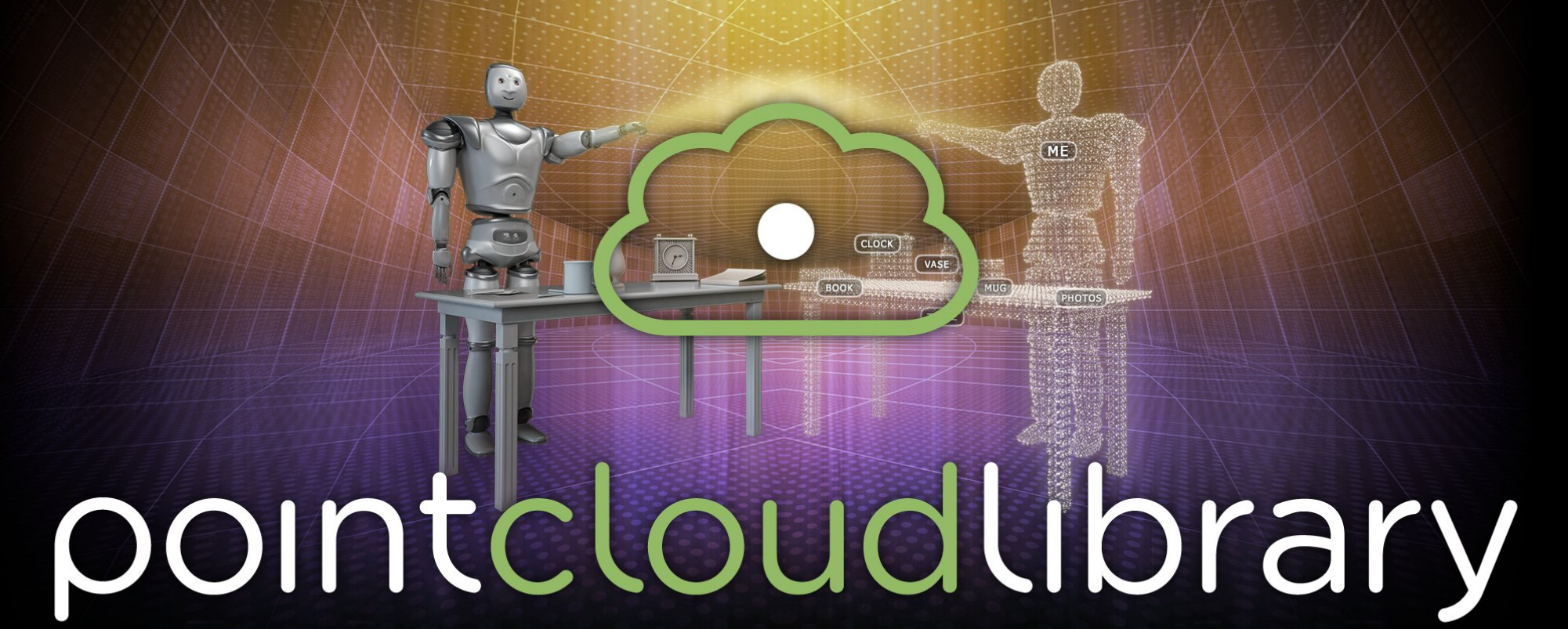


# Mapping and Loop Closing in PCL

**Jochen Sprickerhof**

**Willow Garage, 7. July 2011**


# Outline

1. 6DoF Mapping
2. Algorithms
3. ELCH Algorithm
4. Experiments
5. PCL::API

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# Robots

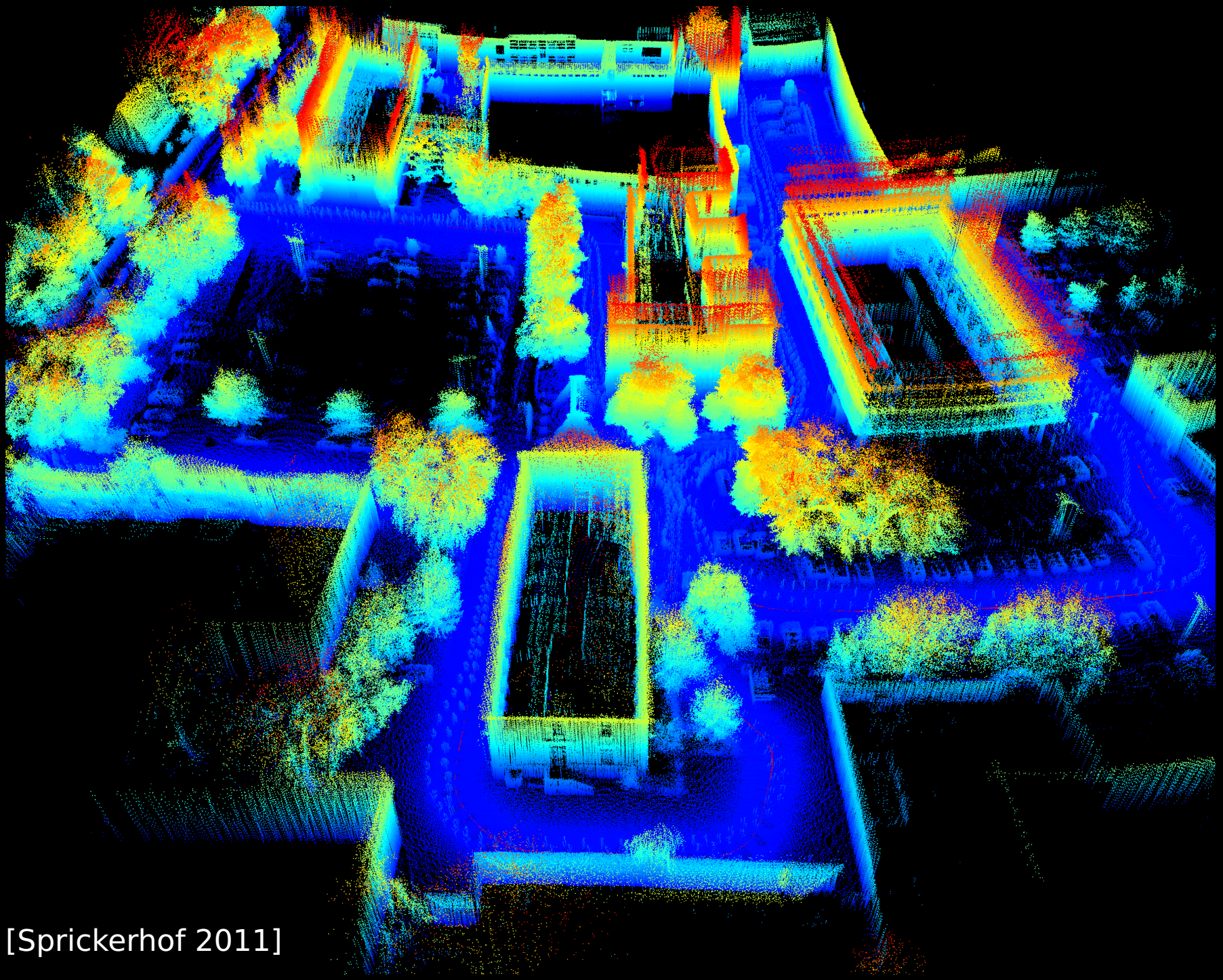
Kurt Robot in Osnabrück


PR2 at Willow Garage

pointcloudlibrary

# Mapping


www.rts.uni-hannover.de

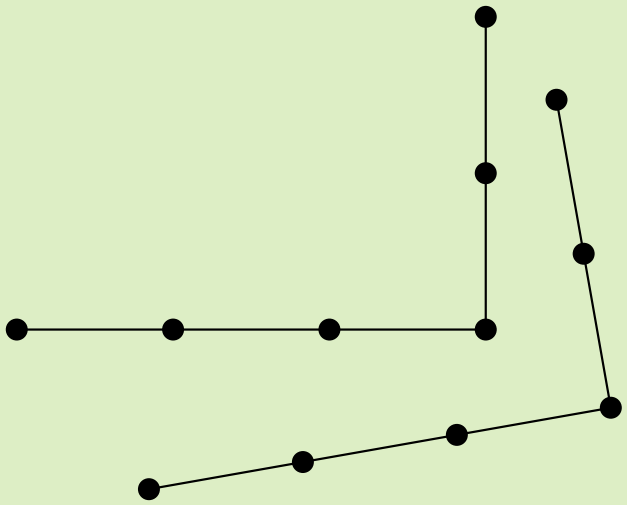
[Sprickerhof 2011]

