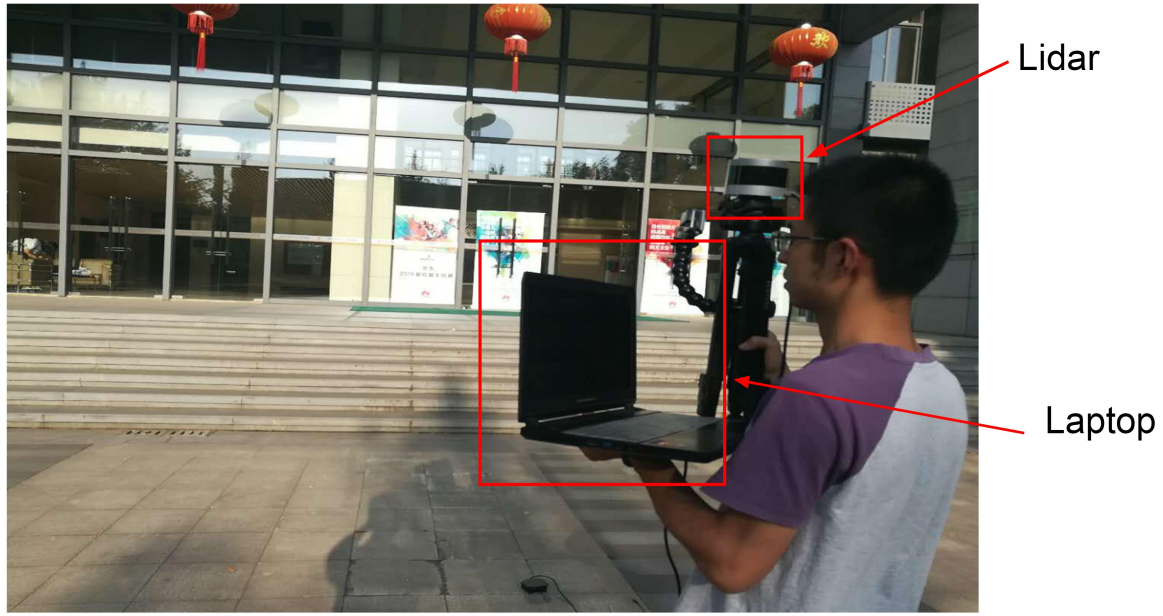
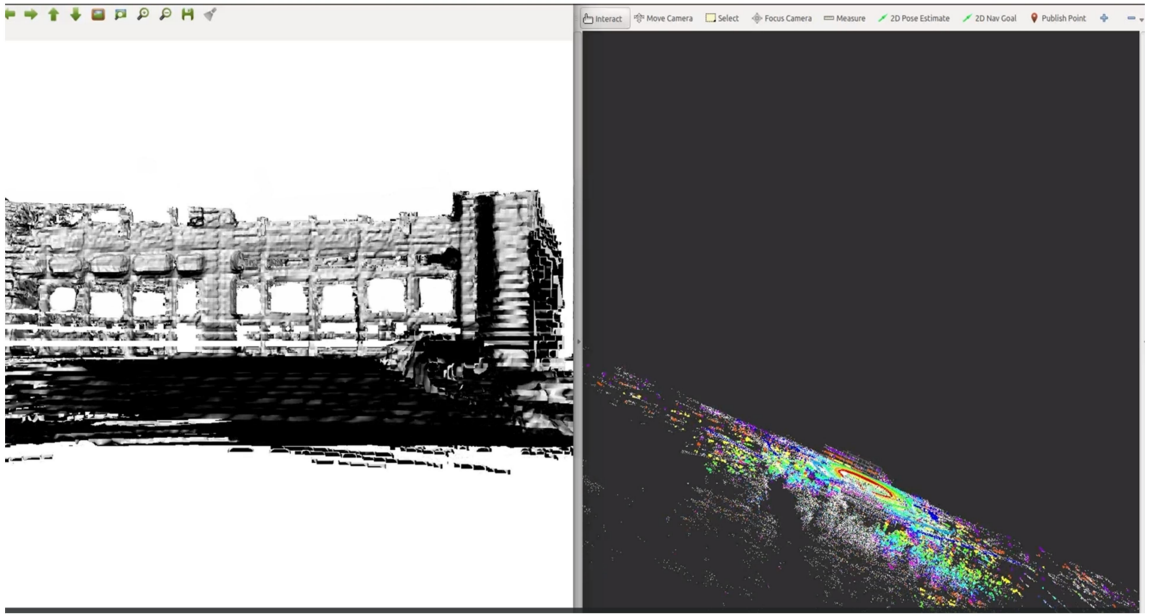
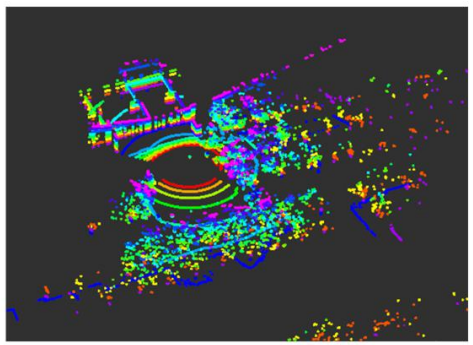
Large-scale Real-time Surface Reconstruction Using Light Detection And Ranging (Lidar)

