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_WA01.doc or pdf

   ONLY PDF or MS Word file formats will be accepted.

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

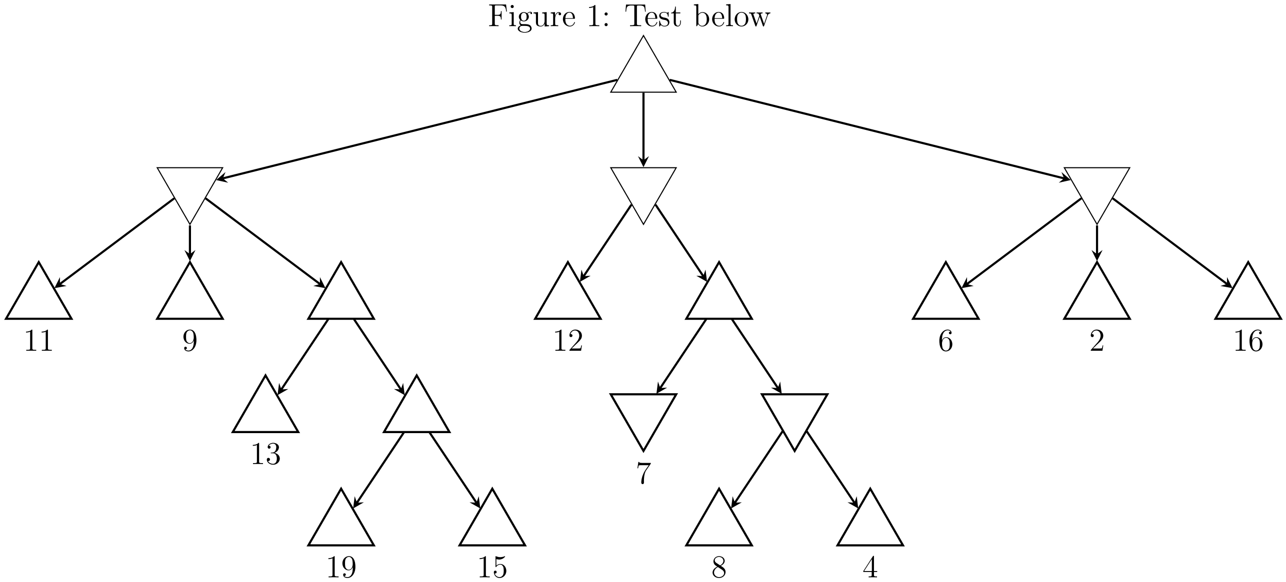
Objectives:

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.

0.1 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?

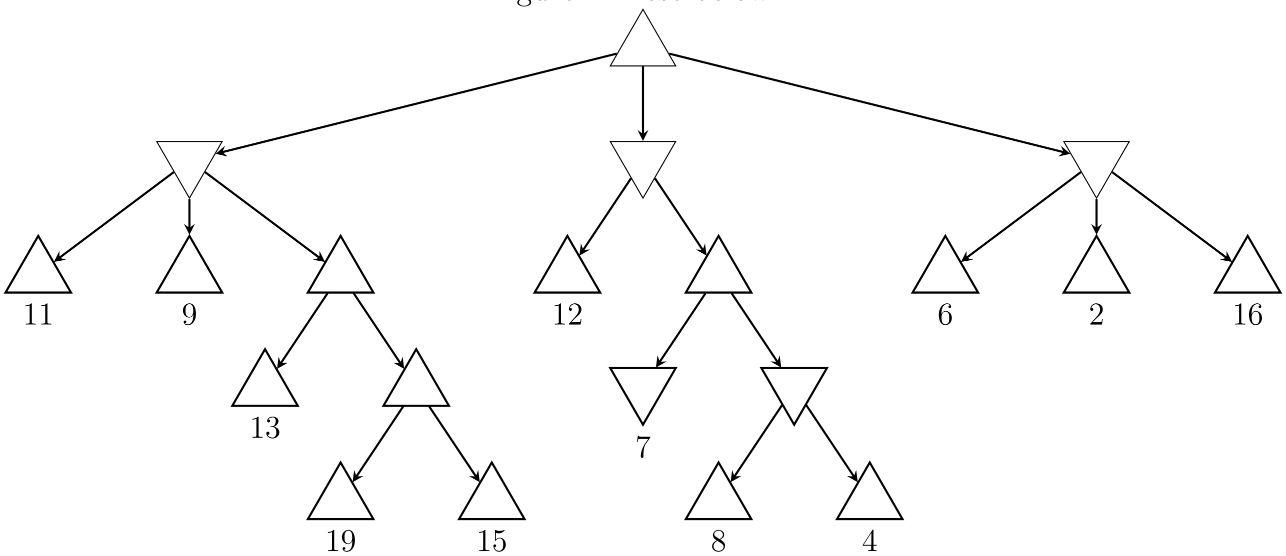
Figure 1: Test below



0.2 Problem 2 [5 pts]:

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

Figure 2: Test below



0.3 Problem 3 [10 pts]:

Consider the following problem **state space** (undirected and weighted) graph (fig. 3) representing a map with cities (vertices) and roads (maps).

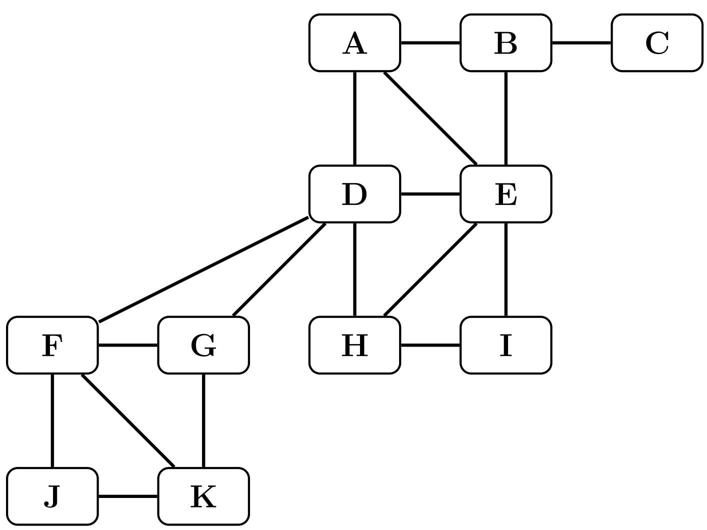


Figure 3: Problem state space ("cities and roads").

The table (Table **??**) 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 heuristic function values, 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 $\leftarrow$ rear]												
Parent												
State												
$f()$												

Reached / visited												
Parent	-											
State	F											
distance from IS	0											

Show your work below (make sure it is legible)

Search Tree diagrams + structures

0.4 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:

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

- 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":
    * $parent_1 \ + \ parent_2 \rightarrow \ child_1$,
    * $parent_2 \ + \ parent_3 \rightarrow \ child_2$,
    * ...
    * $parent_{N-1} \ + \ parent_N \rightarrow \ child_{N-1}$,

* $parent_N + parent_1 \rightarrow child_N$

- 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				
Individual 2				
Individual 3				
Individual 4				
Individual 5				
Individual 6				

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.