pointcloudlibrary

# ICP Algorithm

- matches two scans
- local minimum
- fast

**Example**

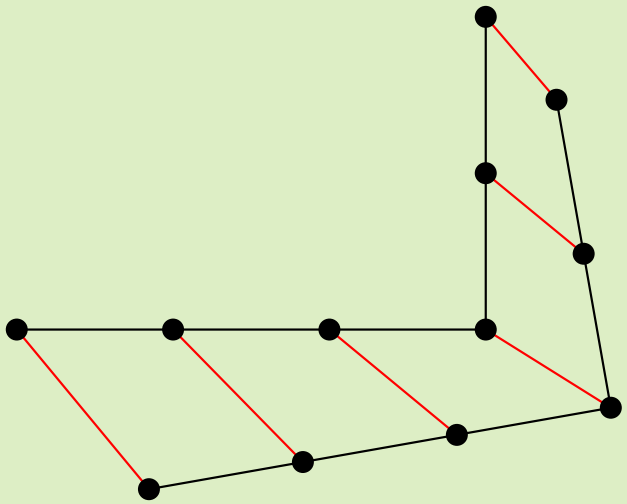


pointcloudlibrary

# ICP Algorithm

- matches two scans
- local minimum
- fast

## Example

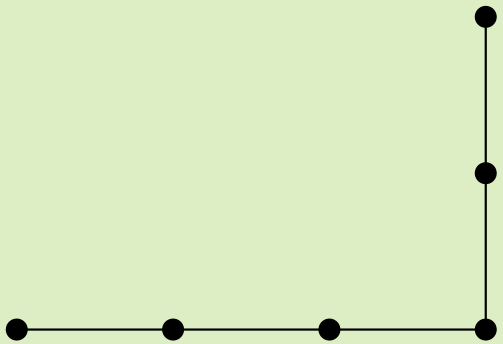


pointcloudlibrary

# ICP Algorithm

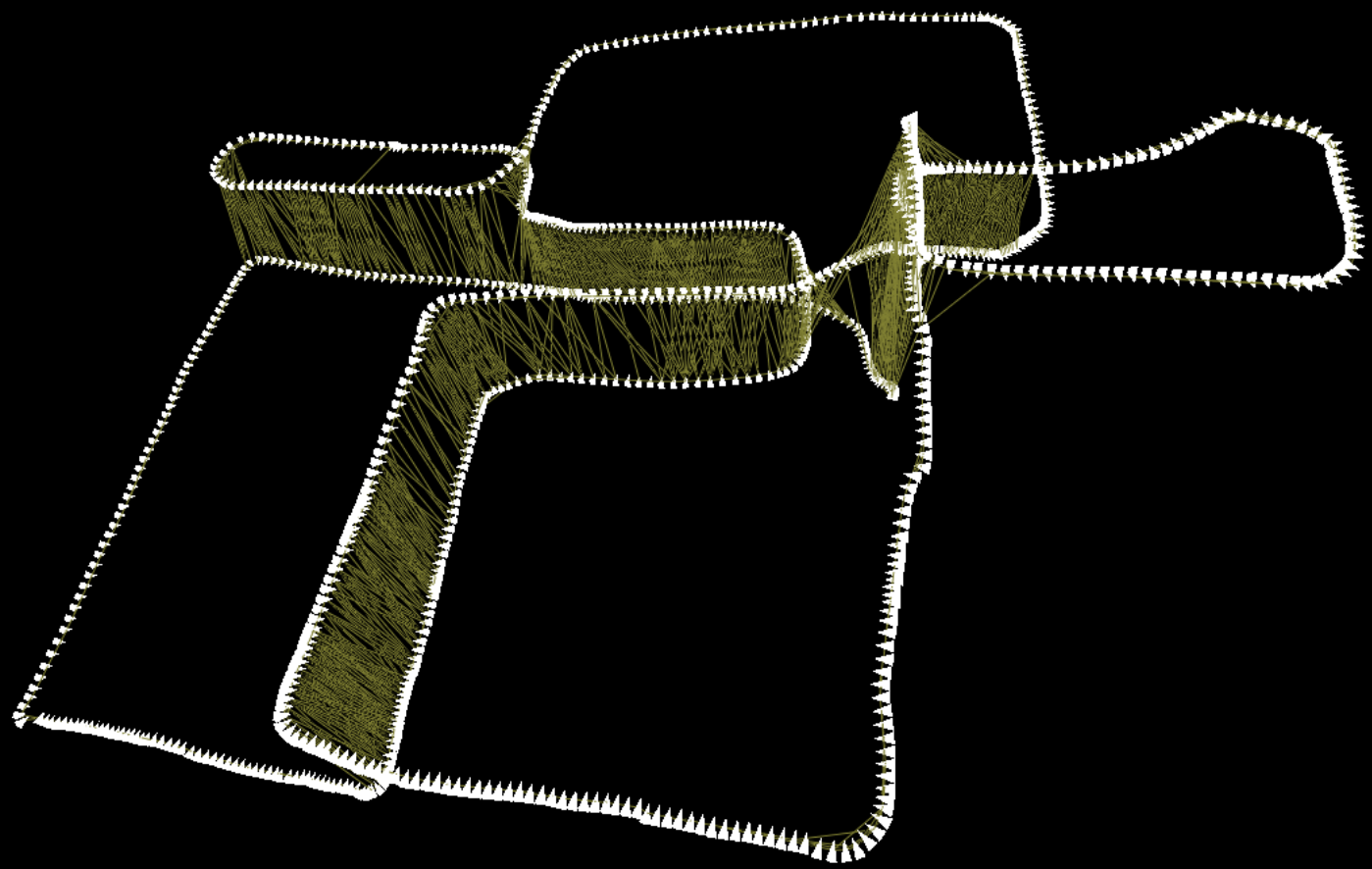
- matches two scans
- local minimum
- fast

**Example**



pointcloudlibrary

# GraphSLAM

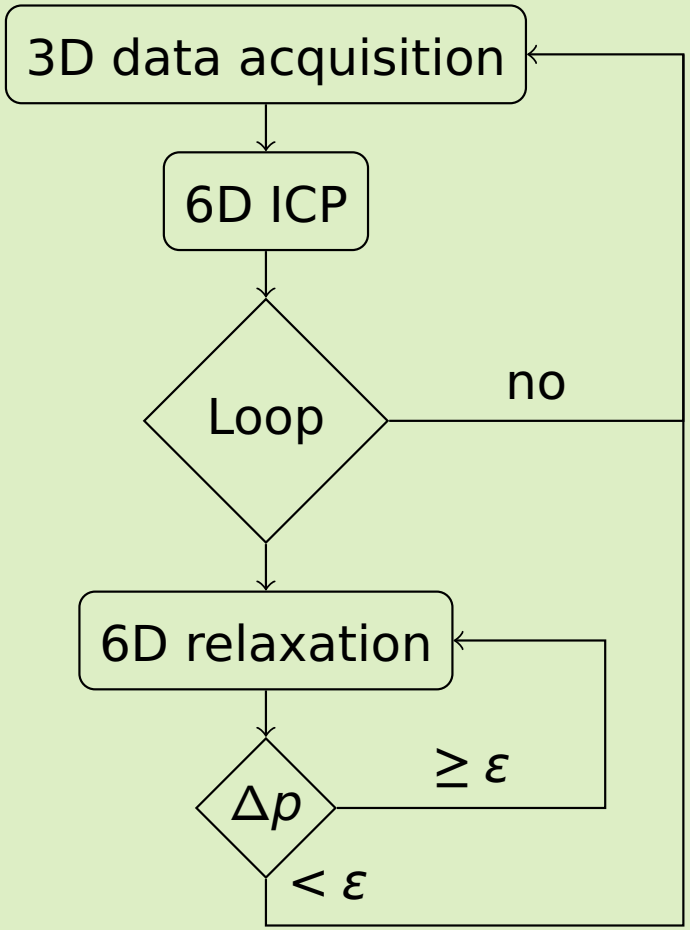


[Steder 2011]

pointcloudlibrary

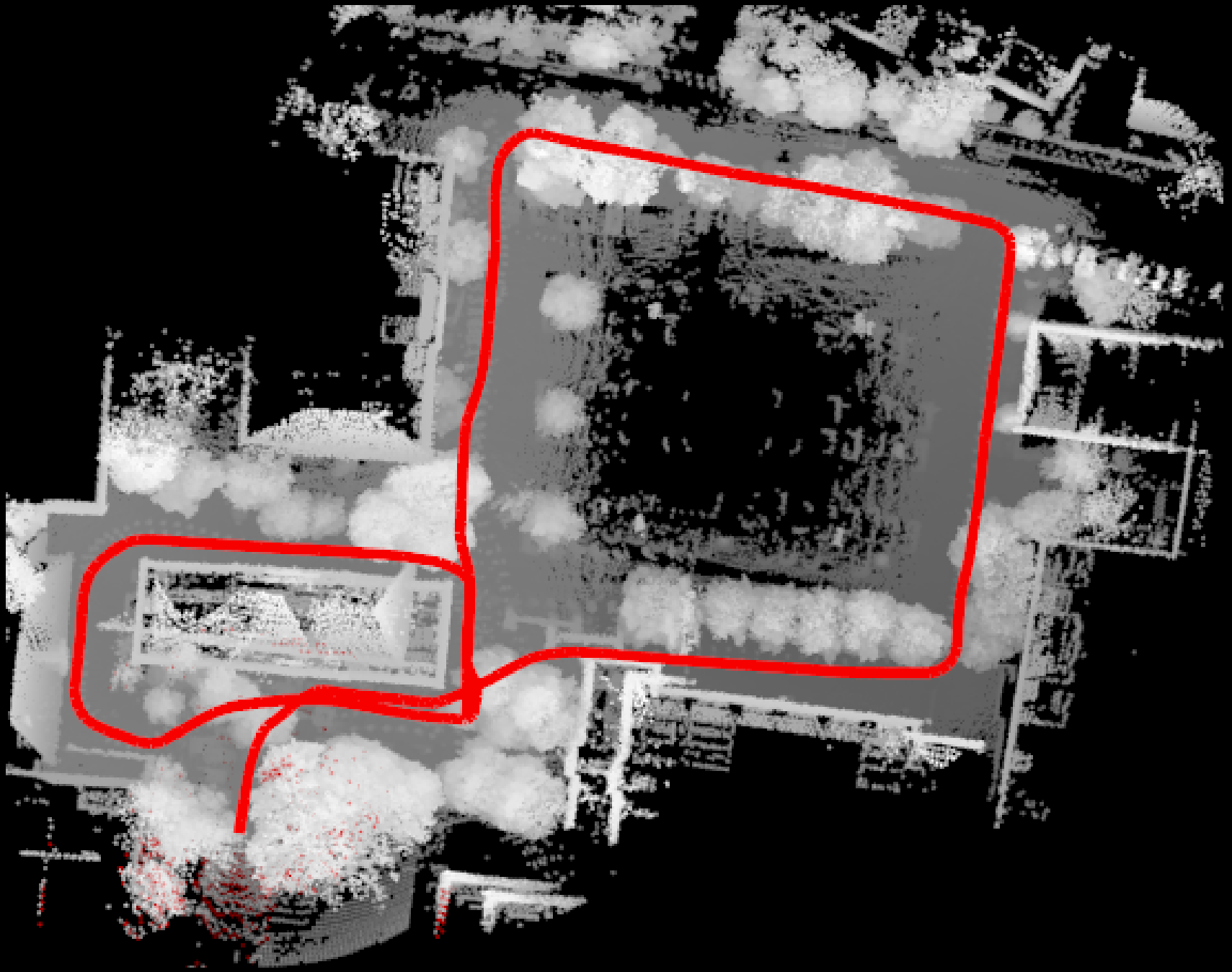
# Global Relaxation

## Pipeline




6D relaxiation:

- 6D Lu & Milios (LUM)
- G2O
- TORO



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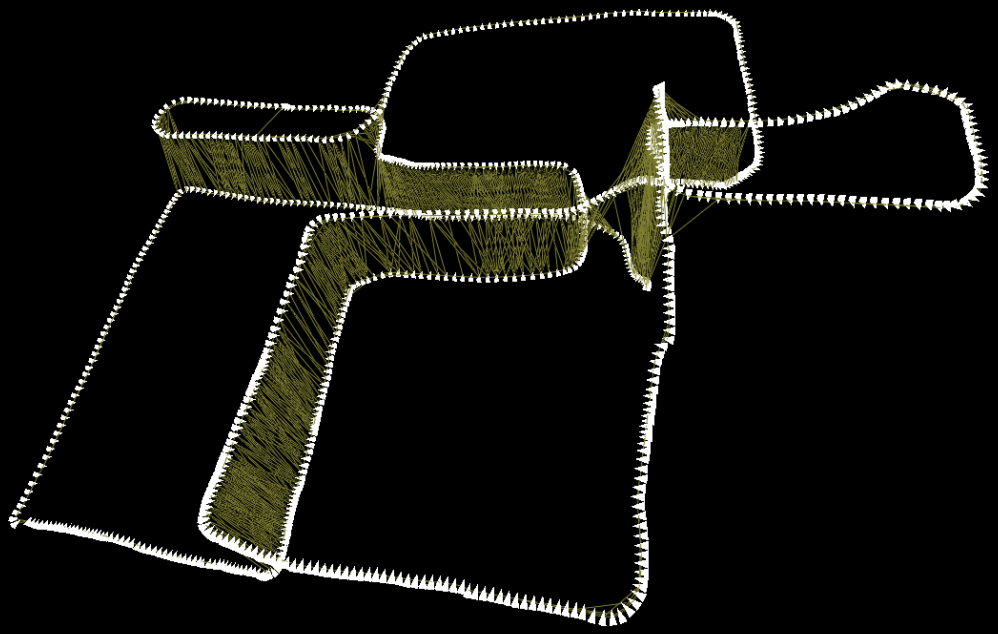
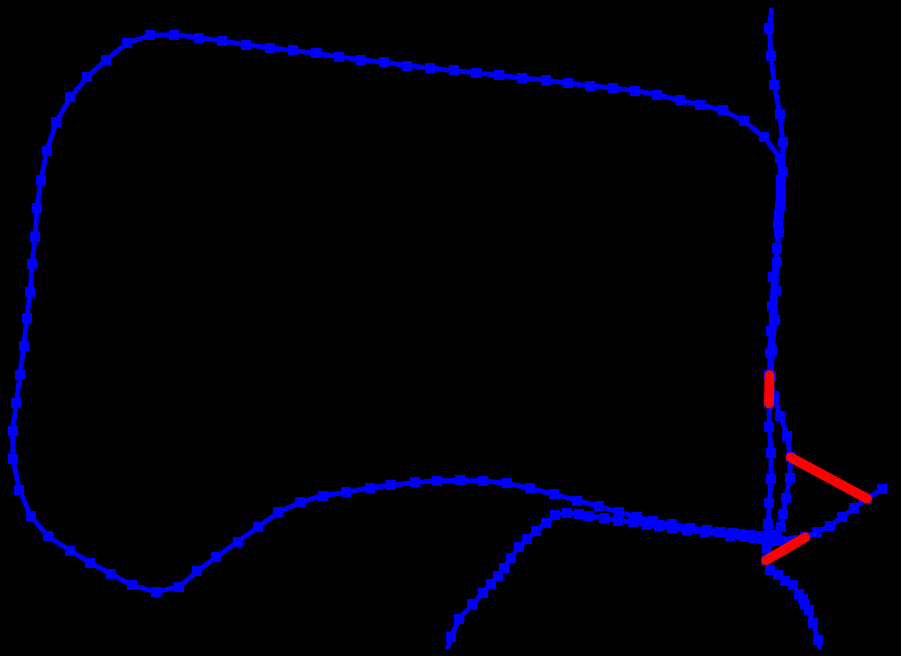
# SLAM Graphs





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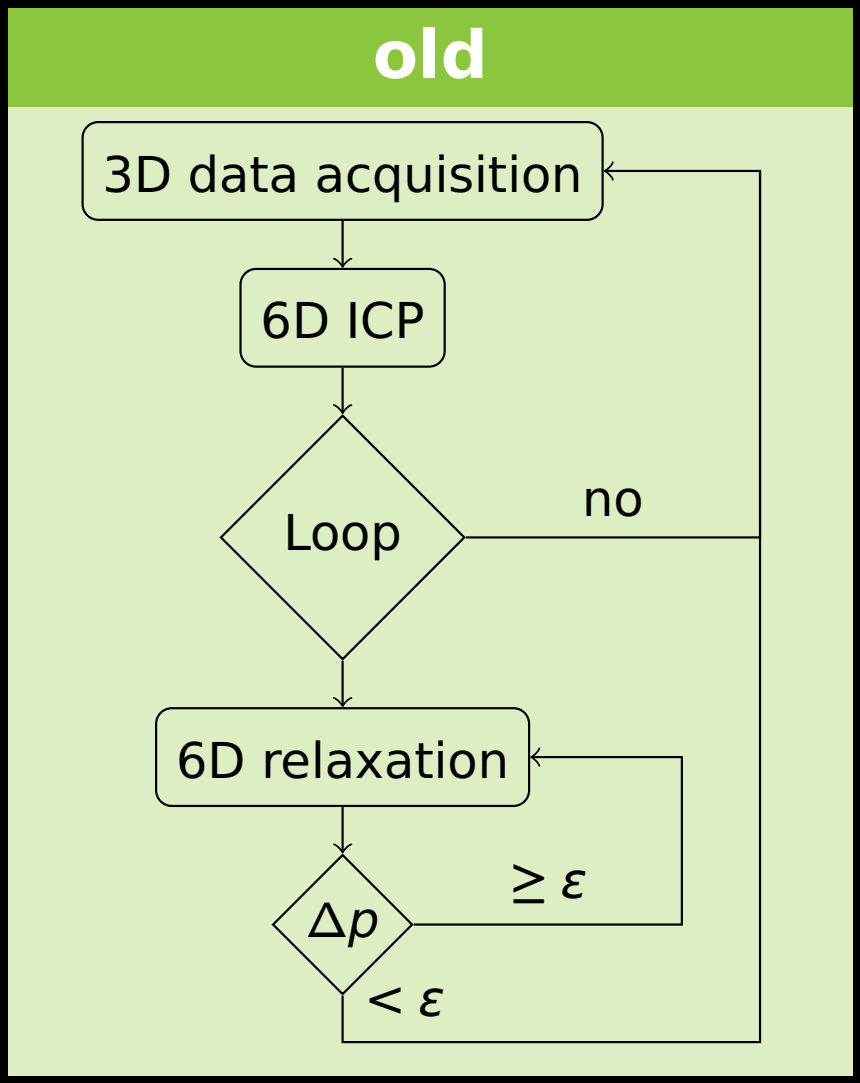
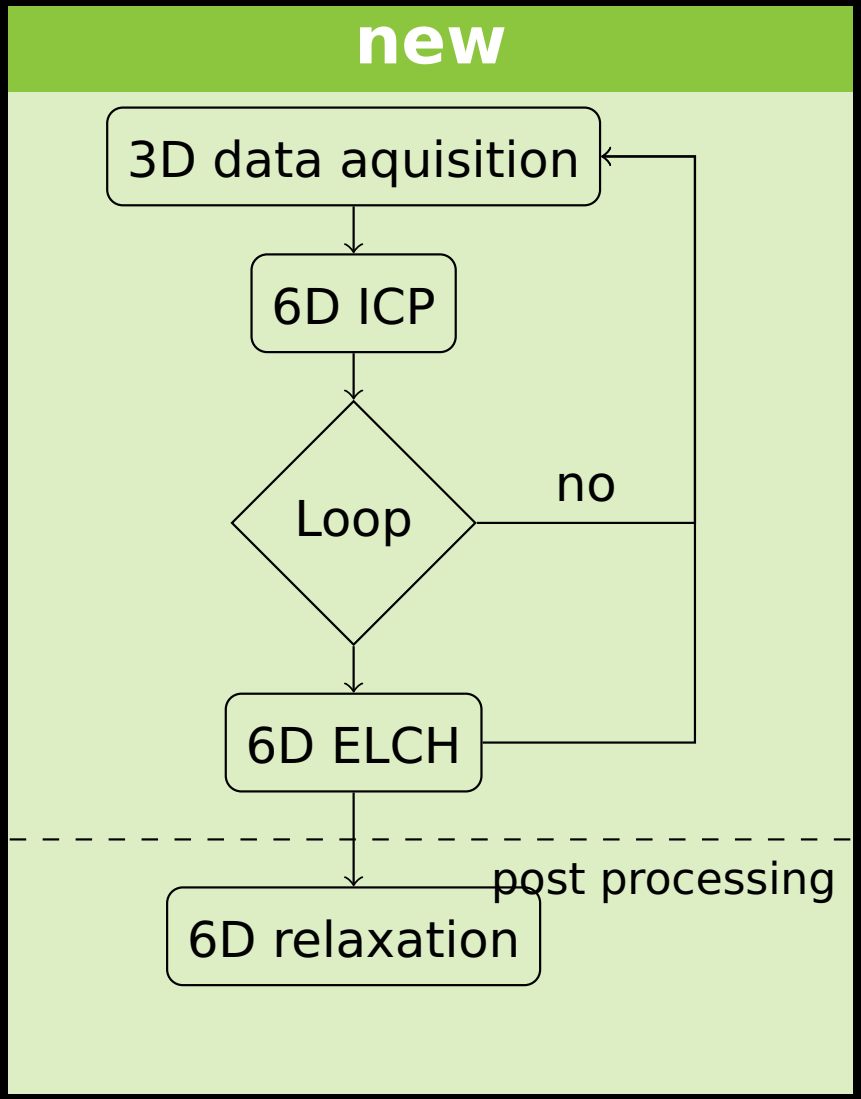
# Program Flow

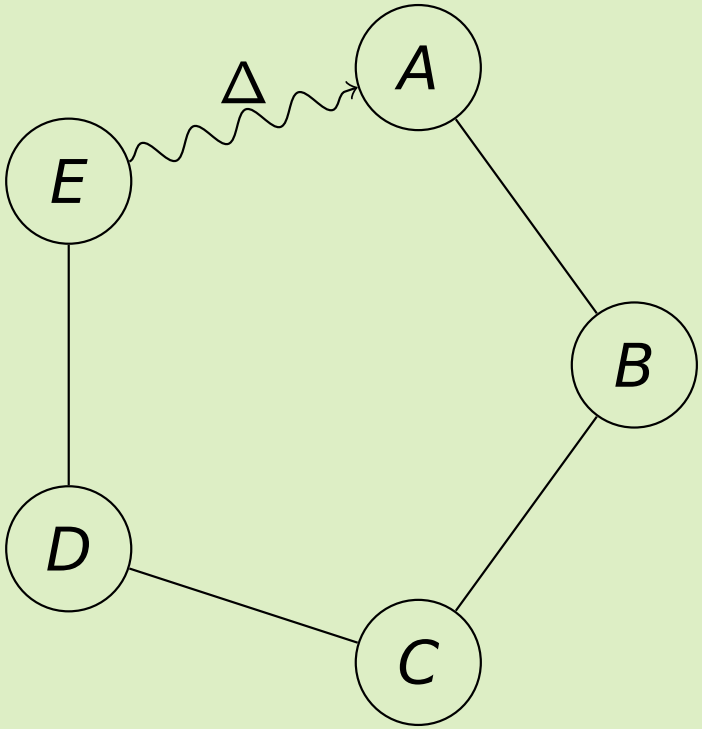


pointcloudlibrary

# One Loop

## Example

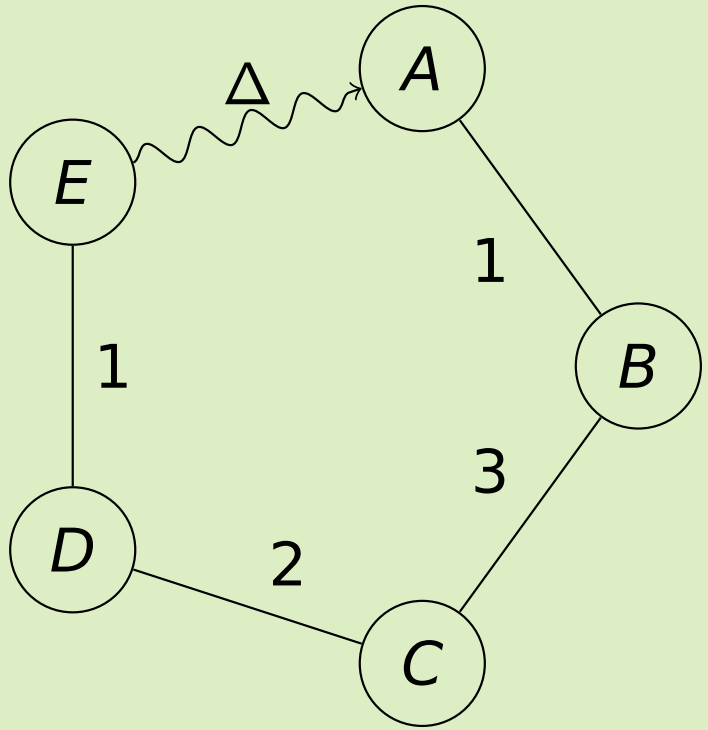



| Vertex | Weight |
|---|---|
| *A* | 0 |
| *B* | 1/4 |
| *C* | 2/4 |
| *D* | 3/4 |
| *E* | 1 |

pointcloudlibrary

# One Loop

## Example




| Vertex | Weight |
|---|---|
| *A* | 0 |
| *B* | 1/7 |
| *C* | 4/7 |
| *D* | 6/7 |
| *E* | 1 |