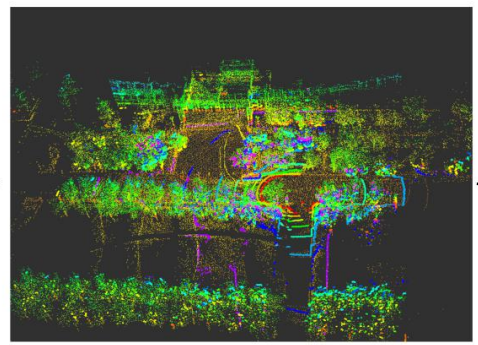
Anyi Rao


Lidar
Laptop

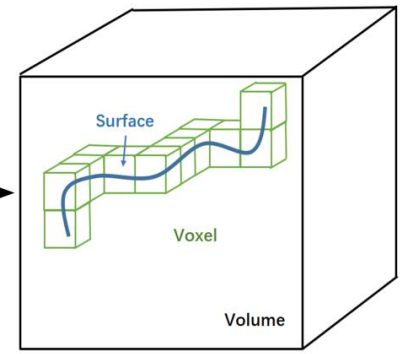

Interact
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
2D Nav Goal
Publish Point



(a) One frame Lidar data



(b) Lidar data registration

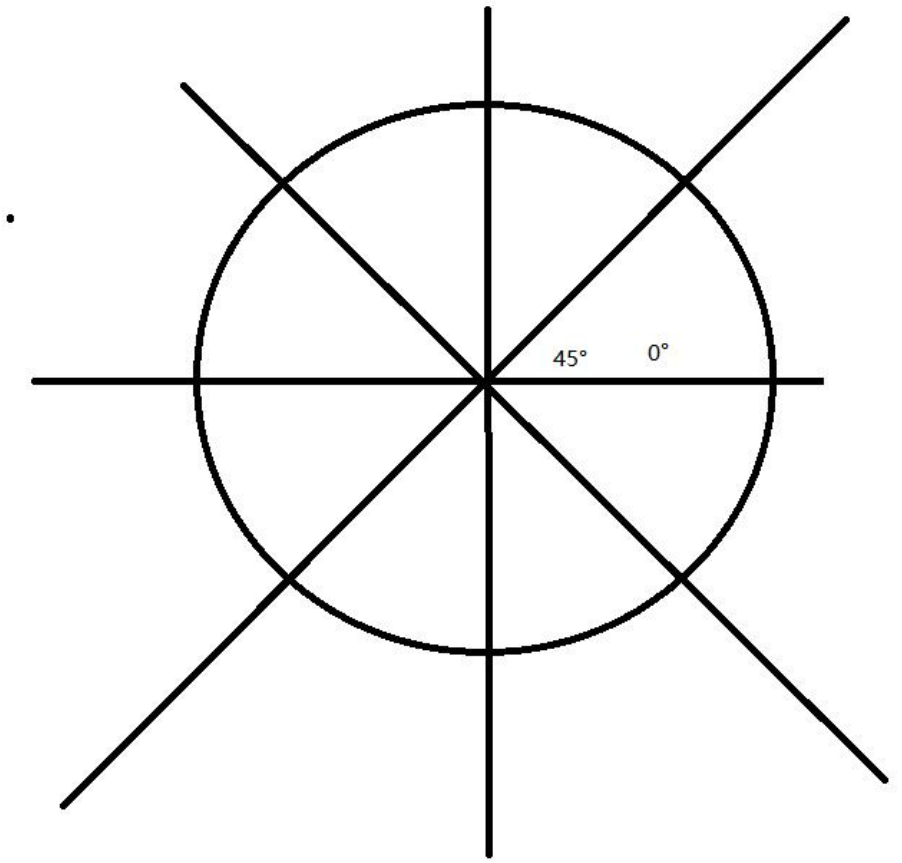


(c) Implicit surface update

(d) Raycasting

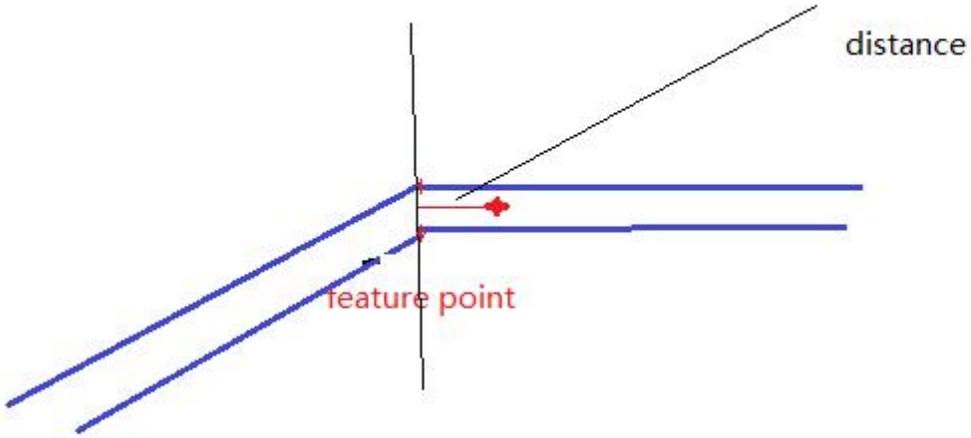
Overview

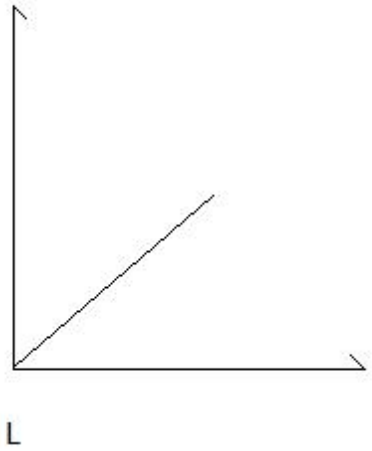
- lidarData:
  - Key: (frame, Vertical_Angle)
  - Value:points3D
- Freature:
  - 8 subregions
    - 45°
  - Smoothness
    - Edge:
      - Threshold: >0.003
      - Numbers:<=2
      - Distance between consecutive points:0.02m
    - Planar:
      - Threshold :<0.003
      - Numbers:<=4
      - Distance between consecutive points:0.04m



Overview

- Correspondence:
- Input data: P_k P_{k+1}
- getFeatures: P_{k+1}
  - edgeLine: P_k
    - Distance: i→line
  - planarPatch: P_k
    - Distance: i→plane



