Multi-agent Communication Disorders: Dynamic Breeding Networks in Genetic Algorithms

Forrest Sondahl
forrest@northwestern.edu

William Rand
wrand@northwestern.edu

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NORTHWESTERN UNIVERSITY

Center for Connected Learning and Computer-Based Modeling

http://ccl.northwestern.edu/

Northwestern Institute on Complex Systems

http://www.northwestern.edu/nico/

Summary

In an ABM, agents communicate.

These interactions form a social network.

We are interested in how the properties of these networks affect group problem solving abilities.

Outline

- **Genetic algorithm model**
- Diffusion of innovation model
- Show and tell
- Experiment
- Results
- Future work

Standard genetic algorithm (GA)

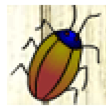
- Start with a tricky problem
  - e.g. scheduling elephant bath time

- Represent possible solutions as bit strings

Bubs & Candy first, then Dumbo alone, then ...

= 1010010101111101101110 = 

Dumbo & Moony, then Bubs & Goober, then ...

= 001111011011011011011 = 

“Bath Schedule” creatures

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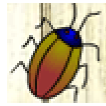
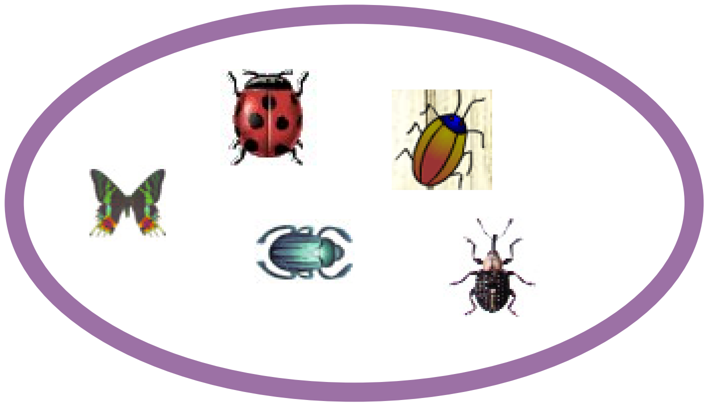
001111011011011011011 = 

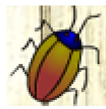
Population



Fitness function:

How good is each bath schedule?

f () = fair = 0.7

f () = poor = 0.3

Genetic operators

Crossover

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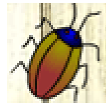
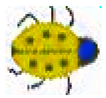
00111101101101011011 = 

10100101011101011011 = 

Cloning

10100101011110110110 = 

10100101011110110110 = 

Mutation

10100101011110110110 = 

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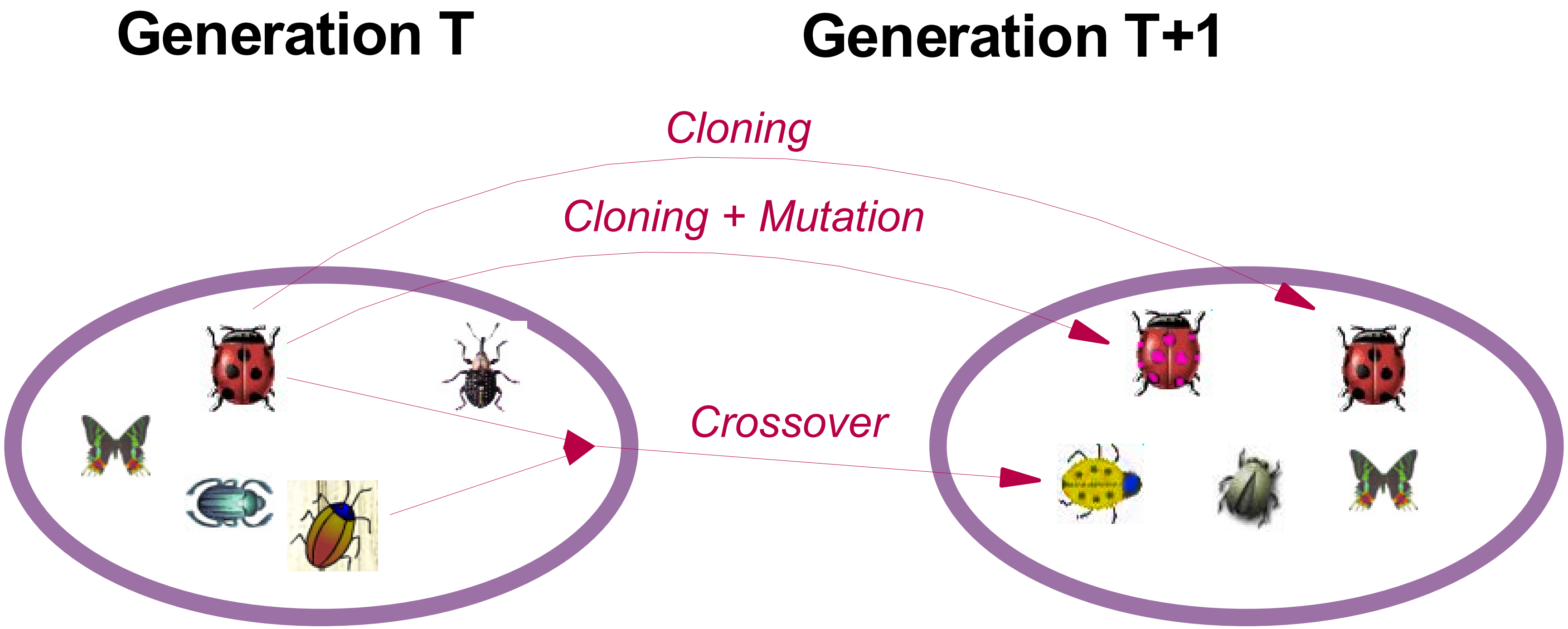
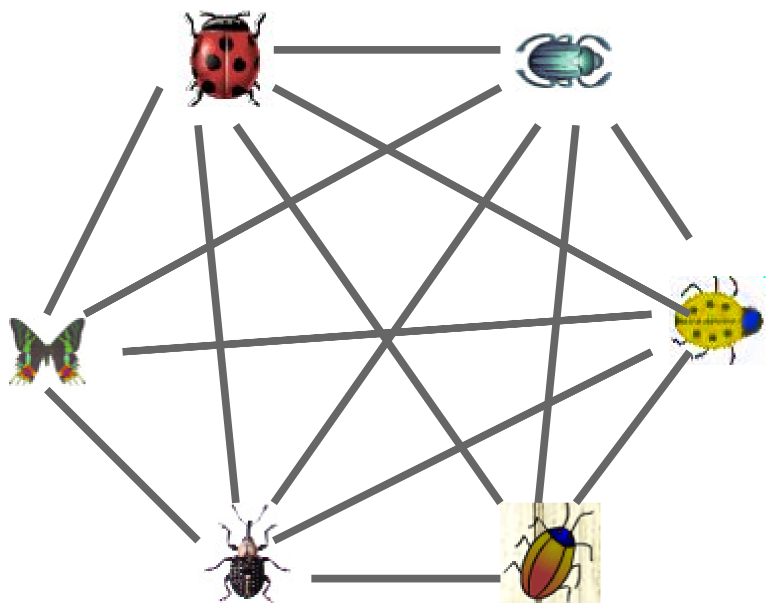
"The Next Generation"



