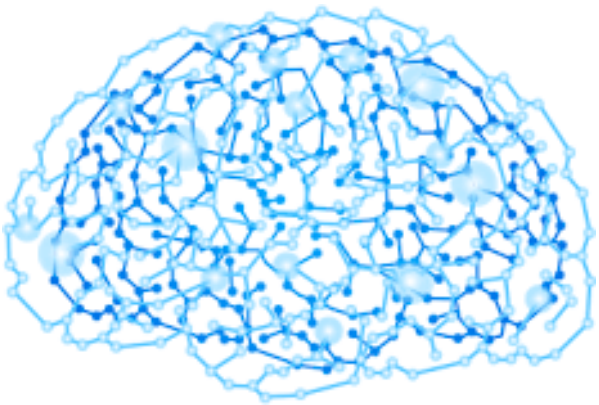
B2 - Introduction to Artificial Intelligence

B-IIA-150

Dante's Star

Journeying through Hell to Generate and Solve Mazes



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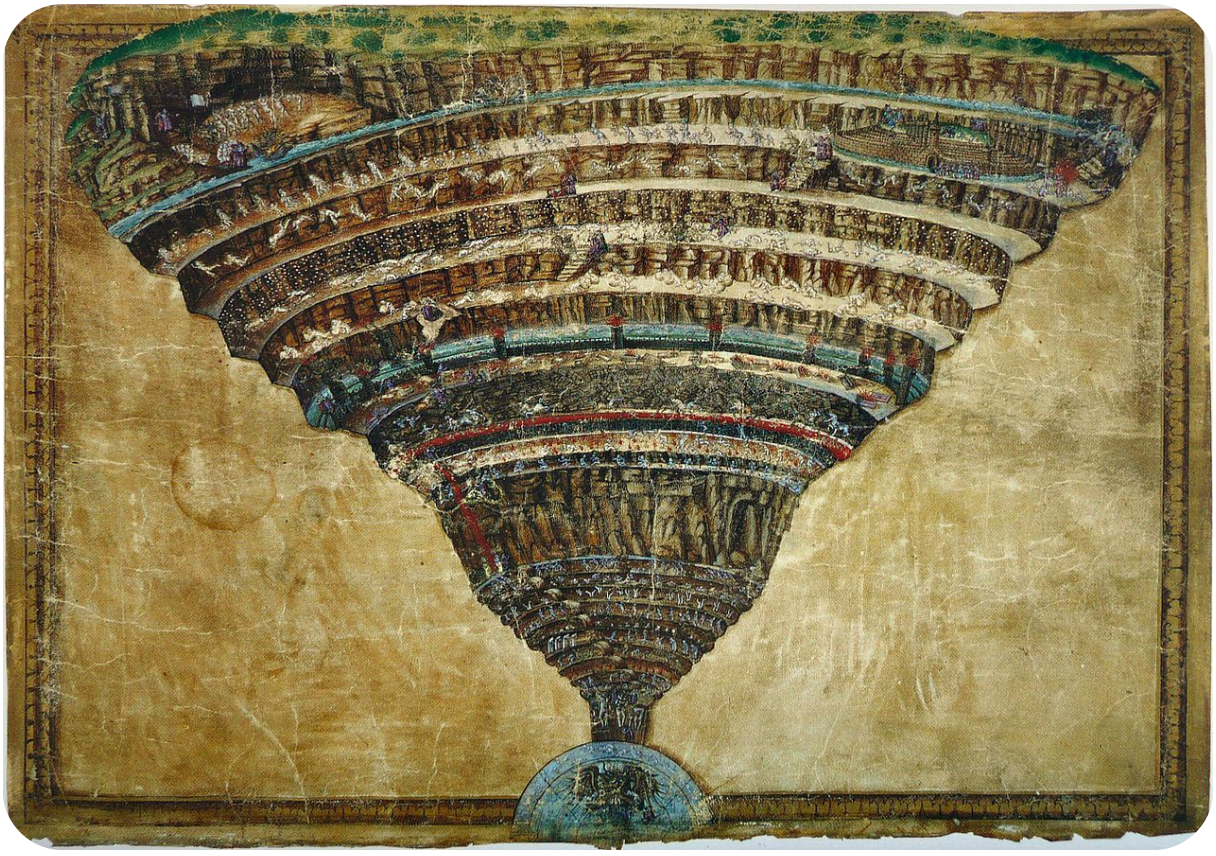
EPITECH.
L'ECOLE DE L'INNOVATION ET DE L'EXPERTISE INFORMATIQUE

Dante's Star

binary name: see below
repository name: dante
repository rights: ramassage-tek
language: C

- Your repository must contain the totality of your source files, but no useless files (binary, temp files, obj files,...).
- All the bonus files (including a potential specific Makefile) should be in a directory named *bonus*.
- Error messages have to be written on the error output, and the program should then exit with the 84 error code (0 if there is no error).



