ARTS1422 Data Visualization

Lecture 10

Network Data Visualization
&
Social Media Visualization

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2024. 03.28

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Network Data

- Compared with hierarchies in tree visualization, network data present more **complex and flexible relations**.
  - Social network
  - Mobile network
  - Mail network
  - Collaboration network

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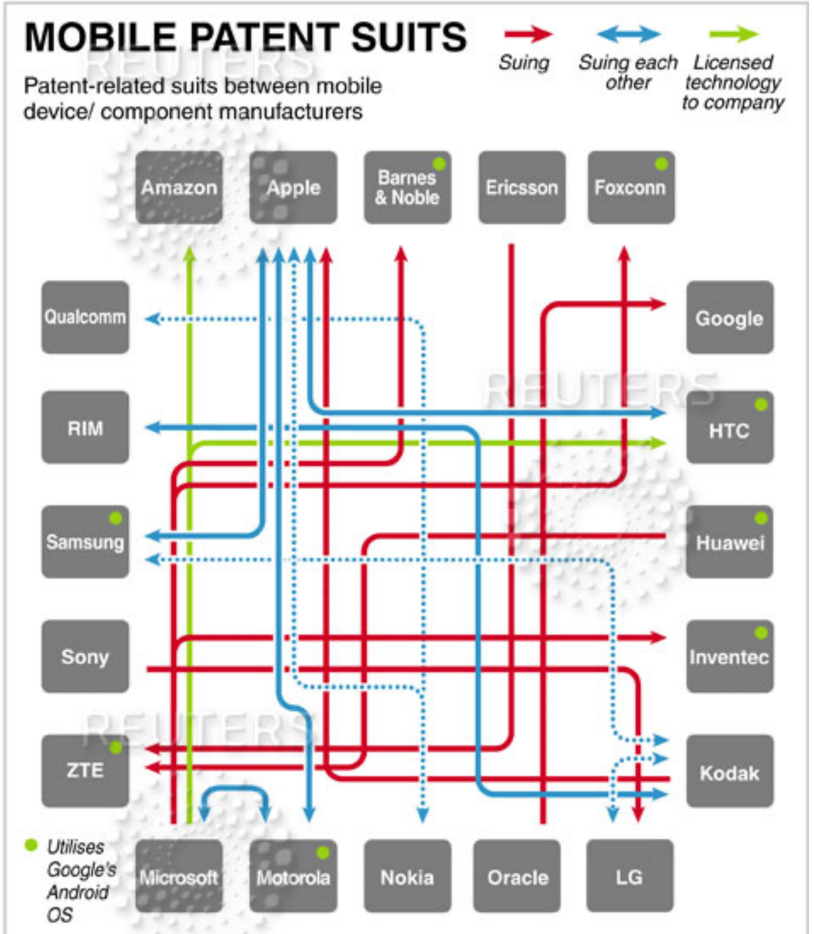
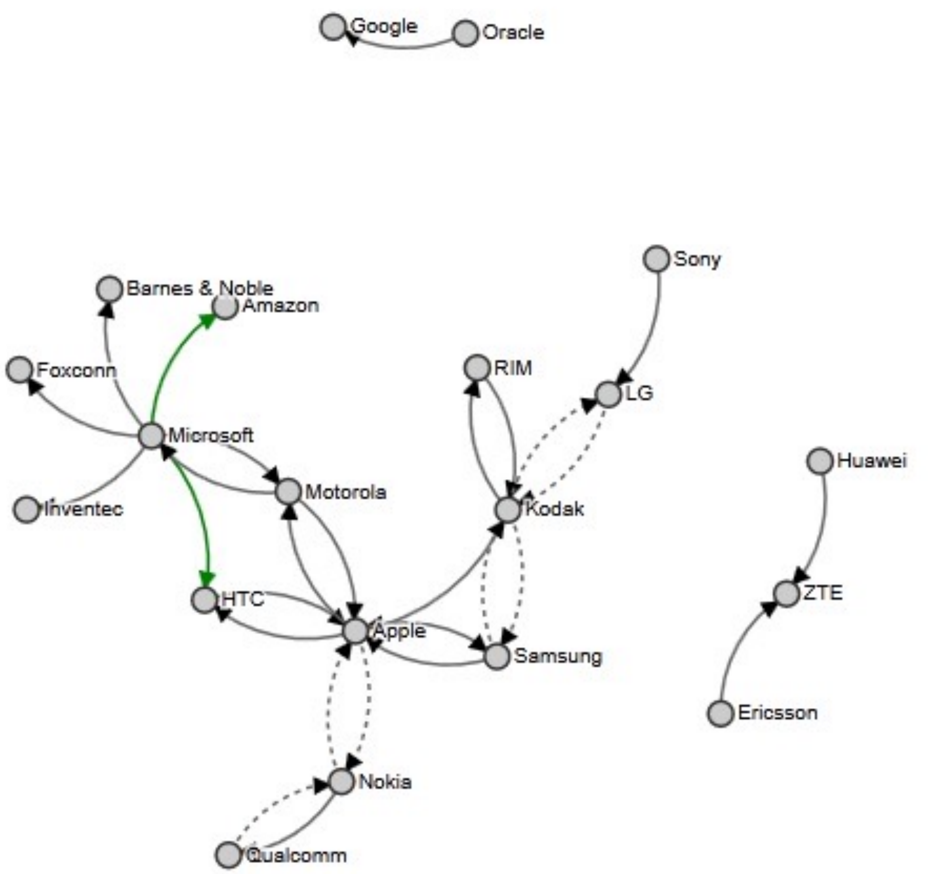
Mobile Patent Lawsuits



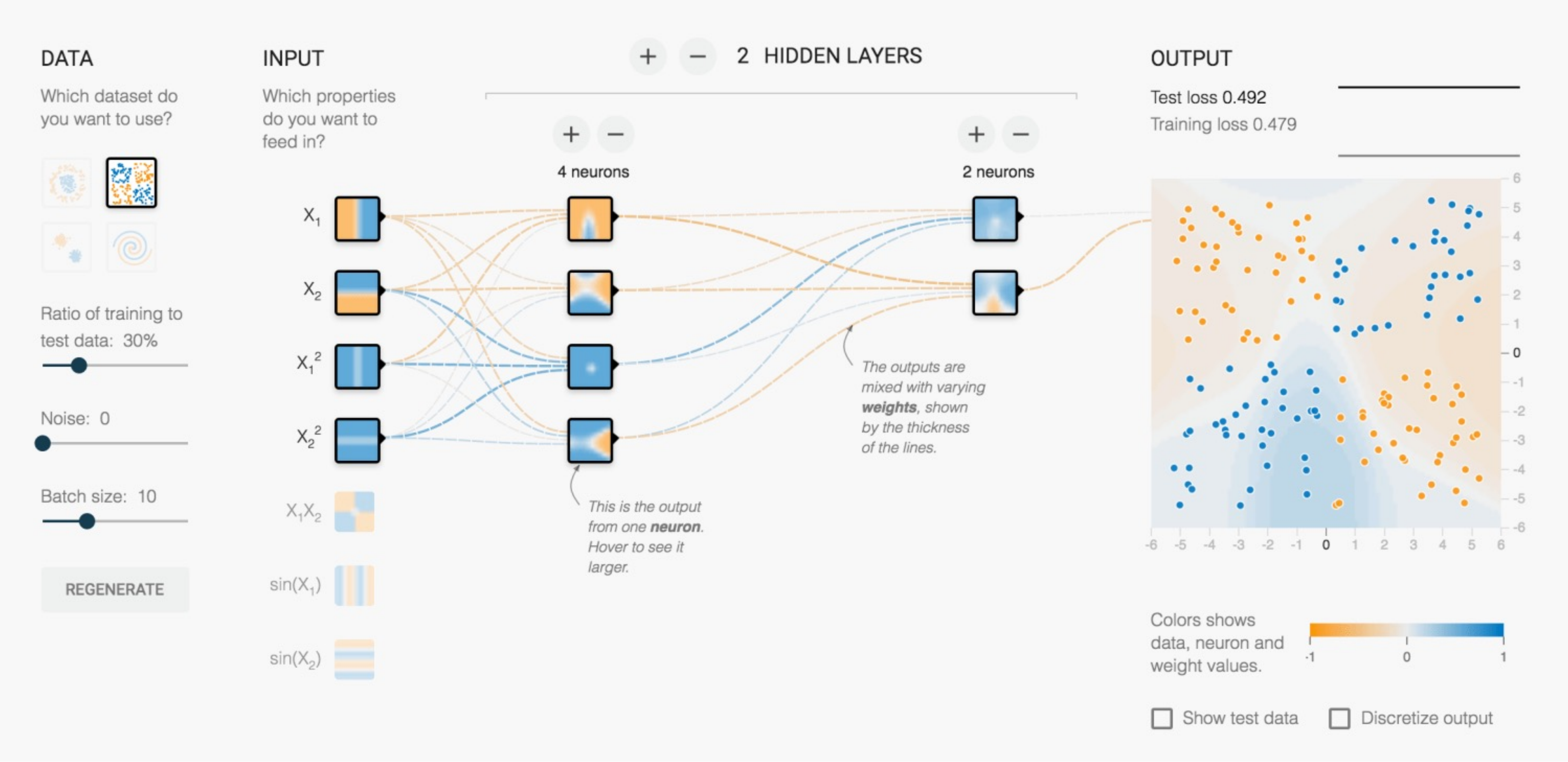
http://blog.thomsonreuters.com/index.php/mobile-patent-suits-graphic-of-the-day/



Based on D3.js

http://bl.ocks.org/1153292

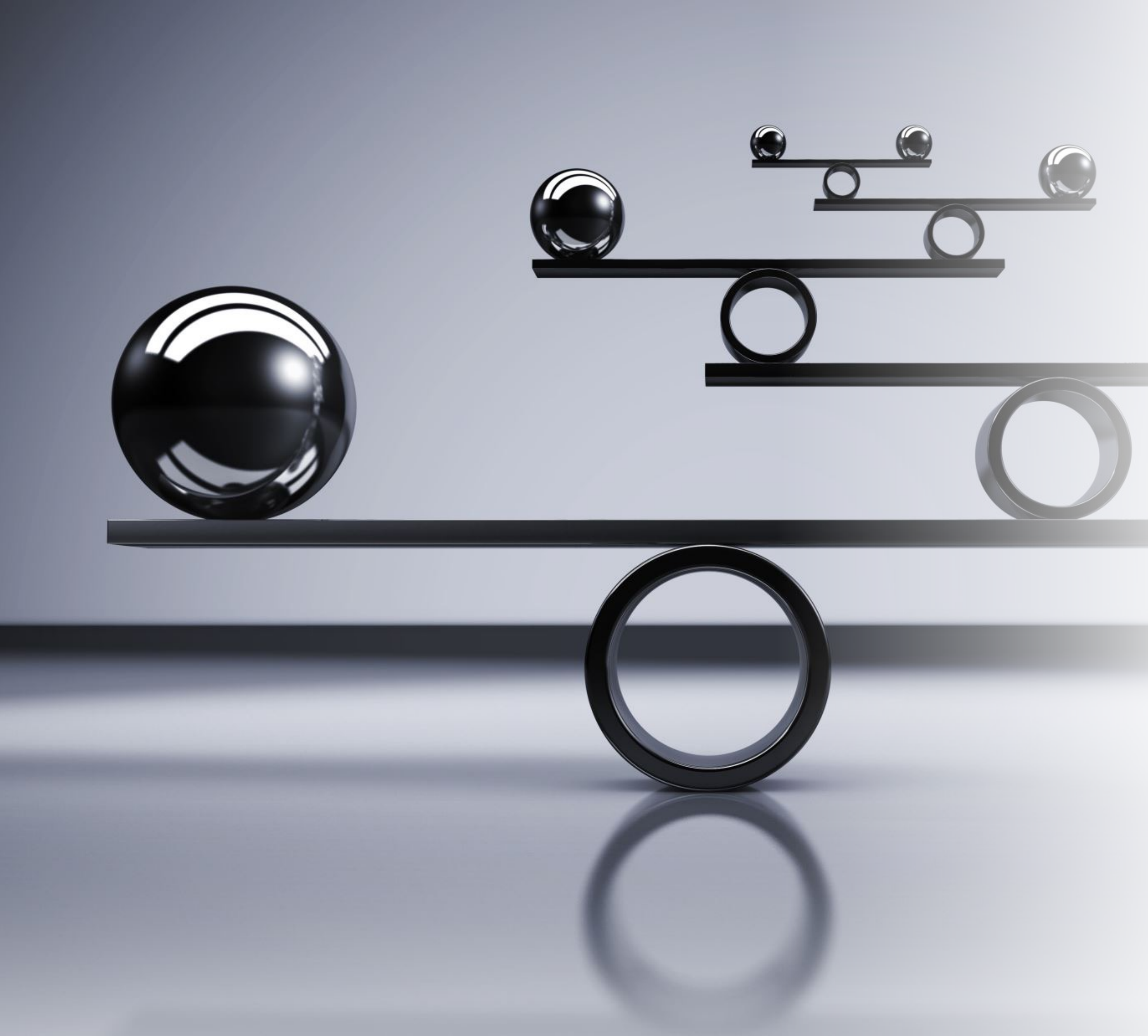
Here's how a neural network works



https://flowingdata.com/2016/04/25/heres-how-a-neural-network-works/

Let’s play

playground.tensorflow.org



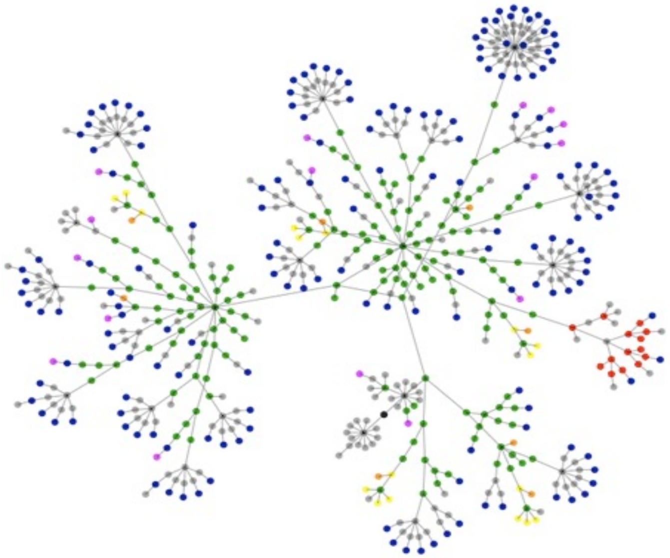
Properties of Network

- Complex relations
  - Directions, weights
- Network centrality
  - Degree
  - Closeness
  - Betweenness
  - Eigenvector

Network Data Visualization

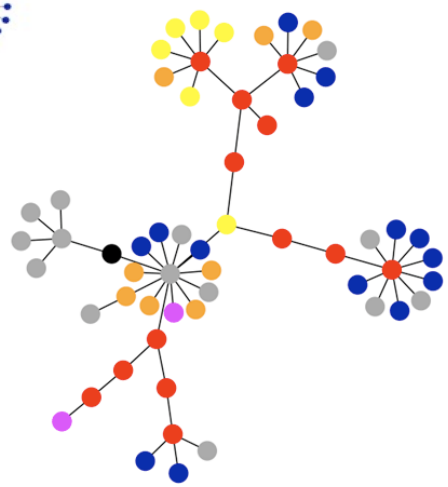
- Node-link diagram
- Adjacency matrix

Website Navigation Graph

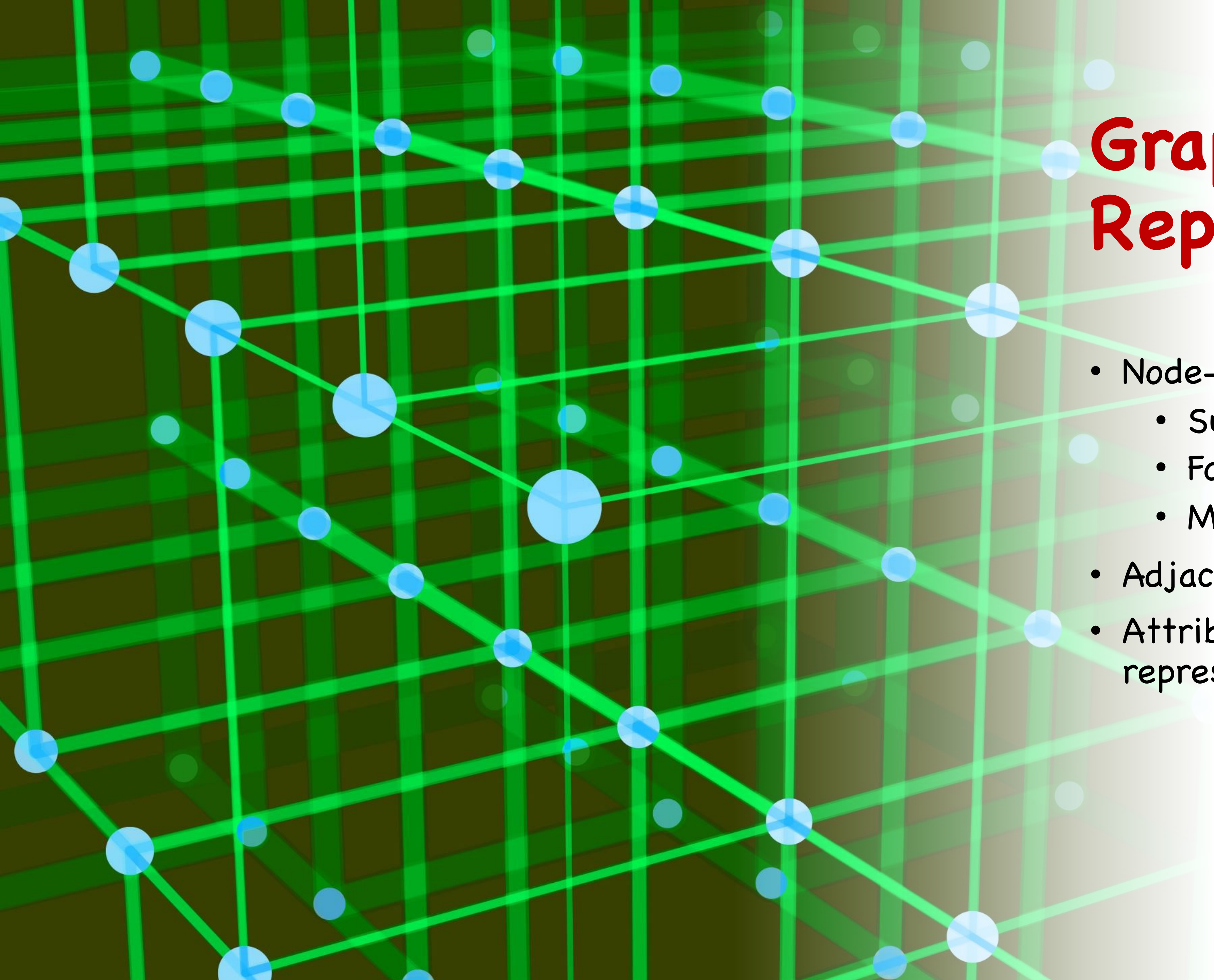


msn.com

CNN.com



Google

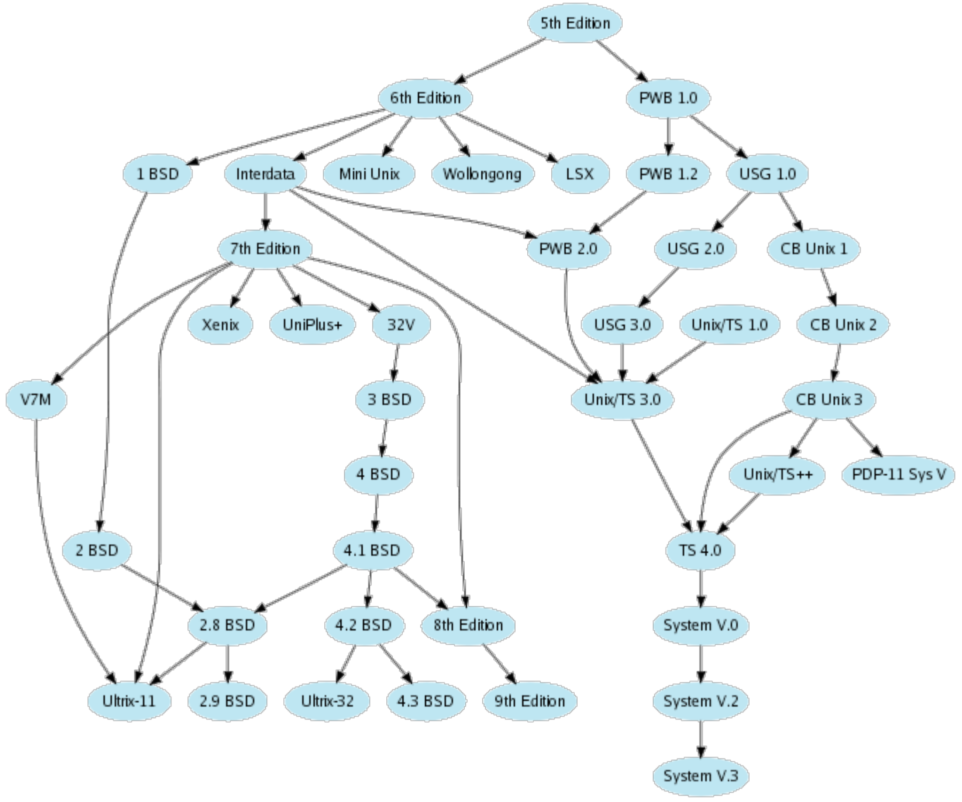


Graph Representation

- Node-link diagram
  - Sugiyama
  - Force-directed layout
  - MDS layout
- Adjacency matrix
- Attribute-based representation

Sugiyama Representation

- Good for **intrinsically ordered** graphs
- Depth of graph can be mapped to axes

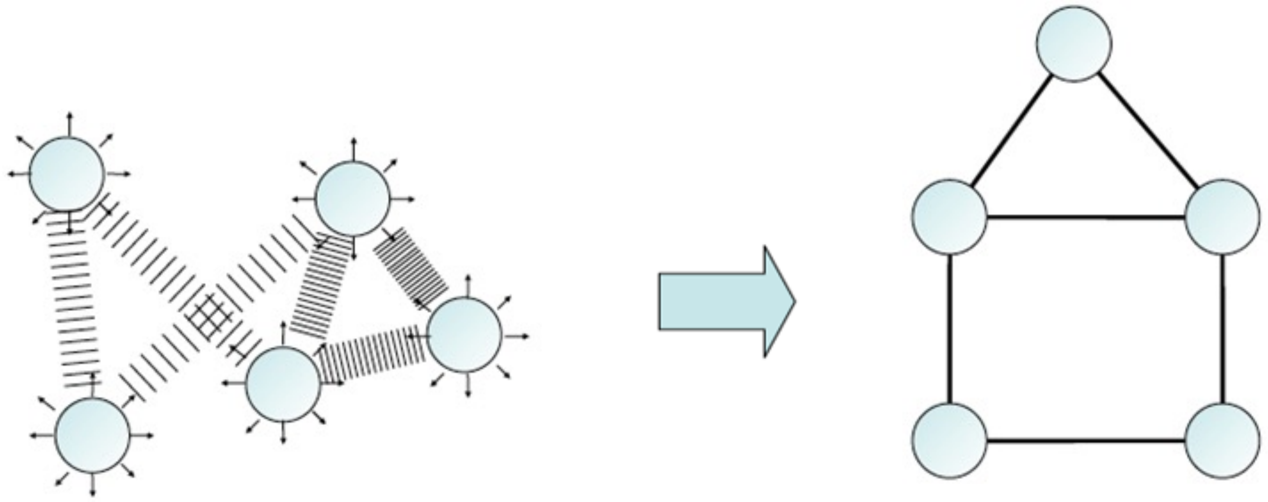


- High readability
- Fast (depends on the heuristic method)
- Not so good for graph without **intrinsic order**
- Easy to implement (free library graphviz, http://www.graphviz.org)

UNIX Family

Force-based algorithm

- What about graphs without intrinsic order?
- Physics model:
  - edge → spring
  - node → mass point



Force-Directed Layout

- Peter Eades introduced the layout in 1984 in the paper A Heuristic for Graph Drawing.
- With the effects of **spring force and gravitation**, nodes far away will be dragged near and vice versa.
- The layout reaches a **balance** and becomes stable after **iterations**.
- Spring Model:
- Energy Model:

$$E_s = \sum_{i=1}^{n}\sum_{j=1}^{n}\frac{1}{2}k(d(i,j) - s(i,j))^2$$

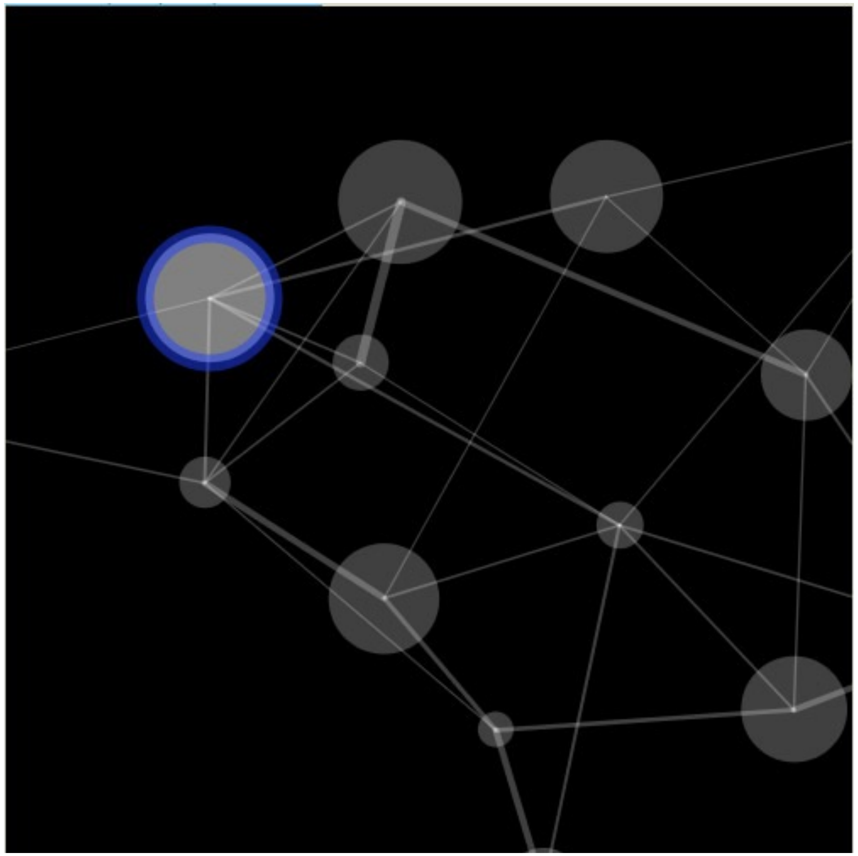
$$E = E_s + \sum_{i=1}^{n}\sum_{j=1}^{n}\frac{rw_iw_j}{d(i,j)^2}$$

Nodes Position Computation*

- From random or initial **configuration**
- Loop:
  - Compute **the repulsion and attraction** force for every pair of nodes.
  - Accumulate the **force** (vector) for every node.
  - Update nodes position **step by step** according to their forces.
- Loop stops when the layout is “good enough”

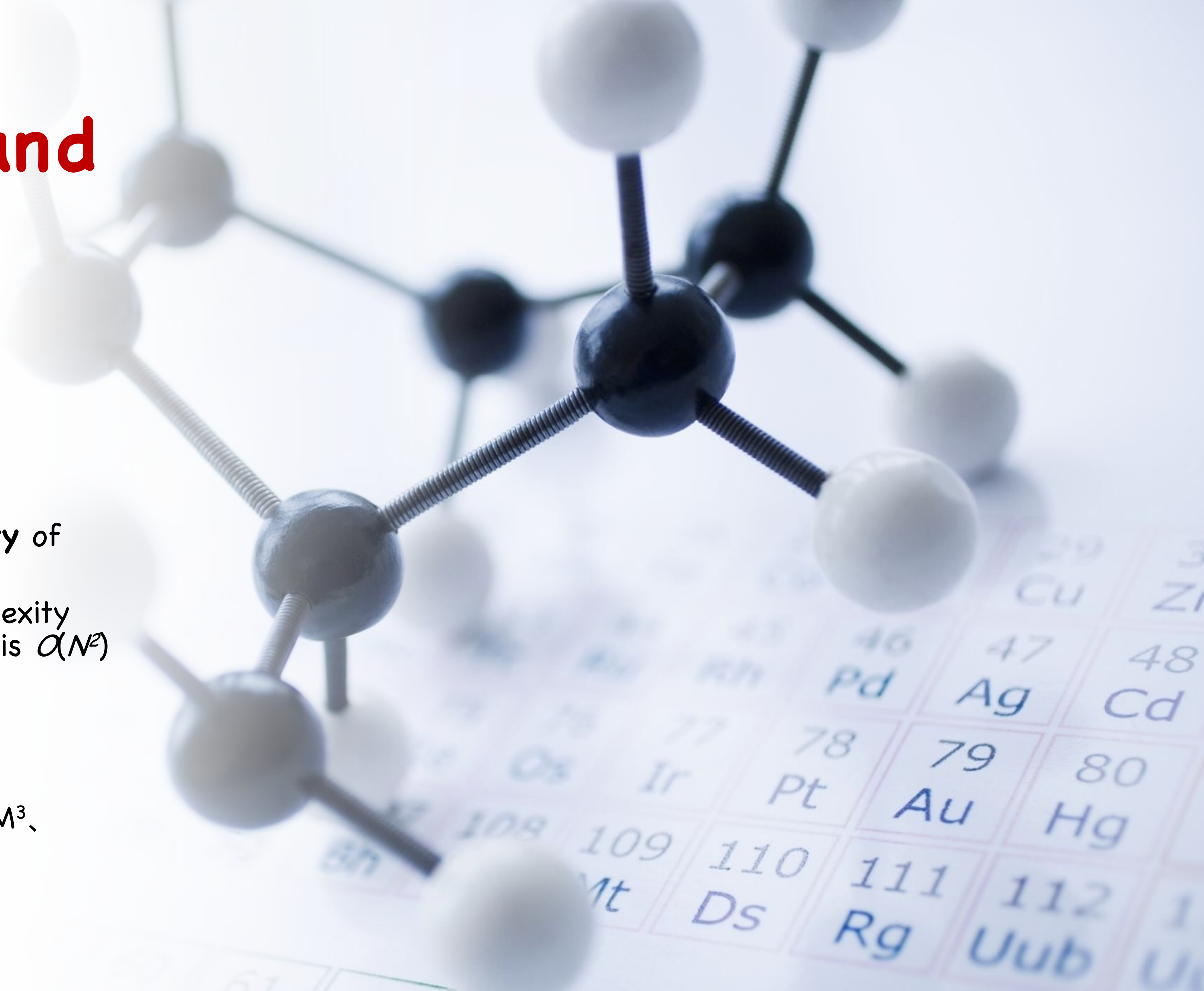
Advantages

- Very flexible for any type of graphs
- Forces can be customized
- Easy to implement



Limitations and Extensions

- Limitations
  - **Local optimal**
  - **Initial configuration** is important
  - **Computation complexity** of iterative algorithm
    - Computation complexity for each iteration is $O(N^2)$
- Extensions
  - Barnes-Hut quadtree decomposition
  - FADE、GRIP、FMS、FM^3、GVA



Results of Force-directed Layout

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Force-directed graph with elliptic forces

