Autonomous Agents and Self Organization
Outline

• What’s an Agent?
• Multi-Agent Systems
  – Cooperative multi-agent systems
  – Competitive multi-agent systems
  – Mobile agents
• Self-organizing systems
What’s an agent?

• Weiss [after Wooldridge and Jennings]:
  – “An *agent* is a computer system that is *situated* in some *environment*, and that is capable of *autonomous action* in this environment in order to meet its design objectives.”

• Russell and Norvig:
  – “An agent is just something that perceives and acts.”

• Rosenschein and Zlotkin:
  – “The more complex the considerations that [a] machine takes into account, the more justified we are in considering our computer an ‘agent,’ who acts as our surrogate in an automated encounter.”
What’s an agent? II

Ferber: “An agent is a physical or virtual entity

a) Which is capable of acting in an environment,
b) Which can communicate directly with other agents,
c) Which is driven by a set of tendencies…,
d) Which possesses resources of its own,
e) Which is capable of perceiving its environment…,
f) Which has only a partial representation of this environment…,
g) Which possesses skills and can offer services,
h) Which may be able to reproduce itself,
i) Whose behavior tends towards satisfying its objectives, taking account of the resources and skills available to it and depending on its perception, its representations and the communications it receives.”
OK, so what’s an environment?

- Isn’t any system that has inputs and outputs situated in an environment of sorts?
What’s autonomy, anyway?

• Jennings and Wooldridge:
  – “[In contrast with objects, we] think of agents as encapsulating behavior, in addition to state. An object does not encapsulate behavior: it has no control over the execution of methods – if an object $x$ invokes a method $m$ on an object $y$, then $y$ has no control over whether $m$ is executed or not – it just is. In this sense, object $y$ is not autonomous, as it has no control over its own actions…. Because of this distinction, we do not think of agents as invoking methods (actions) on agents – rather, we tend to think of them requesting actions to be performed. The decision about whether to act upon the request lies with the recipient.”

• Is an if-then-else statement sufficient to create autonomy?
So now what?

- If those definitions aren’t useful, is there a useful definition? Should we bother trying to create “agents” at all?
Deep Space 1

- “Deep Space 1 launched from Cape Canaveral on October 24, 1998. During a highly successful primary mission, it tested 12 advanced, high-risk technologies in space. In an extremely successful extended mission, it encountered comet Borrelly and returned the best images and other science data ever from a comet. During its fully successful hyperextended mission, it conducted further technology tests. The spacecraft was retired on December 18, 2001.” – NASA Web site
Multi-Agent Systems
Multi-agent systems

• Jennings et al.’s key properties:
  – Situated
  – Autonomous
  – Flexible:
    • Responsive to dynamic environment
    • Pro-active / goal-directed
    • Social interactions with other agents and humans

• Research questions: How do we design agents to interact effectively to solve a wide range of problems in many different environments?
Aspects of multi-agent systems

- Cooperative vs. competitive
- Homogeneous vs. heterogeneous
- Macro vs. micro

- Interaction protocols and languages
- Organizational structure
- Mechanism design / market economics
- Learning
Topics in multi-agent systems

• Cooperative MAS:
  – Distributed problem solving: Less autonomy
  – Distributed planning: Models for cooperation and teamwork

• Competitive or self-interested MAS:
  – Distributed rationality: Voting, auctions
  – Negotiation: Contract nets

• Mobile agents
  – Running code that can move from host to host

• Agent-based simulations
  – e.g., for economics, mobile networks
Swarm Intelligence

“One ant alone is a disappointment; it is really no ant at all. The colony is the organism.” – The Superorganism, B. Holldobler and E.O. Wilson, Journey to the Ants, 1994.

Swarm Intelligence: “Any attempt to design algorithms or distributed problem-solving devices inspired by the collective behavior of social insect colonies and other animal societies.” -- Bonabeau, Dorigo, and Theraulaz, 1999.

