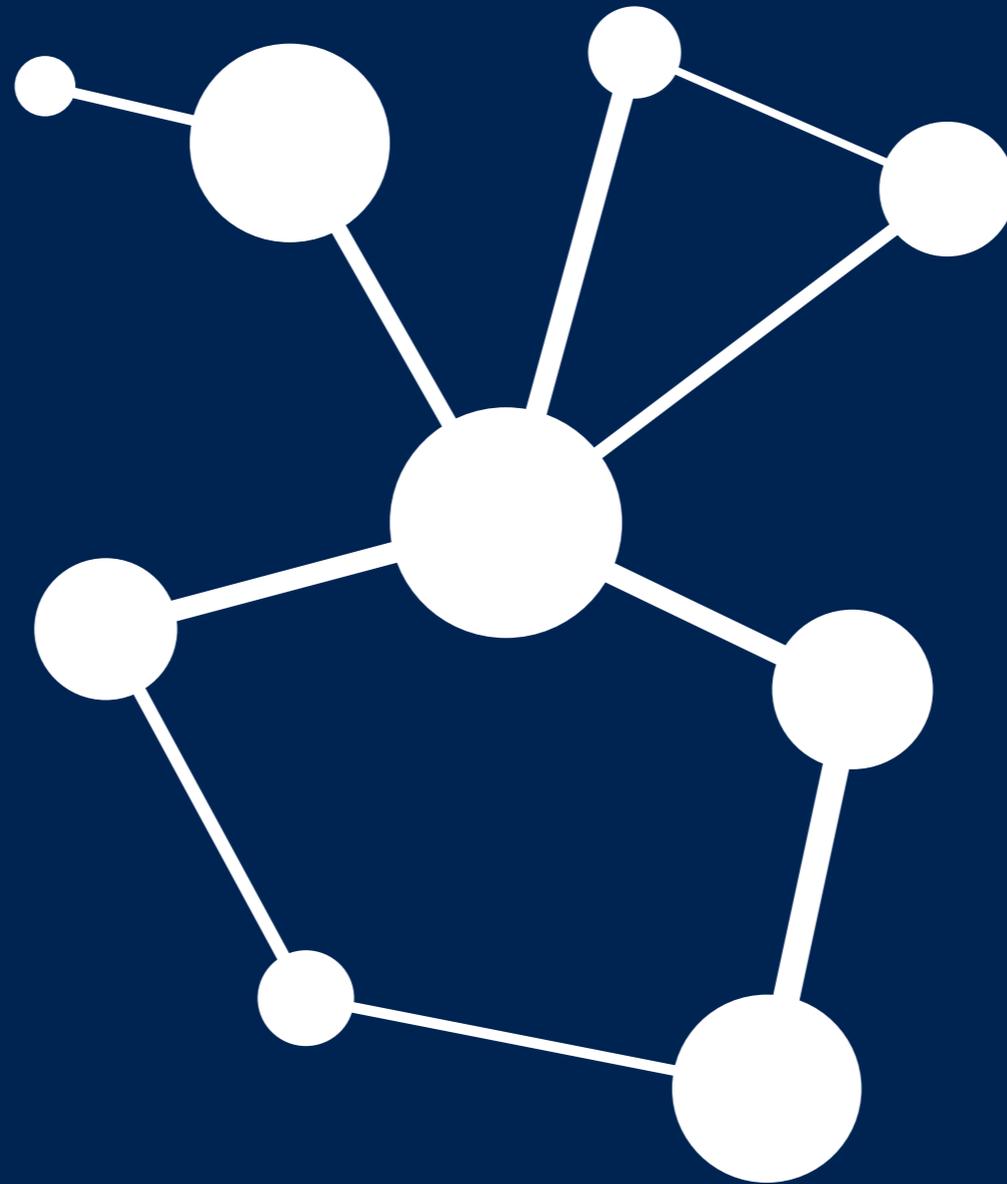


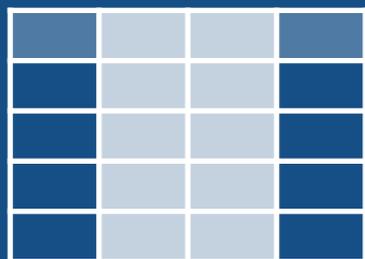
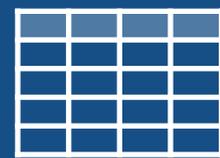
Introdução à visualização interativa de redes complexas



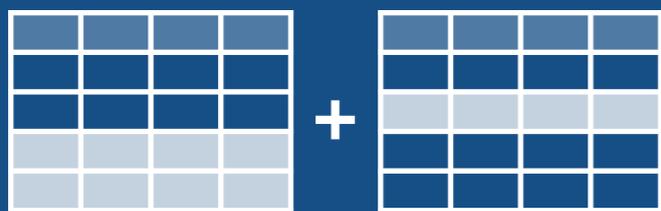
Filipi N. Silva (filipinascimento@gmail.com)

Prof. Luciano da F. Costa

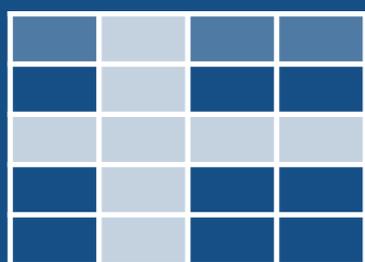
Visualização de dados



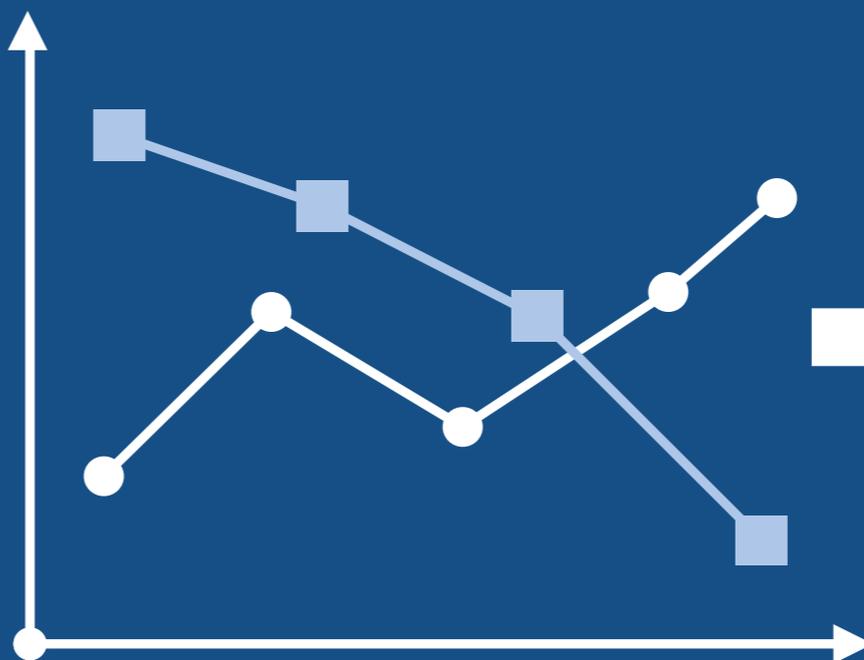
Sumarizar informação



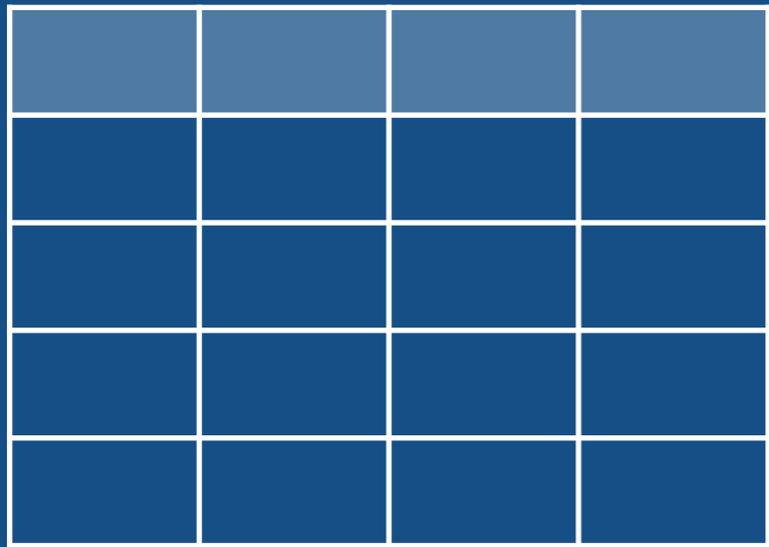
Relações entre elementos



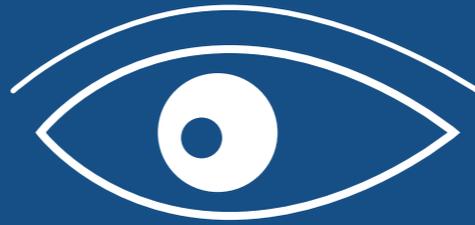
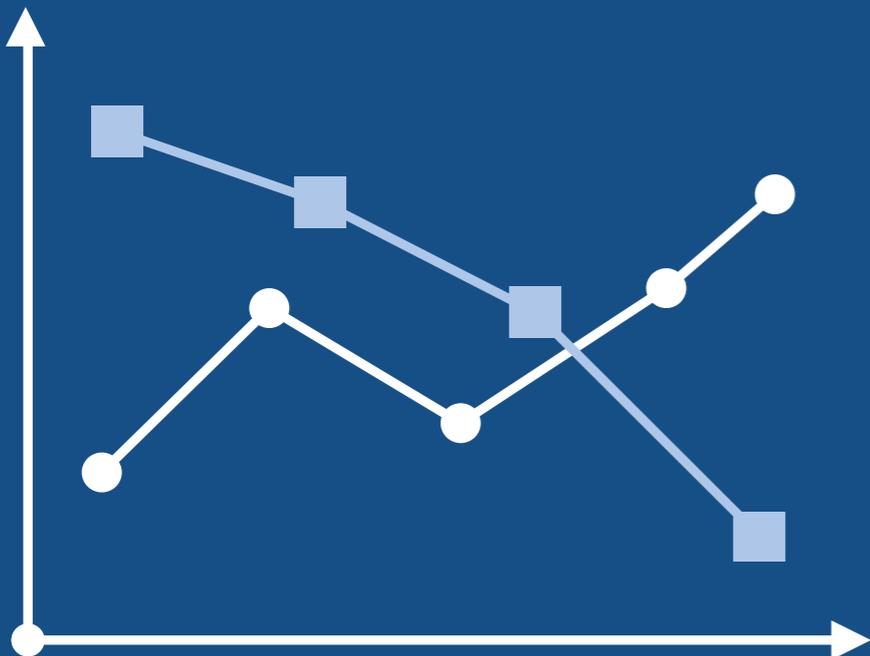
Destacar informação



Visualização de dados

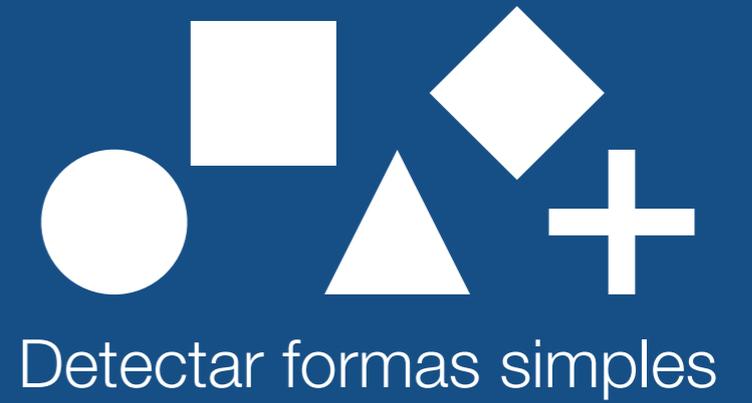


Maior tempo de resposta



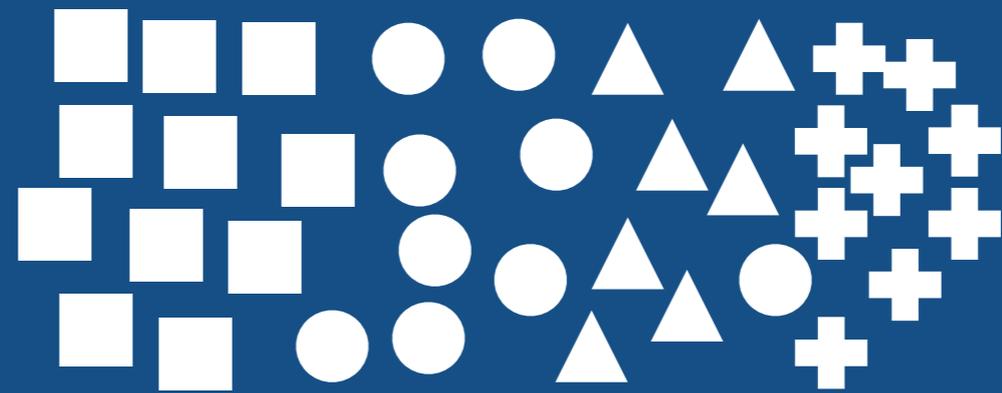
Menor tempo de resposta
maior aproveitamento
do cortex visual

Visualização de dados

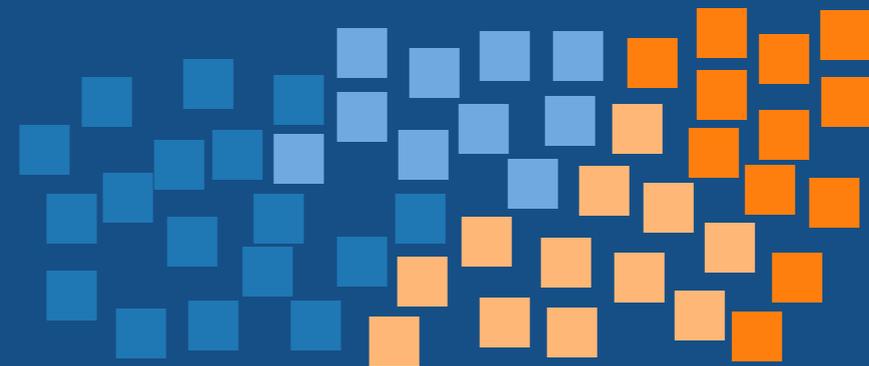


etc

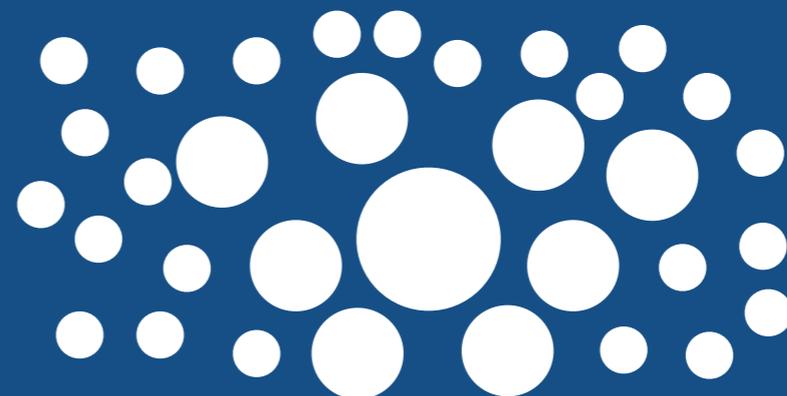
Visualização de dados



Gradiente de formas



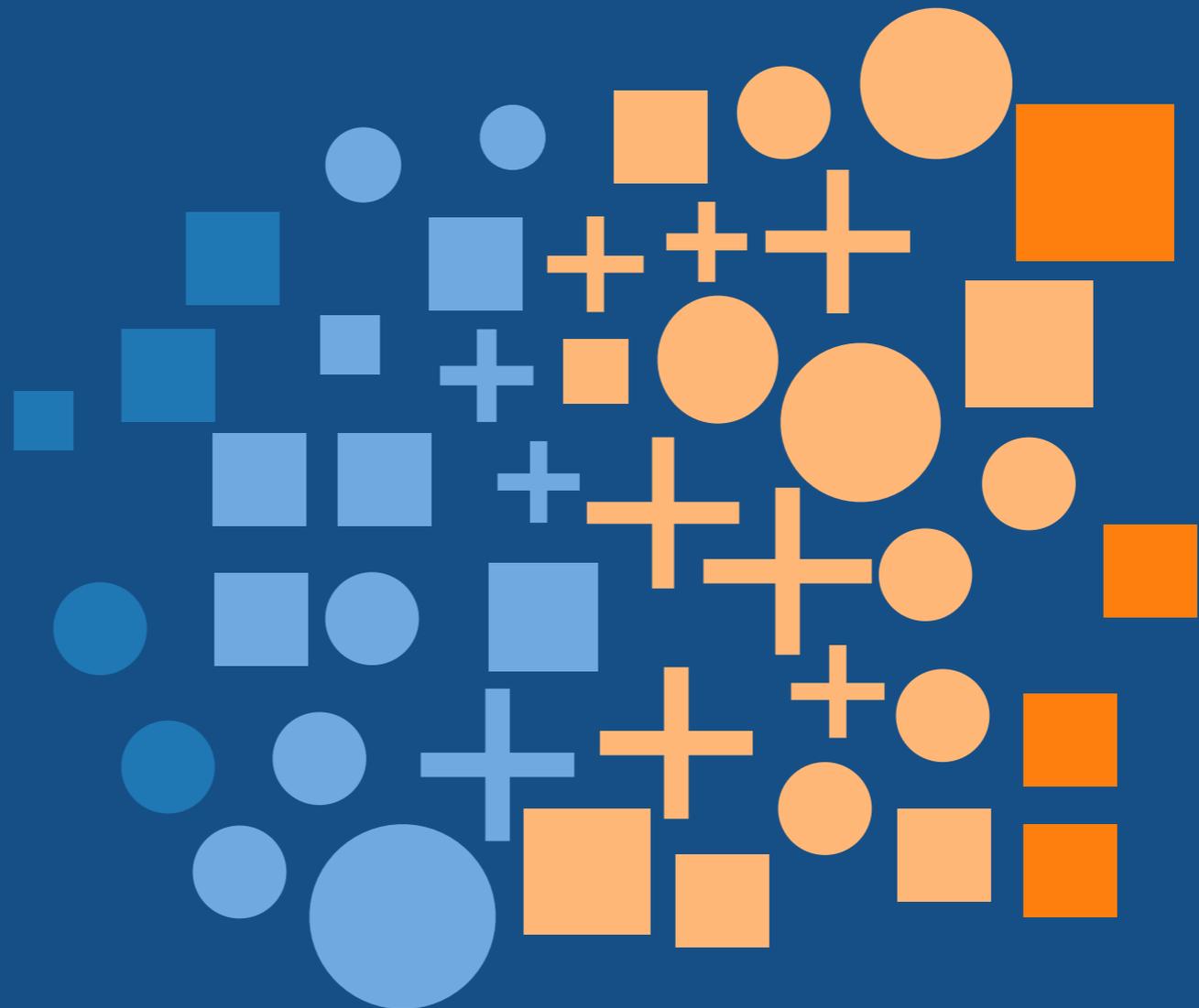
Gradiente de cores



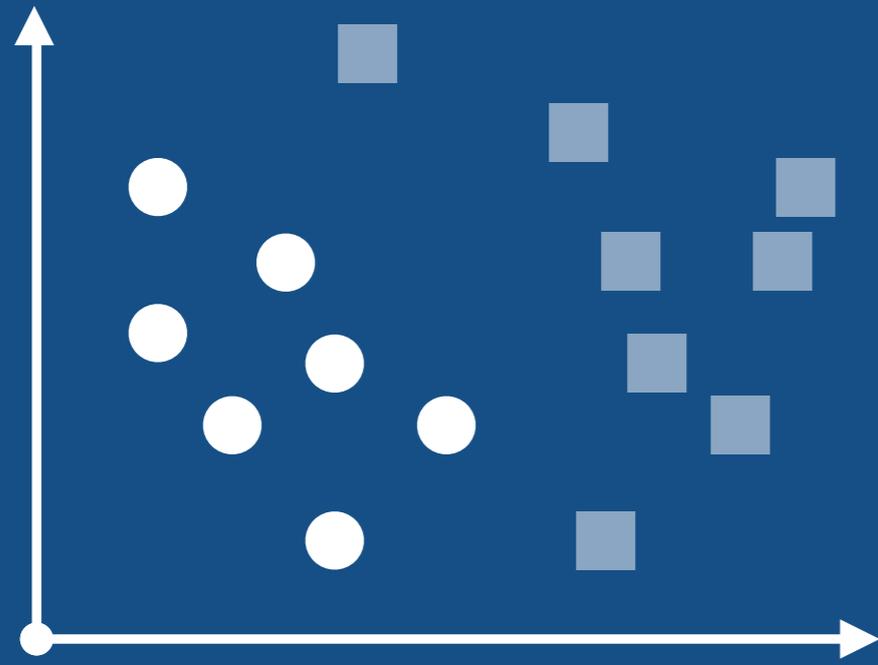
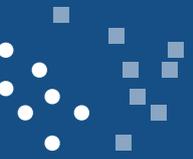
Gradiente de escala



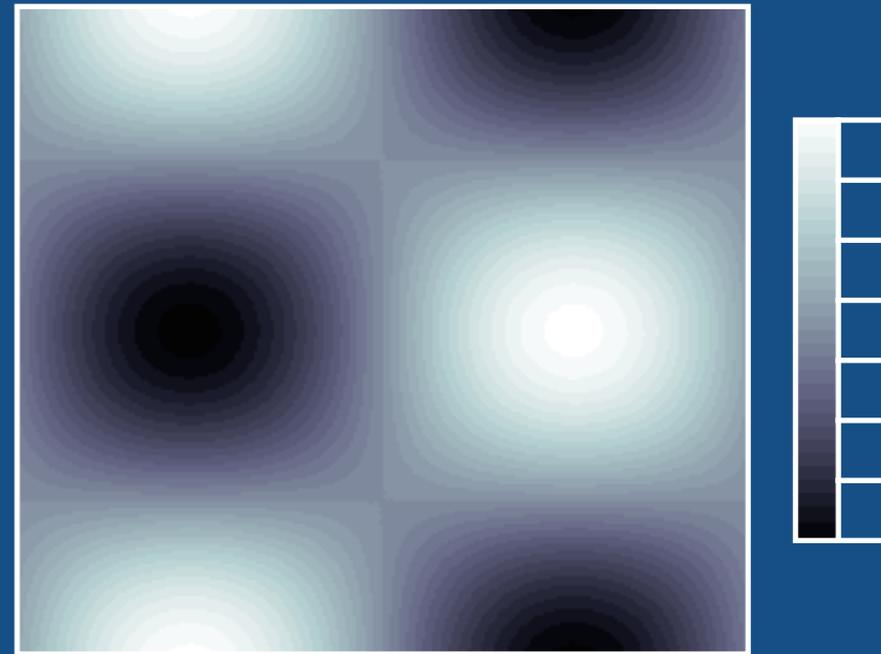
Hierarquia e confusão visual
Tentem identificar os padrões



