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Plane Detection in a 3D environment using a Velodyne Lidar

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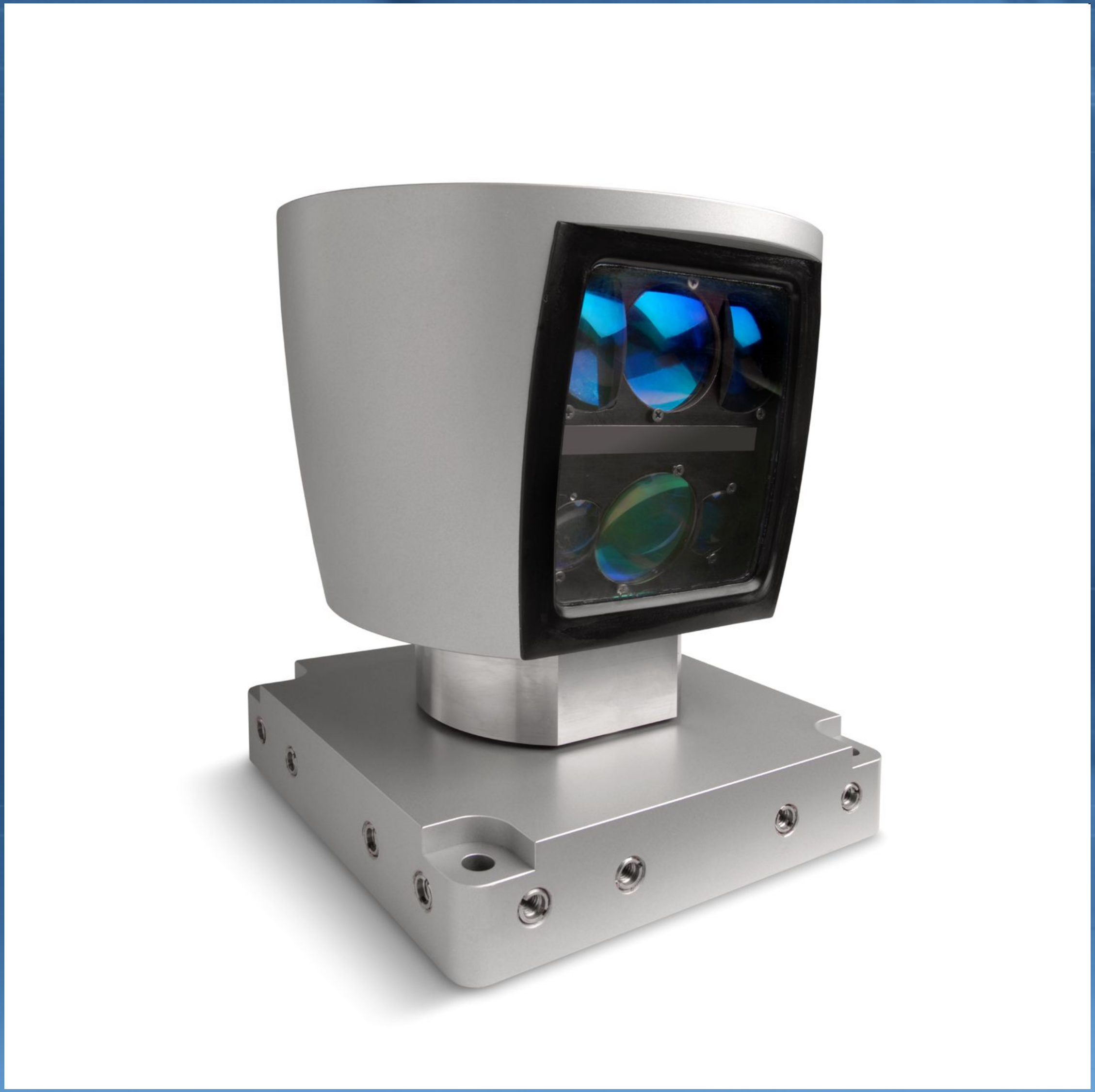
Velodyne Lidar Sensor



