Plane-based Object Categorization using Relational Learning

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Never Stand Still

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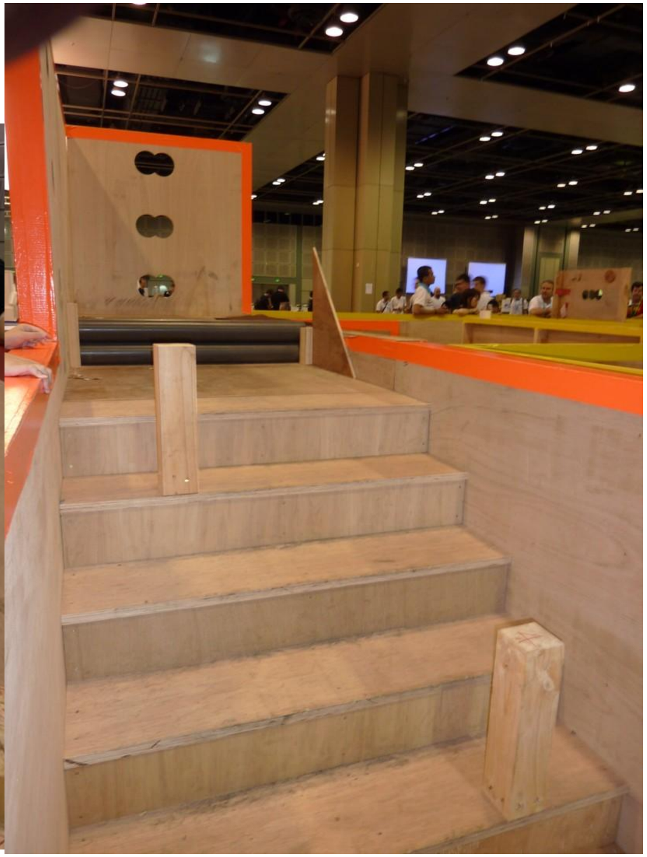
Urban Search and Rescue

