cis3.5 spring2009 lecture IV.2

topics:

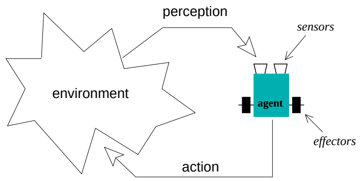
- today we will discuss multiagent-based simulation

software agents

an *agent* is...

- anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors (e.g., motors)

  (Stuart Russell & Peter Norvig, 2003)



- a system that is *situated* in an environment, and which is capable of *perceiving* its environment and *acting* in it to satisfy some objectives

  (Michael Wooldridge, 2002)

different kinds of agents

- human "agent":

environment:	physical world	
sensors:	eyes, ears, ...	← input
effectors:	hands, legs, ...	← output

- software agent:

environment:	e.g., UNIX operating system	
sensors:	`ls`, `ps`, ...	← input
effectors:	`rm`, `chmod`, ...	← output

- internet agent:

environment:	the Internet	
sensors:	`http` requests	← input
effectors:	`http` commands	← output

- embodied (robotic) agent:

environment:	physical world	
sensors:	light meters, bumpers, thermometers, ...	← input
effectors:	motors attached to wheels, legs, grippers, ...	← output

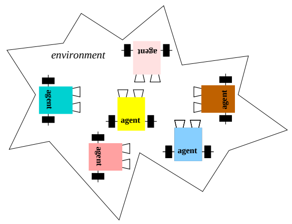
agent decision-making: what to do?

- need to know *what* to do in any given *state*
  - what = an *action* that the agent can take
  - state = a configuration of the agent and its environment
    for example: the position of all the pieces on a chess board, or the robots and the ball on a robot soccer field, or the position of a robot's gripper, or all the bids in an electronic market
- *autonomy*
  - a crucial concern for agents
  - run-time decisions are made by the agent *alone*—i.e., no human remote control
  - means behavior is based on *own* experience
  - implies *learning*, *adaptation*

multiagent system

- a *multiagent system (MAS)* is...

  an environment in which many (well, two or more) agents exist and interact



properties of multiagent systems

- individual agents are *self-interested*
  i.e., they have their own goals, even though there may be team rewards for a group of agents achieving a goal together
- cooperation is not governed
  it is *emergent*
  (and is not necessarily a feature of every multiagent system)
- versus "distributed systems", where
  - goals are only group-based
  - cooperation is engineered to be inherent in the system

artificial life

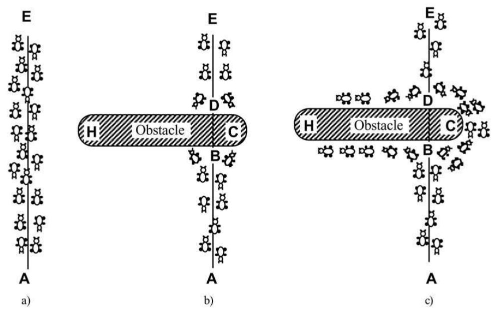
- *Artificial Life as a Tool for Biological Inquiry*,
  by Charles Taylor and David Jefferson (1995)
- "ALife" consists of four levels:
  1. molecular level — "wetware"
  2. cellular level — "software"
  3. organism level — "hardware"
  4. population level — "multiagent systems"

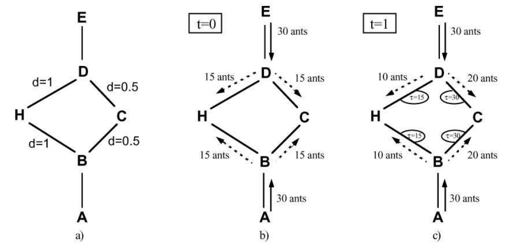
ant systems

- *The Ant System: Optimization by a colony of cooperating agents*,
  by Marco Dorigo, Vittorio Maniezzo and Alberto Colorni (1996)
- the "ant system" as an approach to stochastic combinatorial optimization
- "ant" = simple agent which (sort of) mimics the behavior of real ants
  - real ants lay *pheromone* trails to mark their pathways
  - individual behavior is apparently random
  - collective behavior emerges as *autocatalytic* ($\Rightarrow$ positive feedback); i.e., the probability with which ants subsequently follow the same trail increases as more ants take that trail
- this is <u>not</u> about simulating ant colonies *per se*, but rather about taking advantage of abstract behavioral properties of ant colonies to address a class of combinatorial optimization problems
- major diversions from reality:
  - "ants" have memory
  - "ants" are not blind

– "ants" live in a discretized environment (time and space)

- main experimental example: traveling salesman problem





- ants move randomly at each point
- the distance between towns i and j is the Euclidean distance $(d_{i,j})$
- ants are always in some town (apparently), so their "velocity" varies such that the distance between two towns is covered in one simulated time "step"...
- trails "evaporate" over time ⇒ change in intensity:

$$\Delta\tau_{i,j}$$

- *transition probability* is a trade-off between *visibility* and *trail intensity*
- *tabu list* keeps track of towns that have already been visited

- three algorithmic variations were tested:

1. ant cycle:
$$\Delta\tau_{i,j}^k = \left| \begin{array}{ll} \frac{Q}{L^k} & \text{if ant } k \text{ goes from } i \text{ to } j \text{ between time } t \text{ and } t+1 \\ 0 & \text{otherwise} \end{array} \right.$$
2. ant density:
$$\Delta\tau_{i,j}^k = \left| \begin{array}{ll} Q & \text{if ant } k \text{ goes from } i \text{ to } j \text{ between time } t \text{ and } t+1 \\ 0 & \text{otherwise} \end{array} \right.$$
3. ant quantity:
$$\Delta\tau_{i,j}^k = \left| \begin{array}{ll} \frac{Q}{d_{i,j}} & \text{if ant } k \text{ goes from } i \text{ to } j \text{ between time } t \text{ and } t+1 \\ 0 & \text{otherwise} \end{array} \right.$$

- experiments were conducted over many cycles and conditions
- a linear relationship was discovered between the number of towns and the number of ants
- strengths of approach:
  – good solutions found for all test problems within range of parameter optimality
  – algorithm converges quickly and doesn't exhibit stagnation behavior
  – algorithm and parameter values appear relatively insensitive to increase in problem dimensions

multiagent-based simulation

- *Turtles, Termites, and Traffic Jams: Explorations in Massively Parallel Microworlds*, by Mitchel Resnick (1994)
- centralized versus decentralized models, ways of thinking
- the old way: *centralized* — "by lead or by seed"
- the new way: *decentralized*
- examples of decentralized computational models:
  – neural networks
  – subsumption architecture
  – cellular automata
- properties of decentralized models:
  – *emergent behavior*
  – *evolutionary learning*

multiagent simulation for learning

- *Modeling Nature's Emergent Patterns with Multiagent Languages*, by Uri Wilensky (2002)
- decentralized tools for learning: *constructionism*
  - hands-on exploration
  - no recipe to follow
- **NetLogo**
  - "turtles (agents)
  - "patches" (environment)
- lessons for understanding decentralized thinking:
  1. positive feedback isn't always negative
  2. randomness can help create order
  3. a flock isn't a big bird
  4. a traffic jam isn't just a collection of cars
  5. the hills are alive