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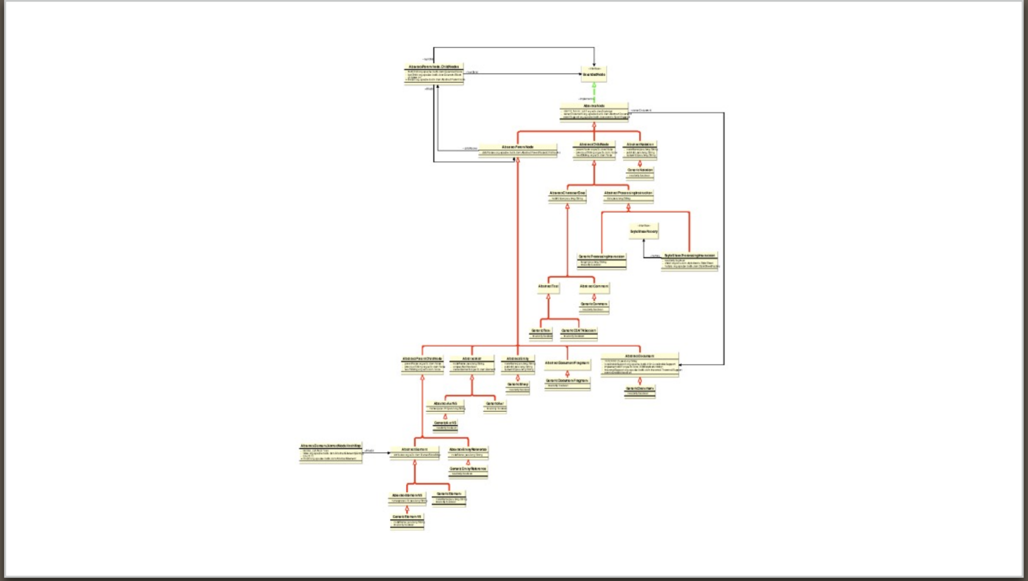
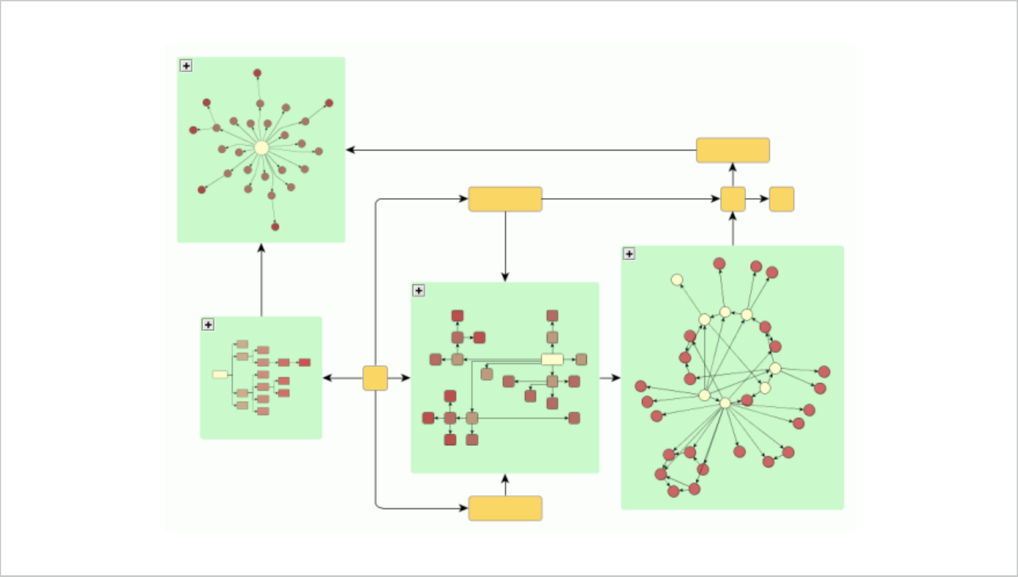
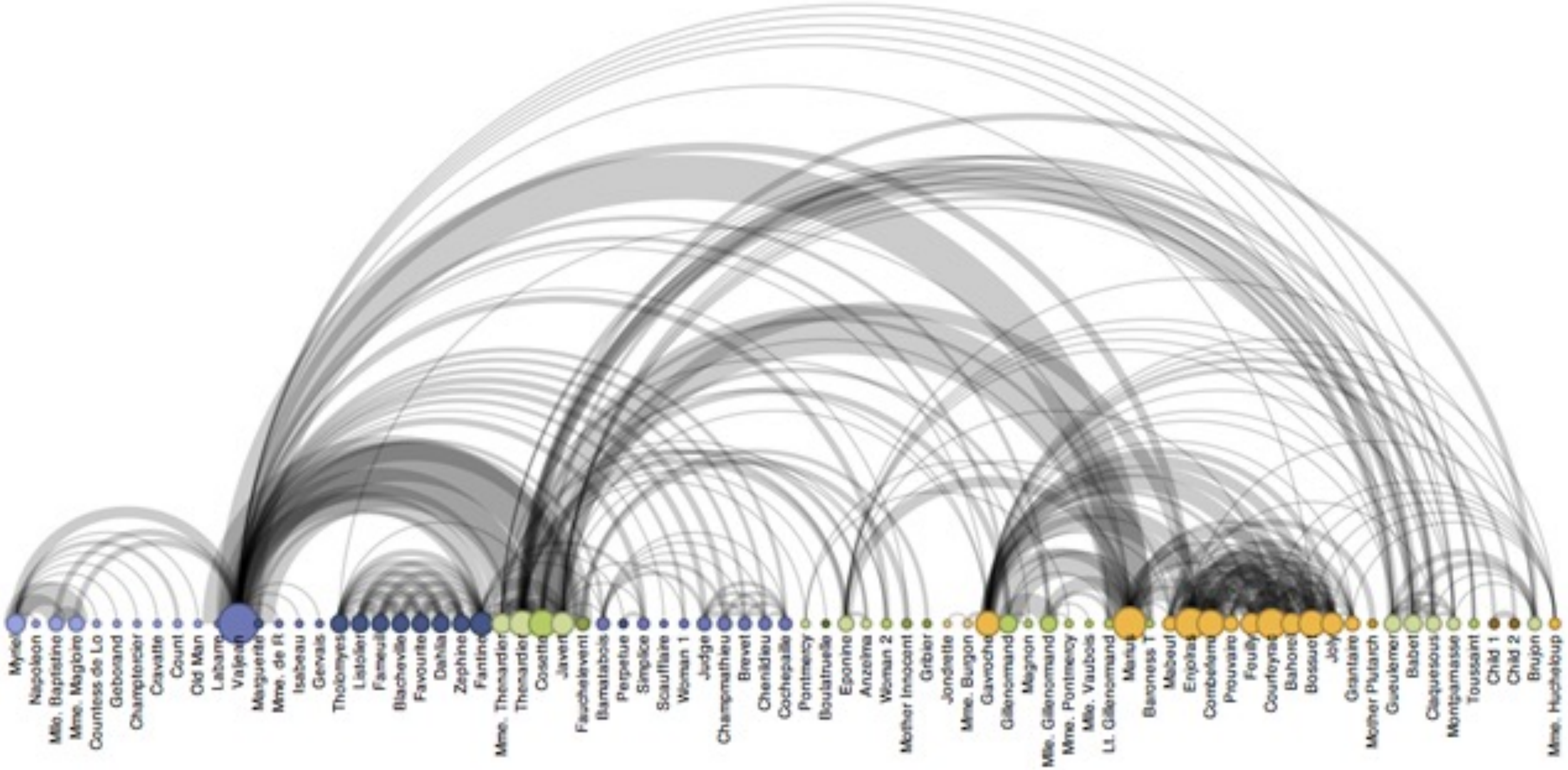
Other presentations of node-link diagram

- Orthogonal Diagram
  - UML diagram
- Ring ordered
  - For ring topology
  - Widely used in social network
- Nested ordered
  - Recursively applying nested layout
  - For intrinsic ordered topology
- Arc Diagram





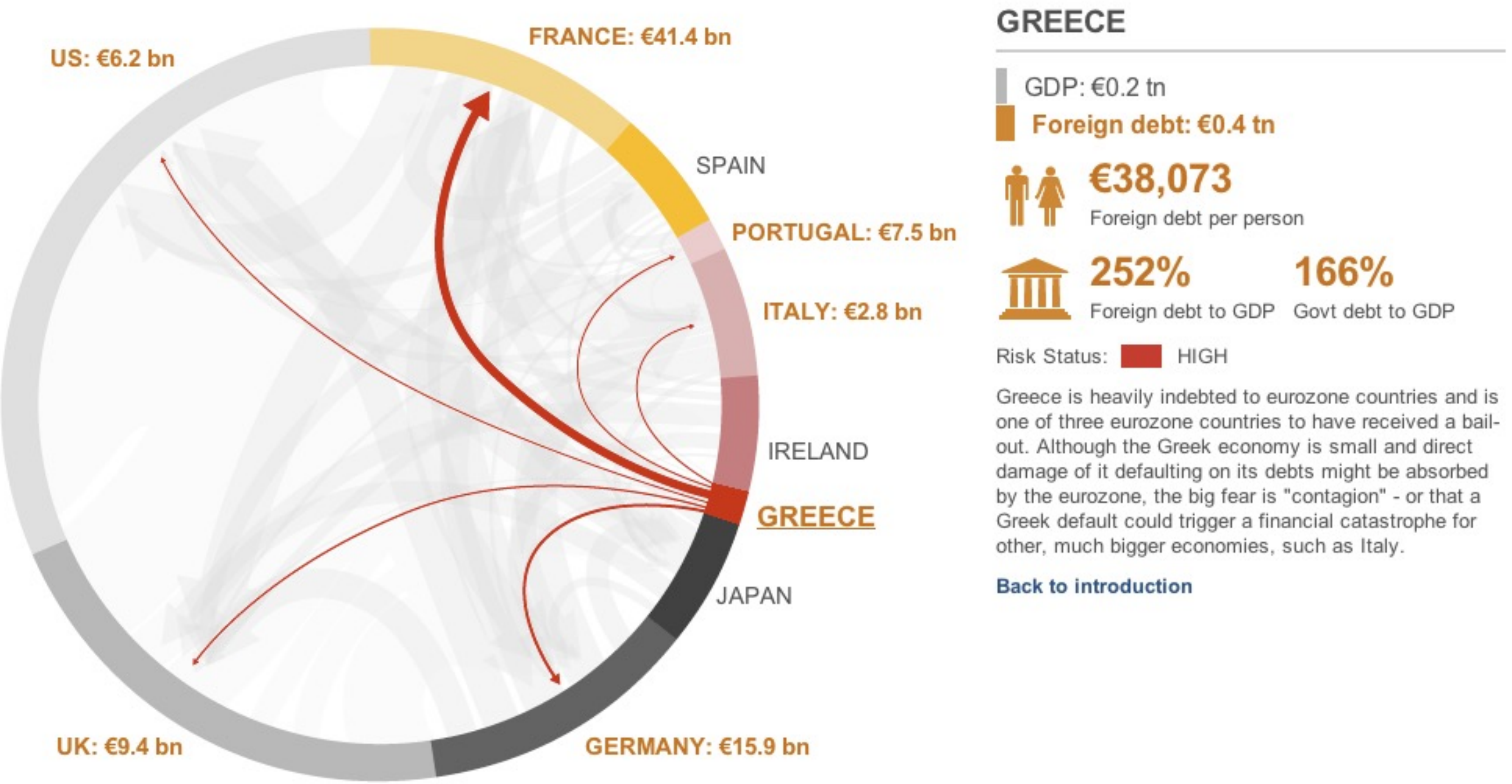
Arc Diagram



Character relations in Les Miserables

http://hci.stanford.edu/jheer/files/zoo/

Arc Diagram



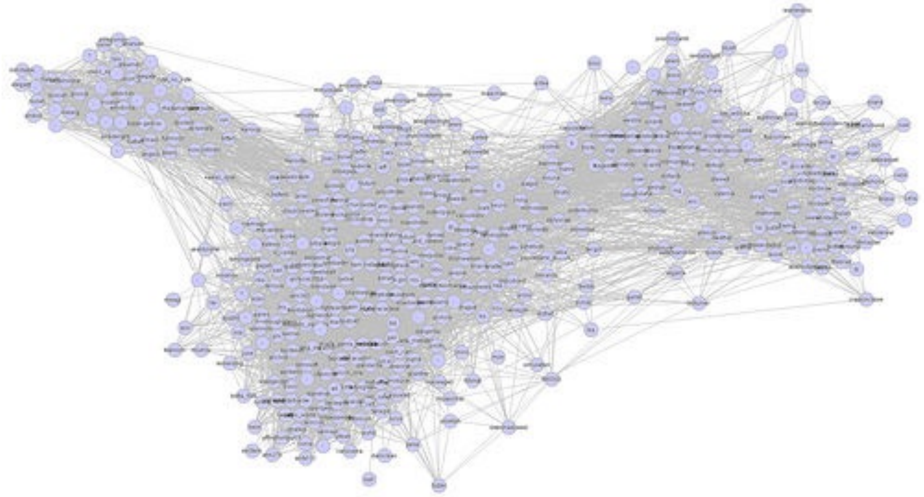
Source: Bank for International Settlements, IMF, World Bank, UN Population Division

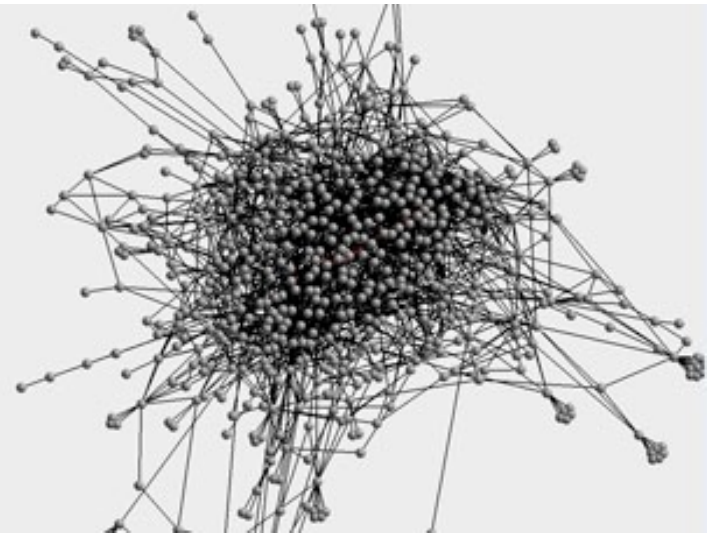
Eurozone debt web: Who owes what to whom?

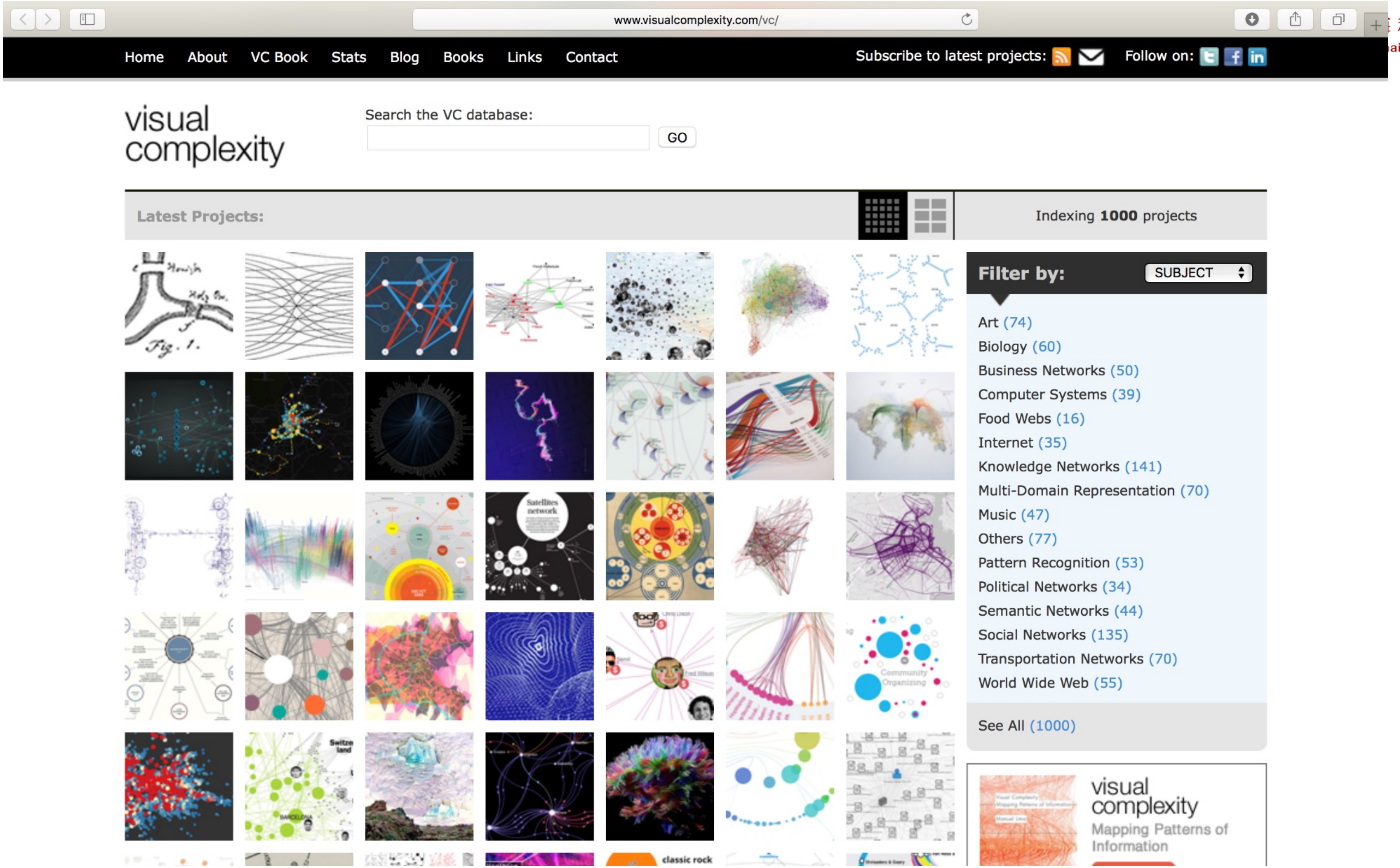
http://www.bbc.co.uk/news/business-15748696

Node-Link Diagram Summary

- Intuitive visual interpretation
- Good representation of topology, clusters and paths
- Flexible, many variants
- Almost for all algorithms, time complexity $>O(N^2)$
- Not so good for cluttered graphs (especially edge cluttered graphs)



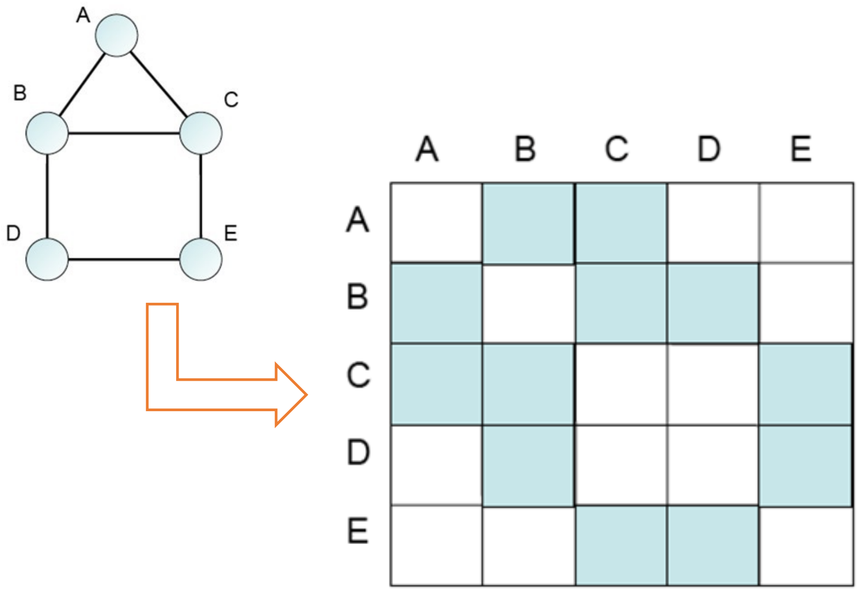




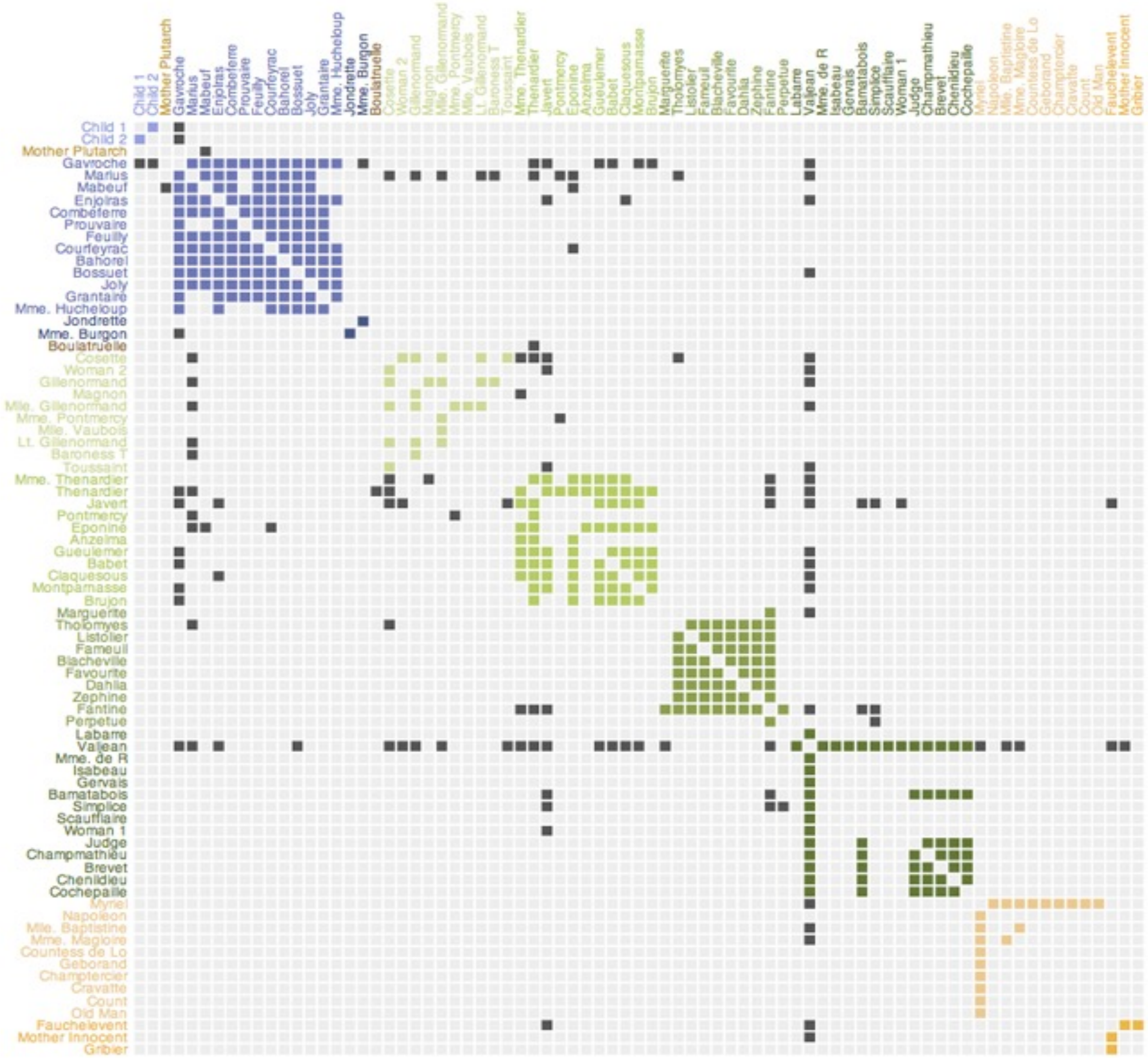
www.visualcomplexity.com/vc/

Adjacency Matrix

- N×N matrix, representing relations among N objects.
- Position (i, j) represents the relation between the ith and the jth object,
  - Weight
  - Direction
  - Self-reflexivity
- Related issues
  - Ordering
  - Path finding



Good Ordering of Adjacency Matrix



http://hci.stanford.edu/jheer/files/zoo

Path Visualization for Adjacency Matrix

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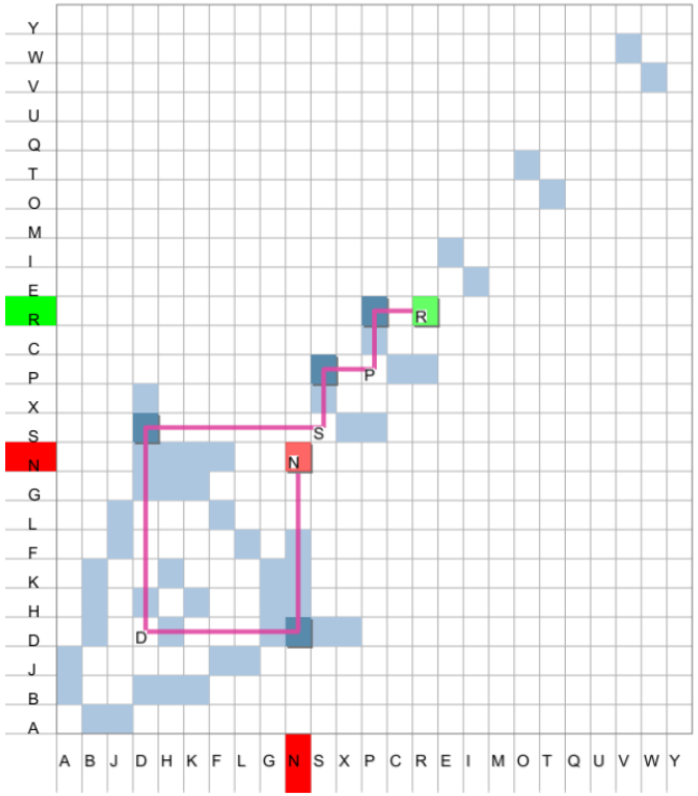

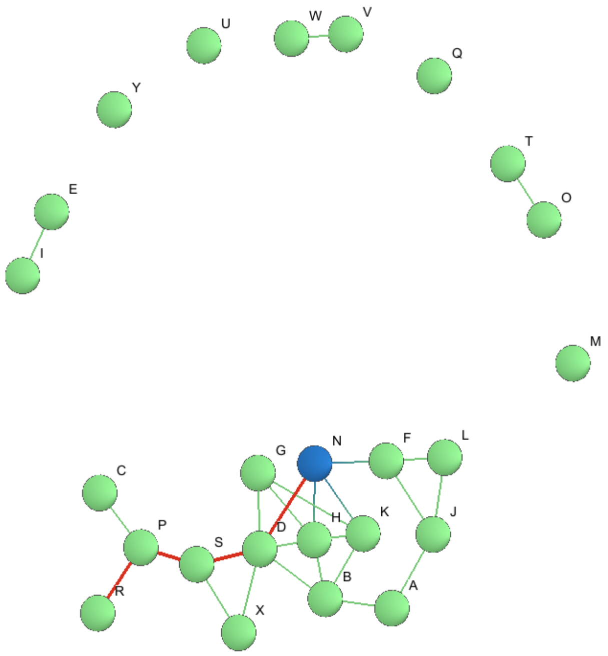

Left: Connecting matrix entries and the diagonal.
Right: Path {N;D;S;P;R} is Highlighted in the Node-link Diagram.

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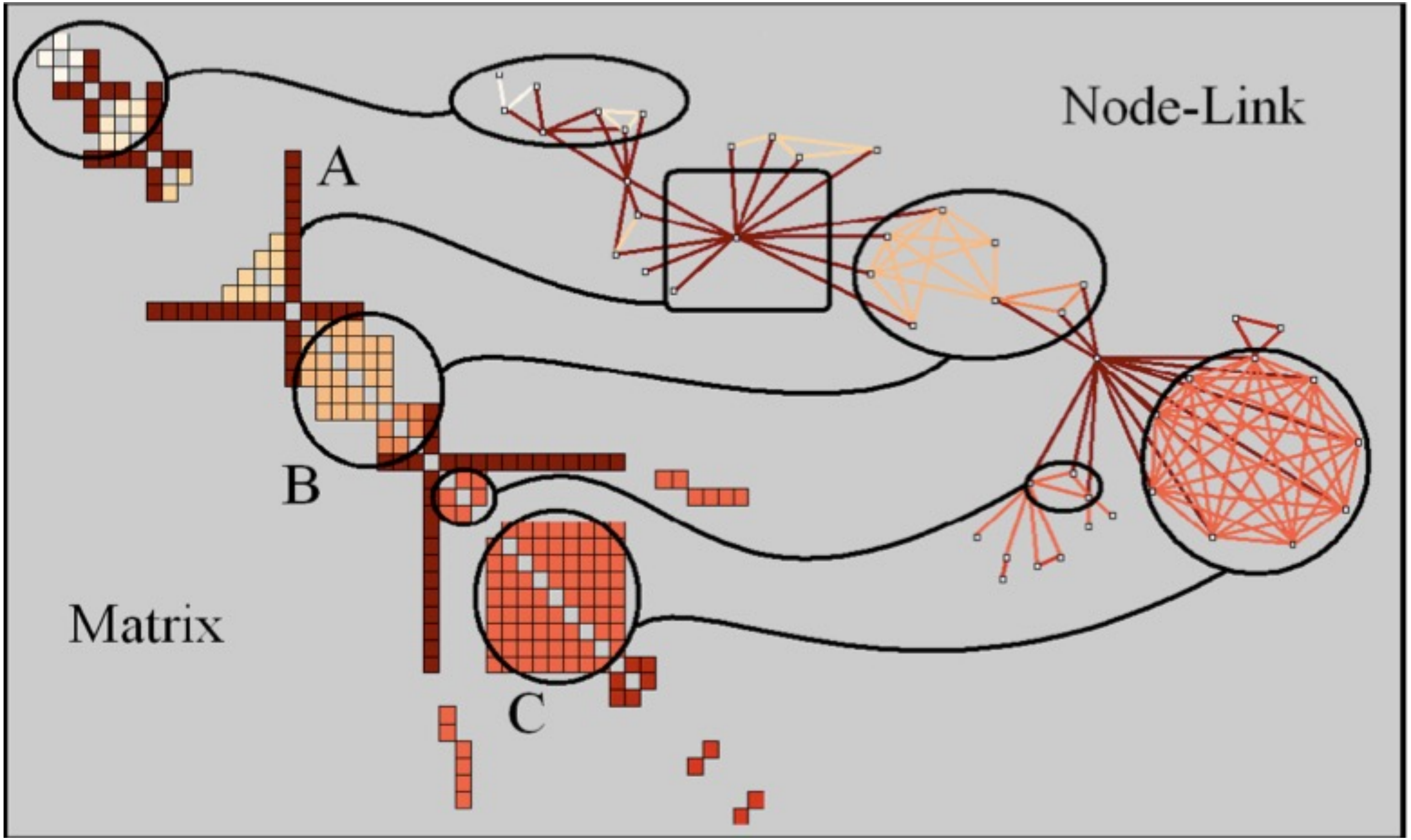
Recognizing the Patterns of Matrix



Adjacency Matrix Summary

- No edge crossing, good for edge cluttered graph
- Good visual scalability
- Good presentation of graph pattern
- Visualization is too abstract to understand
- Difficult to follow a transitive relation path

Hybrid Layout

Hybrid Layout

- Complex edge relations—adjacency matrix
- Too many nodes—node-link diagram
- What if there are so many nodes, and some of them with complex edge relations?

