

# network *visualization*

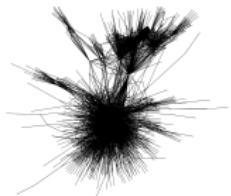
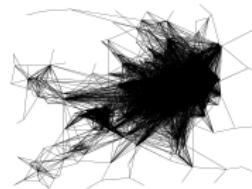
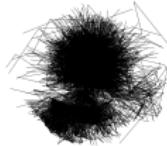
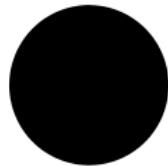
introduction to *network analysis* (*ina*)

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# 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.



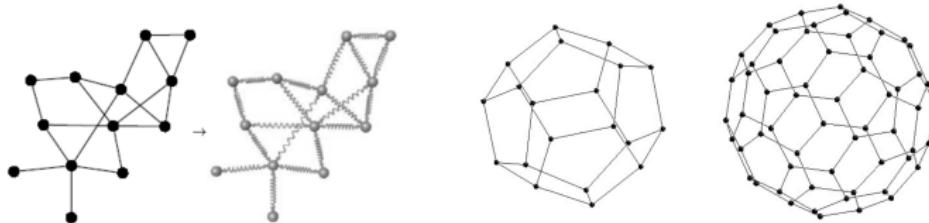
similar link lengths, no crossings, displays symmetry, even node distribution etc.

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\* small/dense graphs better visualized with block models

## visualization *Eades*

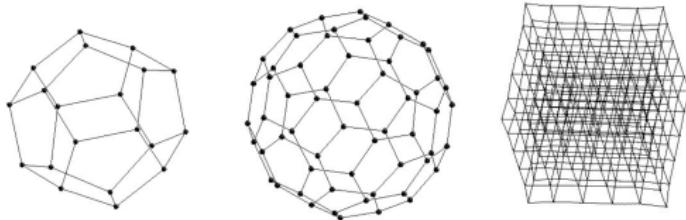
- Eades *spring embedded layout* [Ead84]
- move nodes thus to *minimize layout energy*
- *repulsive force* between *nodes*  $i$  and  $j$  is  $\propto -c_1/l_{ij}^2$
- *attractive force* between *neighbors*  $i$  and  $j$  is  $\propto \log l_{ij}/c_2$ 
  - $l_{ij}$  is *Euclidean distance* between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



aesthetically pleasing with similar link lengths & symmetry

## visualization *Fruchterman-Reingold*

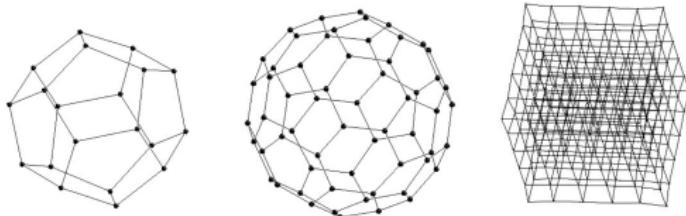
- Fruchterman-Reingold *force-directed layout* [FR91]
- move nodes thus to *minimize layout energy* as before
- *repulsive force* between *nodes i* and *j* is  $\propto -c^2/l_{ij}$
- *attractive force* between *neighbors i* and *j* is  $\propto l_{ij}^2/c$ 
  - $l_{ij}$  is *Euclidean distance* between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



