ANT COLONY OPTIMIZATION

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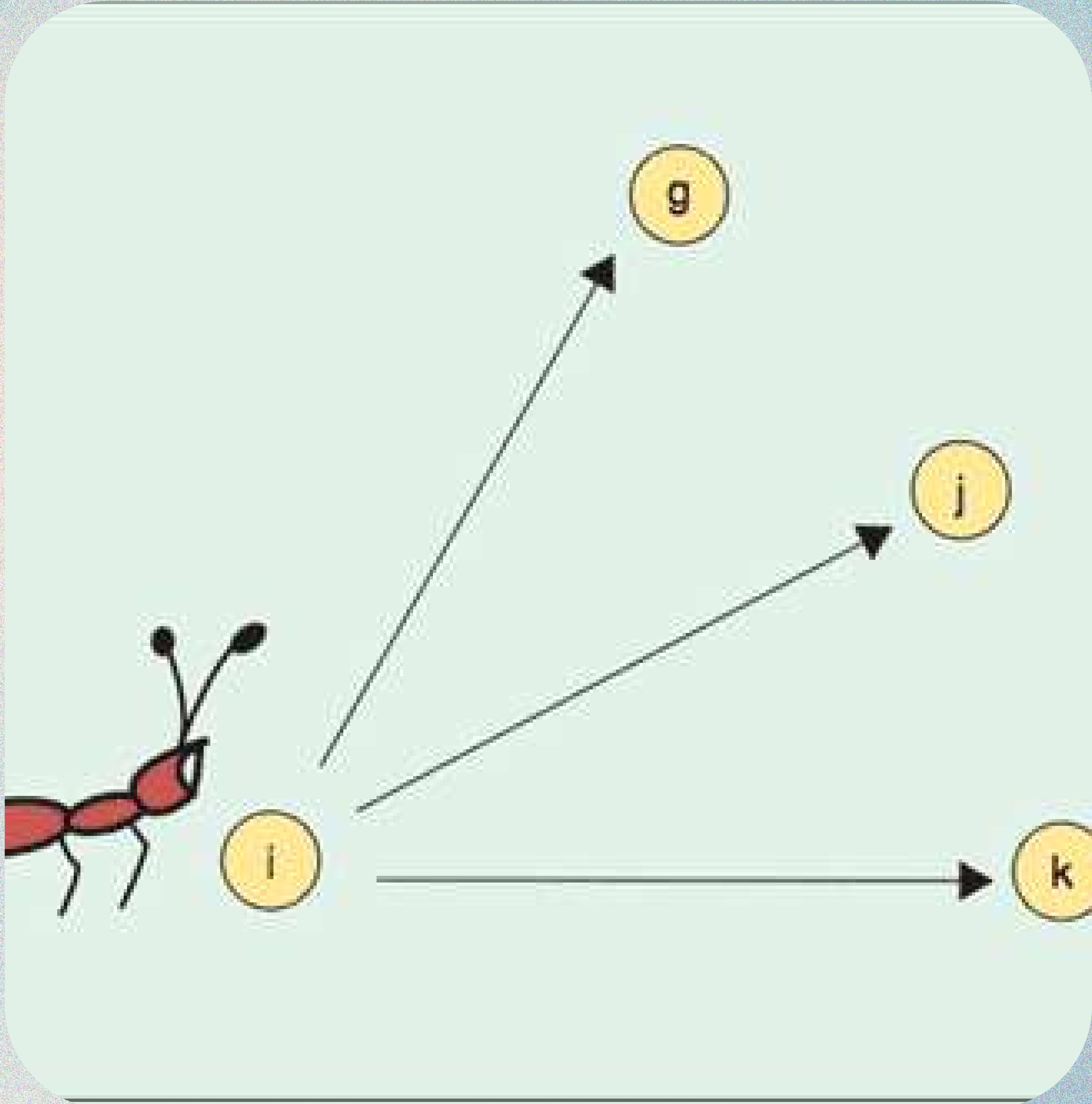
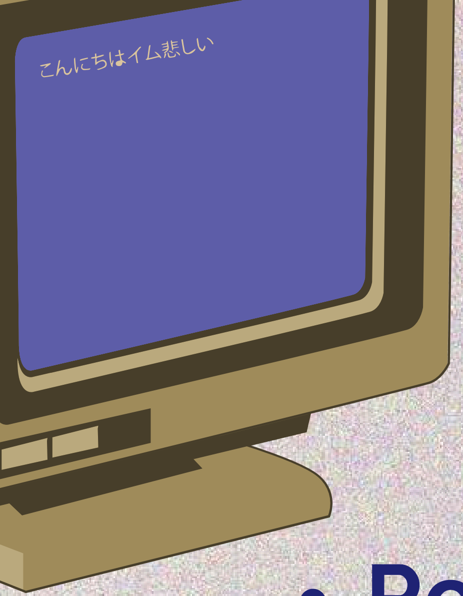


