# HereBoy: A Fast Evolutionary Algorithm

## Delon Levi

# Claims

- Up to **100X faster** than a **Genetic Algorithm**

- Up to **10X faster** than a **Simulated Annealing**

- Significantly better Scalability

# Evolutionary Time

$$\text{Evolutionary Time} = \frac{\text{Time}}{\text{Iteration}} \text{ x Number of Iterations}$$

# Genetic Algorithm

Population of Individuals
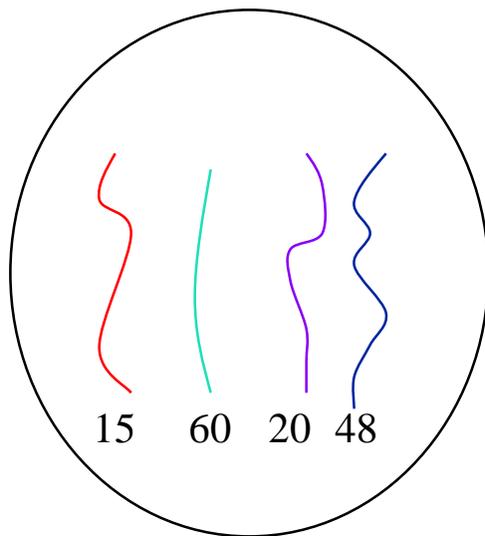
Population of Individuals

**Survival of the Fittest Reproduction with Crossover**

15   60   20   48
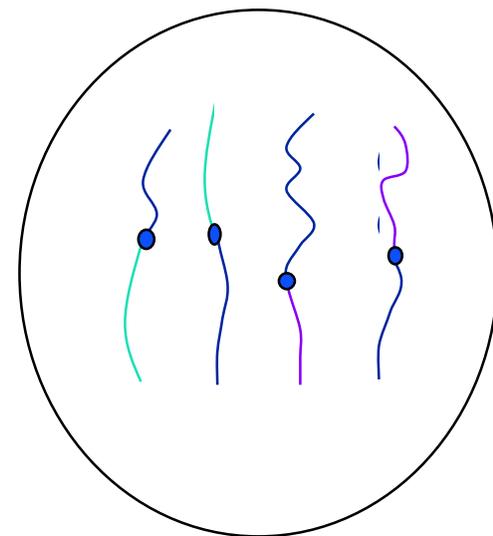
Generation *n*

Generation *n+1*

# Simulated Annealing

**Keep Mutation**

*1-Bit Mutate* → *Evaluate* → ◇ **27** (Score)

