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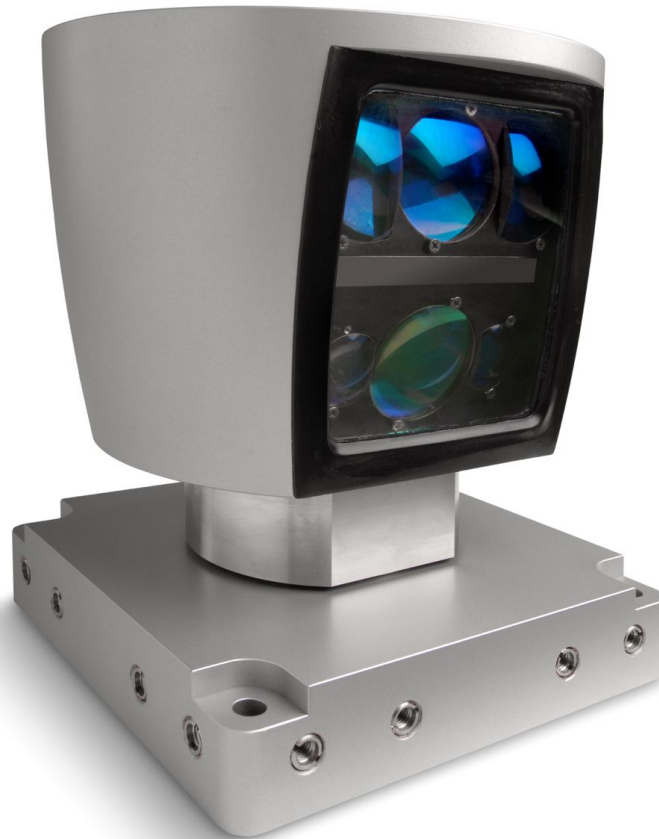
# Plane Detection in a 3D environment using a Velodyne Lidar

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# Velodyne Lidar Sensor





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# Velodyne

Used by CMU and Stanford in DARPA Urban Challenge races







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# Velodyne Technical Specifications

## ■ **Sensor**

- 64 lasers
- 360 degree field of view (azimuth)
- 0.09 degree angular resolution (azimuth)
- 26.8 degree vertical field of view (elevation)  $\pm 2^\circ$  up to  $-24.8^\circ$  down with 64 equally spaced angular subdivisions (approximately  $0.4^\circ$ )
- $<2$  cm distance accuracy
- 5-15 Hz field of view update (user selectable)
- 50 meter range for pavement ( $\sim 0.10$  reflectivity)
- 120 meter range for cars and foliage ( $\sim 0.80$  reflectivity)
- $>1.333$ M points per second
- $<0.05$  milliseconds latency

## ■ **Laser**

- Class 1 - eye safe
- 4 X 16 laser block assemblies
- 905 nm wavelenth
- 5 nanosecond pulse
- Adaptive power system for minimizing saturations and blinding

## ■ **Mechanical**

- 12V input (16V max) @ 4 amps
- $<29$  lbs.
- 10" tall cylinder of 8" OD diameter
- 300 RPM - 900 RPM spin rate (user selectable)

## ■ **Output**

- 100 Mbps UDP Ethernet packets

# Problem Statement & Motivation

- Computer vision has a tough time determining range in real time and gathering data in 360 degrees at high resolution
- There is a need to classify objects in the real world as more than just obstacles, but as roads, driving lanes, curbs, trees, buildings, cars, IEDs, etc.
- 3D laser range finding sensors such as the Velodyne provide 360 degree ranging data that can be used to classify objects in real time