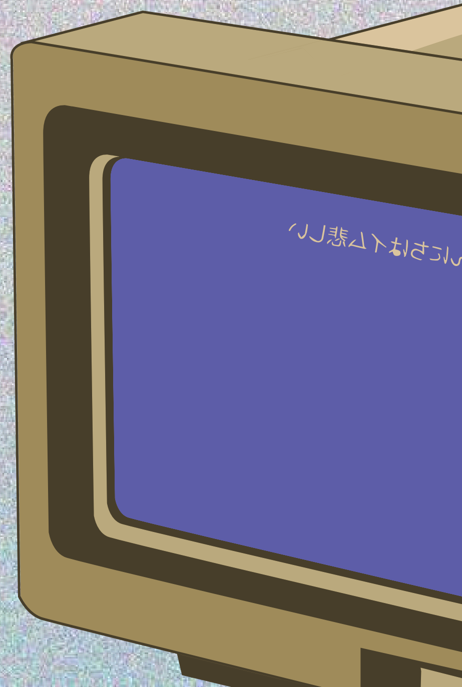
PROBLEM BACKGROUND

- **Traveling Salesman Problem (TSP):** NP-hard problem of finding the shortest route visiting each city exactly once.
- **Exponential Complexity:** Becomes computationally infeasible for large instances.
- **Scalability Issues:** Traditional methods struggle with efficiency.
- **Biomimetic Approach:** Inspired by ant foraging behavior.
- **Stigmergic Communication:** Collective intelligence for optimal pathfinding.



PROJECT OBJECTIVES

- **Robust ACO Algorithm Implementation**
  - Configurable parameters
  - Flexible problem instance handling
- **Interactive Visualization System**
  - Real-time algorithm behavior exploration
  - Intuitive understanding of swarm intelligence
- **Comprehensive Performance Analysis**
  - Parameter sensitivity investigation
  - Comparative evaluation with alternative methods
- **Practical Geographic Routing**
  - Capabilities Support for real-world coordinate systems
  - Haversine distance calculations

