

Estimation of Planar Surfaces in Noisy Range Images for the RoboCup Rescue Competition

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Goal: RoboCup

RoboCup Rescue

3D Polygon Extraction

3D sensors

Determine countour points in 2D

Determine 3D polygons in 2D

Remove spikes

Joining of Polygons

Why and when?

Determine the confidence value

Attract the target plane

Turn of target plane

Intersect two planes

Experiments and Results

Experiments and Results

Conclusion



RoboCup Rescue (Real Robot League)

RoboCup: More than "just" soccer!

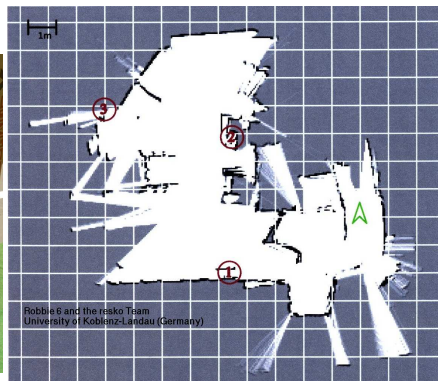


Scenario of RoboCup Rescue:

- ▶ A building has collapsed: Are there victims in the building, and if so, where are they?
- ▶ **The robot generates a map of the building. . .**
- ▶ **and maps the positions of found victims.**
- ▶ Research topics: Mapping, localisation, SLAM, autonomy.

RoboCup Rescue (Real Robot League)

New in 2006: Ramps and victims on several levels



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Laser range camera



Figure: Manufacturer: Daimler-Benz Aerospace

3D laser range finder



Figure: 3D scanner (rotating 2D Hokuyo laser range finder)

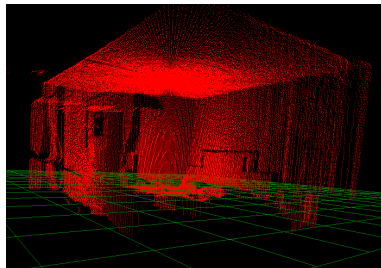


Figure: 3D scan

Overview of the method

1. **Detect puzzle pieces: Extract 3D boundary**
 - ▶ Determine countour points in 2D region image
 - ▶ Determine 3D polygons using Incremental Line Fitting in 2D
 - ▶ Remove spikes
2. Adjust puzzle pieces: Join polygons

2D boundary extraction

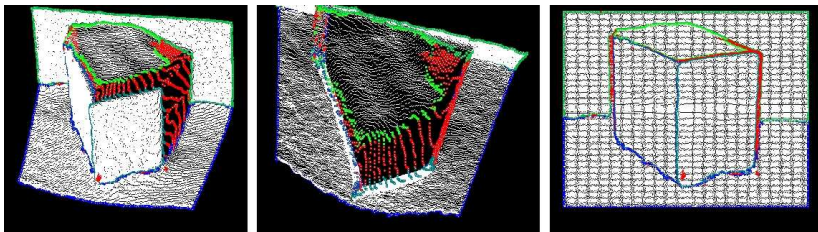


Figure: Outliers and contours

Precondition: Segmented planes – most pixels are assigned to a plane

- ▶ Many outliers that are not assigned to any region (red dots)
- ▶ 3D contour has a fuzzy border: Hard to find lines
- ▶ Solution: orthographic projection of the contour (xy -plane)

Incremental Line Fitting

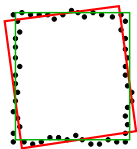


Figure: Incr. line fitting

- ▶ Consecutively add points to a line hypothesis
 - ▶ Calculate the fitting error
 - ▶ If the error gets too high: Start a new line segment
 - ▶ Problem: Resulting polygon is skewed (red square)
-
- ▶ Solution: Remove the last point *and* other recently added points that increased the error significantly (green square)
 - ▶ Cut lines at intersections
 - ▶ Calculate 3D endpoints using the parameters of the plane and the 2D points

Remove spikes

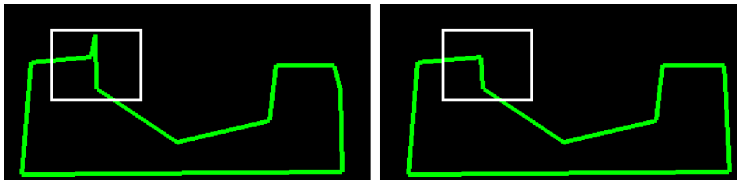


Figure: Spikes

- ▶ Subsequent 3D-lines nearly parallel: intersection located outside the polygon
- ▶ Two lines that enclose an angle smaller than a threshold: merged

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Overview of the method

1. Detect puzzle pieces: Extract 3D boundary
2. **Adjust puzzle pieces: Join polygons**
 - ▶ Determine which plane has a high confidence value
 - ▶ Attract other planes (move, turn and endpoint substitution)
 - ▶ Turn other planes (turn and endpoint substitution)
 - ▶ Intersect two planes

Adjust puzzle pieces: Why?

