

A.I. BVG Project

1- Description of your understanding of the problem:

The problem requires us to create a program that given a start and end U-Bahn stations on any 2 lines, returns a path to the user that goes from the start station to the end station, switching between lines if necessary. The supposed solution to the problem is to create a graph (literally or simulated) containing all U-Bahn stations, which enables us to perform search algorithms on the graph to obtain our solution.

2- A discussion of your implementation of the data structure:

Our data structure simulates a graph using edges and vertices. We have 3 data structures: edge, vertex, and graph. The edge data structure has two attributes: weight (cost) and to (the vertex it connects to). The vertex data structure also has two attributes: String label (station name) and ArrayList edges (ArrayList containing all edges connecting to neighbouring vertices). The graph data structure is basically an ArrayList of vertices containing all the stations as vertices, and each vertex contains the edges leading to its neighbours.

3- A discussion of how you implemented the search algorithm(s):

Greedy Search: Taking the start node and expand it adjacent nodes and replacing the start node by the adjacent node with the minimum heuristic and the cycle continues until it reaches the goal.

Breadth First Search: Taking the start node and expand its adjacent nodes , then it expand each of the adjacent node and the cycle continues until the end node is reached.

Depth First Search: Taking the start node and expanding the size of the ArrayList -1 index of the adjacent node then check if it is not visited expand the node and repeat the process same again.

4- A discussion of the heuristic functions you employed and an argument for their admissibility:

For the heuristic function, we used the Euclidean Distance (ED) using the x and y coordinates of the stations. The ED equation is:

function heuristic(node) =

 dx = abs(node.x - goal.x)

 dy = abs(node.y - goal.y)

 return D * sqrt(dx * dx + dy * dy)

where D = 1.

The heuristic is admissible as the ED uses the pythagorus theorem to calculate a straight line between two points. In the case of subway stations, the ED will always be less than the actual cost (in case of curved lines between stations) or equal to it (in case of straight lines between stations).

5- At least two running examples (input+output) from your implementation:

BFS From U Borsigwerke to U Hermannplatz:

Expanding: U Borsigwerke

Adjacent stations: [U Holzhauser Str., U Alt-Tegel]

Expanding: U Holzhauser Str.

Adjacent stations: [U Otisstr., U Borsigwerke]

Expanding: U Otisstr.

Adjacent stations: [U Scharnweberstr., U Holzhauser Str.]

Expanding: U Scharnweberstr.

Adjacent stations: [U Scharnweberstr., U Holzhauser Str.]

Expanding: U Holzhauser Str.

Adjacent stations: [U Kurt-Schumacher-Platz, U Otisstr.]

Expanding: U Kurt-Schumacher-Platz

Adjacent stations: [U Afrikanische Str., U Scharnweberstr.]

Expanding: U Afrikanische Str.

Adjacent stations: [U Rehberge, U Kurt-Schumacher-Platz]

Expanding: U Rehberge

Adjacent stations: [U Seestr., U Afrikanische Str.]

Expanding: U Seestr.

Adjacent stations: [U Leopoldplatz, U Rehberge]

Expanding: U Leopoldplatz

Adjacent stations: [S+U Wedding, U Seestr., U Amrumer Str., U Nauener Platz]

Expanding: S+U Wedding

Adjacent stations: [S+U Wedding, U Seestr., U Amrumer Str., U Nauener Platz]

Expanding: U Amrumer Str.

Adjacent stations: [S+U Wedding, U Seestr., U Amrumer Str., U Nauener Platz]

Expanding: U Nauener Platz

Adjacent stations: [U Reinickendorfer Str., U Leopoldplatz]
Expanding: U Reinickendorfer Str.

Adjacent stations: [S+U Westhafen, U Leopoldplatz]
Expanding: S+U Westhafen

Adjacent stations: [U Leopoldplatz, U Osloer Str.]
Expanding: U Osloer Str.

Adjacent stations: [U Schwartzkopffstr., S+U Wedding]
Expanding: U Schwartzkopffstr.

