CRITERIA FOR SELECTING SMALL SETS OF ALTERNATIVE ROUTES IN CONSTRAINED FREE SPACE SCENARIOS

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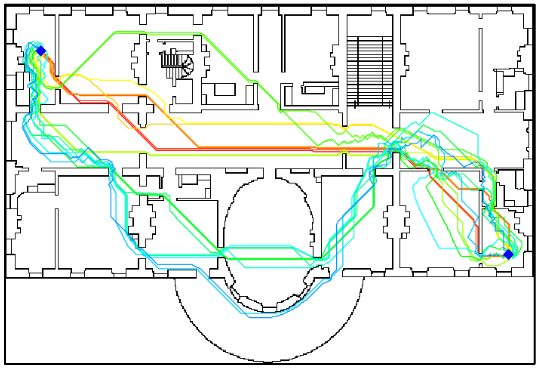
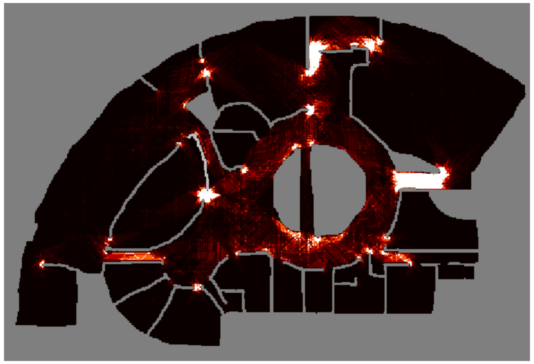
MOTIVATION

"Alternative routes in complex environments"



Indoor Navigation
- Assistance in hospitals, airports, fairs, …
- Mobile robots (smart city, ambient assistant living)
- Non-player character in computer games

Alternative routes
- What is an alternative route? How to find them?
- Is there a quality of alternative routes?
- How to get preferably diverse routes?



Leaving the application level
- Similarity or distance metrics of geospatial trajectories
- In particular regarding indoor scenarios, i.e. floor plans of buildings

MOTIVATION

Alternative routes

- Use cases are clear

Small sets

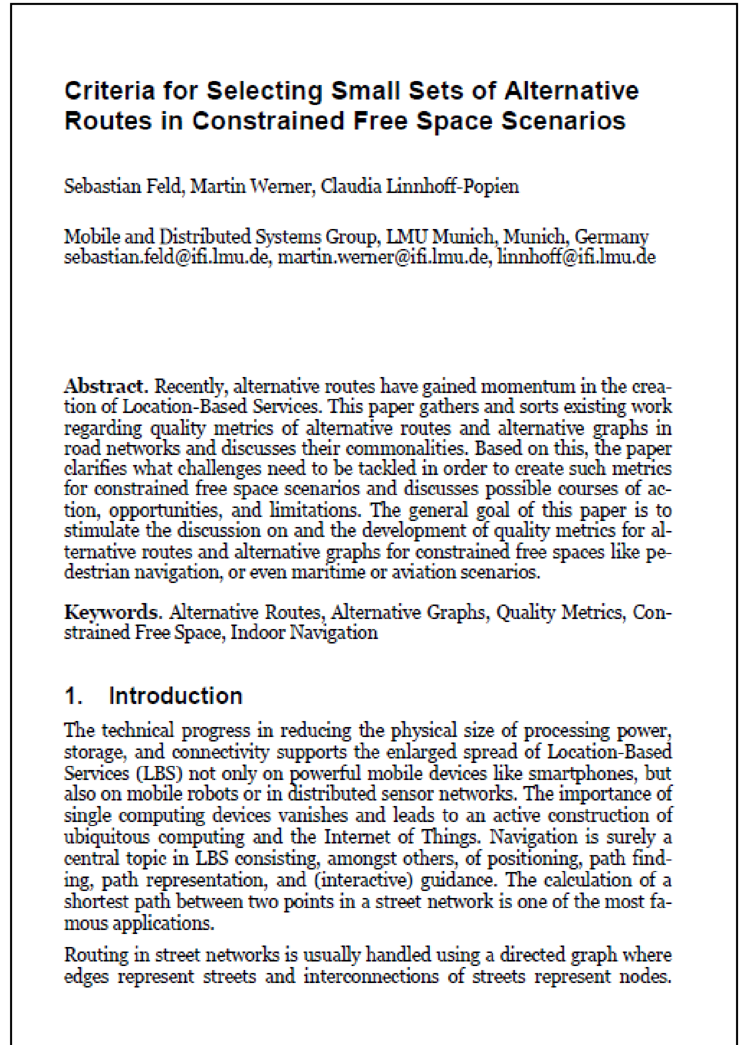
- Uncountably infinite

Criteria

- Quality metrics for AR/AG

Constrained free space

- That's the point! How to transfer?



