Introduction to Artificial Intelligence
Assignment 1: Avengers and Infinity Stone V1.1

Deadline

Week 10 (05.11.23 23:59)

Submission

- Two source code (same language) files have to be uploaded to Codeforces (one for each algorithm)
- Codeforces handle doesn't have to be uploaded to Moodle if was sent during ITP course and not changed after (otherwise, contact course instructor)
- Report describing each algorithm flow in plain English (not more than 2, 3 paragraphs), statistical comparison among algorithms and PEAS description with respect to the Actor agent. Name of the file should be like this *NameSurname.pdf* (For example, *IvanIvanov.pdf*). No other symbols allowed
- Also, report should include Graphical representation of maps that were impossible to solve. You can generate the maps directly through the code or hand draw them for the report after testing them on both algorithms
- Report may include any interesting outcome/map worth highlighting

Programming Language

Java (JDK 17) or C++ (C++11) or Python 3.7+

Requests

- The program must work, the code should be readable, well-structured and should contain comments in a language-specified format
- It has to be only one report **.pdf* file
- It is allowed to use only standard libraries
- NO extension of a deadline. Works sent after the deadline will NOT be evaluated
- Assignment is individual
- We will be using MOSS (Measure of Software Similarity) as a test for plagiarism. Be reminded that a score of 0 will be assigned to any submissions suspected of plagiarism pending a full investigation as per IU policies

Grading Criteria

- 60% for the code correctness
- 10% for code readability and comments quality
- 30% for the well-structured and informative report

Task

According to the *Marvel Comics*, *Thanos* is looking for the *Infinity Stones* to terminate half of the living creatures in the Universe, and *Avengers* at the same time try to prevent this. In one of the Marvel's alternative realities Thanos tries to find one of the Infinity Stones. Currently, he has no stones collected and he just recognized the location of the first one. This stone is located on a very far planet. Thanos is a very strong creature, however, without *Infinity Gauntlet* filled with Infinity Stones his power is very limited. Therefore, he tries to avoid the Avengers sent to the same planet and aiming not to give Thanos to realize his ambitions. The location of the Avengers is unknown to him, but he also knows that only 4 of them were able to achieve this planet: *Captain Marvel*, *Captain America*, *Thor* and *Hulk*. Therefore, it may be completely unsafe to follow the expected shortest path, Thanos may die.

Unintentionally Thanos met with Captain America and had a fight with him, after which both of them were exhausted, Captain America even lost his *sa* made of vibranium after throwing it aiming to hit Thanos. The vibranium is famous for its extraordinary abilities to absorb, store, and release large amounts of kinetic energy. Because of exhaustive fight Captain America was delivered back to the spaceship by other Avengers. The remaining 3 Avengers decided to go the different places of the planet to look for Thanos, because they had no idea where the Infinity Stone could be located. Thanos understands that each of the remaining Avengers is powerful enough to make him stuck in one more exhaustive fight. Therefore, his strategy is to avoid his enemies. Each of his enemies is having different power.

Thor is a God of Thunder from *Asgard* which is owning the *Stormbreaker* and *Mjölnir*, sentient enchanted weapons created out of *Uru* metal forged with the heat of a dying star in the Dwarven kingdom of *Nidavellir*. These weapons are enhancing the power of Thor and can even kill Thanos. To defend himself at least from long distance attacks of Stormbreaker and Mjölnir Thanos has to find the lost Shield of Captain America. Defeating Thor by Thanos is impossible without Infinity Gauntlet. That is the reason to avoid a fight with former. However, finding of the Shield is not a requirement, because it may increase the path. But in some cases, it may extremely helpful.

Hulk is a green-skinned, hulking and muscular humanoid possessing a limitless degree of physical strength. His power and speed are limited only by the level of its anger. Obviously, defeat of Captain America made him very angry on Thanos. Hulk prefers close combats, but for ranged combats he uses hand-clapping creating shock waves. He is almost immortal, but can be defeated by cutting his head. Still, because of reincarnation ability Hulk will survive, but decapitation can neutralize him till the end of the game. To make this possible some really strong metal has to be applied, and Shield of Captain America made of vibranium is an option.