Adjacent stations: [U Birkenstr., U Amrumer Str.]
Expanding: U Birkenstr.

Adjacent stations: [U Pankstr., U Franz-Neumann-Platz, U Nauener Platz]
Expanding: U Pankstr.

Adjacent stations: [U Pankstr., U Franz-Neumann-Platz, U Nauener Platz]
Expanding: U Franz-Neumann-Platz

Adjacent stations: [U Naturkundemuseum, U Reinickendorfer Str.]
Expanding: U Naturkundemuseum

Adjacent stations: [U Turmstr., S+U Westhafen]
Expanding: U Turmstr.

Adjacent stations: [S+U Gesundbrunnen, U Osloer Str.]
Expanding: S+U Gesundbrunnen

Adjacent stations: [U Osloer Str., U Residenzstr.]
Expanding: U Residenzstr.

Adjacent stations: [U Oranienburger Tor, U Schwartzkopffstr.]
Expanding: U Oranienburger Tor

Adjacent stations: [U Hansaplatz, U Birkenstr.]
Expanding: U Hansaplatz

Adjacent stations: [U Voltastr., U Pankstr.]
Expanding: U Voltastr.

Adjacent stations: [U Franz-Neumann-Platz, U Paracelsus-Bad]
Expanding: U Paracelsus-Bad

Adjacent stations: [S+U Friedrichstr., U Naturkundemuseum]
Expanding: S+U Friedrichstr.

Adjacent stations: [S+U Zoologischer Garten, U Turmstr.]
Expanding: S+U Zoologischer Garten

Adjacent stations: [U Bernauer Str., S+U Gesundbrunnen]
Expanding: U Bernauer Str.

Adjacent stations: [U Residenzstr., U Lindauer Allee]
Expanding: U Lindauer Allee

Adjacent stations: [U Französische Str., U Oranienburger Tor]
Expanding: U Französische Str.

Adjacent stations: [U Ernst-Reuter-Platz, U Wittenbergplatz, U Kurfürstendamm, U Hansaplatz]
Expanding: U Ernst-Reuter-Platz

Adjacent stations: [U Ernst-Reuter-Platz, U Wittenbergplatz, U Kurfürstendamm, U Hansaplatz]
Expanding: U Wittenbergplatz

Adjacent stations: [U Ernst-Reuter-Platz, U Wittenbergplatz, U Kurfürstendamm, U Hansaplatz]
Expanding: U Kurfürstendamm

Adjacent stations: [U Rosenthaler Platz, U Voltastr.]

Expanding: U Rosenthaler Platz

Adjacent stations: [U Paracelsus-Bad, S+U Karl-Bonhoeffer-Nervenlinik]

Expanding: S+U Karl-Bonhoeffer-Nervenlinik

Adjacent stations: [U Stadtmitte, S+U Friedrichstr.]

Expanding: U Stadtmitte

Adjacent stations: [U Deutsche Oper, S+U Zoologischer Garten]

Expanding: U Deutsche Oper

Adjacent stations: [U Kurfürstendamm, U Nollendorfplatz, S+U Zoologischer Garten, U Augsburger Str.]

Expanding: U Nollendorfplatz

Adjacent stations: [U Kurfürstendamm, U Nollendorfplatz, S+U Zoologischer Garten, U Augsburger Str.]

Expanding: U Augsburger Str.

Adjacent stations: [U Uhlandstr., U Wittenbergplatz, U Spichernstr., S+U Zoologischer Garten]

Expanding: U Uhlandstr.

Adjacent stations: [U Uhlandstr., U Wittenbergplatz, U Spichernstr., S+U Zoologischer Garten]

Expanding: U Spichernstr.

Adjacent stations: [U Weinmeisterstr., U Bernauer Str.]

Expanding: U Weinmeisterstr.

Adjacent stations: [U Lindauer Allee, U Rathaus Reinickendorf]

Expanding: U Rathaus Reinickendorf

Adjacent stations: [U Mohrenstr., U Hausvogteiplatz, U Kochstr./Checkpoint Charlie, U Französische Str.]