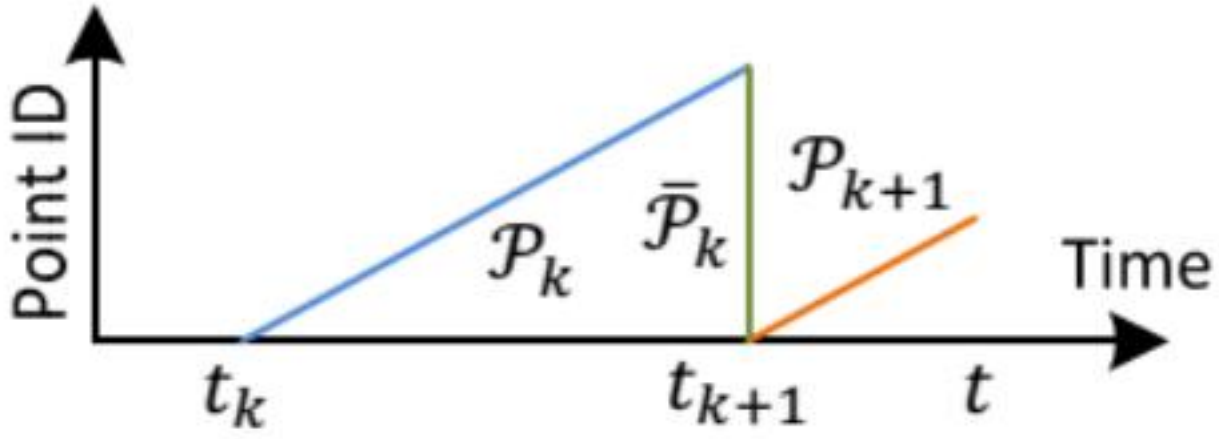


Overview

- Motion Estimation:
- LM:
  - Input data: featurePoints
  - dataModel: $X_i = RX_i + T$
  - Min(distance) $\text{distance}(X_i)$
- projectPoints:

$$RT_i = \frac{index}{len} RT$$

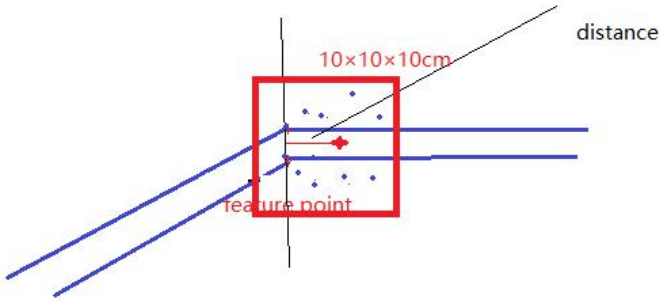
$$\bar{P}^i_{k+1} = R_i P^i_{k+1} + T_i$$