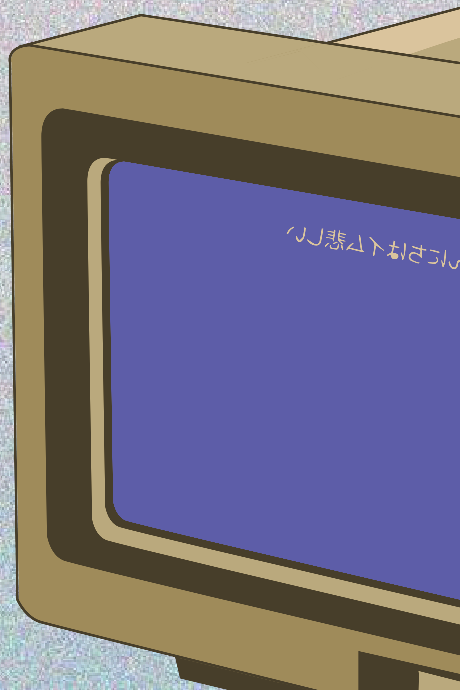


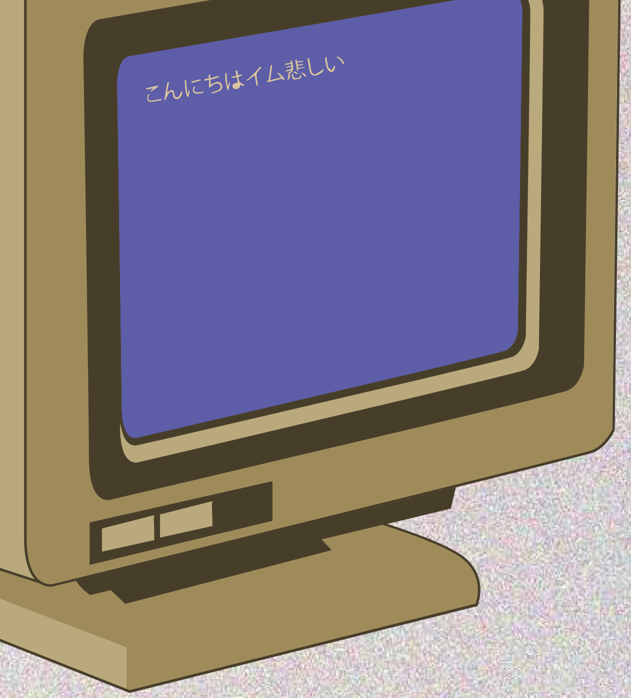
THE INSPIRATION: NATURE'S PROBLEM SOLVERS

- **How Ants Find the Best Path**
  - Ants explore their environment randomly
  - They leave chemical trails (pheromones) while moving
  - Other ants follow stronger pheromone trails
  - Shortest, most efficient paths get reinforced
  - Longer, less efficient paths fade away
- **Key Biological Insight**
  - Collective intelligence emerges from simple individual behaviors
  - No single ant knows the entire optimal route
