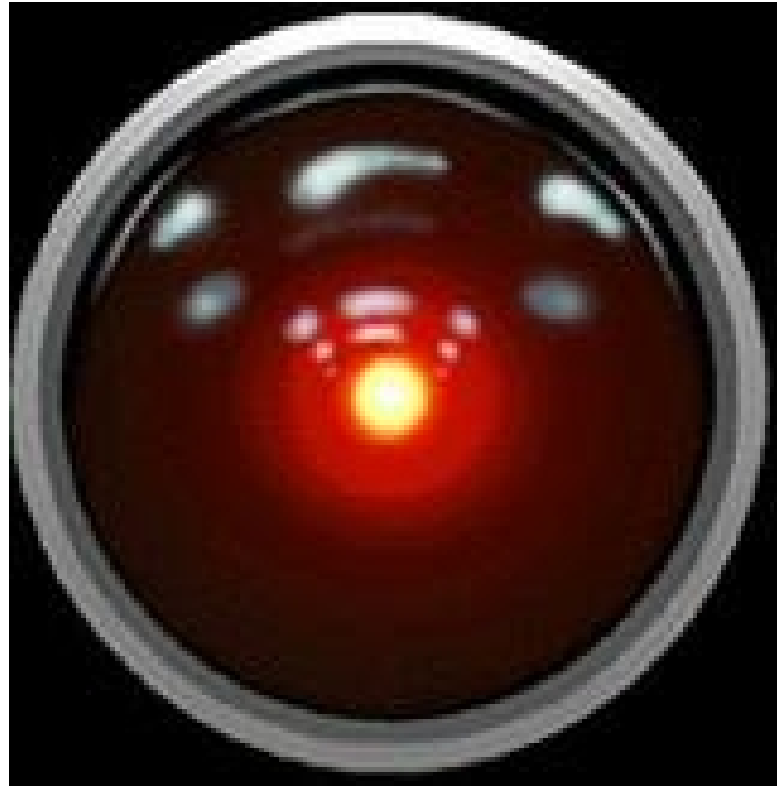




# CS 378: Autonomous Intelligent Robotics

Instructor: Jivko Sinapov

<http://www.cs.utexas.edu/~jsinapov/teaching/cs378/>

# Introduction to Point Cloud Library (PCL)



# Announcements

Homework 6 is out, due 4/5

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# Final Project Timeline

- Project Proposal due: ~~Mar. 29<sup>th</sup>~~ Apr. 1<sup>st</sup>
- Project Presentations / Demos: Last Week of Class (May 3<sup>rd</sup> and 5<sup>th</sup>)
- Final Report due: May 11<sup>th</sup>

# Project Proposal

- Format: PDF, single spaced
- Submit on Canvas
- Also, post PDF on Discussion Forum, state the project name and team members

# Installing our code base

- Github page:
  - <https://github.com/utexas-bwi/bwi>

# Introduction to Point Cloud Library (PCL)



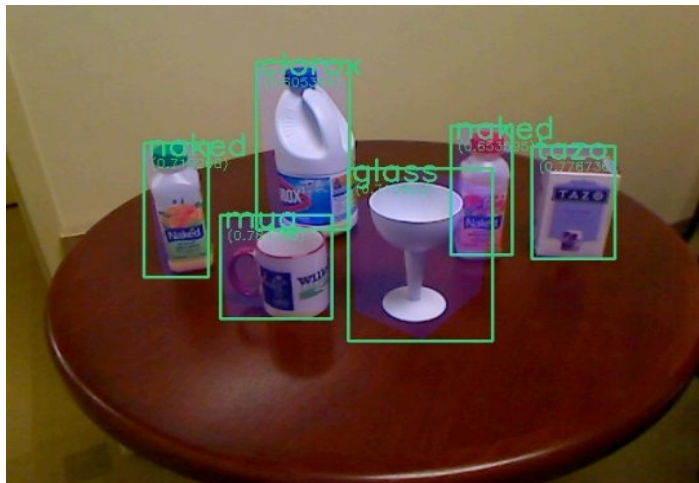
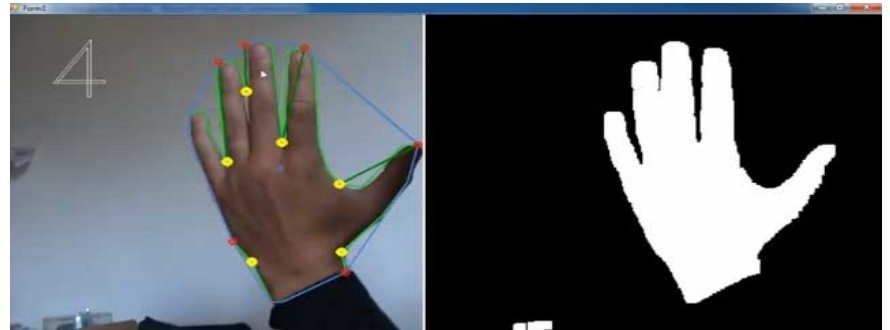
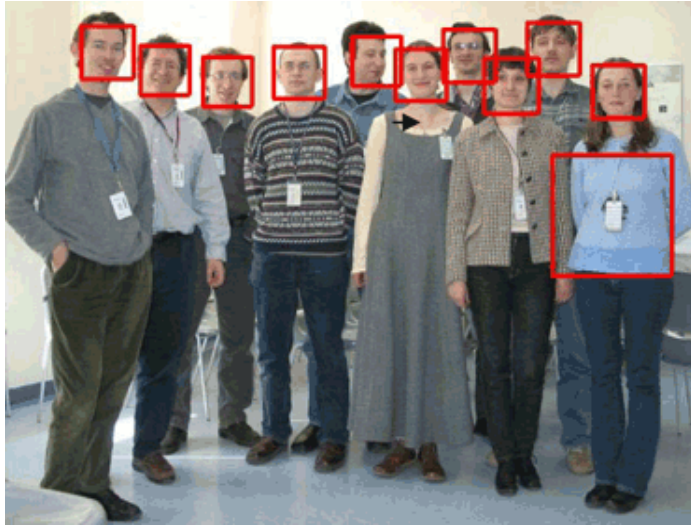


# Main References

- “Rusu, Radu Bogdan, and Steve Cousins. "3d is here: Point cloud library (pcl)." Robotics and Automation (ICRA), 2011 IEEE International Conference on. IEEE, 2011.”
- “Tutorial: Point Cloud Library – USC Robotics Research Lab”

# Why PCL?

# The Impact of OpenCV



# Traditional 3D sensors



# Latest Technology



**KINECT™**  
for  **XBOX 360.**



# 3D is now cheap!



# What is PCL?

- Open Source C++ Library:
  - <http://pointclouds.org/>
- Cross-platform\*
  - (Ubuntu 12.04+, Windows 7+, Mac)
- Strives to be the equivalent of OpenCV for 3D



# Who is developing it?





# Who is paying for it?



# What is a PCL point cloud?

```
# .PCD v0.7 - Point Cloud Data file format
VERSION 0.7
FIELDS x y z
SIZE 4 4 4
TYPE F F F
COUNT 1 1 1
WIDTH 2500
HEIGHT 1
VIEWPOINT 0 0 0 1 0 0 0
POINTS 2500
DATA ascii
-0.0017353802 0.063134596 -0.047117598
-0.00391143 0.064091198 -0.047013
0.00073380599 0.064106099 -0.047437999
0.0021609101 0.063522704 -0.047437999
0.0072039799 0.063331202 -0.0471754
-0.0013178901 0.065206803 -0.0471658
0.00238145 0.0648202 -0.047421999
0.00742169 0.064781599 -0.0471754
-0.00240529 0.065845296 -0.046584301
0.0021517898 0.0657662 -0.047015704
.
.
```

# Types of Point Clouds

- XYZ:



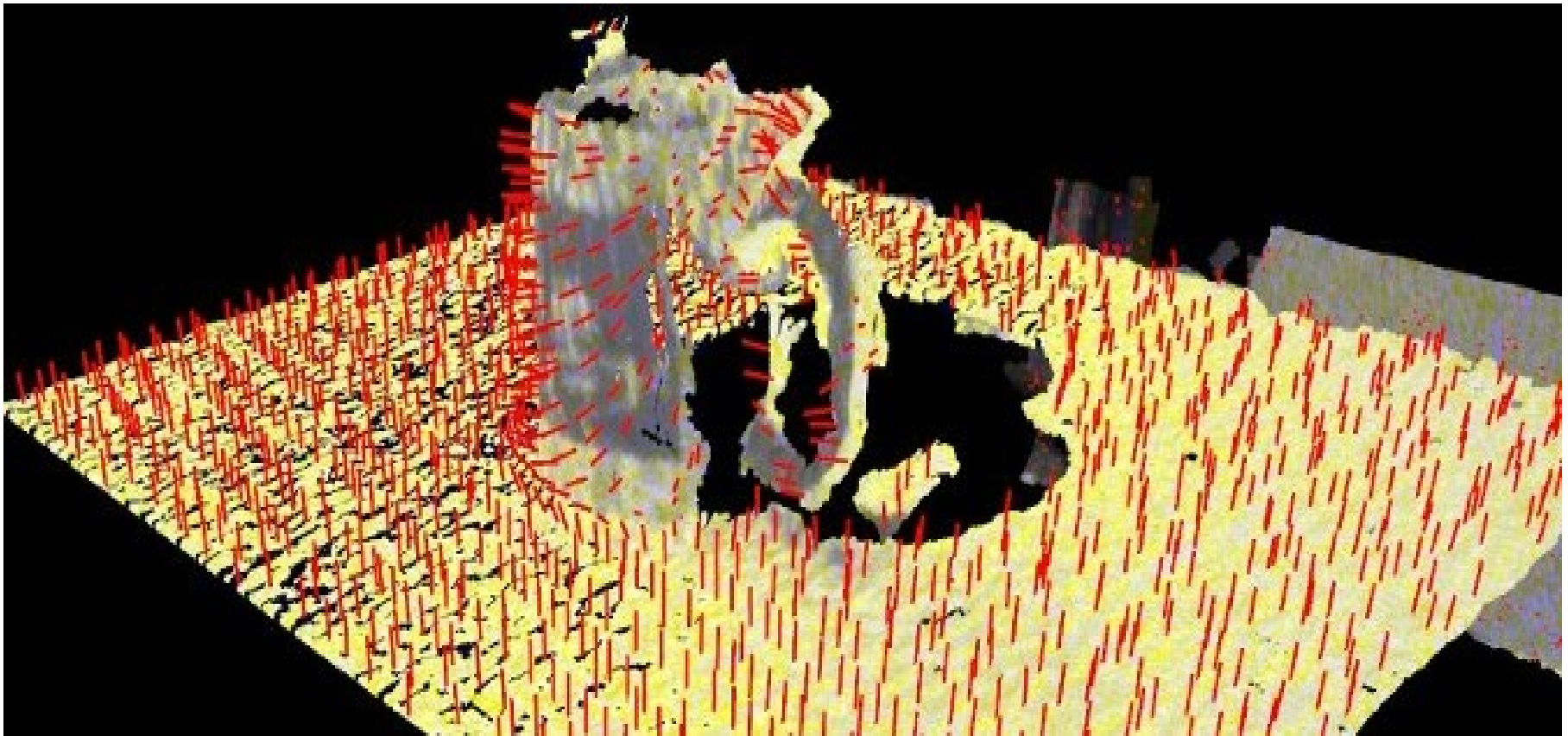
# Types of Point Clouds

- XYZRGB:

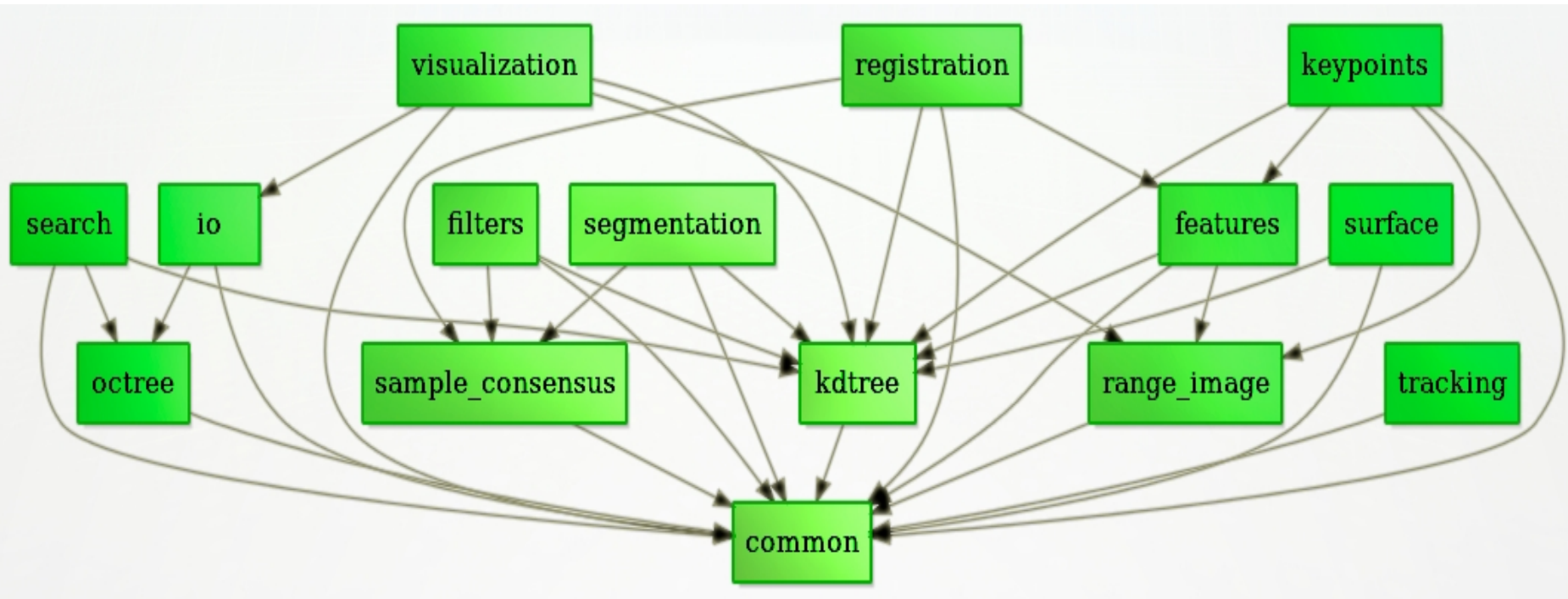


# Types of Point Clouds

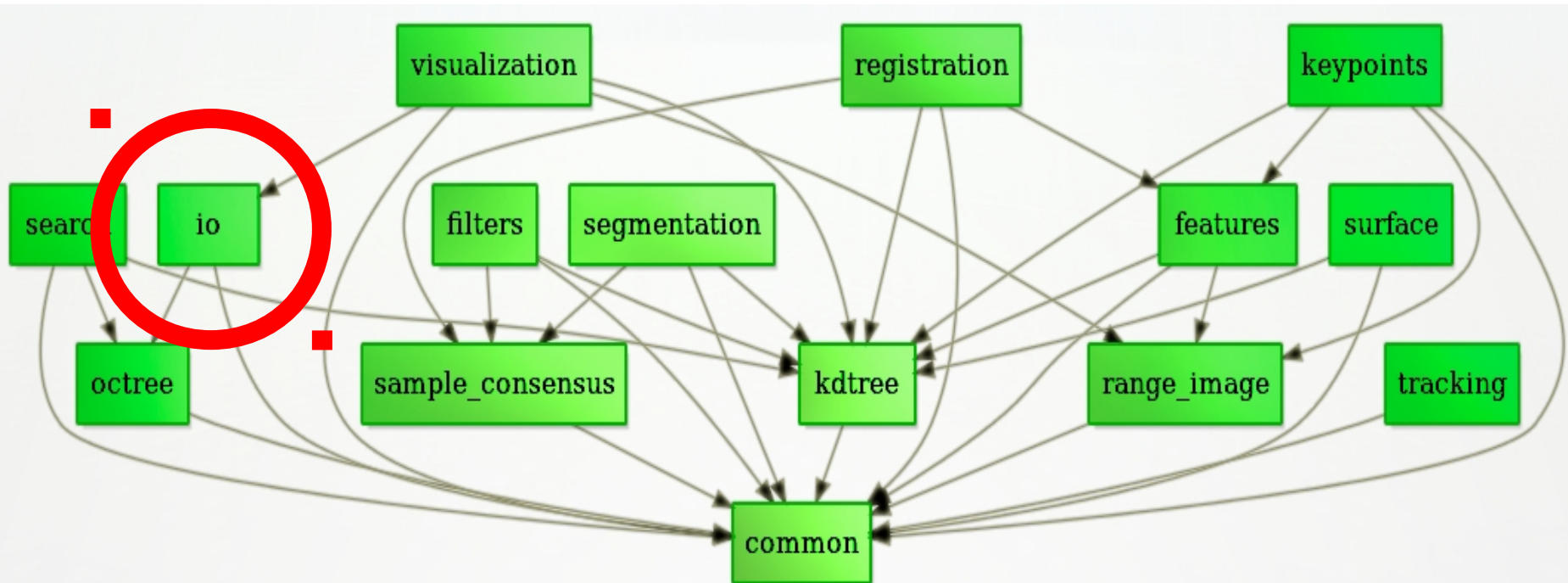
- XYZ+Normals:



# PCL Breakdown



# PCL Breakdown





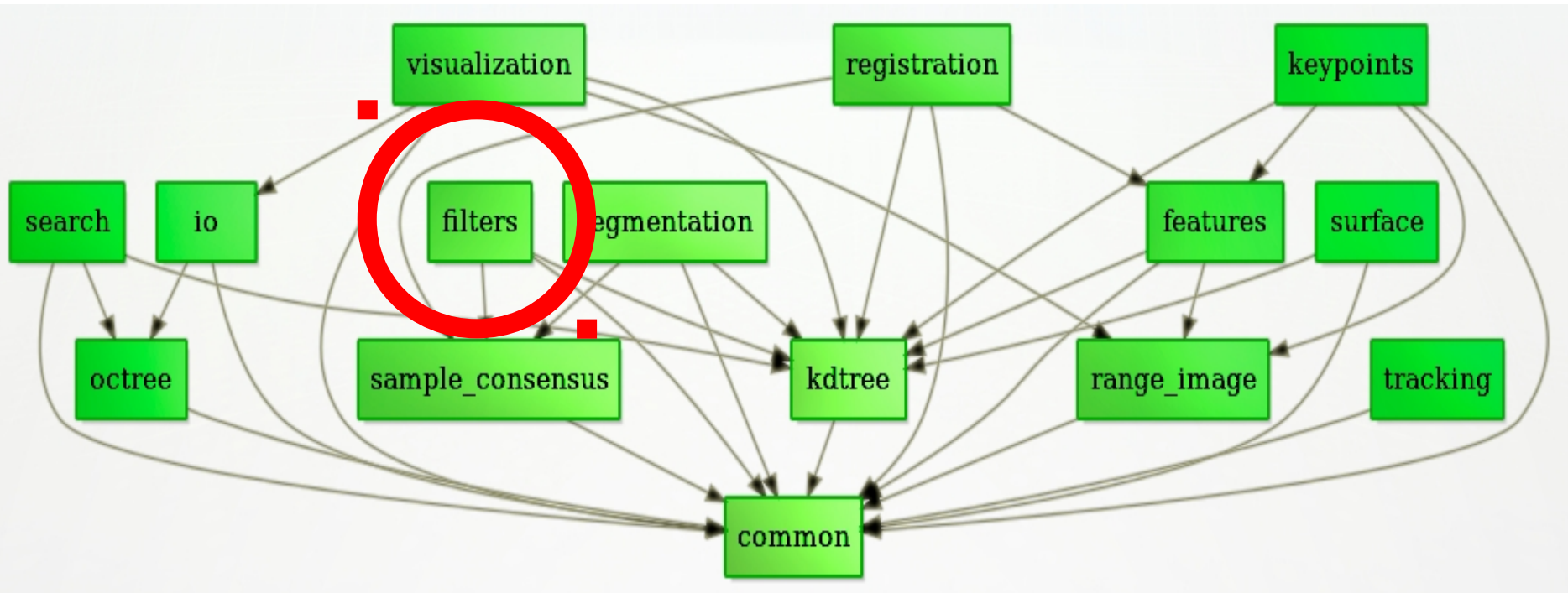
# Getting a Point Cloud from an OpenNI Sensor