Captain Marvel is superhumanly strong thanks both to her hybrid organism and to her ability of enhancing her physique by absorbing energy. The Shield of Captain America is useless in fight against her and the best thing to do for Thanos is just not to get too close to Captain Marvel.

You need to help Thanos to find the Infinity Stone, which location is known to only to Thanos. Avengers are static enemies located somewhere on the map. Your environment is 9*9 square lattice, which represents a partial map of a planet (see Figure 1).

Figure 1. Planet Map Example

Thanos

You always start from top left map corner. Your goal is to find the shortest path till Infinity Stone. Your ability to perceive troubles is defined in the *"variants section"* below. Your algorithms will work on both variants. Thanos can move one step per turn horizontally or vertically. Thanos is also called Actor in this assignment context.

Thor

Thor is randomly generated on the map except inside the positions of Shield, Infinity Stone, Hulk, Captain Marvel and where Thanos starts. Thor can perceive Thanos by throwing the Stormbreaker and Mjölnir to consecutive cells (Moore neighborhood), shown below in Figure 2. Facing Thor or its perception zone leads to the long exhaustive fight, which can lead to defeat of Thanos. Therefore, you may assume that meeting Thor is the end of the game. Thor's position is unknown to you. By using the Shield of Captain America perception zones of Thor disappear because Shield defends from hits of Stormbreaker and Mjölnir. Still, Thor remains on its position being a serious enemy.
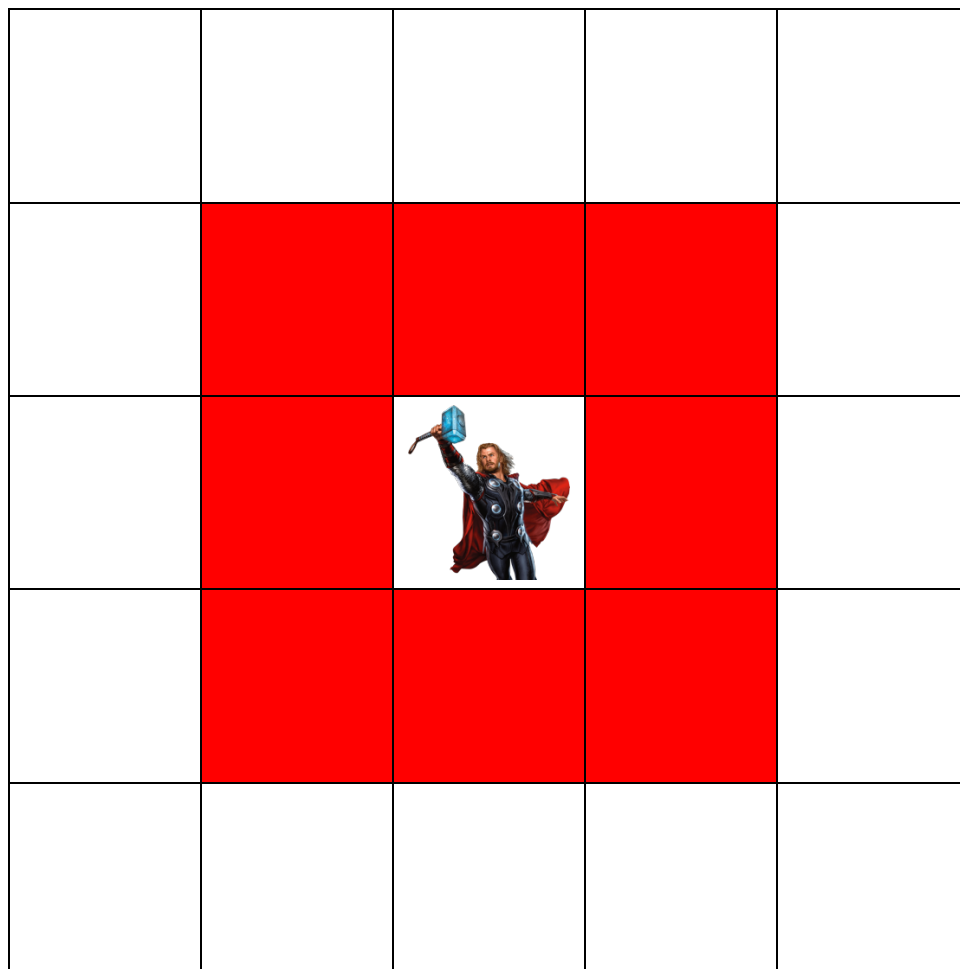
Figure 2. Thor's Perception Zones

