Algorithms for Graph Visualization

Introduction

Tamara Mchedlidze, Marcel Radermacher
19.10.2017
Introduction

Lectures

• Tamara Mchedlidze
• mched@iti.uka.de
• Office 307
• Office hours: request by email

Exercises

• Marcel Radermacher
• radermacher@kit.edu
• Office 306
• Office hours: request by email
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YOU: Name, Field of your Bachelor studies, why you are interested in this lecture
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Mailing list
Overview

About this course

Repetition of the material. We build our Mind Map.

Drawing graphs “by hand”. Complete MindMap.

Formal definition of Layout Problem.

About this course: learning objectives.

Applications gallery.
Overview

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About this Course

• **Lecture:** Thursday 14:00 – 15:30, Room 301
• **Exercise:** Wednesday 14:00 – 15:30, Room 301
• exact plan on the web-page*

Webseite

   i11www.itl.kit.edu/teaching/winter2016/graphvis/

• Latest news
• Lecture slides
• Exercise sheets
• Literature & Additional material
• Lecture notes (skript)
About this Course

Media:
• **Slides** & Blackboard & Pinboard
• Exercise sheets are provided a week before the exercise session
• (incomplete) Lecture notes/Books
• Original literature (papers)
Books (available in the library)

G. di Battista, P. Eades, R. Tamassia, I. Tollis:
Graph Drawing
Prentice Hall, 1998

M. Kaufmann, D. Wagner:
Drawing Graphs: Methods and Models
Springer, 2001

T. Nishizeki, Md. S. Rahman:
Planar Graph Drawing
World Scientific, 2004

R. Tamassia:
Handbook of Graph Drawing and Visualization
CRC Press, 2013

http://cs.brown.edu/~rt/gdhandbook/
About this Course

Master Informatics

• Module: General: M-INFO-102094
  This year: T-INFO-104390
About this Course

Master Informatics

- Module: General: M-INFO-102094
- This year: T-INFO-104390

Suggested time requirements:

- Attending Lecture and Exercises:
- Preparation/post-processing
- Work on the exercises
- Preparation for the exam

\[5LP = 150h\]
ca. 35h
ca. 35h
ca. 40h
ca. 40h
About this Course

Master Informatics

• Module: General: M-INFO-102094
  This year: T-INFO-104390

Suggested time requirements:

• Attending Lecture and Exercises: ca. 35h
• Preparation/post-processing ca. 35h
• Work on the exercises ca. 40h
• Preparation for the exam ca. 40h

Examination procedure:

• In order to take an exam you need to participate actively in
  the exercise sessions
  (e.g. present your own solutions on the board)
• Submit a visualization for the practical task
• Oral exam(app. 20 Minutes)
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Formal definition of Layout Problem.

About this course: learning objectives.

Applications gallery.
Graph and its Representation

What is a Graph?
Graph and its Representation

What is a Graph?

Tuple $G = (V, E)$

Set of nodes $V = \{v_1, \ldots, v_n\}$

Set of edges $E = \{e_1, \ldots, e_m\}$,

$e_i = \{v_j, v_k\}$, $1 \leq i \leq m$, $1 \leq j, k \leq n$
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Representations?
Graph and its Representation

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Representations?

Set representation:

$V = \{v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8, v_9, v_{10}\}$
$E = \{\{v_1, v_2\}, \{v_1, v_8\}, \{v_2, v_3\}, \{v_3, v_5\}, \{v_3, v_9\},$
$\{v_3, v_{10}\}, \{v_4, v_5\}, \{v_4, v_6\}, \{v_4, v_9\}, \{v_5, v_8\},$
$\{v_6, v_8\}, \{v_6, v_9\}, \{v_7, v_8\}, \{v_7, v_9\}, \{v_8, v_{10}\},$
$\{v_9, v_{10}\}\}$
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Representations?

Set representation

Adjacency list

<table>
<thead>
<tr>
<th>v1</th>
<th>v2, v8</th>
</tr>
</thead>
<tbody>
<tr>
<td>v2</td>
<td>v1, v3</td>
</tr>
<tr>
<td>v3</td>
<td>v2, v5, v9, v10</td>
</tr>
<tr>
<td>v4</td>
<td>v5, v6, v9</td>
</tr>
<tr>
<td>v5</td>
<td>v3, v4, v8</td>
</tr>
<tr>
<td>v6</td>
<td>v4, v8, v9</td>
</tr>
<tr>
<td>v7</td>
<td>v8, v9</td>
</tr>
<tr>
<td>v8</td>
<td>v1, v5, v6, v7, v9, v10</td>
</tr>
<tr>
<td>v9</td>
<td>v3, v4, v6, v7, v8, v10</td>
</tr>
<tr>
<td>v10</td>
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</tr>
</tbody>
</table>
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Set of nodes \( V = \{v_1, \ldots, v_n\} \)
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\[ e_i = \{v_j, v_k\}, \quad 1 \leq i \leq m, \quad 1 \leq j, k \leq n \]

Representations?

