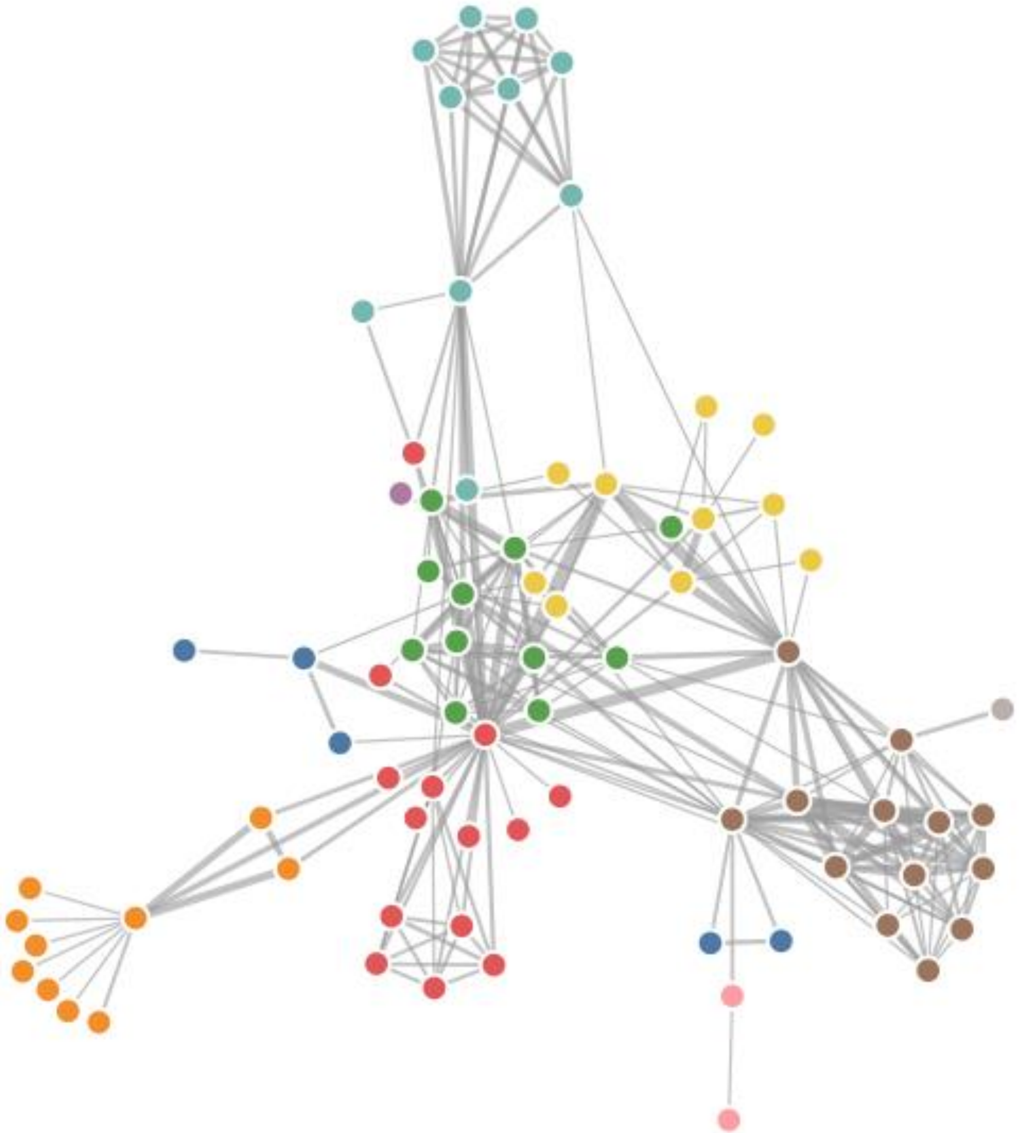
D3: Force Directed

Tommaso Piselli

Force Directed Layout

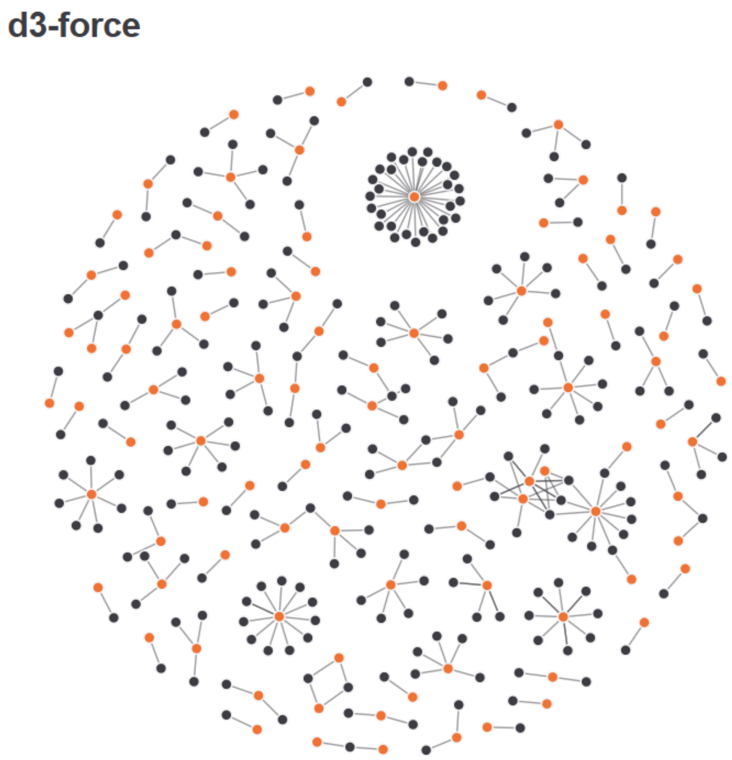
- The **force layout** is a physical inspired layout to determine a network's most optimal graphical representation.
- **Idea**:
  - All the edges have almost equal length and there are as few crossings as possible.
  - The forces are based on the relative positions of the nodes and edges.
  - Then, we use these forces either to simulate the motion of the edges and nodes or to minimize their energy.
- In D3, unlike other layouts, the **force layout** operates in real-time rather than as a preprocessing step before rendering.



https://observablehq.com/@d3/force-directed-graph

Force Directed Layout and D3

- To run a D3 simulation, we call the method `d3.forceSimulation()` from the module [d3-force]
- Based on the forces applied to the simulation, D3 appends two types of information to each node:
  - their next position (`x` and `y`)
  - their next velocity (`vx` and `vy`)