  - The colony solves complex navigation problems together

ANT COLONY OPTIMIZATION (ACO)

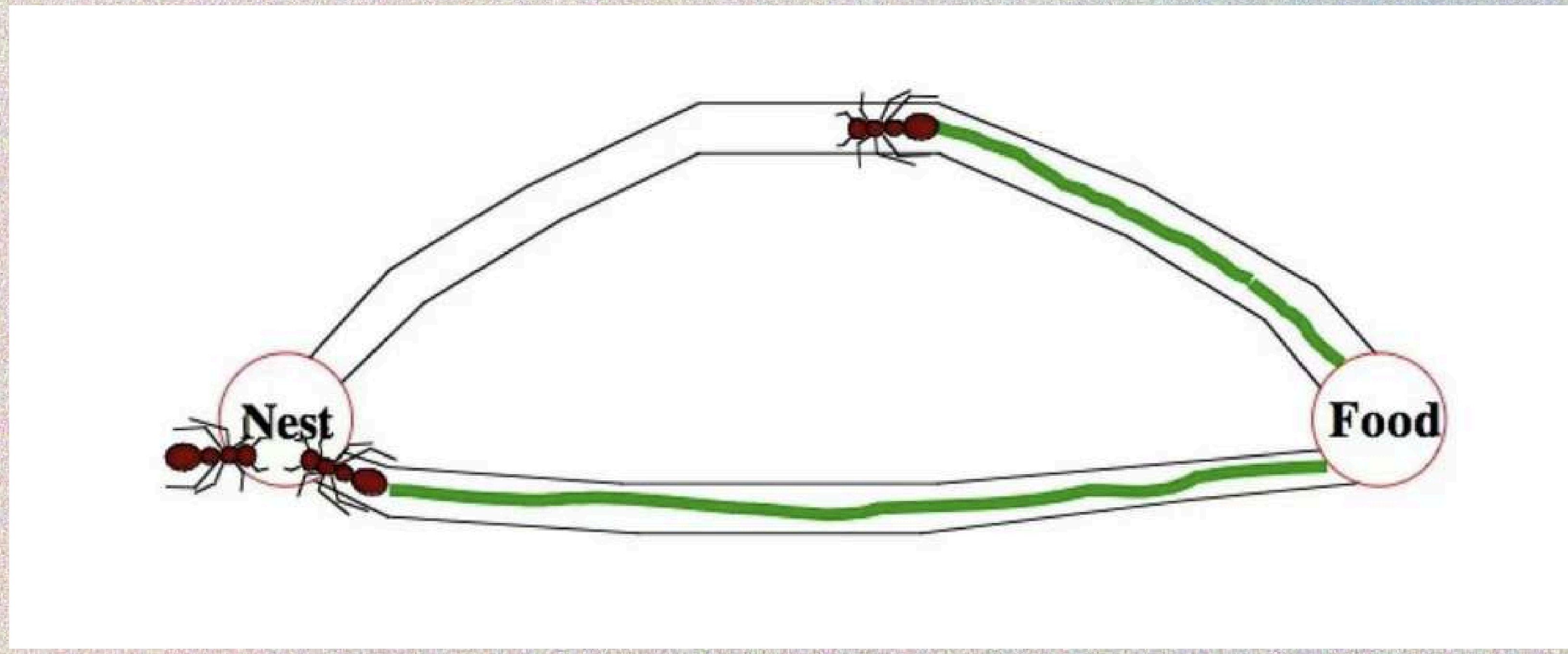
- **Nature-Inspired Algorithm**
  - Mimics ant foraging behavior to solve optimization problems.
- **Solving the Traveling Salesman Problem (TSP)**
  - Finds the shortest route visiting each city once.
- **Pheromone-Based Path Selection**
  - Ants deposit pheromones, reinforcing optimal paths over time.
- **Collective Intelligence**
  - Uses stigmergic communication for adaptive learning.

