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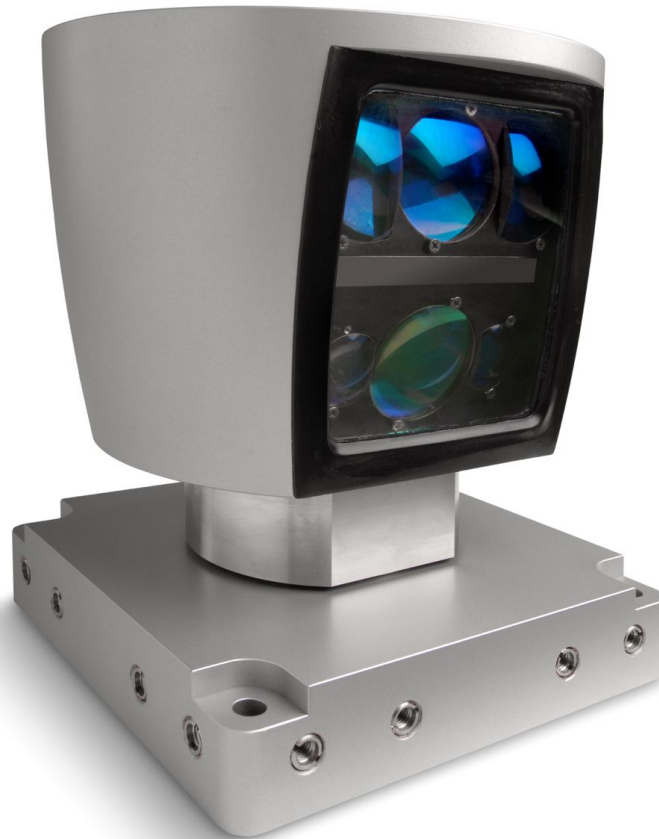
# Plane Detection in a 3D environment using a Velodyne Lidar

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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**

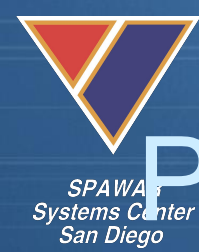
- Class 1 - eye safe
- 4 X 16 laser block assemblies
- 905 nm wavelenth
- 5 nanosecond pulse
- Adaptive power system for minimizing saturations and blinding

