network *visualization*

introduction to *network analysis* (*ina*)

Lovro Šubelj
University of Ljubljana
spring 2023/24

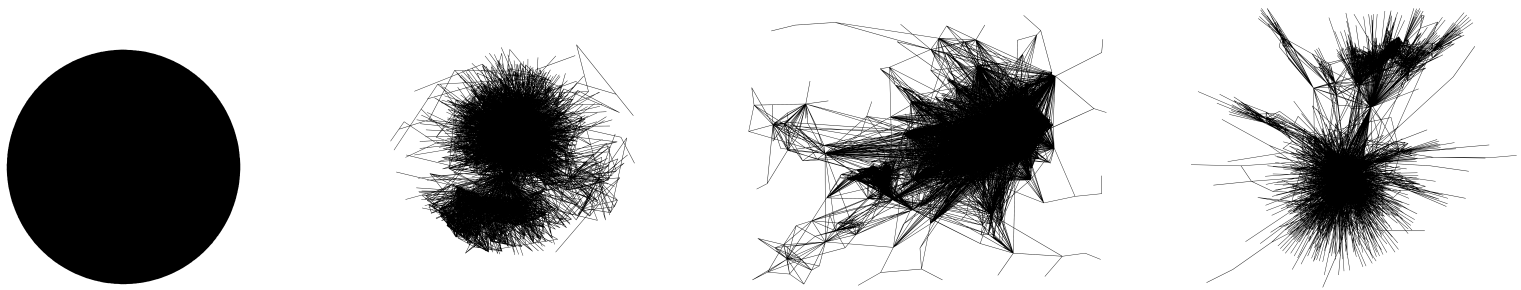
visualization *overview*

network *visualization* with *wiring diagram**

1st compute *network layout* as *coordinates* in Euclidean plane etc.

2nd *representation* of *network links*? strength, pattern, shape, color etc.

3rd *representation* of *network nodes*? size, shape, color, label etc.

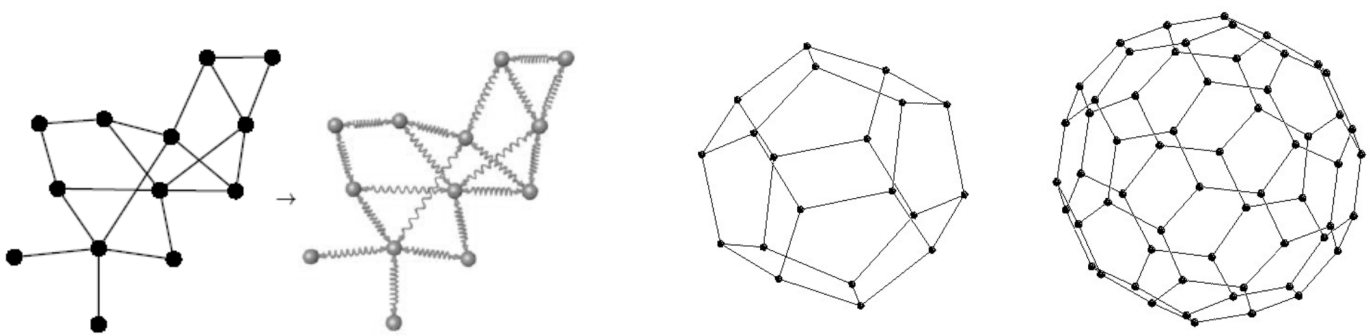


similar link lengths, no crossings, displays symmetry, even node distribution etc.

