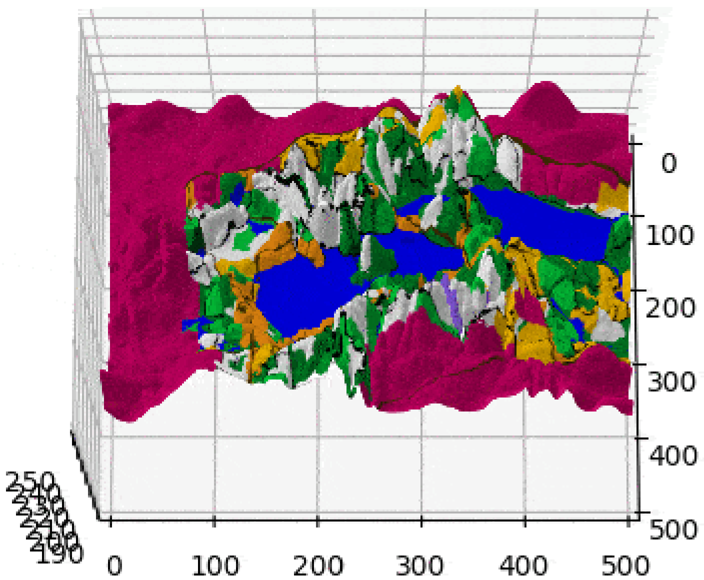
Intro to IS Lab 1 : Year-round Orienteering

In this lab, you will be generating optimal paths for orienteering during different seasons. In the sport (or "activity", depending on your level of fitness/competitiveness) of orienteering, you are given a map with terrain information, elevation contours, and a set or sequence of locations to visit ("controls"). There is a combination of athletic skills and planning skills required to succeed - a smarter competitor who can figure out the best way to get from point to point may beat out a more athletic competitor who makes poor choices! In this lab, you are given computer-friendly inputs so that you can use an algorithm to determine the best path for you to take depending on your ability.



Credit: Eric Dudley

The map(s)

In an ordinary orienteering event, the map you get will be quite detailed. Different background colors show the type of terrain (see the table below), while buildings, boulders, man-made objects and other notable features are shown with different symbols. For this assignment, you are given two separate inputs, both representing Mendon Ponds Park: a text representation of the elevations within an area (500 lines of 400 double values, each representing an elevation in meters) and a 395x500 simplified color-only terrain map (color legend below). To address the difference in width between the elevation and terrain files you should just ignore the last five values on each line of the elevation file. Also, the real-world pixel size is determined by that of the National Elevation Dataset, which in our area is one third of an arc-second, equivalent to 10.29 m in longitude (X) and 7.55 m in latitude (Y). **You must take these dimensions into your account of distance.**

The basic event

As for the points you will need to go visit, those will come in a simple text file, two integers per line, representing the (x,y) pixel (origin at upper left) in the terrain map containing the location. In the classic event type that we are considering, the sequence of points must be visited in the order given. One such classic event was the World Deaf Orienteering Championships, held in Mendon Ponds Park. The local club also had an event using the same courses, the results and maps of which can be seen here. I have done my best to convert the white, brown and red courses into the relevant text files.

The planning

So, you have to get to some controls. However, going in a straight line, even if possible, is often not advisable. First of all, you will be able to proceed at different speeds through different terrains. Rather than telling you how fast, you need to decide based on some representative photos how fast you can travel through these terrains:

Terrain type	Color on map	Photo (legend)
Open land	#F89412 (248,148,18)	A
Rough meadow	#FFC000 (255,192,0)	B
Easy movement forest	#FFFFFF (255,255,255)	C · D
Slow run forest	#02D03C (2,208,60)	E
Walk forest	#028828 (2,136,40)	F
Impassible vegetation	#054918 (5,73,24)	G
Lake/Swamp/Marsh	#0000FF (0,0,255)	H · I · J
Paved road	#473303 (71,51,3)	K · L
Footpath	#000000 (0,0,0)	M · N
Out of bounds	#CD0065 (205,0,101)	

In addition, you will probably go slower uphill, and even slower up steeper hills. How much slower? Again, for you to decide, but in any case, your justifications will be an important part of your writeup.

Then we get to the planning. This is a large environment, so while breadth-first search might be acceptable for individual paths, it is much better (and not much harder!) to implement an A* search to handle complete events. However, consider your heuristic function carefully. Showing that it is admissible (or it is not quite admissible, but you can bound its error) is another important part of your writeup.