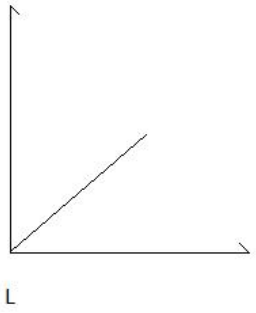


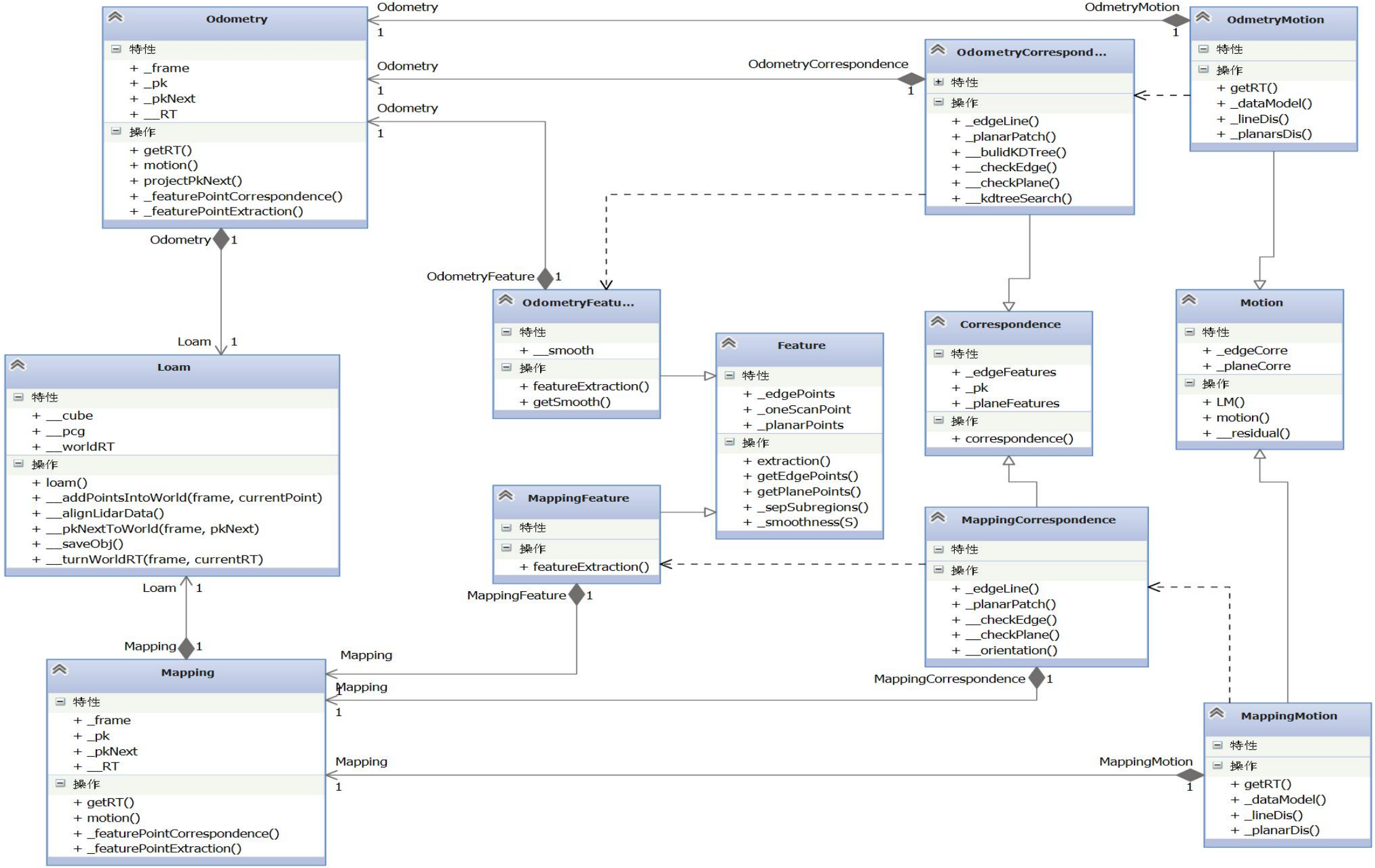
Overview

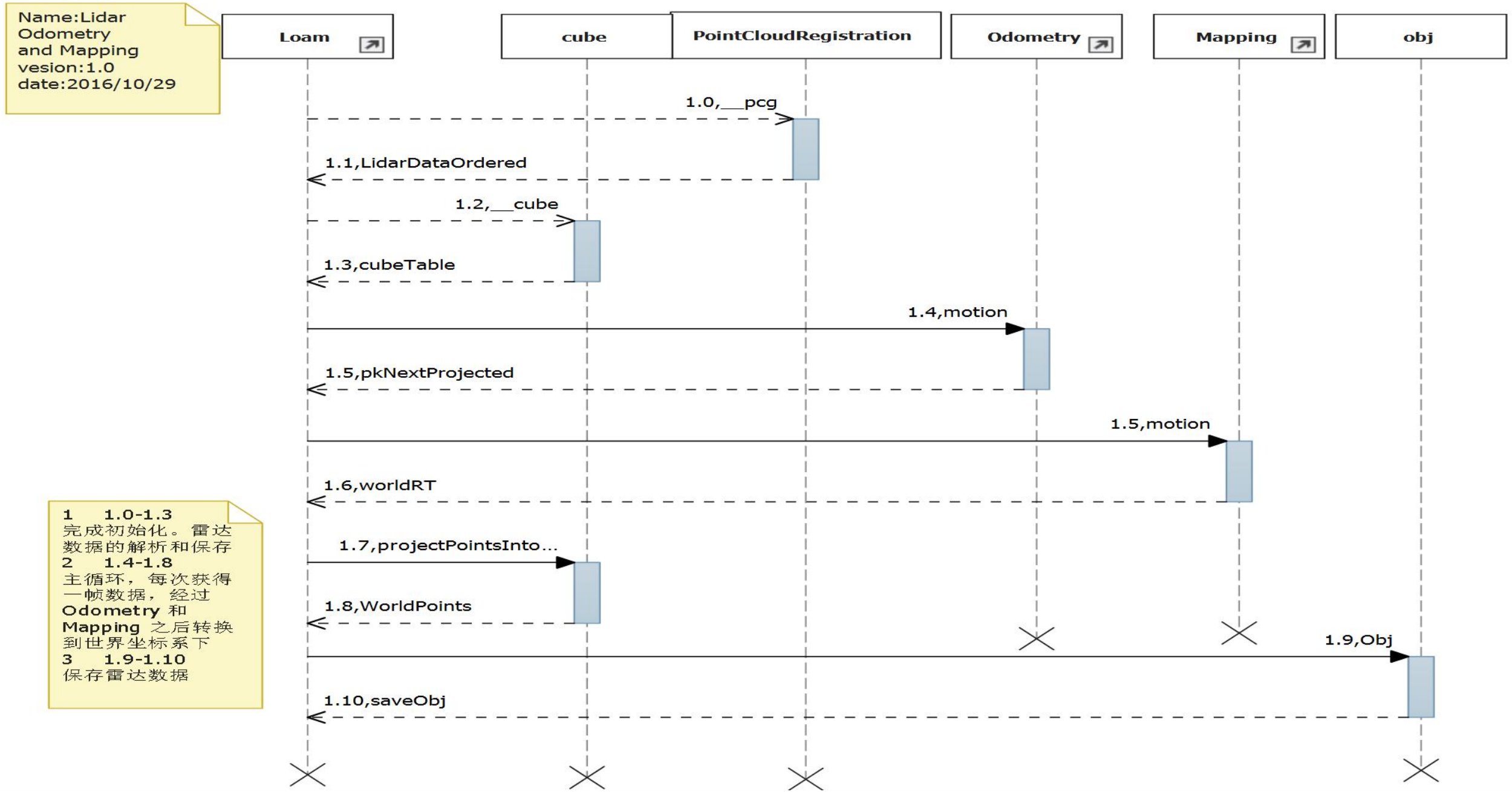
- Mapping:
- Input data: P_{world}
- featurePoints: Q_{k+1}
  - edgePoints:
    - Distance: i→line
  - planarPoints:
    - Distance: i→plane
- LM

