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Accident avoidance by active intervention for Intelligent Vehicles

Highly Accurate Digital Maps for Vehicle Self-localisation Using Landmarks

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interactIVe Summer School

4-6 July, 2012

Contents

Digital maps

- Requirements for perception applications
- Smooth minimum arc path
- Examples and results

Self-Localization with landmarks in digital maps

- Proposed methods
- First results
- References

Summary

A method, called Smooth Minimum Arc Path (SMAP), to represent lanes and road markings with arc splines is introduced. This representation of continuous landmarks in digital maps allows a very fast point-to-curve distance computation usually needed in the applications.

Furthermore with the SMAP-method an approximation with the minimal number of spline segments, given an arbitrary accuracy, is guaranteed. Therefore extremly low storage capacity is needed to represent even the 3D-information of a road.

Using these highly accurate digital maps, a self-localisation of the ego-vehicle in absolute world coordinates with lane accuracy is possible in real-time.

Map requirements

Map requirements

- High-precision landmarks (video)
- Point landmarks (posts, traffic signs)
- Challenge: continuous landmarks representing the course of the road
  - Lane markings
  - Directional arrows

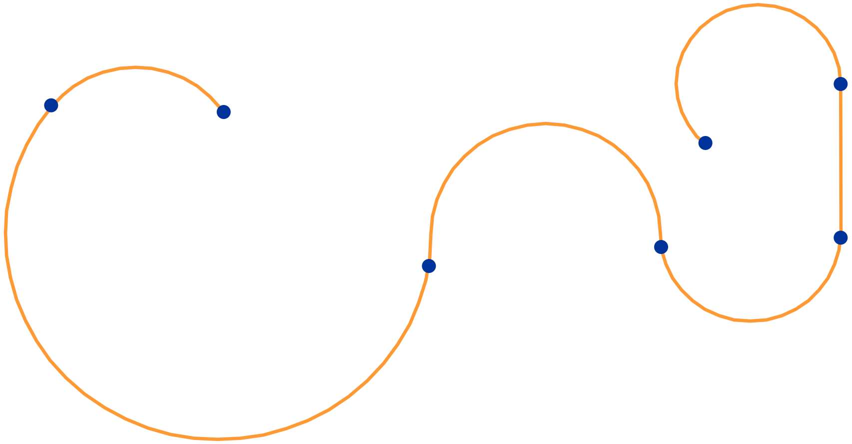
Application requirements w.r.t. perception purposes

- Lane attribution of the host-vehicle and of detected objects
- Curvature information
- Road and lane width / boundaries, conflict-free area

Arc Splines

Definition and Properties

- An Arc Spline is planar curve, composed by circular arcs and line segments.
- An Arc Spline is said to be *smooth* if the tangent unit vectors are equal at the breakpoints.

