

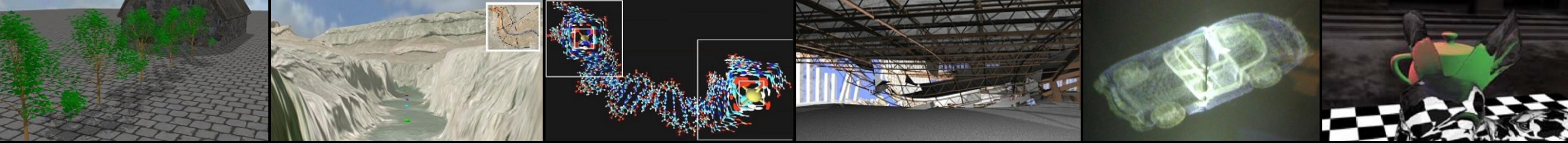
CIS 4930/6930-002

DATA VISUALIZATION



Force Directed Layouts

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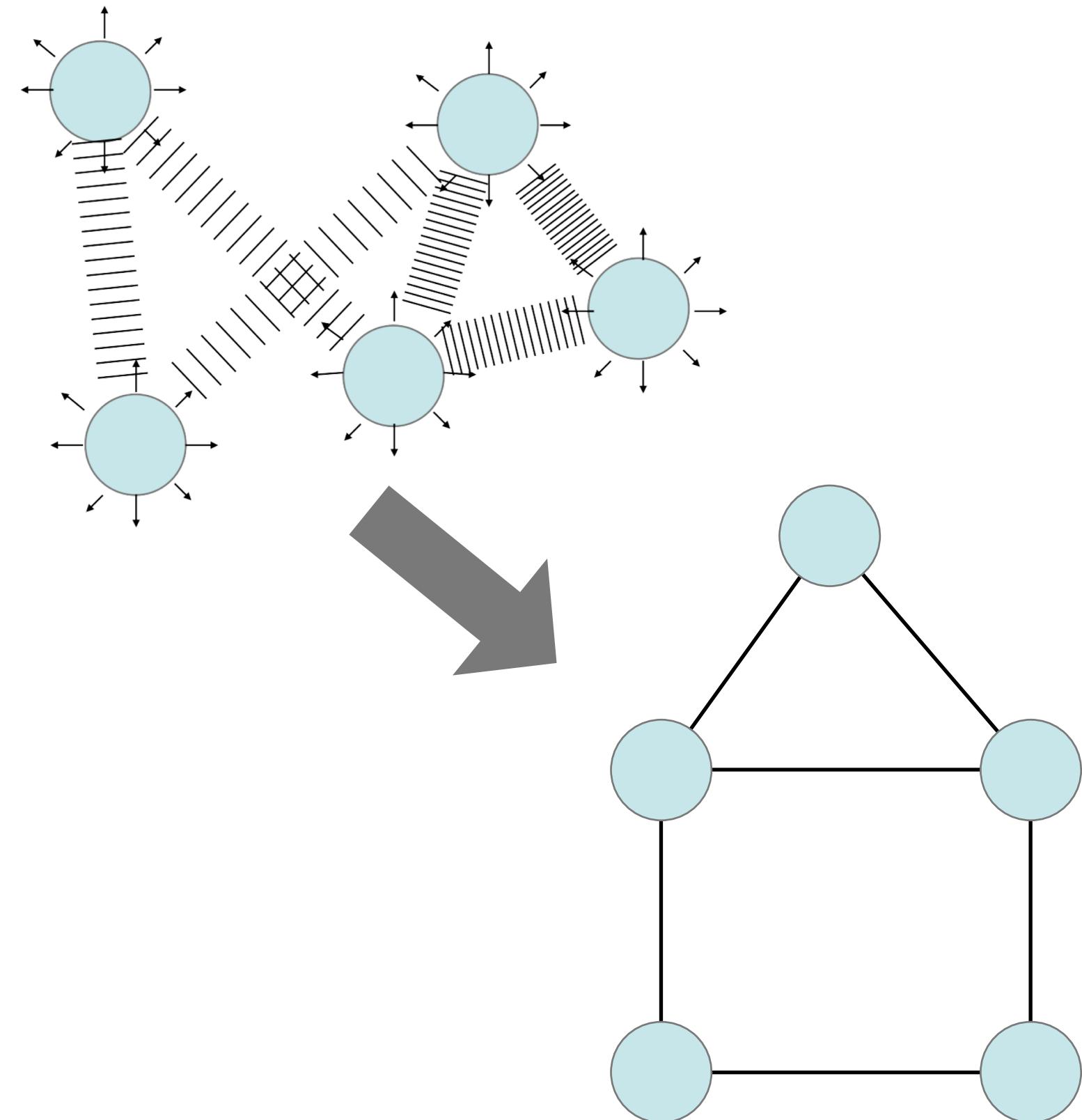


