Evolutionary Computation

IEEE Computational Intelligence Society
Pre-College Subcommittee

Optimization

- We come across optimization problems everyday.
- Anne wants to take a graduation trip to Europe. Which route shall she choose to make the flight fares cheapest?

https://en.wikipedia.org/wiki/Europe

Optimization

- Brian is an archaeologist. He found a digsite and wanted to carry the most valuable things with his bag. Which ones should he choose to fit in his knapsack?

http://www.cs.rpi.edu/academics/courses/spring12/proglang/pa3/pa3.html

Optimization

- These problems are easy to solve. We can try all possible options.
- What if Anne is a postwoman and has to visit 100 different places?
- It takes her 3*10^141 years to find the best trip if she can check a billion solutions in just one second !
- Life of the universe: 1.5*10^9 yrs.

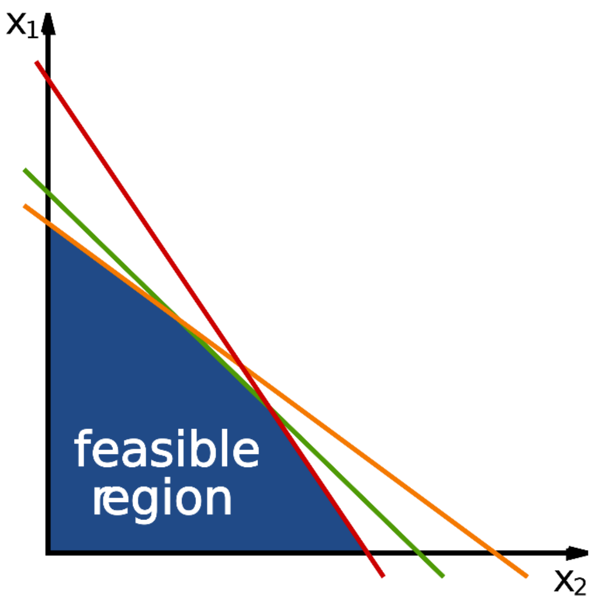
Optimization

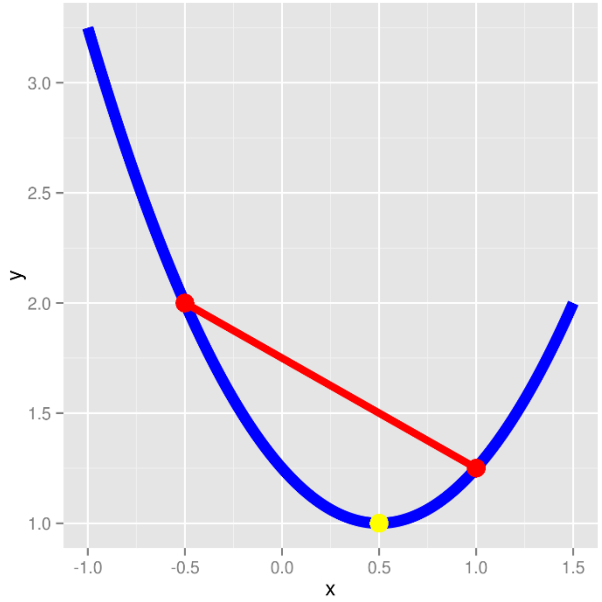
- We need more advanced techniques.

http://stockarch.com/images/abstract/concept/computer-frustration-2886

Evolutionary Computation

- People have developed many techniques to solve optimization problems with special characteristics.