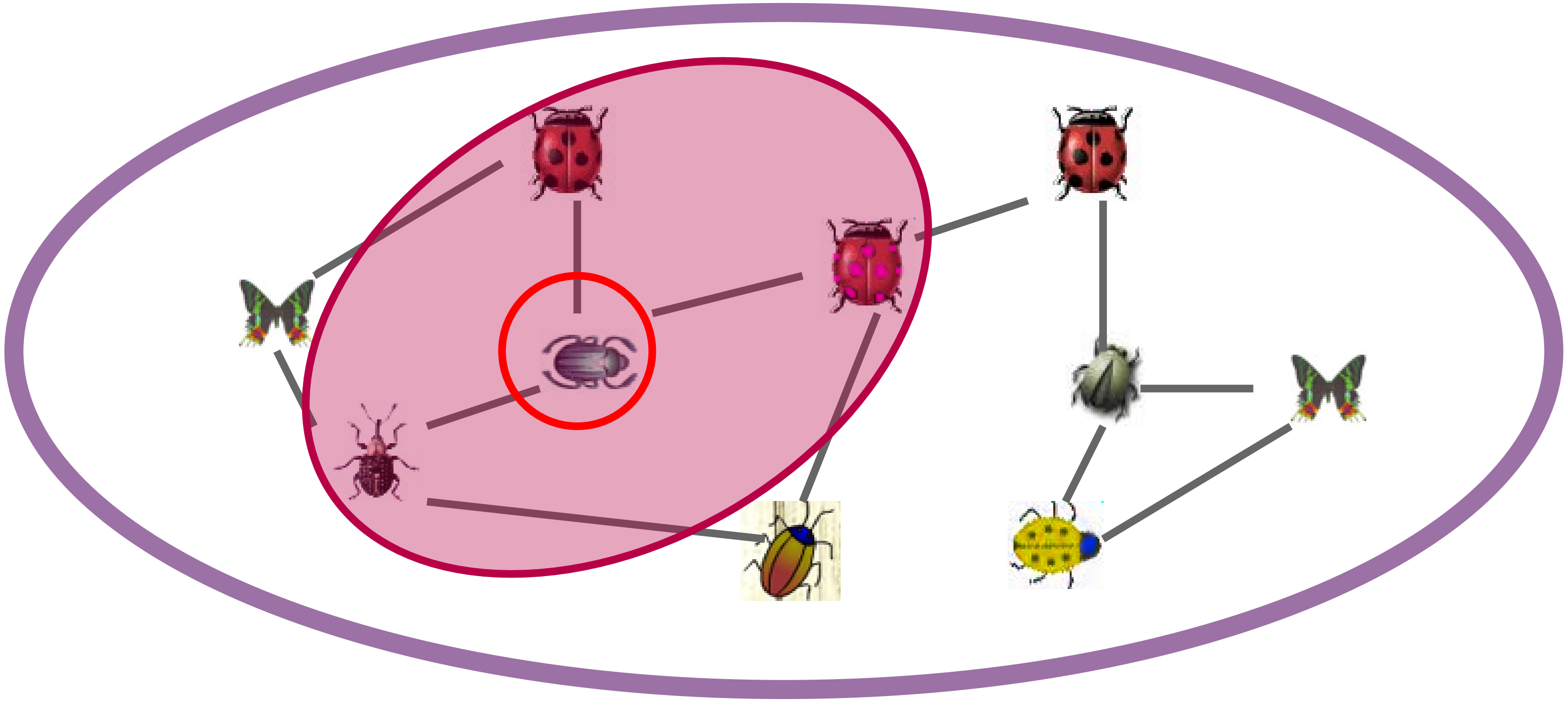
and repeat until satisfied...

Complete Breeding Networks

- In the standard genetic algorithm, every agent can breed with every other agent.
- This can be represented by a complete graph.



