Swarming the Kingdom: A New Multiagent Systems Approach to N-Queens

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Introduction

- Swarm Intelligence – our method
  - What is it
  - Previous work
- N-Queens – the problem
  - ERA: previous solution
- Swarm Queens – our solution

What is Swarm Intelligence (SI)?

- an AI technique
- Involves a Multiagent System (MAS)
  - Use a set of agents to solve a problem
  - Each works on a small part of a big problem
- Solution reached through interaction between agents

Swarm Intelligence (cont.)

- Biologically-inspired AI technique
  - Agent design influenced by nature
  - Study how primitive organisms like ants and bees behave
  - Understand why these organisms are successful at complex tasks
  - Use that knowledge to solve computer science problems

How Is SI Different from Other Multiagent Systems?

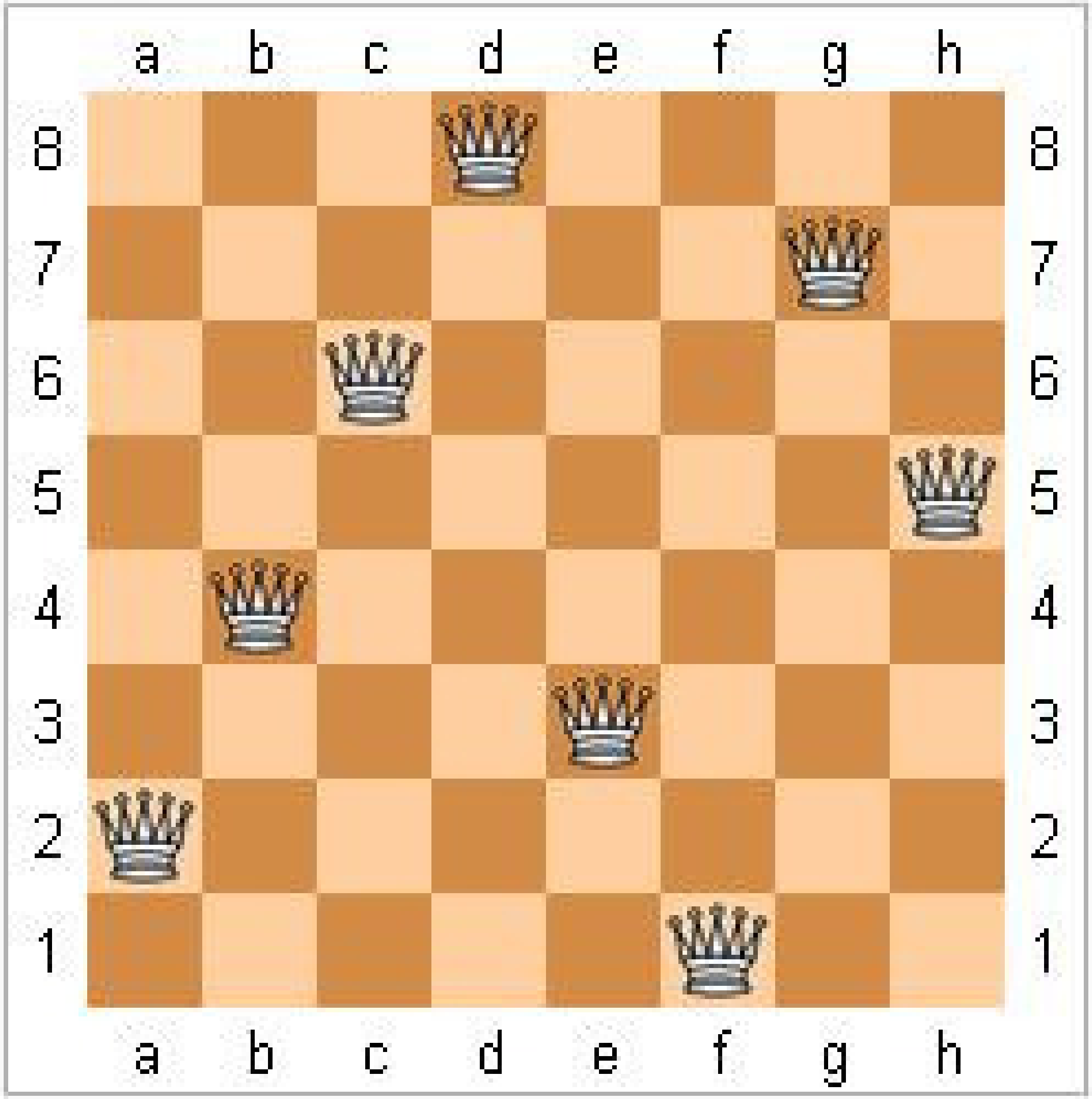
- Agents must be simple
- Each has only a local perspective
- No Direct Communication
- Systems should be easy to design
- Systems should be easy to understand