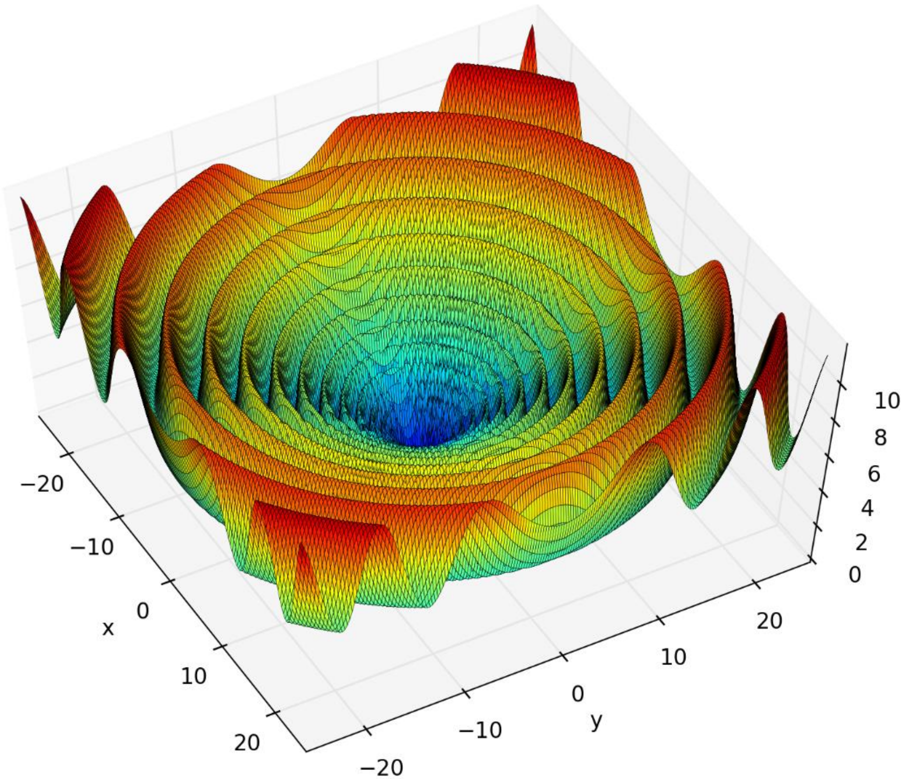




http://blog.ryanwalker.us/2013/09/optimization-in-r-part-i.html

Evolutionary Computation

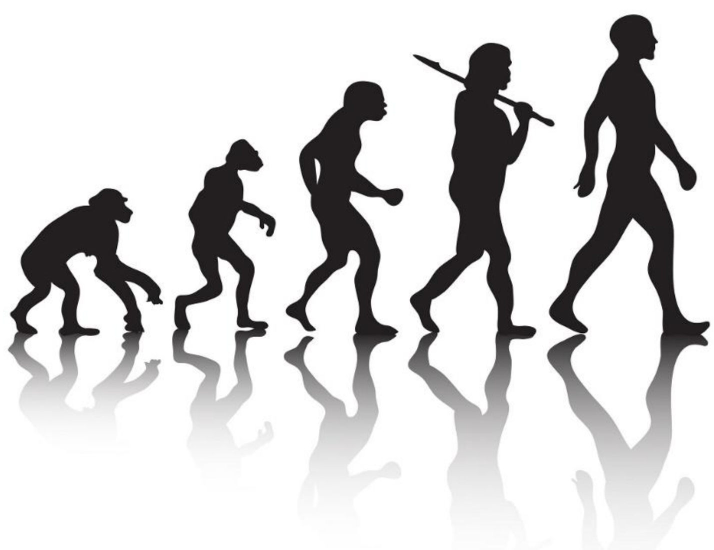
- However they cannot be used to solve too complex ones.



http://deap.gel.ulaval.ca/doc/0.8/api/benchmarks.html

Evolutionary Computation

- Evolutionary computation is among the most efficient techniques to solve these problems.
- It uses the Darwinian principles for automated problem solving.



http://healthimpactnews.com/2015/eugenics-in-the-united-states-today-are-we-on-the-same-path-nazi-germany-followed/

Evolutionary Computation

- It is a kind of algorithm with the following features
  - Iterative progress
  - Population based
  - Random process
  - (Often) biological inspired

Iterative Progress

- In evolutionary computation, the optimization problem is solved in an iterative manner.
- Each iteration tries to improve the solutions to the problem.
  - At first Anne visited all 100 places with a trip of 100km.
  - Then later she worked out another trip of 90km.
- So which solution is better ?

Population Based

- In evolutionary computation, multiple solutions are used interacted.
  - Anne checks five different routes simultaneously.
  - In the next iteration she changed some of them according to others.