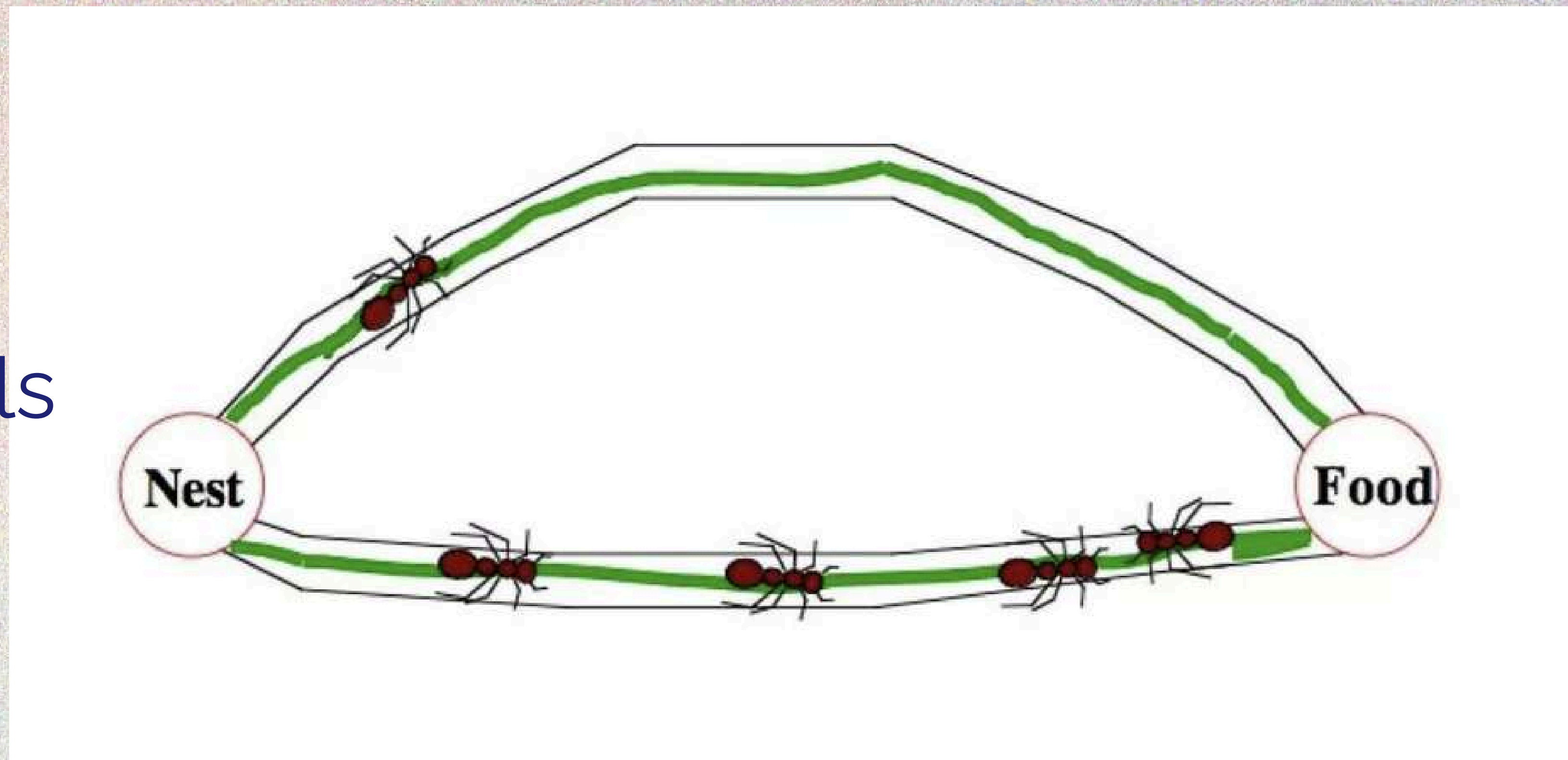


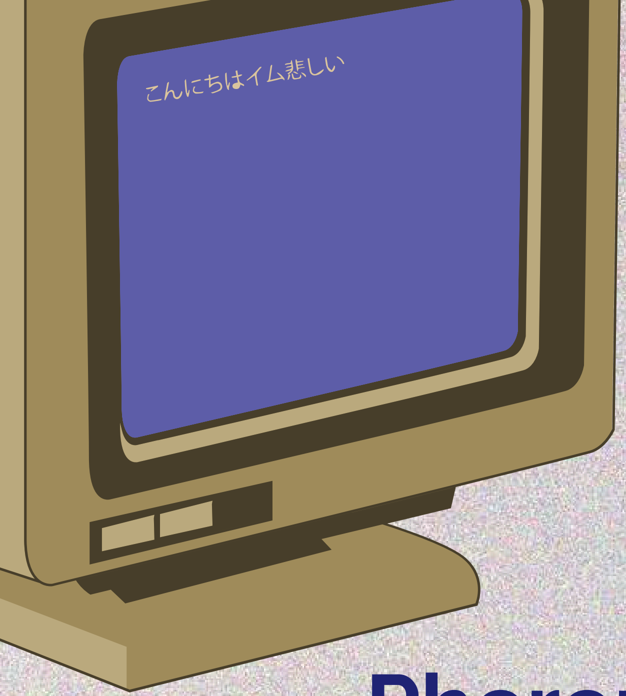


HOW ACO WORKS ?

- **Initialization**
  - Place virtual ants on different cities
  - Create initial pheromone trails
- **Path Construction**
  - Ants build complete routes
  - Choose paths probabilistically
  - Favor paths with stronger pheromone trails