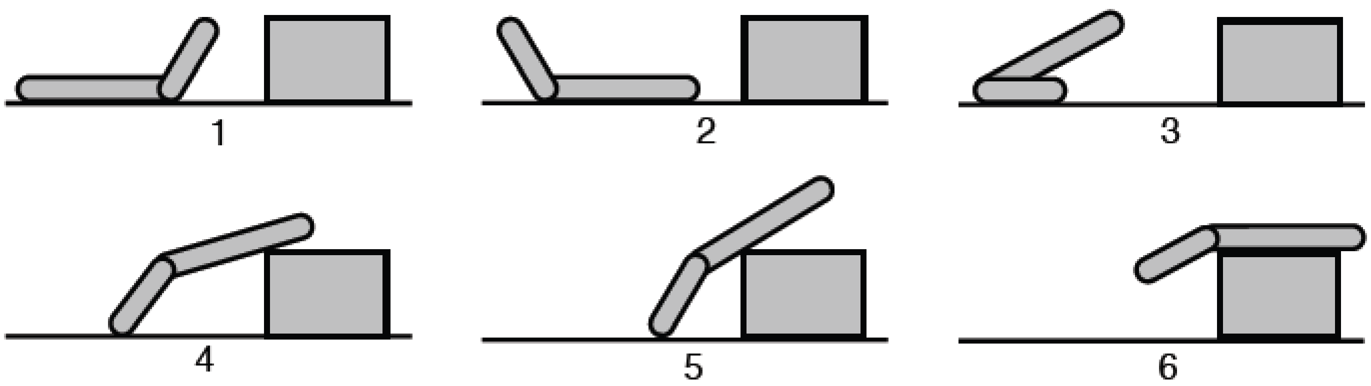
Rescue arena



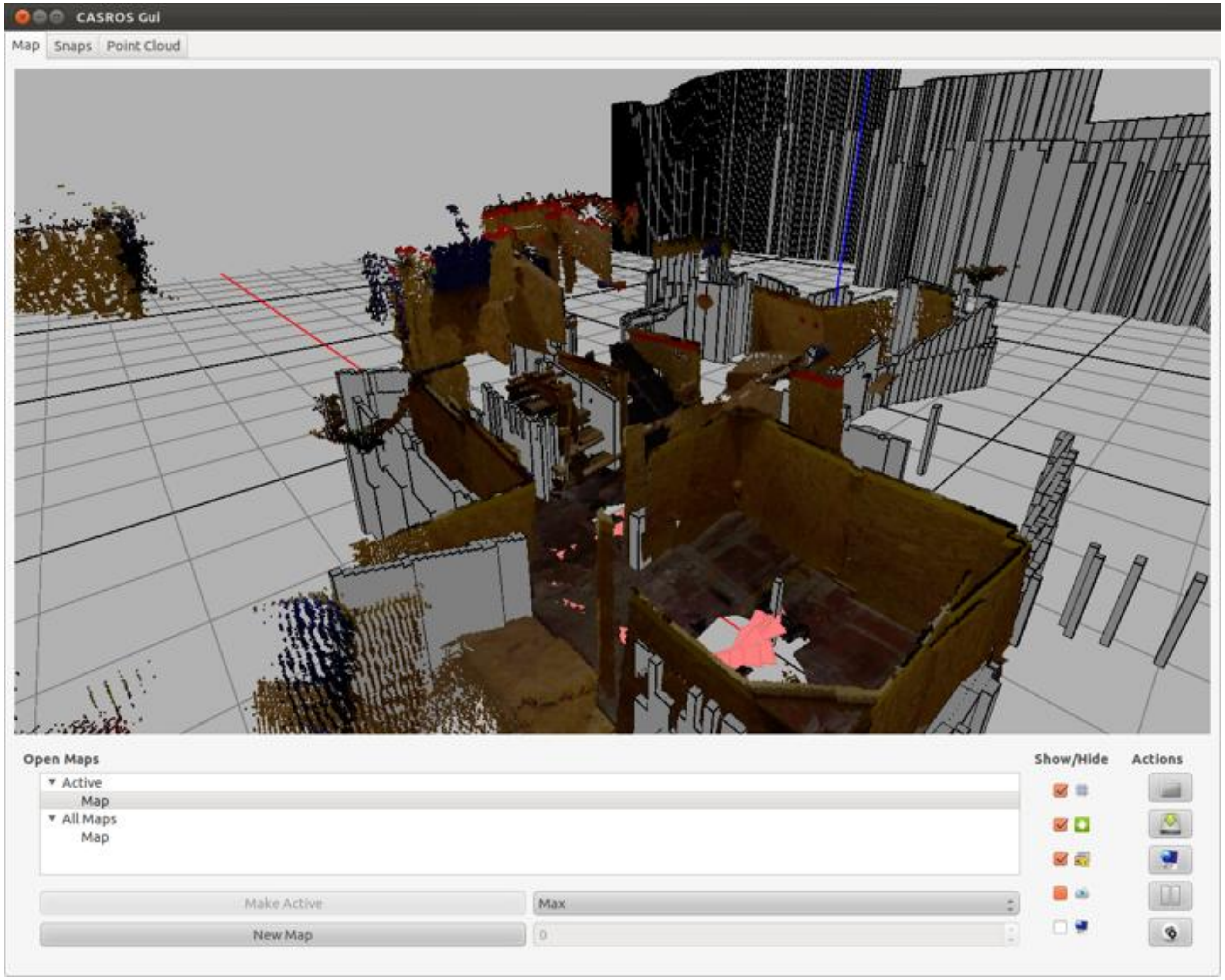
Rescue arena

Related work

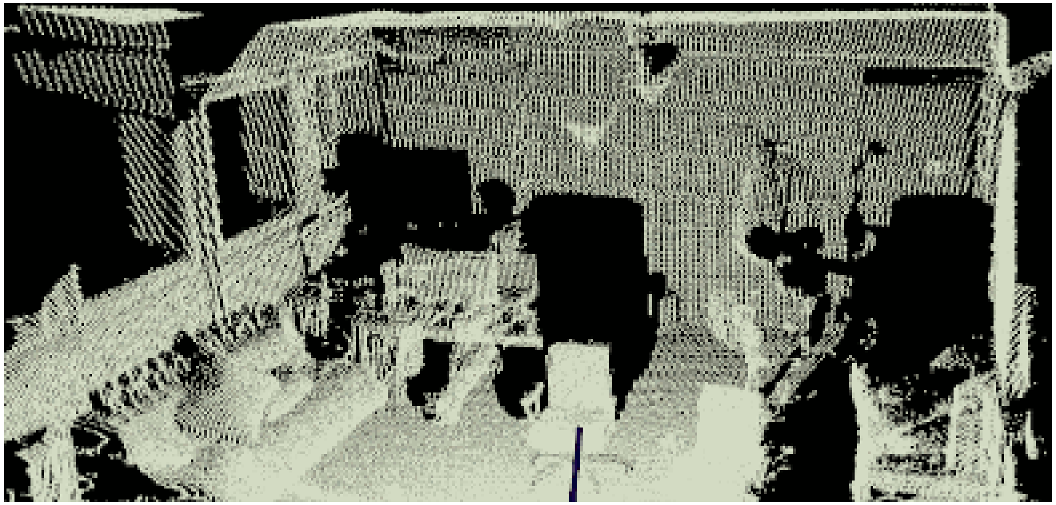
- **Shanahan 2002,2004**
  - Using a logic program as a relational representation for 3D objects in 2D line drawings
