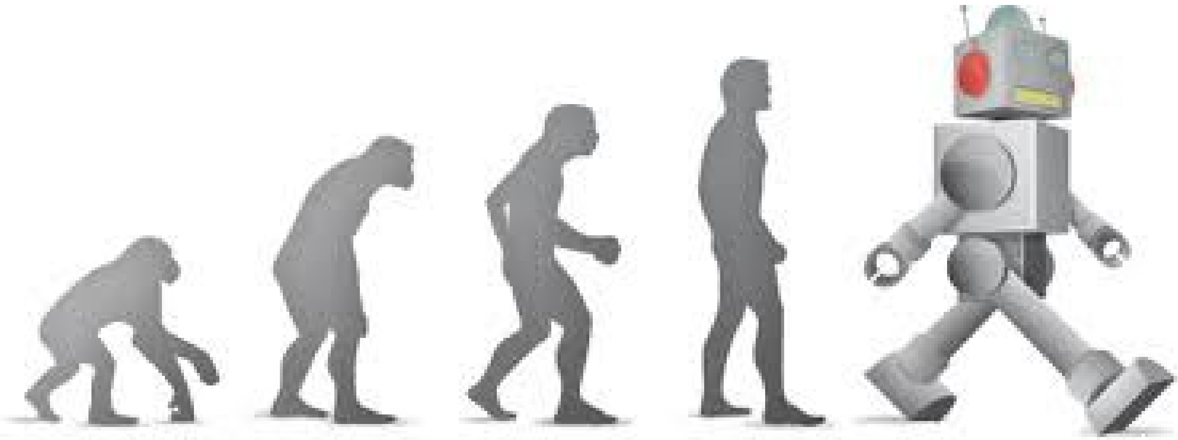
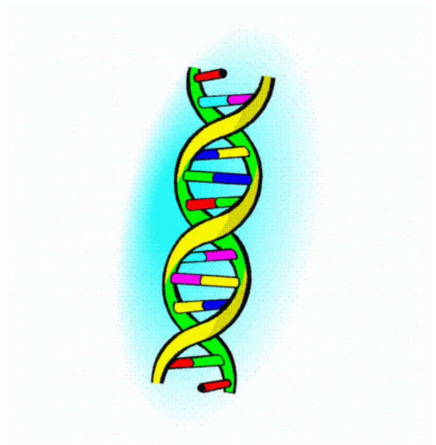
Genetic Algorithms

