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CS 581 Spring 2024 Written Assignment #01

Due: **Saturday, February 10, 2024, 11:59 PM CST**
Points: **30**

Instructions:

1. Use this document template to report your answers. Name the complete document as follows:

`LastName_FirstName_CS581_Written01.doc`

(only MS Word or PDF files accepted!)

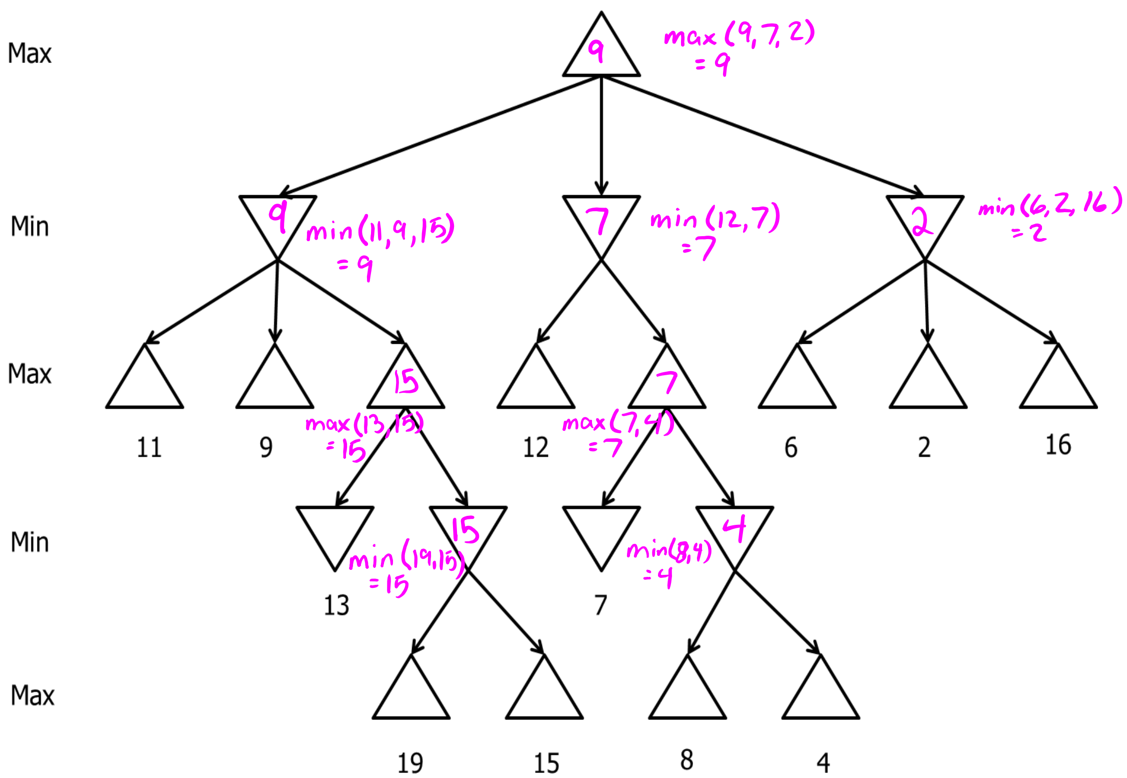
2. Submit the final document to Blackboard Assignments section before the due date. No late submissions will be accepted.

Objectives:

1. (10 points) Demonstrate your understanding of MiniMax search algorithm,
2. (10 points) Demonstrate your understanding of A* search algorithm,
3. (10 points) Demonstrate your understanding of a basic Genetic Algorithm.

Problem 1 [5 pts]:

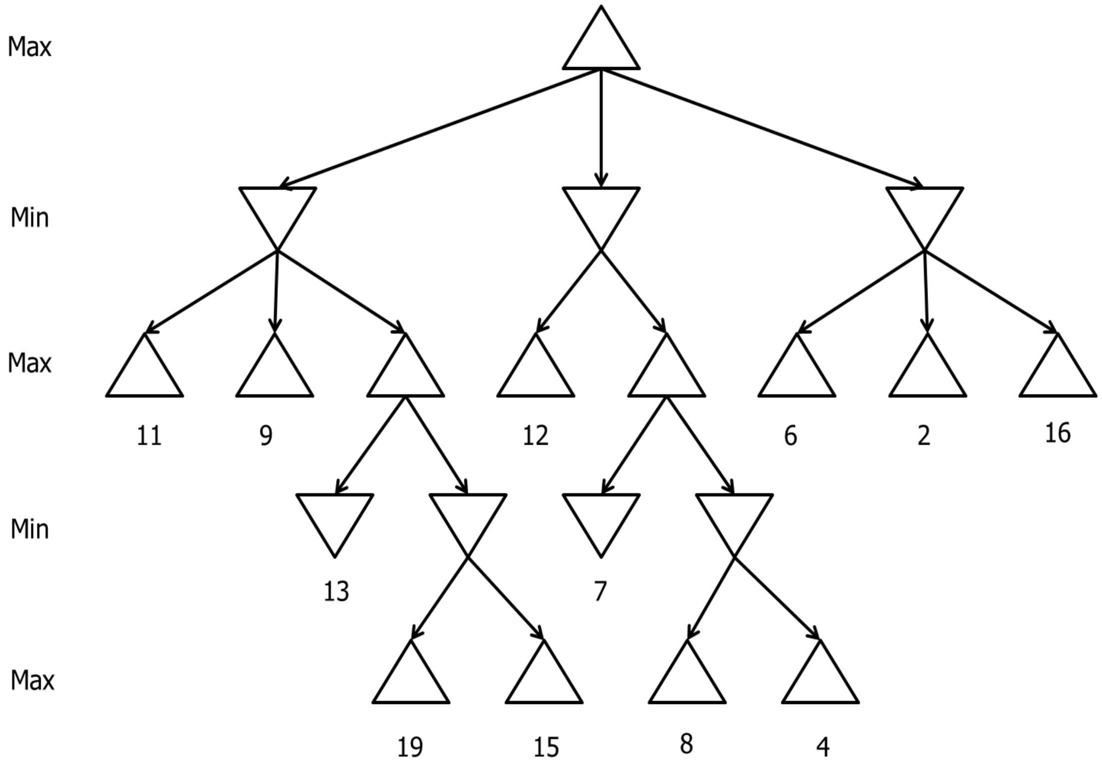
Apply MiniMax algorithm on the following game tree. What is the maximum utility that MAX can achieve, assuming MIN plays optimally?

