**KAUNO TECHNOLOGIJOS UNIVERSITETAS**

**INFORMATIKOS FAKULTETAS**

**Modulio P170B400 „Algoritmų sudarymas ir analizė“**

**Laboratorinio darbo aprašas (ataskaita)**

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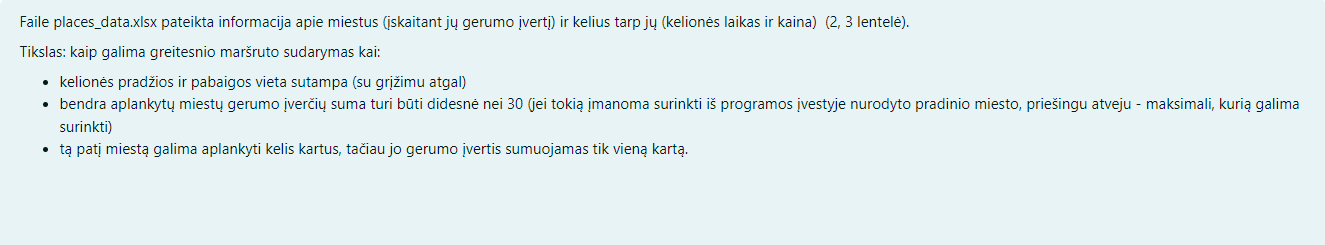
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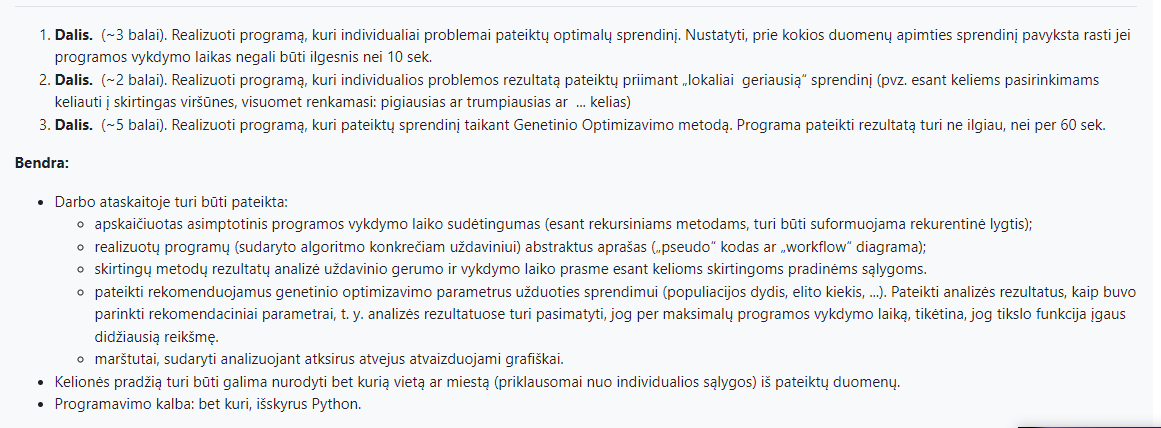
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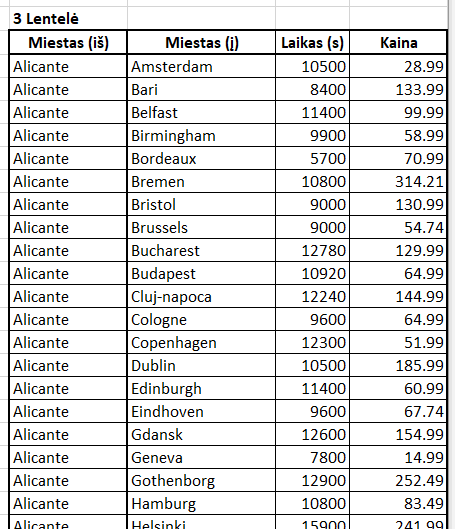
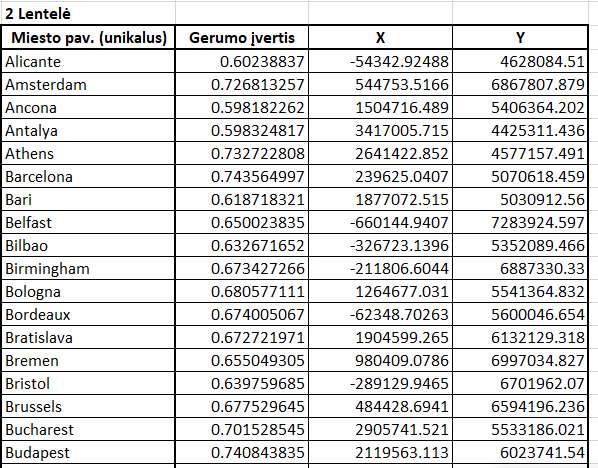
# Darbo užduotis





# Duomenys

Užduoties sprendimui buvo duotas Excel duomenų failas IP\_data.xlsx. Žemiau įdedu dalis lentelės, kurių reikia gabaliukus, nes įdėt visų duomenų neišeis dėl vietos stokos.