- Minimalist but fully autonomous individuals Fully distributed control
- Exploitation of agent-agent and agent-environment interactions
- Exploitation of explicit or implicit (stigmergic) communication
- Scalability (from a few up to thousands individuals)
- Enhanced robustness through redundancy and minimalist design of the individuals
Biological motivation

- Biological Inspiration from: social insects (ants, bees, termites) flocks of birds, herds of mammals, schools of fish, packs of wolves, pedestrians, traffic.
- Colonies of social insects can achieve flexible, reliable, intelligent, complex system level performance from insect elements which are stereotyped, unreliable, unintelligent, and simple.
- Insects follow simple rules, use simple local communication (scent trails, sound, touch) with low computational demands.
- Global structure (e.g. nest) reliably emerges from the unreliable actions of many.
Insect Societies

• A natural model of distributed problem solving
• Collective systems capable of accomplishing difficult tasks, in dynamic and varied environments, without any external guidance or control and with no central coordination
• Achieving a collective performance which could not normally be achieved by any individual acting alone
• Constituting a natural model particularly suited to distributed problem solving
• Many studies have taken inspiration from the mode of operation of social insects to solve various problems in the artificial domain
Insect Societies

• Individual simplicity and collective complexity
• The behavioural repertoire of the insects is limited their cognitive systems are not sufficiently powerful to allow a single individual with access to all the necessary information about the state of the colony to guarantee the appropriate division of labor and the advantageous progress of the colony
• The colony as a whole is the seat of a stable and self-regulated organization of individual behavior which adapts itself very easily to the unpredictable characteristics of the environment within which it evolved
Self Organization

• Systems of collective decision-making
• Insect societies have developed systems of collective decision making operating without symbolic representations, exploiting the physical constraints of the environment in which they evolved, and using communications between individuals, either directly when in contact, or indirectly (stigmergy) using the environment as a channel of communication
• Through these direct and indirect interactions, the society self organizes and, faced with a problem finds a solution with a complexity far greater than that of the insects of which it is composed
Simulating Termites

• Consider a simple model of a termite that follows these simple rules:
  1. Wander around aimlessly until you bump into a wood chip.
  2. If you are carrying a wood chip, drop it and continue to wander.
  3. If you are not carrying a woodchip, pick up the one you bumped into and continue to wander.

• What will happened if we have a colony of such termites? Chaos? Randomness? Order?
Figure 16.1  Termites randomly placing wood chips according to a simple rule produce order
Flocks, Herds and Schools

• In the late 80’s Craig Reynolds created a simple model of animal motion that he called Boids.
• It’s generates very realistic motion for movement from three simple rules which define a boid’s steering behaviour.
• This model, and its variations, has been used to drive animations of birds, insects, people, fish, antelope, etc. in films (e.g., Batman Returns, Lion King)
Boid rules

**Separation:** steer to avoid crowding local flockmates

**Alignment:** steer towards the average heading and speed of local flockmates

**Cohesion:** steer to move toward the average position of local flockmates
Boid Rules

• **Separation**: steer to avoid crowding local flockmates
  – A fundamental rule that has priority over the others
  – Also useful in avoiding collisions with other objects in the environment.

• **Alignment**: steer towards the average heading and speed of local flockmates
  – Enforces cohesion to keep the flock together.
  – Helps with collision avoidance, too.

• **Cohesion**: steer to move toward the average position of local flockmates
  – Agents at edge of the herd more vulnerable to predators
  – Helps to keep the flock together
Boids examples

Anchovies

Lion King
Gary Flakes Simulation

- From Computational Beauty of Nature.
- Adds a fourth rule to maintain a boids field of view.
- **Maintain View:** Move laterally away from any boid that blocks your view.
  
  “See the geese in chevron flight flapping and racing on before the snow”
Is this relevant to people?
Wikipedia

English
The Free Encyclopedia
1135 000+ articles

Deutsch
Die freie Enzyklopädie
398 000+ Artikel

Français
L'encyclopédie libre
285 000+ articles

Polski
Wolna Encyklopedia
234 000+ haseł

日本語
フリー百科事典
212 000+ 記事

Svenska
Den fria encyklopedin
160 000+ artiklar

Nederlands
De vrije encyclopedie
197 000+ artikelen

Italiano
L'enciclopedia libera
158 000+ articoli

Português
A enciclopédia livre
134 000+ artigos

Español
La enciclopedia libre
118 000+ artículos

search · suche · rechercher · szukaj · 検索 · zoeken · sök · ricerca · busca · buscar
The Web becomes a Giant Brain

Some see the Web evolving into a collective brain for humankind

Complete with

– a nervous system (Internet protocols)
– long term memory (Web pages)
– active behaviors (Web services and agents)
– a stream of consciousness (Blogosphere)