3.1 Agents

- This lecture introduces the agent-based modelling environment NetLogo and investigates some of the models of decentralised behaviour.
- Scientists study two types of phenomena:
  1. agents (*e.g.* molecules, cells and organisms)
  2. interactions between agents (*e.g.* chemical reactions, immune systems / ontogeny, mating, and evolution).
- An (autonomous) **agent** is a unit that interacts with its environment (typically composed of other agents) independently, without taking commands from a ‘leader’ or following some global plan.
- Agents are the basic units of modelling for complex systems.

3.2 NetLogo

- NetLogo is a useful computer program for modelling the behaviour of systems made up of many agents operating in parallel.
- Some NetLogo Basics:
  1. The agents that move around are called turtles.
  2. The world is two-dimensional and is divided up into a grid of patches. Each patch is a square piece of “ground” over which turtles can move. (Patches can’t move, but otherwise they’re just as “alive” as turtles.)
  3. The world of patches isn’t bounded, but “wraps” — so when a turtle moves past the edge of the world, it disappears and reappears on the opposite edge.

4. The Interface consists of buttons, sliders, graphs and the world view.
5. Typically models need to be set up by clicking the ‘Set-up’ button.
6. Models are started by clicking the ‘Go’ button and stopped by clicking it again.
7. Sliders are used to change the parameters of a model and typically take effect even if the model is running. An exception to this is changing the number of turtles, which only takes effect before the model is set up. Sliders are linked to input variables in the model.
8. Plots are linked to output variables in the model and update as the model runs.
9. Programs in NetLogo consist of a number of ‘procedures’. Each procedure has a name, preceded by the keyword ‘to’. The keyword ‘end’ marks the end of the commands in the procedure. Comments are preceded by a semicolon.
10. The program can be viewed (and then changed) by clicking on the ‘Procedures’ tab (at top).
11. The ‘Information’ tab (at top) contains useful information as well as questions about the model.
12. NetLogo contains many models already written, which can be opened by clicking on the ‘File’ heading and then ‘Models Library’.
13. To open a model not included with the original software, click on ‘File’, ‘Open’ and then locate the model. NetLogo files have the extension ‘nlogo’.

3.3 Termites

- Description of system (directly from Information tab):

  "This project is inspired by the behaviour of termites gathering wood chips into piles. The termites follow a set of simple rules. Each termite starts wandering randomly. If it bumps into a wood chip, it picks the chip up, and continues to wander randomly. When it bumps into another wood chip, it finds a nearby empty space and puts its wood chip down [then it get respawned elsewhere in the grid]. With these simple rules, the wood chips eventually end up in a single pile."

  "As piles of wood chips begin to form, the piles are not 'protected' in any way. That is, termites sometimes take chips away from existing piles. That strategy might seem counter-productive. But if the piles were 'protected', you would end up with lots of little piles, not one big one."

  "This project is a good example of a **decentralised** strategy. There is no termite in charge, and no special pre-designated site for the piles. Each termite follows a set of simple rules, but the colony as a whole accomplishes a rather sophisticated task."

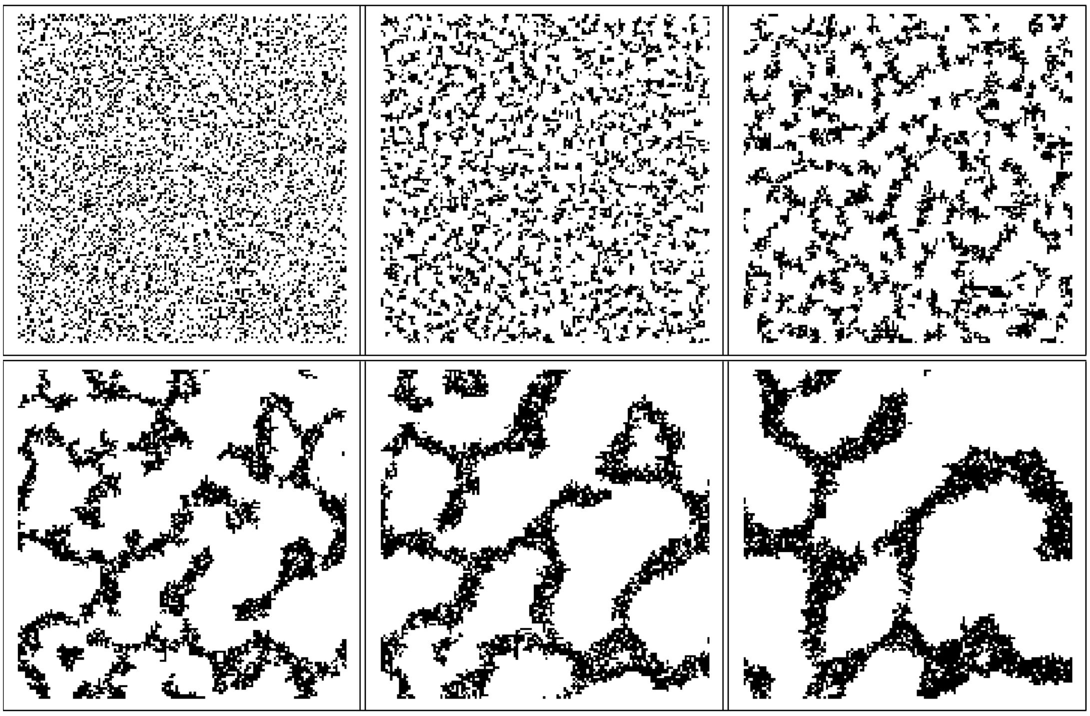


Figure 16.1 Termites randomly placing wood chips according to a simple rule produce order

- Global organisation arises from local interactions.
- As time increases so does the order of the system. This is a remarkable result.

o What happens if there is only a single termite?