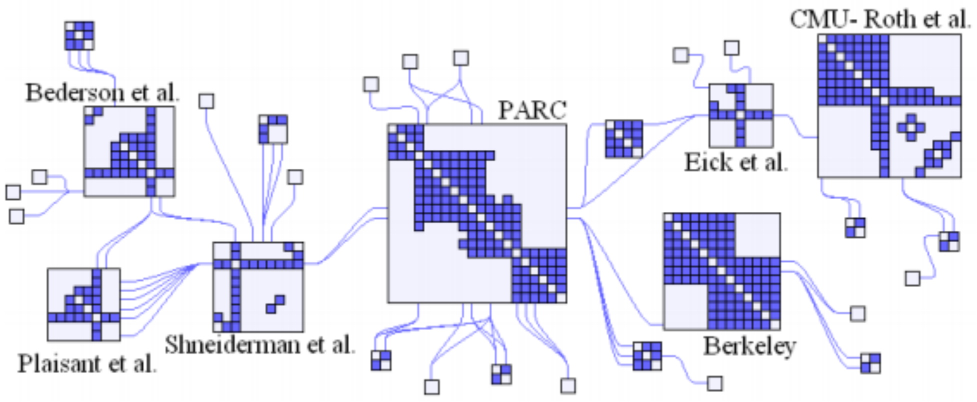
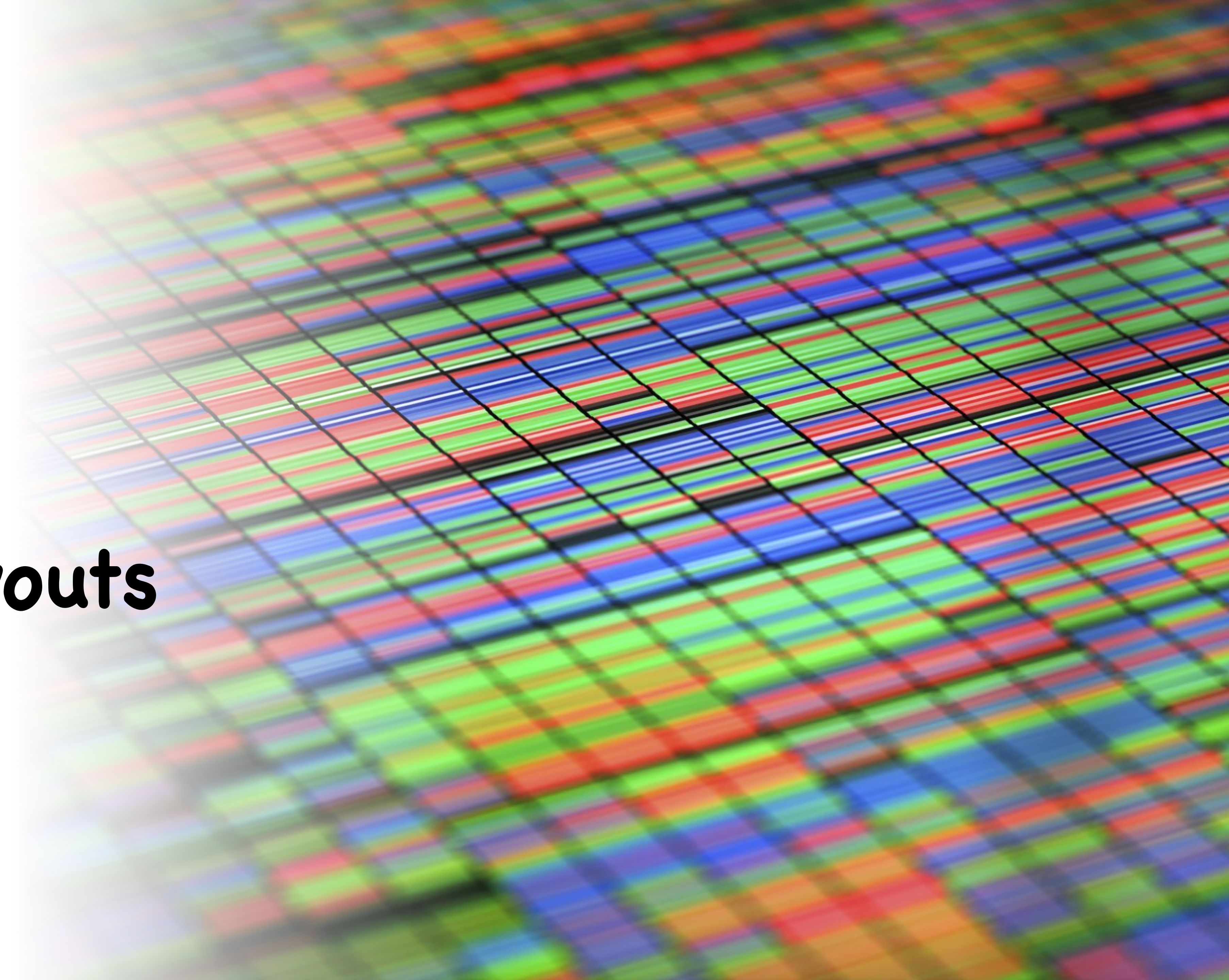


Fig. 1: NodeTrix Representation of the largest component of the Info-Vis Co-authorship Network

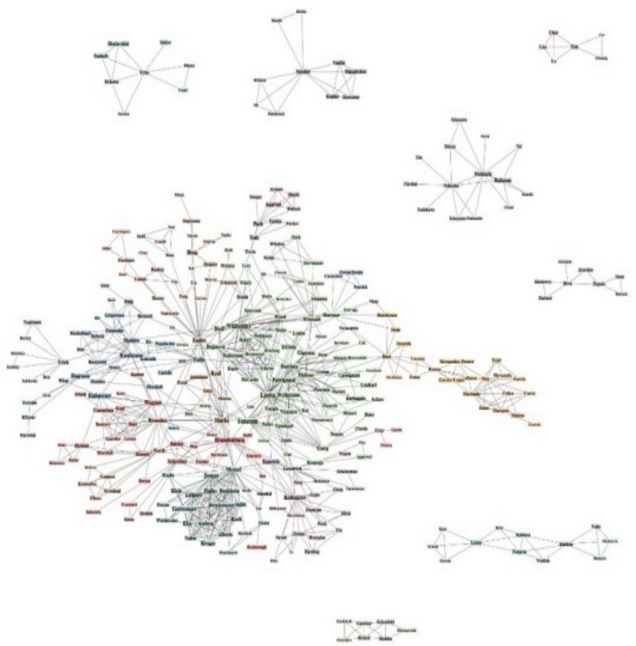
Nathalie Henry, et al. NodeTrix: A Hybrid Visualization of Social Networks. TVCG 2007.

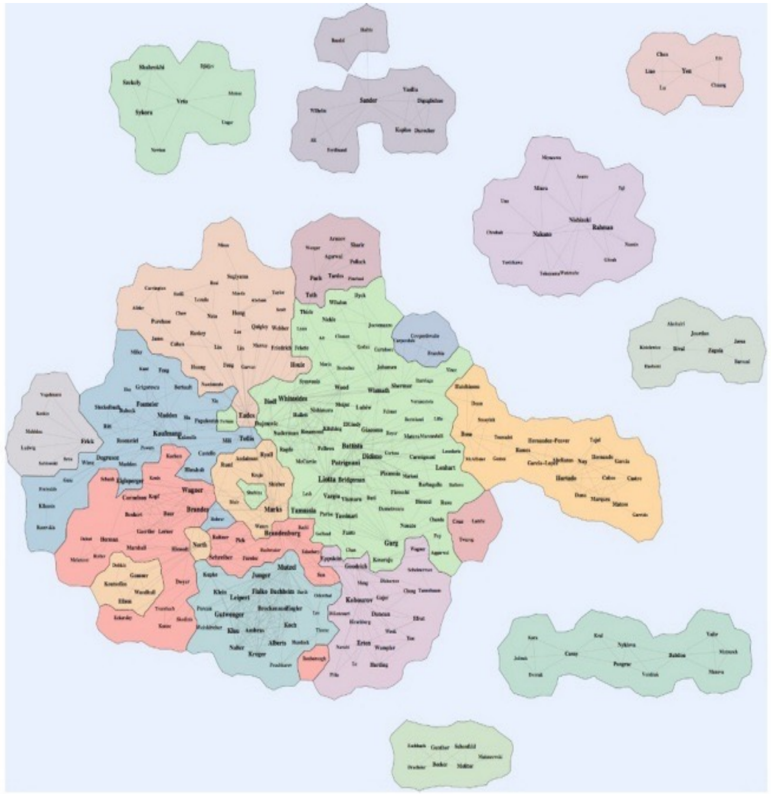
Other layouts



GMap

- Gmap represents object clusters with plane areas.

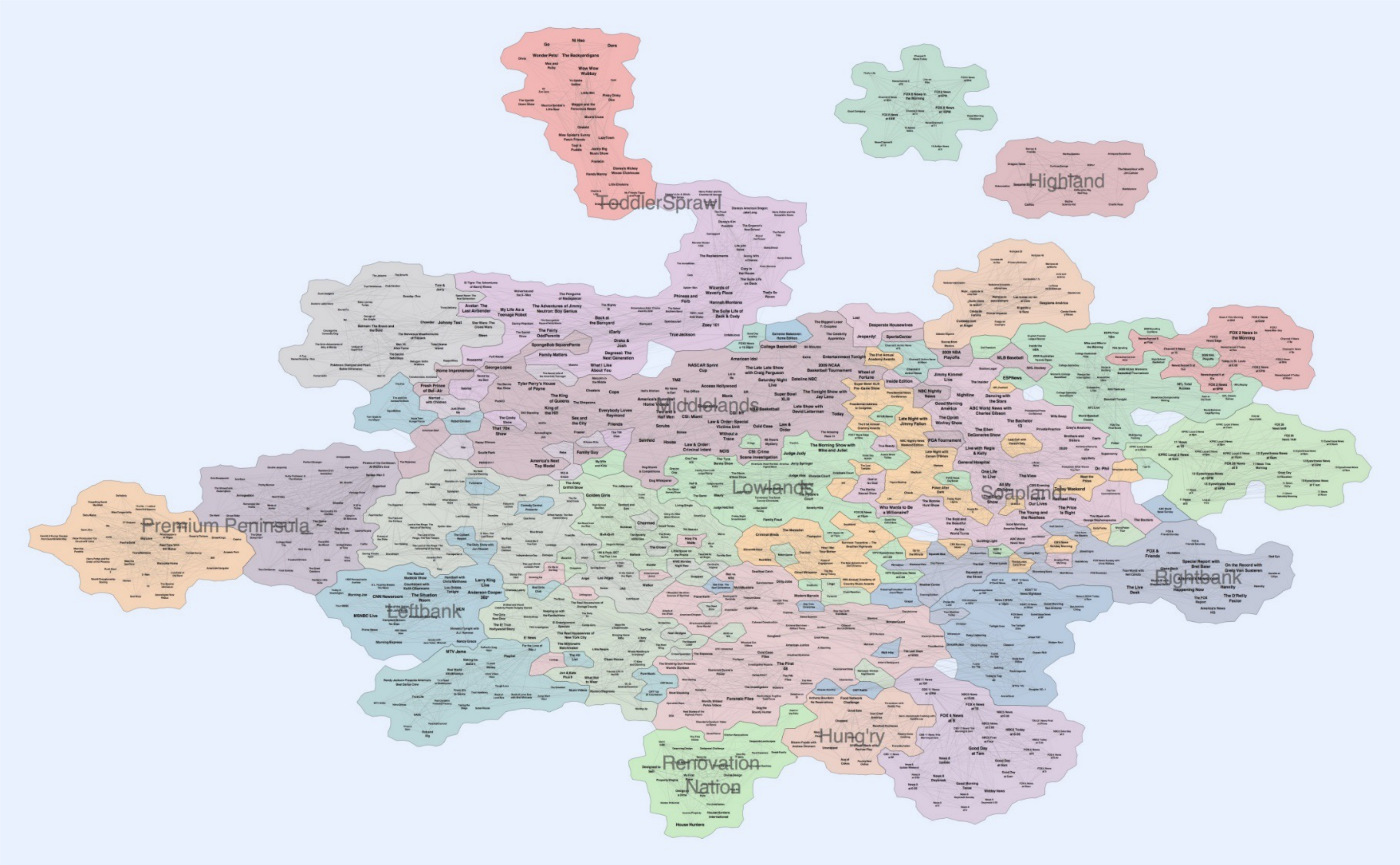




Gmap Procedures*

1. Layout the nodes on the graph
2. Clustering
3. Constructing voronoi diagram for every cluster
4. Coloring

Gmap Procedures*



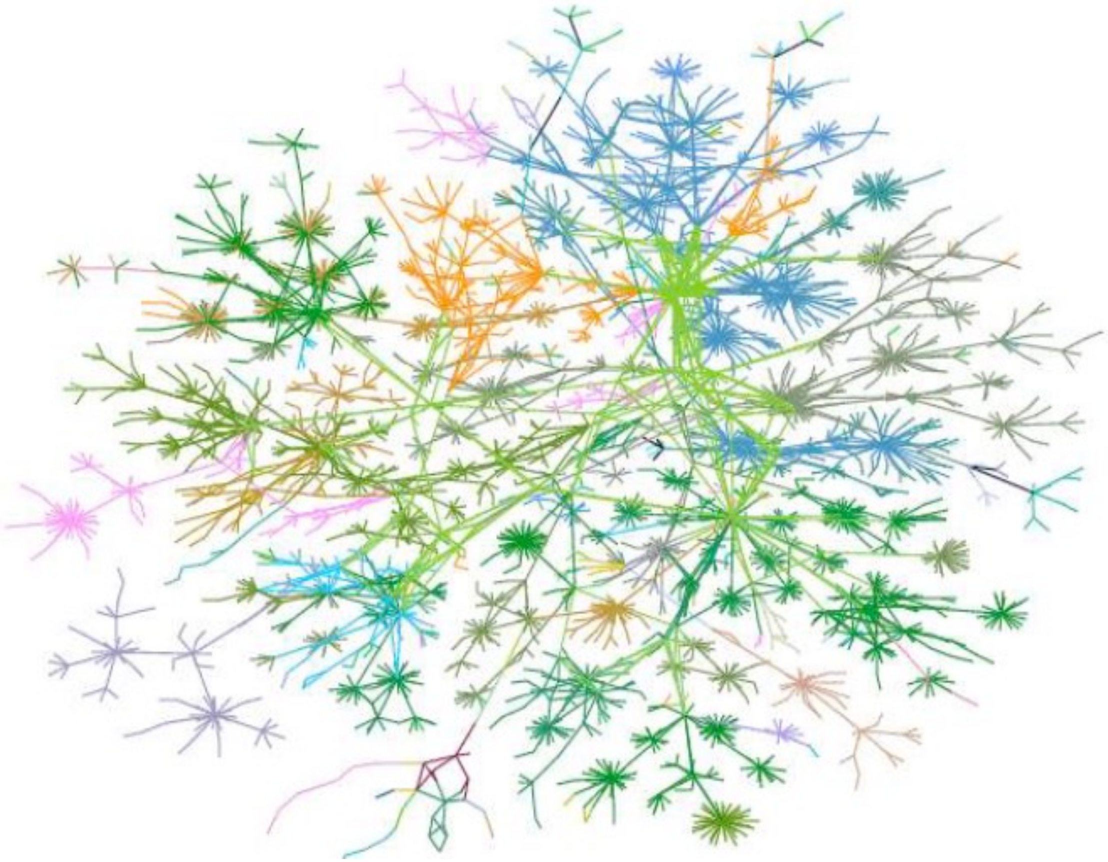
Graph Simplification

Topology Simplification

- Data reduction
  - Nodes reduction
    - Clustering
  - Edge reduction
    - Minimal spanning tree

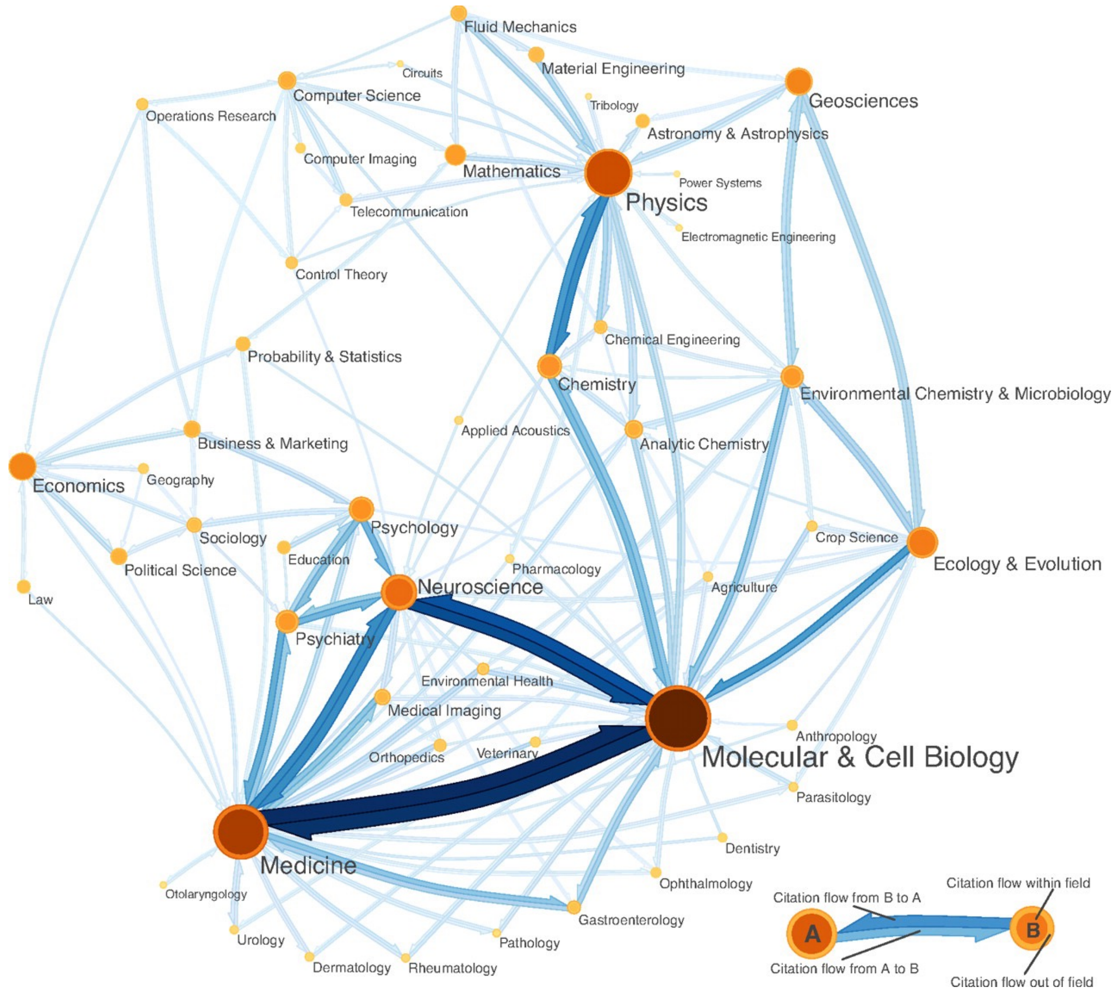
Minimal Spanning Tree

- Edge deletion
- Prim algorithm



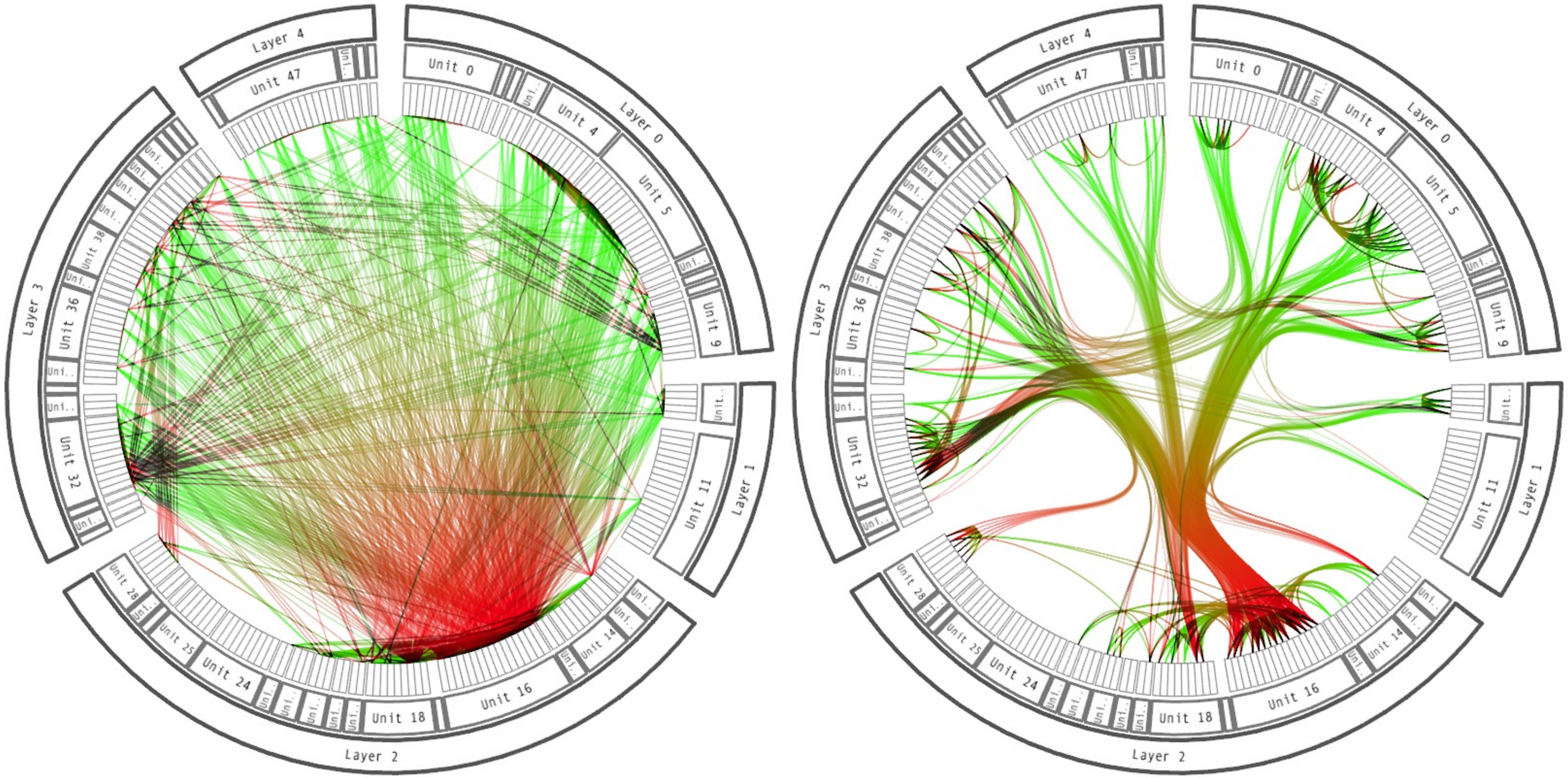
Hal Burch. Measuring an IP Network in situ

Visualization of Clusters

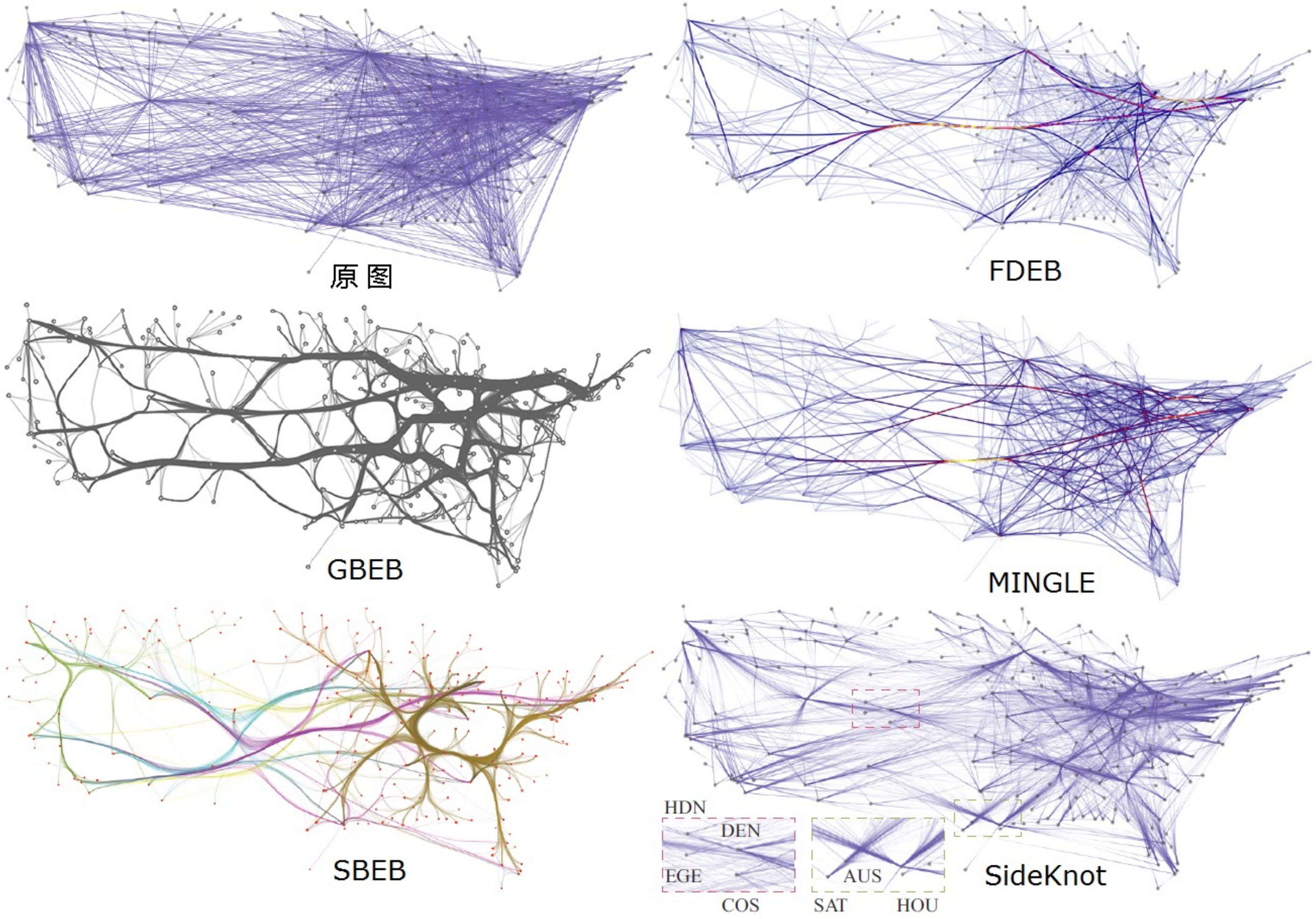


M. Rosvall and C.T. Bergstrom. Maps of Random Walks on Complex Networks Reveal Community Structure

Edge Bundling



Edge Bundling



KDE-based Graph Simplification

Interactive Visualization of Streaming Data with Kernel Density Estimation

Ove Daae Lampe, CMR and UiB *
Helwig Hauser, UiB +

* odl@cmr.no
http://cmr.no

+ Helwig.Hauser@UiB.no
http://http://www.ii.uib.no/vis/

O. D. Lampe and H. Hauser. Interactive visualization of streaming data with kernel density estimation.

Ove Daae Lampe, et al. Interactive visualization of stream data with kernel density estimation. PacificVis 2011

KDE-based Graph Simplification

Michael Zinsmaier, et al. Interactive Level-of-Detail Rendering of Large Graphs. TVCG 2012

KDE-based Graph Simplification

Christophe Hurter, et al. Graph Bundling by Kernel Density Estimation. EuroVis 2012

Attribute-Driven Edge Bundling

Vsevolod Peysakhovich, et al. Attribute-Driven Edge Bundling for General Graphs with Applications in Trail Analysis. PacificVis 2015

Edge bundling of huge graphs

FFTEB:
Edge Bundling of Huge Graphs by the Fast Fourier Transform

Antoine Lhuillier, et al. FFTEB: Edge bundling of huge graphs by the Fast Fourier Transform. PacificVis 2017

Interaction

Labeling

Non-text labels

- Color, size, shape, thickness
- Too many labels lead to misinterpretation

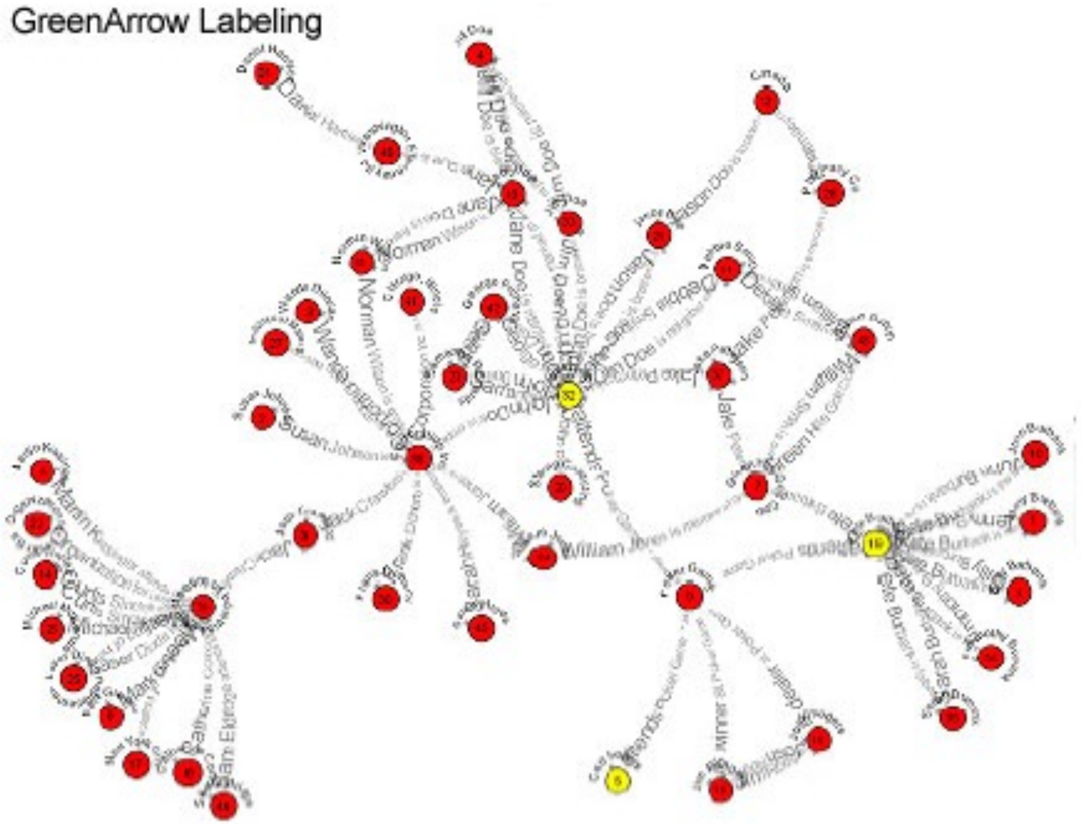
Labels of nodes

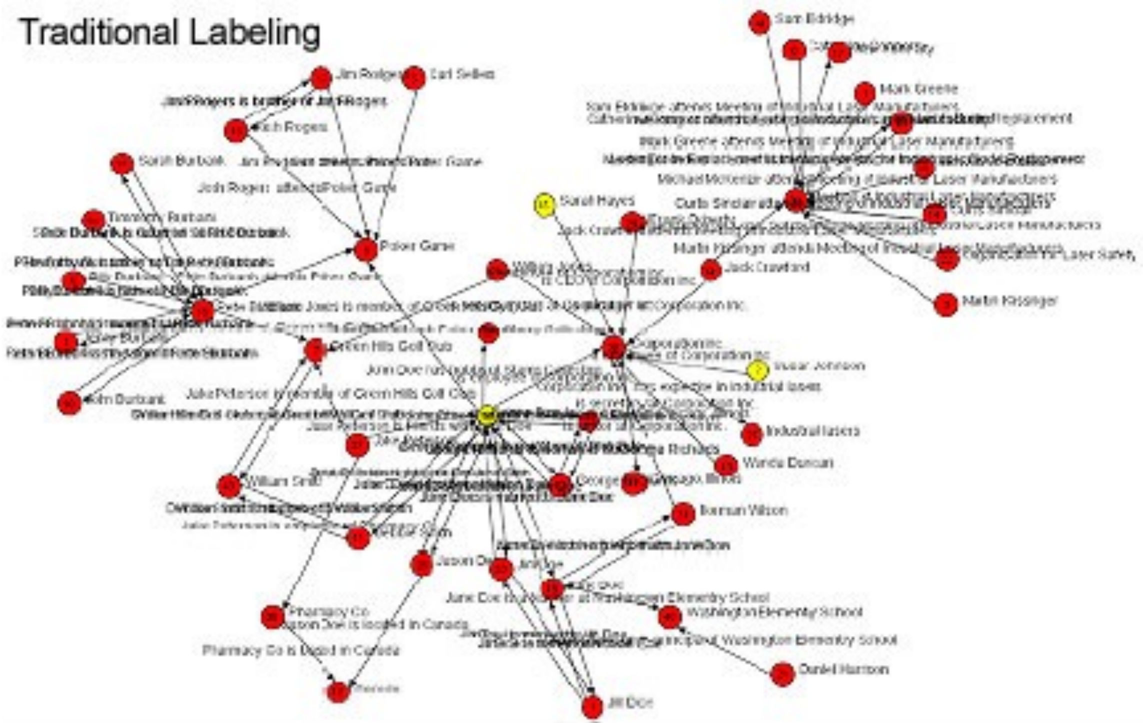
- Inside the node object

Labels of edge

- Along the edge

Labeling





Labels are also nodes and edges

Interactions

View-based interaction

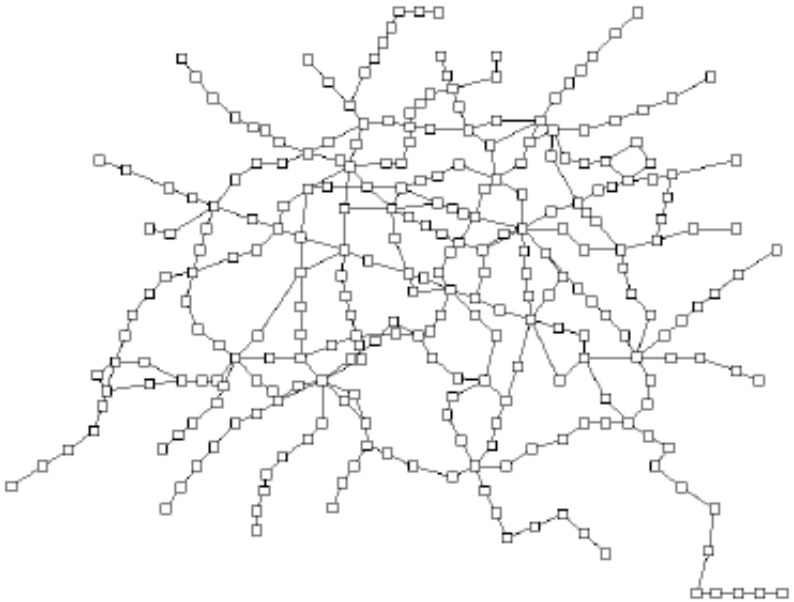
- Panning, zooming, rotating

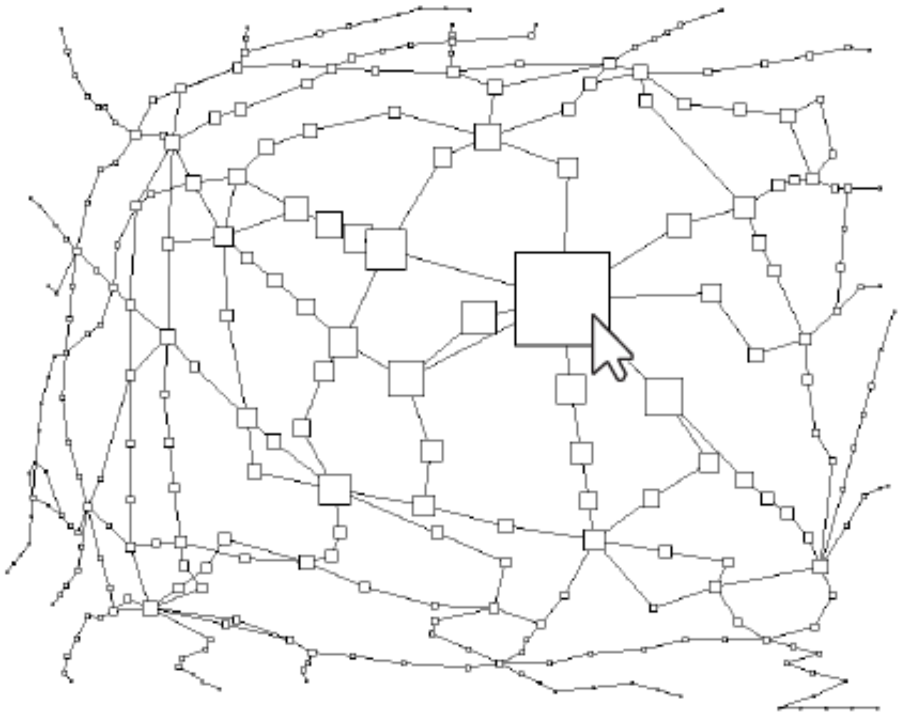
Object-based interaction

- Selecting, highlighting, deleting, dragging

Structure-based interaction

- Reorder, re-layout
- Focus + context
- Roll-up, drill-down





Fisheye

- Originate in wide-angle lens in photography.
- Popping out objects in the center and also covering its context.

