GraDR – WP02

Angular Schematization

Final EuroGIGA Meeting
Berlin, February 17–21, 2014

Alexander Wolff & Philipp Kindermann
Universität Würzburg

... and colleagues from IP2 (Tübingen), AP1-IT (Roma), AP2-NL (Eindhoven), AP3-DE (Karlsruhe), and AP4-DE (Münster)
What I mean is...
What I mean is...

(construction and) layout of complex networks under

*angular restrictions*

centering edges.
What I mean is...

(construction and) layout of complex networks under

*angular restrictions*

concerning edges.

I consider two types of restrictions:
What I mean is...

(construction and) layout of complex networks under **angular restrictions** concerning edges.

I consider two types of restrictions:

\[ \text{discrete} \]
What I mean is...

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discrete
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*angular restrictions*

centering edges.

I consider two types of restrictions:

- **discrete**
- **orthogonal** (rectilinear)
What I mean is...

(construction and) layout of complex networks under

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concerning edges.

I consider two types of restrictions:

- *discrete*
  - orthogonal
  - octlinear
    - (rectilinear)
What I mean is...

(construction and) layout of complex networks under

**angular restrictions**

cconcerning edges.

I consider two types of restrictions:

- **orthogonal**
- **octlinear**
- **rectilinear**

*discrete* *range*
What I mean is...

(construction and) layout of complex networks under

*angular restrictions*

concerning edges.

I consider two types of restrictions:

*discrete*

- orthogonal (rectilinear)
- octlinear

*range*
Orthogonal Layouts – Well-Known Results

[Tamassia, SIAM J Comp’87]
Can minimize number of bends for fixed embedding.
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Can compute drawing on the \((n \times n)\)-grid with \(\leq 2n + 2\) bends for any embedding (and \(\leq 2\) bends/edge – except octahedron)
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[Bläsius, Krug, Rutter, Wagner: GD’10, Algorithmica’14]
Given an embedding and a function \(\text{flex}: E \rightarrow \mathbb{N}_{\geq 1}\), can compute a drawing with \(\leq \text{flex}(e)\) bends/edge (if one exists).
Overview

- Generalized Minimum Manhattan Networks
- Area-Preserving Subdivision Schematization
- Boundary Labeling
- Monotone Drawings of (Embedded) Graphs
- Drawing Metro Maps with Curves
- Smooth Orthogonal Drawings
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Def: Minimum Manhattan Network (MMN)
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Manhattan-connect all terminal pairs.
Def: Minimum Manhattan Network (MMN)

Manhattan-connect all terminal pairs. Minimize ink (total network length)!
Def: Minimum Manhattan Network (MMN)

Manhattan-connect \( u \) \( v \) terminal pairs. Minimize ink (total network length)!
Def: Generalized MMN (GMMN)
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M-connect given terminal pairs.
Def: Generalized MMN (GMMN)

M-connect *given* terminal pairs.
Minimize ink *(total network length)*!
Def: Generalized MMN (GMMN)

M-connect given terminal pairs.
Minimize ink (total network length)!
GMMN & Co. – Open Problems in $\mathbb{R}^2$

2D-GMMN
GMMN & Co. – Open Problems in $\mathbb{R}^2$

2D-GMMN -> x-sep. GMMN
GMMN & Co. – Open Problems in $\mathbb{R}^2$

2D-GMMN \quad \xrightarrow{\log n} \quad x\text{-sep. GMMN}
GMMN & Co. – Open Problems in $\mathbb{R}^2$

2D-GMMN

$\log n$

$x$-sep. GMMN

\[ \begin{align*}
\text{STAB} & \quad + \quad \text{RSA}
\end{align*} \]
GMMN & Co. – Open Problems in $\mathbb{R}^2$

2D-GMMN $\xrightarrow{\log n}$ x-sep. GMMN

$6(1 + \varepsilon)$

STAB + RSA
GMMN & Co. – Open Problems in $\mathbb{R}^2$

2D-GMMN → $\log n$ → x-sep. GMMN

$6(1 + \varepsilon)$

STAB + RSA

Aparna Das
Krzysztof Fleszar
Stephen Kobourov
Joachim Spoerhase
Sankar Veeramoni
Alexander Wolff
[ISAAC’13]
GMMN & Co. – Open Problems in $\mathbb{R}^2$

\[ \log n \quad \downarrow \quad O(1) \]

2D-GMMN

\[ \xrightarrow{\text{x-sep. GMMN}} \]

\[ 6(1 + \varepsilon) \]

STAB + RSA

\{ Aparna Das, Krzysztof Fleszar, Stephen Kobourov, Joachim Spoerhase, Sankar Veeramoni, Alexander Wolff \}

[ISAAC’13]
GMMN & Co. – Open Problems in $\mathbb{R}^2$

2D-GMMN \[\rightarrow\] $O(1) \downarrow \log n \rightarrow x$-sep. GMMN

6(1 + $\varepsilon$)

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[ISAAC’13]
GMMN & Co. – Open Problems in $\mathbb{R}^2$

2D-GMMN \( \xrightarrow{\log n} \) \( O(1) \)

x-sep. GMMN \( \xrightarrow{} \) \( 6(1 + \varepsilon) \)

\[ \underbrace{\text{STAB}}_{\text{Aparna Das}} + \underbrace{\text{RSA}}_{\text{Krzysztof Fleszar, Stephen Kobourov, Joachim Spoerhase, Sankar Veeramoni, Alexander Wolff}} \]

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GMMN & Co. – Open Problems in $\mathbb{R}^2$

2D-GMMN \( \xrightarrow{O(1)} \) \( \log n \) \( \xrightarrow{6(1 + \varepsilon)} \)

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Polygon Simplification and Schematization

Main goal: preserve area!