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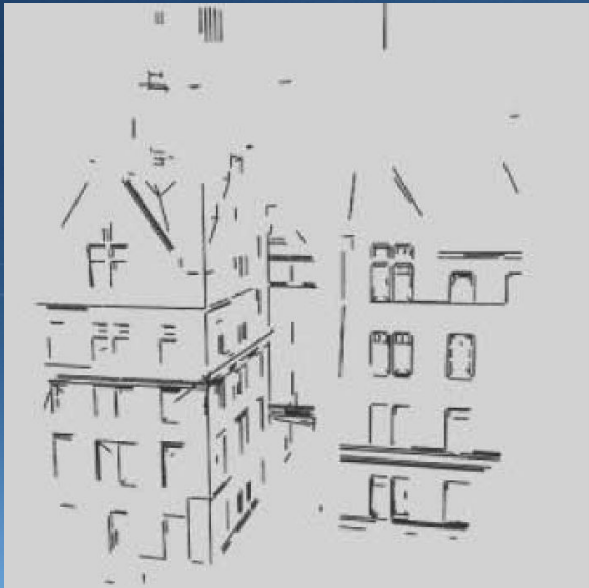
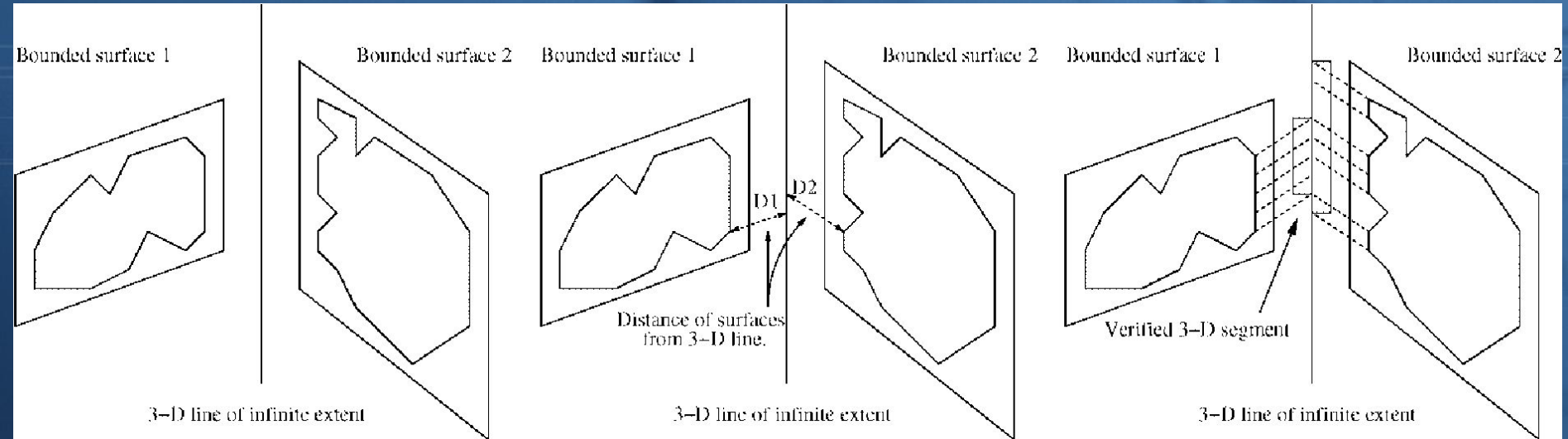
# Related Research & Basic Approach

- Stamos, Allen, "Geometry and texture recovery of scenes of large scale", *Computer Vision and Image Understanding*, Volume 88, Issue 2, pgs 94-118, Nov. 2002
  - Determine surface planes on roads, buildings, etc.
  - Find the intersections of neighboring planes to produce set of edges
  - Compare and match up these edges with those of a 2D photo image



