Introduction to Spring Embedder Layouts

Achievement: You can do anything you set your mind to when you have vision, determination, and an endless supply of expendable labor.
Overview

• Motivation

• Spring Embedder

• Variations
Problem: Finding General Layouts

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- having structural properties
- preprocessing (to find structural properties)
- solving NP-hard problems

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that are

- robust
- flexible
- easy to understand.
Solution: Physical Analogies

in physics:

- models consist of objects and interactions (among them)
- stable configurations (instances) are those with minimal energy levels
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for layout algorithms:

• nodes correspond to (physical) objects

• edges correspond to interactions

• (good?) layouts correspond to stable configurations
Spring-Embedder

**spring model:**

- node are small balls with electrical charge (same sign)
- edges are springs with given constant (ideal length)
- nodes repel each others (repulsive force)
- edges cannot be arbitrary long (attractive force)
Spring-Embedder (2)

- coordinates $p_v$ for each node $v$
- lengths $l_e$ for each edge $e$

$$f_{\text{rep}}(u, v) := \frac{c_1}{\|p_v - p_u\|^2} \cdot \overrightarrow{p_u p_v}$$

$$f_{\text{spring}}(u, v) := c_2 \cdot \log \frac{\|p_u - p_v\|}{l_e} \cdot \overrightarrow{p_u p_v} \quad \text{for } (u, v) = e \in E$$
algorithmic approach:

• choose a random placement (for each node)

• iterate
  – calculate for each node $v$ its force vector $F(v)$
  – move each node $v$ according to its force vector

\[ p_v \leftarrow p_v + \delta \cdot F(v) \]
Spring-Embedder (4)
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Variation [Fruchtermann, Reingold]

• repulsive force:

\[ f_{\text{rep}}(u, v) := \frac{l_{uv}^2}{\|p_u - p_v\|} \cdot \overrightarrow{p_up_v} \]

• attractive force:

\[ f_{\text{attr}}(u, v) := \frac{\|p_u - p_v\|^2}{l_e} \cdot \overrightarrow{p_vp_u} \quad \text{for } (u, v) = e \in E \]

advantage: 'spring' force is super linear in \( l \) (better convergence)
Variations

- grid
- clipping
- rotation

- time dependency
- gravitational forces
- approximation of forces
- multi-level approaches