FORCE-DIRECTED

many variations, but usually physical analogy of repulsion and attraction

Generally...
edges = springs
nodes = repulsive particles

Requires an iterative calculation,
should be updated each time the draw
loop is called



PHYSICS REVIEW

$$F = ma$$

(Force = mass * acceleration)

$$\Delta v = a \Delta t$$

(change in velocity = acceleration * time step)

$$p' = p + v \Delta t + \frac{1}{2} a \Delta t^2$$

(new position = old position + velocity * time step)



PHYSICS REVIEW

$$a' = \frac{F}{m}$$

(acceleration = Force / mass)

$$v' = v + a' \Delta t$$

(new velocity = old velocity + acceleration * time step)

$$p' = p + v' \Delta t + \frac{1}{2} a' \Delta t^2$$

(new position = old position + new velocity * time step)



FOR A GIVEN NODE i

$$\vec{a}'_i = \frac{\vec{F}_i}{m_i}$$

(acceleration = Force / mass)

$$\vec{v}'_i = \vec{v}_i + \vec{a}'_i \Delta t$$

(new velocity = old velocity + acceleration * time step)

$$\dot{p}'_i = \dot{p}_i + \vec{v}'_i \Delta t + \frac{1}{2} \vec{a}'_i \Delta t^2$$

(new position = old position + new velocity * time step + $\frac{1}{2}$ acceleration* time step²)



WHAT VALUES DO WE SET FOR...

time step Δt ?

initial position p_i ?

initial velocity v_i ?

mass m_i ?

Force F_i ?



WHAT VALUES DO WE SET FOR...

time step Δt ?

Fixed timestep, time since last frame was drawn, ...

initial position p_i ?

Start with a random position

initial velocity v_i ?

Zero

mass m_i ?

Depends, however, the heavier it is, the slower it moves

Force F_i ?

That is what we still need to calculate...



FORCE MODEL: REPULSIVE FORCES

$$f_R(d) = \frac{C_R m_1 m_2}{d^2}$$

C_R is a strength constant

m_1, m_2 are node masses

d is a distance between nodes



FORCE MODEL: ATTRACTIVE FORCES

$$f_A(d) = C_A \cdot \max(0, d - L)$$

C_A is a strength constant

d is a distance between nodes

L is the rest length of the spring (i.e. Hooke's Law)



FORCE MODEL

Every node feels repulsion to every other node



FORCE MODEL

Only **connected** nodes feel attracted



WHAT VALUES FOR...

Repulsive constant C_R ?

Attractive constant C_A ?

Rest length of the spring L ?



WHAT VALUES FOR...

Repulsive constant C_R ?

Start with something small (weaker force)

Attractive constant C_A ?

Start with something small (weaker force)

Rest length of the spring L ?

Closest you would *like* 2 nodes to be together (they will be closer) – 10-20 pixels is a good start



FORCE MODEL

Repulsive force:

$$\overrightarrow{F}_R(\dot{P}) = \sum_{all\ nodes:\dot{Q}} f_R(\|\dot{P} - \dot{Q}\|) \frac{(\dot{P} - \dot{Q})}{\|\dot{P} - \dot{Q}\|}$$

Attractive force:

$$\overrightarrow{F}_A(\dot{P}) = \sum_{connected\ neighbors:\dot{Q}} f_A(\|\dot{Q} - \dot{P}\|) \frac{(\dot{Q} - \dot{P})}{\|\dot{Q} - \dot{P}\|}$$