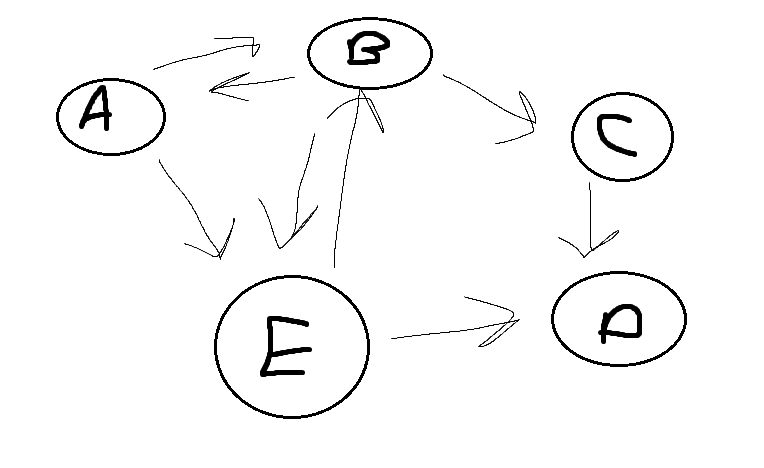
Pav. 1

Pav. 2

# 1 Dalis

Šitas uždavinys yra panašus į keliaujančio pirklio uždavinį su šiokiais tokiais apribojimais ir tam tikromis sąlygomis. Šiam uždaviniui atlikti reikia skaičiuoti miestų reitingus, per kuriuos keliauja „pirklys“. Kiekvieną pirmą kartą aplankius miestą, jo gerumo reitingas pridedamas prie viso kelio reitingo. Tokį uždavinį sprendžiant, dažniausiai sprendimas trunka eksponentinį laiką, dėl užduoties sudėtingumo ir duomenų kiekio, kuris gerokai padidina programos veikimo laiką.

Uždavinys sudarytas iš n miestų. Iš kiekvieno iš n miestų galima patekti į beveik bet kurį kitą miestą atsižvelgiant į kelią tarp miestų, gerumo reitingus. Taigi iš kiekvieno miesto galima patekti į kitą miestą n, o tai sudaro begalinius skirtingus kelius. Vykdant uždavinį mes bandome sudaryti geriausią įmanomą kelionę atsižvelgiant į kiekvieno miesto gerumo reitingus. Vienintelis rimtas apribojimas sprendžiant šitą uždavinį, tai, kad reikia surinkti 30 gerumo reitingą bekeliaujant. Pirmyn ir atgal tarp miestų galima važinėti, bet taip darant papildomai neprisideda gerumo įvertis. Norint surasti geriausią kelią, tiesiog einame per visus kelius ir renkame gerumo įverčius, taip pat atsižvelgami į tai, kad gali reikti rinkti mažesnį atstumą tarp miestų. Kelionės pabaiga yra tik tada, kai pasiekiamas kelionės pradžios miestas.



Pav. 3 Keliavimo tarp miestų pvz

# Programinio kodo analizė:

void FindAllPathsForced(City StartingCity, List<Path> list, double Ratings, City current, Dictionary<City, bool> visited, Path path, bool secondMethod)

{

if (timer.Elapsed.TotalSeconds > 10) { return; } // c1 | 1

Dictionary<City, bool> dic = new Dictionary<City, bool>(visited); // c2 | 1

Path newPath = new Path(path); // c3 | 1

double Rating = Ratings; // c4 | 1

//

newPath.Add(Rating, current); // c5 | 1

foreach (City c in path.Roads) // c6 | n

{ //

Console.Write(c.Name + "->"); // c7 | n\*1

} //

//

Console.Write("\n"); // c8 | 1

//

if (current.Name == StartingCity.Name && Rating > 30) // c9 | 1

{ //

list.Add(newPath); // c10 | 1

return; // c11 | 1

} //

//

for (int i = 0; i < current.Roads.Count(); i++) // c12 | n+1

{ //Šis metodas reikalingas paleisti antrą metodą, dėl to čia vyksta jo kvietimas //

if (secondMethod == false) // c13 | n\*1

{ //

if (newPath.Repeat(current, current.Roads[i].To)) // c14 | n\*1

{ //

if (newPath.Roads.Contains(current.Roads[i].To)) // c15 | n\*1

FindAllPathsForced(StartingCity, list, Rating, current.Roads[i].To, dic, newPath, secondMethod); // T(n - 1) | n\*1

else // c17 | n\*1

FindAllPathsForced(StartingCity, list, Rating + current.Roads[i].To.Rating, current.Roads[i].To, dic, newPath, secondMethod); // T(n - 1) | n\*1

} //

} //

else // c18 | n\*1

{ //

if (newPath.Roads.Contains(current.Roads[i].To)) // c19 | n\*1

{ //

FindAllPaths(StartingCity, list, Rating, current.Roads[i].To, dic, newPath, 10000); // T(n - 1) | n\*1