Force Directed and D3

- Every time D3 completes an iteration of the simulation, named **tick**, we call a custom function.
- In this function, we change the position of the svg circle (a.k.a. the node) according to the data appended by D3.
  - With a spark of fantasy, this function is usually called **ticked()** as a convention.
- We perform this cycle until the **simulation converges**, meaning that the nodes found an optimal position according to the bound forces.

Force Directed and D3

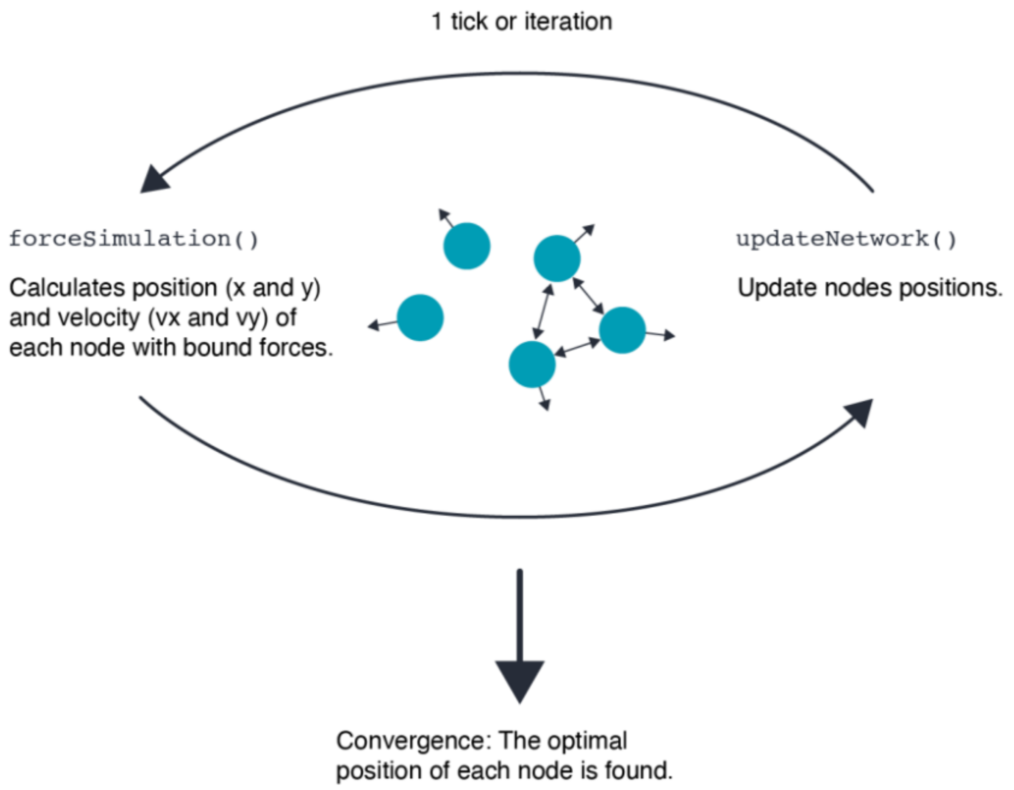


Image from: Chapter 12, “D3.js in Action”

Positioning Forces

- The positioning forces are called with the methods:
  - `forceX():` makes the nodes move toward a horizontal position
  - `forceY():` makes the nodes move toward a vertical position
- So, if we set their relative position values to `0`, the nodes will position themselves into the other direction.
- If we set both their positioning forces to `0`, the nodes will stack one on top of the other.