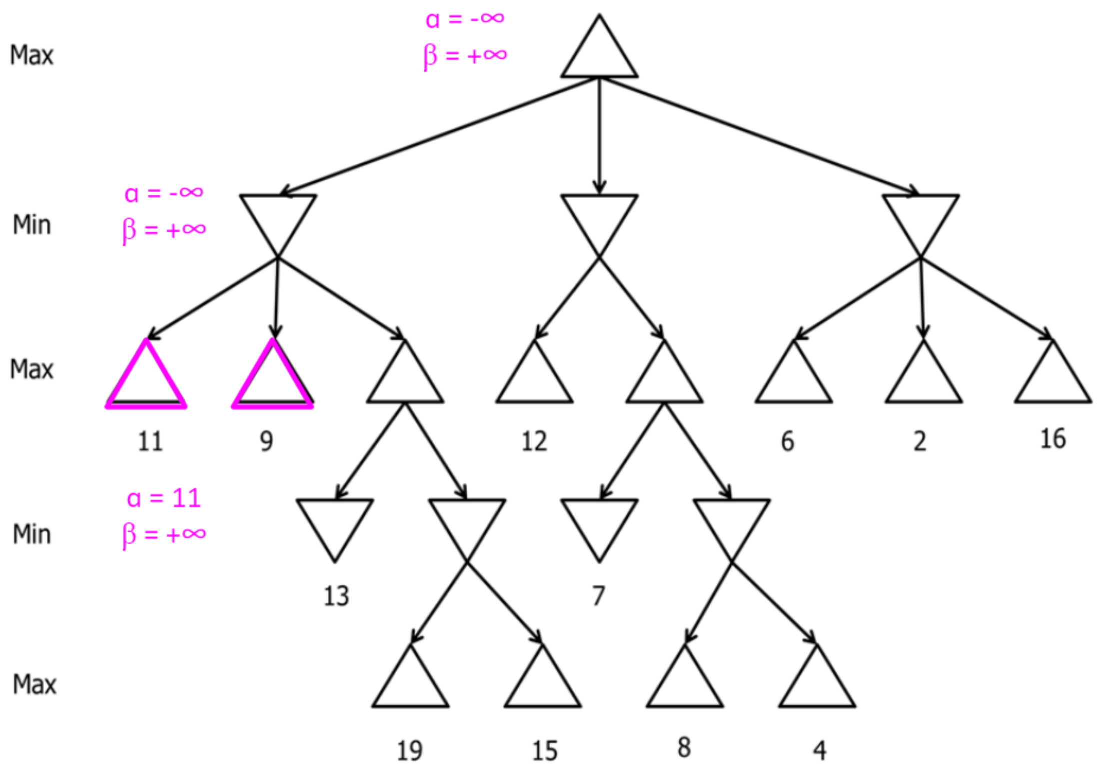


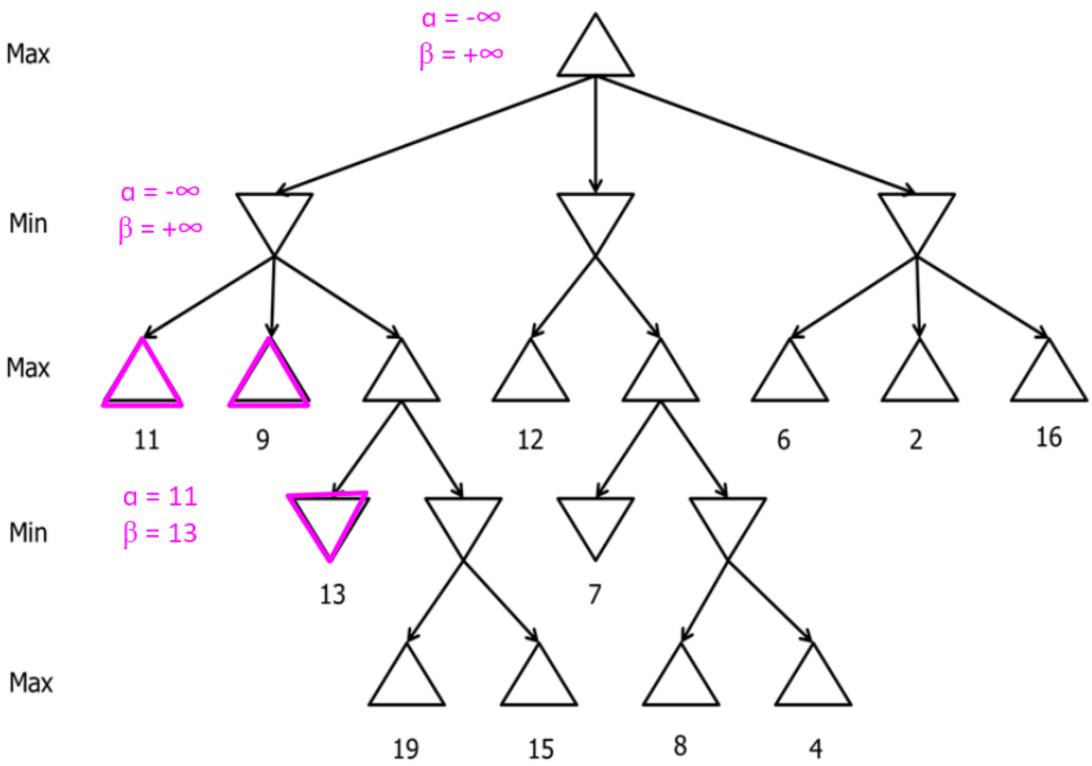
Maximum utility: 9

Problem 2 [5 pts]:

This is the same game as in Problem 1. Hand trace the alpha-beta search. Show the updated bounds on the nodes. Clearly mark which branches are pruned, if any.



