Region-Growing Planar Segmentation for Robot Action Planning

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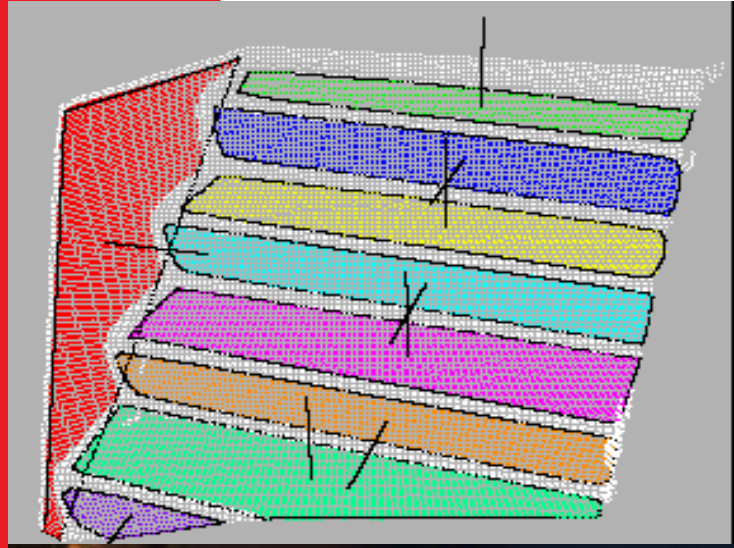
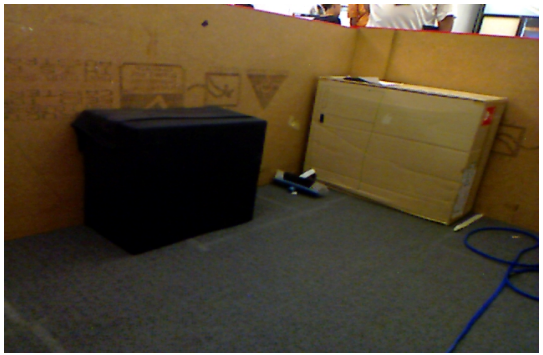


Overview

- Object Classification
- Robot Action Planning
- Use of Planar Segmentation
- RANSAC based methods
- Region-Growing method
  - Number of planes
  - Visual Quality
  - Quality of features
  - No need to define distance threshold

Generic Object Recognition

Training “Box”