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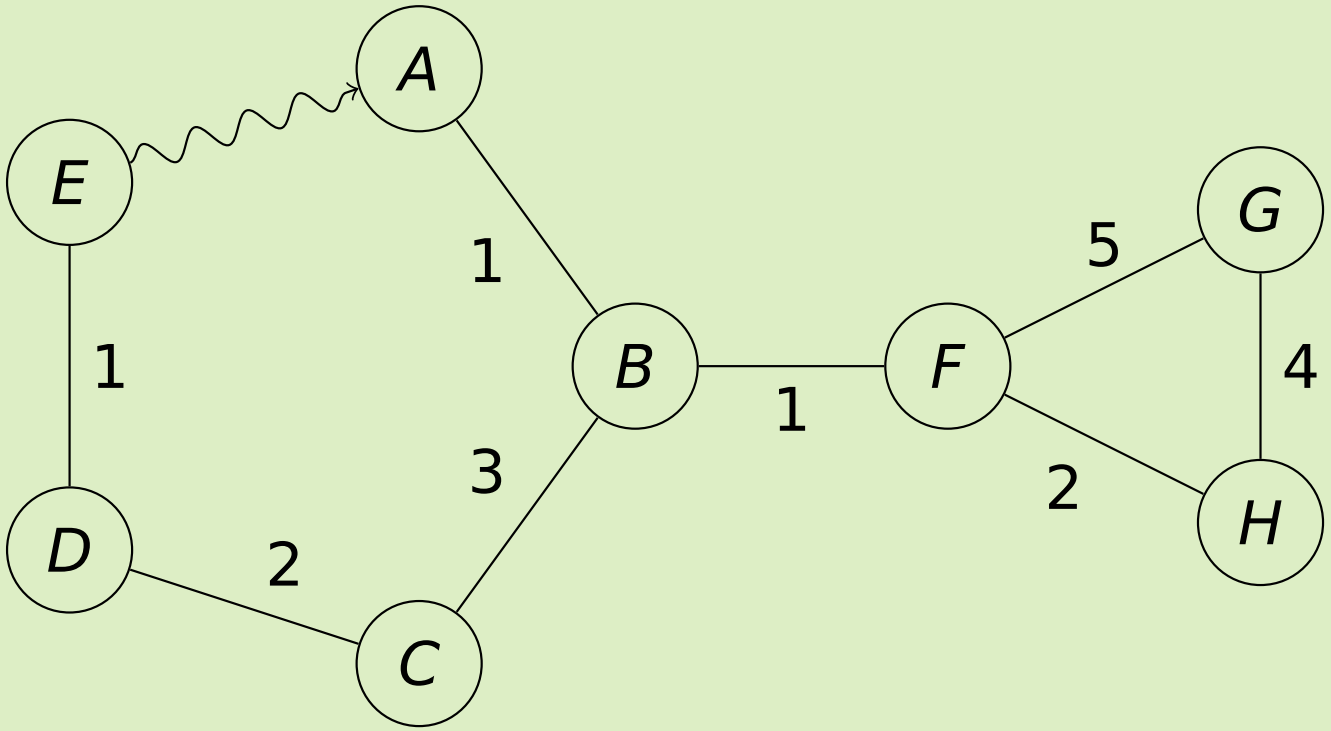
# Loop with a Branch

## Example



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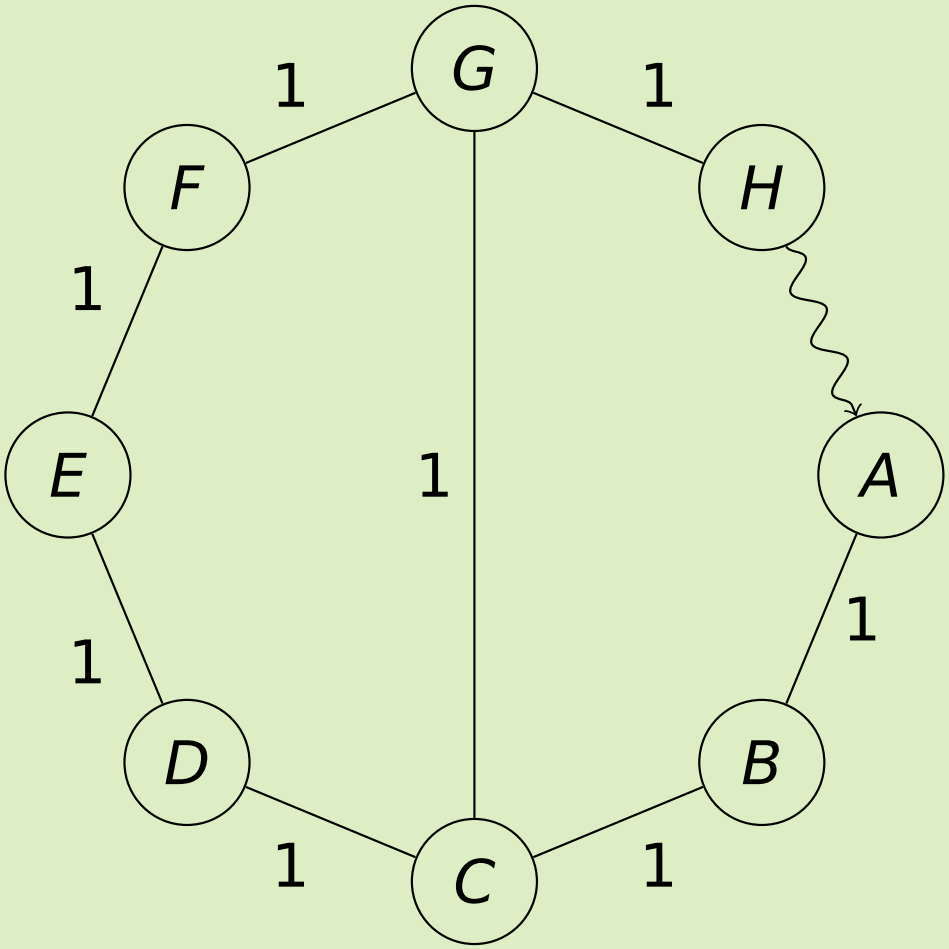
# Two Loops

## Example




| Vertex | Weight |
|---|---|
| $A$ | $0$ |
| $B$ | $1/4$ |
| $C$ | $2/4$ |
| $D$ | $2/4 + 1/16$ |
| $E$ | $2/4 + 2/16$ |
| $F$ | $2/4 + 3/16$ |
| $G$ | $3/4$ |
| $H$ | $1$ |

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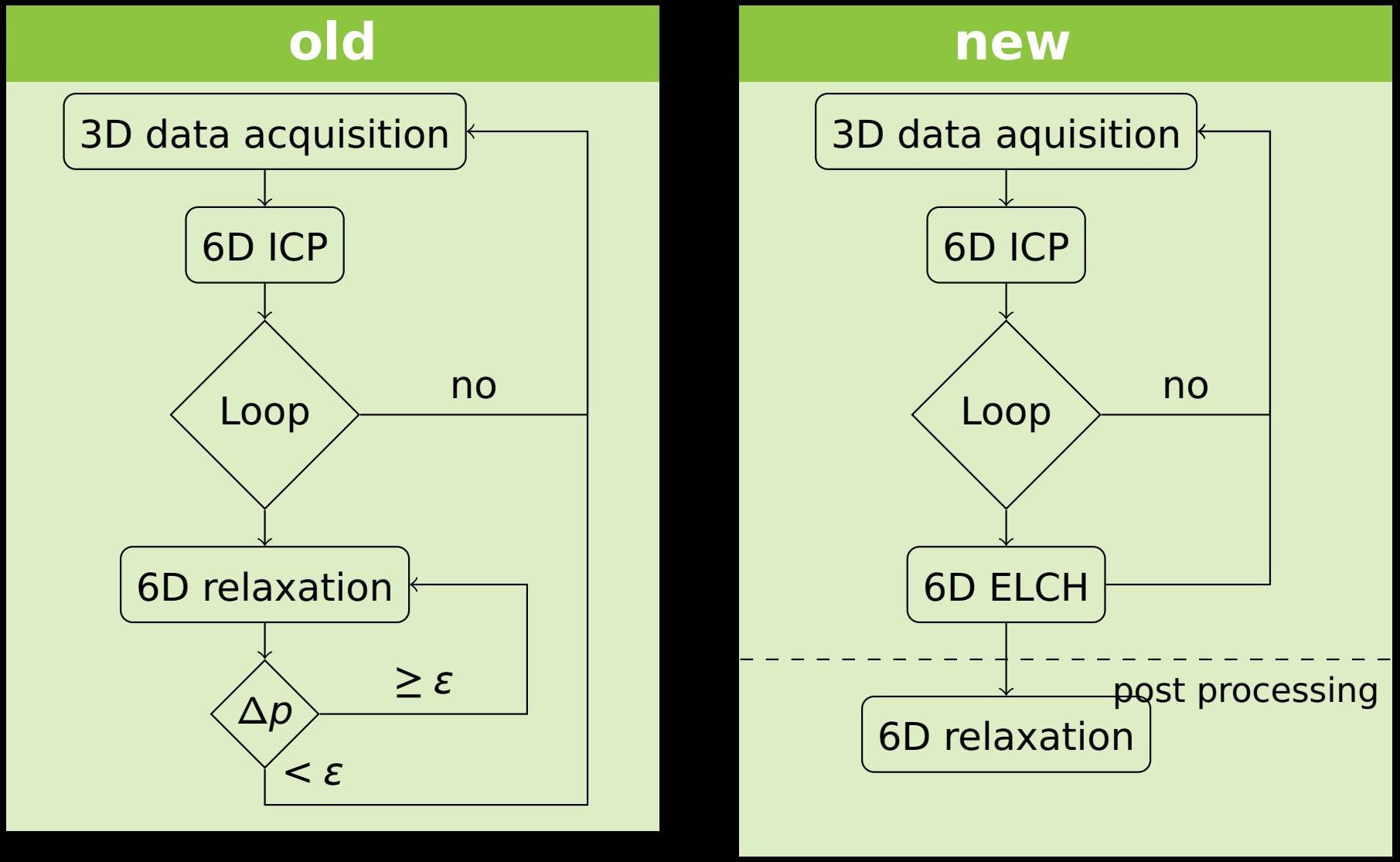
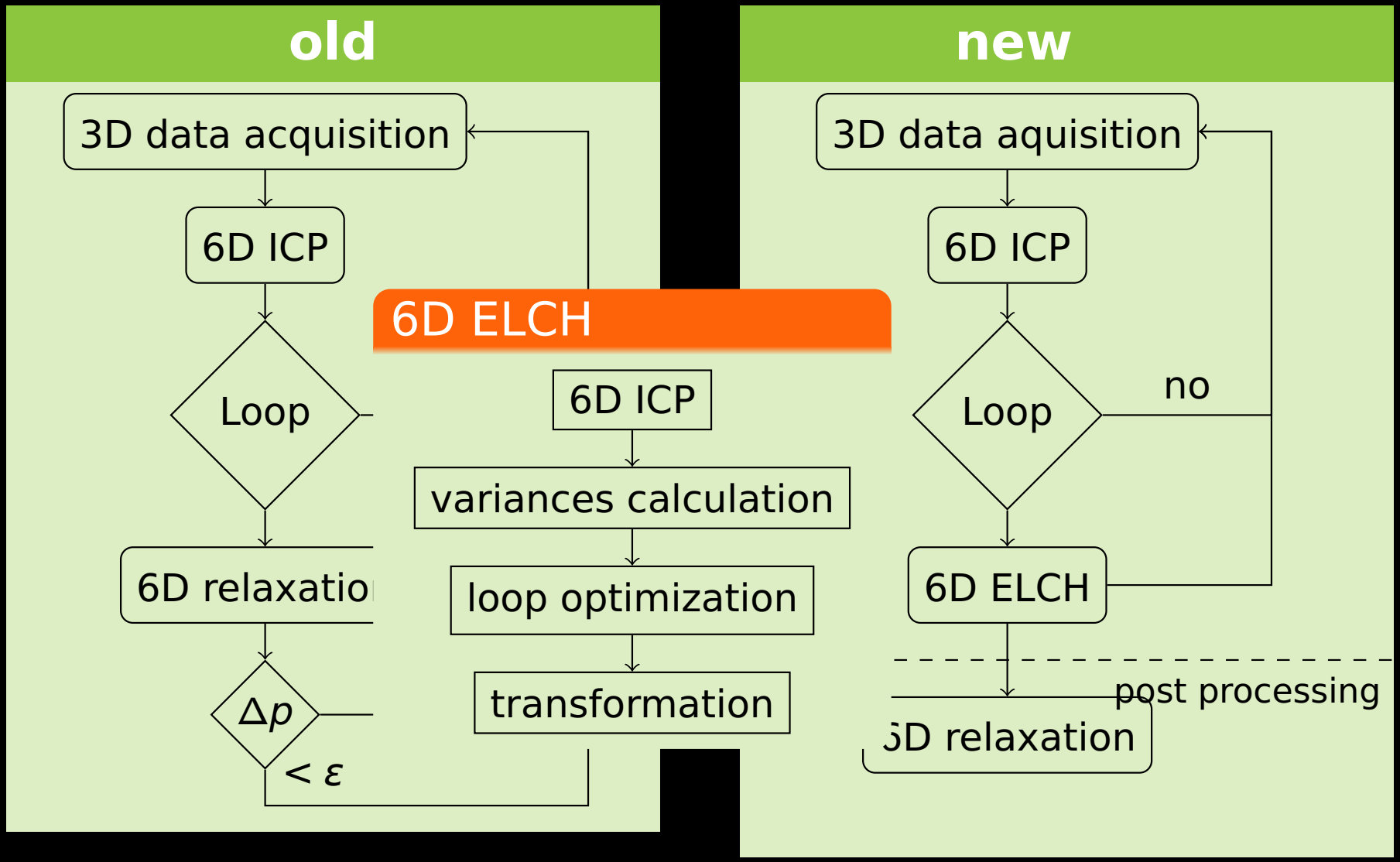
# Program Flow