Restricted Breeding Networks

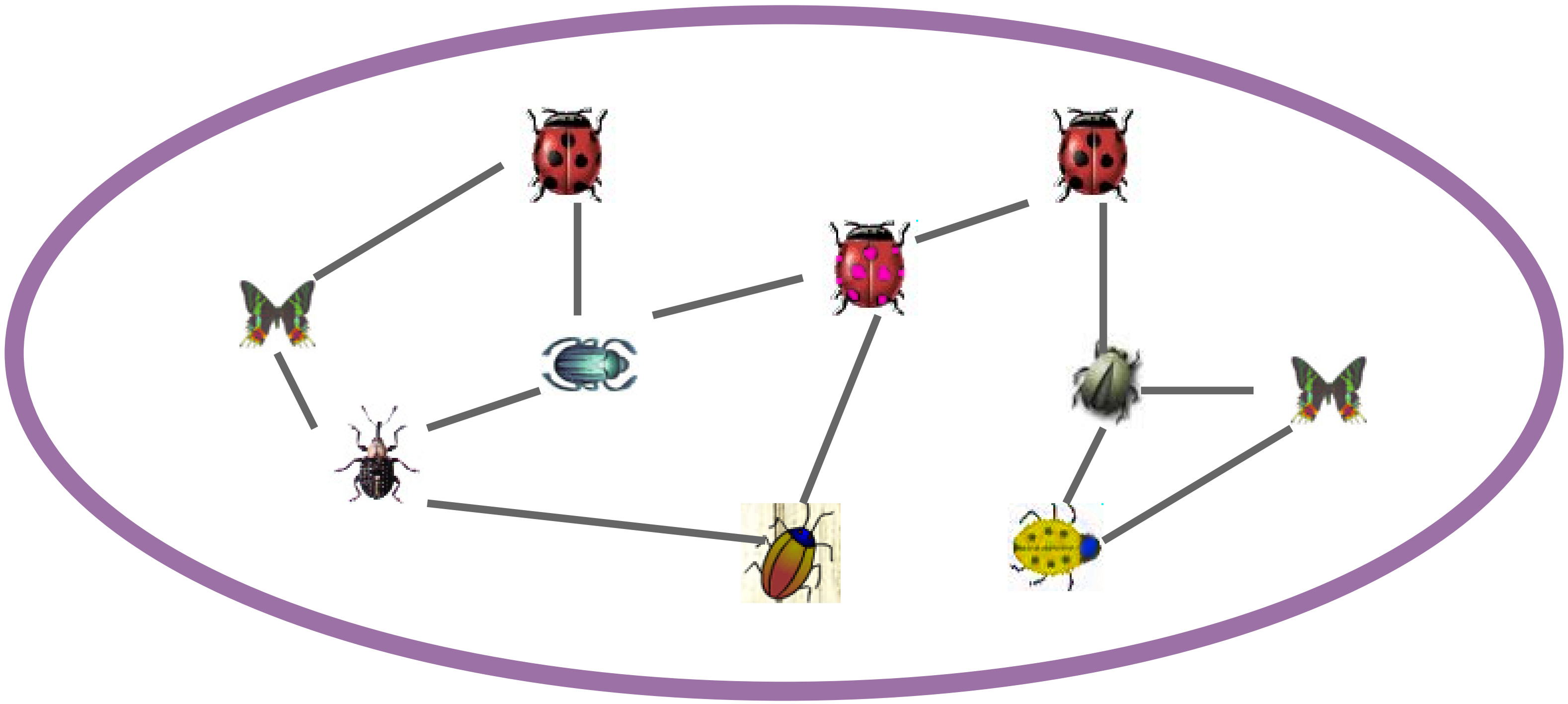


Why should we care?

- Theoretical knowledge in machine learning
  - They might perform better than standard GAs
  - Understanding evolutionary processes
- Applications (parallel GAs)
  - Peer to peer computing
  - Mobile and ad-hoc networks
  - Swarm robots, smart dust?

