Interactive Higher-order Network Analysis

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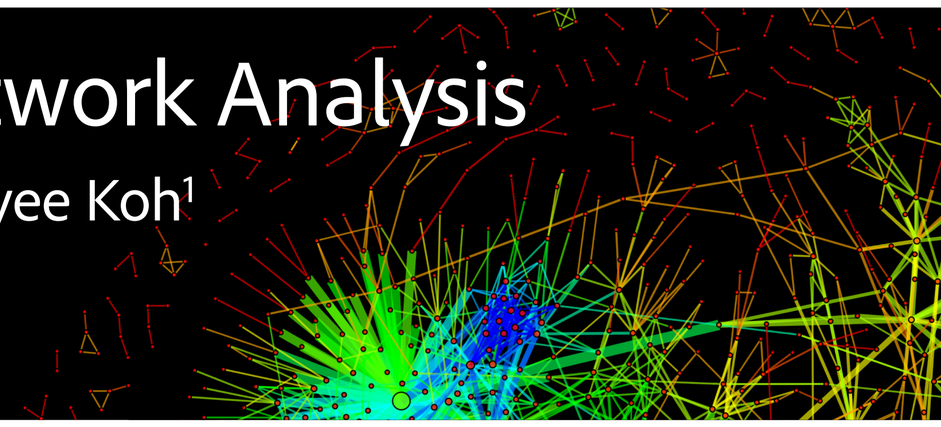
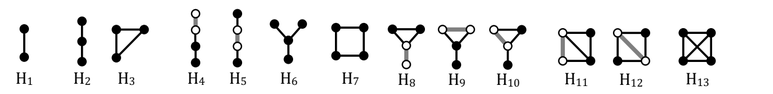
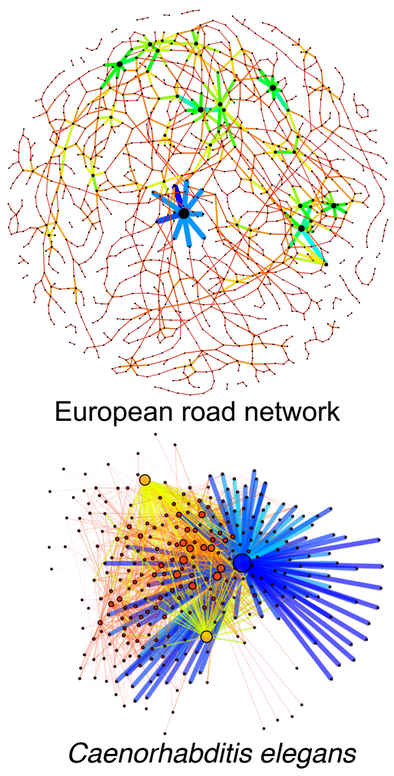




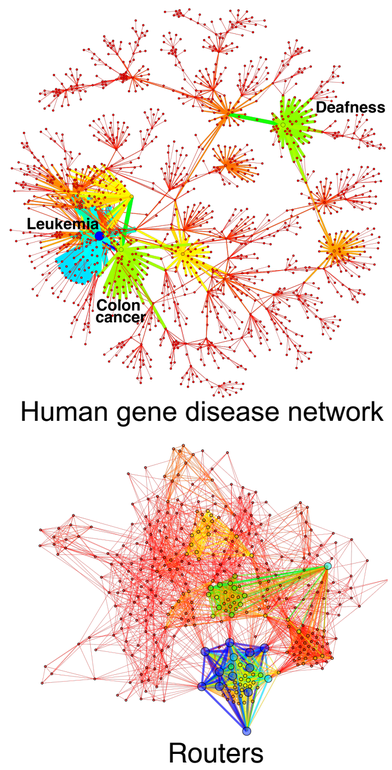
Overview

Higher-order network modeling and analysis is vital to understand the structures governing the configuration and behavior of complex networks. While network motifs are known to be fundamental building blocks of complex networks, the higher-order configuration and organization of complex networks remains widely unknown. In this work, we develop interactive visual higher-order network mining and modeling techniques to gain insight into the higher-order structure and composition of complex networks in real-time. The approach uncovers higher-order configurations including important phenotypes in a human gene interaction network and hubs in a power grid network.