pointcloudlibrary

# Program Flow



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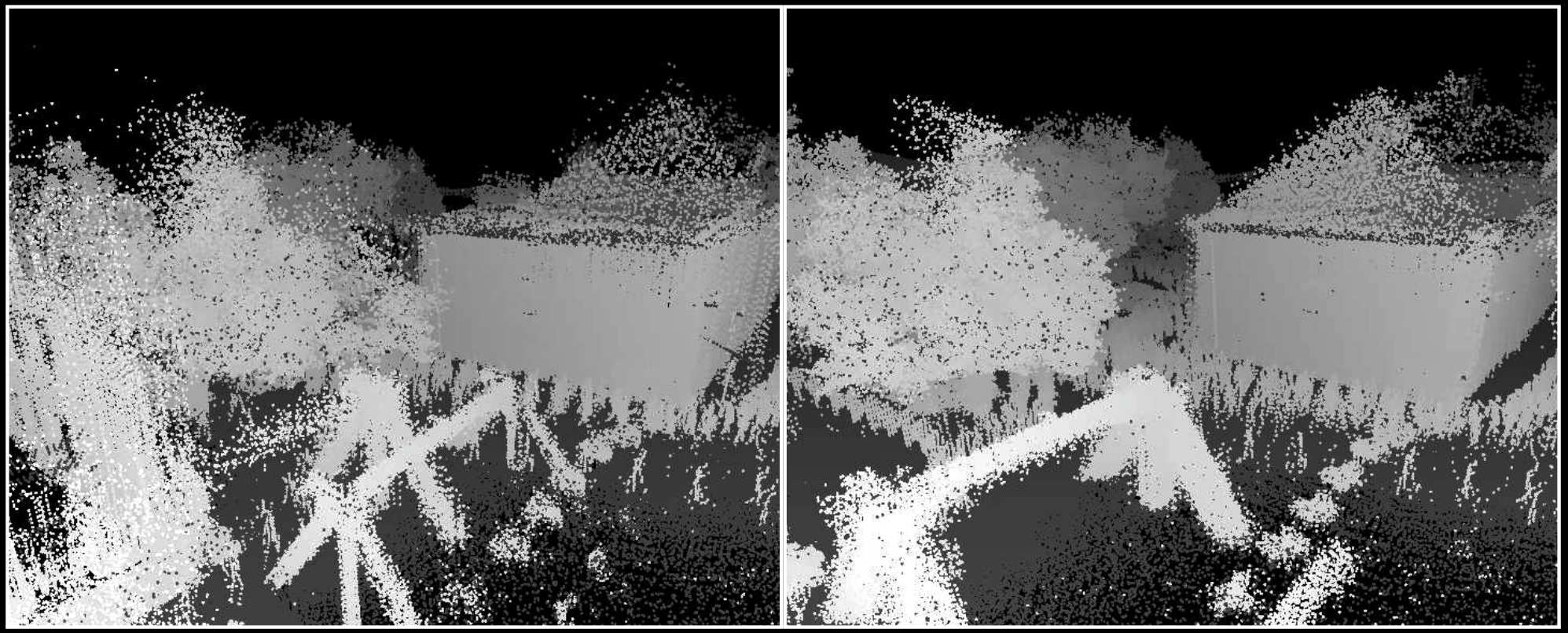
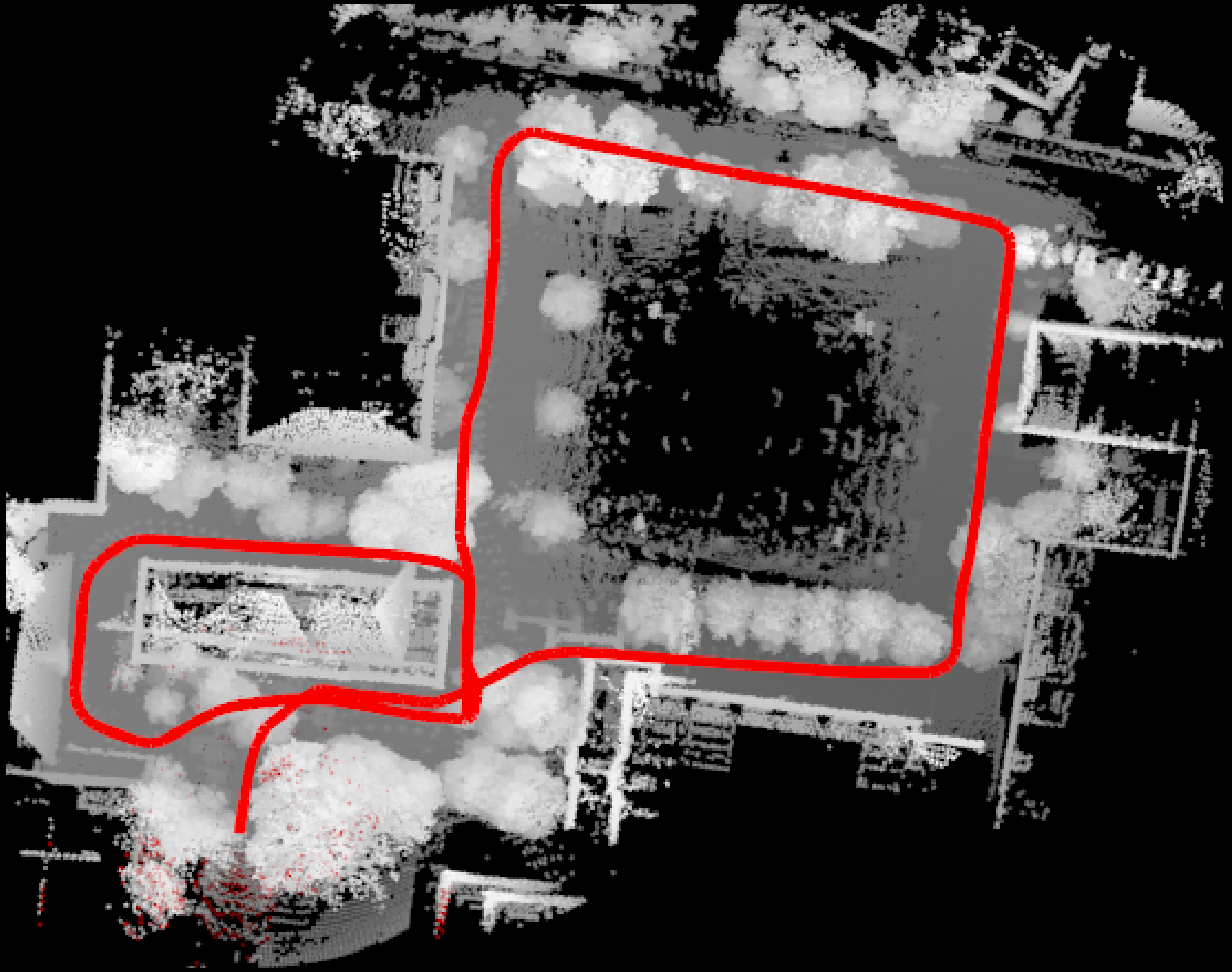