Large Scale Graph Interaction

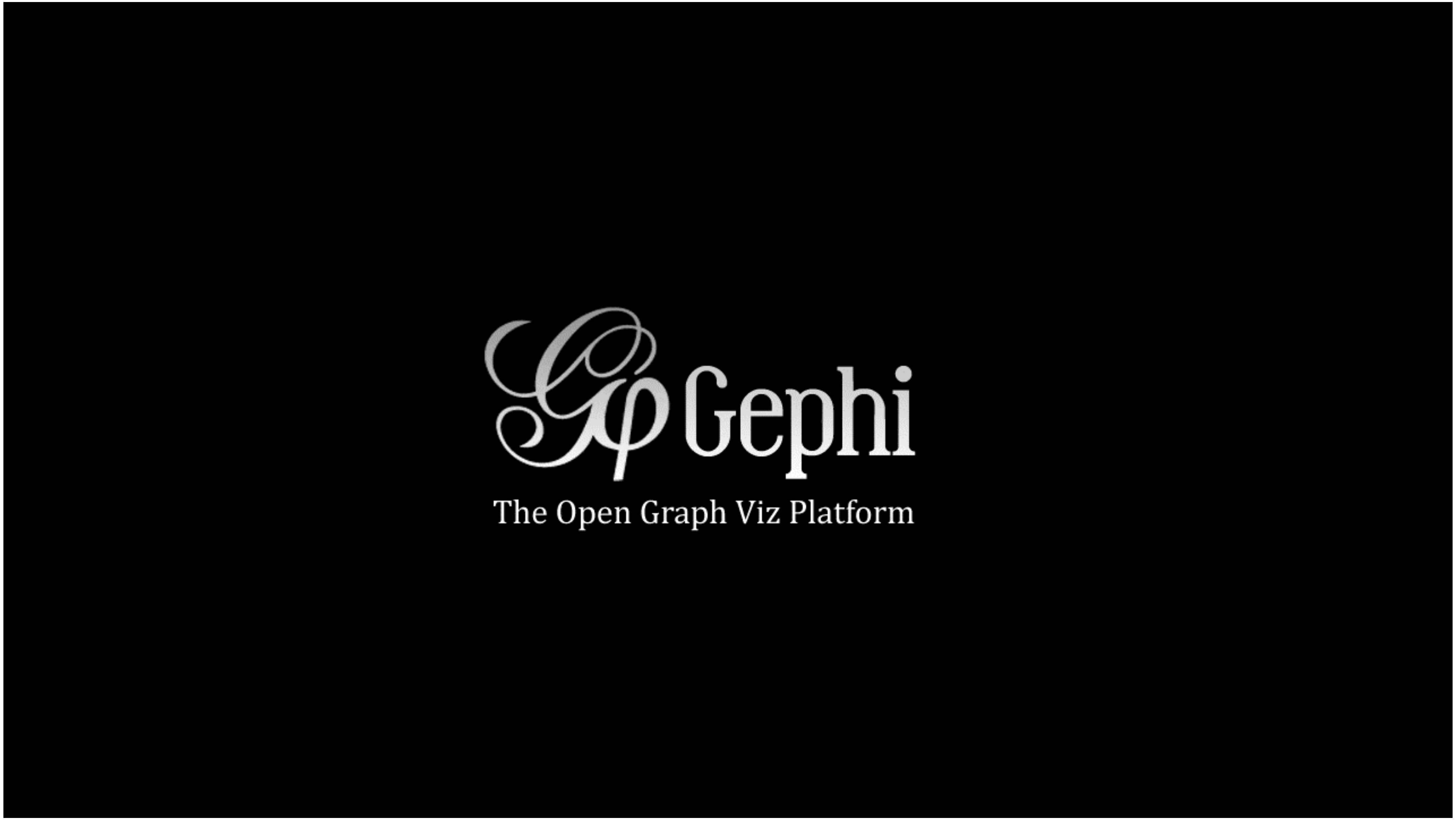
Matthew van der Zwan, et al. CUBu: Universal real-time bundling for large graphs. IEEE VIS 2016

Tools and Applications

Prefuse

http://prefuse.org/

Gephi



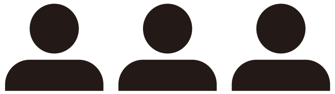
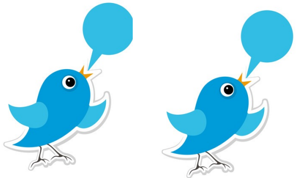
https://gephi.org/

Social Media Visual Analytics

Outline

- Social Media Data Category
- Social Media Visualization
- Social Media Visual Analytics
- Application and System
- Discussion and Summary

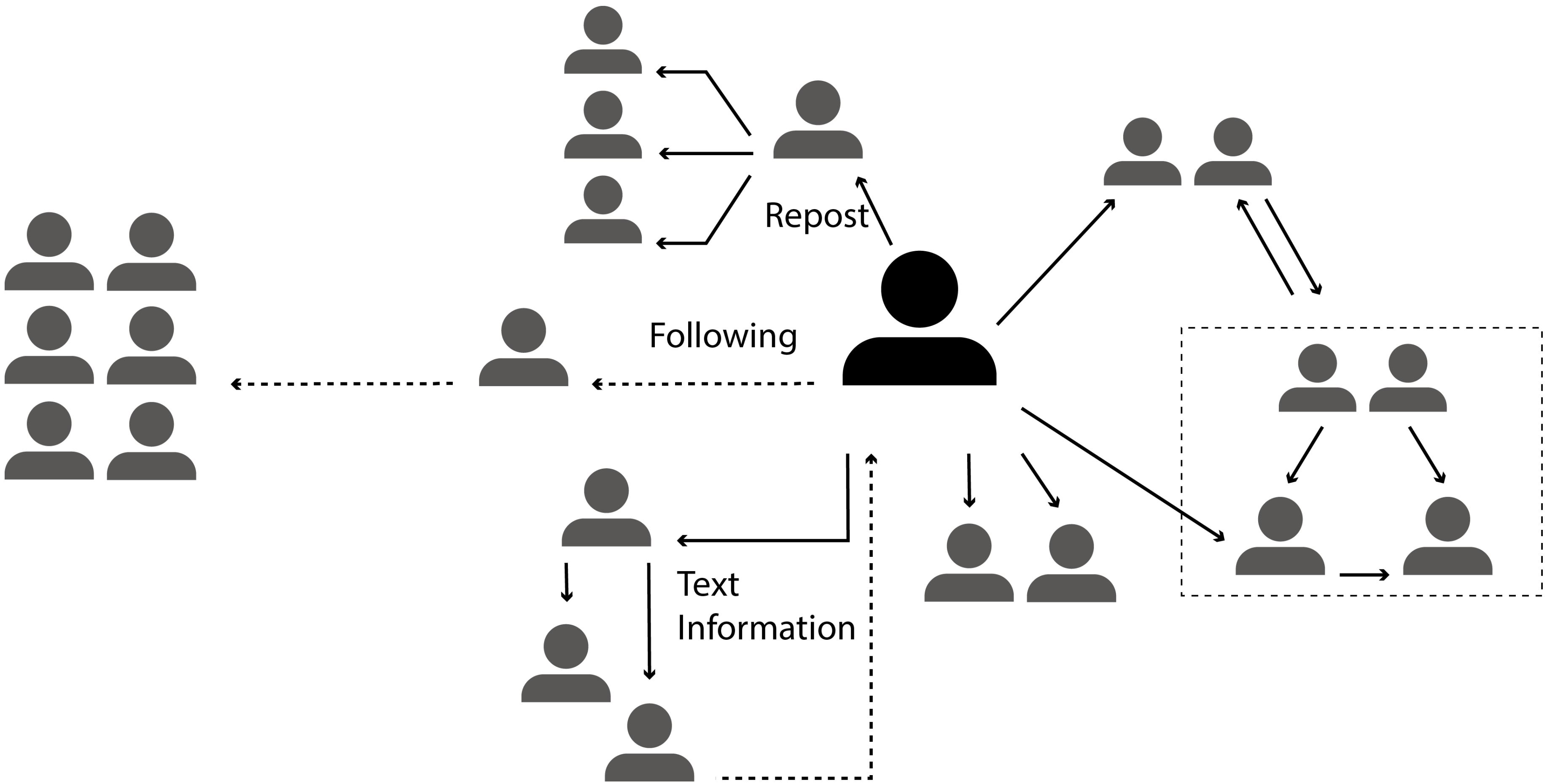
Social Media

- Entity
  - Users 
  - Messages 
- User behaviors
  - Posting messages (Tweet)
  - Commenting and Re-posting (Re-tweet)

Social Media Data

- Users
- Messages
  - Time
  - Location
  - Content
  - Multi Media
- Reposting Behaviors

Social Network in Social Media



Geo-tagged Social Media

垦丁的风景确实很漂亮。 台湾

6 -17 21:23come from iPad客户端

每个城市的夜市都人满为患，摊位上吆喝着各自的黑暗料理。 台湾·花莲火車站

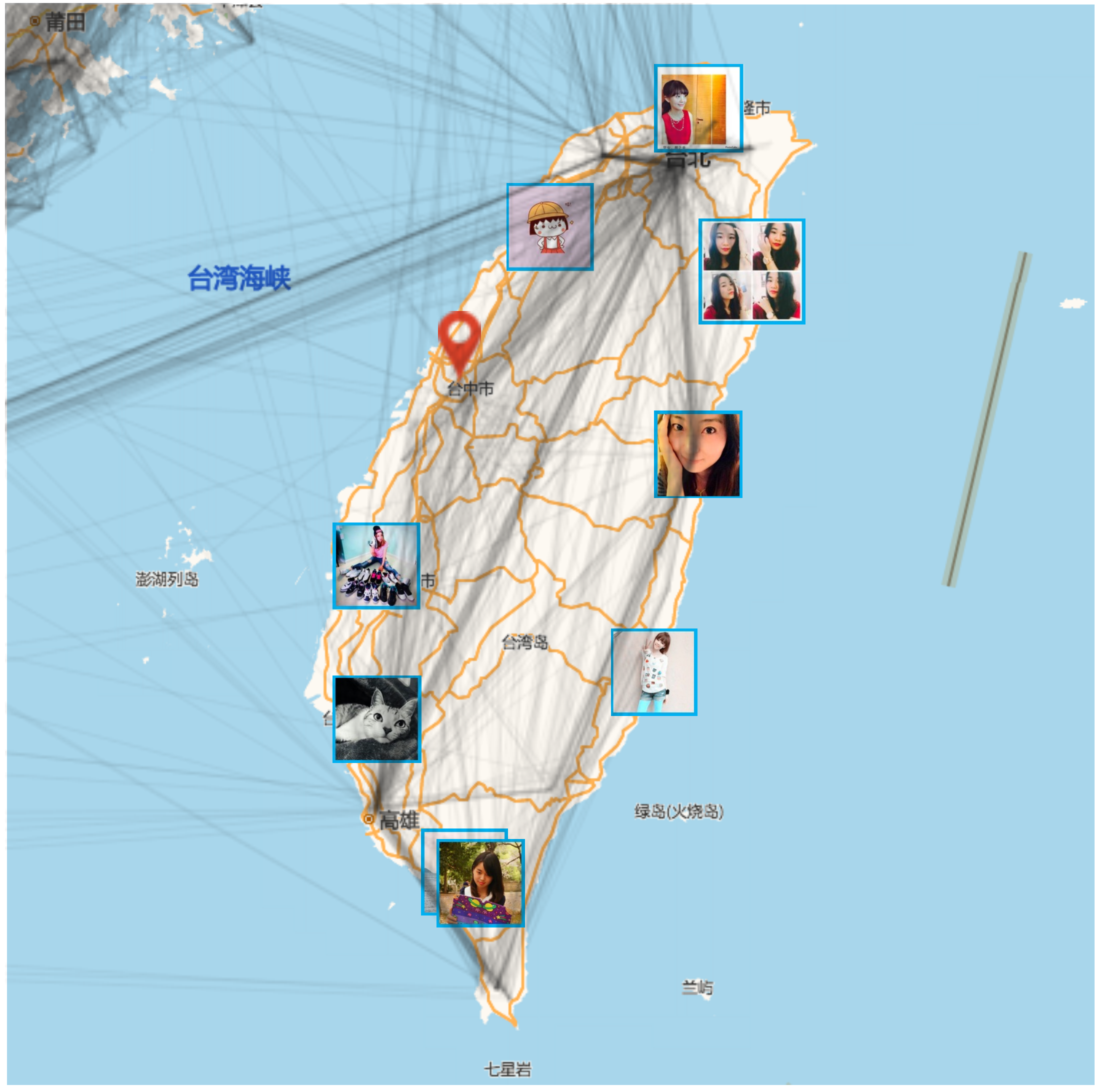
6 -19 22:44come from iPad客户端

看完后很大的感触是，有钱人真会玩。 台湾·台北故宫博...

6 -22 08:55come from iPad客户端

这里有我们丢失的一些东西。 台湾

6 -22 17:59come from iPad客户端



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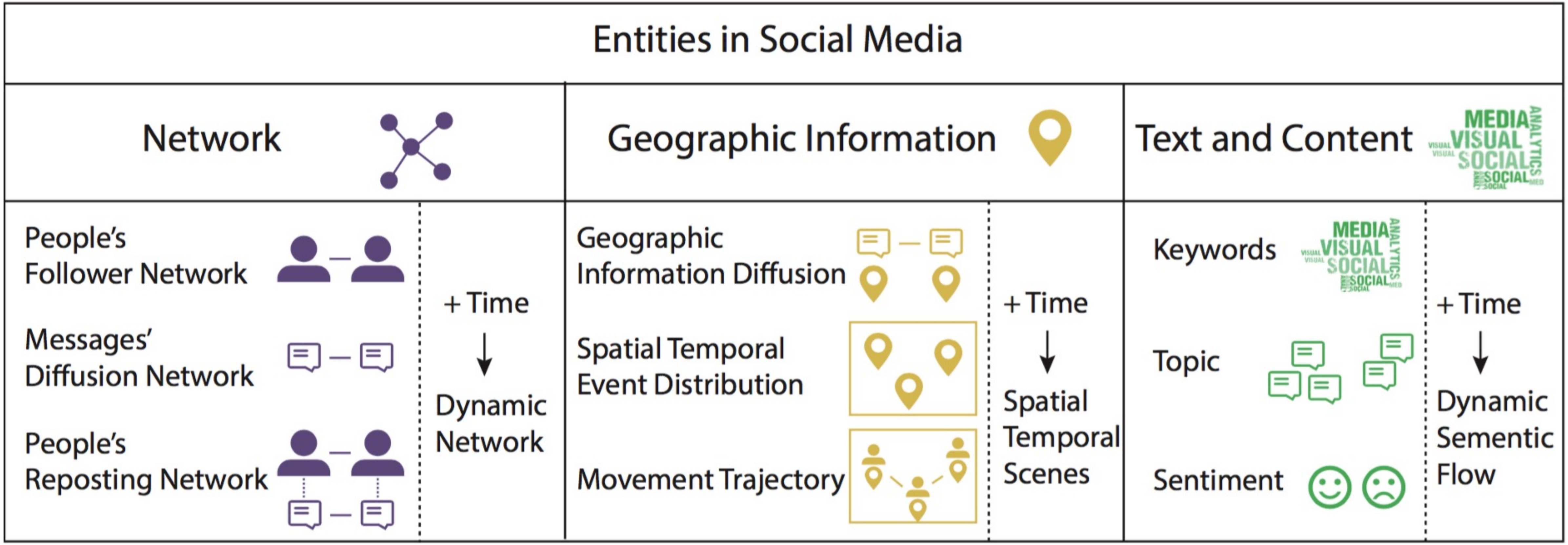
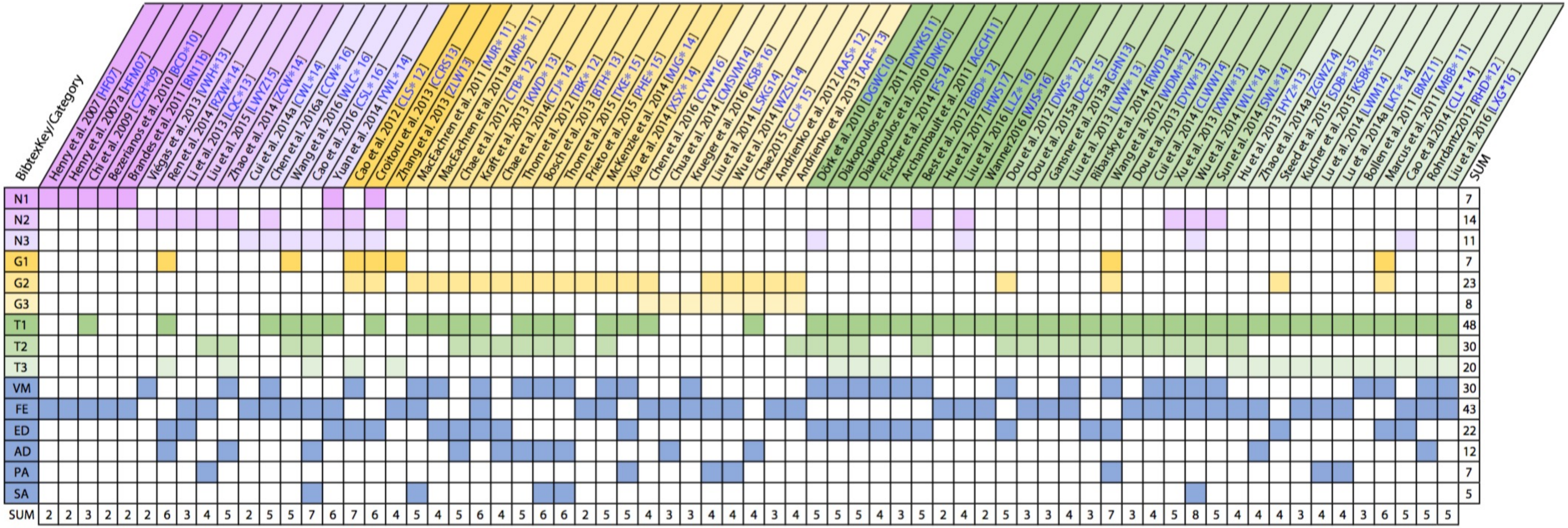
Classification of Social Media Entities and Related Visualization Techniques



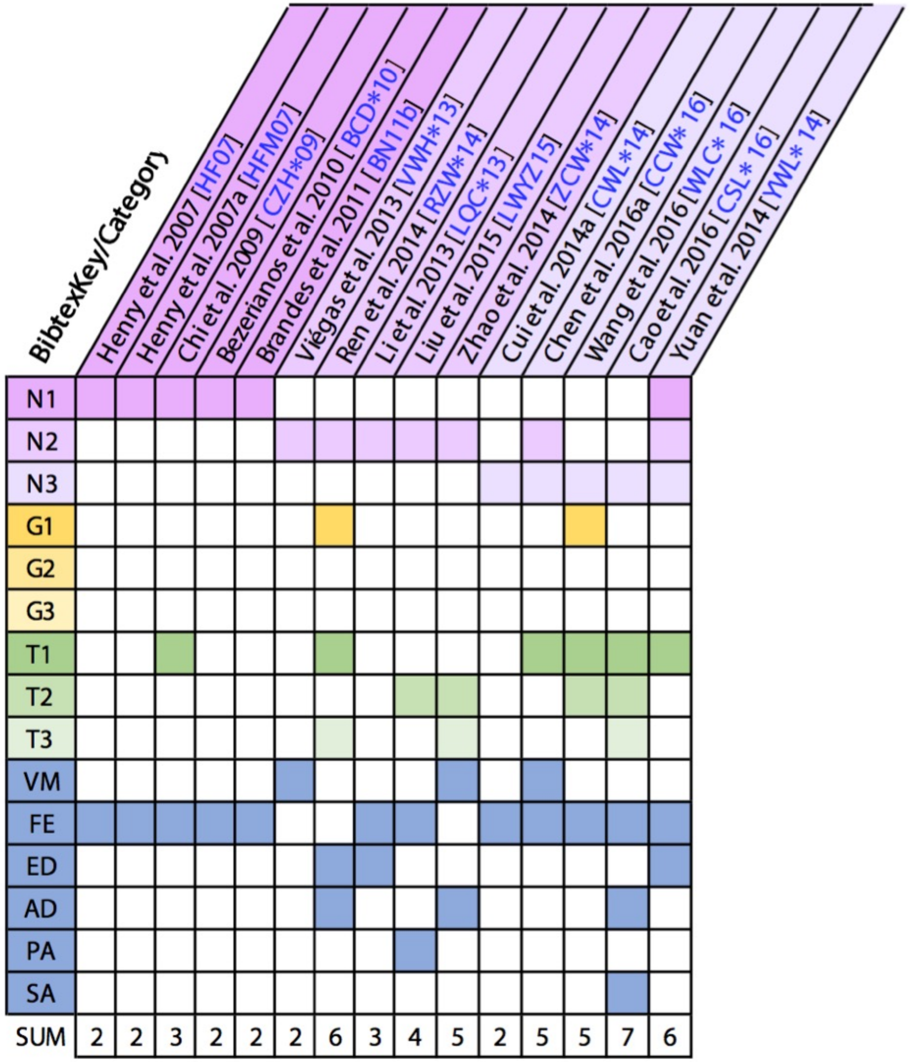
Survey Methodology

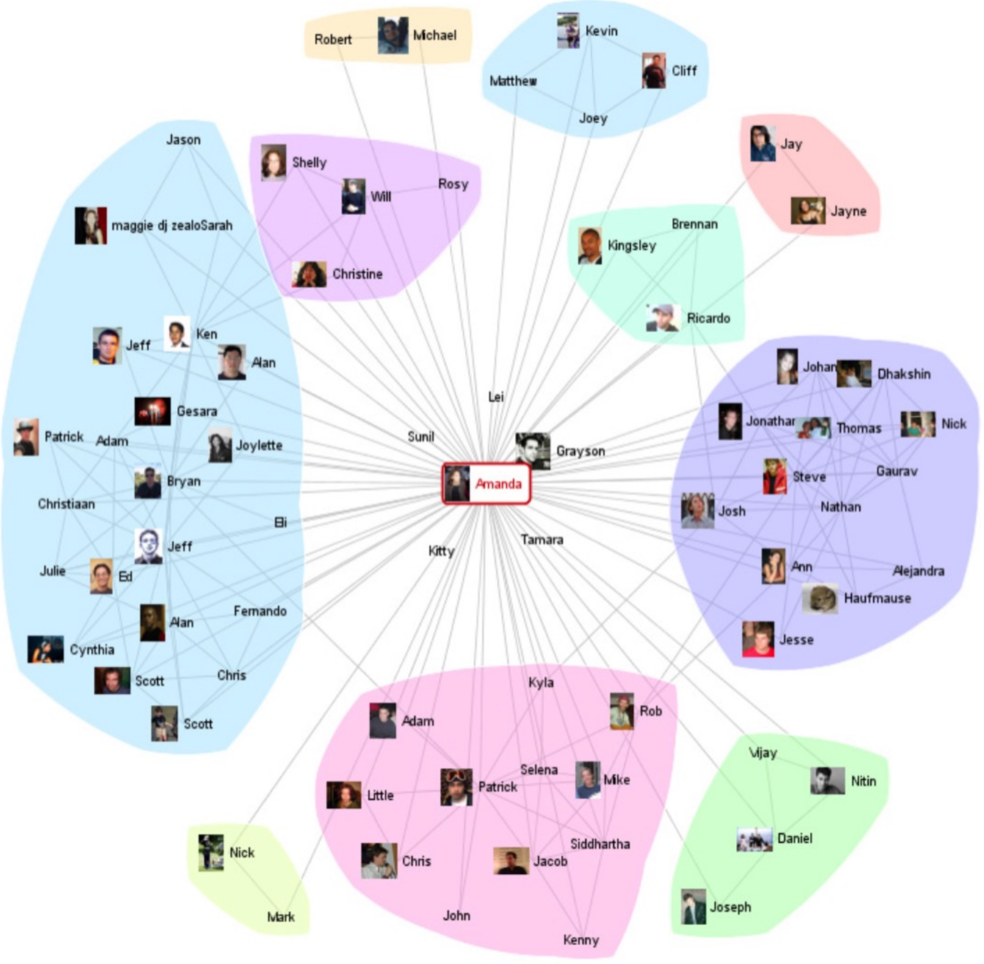


- N1-N3: Following Network, Information Diffusion Network and Reposting Network;
- G1-G3: Geographic Information Diffusion, Spatial Temporal Event Distribution and Movement Trajectories;
- T1-T3: Keywords, Topic and Sentiment

VM: Visual Monitoring;
FE: Feature Extraction;
ED: Event Detection;
AD: Anomaly Detection;
PA: Predictive Analysis;
SA: Situation Awareness

Social Networks





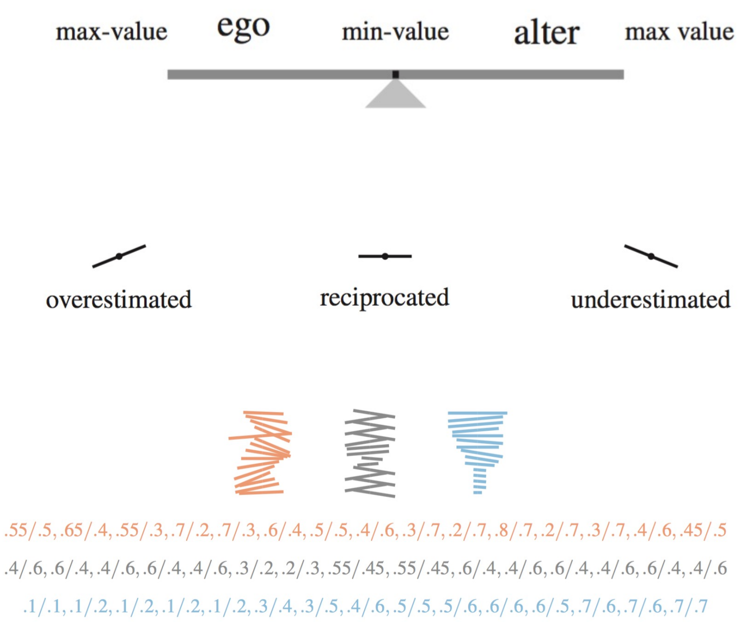
[Vizster: Visualizing Online Social Networks]

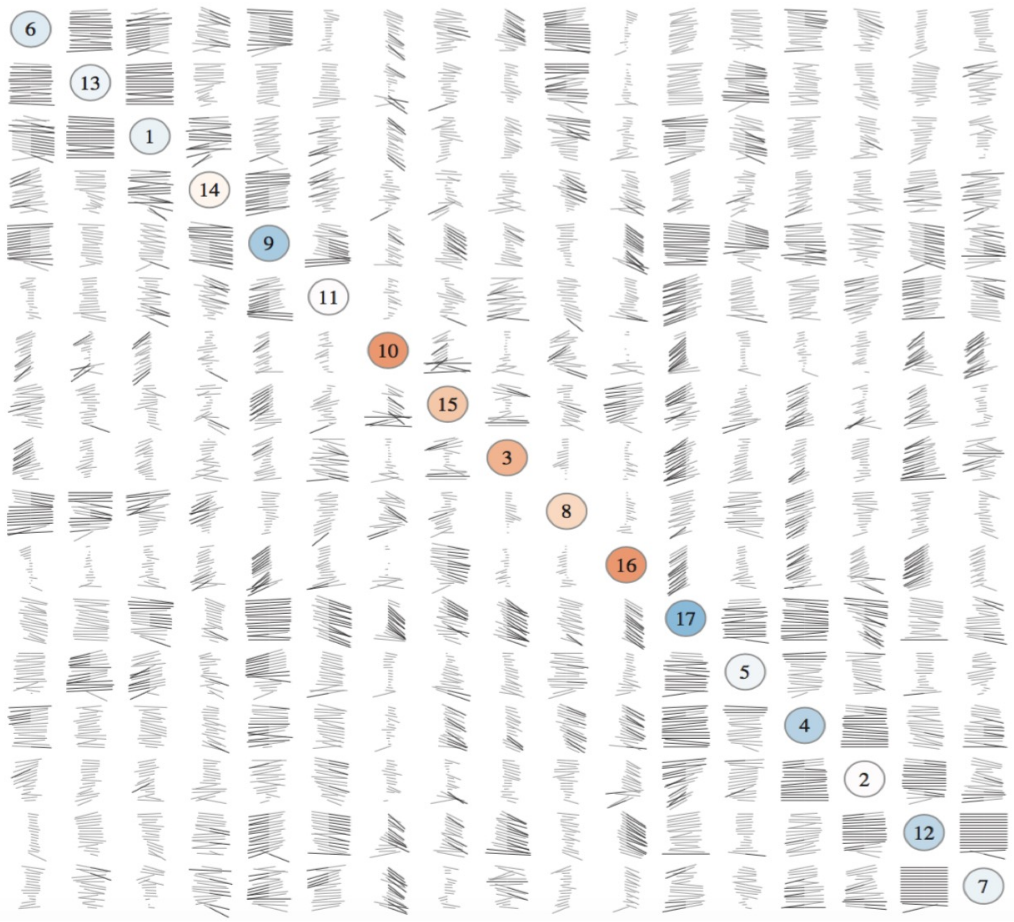
[Jeffrey Heer], danah boyd

IEEE Information Visualization (InfoVis), 32-39, 2005

Social Networks – Follower Network Visualization

- Social Relationship
  - Multiple Attributes
  - Dynamic Features

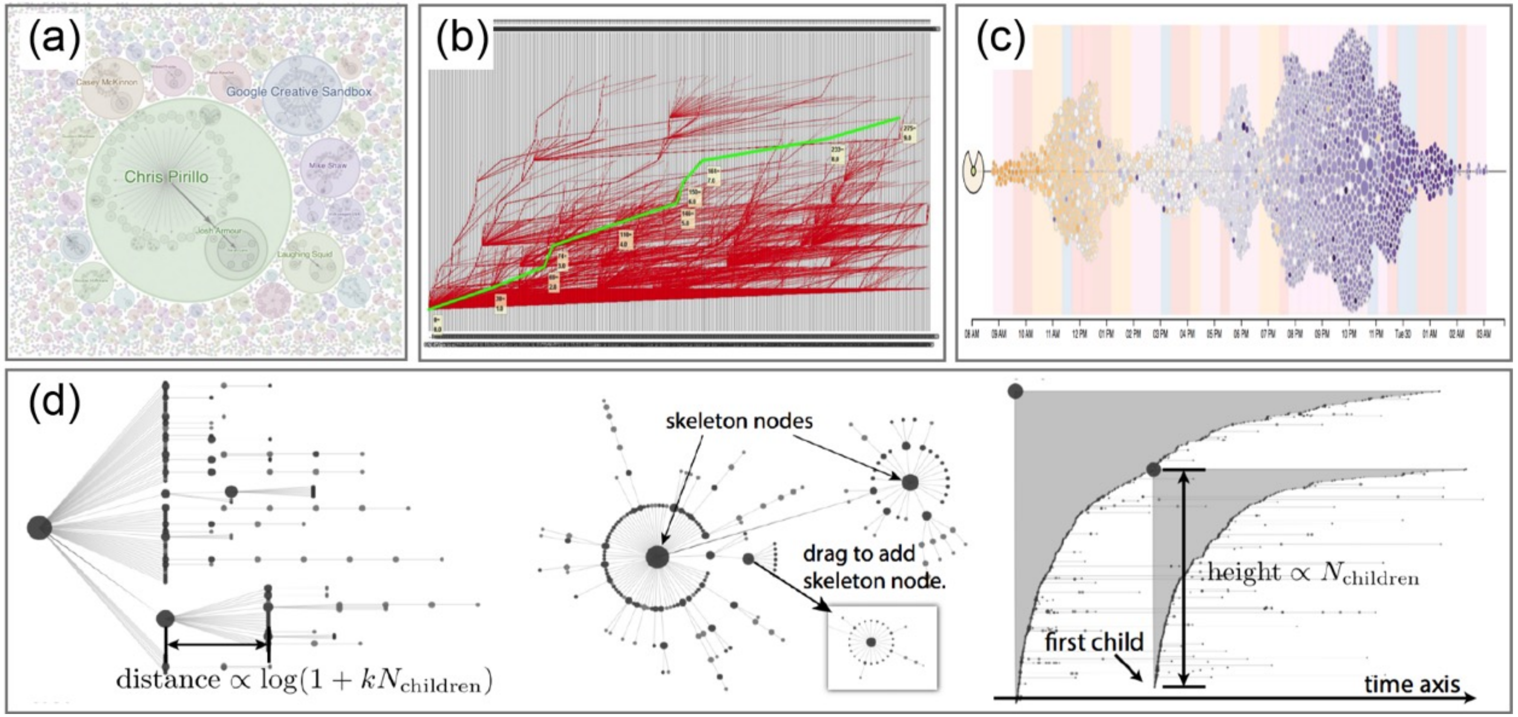




Gestaltmatrix [BN 11]