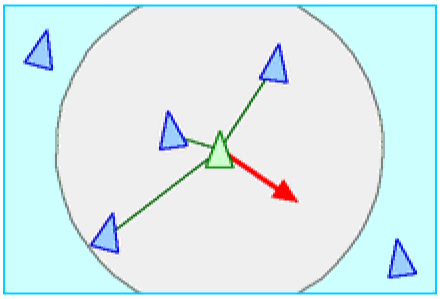
o What happens to the number of piles, the average size of the piles and the number of termites carrying chips as the model runs?

3.4 Swarms

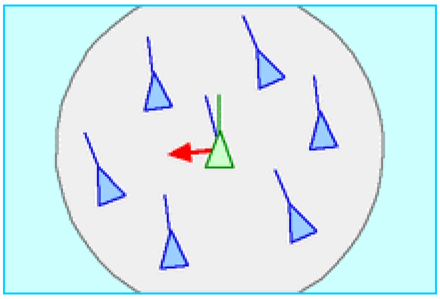
"Where ants move more or less randomly around their physical world, some other social animals move about in more orderly ways. Many species of fish, for instance, swim in schools that seem to take on an emergent life of their own. A fish school appears to move as one, with hundreds if not hundreds of thousands of fish changing direction, darting at what appears to be the exact same instant." Swarm Intelligence, p109

- A very influential model of flocking behaviour (published by Craig Reynolds in 1987) assumes that flocking birds follow 3 simple rules:

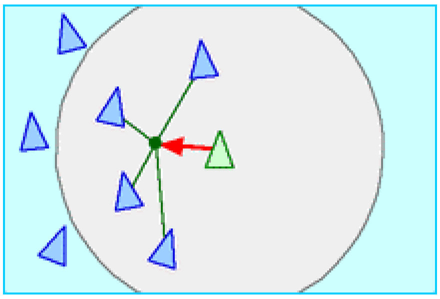
  (http://www.red3d.com/cwr/boids/)



Separation: steer to avoid crowding local flockmates



Alignment: steer towards the average heading of local flockmates



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

- In the NetLogo model ‘Flocking’, agents start with random headings, constant speeds and follow the above rules. There are no random numbers used in the model (except the ICs). The fluid, lifelike behaviour of the birds is produced entirely by deterministic rules.
- Information tab: “Central to the model is the observation that flocks form without a leader. Also, notice that each flock is dynamic. A flock, once together, is not guaranteed to keep all of its members.”
- None of the agents – and not even the programmer – have any idea where they will eventually fly off to.
- There is no leader bird!
  - How does the total number of agents affect the behaviour of the flocks?
  - What would happen in each case if only two of the rules operated? What about if only one rule operated? (Set the other sliders to zero).
- Swarms can avoid obstacles and chase targets.
- Swarm algorithms have been used in optimisation, computer games and movies, for example “The Lion King” and “Star Trek: Voyager”.
- With the addition of a **View** rule, which causes the agents to move laterally away from any other agent that blocks the view, V-shaped flocks can be generated.

“Reductionism claims that the whole can be understood as the sum of the parts. In every case that we have seen, the whole has revealed itself to be a surprise in that it is decidedly more than the sum of its parts.” CBoN, p276

3.5 Traffic Jams

- Traffic jams are another example of how patterns in the system arise out of individual behaviour.
- Crashes aren't necessary for the formation of traffic jams – there can be no centralised cause.
- Each car follows a simple set of rules: it slows down if it sees a car close ahead, and speeds up if it doesn't see a car ahead.
- Density fluctuations serve as the 'seed' for traffic jams then positive feedback comes into play.
- Traffic jams are dynamic with an ever changing set of cars involved.
- Even though all of the cars are moving forward, traffic jams tend to move backwards. This behaviour is common in wave phenomena: the behaviour of the group is often very different from the behaviour of the individuals that make up the group.
    - Is this statement true: "There are so many accidents because traffic jams move backwards and the cars are rushing forwards"?
    - What could be done to minimize the formation of traffic jams?
    - In steady traffic what is the effect of one car slowing down just a little?

3.6 Guiding Heuristics for Decentralised Thinking

- Mitch Resnick has 5 “guiding heuristics” for thinking about decentralised worlds:
- **Positive feedback isn’t always negative.** Positive feedback often plays an important part in creating and extending patterns and structures. The geographic distribution of industries is one example.
- **Randomness can help create order.** Random fluctuations act as the seeds from which patterns grow in self-organising systems with positive feedback. Randomness also encourages exploration.
- **A flock isn’t a big bird.** The idea of levels is important. Emergent patterns occur at a higher level and can have different properties than the constituent parts.
- **A traffic jam isn’t just a collection of cars.** Some ‘emergent objects’ have an ever-changing composition.
- **The hills are alive.** The environment can play an important role in influencing and constraining behaviour.