- Code sample and Demo

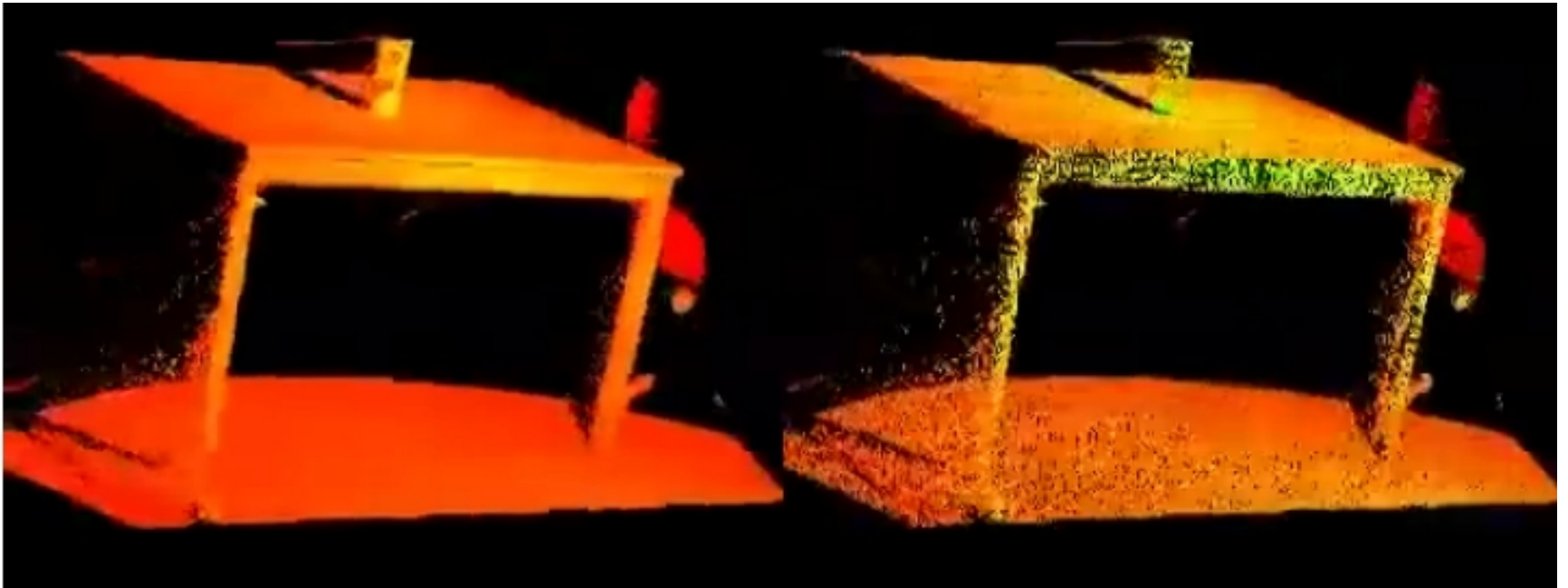




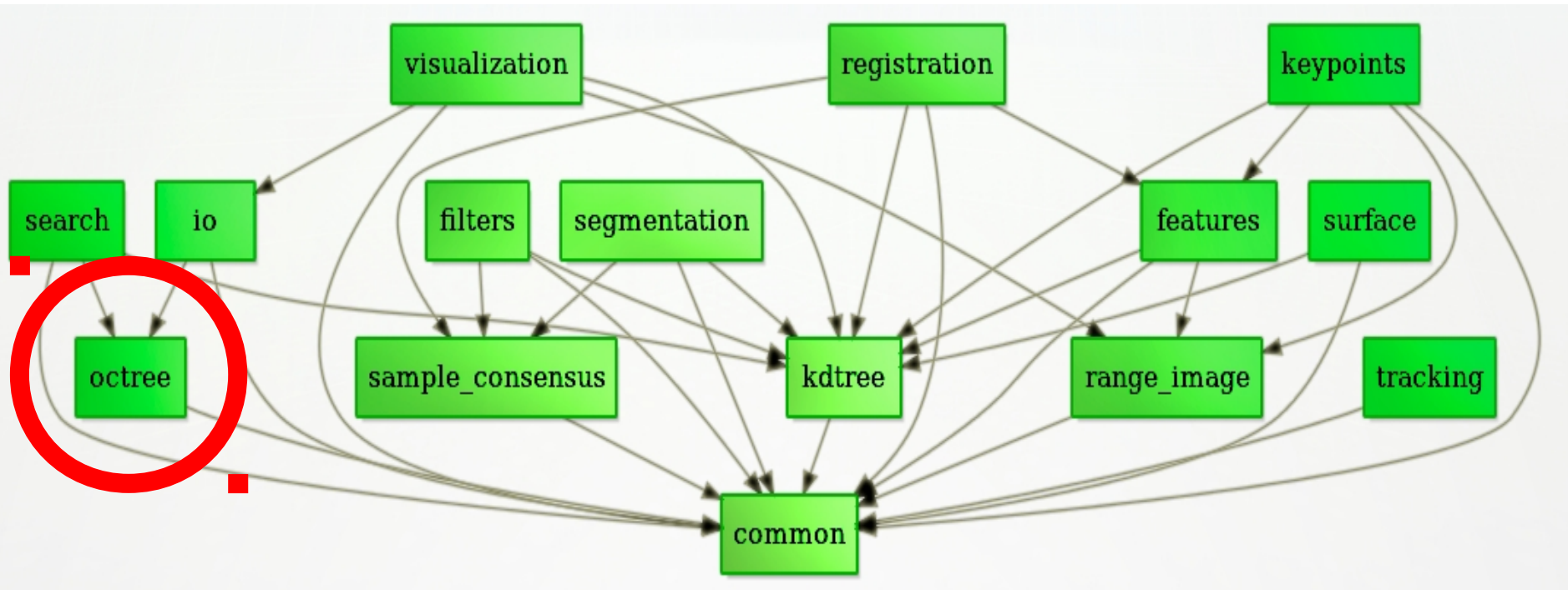
# PCL Breakdown



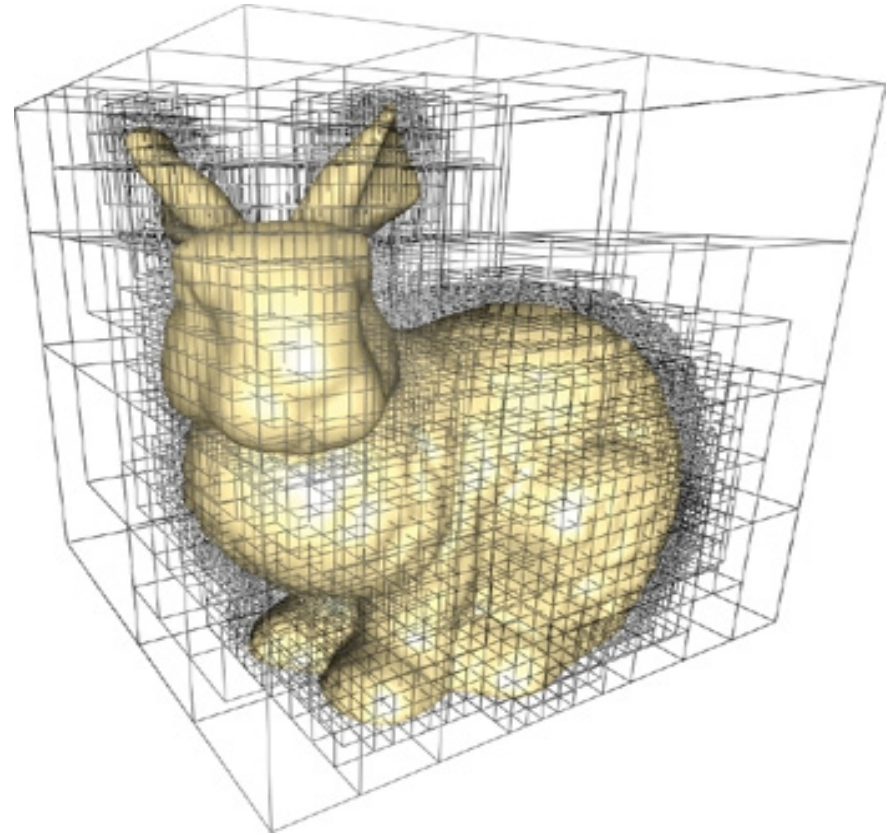
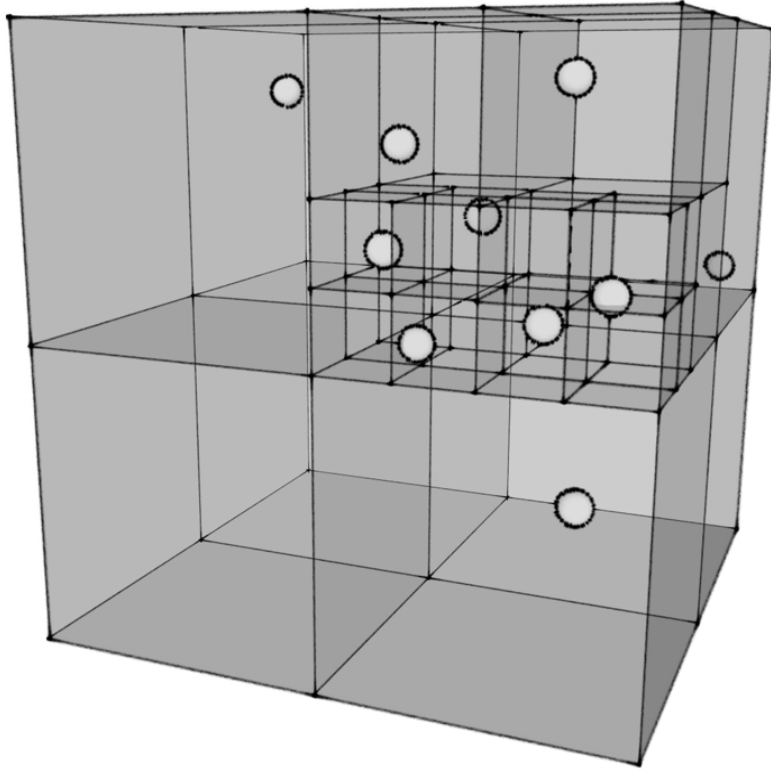
# Downsampling a Point Cloud