> *Dante, lost in a dark forest, struggles to climb a luminous hill so that he can get out. In turns, a panther, a lion, and a wolf block the path and force him to retrace his steps. Virgil appears, who persuades him to visit the eternal kingdoms in order to escape these perils. He offers to take him to Hell and to Purgatory himself, and Beatrice will show him Heaven.*
>
> *Theme of Canto I - The Divine Comedy - Dante Alighieri*

Dante must journey through Hell, a thoroughly maze-like place. Here we're going to generate mazes, find the exit path and try to do this as fast as possible.

The project is divided into nine sections, which represent the nine circles of Hell that Dante must pass through in order to reach purgatory.

The goal of this project is to generate a maze in a file, solve it in a reasonable amount of time, and print the solution.
A tournament comparing the performances will be organized between different students who qualify for the Pitch.

System functions and libC are allowed, but no external libraries.

+ TURN-IN METHODS

You must have 4 folders (tournament, breadth, depth, astar), with a binary named "**solver**" generated by a Makefile at the root of the repository.
You must also turn in a generator folder. The Makefile at the root must create a generator binary in this folder, which will generate the maze.

The Makefile at the root must compile all of the binaries.
Also, the mazes folder must not be in the repository.

The "**perf.sh**" performance script in the root can function in any way you would like.

Terminal

```
~/B-IIA-150> ls -R
. ..
astar breadth depth generator Makefile mazes perf.sh tournament

./astar:
      solver
      [...]

./breadth:
      solver
      [...]

./depth:
      solver
      [...]

./generator:
      generator
      [...]

./mazes:
      [whatever you would like]

./tournament:
      solver
      [...]
```

The solver in “tournament” will be used for the tournament.
Each solver must be able to function as follows:

```
Terminal
~/B-IIA-150> ./solver maze.txt
```

and print the solved maze on the standard output.
If there is no solution you must print **“no solution found”** on the same output.

The generator must function as follows:

```
Terminal
~/B-IIA-150> ./generator x y [perfect]
```

As the perfect argument is optional, the default generation will be an imperfect maze.

You are allowed to add other *optional* arguments; you must show them during the Pitch.

First Circle: Limbo

> *I found myself on the brink*
> *of the abysmal valley of pain, which resounds with*
> *noise of countless wailings; it was so dark and deep*
> *and full of vapors that, straining my sight to reach*
> *the bottom, I could make out nothing there.*
>
> *'Now let us descend into the blind world down there,'*
> *began the Poet, deadly pale; 'I will be the first and*
> *thou the second.'*
>
> *And I, who noted his color, said: 'How shall I come if*
> *thou art afraid who, when I am in doubt, art wont to be*
> *my strength?'*
>
> *Canto IV*

These ambivalent and cowardly spirits, who do not suffer but yearn for happiness without being able to obtain it, are ceaselessly tormented by the horseflies and wasps that goad them in vain. Here we can find: Homer, Horace, Lucian, Lucretius, Ovid, Pluto, Seneca, Socrates, Saladin and all of those who have never come to the Hub.

+ Let's draw a maze!

Here is the maze format description:

- Mazes are rectangular.
- They are coded in ASCII.
- The 'X's represent the walls and the'*'s represent the free spaces.
- It is possible to move to the four surrounding squares (up, down, right, left).
- "Start" is in the upper left-hand corner (0;0)
- "Finish" is in the bottom right-hand corner.
- A solution is a series of free, adjacent squares, from "Start" to "Finish" included.
- "Start" and "Finish" can be occupied. In this case, there is no solution.
- The maze can only have one solution. (When you load it)
- The last line of the maze doesn't terminate with a return line.
- Resolution: in order to write the solution in the maze, we use 'o' for the solution path.