*small/dense graphs better visualized with block models

visualization *Eades*

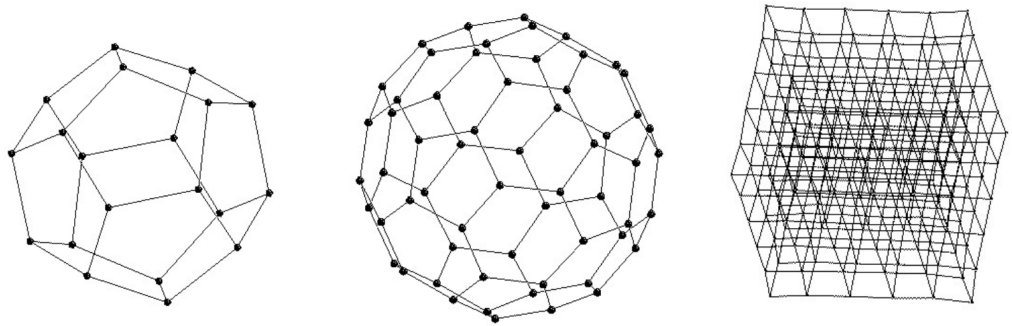
- Eades *spring embedded layout* [Ead84]
- move nodes thus to *minimize layout energy*
- *repulsive force* between *nodes* i and j is $\propto -c_1/l_{ij}^2$
- *attractive force* between *neighbors* i and j is $\propto \log l_{ij}/c_2$
  - l_{ij} is *Euclidean distance* between *nodes* i and j
  - c_1 and c_2 are some *appropriate constants*



aesthetically pleasing with similar link lengths & symmetry

visualization *Fruchterman-Reingold*

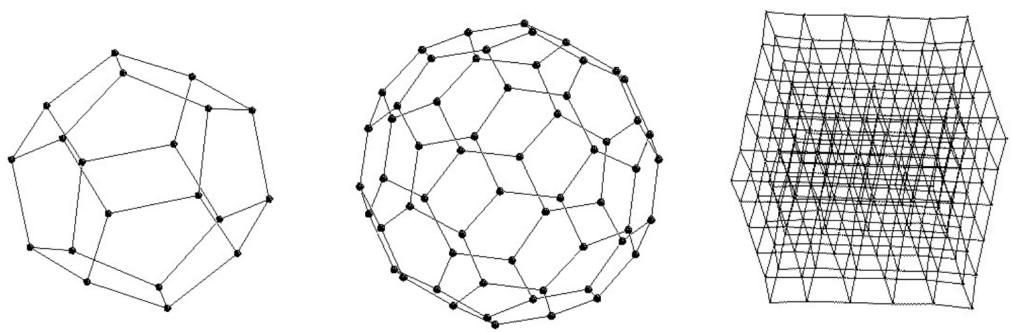
- Fruchterman-Reingold *force-directed layout* [FR91]
- move nodes thus to *minimize layout energy* as before
- *repulsive force* between *nodes* i and j is $\propto -c^2/l_{ij}$
- *attractive force* between *neighbors* i and j is $\propto l_{ij}^2/c$
  - l_{ij} is *Euclidean distance* between *nodes* i and j
  - c is *appropriate constant* set to $\propto \sqrt{area/n}$



pleasing with similar link lengths, symmetry & even distribution

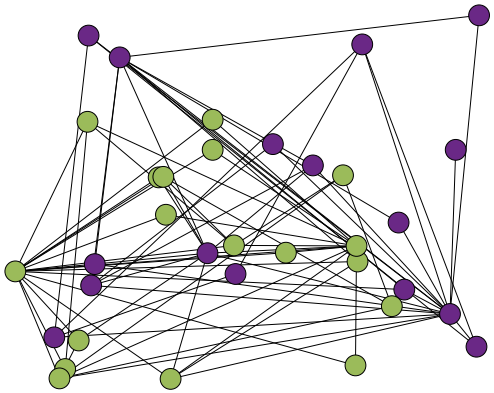
visualization *Kamada-Kawai*

- Kamada-Kawai *graph theoretic layout* [KK89]
- move nodes thus to *minimize layout energy* $l_{ij} \propto d_{ij}$
- *attractive/repulsive force* between *nodes* i and j is $\propto 1/d_{ij}^2$
  - l_{ij} is *layout Euclidean distance* between *nodes* i and j
  - d_{ij} is *graph geodesic distance* between *nodes* i and j