# Change Detection using Octree



# Octrees

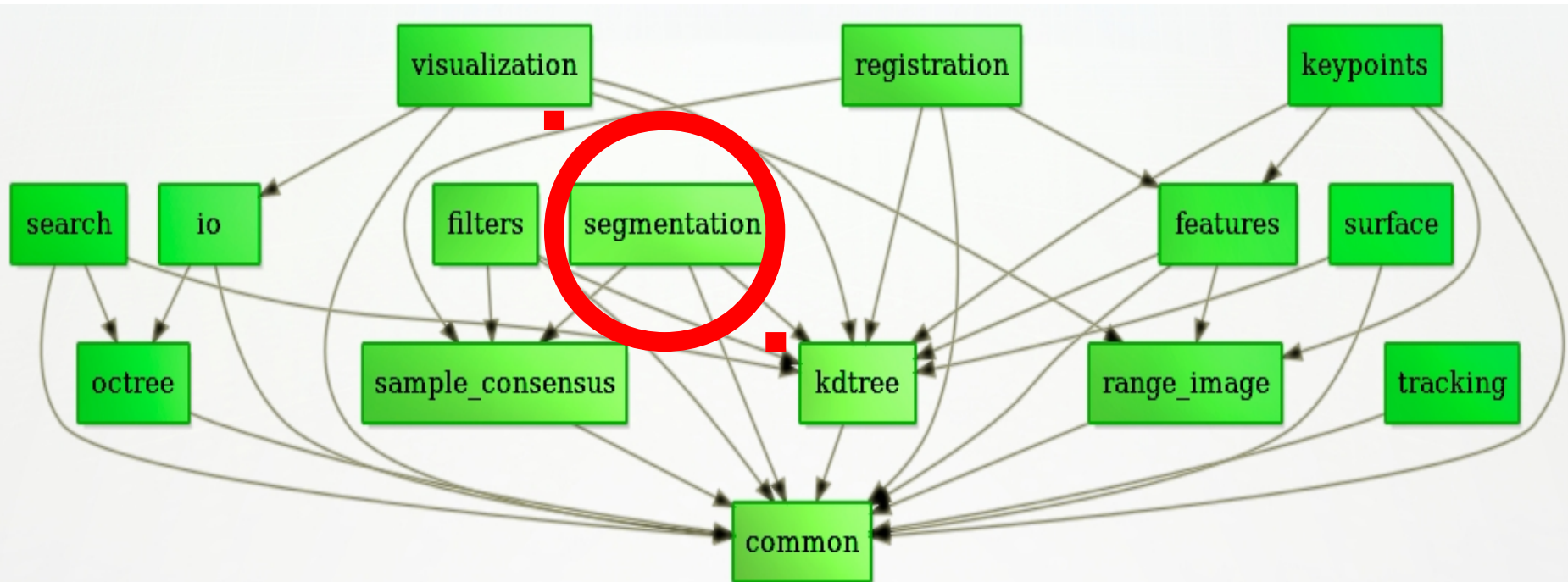


An octree is a *tree data structure* in which each internal node has exactly eight children. Octrees are most often used to partition a three dimensional space by recursively subdividing it into eight octants. Octrees are the three-dimensional analog of quadtrees.