  - Using abduction for object recognition
- **Bo et.al 2011**
  - Local features



Explore, map and find victims



How does the world look like?



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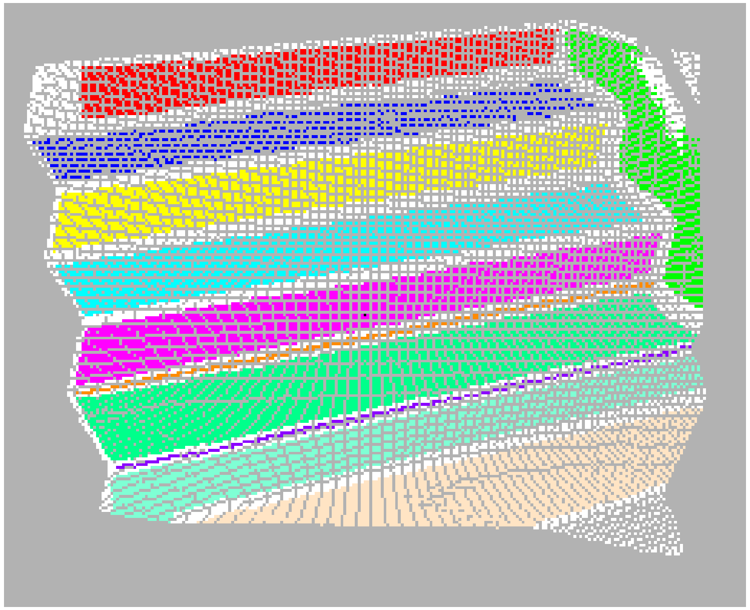
Summary