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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) -+ 2° up to -24.8° down with 64 equally spaced angular subdivisions (approximately 0.4°)
  - <2 cm distance accuracy
  - 5-15 Hz field of view update (user selectable)
  - 50 meter range for pavement (~0.10 reflectivity)
  - 120 meter range for cars and foliage (~0.80 reflectivity)
  - >1.333M 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

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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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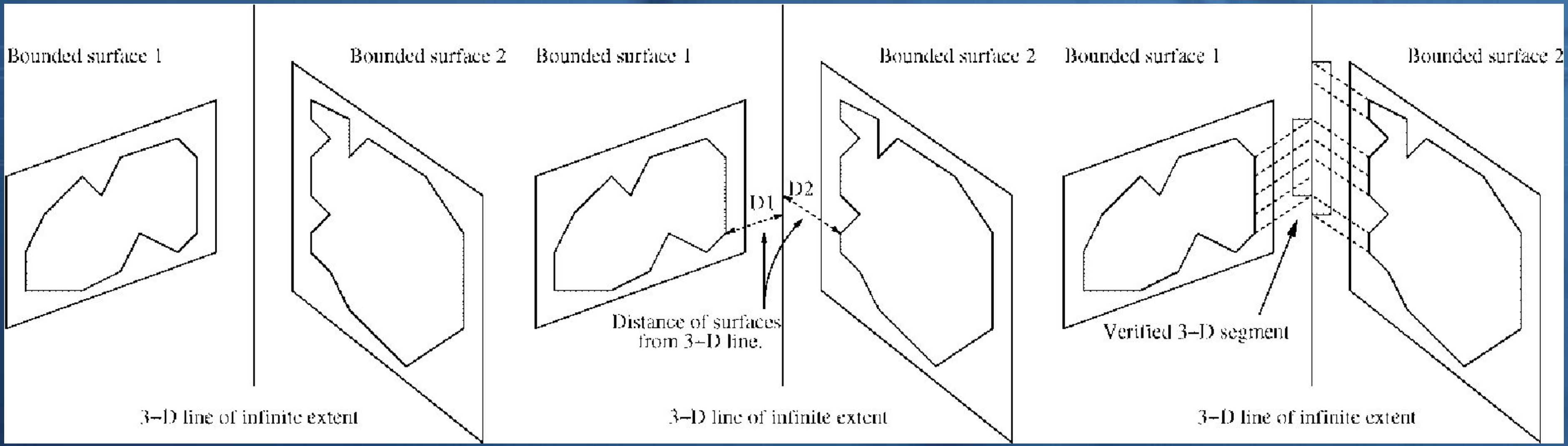
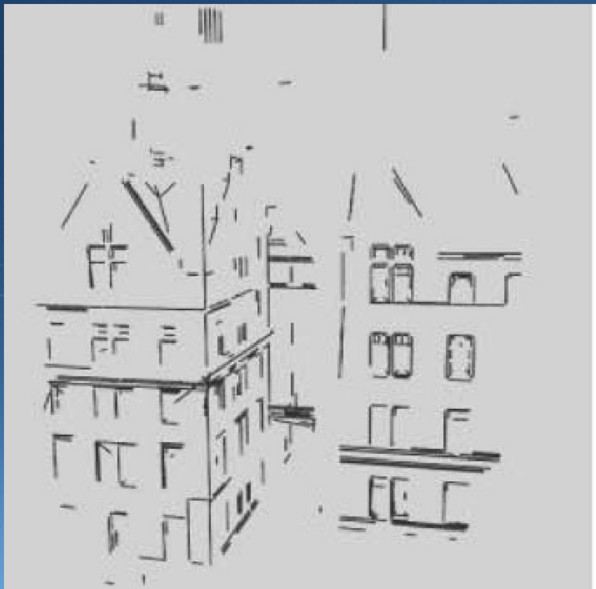
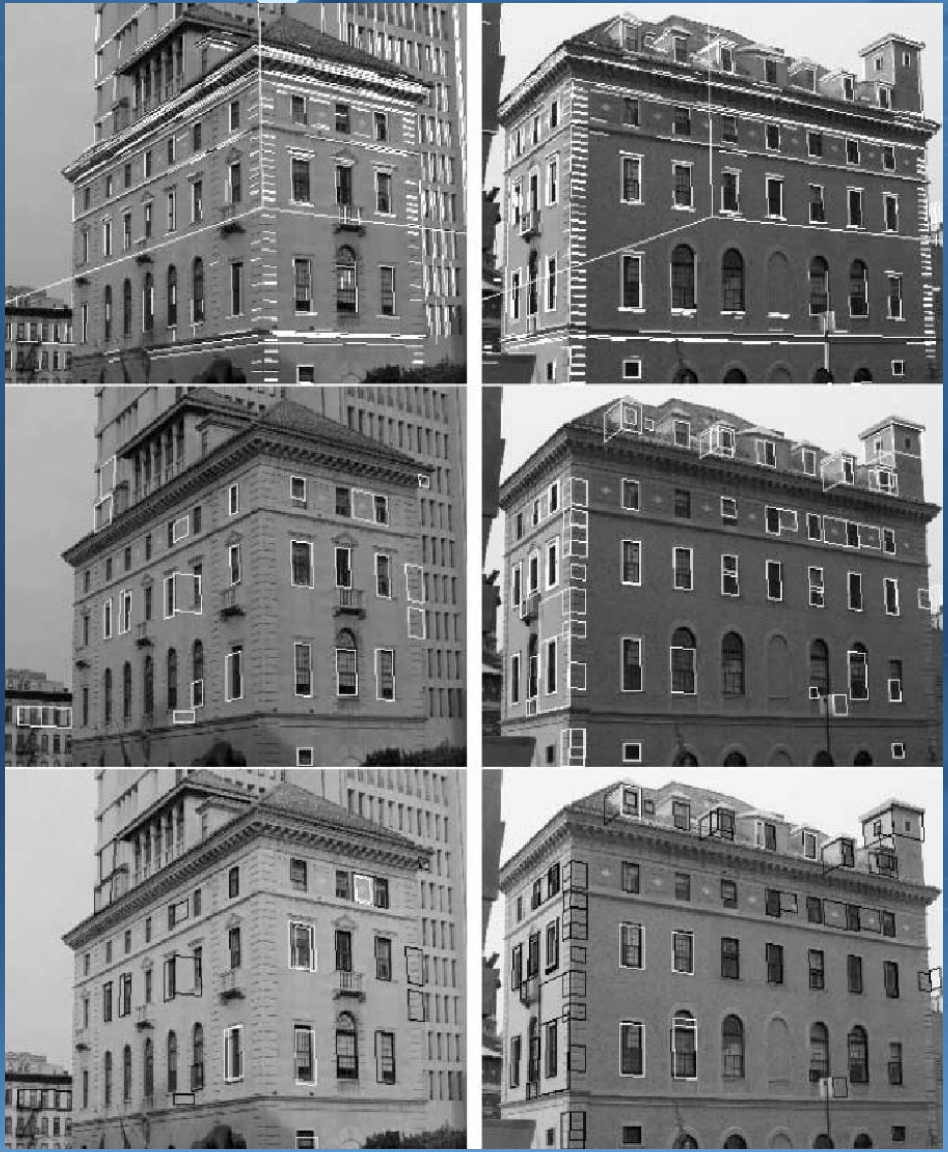
Intersection of Planes





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