If Better → **Keep Mutation**

If Worse → **Probability Test** ◇

You still keep worse solutions with some probability

Chromosome

Mutated Chromosome

**Undo Mutation**

# HereBoy = *n-bit mutate*

**Keep Mutation**

If Better

n-Bit
Mutate

*Evaluate*

27

Score

If Worse

**Probability
Test**

Chromosome
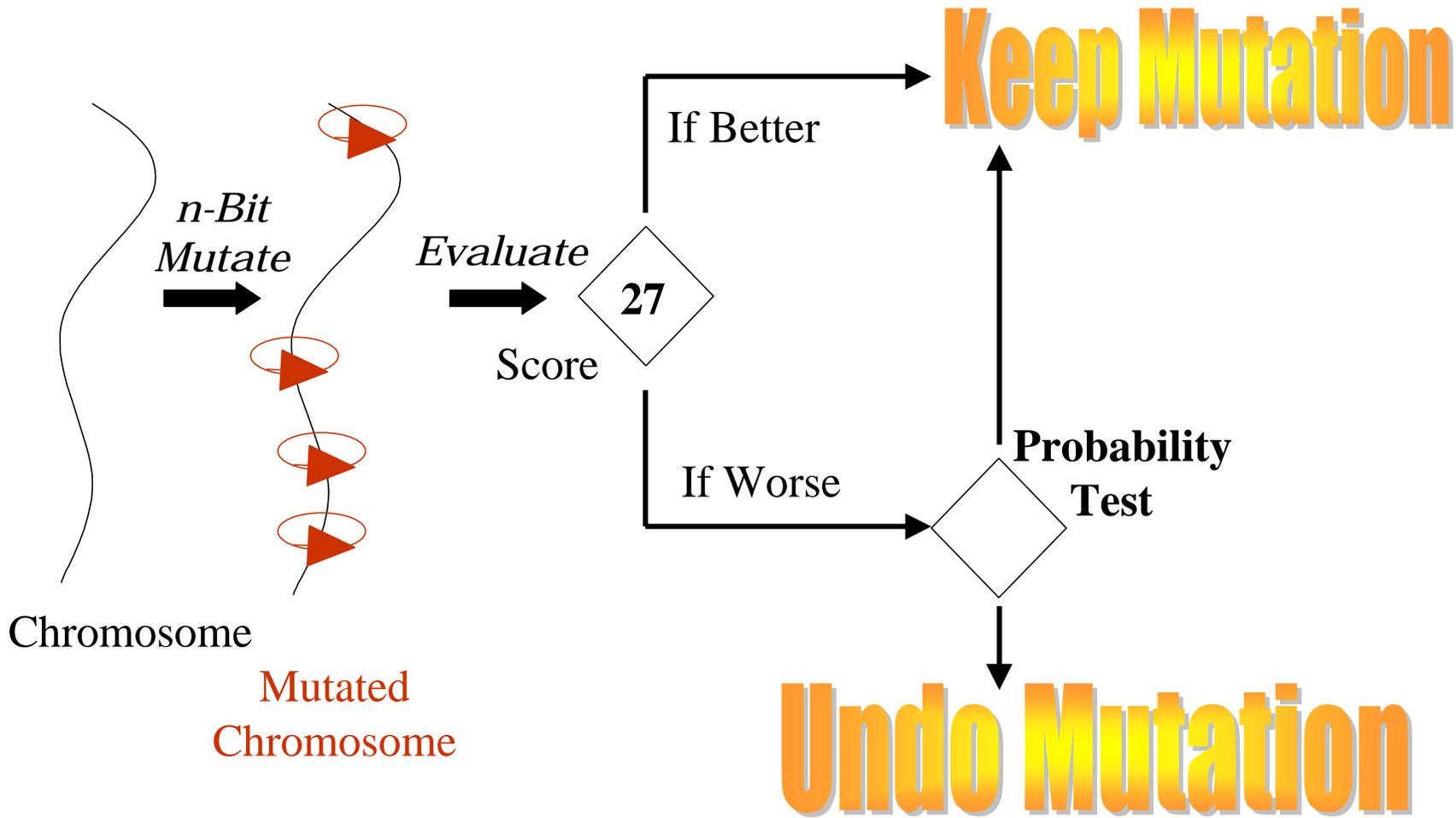
