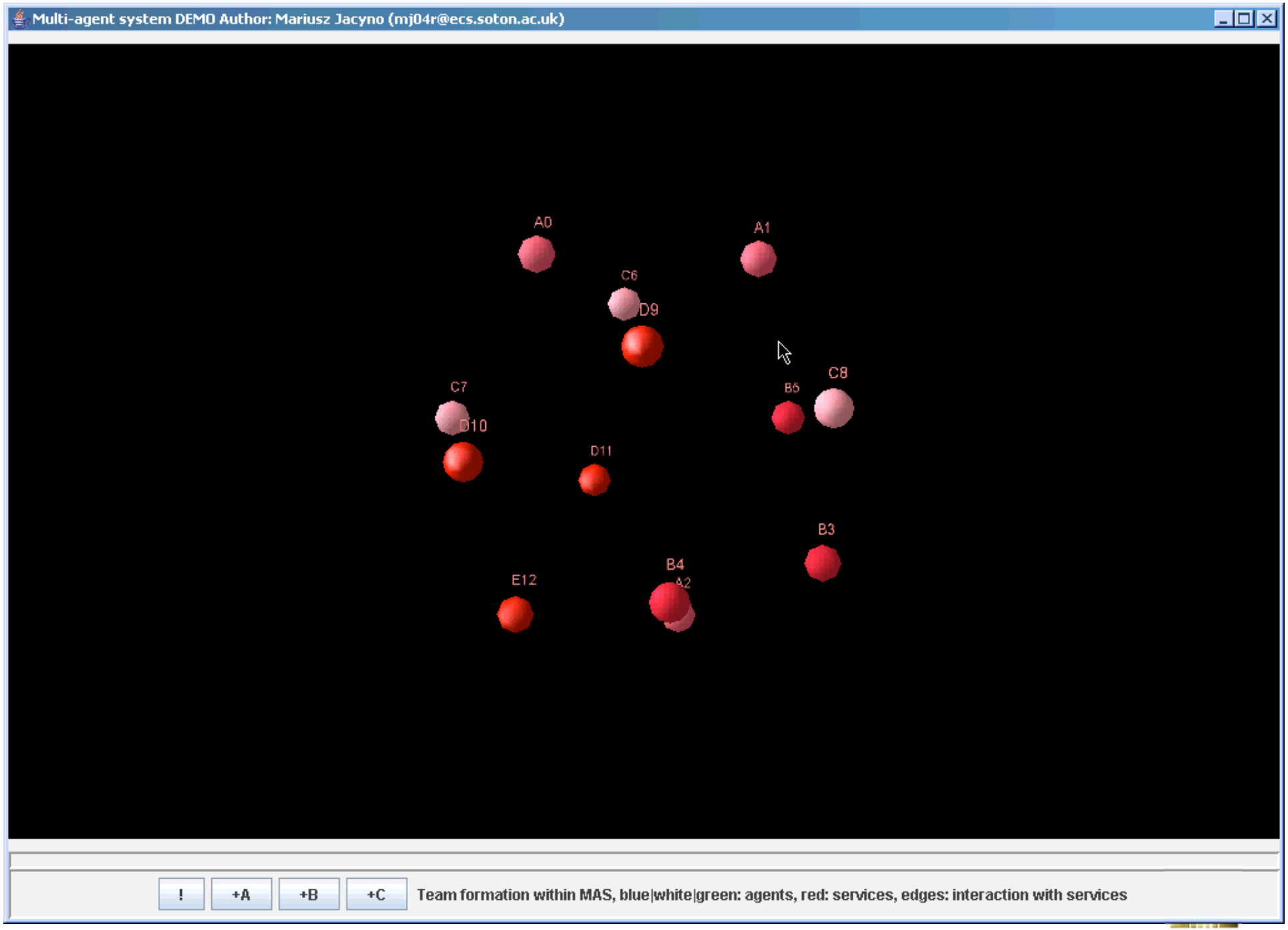
Dependencies within MAS, white: agents, red: services, edges: dependencies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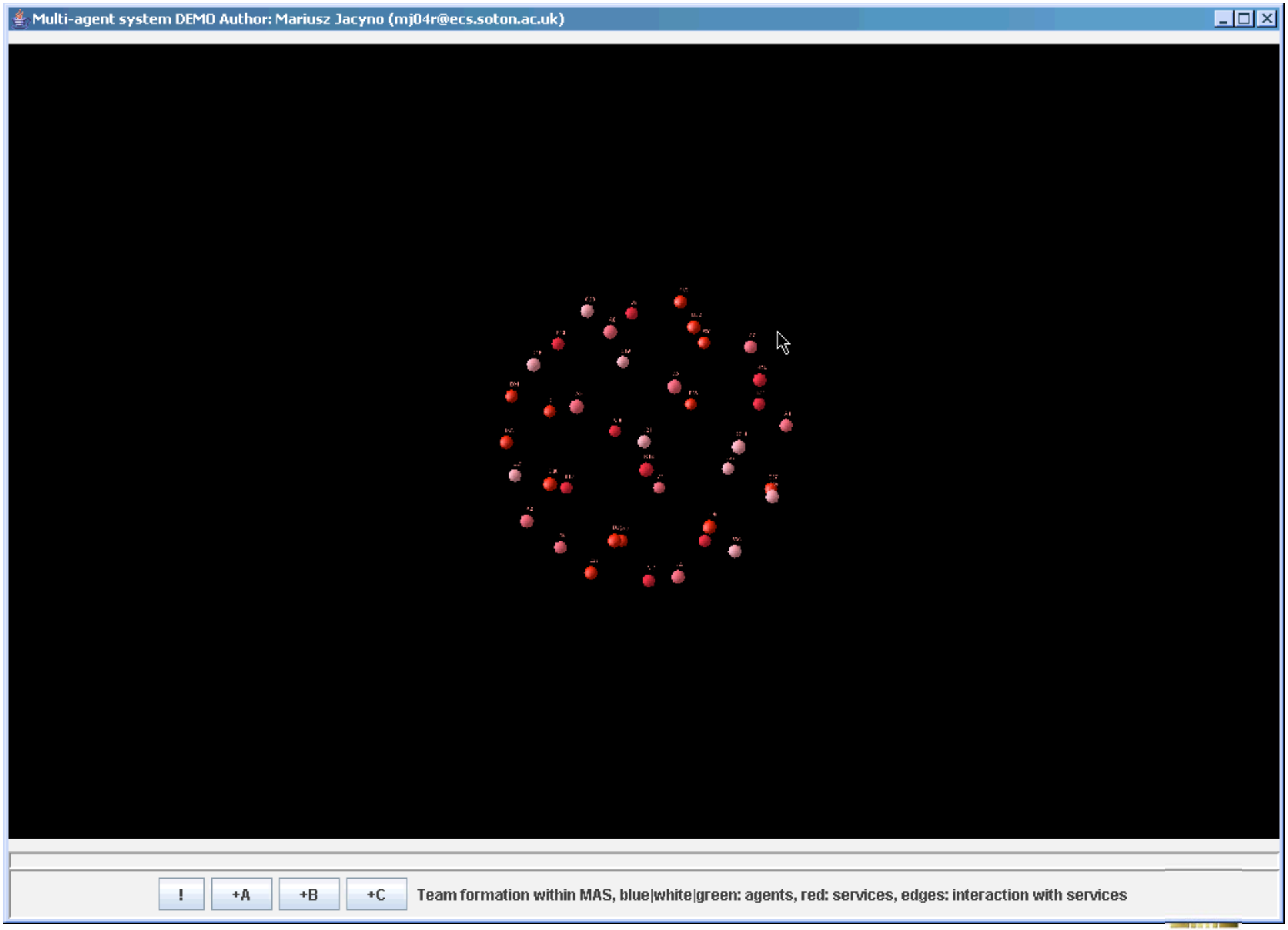
Team formation within MAS, blue|white|green: agents, red: services, edges: interaction with services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Research and Application Opportunities