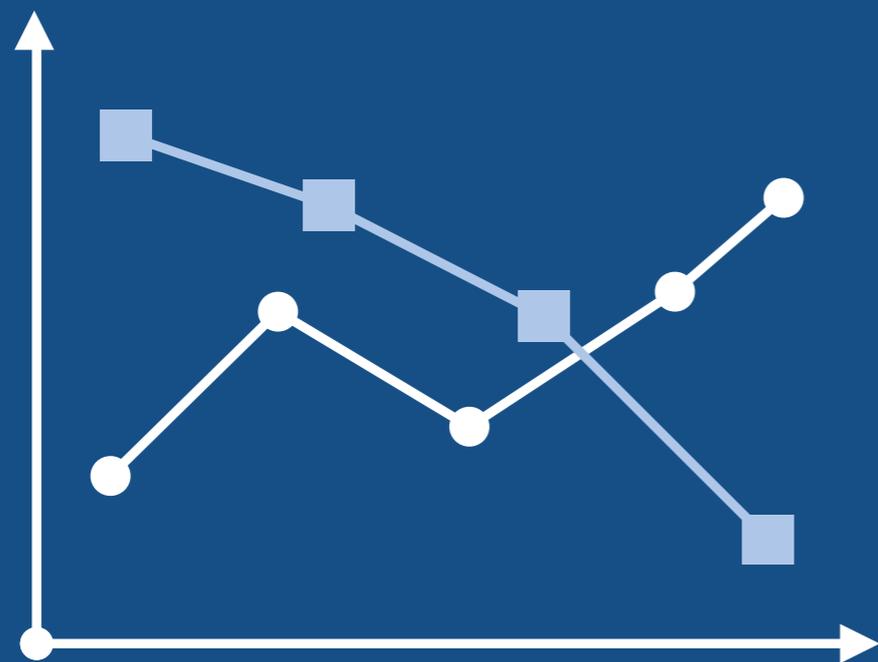
Tipos de visualização de dados



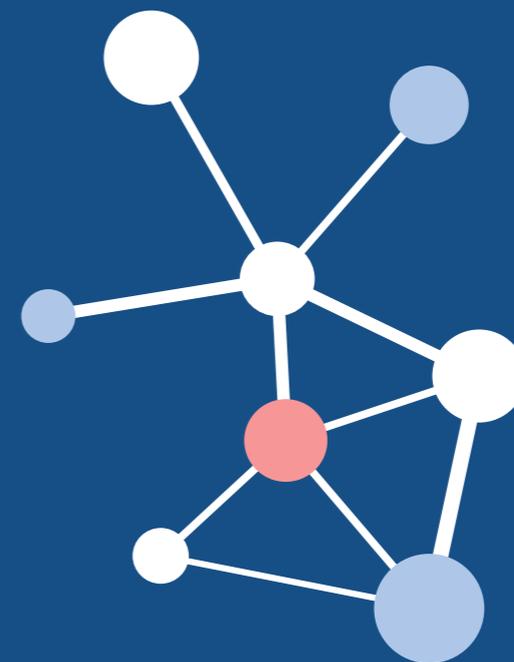
Scatter plots



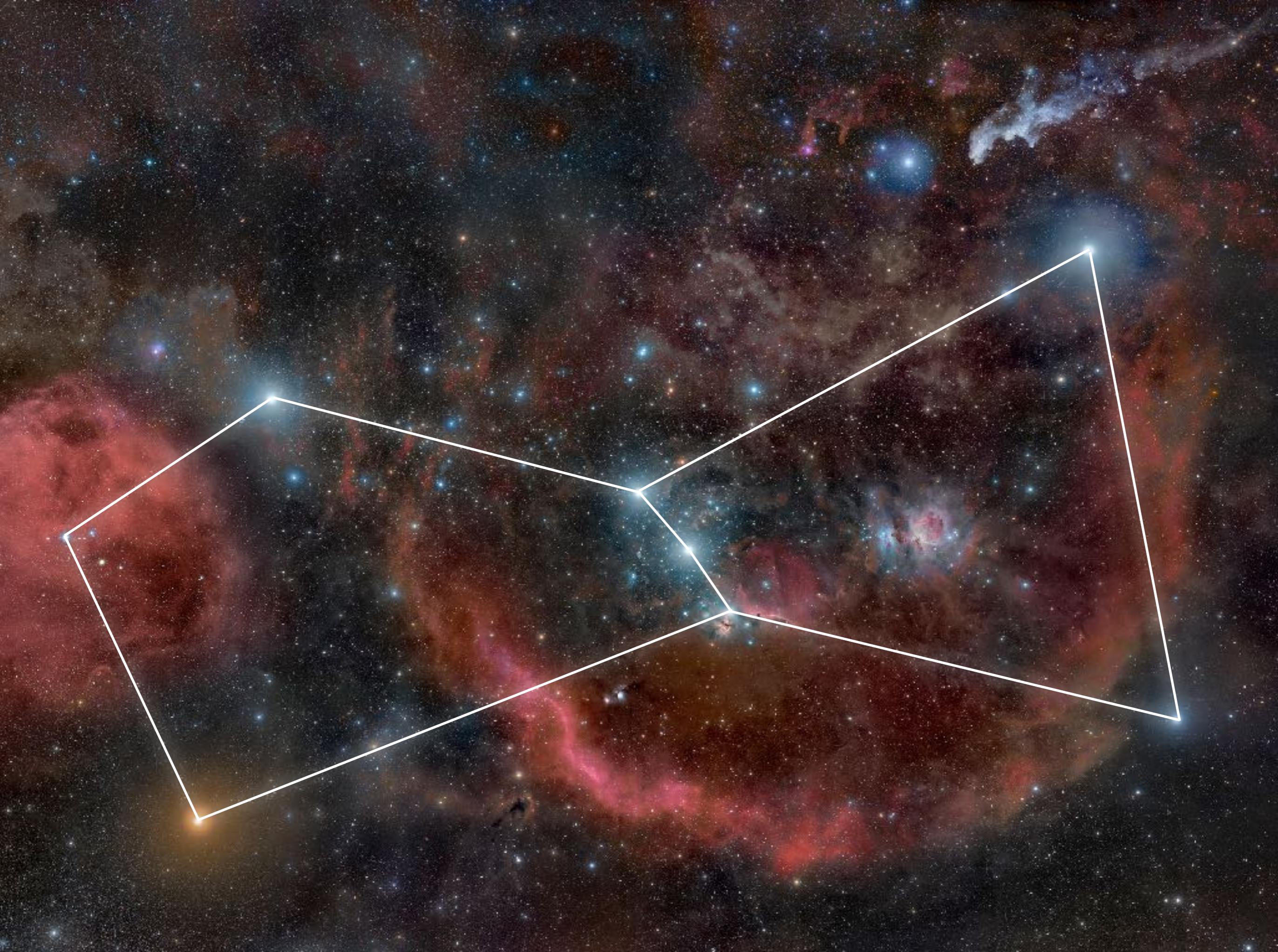
Mapas de superfície

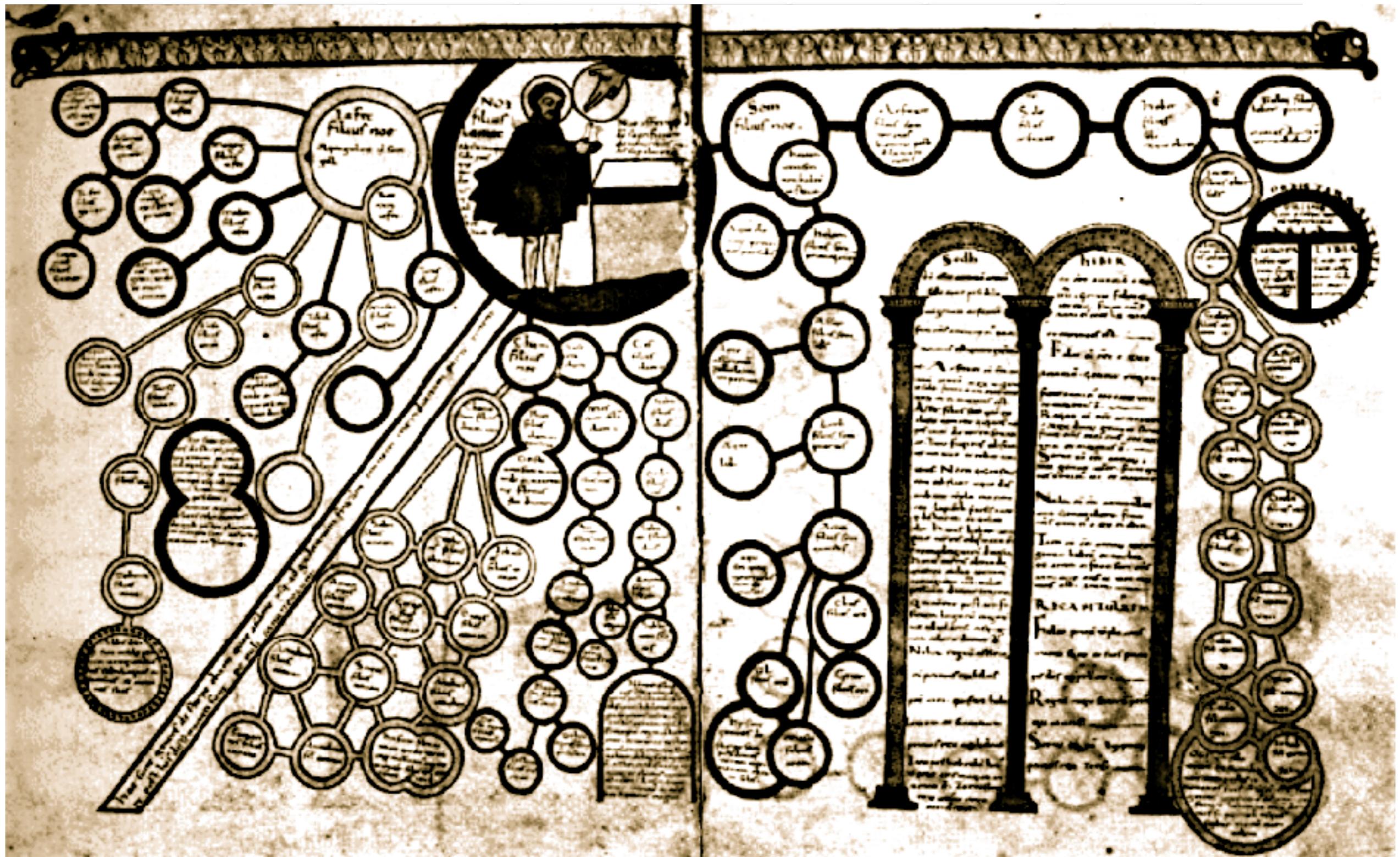


Séries temporais e eixos paralelos



Grafos

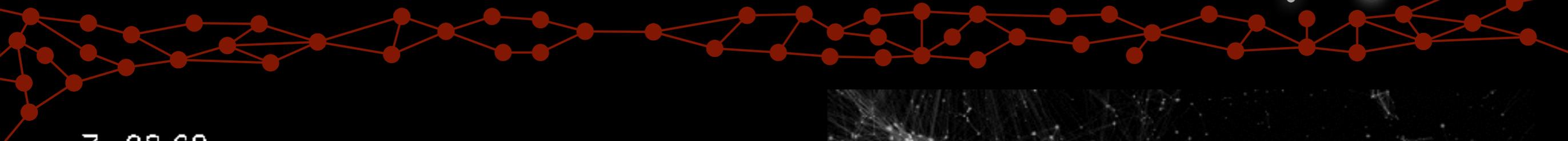
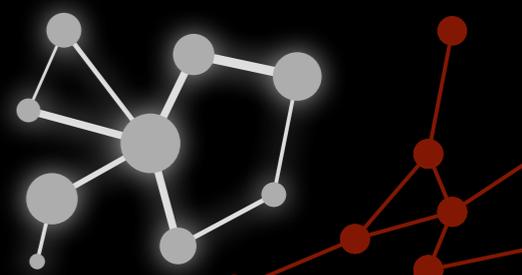




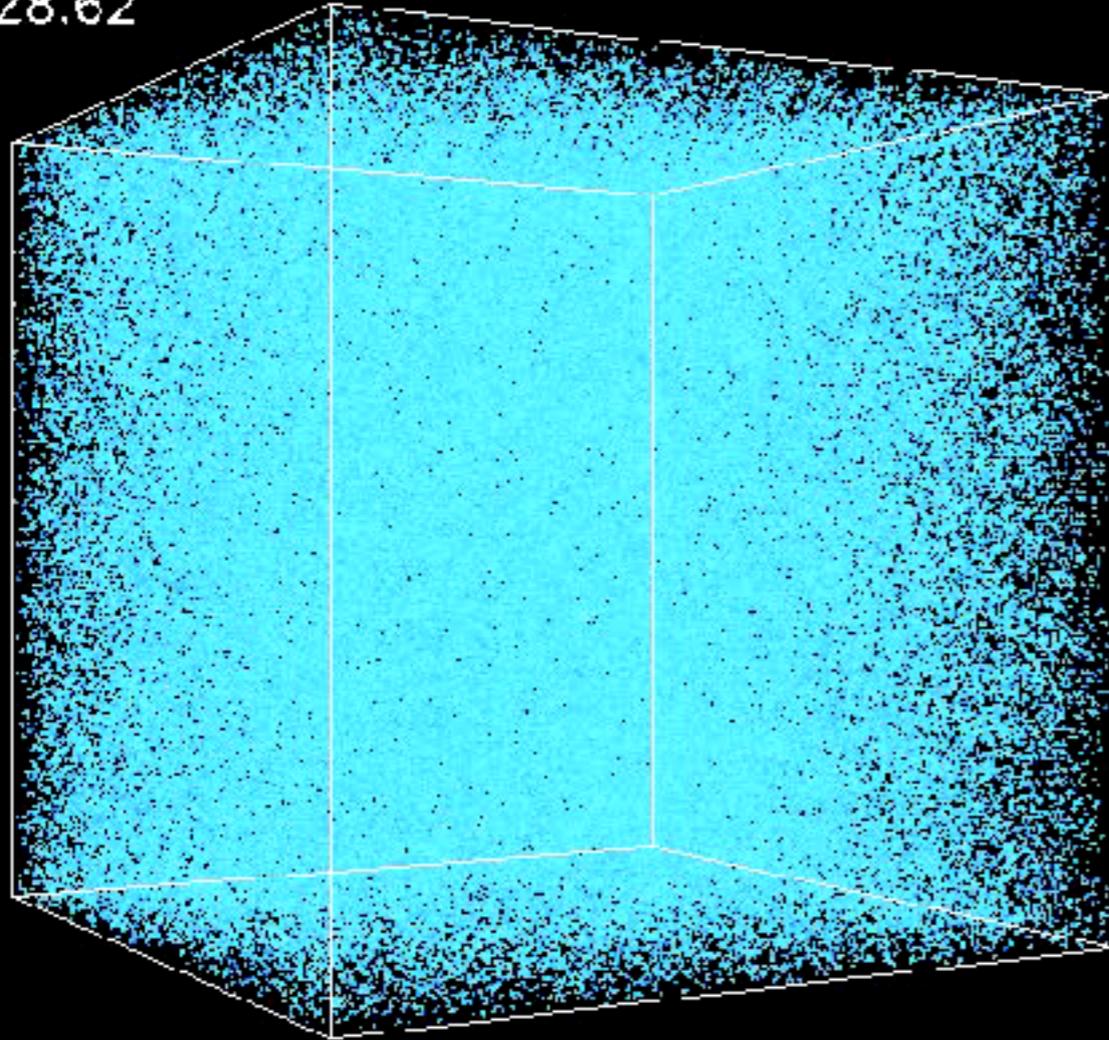
Descendentes de Noé - séc. XI (domínio público)

Kabbalah - séc. XVI (domínio público)

Exemplos de redes complexas

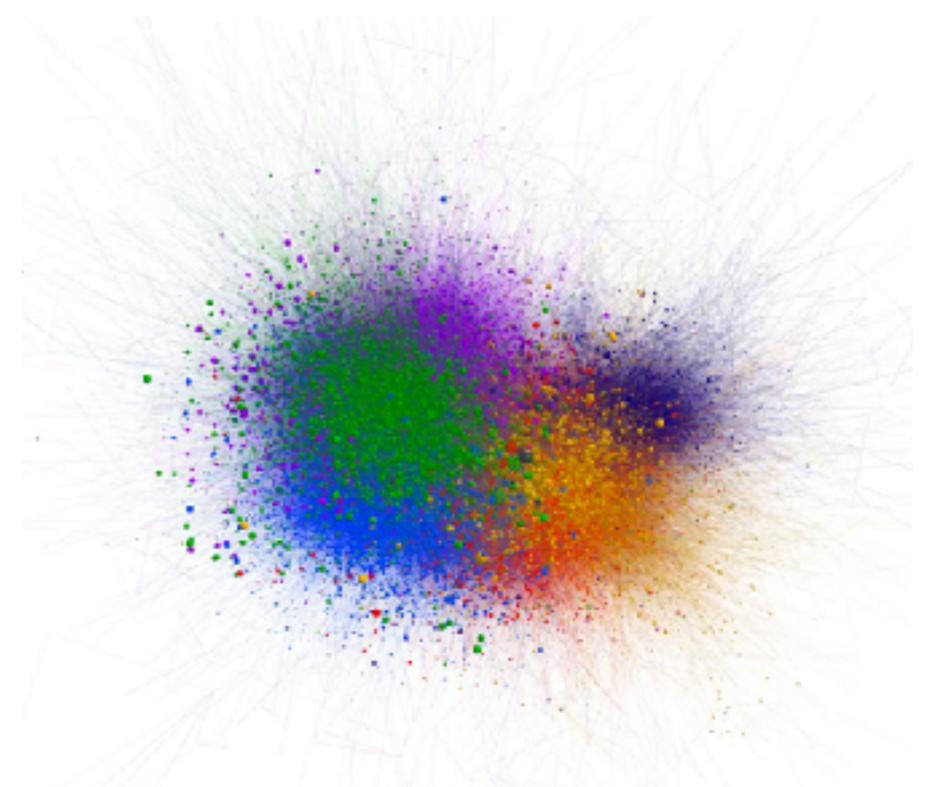
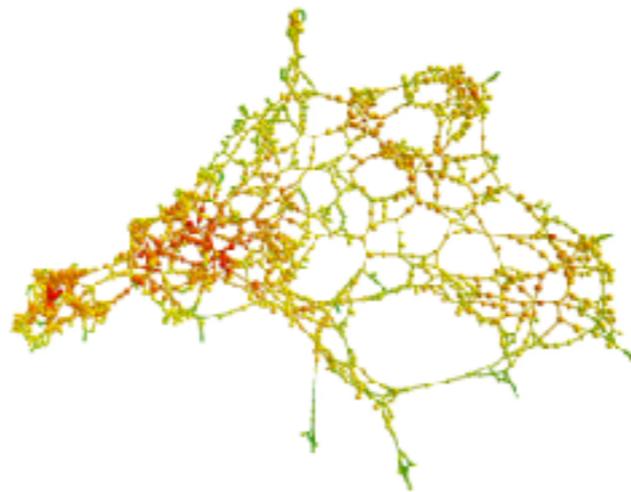
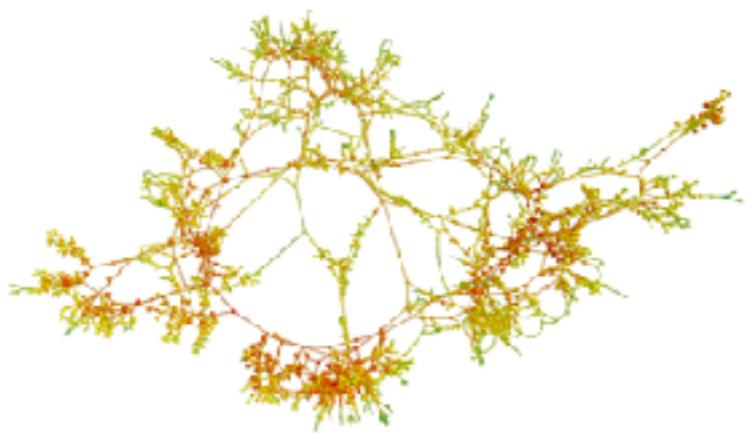
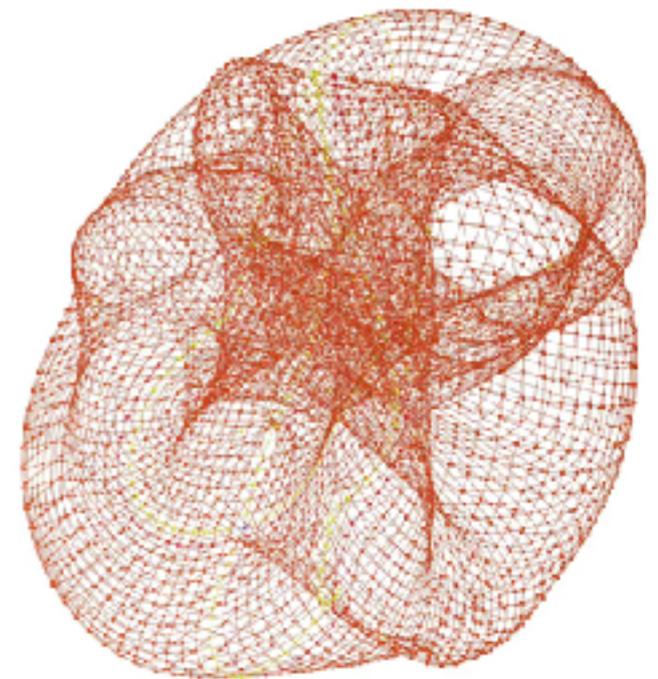
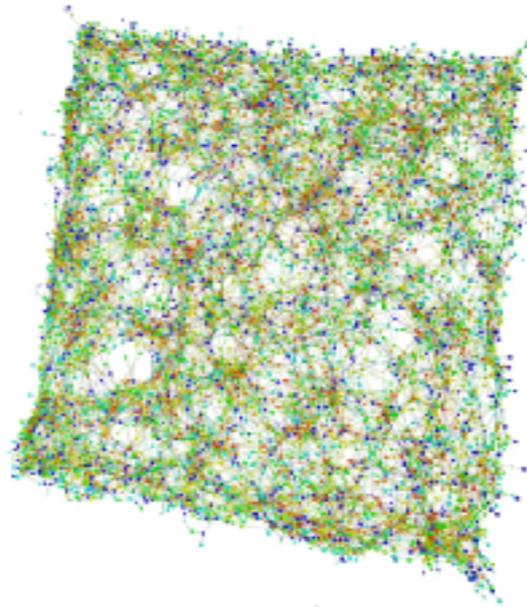
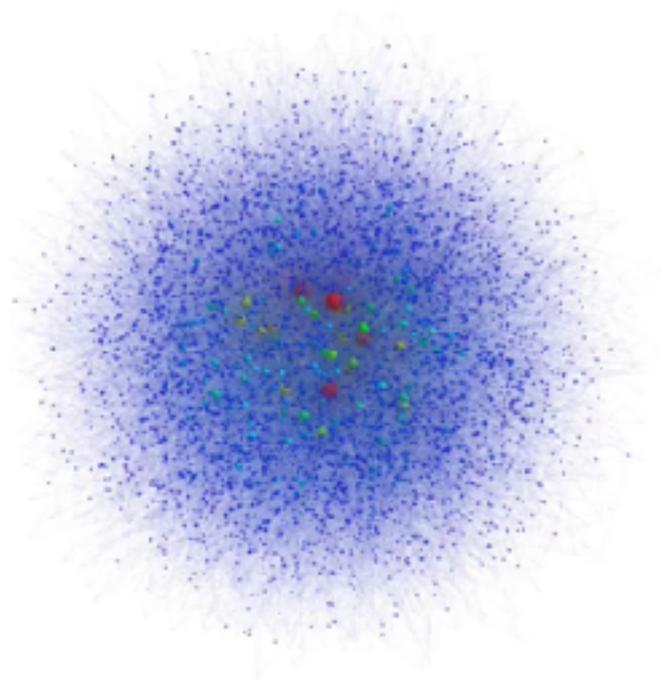


$Z=28.62$

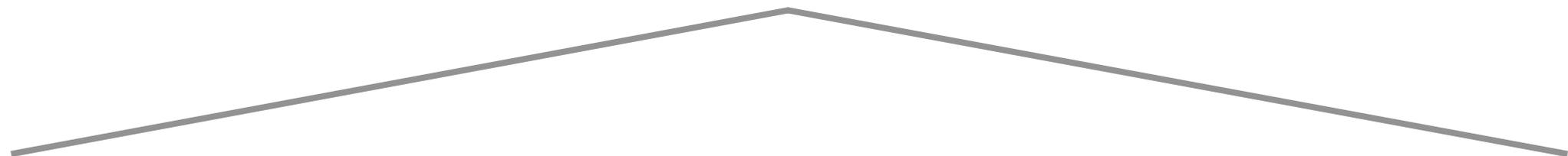
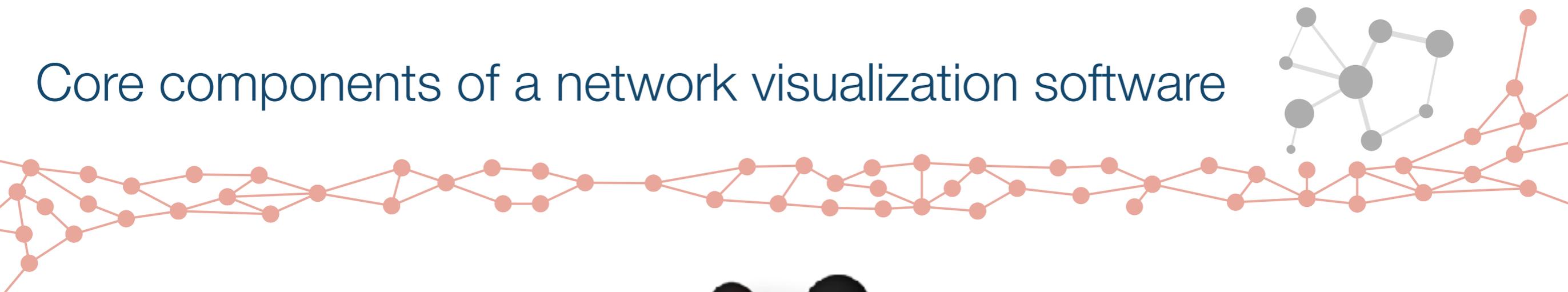


Simulação gerada por:
National Center for Supercomputer Applications
Andrey Kravtsov
(The University of Chicago)
e Anatoly Klypin
(New Mexico State University).

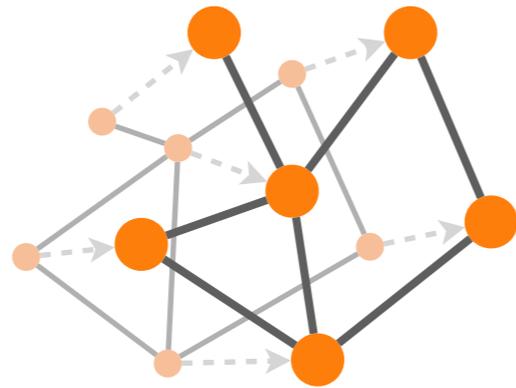
Coutinho, B. C., Hong, S., Albrecht, K., Dey, A., Barabási, A. L.,
Torrey, P., ... & Hernquist, L. (2016). The Network Behind the
Cosmic Web. *arXiv preprint arXiv:1604.03236*.



Core components of a network visualization software



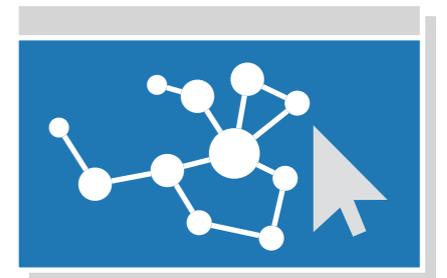
Graph Library



Layout

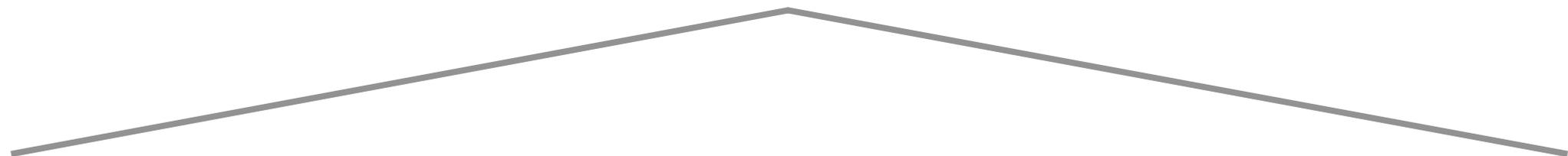
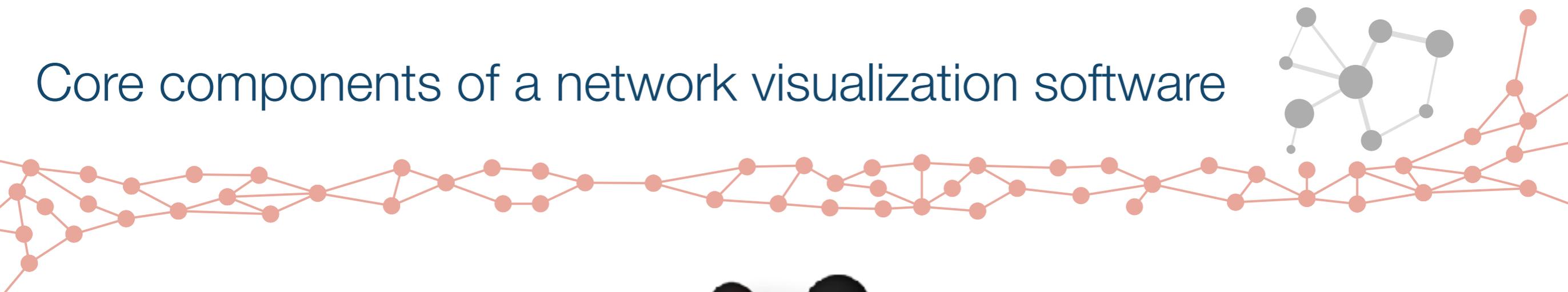