} //

else // c20 | n\*1

{ //

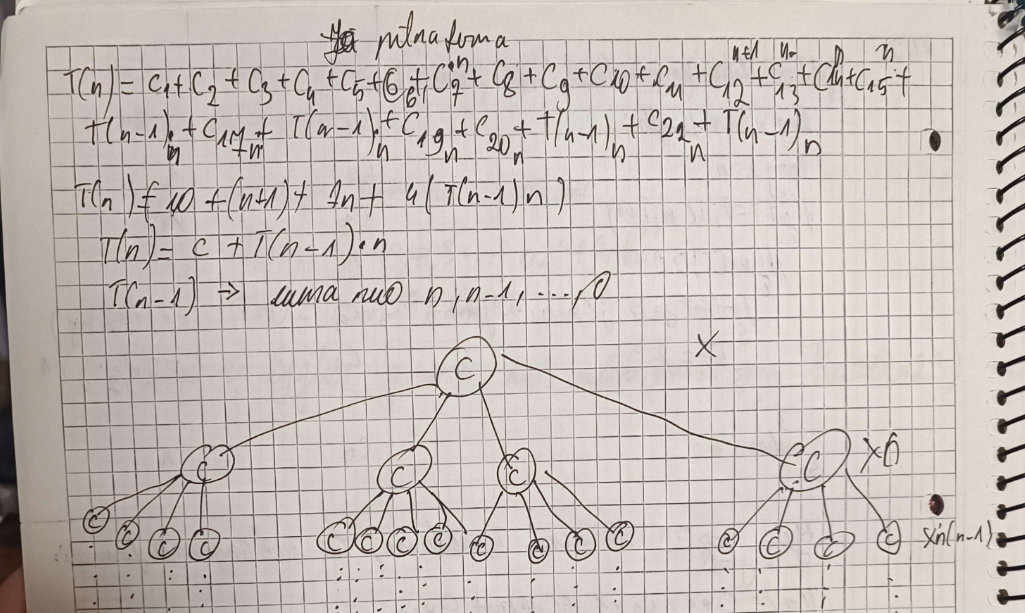
FindAllPaths(StartingCity, list, Rating + current.Roads[i].To.Rating, current.Roads[i].To, dic, newPath, 10000); // T(n - 1) | n\*1

}

}

}

# Asimptotinio kodo skaičiavimas:



Pirmai užduočiai gavome 10 sekundžių apribojimą programos veikimui. Žinant tai, kad kodo sudėtingumas yra faktorialinis, galime spręsti, kad didelies apimties duomenų atveju programa nesugebės jų apdoroti per duotą laiką.

# Rezultatai:

Rezultatai, kurie spausdinami faile, yra atrūšiuoti kad nebūtų duplikatų ir atskirai parodomi 10 geriausių kelių.