Set representation
Adjacency list
Adjacency matrix

\[
\begin{pmatrix}
0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
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0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \\
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Graph and its Representation

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**Drawing** or Node-link diagram
Graph and its Representation

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Adjacency matrix
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Graph and its Representation

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\end{pmatrix}
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\begin{pmatrix}
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\end{pmatrix}
\]
Graph and its Representation

Think and write down

• Why do we need node-link diagrams?
Why to visualize graphs?

- A picture says more than words: human perception of images is better than of text
- To ease revealing information
- Finding patterns in data
- To communicate the data
Let’s Recall

Discuss with your neighbour or in groups of three and then write down

Graph classes you know (planar etc.)

Algorithmic techniques you know (greedy etc.)

Applications of network visualization you have heard about

We will group your knowledge into a MIND MAP
Let’s Recall

Discuss with your neighbour or in groups of three and then write down

Graph classes you know (planar etc.)

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Prerequisites: Algorithms 1 & 2, Theoretical Basics of inf.
Helpful: Algorithms for Planar Graphs
Overview

About this course

Repetition of the material. We build our Mind Map.

Drawing graphs “by hand”. Complete MindMap.

Formal definition of Layout Problem.

About this course: learning objectives.

Applications gallery.
How to draw graphs?

Work with your neighbour or in groups of three

- graphs in form of adjacency matrix/list
- https://www.yworks.com/downloads#yEd
- draw all or some graphs as nice and as readable as possible

We will show and discuss the results afterwards and complete the MIND MAP
Algorithms for Graph Visualization

- Puzzle games
- Social network analysis
- Chip design
- URL diagrams
- Syntax highlighting
- Neural networks
- Dynamic programming
- Heuristic
- Randomized
- Backtracking
- Brute-force
- Approximation
- Divide and conquer (recurse)
- Simulated annealing
- Evolutionary algorithms

- Symmetry
- Crossing Angle
- Number of slopes
- Crossings
- Angle Resolution
- Large faces

- K-regular
- Planar
- Complete graphs
- Directed
- Trees
- Triangulations
- Bipartite
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**Formal definition of Layout Problem.**

About this course: learning objectives.

Applications gallery.
Visual Variables according to Bertin (1967)

- shape
- orientation
- position
- size
- color
- texture
- value

Visual Variables include:
- position
- value
- texture
- size
- color
Visual Variables according to Bertin (1967)

- position
- size
- value
- shape
- orientation
- color
- texture

→ Layout problem
Visual Variables according to Bertin (1967)

- shape
- orientation
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- position
- value
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- texture

→ Layout problem
Layout Problem

**Graph visualization problem**

**given:** Graph $G = (V, E)$

**find:** good drawing $\Gamma$ of $G$

- $\Gamma : V \to \mathbb{R}^2$, nodes $v \mapsto$ point $\Gamma(v)$
- $\Gamma : E \to$ curves in $\mathbb{R}^2$, edge $\{u, v\} \mapsto$ simple open curve $c_{uv} : [0, 1] \to \mathbb{R}^2$ where $c_{uv}(0) = \Gamma(u)$ and $c_{uv}(1) = \Gamma(v)$
Layout Problem

Graph visualization problem

given: Graph $G = (V, E)$
find: **good** drawing $\Gamma$ of $G$

- $\Gamma : V \to \mathbb{R}^2$, nodes $v \mapsto$ point $\Gamma(v)$
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Layout Problem

1) **Drawing conventions**, required properties, for example
   - straight-line edges
   - orthogonal edges (with bends 90 degrees)
   - Drawing on a grid
   - crossing-free
   - ...
Layout Problem

1) **Drawing conventions**, required properties

2) **Aesthetics** (to be optimized), for example:
   - Number of crossing
   - Number of bends
   - Uniform edge length
   - Area/length
   - Angular resolution
   - Symmetry
   - ...
Layout Problem

1) **Drawing conventions**, required properties

2) **Aesthetics** (to be optimized)

3) **Partial/local constraints**, for example:
   - Positions of several vertices
   - Relative positions of vertices
   - Group of nodes drawn close to each other
Layout Problem – Second Attempt

Graph visualization problem

given: Graph $G = (V, E)$
find: a drawing $\Gamma$ of $G$, that
- complies with drawing conventions
- optimizes aesthetics
- satisfies local/partial constraints
Layout Problem – Second Attempt

Graph visualization problem

given: Graph $G = (V, E)$
find: a drawing $\Gamma$ of $G$, that
• complies with drawing conventions
• optimizes aesthetics
• satisfies local/partial constraints