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β = +∞
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β = 13
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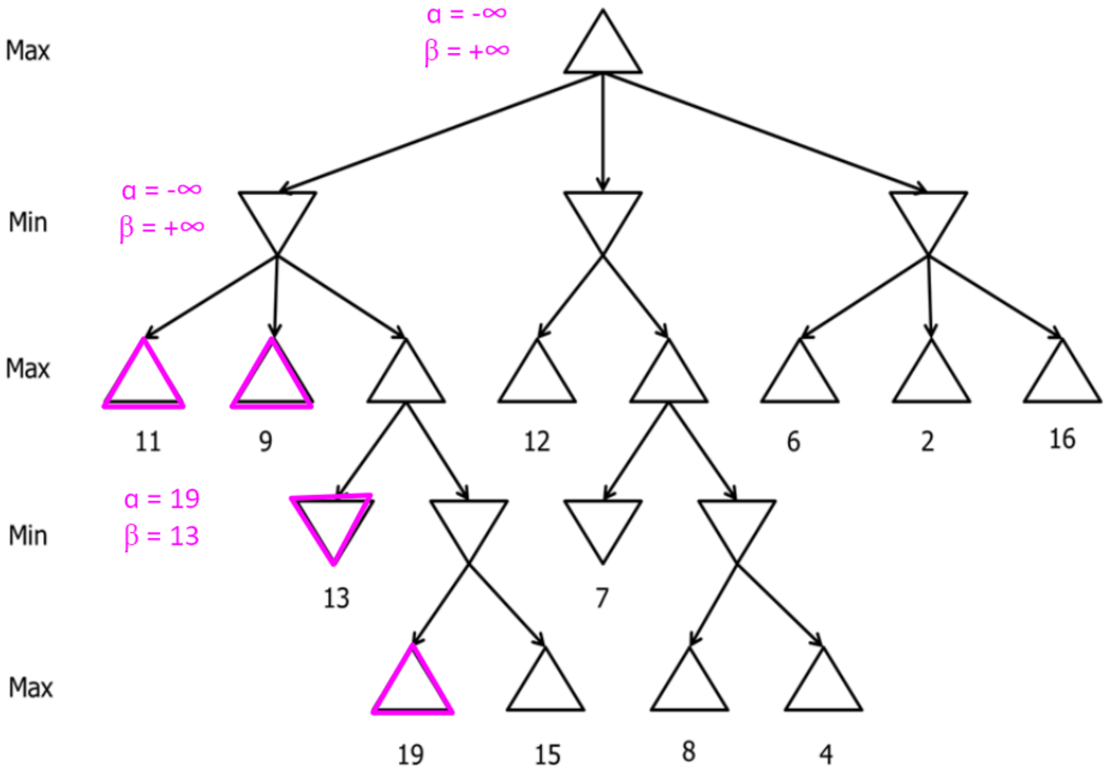
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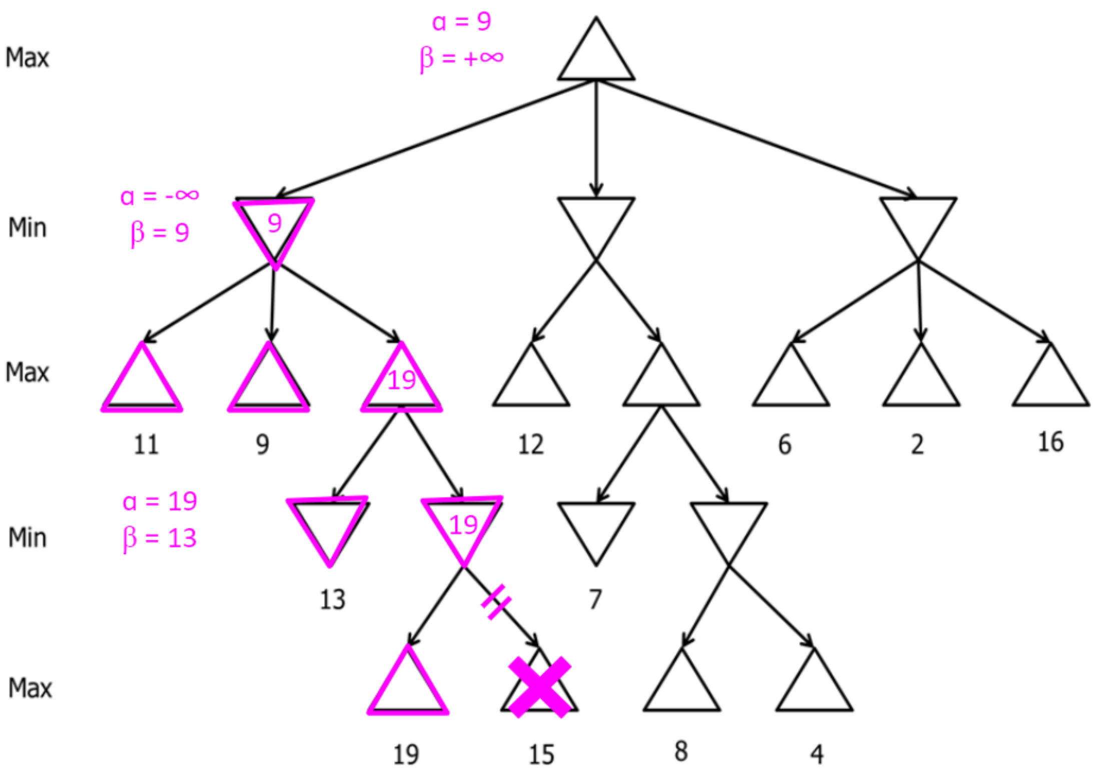
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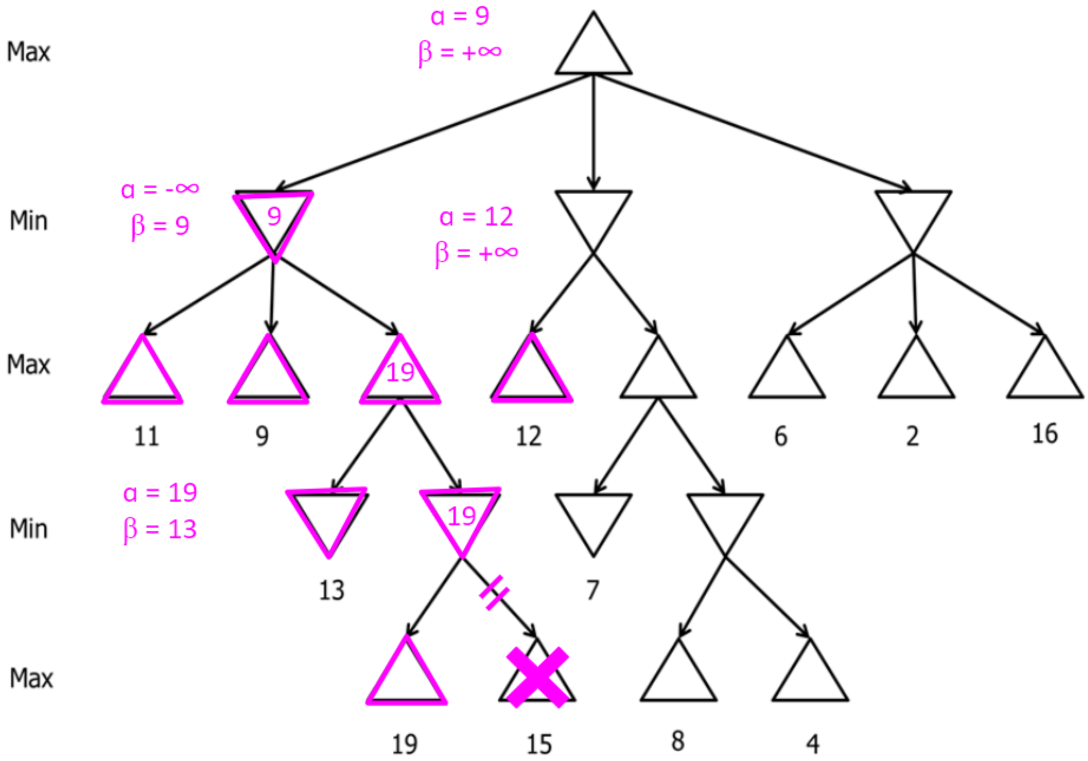
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β = +∞
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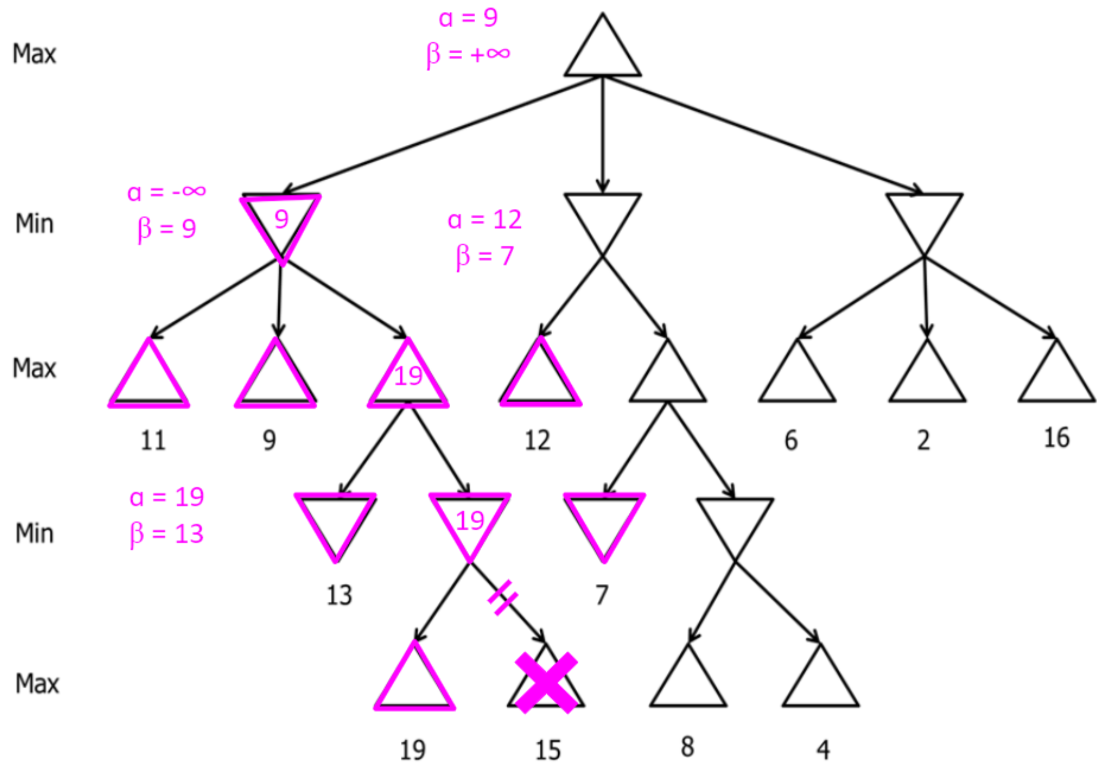