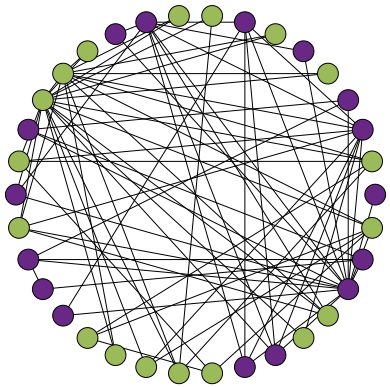


desired layout distance between nodes is their graph distance

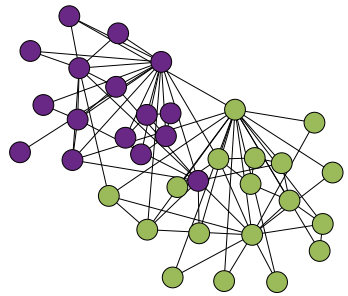
visualization *karate*



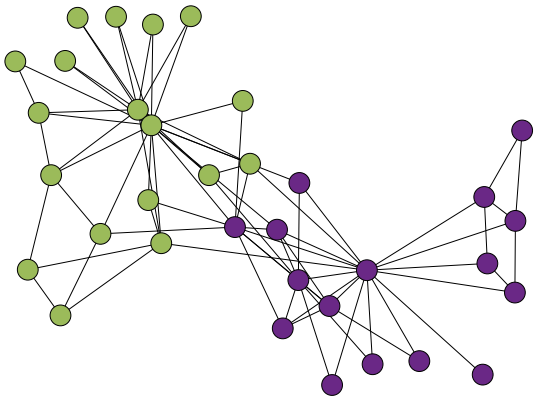
random layout



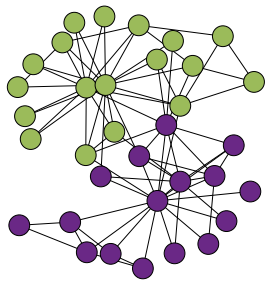
circular layout



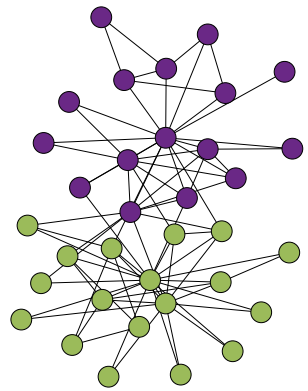
spring embedding layout [Ead84]



Fruchterman-Reingold layout [FR91]

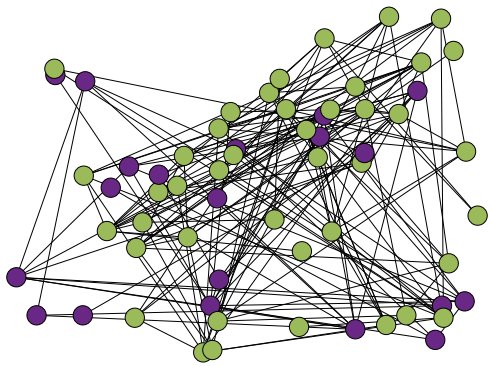


Kamada-Kawai layout [KK89]

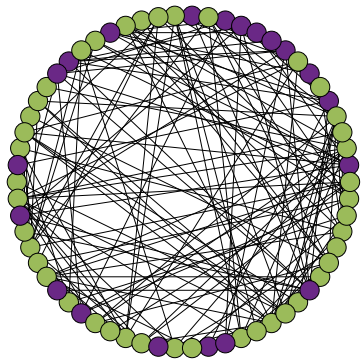


LGL layout [ADWM04]