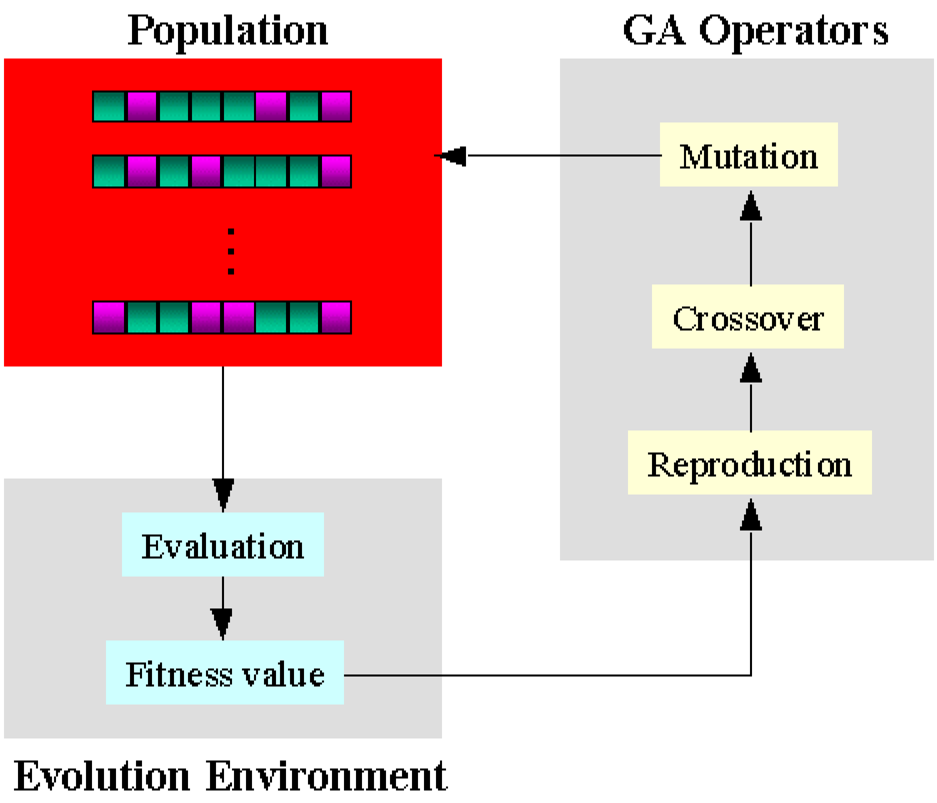
Random Process

- In evolutionary computation, changes to the existing solutions are guided by a random process.
  - Anne tried to change solution A according to B. However, the resultant solution C is not constant if Anne tried another time.

Genetic Algorithm

- Arguably the most famous evolutionary computation technique.
- Developed by John Holland in 1970s.

Genetic Algorithm

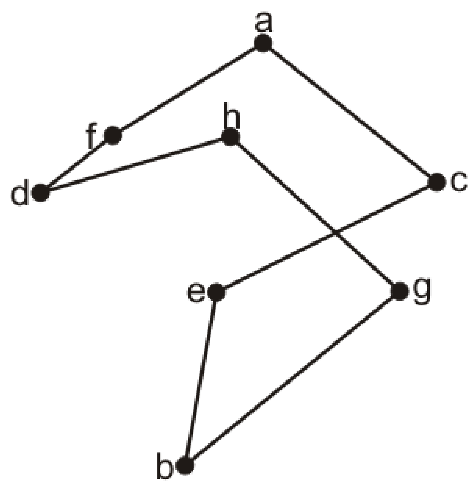


Genetic Algorithm Evolution Flow

http://www.ewh.ieee.org/soc/es/May2001/14/Begin.htm

Genetic Algorithm

- Before optimization
  - How to represent a solution?
  - What is the objective function?
  - What is the population size?