Application Opportunities

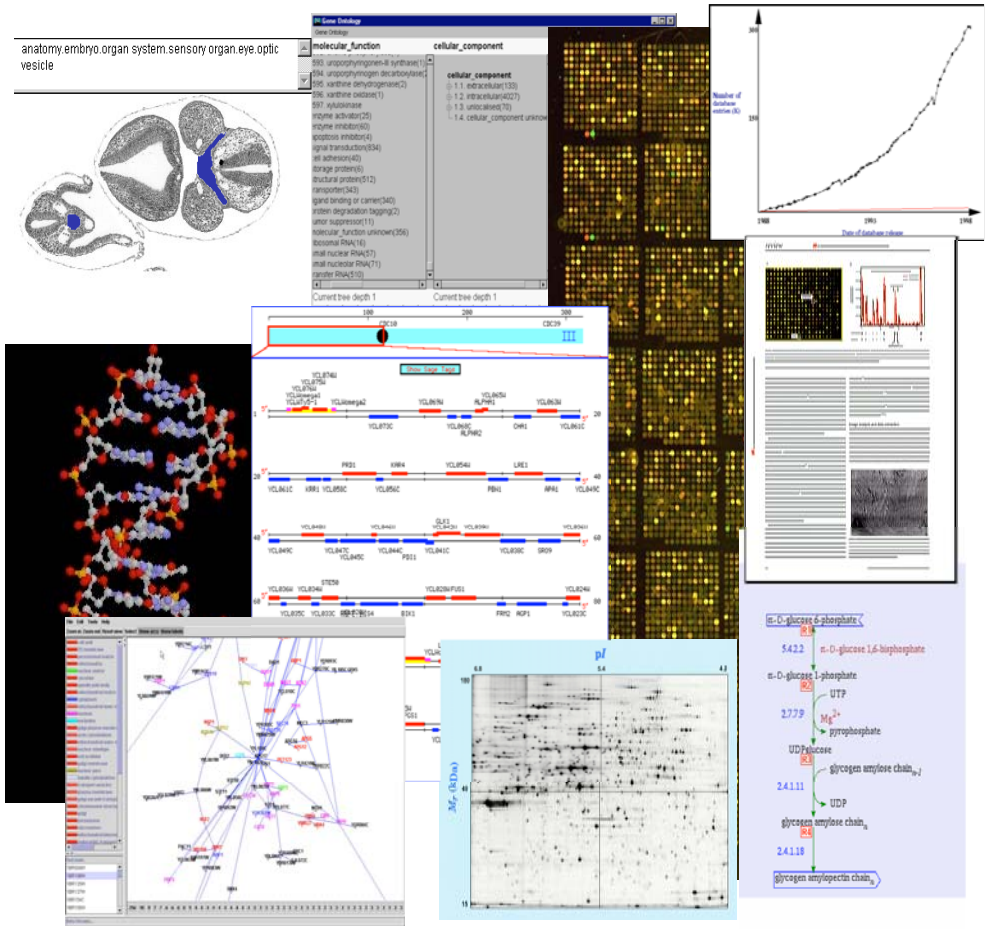
- Bioinformatics and Computational Biology
- Grid Computing
- Electronic Business

Bioinformatics

- Information explosion in genomics and proteomics
- Distributed resources include databases and analysis tools
- Demands automated information gathering and inference tools
- Open, dynamic and heterogeneous
- Examples: Geneweaver, myGrid

Bioinformatics

- Large amounts of data
- Highly heterogeneous
  - Data types
  - Data forms
  - Community
- Highly complex and inter-related
- Volatile



Grid Computing

- Support for large scale scientific endeavour
- More general applications with large scale information handling, knowledge management, service provision
- Suggests virtual organisations and agents
- Future model for service-oriented environments

The Economist, June 2001

"The Grid will become really valuable when people learn to build virtual organisations."

Example: Tycoon

- HP's Information Dynamics Laboratory, 2004
- Does not adopt a centralised planning approach
- Enables customers to bid for computer resources through a marketplace
- Initially envisaged as means of allocating resources within an organisation
- HP sees it as leading to the broader goal of utility computing across organisations

Electronic Business

- Agents currently used in first stage – merchant discovery and brokering
- Next step is real trading – negotiating deals and making purchases
- Potential impact on the supply chain
- Rise in agent-mediated auctions expected
  - Agents recommend
  - But agents do not yet authorise agreements

Electronic Business

- Short term: travel agents, etc
  - TAC is a driver
- Long term: full supply chain integration
- At start of 2001, there were
  - 1000 public eMarkets
  - 30,000 private exchange

Challenge?

- Current state, future challenges and applications in agent-based computing
- Models underlying agent-based computing and CSCW derive from similar sources but are applied to different ends
- Many problems and challenges in one may help to illuminate the other
- The real challenge is for cross-fertilisation and interdisciplinarity

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