Hulk

Hulk is randomly generated on the map except inside the positions of Shield, Infinity Stone, Thor, Captain Marvel and where Thanos starts. Hulk is able to perceive Thanos by clapping hands and understanding where produced shock waves are meeting with enemies. Hulk's perception includes neighbour non-diagonal cells (von Neumann neighborhood), shown below in Figure 3. Facing Hulk or its perception zone leads to the long exhaustive fight, which can lead to defeat of Thanos. Therefore, you may assume that meeting Hulk is the end of the game. Hulk's position is unknown to you. By using the Shield of Captain America perception zones of Hulk disappear because Shield defends from shock waves. Still, Hulk remains on its position being a serious enemy.
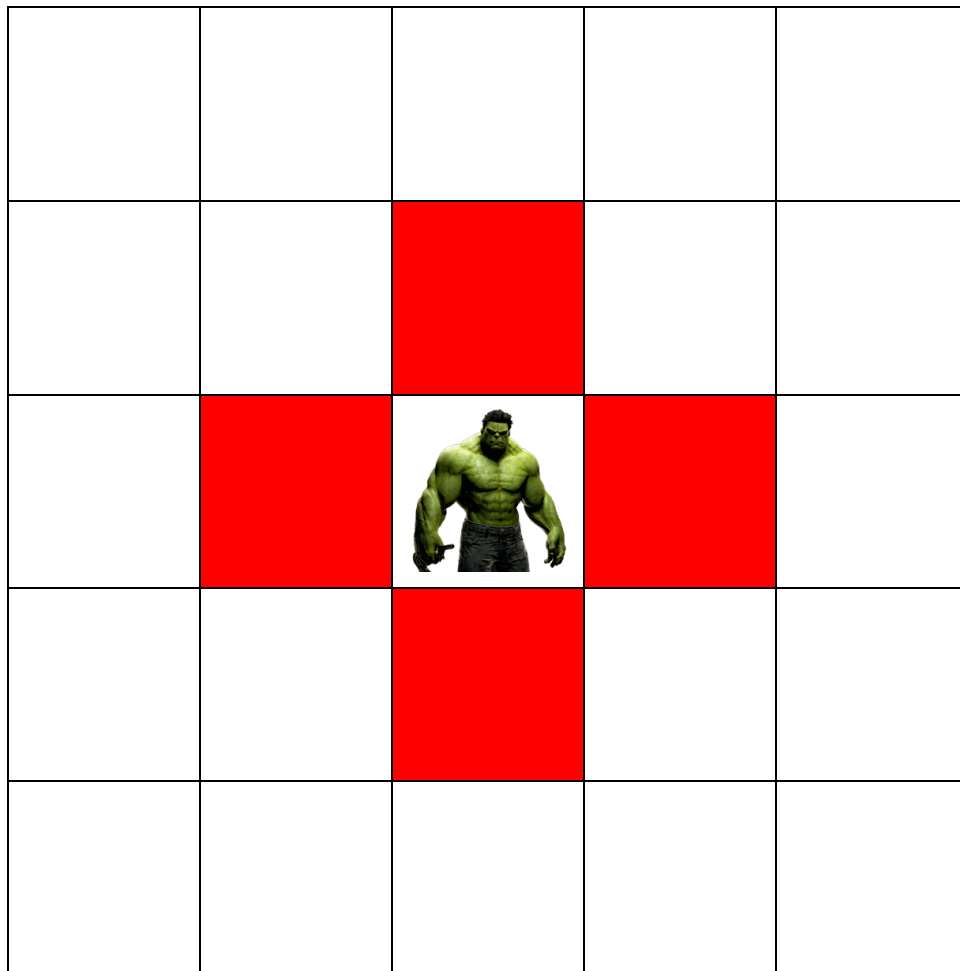