## ■ **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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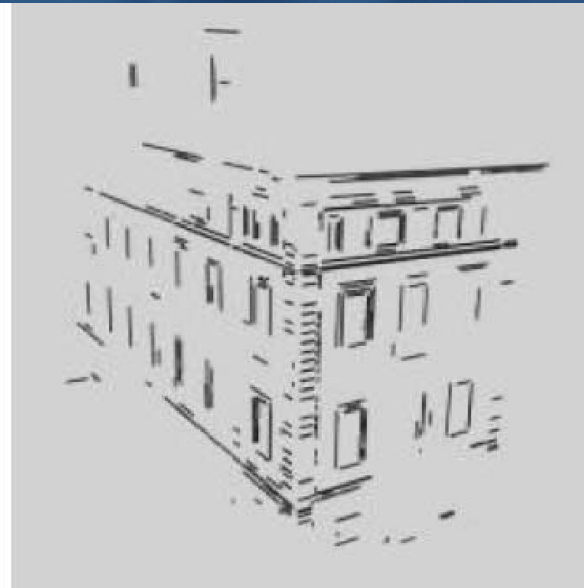
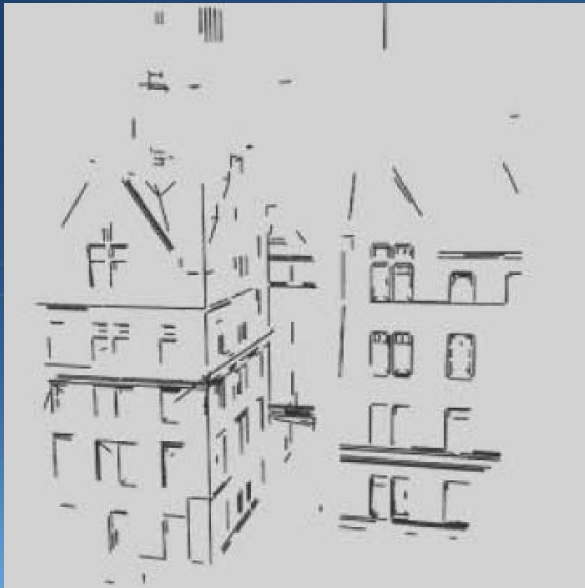
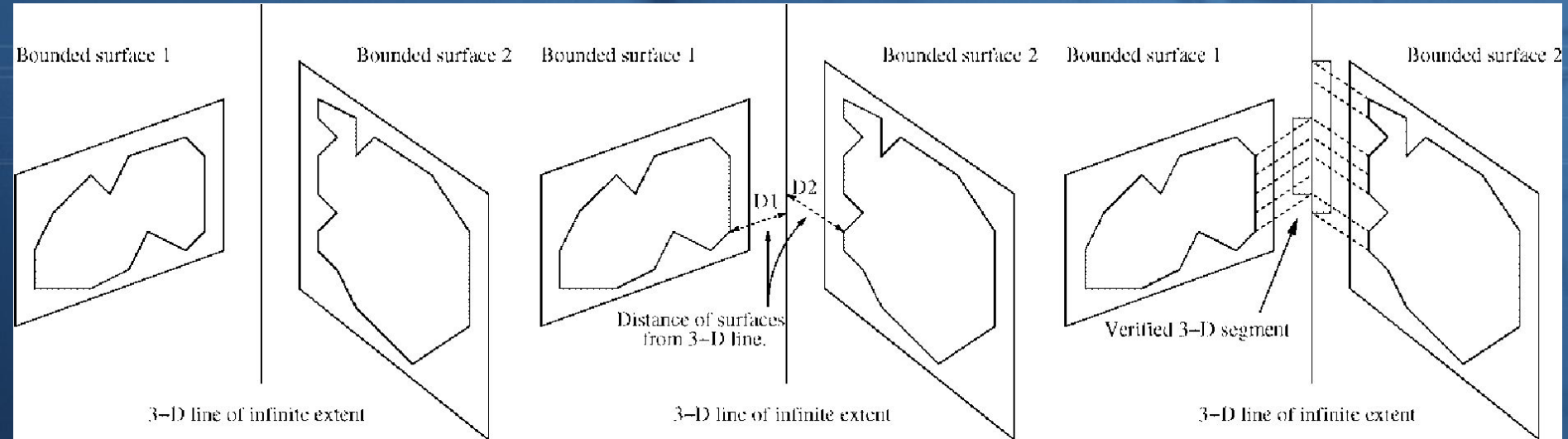
# Related Research & Basic Approach

- 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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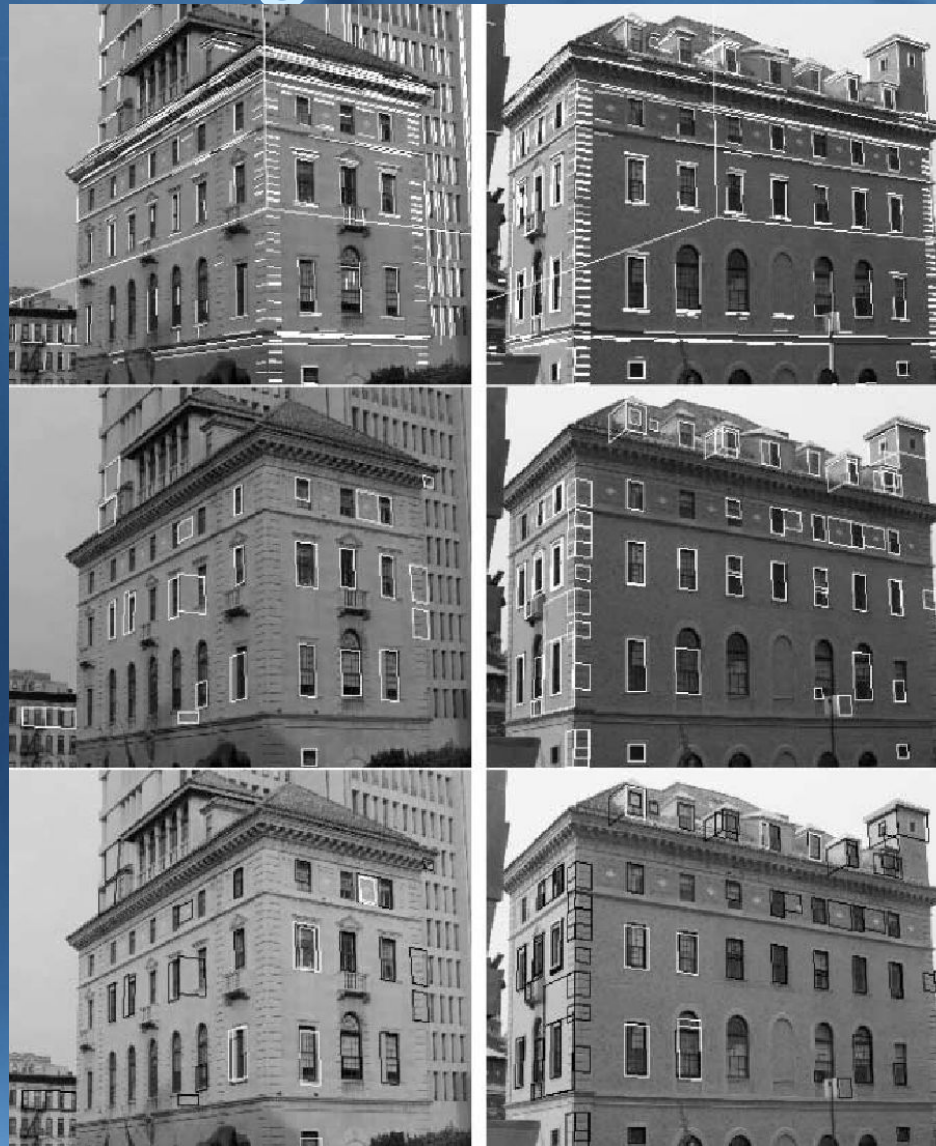
# Intersection of Planes