pleasing with similar link lengths, symmetry & even distribution

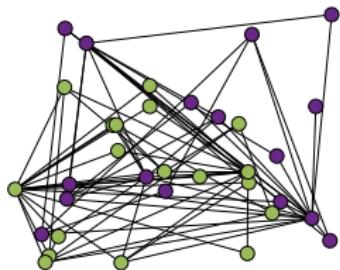
## visualization *Kamada-Kawai*

- 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*

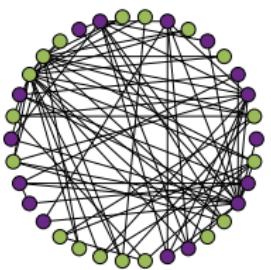


desired layout distance between nodes is their graph distance

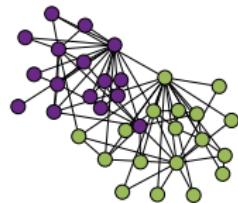
# visualization *karate*



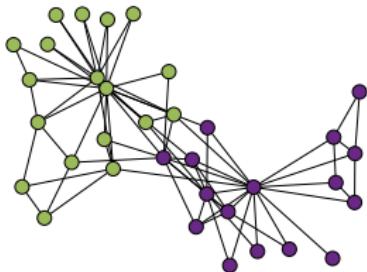
random layout



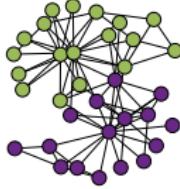
circular layout



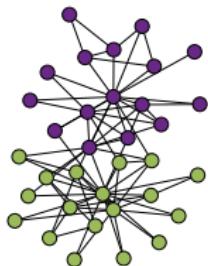
spring embedding layout [Ead84]



Fruchterman-Reingold layout [FR91]

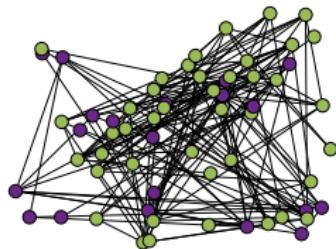


Kamada-Kawai layout [KK89]

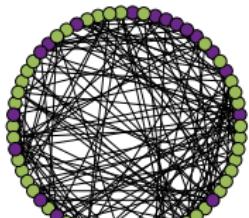


LGL layout [ADWM04]

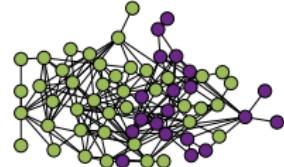
# visualization *dolphins*



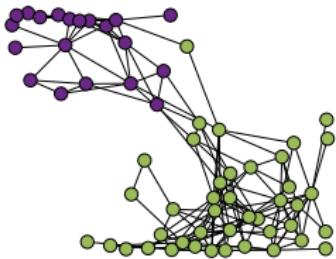
*random layout*



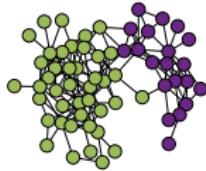
*circular layout*



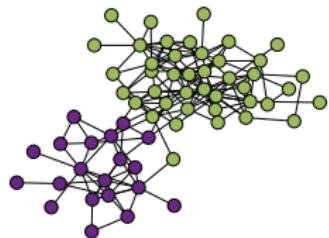
*spring embedding layout* [Ead84]



*Fruchterman-Reingold layout* [FR91]

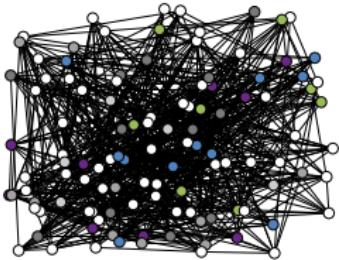


*Kamada-Kawai layout* [KK89]

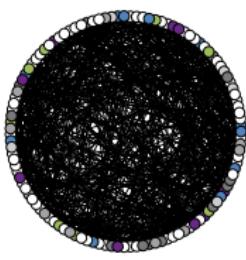


*LGL layout* [ADWM04]

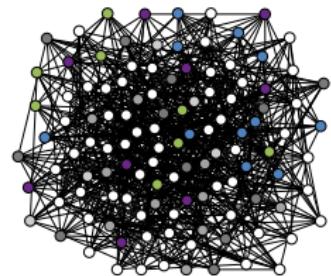
# visualization *football*



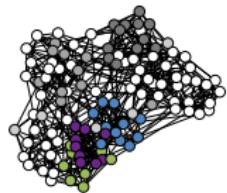
*random layout*



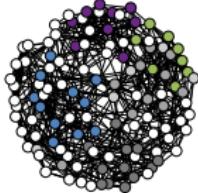
*circular layout*



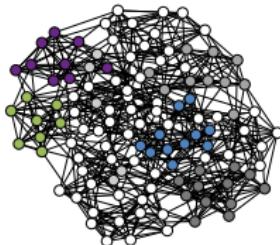
*spring embedding layout* [Ead84]



*Fruchterman-Reingold layout* [FR91]

