Labeling the Active Route in Interactive Navigational Maps

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Outline of the presentation

1. Introduction
2. The goal: active route street-labeling
3. Related work: some important theory (with examples!)
4. Pre-work: concerning the street-labeling algorithm
5. The algorithm: active route street-labeling
6. The implementation: decisions and challenges
7. Conclusion

Current state of navigation devices

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Approximation: current navigation devices...

- label important streets
- label a minimal number of general streets
- render labels parallel to the screen
- do not always use leaders

The goal: active route street-labeling

Improve the active route street-labeling

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- vary leader length, and
- use a force-directed algorithm.

Not part of our goal is

- initial label placement, or
- optimal placement or manipulation of labels.

What do we need to consider?

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- interactive,
- 2.5-dimensional, and
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The label placement should be perfect!

The perfect is the enemy of the good

Le mieux est l'ennemi du bien.
– Voltaire

What is good? A suggestion for the "optimum"

1. Guaranteed visual association between label and feature.
2. Preservation of depth cues in the virtual world.
3. Spatial orientation support for the labels.
4. Minimal label movement (between frames).

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and most importantly. . .

5. The user should
   (a) be able to recognize and process the information,
   (b) not be confused, and
   (c) not be overwhelmed.

Related work: some important theory

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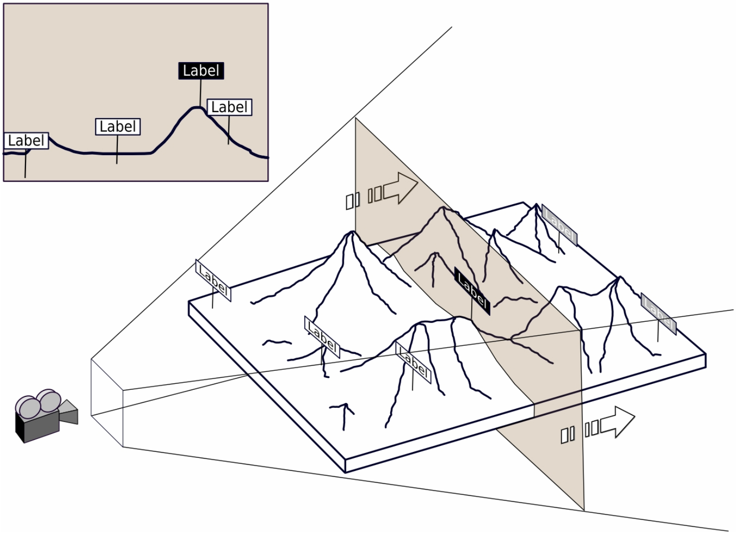
World and screen space

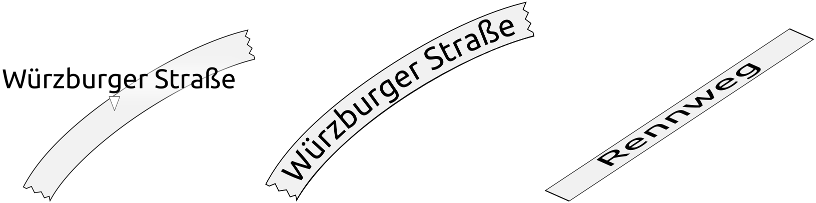
We distinguish between world and screen space.



World and screen space labels

Labels can be in different kinds of "spaces":

- screen space with/out leader
- screen space following street
- world space on street



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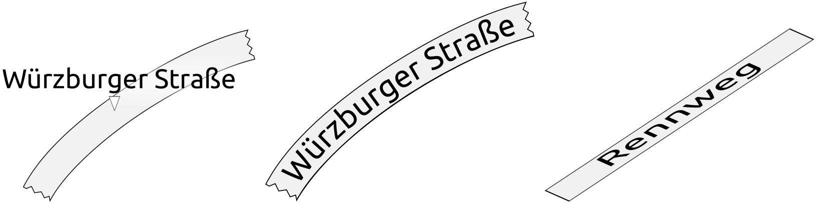


We use the billboarding technique.