Primary Question

How sparse can the breeding networks be, such that the genetic algorithm still works?



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- **Diffusion of innovation model**
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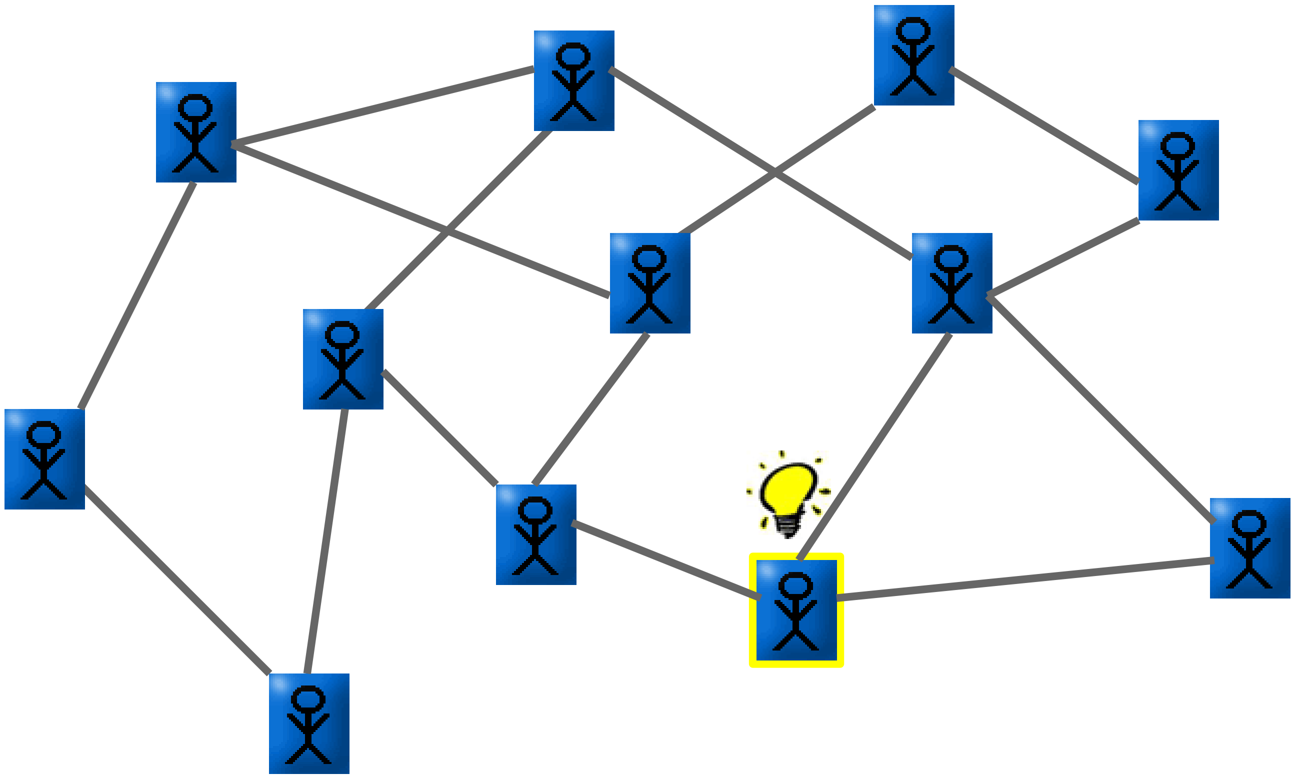
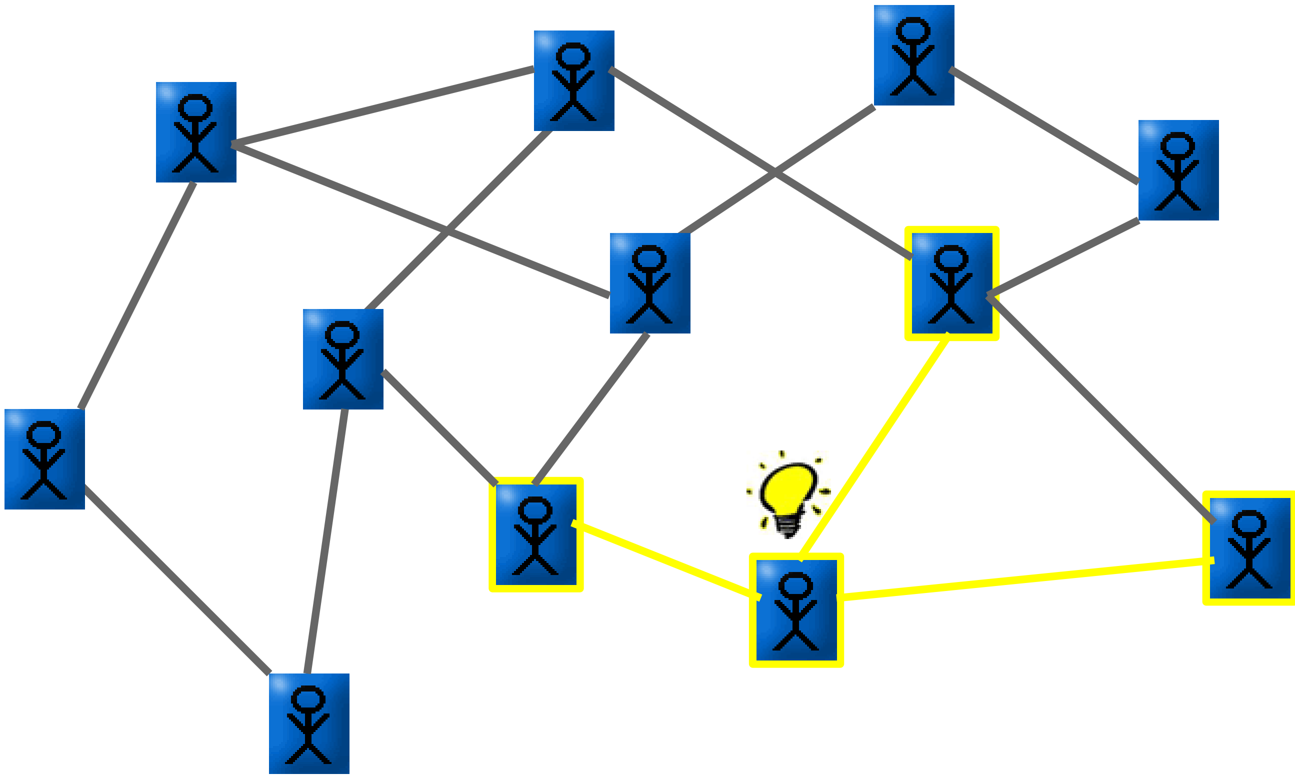
Diffusion of Innovation