[Buchin, Meulemans, Speckmann: GiScience’10, ACMGIS’11]
Fig. 7. An S-contraction.
Polygon Simplification and Schematization

Fig. 7. An S-contraction.  

Fig. 8. A C-contraction.
Polygon Simplification and Schematization

Fig. 7. An S-contraction.  
Fig. 8. A C-contraction.

**Theorem.** Given a rectilinear polygon \( R \) with \( n \) edges and an integer \( k \) with \( 4 \leq k \leq n \), an area-preserving schematization of \( R \) with at most \( k \) edges can be generated using only S- and C-contractions.
→ topologically safe schematization with Bézier curves or circular arcs

[van Goethem, Meulemans, Reimer, Haverkort, Speckmann: Cartogr. J.’13]
[van Goethem, Meulemans, Speckmann, Wood: PacificVis’14]
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$n$ (fixed) labels on top and right side

$n$ point sites
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- not always crossing-free
- orange area empty
- → crossings
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- not always crossing-free
- orange area empty
  → crossings
- decidable for a given mapping
Two-Side Boundary Labeling

*n (fixed) labels on top and right side*

\[ \begin{array}{c}
\text{not always crossing-free} \\
\text{orange area empty} \\
\rightarrow \text{crossings} \\
\text{decidable for a given mapping}
\end{array} \]

\[ n \text{ point sites} \]

*without mapping: NP-hard?*
Two-Side Boundary Labeling

*with* mapping:

\[ n \text{ (fixed) labels on top and right side} \]

- not always crossing-free
- orange area empty
  \[ \rightarrow \text{ crossings} \]
- decidable for a given mapping

without mapping: **NP-hard?**

Idea: find a **stair** to get a good mapping.
Two-Side Boundary Labeling

\( n \) (fixed) labels on top and right side

- not always crossing-free
- \textcolor{orange}{orange} area empty \( \rightarrow \) crossings
- decidable for a given mapping

\( n \) point sites

without mapping: \textbf{NP-hard}?

Idea: find a \textbf{stair} to get a good mapping.

How?
Two-Side Boundary Labeling

$n$ (fixed) labels on top and right side

$n$ point sites

Idea: find a stair to get a good mapping.

without mapping:  NP-hard?

[Kindermann, Niedermann, Rutter, Schaefer, Schulz, W.: WADS’13]

How?

not always crossing-free

orange area empty

→ crossings

decidable for a given mapping
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$n$ (fixed) labels on top and right side

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not always crossing-free

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decidable for a given mapping

without mapping: **NP-hard?**

No!

Idea: find a **stair** to get a good mapping.

[Kindermann, Niedermann, Rutter, Schaefer, Schulz, W.: WADS’13]

**How?** DP.
Boundary Labeling in Focus+Context Maps

[Fink, Haunert, Schulz, Spoerhase, W.: InfoVis’12]
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[Angelini, Colasante, Di Battista, Frati, Patrignani GD’10, JGAA’12]
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monotone drawings of trees
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monotone drawings of trees

area $O(n^{1.6}) \times O(n^{1.6})$ or $O(n^2) \times O(n)$
Monotone Drawings of Graphs

[Angelini, Colasante, Di Battista, Frati, Patrignani GD’10, JGAA’12]

- monotone drawings of trees
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- monotone drawings of graphs
  via monotone drawing of a spanning tree :-)

\[ u \quad v \]
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- planar monotone drawings of biconnected graphs
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  - via SPQR trees...

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**Monotone Drawings of Graphs**

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- monotone drawings of graphs
  - via monotone drawing of a spanning tree :-)
- planar monotone drawings of biconnected graphs
  - via SPQR trees...
Open Problems

Explore *strongly* monotone drawings: each pair of vertices $u, v$ has a joining path that is monotone w.r.t. the line from $u$ to $v$
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Tight bounds on the area requirements for grid drawings of trees.
Mon. Drawings of Graphs with Fixed Embed.

[Angelini, Didimo, Kobourov, Mchedlidze, Roselli, Symvonis, Wismath GD’11]
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bent edges
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- bent edges

- straight-line edges
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- every embedded planar graph admits an embedding-preserving monotone drawing with $\leq 1$ bend in poly. area

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bent edges

- bound on $\#\text{bends}$ is tight

straight-line edges

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**Mon. Drawings of Graphs with Fixed Embed.**

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- **bent edges**
  - every embedded planar graph admits an embedding-preserving monotone drawing with \( \leq 1 \) bend in poly. area
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- **straight-line edges**
  - every outerplane graph admits a straight-line monotone drawing in poly. area
Mon. Drawings of Graphs with Fixed Embed.