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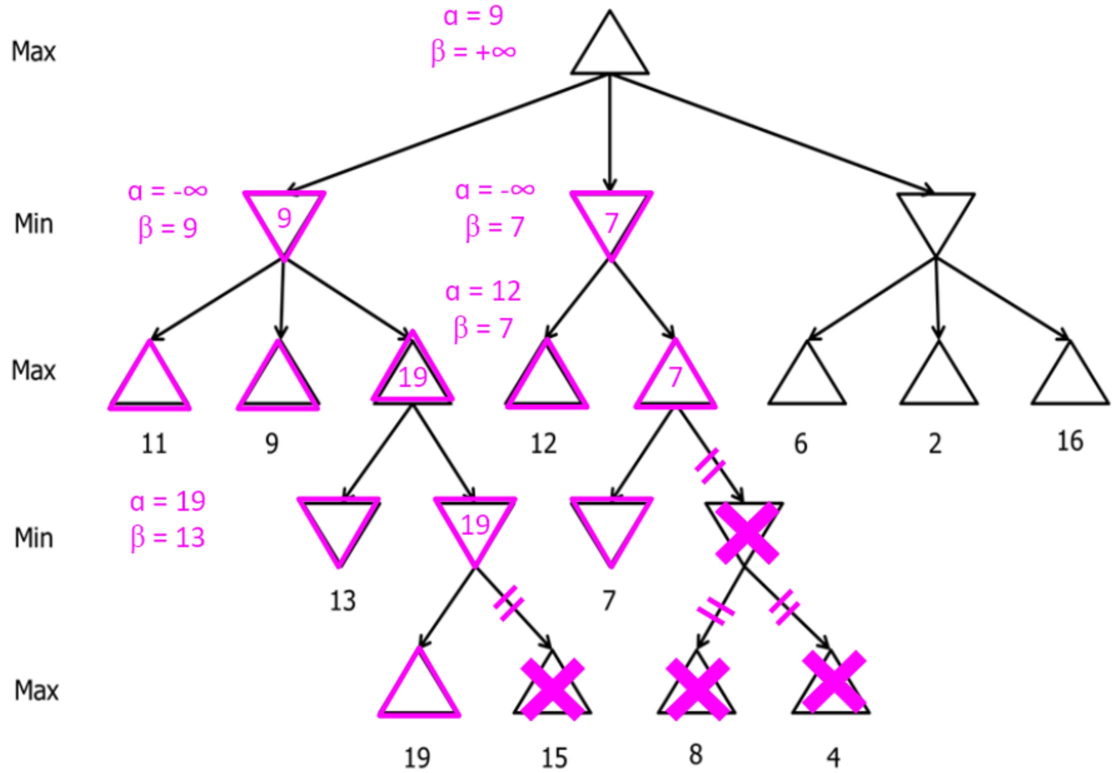