Top10 keliai

Naples -> Amsterdam -> Alicante -> Amsterdam -> Belfast -> Alicante -> Bari -> Alicante -> Belfast -> Amsterdam -> Birmingham -> Alicante -> Birmingham -> Amsterdam -> Bristol -> Alicante -> Bordeaux -> Alicante -> Bremen -> Alicante -> Bristol -> Amsterdam -> Copenhagen -> Alicante -> Brussels -> Alicante -> Bucharest -> Alicante -> Budapest -> Alicante -> Cluj-napoca -> Alicante -> Cologne -> Alicante -> Copenhagen -> Amsterdam -> Dublin -> Alicante -> Dublin -> Amsterdam -> Dubrovnik -> Amsterdam -> Edinburgh -> Alicante -> Edinburgh -> Amsterdam -> Geneva -> Alicante -> Eindhoven -> Alicante -> Gdansk -> Alicante -> Geneva -> Amsterdam -> Lisbon -> Amsterdam -> Liverpool -> Alicante -> Gothenborg -> Alicante -> Hamburg -> Alicante -> Helsinki -> Alicante -> Karlsruhe -> Alicante -> Kaunas -> Alicante -> Krakow -> Alicante -> Leeds -> Alicante -> Liverpool -> Amsterdam -> London -> Alicante -> London -> Amsterdam -> Malaga -> Amsterdam -> Manchester -> Alicante -> Manchester -> Amsterdam -> Milan -> Alicante -> Marseille -> Alicante -> Milan -> Amsterdam -> Naples -> Athens -> Bologna -> Athens -> Bristol -> Antalya -> Bristol -> Athens -> Brussels -> Ancona -> Brussels -> Athens -> Budapest -> Athens -> Cologne -> Barcelona -> Belfast -> Barcelona -> Birmingham -> Barcelona -> Bologna -> Barcelona -> Bordeaux -> Barcelona -> Bristol -> Barcelona -> Brussels -> Barcelona -> Bucharest -> Barcelona -> Budapest -> Barcelona -> Cluj-napoca -> Barcelona -> Cologne -> Bologna -> Bari -> Bologna -> Brussels -> Bari -> Bordeaux -> Bari -> Brussels -> Bologna -> Bucharest -> Bari -> Bucharest -> Birmingham -> Belfast -> Birmingham -> Bordeaux -> Birmingham -> Bucharest -> Bologna -> Budapest -> Bari -> Budapest -> Birmingham -> Budapest -> Bologna -> Cagliari -> Bari -> Cagliari -> Bologna -> Catania -> Bari -> Catania -> Bologna -> Cluj-napoca -> Bari -> Cluj-napoca -> Birmingham -> Bydgoszcz -> Birmingham -> Cluj-napoca -> Bologna -> Cologne -> Bristol -> Belfast -> Bristol -> Bilbao -> Bristol -> Bordeaux -> Bristol -> Bucharest -> Bristol -> Budapest -> Bordeaux -> Brussels -> Bordeaux -> Budapest -> Bristol -> Catania -> Bristol -> Cologne -> Cluj-napoca -> Brussels -> Bratislava -> Brussels -> Bucharest -> Brussels -> Budapest -> Brussels -> Cagliari -> Brussels -> Catania -> Brussels -> Cluj-napoca -> Catania -> Bucharest -> Catania -> Budapest -> Cagliari -> Budapest -> Catania -> Cagliari -> Catania -> Cluj-napoca -> Cologne -> Copenhagen -> Bologna -> Copenhagen -> Bratislava -> Copenhagen -> Bristol -> Copenhagen -> Bucharest -> Copenhagen -> Budapest -> Copenhagen -> Cologne -> Dublin -> Athens -> Dublin -> Barcelona -> Dublin -> Bari -> Dublin -> Birmingham -> Dublin -> Bologna -> Dublin -> Bordeaux -> Dublin -> Bratislava -> Dublin -> Bristol -> Dublin -> Brussels -> Dublin -> Bucharest -> Dortmund -> Bucharest -> Dublin -> Budapest -> Dortmund -> Budapest -> Dublin -> Bydgoszcz -> Dublin -> Cagliari -> Dublin -> Cologne -> Gdansk -> Barcelona -> Edinburgh -> Athens -> Edinburgh -> Barcelona -> Eindhoven -> Barcelona -> Gdansk -> Birmingham -> Edinburgh -> Bari -> Edinburgh -> Belfast -> Edinburgh -> Birmingham -> Gdansk -> Bristol -> Dubrovnik -> Bristol -> Edinburgh -> Bologna -> Edinburgh -> Bordeaux -> Edinburgh -> Bratislava -> Edinburgh -> Bristol -> Gdansk -> Cologne -> Katowice -> Athens -> Geneva -> Antalya -> Geneva -> Athens -> Katowice -> Barcelona -> Geneva -> Barcelona -> Karlsruhe -> Barcelona -> Katowice -> Bristol -> Geneva -> Bilbao -> Geneva -> Birmingham -> Geneva -> Bordeaux -> Geneva -> Bristol -> Katowice -> Catania -> Eindhoven -> Bologna -> Eindhoven -> Bratislava -> Eindhoven -> Budapest -> Edinburgh -> Brussels -> Edinburgh -> Bucharest -> Edinburgh -> Budapest -> Eindhoven -> Catania -> Geneva -> Brussels -> Geneva -> Bucharest -> Eindhoven -> Cluj-napoca -> Dortmund -> Cluj-napoca -> Eindhoven -> Debrecen -> Eindhoven -> Dublin -> Copenhagen -> Dublin -> Dubrovnik -> Dublin -> Edinburgh 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-> Kaunas -> Copenhagen -> Geneva -> Copenhagen -> Kaunas -> Dublin -> Kaunas -> Edinburgh -> Geneva -> Dubrovnik -> Geneva -> Edinburgh -> Gothenborg -> Edinburgh -> Hamburg -> Edinburgh -> Kaunas -> Eindhoven -> Krakow -> Cagliari -> Karlsruhe -> Cagliari -> Krakow -> Catania -> London -> Ancona -> London -> Antalya -> Liverpool -> Antalya -> London -> Athens -> London -> Barcelona -> Liverpool -> Barcelona -> London -> Bari -> London -> Belfast -> Leeds -> Belfast -> Liverpool -> Belfast -> London -> Bilbao -> London -> Bologna -> London -> Bordeaux -> London -> Bratislava -> Leeds -> Bratislava -> London -> Bremen -> London -> Bucharest -> Lisbon -> Budapest -> Lisbon -> Cologne -> London -> Budapest -> Liverpool -> Brussels -> Liverpool -> Bucharest -> Liverpool -> Budapest -> London -> Bydgoszcz -> London -> Cagliari -> London -> Catania -> Lyon -> Barcelona -> Luxemburg -> Barcelona -> Lyon -> Bordeaux -> Lyon -> Bristol -> Lyon -> Bucharest -> London -> Cluj-napoca -> Liverpool 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Cluj-napoca -> Malaga -> Cologne -> Manchester -> Brussels -> Nice -> Amsterdam -> Nice -> Barcelona -> Nice -> Bordeaux -> Nice -> Bristol -> Newcastle -> Alicante -> Newcastle -> Belfast -> Newcastle -> Bristol -> Nice -> Brussels -> Nimes -> Brussels -> Palermo -> Amsterdam -> Palermo -> Barcelona -> Nuernberg -> Alicante -> Nuernberg -> Barcelona -> Palermo -> Bari -> Nuernberg -> Bari -> Palermo -> Bologna -> Nuernberg -> Bologna -> Palermo -> Brussels -> Perugia -> Barcelona -> Paris -> Alicante -> Paris -> Barcelona -> Perugia -> Brussels -> Pisa -> Barcelona -> Pisa -> Bari -> Paris -> Bari -> Pisa -> Bordeaux -> Pisa -> Bristol -> Paris -> Belfast -> Paris -> Bologna -> Paris -> Bristol -> Pisa -> Brussels -> Porto -> Alicante -> Porto -> Barcelona -> Poitiers -> Barcelona -> Porto -> Bari -> Porto -> Birmingham -> Porto -> Bologna -> Porto -> Bordeaux -> Porto -> Bristol -> Porto -> Brussels -> Poznan -> Alicante -> Poznan -> Birmingham -> Poznan -> Bristol -> Poznan -> Brussels -> Prague -> Amsterdam -> Prague -> Barcelona -> Prague -> Bari -> Prague -> Bordeaux -> Prague -> Bristol -> Prague -> Brussels -> Rabat -> Barcelona -> Rabat -> Brussels -> Riga -> Barcelona -> Riga -> Bristol -> Riga -> Brussels -> Rijeka -> Brussels -> Rome -> Amsterdam -> Rome -> Athens -> Naples -> 45.55245089534786