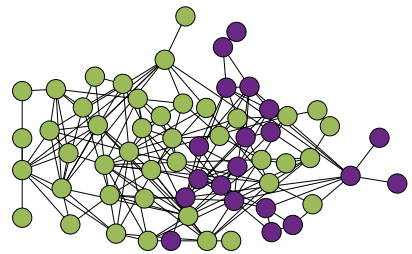
visualization *dolphins*



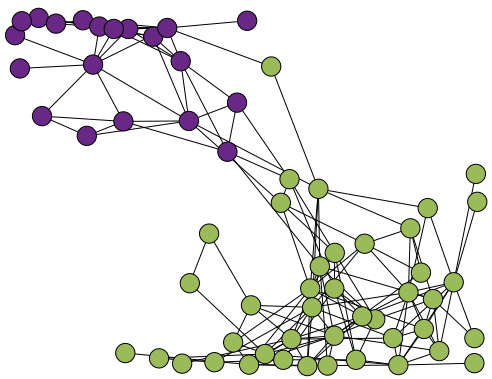
random layout



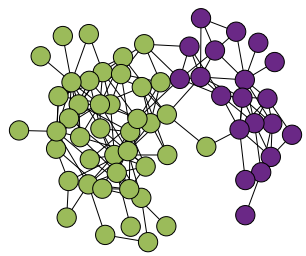
circular layout



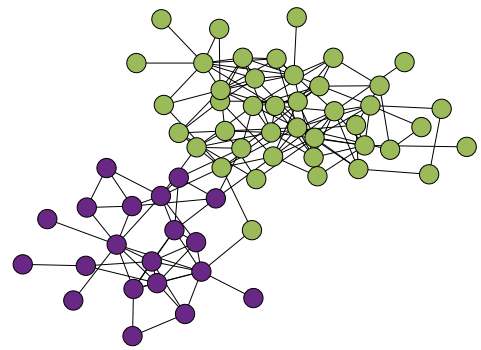
spring embedding layout [Ead84]



Fruchterman-Reingold layout [FR91]

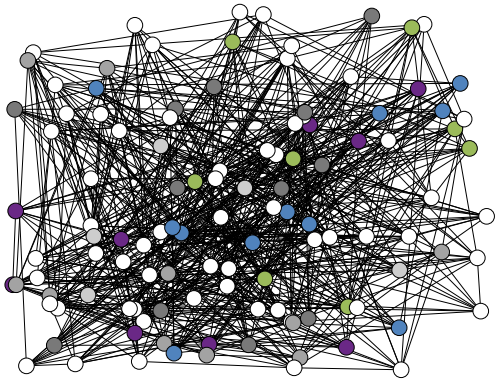


Kamada-Kawai layout [KK89]

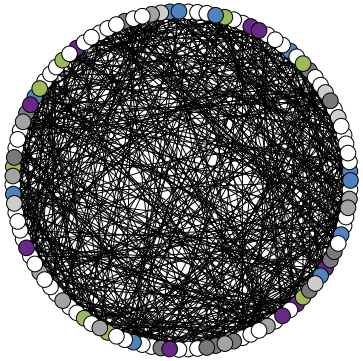


LGL layout [ADWM04]

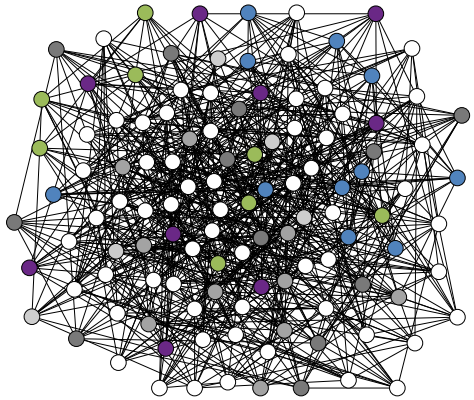
visualization *football*



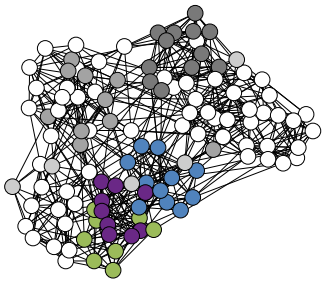
random layout



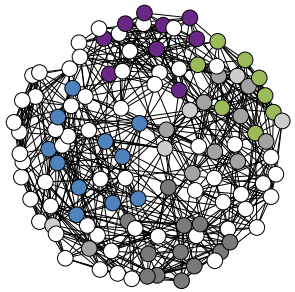
circular layout



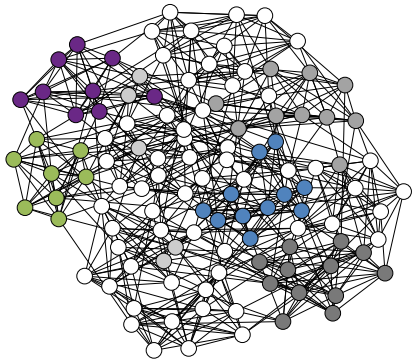
spring embedding layout [Ead84]



Fruchterman-Reingold layout [FR91]

