Genetic Algorithms for Vision and Pattern Recognition

Faiz Ul Wahab

Objective

- To solve for optimization of computer vision problems using genetic algorithms

Timeline

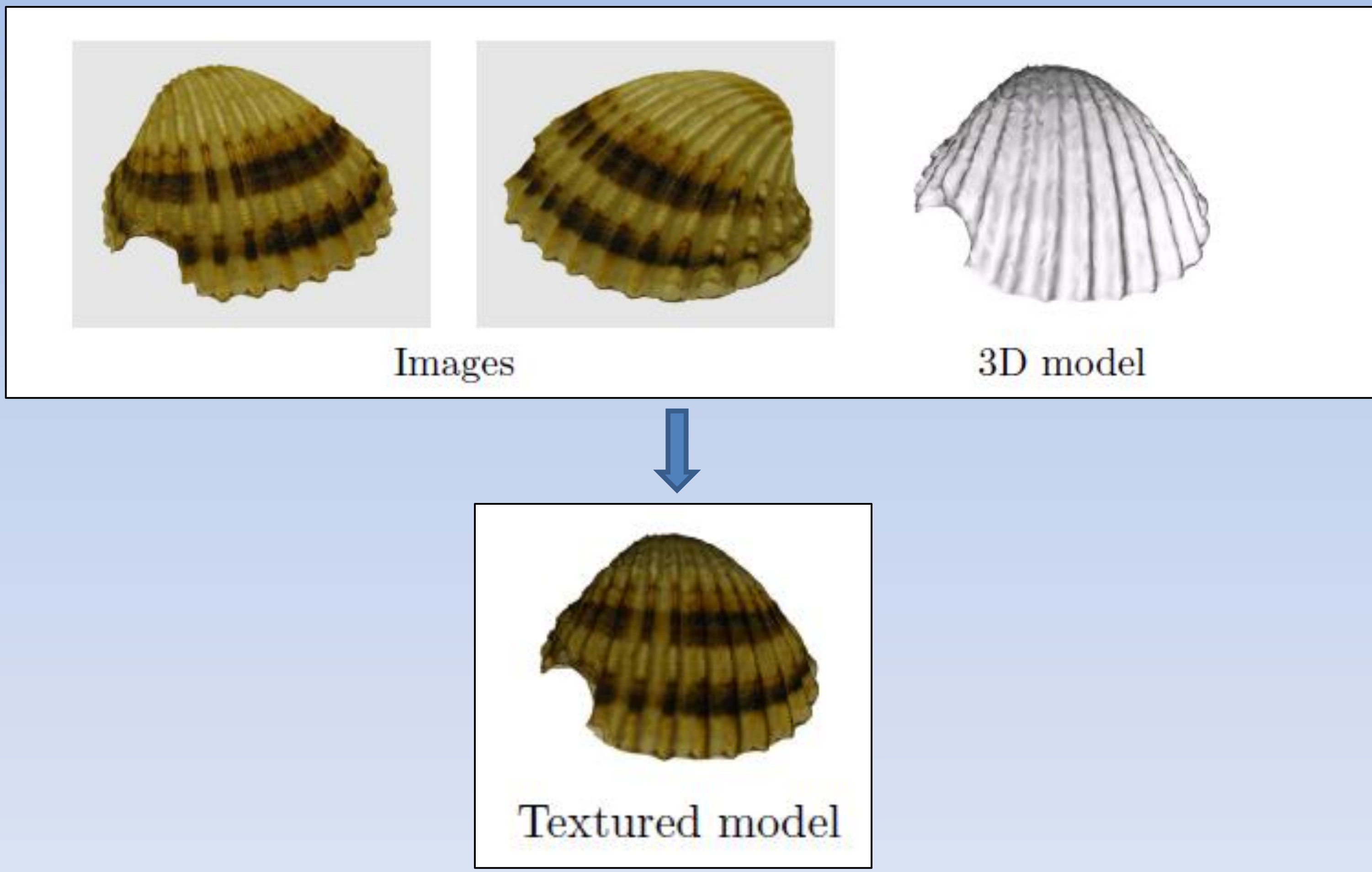
- Problem: Computer Vision
- Genetic Algorithms(GA)
- Solution by Genetic Algorithms
- Results and Discussions
- Questions?

Registration of Images

- Registration Problem is one of the fundamental problems in computer vision

Registration of Images to Images

Registration of Images to 3D Models

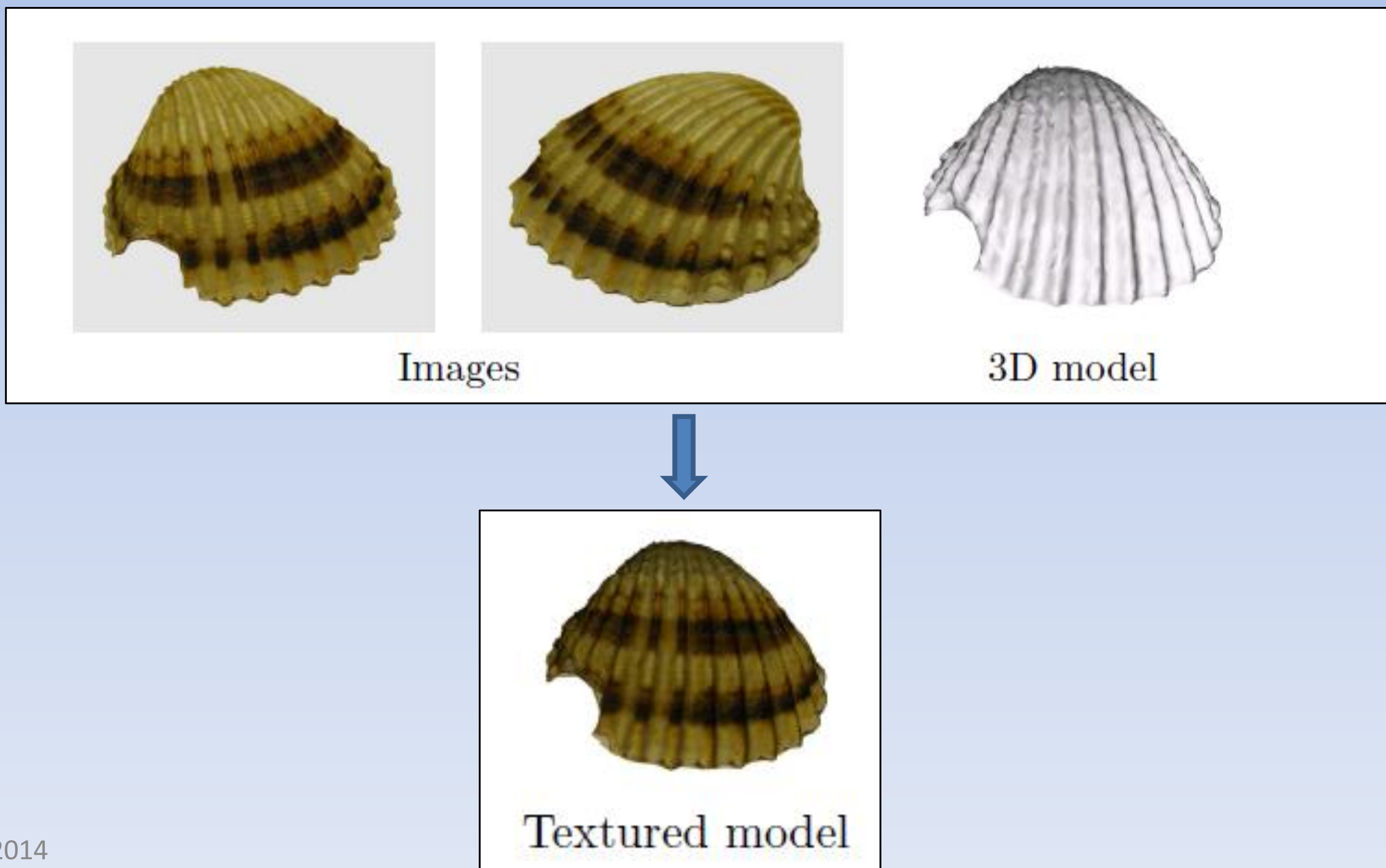


Applications

- Augmented Reality
- Image Guided Surgery
- Rendering real objects in gaming environments

Registration of Images to 3D Models[1]

- Goal: make textured 3D models



How to do that?