$$Q_{k+1} = projectIntoWorld(\bar{P}_{k+1})$$

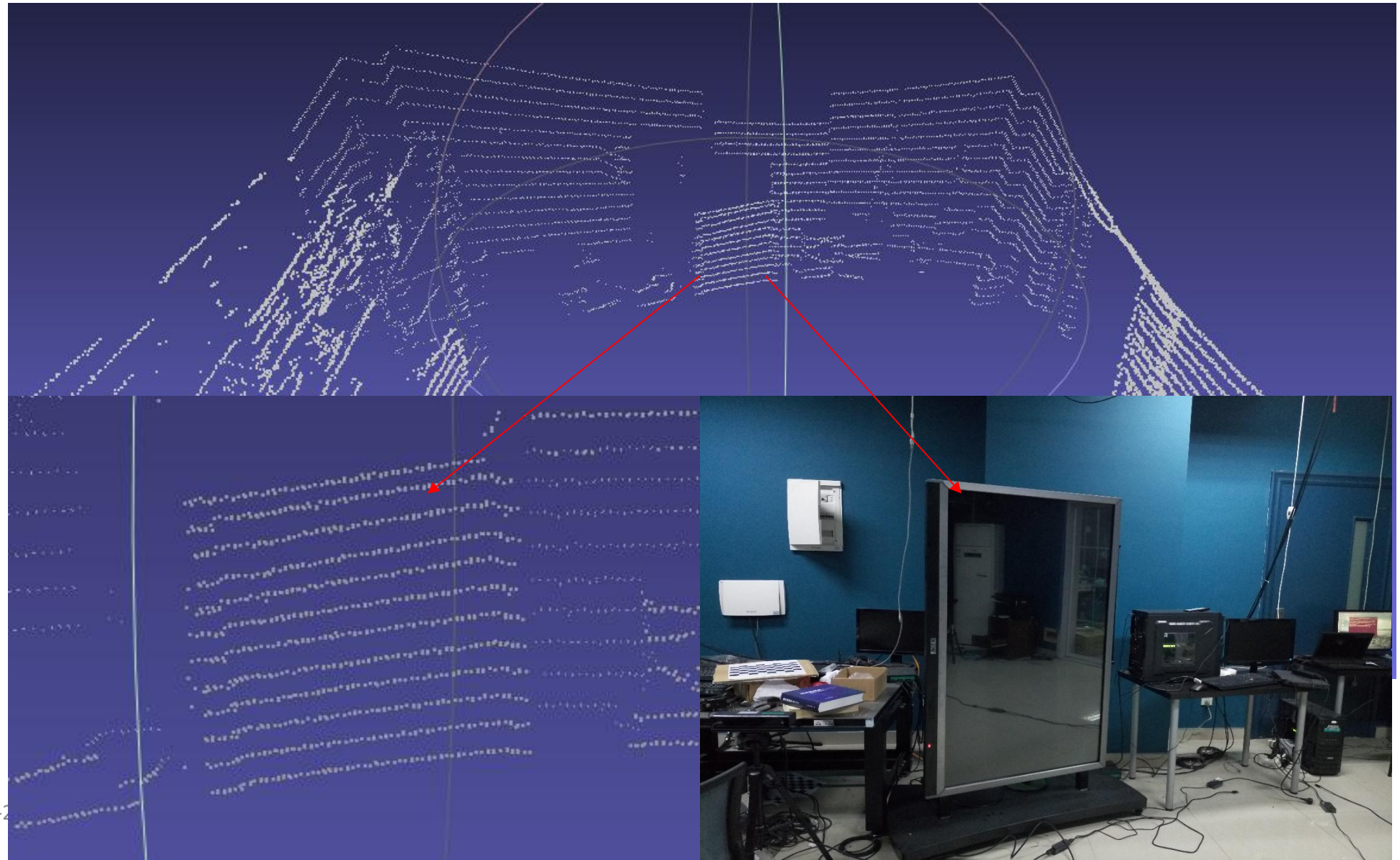




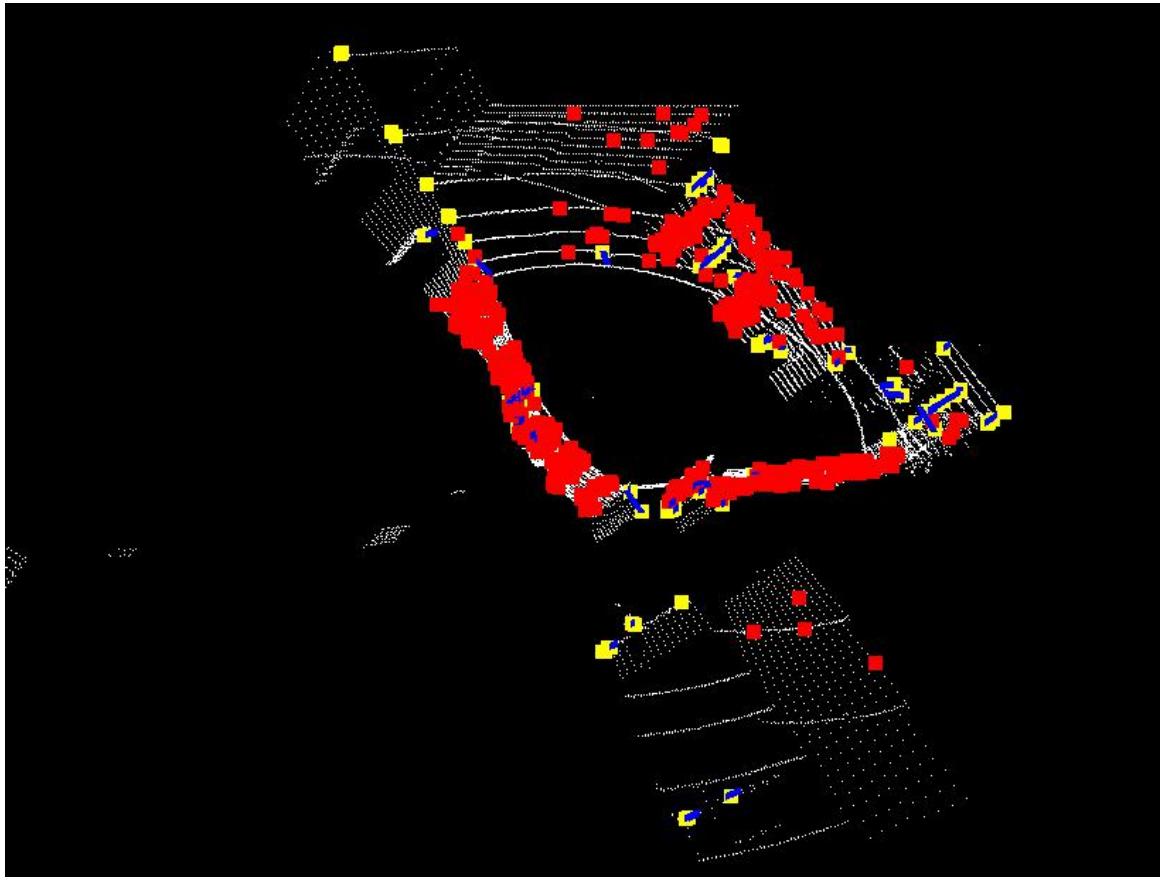

Odometry
特性
+ _frame
+ _pk
+ _pkNext
+ __RT
操作
+ getRT()
+ motion()
+ projectPkNext()
+ _featurePointCorrespondence()
+ _featurePointExtraction()
OdometryCorrespond...
特性
操作
+ _edgeLine()
+ _planarPatch()
+ __bulidKDTree()
+ __checkEdge()
+ __checkPlane()
+ __kdtreeSearch()
OdmetryMotion
特性
操作
+ getRT()
+ _dataModel()
+ _lineDis()
+ _planarsDis()
OdometryFeatu...
特性
+ __smooth
操作
+ featureExtraction()
+ getSmooth()
Feature
特性
+ _edgePoints
+ _oneScanPoint
+ _planarPoints
操作
+ extraction()
+ getEdgePoints()
+ getPlanePoints()
+ _sepSubregions()
+ _smoothness(S)
Correspondence
特性
+ _edgeFeatures
+ _pk
+ _planeFeatures
操作
+ correspondence()
Motion
特性
+ _edgeCorre
+ _planeCorre
操作
+ LM()
+ motion()
+ __residual()
Loam
特性
+ __cube
+ __pcg
+ __worldRT
操作
+ loam()
+ __addPointsIntoWorld(frame, currentPoint)
+ __alignLidarData()