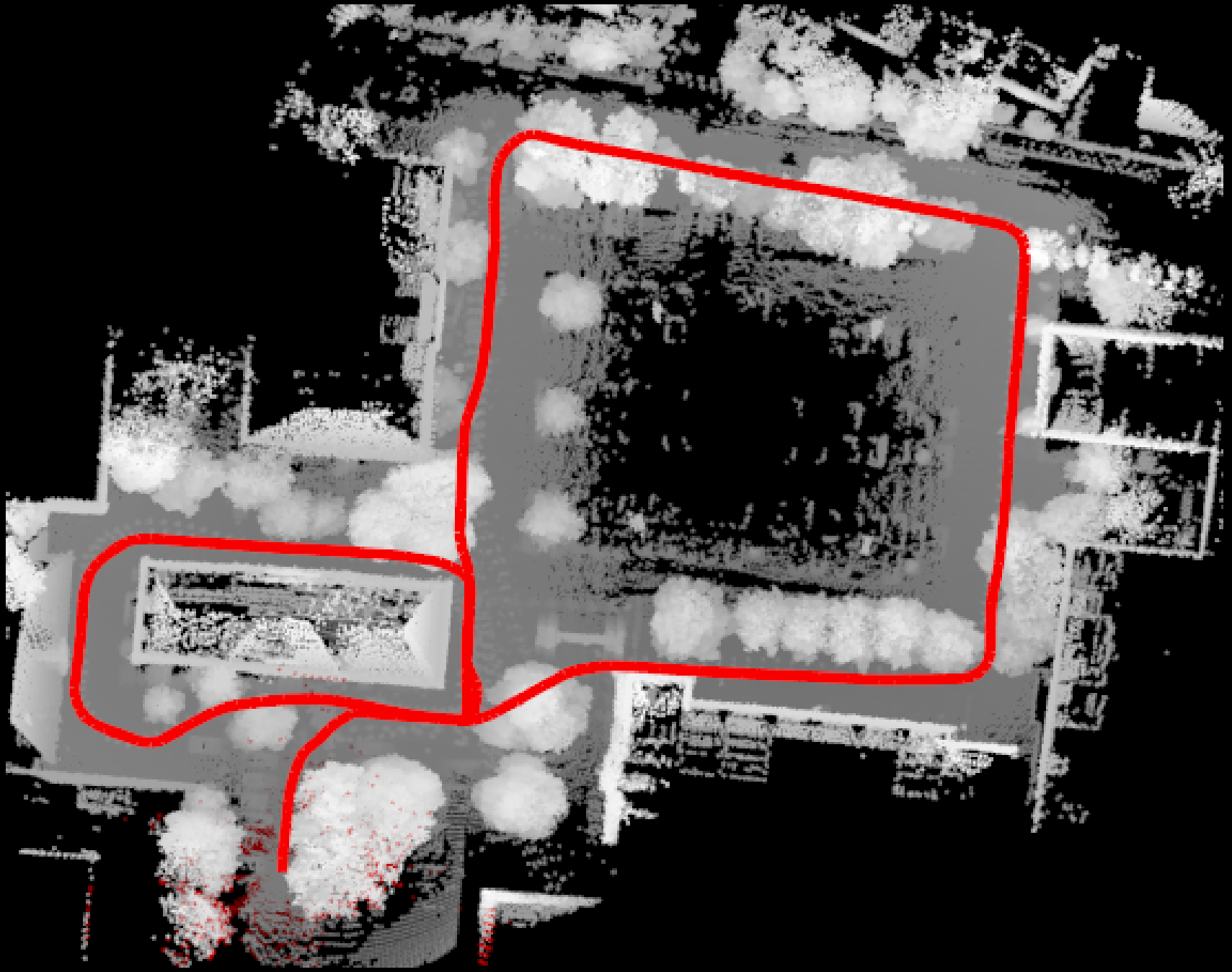
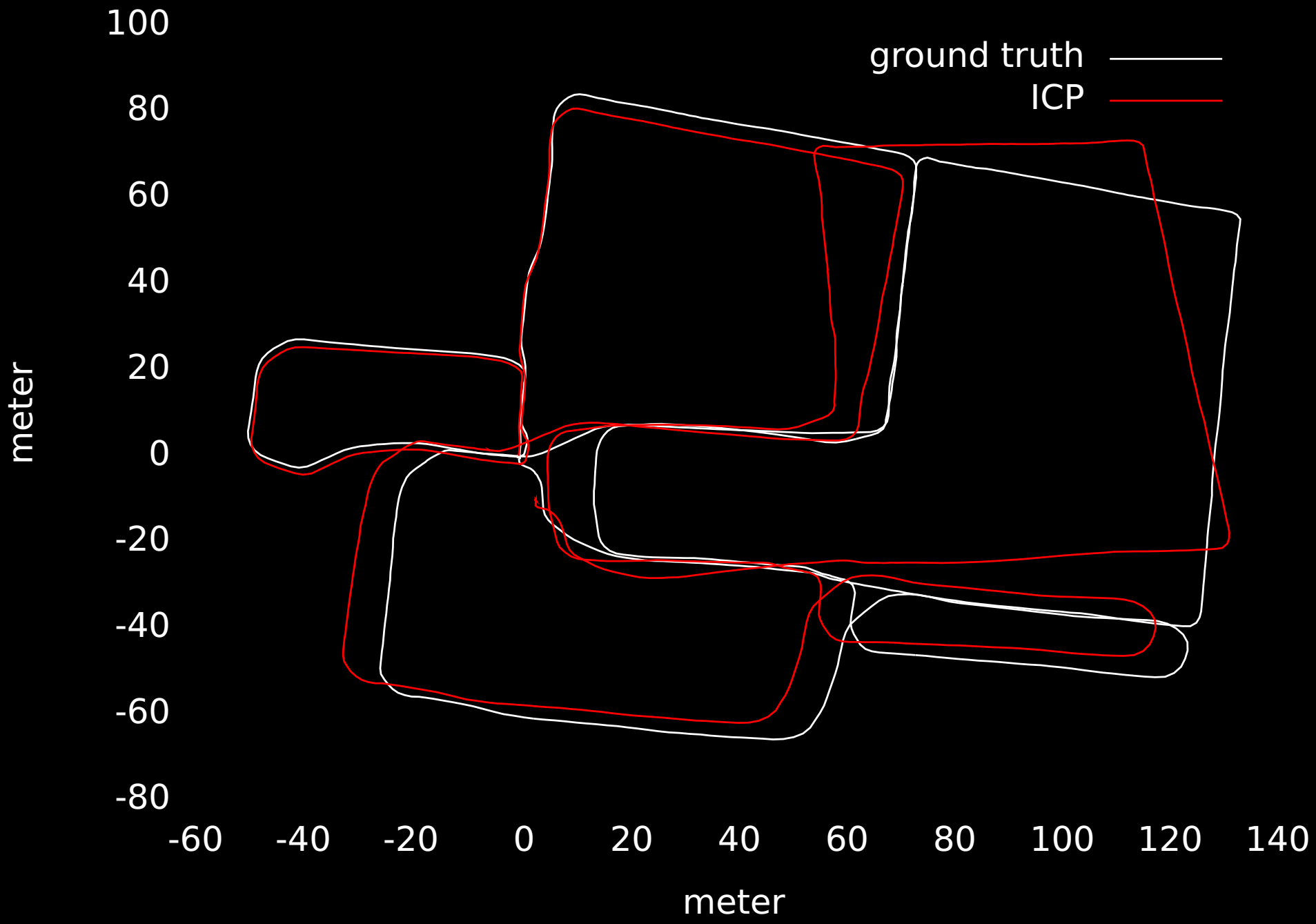
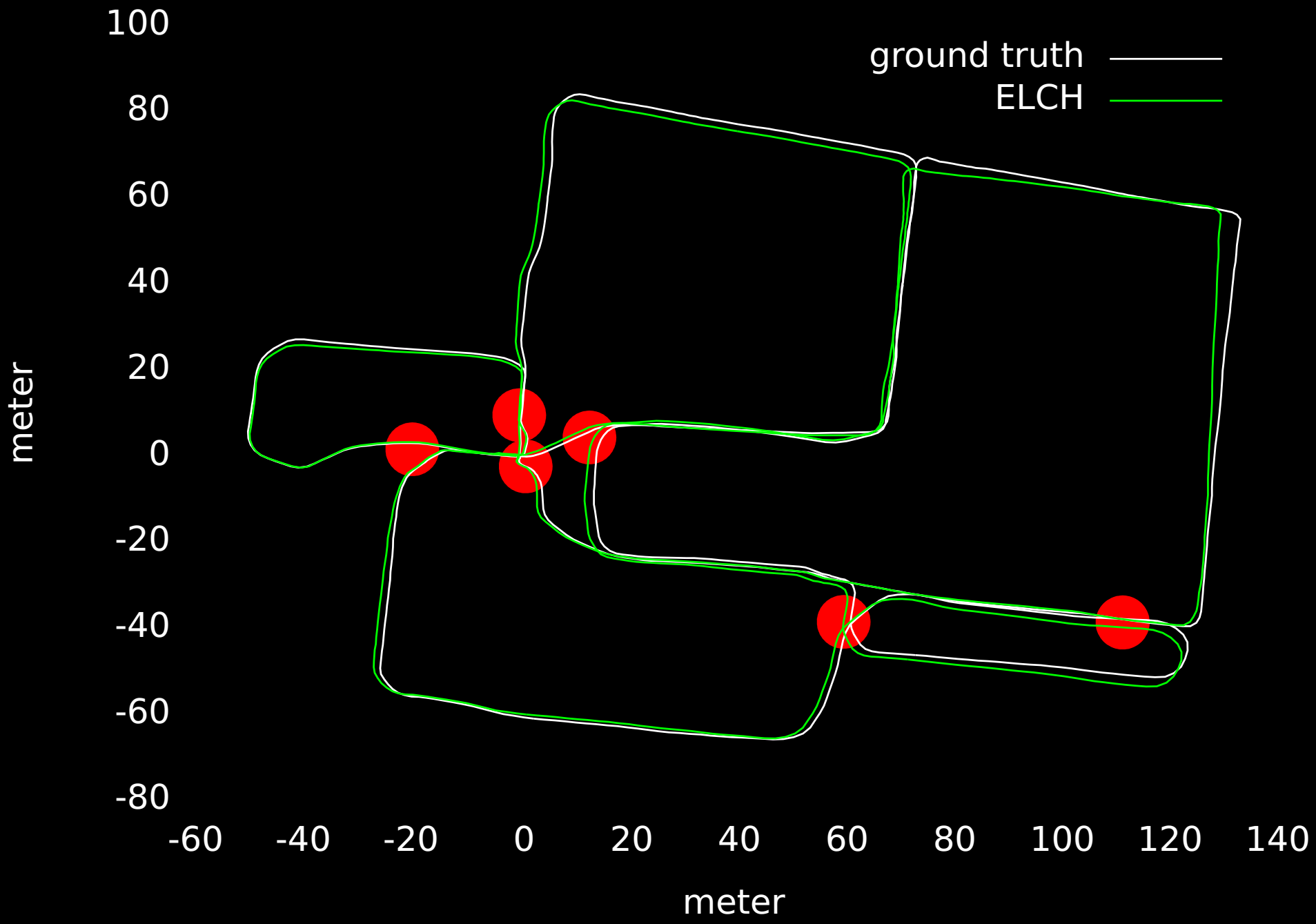
# Loop Correction