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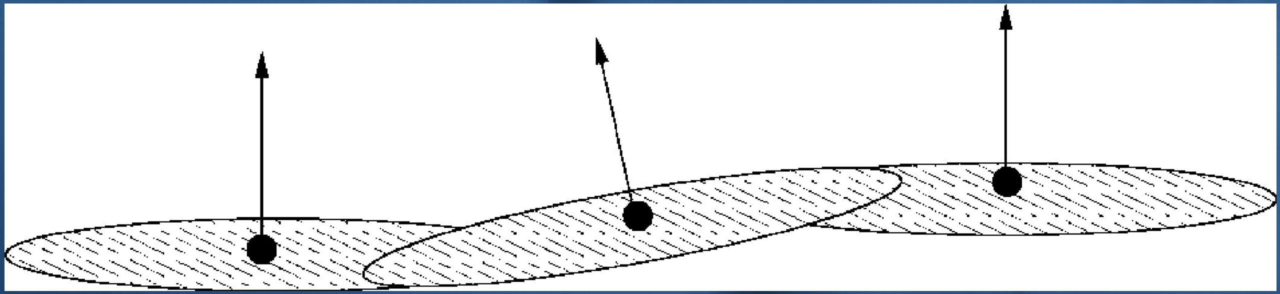
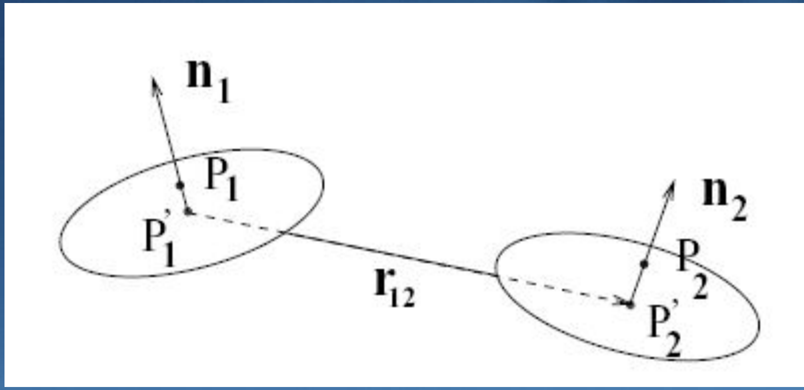
My Approach



Random points and their respective planes and normals



Compare surface normals and planes to group like planes