Mutated
Chromosome

**Undo Mutation**

# Adaptive Mutation



Convergence
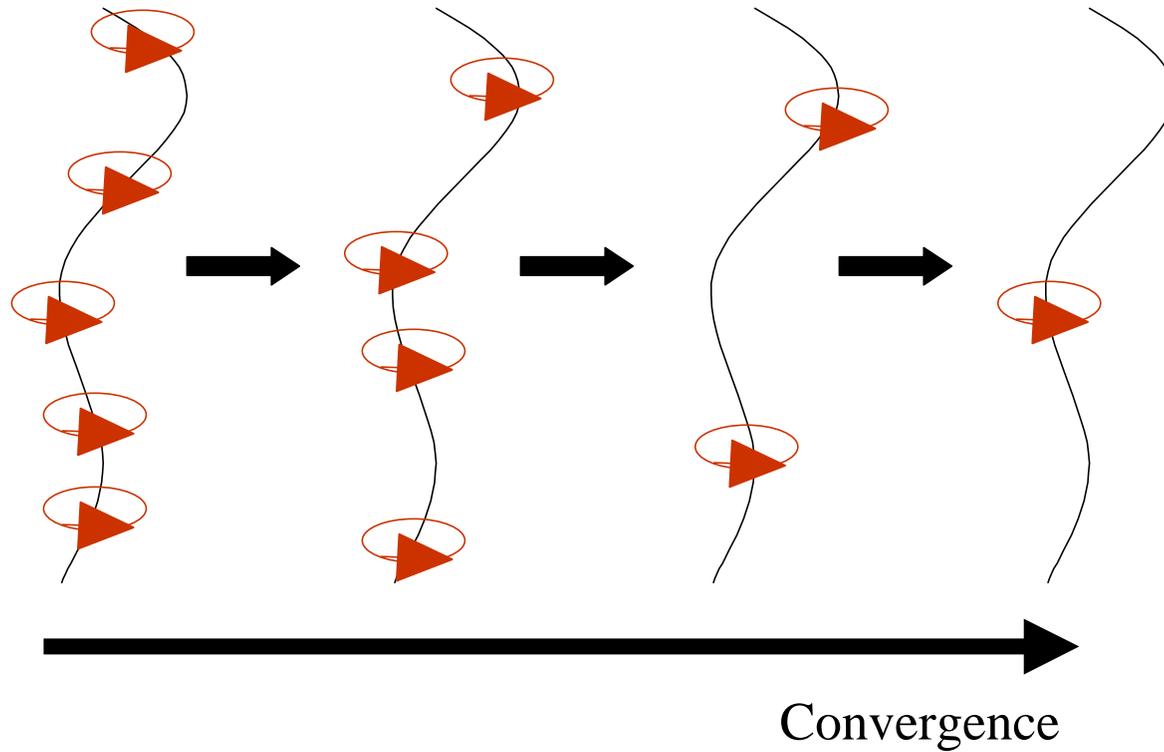
# Adaptive Mutation

Mutation Bits = $\alpha\beta$

$\alpha$ = MaxMutationRate = UserFraction x ChromosomeBits
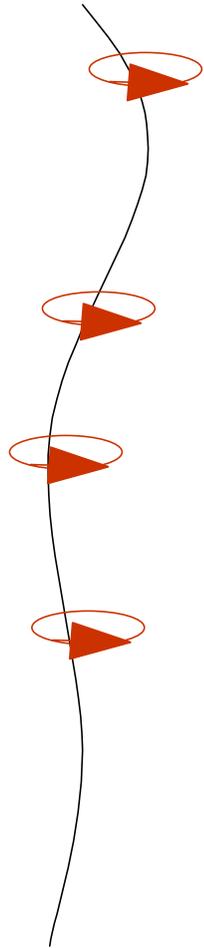
$$\beta = \frac{\text{MaxScore - MaxCurrentScore}}{\text{MaxScore}}$$