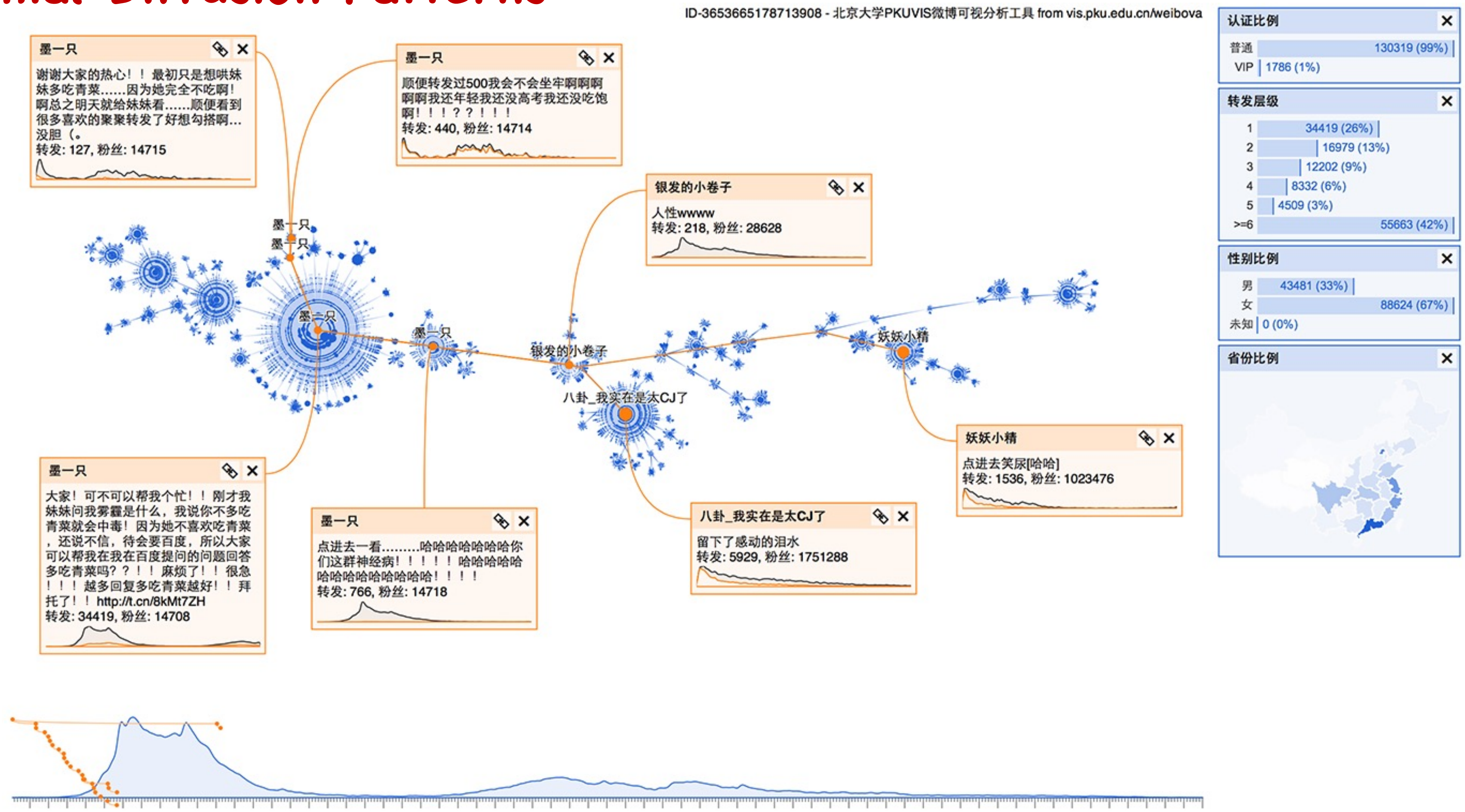
Social Networks – Diffusion Network

- Entity – Messages
- How information diffuse along time
  - Topic
  - Relationship



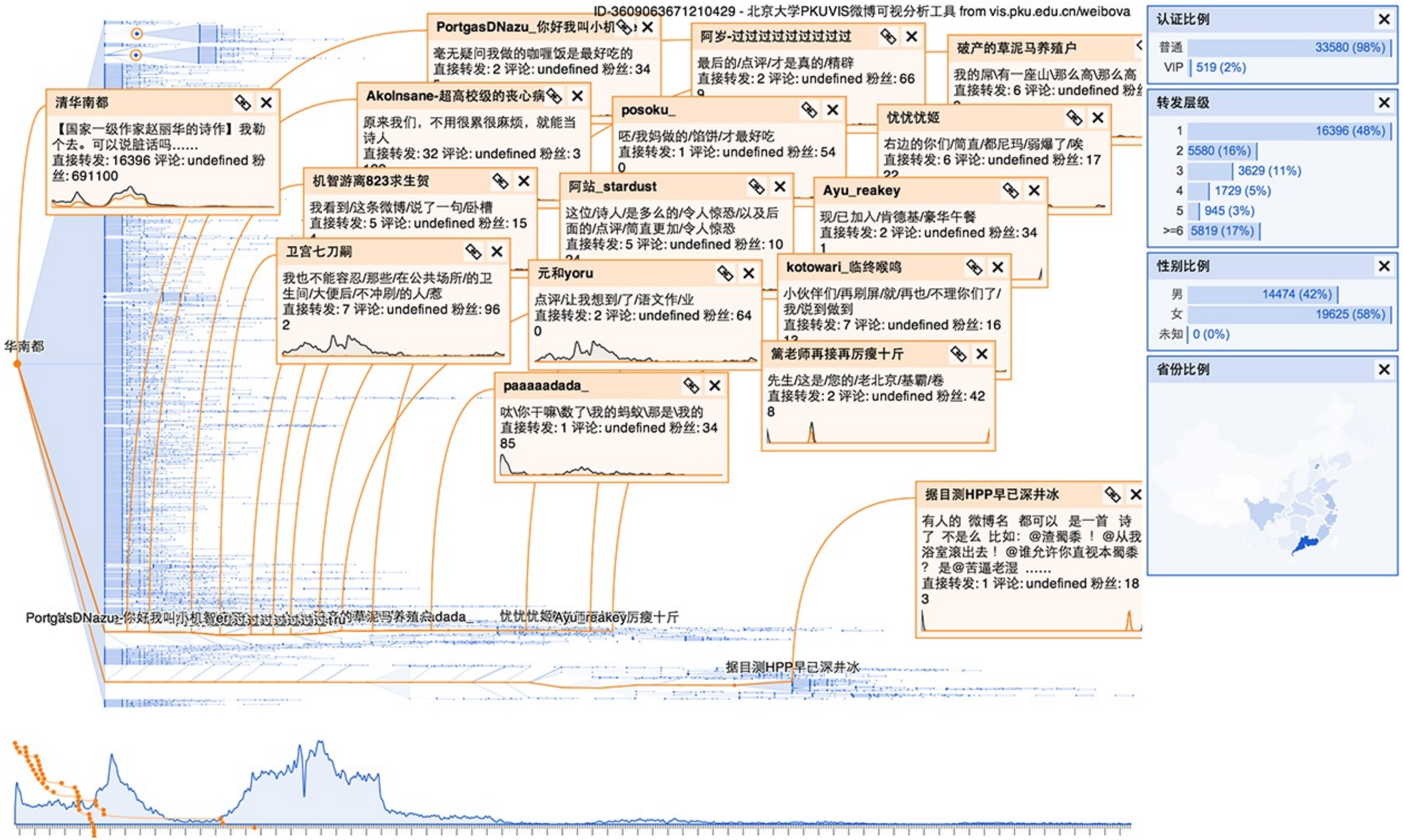
(a) Google+ Ripples [VWH∗13], (b) Li et al. [LQC∗13], (c) FluxFlow [ZCW∗14], (d) WeiboEvents [RZW∗14]

Diffusion Network Visualization: WeiboEvents - Normal Diffusion Patterns



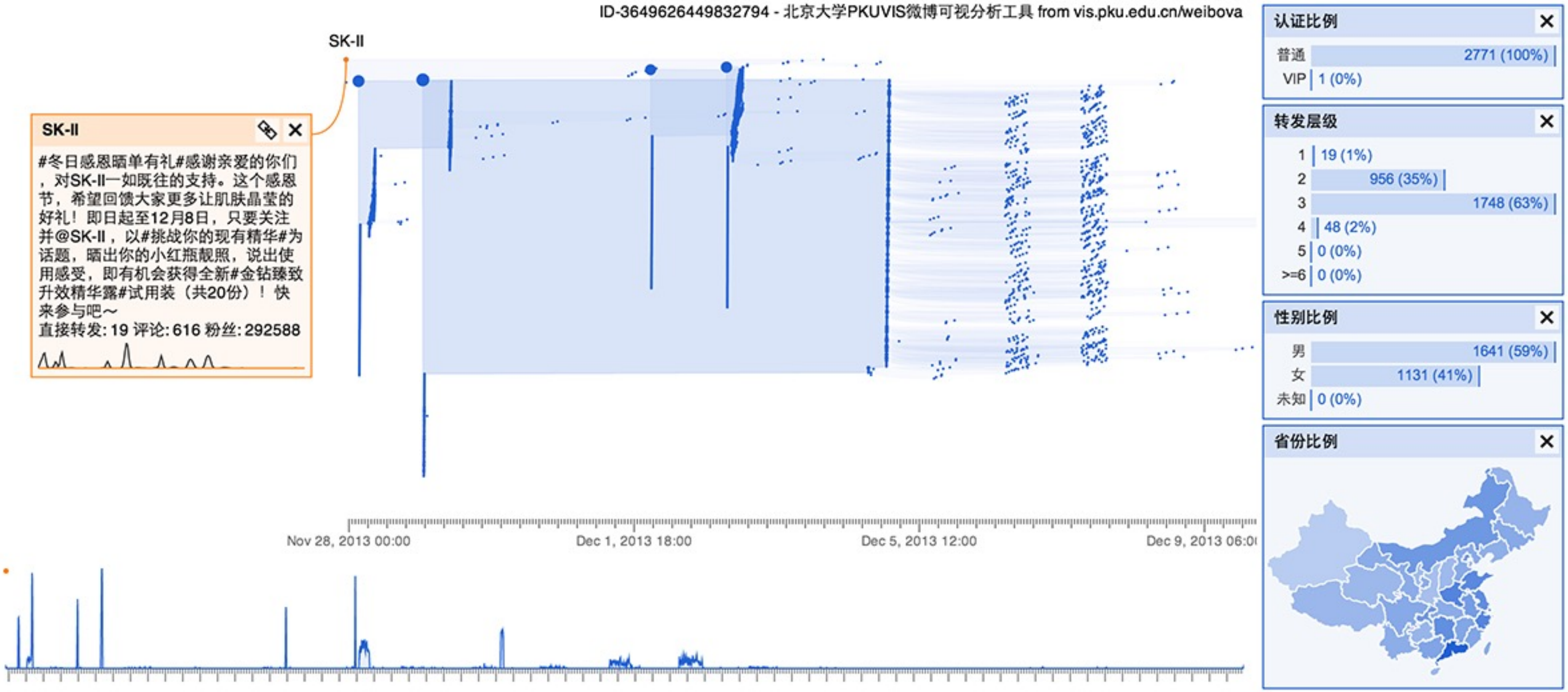
Ren, Donghao, Xin Zhang, Zhenhuang Wang, Jing Li, and Xiaoru Yuan. "WeiboEvents: A Crowd Sourcing Weibo Visual Analytic System." In *Pacific Visualization Symposium (PacificVis) Notes, 2014 IEEE*, pp. 330-334. IEEE, 2014.

Diffusion Network Visualization: WeiboEvents – In-depth Discussions



Ren, Donghao, Xin Zhang, Zhenhuang Wang, Jing Li, and Xiaoru Yuan. "WeiboEvents: A Crowd Sourcing Weibo Visual Analytic System." In *Pacific Visualization Symposium (PacificVis) Notes, 2014 IEEE*, pp. 330-334. IEEE, 2014.

Diffusion Network Visualization: WeiboEvents: Machine Account Behavior



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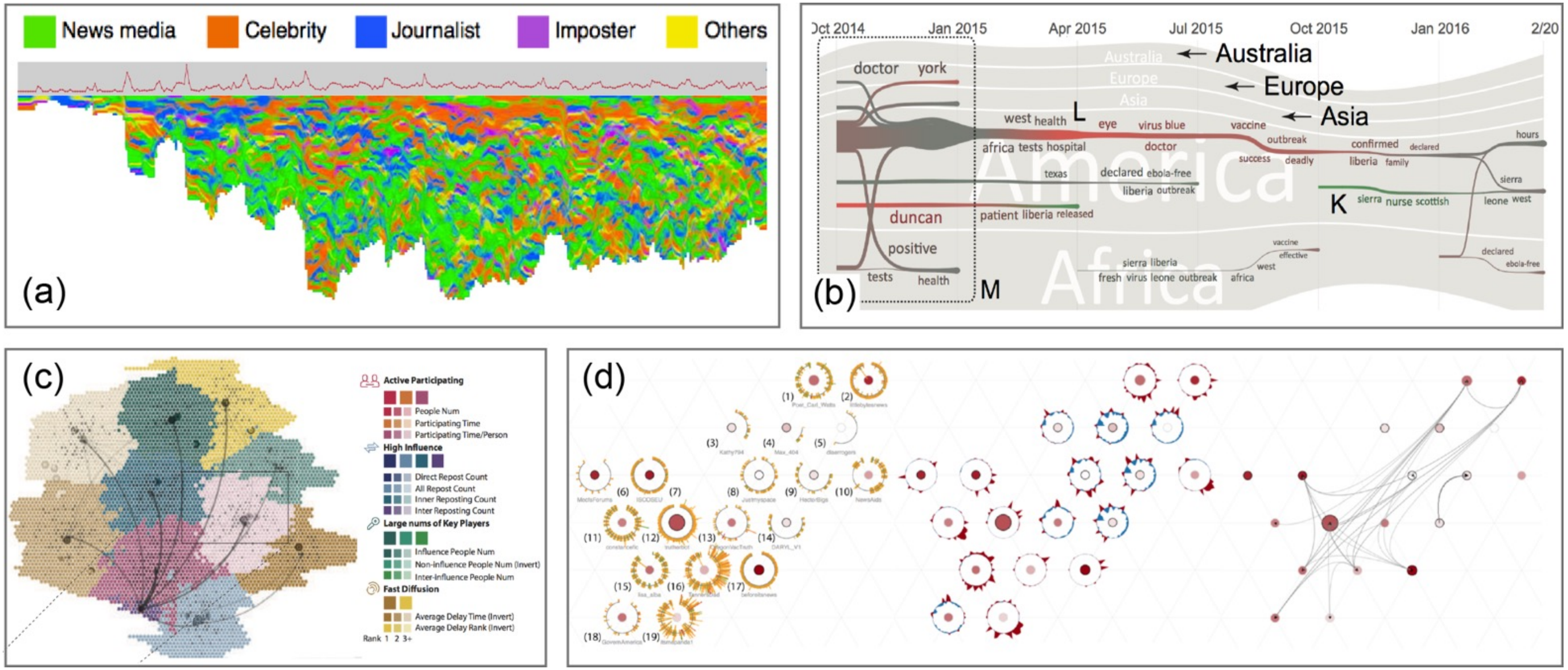
Social Network: Reposter Network

- Entities – Social media users
- Reposting behaviors leading to information diffusion
  - User behavior / type / relationship
  - Dynamic scenarios

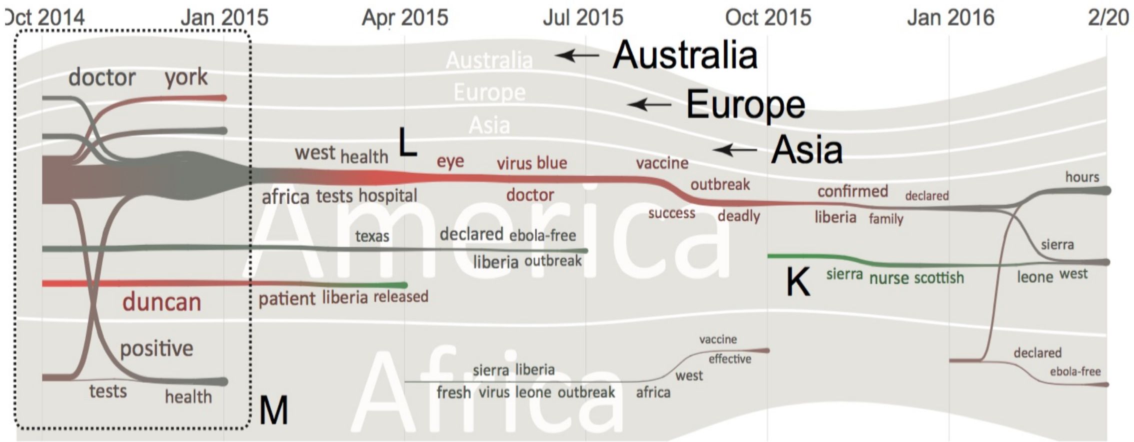


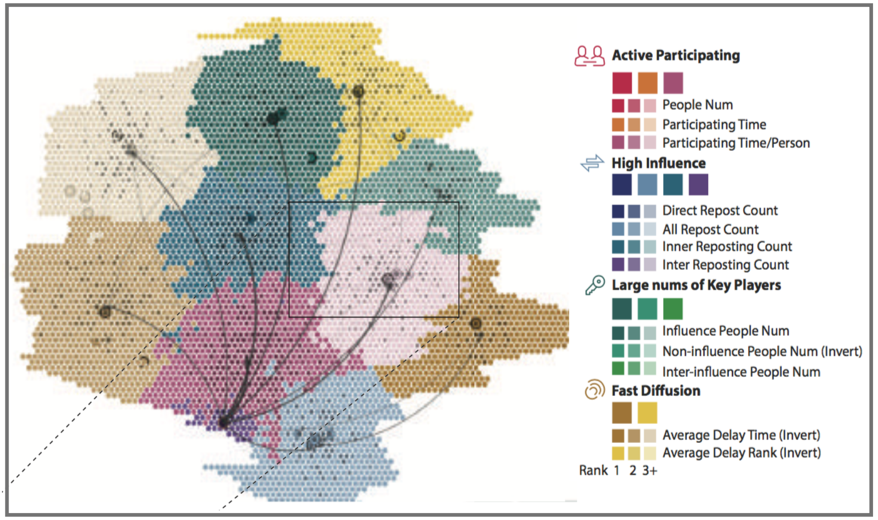
(a) GraphFlow [CWL*14], (b) IdeaFlow [WLC*16], (c) D-Map [CCW*16], (d) TargetVue [CSL*16]

Social Network: Reposter Network

- Dynamic Relationship
- Community Behaviors
- Topic Changes

IdeaFlow [WLC*16]





- River-based Visual Metaphor
- Map-based Visual Metaphor

D-Map [CCW*16]

D-Map: Visual Analysis of Ego-centric Information Diffusion Patterns in Social Media

Siming Chen[1], Shuai Chen[1], Zhenhuang Wang[1], Jie Liang[1,2],
Xiaoru Yuan[1], Nan Cao[3], Yadong Wu[4]

[1]Key Laboratory of Machine Perception (Ministry of Education), and School of EECS, Peking University, China
[2]Faculty of Engineer and Information Technology, The University of Technology, Sydney, Australia
[3]New York University, Shanghai, China
[4]Southwest University of Science and Technology, China

VisPKU

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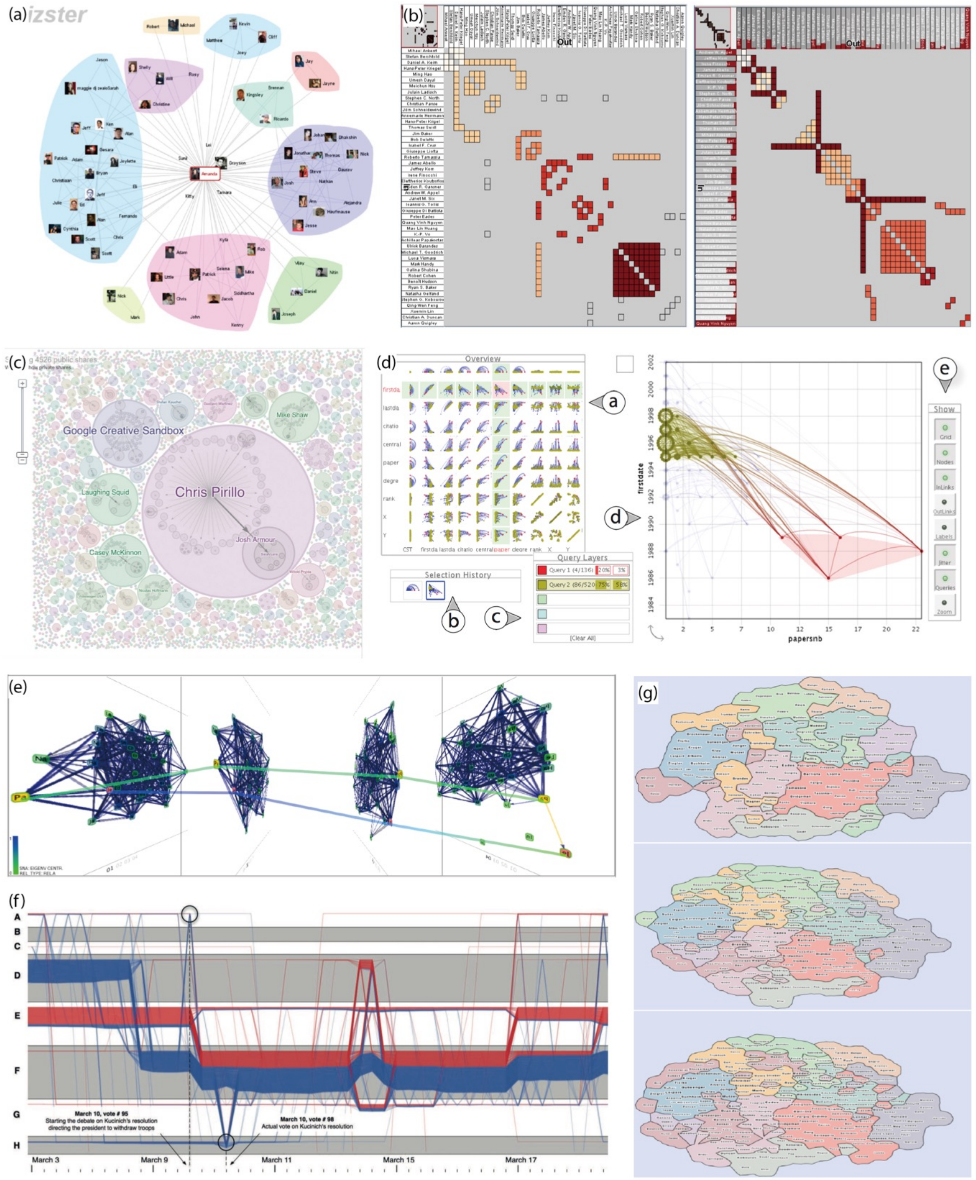
http://vis.pku.edu.cn

Social Network Visualization Techniques: Summary

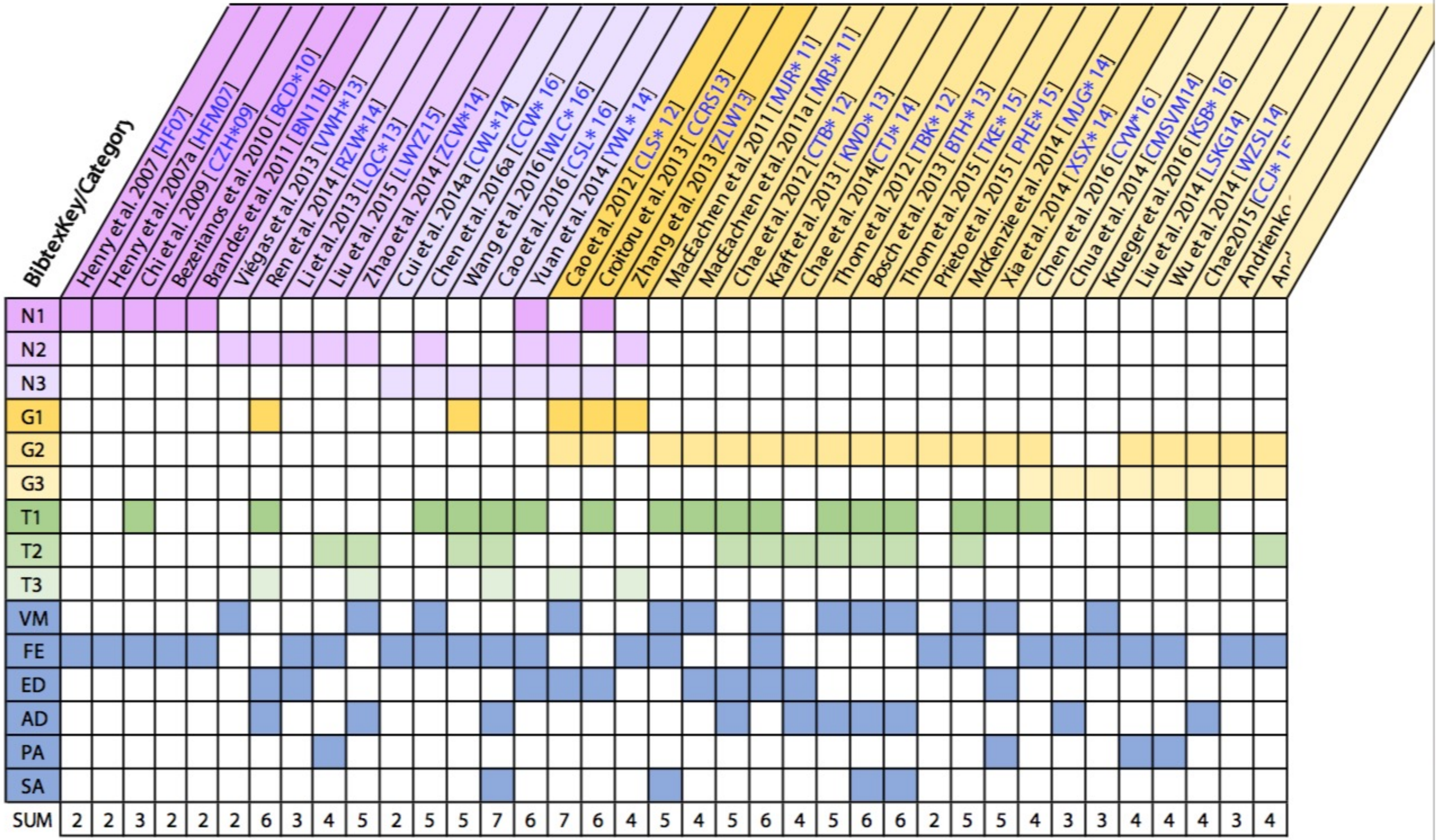
- Graph-based visualization
  - Network [Heer2005]
  - Matrix [Henry2006]
  - Space filling techniques [Viegas2013]
  - Multi-variate exploration [Bezerianos2010]
- Dynamic graph visualization
  - 2.5D representation [Federico2011]
  - Storyline [Reda2011]
  - Map-like visual metaphor [Hu2012]



Classification of Social Media Entities and Related Visualization Techniques

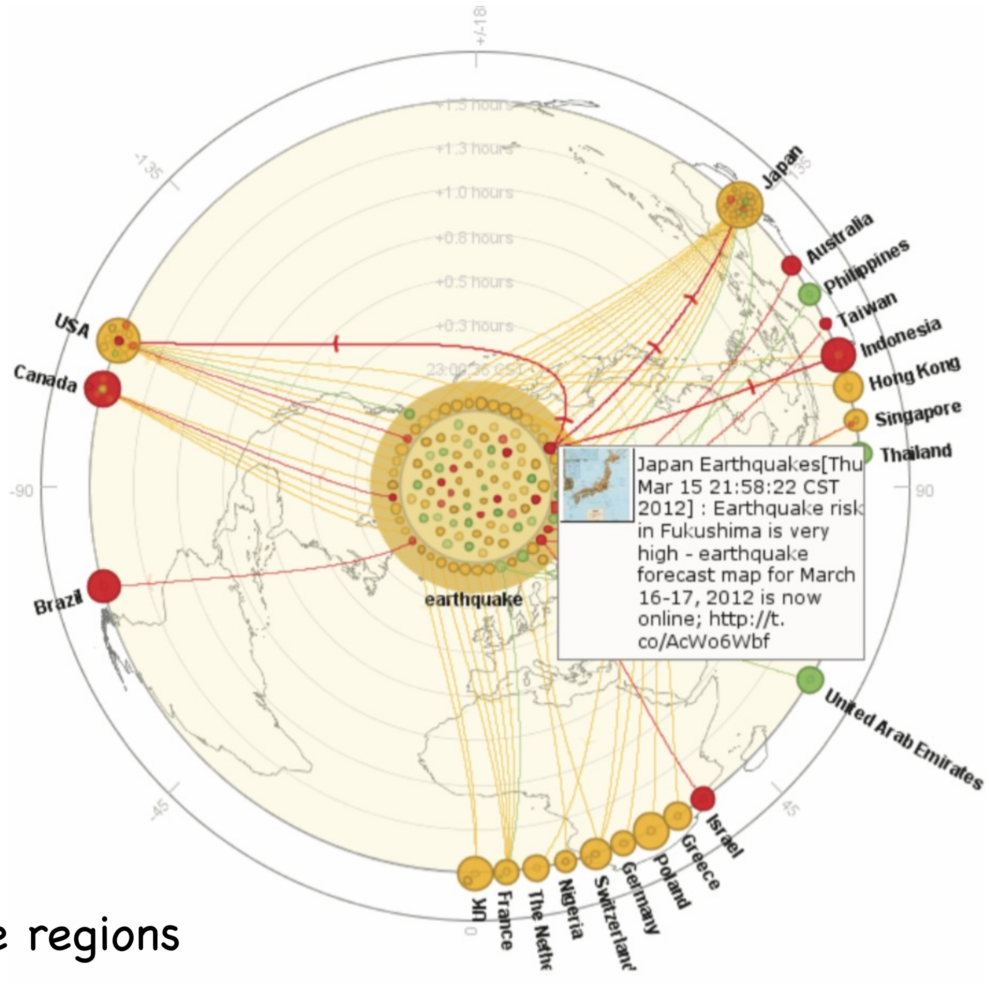
Entities in Social Media		
Network	**Geographic Information**	**Text and Content**
People's Follower Network Messages' Diffusion Network People's Reposting Network + Time → Dynamic Network	Geographic Information Diffusion Spatial Temporal Event Distribution Movement Trajectory + Time → Spatial Temporal Scenes	Keywords Topic Sentiment + Time → Dynamic Sementic Flow

Paper Collections



Geographic Information: Geo-tagged Information Diffusion Visualization

- Two sources of geo information
  - **Where the social media users come from (Relative static)**
  - Where the social media users post the messages (Dynamic)



Whisper [CLS∗12]

Integrating the spatial temporal information and representing the diffusion process across multiple regions