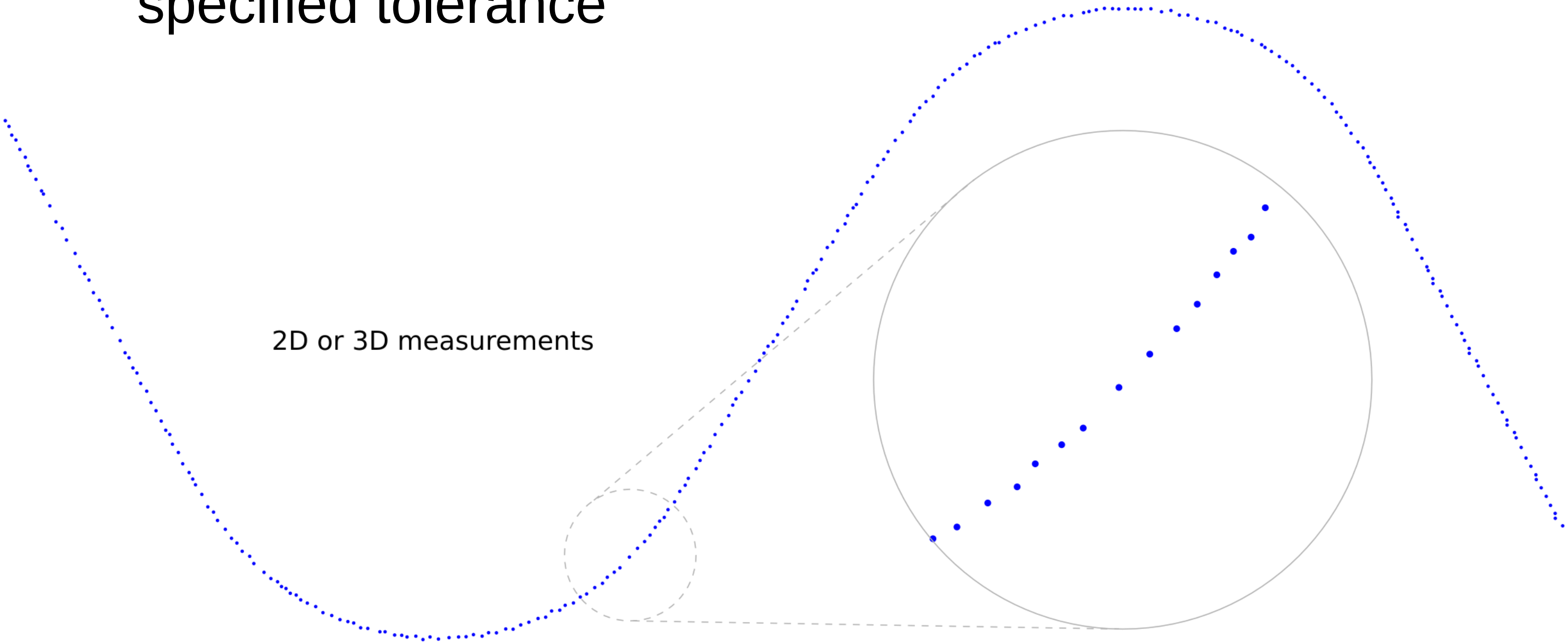


Arc Spline Properties

- Curvature is a step function (inverse to the radius, 0 for line segments)
- Calculation of point to curve distances in closed form
- Invariance with respect to rotations, translations, scalings and offset curves
- Non-parametric description possible
- Compatibility with all established geometry and CAD systems