Naples -> Amsterdam -> Alicante -> Amsterdam -> Belfast -> Alicante -> Bari -> Alicante -> Belfast -> Amsterdam -> Birmingham -> Alicante -> Birmingham -> Amsterdam -> Bristol -> Alicante -> Bordeaux -> Alicante -> Bremen -> Alicante -> Bristol -> Amsterdam -> Copenhagen -> Alicante -> Brussels -> Alicante -> Bucharest -> Alicante -> Budapest -> Alicante -> Cluj-napoca -> Alicante -> Cologne -> Alicante -> Copenhagen -> Amsterdam -> Dublin -> Alicante -> Dublin -> Amsterdam -> Dubrovnik -> Amsterdam -> Edinburgh -> Alicante -> Edinburgh -> Amsterdam -> Geneva -> Alicante -> Eindhoven -> Alicante -> Gdansk -> Alicante -> Geneva -> Amsterdam -> Lisbon -> Amsterdam -> Liverpool -> Alicante -> Gothenborg -> Alicante -> Hamburg -> Alicante -> Helsinki -> Alicante -> Karlsruhe -> Alicante -> Kaunas -> Alicante -> Krakow -> Alicante -> Leeds -> Alicante -> Liverpool -> Amsterdam -> London -> Alicante -> London -> Amsterdam -> Malaga -> Amsterdam -> Manchester -> Alicante -> Manchester -> 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Naples -> Amsterdam -> Alicante -> Amsterdam -> Belfast -> Alicante -> Bari -> Alicante -> Belfast -> Amsterdam -> Birmingham -> Alicante -> Birmingham -> Amsterdam -> Bristol -> Alicante -> Bordeaux -> Alicante -> Bremen -> Alicante -> Bristol -> Amsterdam -> Copenhagen -> Alicante -> Brussels -> Alicante -> Bucharest -> Alicante -> Budapest -> Alicante -> Cluj-napoca -> Alicante -> Cologne -> Alicante -> Copenhagen -> Amsterdam -> Dublin -> Alicante -> Dublin -> Amsterdam -> Dubrovnik -> Amsterdam -> Edinburgh -> Alicante -> Edinburgh -> Amsterdam -> Geneva -> Alicante -> Eindhoven -> Alicante -> Gdansk -> Alicante -> Geneva -> Amsterdam -> Lisbon -> Amsterdam -> Liverpool -> Alicante -> Gothenborg -> Alicante -> Hamburg -> Alicante -> Helsinki -> Alicante -> Karlsruhe -> Alicante -> Kaunas -> Alicante -> Krakow -> Alicante -> Leeds -> Alicante -> Liverpool -> Amsterdam -> London -> Alicante -> London -> Amsterdam -> Malaga -> Amsterdam -> Manchester -> Alicante -> Manchester -> 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# 2 Dalis

Antrai daliai, reikia atrasti lokaliai geriausius kelius, o kad tai padaryti, turime optimizuoti jau turimą kodą iš pirmos dalies. Lokaliai geriausias kelias – kai keliai tarp kiekvieno miesto kely yra artimiausi. T.y. jeigu iš Kauno galime važiuoti į Kėdainius ar į Rygą, žinoma kad važiuosim į Kėdainius, nes tai yra arčiau negu Ryga. Kadangi vaikštant pirmyn atgal per miestus kelionės viso reitingo nepakelia, tai pasinaudosime Dictionary objektu tam, kad galėtume atrinkti ar jau mieste buvome ir kad programa neitų į tą patį miestą kelis kartus, taip optimizuodami randamus kelius.

Kadangi nuo pirmos užduoties skirias tik tuo, kad reikia kuo lokalesnį miestą imti sekantį, taip pat turime padaryti, kad galutinis maršrutas turi būti ne mažiau 30.

# Programinis kodas:

void FindAllPaths(City StartingCity, List<Path> list, double Ratings, City current, Dictionary<City, bool> visited, Path path, int Timerr)

{

Dictionary<City, bool> dic = new Dictionary<City, bool>(visited); // c1 | 1

Path newPath = new Path(path); // c2 | 1

double Rating = Ratings; // c3 | 1

//

for (int r = 0; r < current.Roads.Count(); r++) // c4 | n+1

{ //

if (dic[current] == false) // c5 | n+1\*1

{ //

dic[current] = true; // c6 | 1 \* n+1

} //

else // c7 | n+1\*1

{ //

if (current.Name != StartingCity.Name) // c8 | n+1\*1

{ //

return; // c9 | n+1\*1

} //

} //

// c10 | n+1\*1

int Timer = 10000; // c11 | n+1\*1

City next = current; //

//

if (StartingCity.Name == current.Name) // c12 | n+1\*1

{ //

if (r == 0) // c13 | n+1\*1

{ //

newPath.Add(Rating, current); // c14 | n+1\*1

} //

} //

else // c15 | n+1\*1

{ //

newPath.Add(Rating, current); // c16 | n+1\*1

} //

if (Rating > 30) // c17 | n+1\*1

{ //

if (current.Name == StartingCity.Name) // c18 | n+1\*1

{ //

list.Add(newPath); // c19 | n+1\*1

return; // c20 | n+1\*1

} //

for (int i = 0; i < current.Roads.Count(); i++) // c21 | n+1\*1\*n+1

{ //

if (StartingCity.Name == current.Roads[i].To.Name) // c21 | n+1\*1\*n+1\*1

{ //

FindAllPaths(StartingCity, list, Rating + current.Roads[i].To.Rating, current.Roads[i].To, dic, newPath, Timer); // T(n-1) | n+1\*1\*n+1\*1