Previous Work in SI

- Ant System used to solve Traveling Salesman Problem (Dorigo, 1991)
  - Agents communicate by leaving pheromones on paths
  - Make Random Weight-Moves toward more pheromones
- Particle Swarm Optimization (Kennedy, 2001)
- Other Notable Experiments
  - Chess (Drogoul, 1993)
  - Soccer (Kutsenok, 2004)

Swarm Intelligence: The Big Idea

- We want to deliberately create emergent behavior
- Our Goals:
  - We want to better understand the design process
    - Identify core principles
  - Design solutions for different problem types
    - real-time environments, games, constraint satisfaction problems, …



One solution.

N-Queens

- Constraint Satisfaction Problem (CSP)
- Have an N by N chess board
- Need to arrange N queens, such that they don’t threaten each other
- Human can do it for an 8 by 8, but what if the board size is 100 by 100?

Previous Work on N-Queens

- 150 years of solutions
- Most are highly-domain specific and very complex
- Liu, Han, and Tang came up with ERA (2002)
  - Environment, Reactive rules, and Agents
  - Best Multiagent Systems approach to date
  - Used it successfully on other CSPs
- Can we do better by using Swarm Intelligence?
  - Faster?
  - Simpler?
  - Less Ad Hoc?

ERA: Introduction

- Every queen is an agent
- Every queen has her own row
- Every round, all Queens move to a square in their row
- All keep moving until no Queen is threatened

ERA: Queen Decision-Making

- Queens are selfish
- Each one tries to reduce the number of threats to herself
- Looks at the squares in her row before making a decision
  - Each square has a certain number of threats to it
  - Want to be in squares with fewest threats
- Make a random move based on that information

ERA: Ad Hoc Decisions

- Queens move simultaneously
  - Hard to program
  - Hard to understand emergent behavior
- Where each Queen Moves Each Turn
  - Three different behaviors
  - created their own probabilistic formula for each behavior

Swarm Queens

- We apply Swarm Intelligence to N-Queens

- What We Kept from ERA
  - Queens are agents with local perspective
  - Communicate indirectly by writing threats on the board

- No reason to have simultaneous movement
- Happy Lazy Principle
  - It is unnatural for a "Happy" Queen to leave its square and continue moving
  - What about local optima?
    - another queen can threaten a Happy one to get it out of there

Swarm Queens (cont.)

- The Decision of where to Move
  - Need to make a Random Weight-Move
  - …wait a minute

Random Weight Move

- We’ve heard this phrase before!
- We use exact same formula as Dorigo’s Ant System from 1991
- Why invent our own when an effective, well-known, biologically-inspired concept is available!

ERA vs. Swarm Queens

- Data Collected for N from 1,000 to 70,000
- Time Complexity
  - Era is $O(n^3)$
  - Swarm Queens is $O(n^2)$
- Consistency
  - We want control over the emergent behavior!
  - You are waiting for these Queens to work, so how long will you wait??
  - ERA
    - Standard Deviation = 88% of mean time
    - Times vary wildly from run to run for same N
  - Swarm Queens
    - Standard Deviation is less than 1% of mean time

Other Advantages of Swarm Queens

- Simplicity
  - Same behavior for all agents
  - Only one constant had to be tweaked
    - Came with the Ant System: Exploration vs. Exploitation value
  - Each turn, only one queen moves
- Space Complexity
  - ERA: $O(n^2)$
  - Swarm Queens: $O(n)$
    - We Store threat lines, not threats per square
  - This is a Domain-specific result…so not as important

Future Research

- Explore Big Ideas of Swarm Intelligence:
  - Simple agents working individually
  - Simple, indirect communication
- Design a Multiagent System for other Constraint Satisfaction Problems
  - Sequential movement
  - Random-Weight Move (from Ant System)
  - Happy Lazy Principle

Questions?

Thank you for your time