Expanding: U Mohrenstr.

Adjacent stations: [U Mohrenstr., U Hausvogteiplatz, U Kochstr./Checkpoint Charlie, U Französische Str.]

Expanding: U Hausvogteiplatz

Adjacent stations: [U Mohrenstr., U Hausvogteiplatz, U Kochstr./Checkpoint Charlie, U Französische Str.]

Expanding: U Kochstr./Checkpoint Charlie

Adjacent stations: [U Bismarckstr., U Ernst-Reuter-Platz]

Expanding: U Bismarckstr.

Adjacent stations: [U Wittenbergplatz, U Kurfürstenstr., U Bülowstr., U Viktoria-Luise-Platz]

Expanding: U Kurfürstenstr.

Adjacent stations: [U Wittenbergplatz, U Kurfürstenstr., U Bülowstr., U Viktoria-Luise-Platz]

Expanding: U Bülowstr.

Adjacent stations: [U Wittenbergplatz, U Kurfürstenstr., U Bülowstr., U Viktoria-Luise-Platz]

Expanding: U Viktoria-Luise-Platz

Adjacent stations: [U Hohenzollernplatz, U Augsburger Str., U Güntzelstr., U Kurfürstendamm]

Expanding: U Hohenzollernplatz

Adjacent stations: [U Hohenzollernplatz, U Augsburger Str., U Güntzelstr., U Kurfürstendamm]

Expanding: U Güntzelstr.

Adjacent stations: [S+U Alexanderplatz, U Rosenthaler Platz]

Expanding: S+U Alexanderplatz

Adjacent stations: [S+U Karl-Bonhoeffer-Nervenlinik, S+U Wittenau]

Expanding: S+U Wittenau

Adjacent stations: [S+U Potsdamer Platz, U Stadtmitte]

Expanding: S+U Potsdamer Platz

Adjacent stations: [U Stadtmitte, U Spittelmarkt]

Expanding: U Spittelmarkt

Adjacent stations: [U Hallesches Tor, U Stadtmitte]

Expanding: U Hallesches Tor

Adjacent stations: [U Sophie-Charlotte-Platz, U Deutsche Oper, U Wilmersdorfer Str., U Richard-Wagner-Platz]
Expanding: U Sophie-Charlotte-Platz

Adjacent stations: [U Sophie-Charlotte-Platz, U Deutsche Oper, U Wilmersdorfer Str., U Richard-Wagner-Platz]
Expanding: U Wilmersdorfer Str.

Adjacent stations: [U Sophie-Charlotte-Platz, U Deutsche Oper, U Wilmersdorfer Str., U Richard-Wagner-Platz]
Expanding: U Richard-Wagner-Platz

Adjacent stations: [U Nollendorfplatz, U Gleisdreieck]
Expanding: U Gleisdreieck

Adjacent stations: [U Bayerischer Platz, U Nollendorfplatz]
Expanding: U Bayerischer Platz

Adjacent stations: [U Fehrbelliner Platz, U Spichernstr.]
Expanding: U Fehrbelliner Platz

Adjacent stations: [U Berliner Str., U Spichernstr.]
Expanding: U Berliner Str.

Adjacent stations: [U Kloster str., U Rosa-Luxemburg-Platz, S+U Jannowitzbrücke, U Weinmeisterstr.]
Expanding: U Kloster str.

Adjacent stations: [U Kloster str., U Rosa-Luxemburg-Platz, S+U Jannowitzbrücke, U Weinmeisterstr.]
Expanding: U Rosa-Luxemburg-Platz

Adjacent stations: [U Kloster str., U Rosa-Luxemburg-Platz, S+U Jannowitzbrücke, U Weinmeisterstr.]
Expanding: S+U Jannowitzbrücke

Adjacent stations: [U Mendelssohn-Bartholdy-Park, U Mohrenstr.]
Expanding: U Mendelssohn-Bartholdy-Park

Adjacent stations: [U Hausvogteiplatz, U Märkisches Museum]
Expanding: U Märkisches Museum

Adjacent stations: [U Möckernbrücke, U Prinzenstr., U Mehringdamm, U Kochstr./Checkpoint Charlie]
Expanding: U Möckernbrücke

Adjacent stations: [U Möckernbrücke, U Prinzenstr., U Mehringdamm, U Kochstr./Checkpoint Charlie]
Expanding: U Prinzenstr.