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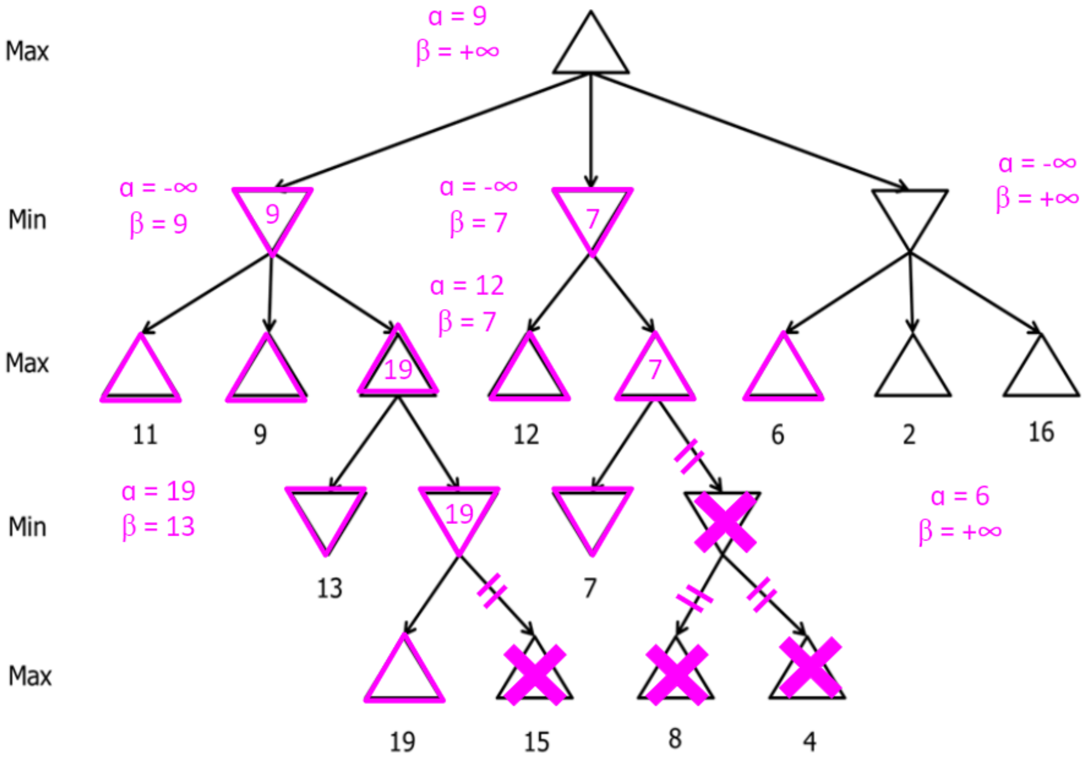

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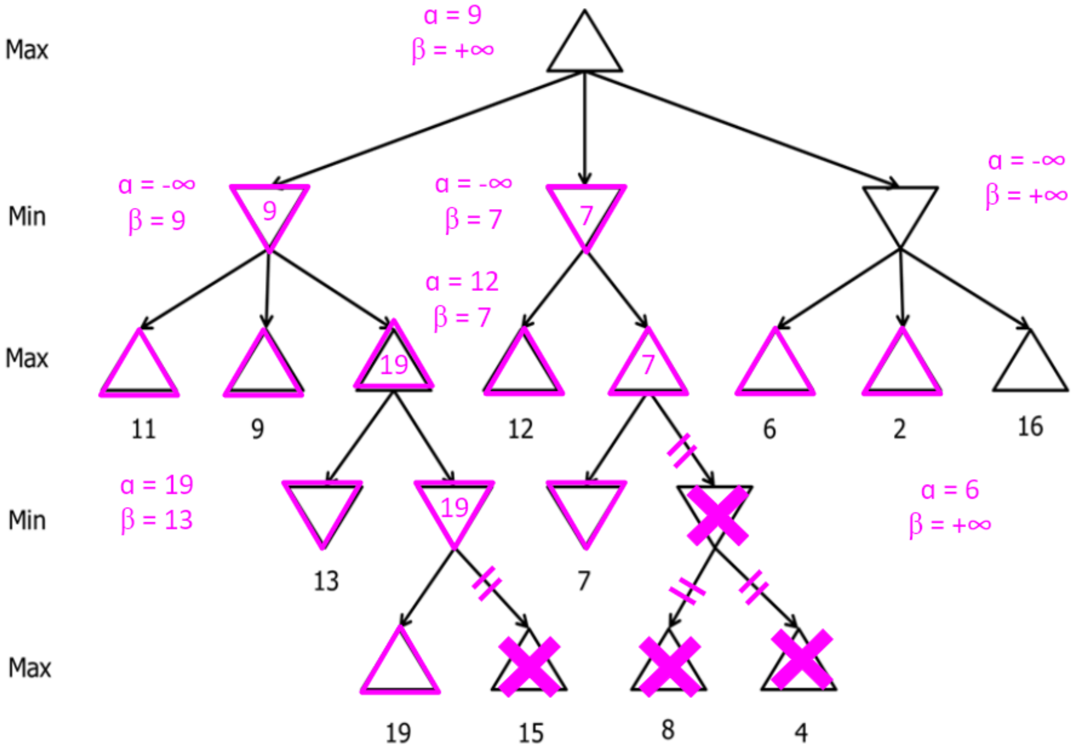