**How many bits to mutate?**
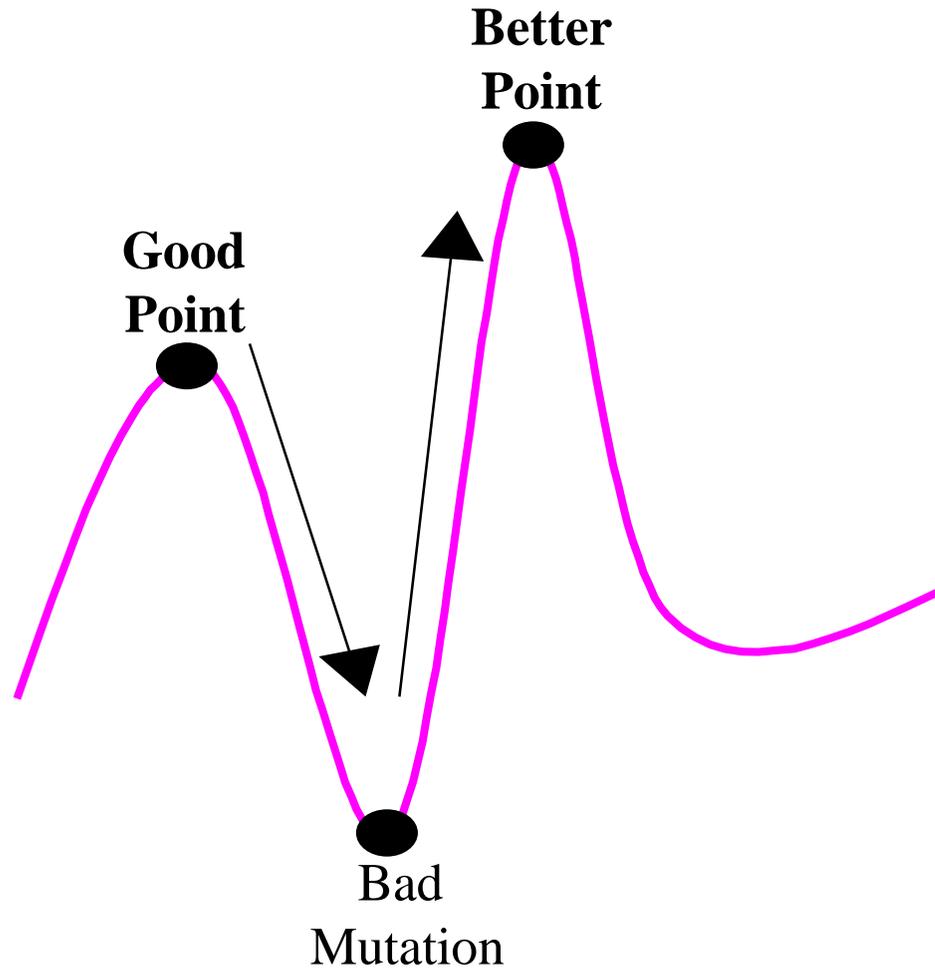
Chromosome

# Search

# Adaptive Search



Acceptance Probability **0.10**

Acceptance Probability **0.05**

Acceptance Probability **0.01**

Convergence
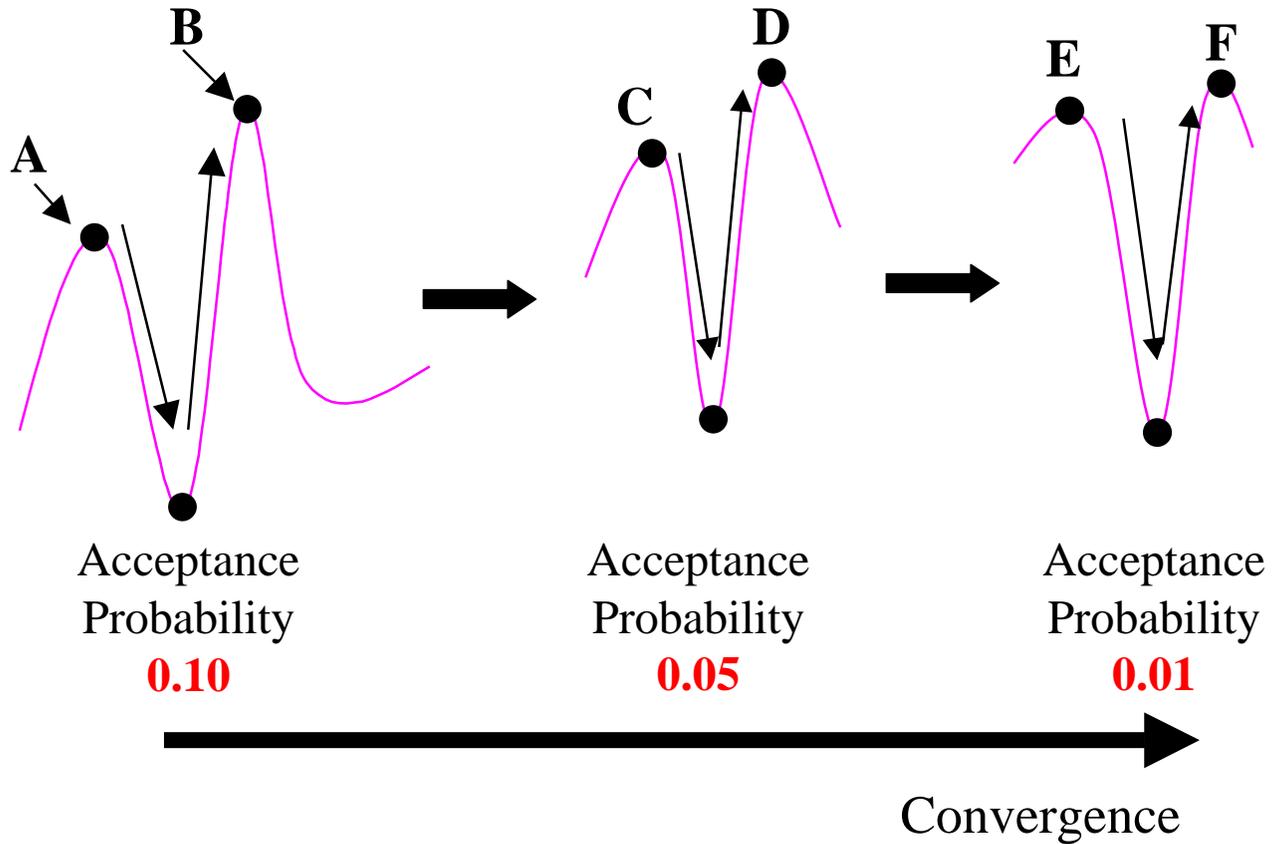
# Adaptive Search
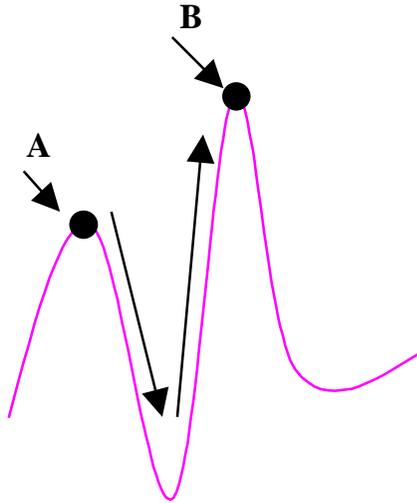
Search Probability = $\rho\beta$