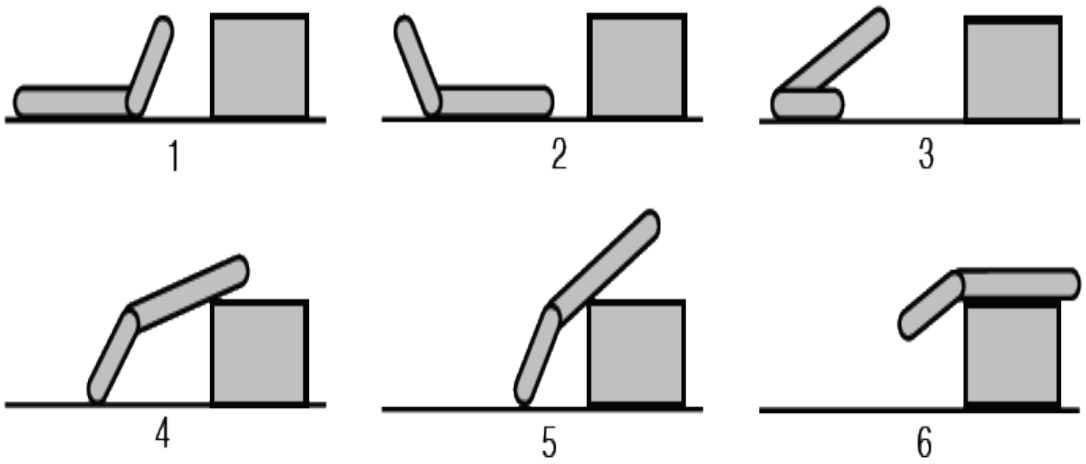


Generic Object Recognition

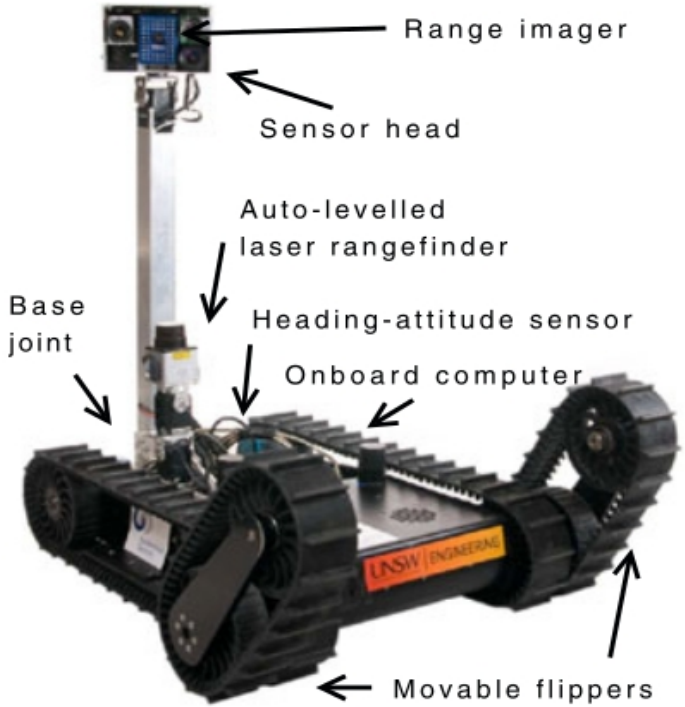
Recognition “Box”

Robot Action Planning

Robot climbing stairs



Platform

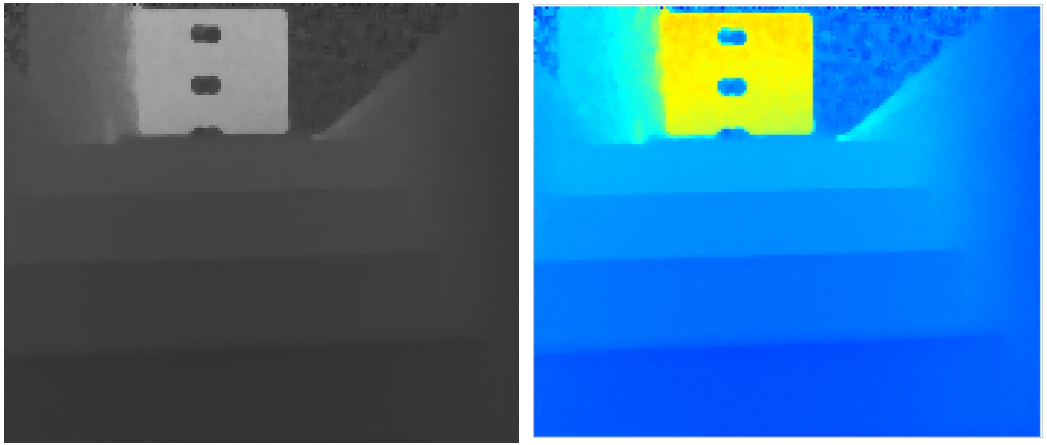

Range imager
Sensor head
Auto-levelled
laser rangefinder
Base
joint
Heading-attitude sensor
Onboard computer
Movable flippers