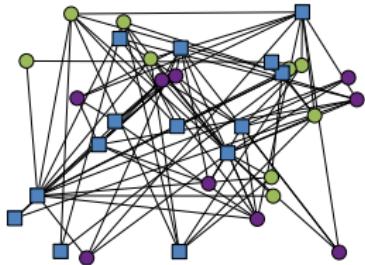


*Kamada-Kawai layout* [KK89]

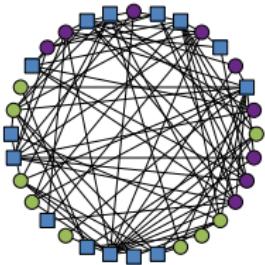


*LGL layout* [ADWM04]

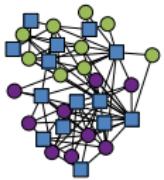
# visualization *women*



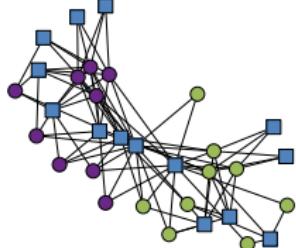
*random layout*



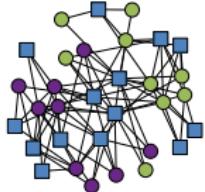
*circular layout*



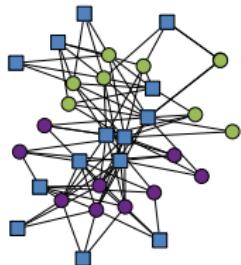
*spring embedding layout* [Ead84]



*Fruchterman-Reingold layout* [FR91]

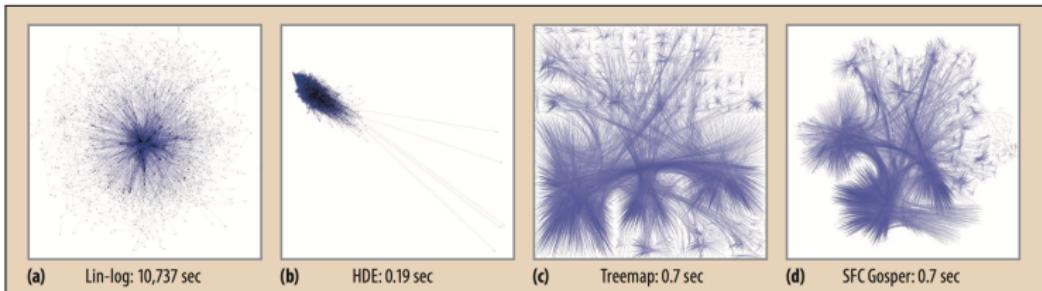


*Kamada-Kawai layout* [KK89]

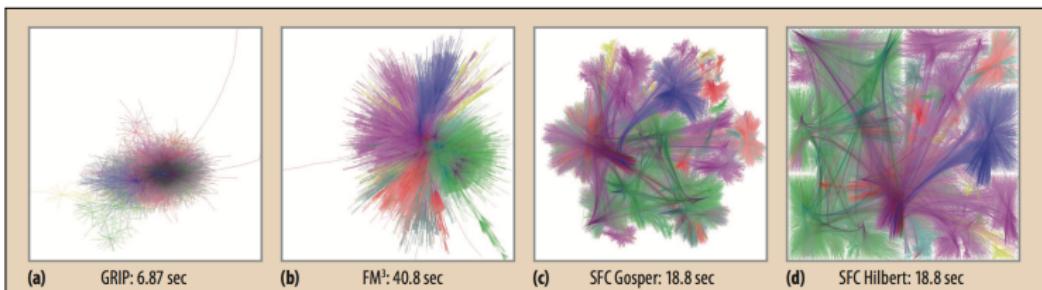


*LGL layout* [ADWM04]