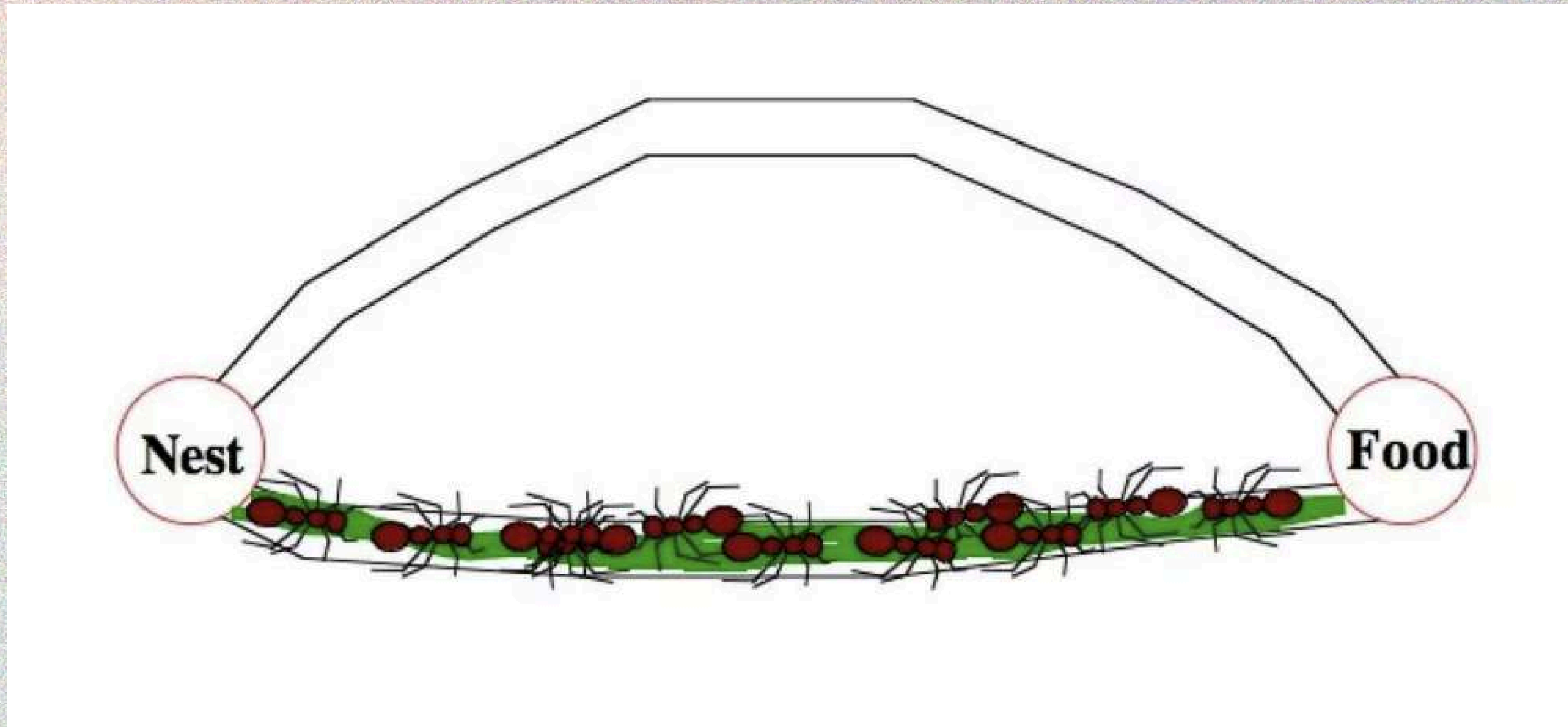


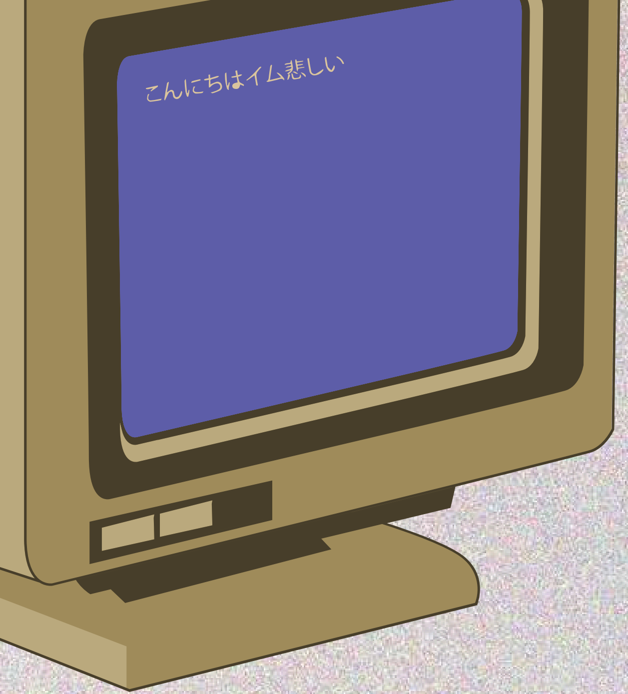




HOW ACO WORKS ?

- **Pheromone Update**
  - Deposit more pheromones on shorter routes
  - Gradually reduce (evaporate) existing pheromones
  - Prevent getting stuck in bad solutions
- **Iteration and Improvement**
  - Repeat the process multiple times
  - Converge towards optimal solution