- Sampling: Slice the 3D model
- Define cost function
- Solve for the optimization

Define Cost Function

- 18 parameters
- K(3x2)
- R(3x2)
- T(3x2)

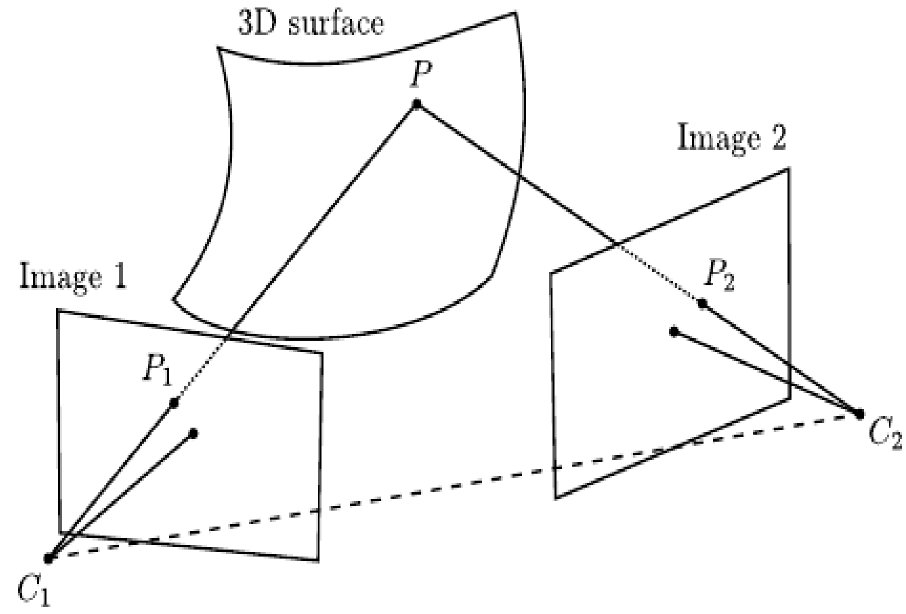


Figure 4.3: Illustration of the basic principles of shape-from-stereo (stereo reconstruction). The reconstruction of a 3D point may be achieved using the epipolar geometry.

Cost Function

$$C(P_1, P_2) = \frac{1}{|P|} \sum_{\boldsymbol{X} \in P} \left(I_1(P_1\boldsymbol{X}) - I_2(P_2\boldsymbol{X}) \right)^2$$

- P_1, P_2 are the projection matrices
- *P* is the number of points in 3D model
- $I_i(P\boldsymbol{X})$ is the color of point X on the image

Why genetic algorithms?

- Unpredictable shape of cost function
- Local minima failure by using:
  - Newton method
  - Levenberg-Marquardt(LM)
  - BGFS variable metric method

Genetic Algorithms[2][3]

Review

Theory Of Evolution

- Organisms evolve to fit into the environment
- Only the best individuals are kept by nature

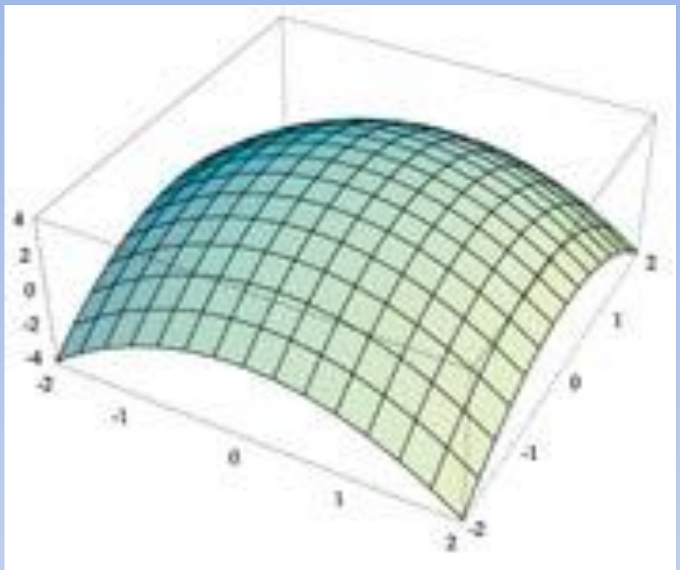
Oh seriously…

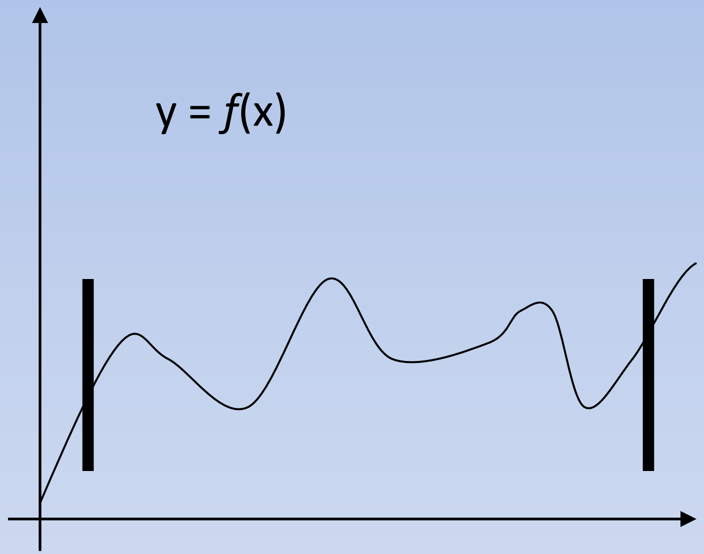
- From a set of random solutions only the best ones are picked

Purpose of Genetic Algorithms

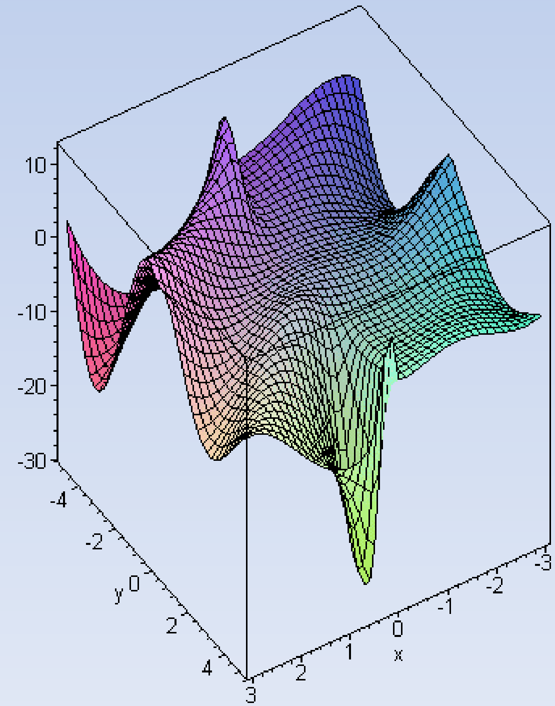
"Genetic Algorithms are good at taking ***large, potentially huge search spaces*** *and* ***navigating*** *them, looking for* ***optimal combinations of things****, solutions you might not otherwise find in a lifetime."*