→ often lead to NP-hard optimization problems!
→ often several competing criteria
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Applications gallery.
Learning Objectives

At the end of the semester you are able to:
Learning Objectives

At the end of the semester you are able to:

• List various network visualization styles
• Formally state a network visualization problem
• Describe several algorithms for network visualization in an intuitive way
• Describe formally several network visualization algorithms
• Identify the techniques behind the algorithms (greedy, iterative, dynamic programming, etc.)
• Analyze the time complexity of algorithms
• Proof correctness of the algorithms
• Use a tool or library to produce a network visualization
• Solve new network visualization problems by selecting and adapting known approaches
Learning Objectives

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Recall Level

Analyze, Apply, Generalize Level
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Applications gallery.
Biblical characters and events (1202)

Source: Joachim de Fiore
"Tree of Life" (1516)
Geometrical Concepts (1587)

Source: Christophe de Savigny
Genealogical Tree (1879)

Source: Ernst Haeckel
Sociogramm (1933)

Source: Moreno, 1933
Social Network – Organization within UBS

- **CEO**
  - Marcel Ospel*

- **UBS Switzerland**
  - Stephan Haeringer*
    - PCC
      - St. Haeringer
    - Individual Clients
      - F. Menotti
    - Corporate Clients
      - E. Hallner
    - Risk Transformation & Capital Mgmt.
      - J. Haller
    - Resources
      - J. F. Sierro
    - Operations
      - St. Zimmermann
    - IT
      - Th. Escher
    - Private Banking
      - G. Gagnebin*
    - Europe/Middle East/Africa
      - R. Weil
    - Overseas (Americas/Asia)
      - C. Gigioni
    - Swiss Clients
      - G. F. Rossetti
    - Private Banks
      - M. Weiss
    - Products and Services
      - A. Decurtins
    - Business Management
      - P. Wuffli
    - Investment Management & Research
      - J. Dietmeier

- **UBS Asset Management**
  - Peter Wuffli*
    - GAM

- **UBS Warburg**
  - Markus Granziol*
    - Equities
      - C. Buchan
    - Corporate Finance
      - R. Tapner
    - Fixed Income
      - J. Costas
    - Treasury Products
      - J. Costas
    - UBS Capital
      - F. de Wet*
    - E & Services
      - V. Johnson
    - Private Clients
      - M. Granziol
    - Logistics
      - M. Granziol

- **Corporate Center**
  - Luqman Arnold*
    - CRO
      - M. Rohner
    - CCO
      - M. Buter
    - Group Controller
      - H. Schaub

* Member of the Group Executive Board
CPAN Developer-Graph

Source: cpan-explorer.org
last.fm Graph of musics as political map

(Gansner, Hu, Kobourov: GMap, 2009)
last.fm Graph of musics as political map

(Gansner, Hu, Kobourov: GMap, 2009)
Blogosphere 2004 Elections USA

Source: Adamic, Glance, 2005
Social Network – World Finance System

World Finance Corporation
© Mark Lombardi
Temporal Graph Layout: Storylines

Source: ABC news, Australia
Traffic network – Highways USA
Traffic network – Highways USA
Co-centric Tube Map

Source: Maxwell Roberts
Curvilinear S/U-bahn map

Source: KVV and Maxwell Roberts
Flight Connections
Flow-Map: Whiskey Export

Source: Verbeek, Buchin, Speckmann., 2011
Monitoring of Energy Network

Source: Eir Grid, Ireland
Medicine – Diseases

[Diagram of diseases and their relationships]

Introduction
Medicine – phylogenetic Tree
Clustered Software-Graph in 3D

Source: Balzer, Deussen, 2007
Software Call-Graph with edge-bundling

Source: Danny Holten, 2011
Web Trend Map

Source: information Architects, 2009
Large Graphs – Object Mesh

Source: Yifan Hu
Alternative Visualizations: Explorer vs Treemap
Alternative Visualizations: Contact map
## Tools

### Libraries for graph visualization
- JUNG [jung.sourceforge.net](http://jung.sourceforge.net) (Java)
- OGDF [www.ogdf.net](http://www.ogdf.net) (C++)

### Visualization tools
- visone [visone.info](http://visone.info)
- graphviz [www.graphviz.org](http://www.graphviz.org)
- yEd [www.yworks.com](http://www.yworks.com)
- Gephi [www.gephi.org](http://www.gephi.org)
Next Meeting

**Lectures** 26.10, 2.11 14:00
**Exercise** on 8.11 14:00
Next Meeting

**Lectures** 26.10, 2.11 14:00
**Exercise** on 8.11 14:00

**Topic** Tree Layouts

**Home task** In which applications we need to construct a tree layout?