+ __pkNextToWorld(frame, pkNext)
+ __saveObj()
+ __turnWorldRT(frame, currentRT)
MappingFeature
特性
操作
+ featureExtraction()
MappingCorrespondence
特性
操作
+ _edgeLine()
+ _planarPatch()
+ __checkEdge()
+ __checkPlane()
+ __orientation()
Mapping
特性
+ _frame
+ _pk
+ _pkNext
+ __RT
操作
+ getRT()
+ motion()
+ _featurePointCorrespondence()
+ _featurePointExtraction()
MappingMotion
特性
操作
+ getRT()
+ _dataModel()
+ _lineDis()
+ _planarDis()
Odometry
OdometryCorrespondence
OdmetryMotion
OdometryFeature
Loam
MappingFeature
Mapping
MappingCorrespondence
MappingMotion
1


Name:Lidar Odometry and Mapping vesion:1.0 date:2016/10/29
Loam
cube
PointCloudRegistration
Odometry
Mapping
obj
1.0,__pcg
1.1,LidarDataOrdered
1.2,__cube
1.3,cubeTable
1.4,motion
1.5,pkNextProjected
1.5,motion
1.6,worldRT
1.7,projectPointsInto...
1.8,WorldPoints
1.9,Obj
1.10,saveObj
1 1.0-1.3
完成初始化。雷达数据的解析和保存
2 1.4-1.8
主循环，每次获得一帧数据，经过Odometry 和Mapping 之后转换到世界坐标系下
3 1.9-1.10
保存雷达数据