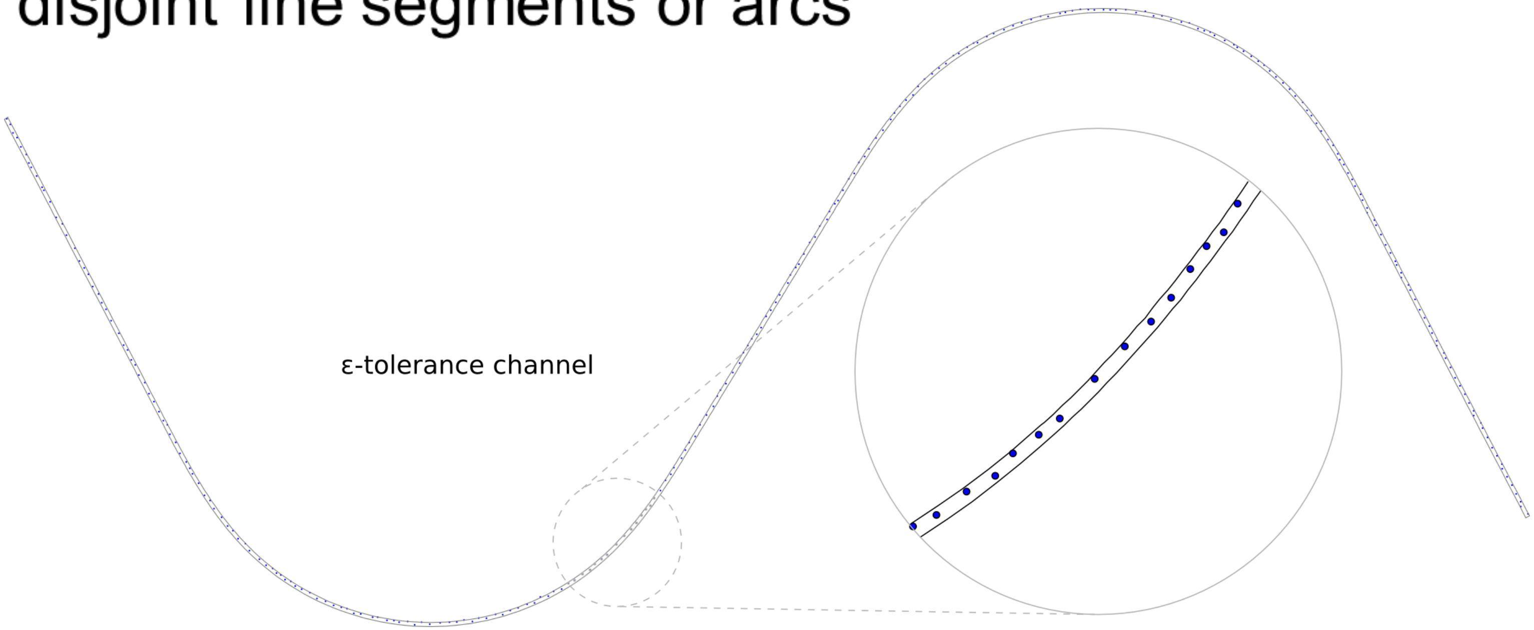
Data points and curve approximation

- Competing optimization criteria: Accuracy versus number of segments → multi-objective optimization
- Minimize the number of segments wrt. to a user specified tolerance



