Efficient Route Planning

SS 2012

Lecture 1, Wednesday April 25th, 2012

(Intro, Organizational, OSM Data, Road Graph)

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Overview of this lecture

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- Introduction
  - Demos + what you will learn in this course
- Organizational
  - Style of the course
  - Course Systems: Wiki, Forum, Daphne, SVN, Jenkins, …
  - Exercises + Exam
- And then let's start
  - Modeling road networks as graphs
  - OpenStreetMap (OSM) data
  - Exercise Sheet #1: build a graph from the OSM data of Saarland and Baden-Württemberg

Demos + what you will learn

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- Demos
  - Routing in road and transit networks on Google Maps
  - http://wiki.openstreetmap.org/wiki/OpenTripPlanner
  - At the end of the course you will be able to build something like this ... and maybe even sth better
- What you will learn in this course
  - How to model road and transit networks
  - Where to get data and making sense of it
  - Clever algorithms for route planning on these networks
  - How to build web applications around this

Style of this course

- What I will do
  - Explain graph models, data, and the various algorithms
  - Give implementation advice + provide code skeletons
- What you will do
  - Implement graph builders (data → graph)
  - Implement the various algorithms
  - Do experiments with these algorithms / graphs
  - Explore variations / new ideas
  - Some theoretical tasks ... but not too many
  - Maybe have a look at some of the relevant research papers

Course systems

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- Various systems supporting this course
  - The course Wiki is the **hub page** with links to each of the following
  - Daphne is our course management system
  - There is an SVN repository for your submissions, in particular for your code
  - There is a forum for asking questions
  - All the course materials will be put online: the lecture slides, the exercise sheets, the lecture recordings, as well as any code we write in the lectures
  - We will also provide a continuous build system (Jenkins) that automatically checks the code you commit to our SVN

Exercises + Exam

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- There will be one exercise sheet per week
  - Usually an implementation / experimentation task
  - You can work on the sheets alone or in groups of 2 people
  - Submit the code to our **SVN** → URL on your Daphne page
  - Follow our **Coding Standards** → next slide
  - You can get 20 points per exercise sheet
  - The exercise sheets are **key** to a real understanding
- Exam in the end
  - You need 50% of the points to be admitted
  - The date of the exam has not been fixed yet, stay tuned ...

Our Coding Standards

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- Please follow these guidelines when writing code
  - Write your programs in C++ or in Java
  - Document each class and each non-trivial method
  - Your code must conform to our style checkers
  - Write a unit test for every non-trivial function
  - Use a standardized Makefile / build.xml file
  - You find a comprehensive example on https://daphne.informatik.uni-freiburg.de/CodingStandards
  - Check your submissions on our build system Jenkins
  - We will walk through an example at the end of the lecture

How much work is it / ECTS points

- ECTS points = working time
  - You get 6 ECTS points for this lecture
  - That is 6 x 30 = 180 hours of work for the whole course
    - 60 hours for the exam + preparation
    - 120 hours for the lectures + exercise sheets
    - There are 12 lectures with exercise sheets
    - That's about 10 hours per week for this course
    - That's about 8 hours per exercise sheet
  - **Note:** when you have done all the exercise sheets (yourself) you are pretty much fit for the exam, without much more preparation needed

Road networks

- Model as graph
  - each crossing of two or road segments is a node in the graph
  - each road segment is a directed arc in the graph
  - in the simplest model, the cost of an arc is the time to travel along the corresponding road segment

OpenStreetMap

- OpenStreetMap (OSM)
  - Is an open-source initiative for gathering geo data
    - not only road network data, but also all kinds of other map data (e.g. where is a forest / river / building)
  - Started in 2004, very good coverage by now
    - 1.4 billion nodes, many 100 billions of arcs (April 2012)
  - Data can be downloaded for free, see link in References
  - Please use the data linked to from the Wiki, so that we all have exactly the same data sets
    - Saarland, version 24-Apr-2012 18:52
    - Baden-Württemberg, version 24-Apr-2012 19:44

Extracting road data from OSM files

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- The OSM files contain not only road data
  - But all kinds of other map data, too
    - e.g. where is a forest / river / building
  - For now (in particular for Ex Sheet 1) all we need is
    - nodes (each with a latitude and a longitude)
    - ways (several arcs together) pertaining to roads
      - that is, with <tag k="highway" ...>
      - ways can also delineate forest boundaries etc.