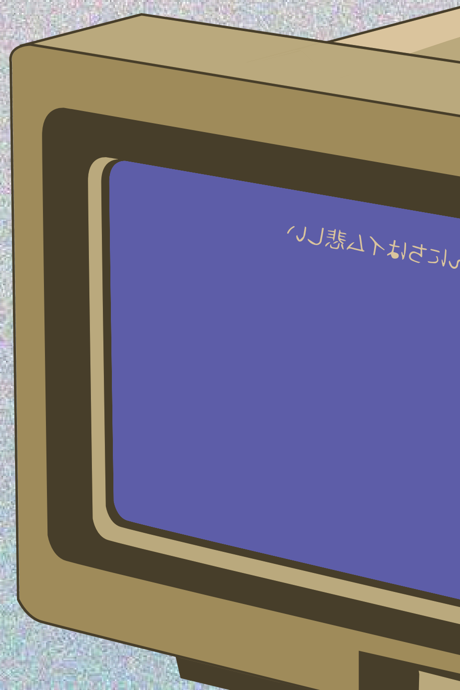


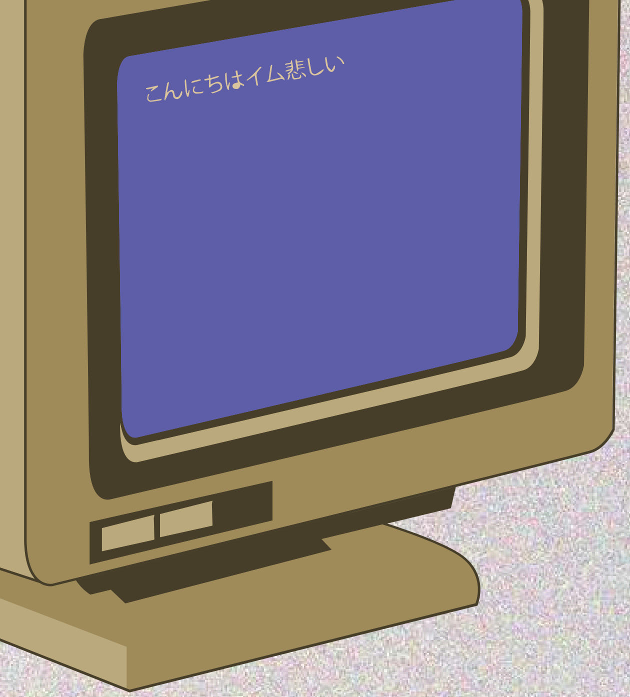


ALGORITHMIC ABSTRACTION

$$p_{ij}^{k} = \begin{cases} \dfrac{[\tau_{ij}]^{\alpha} \cdot [\eta_{ij}]^{\beta}}{\sum_{l \in N_i^k} [\tau_{il}]^{\alpha} \cdot [\eta_{il}]^{\beta}}, & \text{if } j \in N_i^k \\ 0, & \text{otherwise} \end{cases}$$

- **τ**: Pheromone trail intensity
- **η**: Heuristic desirability
- **α**: Pheromone importance
- **β**: Heuristic importance





ALGORITHMIC ABSTRACTION

- **Mathematical Modeling of Ant Behavior**
- **Probabilistic Path Selection**
  - Influenced by pheromone trails
  - Guided by heuristic information
- **Pheromone Dynamics**
  - Trail deposition
  - Evaporation mechanism
  - Positive feedback loop