- Organizations have social structure
- Individuals follow policies
  - ideas, problem-solving methods, etc
- Better “more innovative” policies diffuse through the social network, as individuals adopt those policies.

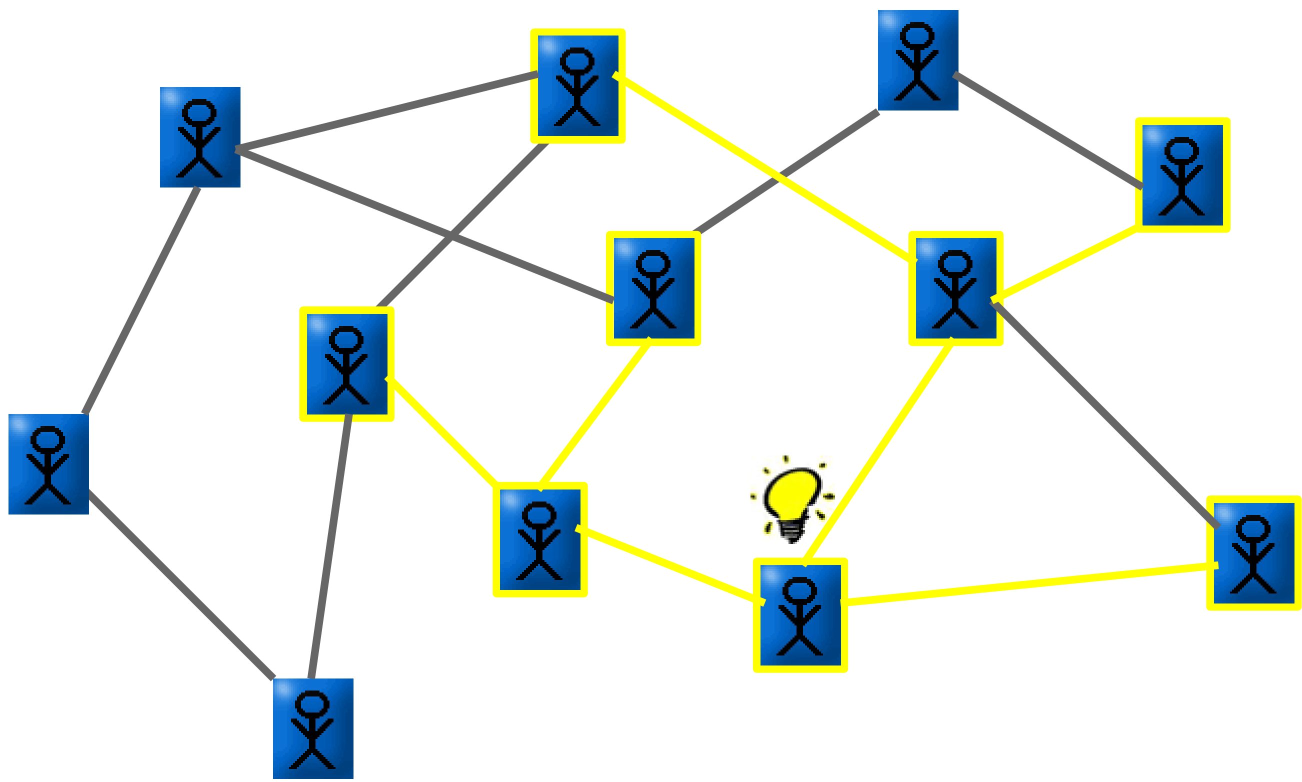
Diffusion of Innovation



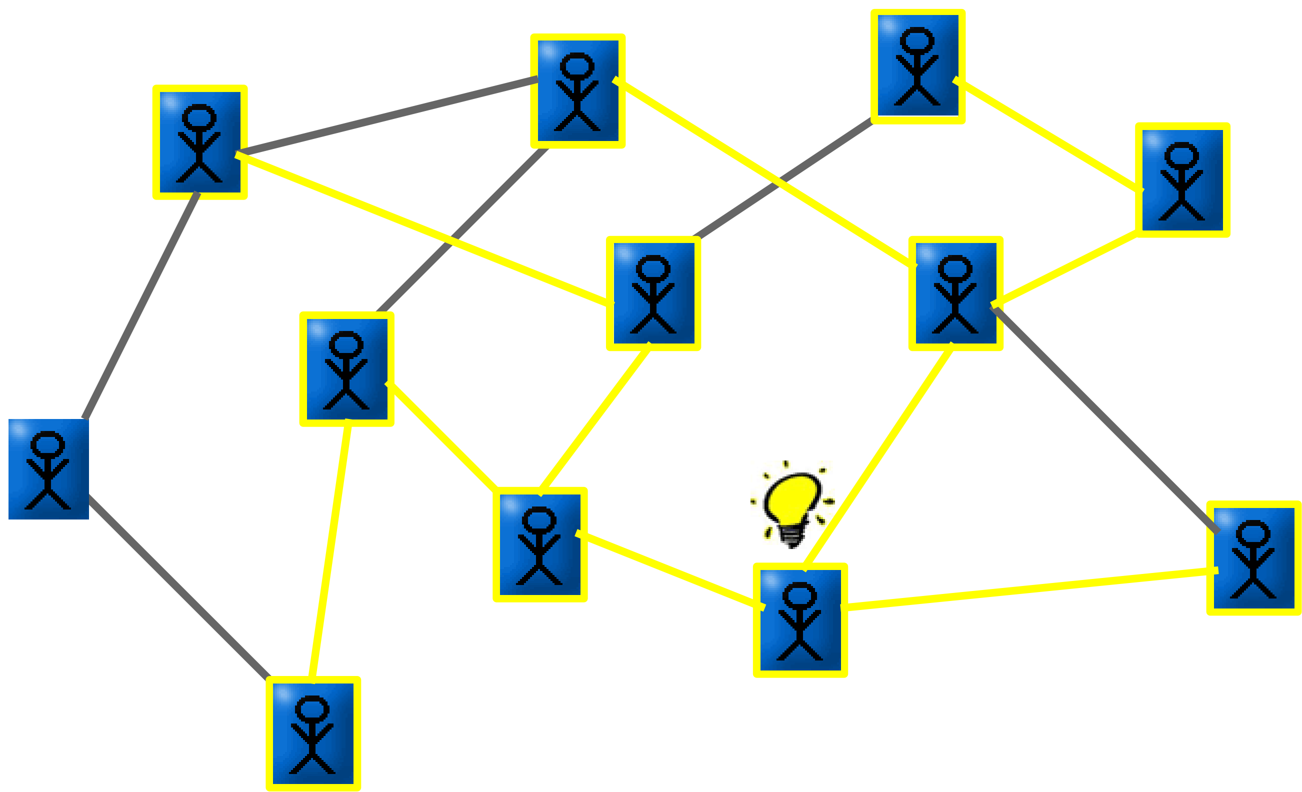
Diffusion of Innovation



Diffusion of Innovation



Diffusion of Innovation



Complexifications

- Policies could be multi-faceted
- Agents could take pieces of policies from other agents
- Adoption shouldn't be deterministic

A Model of Diffusion

- Each person may:
  - Keep their own policy
  - Copycat a neighbor's policy
  - Combine two policies
  - Slightly change their policy

A Genetic Model of Diffusion

- Each person may:
  - Keep their own policy
  - Copycat a neighbor's policy

    } **Cloning**

  - Combine two policies — **Crossover**
  - Slightly change their policy — **Mutation**

Bringing it together

Our model can be viewed from multiple perspectives.

Hopefully it captures generic aspects of information dispersal in the context of solving some problem.

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Network Topologies

- Spatial (fixed):
  - Breeding neighborhood defined by “in-radius”
- Spatial (dynamic):
  - The agents move in the world
- Random (fixed):
  - Erdös-Renyi random graphs
- Random (dynamic):
  - Network “rewired” each generation.

Model Demo

Outline

- Genetic algorithm model
- Diffusion of innovation model
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What's the “problem”?

- We used hyperplane-defined functions (HDFs).
- Goal: produce a certain pattern of bits.

...*****11100**00101********...

- In the fitness function:
  - some sub-patterns are rewarded (schemata)
  - some sub-patterns are penalized (pot-holes)

Constant parameters

- Population size: 256
- Crossover rate: 0.7
- Mutation rate: 1 / [2 x length_of_bitstring]
- Tournament selection with tournament size 3

- “Spatial dynamic” specific parameters
  - wiggle-angle amount = between -15 and 15 degrees
  - forward-step amount = 1% of world diagonal.