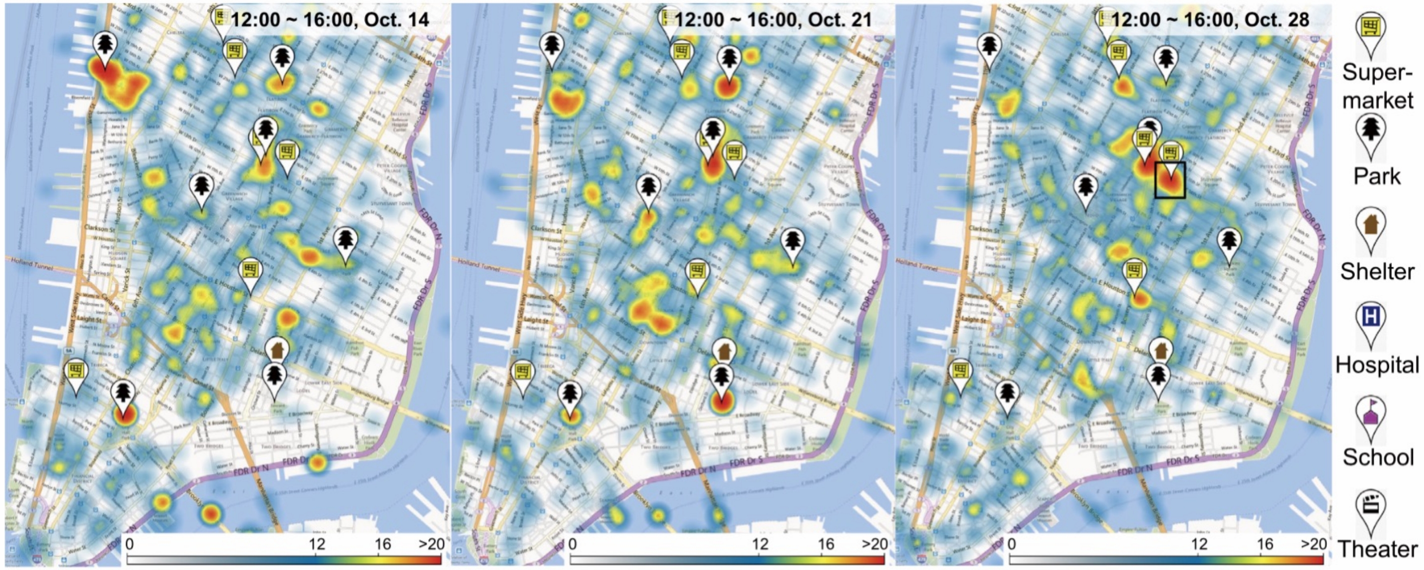
Whisper: Tracing the Spatiotemporal Process of Information Diffusion in Real Time

InfoVis 2012

Nan Cao, Yu-Ru Lin, Xiaohua Sun,
David Lazer, Shixia Liu, and Huamin Qu

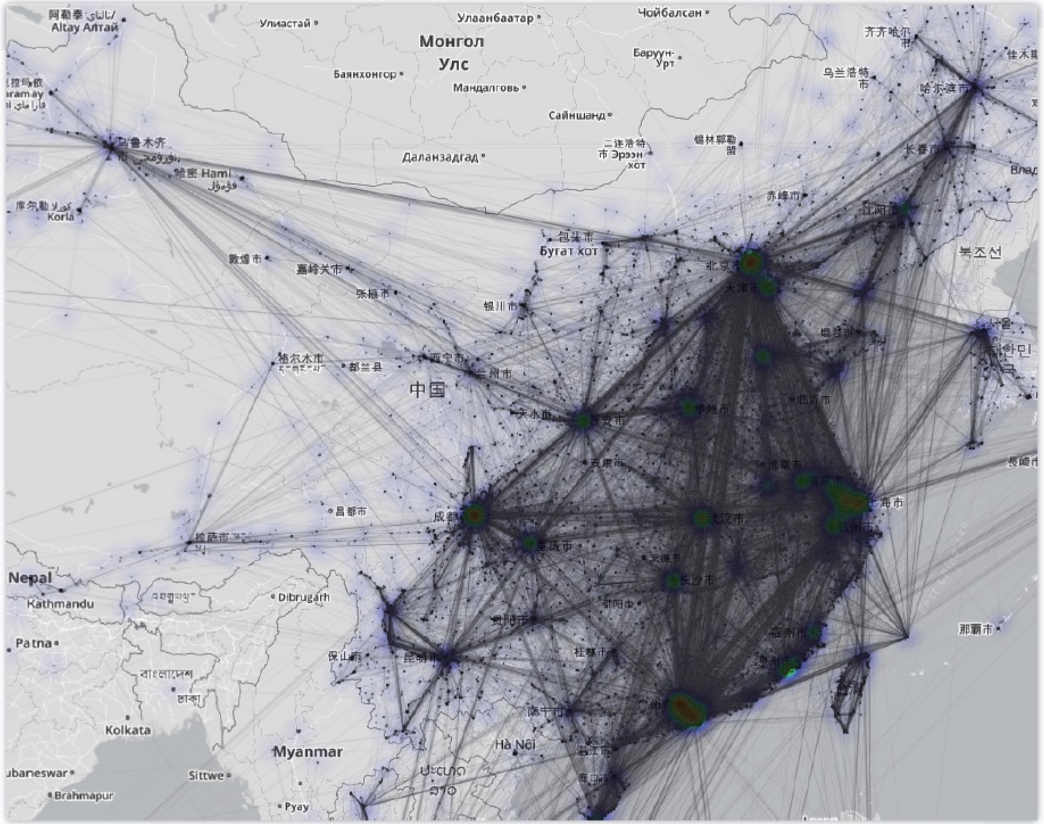
Geographic Information: Spatial Temporal Event Distribution Visualization

- Two sources of geo information
  - Where the social media users come from (Relative static)
  - **Where the social media users post the messages (Dynamic)**



A density map design with the aggregation to show the distribution of the social events [CTJ*14]

Geographic Information: Movement Trajectories Visualization



- Two weeks Weibo distribution in China and its neighborhood

[CYW*16]

Interactive Visual Discovering of Movement Patterns from Sparse Sampling Geo-tagged Socail Media

Siming Chen[1], Xiaoru Yuan[1], Zhenhuang Wang[1], Cong Guo[1], Jie Liang[1],
Zuchao Wang[1], Xiaolong (Luke) Zhang[2], Jiawan Zhang[3]

[1]Key Laboratory of Machine Perception (Ministry of Education), School of EECS, Peking University
[2]Pennsylvania State University
[3]Tianjin University

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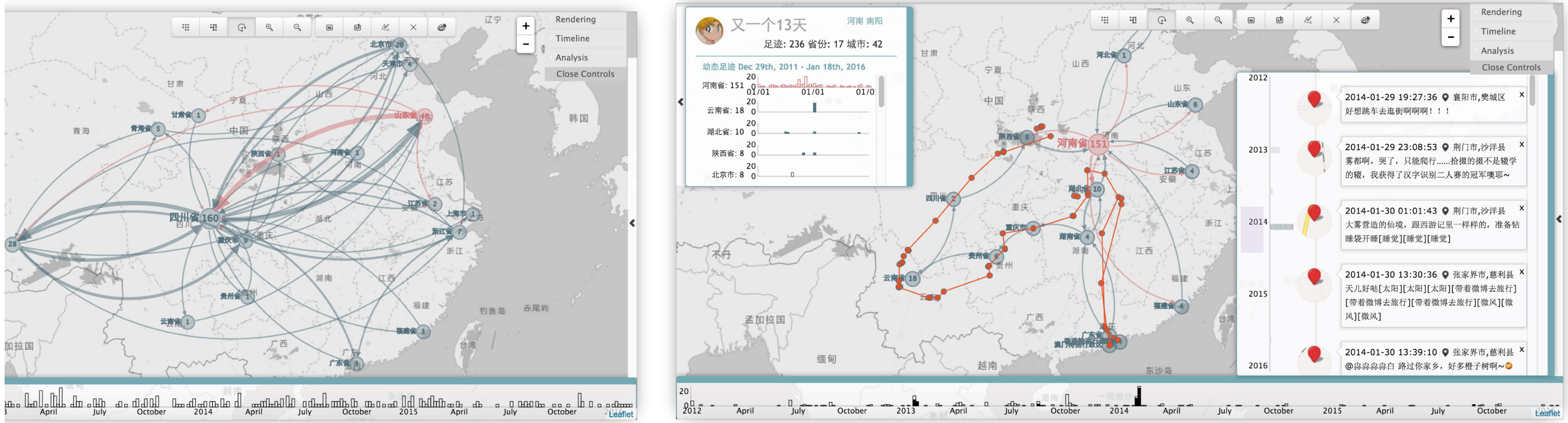
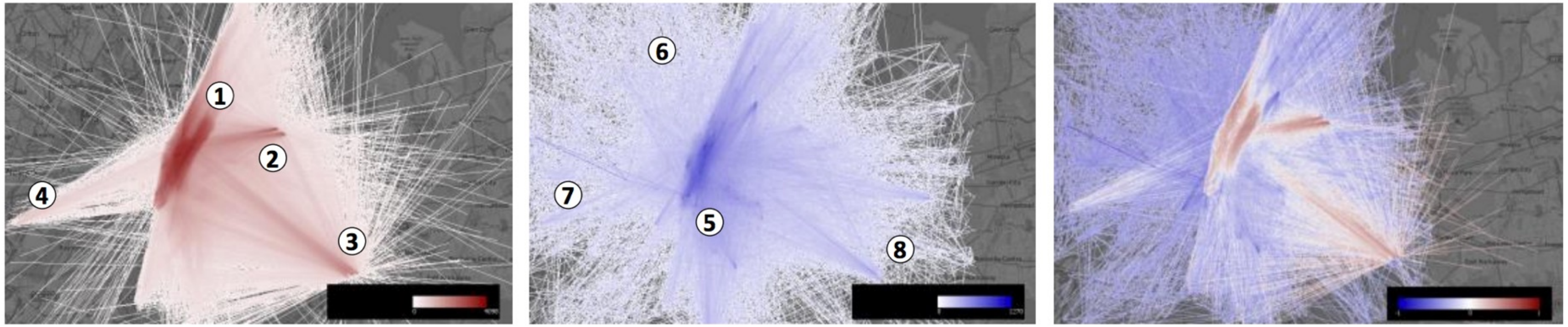
http://vis.pku.edu.cn

Geographic Information: Movement Trajectories Visualization

- Semantic Movement Patterns



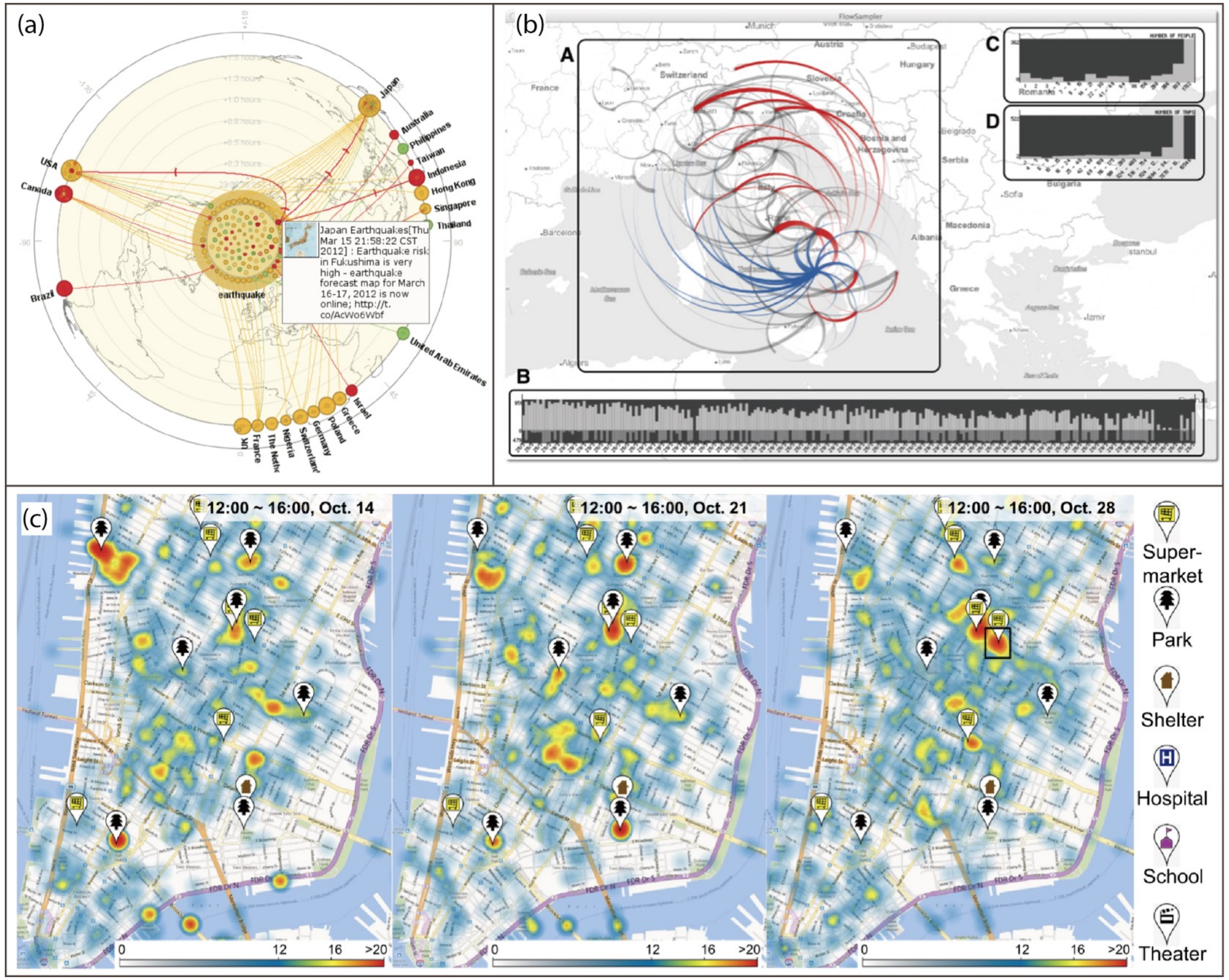
Weibo Footprint [CWLY16]



TravelDiff [KSB*16]

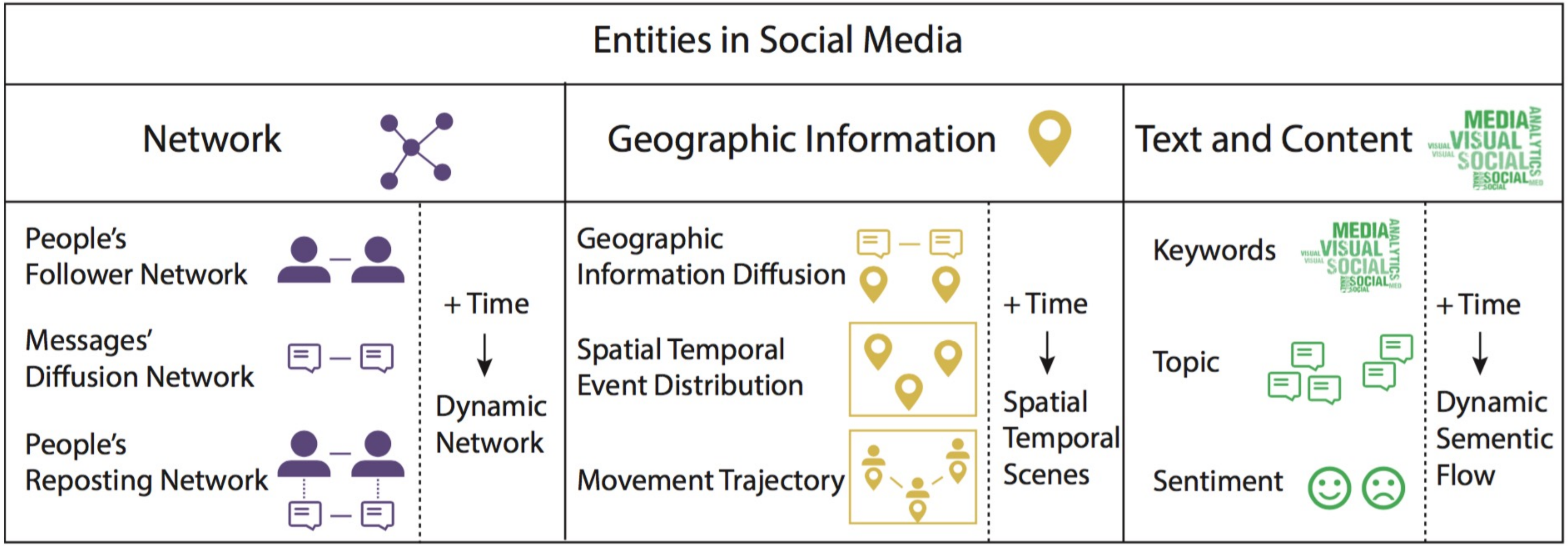
Geographic Information Visualization Summary: Visualization on the Map

- Density-based Visualization
- Flow-based Visualization

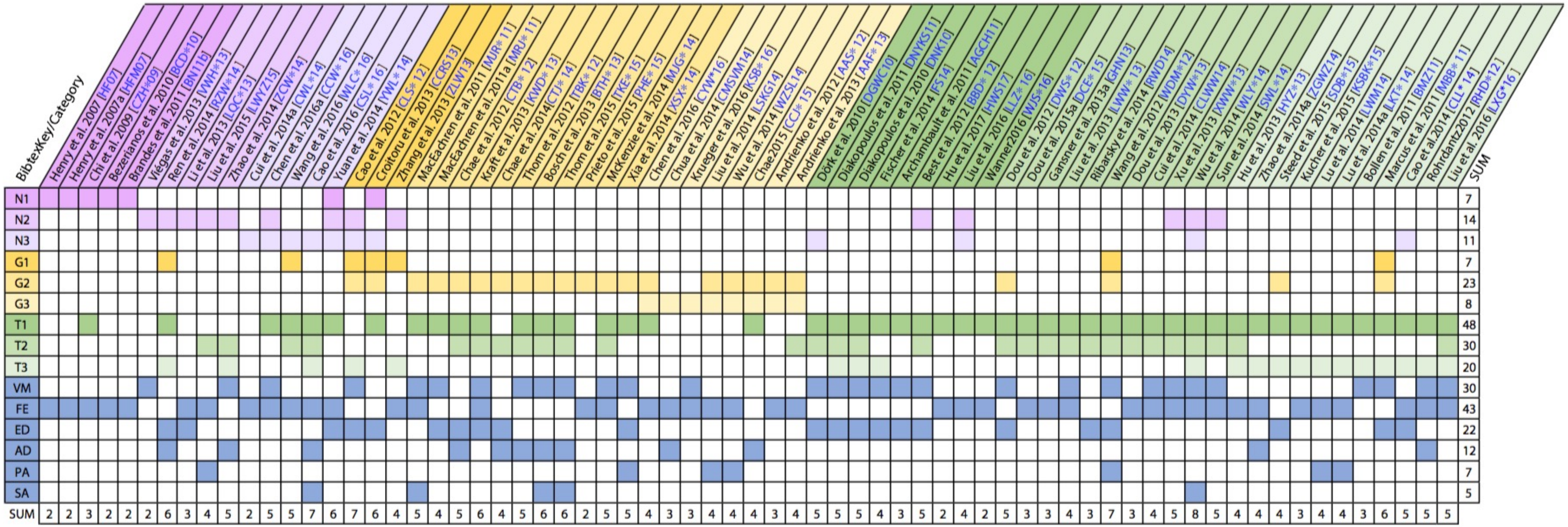


(a) Whisper [CLS∗12], (b) Flowsampler [CMSVM14], (c) Density Map [CTJ∗14]

Classification of Social Media Entities and Related Visualization Techniques

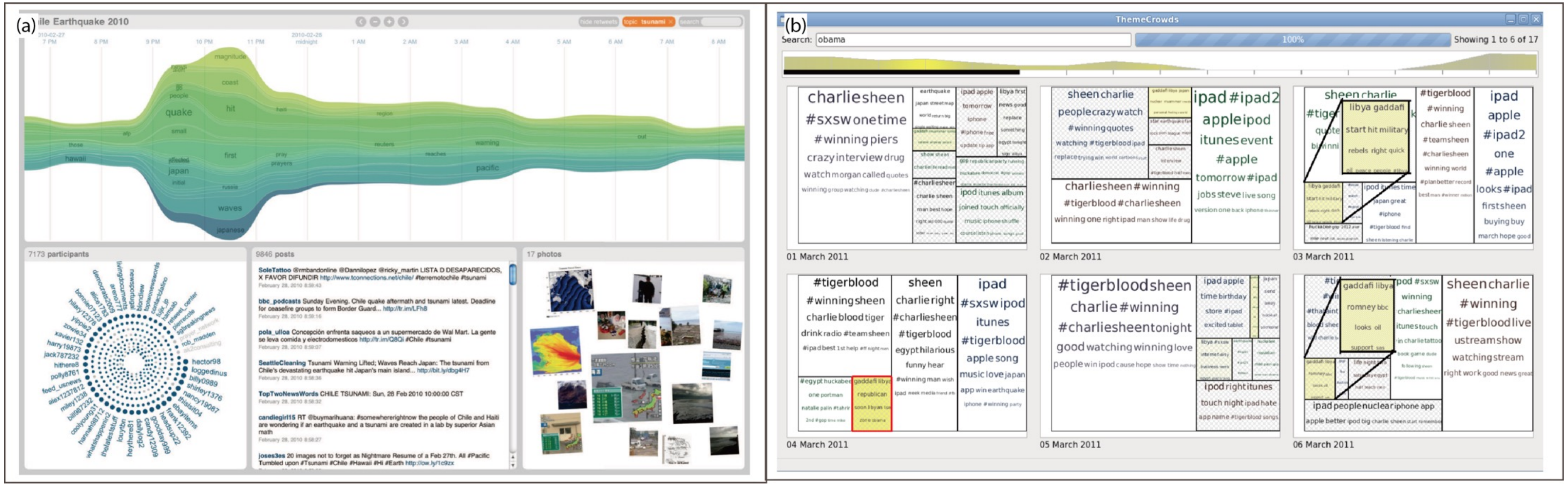


Paper Collections



Text and Content: Keywords Visualization

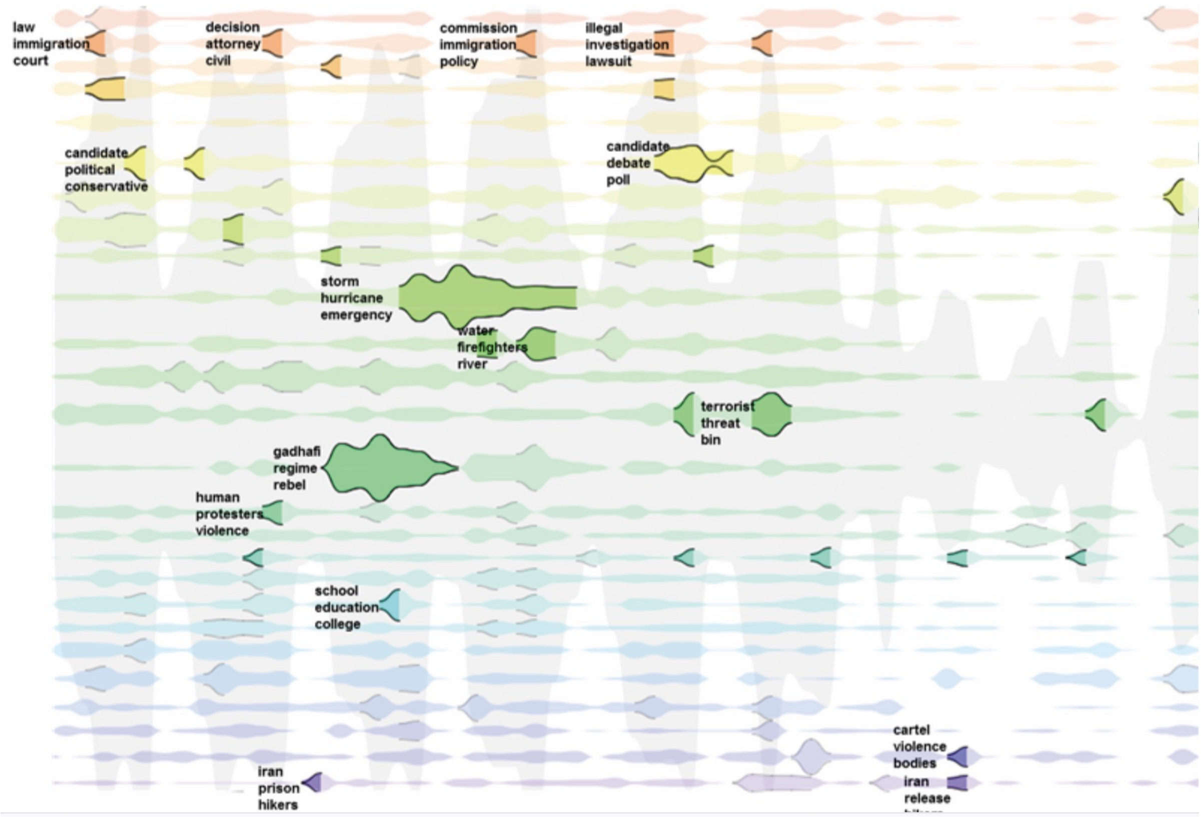
- Extracted keywords from content
  - Dynamic keywords along the time
  - Multi-level aggregation of keywords



(a) Visual BackChannel [DGWC10], (b) ThemeCrowds [AGCH11]

Text and Content: Topic Visualization

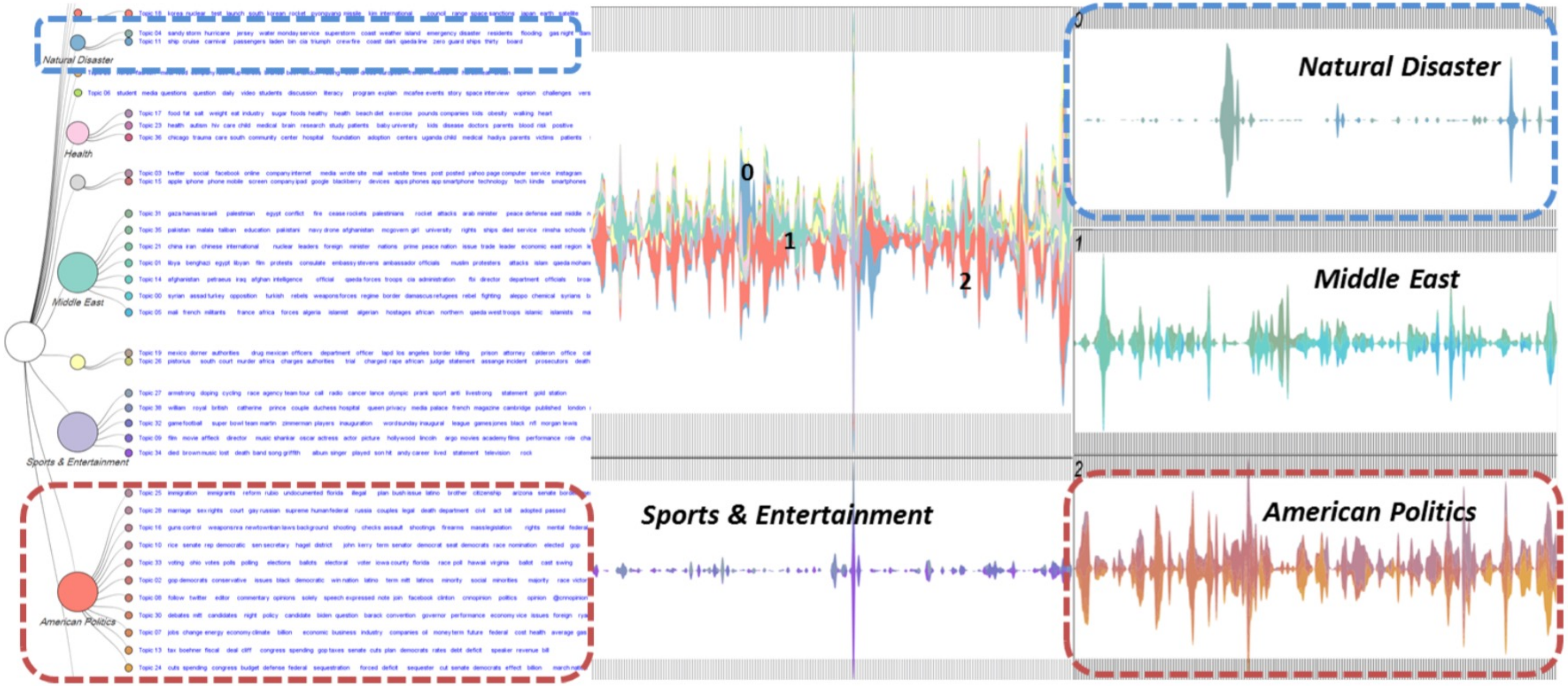
- Topic Structure
  - Dynamic change along the time



LeadLine [DWS*12]

Text and Content: Topic Visualization

- Topic Structure
  - Dynamic change along the time
  - Hierarchical Topics



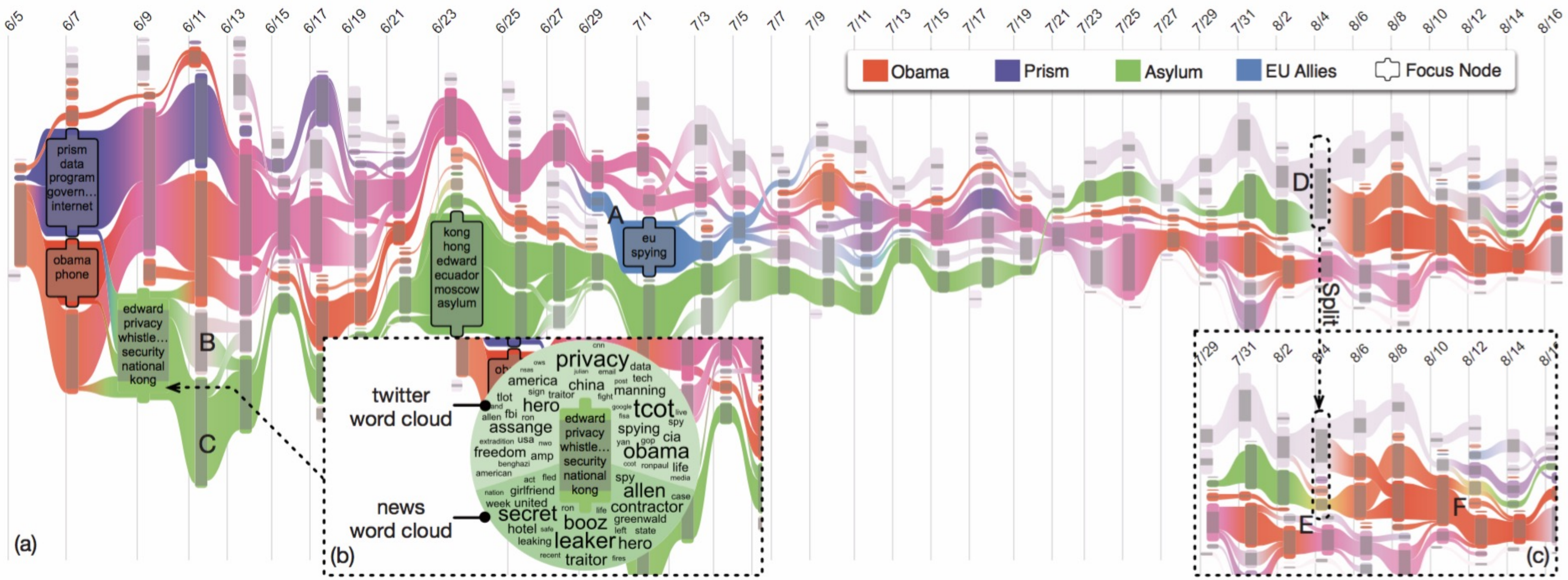
HierarchicalTopics [DYW*13]

HierarchicalTopics: Visually Exploring Large Text Collections Using Topic Hierarchies

Wenwen Dou, Li Yu, Xiaoyu Wang, Zhiqiang Ma, and William Ribarsky
wdou1@uncc.edu
Charlotte Visualization Center
UNC Charlotte

Text and Content: Topic Visualization

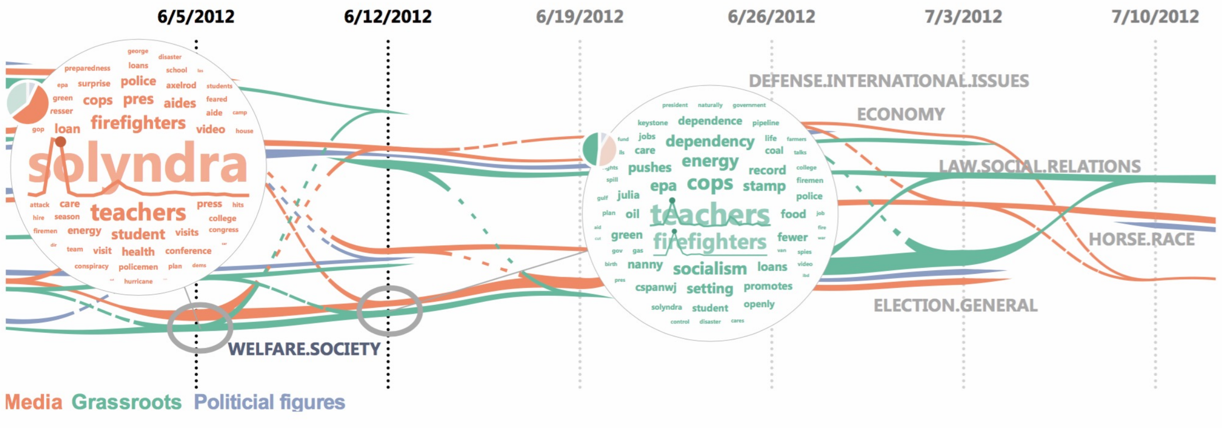
- Topic Structure
  - Dynamic change along the time
  - Hierarchical Topics
  - Dynamic Hierarchical Topics



RoseRiver [CLWW14]

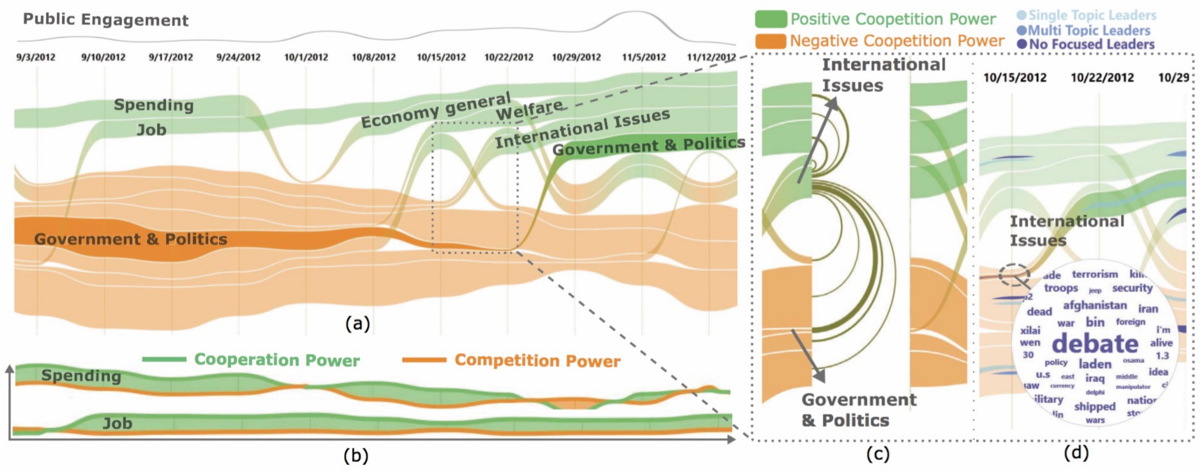
Text and Content: Topic Visualization

- Topic Interactions
  - Competition
  - Collaboration



Topic competition [XWW∗13].