- every embedded planar graph admits an embedding-preserving monotone drawing with $\leq 1$ bend in poly. area
- bound on $\#$bends is tight

- every outerplane graph admits a straight-line monotone drawing in poly. area
- every biconnected embedded planar graph admits a straight-line monotone drawing
Open Problems

Given a (simply connected) planar graph $G$, can we decide efficiently whether there exists an embedding of $G$ that admits a monotone drawing with 0 bends (with 1 bend)?
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- Is there a simply connected planar graph that requires bends in any embedding?
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Metro Maps
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octilinear schematic
⇒ “orderly”
Metro Maps

octilinear schematic ⇒ “orderly”
Metro Maps

- octilinear schematic ⇒ “orderly”
- no sharp bends ⇒ improved planning speed

[Roberts et al., IJHCS 2013]
Our Approach

- use cubic Bézier curves for representing edges
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- use force-directed approach ("spring embedder")

[Fink, Haerkort, Nöllenburg, Roberts, Schuhmann, W., GD’12]
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[Hu et al., CAD’01]
Test Case – Vienna

octilinear map
Test Case – Vienna

without merging edges

90 curves
Test Case – Vienna

with merging edges at intermediate stations (degree 2)

25 curves
Test Case – Vienna

additionally merging edges at interchange stations (degree 4)

9 curves
Montréal
Sydney
London
Open Problem:
Avoid wiggly lines in drawings of large networks
Circular-Arc Metro Maps

input
Circular-Arc Metro Maps

input
deformed
Circular-Arc Metro Maps

input
deformed

24 arcs
Circular-Arc Metro Maps

input

24 arcs

deformed

18 arcs
Circular-Arc Metro Maps

[van Dijk, van Goethem, Haunert, Meulemans, Speckmann
SchematicMapping’14]
Concentric Metro Maps

[Fink, Lechner, Wolff, SchematicMapping’14]
Coalition treaty 2013

Words that were more important in the 2013 treaty than in the 2009 treaty

Spiegel Online
Nov. 2013
Coalition treaty 2013

Words that were more important in the 2013 treaty than in the 2009 treaty

Spiegel Online Nov. 2013
Words that were more important in the 2013 treaty than in the 2009 treaty:

- Energiewende
- Innovation
Contact Representation Of Word Networks

Input

- (integral) box dimensions
Contact Representation Of Word Networks

Input

- (integral) box dimensions
- desired contact graph
Contact Representation Of Word Networks

- (integral) box dimensions
- desired contact graph
Contact Representation Of Word Networks

Input

- (integral) box dimensions
- desired contact graph

Output

- placement of boxes
Contact Representation Of Word Networks

Input

- (integral) box dimensions
- desired contact graph

Output

- placement of boxes
- realized desired contacts
Contact Representation Of Word Networks

Input

- (integral) box dimensions
- desired contact graph

Output

- placement of boxes
- realized desired contacts
- profit: 1 unit per desired edge
Contact Representation Of Word Networks

Input

- (integral) box dimensions
- desired contact graph

Output

- placement of boxes
- realized desired contacts
- profit: 1 unit / desired edge

Max-Crown: Maximize profit!
## Our Results – Approximation Factors

<table>
<thead>
<tr>
<th>Graph class</th>
<th>Weighted</th>
<th>Unweighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>cycle, path</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>star</td>
<td>$1 + \varepsilon$</td>
<td></td>
</tr>
<tr>
<td>tree</td>
<td>$2 + \varepsilon$</td>
<td>2</td>
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<tr>
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<td>$[(\Delta + 1)/2]$</td>
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<td>outerplanar</td>
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<td>planar</td>
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</tr>
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<td>$5 + 16\alpha/3 \approx 13.4$</td>
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<td>det.: $40\alpha/3 \approx 21.1$</td>
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$\alpha = e/(e - 1) \approx 1.58$

[Barth, Fabrikant, Kobourov, Lubiw, Nöllenburg, Okamoto, Pupyrev, Squarcella, Ueckerdt, W.: LATIN'14]

[Bekos, van Dijk, Fink, Kindermann, Kobourov, Pupyrev, Spoerhase, W.: submitted]
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Milestones of WP02
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- Design approximation algorithms for MMN in dimension $\geq 3$. ✓
- Attack open questions about Manhattan-geodesic drawing convention. ❓
- Consider area-preserving schematization with diagonals. ✓
- Investigate complexity / design algorithms for monotone straight-line drawings. ✓
- Combine IP and heuristic methods for drawing large-scale (labeled) metro maps (including rectangular stations and parallel lines). ❍
- Show hardness or give efficient algorithm for bend minimization in Kandinsky framework. ❄
Int. Symposium on Graph Drawing 2014

September 24–26

http://gd2014.informatik.uni-wuerzburg.de/

See you in Würzburg!
Int. Symposium on Graph Drawing 2014

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See you in Würzburg!
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