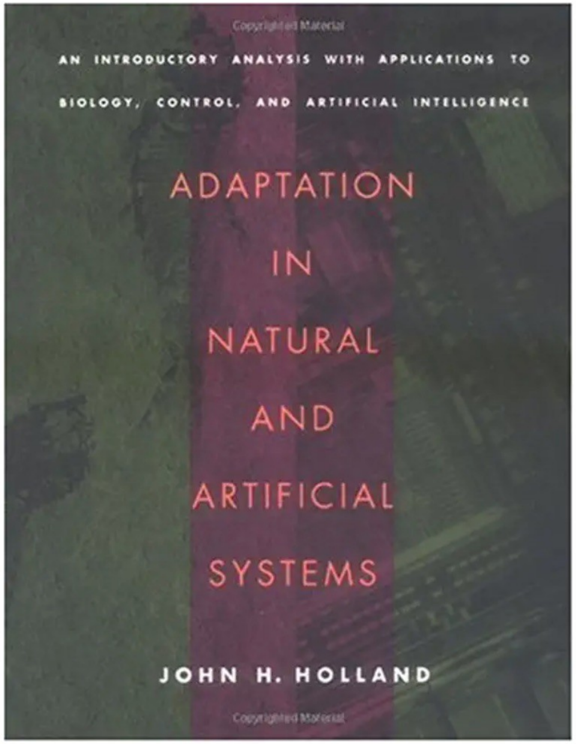




Genetic Algorithms

- Invented by John Holland in the 1960s

1929 - 2015



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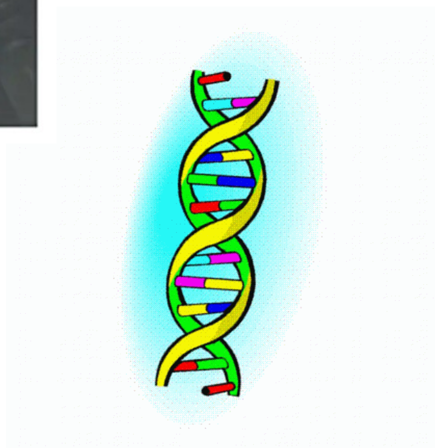
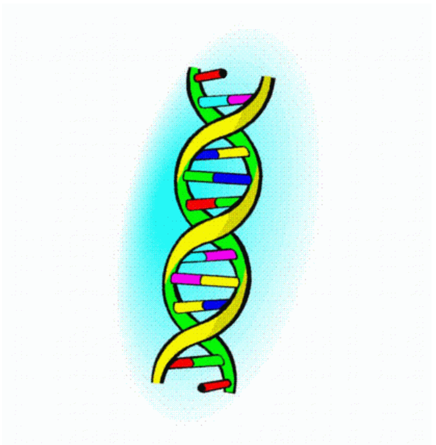


Genetic Algorithms

- **Genome**
  - An encoded representation of a candidate solution to the problem (typically a sequence of numbers or bits)
- **Population of genomes**
  - A pool of candidate solutions, initially generated at random
- **Fitness function**
  - $f(genome) \Rightarrow$ numerical estimate of quality
- **Operators**
  - *Selection:* survival of the fittest
  - *Crossover:* genetic recombination
  - *Mutation:* random variation



Outline of a Genetic Algorithm

1. Create a population of random genomes

000011101001100

110010011110011

100110100110100

00000100100010

111101011111101

101001101010101

000010000101011

110100100010001

Outline of a Genetic Algorithm

1. Create a population of random genomes

2. Evaluate the fitness of each genome in the population

$f($ 000011101001100 $) = 6$

$f($ 110010011110011 $) = 9$

$f($ 100110100110100 $) = 7$

$f($ 111101011111101 $) = 12$

$f($ 000000100100010 $) = 3$

$f($ 101001101010101 $) = 8$

$f($ 000010000101011 $) = 5$

$f($ 110100100010001 $) = 6$

Outline of a Genetic Algorithm

1. Create a population of random genomes

2. Evaluate the fitness of each genome in the population

3. Build a new population of genomes:

   (a) **select** 2 genomes probabilistically, based on fitness

$f(000011101001100) = 6$

$f(110010011110011) = 9$

$f(100110100110100) = 7$

$f(111101011111101) = 12$

$f(00000100100010) = 3$

$f(101001101010101) = 8$

$f(000010000101011) = 5$

$f(110100100010001) = 6$

Outline of a Genetic Algorithm

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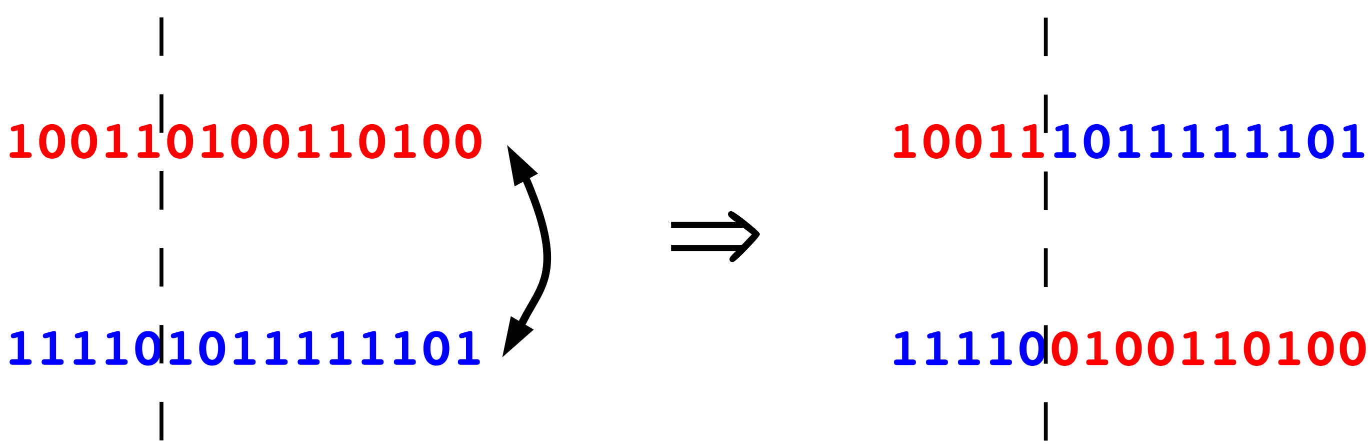