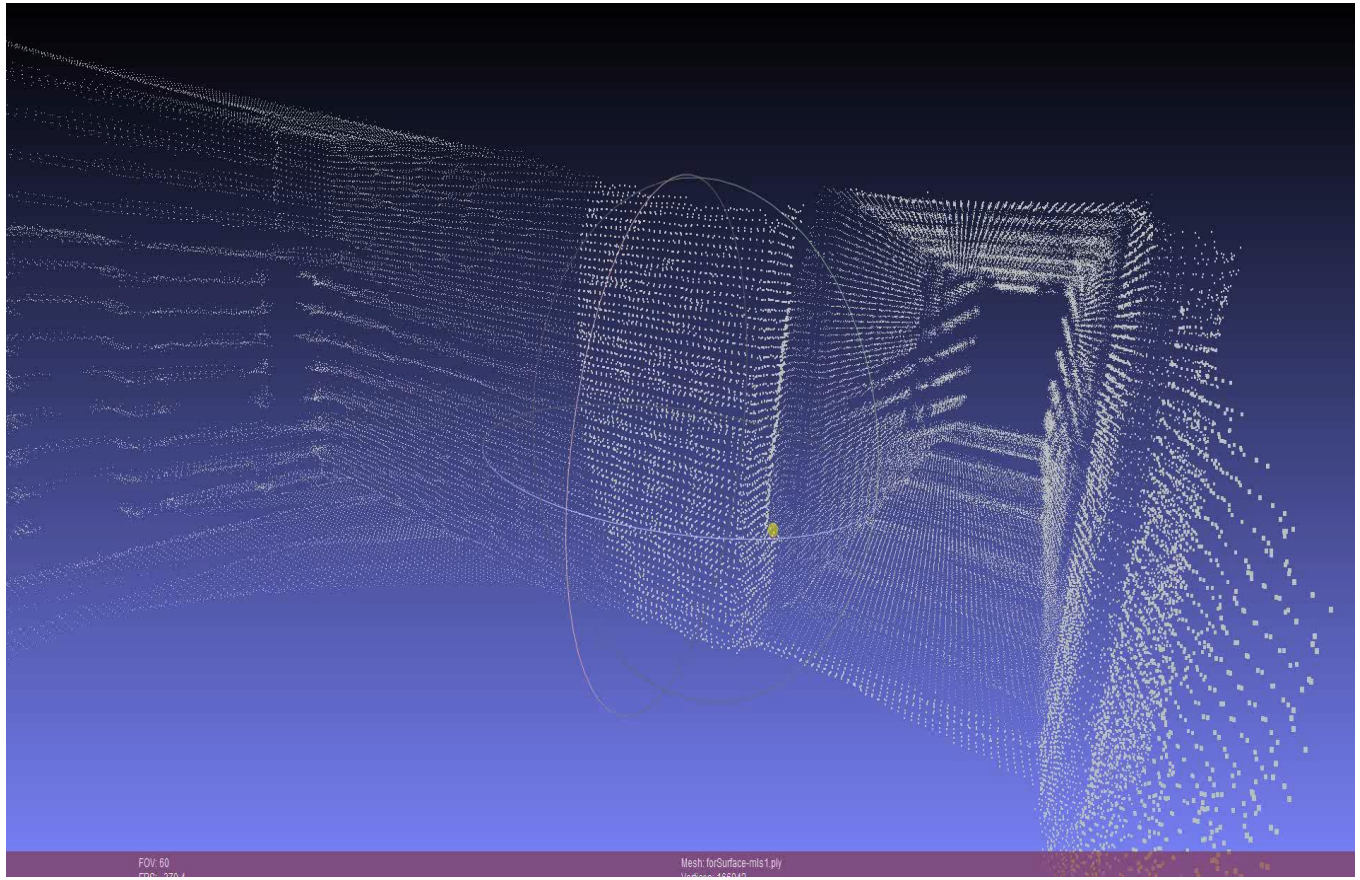
Lidar point cloud



Feature point



Point cloud registration



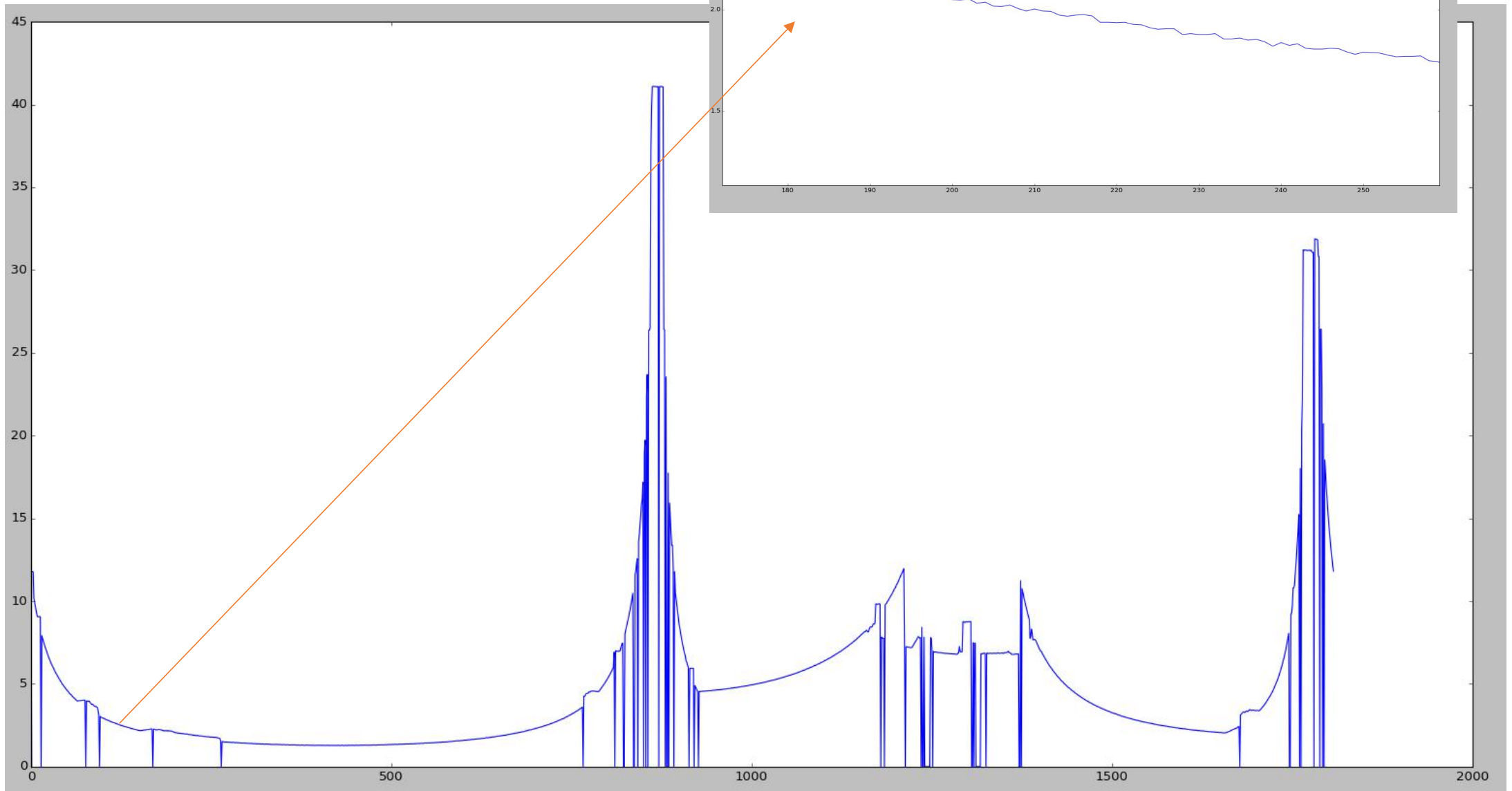
Analysis

OdometryCorrespondence	buildKDTree	edgeCorre	planeCorre	
time	0.387	0.095	0.146	
MappingCorrespondence		edgeCorre	planeCorre	
time		0.153	0.322	
Odometry	featurePointExtraction	Correspondence	Motion	projectPkNext
time	0.139	0.665	0.60	0.29
Mapping	featurePointExtraction	Correspondence	Motion	
time	0.179	0.465	0.463	