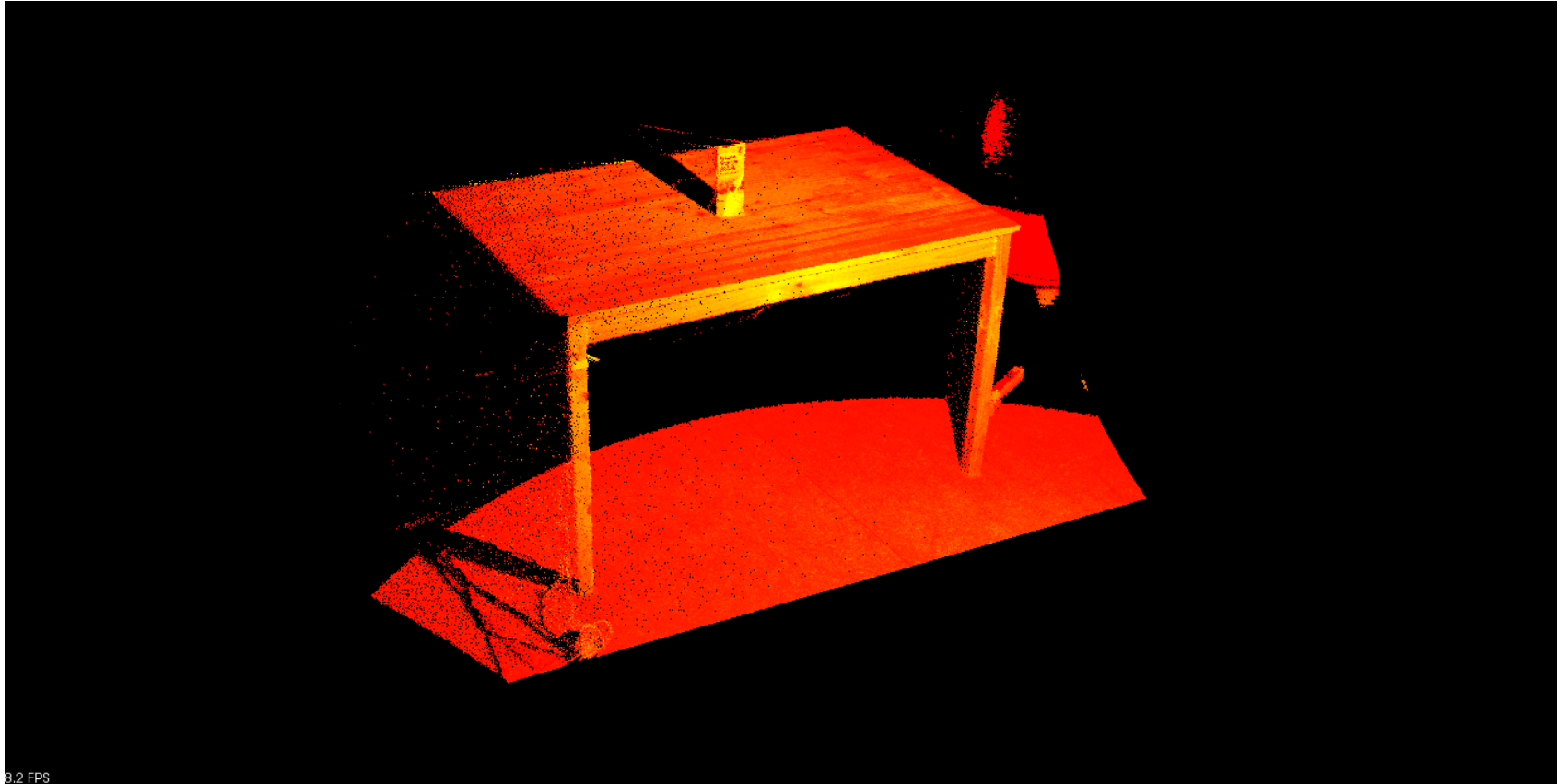
# Octrees

Application: change detection

# Segmentation

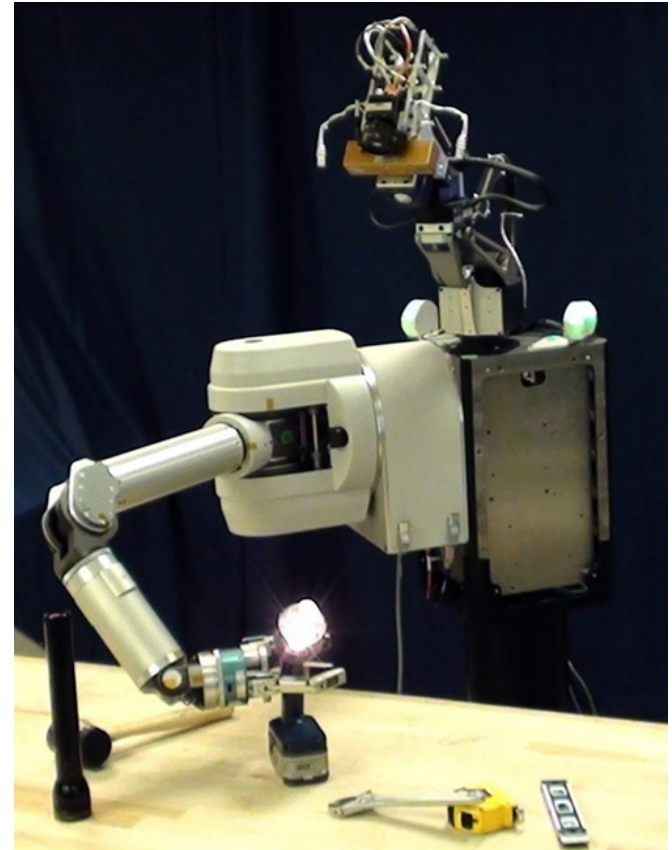


# Example: finding the floor and the table



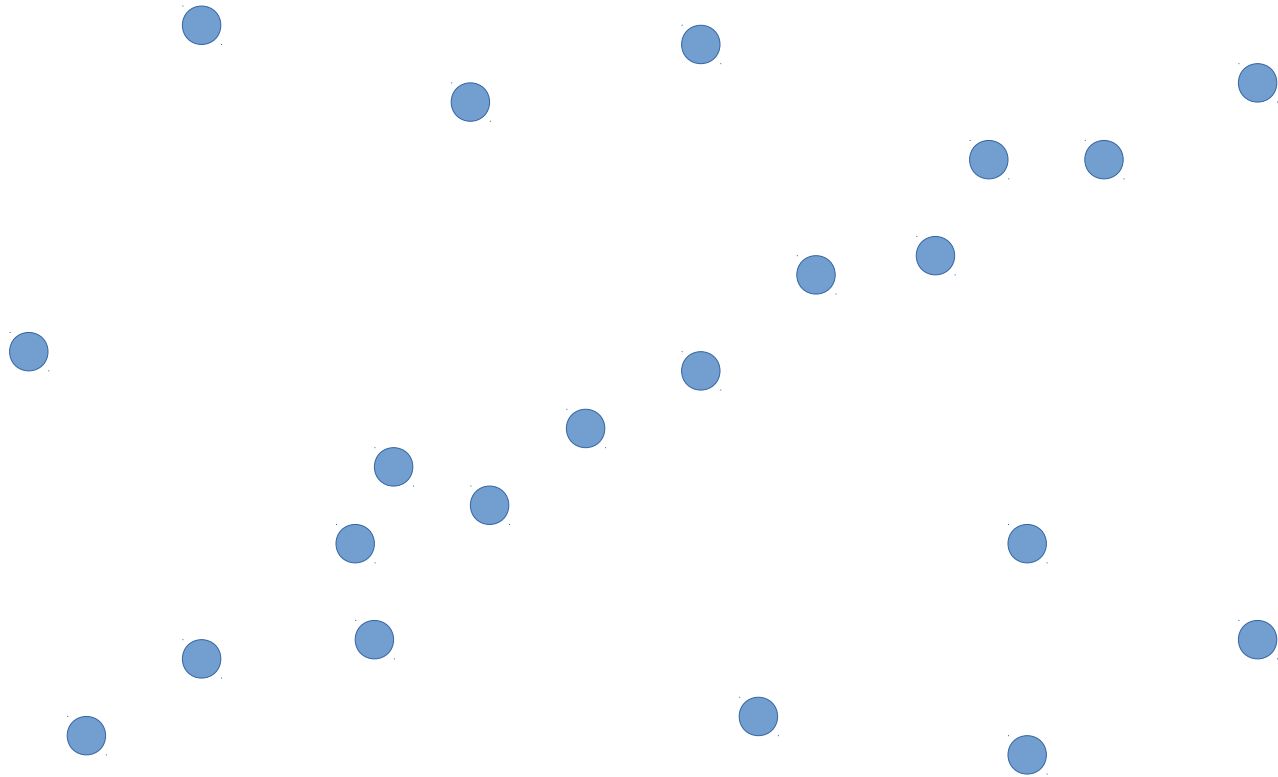


# Robots and Tables

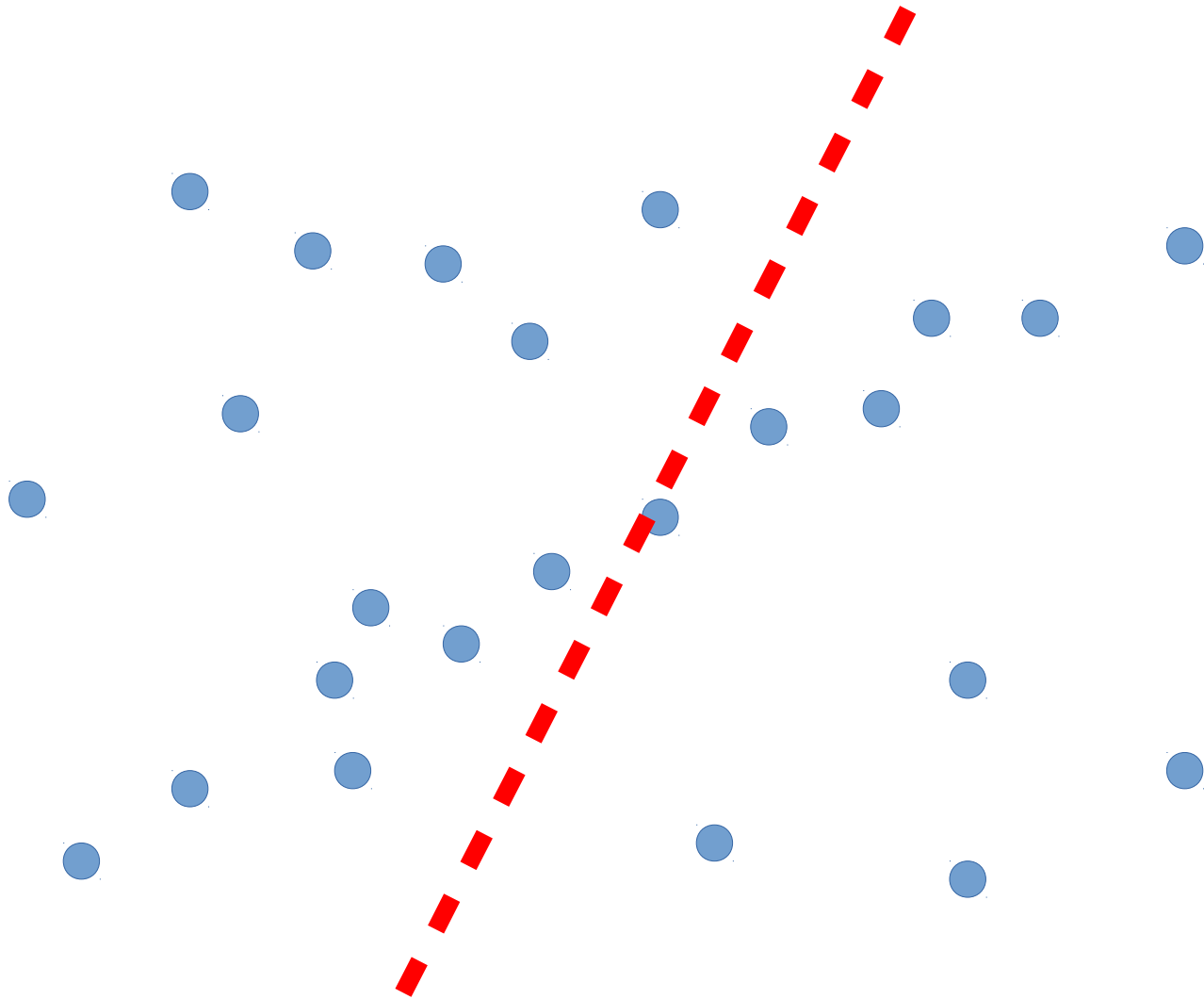




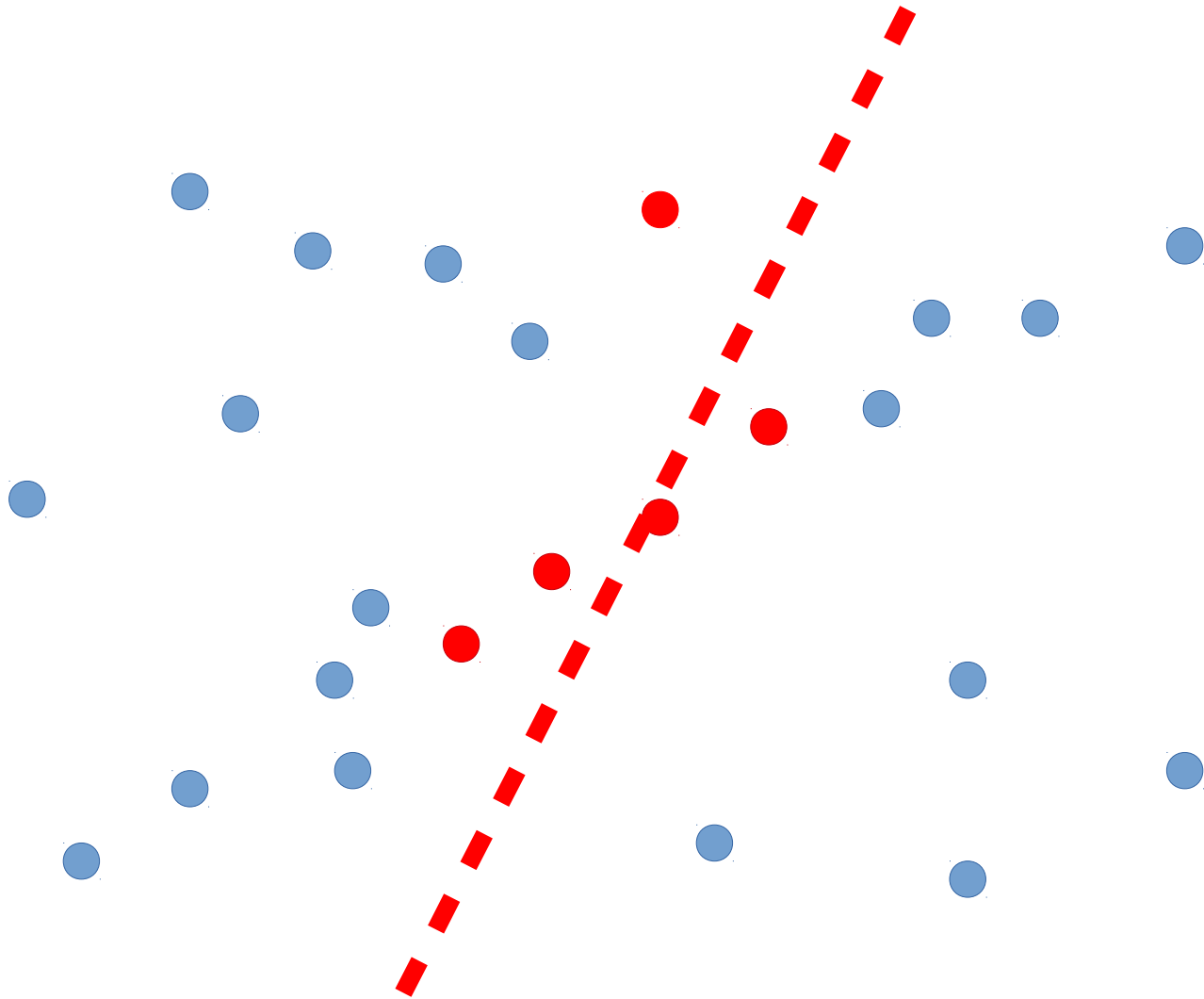
# An Example in 2D



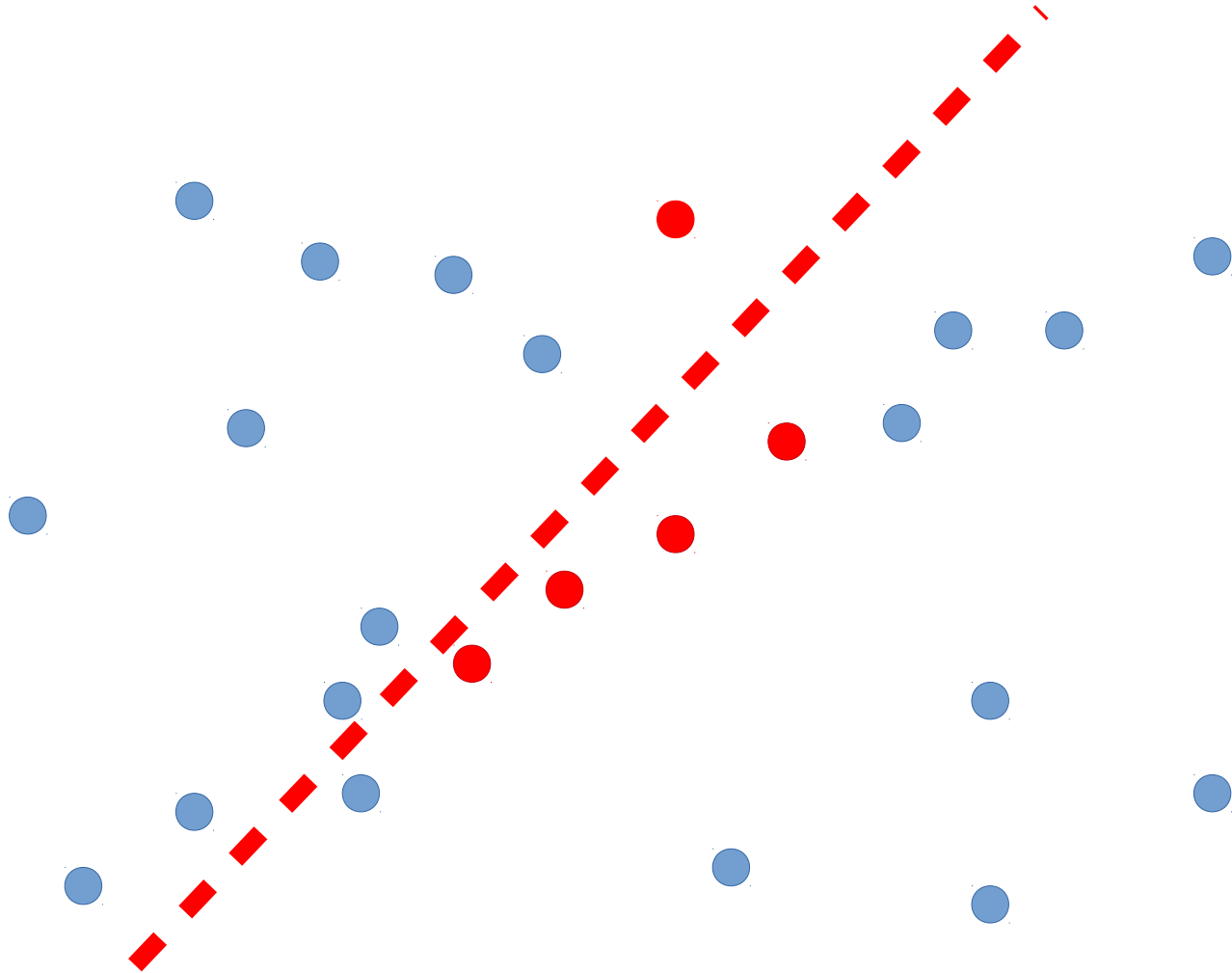