Display it with a monospaced font (such as Courier New)

+ EXAMPLE

Here is a 24x6 maze...

```
*****XX****X********XXXX
XX******XX***XXXXX***XXX
XX***XXXX**XXXXX****XXXX
XX***XXXXXXXXXXXXX****X
*****XXXXXX****XX***XXXX
XX************XXXX*****
```

...and a way to solve it.

```
oooooXXooooXoooooooooXXXX
XX**oooXXoooXXXXX*o*XXX
XX***XXXX**XXXXX***oXXXX
XX***XXXXXXXXXXXXXo***X
*****XXXXXX****XX**oXXXX
XX************XXXXooooo
```

Second Circle: Lust

> *There Minos stands,*
> *Grinning with ghastly feature: he of all*
> *Who enter, strict examining the crimes,*
> *Gives sentence, and dismisses them beneath,*
> *According as he foldeth him around:*
> *For when before him comes the ill-fated soul,*
> *It all confess; and that judge severe*
> *Of sins, considering what place in Hell*
> *Suits the transgression, with his tail so oft*
> *Himself encircles, as degrees beneath*
> *He dooms it to descend.*
>
> *Canto V*

The lustful are brutally thrown into an infernal tempest where they are tormented by the struggle of their carnal desires.
Among others we find:

- **Dido**: queen of Carthage, who "killed herself for love" when she was abandoned at Aeneas after having betrayed her promise of fidelity to her late husband, Sichaeus.
- **Cleopatra**: queen of Egypt, Caesar and Antony's mistress.
- **Helen**: the cause of the Trojan War.
- **Achilles**: trapped by his love for Polyxena.
- **Francesca da Rimini**: killed by her husband in the arms of her lover, who was her husband's brother.
- **Lancelot**: the valiant knight, lovesick for his king's wife.

+ Building make a perfect maze...

First you are going to generate a perfect maze.
A perfect maze is a maze that has no loops and no clusters; therefore, following a wall makes us cross the entire maze.

The generation method is up to you, but it must work in an acceptable amount of time.
Input: maze size (width/height).
Output: a maze with the required size on the standard output.

The maze must have a solution.

Third Circle: Gluttony

> *In the third circle I arrive, of showers*
> *Ceaseless, accursed, heavy and cold, unchanged*
> *For ever, both in kind and in degree.*
> *Large hail, discolor'd water, sleety flaw*
> *Through the dun midnight air stream'd down amain:*
> *Stank all the land whereon that tempest fell.*
>
> *Canto VI*

The circle reserved for gluttons has eternal rain composed of dark and heavy water, snow and hail that makes the Earth reek.
The banqueteurs are torn apart by a three-headed Cerberus.

+ Let's make a imperfect maze...

An imperfect maze can contain clusters.
The requirements are the same as for perfect mazes.
The generation method is up to you, but it must work in an acceptable amount of time.
Input: maze size
Output: a maze with the required size on the standard output.

The maze must have at least one solution.

Fourth Circle: Greed and Extravagance

> *Thus we, descending to the fourth step ledge,*
> *Gain'd on the dismal shore, that all the woe*
> *Hems in of all the universe. Ah me!*
> *Almighty justice! in what store thou heap'st*
> *New pains, new troubles, as I here beheld.*
> *Whereforth doth fault of ours bring us to this?*
>
> *Canto VII*

Each one caught up in their excesses, Greed and Extravagance bump into and suffocate each other.
Their excess condemns them to never being able to advance: their trepidation energy does not produce anything; their attitude is in vain.

+ Depth-First Search

Now it's time to solve those mazes you've generated!
Your resolution program should take the name of a file containing the perfect maze and write the solution on the standard output.
This first resolution algorithm should work with a depth-first search.

+ Fifth Circle: Wrath

> *How many now hold themselves mighty kings,*
> *Who here like swine shall wallow in the mire,*
> *Leaving behind them horrible dispraise.*
>
> *Canto VIII*

+ Breadth-First Search

You might have noticed that in imperfect mazes, the depth-first searches pose a few problems.
What if we used a different algorithm?
In the same way, you are going to produce an algorithm that solves perfect and imperfect mazes with a breadth-first scan.