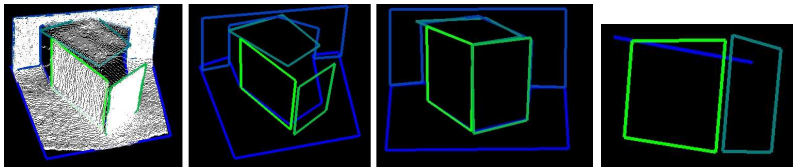


Figure: Result of line fitting: Original range data, extracted polygons, orthographic projection, incoherent polygons of the box

- ▶ The extracted polygons don't have the original shape
- ▶ The position of the polygons has changed
- ▶ Simple intersection of planes would distort the the shape

Adjust puzzle pieces: When?

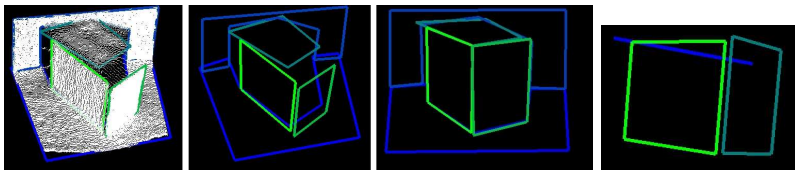


Figure: Result of line fitting: Original range data, extracted polygons, orthographic projection, incoherent polygons of the box

- ▶ The 2D edges are nearly parallel
- ▶ The midpoints of the 2D edges are near
- ▶ The 2D edges have nearly equal length
- ▶ The 3D edges are nearly parallel

Determine the confidence value

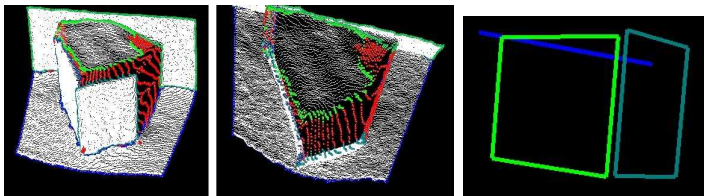


Figure: Sparse range data on the top of the box

- ▶ Problem: Planes whose normal encloses a large angle with the optical axis of the camera: sparse range data
- ▶ Result: Erroneous orientation of the fitted plane
- ▶ Idea: Adapt the orientation of such planes
- ▶ High conf. → "Winner plane". Low conf. → "Target plane"
- ▶ Planes with high confidence force planes with lower confidence to move