Adjacent stations: [U Möckernbrücke, U Prinzenstr., U Mehringdamm, U Kochstr./Checkpoint Charlie]
Expanding: U Mehringdamm

Adjacent stations: [U Kaiserdamm, U Bismarckstr.]
Expanding: U Kaiserdamm

Adjacent stations: [U Adenauerplat, U Bismarckstr.]
Expanding: U Adenauerplat

Adjacent stations: [U Bismarckstr., U Mierendorffplatz]
Expanding: U Mierendorffplatz

Adjacent stations: [U Rathaus Schöneberg, U Viktoria-Luise-Platz, U Eisenacher Str., U Berliner Str.]
Expanding: U Rathaus Schöneberg

Adjacent stations: [U Rathaus Schöneberg, U Viktoria-Luise-Platz, U Eisenacher Str., U Berliner Str.]
Expanding: U Eisenacher Str.

Adjacent stations: [S+U Heidelberger Platz, U Hohenzollernplatz, U Blissestr., U Konstanzer Str.]
Expanding: S+U Heidelberger Platz

Adjacent stations: [S+U Heidelberger Platz, U Hohenzollernplatz, U Blissestr., U Konstanzer Str.]
Expanding: U Blissestr.

Adjacent stations: [S+U Heidelberger Platz, U Hohenzollernplatz, U Blissestr., U Konstanzer Str.]
Expanding: U Konstanzer Str.

Adjacent stations: [U Bayerischer Platz, U Blissestr., S+U Bundesplatz, U Güntzelstr.]

Expanding: S+U Bundesplatz

Adjacent stations: [S+U Alexanderplatz, U Senefelderplatz]

Expanding: U Senefelderplatz

Adjacent stations: [U Heinrich-Heine-Str., S+U Alexanderplatz]

Expanding: U Heinrich-Heine-Str.

Adjacent stations: [U Gleisdreieck, U Hallesches Tor, U Mehringdamm, S+U Yorckstr.]

Expanding: S+U Yorckstr.

Adjacent stations: [U Hallesches Tor, U Kottbusser Tor]

Expanding: U Kottbusser Tor

Adjacent stations: [U Platz der Luftbrücke, U Hallesches Tor, U Gneisenastr., U Möckernbrücke]

Expanding: U Platz der Luftbrücke

Adjacent stations: [U Platz der Luftbrücke, U Hallesches Tor, U Gneisenastr., U Möckernbrücke]

Expanding: U Gneisenastr.

Adjacent stations: [U Theodor-Heuss-Platz, U Sophie-Charlotte-Platz]

Expanding: U Theodor-Heuss-Platz

Adjacent stations: [U Richard-Wagner-Platz, S+U Jungfernheide]

Expanding: S+U Jungfernheide

Adjacent stations: [S+U Innsbrucker Platz, U Bayerischer Platz]

Expanding: S+U Innsbrucker Platz

Adjacent stations: [U Kleistpark, U Bayerischer Platz]

Expanding: U Kleistpark

Adjacent stations: [U Rüdesheimer Platz, U Fehrbelliner Platz]

Expanding: U Rüdesheimer Platz

Adjacent stations: [U Friedrich-Wilhelm-Platz, U Berliner Str.]

Expanding: U Friedrich-Wilhelm-Platz

Adjacent stations: [U Rosa-Luxemburg-Platz, U Eberswalder Str.]

Expanding: U Eberswalder Str.

Adjacent stations: [U Moritzplatz, S+U Jannowitzbrücke]

Expanding: U Moritzplatz

Adjacent stations: [U Prinzenstr., U Görlitzer Bahnhof, U Schönleinstr., U Moritzplatz]

Expanding: U Görlitzer Bahnhof

Adjacent stations: [U Prinzenstr., U Görlitzer Bahnhof, U Schönleinstr., U Moritzplatz]

Expanding: U Schönleinstr.