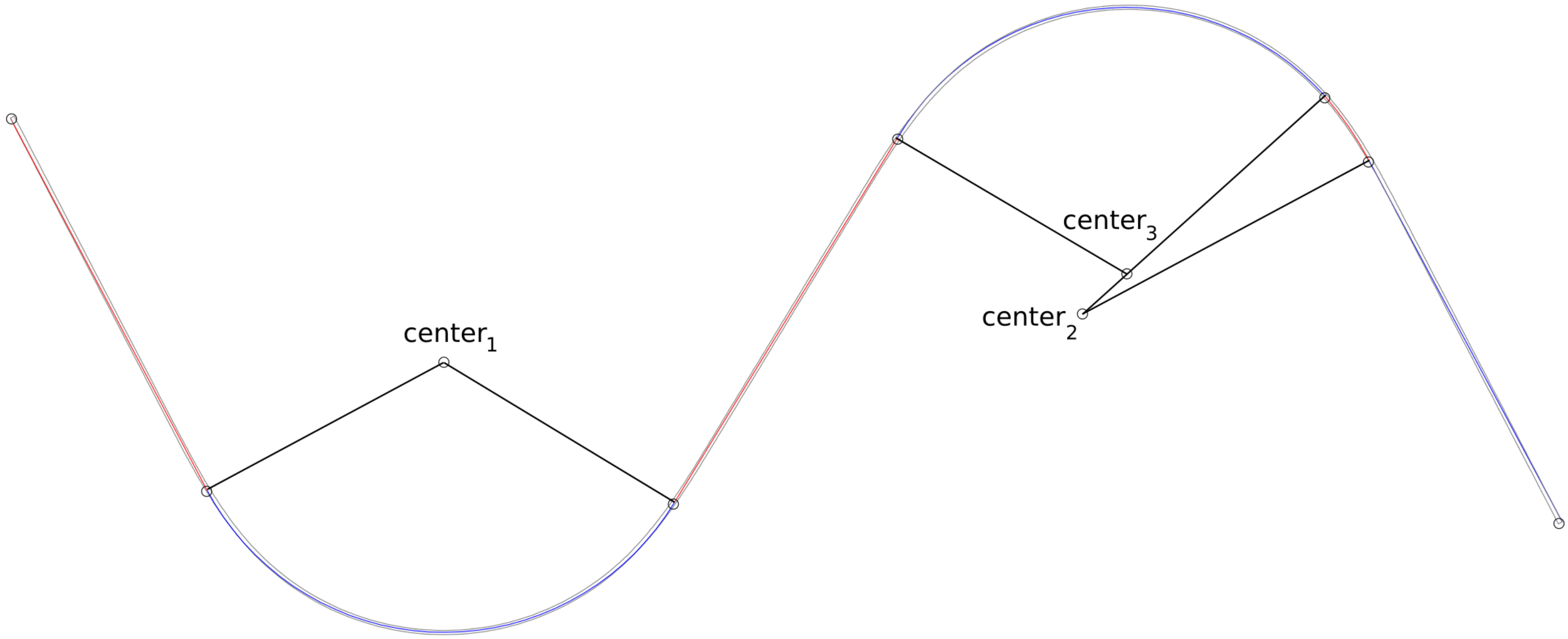
Tolerance channel

- Triple (K, s, d) with $K = tr(\omega)$, where ω is a piecewise restricted analytic Jordan curve,
  start s and destination d with $tr(s), tr(d) \subset K$ maximal, disjoint line segments or arcs