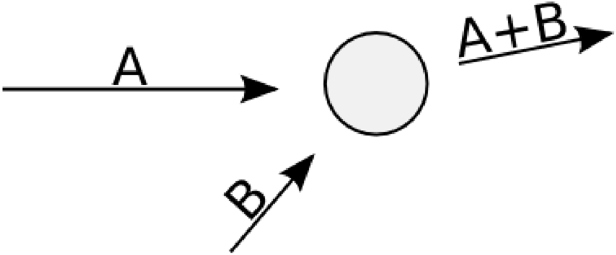
Force-directed algorithms

Think of electrons:

How does force-directed ∗ work?

Force-directed *anything* in its basic form:

1. Each node applies directional force on others.
2. Each node tries to reach an equilibrium of forces.
3. Eventually every node is in a local optimum state.



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Advantage #1. Fast with good results.

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Solution to these disadvantages: simulated annealing.

Pre-work: concerning the street-labeling algorithm

We build our *own* navigation device!

With the help of *C++*, *Boost*, *OpenSceneGraph*, *ShapeLib*, and *OpenStreetMap*:

The algorithm: active route street-labeling

Finally, the juicy part of the talk!

Our control: a static street-labeling algorithm.

Algorithm:

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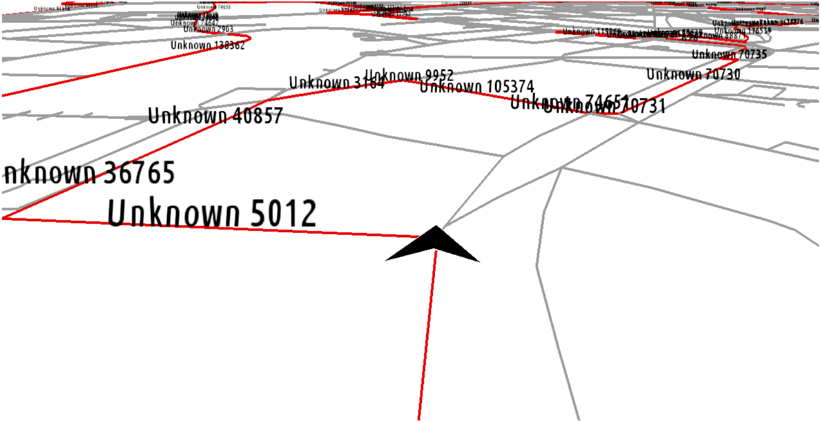
Obvious **advantages**:

- extremely efficient
- minimal label movement
- good visual association
- labels act as depth cues
- labels support spatial orientation

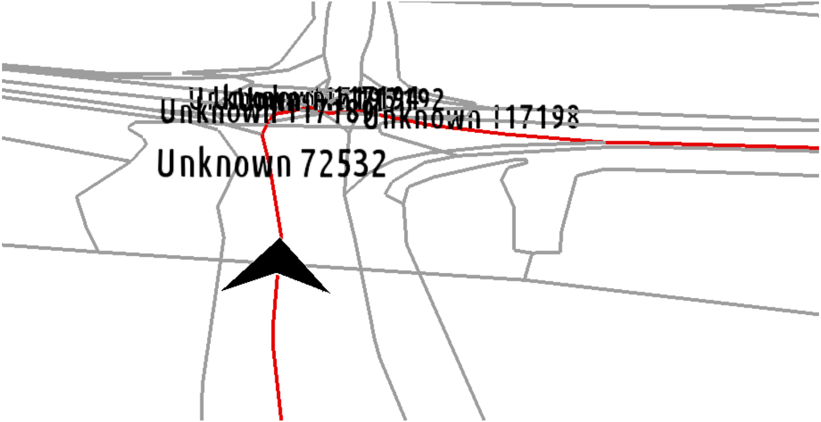
Static-labeling example 1

Disadvantage #1. Only one label is placed per street segment.



Static-labeling example 2

Disadvantage #2. Labels are placed without regard to anything.



Force-directed street labeling!

Babysitting the little labels. . .

Labels avoid collisions through repulsive forces.