Attract the target plane

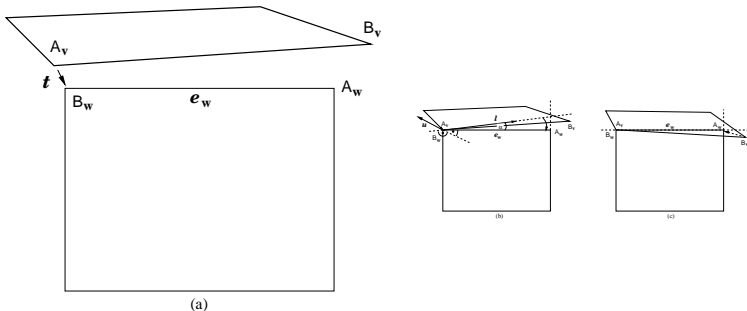


Figure: Attracting the target plane: Translation

- Step 1: Translation of the target plane towards the winner plane

Attract the target plane

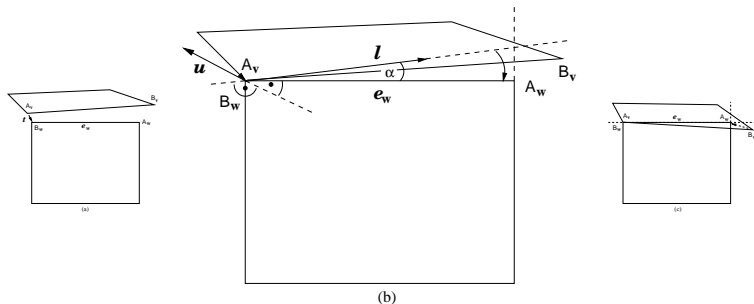


Figure: Attracting the target plane: Rotation

- Step 2: Rotation of the target plane onto winner edge

Attract the target plane

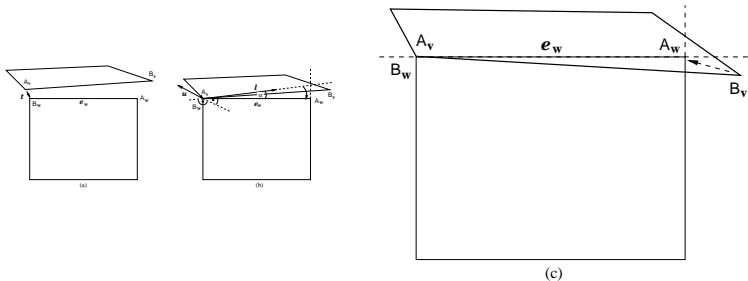


Figure: Attracting the target plane: Endpoint correction

- ▶ Step 3: Substitution of the endpoint of the target edge by the endpoint of the winner edge
- ▶ Label target plane as "joined"

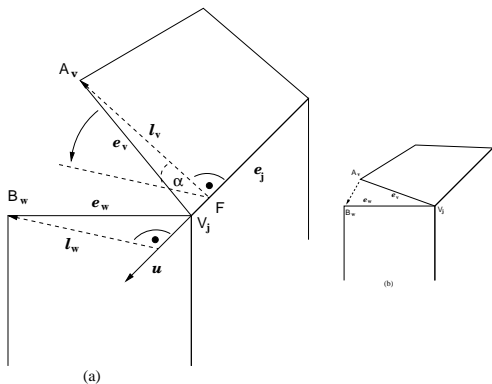


Figure: Turning of target polygon around the joined edge e_j

- Step 1: Turning of the target polygon onto the winner edge

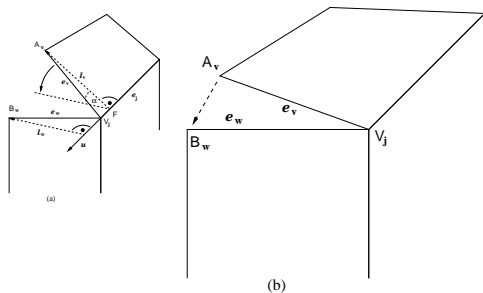


Figure: Endpoint adjustment

- ▶ Step 2: Substitution of the free endpoint of the target edge
- ▶ Label the target plane as "fixed"

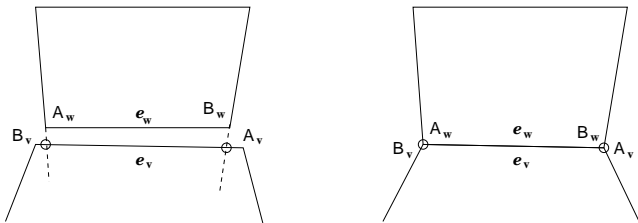


Figure: Intersection of two planes

- ▶ Determine the intersection of both planes
- ▶ Line segment: Check where the pervious/next edge intersects the other plane
- ▶ (Used if the target plane is "fixed")

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Results: Laser range camera /1

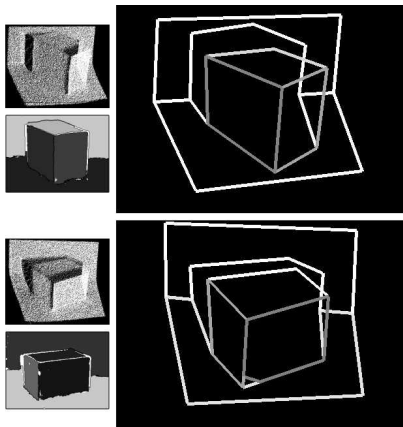


Figure: Example results

Results: Laser range camera /2

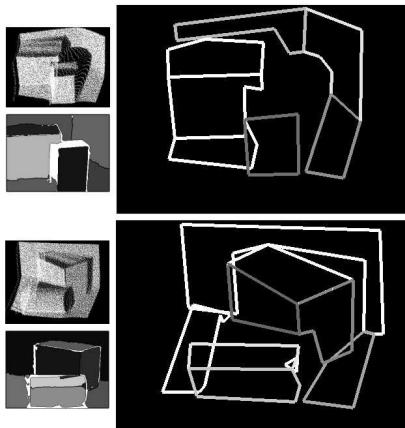


Figure: Example results

Results: Laser range camera /3

Image	Edges to join		Joined	
	before	after	correct	wrong
	polygon extraction			
p01	7	7	7	0
p02	4	4	4	0
p03	7	5	4	0
p04	7	7	5	0
p05	7	7	7	0
p06	2	2	2	0
p07	7	3	3	0
p08	8	4	4	0
m01	6	5	3	1
m02	6	6	3	0
m03	2	2	0	0
m04	9	6	6	0
m05	6	4	3	0
Total	78	62	52	1