European road network

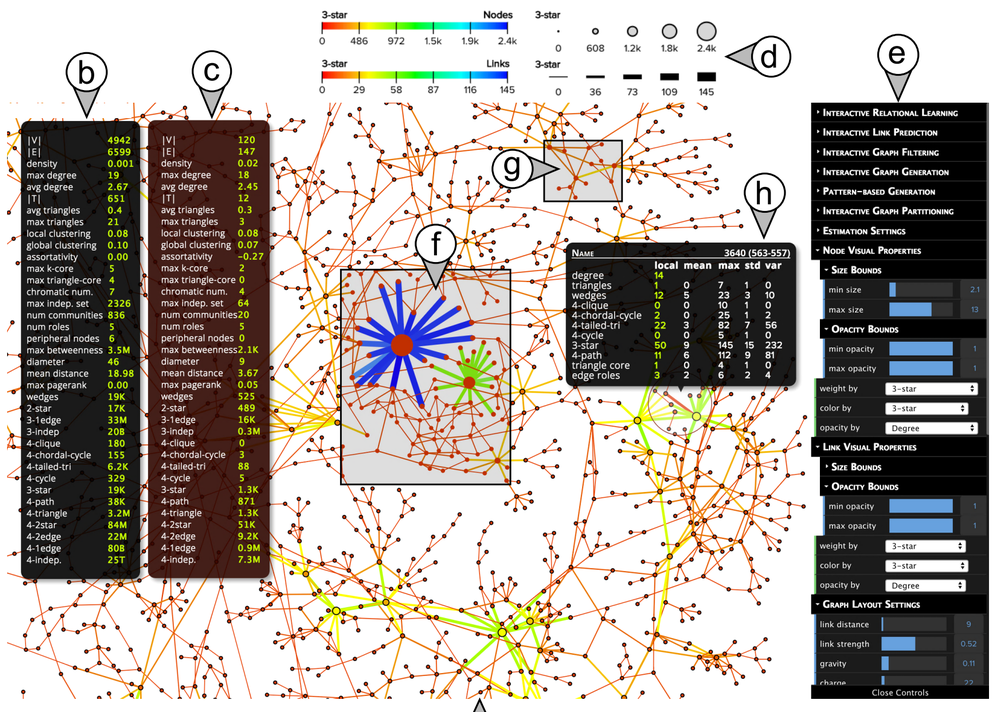
Caenorhabditis elegans

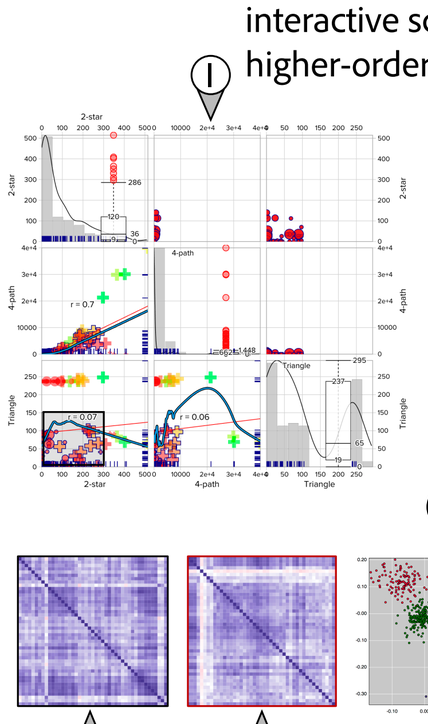


Human gene disease network

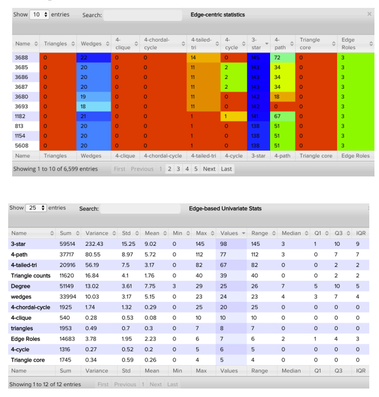
Routers

Interactive Higher-order Network Analysis Platform





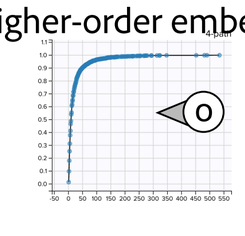
l interactive scatter plot matrix for exploring higher-order edge statistics



