Structural Properties of Sidewalk Netowrks

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Thesis Motivation

- Designing a future algorithm for sidewalk generation
- First step – Analysis of the “correct” networks
- Properties can be used as
  - Sample data (“correct solution for given part of the world”)
  - Designing the algorithm so it fits certain property

Thesis Goals

1. Obtain the data of real-world sidewalk networks
2. Measure non-trivial structural properties of these networks

Obtaining the Data

- OpenStreetMap data used
- Used Python package OSMnx

Chosen Locations

- Černý Most, Prague, Czech Republic
- Cēsis, Latvia
- College Park, Maryland, United States of America
- Dejvice, Prague, Czech Republic
- Grenoble, France
- Helsinki, Finland
- Karlín, Prague, Czech Republic
- Raleigh, North Carolina, United States of America
- San Sebastián, Spain
- Santa Cruz, California, United States of America

Data Visualization

Figure: Visualization of sidewalk data for Černý Most

Properties for Measurement

- Feedback Edge Set Number
- Feedback Vertex Set Number
- Treewidth
- Vertex Cover Number
- Edge Cover Number

Feedback Edge Set Number

- Smallest possible number of edges to remove to create an acyclic graph
- Simple measurement by finding MST/MSF

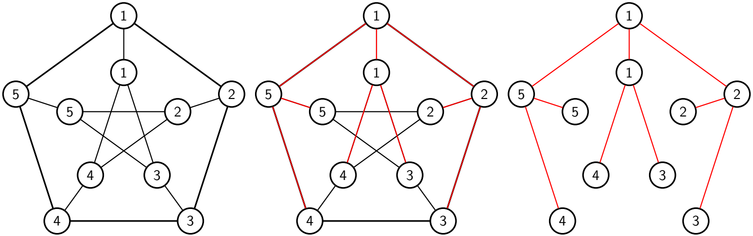

Figure: Feedback Edge Set Number Visualisation on Petersen Graph

Feedback Vertex Set Number

- Smallest possible number of vertices to remove to create an acyclic graph
- NP-hard problem
- ILP used for finding the lower bound, solver by Yoichi Iwata and Kensuke Imanishi for upper bound

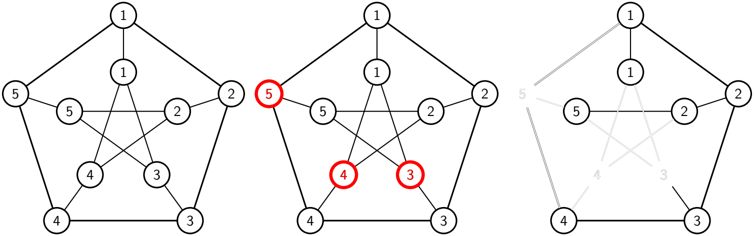

Figure: Visualization of Feedback Vertex Set Number on Petersen Graph

Treewidth

- Algorithmic distance of the given graph to a tree using a tree decomposition
- NP-hard problem
- Used twalgor solver developed by Hisao Tamaki

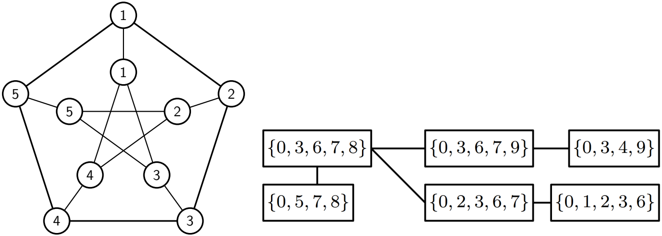

Figure: Optimal Tree Decomposition of Petersen Graph

Vertex Cover Number

- Minimal subset of vertices, such that every edge is incident with at least one vertex in the subset
- Solved using ILP (NP-hard problem)

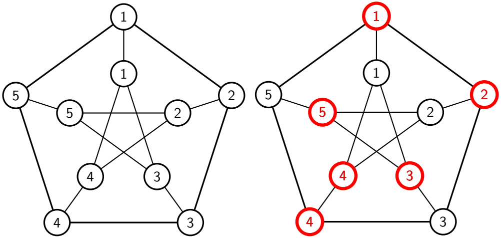

Figure: Optimal Vertex Cover of Petersen Graph

Edge Cover Number

- Minimal subset of edges, such that every vertex is contained in at least one edge in the subset
- Solved using ILP

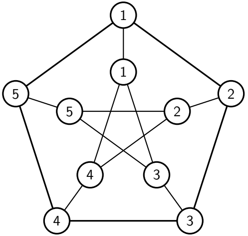

Figure: Optimal Edge Cover of Petersen Graph

Results

Dataset	‖V‖	‖E‖	FESN	FVSN	TW	VCN	ECN
Černý Most, PRG, CZE	1 553	1 893	377	146–167	10	764	806
Cēsis, LAT	1 122	1 244	245	110–113	10	521	606
College Park, MD, USA	5 110	6 392	1 534	571–595	15–22	2 440	2 725
Dejvice, PRG, CZE	1 675	1 907	372	173	9	790	900
Grenoble, FRA	9 647	11 688	2 711	1 017–	14–25	4 672	5 093
Helsinki, FIN	115 318	123 291	18 483	7 842–		52 824	63 343
Karlín, PRG, CZE	1 070	1 364	345	138–153	8	535	549
Raleigh, NC, USA	36 385	39 930	5 667	2 472–		16 576	19 942
San Sebastián, ESP	4 782	4 961	813	407	7	2 173	2 639
Santa Cruz, CA, USA	13 060	14 494	2 710	1 168–	13–16	6 059	7 135

Table: Measured values of all parameters.

Data Quality Assurance

- Locations were picked based on the presence of sidewalk data in OpenStreetMap
- Data were checked mainly for the missing parts, rather than the superfluous data
- The data were mainly checked on the level of visualization than on the graph level

Selection of Properties

- Selected properties that could be handy for future algorithm, or could be academically interesting
- All properties, apart from edge cover number, were mentioned in the assignment
- I have added the edge cover number as I wanted another parameter computable in polynomial time

Are the Values of Edge Cover Number Low?

- Edge cover number, for a graph of n vertices, will be equal to a natural number e, where $\lceil \frac{n}{2} \rceil \leq e \leq n - 1$
- The values may not be nominally low, but relatively to the graph size, the number is low, as it falls always in the bottom 11 % of possible values in all cases

Dataset	$\|\mathbf{V}\|$	$\|\mathbf{E}\|$	**ECN**	**Minimal**	**Maximal**	**Percentile**
Černý Most, PRG, CZE	1 553	1 893	806	777	1 552	3.74 %
Cēsis, LAT	1 122	1 244	606	561	1121	8.04 %
College Park, MD, USA	5 110	6 392	2 725	2 555	5 109	6.66 %
Dejvice, PRG, CZE	1 675	1 907	900	838	1 674	7.42 %
Grenoble, FRA	9 647	11 688	5 093	4 824	9 646	5.58 %
Helsinki, FIN	115 318	123 291	63 343	57 659	115 317	9.89 %
Karlín, PRG, CZE	1 070	1 364	549	535	1 069	0.26 %
Raleigh, NC, USA	36 385	39 930	19 942	18 193	36 384	9.61 %
San Sebastián, ESP	4 782	4 961	2 639	2 391	4 781	10.38 %
Santa Cruz, CA, USA	13 060	14 494	7 135	6 530	13 059	9.27 %

Used Scripts and Data

- Made publicly available on https://github.com/VojtechKopal/StructuralPropertiesOfSidewalkNetworks