Rendering

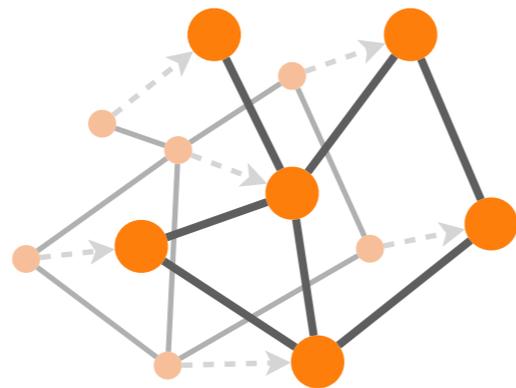


Interface

Core components of a network visualization software



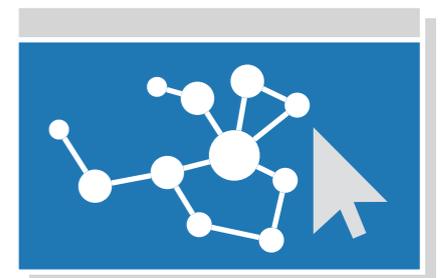
Graph Library



Layout

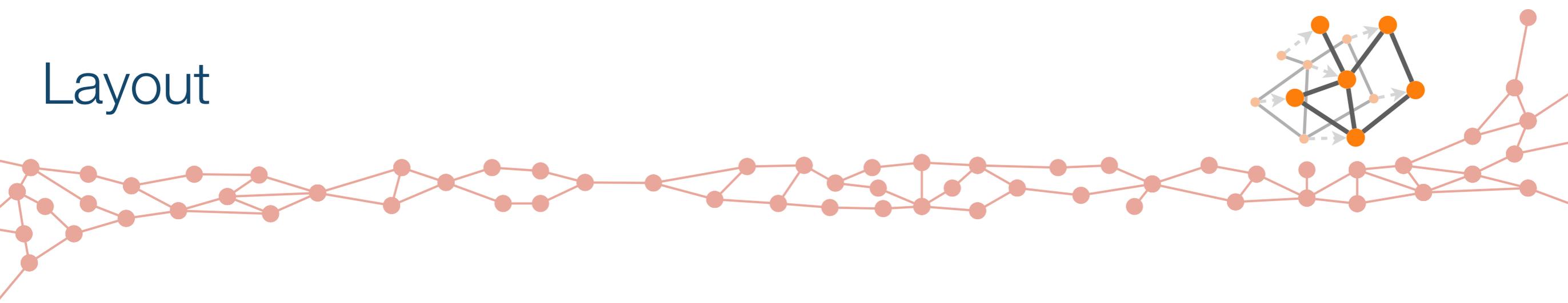


Rendering



Interface

Layout

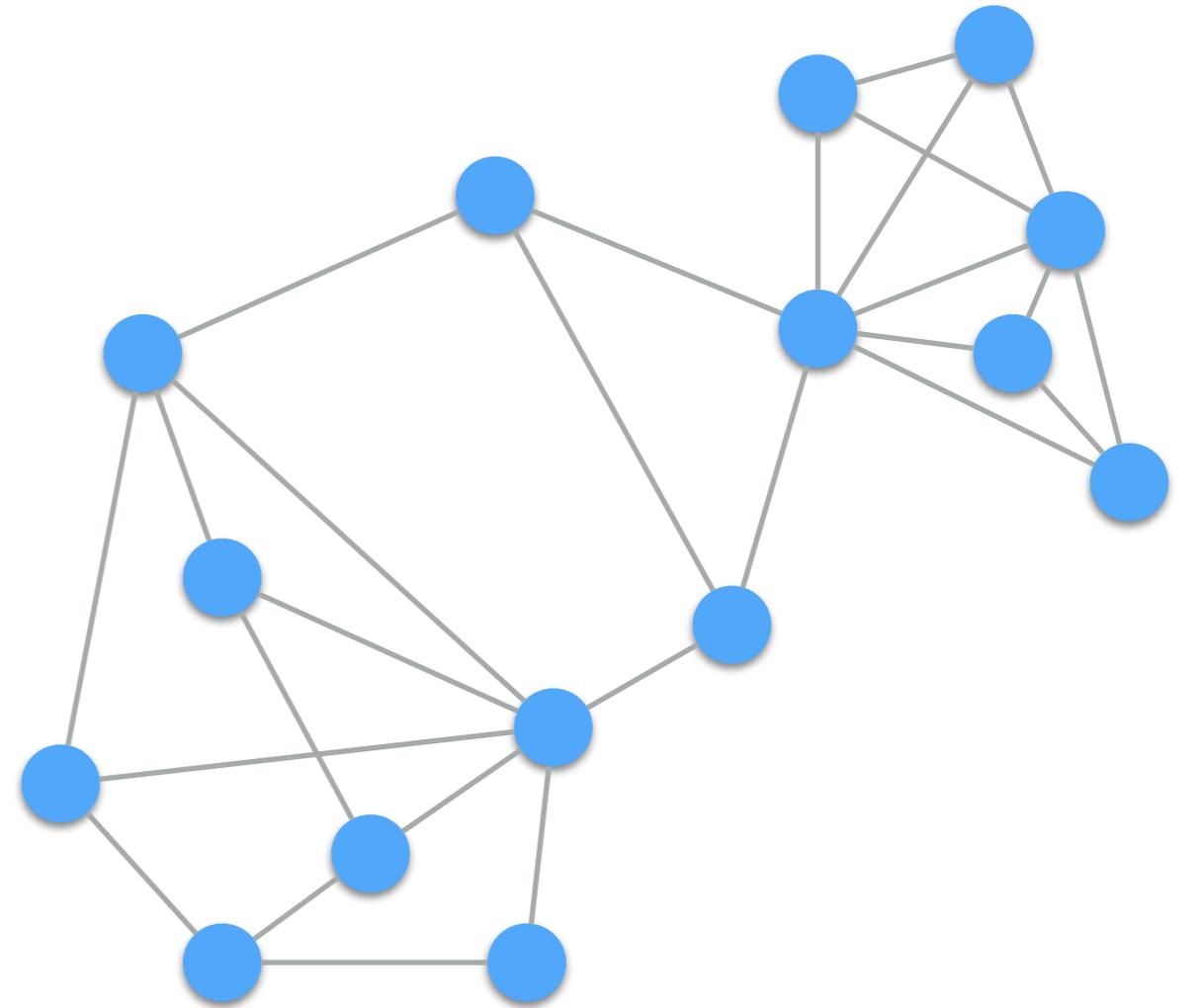


\mathcal{N}

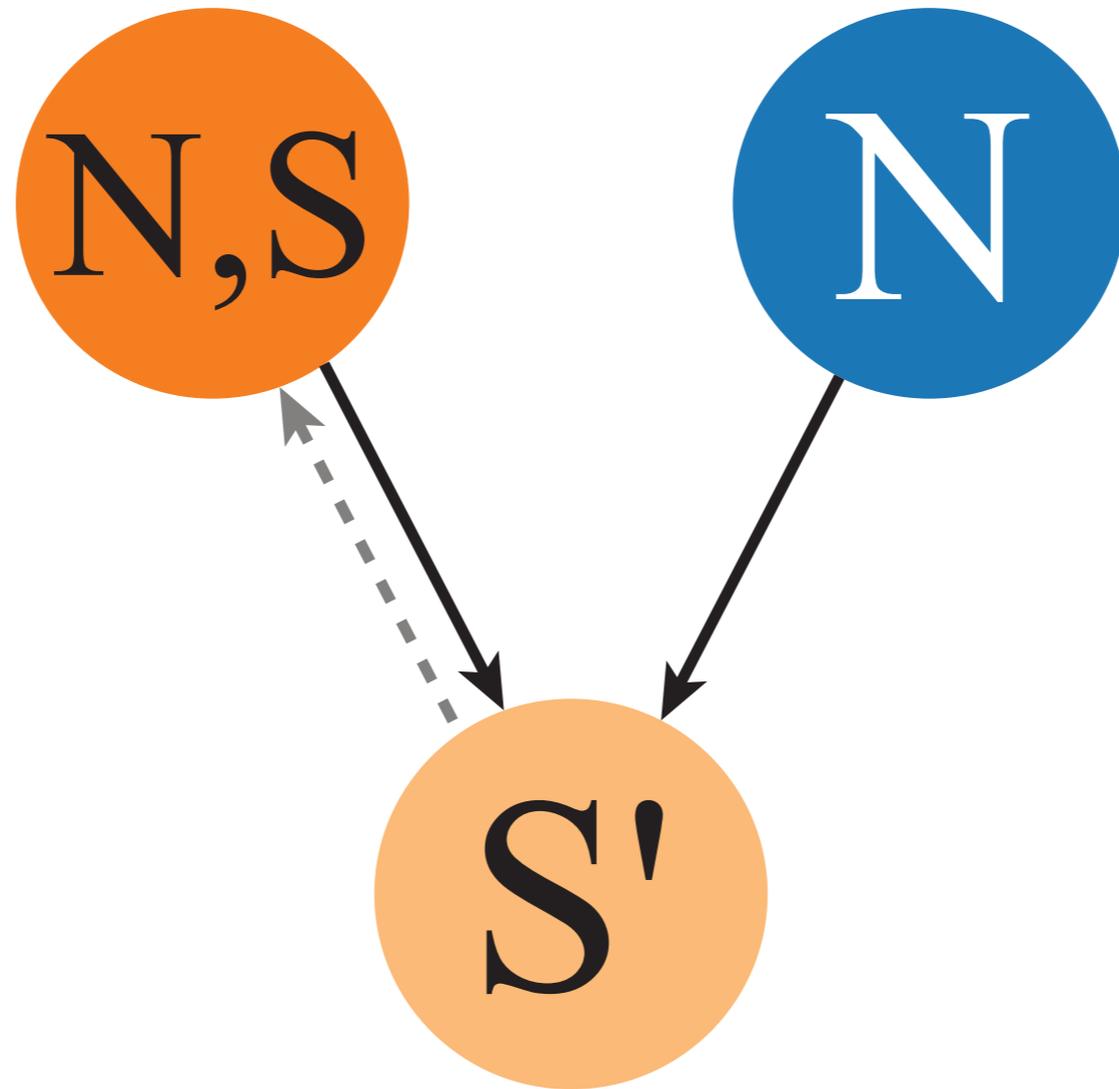
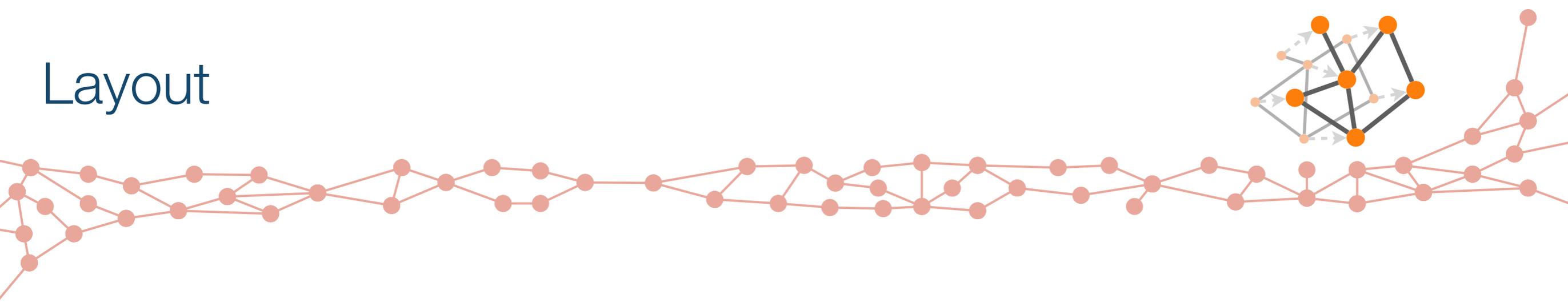
0	1	1		
	0			
1		0	1	...
		1	0	1
1			1	0
	⋮			⋮



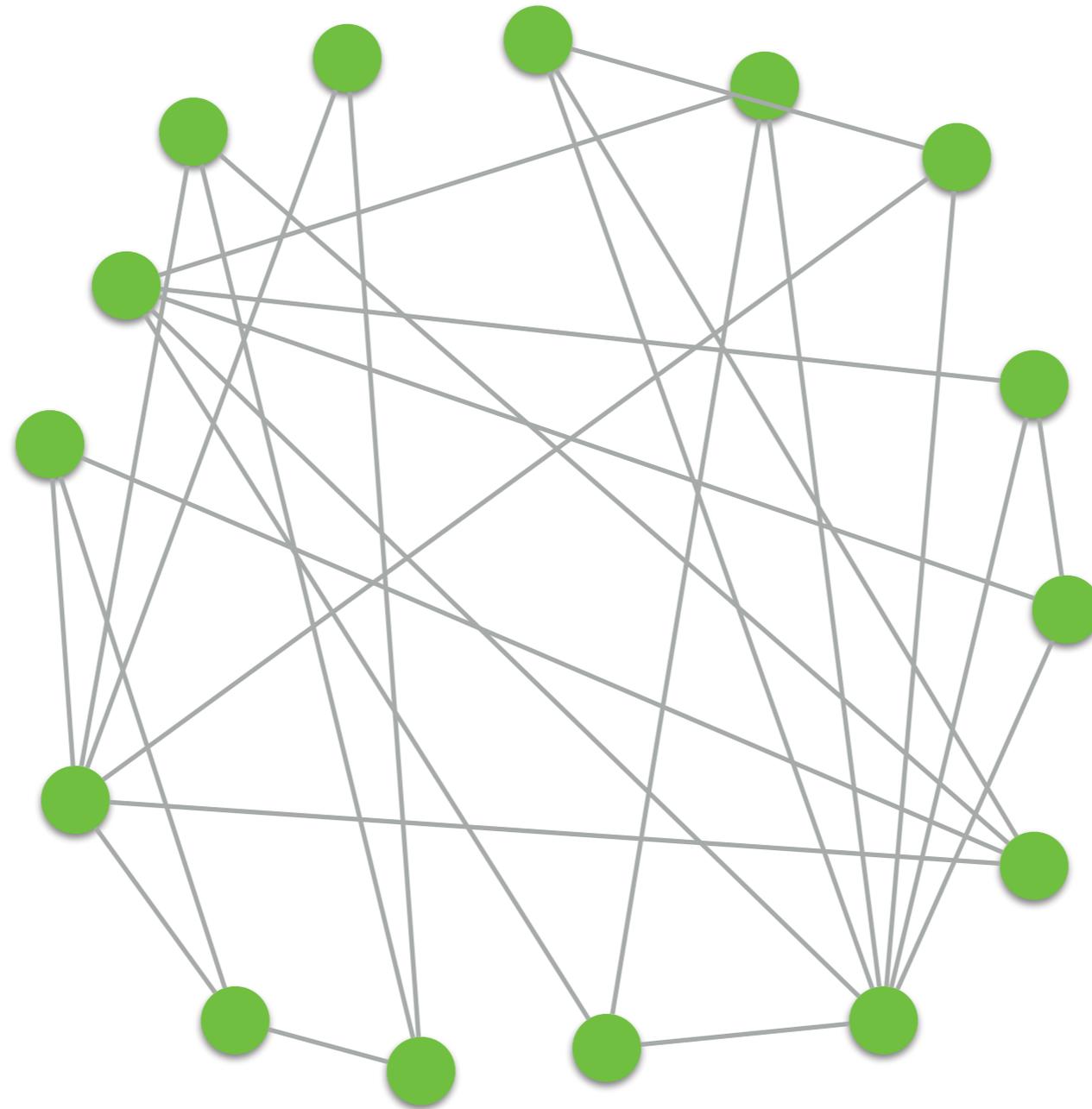
\mathcal{S}'



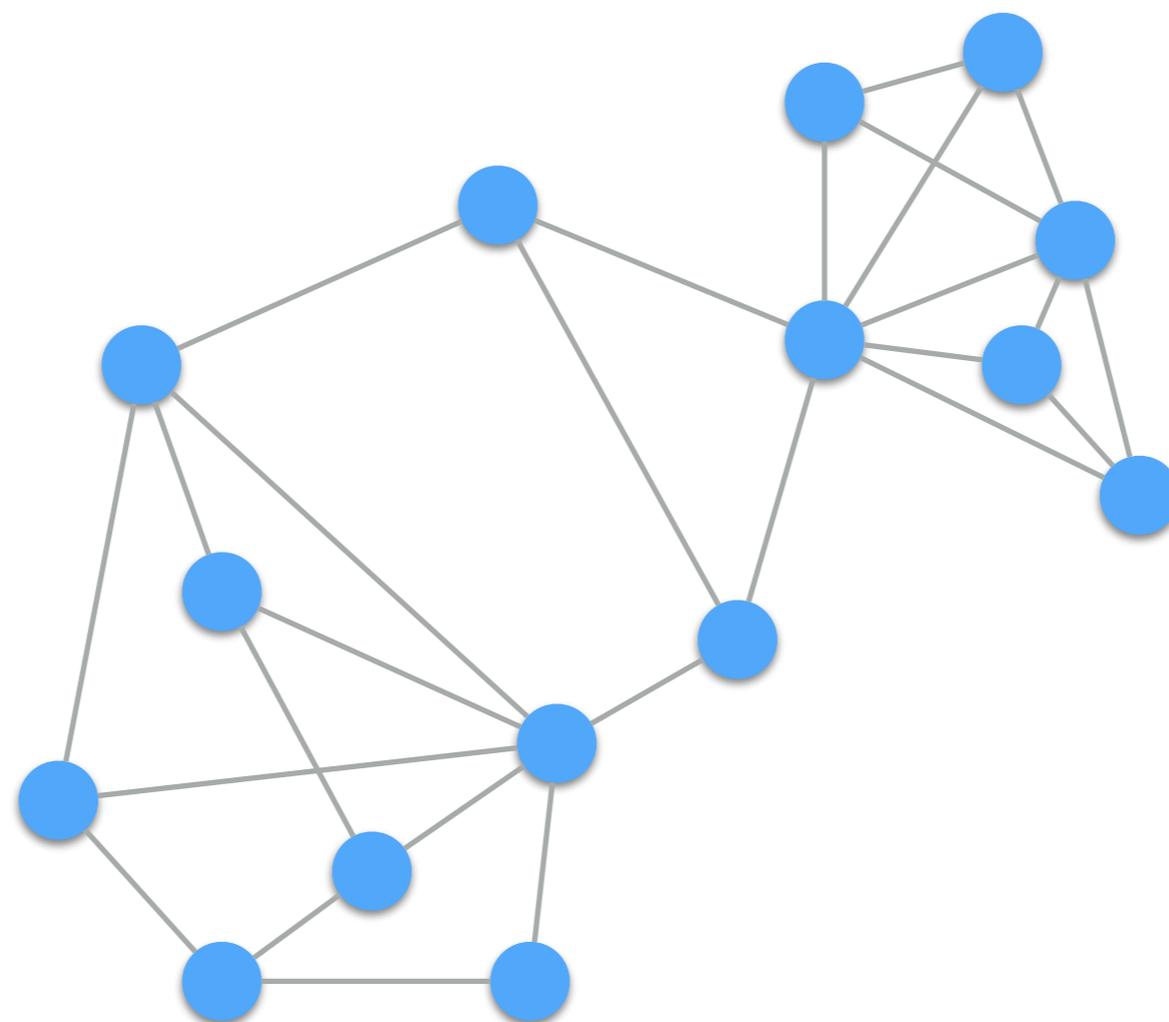
Layout



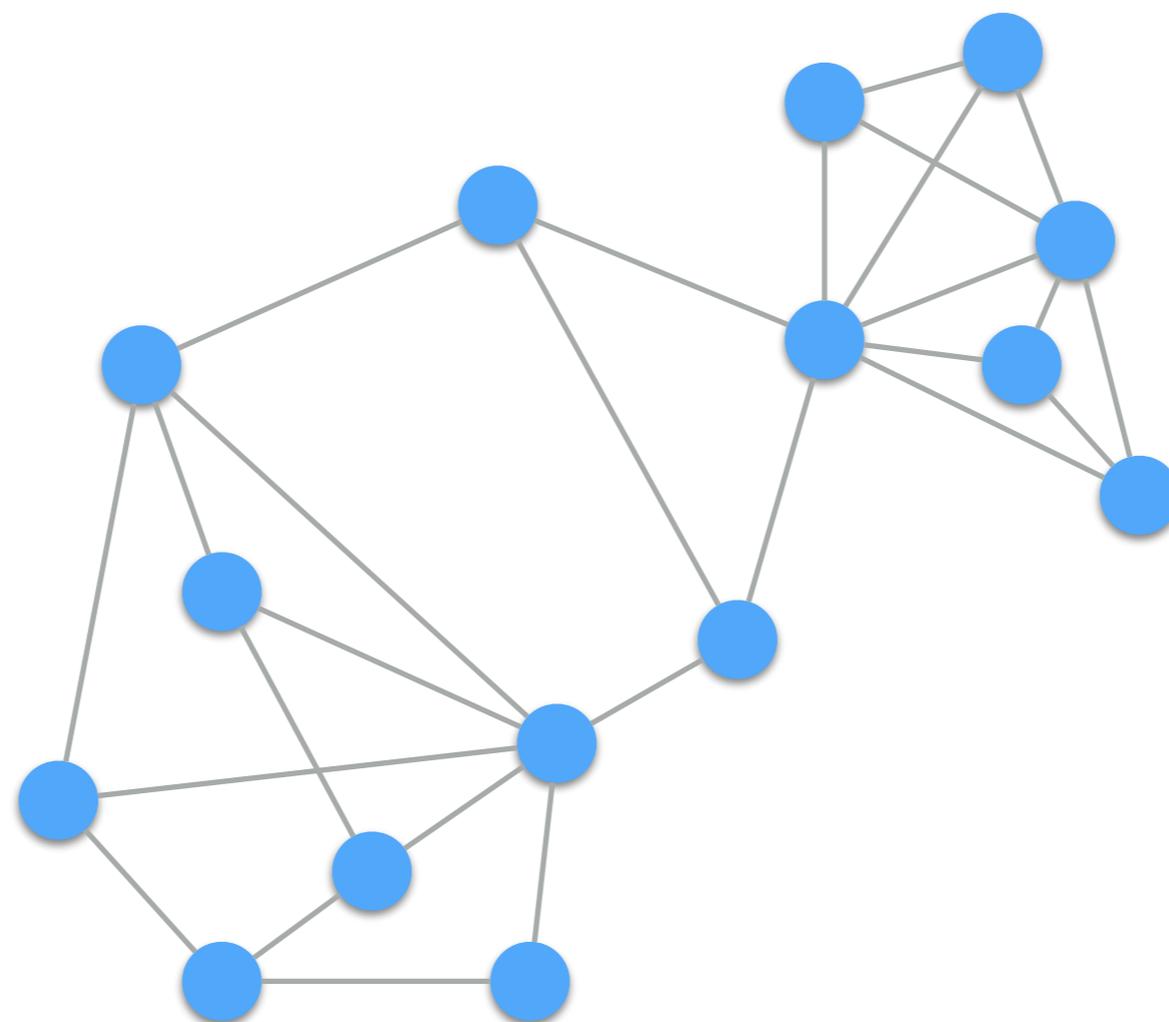
Visualização de redes complexas



Visualização de redes complexas



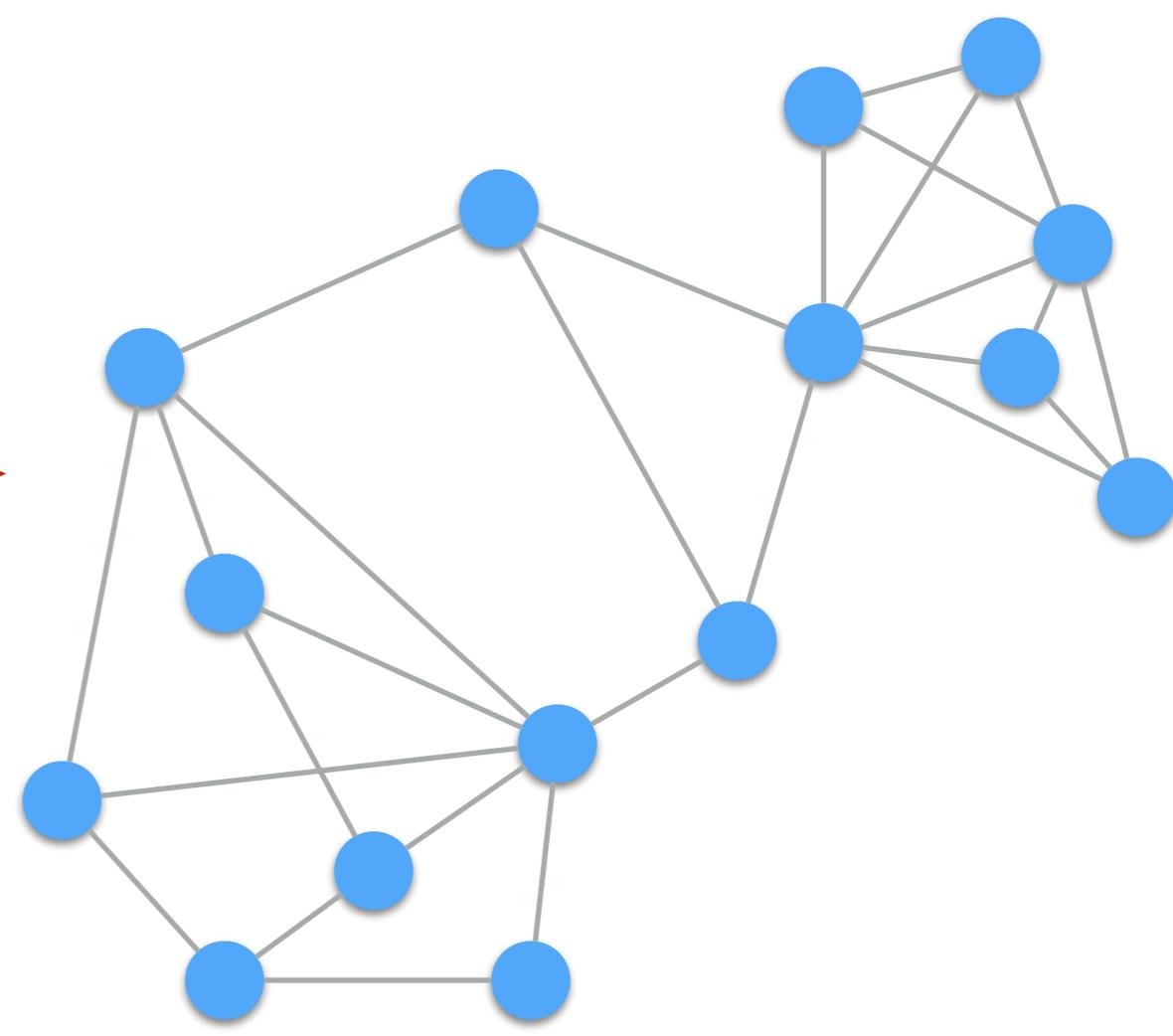
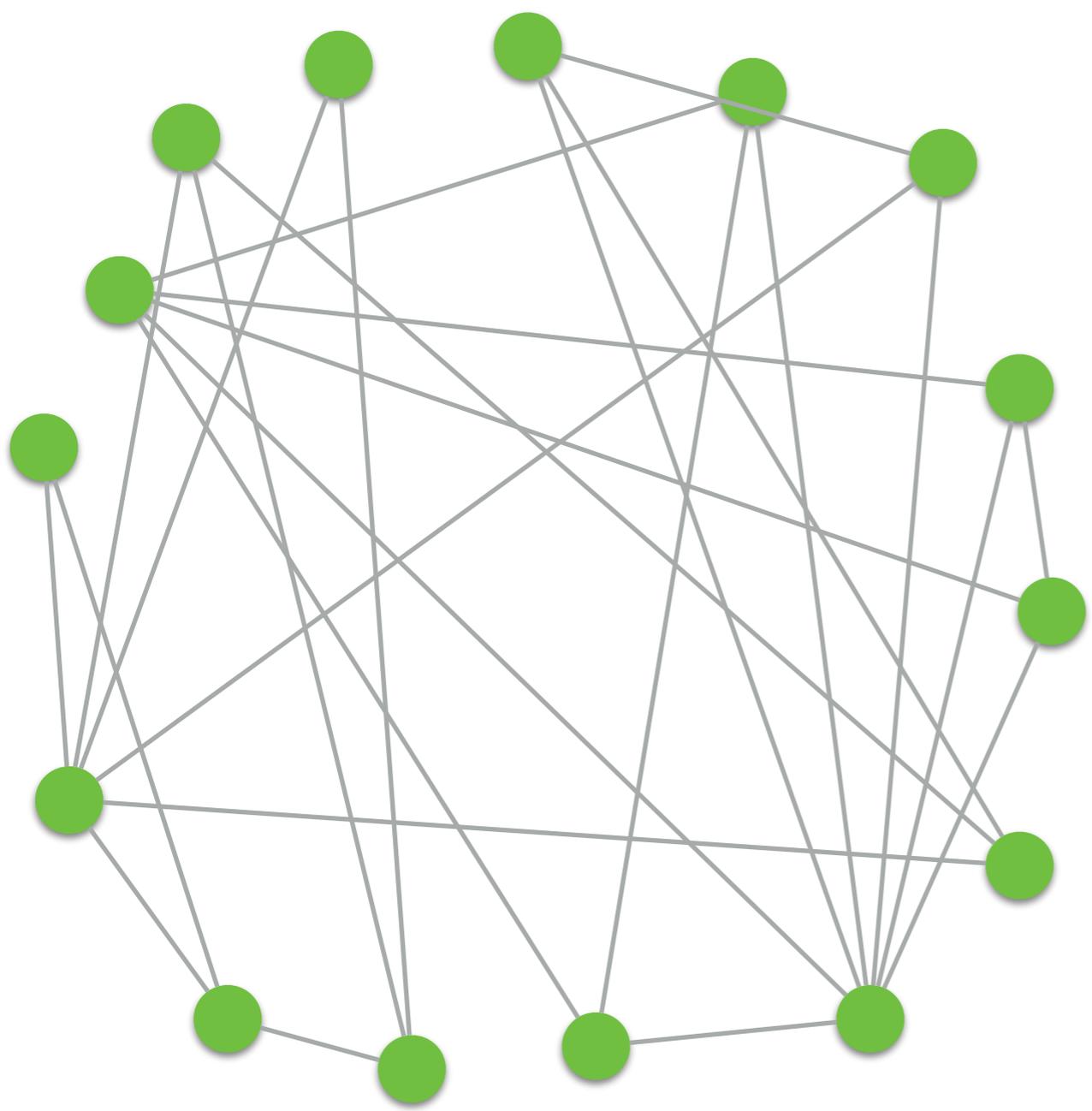
Visualização de redes complexas



