topics in artificial life: insects

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overview

- Marco Dorigo, Vittorio Maniezzo and Alberto Colorni, The Ant System: Optimization by a colony of cooperating agents, IEEE Transactions on Systems, Man and Cybernetics-Part B, Vol 26, No 1, p1-13, 1996.
- Barry Brian Werger and Maja Mataric, Broadcast of Local Eligibility for Multi-Target Observation, Distributed Autonomous Robotic Systems (DARS), p347-356, 2000.
- Tucker Balch, Zia Khan and Manuela Veloso, Automatically Tracking and Analyzing the Behavior of Live Insect Colonies, In the Proceedings of AGENTS'01, 2001

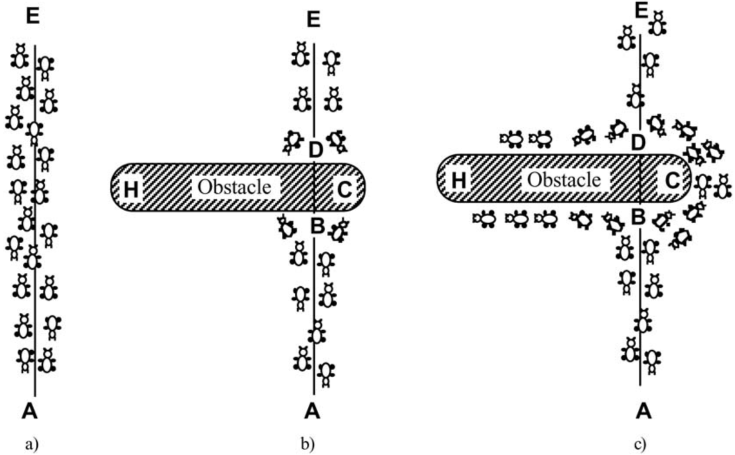
The Ant System: Optimization by a colony of cooperating agents, by Marco Dorigo, Vittorio Maniezzo and Alberto Colorni (1996)

- the “ant system” as a new 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* ($\Longrightarrow$ positive feedback)
  - i.e., probability with which ants subsequently follow the same trail increases as more ants take that trail

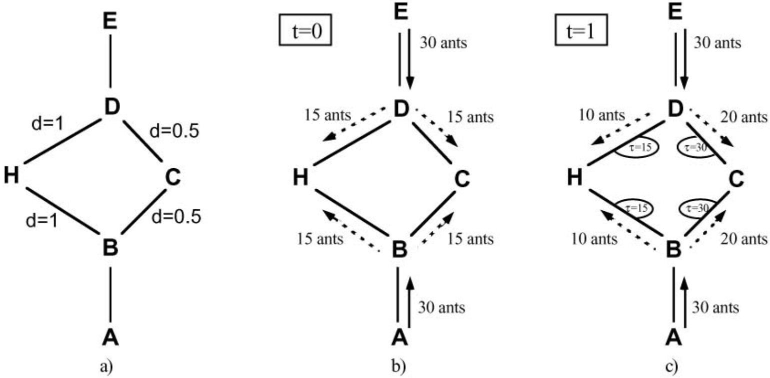
dorigo, p2

- NOTE that they are NOT interested in simulating ant colonies *per se*, but rather in taking advantage of the 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 example: traveling salesman problem

dorigo, p3



dorigo, p4


E
D
d=1
d=0.5
H
C
d=1
d=0.5
B
A
a)
t=0
E
30 ants
D
15 ants
15 ants
H
C
15 ants
15 ants
B
30 ants
A
b)
t=1
E
30 ants
D
10 ants
20 ants
τ=15
τ=30
H
C
τ=15
τ=30
10 ants
20 ants
B
30 ants
A
c)

dorigo, p5

- ants move randomly at each point
- distance between towns i and j is Euclidean distance $d_{i,j}$
- SKLAR NOTE: ants are always in some town (apparently), so “velocity” varies such that the distance between two towns can always be covered in one timestep...
- trails “evaporate” over time $\Longrightarrow$ 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
- they discovered a linear relationship between the number of towns n and the number of ants m