XBOX 360
KINECT

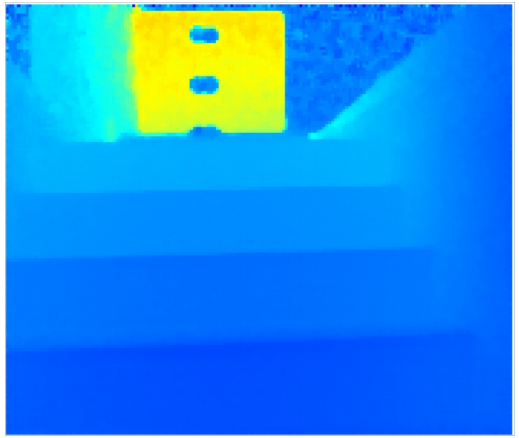

ASUS

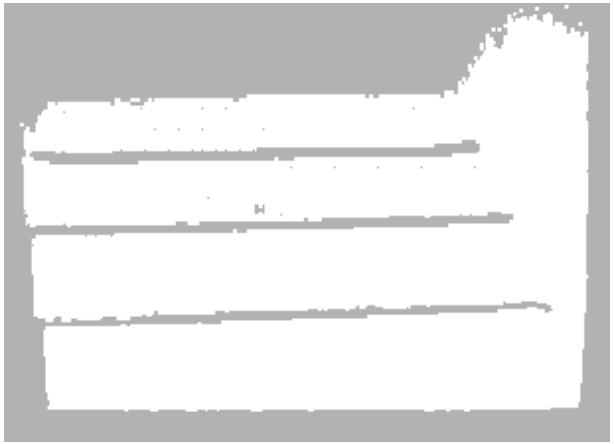
Range image and Point Cloud

Range image and Point Cloud

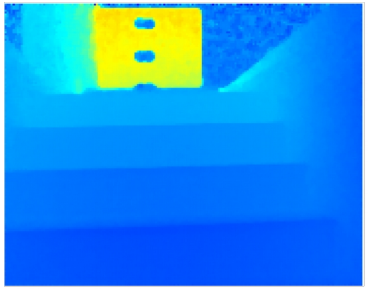


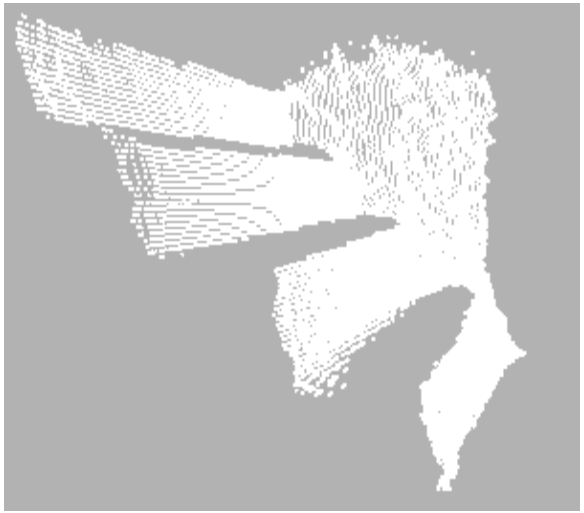
Range image and Point Cloud

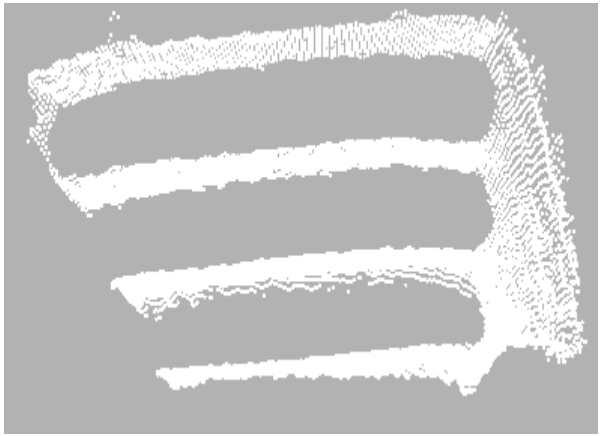




Range image and Point Cloud







Summary of our relational learning method

- **Segmentation**
  - Fit **planes** to surfaces
  - ... may also use other geometric objects
- **Feature extraction**
  - Extract features of **planes**
  - Find relations between **planes**
- **Training**
  - Label set of **planes** as belonging to an example of an object class
- **Learning Evaluation**
  - 10-fold cross validation

Evaluation

Results for 10-fold cross validation, some noise accepted

Object	No. positive	No. negative	Accuracy	Precision	Recall
Step	197	718	95.63	89.05	90.86
Staircase	237	656	99.33	98.33	99.16
Wall	105	803	97.58	87.39	92.38
Box	143	771	95.84	85.23	88.81
Pitch/roll ramp	131	201	97.89	95.59	99.24
mean ± std. (percentage)			97.25 ± 1.54	91.12 ± 5.59	94.09 ± 4.83

(Farid and Sammut, 2014)

Object Classification Steps

- **Segmentation**
  - Fit primitives **(**such as **planes)** to surfaces
- **Planar Segmentation**
  - Useful features in built environment including urban search and rescue
- **Modelling a scene by planar patches**
  - Computer Vision
  - Robotics
  - Augmented reality
  - ...