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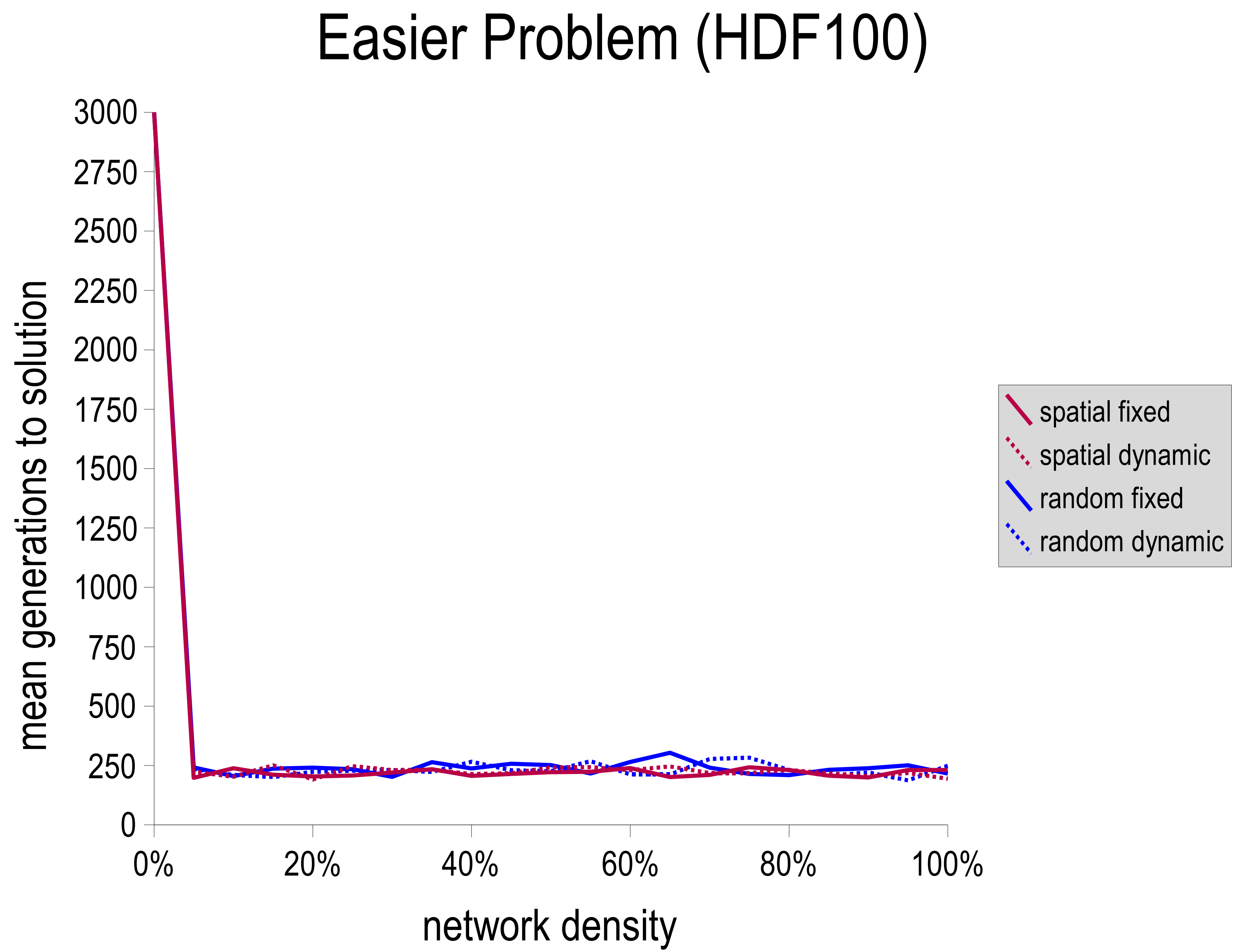
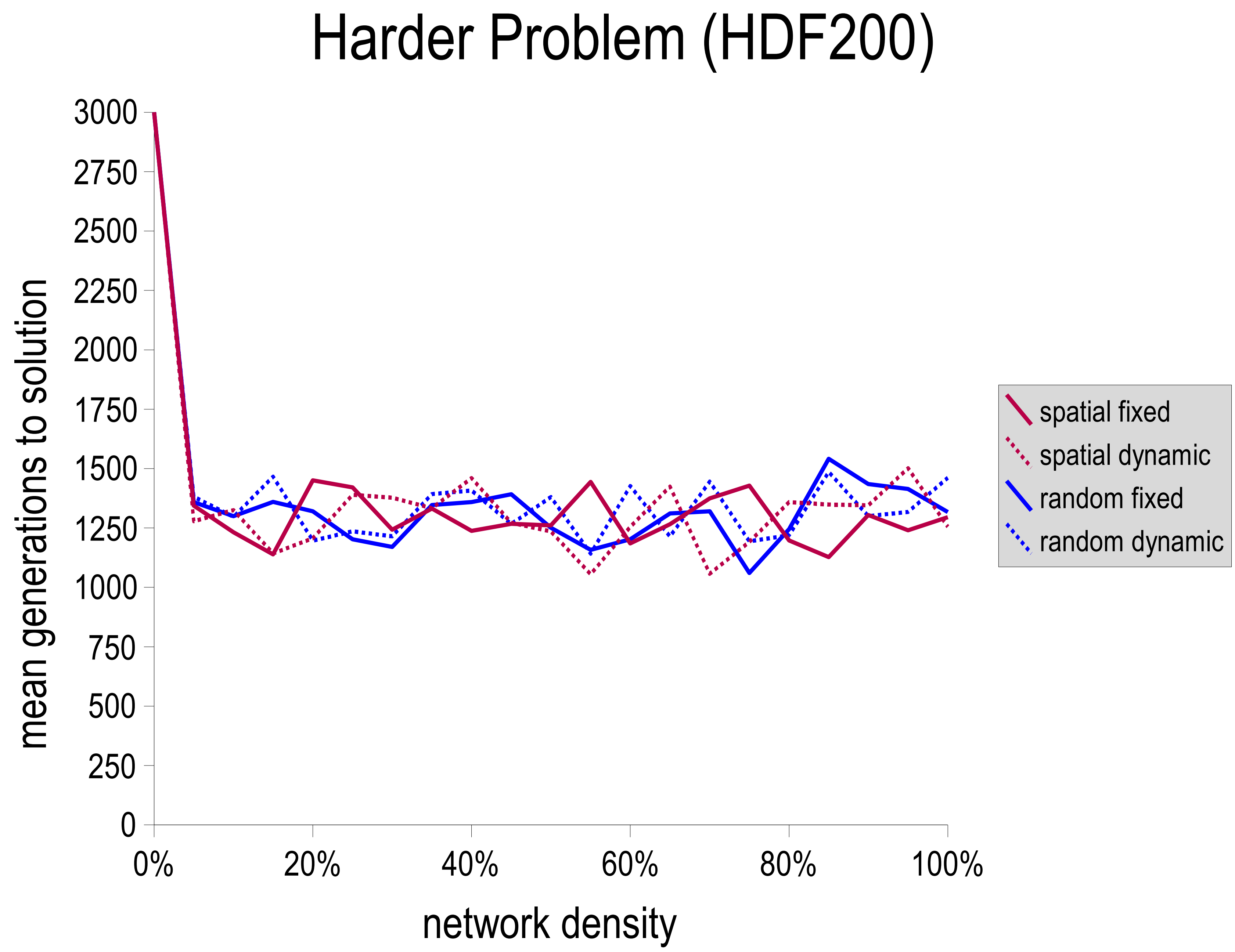
Experiment 1

- Vary the network density from 0% to 100%
  - Run the model until a "perfect" solution is found.
  - Measure how many generations it took.
  - (Give up after 3000 generations.)
- We ran 60 repetitions for each network density, and present the average.