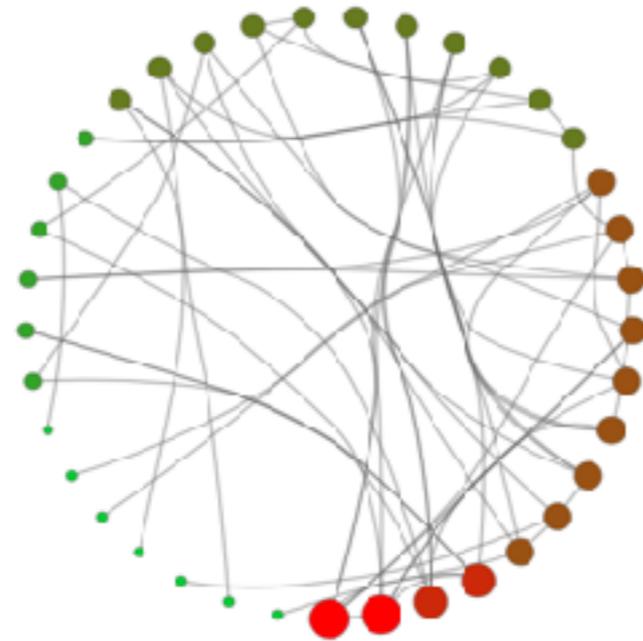
Visualização de redes complexas



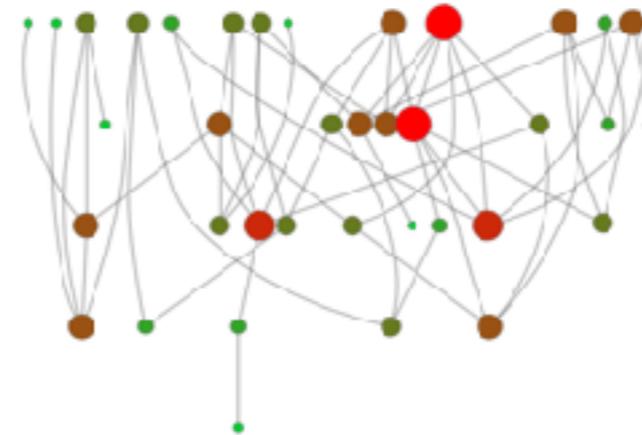
Visualização de redes complexas



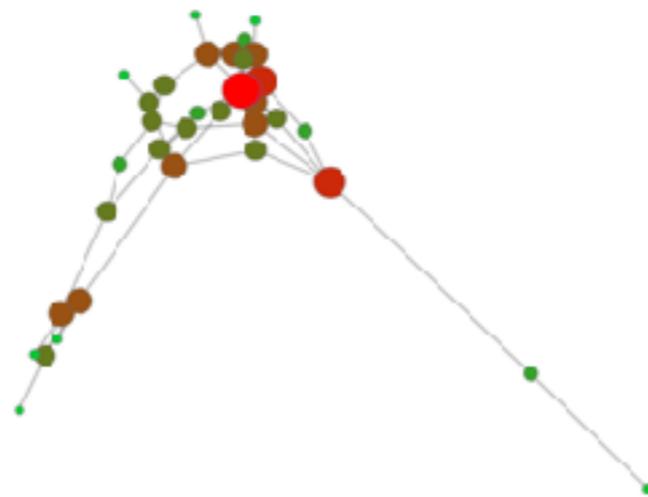
Visualização de redes complexas



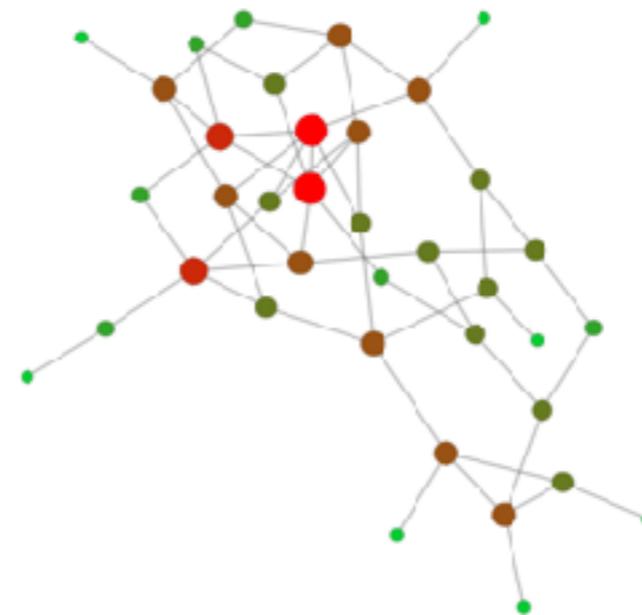
(a) Circular layout



(b) Hierarchical layout



(c) Spectral layout



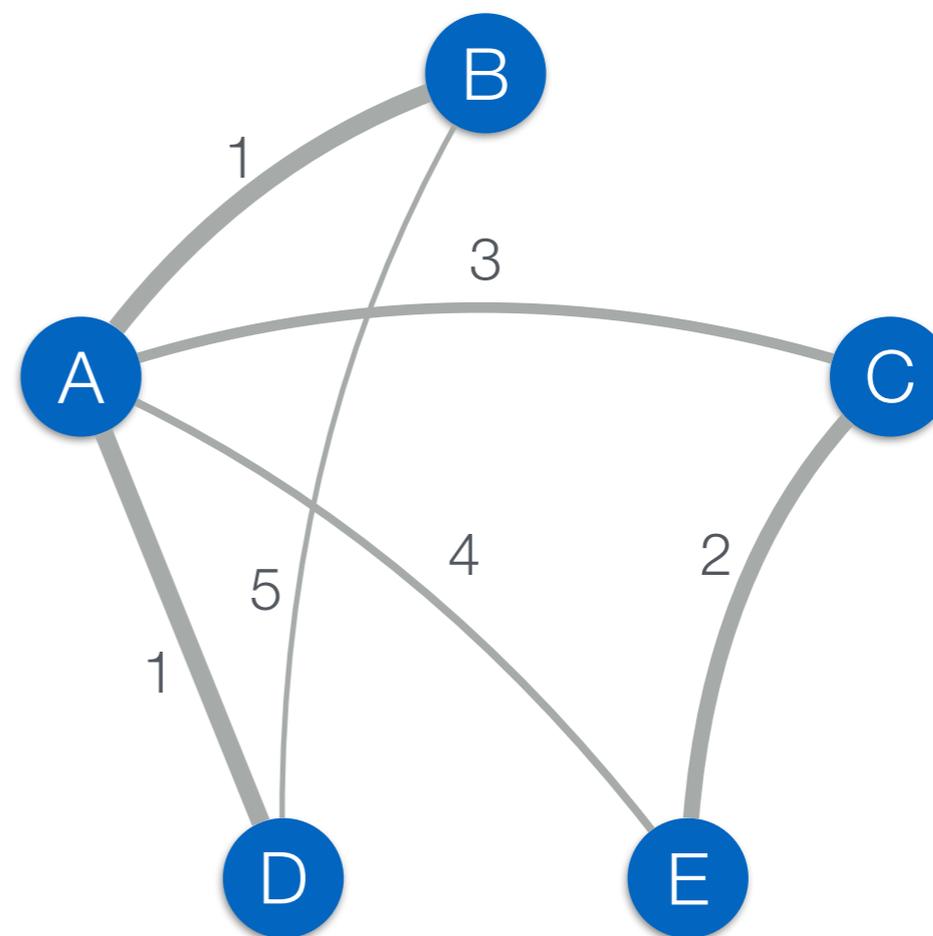
(d) Force-directed layout

Visualização de redes complexas

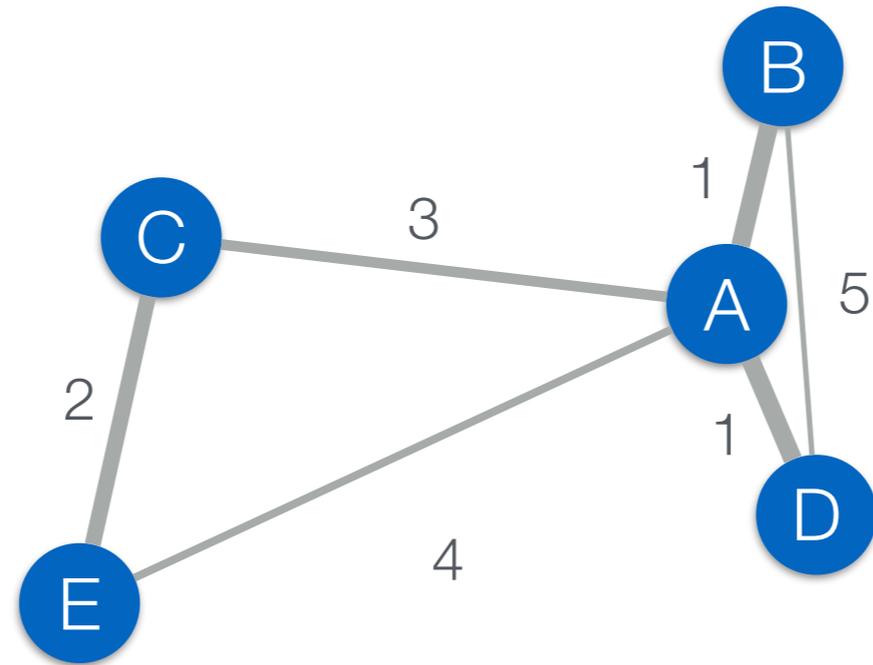


Matriz de distâncias

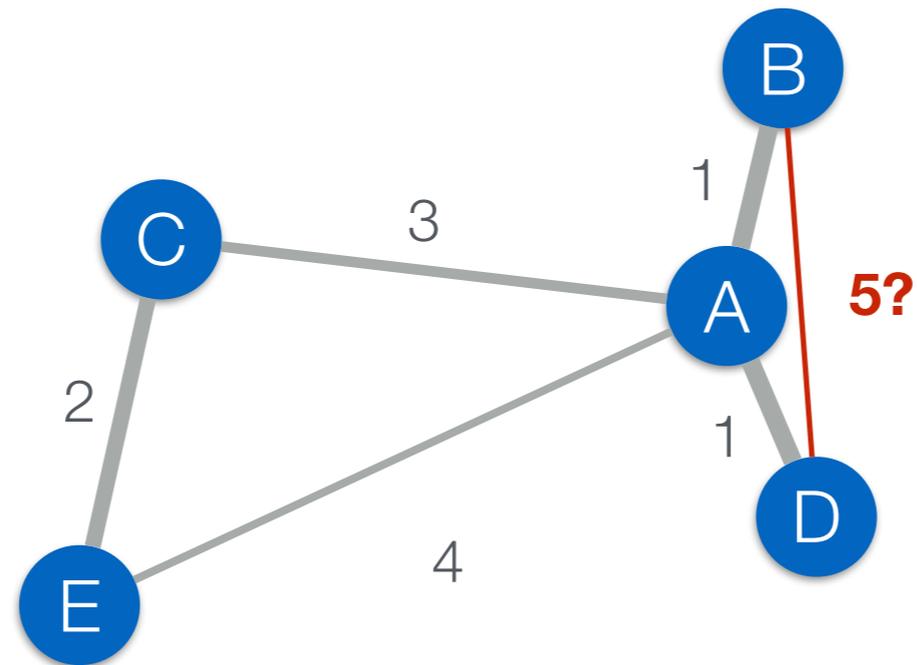
	A	B	C	D	E
A	0	1	3	1	4
B	1	0		5	
C	3		0		2
D	1	5		0	
E	4		2		0



Método direcionado por forças



Método direcionado por forças

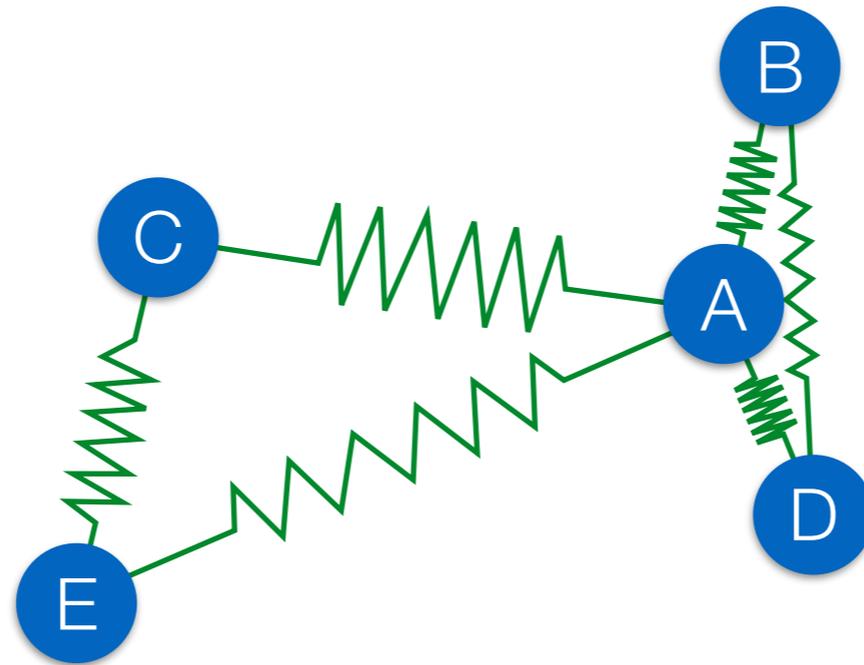


Conseguem imaginar um método físico para resolver o problema?

Método direcionado por forças



Forças do tipo massa-mola

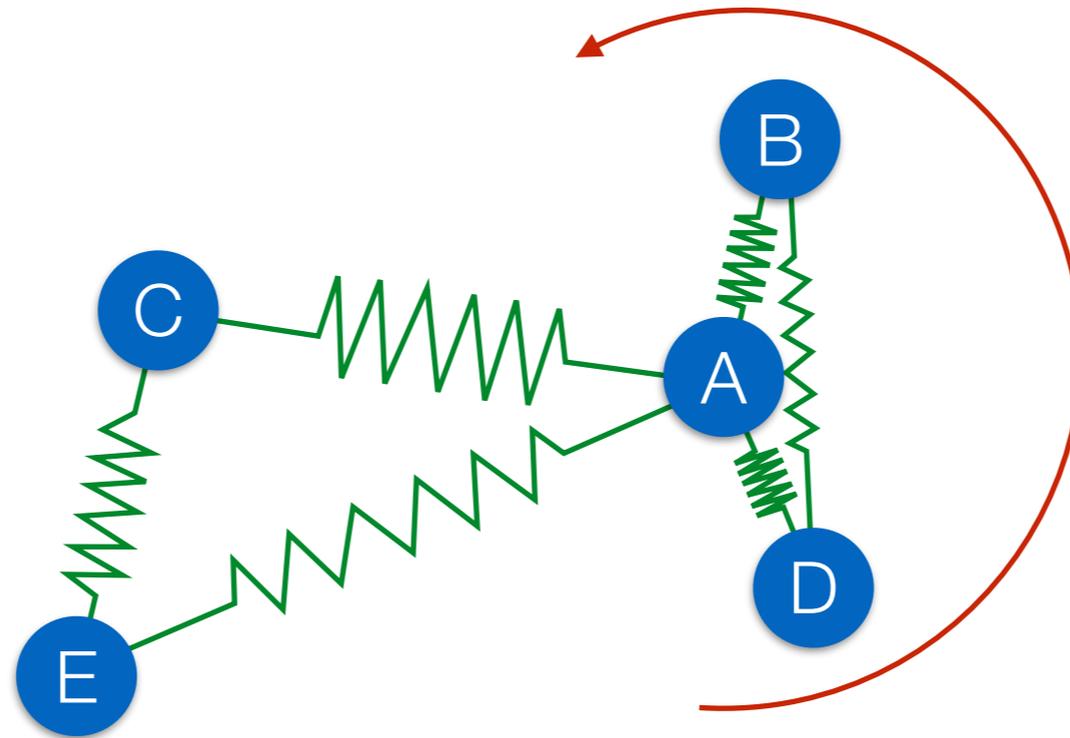


Problemas?

Método direcionado por forças



Forças do tipo massa-mola

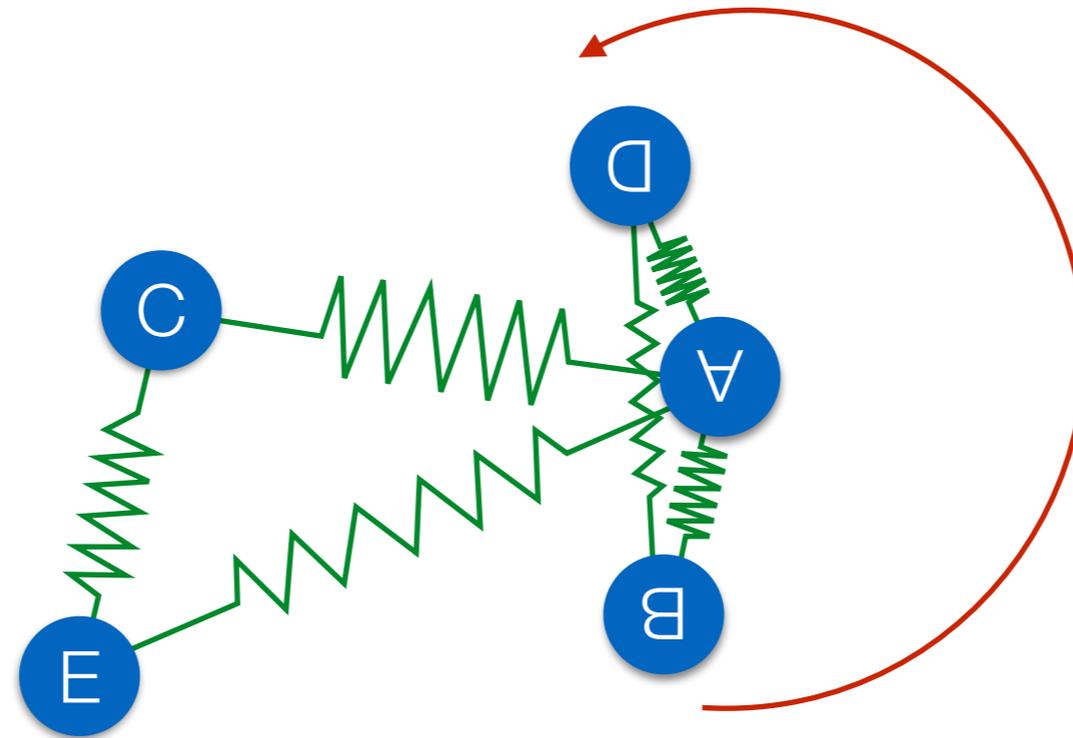


Problemas?

Método direcionado por forças



Forças do tipo massa-mola

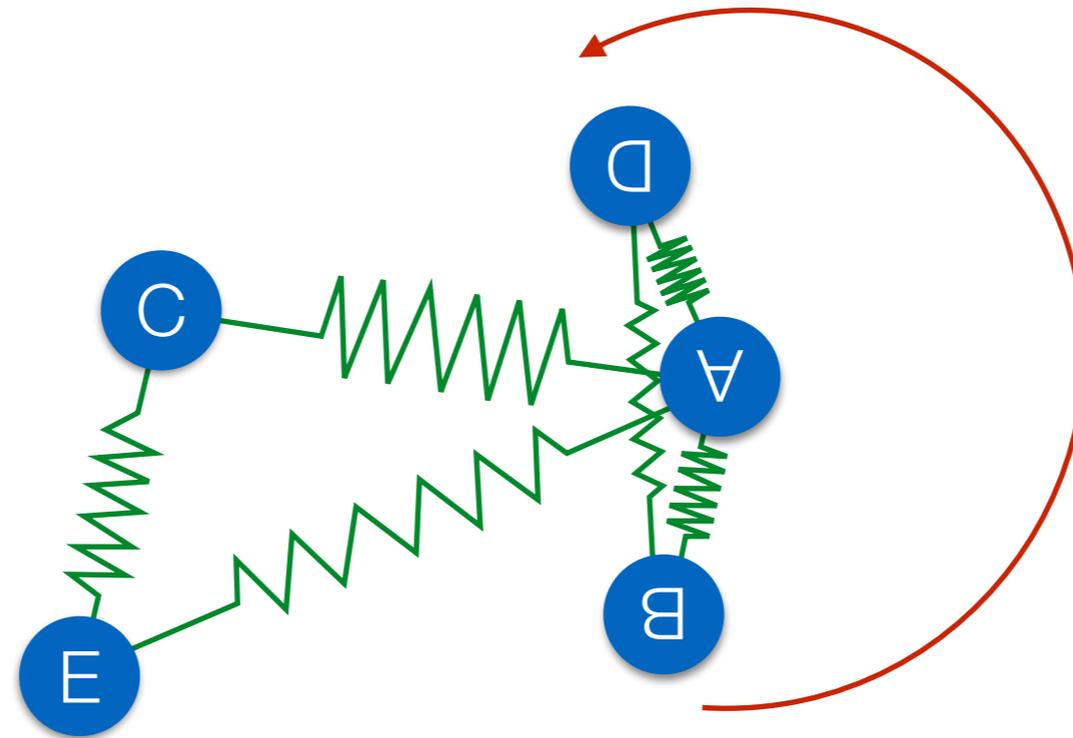


Alternativas?

Método direcionado por forças



Forças do tipo massa-mola

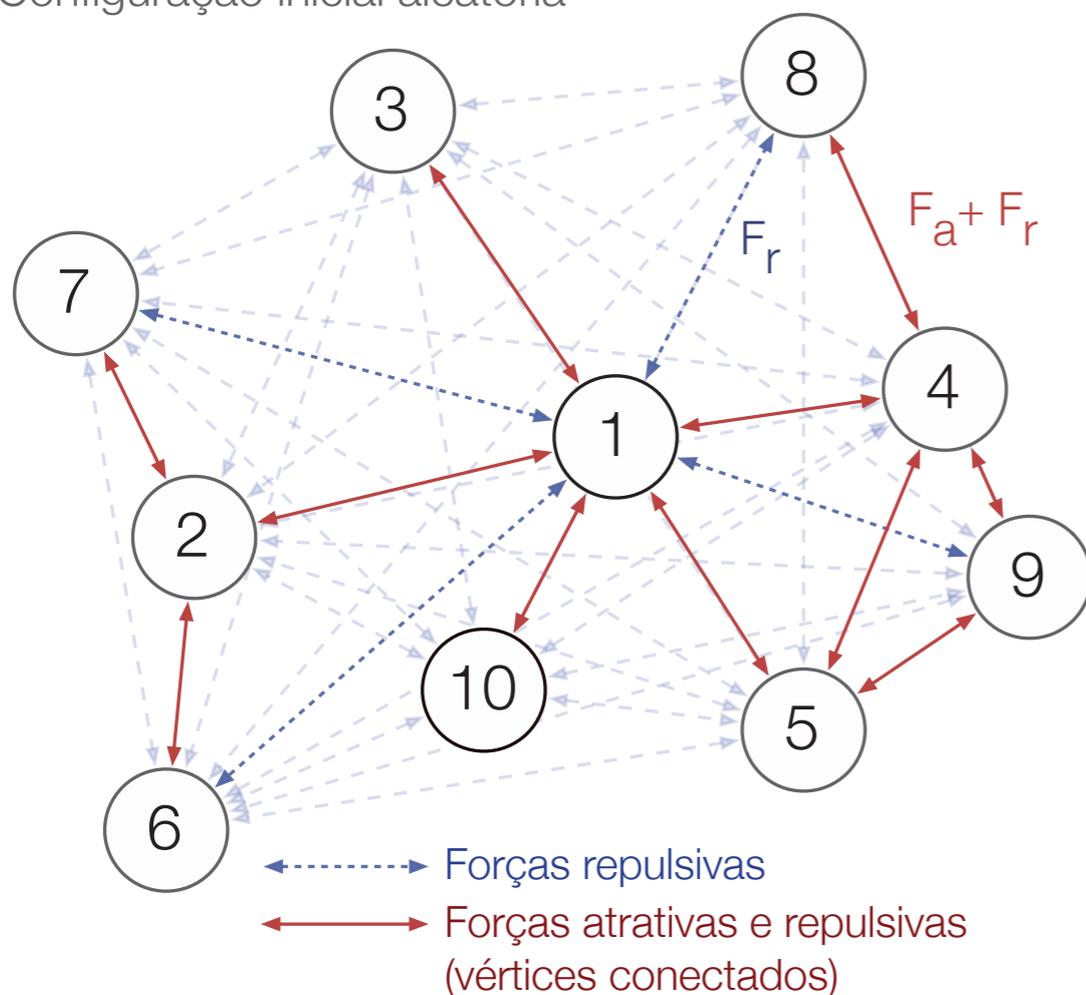


Alternativas?

Método direcionado por forças

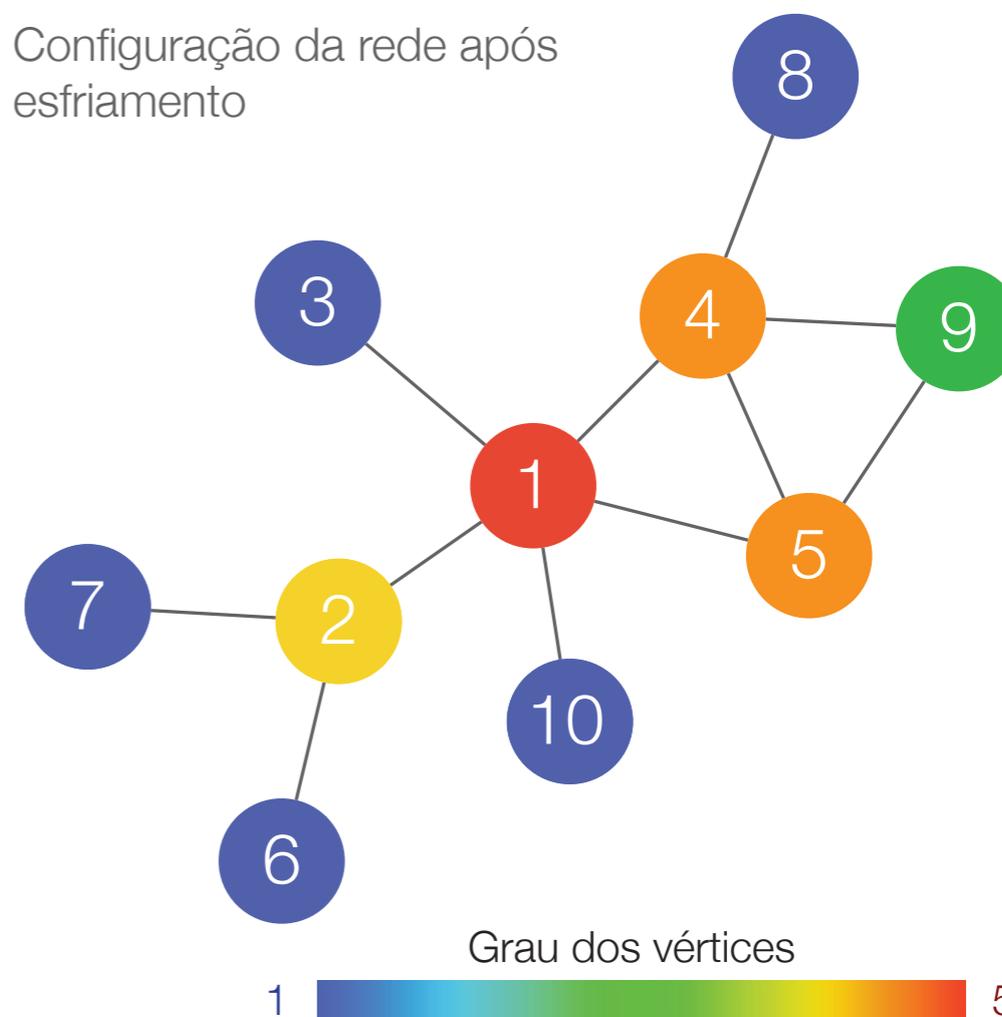


Configuração inicial aleatória



Simulação de dinâmica molecular

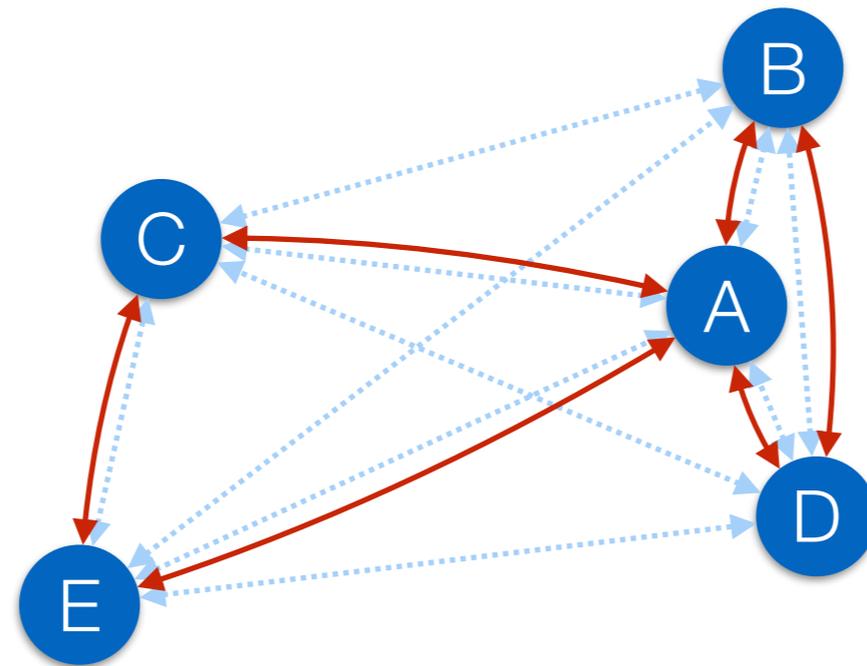
Configuração da rede após esfriamento



Método direcionado por forças



Forças do tipo elétrica + massa-mola



↔ Força Atrativa
↔ Força Repulsiva

Técnicas de simulação molecular

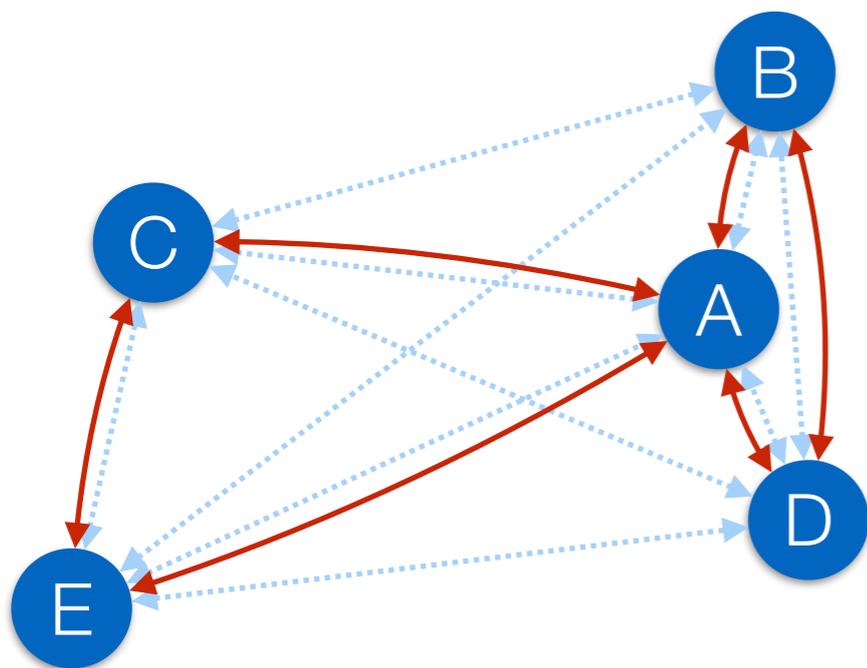
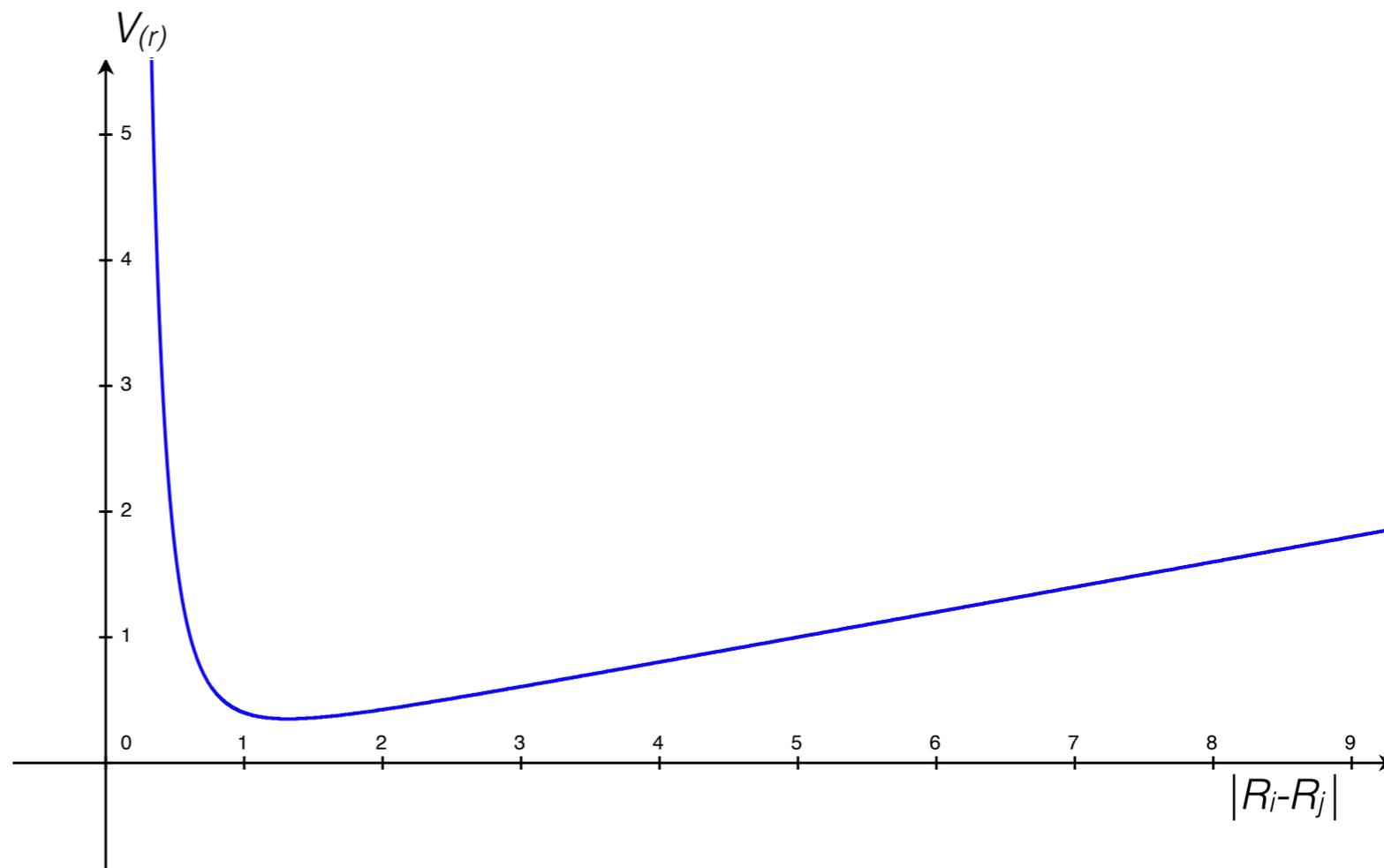


