Labeling the Active Route in Interactive Navigational Maps

Benjamin Morgan

University of Würzburg

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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

I conducted an extensive survey of current PND technology.
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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
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Improve the active route street-labeling

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- use a force-directed algorithm.
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?

The environment of such moving labels is

- interactive,
- 2.5-dimensional, and
- with a free view-point.
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The efficiency requirements are

- real-time rendering, and
- minimal resource usage.
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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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2. Preservation of depth cues in the virtual world.

3. Spatial orientation support for the labels.

4. Minimal label movement (between frames).

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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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
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

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.
Advantages and disadvantages...

**Advantage #1.** Fast with good results.

**Advantage #2.** Simple and easy to understand and implement.

**Advantage #3.** Looks structured and captures symmetries.

**Disadvantage #1.** Easily caught in local minima.

**Disadvantage #2.** Initial placement is significant.

Solution to these disadvantages: simulated annealing.
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We build our *own* navigation device!

With the help of C++, Boost, OpenSceneGraph, ShapeLib, and OpenStreetMap:
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Finally, the juicy part of the talk!

Our control: a *static* street-labeling algorithm.

**Algorithm:**

1. Create label and place in the middle of each segment.
Finally, the juicy part of the talk!

Our control: a static street-labeling algorithm.

Algorithm:

1. Create label and place in the middle of each segment.

Obvious advantages:

- extremely efficient
- minimal label movement
- good visual association
- labels act as depth cues
- labels support spatial orientation
Disadvantage #1. Only one label is placed per street segment.
**Disadvantage #2.** Labels are placed without regard to anything.
Force-directed street labeling!
Babysitting the little labels. . .

Labels avoid collisions through repulsive forces.
Babysitting the little labels...

Labels avoid collisions through repulsive forces.

To keep the label $\lambda_i$ on the ground, the leader exerts a force too.

**Hooke's law**: $\hat{F}_i = -k \cdot x_i$
The force of multiple labels on $\lambda_i$ 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
What is the leader length adjustment?

We need: leader length adjustment.
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**Solution 1.** Find the equilibrium of forces:

\[ \hat{F}_i + \tilde{F}_i = 0 \]
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Difficult.

**Solution 2.** Apply black-box function \( \beta \) on net force:

\[
\beta(\hat{F}_i + \tilde{F}_i)
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New Problem: How do we define \( \beta \)?
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New Problem: How do we define \( \beta \)?

**Runtime complexity:** \( \eta := |l| \implies O(\eta^2) \)
Advantage #1. Labels do not collide.
Disadvantage #1. Initial position affects outcome strongly.
Inherent advantages and disadvantages

**Advantage #1.** Labels do not collide.

**Advantage #2.** Labels move predictably.
Inherent advantages and disadvantages

**Advantage #1.** Labels do not collide.

**Advantage #2.** Labels move predictably.

**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

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Difficulty defining function $d$

Problems with modeling real-world physics:

**Problem 1.** Hooke’s law breaks down with extremes.
Difficulty defining function $d$

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**Problem 2.** Distance formula breaks down with overlapping.
Difficulty defining function $d$

Problems with modeling real-world physics:

**Problem 1.** Hooke’s law breaks down with extremes.

**Problem 2.** Distance formula breaks down with overlapping.

⇒ Solution: define $d$ ourselves.
A revisit to world-screen-space relationships

Example situation:

- My Long Street
- Label: "Other Streets"
- Acrobat on Another
A revisit to world-screen-space relationships

Example situation:

Angled view:
A revisit to world-screen-space relationships

Example situation:

Angled view:

Top-down view:
Constant definitions are not trivial

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

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Future work

1. Completion: implement other strategies presented.
2. Prioritization: augment forces model with mass and gravity.
4. Freedom: labels could have two degrees of movement freedom.
5. Space: label leaders could slant left/right.
7. Placement: more intelligent initial placement.
Future work

1. Completion: implement other strategies presented.
2. Prioritization: augment forces model with mass and gravity.
4. Freedom: labels could have two degrees of movement freedom.
5. Space: label leaders could slant left/right.
7. Placement: more intelligent initial placement.

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 $\beta$

Simple definition: $\beta(F) = \zeta \cdot F$

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?
Questions of the black-box function $\beta$

**Simple definition:**  $\beta(F) = \zeta \cdot F$

**Question:** Given force $F$ on $\lambda$, how should $\lambda$ move in one iteration?
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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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\tilde{F}_i = c \cdot \sum_{j \in I \setminus \{i\}} m_i m_j \cdot \sigma(\lambda_i, \lambda_j) \frac{1}{d(\lambda_i, \lambda_j)^2}.
\]
Where the screenshots come from...

My **current** implementation:

- Bad energy perspective
- Label overlapping $= \text{energy}$
- Complex gradient method black-box function
- Everything in world space
Where the screenshots come from . . .

**My current implementation:**

- Bad energy perspective
- Label overlapping \(=\) energy
- Complex gradient method black-box function
- Everything in world space

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