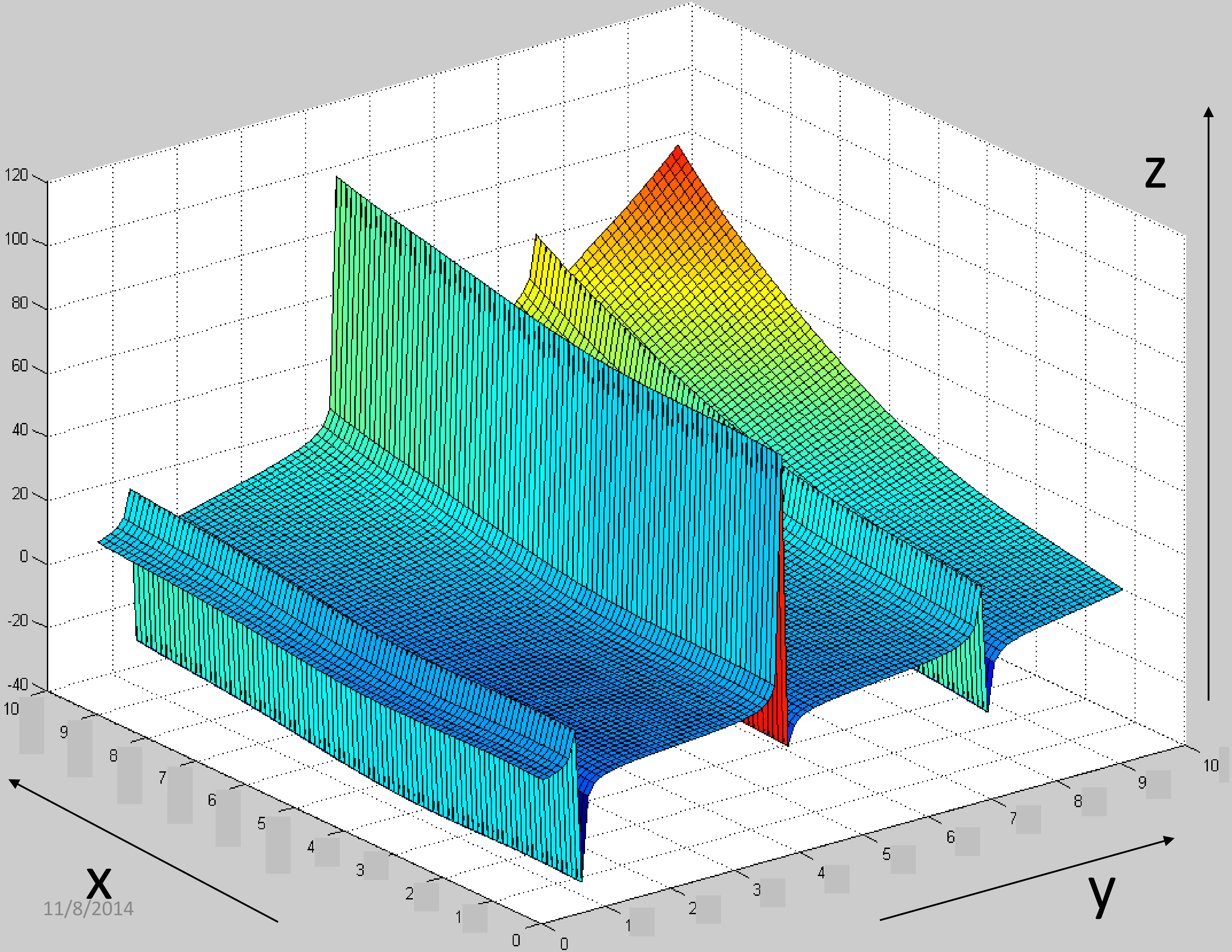
Example Problem I





Finding the maximum (minimum) of some function (within a defined range).




120
100
80
60
40
20
0
-20
-40
10
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
5
6
7
8
9
10
z
x
y

Problem?

- Numbers from 1..100
- Find the set of numbers that give a sum of 313

- Any ideas??

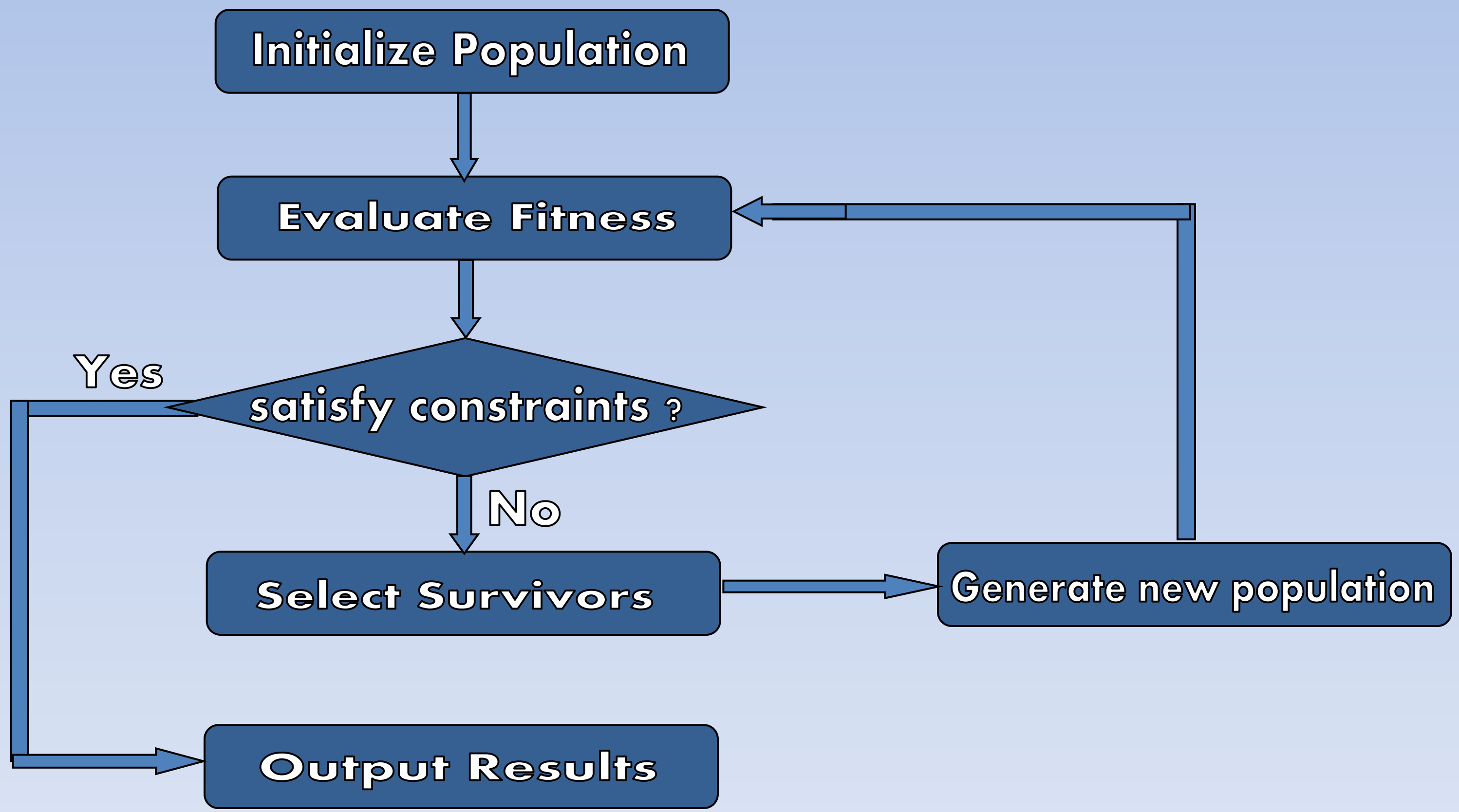
Genetics - Promo

- A **gene** is hereditary unit of inheritance
- Multiple **genes** are stringed together to form **chromosomes**
- A gene, if expressed in an organism in called a **trait**
- Offsprings **inherit** traits from their parents
- A gene may get **mutated** during mating process

How is the process done?