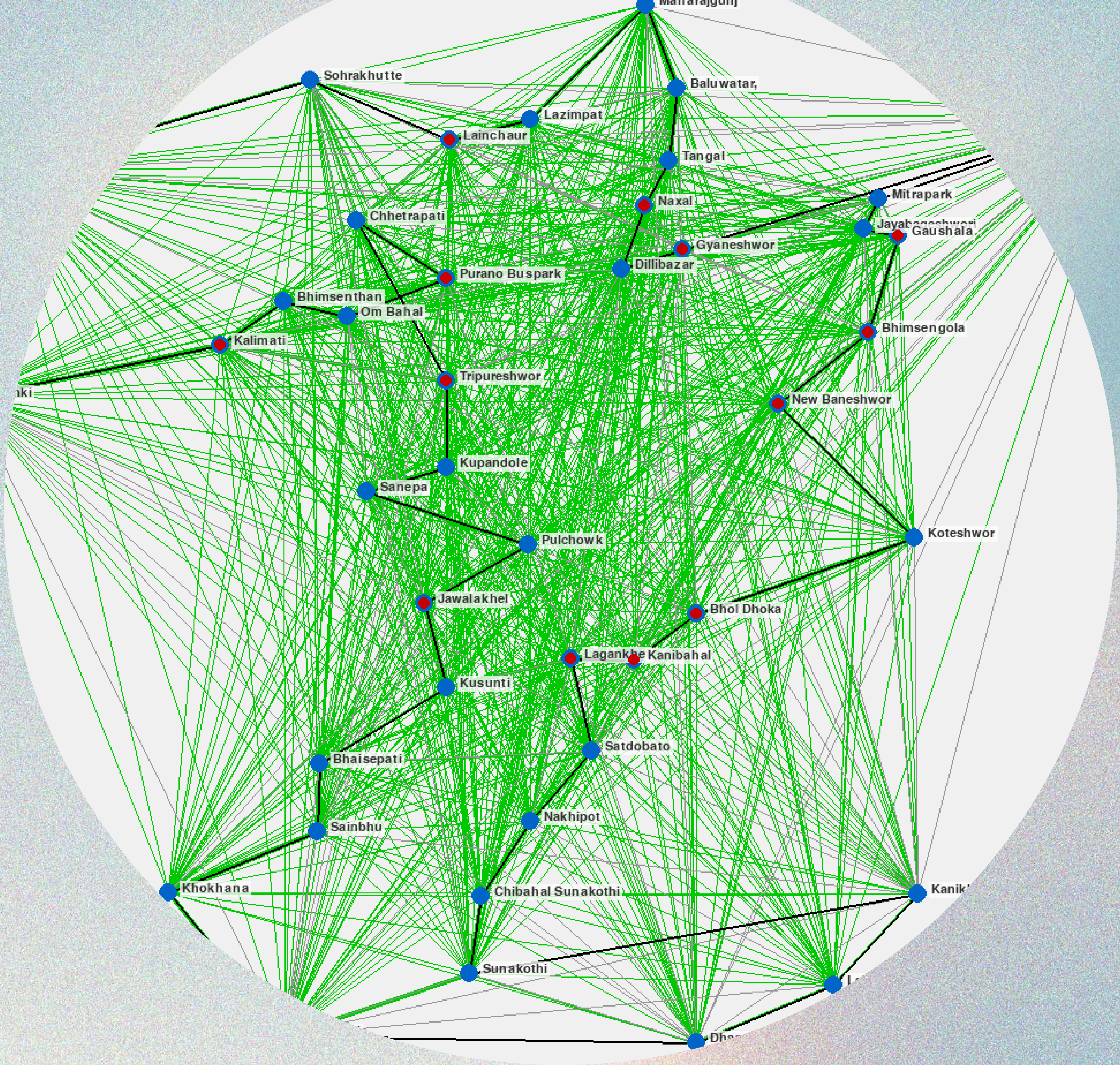
PERFORMANCE AND EFFECTIVENESS

- **Comparative Results**

Problem Size	Nearest Neighbor	Simulated Annealing	Genetic Algorithm	ACO
20 Cities	15.7%	3.2%	1.8%	0.9%
50 Cities	22.4%	7.9%	5.3%	4.1%
100 Cities	28.3%	12.6%	8.7%	7.2%

- **Key Strengths**
  - Adaptable to various problem types
  - Handles complex optimization challenges
  - Mimics natural problem-solving strategies

RESULTS


Sohrakhutte
Baluwatar,
Lazimpat
Lainchaur
Tangal
Mitrapark
Naxal
Gaushala
Chhetrapati
Gyaneshwor
Dillibazar
Purano Buspark
Bhimsenthan
Om Bahal
Kalimati
Bhimsengola
Tripureshwor
New Baneshwor
Kupandole
Sanepa
Koteshwor
Pulchowk
Jawalakhel
Bhol Dhoka
Kanibahal
Kusunti
Satdobato
Bhaisepati
Nakhipot
Sainbhu
Khokhana
Chibahal Sunakothi
Sunakothi

EXPANDED APPLICATION DOMAINS

- Vehicle routing
- Network design
- Resource allocation problems

CHALLENGES AND SOLUTIONS

Challenges

- Sensitive to parameter settings
- Computationally intensive
- No guaranteed global optimal solution
- Performance varies with problem complexity

Ongoing Research Directions

- Hybrid algorithm development
- Adaptive parameter mechanisms
- Integration with machine learning
- Expanding application domains

FUTURE POTENTIAL

- **Advanced Optimization Techniques**
  - Combining with other AI methods
  - More sophisticated decision mechanisms
- **Broader Application Domains**
  - Complex network design
  - Dynamic optimization problems
  - Real-time decision support systems
- **Computational Efficiency**
  - Parallel processing
  - Improved algorithmic variants

CONCLUSION

- **The Power of Nature-Inspired Computing**
  - Demonstrates collective intelligence
  - Solves complex problems through simple rules
  - Bridges biological observation and computational methods
- **Key Takeaways**
  - Optimization can emerge from simple interactions
  - Nature provides powerful problem-solving strategies
  - Interdisciplinary approach to computational challenges

THANK YOU!