Força Atrativa

$$\vec{F}_{(a)j} = \sum_{(i,j) \in \mathcal{E}} a_{ij} (\vec{R}_i - \vec{R}_j)^2 \hat{r}_{ij}$$

Força Repulsiva

$$\vec{F}_{(r)j} = \sum_{i \in \mathcal{V}} \frac{-b}{(\vec{R}_i - \vec{R}_j)^2} \hat{r}_{ij}$$



Viscosidade

$$\frac{d^2 \vec{R}_j}{dt^2} = \vec{F}_{(a)i} + \vec{F}_{(r)j} - \mu \frac{d\vec{R}_j}{dt}$$



Método numérico - Verlet

$$\frac{d^2 \vec{R}_j}{dt^2} = \vec{F}_{(a)i} + \vec{F}_{(r)j} - \mu \frac{d\vec{R}_j}{dt}$$

$$\frac{\Delta^2 \vec{R}(t)}{\Delta t^2} = \frac{\frac{\vec{R}(t+\Delta t) - \vec{R}(t)}{\Delta t} - \frac{\vec{R}(t) - \vec{R}(t-\Delta t)}{\Delta t}}{\Delta t} = \frac{\vec{R}(t + \Delta t) - 2\vec{R}(t) + \vec{R}(t - \Delta t)}{\Delta t^2} = \vec{F}_{\text{total}}(\vec{R}(t))$$

$$\vec{R}(t + \Delta t) = 2\vec{R}(t) - \vec{R}(t - \Delta t) + \vec{F}_{\text{total}}(\vec{R}(t))\Delta t^2$$



Erro - método de verlet

$$\vec{R}(t + \Delta t) = \vec{R}(t) + \vec{v}(t)\Delta t + \frac{\vec{a}(t)\Delta t^2}{2} + \frac{\vec{b}(t)\Delta t^3}{6} + \mathcal{O}(\Delta t^4)$$

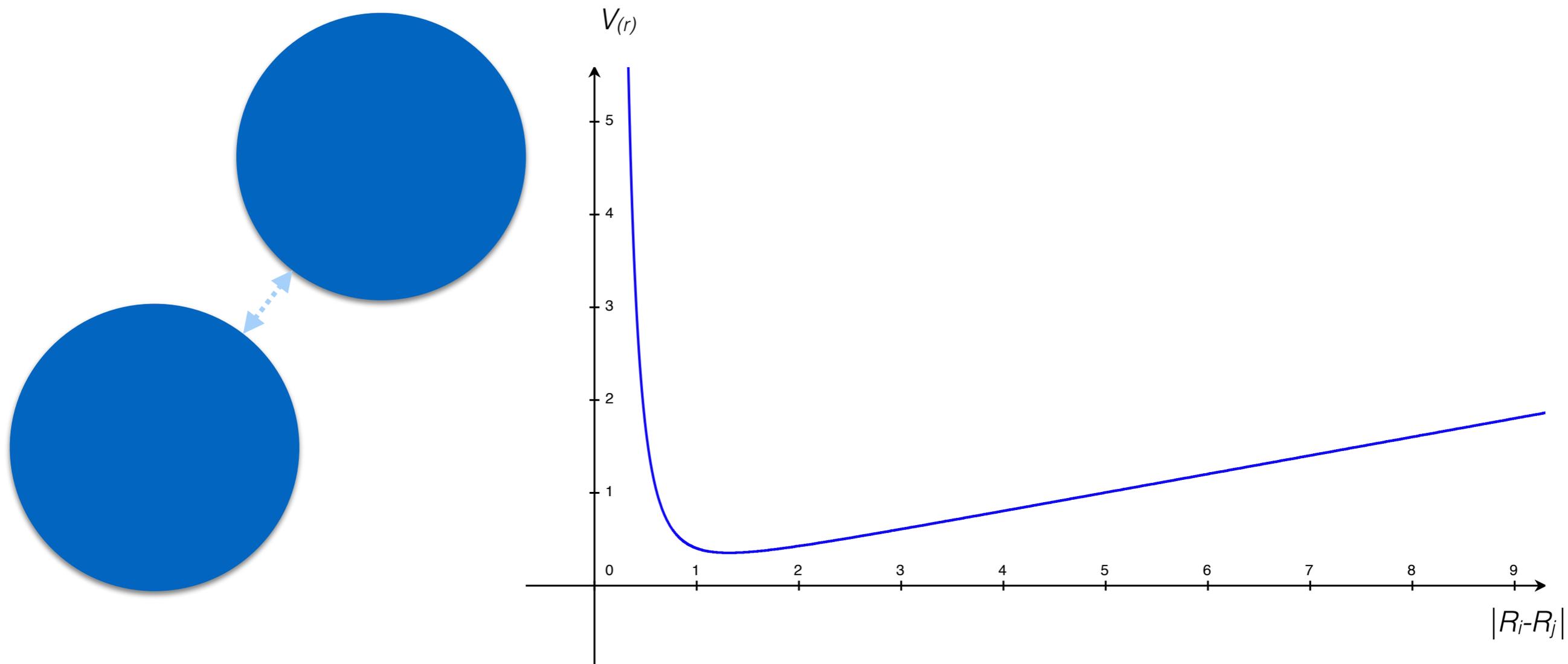
+

$$\vec{R}(t - \Delta t) = \vec{R}(t) - \vec{v}(t)\Delta t + \frac{\vec{a}(t)\Delta t^2}{2} - \frac{\vec{b}(t)\Delta t^3}{6} + \mathcal{O}(\Delta t^4)$$

$$= \vec{R}(t + \Delta t) = 2\vec{R}(t) - \vec{R}(t - \Delta t) + \vec{a}(t)\Delta t^2 + \mathcal{O}(\Delta t^4)$$

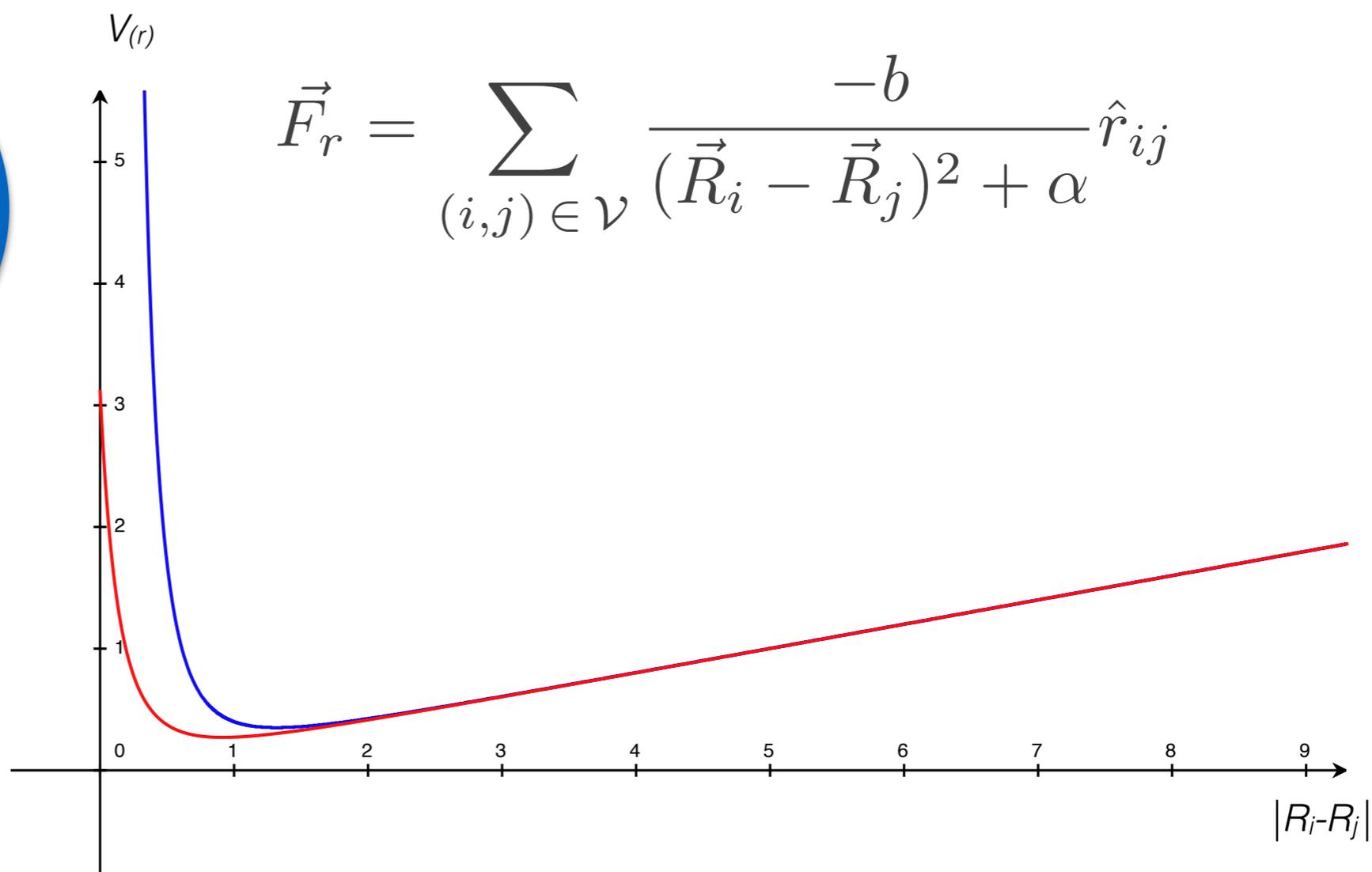
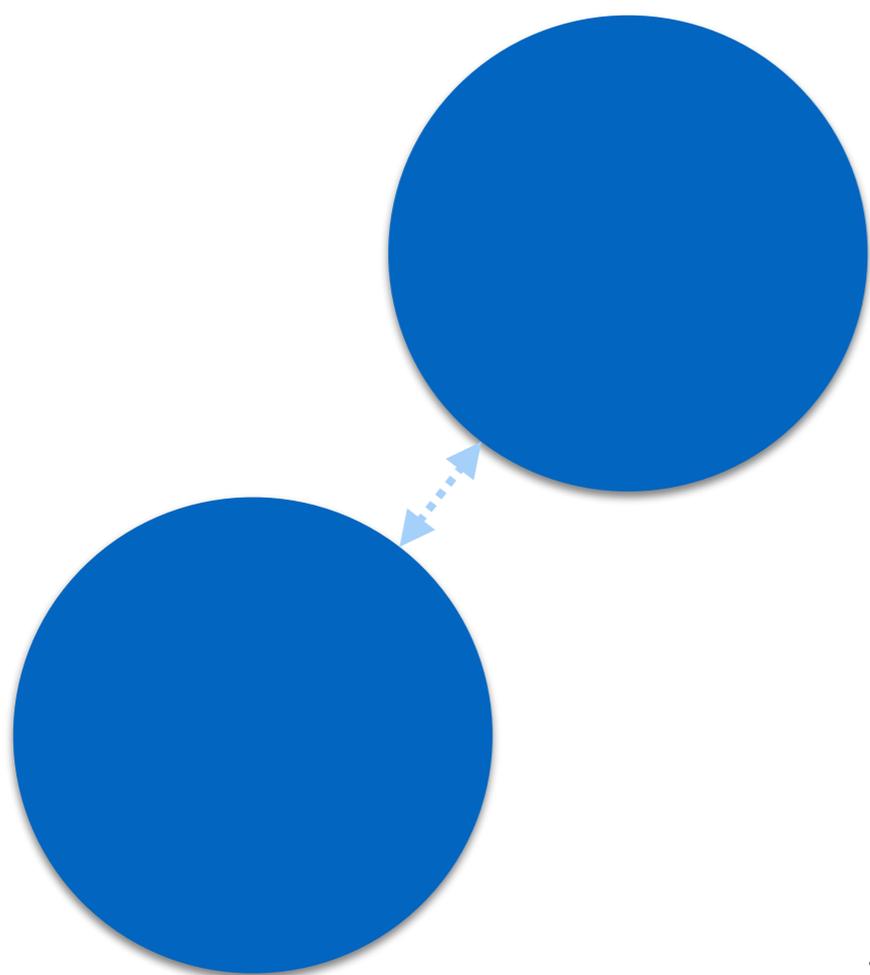


Correção na lei de força





Correção na lei de força



Optimizações por expansão multipolar

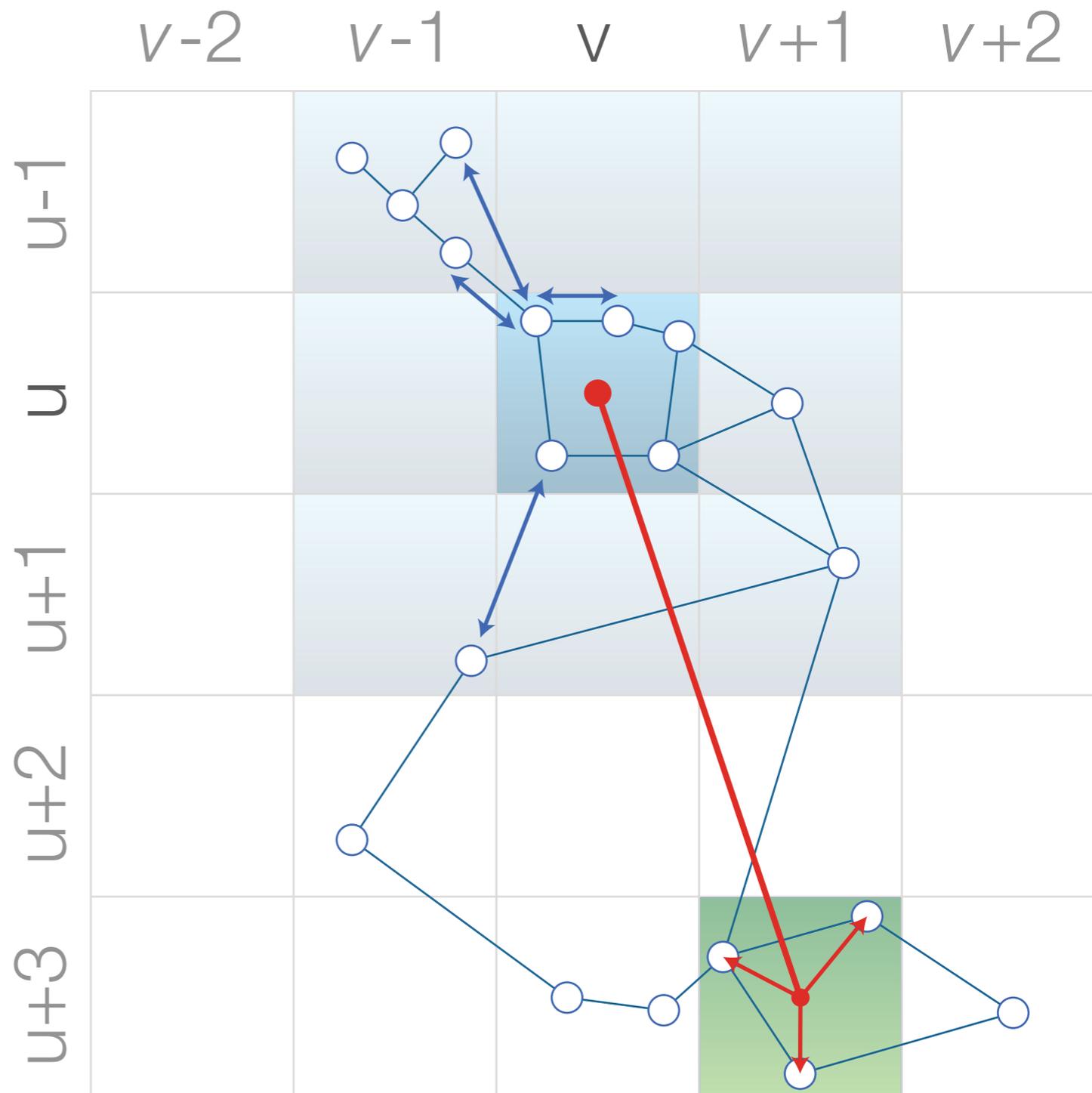


- O problema é $O(N^2)$
- A técnica de **expansão multipolar** aproxima as forças de **objetos distantes**:

$$\sum_{i \in \mathcal{V}} \frac{\hat{r}_{ij}}{(\vec{R}_i - \vec{R}_j)^2} = -\vec{\nabla} \sum_{i \in \mathcal{V}} \frac{1}{|\vec{R}_i - \vec{R}_j|} = -\vec{\nabla} \phi(\vec{R}_j)$$

$$\phi(\vec{R}_j) \propto \frac{N_{u,v}}{|\vec{R}_j|} + \frac{\vec{p}_{u,v} \cdot \vec{R}_j}{|\vec{R}_j|^3} + \frac{1}{2} \sum_m^3 \sum_n^3 \frac{(Q_{u,v})_{mn} (R_j)_m (R_j)_n}{|\vec{R}_j|^5} + \dots$$

- Onde $N_{u,v}$, $\vec{p}_{u,v}$ e $Q_{u,v}$ são os **momentos de monopolo, dipolo e quadrupolo** calculados em cada **caixa** (u,v) .
- A expansão **até quadrupolo** apresentou **bons resultados** para a maioria das redes.

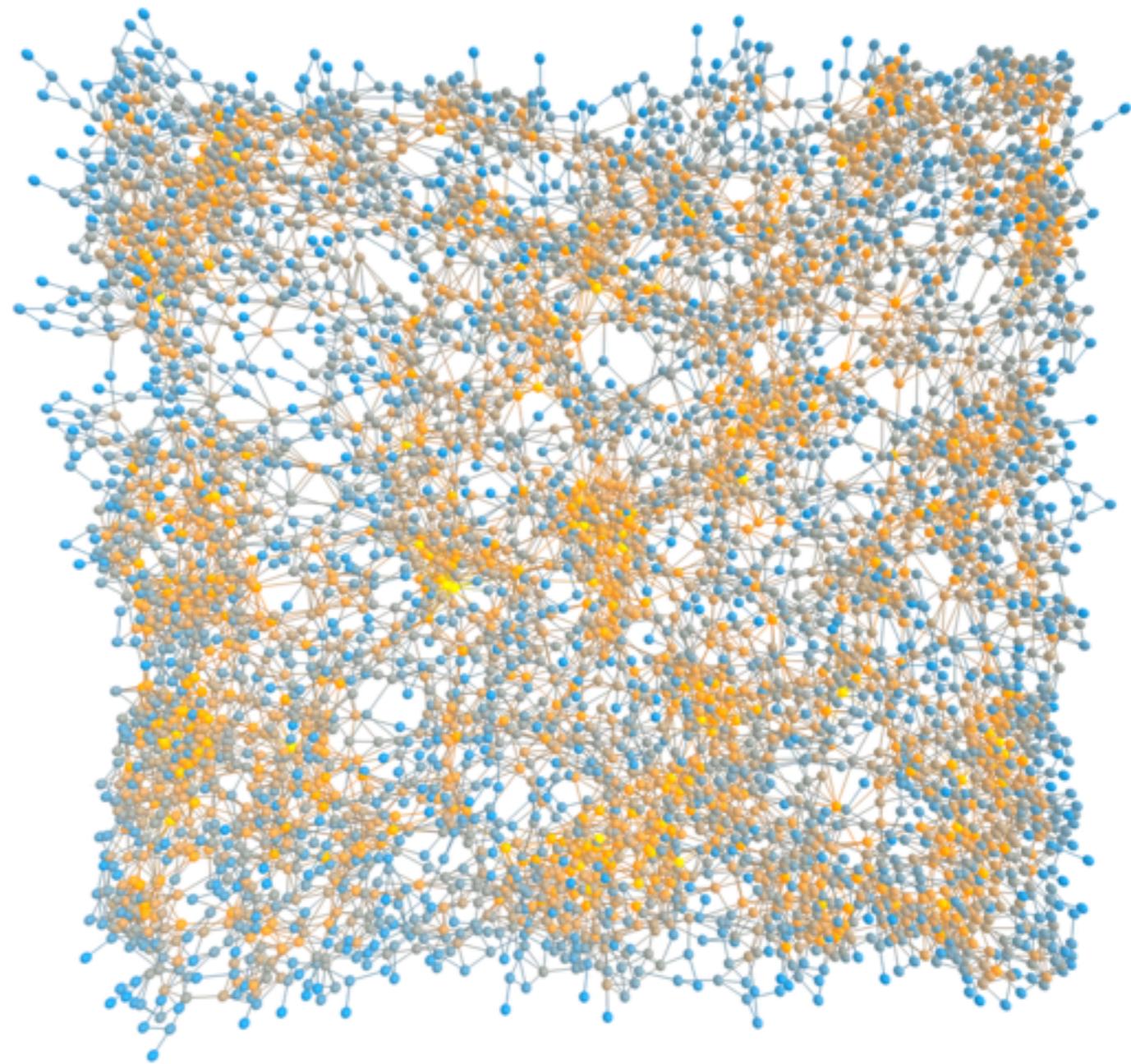
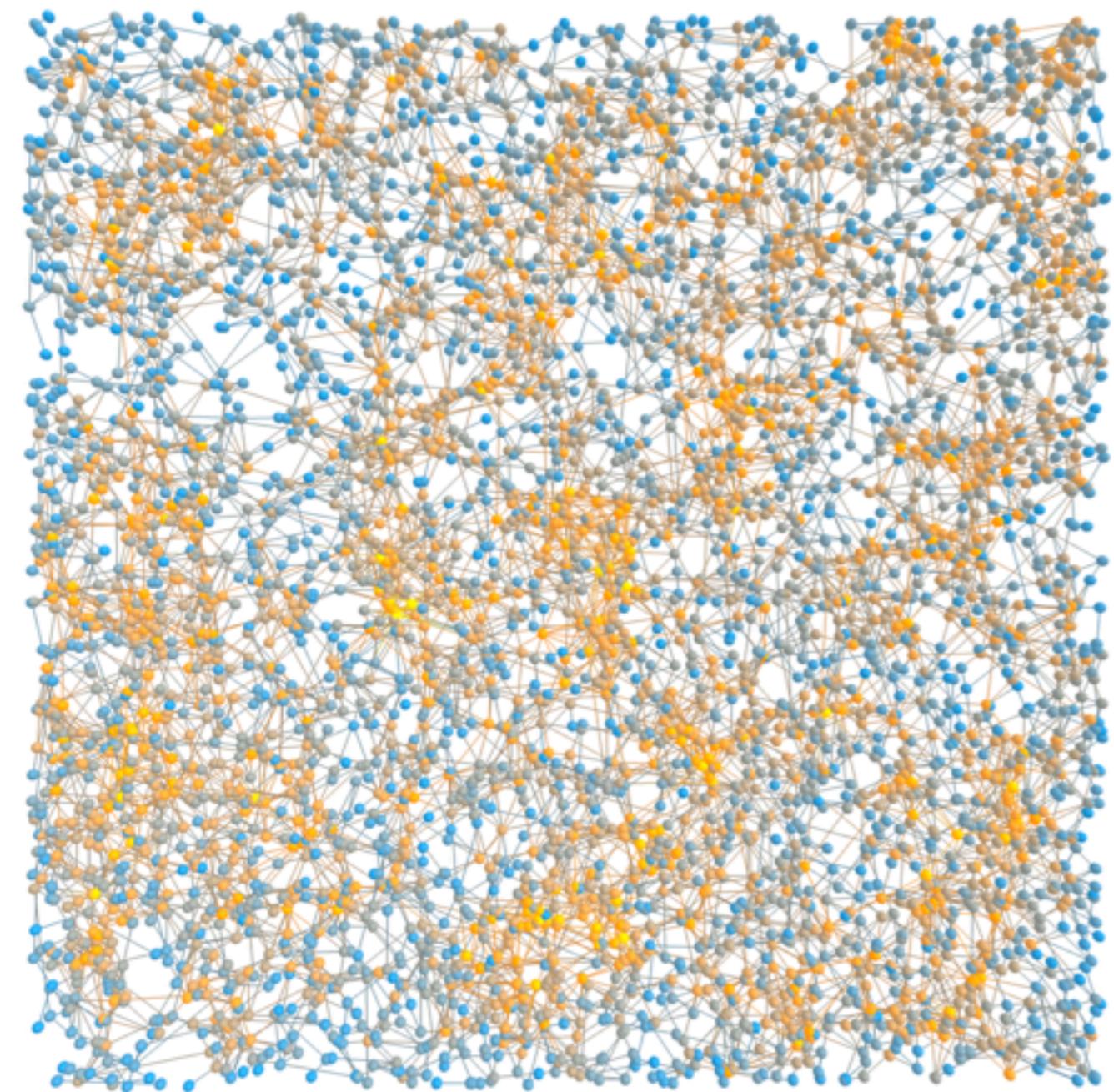