Travel time along an arc

- The OSM data provides
  - ... node coordinates and road types
  - See the link to the OSM Map Features in the References
  - See our Wiki for a translation: road type → speed
  - This gives us travel time via the formula

    speed = distance traveled / travel time (v = s / t)
  - The obvious formula for the distance between nodes is the Euclidean distance between the corresponding points in 2D
  - More precisely, however, the path between two points on the earth's surface is **not** a straight line, but follows a so-called great circle (Großkreis) http://en.wikipedia.org/wiki/Great_circle
  - But for us here, Euclidean distance is good enough

Graph representation

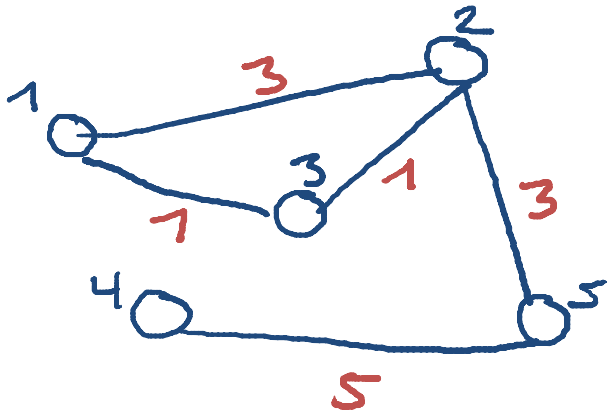
- Adjacency matrix
  - Store the arc costs in an $n \times n$ matrix, where n = #nodes
    - if arc does not exist, put some special value, e.g. ∞
  - Needs space $\Theta(n^2)$
  - Ok when m = #arcs is very large (so-called dense graphs)
- Adjacency lists
  - For each node, store an array of the outgoing arcs + their costs
  - Needs space $\Theta(n + m)$
  - Method of choice when $m << n^2$ (so-called sparse graphs)
  - For road networks, average degree of a node is around 2.5

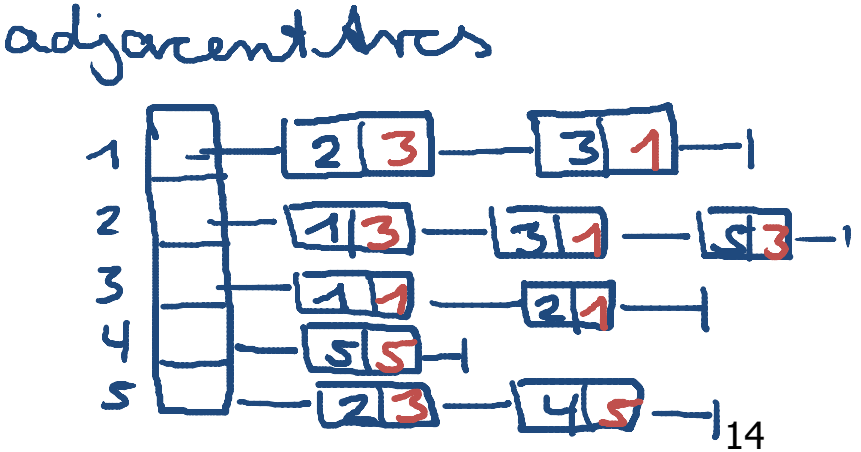
Adjacency lists

- Implementation advice
  - The straightforward implementation is

    Array<Array<Arc>> adjacentArcs;

    where Array could be vector in C++ and ArrayList in Java
  - The Arc class simply contains a data member for
    - the head node of each arc (the tail node is already implicit in the position of the Arc object in the Array)
    - the cost of the arc (in our case, the travel time)





Unit Tests, why and how

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- Correctness check for each (non-trivial) method
  - Otherwise 1: debugging becomes a nightmare
  - Otherwise 2: no trust in your experimental results
  - Let's look at some unit tests together ...
- Problem: testing equality of complex objects
  - For example, a whole road network object
  - Simple solution: for each class provide a method DebugString which outputs the object in a simple human-readable form
  - Then your test can check simple string equality, e.g.

```
rn.readFromOsmFile("test-file.osm");
ASSERT_EQ("[3,2,{(1,2)},{2,3},{3,1}]", rn.asString());
```

References

- OpenStreetMap (OSM)
  - http://www.openstreetmap.org/
  - http://en.wikipedia.org/wiki/OpenStreetMap
  - http://wiki.openstreetmap.org/wiki/Stats
  - http://wiki.openstreetmap.org/wiki/XML
  - http://wiki.openstreetmap.org/wiki/Data_Primitives
  - http://wiki.openstreetmap.org/wiki/Map_Features#Highway
- Download of OSM extracts by country / region
  - http://download.geofabrik.de/osm
  - http://download.geofabrik.de/osm/europe/germany