# visualization *static*

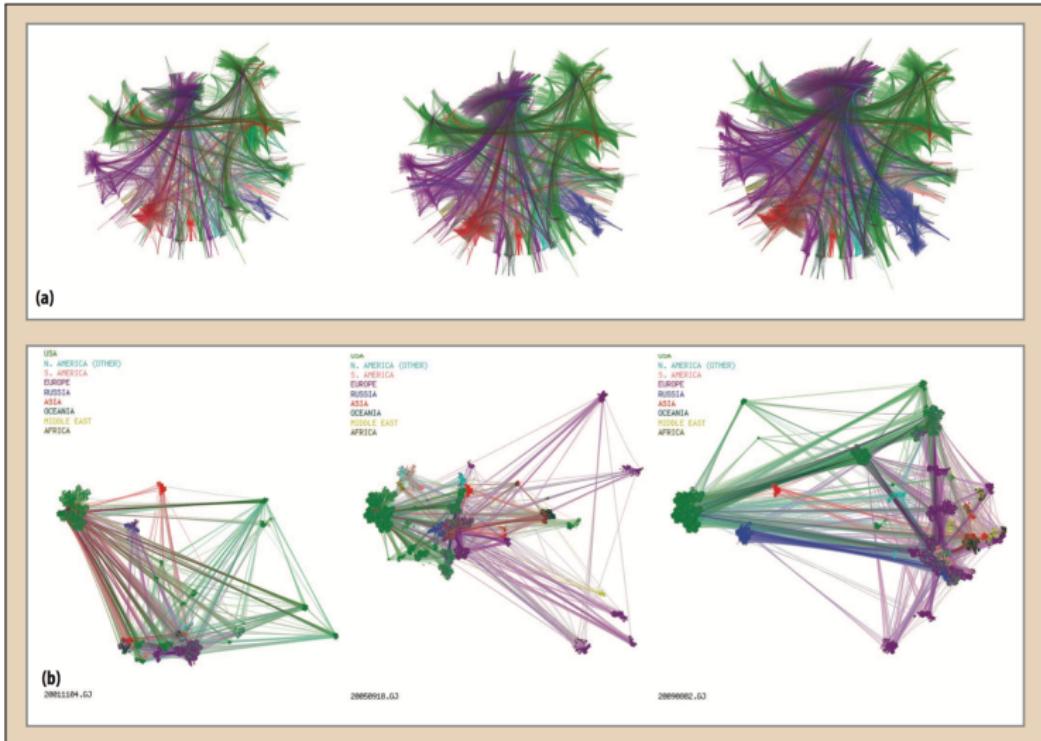


(a) *traditional* (b) *algebraic* (c) *hierarchical* and (d) *clustering-based force-directed layouts* of web graph



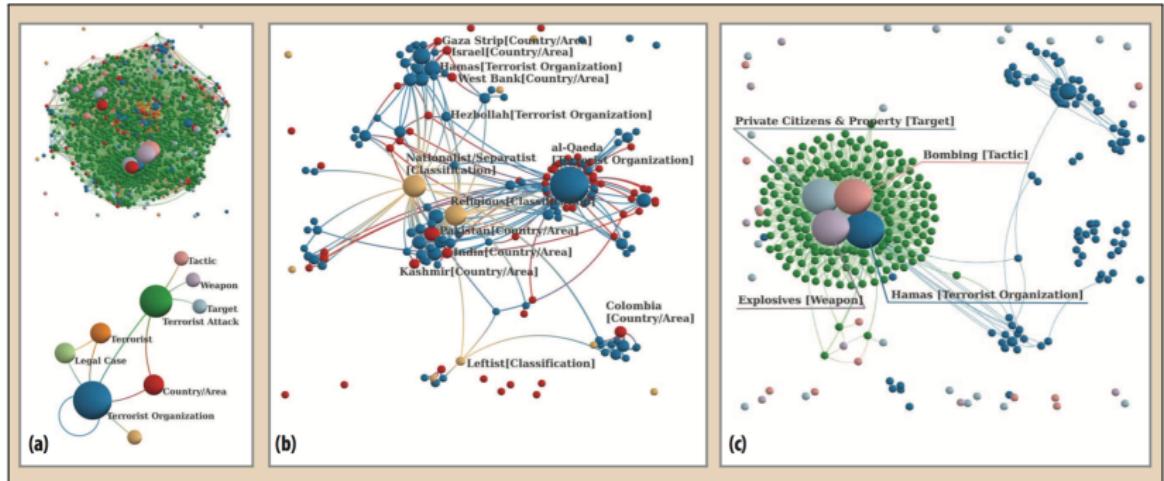
(a,b) *multilevel* and (c,d) *clustering-based force-directed layouts* of autonomous systems by continent

# 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*

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