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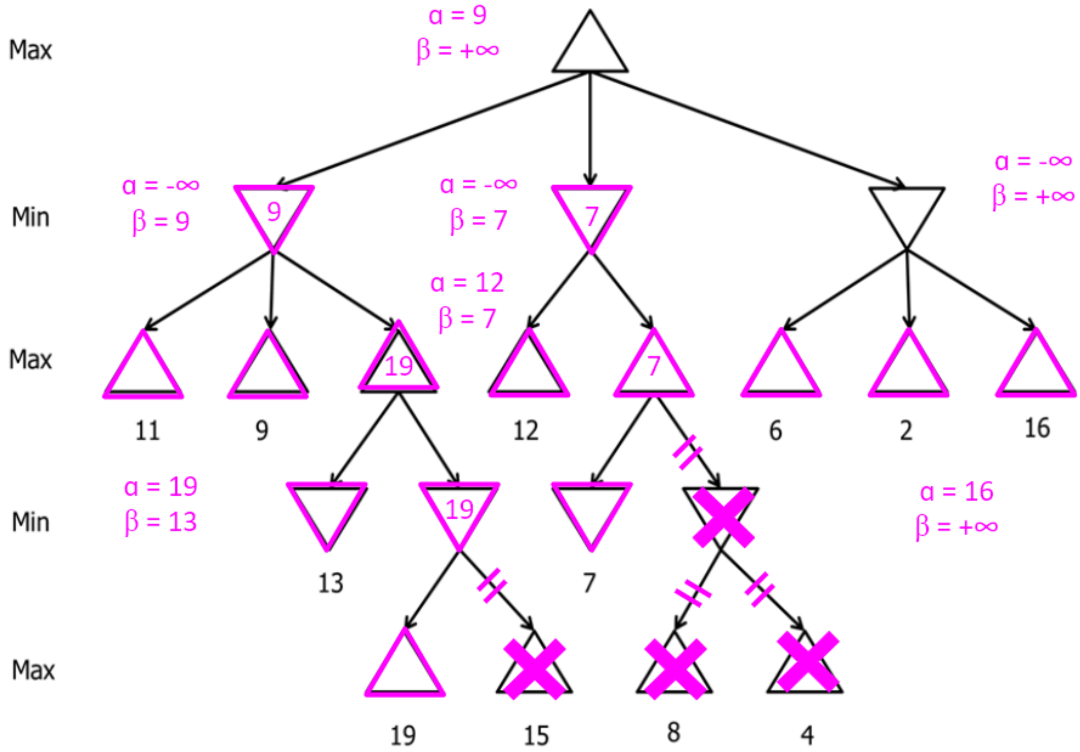
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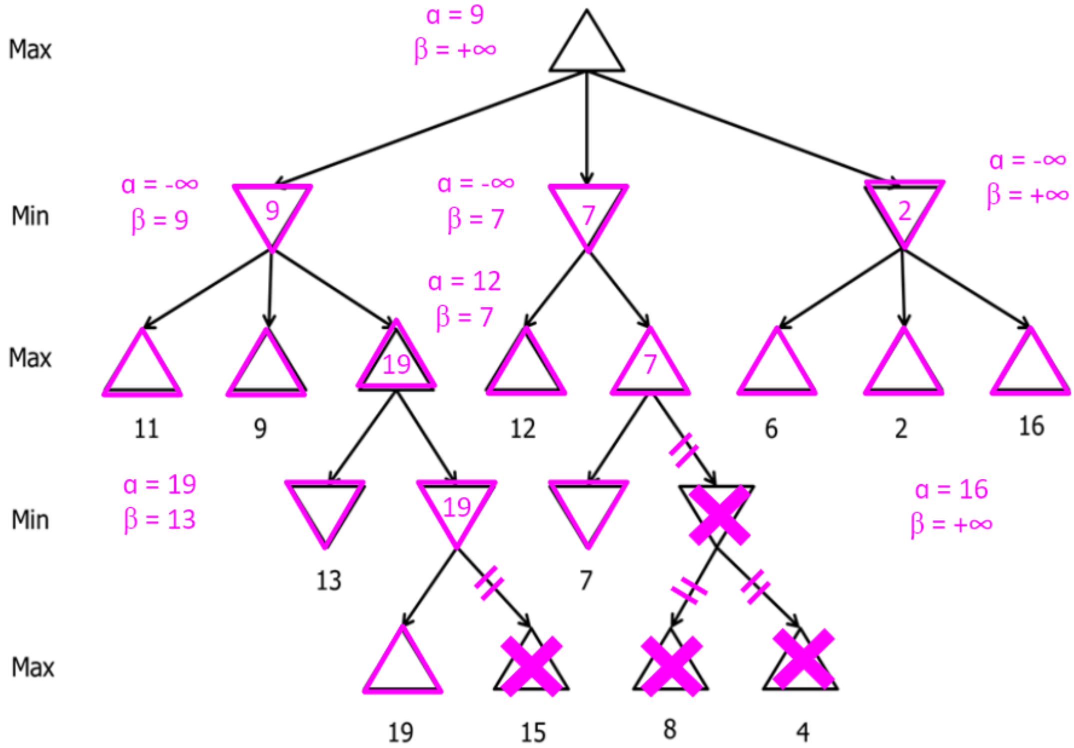
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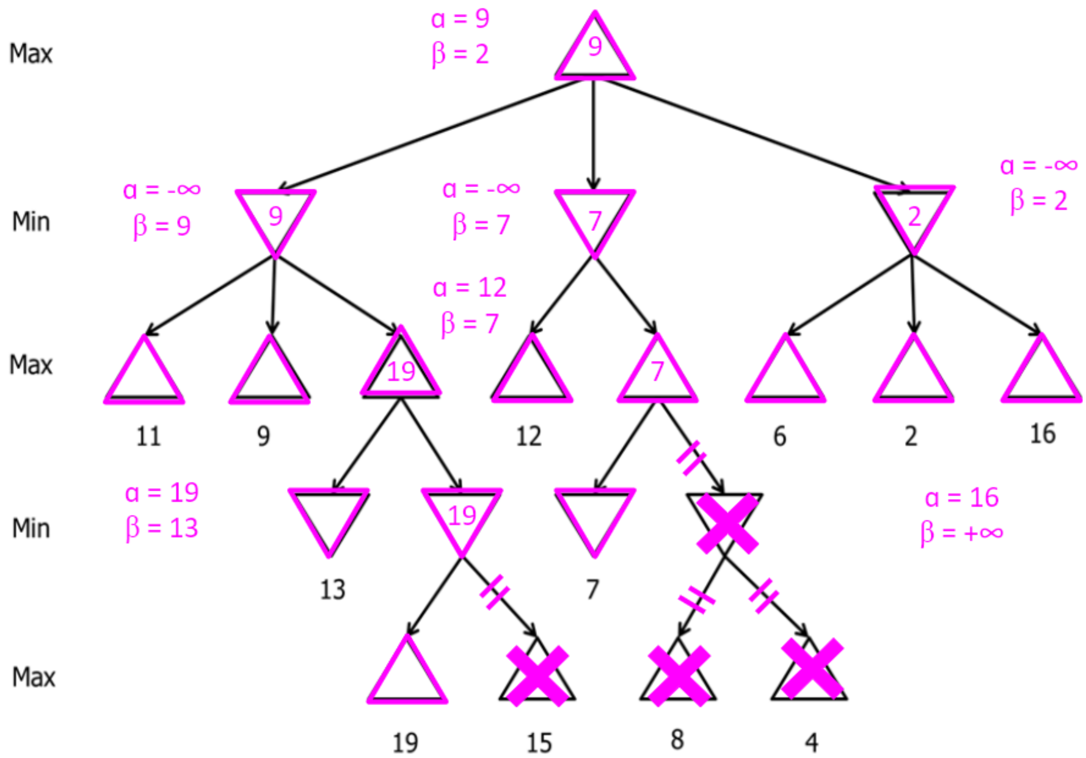
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α = 19
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α = 16
β = +∞
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Problem 3 [10 pts]:

Consider the following problem **state space** (undirected and weighted) graph (fig. 1) representing a map with cities (vertices) and roads (maps).

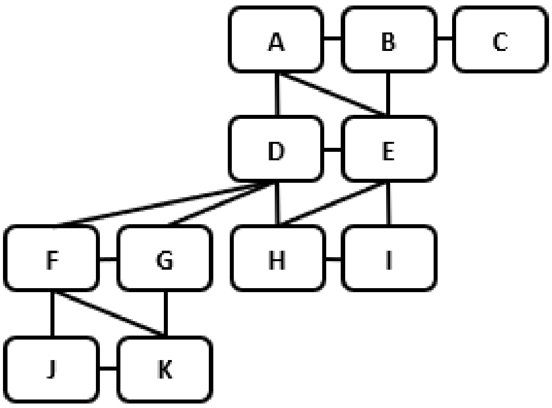


Figure 1: Problem state space ("cities and roads").

The table (Table 1) below provides adjacency matrices for the state space graph above (Driving distances) and a corresponding (but not shown) straight-line distances graph. Data in matrices represents action host and heurisitic function value, respectively.

a) Driving distances

	H	**K**	**E**	**J**	**C**	**B**	**G**	**D**	**F**	**I**	**A**
H	0	0	102	0	0	0	0	114	0	87	0
K	0	0	0	64	0	0	112	0	129	0	0
E	102	0	0	0	0	68	0	170	0	50	180
J	0	64	0	0	0	0	0	0	112	0	0
C	0	0	0	0	0	164	0	0	0	0	0
B	0	0	68	0	164	0	0	0	0	0	116
G	0	112	0	0	0	0	0	205	127	0	0
D	114	0	170	0	0	0	205	0	293	0	158
F	0	129	0	112	0	0	127	293	0	0	0
I	87	0	50	0	0	0	0	0	0	0	0
A	0	0	180	0	0	116	0	158	0	0	0

b) Straight-line distances

	H	**K**	**E**	**J**	**C**	**B**	**G**	**D**	**F**	**I**	**A**
H	0	234	93	278	229	116	151	82	242	66	172
K	234	0	322	53	463	348	84	258	105	284	384
E	93	322	0	368	149	63	242	139	335	41	152
J	278	53	368	0	505	390	126	291	91	332	417
C	229	463	149	505	0	116	380	230	458	191	138
B	116	348	63	390	116	0	265	119	342	96	89
G	151	84	242	126	380	265	0	176	113	206	301
D	82	258	139	291	230	119	176	0	231	133	126
F	242	105	335	91	458	342	113	231	0	305	353
I	66	284	41	332	191	96	206	133	305	0	178
A	172	384	152	417	138	89	301	126	353	178	0

Table 1: Adjacency matrices for the problem.