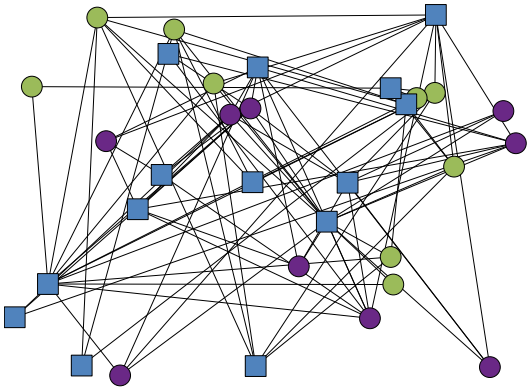


Kamada-Kawai layout [KK89]

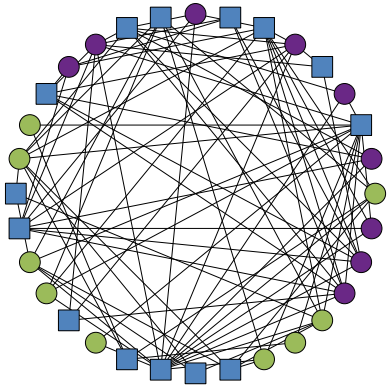


LGL layout [ADWM04]

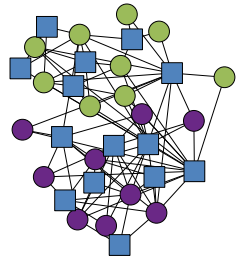
visualization *women*



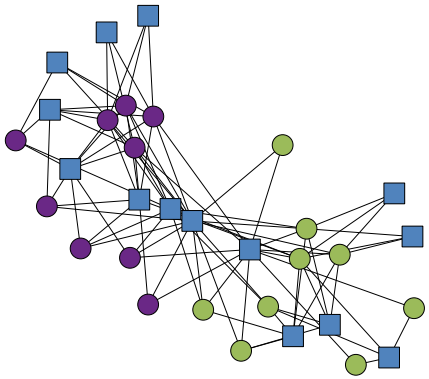
random layout



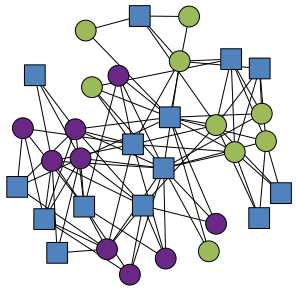
circular layout



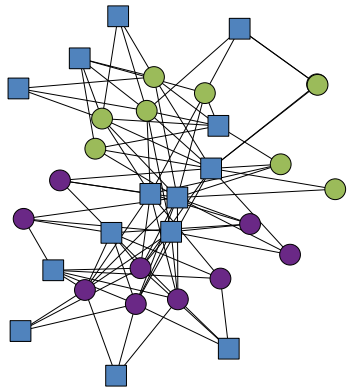
spring embedding layout [Ead84]



Fruchterman-Reingold layout [FR91]