Easier Problem (HDF100)
mean generations to solution
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
0%
20%
40%
60%
80%
100%
network density
spatial fixed
spatial dynamic
random fixed
random dynamic

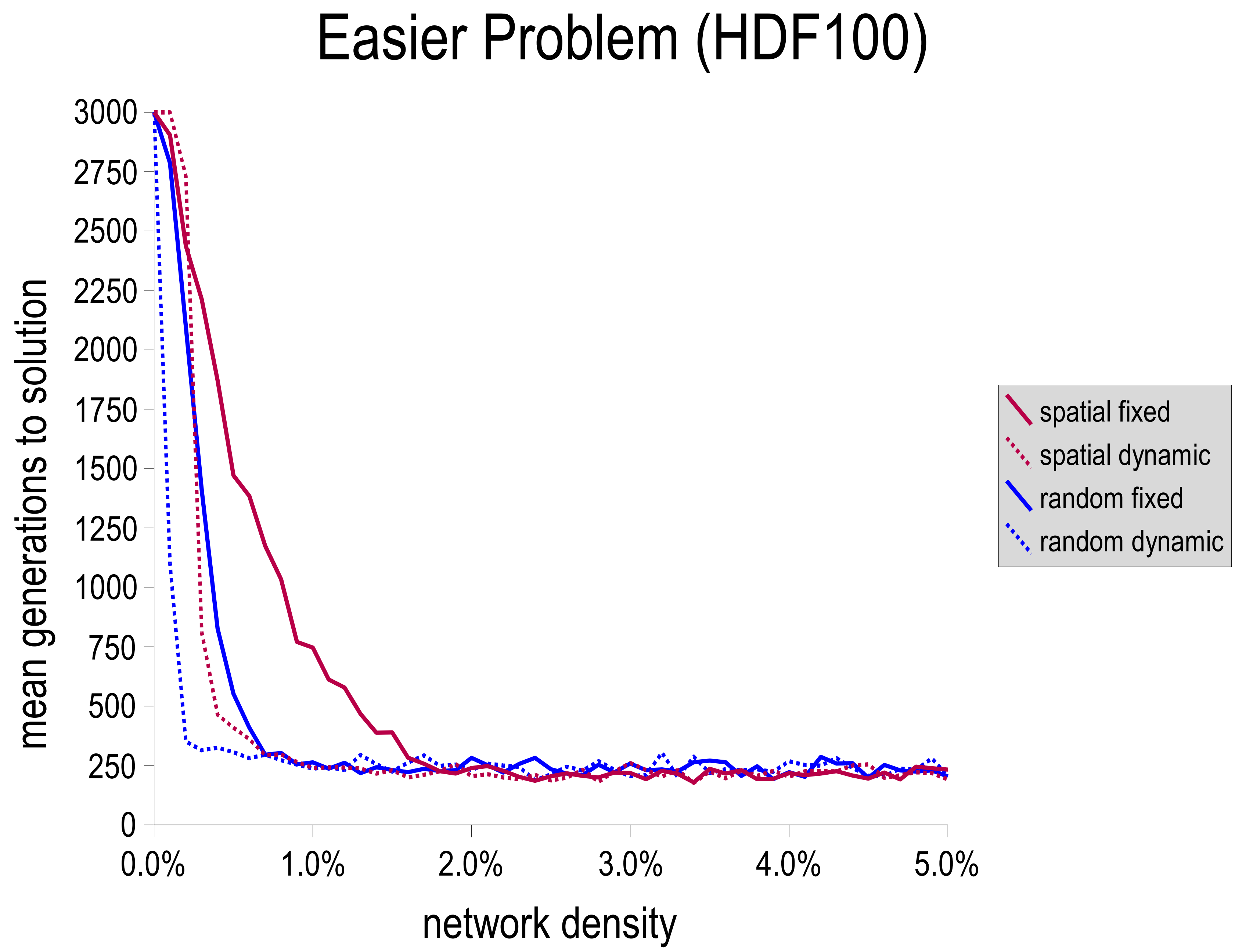

Harder Problem (HDF200)
mean generations to solution
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
0%
20%
40%
60%
80%
100%
network density
spatial fixed
spatial dynamic
random fixed
random dynamic

Observations

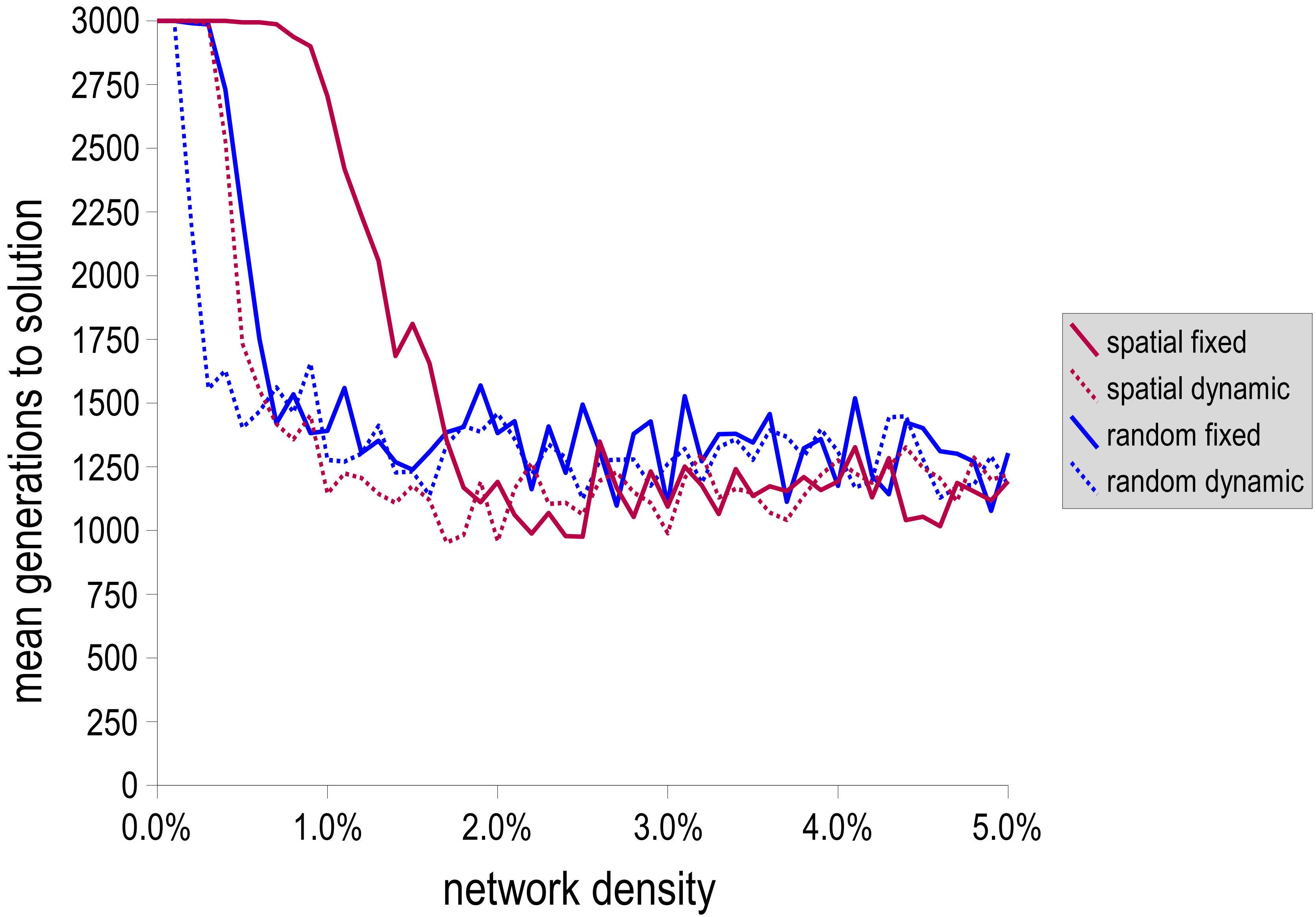
- The genetic algorithm is robust, even for sparse networks ($\leq$ 5% density).
- We can't see much else.