- **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

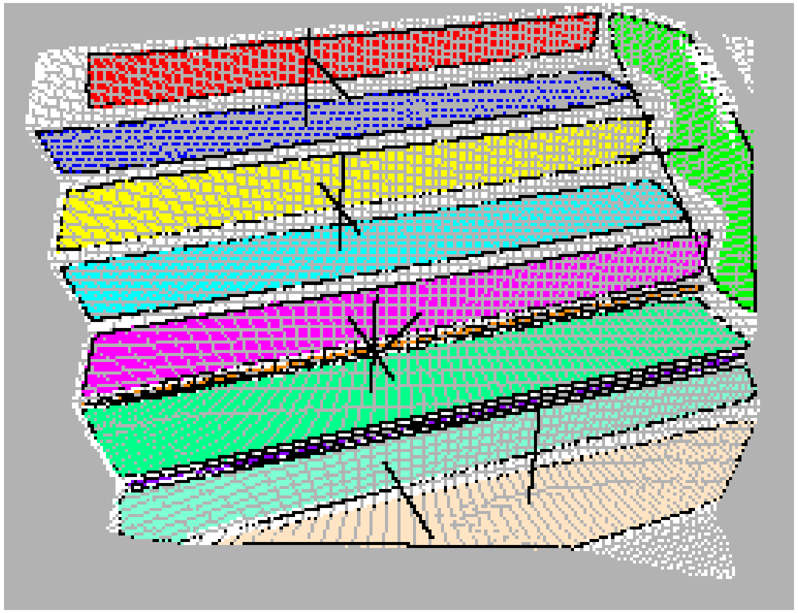
Segmentation

- Point cloud segmentation
- Using Planes as Primitives



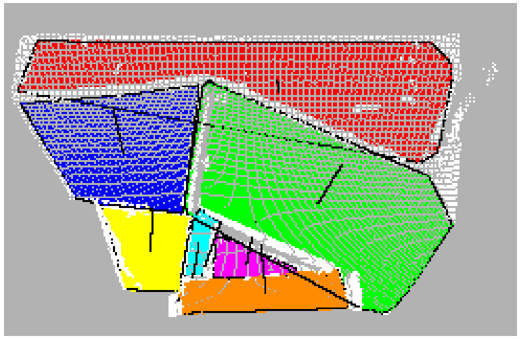
Segmentation

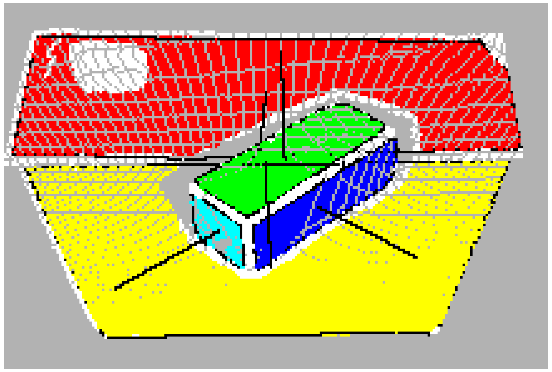
- Point cloud segmentation
- Using Planes as Primitives
- Represent each region’s boundary by a convex hull
- Using Plane’s normal vector for orientation



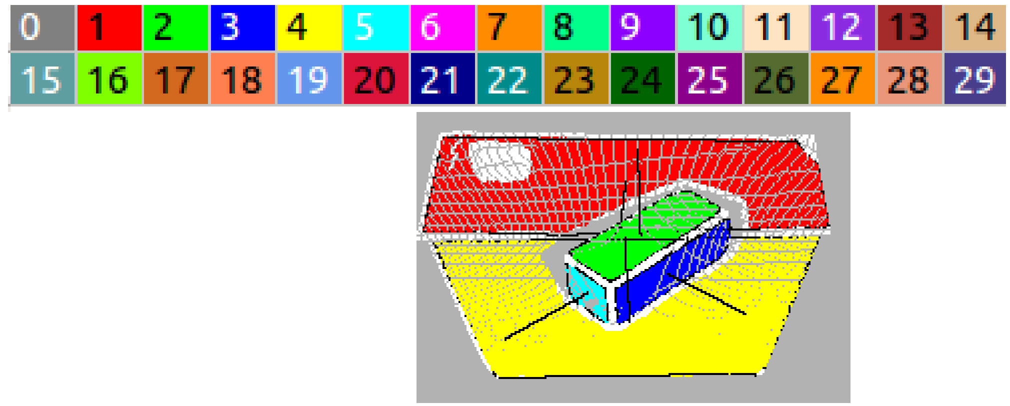
Segmentation

- More example



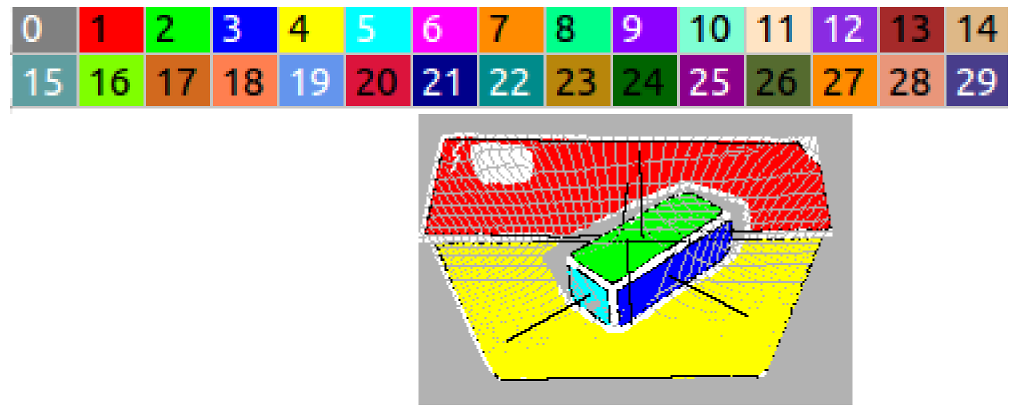


Feature extraction



- Two sets of features
  - Properties of individual planes
  - Relationships between pairs of planes
- Represented as PROLOG predicates