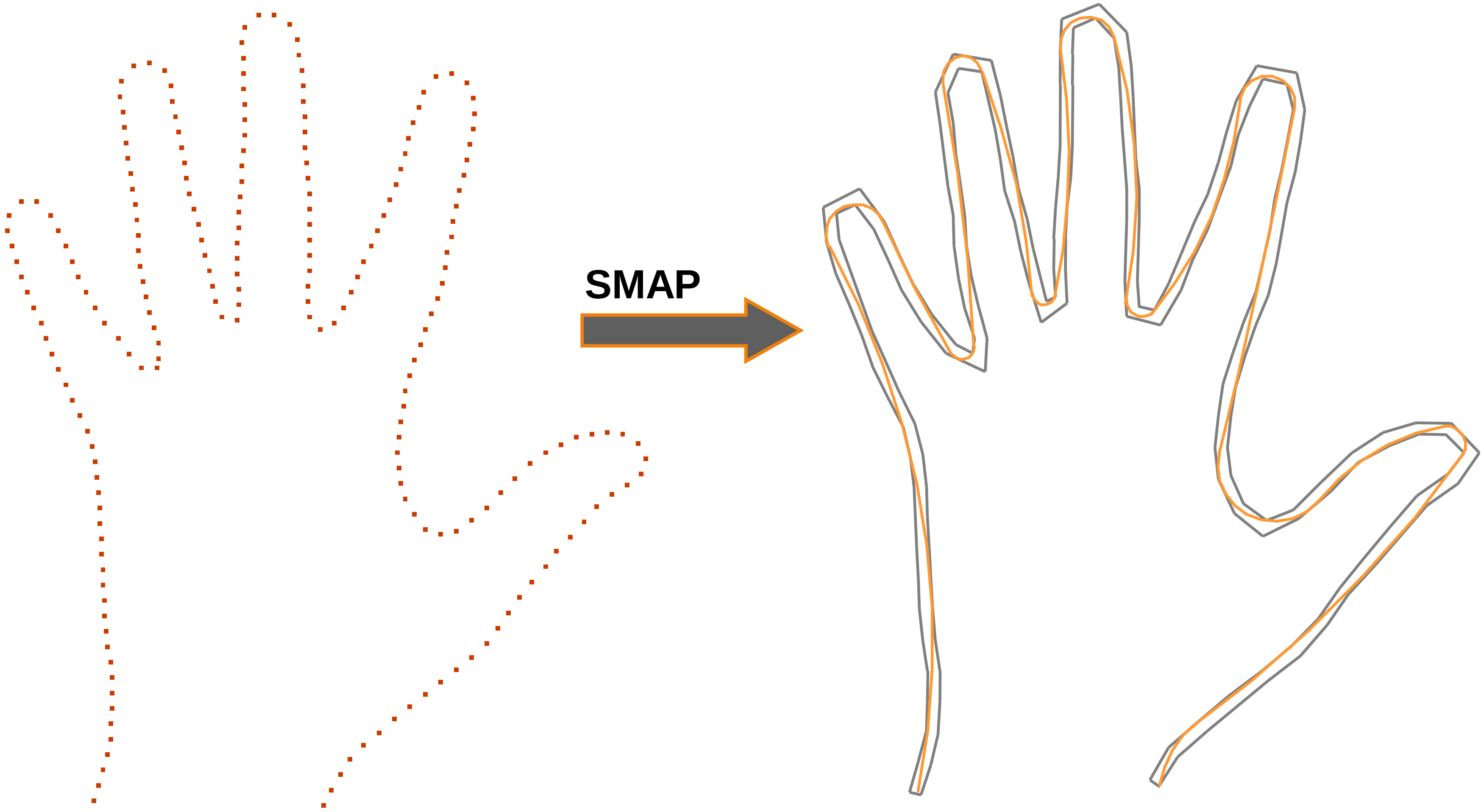


Smooth arc spline

- Search for a smooth arc spline with minimal segment number within the tolerance channel



Solution: Smooth Minimum Arc Path



SMAP properties useful for digital maps

The arc spline representation enables

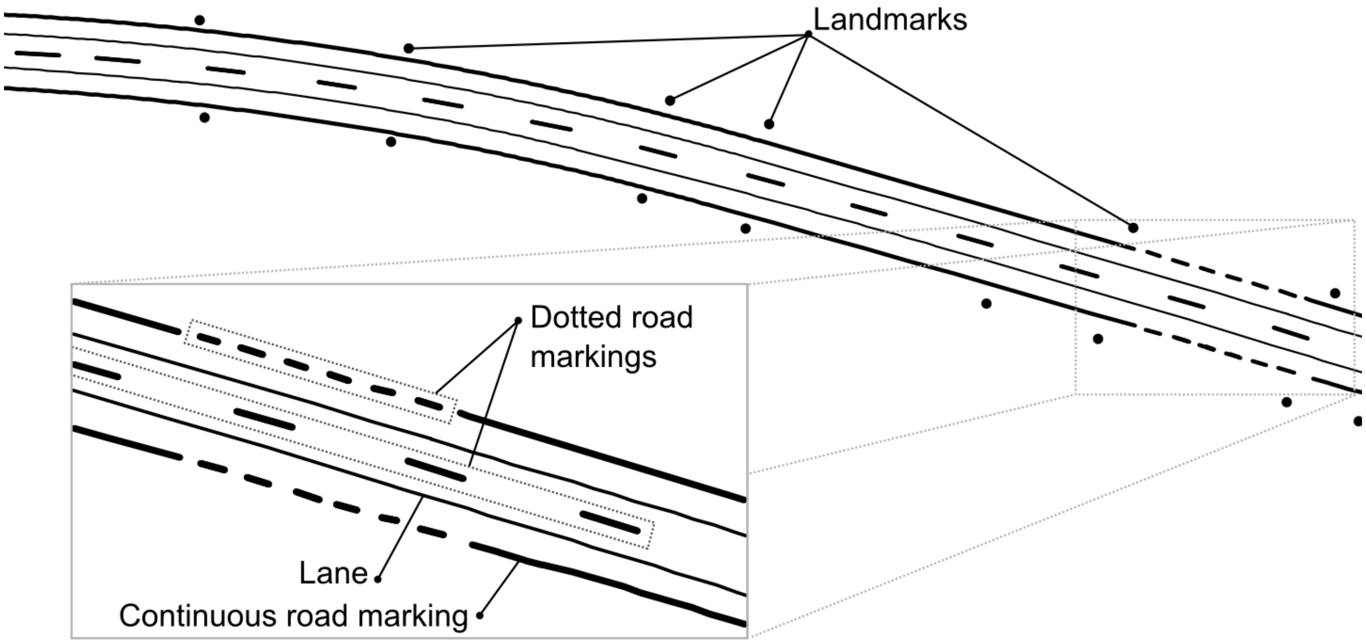
- Approximation with arbitrary accuracy while the minimal number of spline segments is guaranteed
- Flexible modelling of lanes (also roundabouts)
- Computation of point to curve distances in closed form
- Generation of offset curves
- Curvature information
- Efficient data representation
- Simple or extended description of the elevation (3D representation!)
- Simple or extended description of the lane width
- Compatibility with all established geometry systems
- Direct conversion to a polygonal representation if needed