dorigo, p6

- tested three algorithmic variations:
  1. ant cycle: $\Delta\tau_{i,j}^{k} = \frac{Q}{L^k}$ if ant k goes from i to j between time t and $t+1$, or 0 otherwise
  2. ant density: $\Delta\tau_{i,j}^{k} = Q$ if ant k goes from i to j between time t and $t+1$, or 0 otherwise
  3. ant quantity: $\Delta\tau_{i,j}^{k} = \frac{Q}{d_{i,j}}$ if ant k goes from i to j between time t and $t+1$, or 0 otherwise

dorigo, p7

- experiments conducted over many cycles and conditions (thorough)
- tuned parameters and explored/characterized parameter space
- benchmark: *Oliver30* problem (standard)
- best result: shortest tour = 423.741
- almost the same as GA approach (424.635) [Whitley, Starkweather and Fuquay, 1989]

dorigo, p8

- 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

dorigo, p9

- experiment 2
  - synergistic effects: runs with “communication” (?) work better
  - initialization: uniform distribution works better than all ants starting in the same city
  - elitism: there’s an optimal range for the number of “elite” ants
  - increased problem dimensions: works okay up to 64 cities

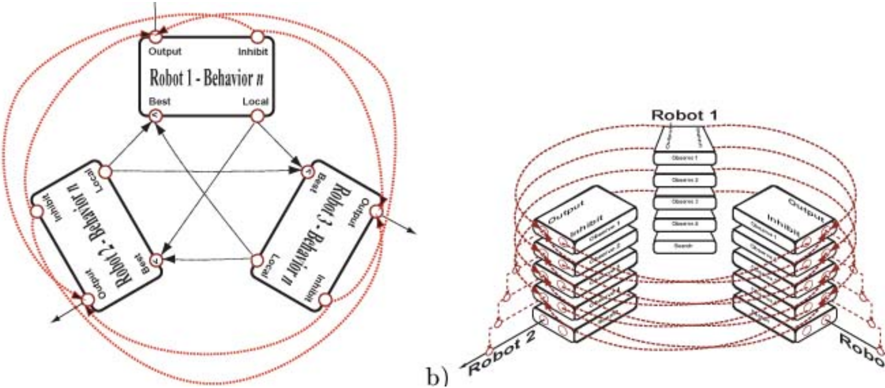
dorigo, p10

- contributions
  1. successfully employ *positive feedback* as a search and optimization tool
  2. demonstrate how *synergy* can arise and be used effectively
  3. demonstrate applicability of ant system to other optimization problems (not just TSP)

Broadcast of Local Eligibility for Multi-Target Observation, by Barry Brian Werger and Maja Mataric (2000)

- approach to CMOMMT problem (cooperative multi-robot observation of multiple moving targets)
- goal: to find the best way for multiple robots to track (observe) a set of targets
- "broadcast of local eligibility" (BLE) — robots determine locally their eligibility to observe target(s) and they broadcast this "fitness"; they "merge" their fitness with others received and either act or inhibit...

werger, p2


Output
Inhibit
Robot 1 - Behavior n
Best
Local
Robot 2 - Behavior n
Robot 3 - Behavior n
Robot 1
Robot 2
b)

werger, p3

- cross-inhibition of behaviors: arbitration of peer behaviors (instances of the same BLE behavior on different robots)
- cross-subsumption: arbitration of different behaviors on the same robot
- behaviors:
  - common behaviors: observe, search
  - BLE coordination: local subsumption (LS), local greedy, random
- results: *BLE* $>$ *greedy* $>$ *LS*

Automatically Tracking and Analyzing the Behavior of Live Insect Colonies, by Tucker Balch, Zia Khan and Manuela Veloso (2001)

- tracking real ants
- long-term goals — full automation of simultaneous tracking of multiple ants, recognition of individual and colony behaviors, acquisition of single and multi-agent behavior models, application of models to multi-agent and multi-robot systems
- short-term goals — setting up ant colonies for automated observation, machine vision algorithms for tracking, novel methods of analysis
- issues — occlusion, clumping, splitting, motionless ants