Universität Hamburg
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Resilient Networks

Exercise Sheet: Graph Theory

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Goals and Objectives Recapitulate the lecture on graph theory and then apply this knowledge to analyze some real-world graphs. Get yourself familiar with using established metrics and techniques to characterize and describe a given network graph. All necessary tools and potential graphs are described in the remainder of this document.

Submission Solve this task sheet in groups of two people. Apart from your written code, your solution should be handed in as a PDF document that describes your results and how you got there. We recommend you to try jupyter notebooks. In particular, your solution should document the following:

- Some hints on the used tools (applications, libraries, programming language. . .)
- A description of your approach and methodology towards the solution (an abstract description in addition to your submitted code)
- A summary and interpretation of your results (figures, tables, examples. . .)

Submit your group solution to this task sheet in Moodle.

1 Graph Analysis

Task Analyze at least *two* graphs according to some metrics. Implement the calculation of these metrics in a programming language of your choice. You can choose from the following graphs, metrics, and tools or any appropriate alternative. Calculate metrics (at least five) and discuss their values in combination to derive meaningful characteristics of the graphs and insights into them.

Suggested Graphs Choose two graphs:

- Various graphs from `http://snap.stanford.edu/data/index.html`
  - Social networks (Facebook, Twitter)

  - Communication networks
  - Citation networks
  - ...
- P2P Botnet graphs for Sality and ZeroAccess from `https://github.com/iBigQ/botnet-graphs`
- Alternatively: any self-chosen graph that you find suitable for analysis.

Suggested Graph Metrics For example, the following graph properties can be anaylzed:

- Power-law properties
- Characteristic path length
- Density
- Average clustering coefficient and distribution of clustering coefficient
- Distribution of Cohesiveness
- Edge persistence under greedy attack (removing nodes with highest node degree first)
- Resilience/Survivability against random and targeted attacks (greedy attack)

Suggested Tools The following tools/frameworks can be used for your analysis. However, you are not restricted to them. Use whatever tool you like.

- Python library igraph `https://igraph.org/python/`
- Python library networkx `https://networkx.github.io/`
- SNAP graph analysis platform `http://snap.stanford.edu/`
- Boost graph libraries - for the purists among you ;) `www.boost.org`

In case you want to go with the first option (Python igraph), this is how you can get started by typing into the terminal of your Linux VM:

```
$ cd ~/Desktop
$ wget https://svs.informatik.uni-hamburg.de/teaching/rn/exercise/01/graphs_setup.sh
$ chmod +x ./01_graphs_setup.sh
$ ./01_graphs_setup.sh
```

Furthermore, download a simple example to demonstrate how to use igraph:

```
$ cd ~/Desktop
$ wget https://svs.informatik.uni-hamburg.de/teaching/rn/exercise/01/graphs_example.py
$ python3 ./01_graphs_example.py
```