} //

if ((dic[current.Roads[i].To] == false || current.Roads[i].To.Name == StartingCity.Name)) // c22 | n+1\*1\*n+1\*1

{ //

next = current.Roads[i].To; // c23 | n+1\*1\*n+1\*1

} //

} //

FindAllPaths(StartingCity, list, Rating + next.Rating, next, dic, newPath, Timer); // T(n-1) | n+1\*1\*n+1\*1

dic[next] = true; // c24 | n+1\*1\*n+1\*1

} //

else // c25 | n+1\*1\*1

{ //

if (current.Name == StartingCity.Name) // c26 | n+1\*1\*1

{ //

list.Add(newPath); // c27 | n+1\*1\*1

return; // c28 | n+1\*1\*1

} //

//

for (int i = 0; i < current.Roads.Count(); i++) // c29 | n+1\*1\*1\*n+1

{ //

if (Timer > current.Roads[i].Time && (dic[current.Roads[i].To] == false || current.Roads[i].To.Name == StartingCity.Name)) // c30 | n+1\*1\*1\*n+1

{ //

Timer = current.Roads[i].Time; // c31 | n+1\*1\*1\*n+1\*1

next = current.Roads[i].To; // c32 | n+1\*1\*1\*n+1\*1

} //

} //

FindAllPaths(StartingCity, list, Rating + next.Rating, next, dic, newPath, Timer); // c33 | n+1\*1\*1

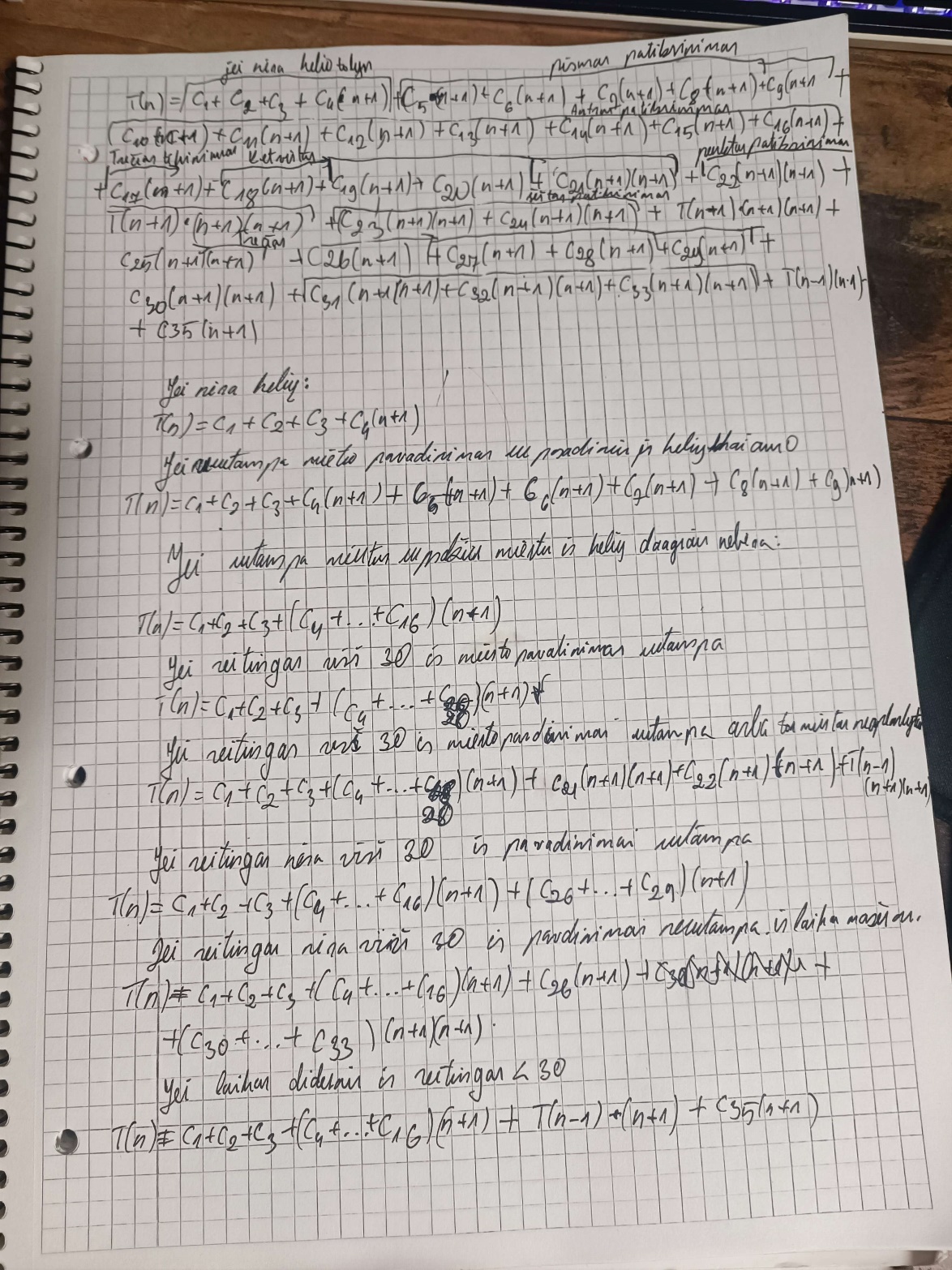
dic[next] = true; // c34 | n+1\*1\*1

}

}

}

# Programinio kodo analizė:



Sudėtingumo skaičiavimas šiam metodui yra gan sudėtingas, nes reikia atsižvelgti į kiekvieną IF sąlygą, dėl to asimptotinis sudėtingumo įvertinimas gali žymiai skirtis.