- Genetic algorithm (GA) introduces
  - the principle of evolution genetics into search among possible solutions to given problem
- To simulate the process in natural systems
- How: by the creation within a machine a population of individuals

Genetic Algorithms: Process



Parameters of GA

- Fitness Function
- Mechanism of selection
- Crossover
- Mutation

Fitness Function

- Evaluates how good an individual is
- Computes this for each individual in a population

- Fitness function is application dependent
- Examples: Mean squared error, Classification rate

Mechanism of Selection

- Parent/Survivor Selection
  - Roulette Wheel Selection
  - Tournament Selection
  - Rank Selection
  - Elitist Selection

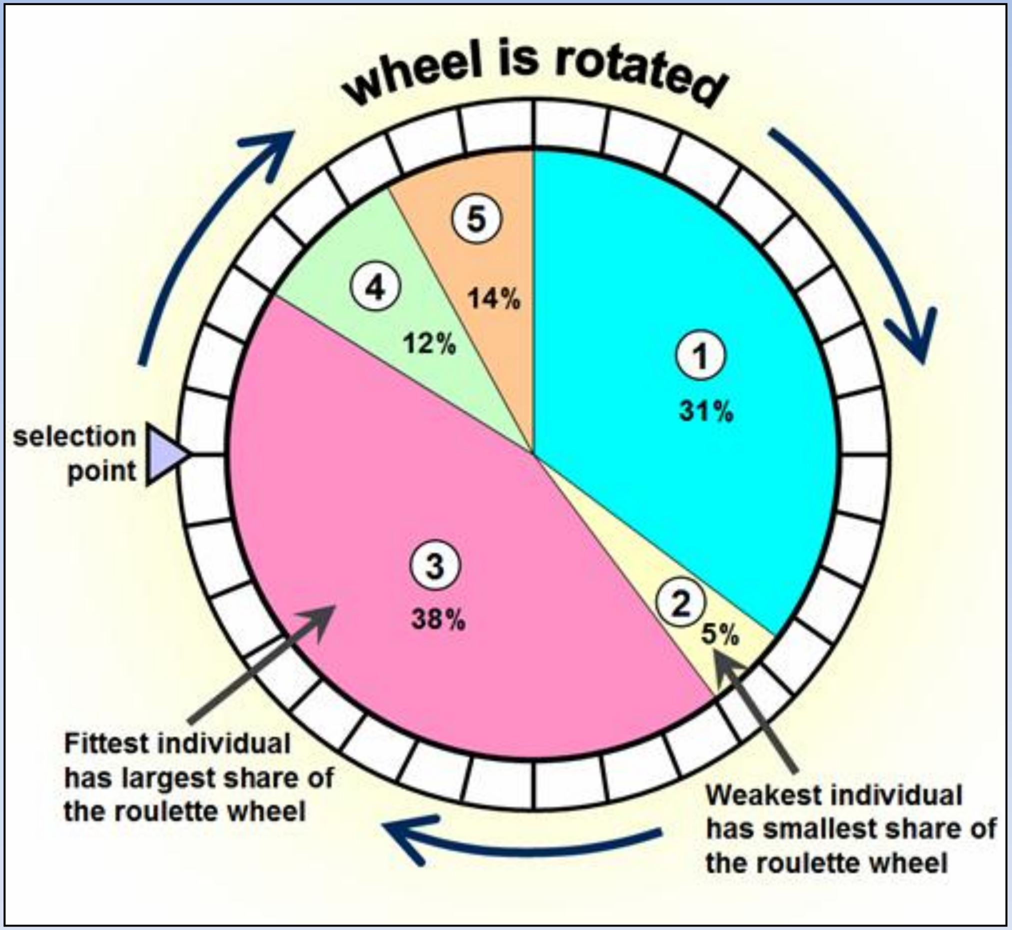
Roulette Wheel Selection

- **Main idea:** better individuals get higher chance
- Individuals are assigned a probability of being selected based on their fitness.

$$p_i = f_i / \Sigma f_j$$

  - p_i probability that individual i will be selected
  - f_i is the fitness of individual I
  - Σf_j represents the sum of all the fitness(s) of the individuals with the population

Roulette Wheel: Mechanism



Tournament Selection

- Binary tournament
  - Two individuals are randomly chosen; the fitter of the two is selected as a parent
- Larger tournaments
  - *n* individuals are randomly chosen; the fittest one is selected as a parent

Other Methods

- Rank Selection
  - Each individual in the population is assigned a numerical rank based on fitness, and selection is based on this ranking.

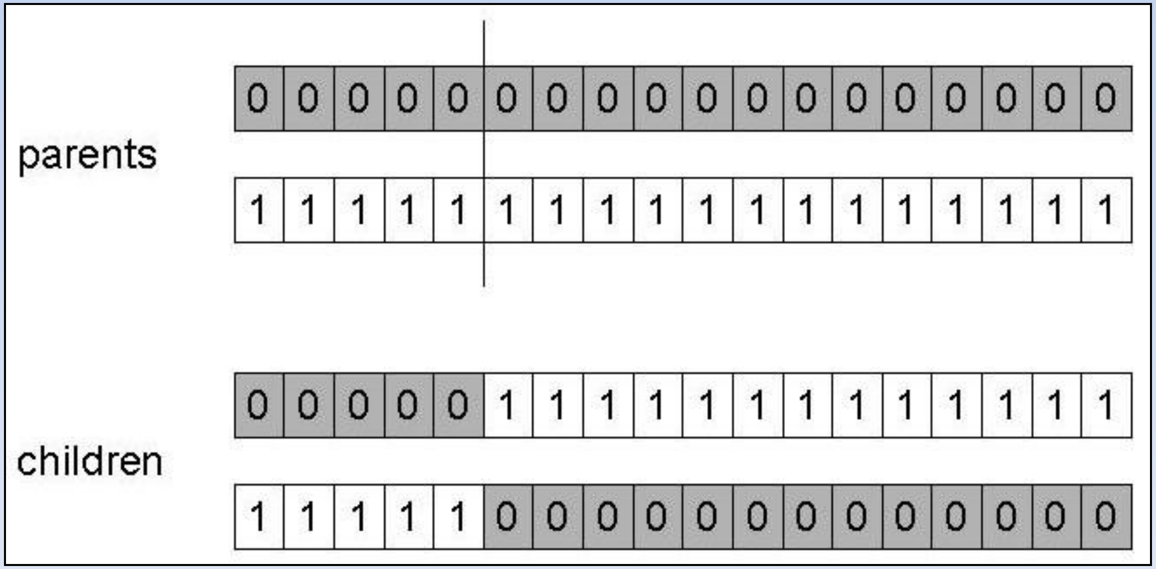
- Elitism
  - Reserve *k* slots in the next generation for the highest scoring/fittest chormosomes of the current generation

Crossover

- Generating offspring from two selected parents
  - Single point crossover
  - Two point crossover (Multi point crossover)
  - Uniform crossover

One Point Crossover

- Choose a random point on the two parents
- Split parents at this crossover point
- Create children by exchanging tails



One Point Crossover

- Choose a random point on the two parents
- Split parents at this crossover point
- Create children by exchanging tails

Parent 1:	**X X** | X X X X X
Parent 2:	Y Y | **Y Y Y Y Y**
Offspring 1:	**X X Y Y Y Y Y**
Offspring 2:	Y Y X X X X X

Uniform Crossover

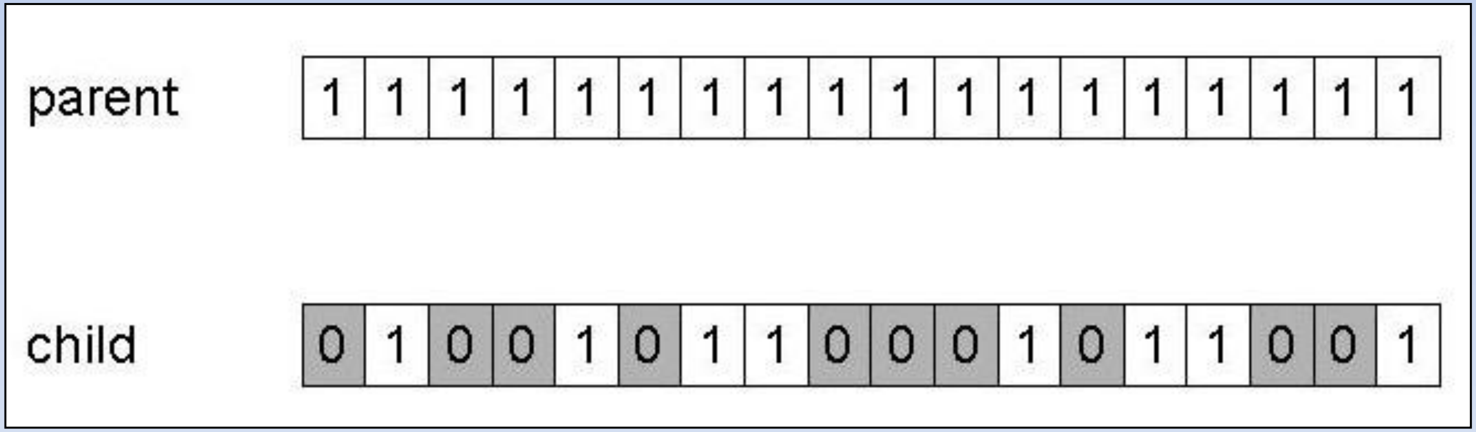
- A random mask is generated
- The mask determines which bits are copied from one parent and which from the other parent
- Bit density in mask determines how much material is taken from the other parent

```
Mask:        0110011000     (Randomly generated)
Parents:     1010001110     0011010010

Offspring:   0011001010     1010010110
```