Figure 3. Hulk's Perception Zones

Captain Marvel

Captain Marvel is randomly generated on the map except inside the positions of Shield, Infinity Stone, Thor, Hulk, and where Thanos starts. Captain Marvel is guaranteed not to be generated in the place, from which she immediately kills Thanos by no means to identify her. Captain Marvel can perceive Thanos by flying up (Von Neumann neighborhood of range 2), shown below in Figure 4. Facing Captain Marvel or its perception zone leads to the long exhaustive fight, which can lead to defeat of Thanos. Therefore, you may assume that meeting Captain Marvel is the end of the game. Captain Marvel's position is unknown to you.
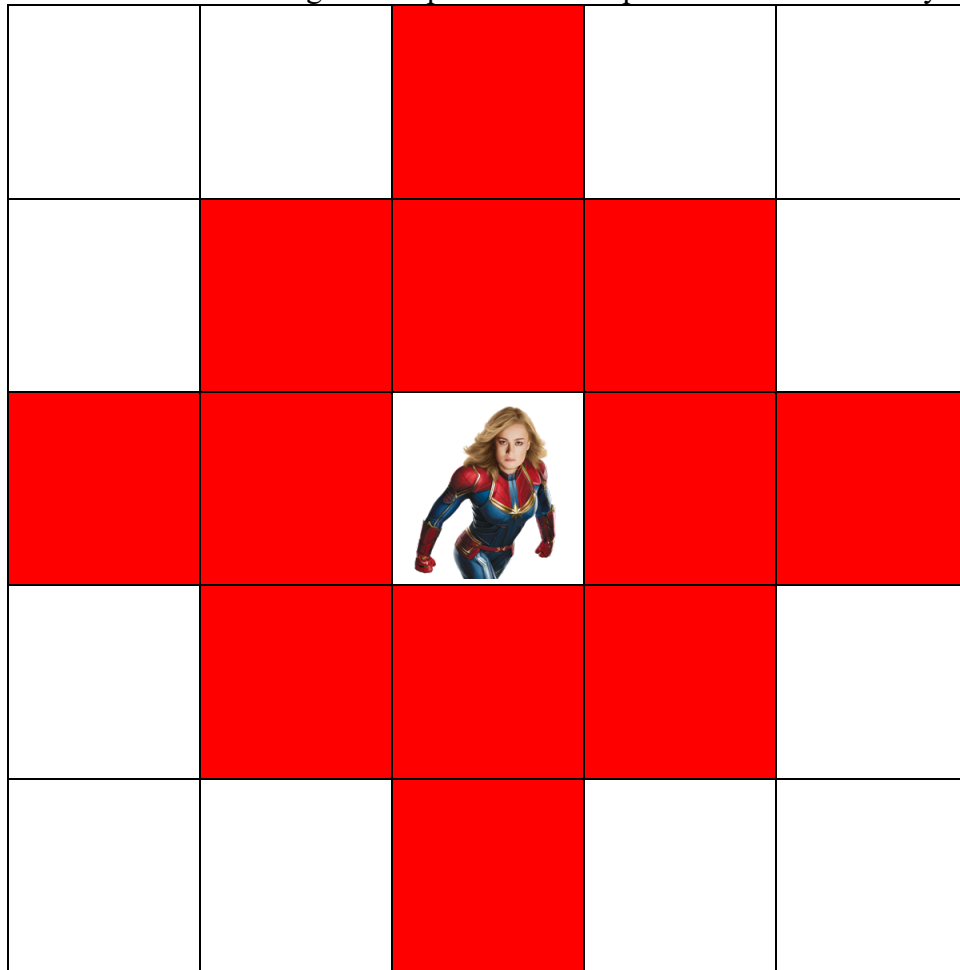

Figure 4. Captain Marvel's Perception Zones

Infinity Stone

The Infinity Stone is randomly generated on the map except inside the danger zones (Avengers and their perception zones), Shield and where the Thanos starts. You are the only who knows the location of the Infinity Stone.