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    (c) **mutate** each offspring with some small probability

1001111111111111

0111001001101100

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    (d) add the offspring to the new population

continue steps (a) - (d)

Outline of a Genetic Algorithm

1. Create a population of random genomes

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    (c) **mutate** each offspring with some small probability

    (d) add the offspring to the new population

    continue steps (a) - (d)

4. When the new population has reached the same size as the current population, replace the current population by the new population … and repeat

Outline of a Genetic Algorithm

- Over time, the **average fitness** of the population will increase
- Even the **best-fit** individuals are not guaranteed to survive to the next generation
- Even the **worst-fit** individuals have some (small) probability of surviving
- Some GAs use **elitism** to ensure that the best individuals do survive
- Many ways of probabilistically selecting individuals
  - **fitness-proportionate** selection (“roulette-wheel sampling”)
  - **rank** selection
  - **tournament** selection

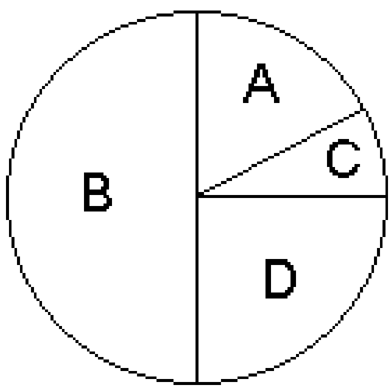
A Simple Example

Genome	Fitness	New population
A: **00000110**	2	
B: **11101110**	6	
C: **00100000**	1	
D: **00110100**	3	

Average fitness of current population = 12 / 4 = 3.0

A Simple Example

	Genome	Fitness	New population
A:	**00000110**	2	
B:	**11101110**	6	
C:	**00100000**	1	
D:	**00110100**	3	



Fitness-proportionate selection
("roulette-wheel sampling")

B: **11101110** and C: **00100000** are selected

A Simple Example

Genome	Fitness	New population
A: **00000110**	2	
B: **11101110**	6	
C: **00100000**	1	
D: **00110100**	3	

No crossover

B: **11101110**

C: **00100000**

A Simple Example

Genome	Fitness	New population
A: **00000110**	2	E: **01101110**
B: **11101110**	6	C: **00100000**
C: **00100000**	1	
D: **00110100**	3	

No crossover B is mutated

B: **11101110** → E: **01101110**

C: **00100000**

A Simple Example

Genome	Fitness	New population
A: **00000110**	2	E: **01101110**
B: **11101110**	6	C: **00100000**
C: **00100000**	1	
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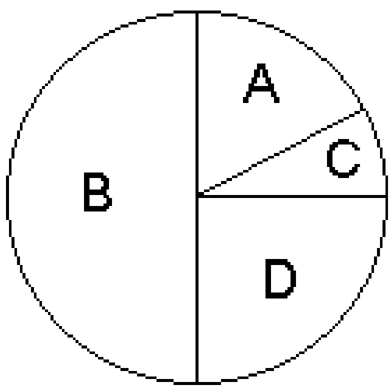


Fitness-proportionate selection
("roulette-wheel sampling")