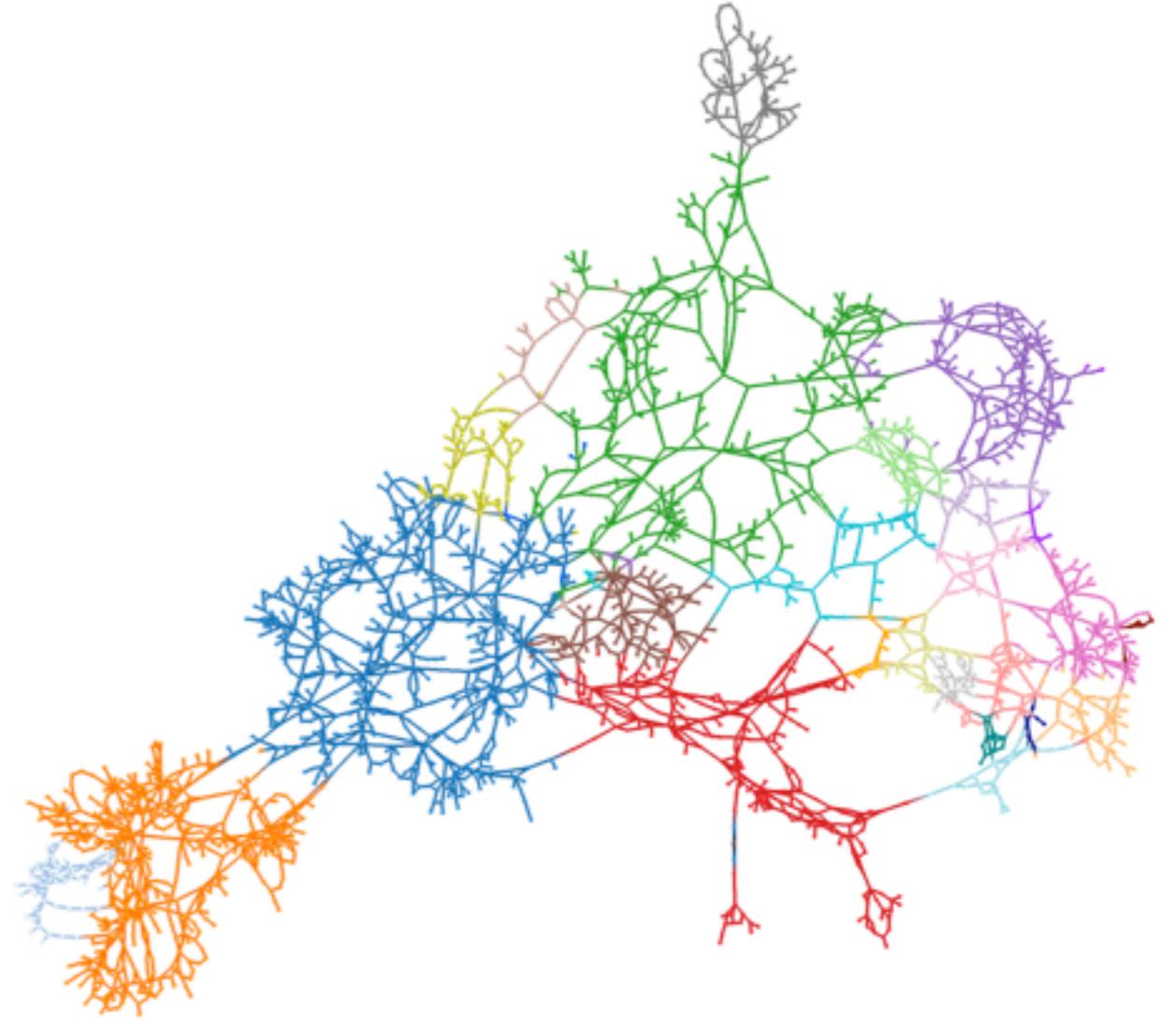


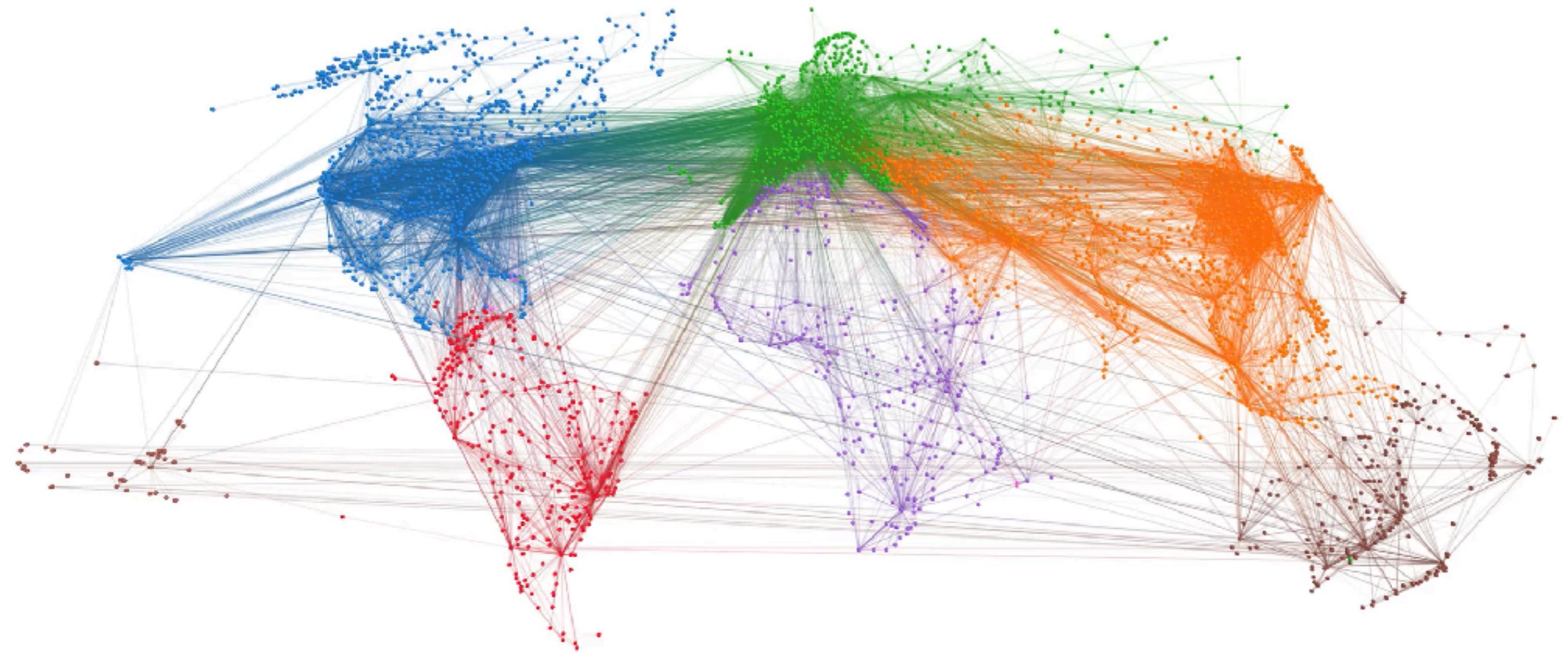




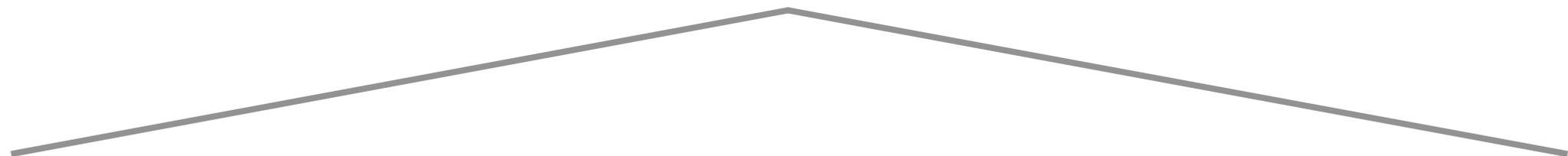
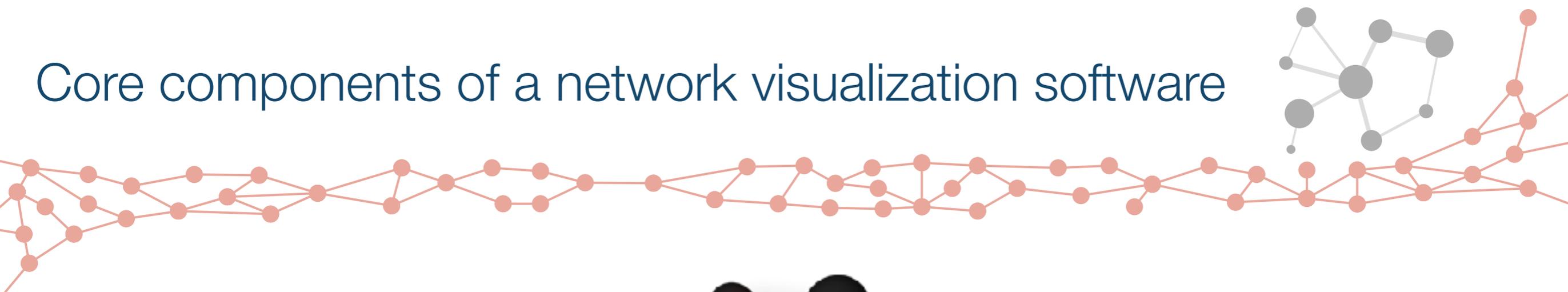




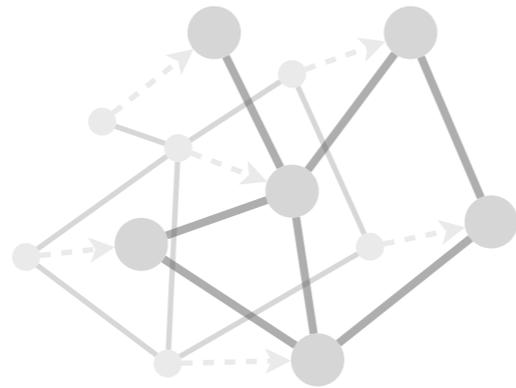




Core components of a network visualization software



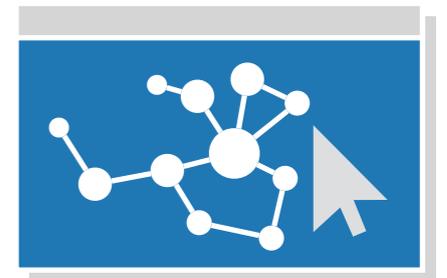
Graph Library



Layout

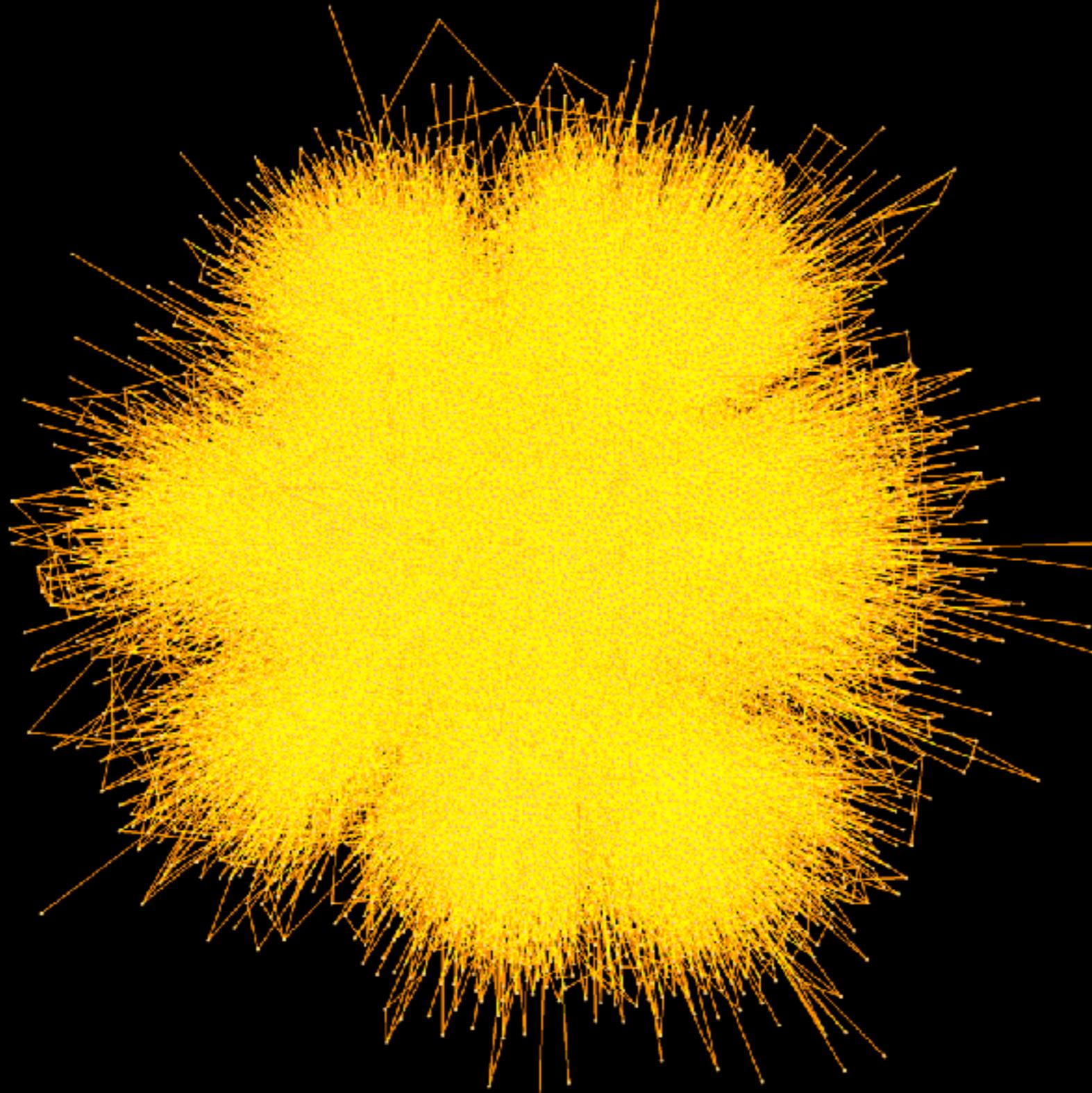
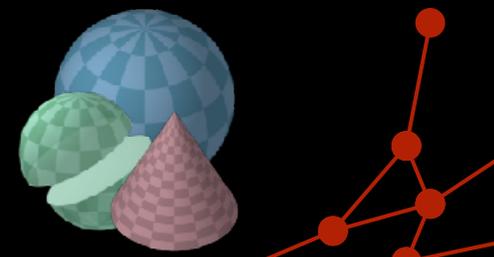


Rendering

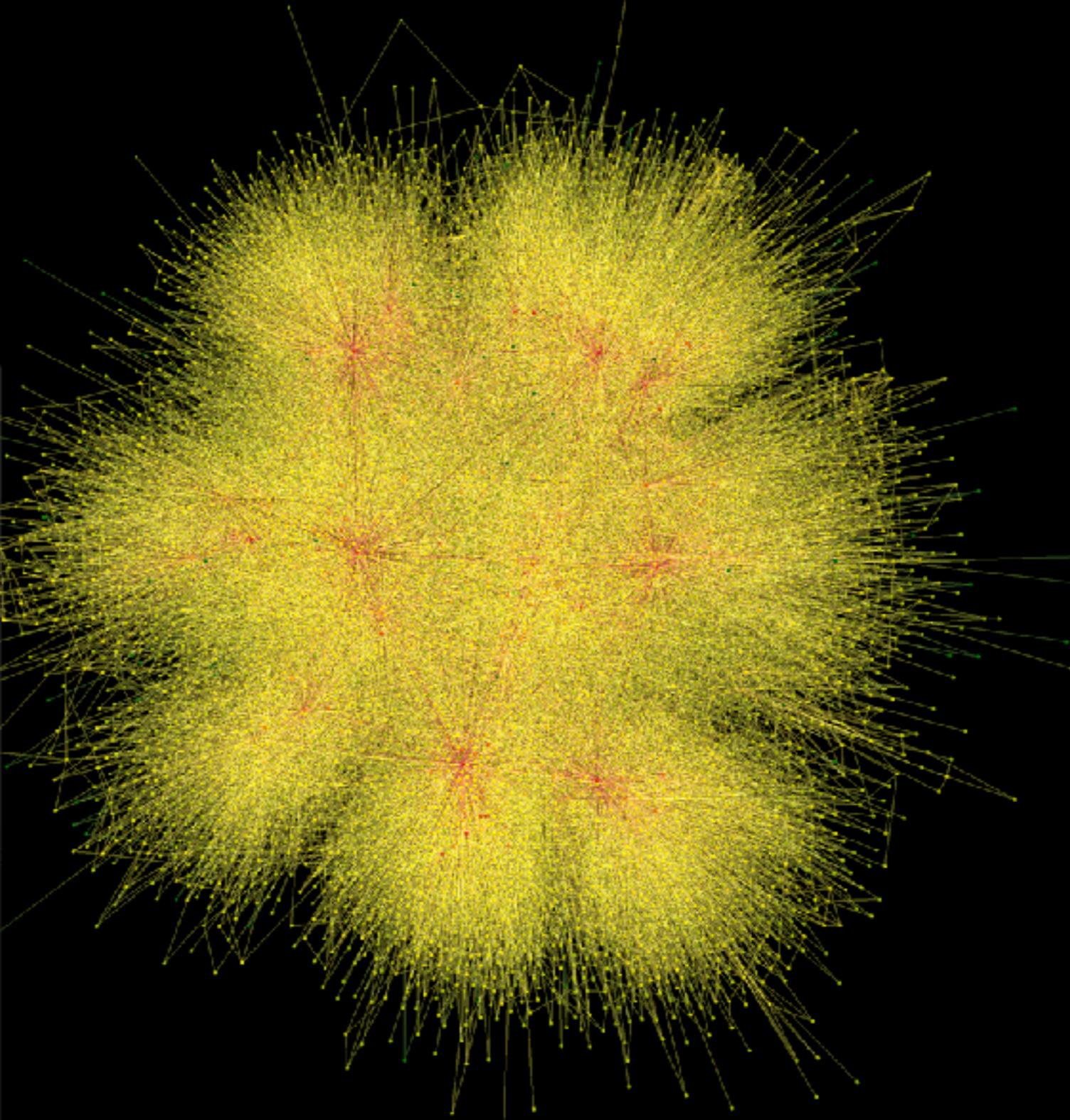
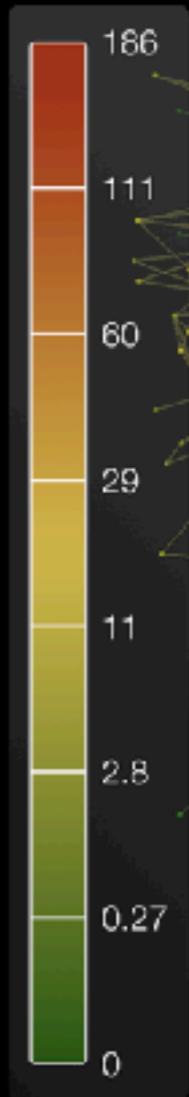
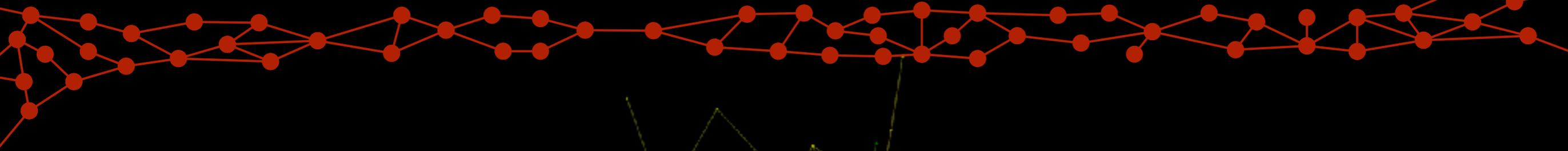


