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# MONTE-CARLO SIMULATION OF PROFILE SCANS FROM KINEMATIC TLS

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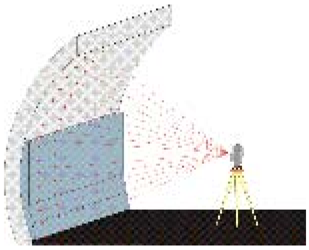
## Contents

- Introduction
- Kinematic terrestrial laser scanning (k-TLS)
- Object and setup
- Monte-Carlo simulation and validation
- Conclusions

## Introduction

### Characterization of TLS



**Observation properties**

- Centric (φ, λ, s → X ,Y, Z)
- Very fast
- High spatial resolution
- Rapid
- High data rates

**Z+F Imager 5006**
- 500 kHz data rate
- 360° x 270° FOV
- 79 m distance
- 1-3 mm precision

- On (mostly) arbitrary surfaces
- Immanently related to surfaces but not single points (!)

## Kinematic terrestrial laser scanning
for geodetic monitoring

### Kinematic TLS approach (k-TLS)

*Time is a relevant process parameter.*

**Approach: Derivation of time series**

⇨ Rapidly deforming objects in motion
⇨ High spatial level of detail
⇨ High temporal level of detail
⇨ Efficient capture of object geometry

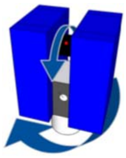
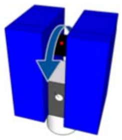
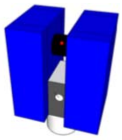
**Note: Fixed scanner – deforming and moving object**

Alternative view: Mobile Mapping

GIH

# Kinematic terrestrial laser scanning
## for geodetic monitoring

### Observation strategy ⇔ Observation velocity

| 3D mode | 2D mode | 1D mode |
| --- | --- | --- |
|  Point cloud |  Vertical profile |  Single distance |
| Repetition frequency: < 0.03 Hz<br>Control:<br>• Point density<br>• Observation precision<br>• Chosen field of view | Repetition frequency: 10 Hz … 50 Hz<br>Control:<br>• Horizontal direction<br>• Rotation velocity<br>• Point density | Repetition frequency: 1 kHz … 500 kHz<br>Control:<br>• Horizontal direction<br>• Vertical angle<br>• Sampling rate |

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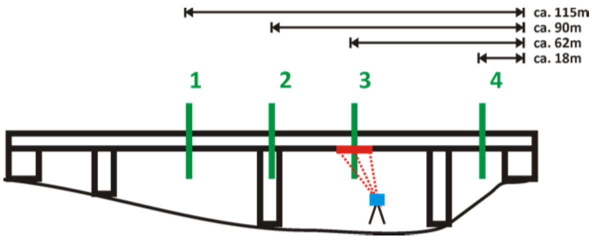
# Object and setup

**Autobahn bridge in southern Germany**

Experiment: Deformations due to defined traffic loads

- Static loads in four positions, dynamic loads
- Monitoring in all spatial modes: 3D / 2D / 1D
- Fixed scanner position

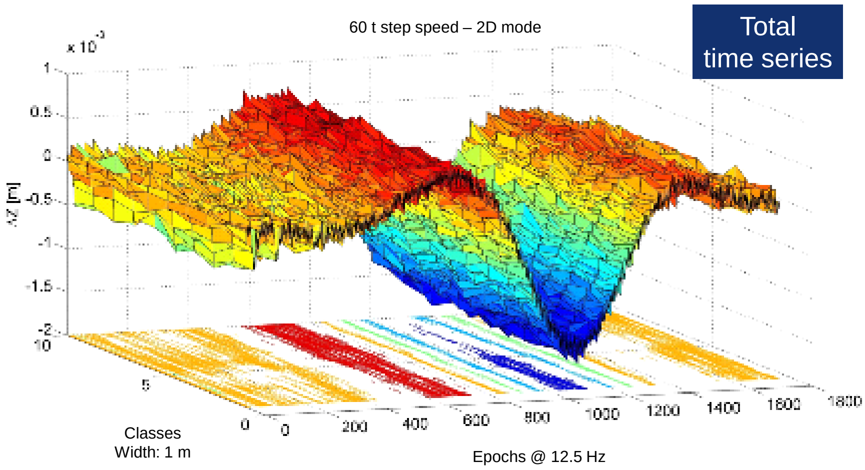



**Scanner in use: Z+F Imager 5006**

## Monte-Carlo simulation and validation

**Impression**

k-TLS vertical profiles during a dynamic bridge loading



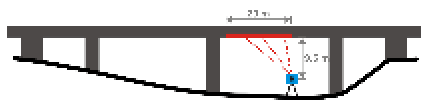

Total time series

## Monte-Carlo simulation and validation

**Simulation of 2D k-TLS profile observations**

**Purpose**

- Planning and modeling
- Analysis and diagnosis



Approach: Reproduction of the real situation by

- identical geometrical configuration
- identical repetition rate
- randomly varying observation values (Monte-Carlo)
  - Distance: constant metric component
  - Distance: distance proportional metric component
  - Zenith angle: constant angular component