Adjacent stations: [U Paradedstr., U Mehringdamm]

Expanding: U Paradedstr.

Adjacent stations: [U Südsterne, U Mehringdamm]

Expanding: U Südsterne

Adjacent stations: [U Neu-Westend, U Kaiserdamm]

Expanding: U Neu-Westend

Adjacent stations: [U Mierendorffplatz, U Jakob-Kaiser-Platz]

Expanding: U Jakob-Kaiser-Platz

Adjacent stations: [U Breitenbachplatz, S+U Heidelberger Platz]

Expanding: U Breitenbachplatz

Adjacent stations: [U Walther-Schreiber-Platz, S+U Bundesplatz]

Expanding: U Walther-Schreiber-Platz

Adjacent stations: [U Senefelderplatz, S+U Schönhauser Allee]

Expanding: S+U Schönhauser Allee

Adjacent stations: [U Kottbusser Tor, U Schlesisches Tor]

Expanding: U Schlesisches Tor

Adjacent stations: [U Hermannplatz, U Kottbusser Tor]

Expanding: U Hermannplatz

Path of search: [U Borsigwerke, U Otisstr., U Scharnweberstr., U Holzhauser Str., U Kurt-Schumacher-Platz, U Afrikanische Str., U Rehberge, U Seestr., U Leopoldplatz, S+U Wedding, U Amrumer Str., U Nauener Platz, U Reinickendorfer Str., S+U Westhafen, U Osloer Str., U Schwartzkopffstr., U Birkenstr., U Pankstr., U Franz-Neumann-Platz, U Naturkundemuseum, U Turmstr., S+U Gesundbrunnen, U Residenzstr., U Oranienburger Tor, U Hansaplatz, U Voltastr., U Paracelsus-Bad, S+U Friedrichstr., S+U Zoologischer Garten, U Bernauer Str., U Lindauer Allee, U Französische Str., U Ernst-Reuter-Platz, U Wittenbergplatz, U Kurfürstendamm, U Rosenthaler Platz, S+U Karl-Bonhoeffer-Nervenklinik, U Stadtmitte, U Deutsche Oper, U Nollendorfplatz, U Augsburger Str., U Uhlandstr., U Spichernstr., U Weinmeisterstr., U Rathaus Reinickendorf, U Mohrenstr., U Hausvogteiplatz, U Kochstr./Checkpoint Charlie, U Bismarckstr., U Kurfürstenstr., U Bülowstr., U Viktoria-Luise-Platz, U Hohenzollernplatz, U Güntzelstr., S+U Alexanderplatz, S+U Wittenau, S+U Potsdamer Platz, U Spittelmarkt, U Hallesches Tor, U Sophie-Charlotte-Platz, U Wilmersdorfer Str., U Richard-Wagner-Platz, U Gleisdreieck, U Bayerischer Platz, U Fehrbelliner Platz, U Berliner Str., U Kloster str., U Rosa-Luxemburg-Platz, S+U Jannowitzbrücke, U Mendelssohn-Bartholdy-Park, U Märkisches Museum, U Möckernbrücke, U Prinzenstr., U Mehringdamm, U Kaiserdamm, U Adenauerplatz, U Mierendorffplatz, U Rathaus Schöneberg, U Eisenacher Str., S+U Heidelberger Platz, U Blissestr., U Konstanzer Str., S+U Bundesplatz, U Senefelderplatz, U Heinrich-Heine-Str., S+U Yorckstr., U Kottbusser Tor, U Platz der Luftbrücke, U Gneisenaustr., U Theodor-Heuss-Platz, S+U Jungfernheide, S+U Innsbrucker Platz, U Kleistpark, U Rüdesheimer Platz, U Friedrich-Wilhelm-Platz, U Eberswalder Str., U Moritzplatz, U Görlitzer Bahnhof, U Schönleinstr., U Paradestr., U Südstern, U Neu-Westend, U Jakob-Kaiser-Platz, U Breitenbachplatz, U Walther-Schreiber-Platz, S+U Schönhauser Allee, U Schlesisches Tor, U Hermannplatz]