Mutation

- Alter each gene independently with a probability p_m
- p_m is called the mutation rate



Summary – Reproduction cycle

- Select parents for producing the next generation
- For each consecutive pair apply crossover with probability p_c , otherwise copy parents
- For each offspring apply mutation (bit-flip with probability p_m)
- Replace the population with the resulting population of offsprings

How to solve cost?

$$C(P_1, P_2) = \frac{1}{|P|} \sum_{\boldsymbol{X} \in P} \left(I_1(P_1 \boldsymbol{X}) - I_2(P_2 \boldsymbol{X}) \right)^2$$

- P_1, P_2 are the projection matrices
- P is the number of points in 3D model
- $I(P\boldsymbol{X})$ is the color of point X on the image

Initial Settings for GA[1]

- Initial estimation of projection matrices by manual registration
- This acts as initial population of the genetic algorithm

Pipeline for Images to 3D Models

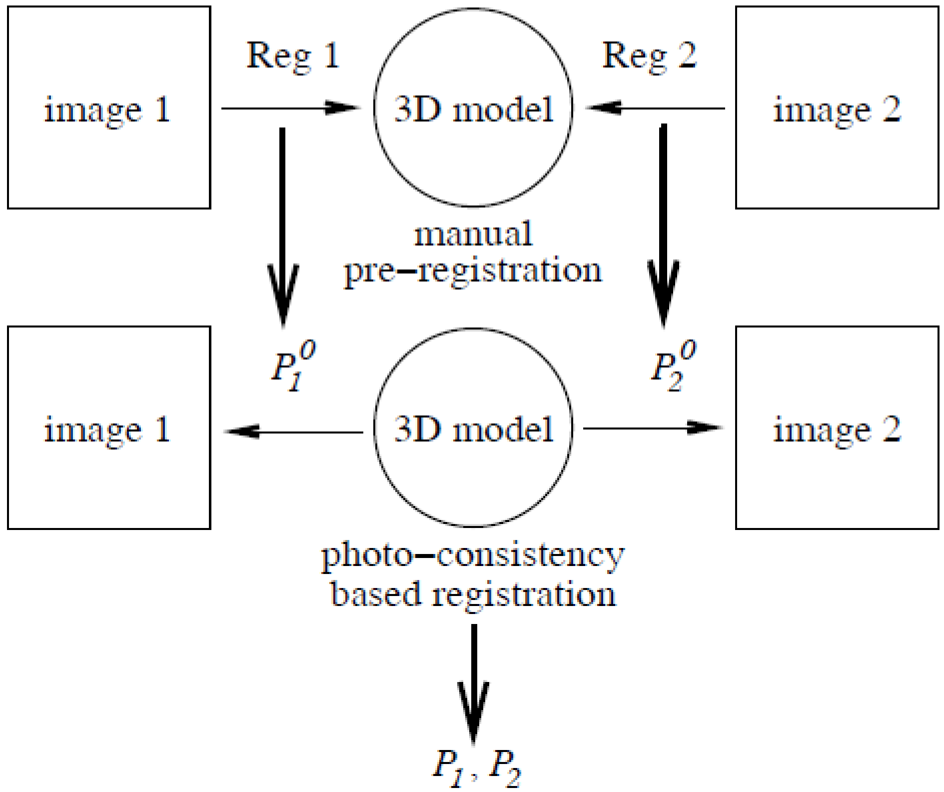
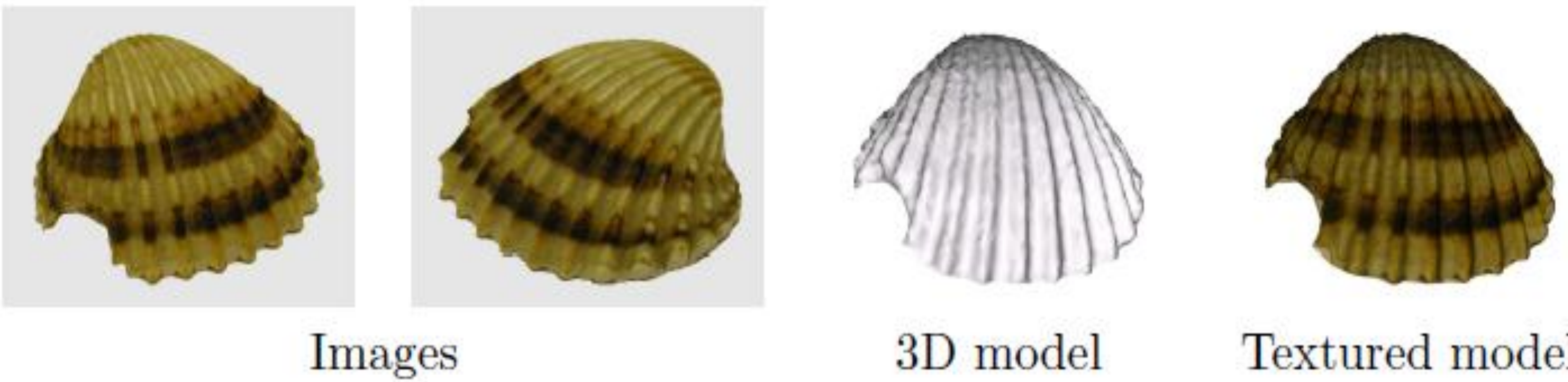
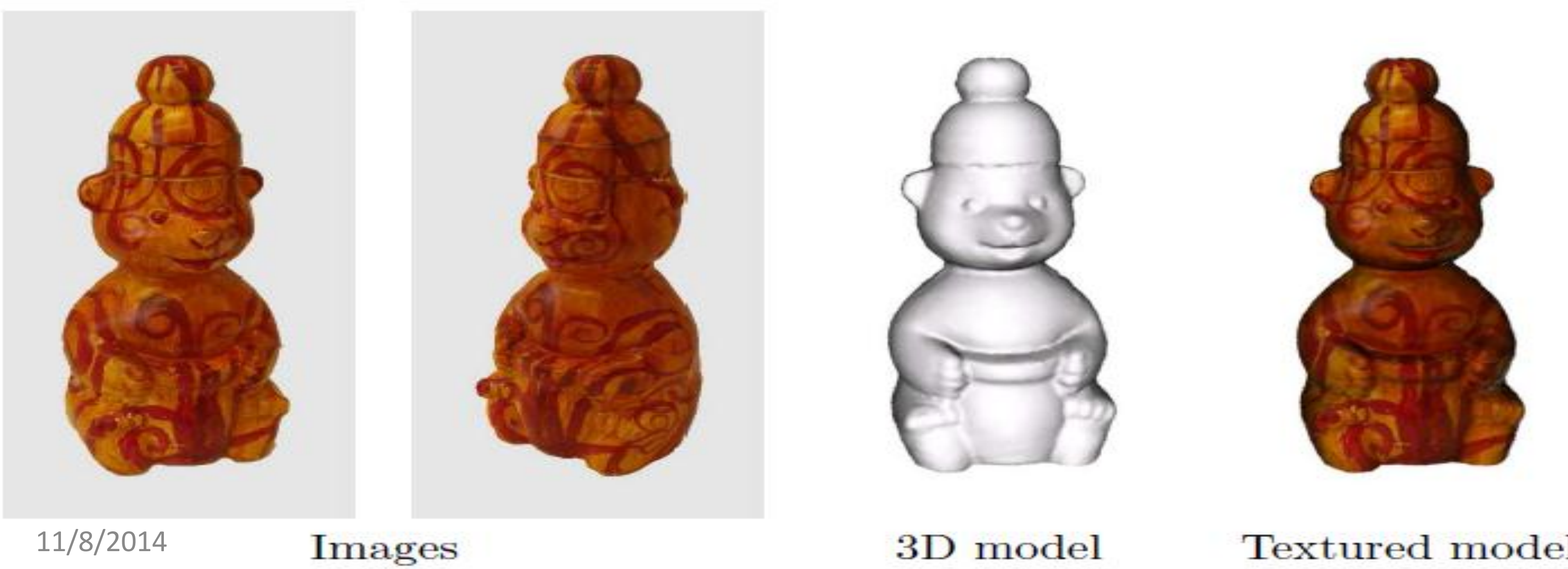


Figure 2: Block-diagram of proposed method.