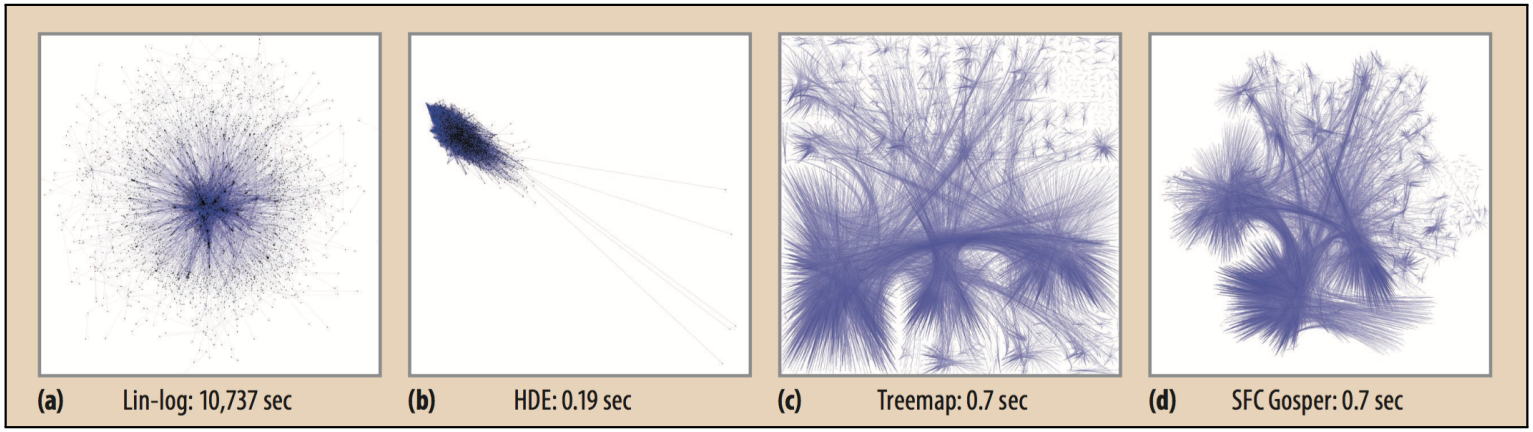


Kamada-Kawai layout [KK89]

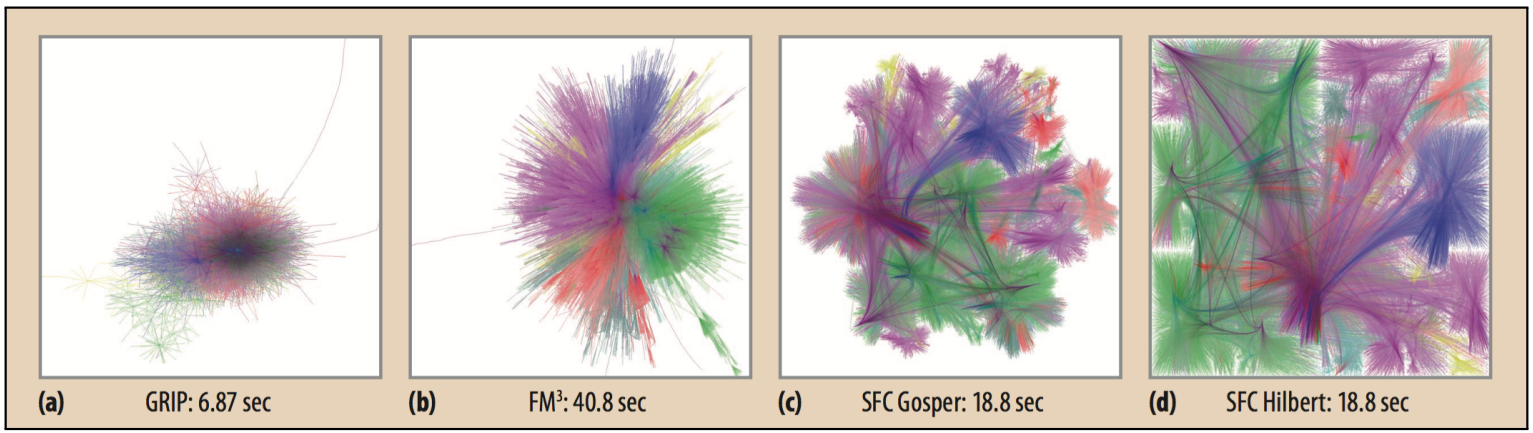


LGL layout [ADWM04]