Region-Growing Planar Segmentation

- All points belonging to the same plane are supposed to have **approximately** the same normal vector
  - Algorithm: http://rfarid.altervista.org/ocrl/alg/alg_planar_segmentation.html
- Starting from a point
- Traverse the neighbours
- Check if a neighbour can be added to the current plane
- **Distance threshold** to accept a point as an adjacent neighbour
- **Angle threshold** to add a point to the current plan
- Minimum Region Size

Experimental Evaluation

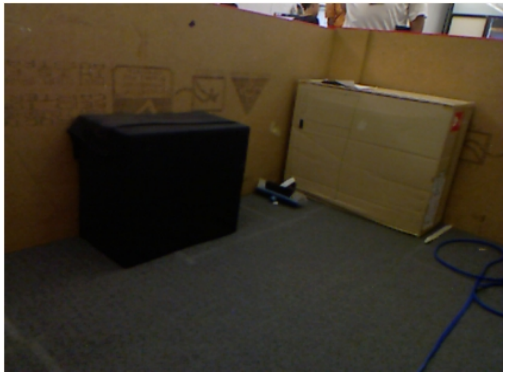
- **Comparing with PCL RANSAC methods**
  - SP: using points without normals
  - SNP: using normals and angle threshold

Experimental Evaluation

- **Dataset**
  - captured data during RoboCup Rescue competitions
  - from rescue laboratories and
  - other indoor locations.
  - URL: http://rfarid.altervista.org/plane_seg_compare/index.html
  - In this paper, we use a subset (**45 images**) of such data which we used for learning classes as:
    - **box** (12 images),
    - **stairs** (15 images) and
    - **pitch/roll ramp** in a maze(18 images).

Experimental Evaluation - Dataset

RGB images are shown instead of Range Images here.



Experimental Evaluation - Dataset

RGB images are shown instead of Range Images here.



Experimental Evaluation - Dataset

RGB images are shown instead of Range Images here.



Evaluating SP

Table 1: Total and average number of planes using SP

	Sum				Average			
	Distance Threshold				Distance Threshold			
Class	**0.005**	**0.01**	**0.03**	**0.05**	**0.005**	**0.01**	**0.03**	**0.05**
box	182	108	67	60	15.17	9	5.58	5
pitch/roll ramp	493	281	144	116	27.39	15.61	8	6.44
stairs	329	226	124	84	21.93	15.07	8.27	5.6
Total	1004	615	335	260				

The number of planes is closer and more **reliable** using distance thresholds **0.03** and **0.05**

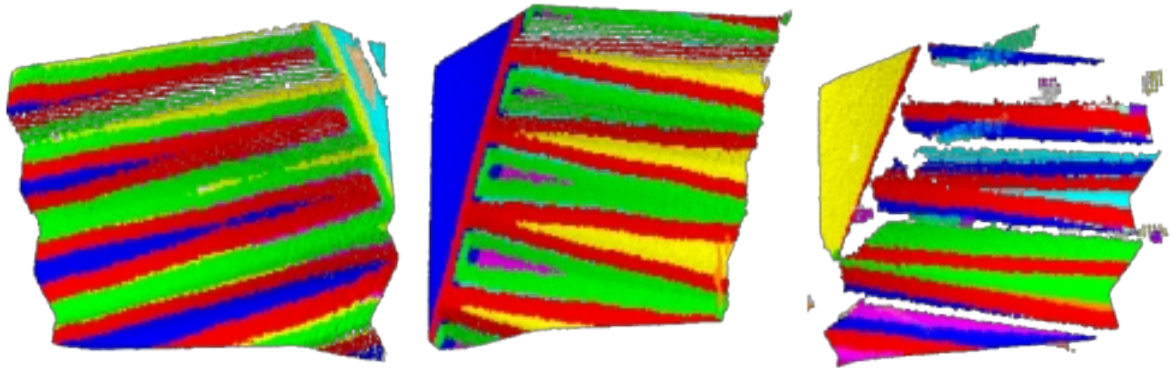
Evaluating SP-Visual Quality

Table 2: Distribution of segmentation quality using SP

Distance Threshold	Segmentation quality level			
	H	**MH**	**ML**	**L**
0.005	2.22%	11.11%	8.89%	77.78%
0.01	11.11%	6.67%	53.33%	28.89%
0.03	0.00%	33.33%	62.22%	4.44%
0.05	0.00%	24.44%	71.11%	4.44%

Using threshold as 0.03 and 0.05 produces results with the **mid to low** and **mid to high** level of segmentation quality.