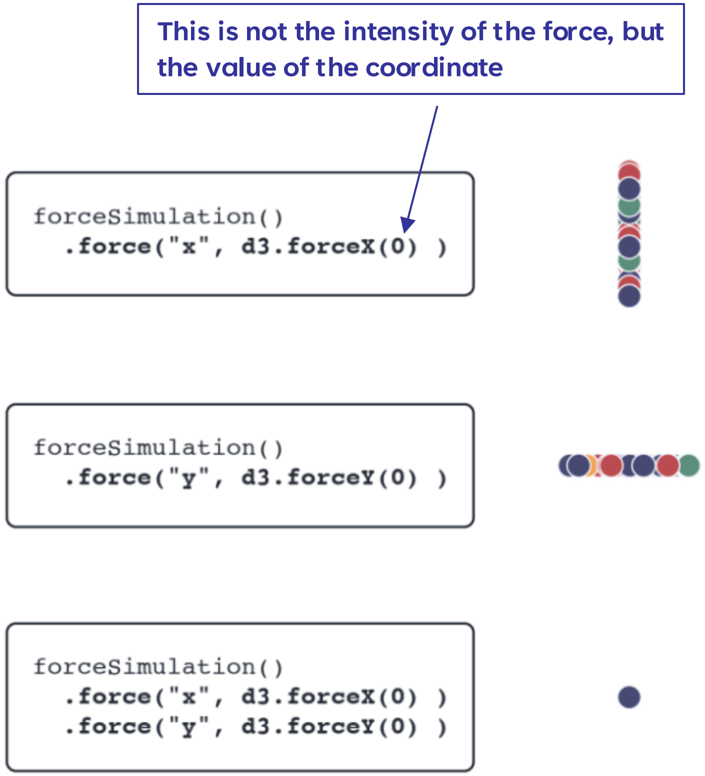


Image from: Chapter 12, “D3.js in Action”

Positioning Forces: Strength

- We can control the intensity of the forces with the `strength()` accessor function of the positioning forces.
  - By default, it is set to `1`.

```
forceSimulation()
  .force("x", d3.forceX(0) )
  .force("y", d3.forceY(0) )
```

```
forceSimulation()
  .force("x", d3.forceX(0).strength(0.01) )
  .force("y", d3.forceY(0) )
```

Here, by setting the **`strength`** of the force in the **X** direction to **`0.01`**, we strengthen the attraction towards the coordinate **`(0, 0)`** from the vertical direction.

```
forceSimulation()
  .force("x", d3.forceX(0) )
  .force("y", d3.forceY(0).strength(0.01) )
```

Image from: Chapter 12, "D3.js in Action"

Collision Forces

- To prevent node overlapping, we can use the collision force `d3.forceCollide().`
- As a parameter, this function takes a **radius** used to set the minimum distance between the nodes.
  - The radius is considered from the center of the nodes.
- If we apply the `forceCollide()` into specific directions, we obtain a **beeswarm layout.**

