Lecture 12

Extra-Credit Homework

- See: cs.utk.edu/~mclennan/Classes/420/handouts/Extra-Credit-1.pdf
- or look under "Projects and Assignments"
- Due October 8
- Extra-credit for CS 420 & 594 students

Effects of Randomness (Coordinated Algorithm)

- Specifically different (i.e., different in details)
- Generically the same (qualitatively identical)
- Sometimes results are fully constrained

 Fig. from Bonabeau & al., *Swarm Intell.*

Effects of Randomness (Non-coordinated Algorithm)

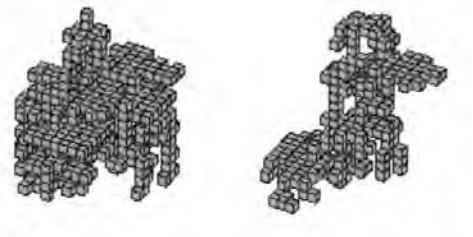


 Fig. from Bonabeau & al., *Swarm Intell.*

Non-coordinated Algorithms

- Stimulating configurations are not ordered in time and space
- Many of them overlap
- Architecture grows without any coherence
- May be convergent, but are still unstructured

Coordinated Algorithm

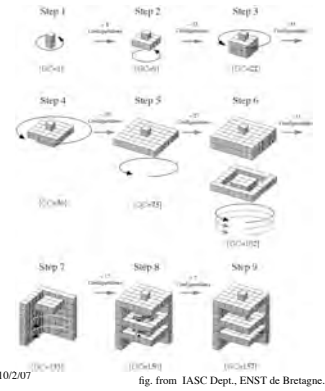
- Non-conflicting rules
  - can't prescribe two different actions for the same configuration
- Stimulating configurations for different building stages cannot overlap
- At each stage, "handshakes" and "interlocks" are required to prevent conflicts in parallel assembly

More Formally…

- Let $C = \{c_1, c_2, \ldots, c_n\}$ be the set of local stimulating configurations
- Let $(S_1, S_2, \ldots, S_m)$ be a sequence of assembly stages
- These stages partition C into mutually disjoint subsets $C(S_p)$
- Completion of S_p signaled by appearance of a configuration in $C(S_{p+1})$

Example

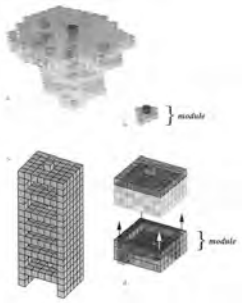
 Fig. from Camazine &al., *Self-Org. Biol. Sys.*



Example

 fig. from IASC Dept., ENST de Bretagne.

Modular Structure



- Recurrent states induce cycles in group behavior
- These cycles induce modular structure
- Each module is built during a cycle
- Modules are qualitatively similar

 Fig. from Camazine &al., *Self-Org. Biol. Sys.*

Possible Termination Mechanisms

- Qualitative
  - the assembly process leads to a configuration that is not stimulating
- Quantitative
  - a separate rule inhibiting building when nest a certain size relative to population
  - "empty cells rule": make new cells only when no empties available
  - growing nest may inhibit positive feedback mechanisms

Observations

- Random algorithms tend to lead to uninteresting structures
  - random or space-filling shapes
- Similar structured architectures tend to be generated by similar coordinated algorithms
- Algorithms that generate structured architectures seem to be confined to a small region of rule-space

Analysis

- Define matrix M:
  - 12 columns for 12 sample structured architectures
  - 211 rows for stimulating configurations
  - M_{ij} = 1 if architecture *j* requires configuration *i*

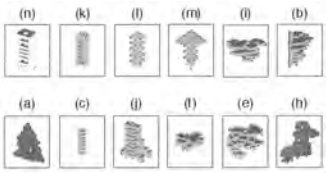


Fig. from Bonabeau & al., *Swarm Intell.*

Factorial Correspondence Analysis

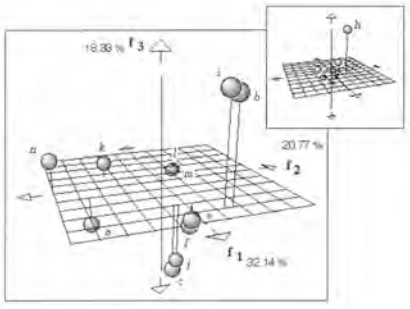


Fig. from Bonabeau & al., *Swarm Intell.*

Conclusions

- Simple rules that exploit discrete (qualitative) stigmergy can be used by autonomous agents to assemble complex, 3D structures
- The rules must be non-conflicting and coordinated according to stage of assembly
- The rules corresponding to interesting structures occupy a comparatively small region in rule-space

Part 3B

Langton's Vants (Virtual Ants)

Vants

- Square grid
- Squares can be black or white
- Vants can face N, S, E, W
- Behavioral rule:
  - take a step forward,
  - **if** on a white square **then** paint it black & turn 90° right
  - **if** on a black square **then** paint it white & turn 90° left

Example

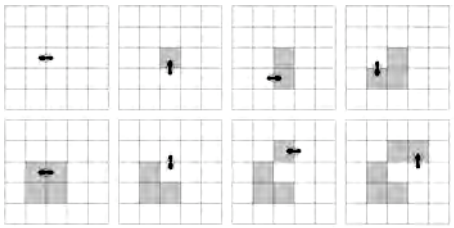


Figure 16.2 Eight steps of Langton's virtual ant, starting from an initially blank grid

Time Reversibility

- Vants are time-reversible
- But time reversibility does not imply global simplicity
- Even a single vant interacts with its own prior history
- But complexity does not always imply random-appearing behavior

Demonstration of Vants
(NetLogo Simulation)

Run Vants-Large-Field.nlogo

Demonstration of Generalized Vants
(NetLogo Simulation)

Run Generalized-Vants.nlogo

Conclusions

- Even simple, reversible local behavior can lead to complex global behavior
- Nevertheless, such complex behavior may create structures as well as apparently random behavior
- Perhaps another example of “edge of chaos” phenomena