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# Intersection of Planes

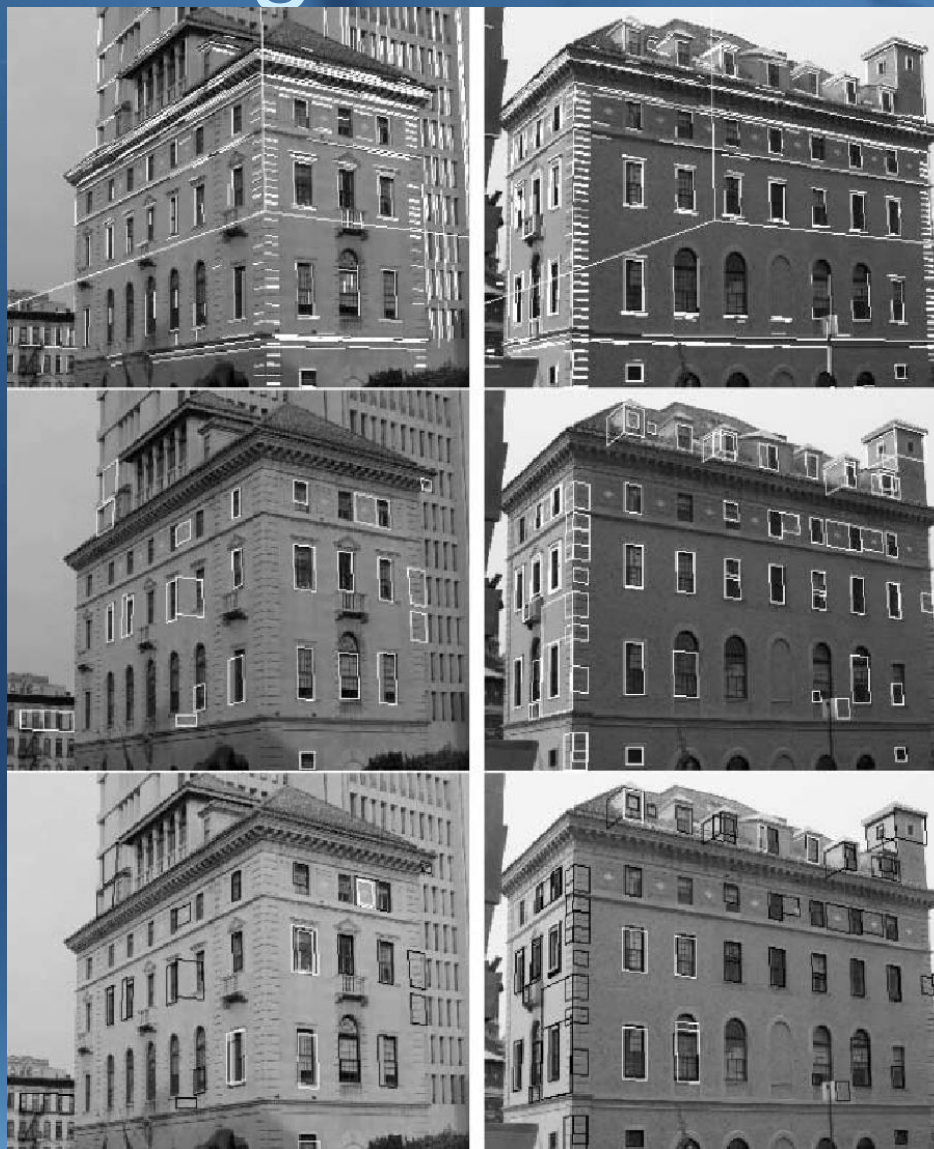






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# Edges of Photos







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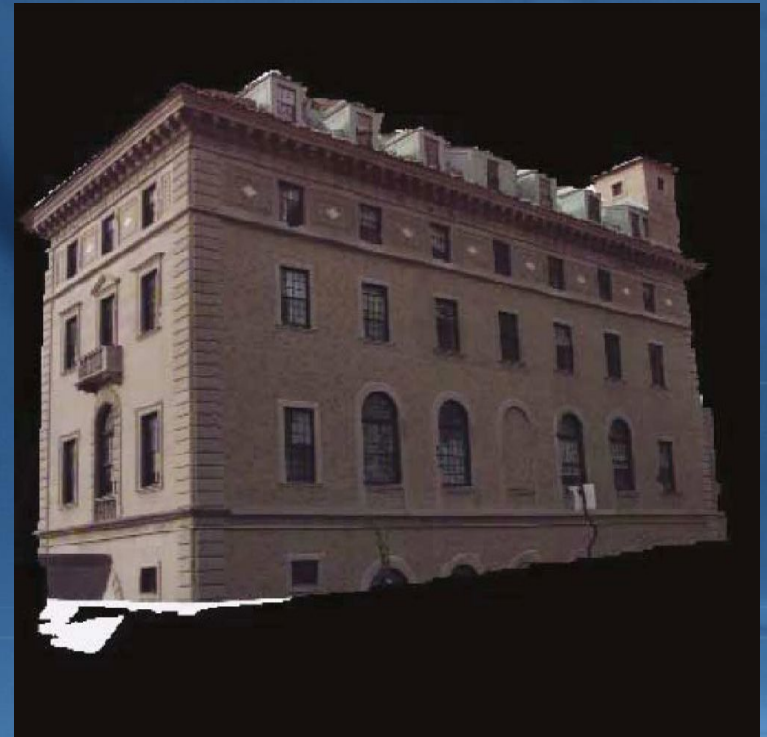
# Combine Intersections and Edges