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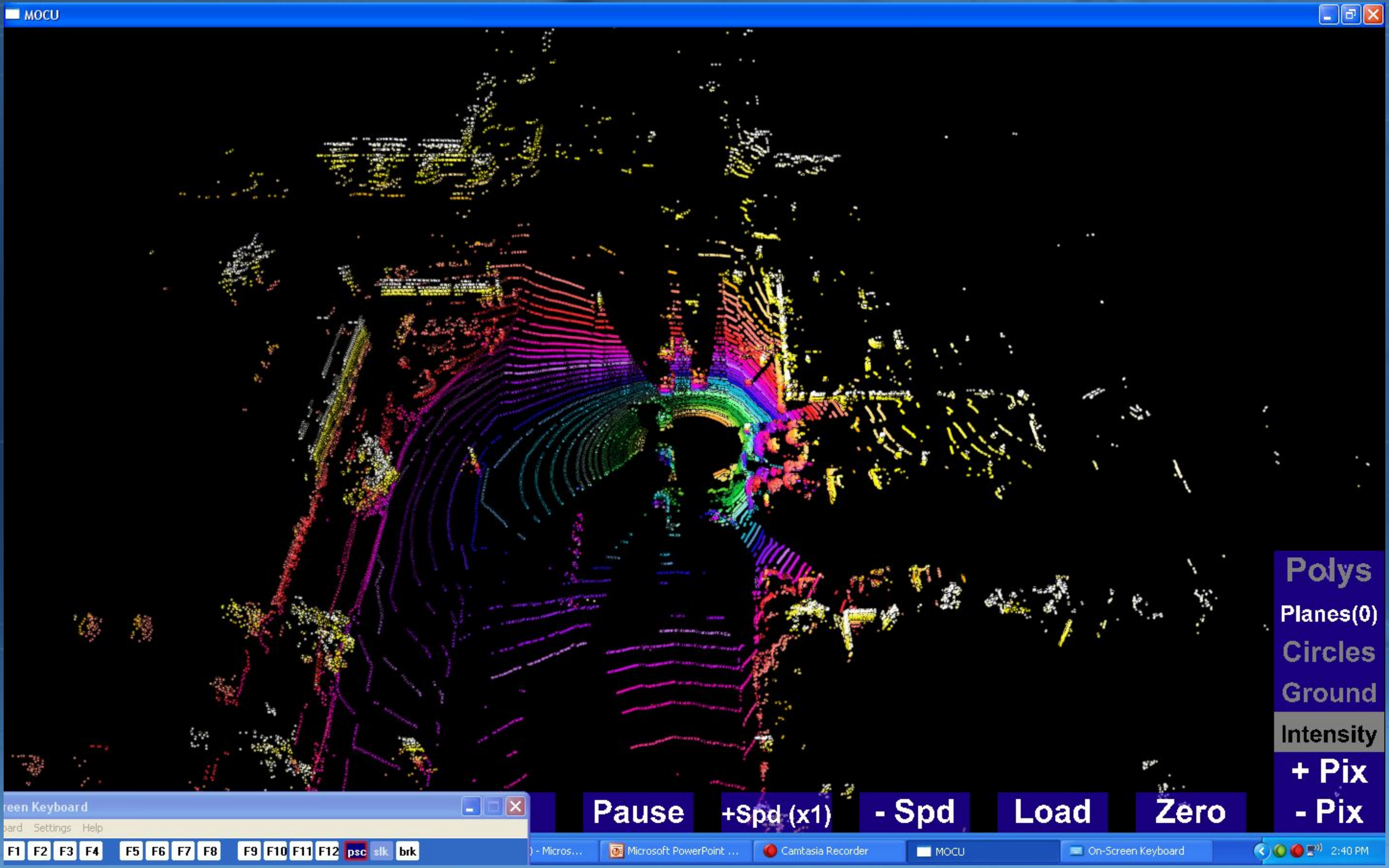
Demonstration



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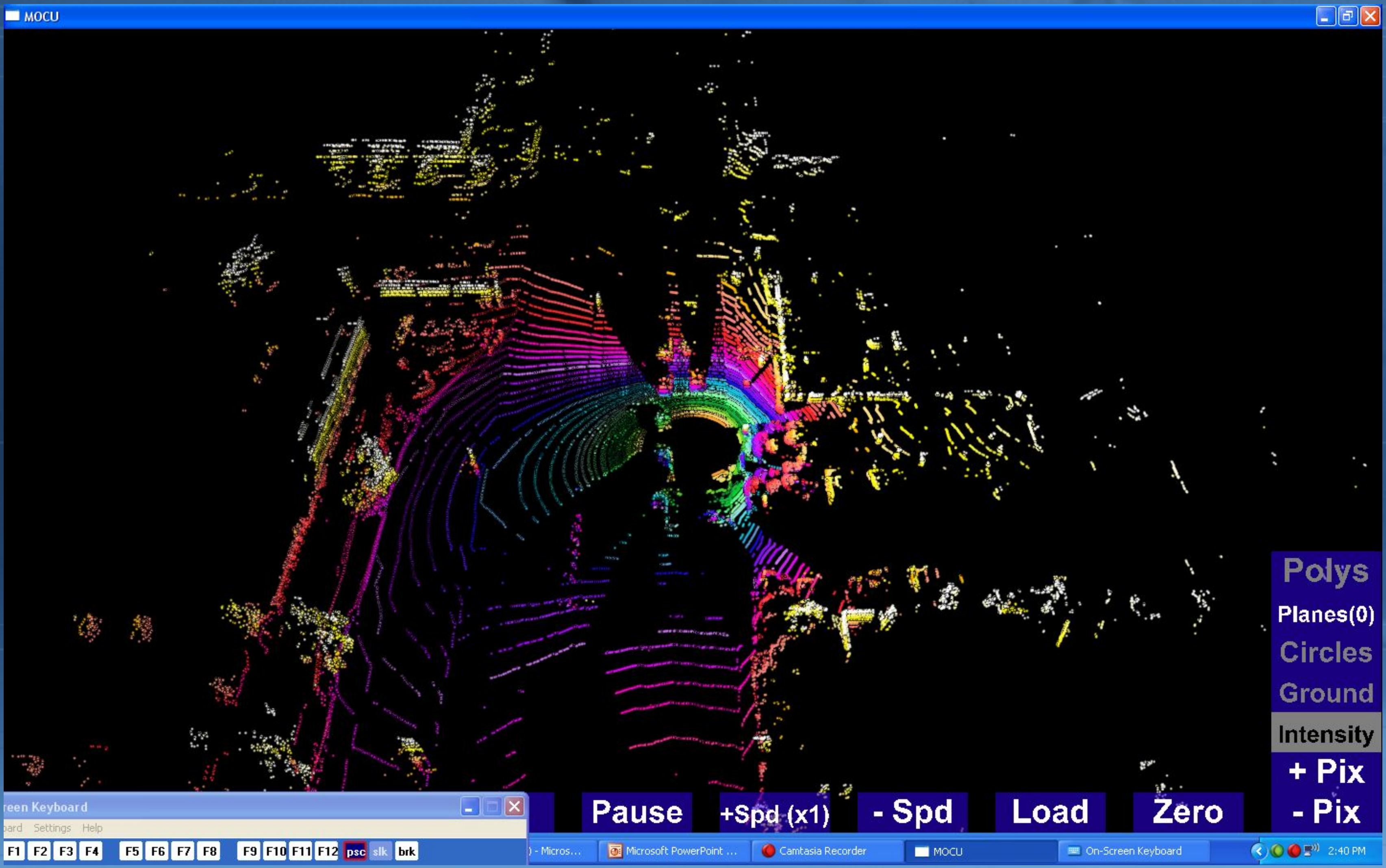
Screenshots