Different times of year

As you may have noticed, the landscape changes significantly throughout the year. This can have a big impact on orienteering, as the map itself indicates a sort of default terrain, but may have been made at a different time of year than the competition. (For example, this past spring, a local meet was held in which some "open land" and "slow run forest" was in fact six inches or more underwater.) So, for this part of the assignment, you will need to adapt your search process as follows (some of this is a little exaggerated, for the purposes of making an interesting assignment, but the seasonal variations are real!):

- **Summer:** the photos above were taken during summer, so we can assume the map and photos to be accurate for this season. (That is, what you have done up to this point is "summer".)
- **Fall:** In the fall, leaves fall. In the park, what happens is that paths through the woods can become covered and hard to follow. So, for fall, you should increase the time for any paths through (that is, adjacent to) easy movement forest (but only those paths).
- **Winter:** In winter, the waters can freeze. For this particular assignment, we will assume that any water within seven pixels of non-water is safe to walk on. Please note: you should **not** handle this by looking seven pixels out from every water pixel - it is much more efficient to find the edges of the waters and

search out from there all at once. This can and should be cast as a BFS problem. You will be deducted points if you only perform a naive (and costly) search.

- **Spring:** aka "mud season". Any pixels within fifteen pixels of water that can be reached from a water pixel without gaining more than one meter of elevation (total) are now underwater. (Note that the water pixels represent different ponds and are therefore at different heights. The best thing to do is probably to start at water pixels and search outward to the non-water adjacent, but keeping track of the elevation of the particular water pixel that you came from for each non-water pixel.) You may choose whether you wish to run through this water or not :) but note that one of the controls on the white course linked above should now be underwater! Like in the case of Winter, this can and should be cast as a BFS problem. You will be deducted points if you only perform a naive (and costly) search.

Note that if any of these alterations would make your heuristic inadmissible, you should change it!

Input

Name your program 'lab1'. It should take 5 aruguments, in order: terrain-image, elevation-file, path-file, season (summer,fall,winter,or spring), output-image-filename.

Python would look like, $python3 lab1.py terrain.png mpp.txt red.txt winter redWinter.png

Output

For testing purposes, when your algorithm finishes, you should output an image of the input map with your path drawn on top. **Indicate which pixels you are changing due to the seasons by coloring them with a unique color.** E.g. in the winter, the water pixels you are treating as walkable should be colored differently. You should also output the total path length in meters either to the terminal or drawn on the map itself. Here is an example path for the brown trail in the Summer. Here is one for winter. Note that your solution may correctly produce a different result; a solution similar to the one shown here is sufficient for full credit.

Writeup

As discussed above, your writeup should include all relevant decisions made in the implementation of your code. That is, how you implemented your cost function, how you implemented your heuristic, and justification for their correctness. You should also outline your different seasonal algorithms and your algorithm for human-consumable output should also be clearly described.

Some hints/tips

- You are welcome to write your solution in Python, Java, C, or C++. If you would like to use a different language, please consult with me first. Regardless, your program should run on a Linux-based CS machine, and your code should operate there without modification.
- In Python, you can use the Python Image Library to both read an image in to an array of pixels as well as to modify those pixels to output your results. (I used `Image.open()`, `.load()` and `.save()` on the CS machines.)
- In Java, you can use the ImageIO class to read in an image into a BufferedImage object and get/set pixels from there.
- You are welcome to hard-code things which make sense to hard code, such as the color values. Be careful if you hard code file names that it will still work when downloaded and run out of CS account.
- Some overall suggestions to approach the work: First just get a single simple path planned. Here is a simple one, but try some others and some longer ones. Get the graphical output working first, it will help you debug everything. Once you have summer working, the other seasons increase in difficulty in the order listed (more or less).

Grading

- Proper interpretation of input files: 5%
- Proper A* search algorithm and heuristic: 25%
- Summer planning: 5%
- Other seasons: 25%
    - Fall 5%
    - Winter 10%
    - Spring 10%
- Human-readable output: 20%
- Efficiency of solution*: 5%
- Writeup: 15%

Resources

Check these tests cases out! If your solution runs in a reasonable amount of time and matches the supplied output then you are *probably* fine.

* As a point of comparison, most solutions in Python produces a plan for the red course above in summer in about 3 seconds with a conservative admissible heuristic. The other seasons run in (at most) about 1-2 seconds more. Anything within the same range of time is sufficiently efficient. If your program takes longer than 20 seconds there is likely something wrong with your heuristic.

** Here is a bmp image for those who want it.