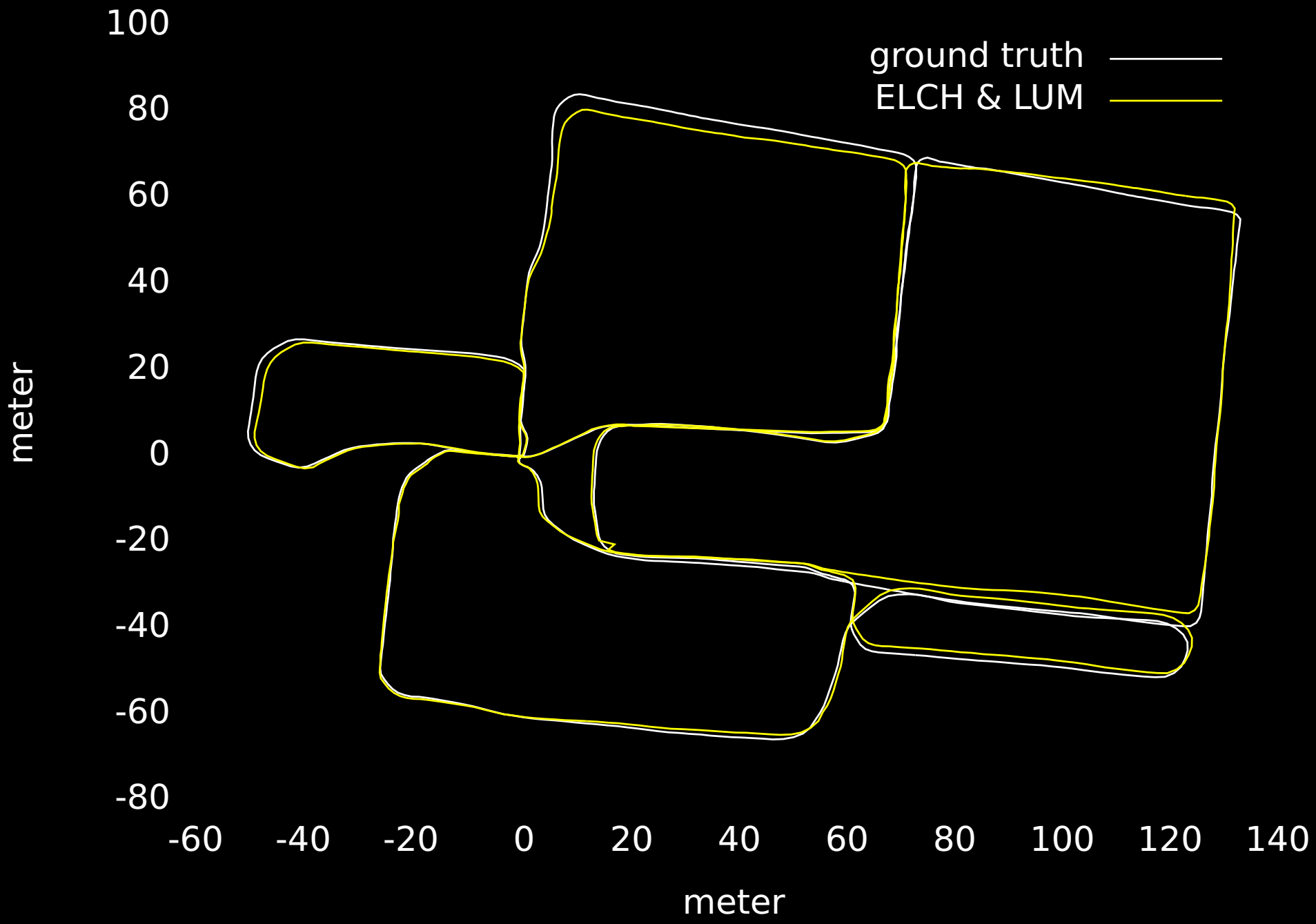







ground truth
ICP
100
80
60
40
20
0
-20
-40
-60
-80
meter
-60
-40
-20
0
20
40
60
80
100
120
140
meter


ground truth
ELCH
100
80
60
40
20
0
-20
-40
-60
-80
meter
-60
-40
-20
0
20
40
60
80
100
120
140
meter


ground truth
ELCH & LUM
meter
meter
100
80
60
40
20
0
-20
-40
-60
-80
-60
-40
-20
0
20
40
60
80
100
120
140

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# Runtime

| algorithm | runtime [min] |
|---|---|
| ICP | 0.4 |
| LUM | 18.2 |
| ELCH | 0.6 |
| ELCH & LUM | 2.9 |

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# Accuracy

| Algorithm | Translation [m] | Rotation [°] |
|---|---|---|
| ICP | 9,16 ± 6,70 | 3,31 ± 2,64 |
| LUM | 6.24 ± 7.07 | 3.44 ± 2.55 |
| ELCH | 4.35 ± 4.96 | 2.61 ± 1.84 |
| ELCH & LUM | 4.05 ± 4.33 | 2.90 ± 2.03 |

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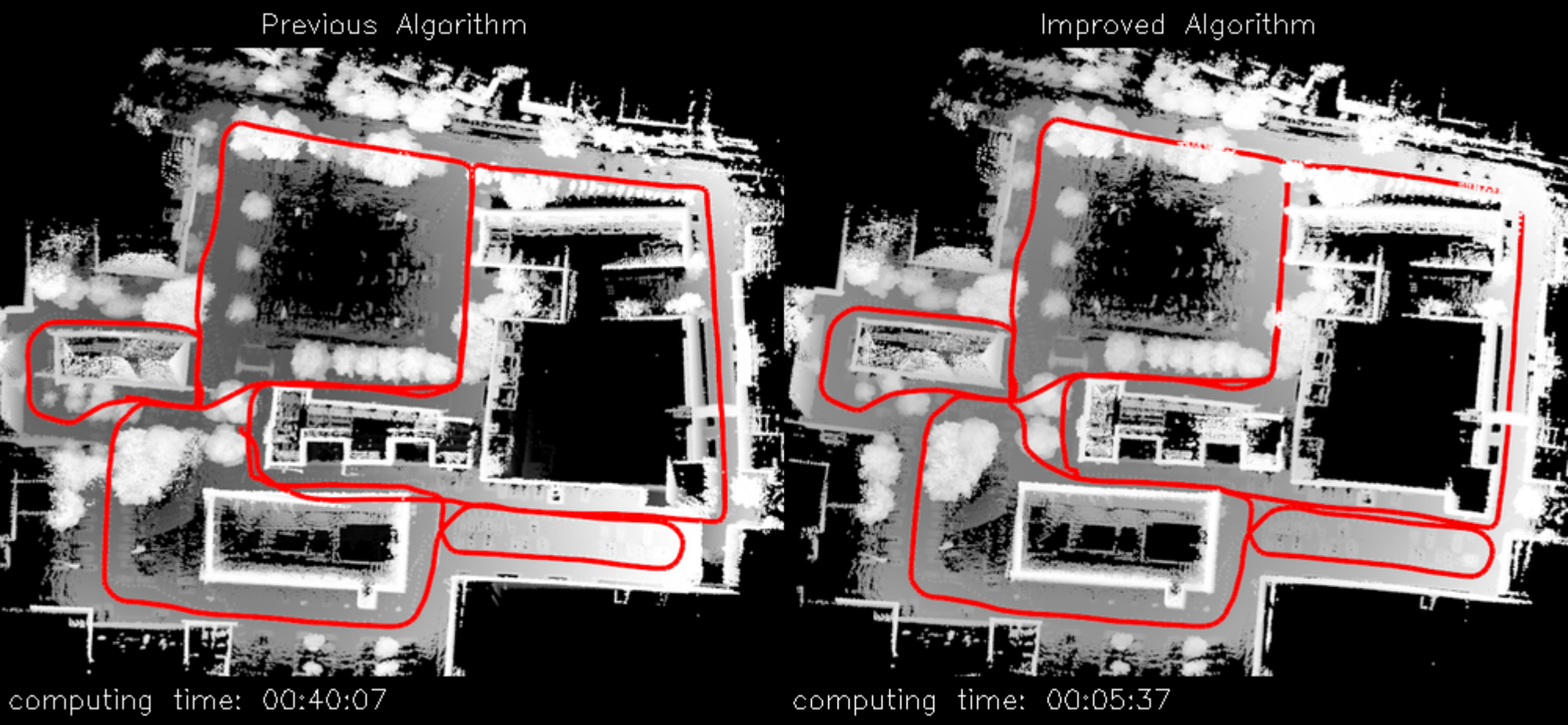
# Video



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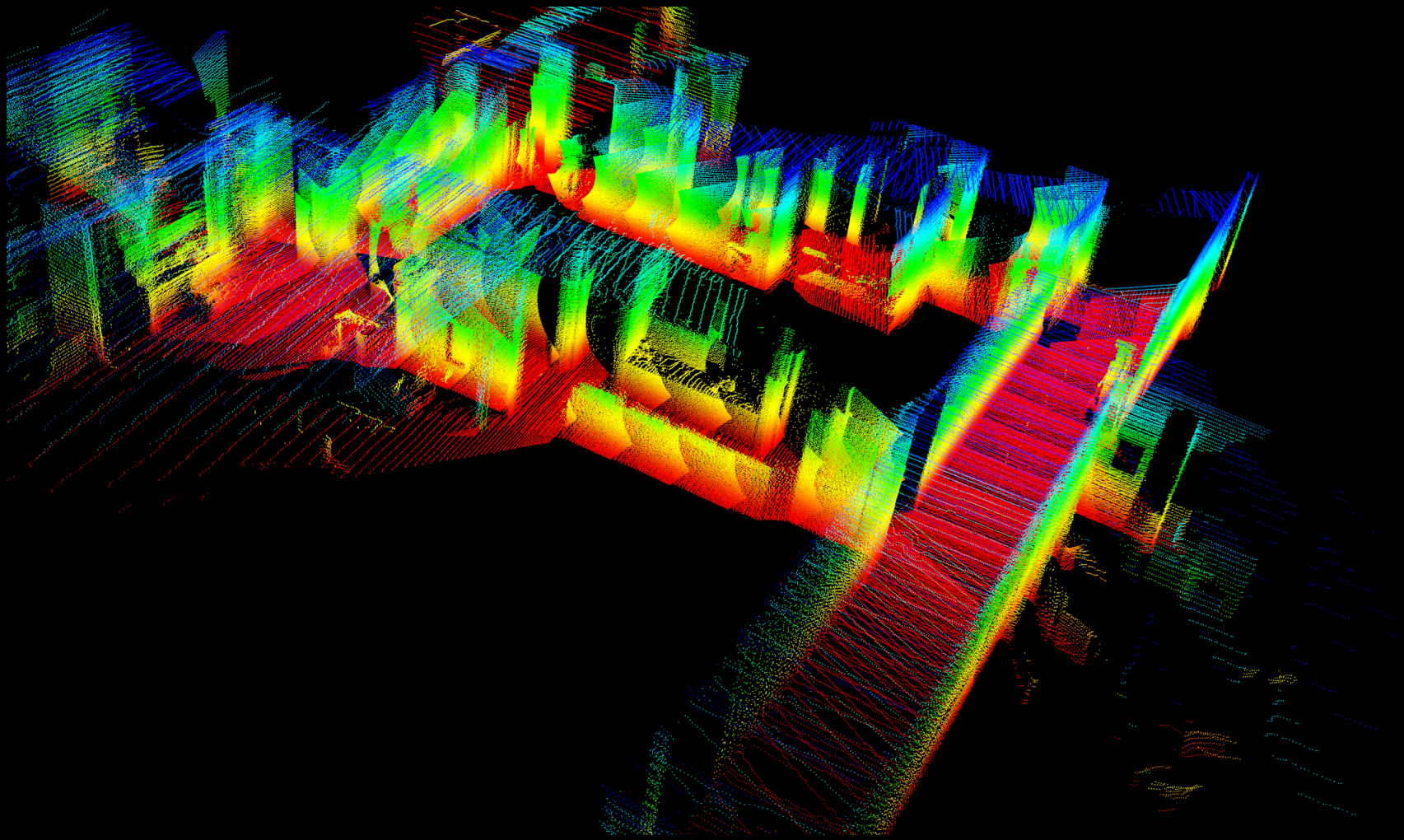
# PR2 Data