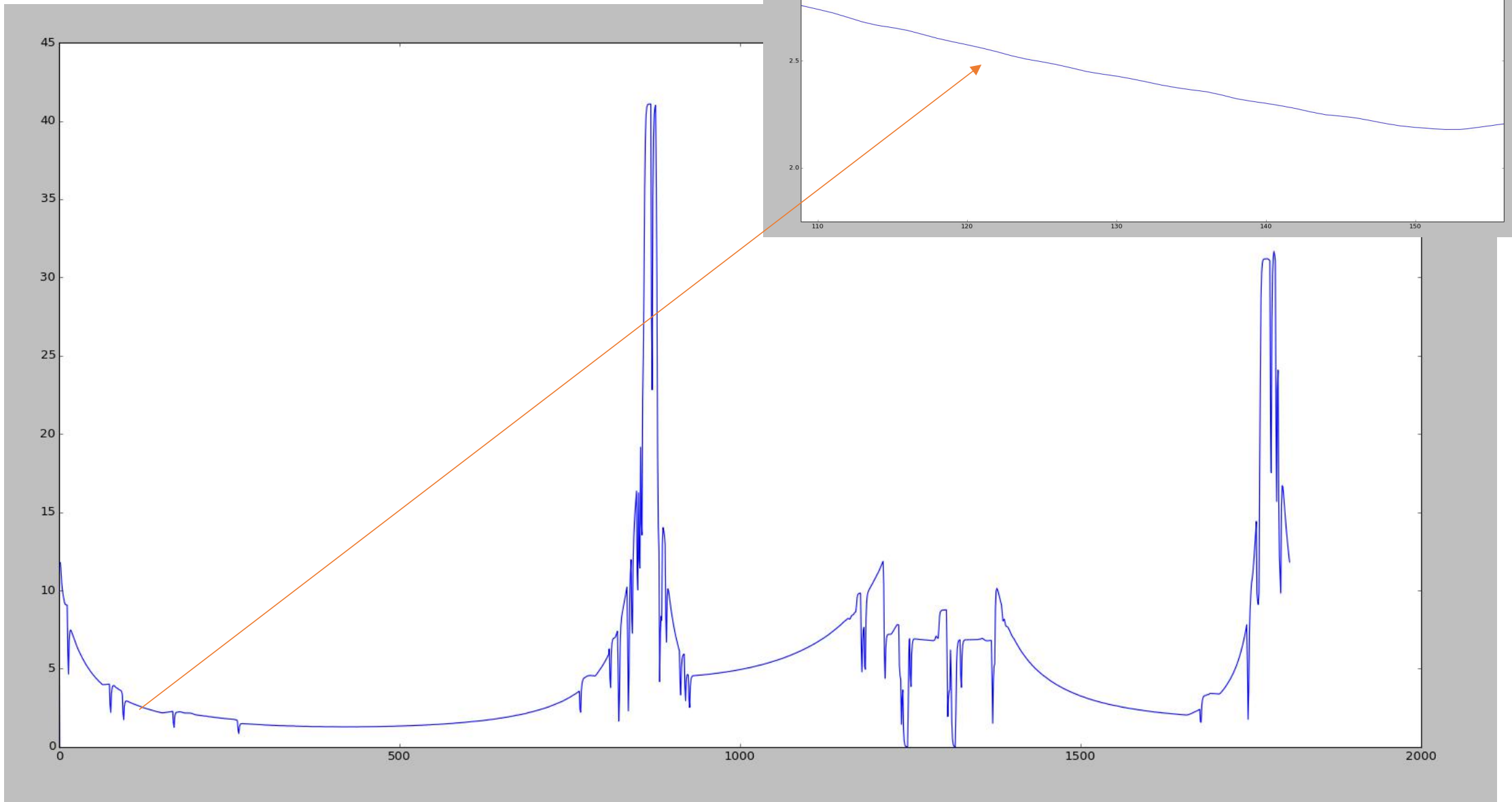
Error

featureSelect(edge,plane)(cm)	2,4	2,4	4,8	1,2	4,8	8,16	2,4	2,4	2,4	2,4	2,4	2,4	2,4
Mapping_featurePointExtraction(edge,plane)	10,20	20,40	10,20	10,20	20,40	20,40	10,20	10,20	10,20	10,20	10,20	10,20	10,20
Mapping_searchRegion(cm)	15*15*15	15*15*15	15*15*15	15*15*15	15*15*15	15*15*15	12*12*12	18*18*18	21*21*21	24*24*24	27*27*27	27*27*27	27*27*27
downsize(cm)	3*3*3	3*3*3	3*3*3	3*3*3	3*3*3	3*3*3	3*3*3	3*3*3	3*3*3	3*3*3	3*3*3	4*4*4	5*5*5
frames	99	99	99	99	99	99	99	99	99	99	99	99	99
std_dis(cm)	120	120	120	120	120	120	120	120	120	120	120	120	120
Exp_dis(cm)	117.4	116.7	117.0	117.4	117.2	116.8	100.9	117.6	117.9	118.4	118.6	118.7	119.0
Error(%)	2.1	2.7	2.4	2.1	2.3	2.6	15.8	2.0	1.7	1.3	1.1	1.1	0.7
Time(s)	338	509	275	393	380	299	382	350	346	349	357	360	325

Features


45
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2.5
2.0
1.5
180
190
200
210
220
230
240
250

Smooth


45
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
3.0
2.5
2.0
110
120
130
140
150