ALGORITHM

start from random layout

(draw) loop:

Calculate forces (you need to do this)

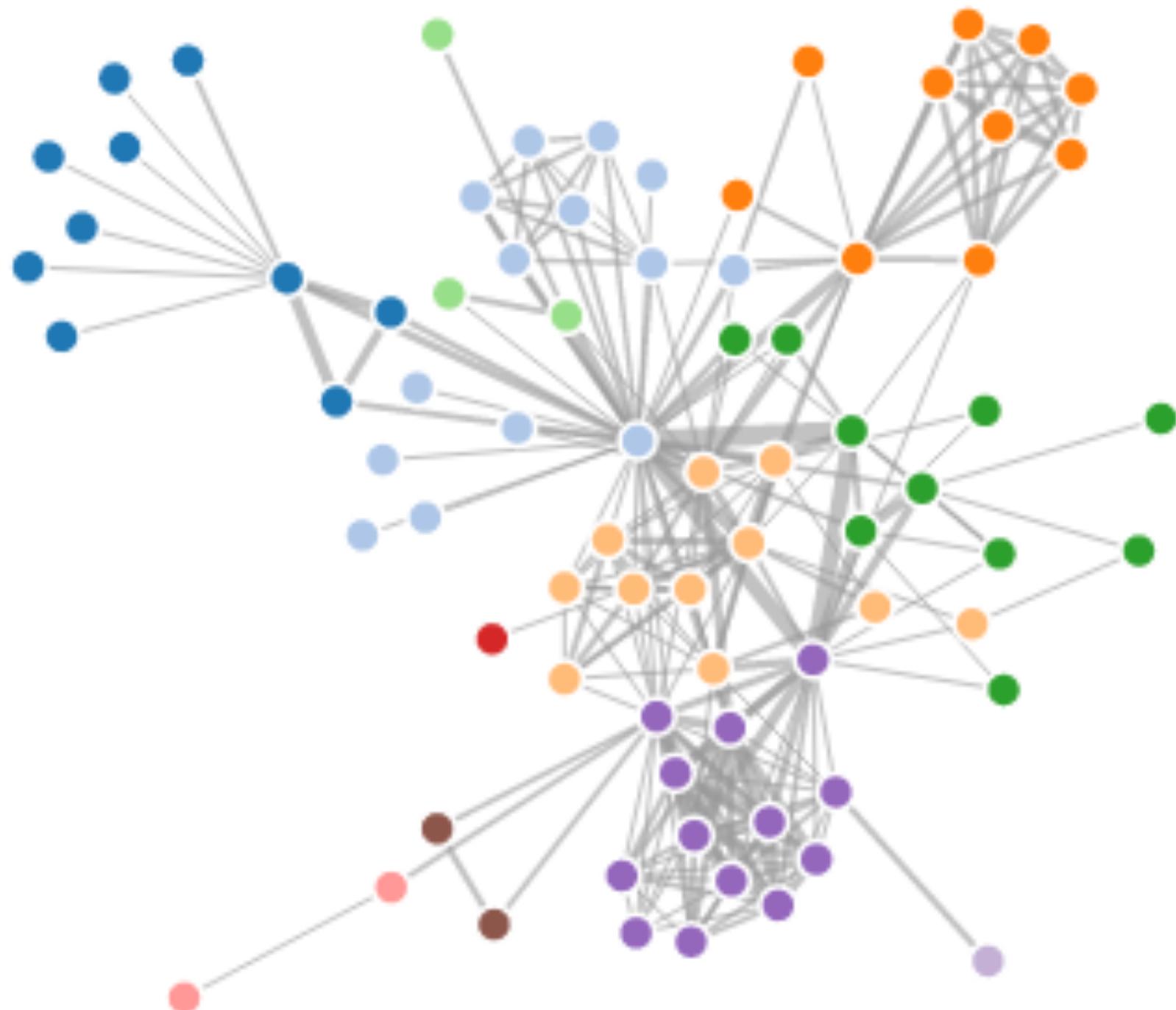
Update acceleration (done for you)

Update velocity (done for you)

Update position (done for you)