Shield

The lost Shield of Captain America which position is randomly generated on the map except inside danger zones (Avengers and their perception zones), where the Infinity Stone is located and where the Thanos starts. You don't know the location of the Shield.

Algorithms

- A backtracking search
- A*

You are allowed to use modified versions of algorithms, do not forget to describe modifications in the report, if there will be any

Variants

The algorithms consider two scenarios:

1. You can perceive the enemy and its perception zones by using his spectroscopic vision in Moore neighborhood cells. This can be done if you are standing next to their perception zone or even next to them in case of some enemies, shown below in Figures 5a and 5b. In figure 5a, you are able to perceive 3 orange cells, in Figure 5b only 1. Orange cells indicate the Actor's perception of the enemy and its zones

Figure 5a. Thanos's Perception Zones (variant 1)

Figure 5b. Thanos's Perception Zones (variant 1)

2. You can perceive the enemy and its perception zones using his spectroscopic vision in Moore neighborhood with "ears", which extends your vision abilities in a way shown below in Figures 6a and 6b. In Figure 6a from the Actor's cell, you are able to perceive 3 orange cells. In Figure 6b, you can perceive only 1 orange cell.

Figure 6a. Thanos's Perception Zones (variant 2)

Figure 6b. Thanos's Perception Zones (variant 2)

While perceiving the danger zone of enemies, Thanos can't understand whose zone it is. But perception of the enemy's cell allows to identify it, also analysis of perception zones sometimes allows to understand where is the enemy.

Inputs and Outputs

You will be communicating with Codeforces interactor through standard inputs and outputs (print/cout) in your code, and the interactor checks it. Your code should start by accepting an integer (1 or 2) that represents the variant number for Thanos' perception scenario. Then you should accept a pair of integers representing the coordinates (x, y) of the Infinity Stone. After that, you should start interacting with the interactor to explore the map. You always start at position $(0, 0)$. The interactor accepts one of 2 arguments:

1. **m** *x y*:
    - **m** is given to tell the interactor that you want to make a **m**ove
    - *x* and *y* are the coordinates you want to move to, where *x* stands for rows, and *y* stand for columns (value in range $[0; 8]$)
    - The interactor will then return for you the dangers around you if there are any. If the cell is dangerous (contains any Avenger or his/her perception zone), you will receive the coordinates of this cell and the danger type from the interactor.
    - Note that you can only move to the allowed neighboring cells; you cannot teleport through the map. For example, if you are currently at position (3,4), you cannot send the command *m 5 6* (will lead to to a failed test)
    - Output example (given you just moved to (3,4)):

            3

            2 3 P

            2 4 H

            3 3 P

        where:
        - First row is the number of surrounding dangers (0 if no dangers)
        - Numbers in the other rows (if any) are the coordinates of the danger followed by the danger:
            1. **P** is **P**erception zone of enemy
            2. **H** for **H**ulk
            3. **I** for **I**nfinity Stone
            4. **T** for **T**hor
            5. **M** for Captain **M**arvel
            6. **S** for **S**hield
            7. And Thanos is represented with **A** on the map.
2. **e** followed by integer
    - **e** represents that you reached the **e**nd
    - -1 for valid unsolvable map
    - Any integer greater than 0 for the length of the shortest path to the Infinity Stone

- Note that invalid maps won't be provided in Codeforces tests. However, you are asked to think about it carefully for the report statistics

You always start in coordinates (0,0) and given your initial perception zone. When you die, the game is over for the current test. For the next test you go back to (0,0) and start all over again.

Statistical Analysis

Comparison of algorithms through statistical analysis based upon 1000 test maps generated. The statistics should provide the mean, mode median and standard deviation for execution time, number of wins and number of loses. Also, the percentage of wins and loses should be provided. Statistical analysis is required for both variants (described above). For each map, comparison would be:
1. Backtracking (variant 1) compared to A* (variant 1)
2. Backtracking (variant 2) compared to A* (variant 2)
3. Backtracking (variant 1) compared to Backtracking (variant 2)
4. A* (variant 1) compared to A* (variant 2)