Experiment 2

- Vary the network density from 0% to 5%
  - Run the model until a “perfect” solution is found.
  - Measure how many generations it took.
  - (Give up after 3000 generations.)
- We ran 60 repetitions for each network density, and present the average.

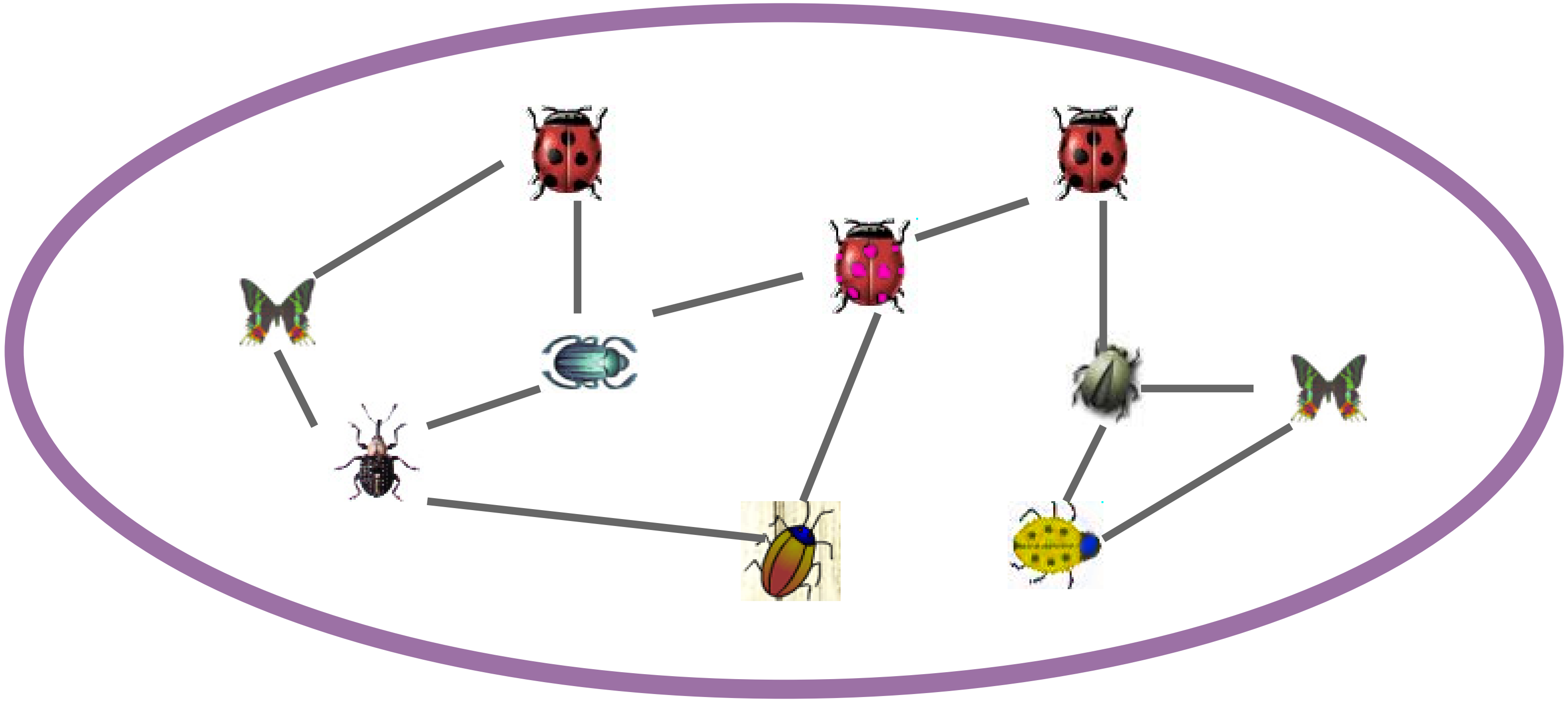

Easier Problem (HDF100)
mean generations to solution
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
network density
spatial fixed
spatial dynamic
random fixed
random dynamic

Harder Problem (HDF200)



Primary Question (revisited)

How sparse can the breeding networks be,
such that the genetic algorithm still works?



Primary Question (revisited)

How sparse can the breeding networks be,
such that the genetic algorithm still works?

Answer:

**It depends somewhat on the network topology,
but our results suggest < 2%**

New Question

- It appears that at very low densities:
  - **random** is better than **spatial**
  - **dynamic** is better than **fixed**

Why?

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Why?

- Giant component?
  - Spatial fixed in particular is segmented.
- (Dynamic) average path length
  - Less time to spread good news everywhere.
- (Dynamic) clustering coefficient
  - Faster rate of initial dispersion.

Extensions

- More network topologies
  - Small world networks *(Watts/Strogatz)*
  - Scale-free networks *(Barabasi)*
- Explore mutation rate
  - Do destructive mutations kill innovation before it has a chance to spread?
- Vary the rate of agent movement

Acknowledgments

- To my co-author, William Rand.
- To my advisor, Uri Wilensky, for his support.

Questions?