Time taken for search: 19ms

Greedy From U Cottbusser Platz to S+U Frankfurter Allee:

Adjacent stations: [U Kienberg (Gärten der Welt), $h = 0.0072350516$, U Hellersdorf, $h = 0.022738904$]

Expanding: U Kienberg (Gärten der Welt), $h = 0.0072350516$

Adjacent stations: [U Kaulsdorf-Nord, $h = 0.008466179$, U Cottbusser Platz, $h = 0.0072350516$]

Expanding: U Kaulsdorf-Nord, $h = 0.008466179$

Adjacent stations: [S+U Wuhletal, $h = 0.016018119$, U Kienberg (Gärten der Welt), $h = 0.008466179$]

Expanding: S+U Wuhletal, $h = 0.016018119$

Adjacent stations: [U Elsterwerdaer Platz, $h = 0.01543053$, U Kaulsdorf-Nord, $h = 0.016018119$]

Expanding: U Elsterwerdaer Platz, $h = 0.01543053$

Adjacent stations: [U Biesdorf-Süd, $h = 0.01615512$, S+U Wuhletal, $h = 0.01543053$]

Expanding: U Biesdorf-Süd, $h = 0.01615512$

Adjacent stations: [U Tierpark, $h = 0.023157796$, U Elsterwerdaer Platz, $h = 0.01615512$]

Expanding: U Tierpark, $h = 0.023157796$

Adjacent stations: [U Friedrichsfelde, $h = 0.0134618655$, U Biesdorf-Süd, $h = 0.023157796$]

Expanding: U Friedrichsfelde, $h = 0.0134618655$

Adjacent stations: [S+U Lichtenberg, $h = 0.01654305$, U Tierpark, $h = 0.0134618655$]

Expanding: S+U Lichtenberg, $h = 0.01654305$

Adjacent stations: [U Magdalenenstr., $h = 0.010288429$, U Friedrichsfelde, $h = 0.01654305$]

Expanding: U Magdalenenstr., $h = 0.010288429$

Adjacent stations: [S+U Frankfurter Allee, $h = 0.012467321$, S+U Lichtenberg, $h = 0.010288429$]

Expanding: S+U Frankfurter Allee, $h = 0.012467321$

Path = [U Cottbusser Platz, U Kienberg (Gärten der Welt), U Kaulsdorf-Nord, S+U Wuhletal, U Elsterwerdaer Platz, U Biesdorf-Süd, U Tierpark, U Friedrichsfelde, S+U Lichtenberg, U Magdalenenstr., S+U Frankfurter Allee]

Time taken for search: 2ms

6- A comparison of the performance of the implemented search strategies on your running examples in terms of completeness, optimality, and the number of expanded nodes. You should comment on the differences in the number of expanded nodes between the implemented search strategies:

Breadth First : complete , optimal , space is $O(b^d)$ where d is depth and b is the maximum branching factor.

Depth First : not Complete , not Optimal , space is $O(bm)$ where m is maximum depth of the state space

Greedy : not Complete , not Optimal , space is $O(b^m)$

Breadth search is expanding a lot of nodes as it expands each of the adjacent nodes , then comes Depth Search as it also expands each of the nodes in a certain path to the goal. And third is the Greedy search as it checks with minimum heuristic and that node with minimum heuristic is visited or not.

7- Proper citation of any sources you might have consulted in the course of completing the project:

- Patel, Amit. "Heuristics From Amit's Thoughts on Pathfinding." Heuristics, 12 Oct. 2019, theory.stanford.edu/~amitp/GameProgramming/Heuristics.html

8- If your program does not run, your report should include a discussion of what you think the problem is and any suggestions you might have for solving it:

The DFS was working on a single-direction graph. When we switched the graph to a bidirectional one, the search keeps running till the end of the tree in an infinite loop.