m interactive data table for local higher-order edge statistics

n global higher-order edge/node statistics

k 2D higher-order embedding of the nodes



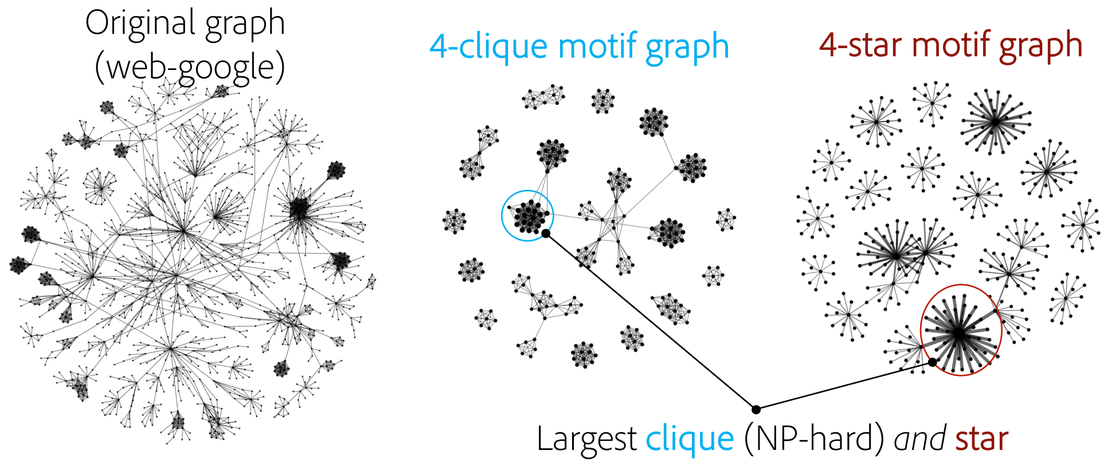
o a cumulative distribution function (CDF) for a user-specified motif.

i j interactive correlation matrix for the selected subgraph(s)

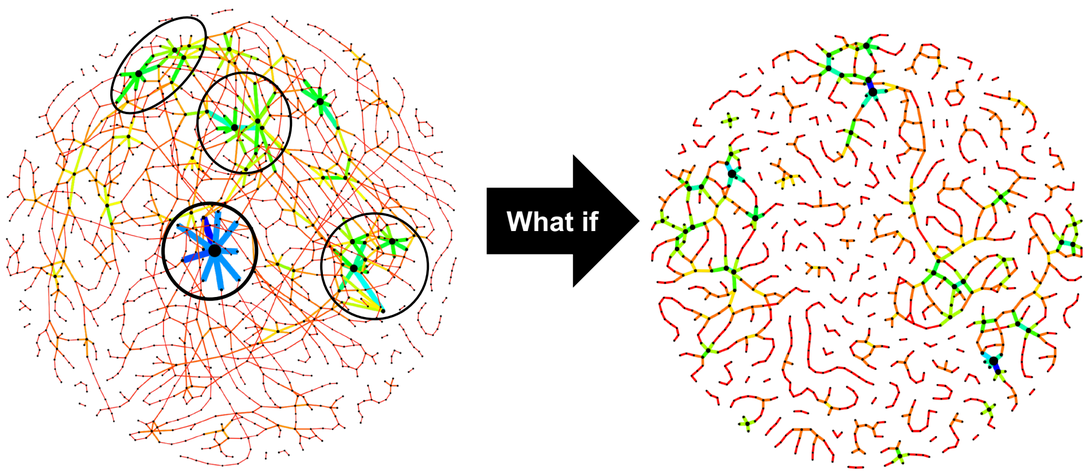
a linked interactive pairwise feature correlation matrix for the current set of higher-order features

The main visualization window includes **(a)** an interactive node-link diagram; **(b)** global higher-order network statistics of the entire graph and **(c)** the selected subgraph(s); **(d)** a legend summarizing the network motifs used to map the color, size, and opacity of nodes and edges; **(e)** an interactive interface for customizing and tuning interactive filters, visual properties of nodes and edges; **(f)**-**(g)** interactive visual graph queries by lasso-selecting/brushing over a subgraph of interest by directly interacting with the node-link diagram; and **(h)** local higher-order network properties of a selected edge (or node).

$$(\mathbf{W}_t)_{ij} = \text{\# of instances of motif } H_t \text{ that contain nodes i and j}$$



Link color = # of 4-stars



The 4-node star motif reveals **large essential hubs** in the European international road network.

Impact after removing the large stars (hubs)

Main Findings & Contributions

1. Formulated interactive higher-order network analysis
2. Described an interactive visual graph analytics platform for uncovering the higher-order configuration of complex networks
3. Results indicate that complex networks contain non-trivial higher-order structural configurations that are quickly uncovered by the interactive visual analytic platform for higher-order network analysis.

A video demo is available at https://youtu:be/VE-GsP4p9n8