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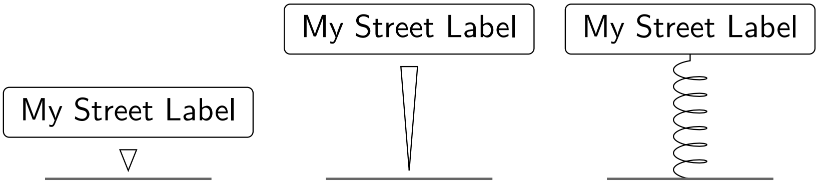
To keep the label λ_i on the ground, the leader exerts a force too.

$$\textbf{Hooke's law:}\ \hat{F}_i = -k \cdot x_i$$



The force of multiple labels on λ_i is

$$\tilde{F}_i = c \cdot \sum_{j \in I \setminus \{i\}} \sigma(\lambda_i, \lambda_j) \frac{1}{d(\lambda_i, \lambda_j)^2}.$$

Constants and functions:

- k *spring constant*
- c *repulsion constant*
- I *indices set of all displayed labels* (e.g. $\{1, 2, \ldots, n\}$)
- $\sigma(\lambda_i, \lambda_k)$ *sign operator*
- $d(\lambda_i, \lambda_k)$ *distance function*

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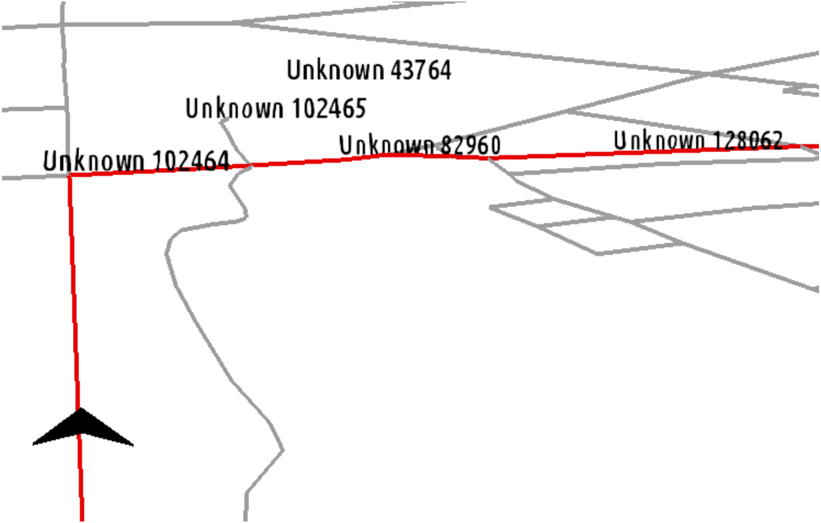
Runtime complexity: $\eta := |I| \quad \Rightarrow \quad O(\eta^2)$

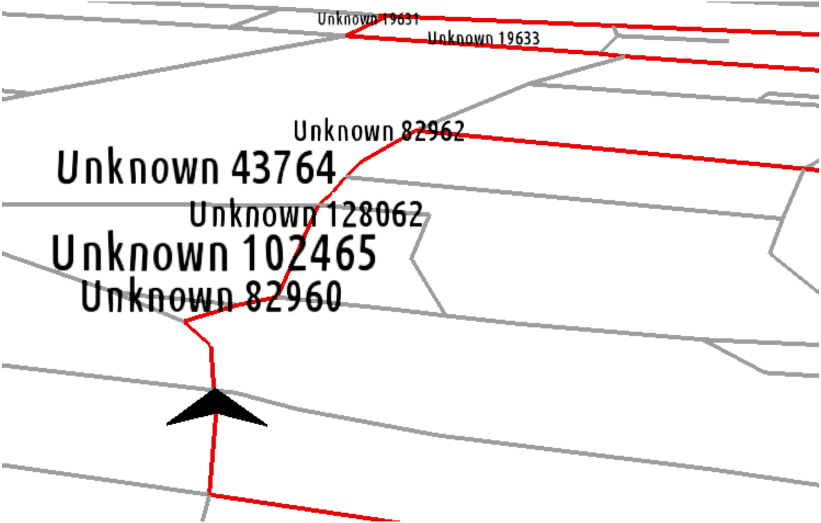
Force-directed labeling example 1

Advantage #1. Labels do not collide.