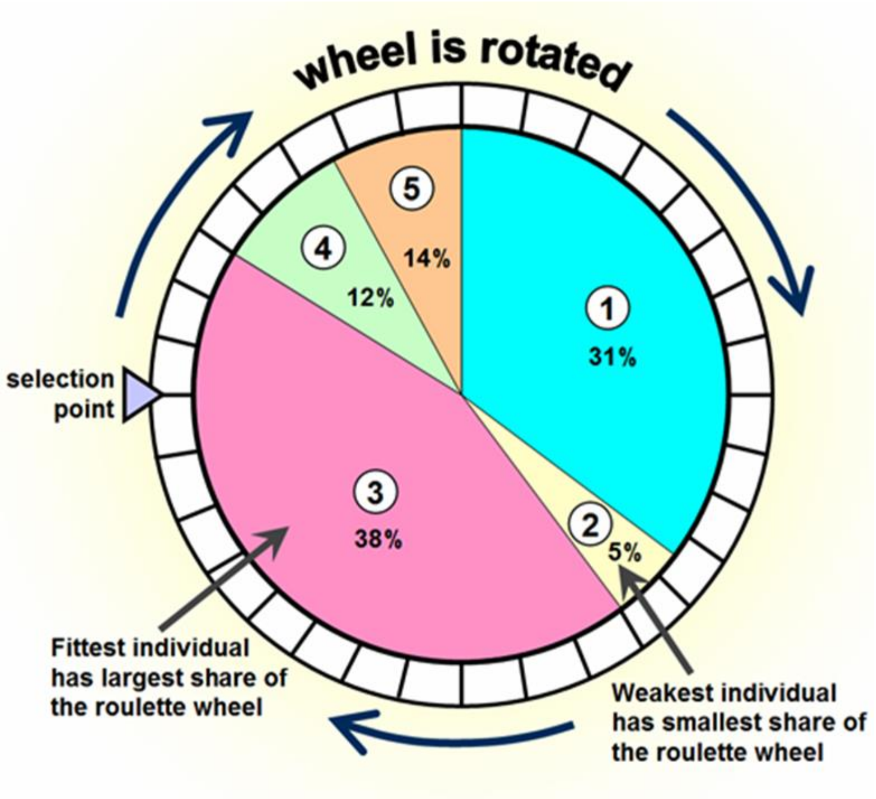


a	c	e	b	g	h	d	f

http://www.codeproject.com/Articles/26203/Genetic-Algorithm-Library

Genetic Algorithm

- Reproduction: how to select two solutions?
  - Roulette Wheel



http://www.edc.ncl.ac.uk/highlight/rhjanuary2007g02.php

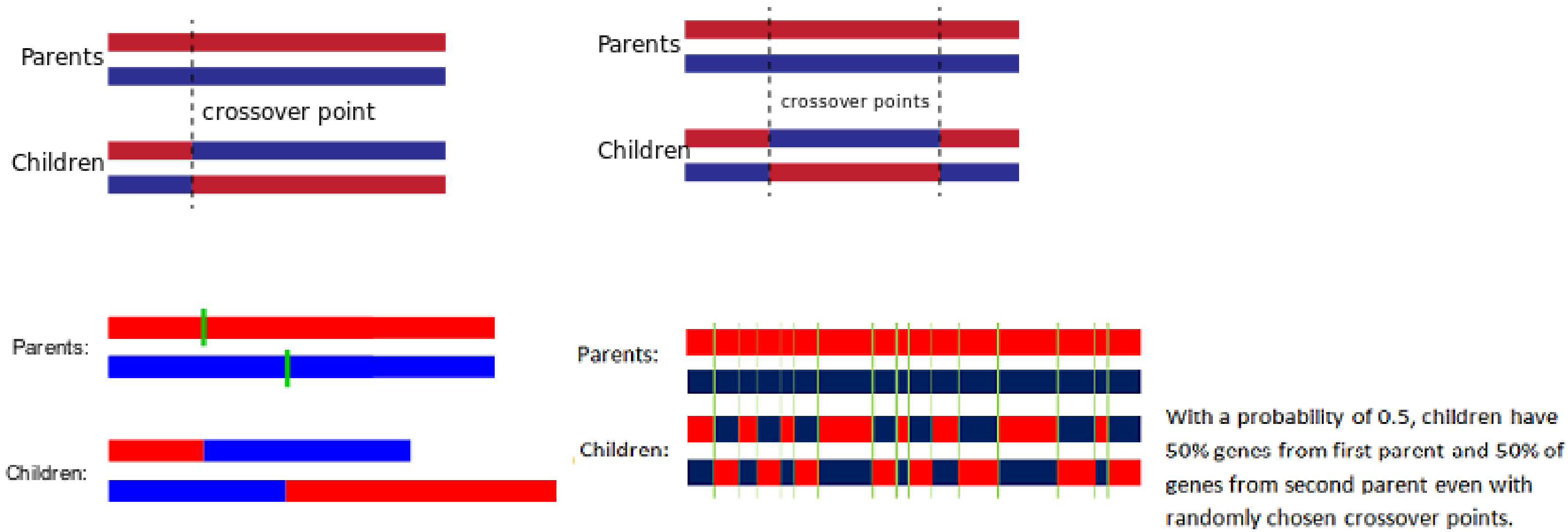
Genetic Algorithm

- Reproduction: how to select two solutions?
  - Tournament

http://www.snipview.com/q/Tournament_selection

Genetic Algorithm

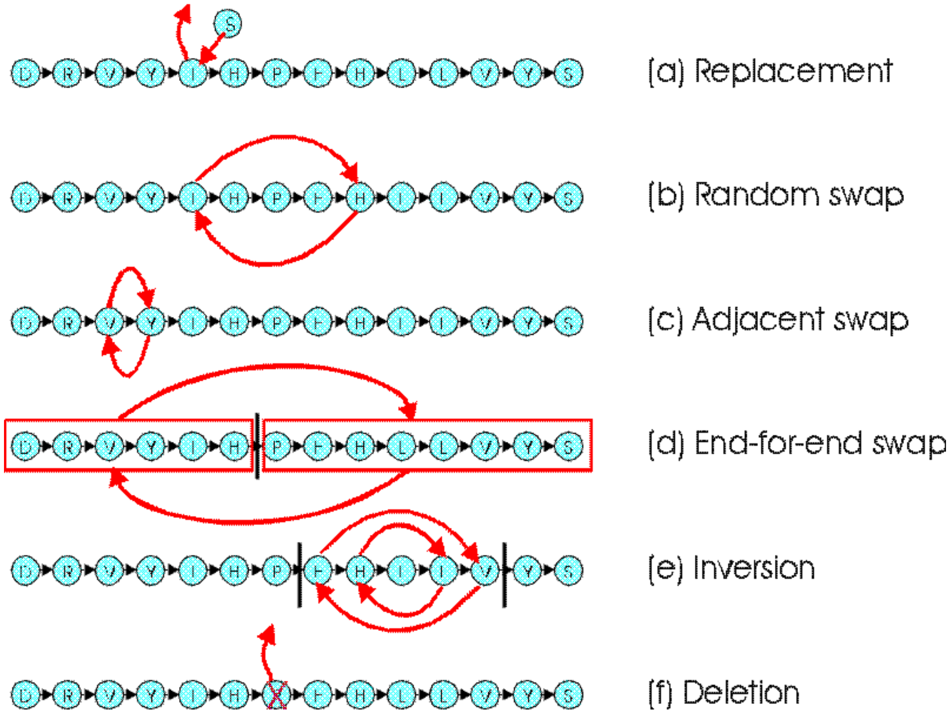
- Crossover: how to change two solutions?
  - Depends on solution representation



https://en.wikipedia.org/wiki/Crossover_(genetic_algorithm)

Genetic Algorithm

- Mutation: how to randomly change solutions?
  – Also depends on solution representation



https://www.abrf.org/jbt/1998/december98/dec98rcstranz.html

Genetic Algorithm

- Advantages
  - Robust
  - Simple
  - Little knowledge/assumption required
  - Wide adaptability
  - And more…
- Disadvantages
  - No guaranteed optima
  - Computationally expensive (or, slow)

Example

- Suppose you are Brian. Now you find 7 items with different values and weights

Item:	1	2	3	4	5	6	7
Value:	5	8	3	2	7	9	4
Weight:	7	8	4	10	4	6	4

- And you can carry 22 pounds of items.
- Which ones to choose?

Example