Criteria for Selecting Small Sets of Alternative Routes in Constrained Free Space Scenarios

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Abstract. Recently, alternative routes have gained momentum in the creation of Location-Based Services. This paper gathers and sorts existing work regarding quality metrics of alternative routes and alternative graphs in road networks and discusses their commonalities. Based on this, the paper clarifies what challenges need to be tackled in order to create such metrics for constrained free space scenarios and discusses possible courses of action, opportunities, and limitations. The general goal of this paper is to stimulate the discussion on and the development of quality metrics for alternative routes and alternative graphs for constrained free spaces like pedestrian navigation, or even maritime or aviation scenarios.

Keywords. Alternative Routes, Alternative Graphs, Quality Metrics, Constrained Free Space, Indoor Navigation

1. Introduction

The technical progress in reducing the physical size of processing power, storage, and connectivity supports the enlarged spread of Location-Based Services (LBS) not only on powerful mobile devices like smartphones, but also on mobile robots or in distributed sensor networks. The importance of single computing devices vanishes and leads to an active construction of ubiquitous computing and the Internet of Things. Navigation is surely a central topic in LBS consisting, amongst others, of positioning, path finding, path representation, and (interactive) guidance. The calculation of a shortest path between two points in a street network is one of the most famous applications.

Routing in street networks is usually handled using a directed graph where edges represent streets and interconnections of streets represent nodes.

PAPER'S MOTIVATION / CONTRIBUTION

State-of-the-art

- Gather and sort existing work regarding quality metrics of alternative routes and alternative graphs in road networks

Constrained free space

- Clarify what challenges need to be tackled in order to create such metrics for constrained free space scenarios
- Discuss possible courses of action, opportunities, and limitations

Discussion

- Discuss and develop quality metrics for quality metrics for alternative routes and alternative graphs for constrained free space scenarios
- Pedestrian navigation, even maritime or aviation scenarios

CALCULATING ALTERNATIVE ROUTES

Dijsktra's algorithm

- (Dijkstra, 1959)

K-shortest-paths

- (Yen, 1971, Eppstein, 1994, Scott, 1997)

Multicriteria optimization (pareto-optimality)

- (Martins, 1984, Delling & Wagner, 2009, Geisberger et al., 2010, Graf et al., 2010)

Penalty

- (Chen et al., 2007, Bader et al., 2011)

Via-nodes / plateaus

- (Camvit, 2009, Abraham et al., 2010, Bader et al., 2011, Luxen & Schieferdecker, 2012, Kobitzsch, 2013, Werner & Feld, 2014)

QUALITY METRICS FOR ALTERNATIVE ROUTES

Central reference

- (Abraham et al., 2013) with predecessor (Abraham et al., 2010)
- Finding good alternatives by defining an “**admissible path**” using three measures

Limited Sharing

- The alternative path has to be **significantly different** to the reference path
- I.e., the total length of edges shared must be a small fraction of the reference route’s length

Local Optimality

- The alternative path must be **reasonable**
- I.e., no unnecessary detours are allowed
- Every local decision must make sense, so every subpath up to a certain length is a shortest path

Uniformly Bounded Stretch

- The alternative path must **not be much longer** than the reference path
- I.e., every subpath needs to have a good stretch
- This enhances local optimality: a path with high optimality may be shortened with a shortcut

QUALITY METRICS FOR ALTERNATIVE ROUTES

Approach

- Three measures as hard constraints for a target function
- Sort candidates and return first admissible path

Possible target function

- Low limited sharing
- High local optimality
- Low uniformly bounded stretch

Further improvements

- (Luxen & Schieferdecker, 2012)
- (Kobitzsch, 2013)

QUALITY METRICS FOR ALTERNATIVE GRAPHS

Central reference

- (Bader et al., 2011), based Dees' master's thesis (Dees, 2012)
- Preliminary aspects published before in (Dees et al., 2010)
- Definition of an **alternative graph** (AG) as the union of several paths having the same start and goal as a compact representation of multiple alternative routes

Total Distance

- Describing the extent to which the routes defined by the AG are **non-overlapping**
- Maximum value when the AG consists of disjoint paths only

Average Distance

- Describing the quality as the **average stretch** of an alternative path

Decision Edges

- Describing the **complexity** of the AG
- Used to retain the representation easily understandable for human users

QUALITY METRICS FOR ALTERNATIVE GRAPHS

Approach
- Calculate shortest path
- Insert into AG
- Gradually calculate further alternative paths
- Insert greedily into AG optimizing a target function

Further work
- Efficient implementations: (Radermacher, 2012, Kobitzsch et al., 2013)
- Higher quality: (Paraskevopolous & Zaroliagis, 2013)

LIMITED SHARING & TOTAL DISTANCE

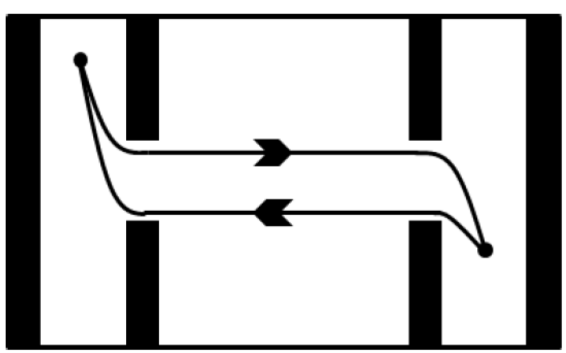
Limit the length of edges that alternatives have in common