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# Final Result





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# My Approach

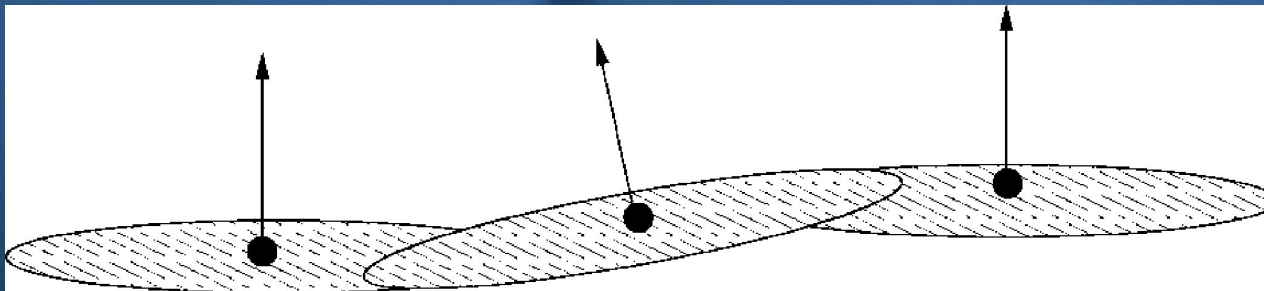
- Select points randomly from lidar (1 million/second)
  - This should allow real-time processing whereas their approach was done offline because they looked at all data points
- Compare neighbors of random point to determine if the surface is planar and come up with a surface normal
- Combine those points with similar surface normals
- Select the group who's surface normal matches the expected road normal
- Create a polygon from those points (Convex Hull vs. Alpha Shapes)
- Draw them on the screen