Evaluating SP



Example of SP segmentation result for *stairs* using dis. thr. as 0.03

Evaluating SNP

Table 4: Total and average number of planes using SNP

	Sum			Average		
	Distance Threshold					
Class	**0.01**	**0.03**	**0.05**	**0.01**	**0.03**	**0.05**
box	235	98	89	19.58	8.17	7.42
pitch/roll ramp	456	269	177	25.33	14.94	9.83
stairs	174	205	191	12.43	13.67	12.73
Total	865	572	457	19.22	12.71	10.16

The number of planes is closer and more **reliable** using distance thresholds **0.03** and **0.05**

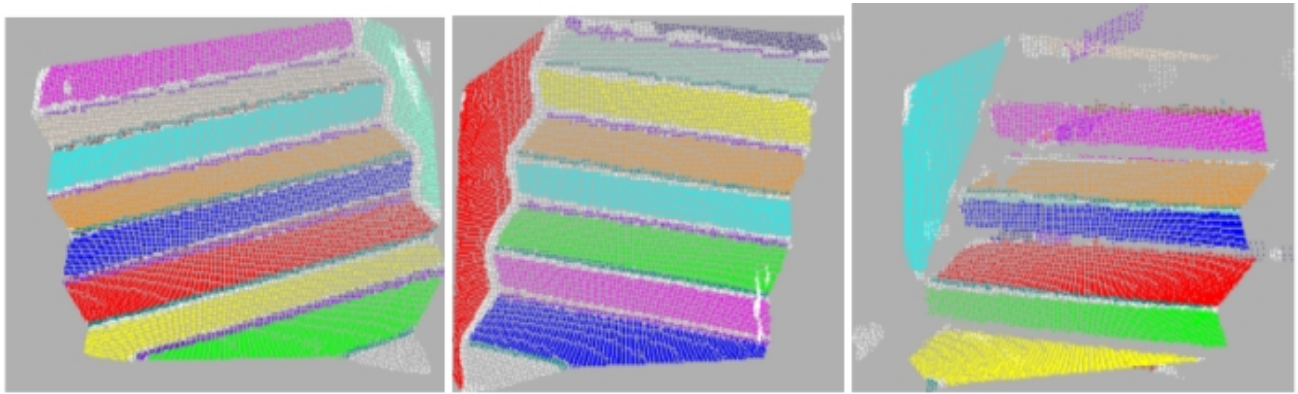
Evaluating SNP- Visual Quality

Table 5: Distribution of segmentation quality using SNP

Distance Threshold	Segmentation quality level			
	H	**MH**	**ML**	**L**
0.01	0.0%	0.0%	2.2%	97.8%
0.03	0.0%	51.1%	48.9%	0.00%
0.05	4.4%	80.0%	15.6%	0.00%

Using threshold as 0.05 produces more **mid to high** quality segmentation.

Evaluating SNP



Example of SNP segmentation result for *stairs* using dis. thr. as 0.05

SNP outperforms SP

We compare Our method with SNP only

Comparing SNP and our method

- **Distance threshold=0.05**
- **Considering Average Number of planes:**
  - SNP: 10.16
  - Our Method: **9.44**

Comparing SNP and our method

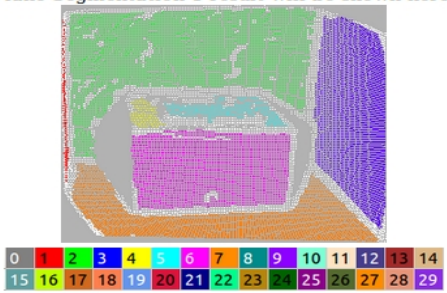
- **Visual Quality with comparing to human manual segmentation**
  - **Approach 1**: We split score 100 between the result of each method on the same data
    - SNP: **47.51** on average
    - Our Method: **52.49**
  - **Approach 2**: We asked some participants to do that based on their expectation of **human manual segmentation**
    - Using a Web GUI
    - URL: http://rfarid.altervista.org/plane_seg_compare/comp.html
    - The participant does not know which result belongs to which method

Comparing SNP and our method

Image# 001 of 45

RGB version
RGB image will be shown here.