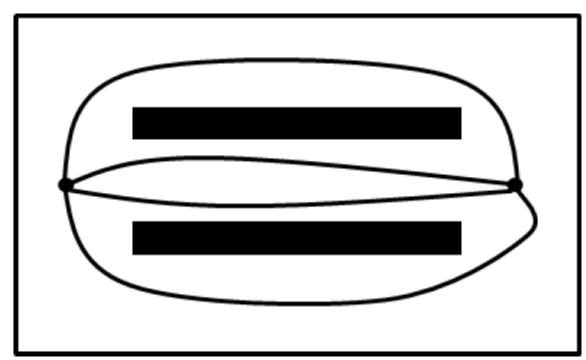
Most important question: How to define overlap or sharing in an unambiguous way

Even decisions in implementation design may have impact (“left-handed Dijkstra”)

High ambiguity of equivalent routes having equivalent meanings

- Continental scale, no interaction, e.g. airplane navigation
- Pedestrians seeing and talking to each other





LIMITED SHARING & TOTAL DISTANCE

General strategies

- Decision which points actually “overlap” in an application-dependent and map-dependent way
- Three possible general strategies

Strategy 1: Map representation

- Definition of original measures for paths in graphs
- Consistently map all free space paths to a graph such that different edges mean semantically different movements
- Problem: Tradeoff between map complexity and expressiveness, see existing map representations
- Also: Number of edges and quality of overlap depends on complexity of involved geometry

LIMITED SHARING & TOTAL DISTANCE

Strategy 2: Connected space

- Define overlap from the space that two routes have in common
- Some kind of map topology
- Homotopy? Has some drawbacks…

Strategy 3: Distance

- Replace binary and counting nature of overlap by continuous framework in which distances of routes are used
- Threshold for overlap
- Classical graph-based definitions are special cases with distance of zero or non-zero

UNIFORMLY BOUNDED STRETCH & AVERAGE DISTANCE

Bounding the stretch

- Too small prevents some alternatives
- Ideal amount of stretch is application-dependent (airport vs. manufacturing)

Route’s length

- Length in map representation can be highly different than in reality
- For example: Navigation mesh with central points vs. corner graphs

LOCAL OPTIMALITY

Handle it in post-processing anyways?

How to treat detours due to inaccuracies in map-to-graph-translations?

Do we want the shortest? Or the simplest? (wall scraping etc.)

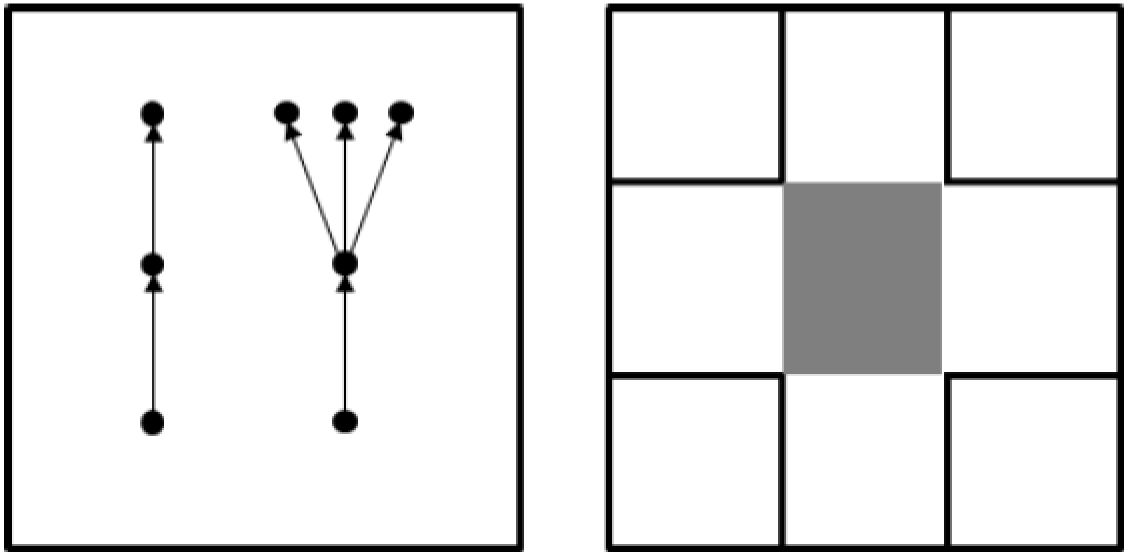
In a nutshell
- What is an “optimal” path and what is a “locally optimal” path?
- Perhaps: Considering local optimization as an application-dependent post-processing step

DECISION EDGES

Similarity to overlap

- Use overlap as a definition for decision
- A decision is taken place where overlap changed
- In some sense: we extend overlap from edges to vertices

Integration into map creation process?



CONCLUSION

Transforming the concepts of alternative routes and alternative graphs from street networks to constrained free space

There is a huge mutual interference of quality metrics

We need an integrated treatment of environments and alternatives

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