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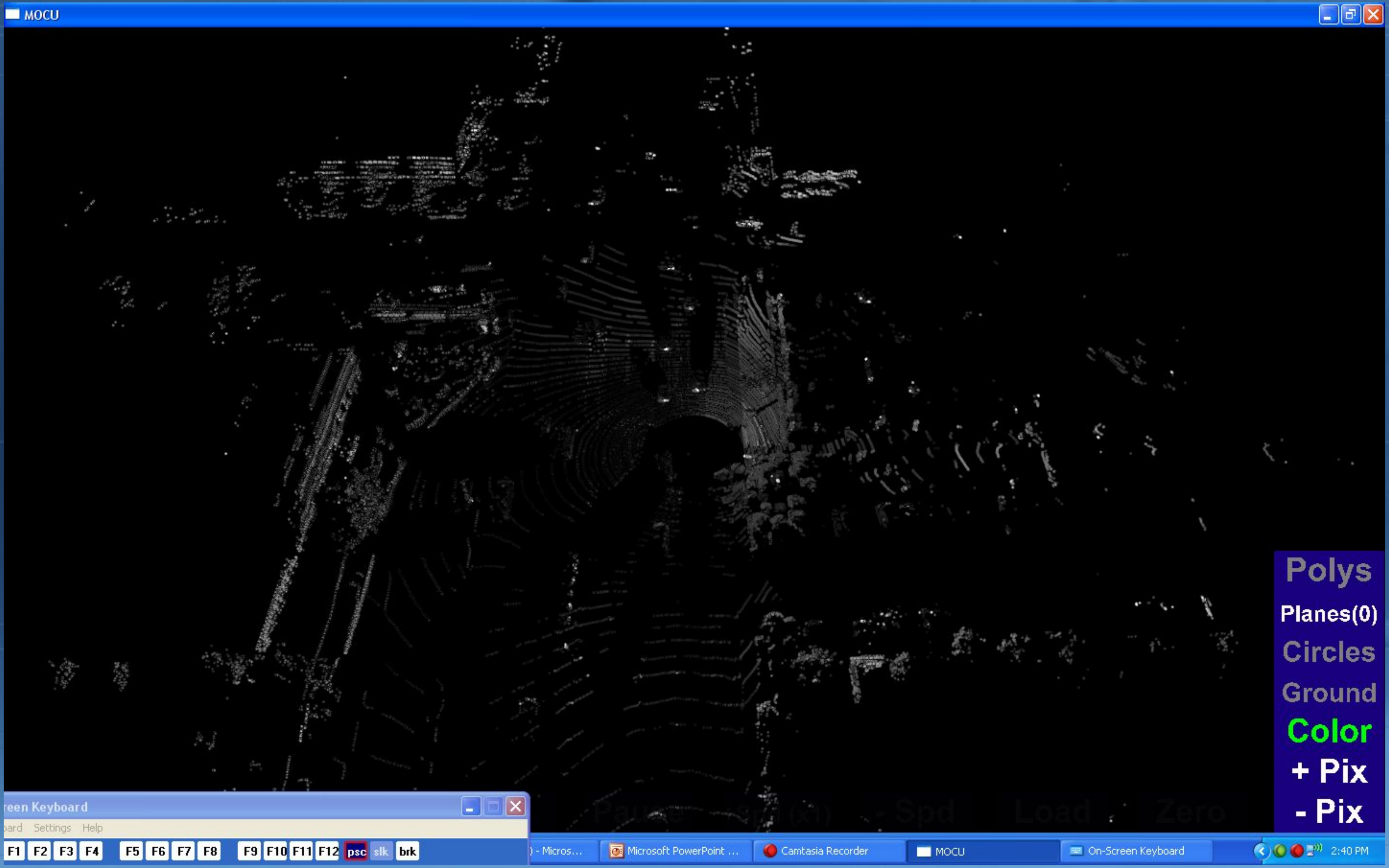

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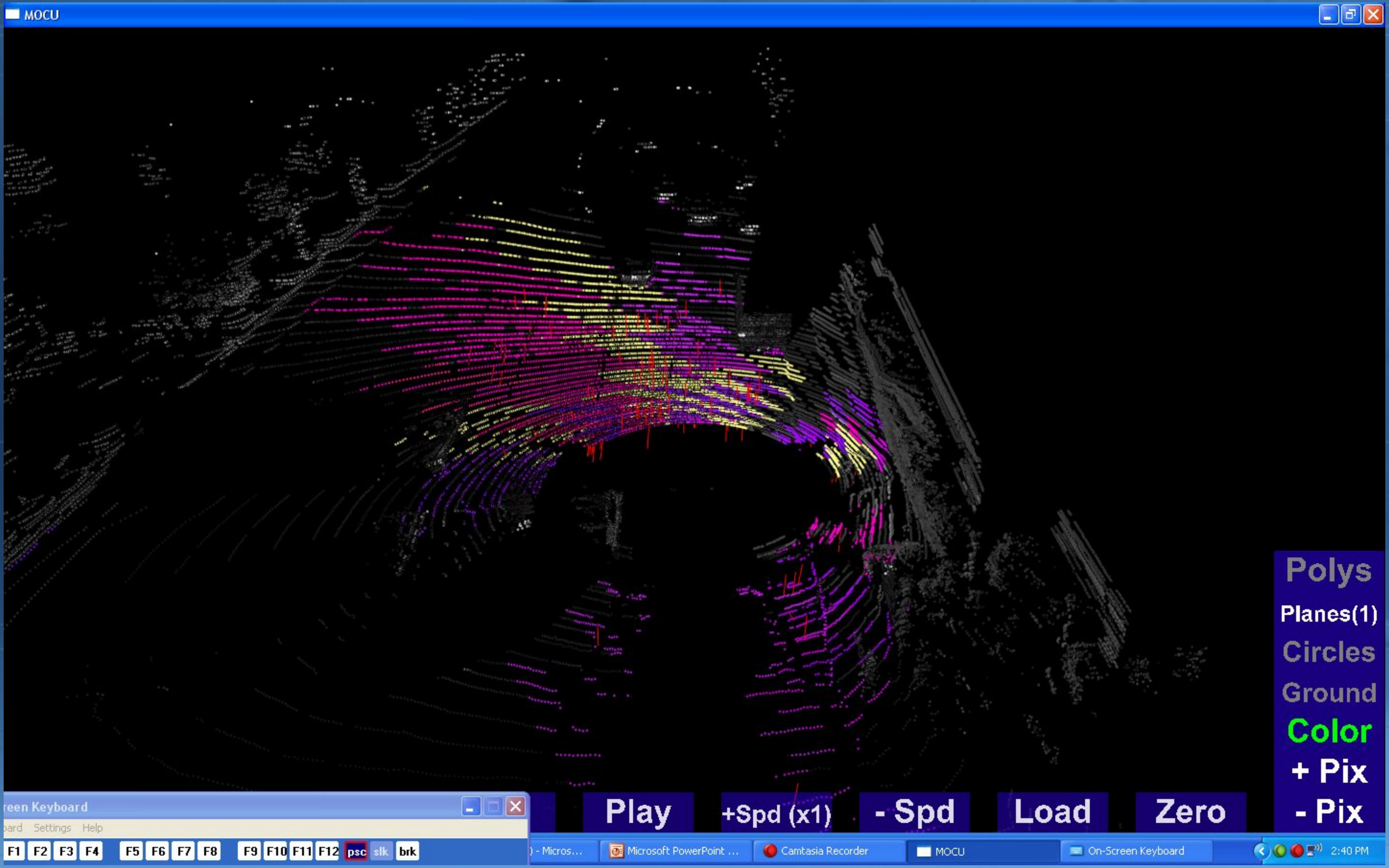

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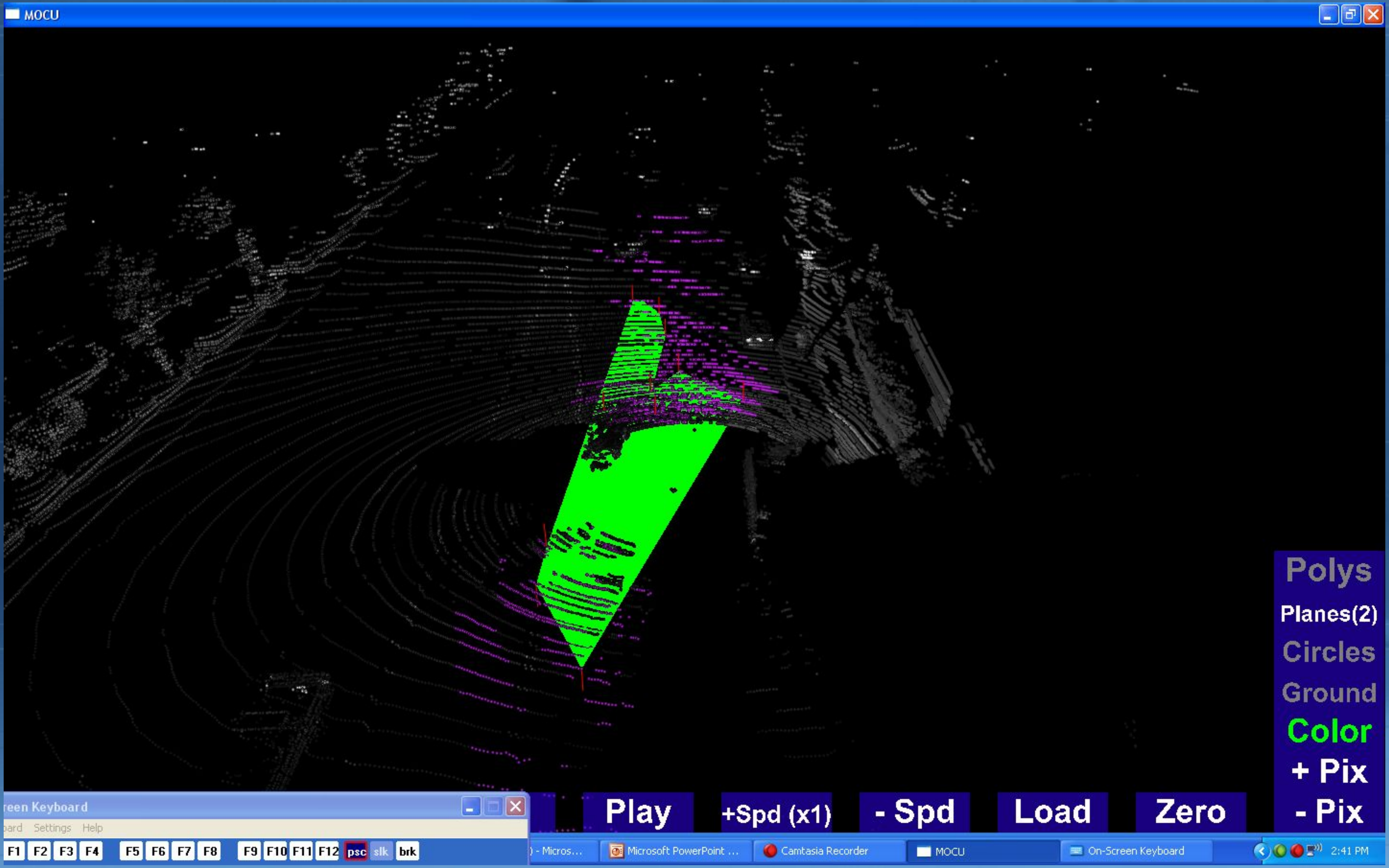