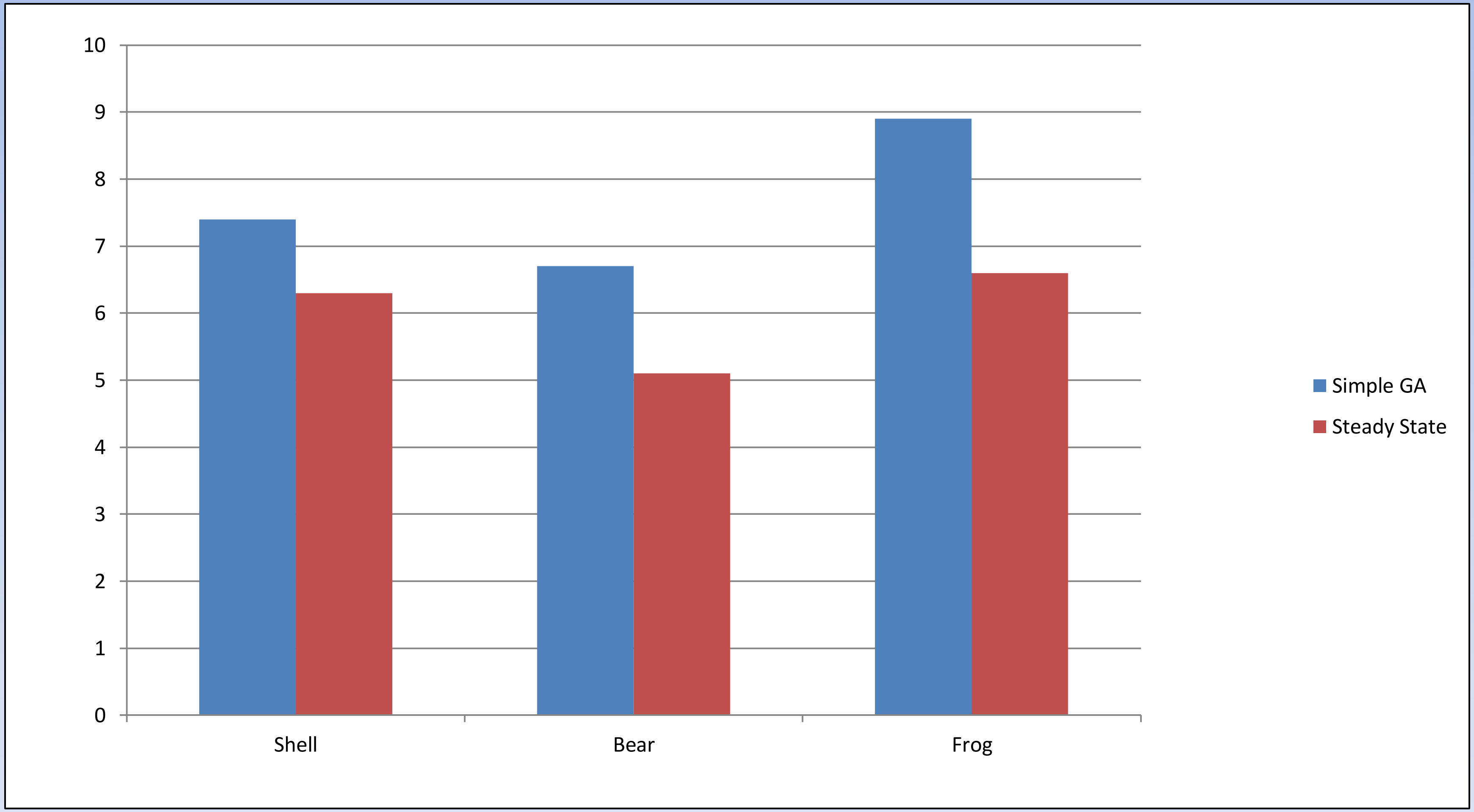
Results


Images
3D model
Textured model

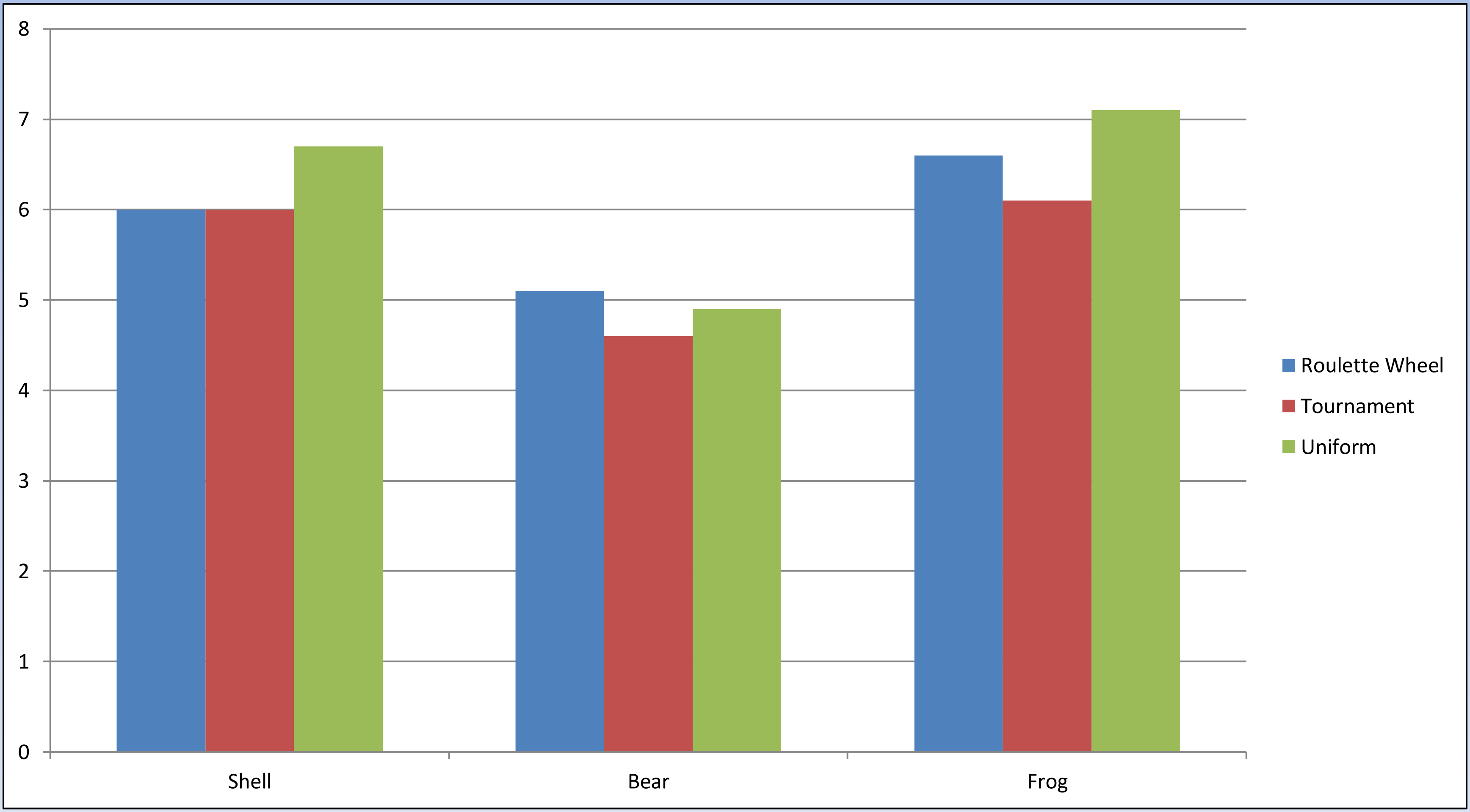

Images
3D model
Textured model

Results

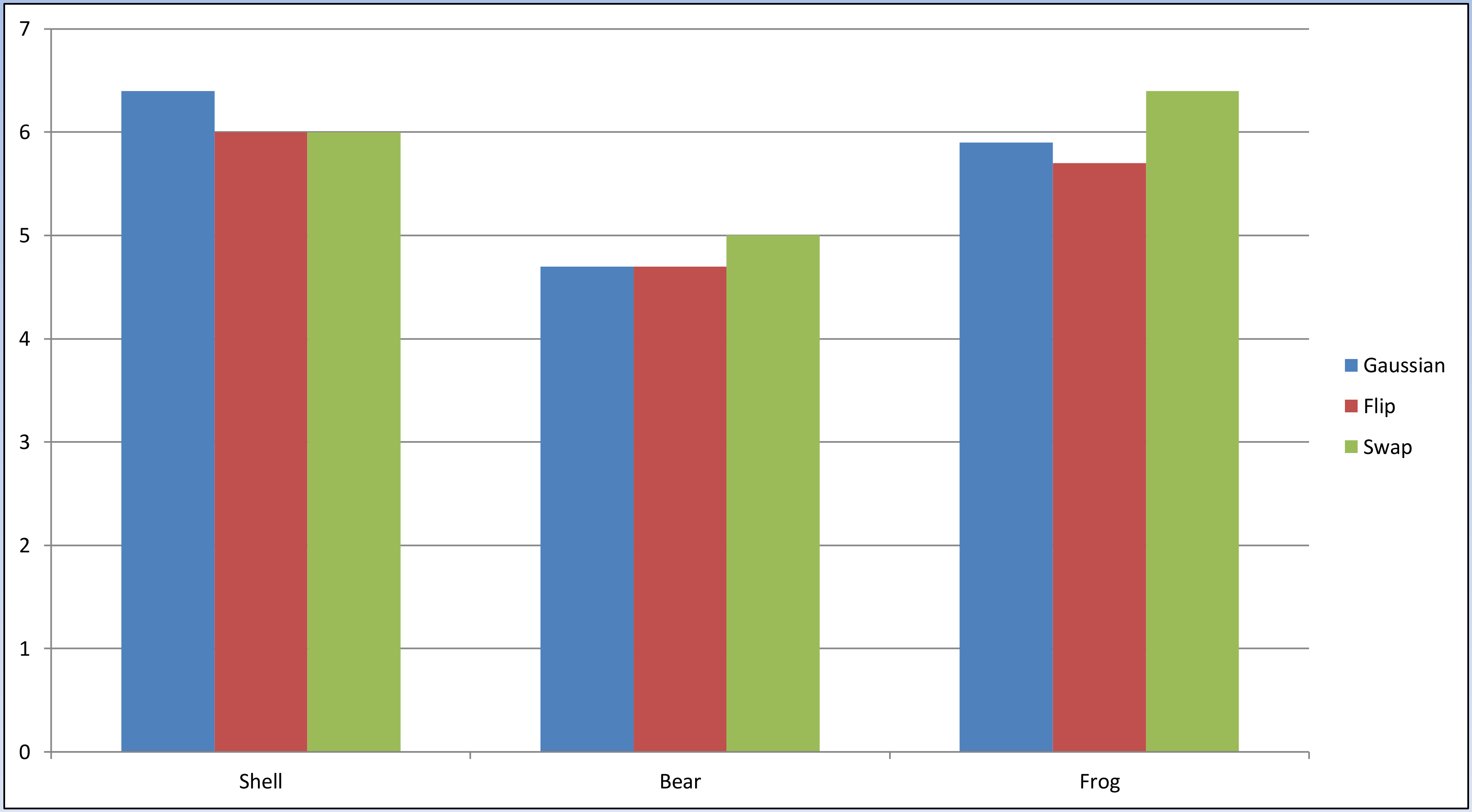
Discussions: Preservation



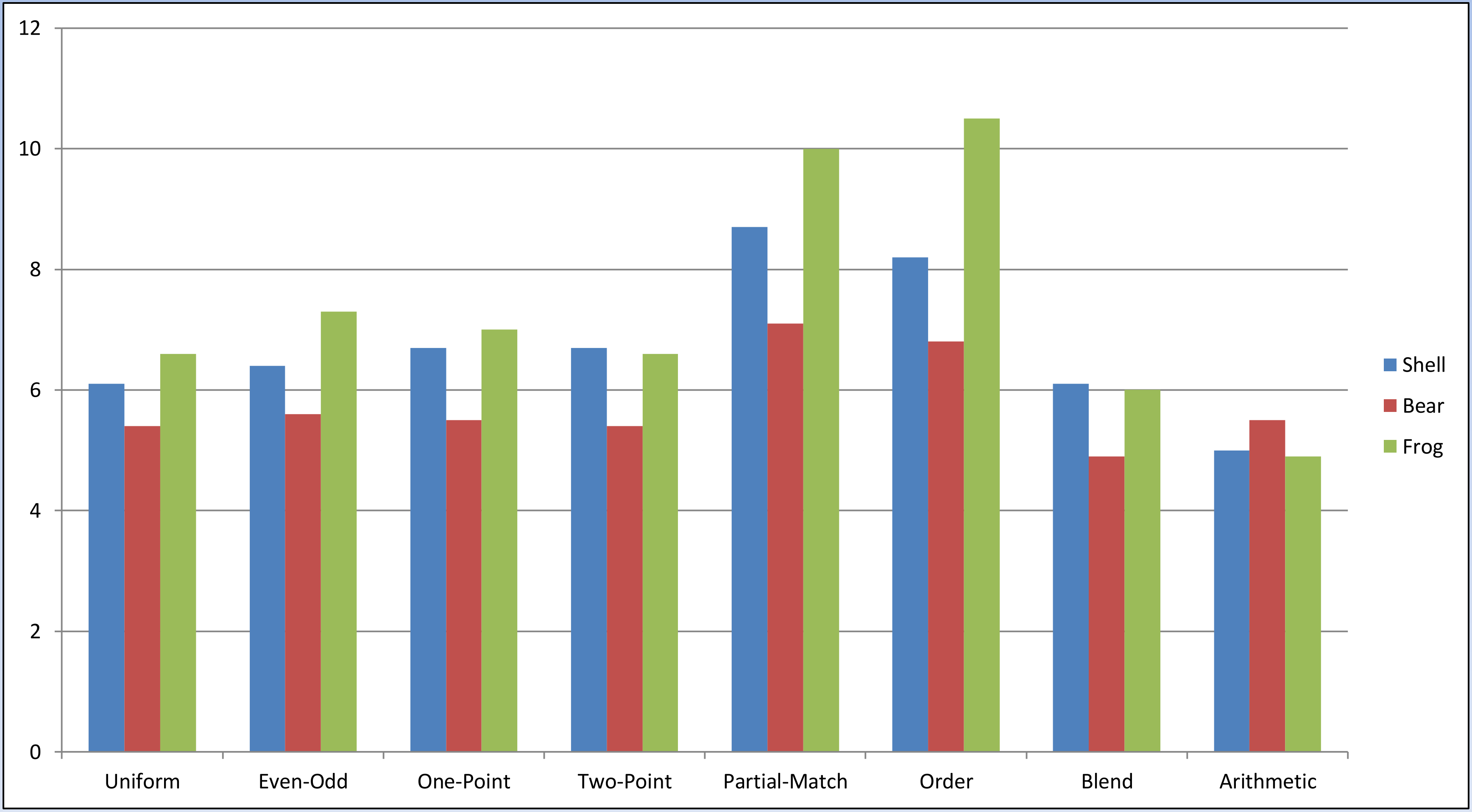
Discussions: Selections Criteria



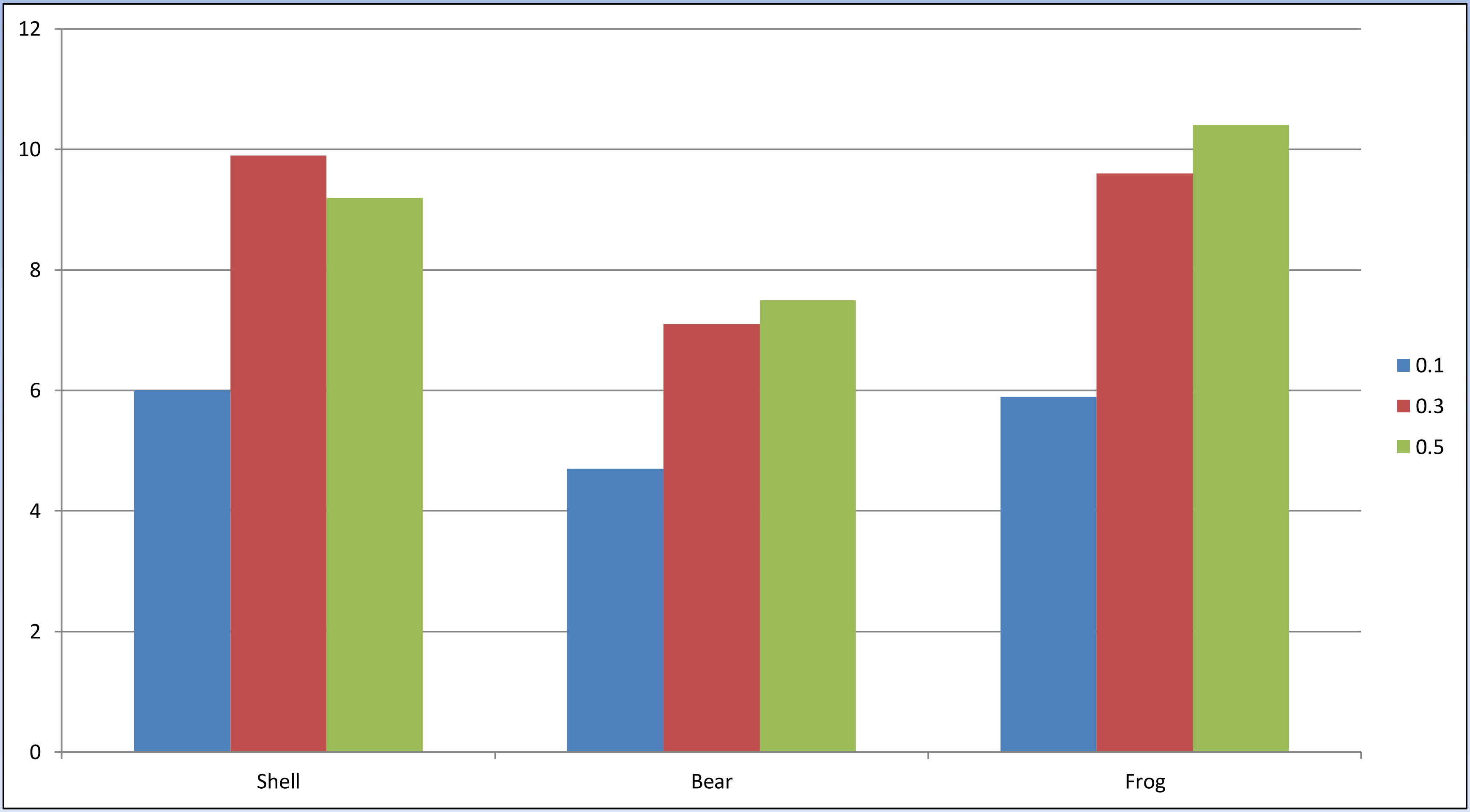