The digital map in rural areas

Contents

- Individual lane representations
- Road markings
- Landmarks

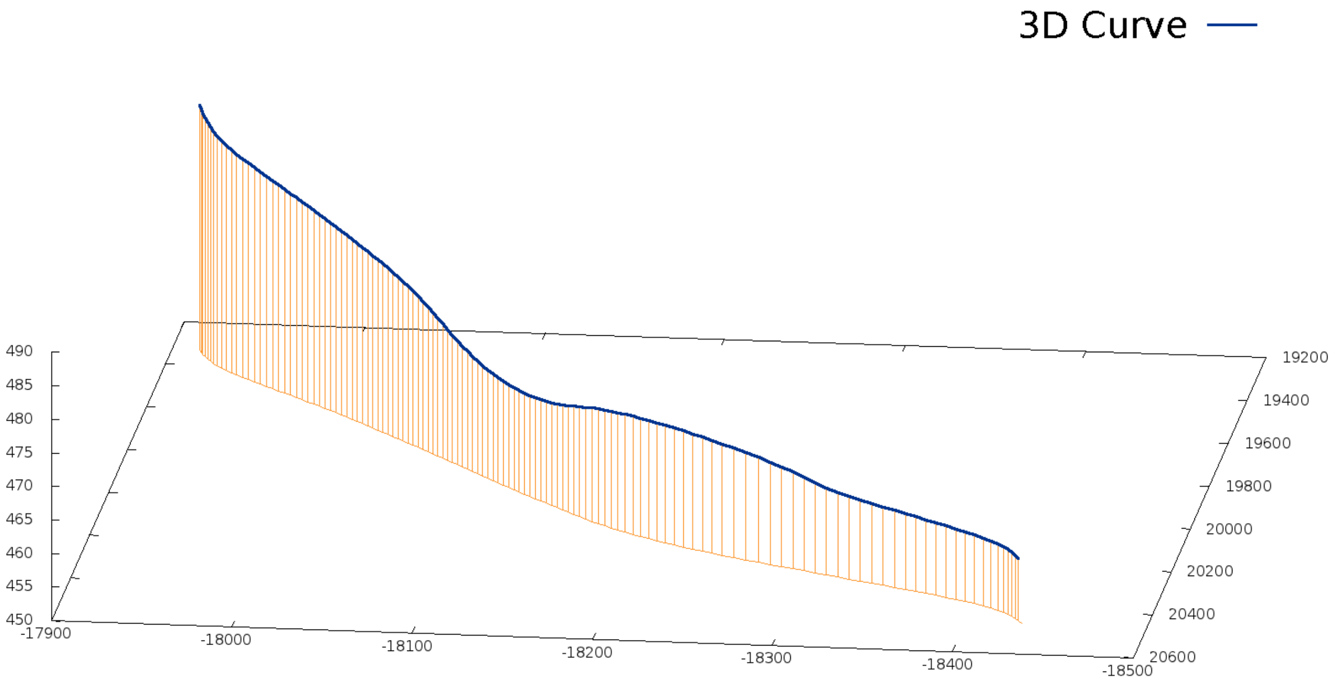
Smooth arc splines with controlled accuracy and minimal segment number



Lane representation

Planar arc spline including height profile

Length of the height profile = length of the 3D curve



Future work

Long-term goals:

- Automatisation of the map generation
- Refinement of the map modeling
  - Urban areas
  - Intersections
  - Turning lanes
  - Highways
- Stabilisation of the localization results

Lessons learned

- Currently: limited number of input points
- Line segments versus arc segments
- SMAP uses the whole tolerance channel

○ Further modeling required

+ Controlled accuracy

++ very high compression rate, very efficient to store

++ application oriented: extremely fast point-to-curve distance computation

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Thank you.

Co-funded and supported by the European Commission

SEVENTH FRAMEWORK PROGRAMME

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