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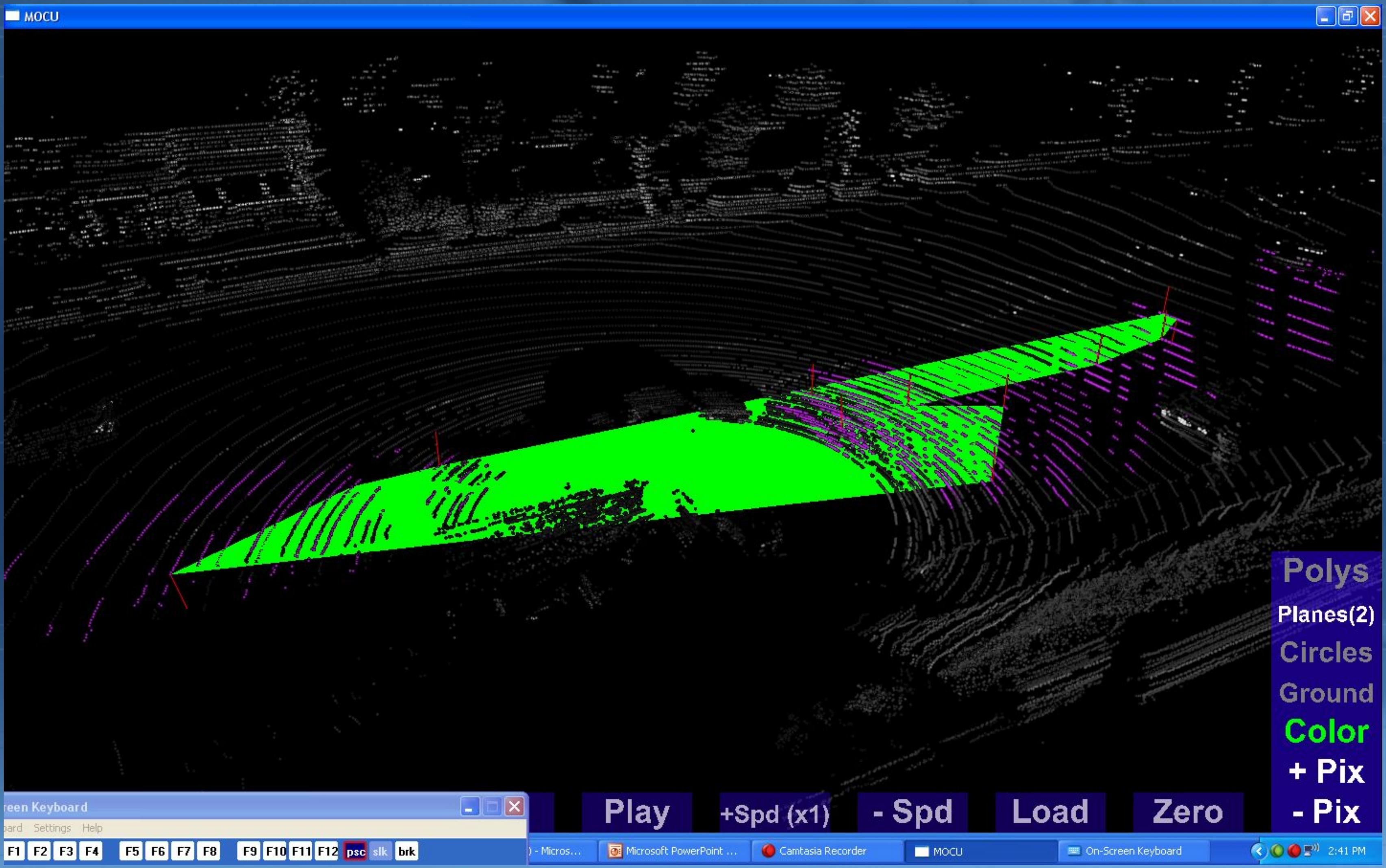

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Results

- 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 sequencial 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?