Geriausiu atveju, gauname, kad metodo asimptotinis sudėtingumas yra Ω(T(n)) = c

Blogiausiu atveju laikas būtų sprendžiamas, kai reitingas virš 30 ir miesto pavadinimas nesutampa su pradiniu miestu ir laikas mažesnis.

# Rezultatai:

Programai atlikus darbus, gauname, kad šie keliai yra top10 tarp geriausių kelių.

Kaip matome, jie yra gerokai mažesni, negu su Forced metodu. Taip pat ieškant šių kelių, buvo rasti 1607 keliai, kai palyginus su pirmu metodu, buvo terasta tik apie 400 kelių.

Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Alicante -> 45.166940028262836

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Gothenborg -> 45.242046051832084

Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Alicante -> 45.90544048017451

Riga -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> 45.96964655667932

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> 46.64714095007715

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Bucharest -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Bucharest -> 47.95105786493883

Hamburg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Hamburg -> 47.97505496621456

Amsterdam -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Amsterdam -> 47.976342576681496

# 3 Dalis

Genetinis optimizavimas yra laikomas evoliucinio algoritmo klase, kuri naudojama spręsti optimizavimo problemas. Šis metodas yra sprendžiamas remiantis biologinės evoliucijos principais. Šio algoritmo esmė, kad galima rasti sprendimą atliekant iteratyvų sprendimų paieškos procesą.

Genetinio optimizavimo metu, kaip ir kitais mašininio mokymosi (machine learning) algoritmais, yra sukuriama pradinė populiacija, kurią sudaro sprendimų kandidatai vadinami genotipais, šiuo atveju kandidatai yra Paths. Kiekvienas genotipas yra atsakingas už vieną potencialų sprendimą ir šių sprendimų kokybė yra vertinama su tinkamumo funkcija (fitness function).

Šio algoritmo procesas pradedamas nuo atsitiktinai pasirinktų miestų kaip populiacijos vienetų. Toliau vyksta selekcija, rekombinacija ir mutacija.

Selekcijos proceso metu parenkami geriausi populiacijos vienetai, kurie toliau dalyvauja rekombinacijoje.

Rekombinacijos metu yra atsitiktinai parenkami du populiacijos vienetai iš kurių sukuriama nauja karta populiacijos vienetų. Tai dažniausiai atliekama crossover būdu. Toliau palikuoniai mutuoja įgaudami šiokius tokius skirtumus ir leisdami platesnes tyrimo galimybes.

Šie etapai kartojami kelis kartus, kol būna gaunamas geriausias sprendimas numatytiem tikslam įvykdyti.

Genetinis optimizavimas yra plačiai naudojamas daugelyje optimizavimo problemų sprendimui. Galimos problemos, kurias sprendžia su genetinio optimizavimo pagalba: inžinerinės konstrukcijos, planavimo uždaviniai.

Šis algoritmas labai praverčia kai yra didelis kiekis duomenų ir sudėtinga gauti optimalų sprendimą pasitelkiant tradicinius metodus.

public class GeneticOptimization

{

private const double Mutation = 1.5;

private const int TournamentSize = 3;

private static Path SelectViaTournament(Population Population, List<Road> roads)

{

Population Tournament = new Population(TournamentSize);

Random Randomizer = new Random();

for (int i = 0; i < TournamentSize; i++)

Tournament.PathAdd(Population.Paths[Randomizer.Next(0, Population.Paths.Count)]);

return Tournament.GetFittest();

}

private static Path CrossoverAndMutate(Path first, Path second, List<Road> roads)

{

Random randomizer = new Random();

// Create a new path object for the offspring

Path offspring = new Path();

// Randomly select a crossover point

int crossoverPoint = randomizer.Next(1, first.Roads.Count - 1);

// Add cities from the first parent up to the crossover point

for (int i = 0; i < crossoverPoint; i++)

{

City city = first.Roads[i];

offspring.Roads.Add(city);

offspring.Rating += city.Rating;

}

// Add cities from the second parent after the crossover point

for (int i = crossoverPoint; i < second.Roads.Count - 1; i++)

{

City city = second.Roads[i];

// Check if the city is already present in the offspring

if (!offspring.Roads.Contains(city))

{

offspring.Roads.Add(city);

offspring.Rating += city.Rating;

}

}

// Add the starting city at the end to represent the round trip

offspring.Roads.Add(offspring.Roads[0]);

//offspring.Time += offspring.Roads.Last().Roads.Find(r => r.To == offspring.Roads[0]).Time;

// Perform mutation

if (randomizer.NextDouble() < Mutation)

{

int mutationPoint1 = randomizer.Next(1, offspring.Roads.Count - 1);

int mutationPoint2 = randomizer.Next(1, offspring.Roads.Count - 1);

// Swap the cities at the mutation points

City temp = offspring.Roads[mutationPoint1];

offspring.Roads[mutationPoint1] = offspring.Roads[mutationPoint2];

offspring.Roads[mutationPoint2] = temp;