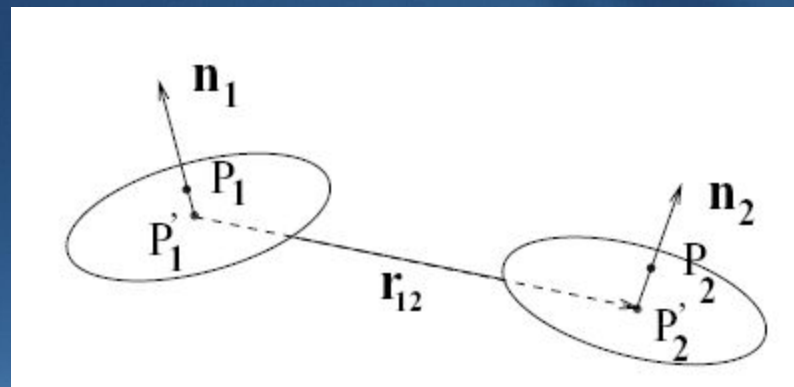


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# My Approach



Random points and their respective planes and normals



Compare surface normals and planes to group like planes



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# Demonstration

MOCU

Polys  
Planes(0)  
Circles  
Ground  
Intensity  
+ Pix  
- Pix

Pause +Spd (x1) - Spd Load Zero + Pix - Pix

F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 psc slk brk

Microsoft PowerPoint ... Camtasia Recorder MOCU On-Screen Keyboard 2:40 PM



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# Screenshots

The screenshot displays a software application window titled "MOCU". The main area shows a 3D visualization of a complex structure, possibly a ship's hull or a large industrial component, rendered with a grid of colored lines (purple, green, yellow, red) and points. The structure is set against a dark background. The interface includes a toolbar at the bottom with buttons for "Pause", "+Spd (x1)", "- Spd", "Load", "Zero", "+ Pix", and "- Pix". A taskbar at the bottom shows the Windows taskbar with several open applications: "On-Screen Keyboard", "MOCU", "Camtasia Recorder", "Microsoft PowerPoint", and "Micros...". The system tray shows the time as 2:40 PM.

Polys  
Planes(0)  
Circles  
Ground  
Intensity  
+ Pix  
- Pix





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# Screenshots

MOCU

On-Screen Keyboard

Color  
+ Pix  
- Pix

Polys  
Planes(0)  
Circles  
Ground

Microsoft PowerPoint ...  
Camtasia Recorder  
MOCU  
On-Screen Keyboard

2:40 PM



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# Screenshots

The screenshot displays a software application window titled "MOCU". The main area shows a 3D visualization of a tunnel or structure, rendered with a grid of colored lines (purple, yellow, green) and a dark background. The visualization is viewed from an elevated perspective, showing the curved walls and floor of the tunnel. The lines are arranged in a pattern that suggests a complex structure or a specific data set.

At the bottom of the window, there is a control panel with several buttons: "Play", "+Spd (x1)", "- Spd", "Load", "Zero", and "- Pix". To the right of these buttons is a vertical list of options: "Polys", "Planes(1)", "Circles", "Ground", "Color", "+ Pix", and "- Pix". The "Color" option is highlighted in green.

The Windows taskbar at the bottom shows the following elements: a taskbar with function keys (F1-F12), a taskbar with application icons (Microsoft PowerPoint, Camtasia Recorder, MOCU, On-Screen Keyboard), and a system tray with the time 2:40 PM.



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# Screenshots

MOCU

Polys  
Planes(2)  
Circles  
Ground  
Color  
+ Pix  
- Pix

Play +Spd (x1) - Spd Load Zero

On-Screen Keyboard 2:41 PM





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# Screenshots

The screenshot displays a software window titled "MOCU" with a blue title bar. The main area shows a 3D visualization of a ship's hull, rendered in a dark, textured style. The hull is highlighted with a bright green color, and there are purple and red lines and markers overlaid on it. The background is black with some faint, glowing patterns. In the bottom right corner, there is a control panel with the following elements:

- Polys
- Planes(2)
- Circles
- Ground
- Color
- + Pix
- Pix

Below the control panel, there is a toolbar with buttons for "Play", "+Spd (x1)", "- Spd", "Load", and "Zero". At the bottom of the screen, there is a taskbar with several open applications: "Microsoft PowerPoint ...", "Camtasia Recorder", "MOCU", and "On-Screen Keyboard". The system tray shows the time as 2:41 PM.



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# Results

## ■ Good

- Able to produce a polygon of the road surface
- When classifying a set of data points as planar, the data was more trustworthy when searching lots of neighbors
- Finds buildings and roads very easily
- Real-time processing

## ■ Bad

- Polygon algorithm I used wasn't too robust and doesn't handle holes (could use alpha shapes algorithm)
- Velodyne laser firings aren't sequential so looking at many neighbors can include too much area and reduce number of true planar surfaces
- Didn't have enough time to find planar intersections and compare with 2D photos



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# Future Work

- Once full width of the road has been detected, it should be fairly simple to do lane detection and curb detection
- Building detection can be done by searching for orthogonal normals
- Detection and classification of cars (using data from the road)
- Detection and classification of boats
- Detection and classification of road signs
- Still would like to merge 2D photos with 3D lidar data for more complete 3D modeling
- Create an automatic photo-lidar registration module to reduce set up time
- Contact Google to create 3D model of the world for their Google Maps.





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# Questions?