EvoRiver, visualizing the competition and collaboration relationships of topics [SWL∗14].



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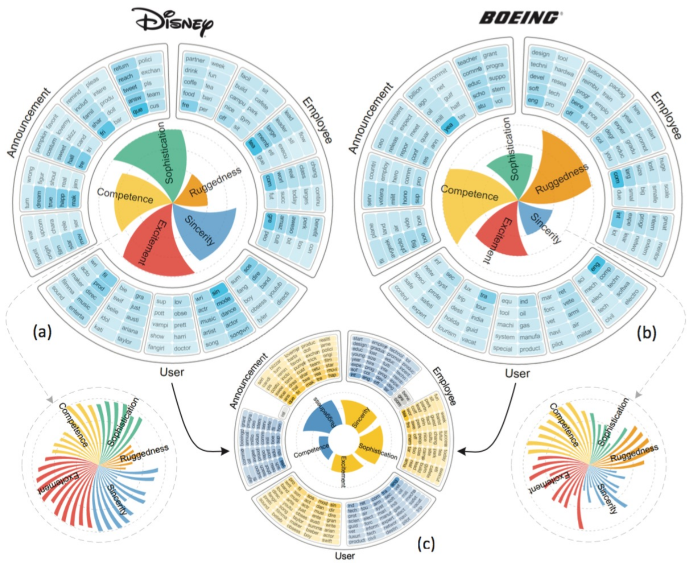
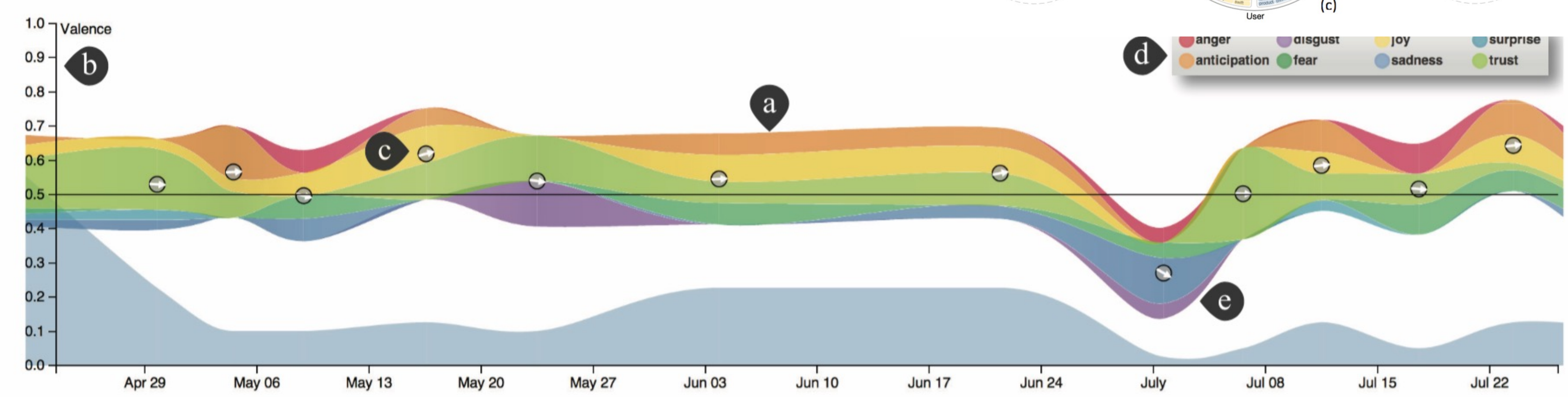
Text and Content: Sentiment Visualization

- Sentiment
  - Attitude Distribution
  - Dynamic Sentiment Change

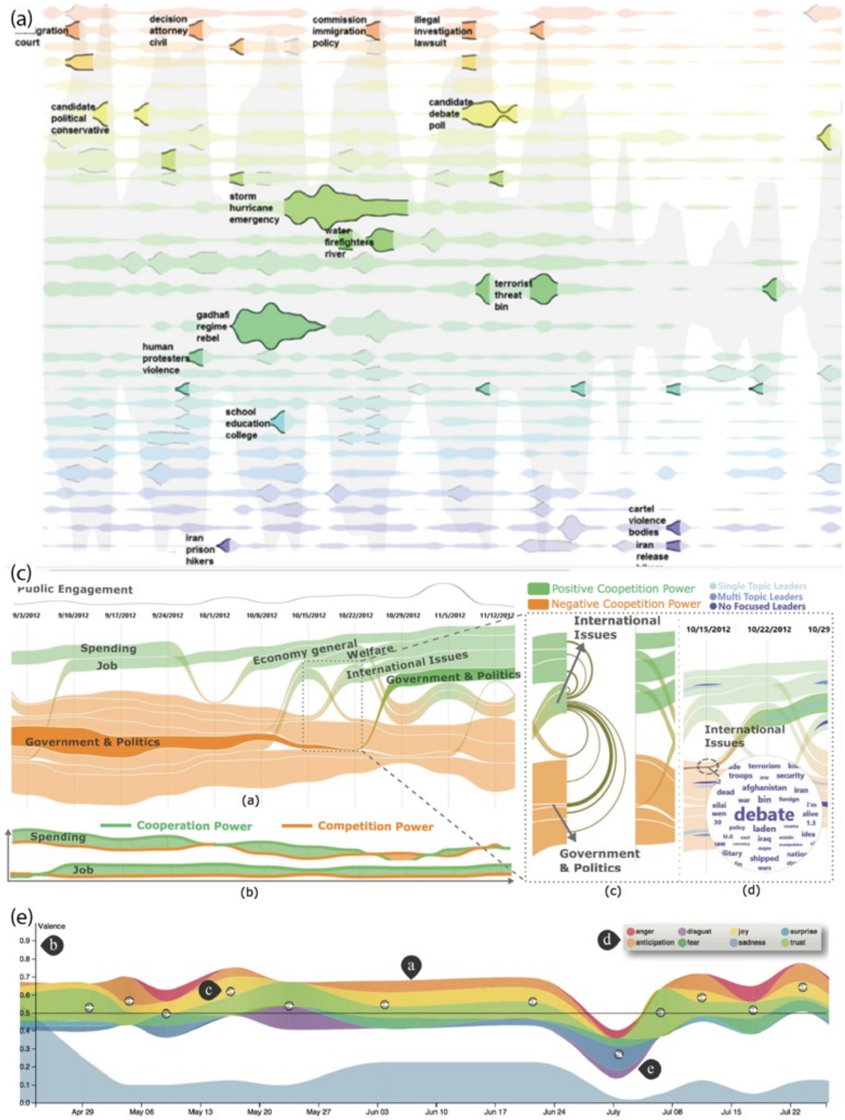
SocialBrands [LXG*16]

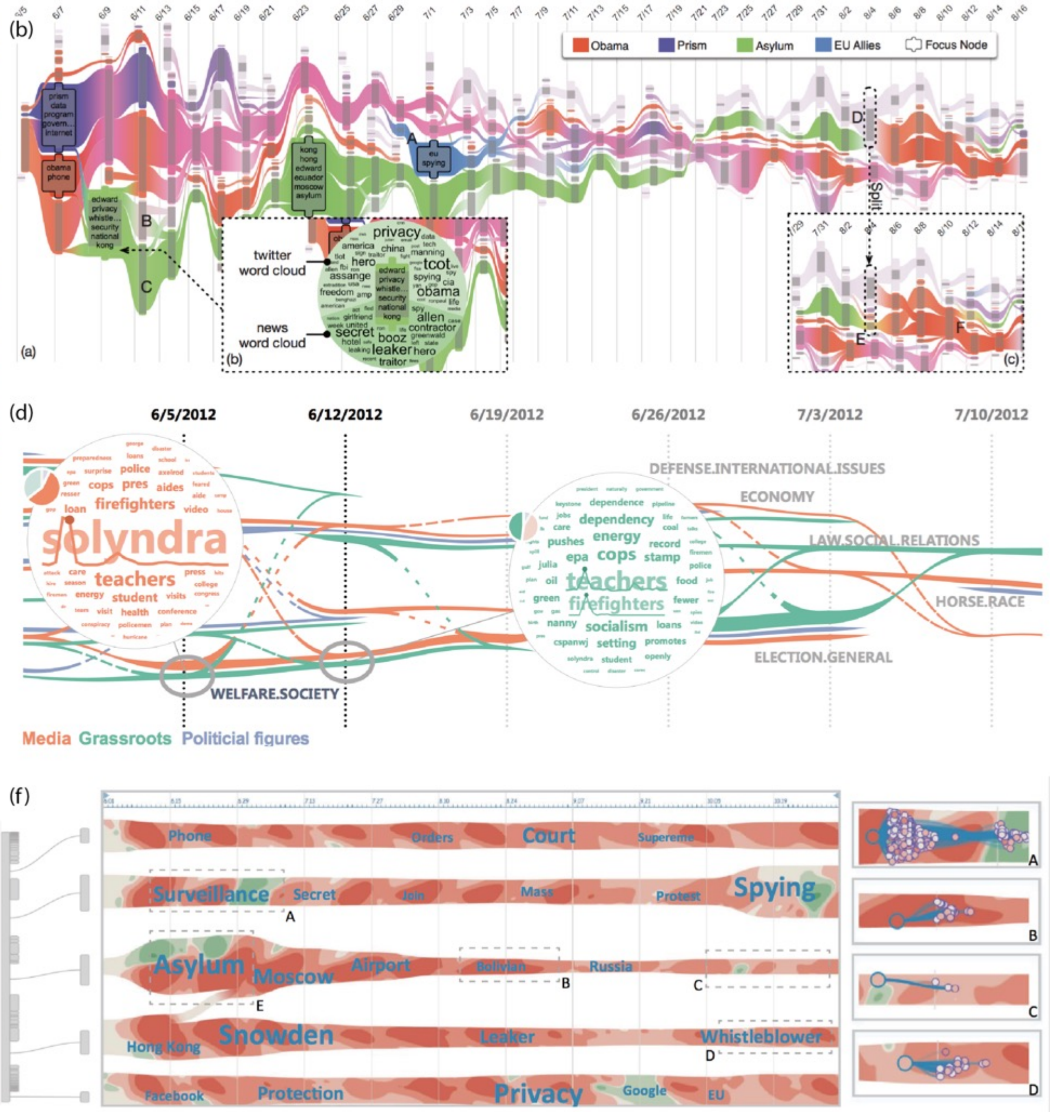


Sentiment visualization [ZGWZ14]



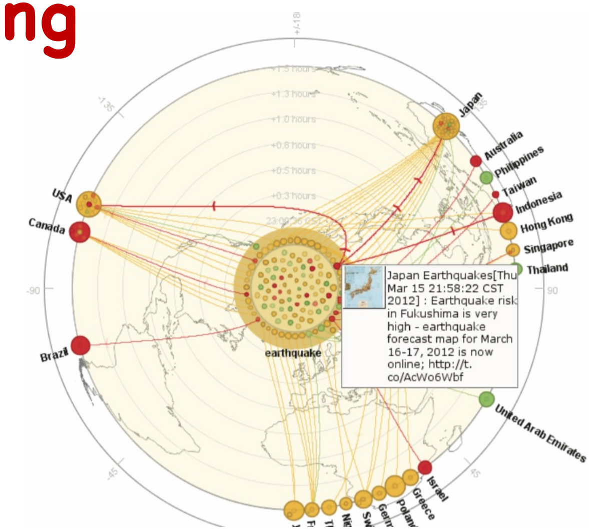
Text and Content Visualization Summary: River-like Visual Metaphor

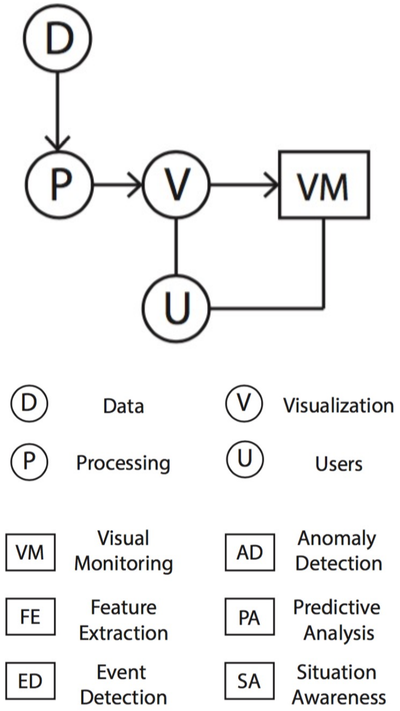


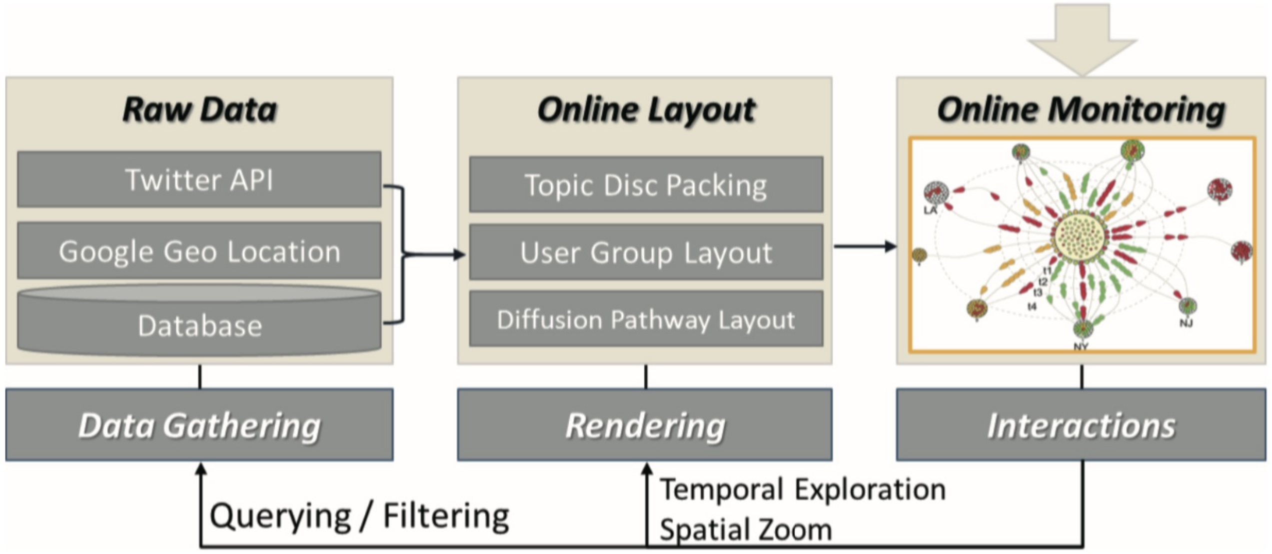


Social Media Visual Analytics (1) – Visual Monitoring

- Monitoring (e.g., Information diffusion process, reposting behaviors, moving behaviors etc.)
  - Overview design
  - Streaming Data
  - Animation



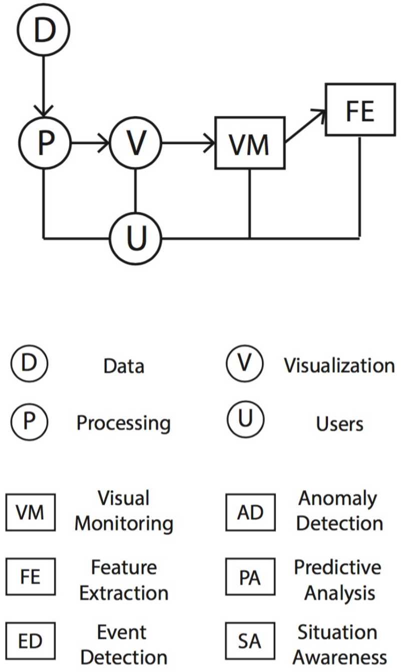


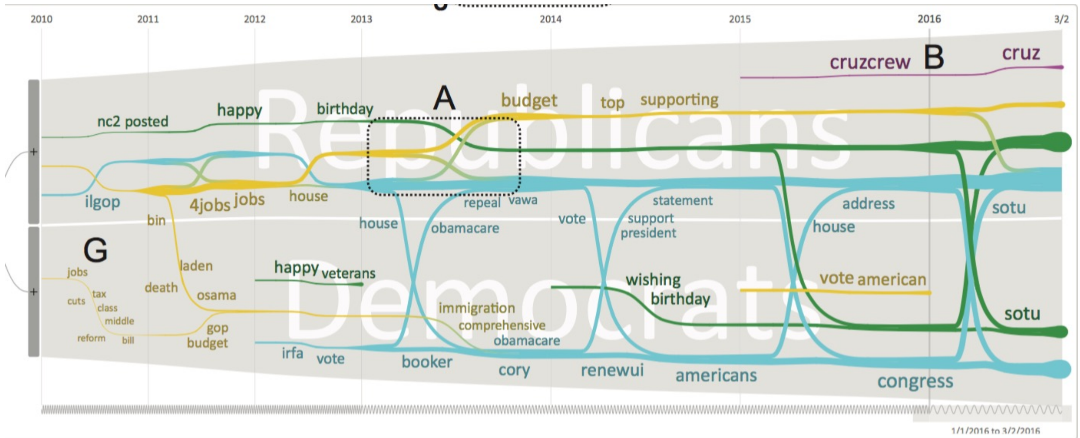


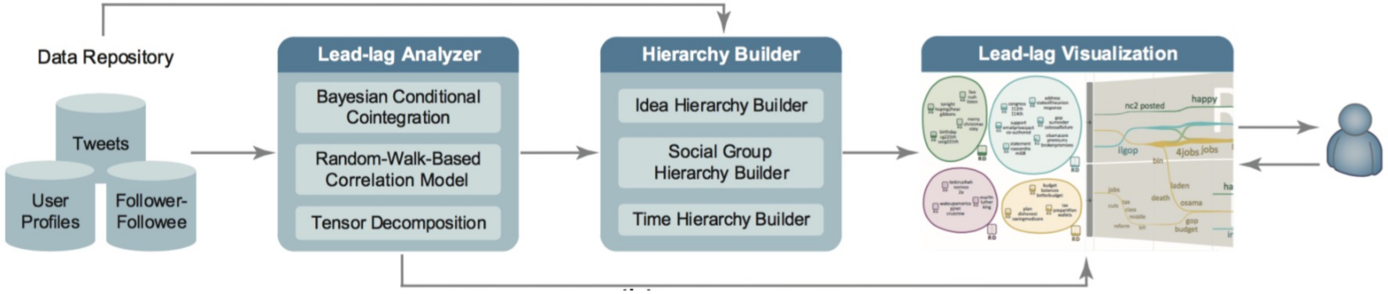
Whisper [CLS∗12]

Social Media Visual Analytics (2) – Feature Extraction

- Feature Extraction (e.g. summarized diffusion patterns, movement trajectories with semantics, etc.)
  - Significant characteristics of specific data attributes
  - Combining data mining algorithms
  - Preprocessing



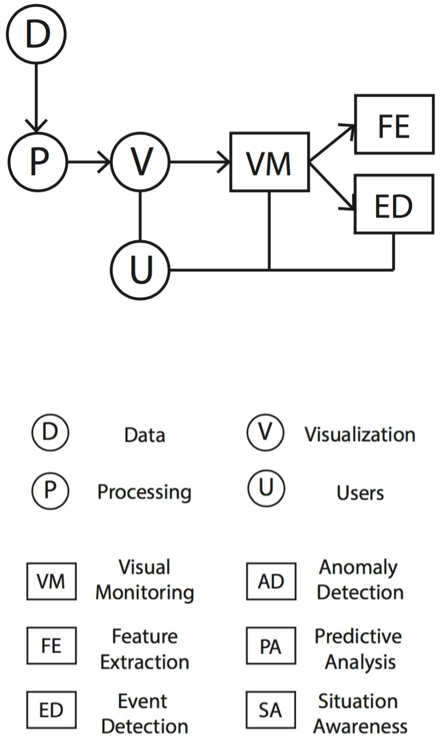


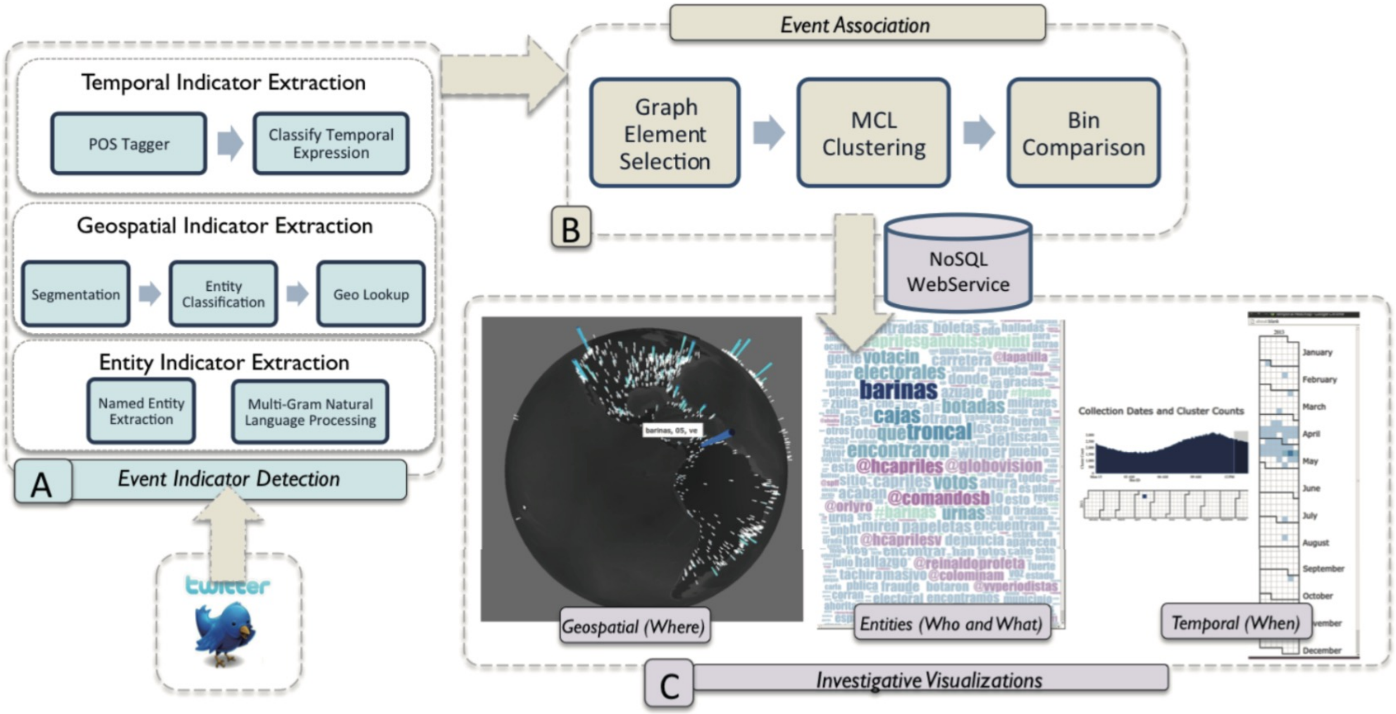


IdeaFlow [WLC*16]

Social Media Visual Analytics (3) - Event Detection

- Event: <*People, Messages, Time, [Reposting, Location, Themes*]>
  - Event extraction
  - Event visualization
  - Event analysis

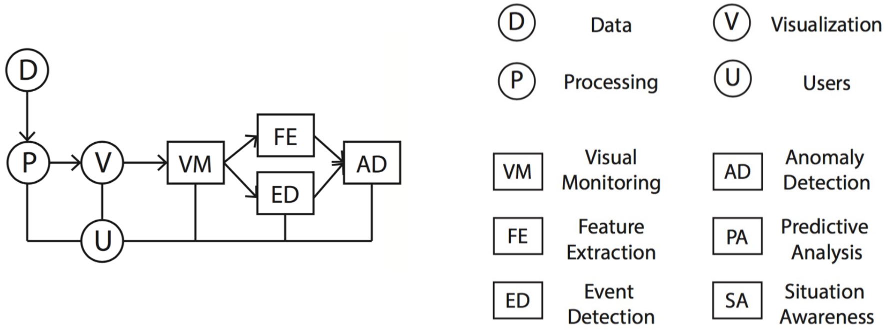


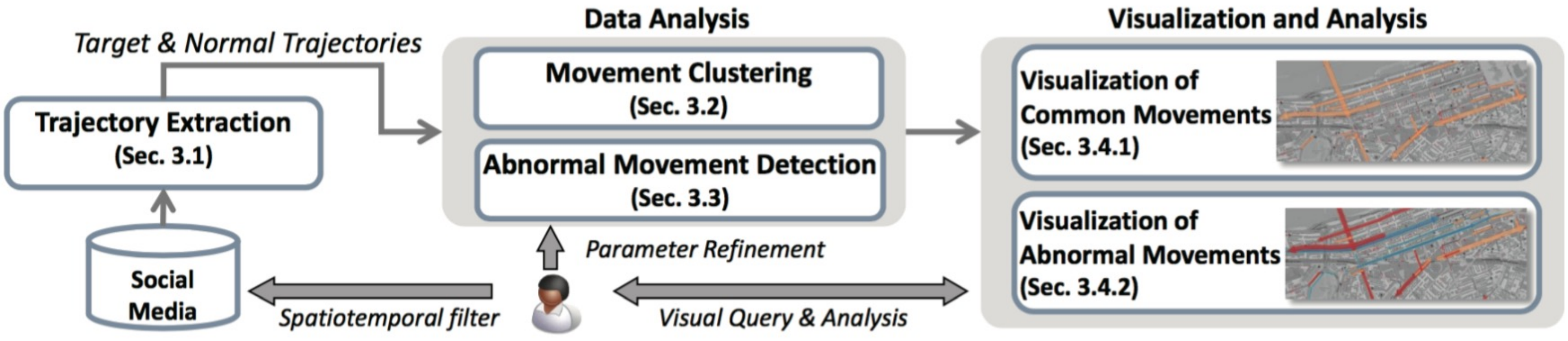


GCAT [KWD*13]

Social Media Visual Analytics (4) - Anomaly Detection

- Normal patterns: data is around average / common ranges of its attributes
- Abnormal patterns
  - Classification model
  - Visual query and analysis

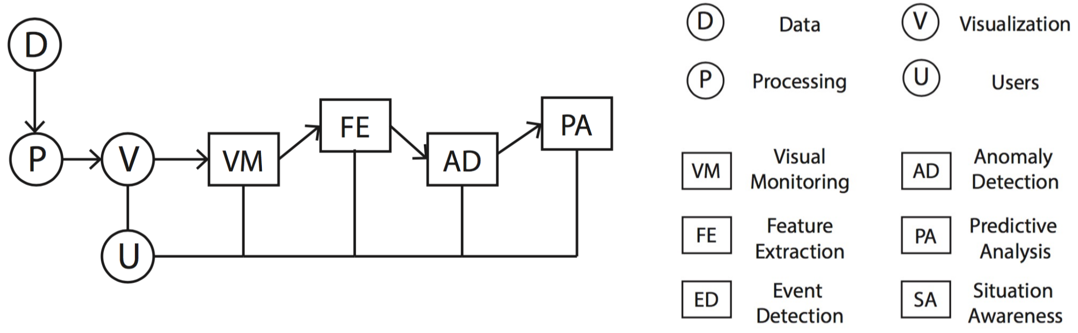


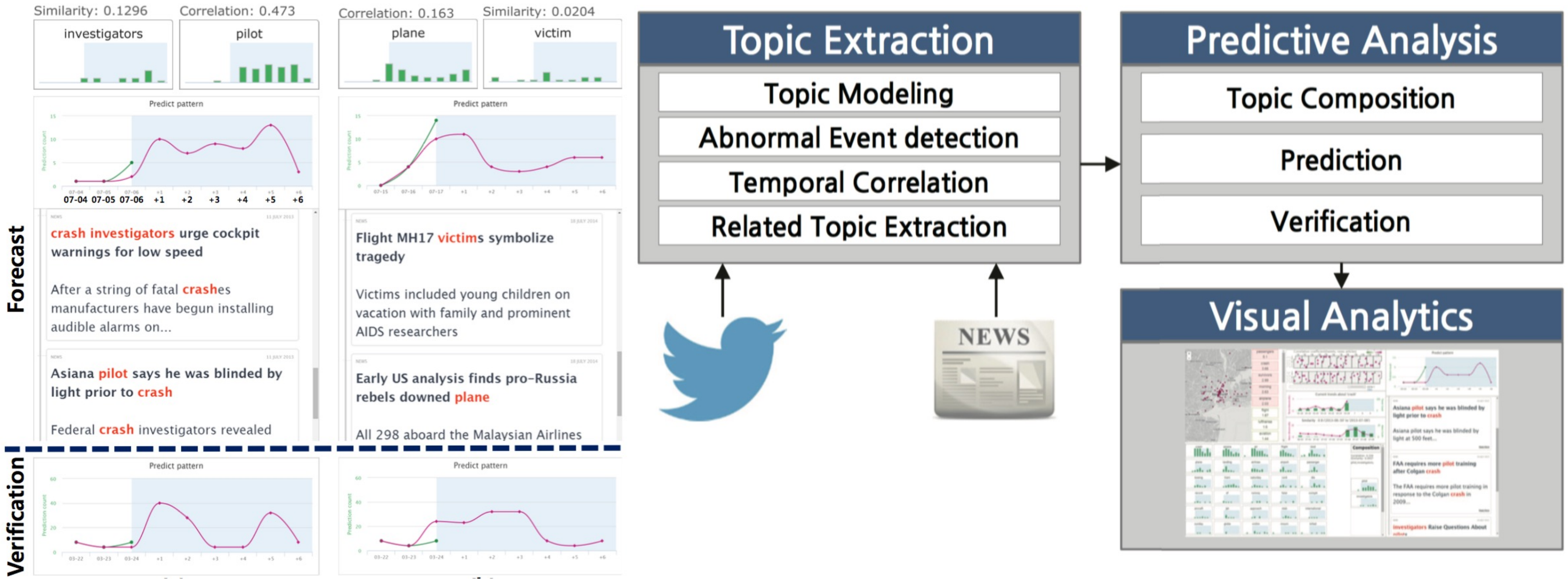


Public Response Analysis [CCJ*15]

Social Media Visual Analytics (5) – Predictive Analysis

- Predictive Analysis (Topic trend, keywords rating, etc.)
  - Event detection
  - Abnormal event detection
  - Similarity analysis
  - Prediction and verification





Topic Decomposition [YJ15]