Feature extraction



plane(pl1). *plane(pl2).*

plane(pl3). *plane(pl4).* *plane(pl5).*

distributed_along(pl1,axisX). *distributed_along(pl2,axisX).*

distributed_along(pl3,axisX). *distributed_along(pl4,axisX).*

distributed_along(pl5,axisY).

Feature extractions

- **Convex Hull Ratio**

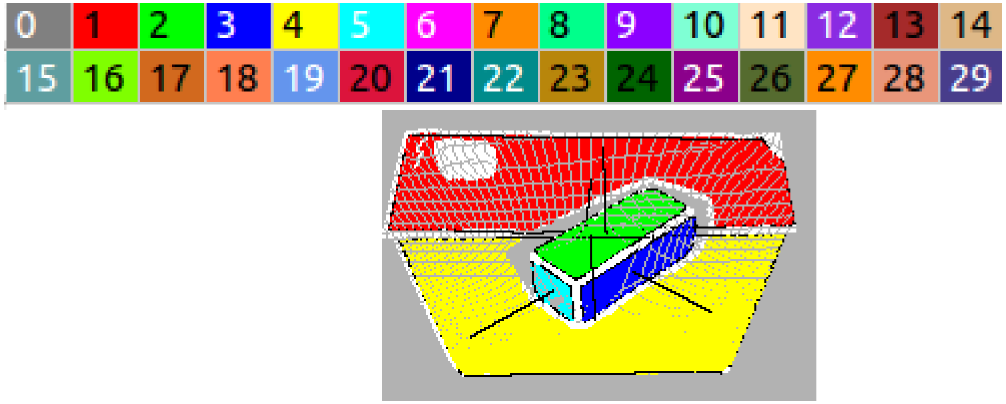
ch_ratio(pl1,'4.0±0.25').

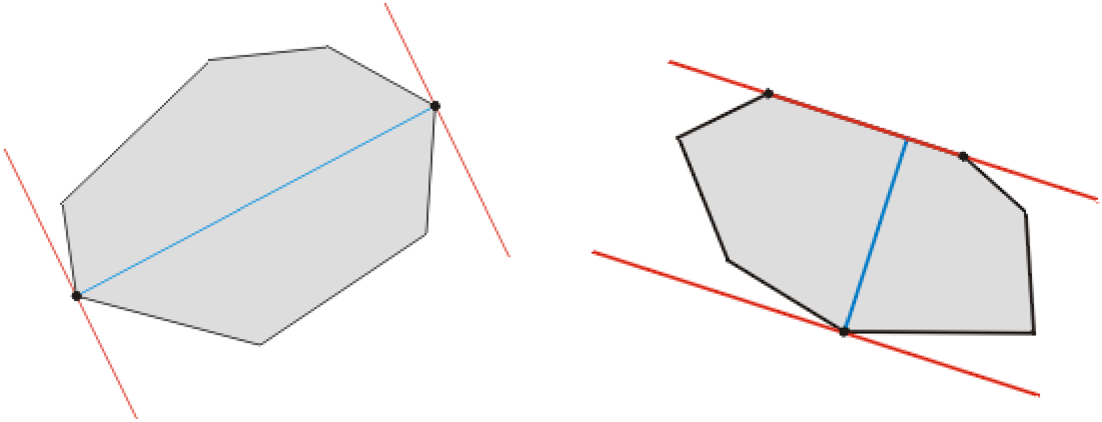
ch_ratio(pl2,'2.5±0.25').

ch_ratio(pl3,'3.5±0.25').

ch_ratio(pl4,'2.0±0.25').