visualization *static*

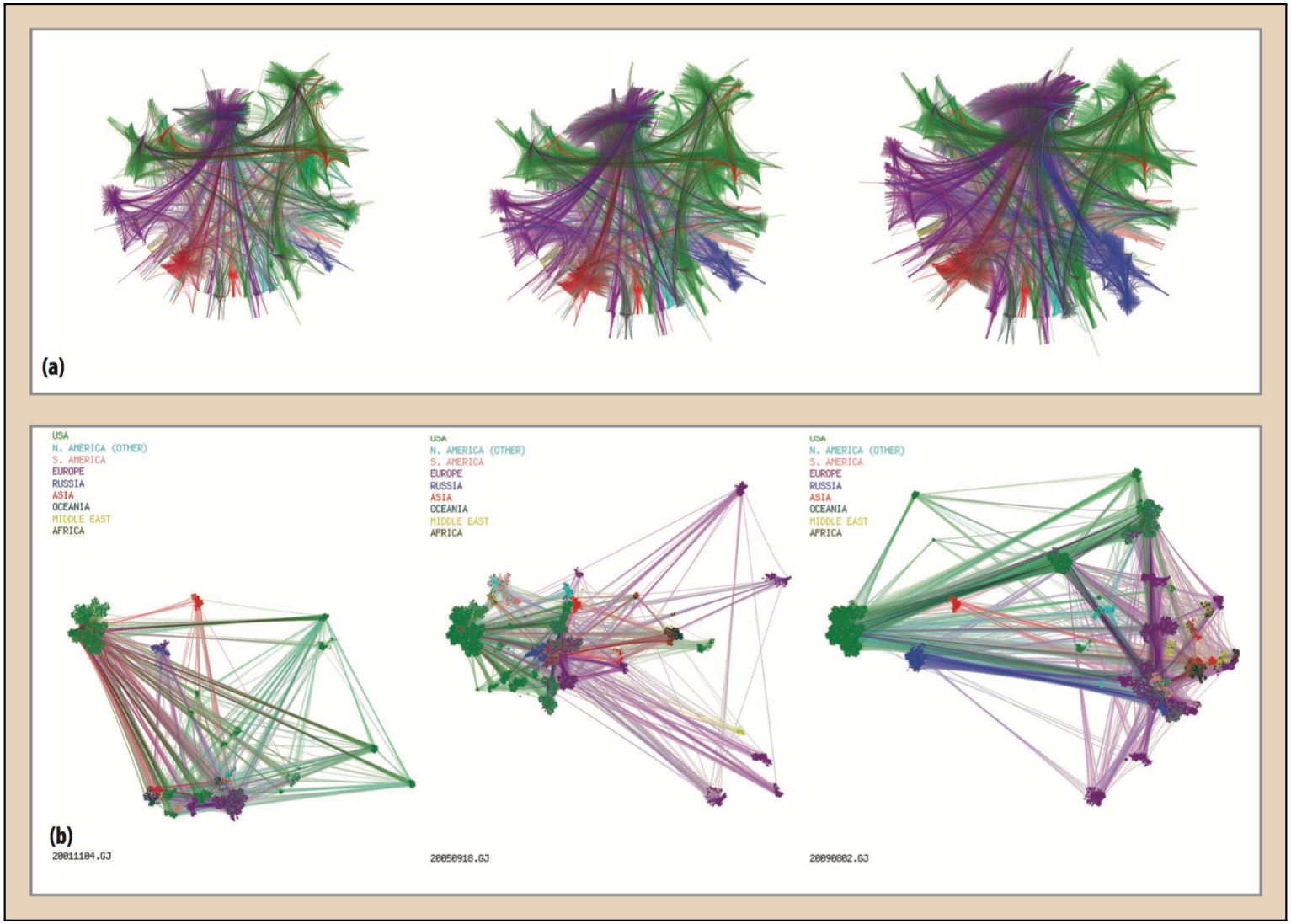


(*a*) *traditional* (*b*) *algebraic* (*c*) *hierarchical* and (*d*) *clustering-based force-directed layouts* of web graph



