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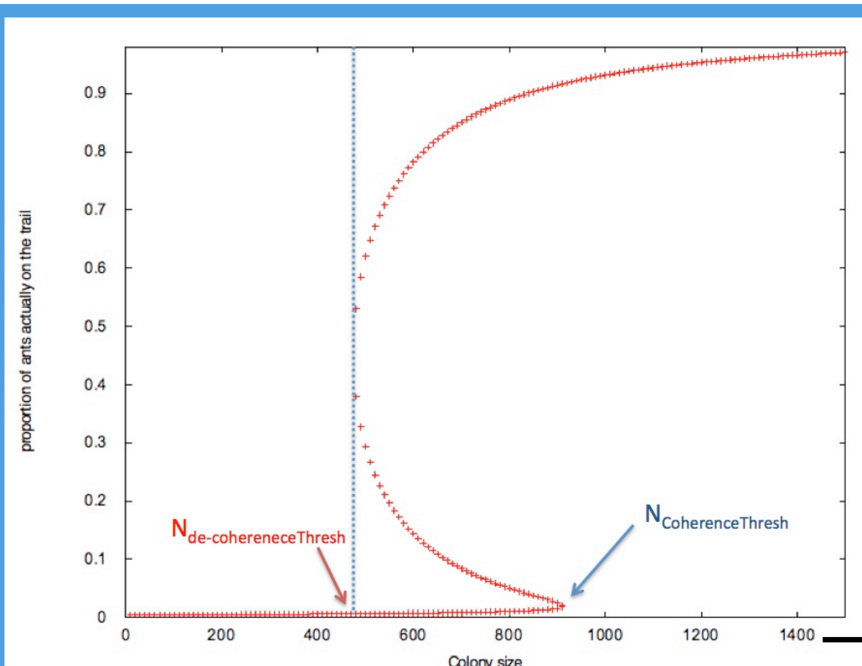
IMAGE OF THE MONTH

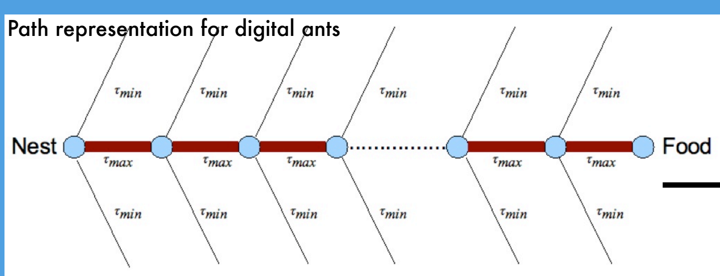
May

Phase Transitions in Agent-Based Digital Ant Colony Optimization (ACO)



We are developing methods of predicting phase transitions with efficient solutions. Parallel optimization algorithms open larger problems in important areas to solution, but have historically been difficult to implement. In our previous paper on distributed optimization titled: "A Data Flow Implementation of Agent-Based Graph Search" we showed that a well-known agent-based graph search algorithm can be scaled up to large search spaces under the NIST Data Flow System. The paper describes our approach to parallel graph search and uses multiple ant agent populations distributed across processors and clustered computers to solve large-scale graph search problems efficiently.

Solutions to the Beekman equations for phase transition show two kinds of stable solutions. The first, above the coherence threshold, results in most agents adhering to a locally optimal solution. The second, below the decoherence threshold, results in agents executing independent random walks. The middle region, between the decoherence threshold and the coherence threshold is unstable.



Characterizing the pathway for digital ant agents in terms of the average merit levels. Arcs of the optimal solution will converge to maximal merit while arcs not on the optimal path will converge to the minimum merit as agents explore the search space.

A Data Flow Implementation of Agent-Based Distributed Graph Search, Hamchi et al, in proceedings IASTED 2009.

Yet it has also been shown that this type of agent-based meta-heuristic exhibits a threshold phenomenon such that inadequate numbers of agents relative to the search space size improve solutions very slowly, while adequate numbers of agents collaborate to converge rapidly on good problem solutions. It is therefore important to be able to estimate this threshold number for good performance before committing large-scale computing resources to the problem if we want to avoid large-scale waste.

The present study concerns our efforts to characterize this threshold in terms of average parameters of the search space, the solution length, and the agent characteristics, such as: the number of graph nodes, number of arcs, number of agents, and other parameters. Madeleine Beekman and her colleagues published results in the PNAS that showed this type of threshold phenomenon biological insect foragers. Their description of the forager operating characteristics was characterized by a differential equation that suggested a first order phase transition. Our large scale discrete simulations corroborate the essentials of this mathematical description.

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The Complex Systems Program is part of the National Institute of Standards and Technology's Information Technology Laboratory. Complex Systems are composed of large interrelated, interacting entities which taken together, exhibit macroscopic behavior which is not predictable by examination of the individual entities. The Complex Systems program seeks to understand the fundamental science of these systems and develop rigorous descriptions (analytic, statistical, or semantic) that enable prediction and control of their behavior.

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