B: **11101110** and D: **00110100** are selected

A Simple Example

Genome	Fitness	New population
A: **00000110**	2	E: **01101110**
B: **11101110**	6	C: **00100000**
C: **00100000**	1	
D: **00110100**	3	

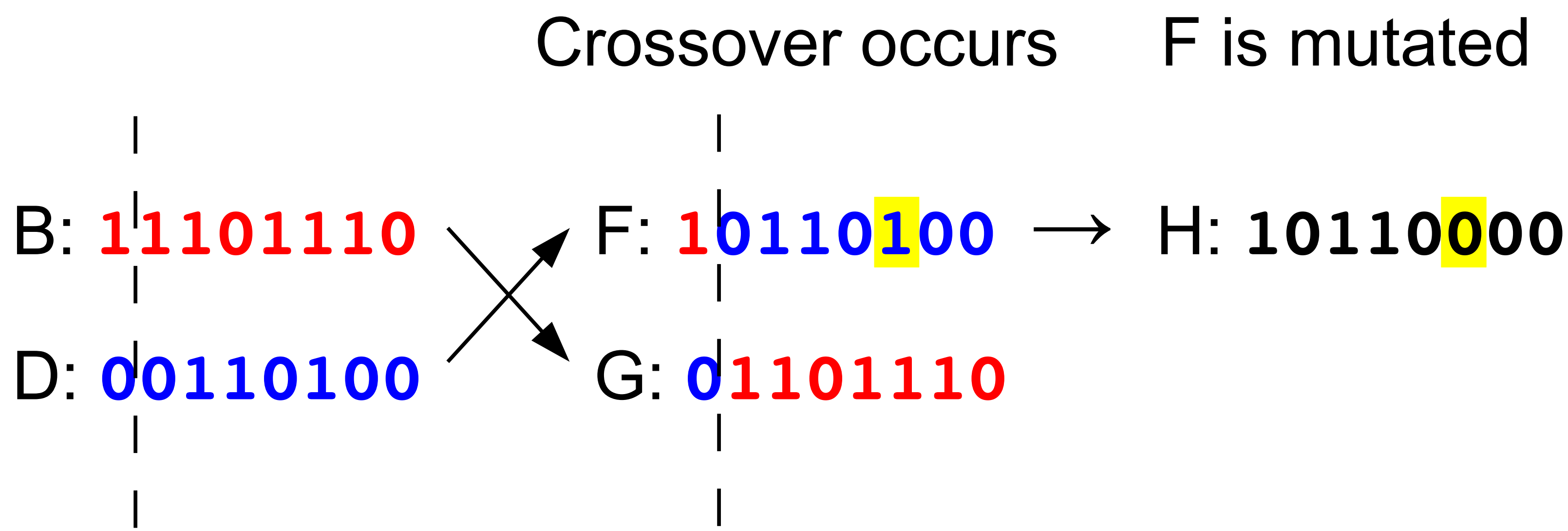
Crossover occurs

B: **11101110** → F: **10110100**

D: **00110100** → G: **01101110**

A Simple Example

Genome	Fitness	New population
A: **00000110**	2	E: **01101110**
B: **11101110**	6	C: **00100000**
C: **00100000**	1	H: **10110000**
D: **00110100**	3	G: **01101110**



A Simple Example

Genome	Fitness	New population	Fitness
A: **00000110**	2	E: **01101110**	5
B: **11101110**	6	C: **00100000**	1
C: **00100000**	1	H: **10110000**	3
D: **00110100**	3	G: **01101110**	5

Average fitness of new population = 14 / 4 = 3.5

Best-fit genome from previous population was lost

Demo: Evolving an English Phrase

- Genome
  a sequence of letters representing an English phrase
- Fitness function
  the number of letters in the genome that match
  “the rain in spain stays mainly in the plain”
- Example
  “the yain in szbin stays mainly ik the ploin”
  fitness = 38
- GA parameters
  population size: 100
  crossover probability: 0.75
  mutation probability: 0.005 per locus

Key Concepts

- Search space
- Fitness landscape
- Local minimum / maximum
- Hill-climbing search
- Population-based search