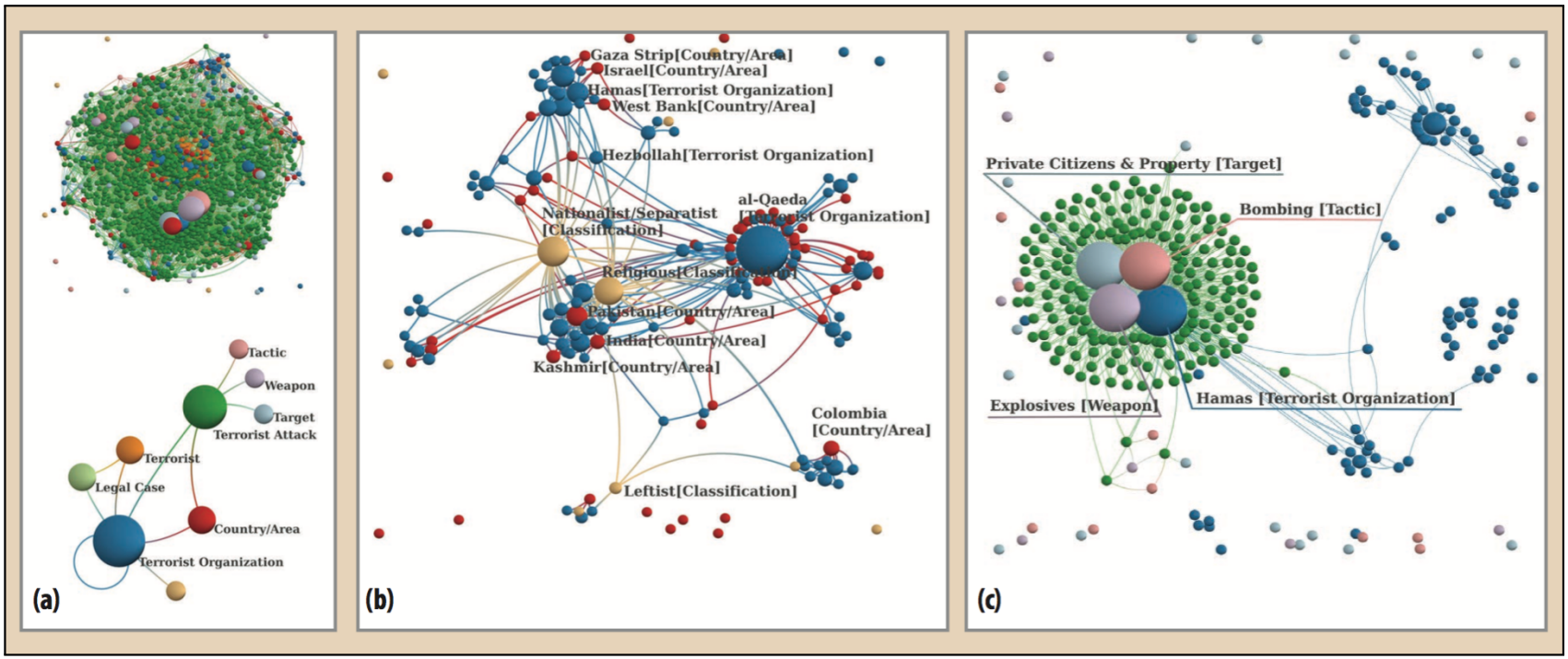
(*a*,*b*) *multilevel* and (*c*,*d*) *clustering-based force-directed layouts* of autonomous systems by continent

visualization *dynamic*



(*a*) *incremental* and (*b*) *global* clustering-based *force-directed layouts* of Internet by continent

visualization *heterogeneous*



terrorist network (*a*) *force-directed layout* with *semantic ontology* and (*b*) *active organizations* (*c*) *attack behaviour*

visualization *references*

Alex T. Adai, Shailesh V. Date, Shannon Wieland, and Edward M. Marcotte.

LGL: Creating a map of protein function with an algorithm for visualizing very large biological networks.
J. Mol. Biol., 340(1):179–190, 2004.

A.-L. Barabási.

Network Science.
Cambridge University Press, Cambridge, 2016.

Wouter de Nooy, Andrej Mrvar, and Vladimir Batagelj.

Exploratory Social Network Analysis with Pajek: Expanded and Revised Second Edition.
Cambridge University Press, Cambridge, 2011.

Peter Eades.

A heuristic for graph drawing.
Congressus Numerantium, 42:149–160, 1984.

David Easley and Jon Kleinberg.

Networks, Crowds, and Markets: Reasoning About a Highly Connected World.
Cambridge University Press, Cambridge, 2010.

Ernesto Estrada and Philip A. Knight.

A First Course in Network Theory.
Oxford University Press, 2015.

Thomas M. J. Fruchterman and Edward M. Reingold.

Graph drawing by force-directed placement.
Softw: Pract. Exper., 21(11):1129–1164, 1991.

Helen Gibson, Joe Faith, and Paul Vickers.

A survey of two-dimensional graph layout techniques for information visualisation.
Infor. Visual., 12(3-4):324–357, 2013.

visualization *references*

Tomihisa Kamada and Satoru Kawai.

An algorithm for drawing general undirected graphs.

Inform. Process. Lett., 31(1):7–15, 1989.

Stephen G. Kobourov.

Force-directed drawing algorithms.

In Roberto Tamassia, editor, *Handbook of Graph Drawing and Visualization*, pages 383–408. CRC Press, 2013.

Kwan-Liu Ma and Chris W. Muelder.

Large-scale graph visualization and analytics.

Computer, 46(7):39–46, 2013.

Mark E. J. Newman.

Networks.

Oxford University Press, Oxford, 2nd edition, 2018.