# An Example in 2D



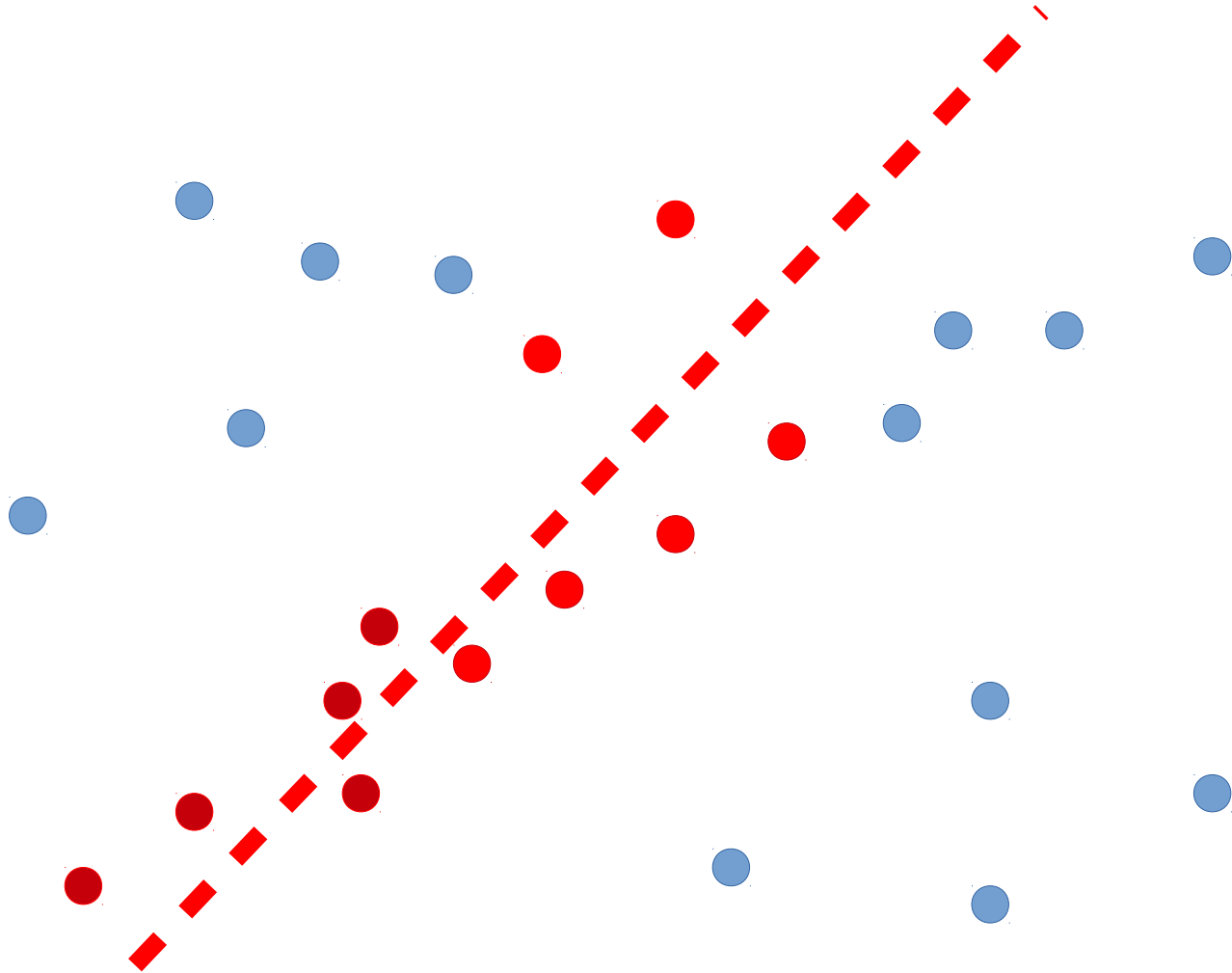
# An Example in 2D



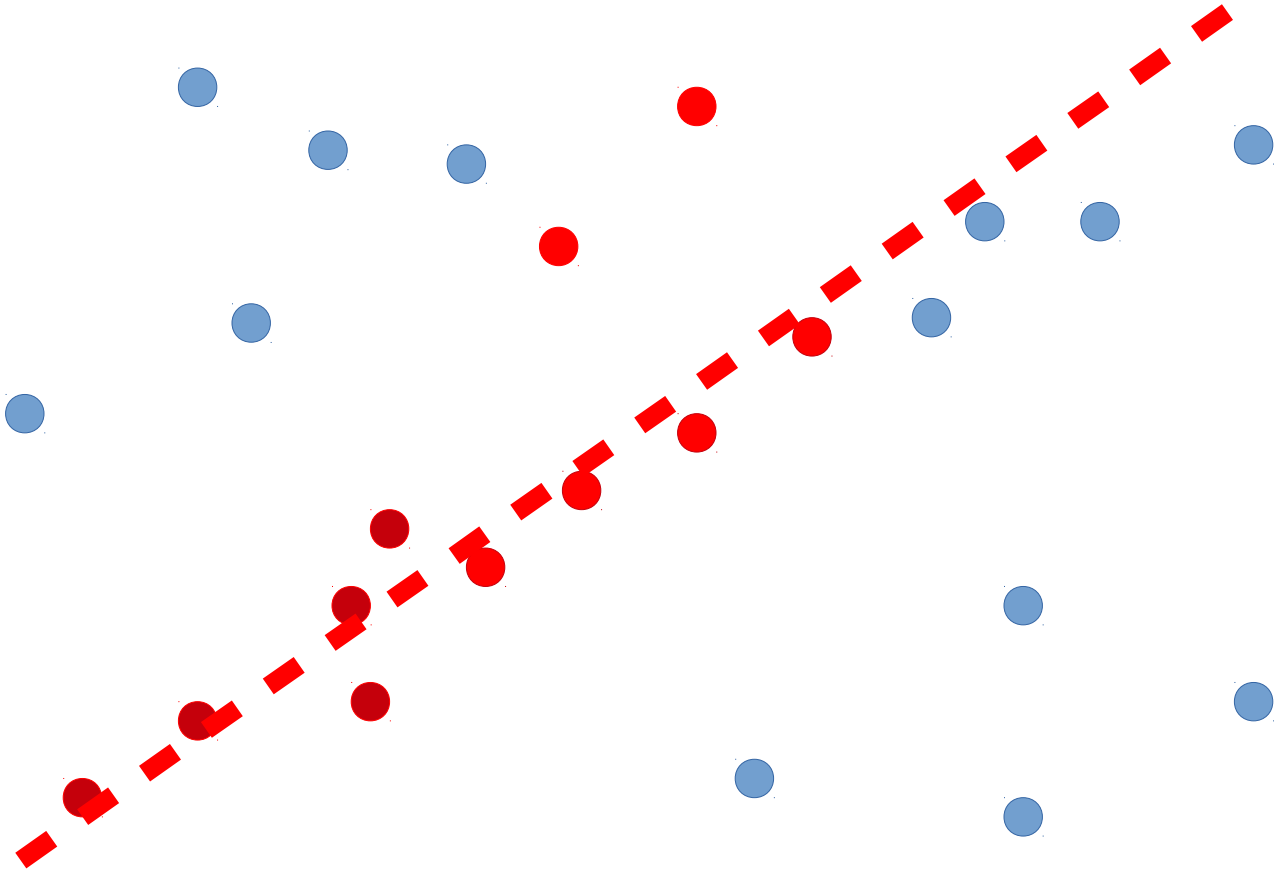
# An Example in 2D



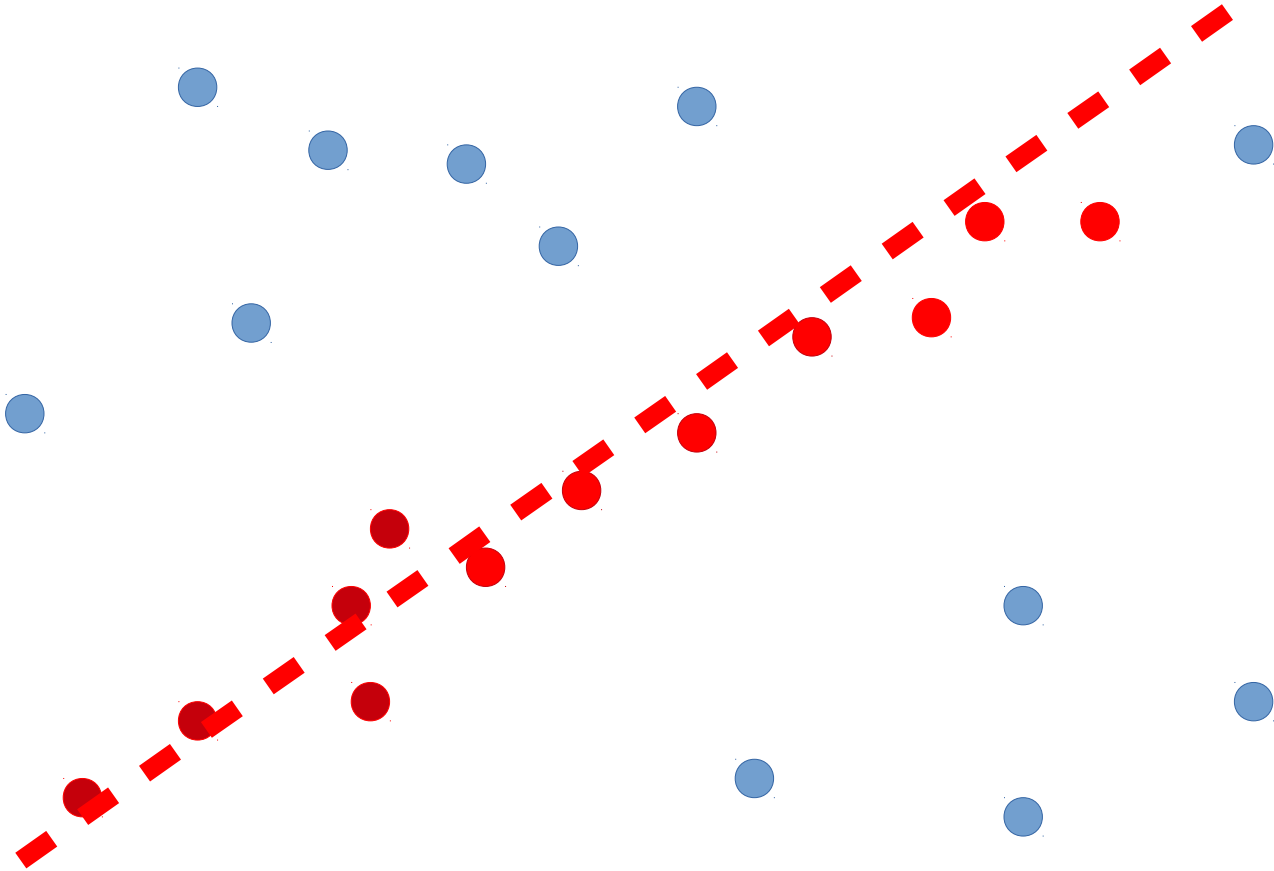
# An Example in 2D



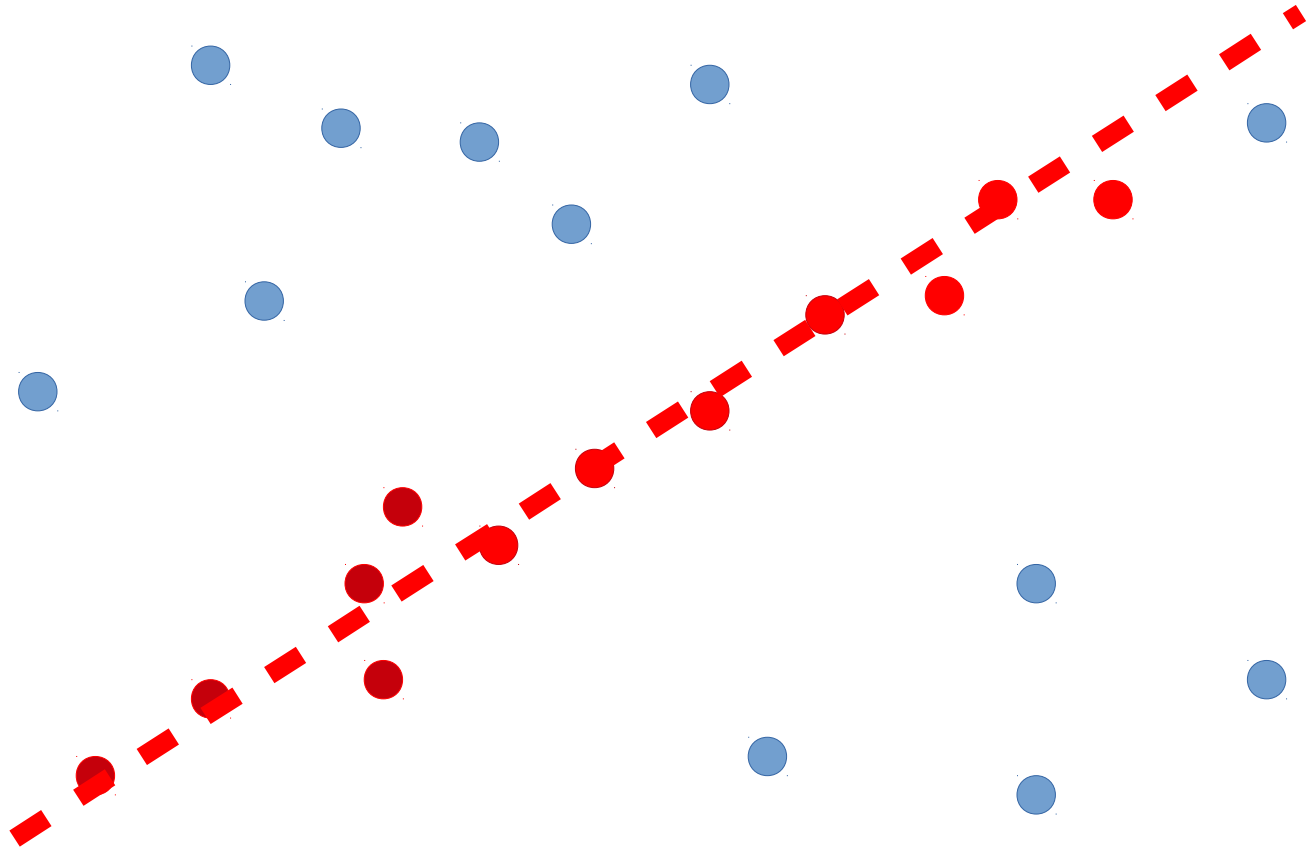
# An Example in 2D



# An Example in 2D

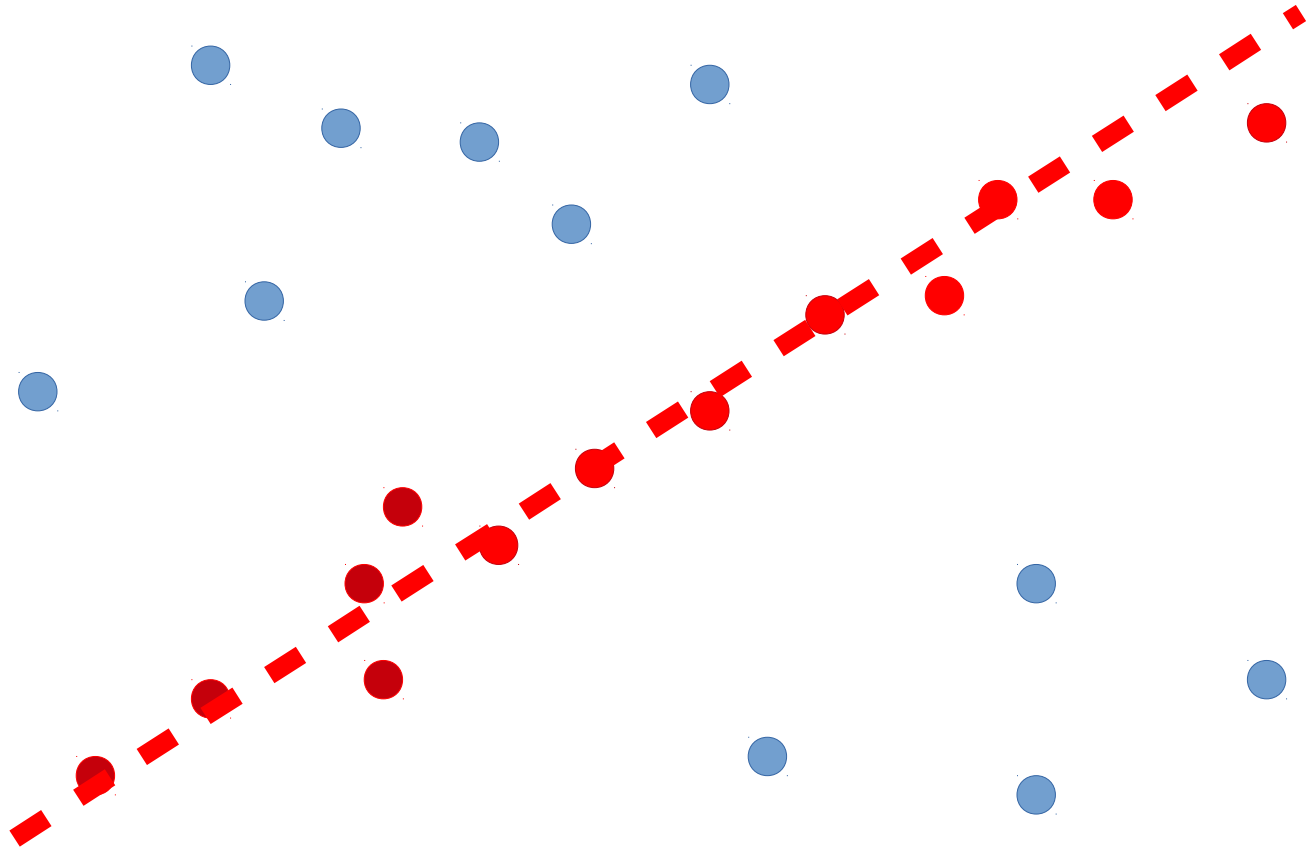


# An Example in 2D

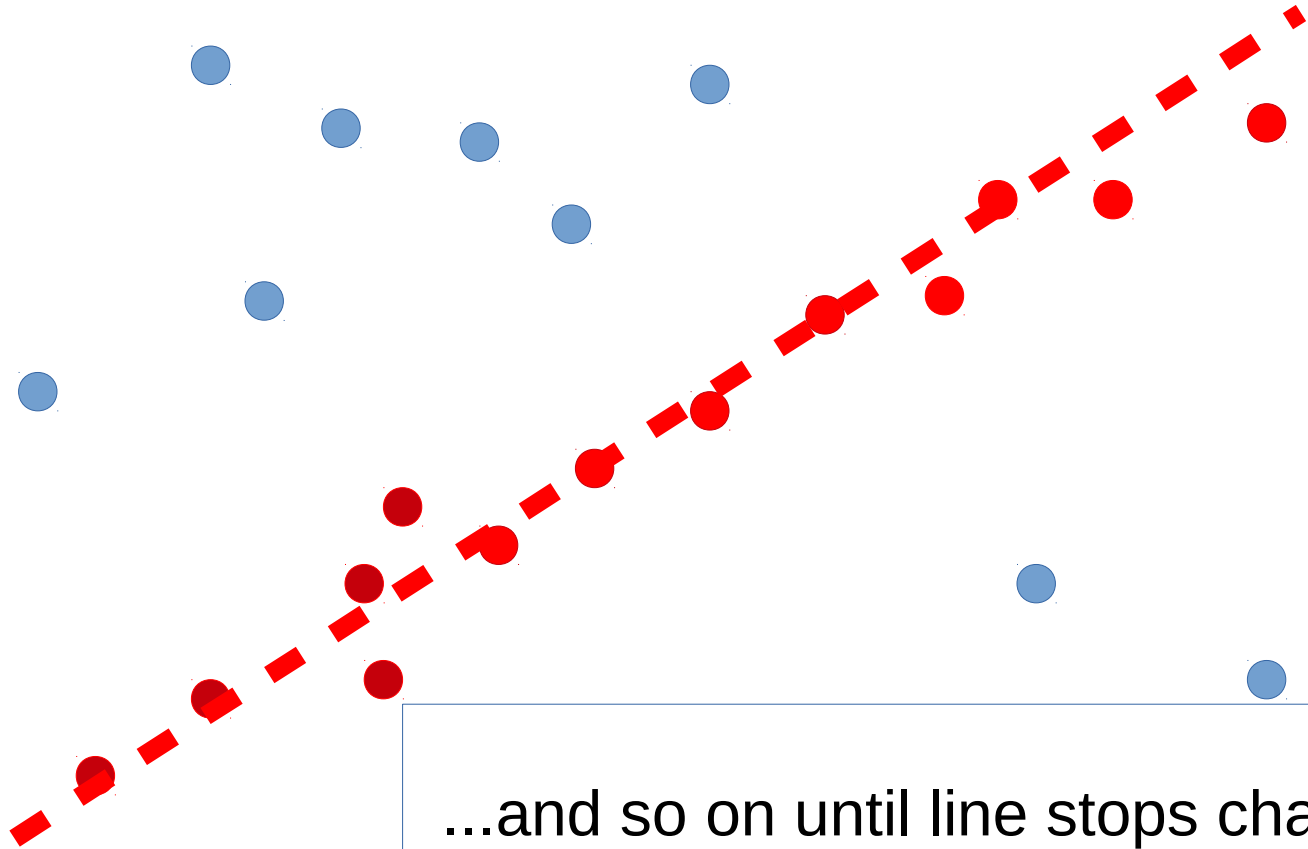