Interface

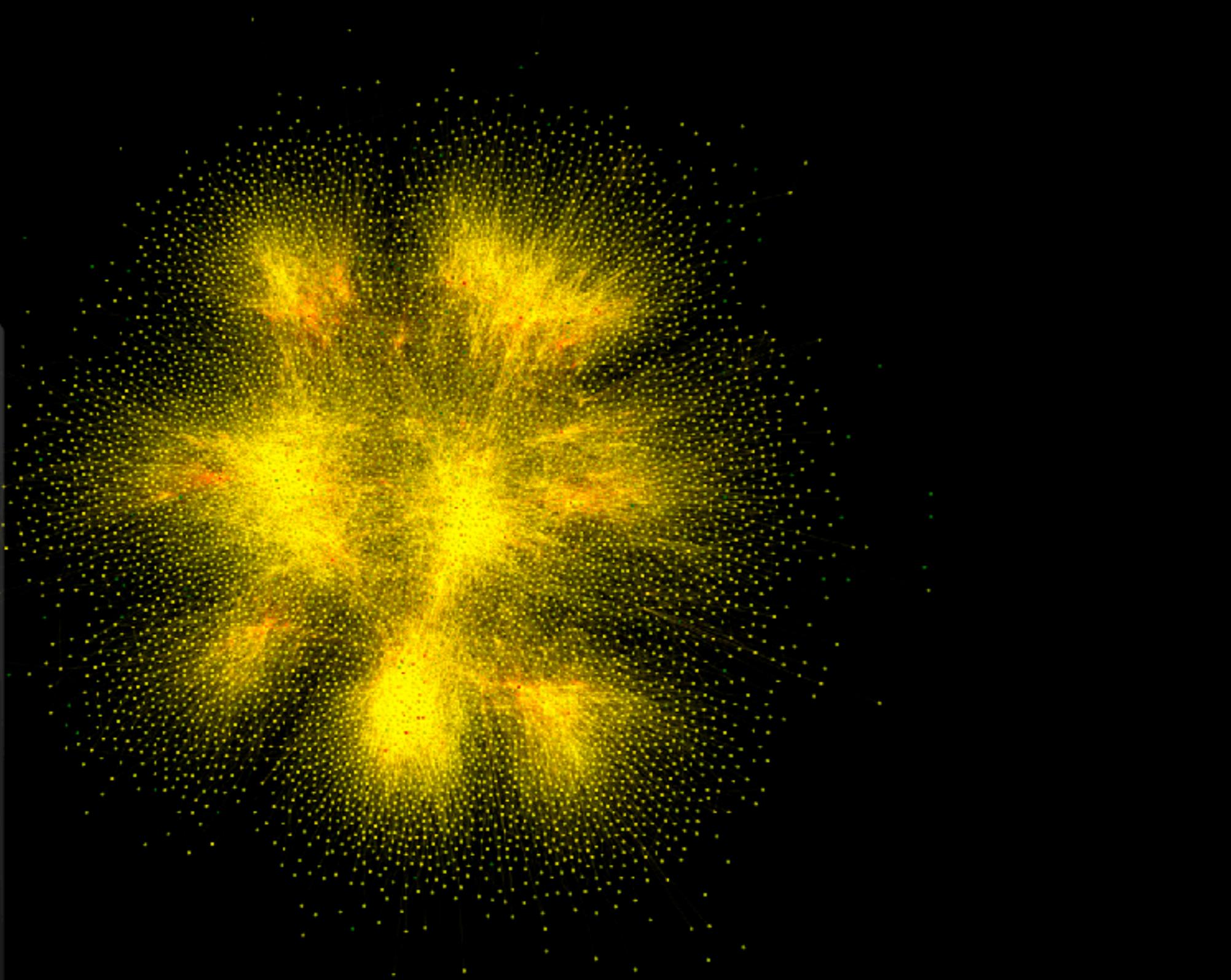
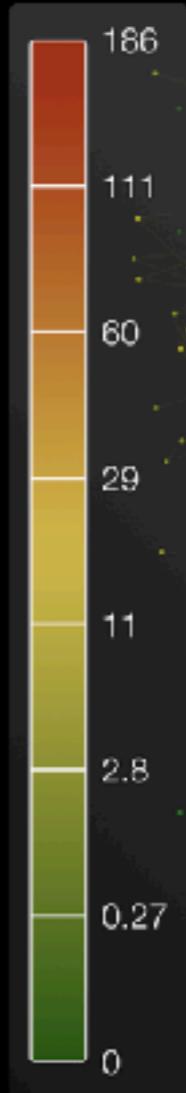
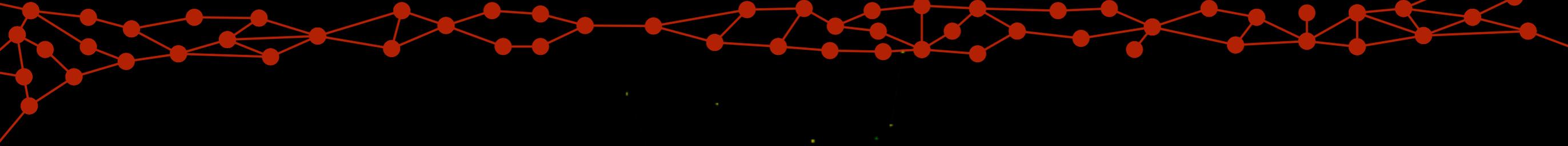
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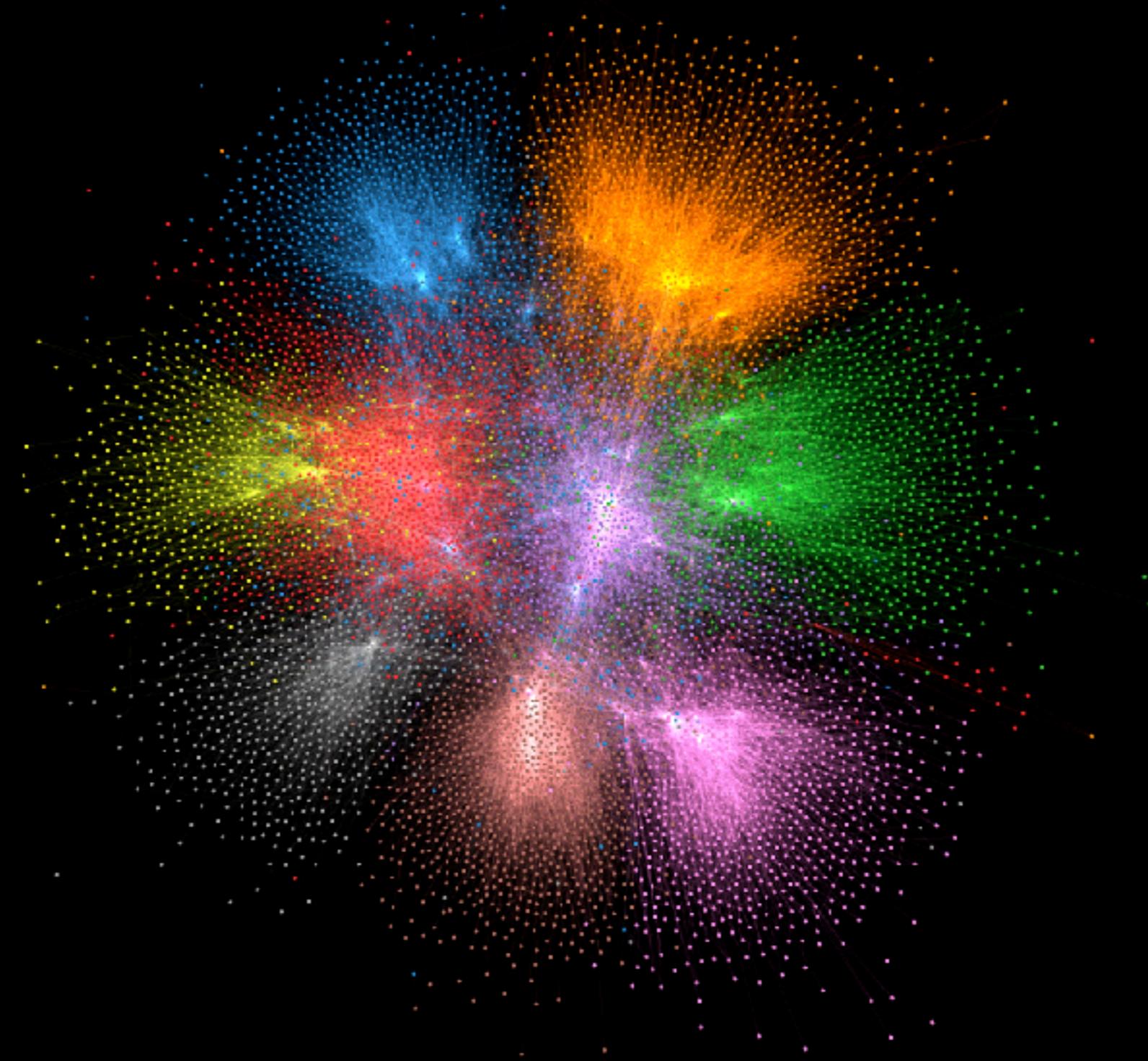
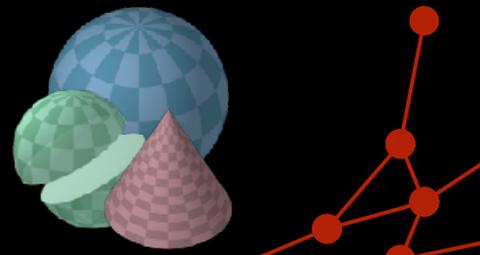
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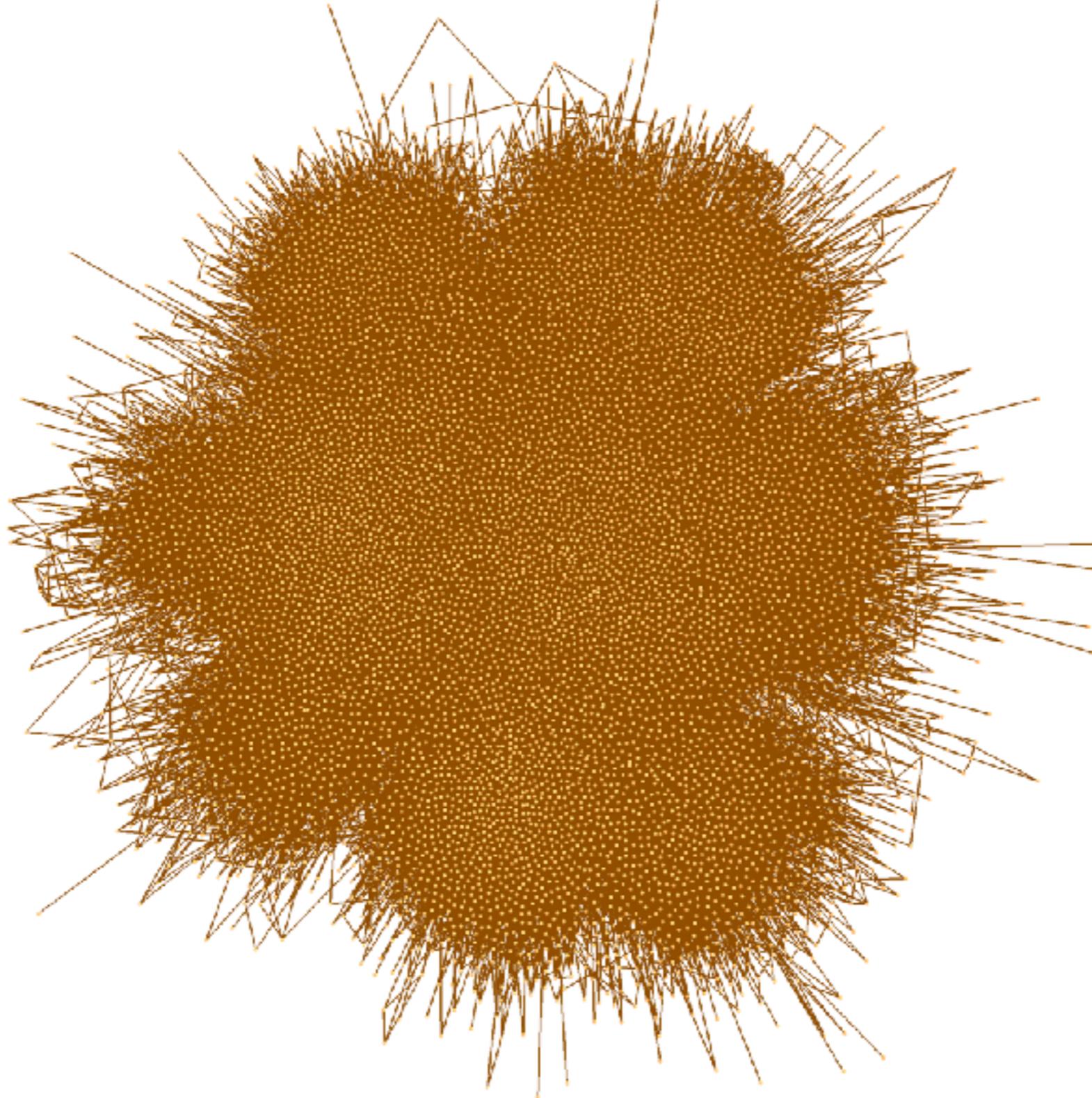
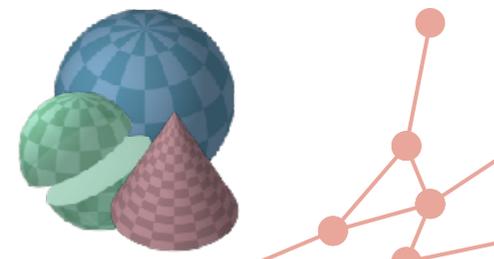
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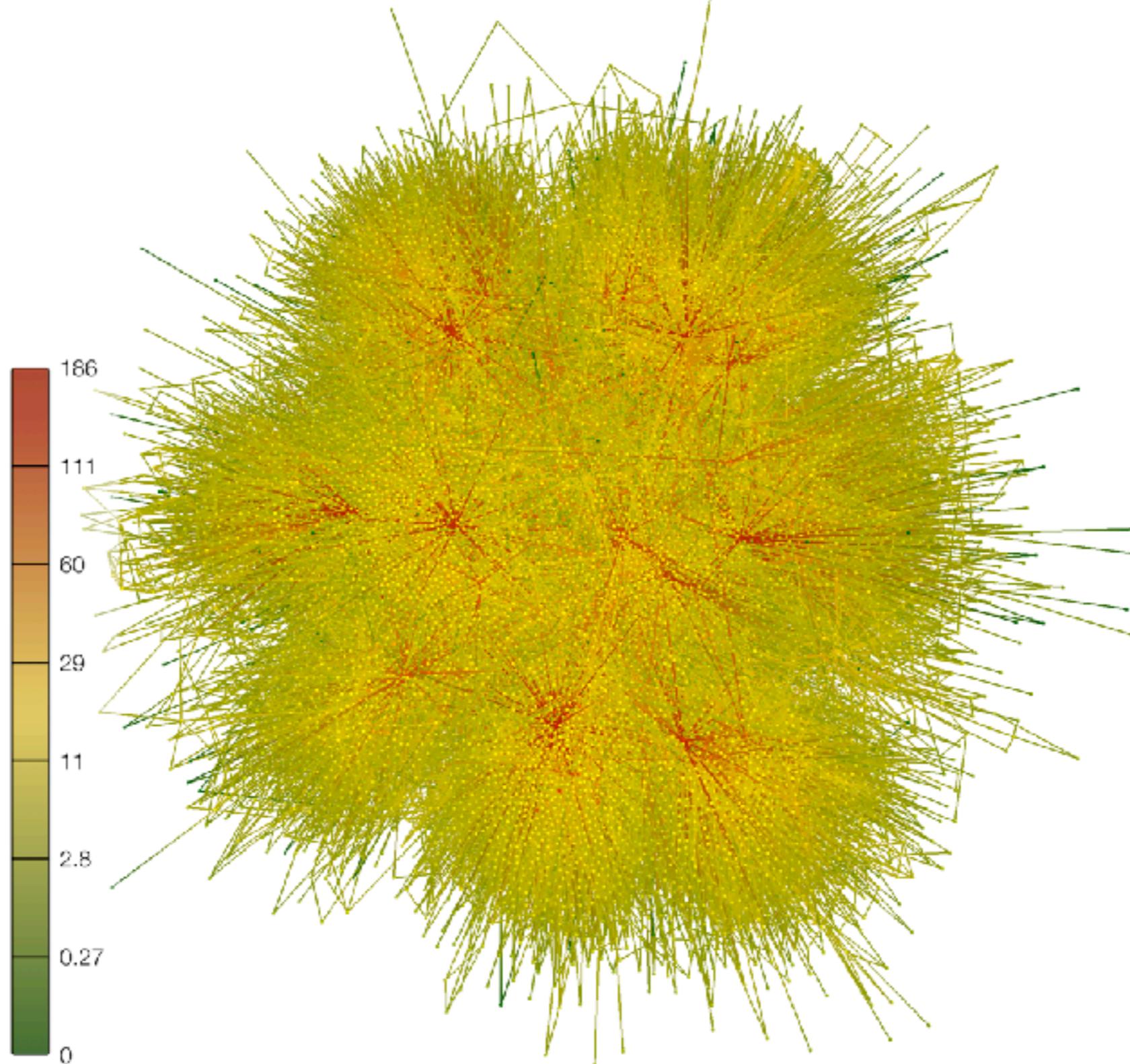
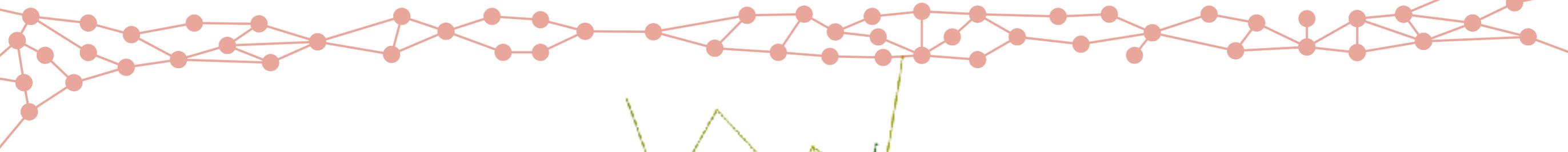
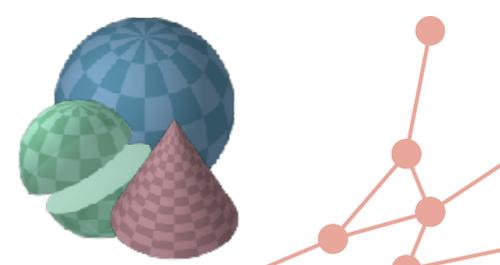
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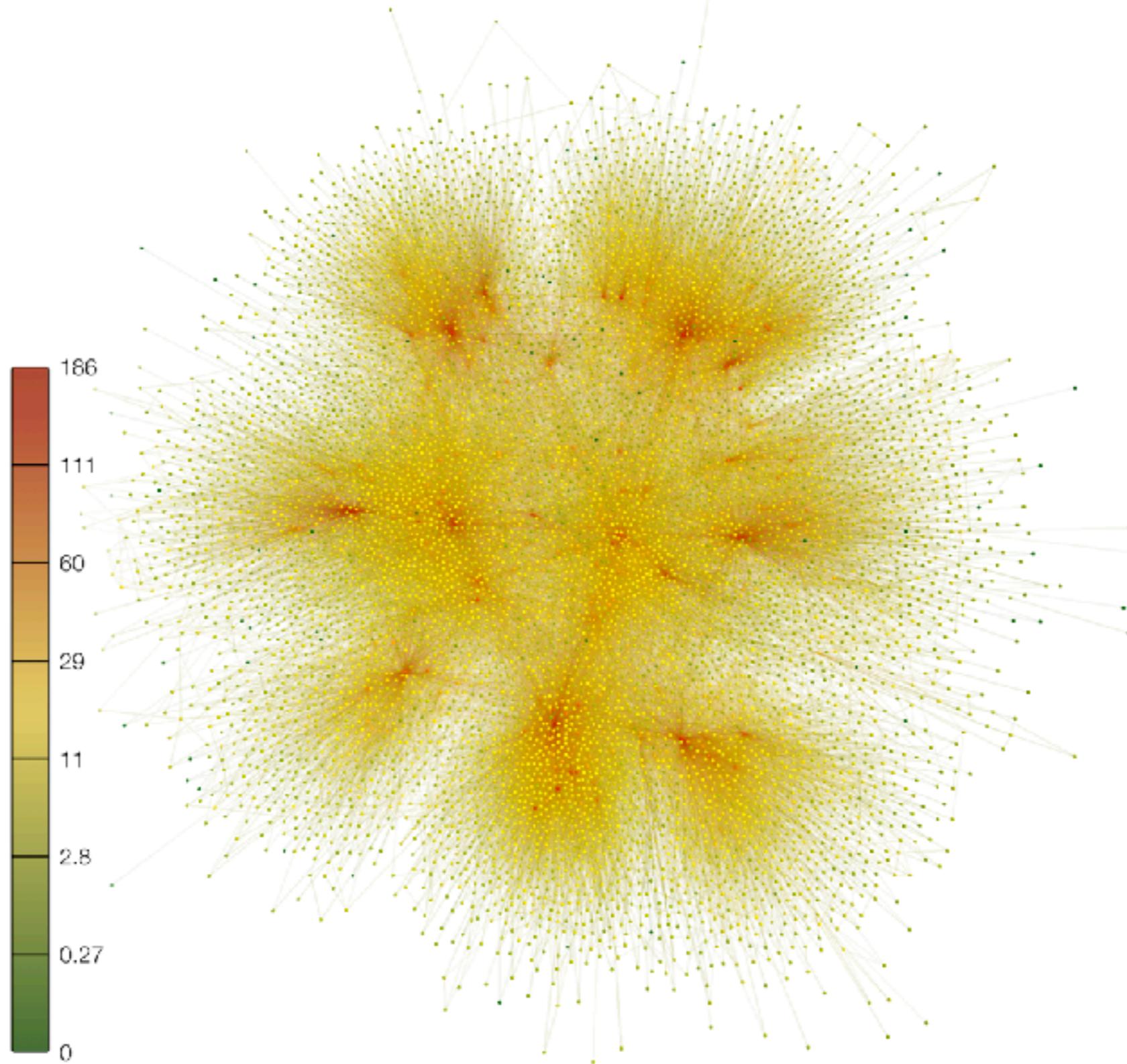
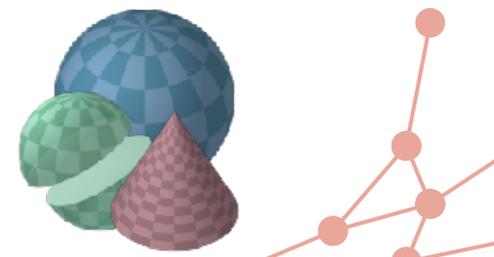
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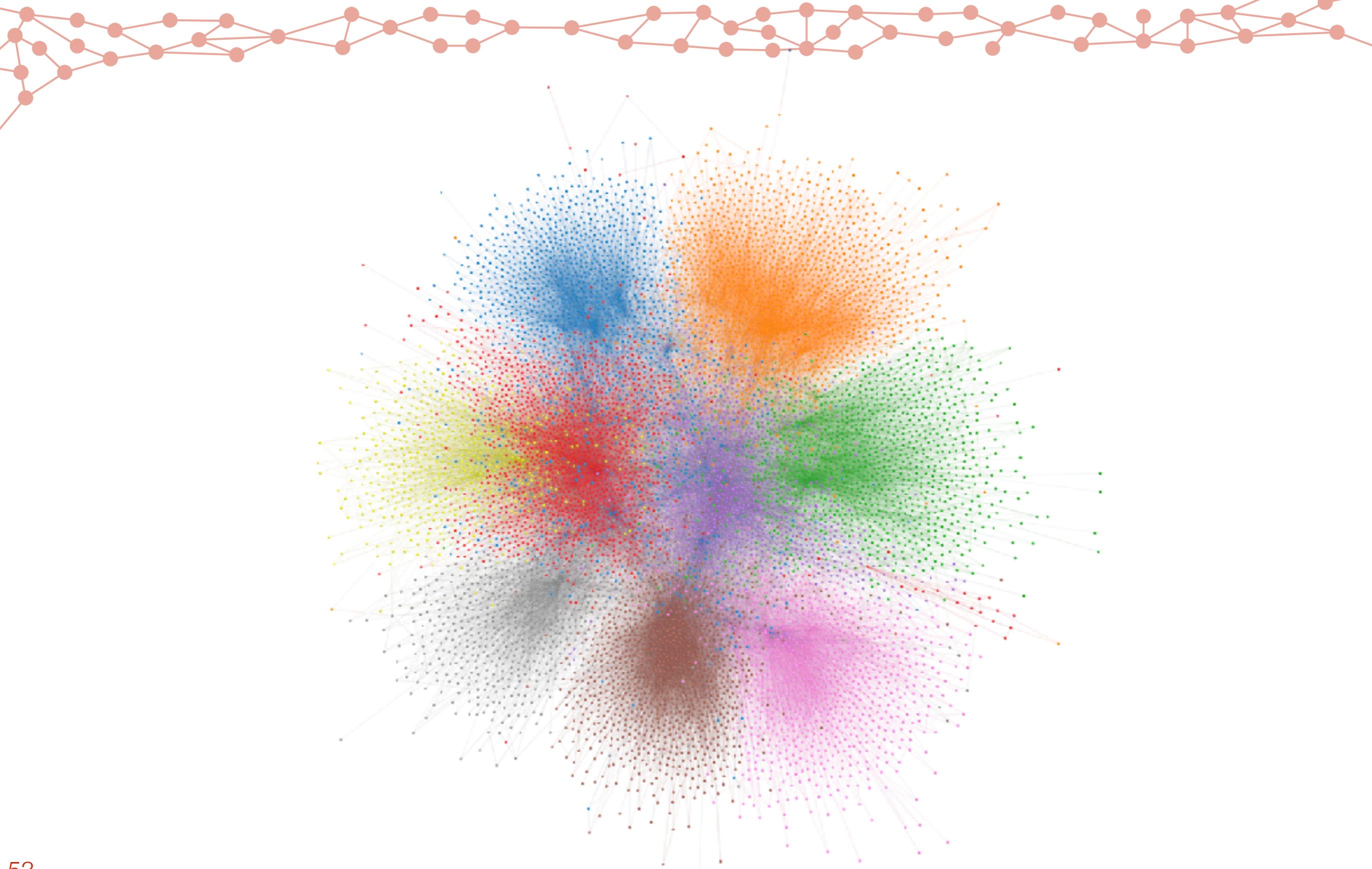
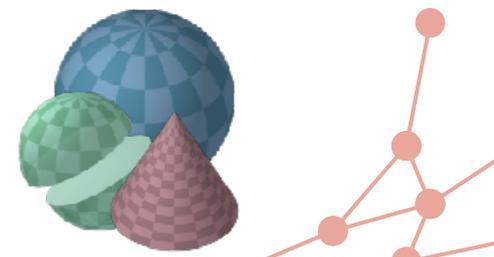
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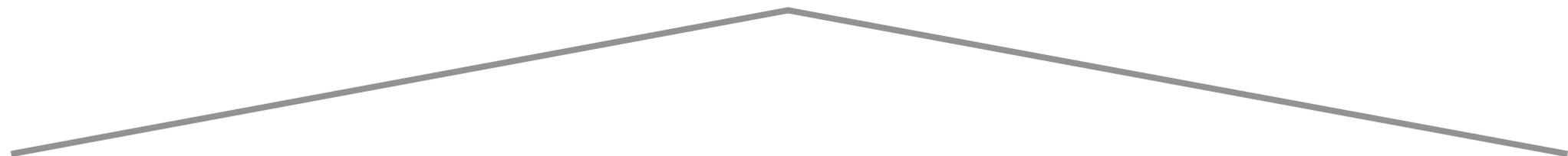
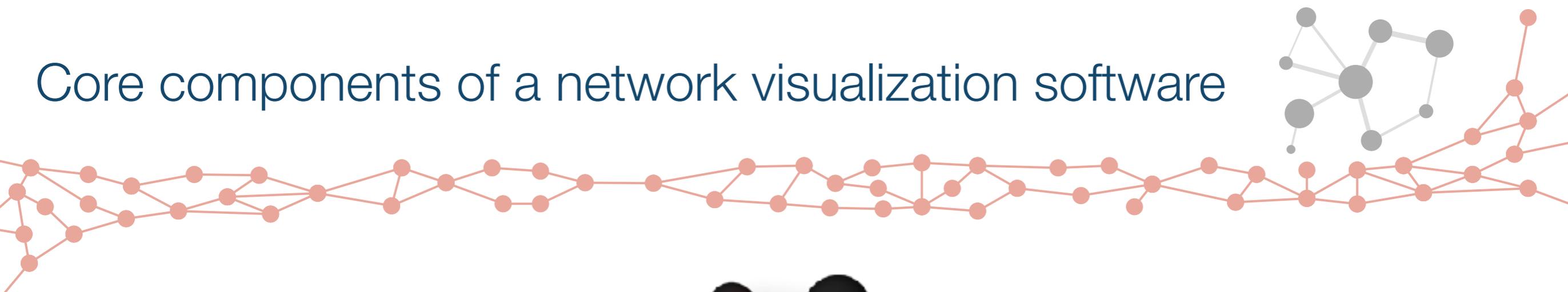
Rendering



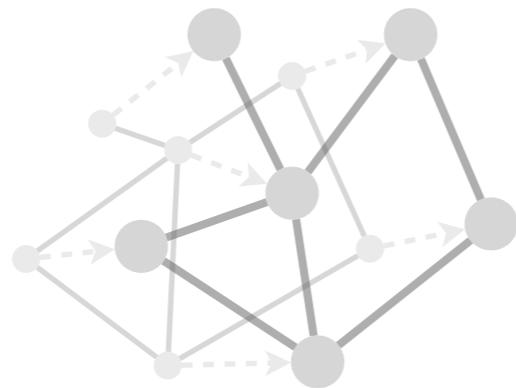
Rendering



Core components of a network visualization software



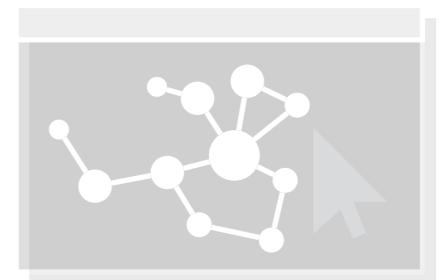
Graph Library



Layout

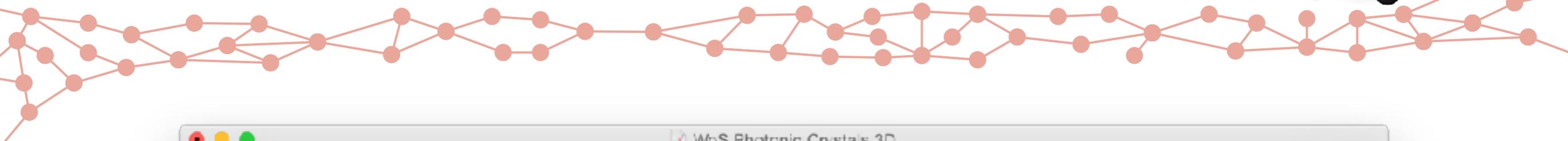


Rendering



Interface

Examples



WoS Photonic Crystals 3D

Iterate Export Image Colors Python Shell Show Utility

Simulation: Default

Attraction: 0.001

Repulsive: 10

Gravity: 0.001

Viscosity: 0.05

Preferred Dist.: 0

Filter by Property: Node Degree

Min value: 0

Max value: 116

Other Properties:

Iterations: 1

Line Width: 2.0

Weight Threshold:

Min value: 0

Max value: 1

View Options:

Show Nodes Show Edges

Blend Lines Shade

Filter Nodes Filter Edges

Simplify Shapes Dark Background

Opaque Nodes Depth for edges

Show Gen. Info Show Node Info

Show Cam. Info Show Legends

Edges Alpha: 0.1795

Use edge weights as distance.

Scale: 1.4x Front Top Side Near: 1.0x Far: 1.0x

I - colloidal, opal, thin film, pattern, enhancement, solar cell

J - negative refraction, self-collimation

F - sensor, sensitivity, acoustic, detection

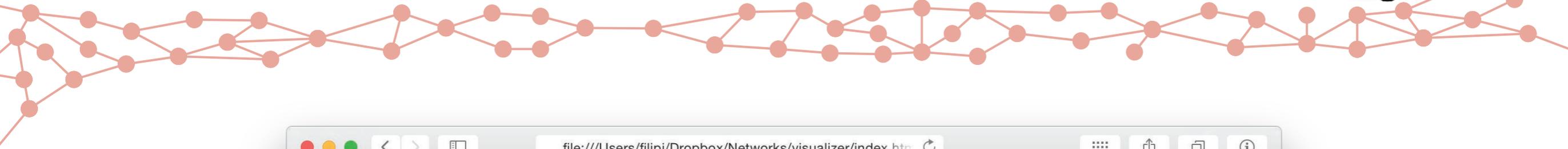
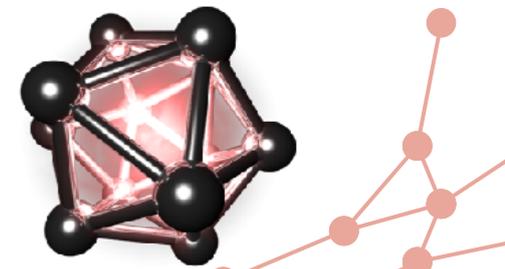
E - gain medium, laser base, stable, switchable, less cb, noise ratio...

D - dispersion wavelength, supercontinuum generation, zero dispersion...

B - femtosecond, color pulse, delivery, nihz

Software Interface

Examples



file:///Users/filipi/Dropbox/Networks/visualizer/index.htm

Combine List... Mathematica Particle Pra... arn Japanese Last Remove Folha MM Network Daring Fireball Touch Arcade Blog iPhone

Network 3D Web

Edges Vertices

Dark Background

Perspective Orthogonal

Edges Intensity: 22

Edges Depth Test

Vertex Scale: 1.58

Vertex Intensity:

Opaque Vertices

Edges Colors Property:

- Node Degree
- Category
- Main Category
- Node InDegree

Vertices Colors Property:

- Node Degree
- Category
- Main Category
- Node InDegree

Scale Property:

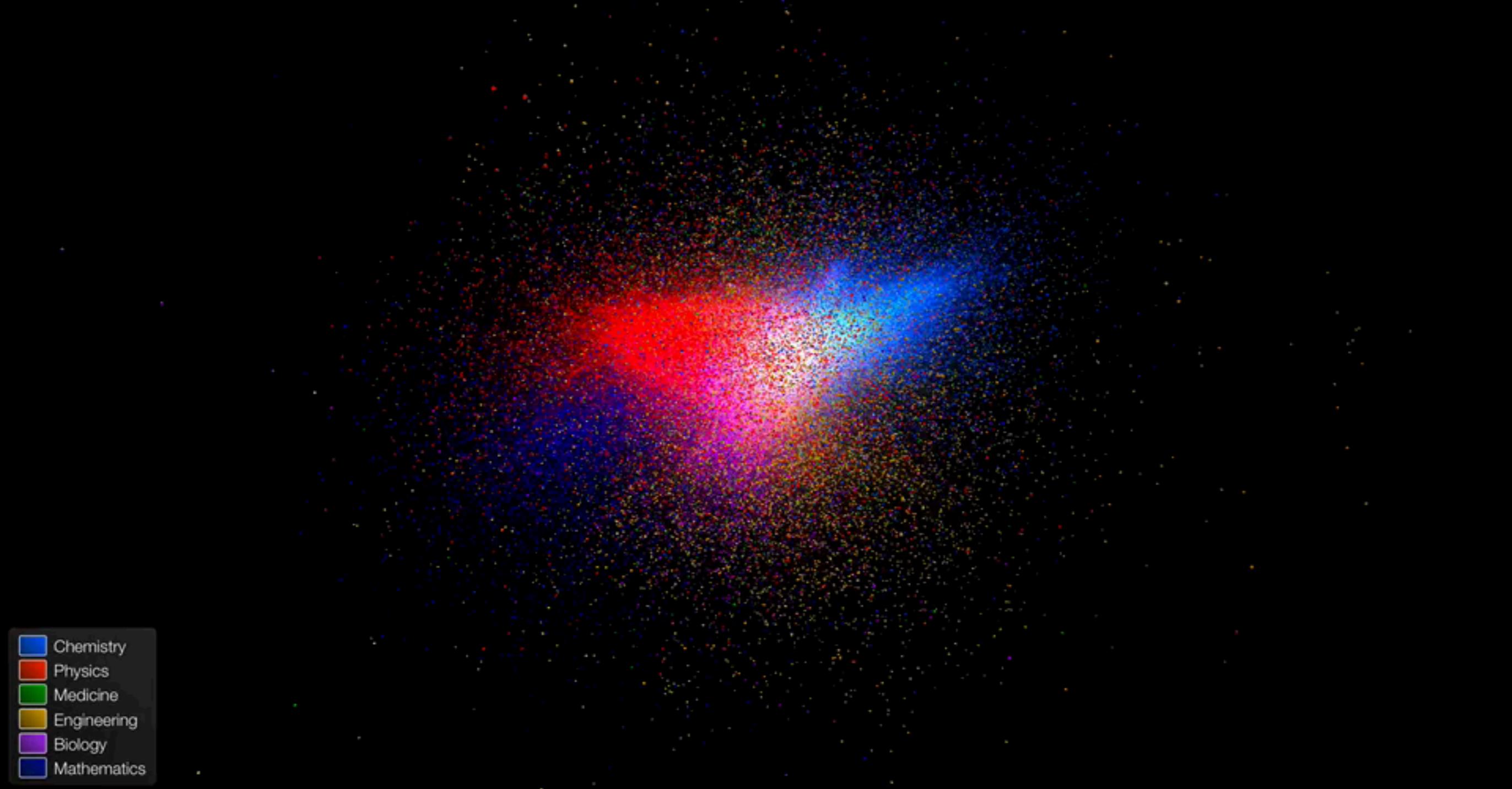
- Node Degree

Web interface

Visualização de redes

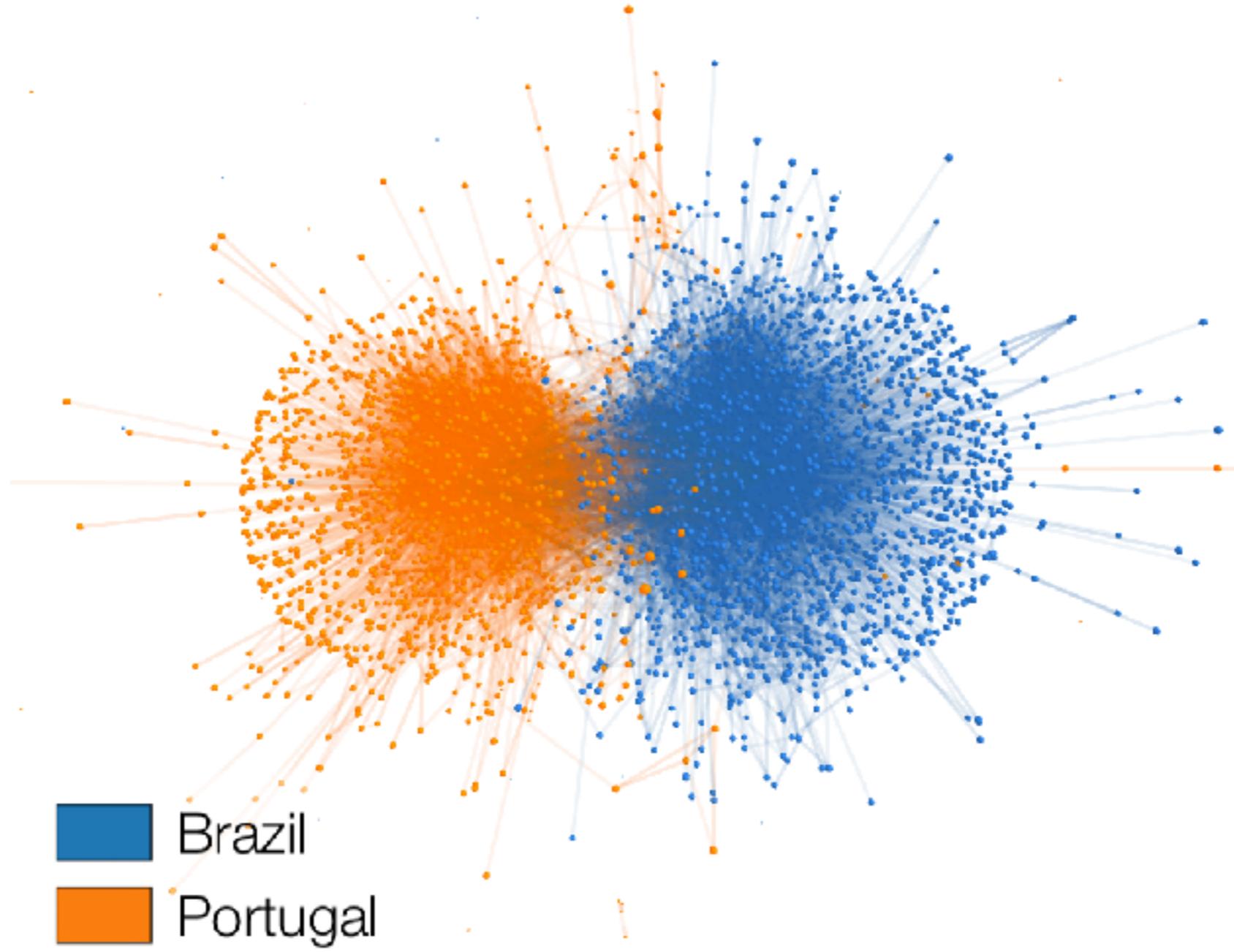
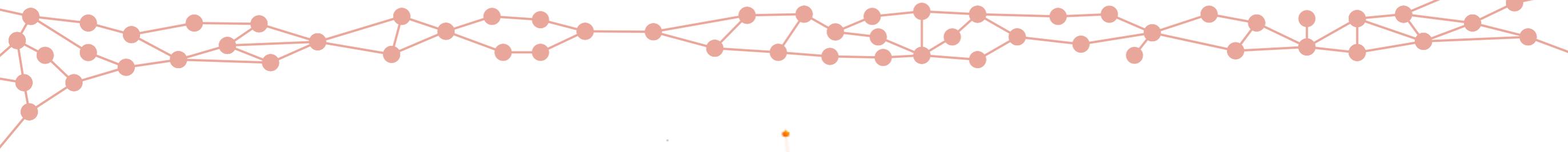
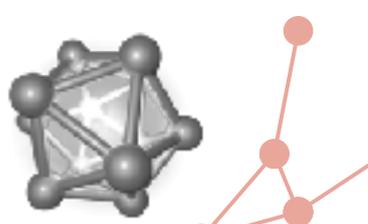