Discussions: Mutations



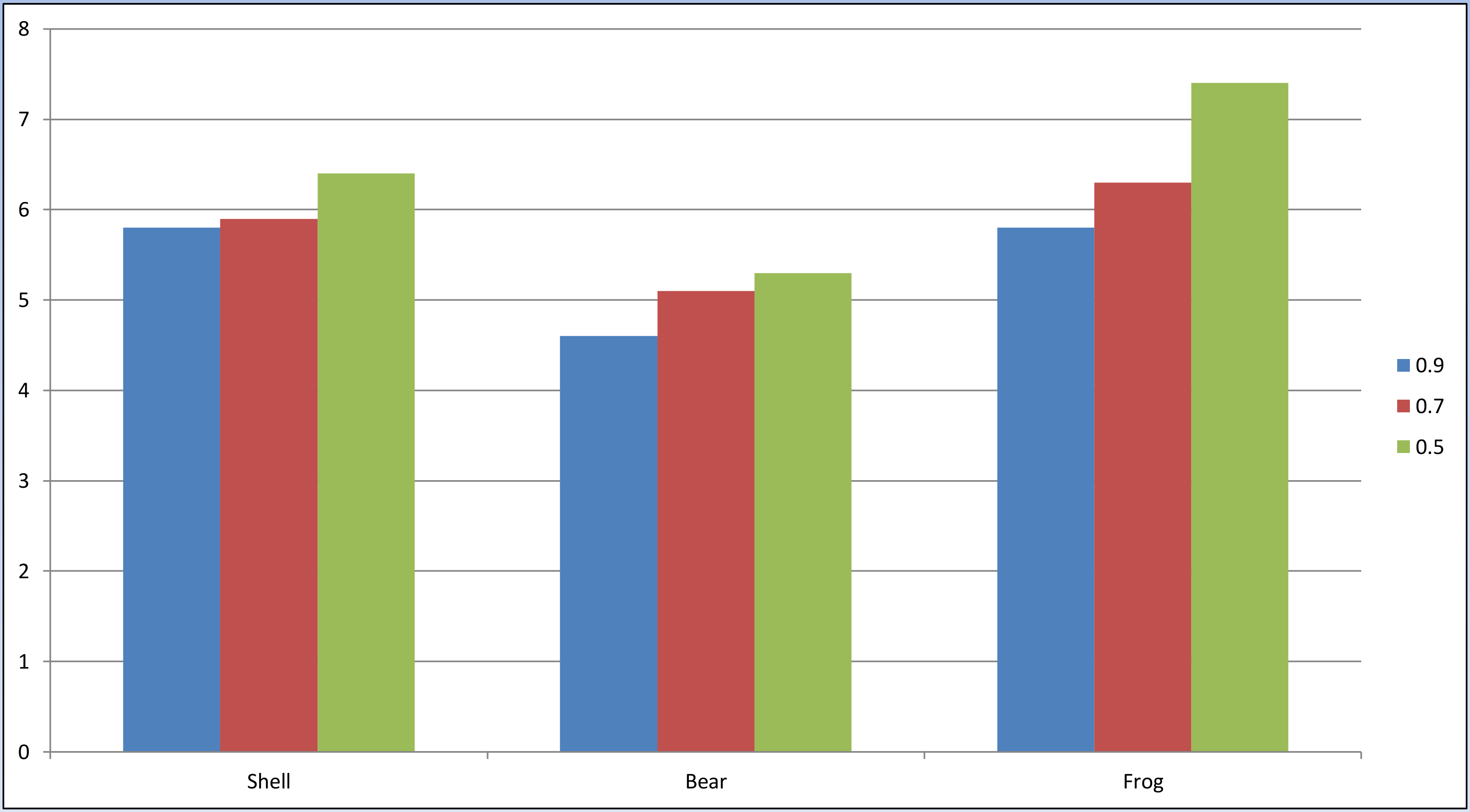
Discussions: Crossover



Discussions: P(Mutation)



Discussions: P(CrossOver)



Summary

- Genetic Algorithms useful for solving optimization problems
- Four elements:
  - Fitness Function
  - Mechanism of Selection
  - Crossover Mechanism and Frequency
  - Mutation Mechanism and Frequency
- Important! Problem representation for GA

Bibliography

1. Janko, Z., Chetverikov, D., Ekart, A., *Using Genetic Algorithms in Computer Vision: Registering Images to 3D Surface Model,* Acta Cybernetica, 2007.
2. Eiben, A., Smith, J., *Introduction to Evolutionary Computing*, Springer, 2008.
3. http://www.cs.cmu.edu/afs/cs/project/theo-20/www/mlbook/ch9.pdf

Questions