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# Edges of Photos







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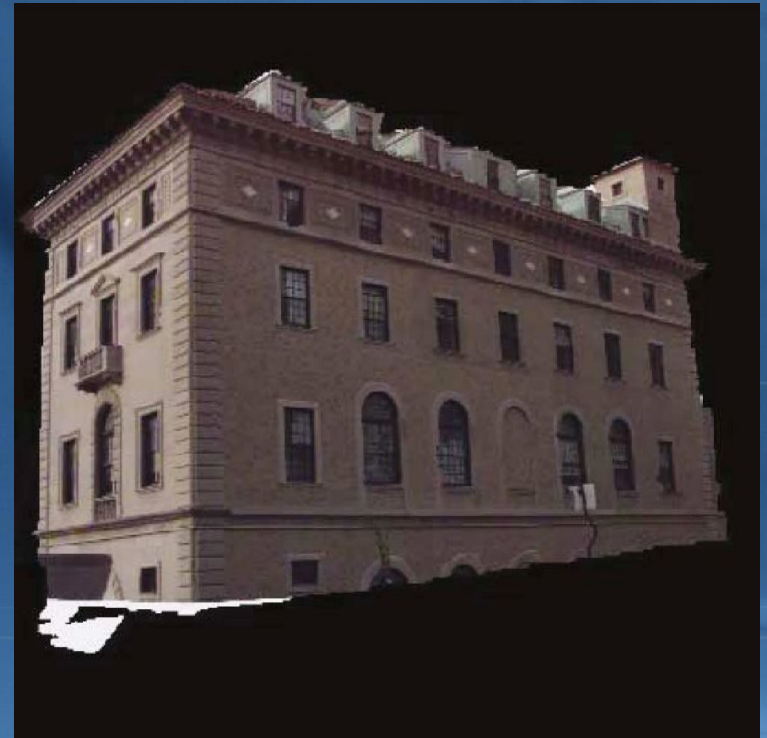
# Combine Intersections and Edges





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# Final Result





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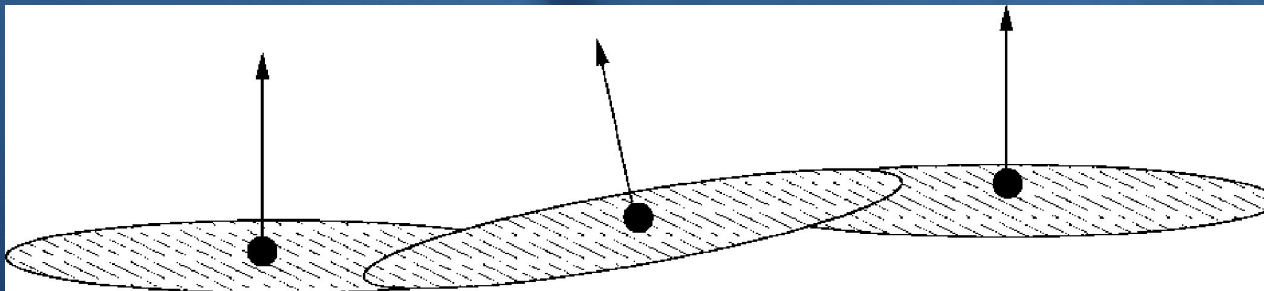
# My Approach