Force Directed 3D embedding

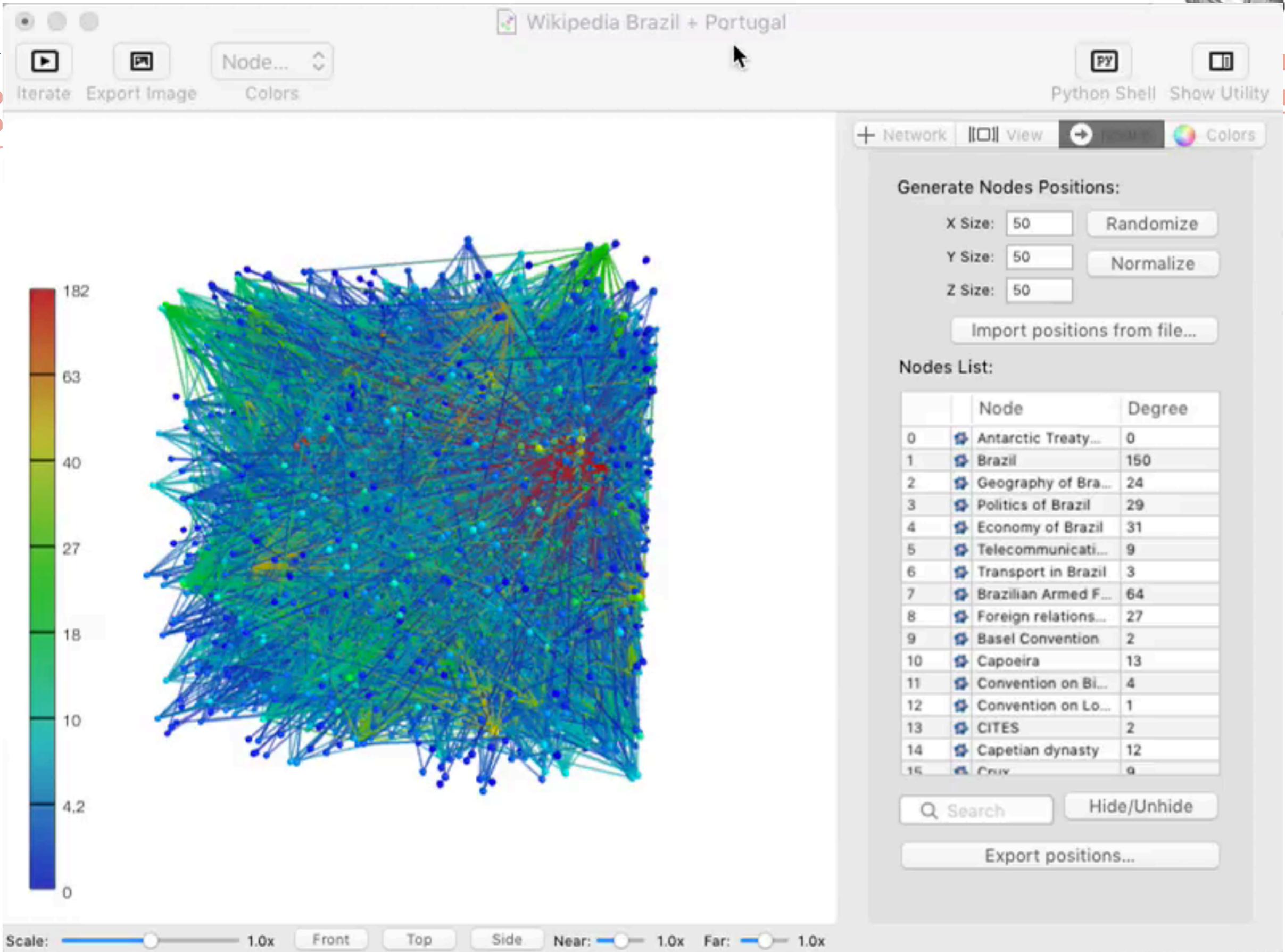


- Chemistry
- Physics
- Medicine
- Engineering
- Biology
- Mathematics

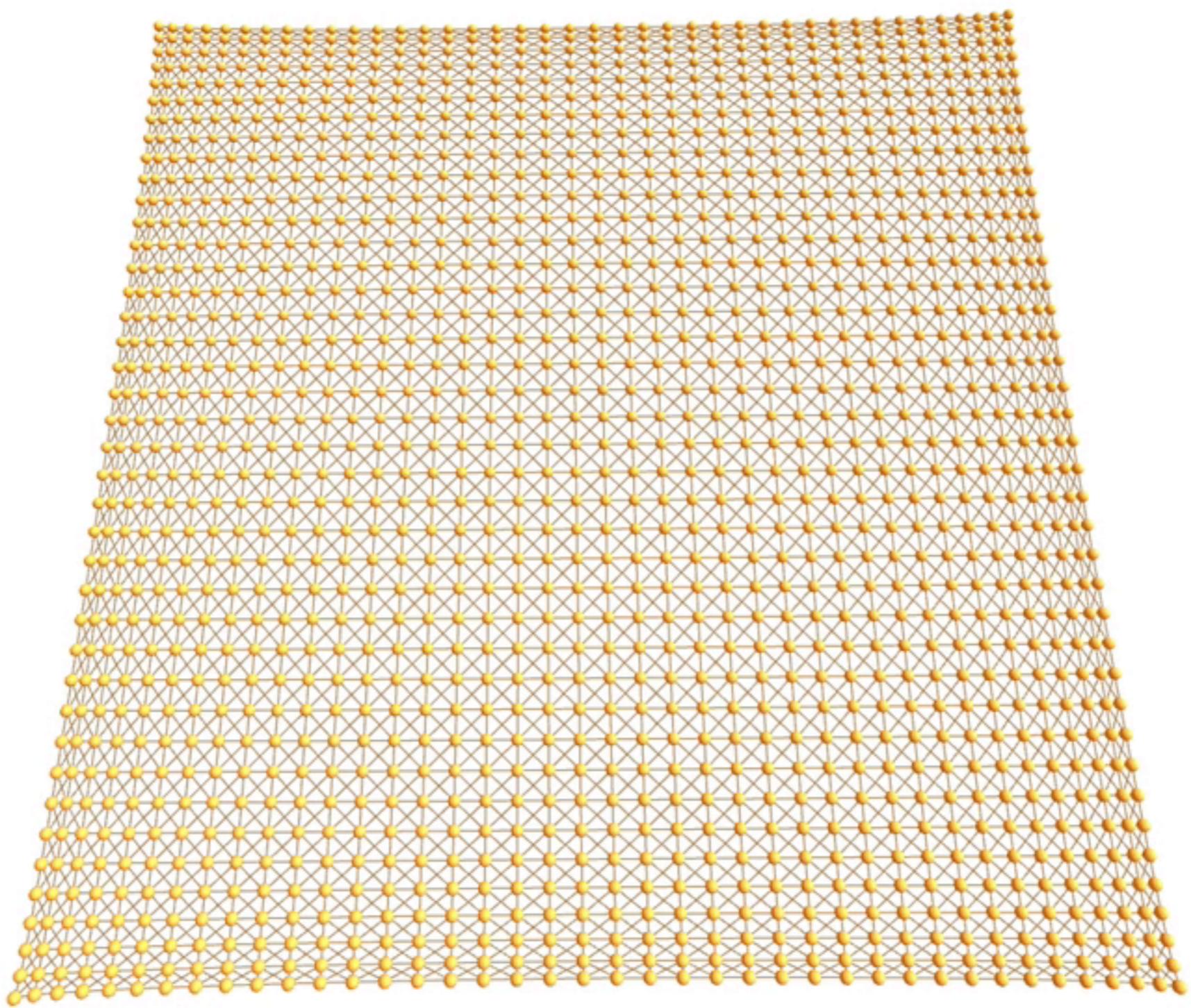
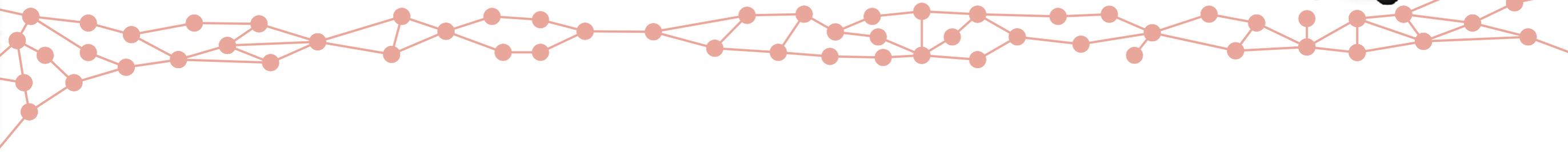
Exemplos de visualização



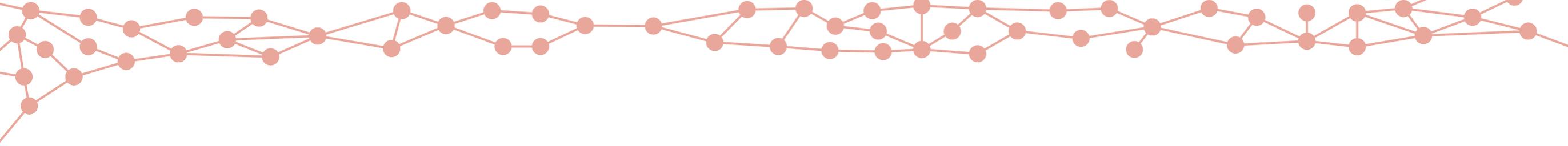
Ex



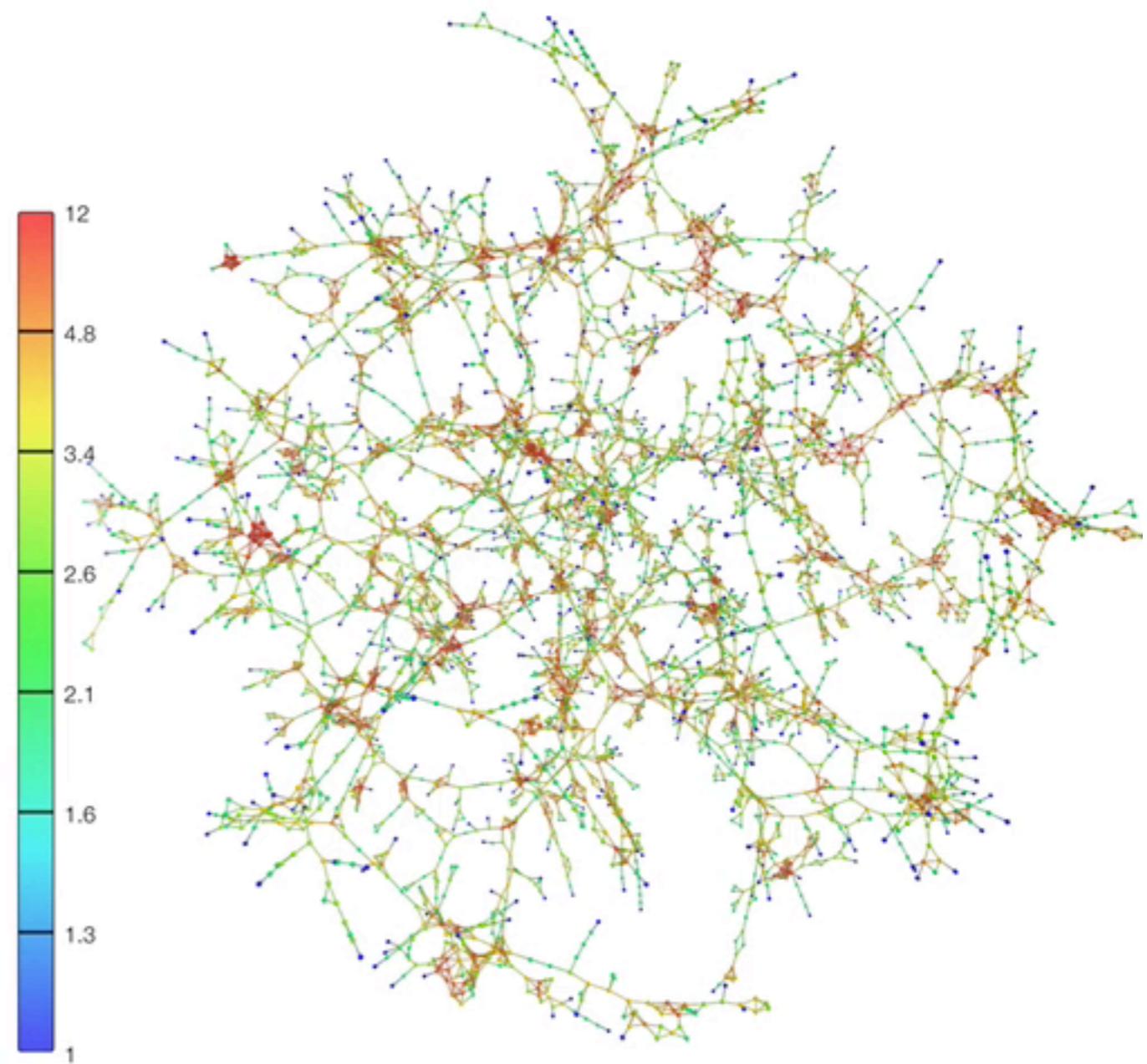
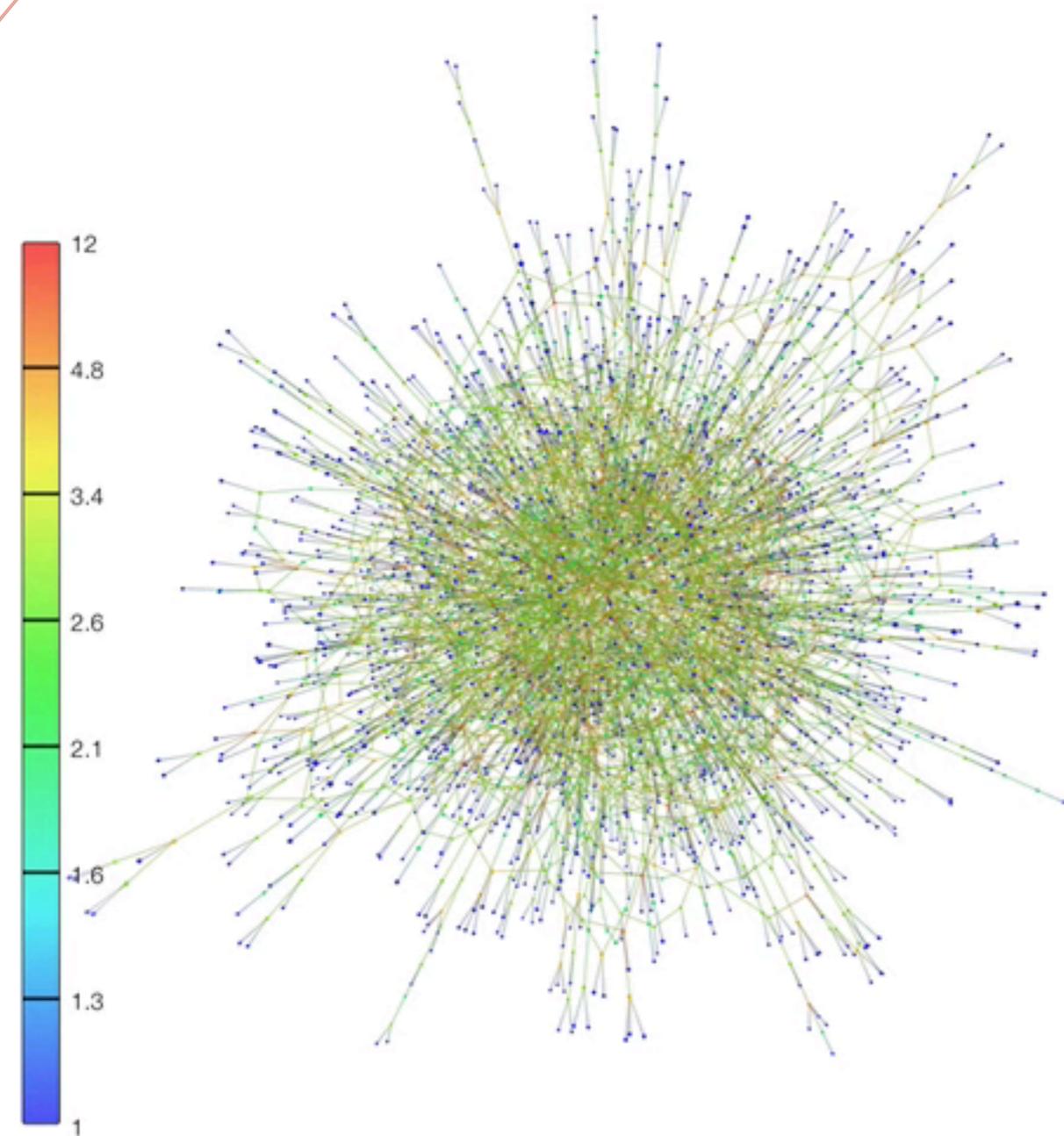
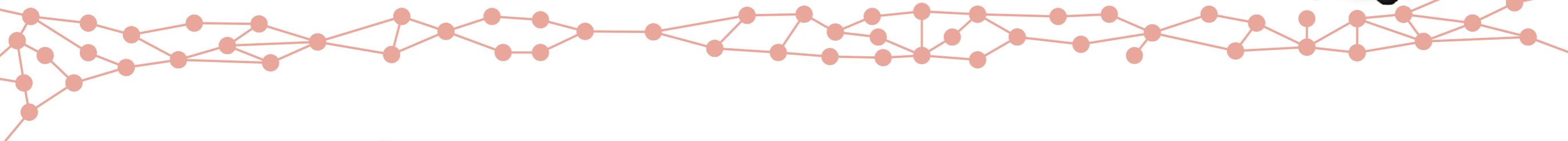
Examples



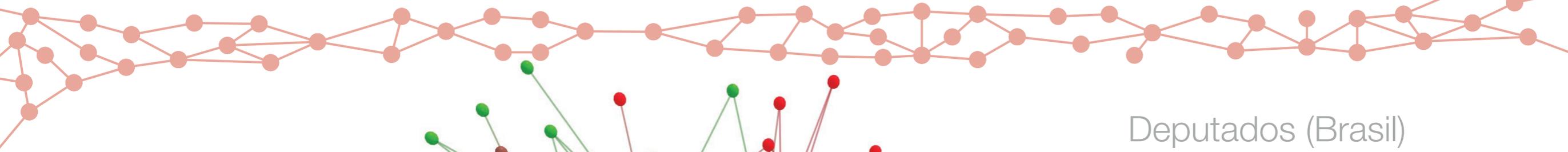
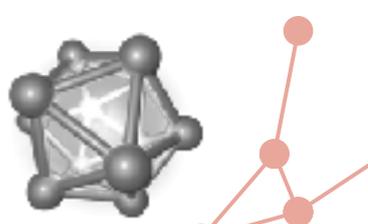
Examples



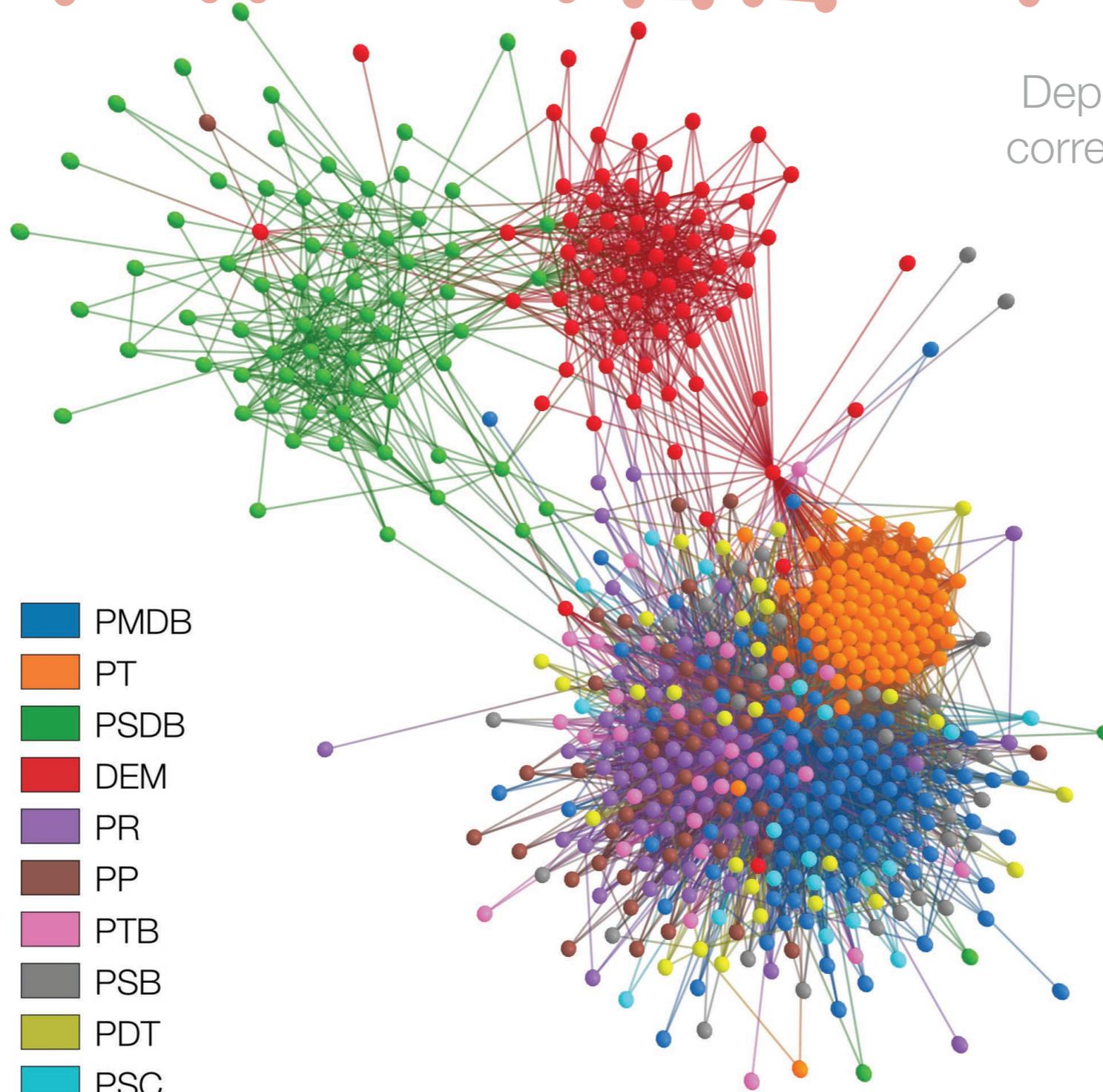
Examples



Exemplos de visualização

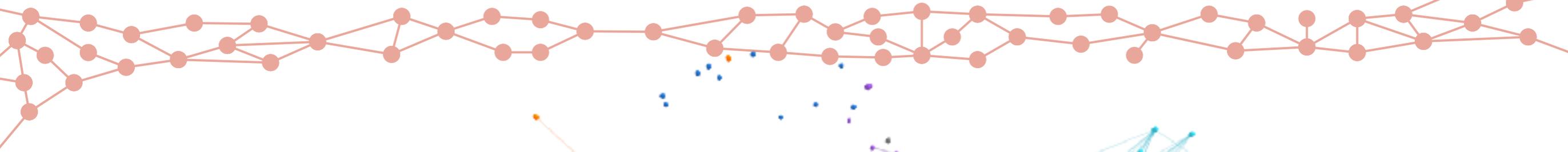


Deputados (Brasil)
correlação de votos

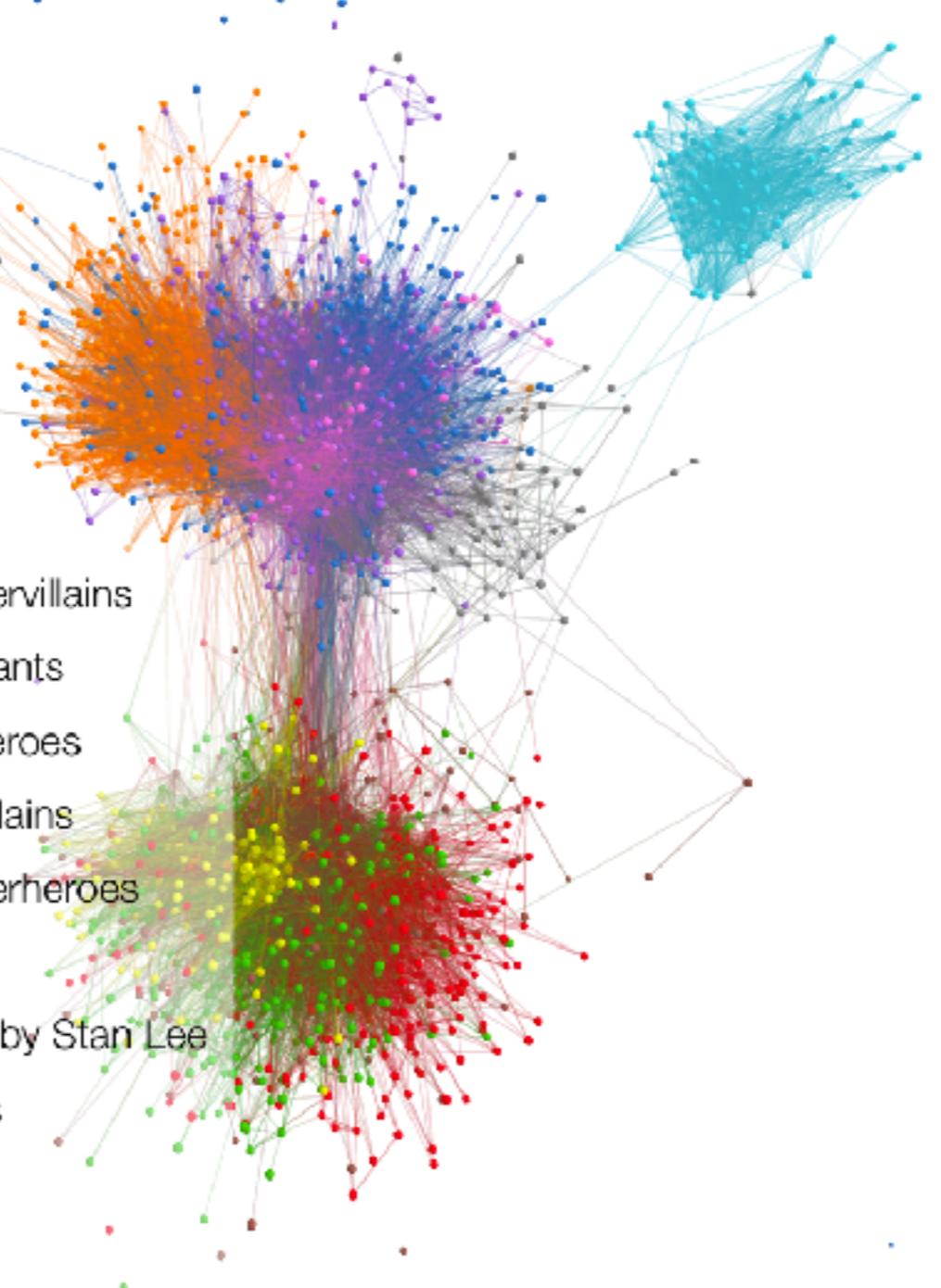


- PMDB
- PT
- PSDB
- DEM
- PR
- PP
- PTB
- PSB
- PDT
- PSC

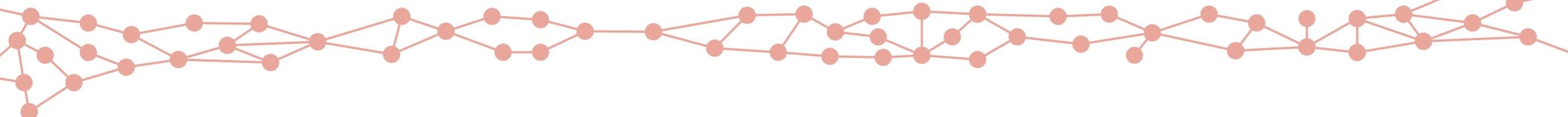
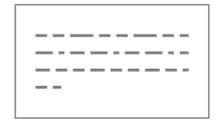
Exemplos de visualização



- Marvel Comics supervillains
- Marvel Comics mutants
- DC Comics superheroes
- DC Comics supervillains
- Marvel Comics superheroes
- DC Comics titles
- Characters created by Stan Lee
- Marvel Comics titles
- DC Comics aliens
- G.I. Joe characters



References and Links



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Journal of Informetrics. v. 7, n. 2, p. 469-477 (2013)

References and Links



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<http://cyvision.ifsc.usp.br/software/networks3d>

Network Viewer for the Web

<http://filipinascimento.github.io/cgicmcprojects/networkviewer/>

Suite Sparse Matrix Collection

<https://sparse.tamu.edu>

Visual Complexity

<http://www.visualcomplexity.com/vc/>

Gephi

<https://gephi.org>

Graph-tool

<https://graph-tool.skewed.de>

GraphViz

<http://www.graphviz.org>

d3.js

<http://d3js.org>

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filipinascimento.github.io

Thank you!