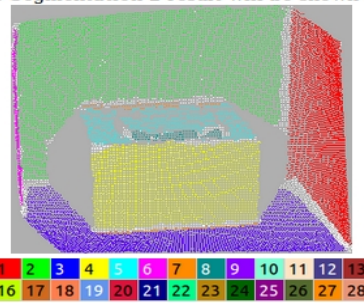
Plane Segmentation 1
Plane Segmentation 1 result will be shown here.



0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

Number of Segments: 7

Plane Segmentation 2
Plane Segmentation 2 result will be shown here.



0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

Number of Segments: 8

Considering the RGB version and the number of segments,
split the score 100
between **Plane** Segmentations 1 and 2 results.
(For example, if you score 45 for the Segmentation 1,
it means the Segmentation 2 will be scored 55.)
Press Next when done.

Each region is represented by a different colour.

The score share for Plane Segmentation 1: 50

Back Next

URL: http://rfarid.altervista.org/plane_seg_compare/comp.html

Comparing SNP and our method

- **Visual Quality with comparing to human manual segmentation**
  - **Approach 1**: We split score 100 between the result of each method on the same data
    - SNP: **47.51** on average
    - Our Method: **52.49**
  - **Approach 2**: We asked some participants to do that based on their expectation of **human manual segmentation**
    - Using a Web GUI
    - The participant does not know which result belongs to which method
    - SNP: **46.86** on average
    - Our method: **53.14** on average

Comparing SNP and our method

- **Comparison based on the quality of the features**
  - the result of segmentation can be passed to a robot as **features** for **action planning**
  - it is important to evaluate the **correctness** of these features
  - **visual** comparison does not evaluate this
  - a plane can be represented by a **point** belonging to the plane, its **normal** vector and its **boundaries**.
  - the boundary can be represented by a **convex hull**

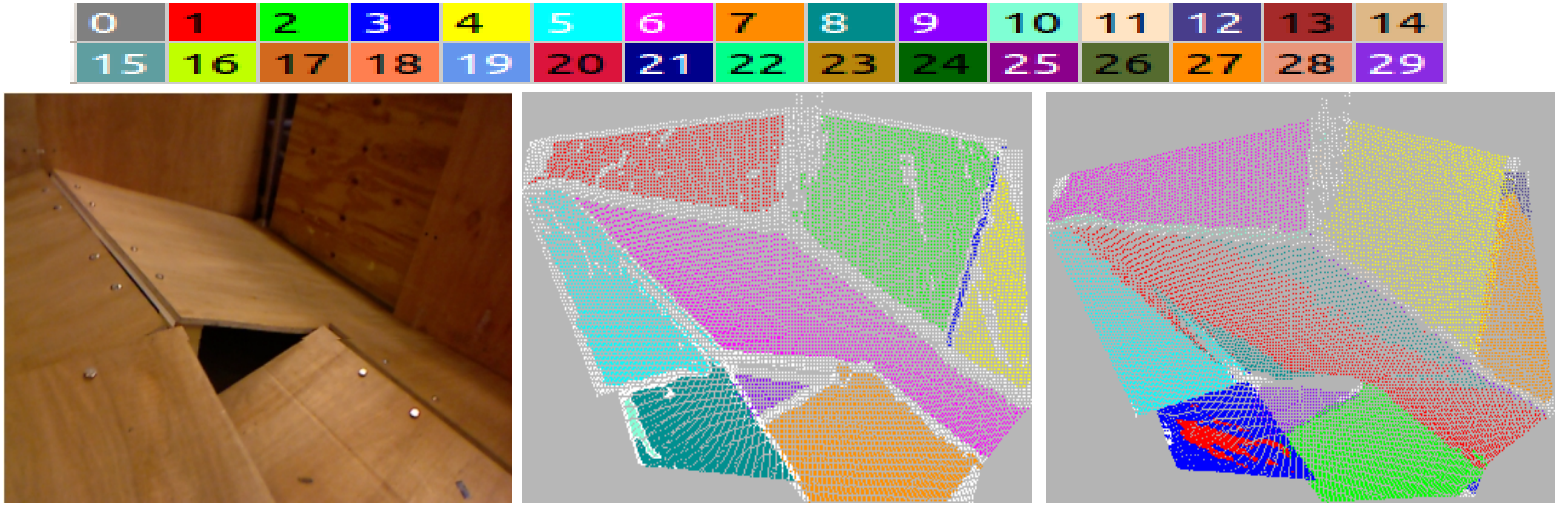
Comparing SNP and our method

- **Comparison based on the quality of the features**
  - **SNP** uses **RANSAC** and produces planes that cover many **sparse** points, which means
  - two set of points, which are very far from each other, are put together in the same plane, while **there is no such planar surface in the reality**.
  - These virtual planes can interfere with robot action planning
  - since there is no planar surface where the robot expects one based on the features provided.