- 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

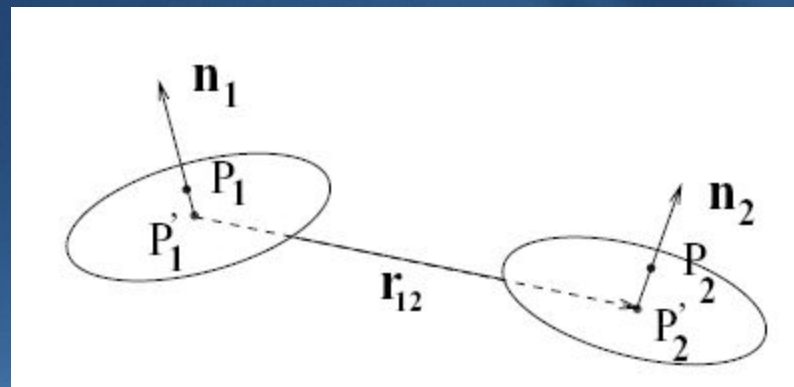


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# My Approach



Random points and their respective planes and normals



Compare surface normals and planes to group like planes



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# Demonstration

The screenshot displays a software window titled "MOCU" with a blue title bar. The main area shows a 3D visualization of a complex, multi-layered structure, possibly a circuit board or a mechanical assembly, rendered in various colors (purple, green, yellow, red) against a black background. The structure is composed of many thin, parallel lines and planes, creating a dense, layered appearance. The colors vary across different sections, suggesting different materials or properties. The structure is viewed from a perspective that shows its depth and complexity.

On the right side of the visualization, there is a control panel with the following elements:

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

At the bottom of the window, there is a toolbar with several buttons:

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

The bottom of the screenshot shows a Windows taskbar with the following elements:

- Taskbar icons: On-Screen Keyboard, MOCU, Camtasia Recorder, Microsoft PowerPoint, Micros...
- System tray: On-Screen Keyboard, 2:40 PM
- Function keys: F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11, F12, psc, slk, brk



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# Screenshots

The screenshot displays a software application window titled "MOCU". The main content area shows a 3D visualization of a complex, multi-layered structure, possibly a circuit board or a mechanical assembly, rendered with various colors (purple, green, yellow, red) and lines. The structure is viewed from a perspective that shows its depth and complexity. The interface includes a toolbar at the bottom with several buttons: "Pause", "+Spd (x1)", "- Spd", "Load", "Zero", "+ Pix", and "- Pix". A vertical panel on the right side of the window contains a list of options: "Polys", "Planes(0)", "Circles", "Ground", "Intensity", "+ Pix", and "- Pix". The taskbar at the bottom shows several open applications, including "Microsoft PowerPoint", "Camtasia Recorder", and "MOCU". The system tray on the right indicates the time as 2:40 PM.



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# Screenshots

MOCU

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

On-Screen Keyboard

2:40 PM



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# Screenshots

The screenshot displays a software application window titled "MOCU" with a blue title bar. The main content area shows a 3D visualization of a tunnel or cavernous structure. The interior surfaces are rendered with a grid of lines, colored in a gradient from purple to yellow. The background is dark, with some faint, illegible text visible on the left side. In the bottom right corner, there is a control panel with several buttons: "Polys", "Planes(1)", "Circles", "Ground", "Color", "+ Pix", and "- Pix". Below the main window, there is a 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.

MOCU

Polys  
Planes(1)  
Circles  
Ground  
Color  
+ Pix  
- Pix

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

At the bottom of the window, there is a control panel with several buttons: "Play", "+Spd (x1)", "- Spd", "Load", and "Zero". To the right of these buttons is a vertical list of controls: "Polys", "Planes(2)", "Circles", "Ground", "Color", "+ Pix", and "- Pix".

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?