// Update the rating for the mutated path

offspring.Time = Utils.CalculateRating(offspring.Roads, roads);

}

return offspring;

}

public static Population EvolvePopulation(Population population, List<Road> roads)

{

Population newPopulation = new Population(population.PopulationSize);

// Add the fittest individuals from the previous population (elitism)

Path bestPath = Utils.BestPath(population.Paths);

newPopulation.PathAdd(bestPath);

for (int i = 1; i < population.PopulationSize; i++)

{

// Select parents via tournament selection

Path parent1 = SelectViaTournament(population, roads);

Path parent2 = SelectViaTournament(population, roads);

// Perform crossover and mutation to create offspring

Path offspring = CrossoverAndMutate(parent1, parent2, roads);

// Add the offspring to the new population

newPopulation.PathAdd(offspring);

}

newPopulation.Paths = newPopulation.Paths.OrderBy(path => path.Rating).ToList();

return newPopulation;

}

}

public class Population

{

public int PopulationSize;

public List<Path> Paths;

public Population(List<Path> Paths, int PopulationSize, bool Initialize)

{

this.Paths = new List<Path>();

this.PopulationSize = PopulationSize;

for (int i = 0; i < PopulationSize; i++)

{

Random rnd = new Random();

int number = rnd.Next(0, Paths.Count);

if (Paths[number].Time / 3600 < 48)

{

this.Paths.Add(Paths[number]);

}

else

{

i--;

continue;

}

}

}

public Population(int PopulationSize)

{

this.Paths = new List<Path>();

this.PopulationSize = PopulationSize;

}

public void PathAdd(Path path)

{

this.Paths.Add((Path)path);

}

public Path GetFittest()

{

//Console.WriteLine(Utils.BestPath(Paths).Time+ " "+ Utils.BestPath(Paths).Rating);

return Utils.BestPath(Paths);

}

public void printer()

{

InOutUtils.PrintPaths(this.Paths);

}

# Gaunami rezultatai:

-------------------------- Genetic Paths -------------------------------------

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> 46.64714095007715

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Amsterdam -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Amsterdam -> 47.976342576681496

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Gothenborg -> 45.242046051832084

Bucharest -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Bucharest -> 47.95105786493883

Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Alicante -> 45.166940028262836

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Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Alicante -> 45.166940028262836

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Bucharest -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Bucharest -> 47.95105786493883

Bucharest -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Bucharest -> 47.95105786493883

Bucharest -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Hamburg -> Bucharest -> 48.67658351124766

Bucharest -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Bucharest -> 47.95105786493883

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Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Alicante -> 45.90544048017451

Riga -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> 45.96964655667932

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> 46.64714095007715

Bucharest -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Bucharest -> 47.95105786493883

Riga -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> 45.96964655667932

Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Alicante -> 45.166940028262836

Bucharest -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Hamburg -> Bucharest -> 48.67658351124766

Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Alicante -> 45.166940028262836

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> 46.64714095007715

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Bucharest -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Bucharest -> 47.95105786493883

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Gothenborg -> 45.242046051832084

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Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Alicante -> 45.166940028262836

Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Alicante -> 45.90544048017451

Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> 47.24952931990573

Hamburg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Hamburg -> 47.97505496621456

Amsterdam -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Amsterdam -> 47.976342576681496

Hamburg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Hamburg -> 47.97505496621456

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> 46.64714095007715

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> 46.64714095007715

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Gothenborg -> 45.242046051832084

Amsterdam -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Amsterdam -> 47.976342576681496

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Gothenborg -> 45.242046051832084

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> 46.64714095007715

Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Alicante -> 45.166940028262836

Gothenborg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Gothenborg -> 45.242046051832084

Bucharest -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Hamburg -> Bucharest -> 48.67658351124766

Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Alicante -> 45.166940028262836

Riga -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> 45.96964655667932

Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> 47.24952931990573

Alicante -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Alicante -> 45.166940028262836

Amsterdam -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Amsterdam -> 47.976342576681496

Bucharest -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Hamburg -> Bucharest -> 48.67658351124766

Hamburg -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Malaga -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Oslo -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Hamburg -> 47.97505496621456

--------------------------Genetic Best Path-------------------------------------

Best Path: Amsterdam -> Manchester -> Belfast -> Liverpool -> Dublin -> Leeds -> Poznan -> Budapest -> Prague -> Krakow -> Vienna -> Bologna -> Bari -> Palermo -> Naples -> Catania -> Cagliari -> Rome -> Nice -> Geneva -> Paris -> Bristol -> Newcastle -> Gdansk -> Lublin -> Eindhoven -> London -> Cologne -> Milan -> Marseille -> Bordeaux -> Lyon -> Toulouse -> Nantes -> Porto -> Sevilla -> Lisbon -> Madrid -> Rabat -> Oslo -> Valencia -> Pisa -> Barcelona -> Poitiers -> Edinburgh -> Birmingham -> Warsaw -> Venice -> Vilnius -> Malaga -> Katowice -> Malmoe -> Zagreb -> Thessaloniki -> Stockholm -> Tallinn -> Nuernberg -> Varna -> Sofia -> Karlsruhe -> Timisoara -> Brussels -> Zaragoza -> Cluj-napoca -> Turin -> Copenhagen -> Kaunas -> Helsinki -> Riga -> Gothenborg -> Alicante -> Hamburg -> Amsterdam

Rating: 48.70186822299032