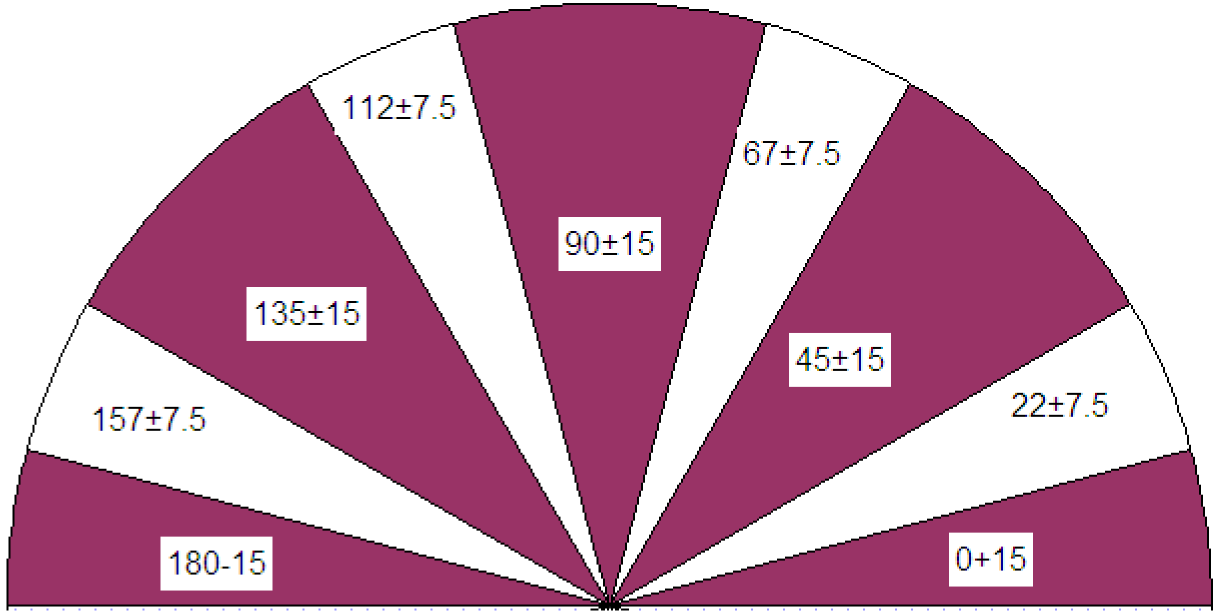
ch_ratio(pl5,'1.5±0.25').





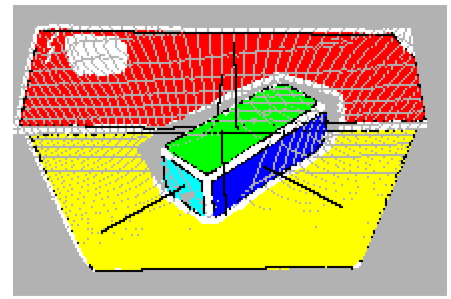
Binning

- Angle bins



Feature extraction

- **Region's normal vector in spherical coordinates**



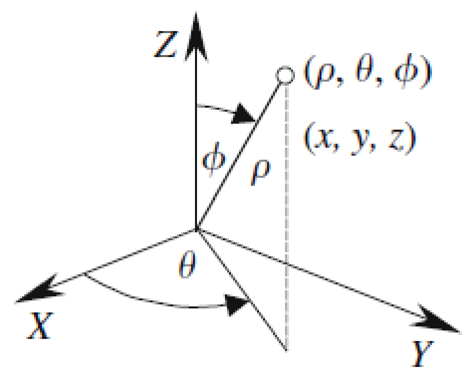
normal_spherical_theta(pl1,'-90±15').

normal_spherical_phi(pl1,'135±15').

…

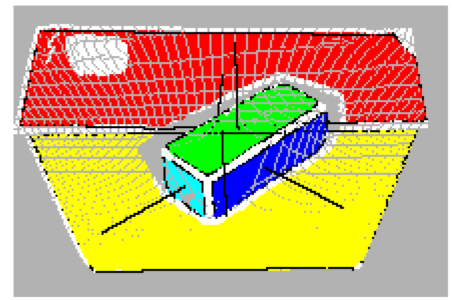
normal_spherical_theta(pl5,'-135±15').

normal_spherical_phi(pl5,'112±15').