Unloaded state:
500 profiles
12.5 profiles/s
7216 pts/profile

500 samples per random quantity

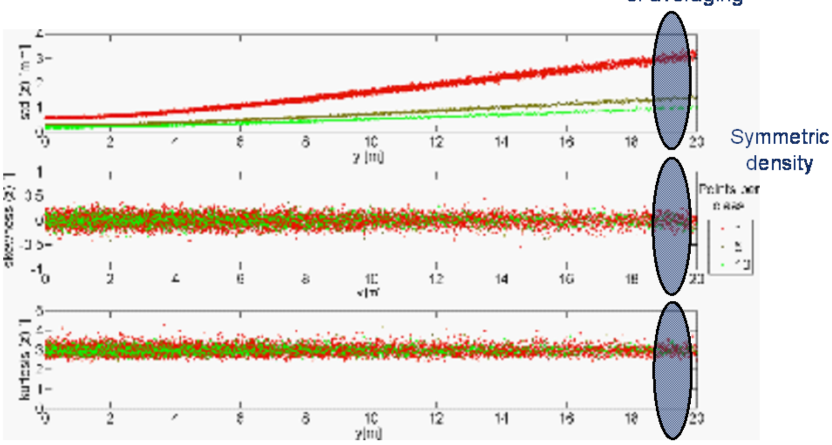
## Monte-Carlo simulation and validation

### Simulation parameters

| Simulation I: | | |
|---|---|---|
| Input quantity | Prob. density | Num. value (std.dev.) |
| Distance: constant | Normal | 0.5 mm |
| Distance: proportional | Normal | 30 ppm |
| Zenith angle | Normal | 10 mgon |

## Monte-Carlo simulation and validation

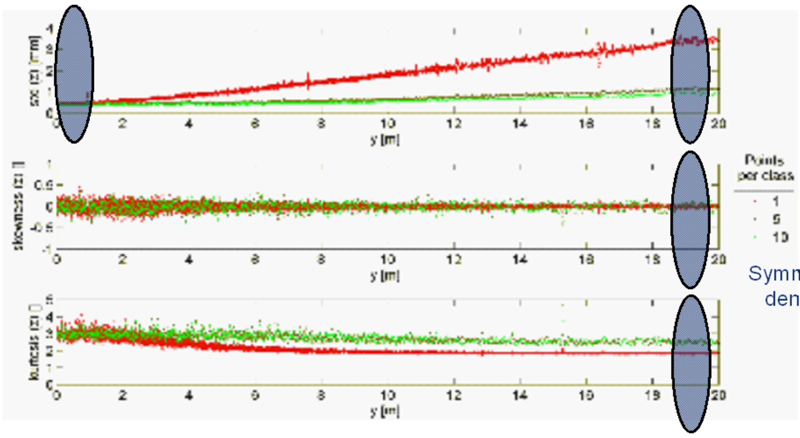
### Results of Simulation I – statistical moments



## Monte-Carlo simulation and validation

### Results of real-data analysis

„About" square-rot law




Symmetric density

**Kurtosis smaller than Normal distribution!**

## Monte-Carlo simulation and validation

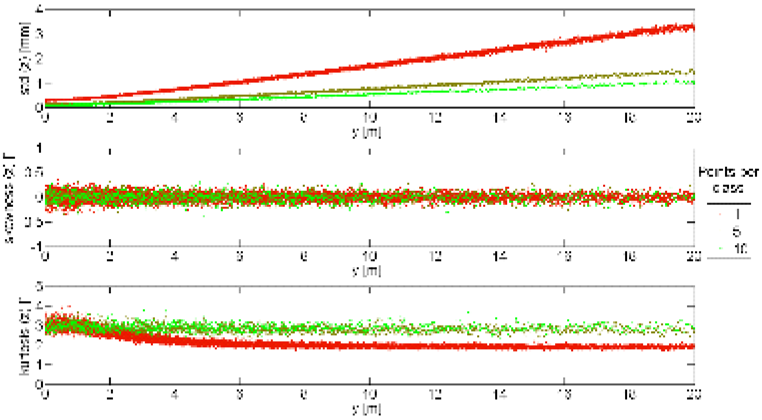
### Simulation parameters

| Simulation I: | | |
|---|---|---|
| Input quantity | Prob. density | Num. value (std.dev.) |
| Distance: constant | Normal | 0.5 mm |
| Distance: proportional | Normal | 30 ppm |
| Zenith angle | Normal | 10 mgon |

| Simulation II: Including vertical step motor | | |
|---|---|---|
| Input quantity | Prob. density | Num. value (std.dev.) |
| Distance: constant | Normal | 0.3 mm |
| Distance: proportional | Normal | 30 ppm |
| Zenith angle | Normal | 5 mgon |
| Vertical increment | **Uniform** | 20 mgon |

## Monte-Carlo simulation and validation

Results of Simulation II – statistical moments




**Comprehensive reproduction of the real-data results !**

## Conclusions

- Simulation of observation processes is important for both pre-analysis and post-analysis.
  - Monte-Carlo techniques are effective and easy-to-implement.
  - An extended error model is required for a meaningful simulation.
- Real-data series give evidence for non-normal random influences.
  - Filtering techniques mitigate such deviations.
  - More refined models and statistical analyses are required.