Sixth Circle: Heresy

> *We, unopposed,*
> *There enter'd; and, my mind eager to learn*
> *What state a fortress like to that might hold,*
> *I, soon as enter'd, throw mine eye around,*
> *And see, on every part, wide-stretching space,*
> *Replete with butter pain and torment ill.*
> *As where Rhone stagnates on the plains of Arles,*
> *Or as at Pola, near Quarnaro's gulf,*
> *That closes Italy and laves her bounds,*
> *The place is all thick spread with sepulchres;*
> *So was it here, save what in horror here*
> *Excell'd: for 'midst the graves were scattered flames,*
> *Wherewith intensely all throughout they burn'd,*
> *That iron for no craft there hotter needs.*
> *I thus: "Master! say who are these, interr'd*
> *Within these vaults, of whom distinct we hear*
> *The dolorous sighs." He answer thus return'd:*
> *"The arch-heretics are here, accompanied*
> *By every sect their followers; and much more*
> *Than though believest, the tombs are freighted: like*
> *With like is buried; and the monuments*
> *Are different in degrees of heat." This said,*
> *He to the right hand turning, on we pass'd*
> *Betwixt the afflicted and the ramparts high.*
>
> *Canto IX*

Here we can find Epicurious, his disciples and Pope Anastasius.

+ Performance measurement

You now have two different algorithms to solve a maze. What if we compare their efficiency? Make a shell script, as simple as it is necessary, that will test your algorithm on one of the given mazes and display the program execution time.

+ About:

Measuring the rapidity of your program poses two problems here:

- the first is your system: the machine is not always strictly in the same state when the program is launched (resource consumption, sticky bit etc.).

- the second, more obvious: you will have different results for different mazes.
  Also, if it turns out that your algorithm uses random, the results will vary even for the same maze.

You must take this into consideration when thinking about your analysis.

Your ability to objectively recognize your progress depends on it.

Seventh Circle: Violence

> *First ring: violence against their neighbors*
> *Second ring: violence against themselves*
> *Third ring: violence against God and nature*
>
> *Thereat the trunk breathed hard, and the wind soon*
> *Changed into sounds articulate like these:*
> *"Briefly ye shall be answer'd. When departs*
> *The fierce soul from the body, by itself*
> *Thence torn asunder, to the seventh gulf*
> *By Minos doom'd, into the wood it falls,*
> *No place assign'd, but wheresoever chance*
> *Hurls it; there sprouting, as a grain of spelt,*
> *It rises to a sapling*
>
> *Canto XIII*

+ An heuristic for A*

When we simply scan our state space, you might get the idea to scan it in a slightly more enlightened manner. Let's integrate a heuristic!
Your search should therefore contain an A*.

Don't forget to measure the newly obtained performance.

Is it more efficient? Is it the case for all of the mazes?

Eighth Circle: Fraud

> *Bolgia 1: Panderers and seducers*
> *Bolgia 2: Flatterers*
> *Bolgia 3: Simoniacs*
> *Bolgia 4: Sorcerers*
> *Bolgia 5: Barrators*
> *Bolgia 6: Hypocrites*
> *Bolgia 7: Thieves*
> *Bolgia 8: Counsellors of Fraud*
> *Bolgia 9: Sowers of Discord*
> *Bolgia 10: Falsifiers*
>
> *On our right hand new misery I saw*
>
> *Canto XVIII*

+ Further into optimization

Here you are, faced with yourselves for this ultimate test.
The project will conclude with a tournament that will enable you to earn points.
You are already equipped with the basics, now you have to go faster!

There are a lot of possible optimizations, whether it be heuristic searches, data structure work, local optimizations, maze preprocessing,...

Be creative!

Ninth Circle: Treachery

> *Round 1: Traitors to their Kindred*
> *Round 2: Traitors to their Country*
> *Round 3: Traitors to their Guests*
> *Round 4: Traitors to their Lords*
>
> *As down we stood*
> *In the dark pit beneath the giants' feet,*
> *But lower far than they, and I did gaze*
> *Still on the lofty battlement, a voice*
> *Bespake me thus: "Look how thou walkest. Take*
> *Good heed, thy soles do tread not on the heads*
> *Of thy poor brethren." Thereupon I turn'd,*
> *And saw before and underneath my feet*
> *A lake, whose frozen surface liker seem'd*
> *To glass than water.*
>
> *Canto XXXII*

In this last circle flows the rivers of Hell: the Cocytus, a river of ice.
Here the traitors shiver in an eternal cold.
Dante declaims them thusly:

> *"Plebs cursed among all, rejected in this place of which it is terrifying to speak.*
> *You would have been better off as sheep or goats."*