Force-directed labeling example 2

Disadvantage #1. Initial position affects outcome strongly.



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Disadvantage #1. Initial position affects outcome strongly.

Disadvantage #2. Labels cannot get by each other.

Disadvantage #3. Labels start with height 0.

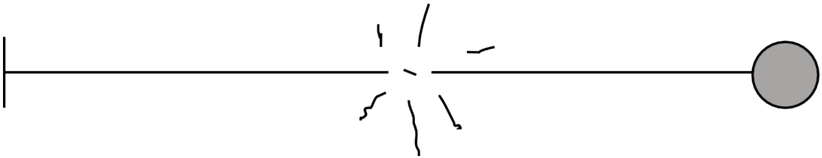
Disadvantage #4. Labels stack.

The implementation: decisions and challenges

Difficulty defining function d

Problems with modeling real-world physics:

Problem 1. Hooke's law breaks down with extremes.



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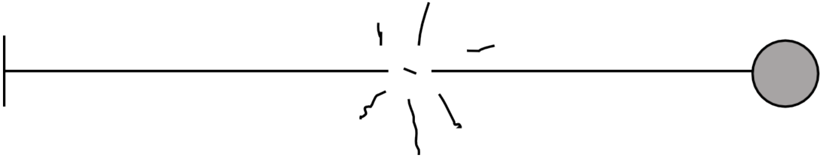
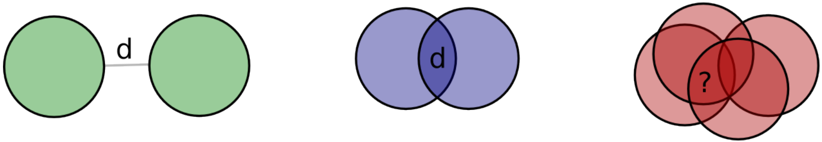


Problem 2. Distance formula breaks down with overlapping.



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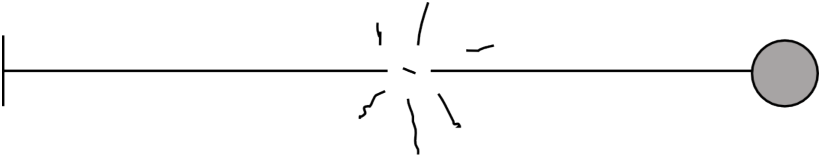

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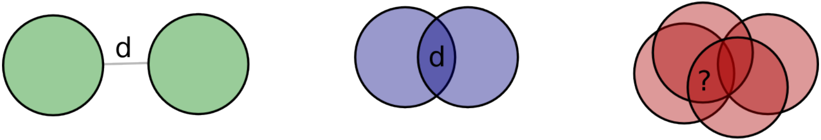

$\Rightarrow$ Solution: define d ourselves.

A revisit to world-screen-space relationships

Example situation:

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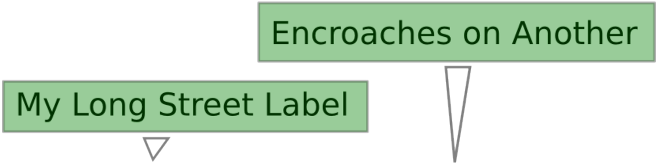
Angled view:



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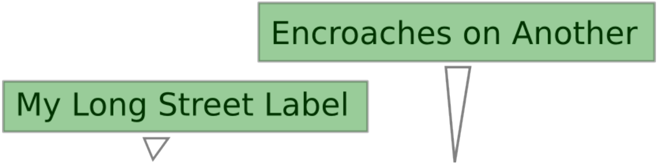
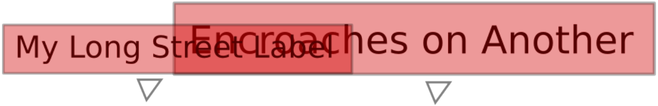
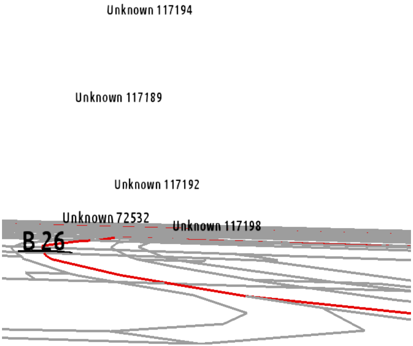