$\rho$ = MaxSearchProbability = UserFraction

$$\beta = \frac{MaxScore - MaxCurrentScore}{MaxScore}$$

**How to select the probability value?**

# Curve Optimization Experiment

Hard Problem

Easy Problem
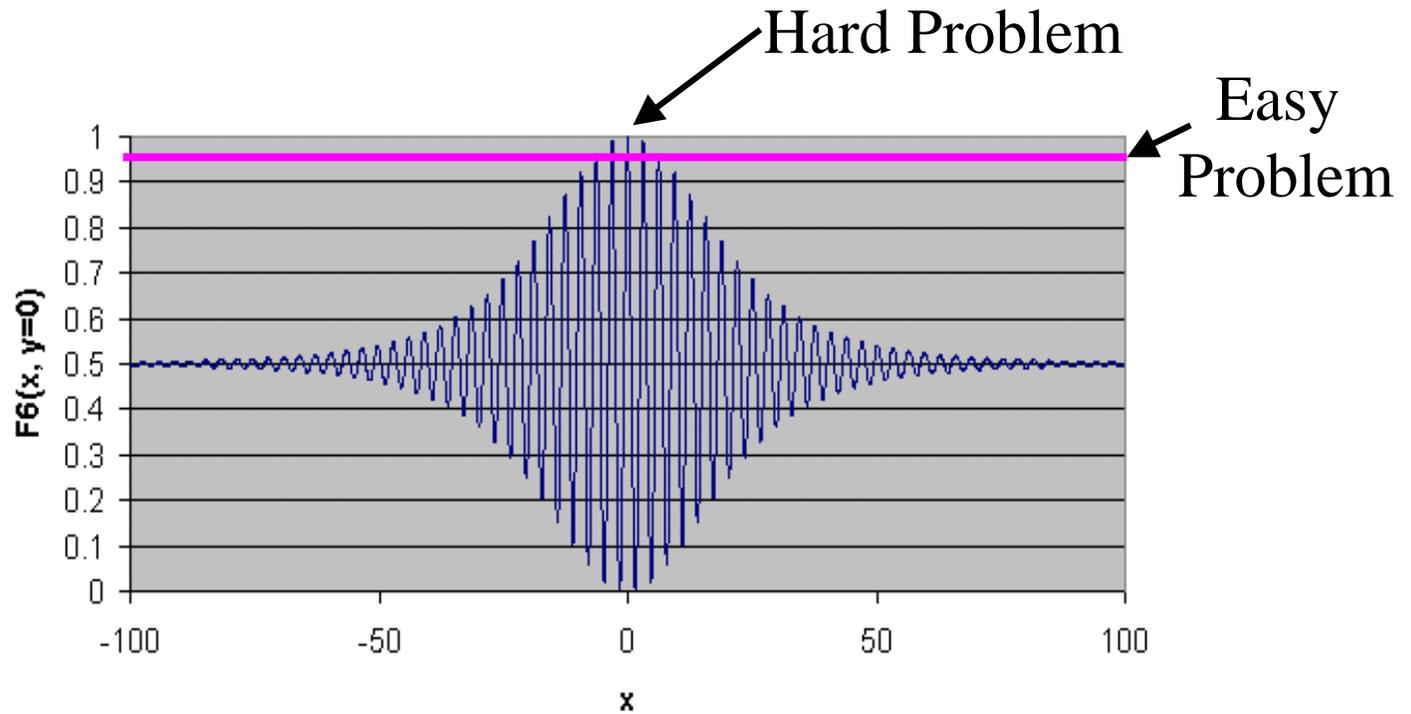


$$F6(x,y) = \frac{0.5 - (\sin\sqrt{x^2 + y^2})^2}{(1.0 + 0.0001(x^2 + y^2))^2}$$

# Curve Optimization Results

| Iterations Solving Binary F6 | | | | |
|---|---|---|---|---|
| | **99% Complete** | | **100% Complete** | |
| | $\hat{x}$ | $\sigma$ | $\hat{x}$ | $\sigma$ |
| **Genetic Algorithm** | 8,410 | 5,330 | 1,000,000+ | - |
| **Simulated Annealing** | 3,771 | 3,934 | 18,218 | 16,700 |
| **HereBoy** | 1,664 | 2,213 | 4,309 | 4,121 |

**Number of iterations**

| Scale Between Easy and Hard Binary F6 Experiments | | |
|---|---|---|
| **HereBoy** | **Simulated Annealing** | **Genetic Algorithm** |
| 2,645 | 14,447 | 1,000,000+ |