Comparing SNP and our method

RGB version, Segmentation result for Our method (Left) and SNP(Right)

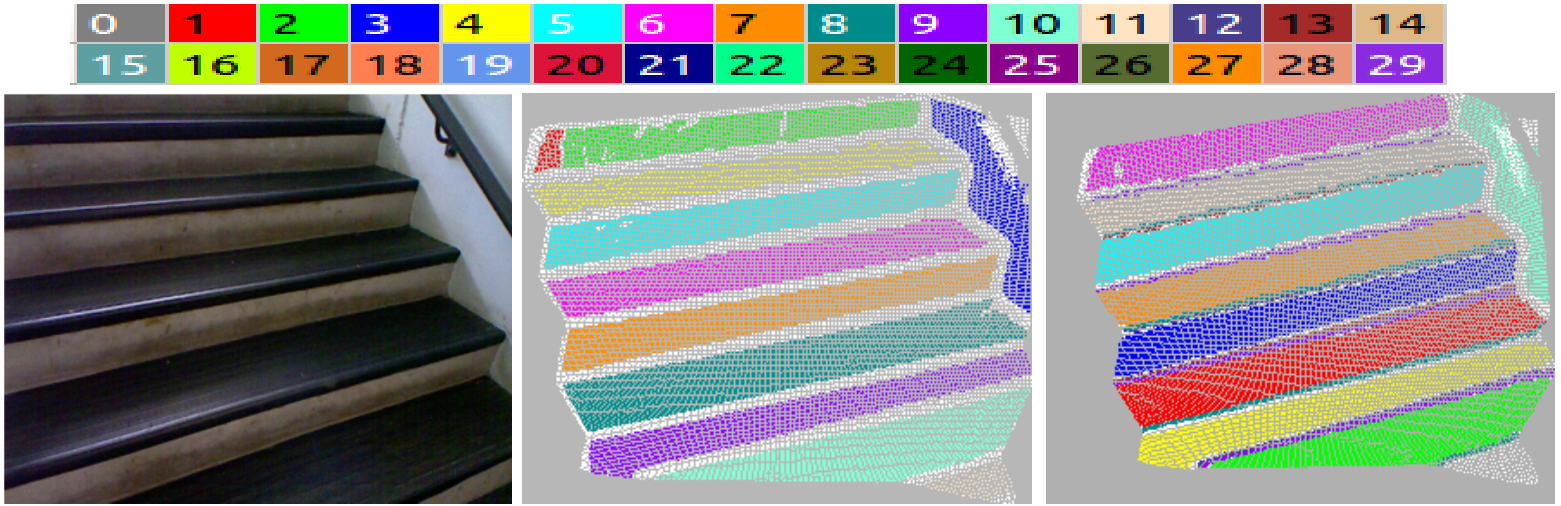
Regions 1,3,8,9 and 10 of SNP are sparse and corresponding features are problematic.



Comparing SNP and our method

RGB version, Segmentation result for Our method (Left) and SNP(Right)

Regions 8,9,12, and 13 of SNP are putting edges together



Comparing SNP and our method

- **96** planes of total **457** planes for **45** images had this sparse issue due to SNP segmentation.
- That is, there is an average of **2.13** planes per image affected by this issue.

- SP and SNP are sensitive to **Distance threshold**
- They do not provide a systematic way to set this threshold.

Table 7: Distribution of sparse planes using SNP (distance threshold=0.05)

Number of Sparse Planes	Frequency
0	**5**
1	**13**
2	**9**
3	**9**
4	**7**
5	**2**

Conclusion

- Object Classification
- Robot Action Planning
- Use of Planar Segmentation
- RANSAC based methods
- Region-Growing method
  - Number of planes
  - Visual Quality
  - Quality of features
  - No need to define distance threshold

?