# An Example in 2D



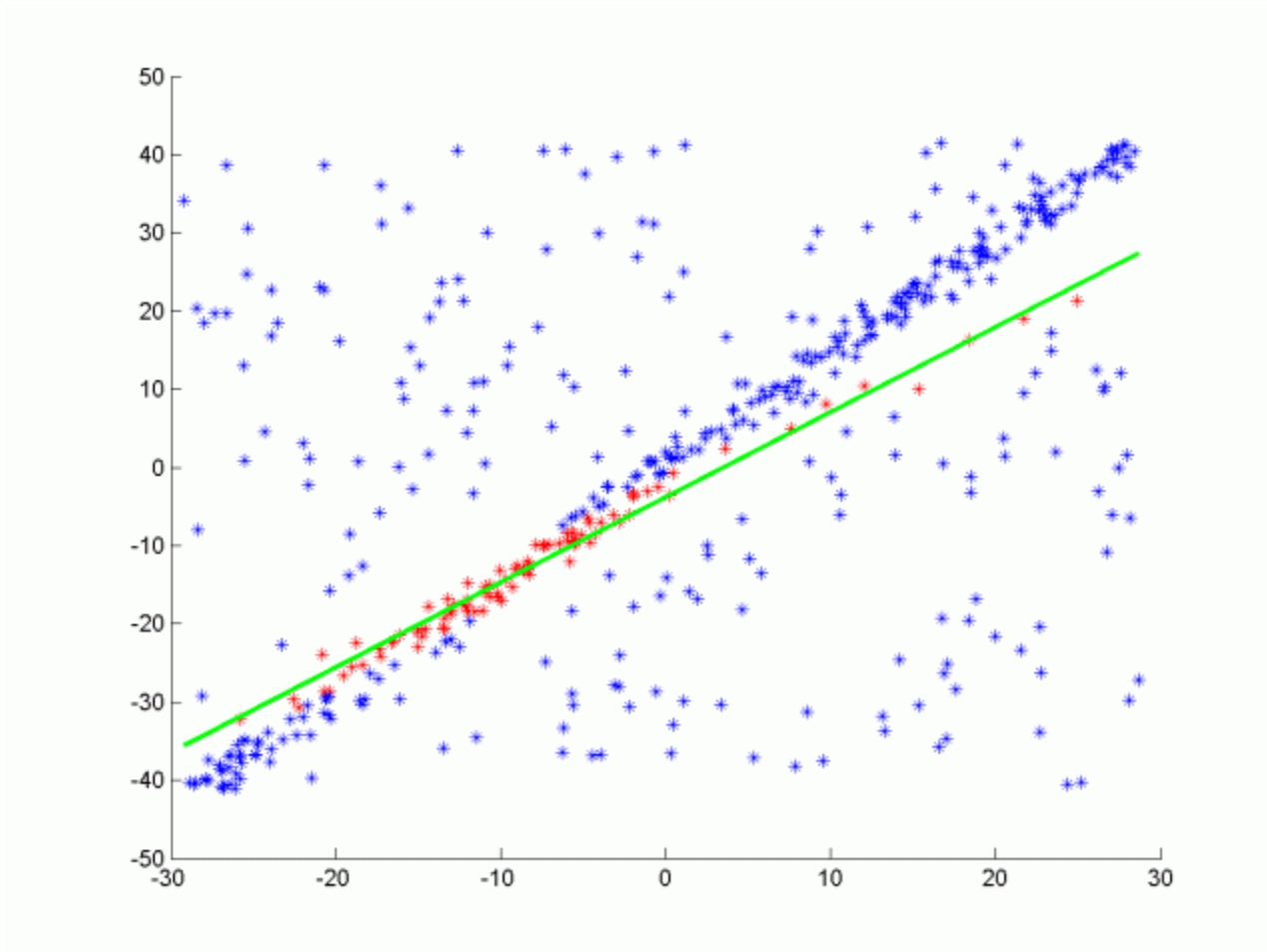
# An Example in 2D



# RANSAC

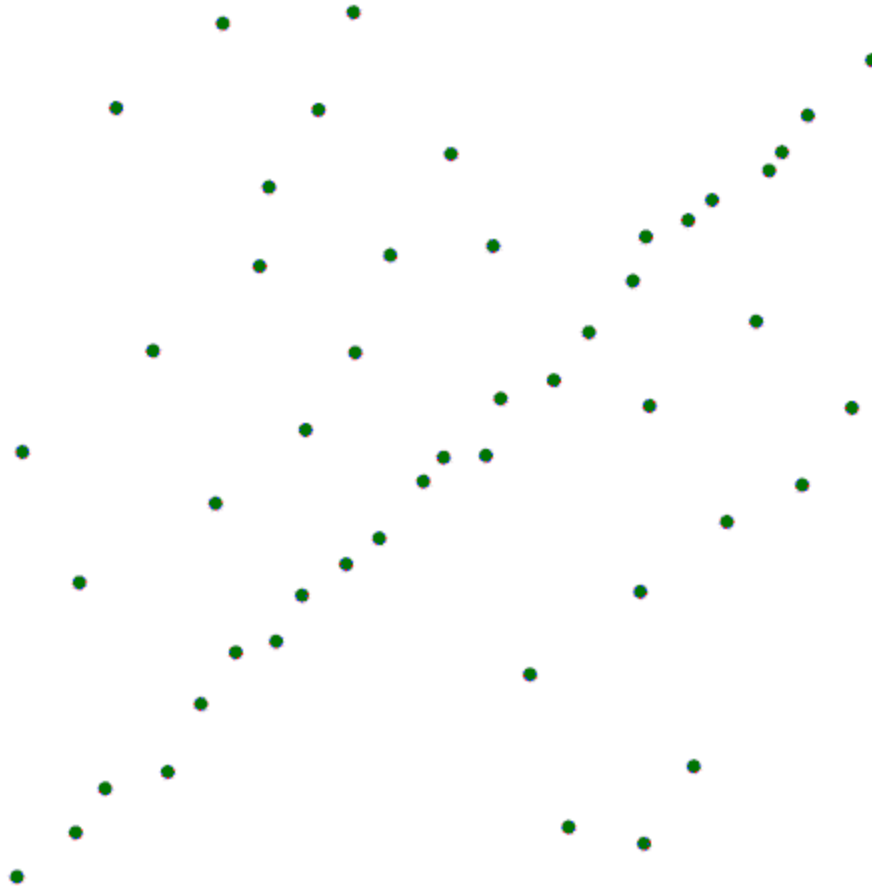
“Random sample consensus (RANSAC) is an iterative method to estimate parameters of a mathematical model from a set of observed data which contains outliers. “ - Wikipedia

# RANSAC



[[https://upload.wikimedia.org/wikipedia/commons/c/c0/RANSAC\\_LINIE\\_Animiert