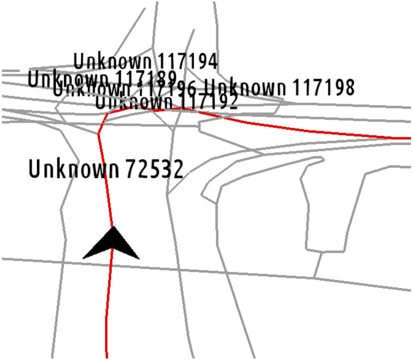
Top-down view:



Constant definitions are not trivial

If spring constant k not correctly tuned to repulsion constant c, problems occur.





Conclusion

Future work

1. Completion: implement other strategies presented.
2. Prioritization: augment forces model with mass and gravity.
3. Smoothness: research effects of acceleration/deceleration.
4. Freedom: labels could have two degrees of movement freedom.
5. Space: label leaders could slant left/right.
6. Goodness: research for escaping local optima.
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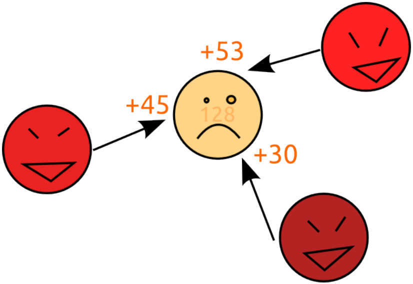
Thank you for listening!

How does force-directed ∗ work?

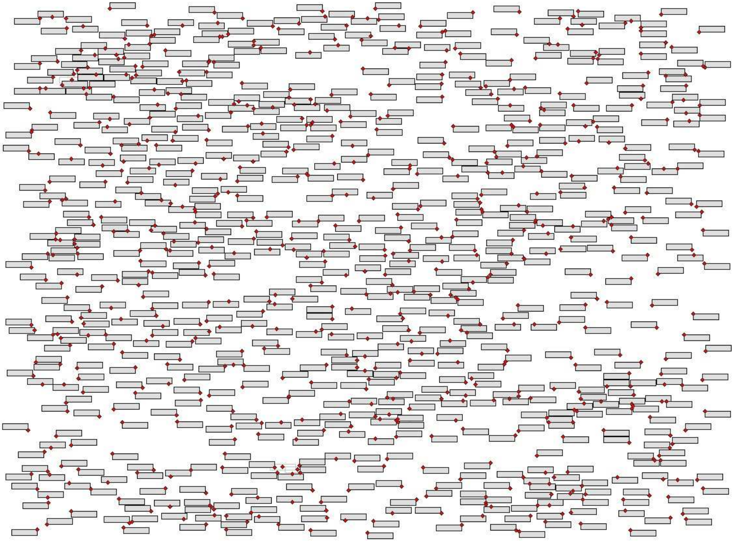
Alternative perspective:

1. Each node applies bad energy on others.
2. Each node tries to minimize its energy by moving elsewhere.
3. Eventually every node is in a local optimum state.



Results of force-directed labeling

Ebner et. al [2003] computed this in < 5 seconds:



Questions of the black-box function β

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1. How do labels settle?
2. How does movement scale with force?
3. Iterations/second vs. frames per second?
4. What is the optimum adjustment speed?
5. Maximum movement in one iteration?

A solution: keep modeling physics?

Answer: Labels have mass (charge) that determines movement.

- Allows dynamic prioritization!
- With acceleration and deceleration?

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Not trivial, e.g.:

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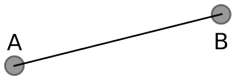
Where the screenshots come from...

My current implementation:

- Bad energy perspective
- Label overlapping = energy
- Complex gradient method black-box function



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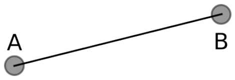

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Good news: there is room for improvement, and we know where!