Evaluation of joining of edges of polygons

Results: Laser range camera /4

Image	Number of orthogonal planes	Average angle between planes	Diff. to 90°
p01	7	86.94	3.06
p02	7	84.14	5.86
p03	7	83.99	6.01
p04	10	85.54	4.46
p05	7	85.47	4.53
p07	1	83.90	6.10
p08	5	83.32	6.68
m01	10	84.00	6.00
m02	7	83.49	6.51
m03	4	82.65	7.35
m04	3	87.27	2.73
Total	68	84.66	5.34

Evaluation of angles between orthogonal planes.
Angles are given in degree.

Results: 3D laser range finder

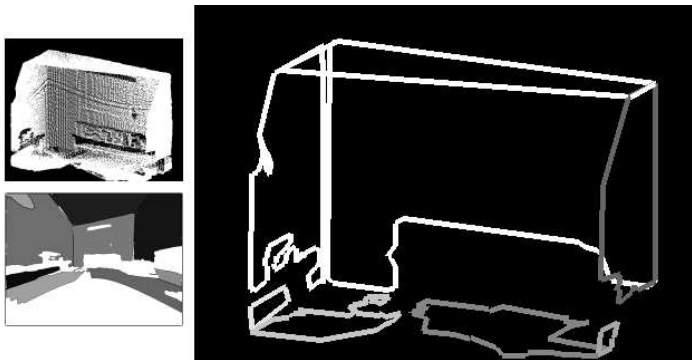
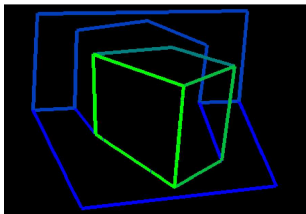


Figure: Pointcloud and segmented planes

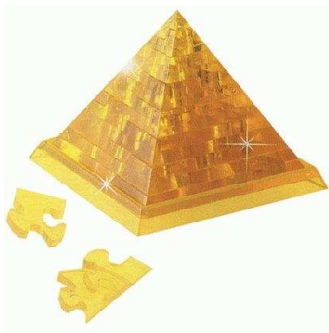
- ▶ Works also with our low-cost 3D laser range scanner

Conclusion



- ▶ Goal: Good maps for the RoboCup Rescue Competition
 - ▶ Method to **extract 3D polygons using the 2D xy-projection**
 - ▶ Determine which plane has a high **confidence value**
 - ▶ **Attract or turn other planes**
 - ▶ **Intersect** two planes
- ▶ Method works with laser camera and 3D laser range scanner
 - ▶ Next step: Interpret the planes and their topology

If you want to solve a 3D puzzle. . .



- ▶ start to sort out the pieces in 2D anyway :-)

Backup

Laser range finder URG-04LX



Figure: Manufacturer: Hokuyo

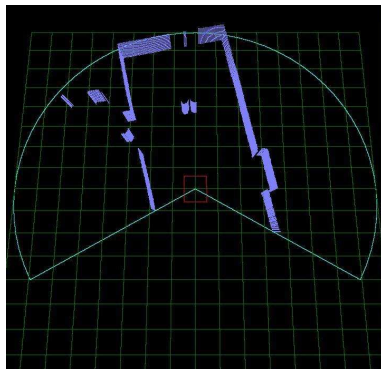


Figure: 2D scan

Goal of the RoboCup



- ▶ Challenge for robotics and AI
- ▶ Test bed for state of the art robot techniques
- ▶ Comparison and exchange of creative ideas
- ▶ Great for teaching (e.g. for programming projects)
- ▶ OK, and also its fun!

RoboCup leagues



Much more than "only" soccer:

- ▶ RoboCupSoccer (different sizes, simulation)
- ▶ **RoboCupRescue** (Robot, simulation)
- ▶ RoboCupJunior
- ▶ RoboCup@Home

RoboCup Rescue (Real Robot League)



"Rules":

- ▶ Remote control allowed
- ▶ Special competition for autonomous robots
- ▶ 20 minutes for each run
- ▶ Victims have to be marked by 1 meter accuracy in the map
- ▶ Extra points for reports about the state of the victim

RoboCup

Since 2006: Ramps



- ▶ New ramps have guardrails on the left and on the right side
- ▶ Distorted scans on the ramps
- ▶ For upright walls, the distortion is α : $dist_{new} = \frac{dist}{\cos(\alpha)}$
- ▶ Consequence: Risk of accident and bad maps
- ▶ Fast 2D range finder preferred in open space

Idea: Use low-cost 2D laser range finder and turn it if appropriate