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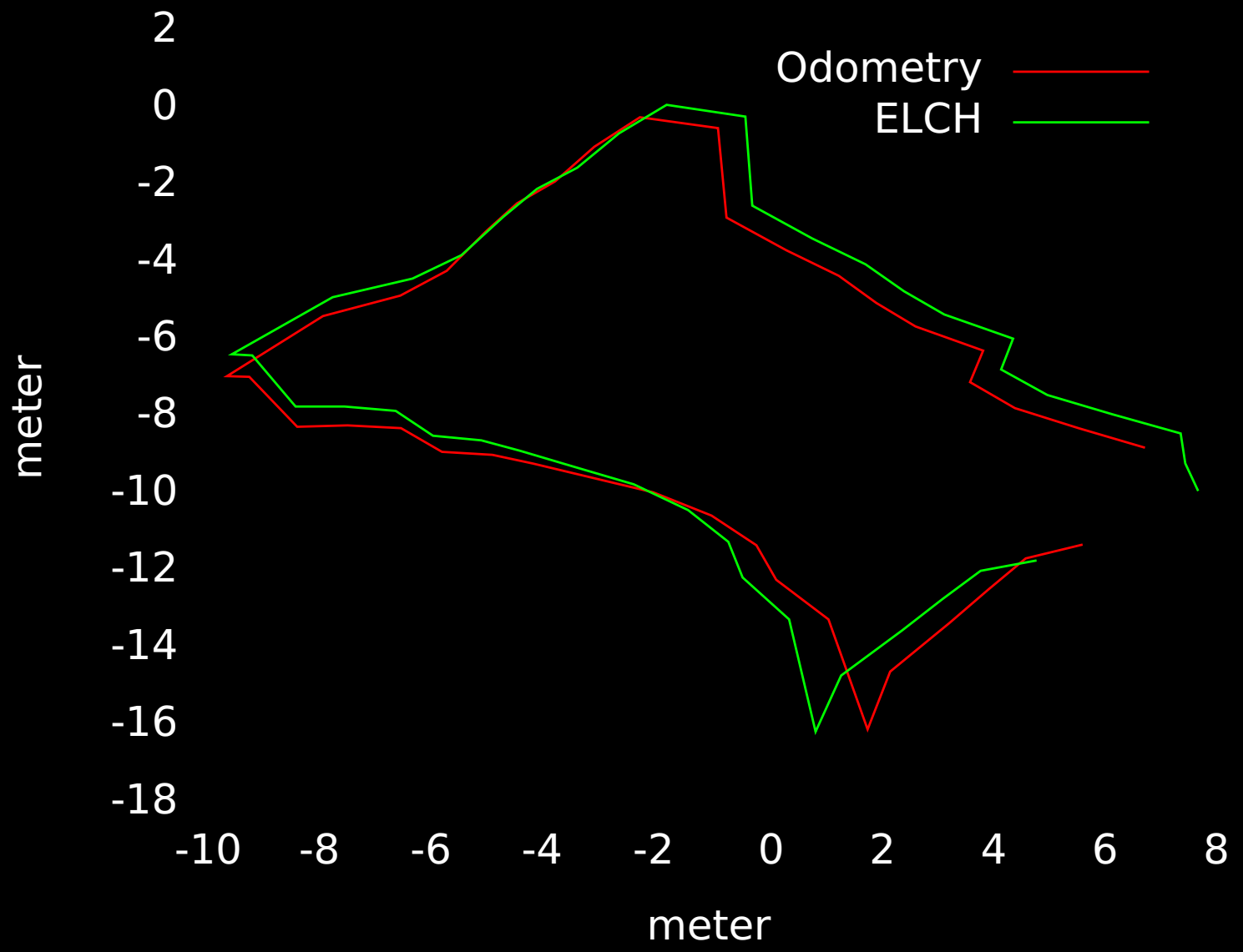
# Trajectory



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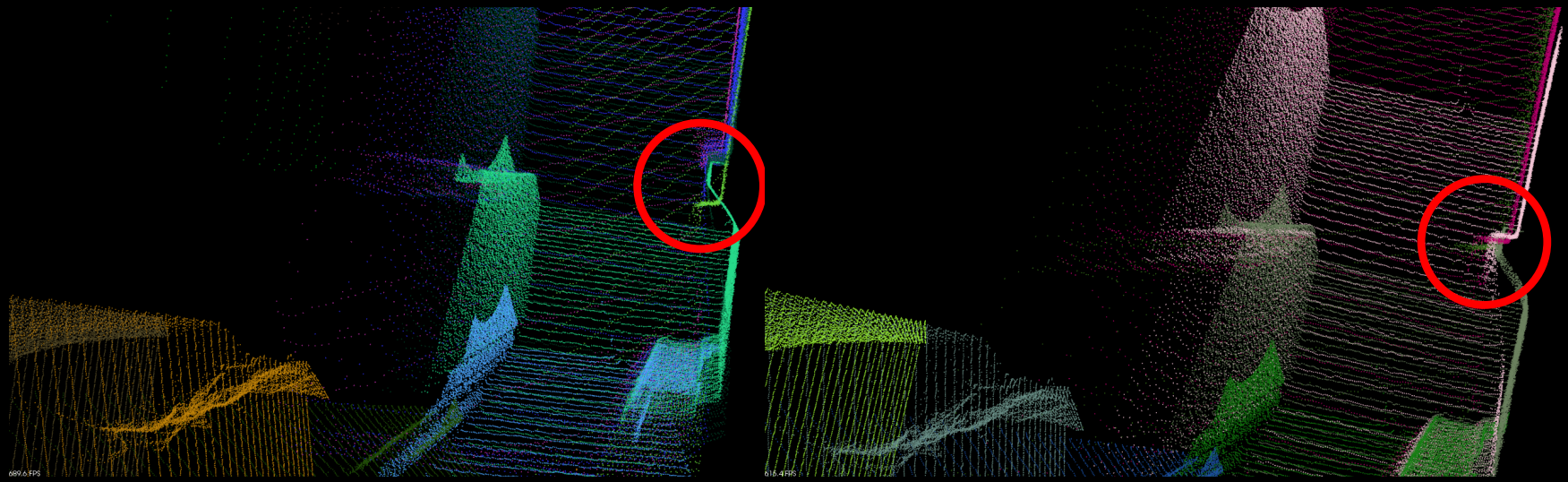
# Loop Closing



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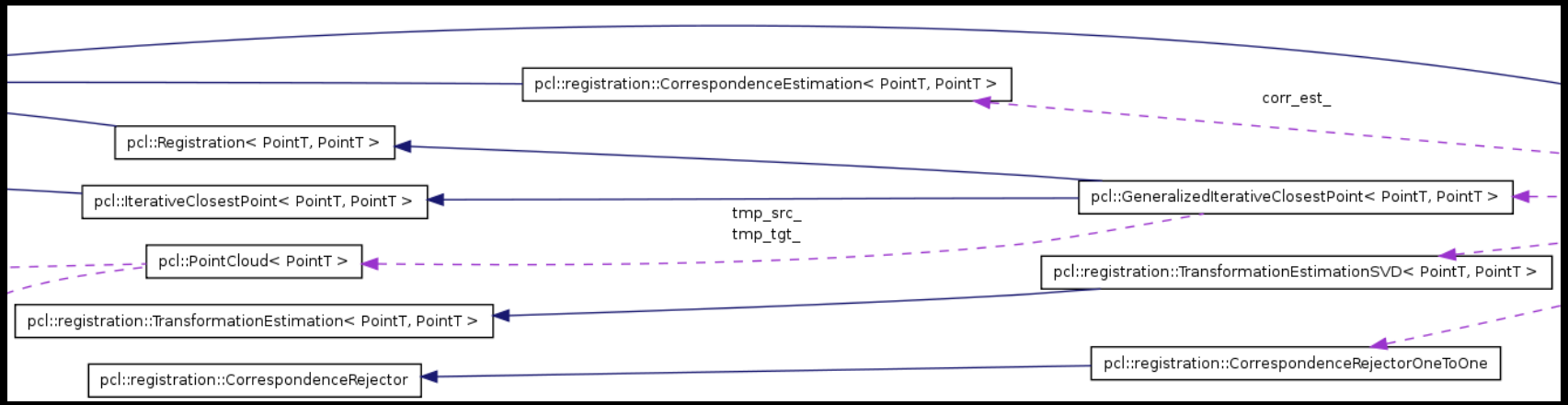
# PCL::Registration




- PCL v2 API design
- GICP port (with Nizar and Marius)
- new file format (with Julius)
- registration API (with Nicola)

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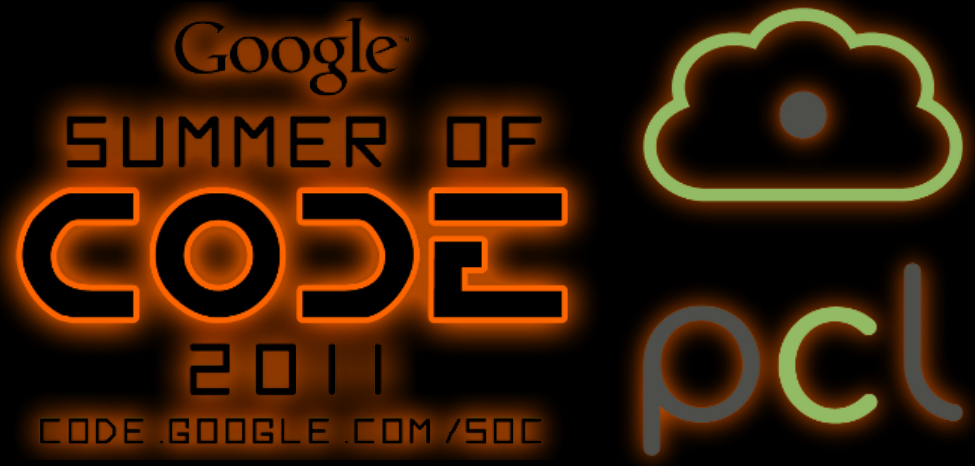
# Other Things




- PCL Ubuntu PPA
- TeamCity continuous integration
- RSS tutorial
- OpenNI bugfixing
- GSoC mentor