Algorithms for Graph Visualization

Summer Semester 2019
Lecture #1

Introduction

(based on slides from Martin Nöllenburg and Robert Görke, KIT)
Organization

Lecturer

- Steven Chaplick
- Office E12

Tutorials

- Oksana Firman
- Office E16

Schedule (for most of the lectures and tutorials)

- Lectures: Thurs. 10:15–11:45, SE III
- Tutorials: Mon. 16:00–17:30, SE III
## Organization

### Course webpage

- [https://wuecampus2.uni-wuerzburg.de/moodle/course/view.php?id=32265](https://wuecampus2.uni-wuerzburg.de/moodle/course/view.php?id=32265)

- General Information
- Lecture Slides
- Exercise Sheets
- Additional Materials
Required Knowledge

Basics in Graph Theory

- Graph, Vertices, Edges
- Vertex degree, neighbourhood, adjacency, incidence
- Connectivity, Trees, Cycles, Paths
- BFS & DFS
- Flows and Matchings

Basics in Algorithms and Data Structures.

- Runtime analysis, $O$-notation
- Complexity, NP-hardness
- Linear Programming

Otherwise: Review these concepts!
## Evaluation

**Successful Completion of**

- *some* excersises (bonus of 0.3 for 50% completion)
- an oral exam at the end of the semester.

## Learning Objectives

- Overview of graph visualization
  ⇝ a topic well suited for theses :-)
- Improved knowledge of modeling and solving problems via graph algorithms.
Lectures

Media
- Blackboard and Slides
- Exercises to solidify concepts

Content
- Reducing the visualization problem to its algorithmic core
- Modeling, Algorithms, and techniques:
  - forced based methods
  - combinatorial optimization (flows, ILPs)
  - algorithms for special graphs (e.g., trees)
Literature
Introducing Graph Visualization
Graphs and their representations

\[ V = \{v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8, v_9, v_{10}\} \]
\[ E = \{\{v_1, v_2\}, \{v_1, v_8\}, \{v_2, v_3\}, \{v_3, v_5\}, \{v_3, v_9\}, \{v_3, v_{10}\}, \{v_4, v_5\}, \{v_4, v_6\}, \{v_4, v_9\}, \{v_5, v_8\}, \{v_5, v_{10}\}, \{v_6, v_8\}, \{v_6, v_9\}, \{v_7, v_8\}, \{v_7, v_9\}, \{v_8, v_10\}, \{v_9, v_{10}\}\} \]
Why draw graphs?

- Graphs are a mathematical representation of networks.
- Networks occur in various practical applications.
- Without proper visualization, networks are difficult to understand.
- Visualizations are used to exhibit of known properties of and discover unknown properties of networks

The aim is to design algorithms to draw graphs automatically to provide deeper understanding of them.
Examples

a *small* slideshow
Transportation Networks – Highways USA
Transportation Networks – Continental Flights
Transportation Networks – London Tube map
Social Networks – Terrorist Cell
Social Networks – Company Investments

The German Company Network of 1996
Social Networks – Sovereign Wealth Funds

The 20 Biggest Cross-Border Sovereign Wealth Fund Deals Since 2005

The Lawyers
Selected lawyers who worked on more than one of the top 20 deals.

CITIGROUP
MORGAN STANLEY
MERRILL LYNCH

CITIGROUP
MERRILL LYNCH

The Buyers

The Targets

The Advisors
Selected social advisors who worked on more than one of the top 20 deals.

The New Global Wealth Machine

Social networks have become an essential tool for sovereign wealth funds. These funds have revolutionized the way they do business, and their influence has grown significantly in recent years. The increased activity of sovereign wealth funds has provided new opportunities for investment, but it has also raised concerns about transparency and accountability.

The chart above illustrates the 20 biggest cross-border sovereign wealth fund deals since 2005, highlighting the key players involved in these transactions. The deals are categorized by the nationality of the buyer and target, with a focus on the top 10 deals by value.

The chart also includes a list of the lawyers who worked on more than one of the top 20 deals, as well as the social advisors who were involved in the process.

FOLLOW THE MONEY

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Patents: cash flow by the applicant for inventors

Kontinentale Aufteilung

2001 - 2005

Legende:

Kantengewicht:
- Red: Maximum
- Blue: Minimum

Ausgangsgrad:
- Yellow: Maximum
- Gray: Minimum

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Biomedicine – Disease Interaction
Biomedicine – Molecular Metabolic Networks
Biomedicine – Protein
Biomedicine – Phylogenetic Trees

- Kinesin-13 (MCAK/KIF2)
- Kinesin-8 (Kip3)
- Kinesin-7 (CENP-E)
- At2
- At1
- Kinesin-3 (Unc104/KIF1)
- Kinesin-4 (ChrKin/KIF4)
- Kinesin-1 (KHC)
- Kinesin-5 (BimC)
- Kinesin-2 (KRP85/95)
- Kinesin-6 (MKLP1)
- Kinesin-14 (C-Terminal Motor)

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Elise M. Dagenbach & Sharyn A. Endow
Telecommunication Networks – Internet USA
Technical Networks – Webtrends
Technical Networks – Wiring Diagram
General Graphs – Large Graphs
Alternative Interpretations – Inclusion Diagrams

Figure 1: Traditional Tree Diagram Representation.

Figure 2: Venn Diagram Representation.
Node size is proportional to weight.
Alternative Interpretations – Contact Graphs
Underlying Definition
Visualizing Variables by Bertin (1967)

- **Position**
- **Size**
- **Shape**
- **Orientation**
- **Colour**
- **Shading**
- **Texture**

→ **Layoutproblem**
Definition Layoutproblem

Restricting to so-called Point-Line Diagrams. *(standard representation)*

**Problem: Graphlayout**

| in:  | Graph $G = (V, E)$ |
| out: | *nice* Drawing $\Gamma: V \cup E \to \mathcal{P}(\mathbb{R}^2)$ |
|      | • vertices $v \mapsto$ points $\Gamma(v)$ |
|      | • edges $uv \mapsto$ simple, open curves $\Gamma(uv)$ with endpoints $\Gamma(u)$ and $\Gamma(v)$ |

But what is a *nice* drawing?
Requirements of a Graph Layout

1) Drawing conventions and requirements, e.g.,
Requirements of a Graph Layout

1) Drawing conventions and requirements.

2) Aesthetics to be optimized, e.g.
Requirements of a Graph Layout

1) Drawing conventions and requirements.

2) Aesthetics to be optimized.

3) Local Constraints, e.g.
Problem: Graphlayout

\[
\text{in: Graph } G = (V, E) \\
\text{out: Drawing } \Gamma : V \cup E \rightarrow \mathcal{P}(\mathbb{R}^2), \text{ such that} \\
\quad \bullet \text{ the drawing conventions are met.} \\
\quad \bullet \text{ the asthetic criteria is optimized.} \\
\quad \bullet \text{ some additional constraints are satisfied.} \\
\]

\bullet \text{ many algorithmically interesting questions arise.}