- Before optimization
  - How to represent a solution?
    - If an item is selected, it is represented by 1's. Otherwise 0's.
    - Some possible solutions
      - `0101010`
      - `1101100`
      - `0100111`
  - What is the objective function?
    - The total value of all selected items
  - What is the population size?
    - Reasonable sizes, e.g., 20.

Example Solution 1

Item:	1	2	3	4	5	6	7
Value:	5	8	3	2	7	9	4
Weight:	7	8	4	10	4	6	4
Select:	0	1	0	1	0	1	0

- Total value: 8 + 2 + 9 = 19
- Total weight: 8 + 10 + 6 = 24 > 22 !
  – It won’t work!

Example Solution 2

• Item:	1	2	3	4	5	6	7
• Value:	5	8	3	2	7	9	4
• Weight:	7	8	4	10	4	6	4
• Select:	1	1	0	0	1	0	0

- Total value: 5 + 8 + 7 = 20
- Total weight: 7 + 8 + 4 = 19
  - Is this one the best solution?

Example Solution 3

• Item:	1	2	3	4	5	6	7
• Value:	5	8	3	2	7	9	4
• Weight:	7	8	4	10	4	6	4
• Select:	0	1	0	0	1	1	1

- Total value: 8 + 7 + 9 + 4 = 28
- Total weight: 8 + 4 + 6 + 4 = 22
  - This one is better!

Example

- Putting items in a knapsack is simple.
- It can be applied to really big scenarios
  - Space ship missions have limited loads.

https://en.wikipedia.org/wiki/STS-1

More?

- IEEE Computational Intelligence Society Video Competition winning video:
  - https://vimeo.com/76702412