Feature extraction

- **Angle between two regions**



angle(pl1,pl2,'90±15').
angle(pl1,pl3,'45±15').
angle(pl1,pl4,'90±15').
angle(pl1,pl5,'45±15').
angle(pl2,pl3,'90±15').
angle(pl2,pl4,'0±15').
angle(pl2,pl5,'90±15').
angle(pl3,pl4,'90±15').
angle(pl3,pl5,'90±15').
angle(pl4,pl5,'90±15').

Learning Object classes

- Object classes (positive/negative examples)
  - Step 199/731
  - Wall 105/819
  - Box 144/780
  - Pitch/roll ramp 131/205

- Training by labelling
  - **Segmented** point cloud as planes
  - User interface to group extracted planes into objects
  - Label each selected set as positive example of an object class and negative example for other object classes

  Example: Staircase 4 to 7 planes for each set

Learning Object classes

staircase([pl1,pl2,pl4,pl5]).

staircase([pl2,pl4,pl5,pl7]).

staircase([pl4,pl5,pl7,pl8]).

staircase([pl5,pl7,pl8,pl10]).

staircase([pl1,pl2,pl4,pl5,pl7]).

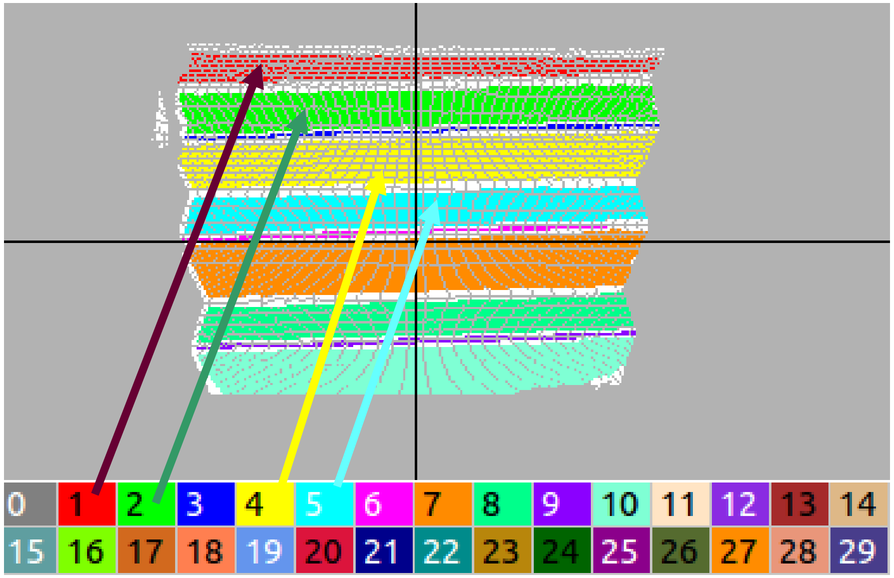
staircase([pl2,pl4,pl5,pl7,pl8]).

staircase([pl4,pl5,pl7,pl8,pl10]).

staircase([pl1,pl2,pl4,pl5,pl7,pl8]).

staircase([pl2,pl4,pl5,pl7,pl8,pl10]).

staircase([pl1,pl2,pl4,pl5,pl7,pl8,pl10]).



Learning Object classes

- Positive and negative example for each object class
- The result of labelling as PROLOG predicates
- Using **ALEPH** to construct one classifier for each type of object

Description of a Staircase

Staircase(PLANESET_B) :-
member(C, PLANESET_B),
member(D, PLANESET_B),
member(E, PLANESET_B),
angle(D, C, '0±15'),
angle(E, D, '90±15'),
angle(E, C, '90±15'),
distributed_along(E, axisX).

Staircase(PLANESET_B) :-
member(C, PLANESET_B),
member(D, PLANESET_B),
angle(D, C, '0±15'),
member(E, PLANESET_B),
member(F, PLANESET_B),
angle(F, D, '0±15'),
angle(F, C, '0±15'),
dr_xy(E, F, south).

Staircase(PLANESET_B) :-
n_of_parts(PLANESET_B, 4),
member(C, PLANESET_B),
distributed_along(C, axisX).