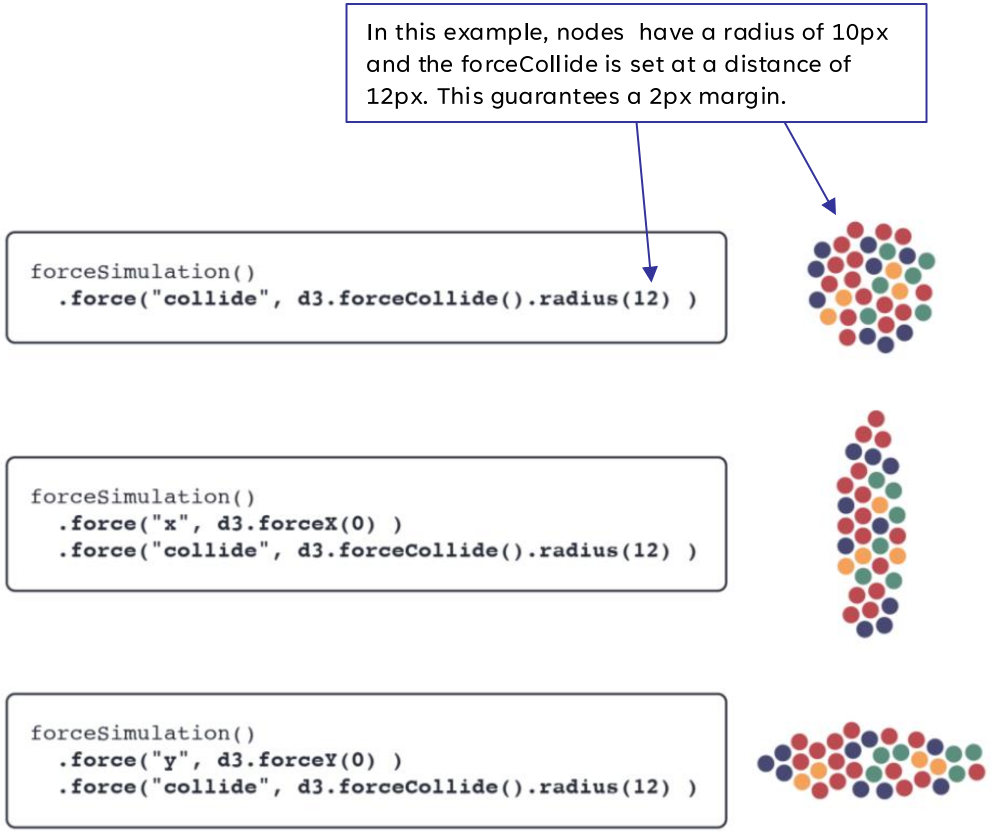


Image from: Chapter 12, “D3.js in Action”

Centering Force

- The `d3.forceCenter()` moves a group of nodes toward a specific position.
- The positioning forces `forceX()` and `forceY()` move nodes individually and this can flatten the layout.
- Meanwhile, `forceCenter()` moves the whole system together, which keeps its original shape.

Image from: Chapter 12, “D3.js in Action”

Many-body Force

- The `d3.forceManyBody()` mimics an attraction / repulsion force:
  - A positive value means **attraction** 🥰
  - A negative value means **repulsion** 😟

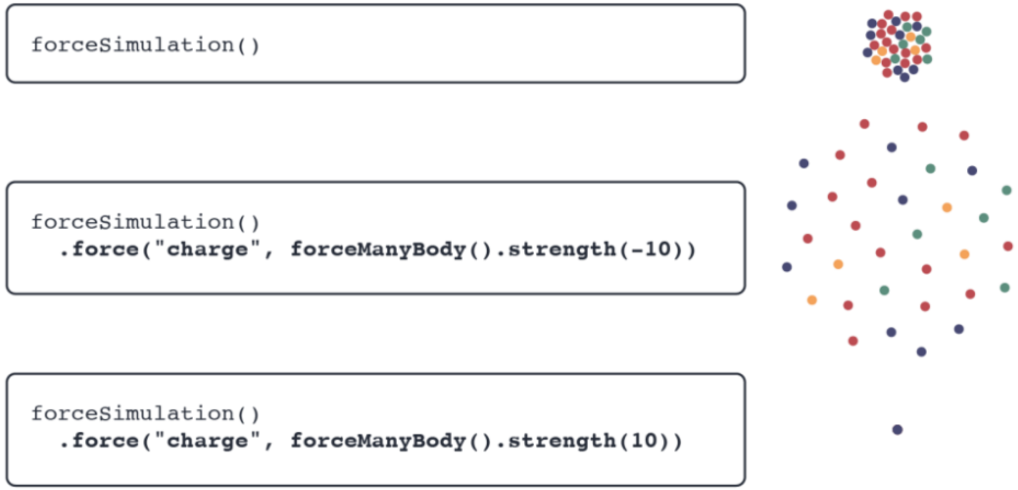


Image from: Chapter 12, "D3.js in Action"

Links

- The `d3.forceLink()` applies a force between connected nodes.
- The more strongly two nodes are connected, the closer the link force will pull them together.
- The combination of all the forces we presented is usually used to create a **forceSimulation()**.

```
// add forces to the simulation
function initializeForces() {
  // add forces and associate each with a name
  simulation
    .force("link", d3.forceLink())
    .force("charge", d3.forceManyBody())
    .force("collide", d3.forceCollide())
    .force("center", d3.forceCenter())
    .force("forceX", d3.forceX())
    .force("forceY", d3.forceY());
  // apply properties to each of the forces
  updateForces();
}
```

Control the Simulation

- The force layout is designed to stop after the nodes are placed on their optimal position.
- However, we can use the following three functions to control a simulation:
  - `simulation.stop():` used to stop a simulation. This is useful if there is an interaction between your network and another object on the page.
  - `simulation.restart():` easy function to restart the simulation.
  - `simulation.tick():` moves the layout of the simulation to the next step. We can also pre-compute the step of the simulation by setting the value of the parameter. So, the `simulation.tick(42)` will compute the 42nd interaction of the simulation.

Bibliography

- All the slides are based on “D3.js in Action, Third Edition” book;
- MDN for anything related the Web;
- D3 documentation.