Your task: Apply the **A* Search** algorithm to the problem with following initial/goal states:

initial state (IS): F **goal state (GS): I**

Show how the tree search develops:

- assume that **root node (corresponding to F) was already dequeued from the frontier** (see updated Reached structure below) and is ready to be expanded,
- **show the search tree after first TWO (2) expansions,**
- **show changes in the frontier and reached/visited structures BEFORE AND AFTER EVERY NODE EXPANSION**

Frontier structure [front ← rear]												
Parent	F											
State	G											
f()	333											

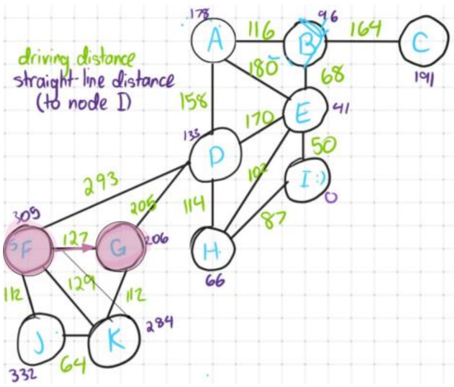
Reached / visited												
Parent	-	F	G	D	H							
State	F	G	D	H	I							
distance from IS	0	206	133	66	0							

Show your work below (make sure it is legible)

Search Tree diagrams + structures

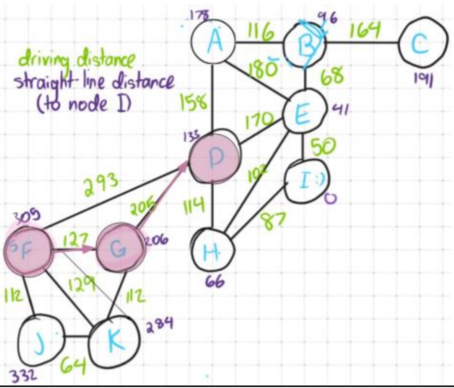
After expanding F

	Node	Value
Active	G	333
	K	413
	D	426
	J	444
Visited	F	305



After expanding G

	Node	Value
Active	D	465
	K	413
	J	444
Visited	F	305
	G	333



Problem 4 [10 pts]:

You are solving an optimization problem using a basic Genetic Algorithm. Algorithm parameters are:

- Individual representation:
  - binary with 16th bits,
  - first 8 bits correspond to a $base_2$ (binary) encoding of $base_{10}$ variable ("gene") X value,
  - second 8 bits correspond to a $base_2$ (binary) encoding of $base_{10}$ variable ("gene") Y value,
- Population size N = 6,
- Fitness function:

$$f(X,Y) = -(X^2 + Y^2) + 28000$$

- Selection mechanism:
  - order individuals according to their fitness in **descending order** (in case of ties: the individual that was first in unordered population goes first here as well)
  - offspring is created by pairing two subsequent parents with "wraparound":
    - $parent_1 + parent_2 \rightarrow child_1$,
    - $parent_2 + parent_3 \rightarrow child_2$,
    - ….,
    - $parent_{N-1} + parent_N \rightarrow child_N$,
    - $parent_N + parent_1 \rightarrow child_N$
- Probability of crossover $P_c = 1$,
- Crossover mechanism: 2-point crossover with crossover points after the 4th and 12th bit (counting from the left),
- Probability of mutation $P_m = 0$.

Your initial population is shown below:

Generation 1																
Individual 1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
Individual 2	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
Individual 3	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1
Individual 4	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0
Individual 5	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Individual 6	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Generation 1 Evaluation				
Individual	**X**	**Y**	**Fitness**	**Fitness ratio [%]**
Individual 1	255	0	0	0.00%
Individual 2	0	255	0	0.00%
Individual 3	240	15	7,200	9.97%
Individual 4	15	240	7,200	9.97%
Individual 5	85	85	50,575	70.05%
Individual 6	170	170	7,225	10.01%

Now, apply the Genetic Algorithm specified above. Stop after Generation 4 is created and evaluated:

- populate and show Generation and Generation Evaluation tables every time a new generation is created,
- generate Fitness = f(Generation) plot. It is enough to plot best individual of the generation's fitness.

Generation 2																
Individual 1	0	1	0	1	1	0	1	0	1	0	1	0	0	1	0	1
Individual 2	1	0	1	0	0	1	0	1	0	1	0	1	1	0	1	0
Individual 3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Individual 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Individual 5	0	1	0	1	0	0	0	0	1	1	1	1	0	1	0	1
Individual 6	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1

	X	Y	Fitness	Fitness (Scaled)	Fitness ratio [%]
1	90	165	-7,325	94,725	20.42%
2	165	90	-7,325	94,725	20.42%
3	255	255	-102,050	0	0.00%
4	0	0	28,000	130,050	28.03%
5	240	240	-87,200	14,850	3.20%
6	15	15	27,550	129,600	27.93%

Generation 3																
Individual 1	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
Individual 2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Individual 3	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Individual 4	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Individual 5	0	1	0	1	1	1	1	1	1	1	1	1	0	1	0	1
Individual 6	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1

	X	Y	Fitness	Fitness (Scaled)	Fitness ratio [%]
1	15	0	27,775	122,400	25.97%
2	0	15	27,775	122,400	25.97%
3	85	85	13,550	108,175	22.95%
4	170	170	-29,800	64,825	13.75%
5	95	245	-41,050	53,575	11.37%

6	240	255	-94,625	0	0.00%

Generation 4																
Individual 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Individual 2	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
Individual 3	0	1	0	1	1	0	1	0	1	0	1	0	0	1	0	1
Individual 4	1	0	1	0	0	1	0	1	0	1	0	1	1	0	1	0
Individual 5	0	1	0	1	0	0	0	0	1	1	1	1	0	1	0	1
Individual 6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	X	Y	Fitness	Fitness (Scaled)	Fitness ratio [%]
1	0	0	28,000	130,050	25.36%
2	15	15	27,550	129,600	SS
3	90	165	-7,325	94,725	18.47%
4	165	90	-7,325	94,725	18.47%
5	80	245	-38,425	63,625	12.41%
6	255	255	-102,050	0	0.00%