# Evolvable Hardware Experiment
## *Pattern Generation*
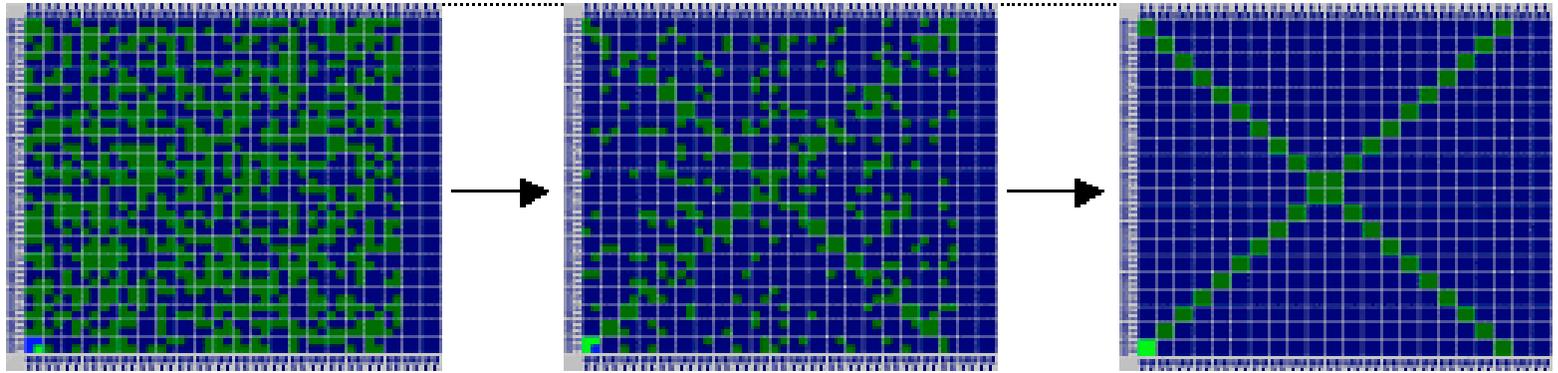


Iteration = 0
Score = 800

Iteration = 3,357
Score = 1,371

Iteration = 65,599
Score = 1,600

| Pattern Generator Circuit Statistics | | |
|---|---|---|
| | **10x10** | **20x20** |
| **Search Space Size** | $2^{6400}$ | $2^{25,600}$ |
| **Probability of Randomly Creating 100% Solution** | $2^{-400}$ | $2^{-1600}$ |

# Evolvable Hardware Results

| Iterations Solving "X" Pattern Generation 60% Completion | | | | |
|---|---|---|---|---|
| | **10x10** | | **20x20** | |
| | $\overset{\wedge}{x}$ | $\sigma$ | $\overset{\wedge}{x}$ | $\sigma$ |
| **Genetic Algorithm** | 1,510 | 870 | 76,562 | 10,597 |
| **Simulated Annealing** | 1,382 | 373 | 5,629 | 645 |
| **HereBoy** | ⎸59 | 13 | 231 | 27 |

| Scaling Between 10x10 and 20x20 Pattern Generator | | |
|---|---|---|
| **HereBoy** | **Simulated Annealing** | **Genetic Algorithm** |
| 172 | 4,247 | 75,052 |

# Qualitative Comparison