Cumulative Learning

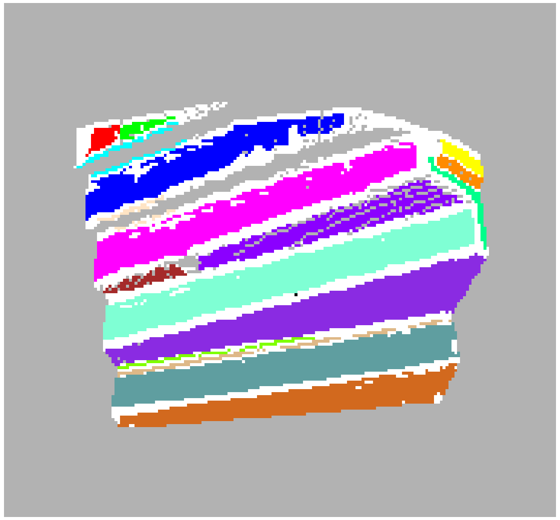
```
staircase(PlaneSet) :-
    member(C, PlaneSet),
    ratio_xz(C, '5.0±0.25'),
    subset(Set1, PlaneSet),
    subset(Set2, PlaneSet),
    step(Set1),
    step(Set2),
    intersect(Set1, Set2).
```

Evaluation

Table 1. Results for 10-fold cross validation

Object	No. positive	No. negative	Accuracy =(TP+TN)/N	Error rate =(FP+FN)/N	Precision =TP/(TP+FP)	Recall =TP/(TP+FN)
Step	199	731	0.9645	0.0355	0.9368	0.8945
Staircase	241	665	0.9956	0.0044	0.9917	0.9917
Wall	105	819	0.9881	0.0119	0.9608	0.9333
Box	144	780	0.9741	0.0259	0.9618	0.8690
Pitch/roll ramp	131	205	0.9464	0.0536	0.9520	0.9084

Evaluation on New data, New camera



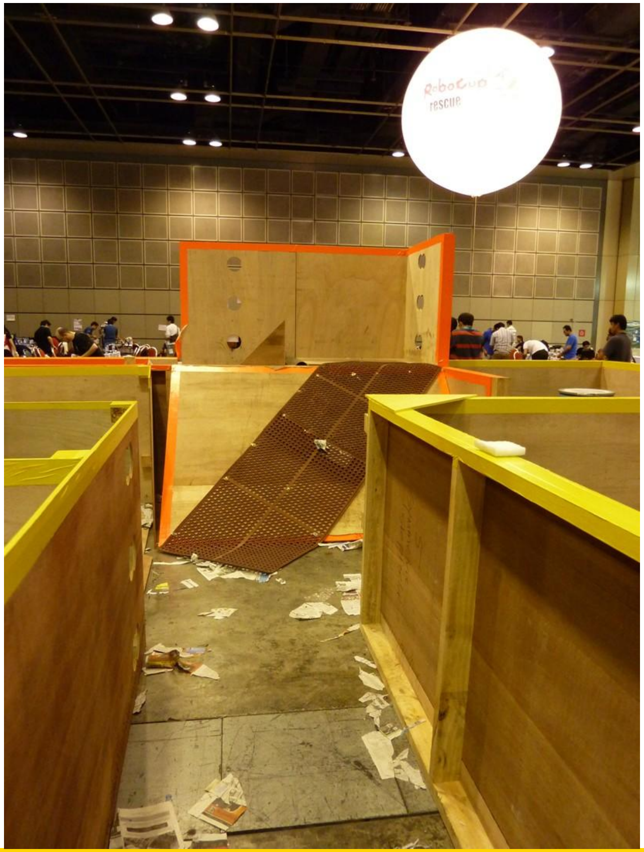
- Spiral stairs

  950 more positive example

  accuracy: 99% (sampled from one staircase over several floors)

Future Work

- Noise reduction for better segmentation
- Greater variety of objects like barrels and ramps
- Learning bins (angles bin and ratio bins)



Future Work

- Noise reduction for better segmentation
- Greater variety of objects like barrels and ramps
- Learning bins (angles bin and ratio bins)
- more primitive especially for non-flat surfaces
- Unsupervised learning

Questions

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