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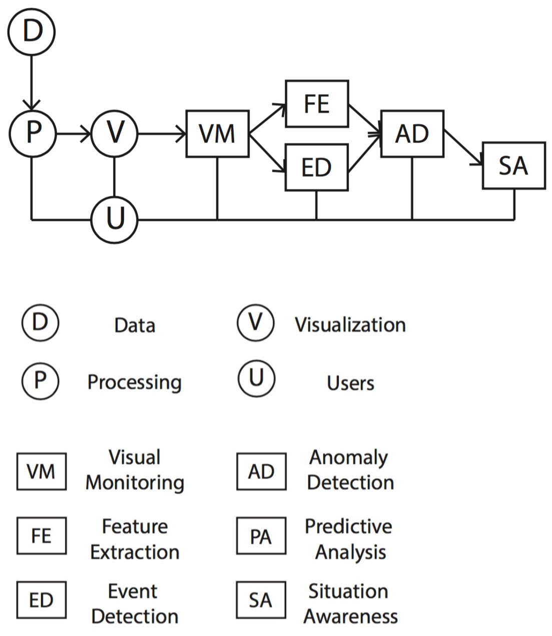
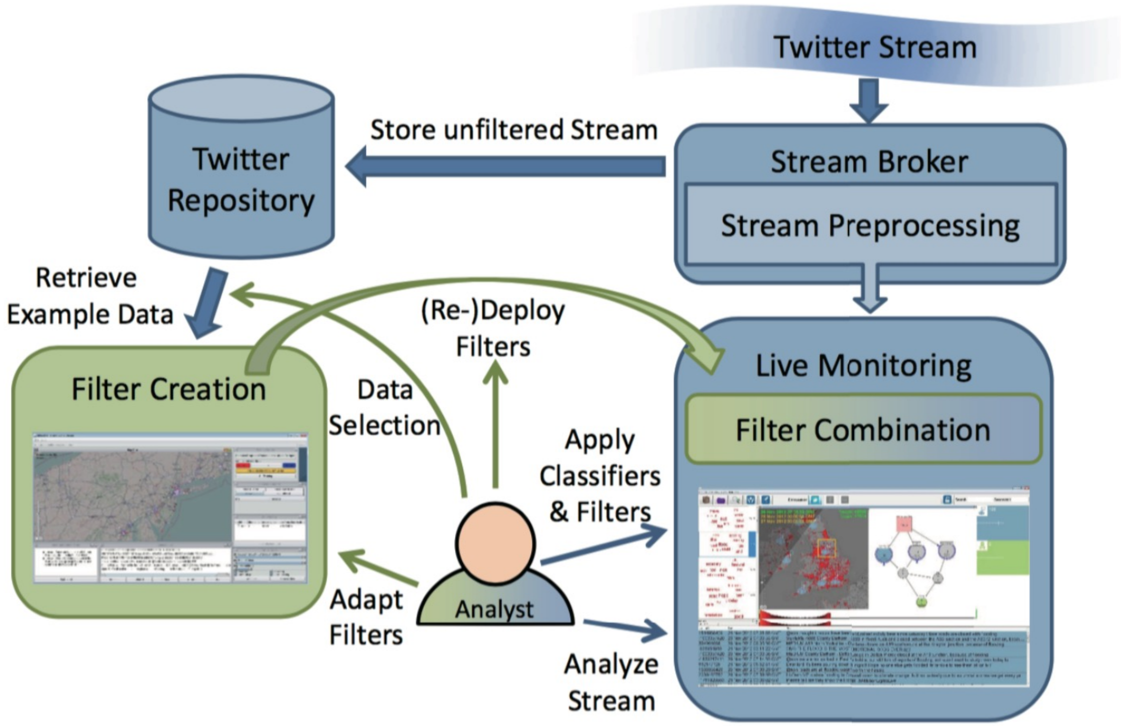
Social Media Visual Analytics (6) – Situation Awareness

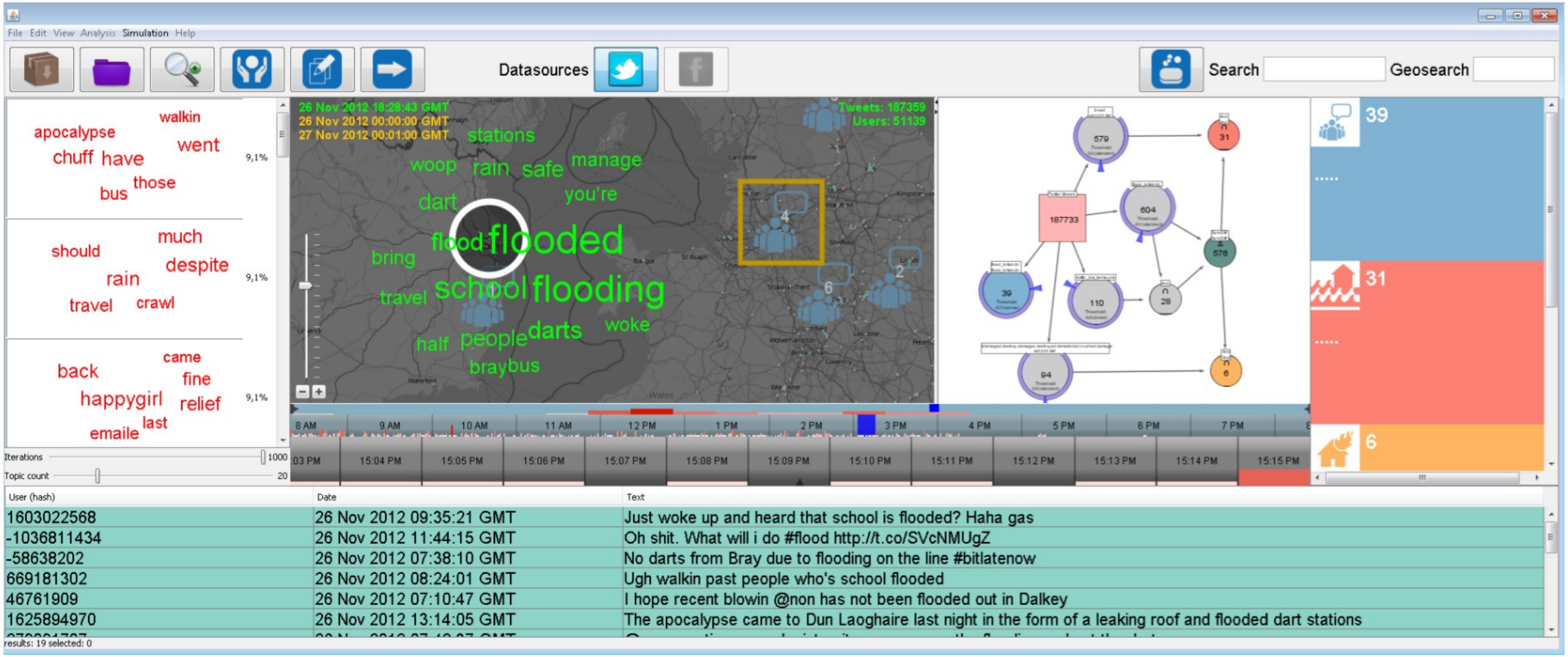
- Situation Awareness (Combination of spatial temporal events, topic and social networks) – for Decision Making
  - Visual monitoring
  - Feature extraction / Event detection
  - Anomaly detection





ScatterBlogs2 [BTH*13]

Social Media Visual Analytics (6) - Situation Awareness

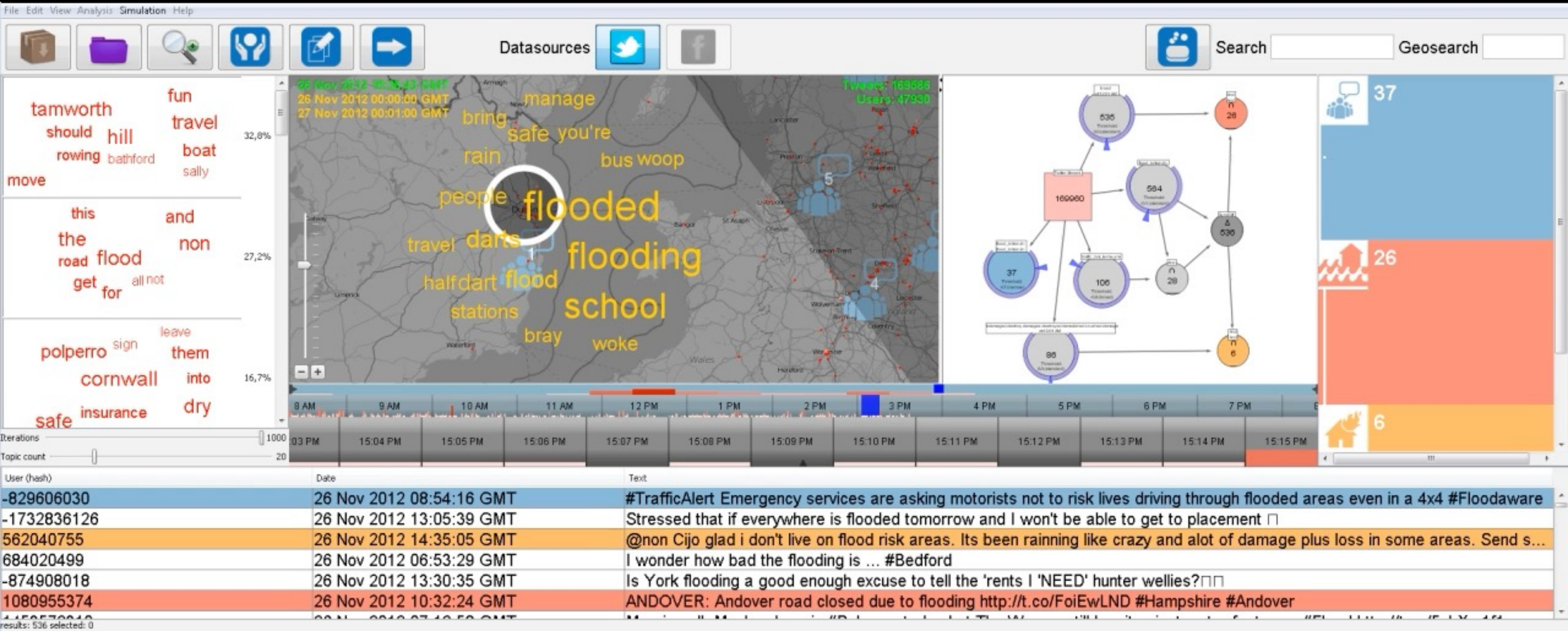


Can Twitter Really Save Your Life? A Case Study of Visual Social Media Analytics for Situation Awareness

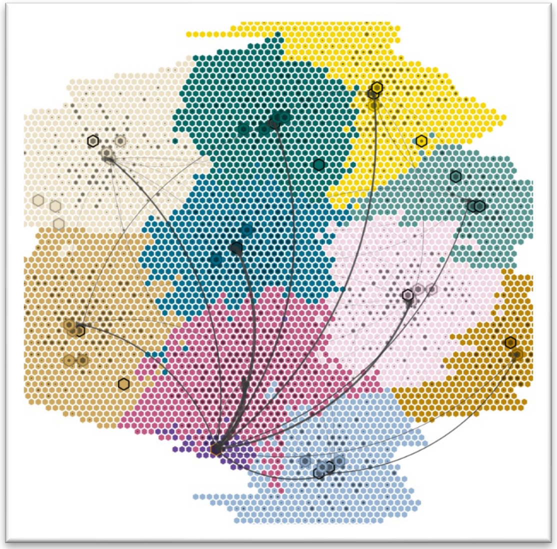
ScatterBlogs2 [BTH∗13, TKE∗ 15]

ScatterBlogs2: Real-Time Monitoring of Microblog Messages through User-Guided Filtering

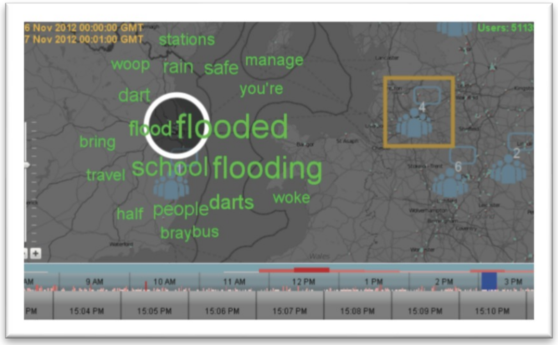
Harald Bosch, Dennis Thom, Florian Heimerl, Edwin Püttmann, Steffen Koch, Robert Krüger, Michael Wörner, Thomas Ertl
Institute for Visualization and Interactive Systems, University of Stuttgart
www.vis.uni-stuttgart.de



Applications and Systems

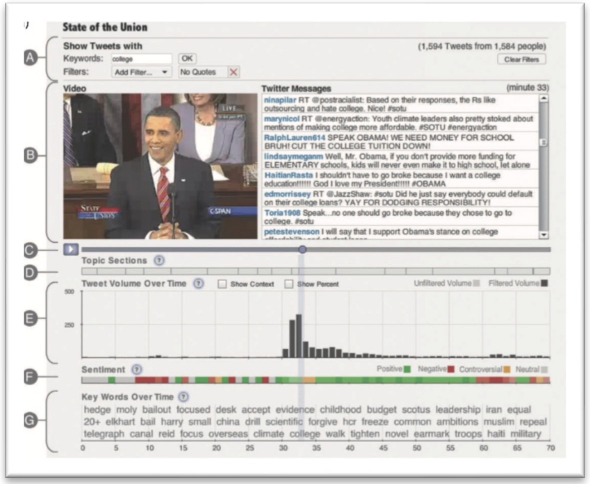


Social Science Research [CCW*16]

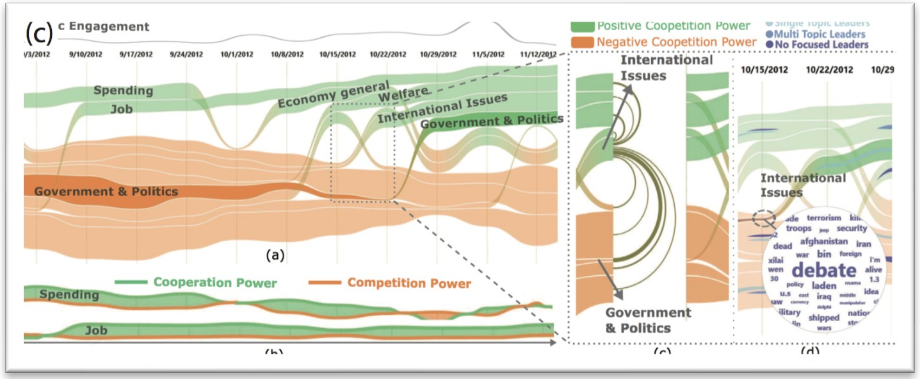


Crisis Management [DTH*13]

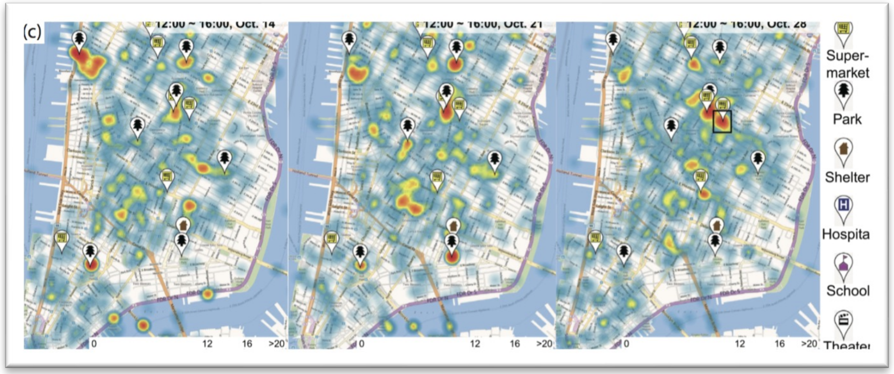
Applications and Systems



Journalism [DNYKS11]

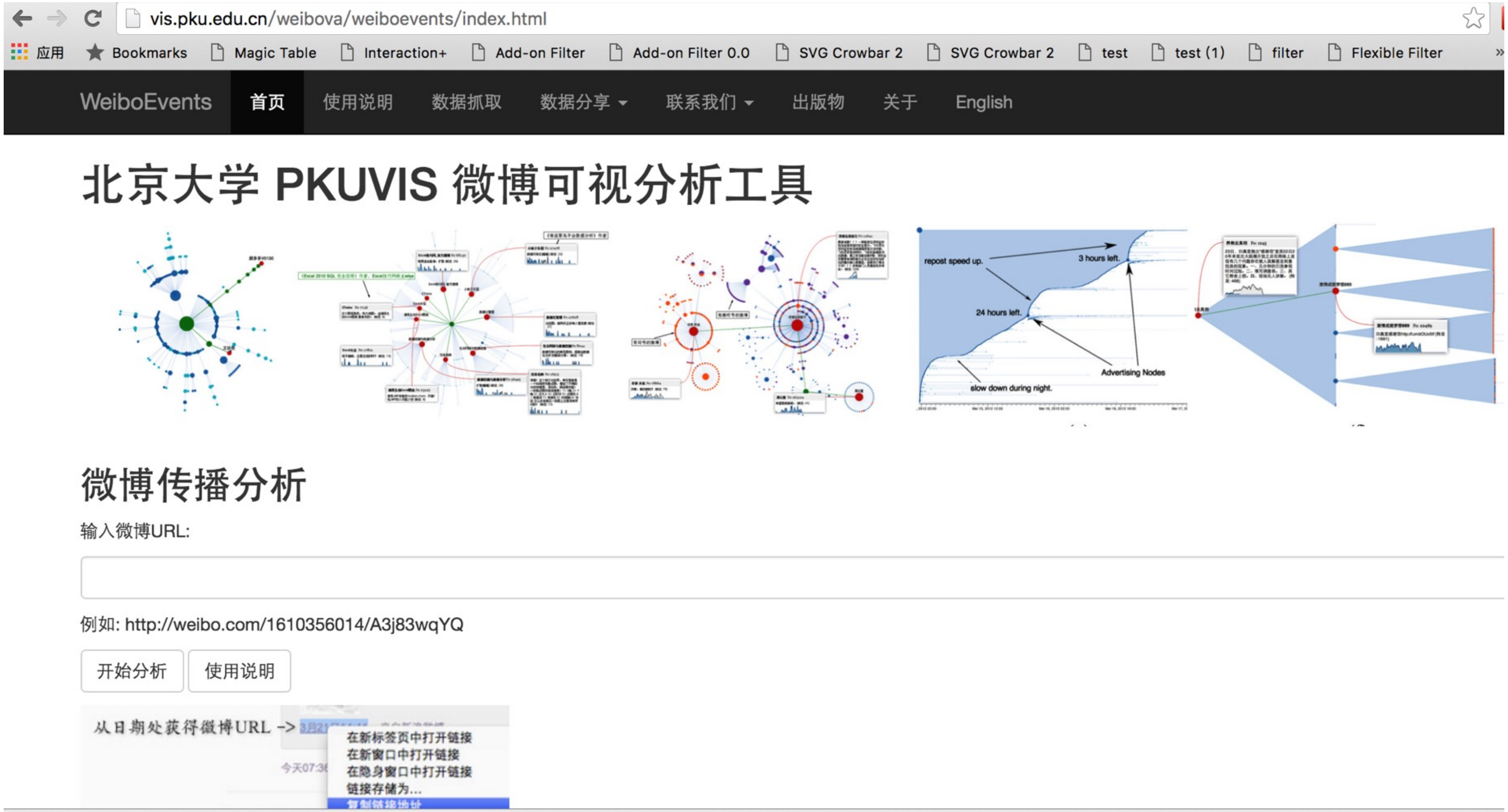


Politics [SWL*14]



Disaster and Emergency Management [CTH*14]

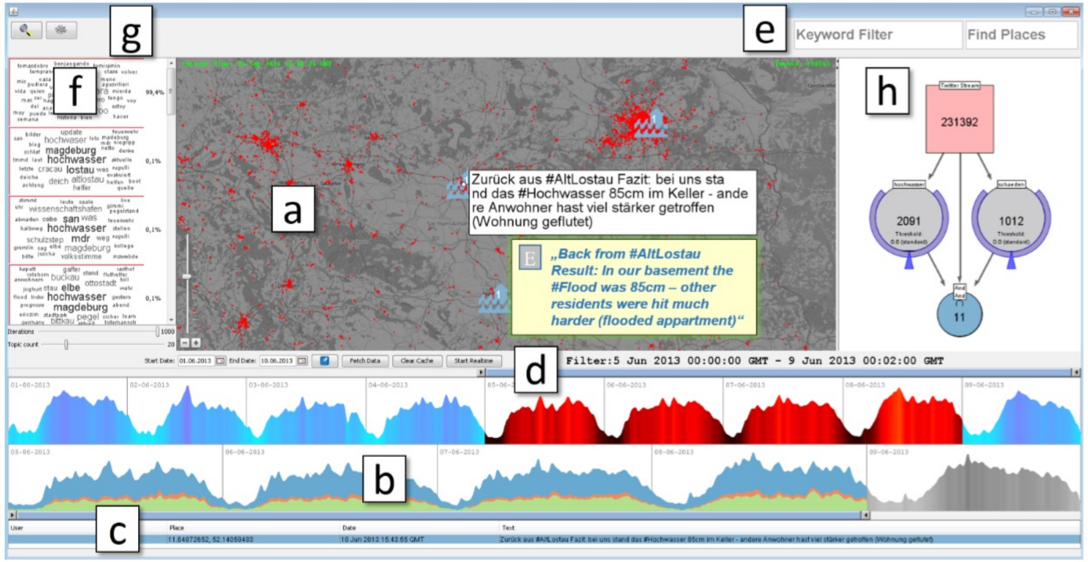
Journalism Application: WeiboEvents

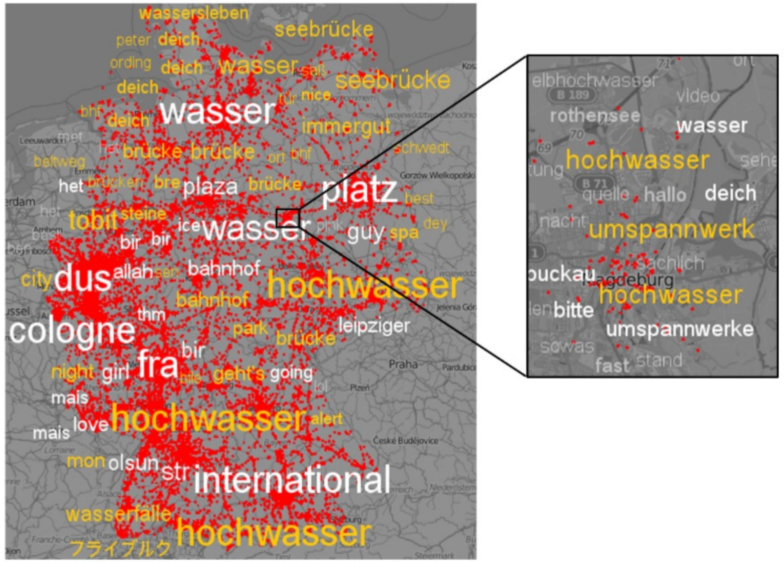


WeiboEvents [RZW*14]

Emergency/Disaster/Crisis Management

- Gain a general overview
- Investigate prominent topics
- Analyze message in detailed regions
- Examine where the emergency is the most severe





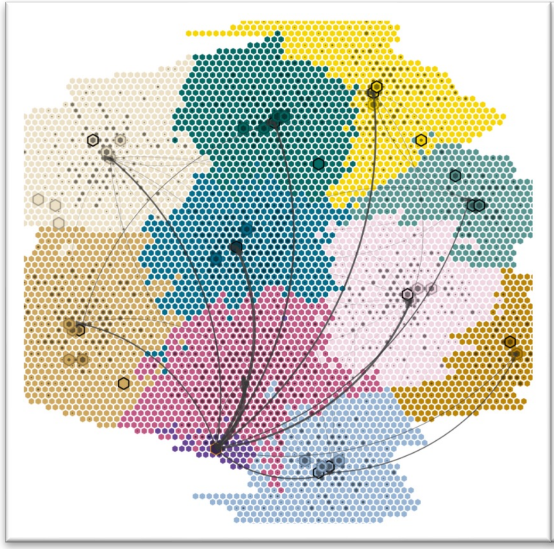
ScatterBlogs2 [BTH∗13, TKE∗ 15]

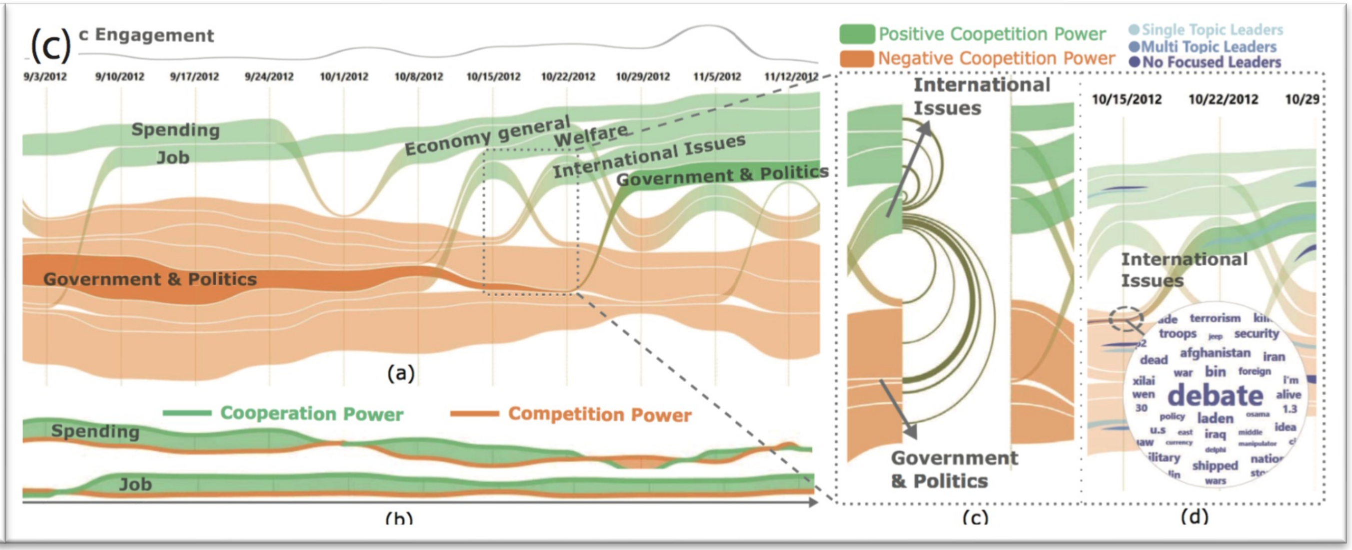
Discussion – Challenges and Opportunities

- Social Media Data Content
  - Content analysis - Extracted keyword/topic analysis
  - Multi-media visual analytics
  - How to deal with bias / trustiness of sampling
  - How to deal with privacy issues

Discussion – Challenges and Opportunities

- Social Network Evolution Analysis
  - Challenge: both relationship and temporal analysis
  - Visualization: river-like and map-like visual metaphor
  - Visual analytics approach: pattern analysis
  - How to detect (subtle) anomaly? It's still in the exploration stage





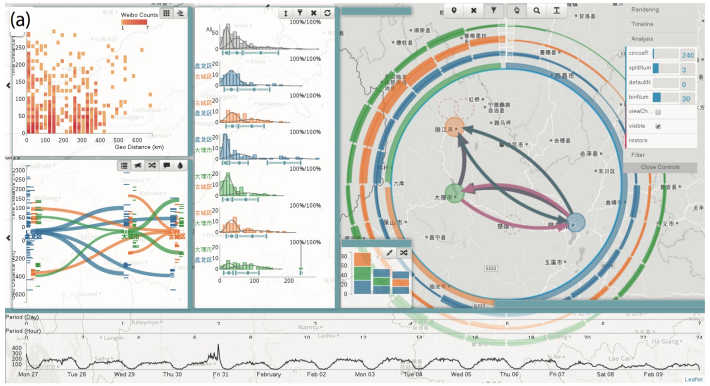
Map-like Visualization [CCW*16]

River-like Visualization [SWL*14]

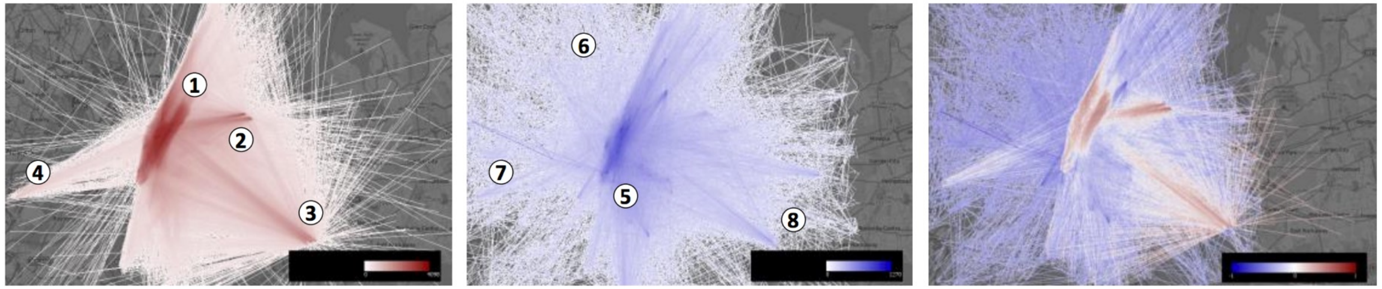
Discussion – Challenges and Opportunities

- Movement and Trajectory Analysis
  - Challenge: Understand trajectory patterns with semantics
  - Detecting movement patterns considering periodical behaviors / uncertainty
  - Comparison with other data sources

Visits [TBC13]



WeiboGeo [CYW*16]



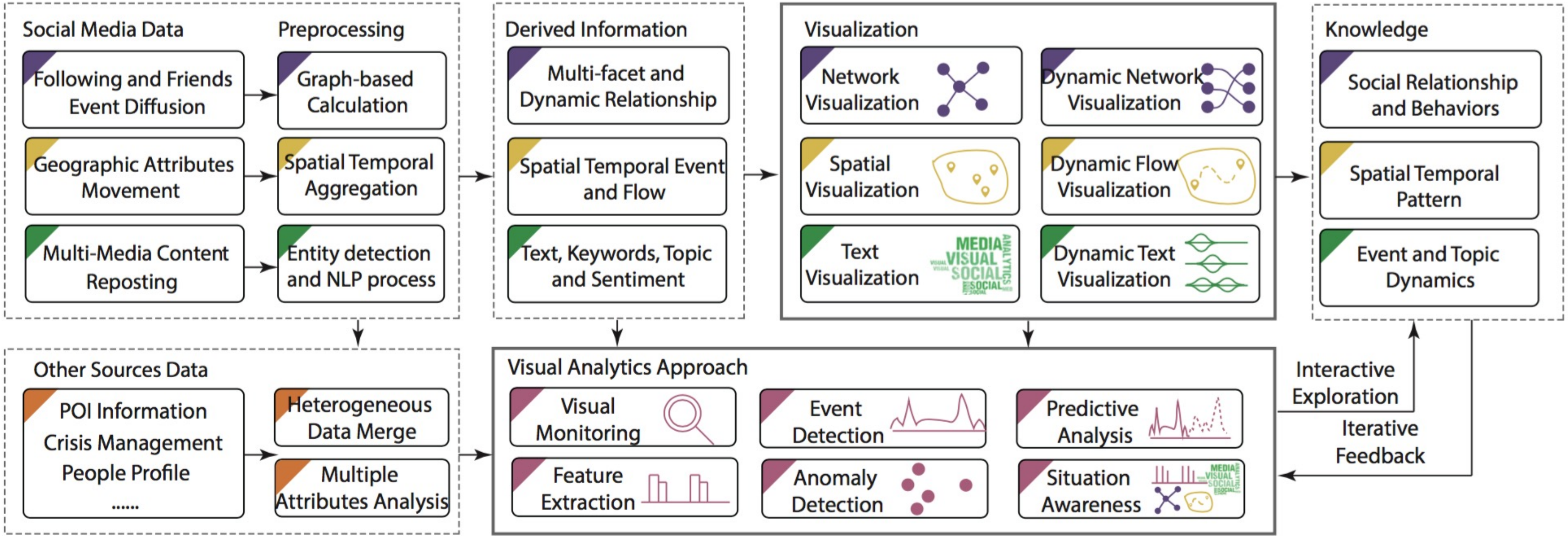
TravelDiff [KSB∗16]

Discussion - Challenges and Opportunities

- Heterogeneous visual analytics
  - Attribute level - Profiling social media users
  - Data level - Enriching behavior understanding with additional data source
  - Analysis level: Social Media + other discipline's analytical pipeline
- Evaluation of Social Media Visual Analytics
  - Target users
  - Tasks
  - User study
  - Expert feedback

Summary

- Social Media Data Category
- Social Media Visualization
- Social Media Visual Analytics
- Application and System
- Discussion and Summary



Questions?
Thank you ☺

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