Draw the graph





<HTTP://BLOCKS.ORG/MBOSTOCK/4062045>



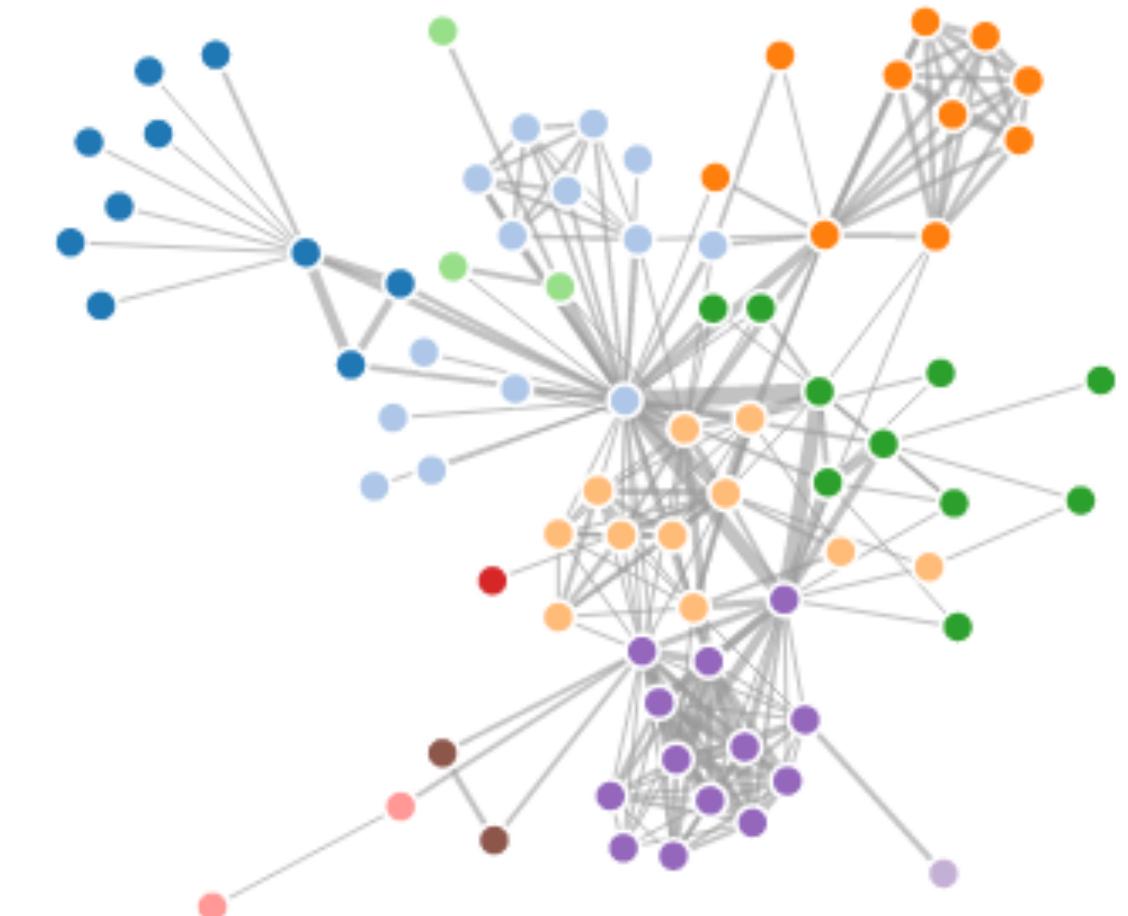
FORCE DIRECTED

- + very flexible, aesthetic layouts on many types of graphs
 - + can add custom forces
 - + relatively easy to implement



FORCE DIRECTED

- repulsion loop is $O(n^2)$ per iteration
can speed up to $O(n \log n)$ using quadtree or k-d tree
 - prone to local minima
can use simulated annealing
- doesn't work well on highly connected
(low diameter) graphs



IDEAS TO MAKE IT BETTER

Add extra forces, such as repulsion from the boundary or attraction to the center of the screen.

Allow overriding node positions using the mouse (dragging vertices)

Allow fixing the position of certain nodes

Other ideas?