.gif](https://upload.wikimedia.org/wikipedia/commons/c/c0/RANSAC_LINIE_Animiert.gif)]

# RANSAC



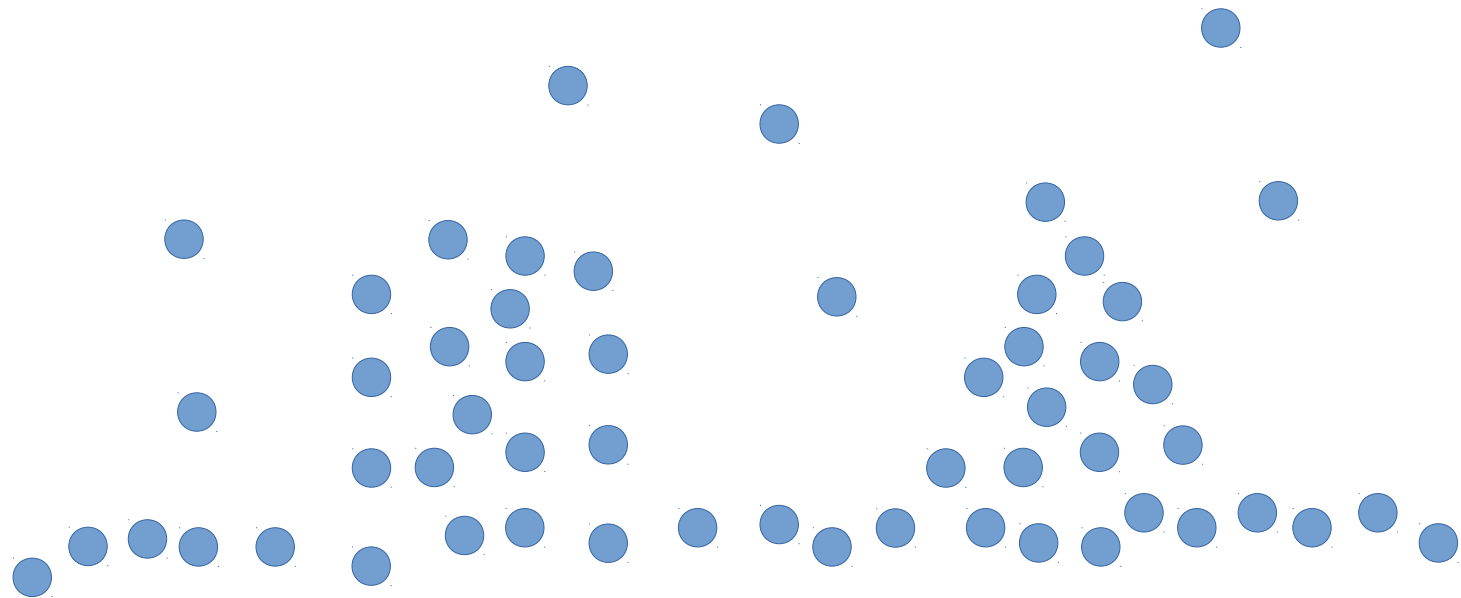
[[http://www.visual-experiments.com/blog/wp-content/uploads/2012/04/ransac\\_line\\_fitting1.gif](http://www.visual-experiments.com/blog/wp-content/uploads/2012/04/ransac_line_fitting1.gif)]

# Finding a plane using RANSAC

# Cylinder Detection with RANSAC

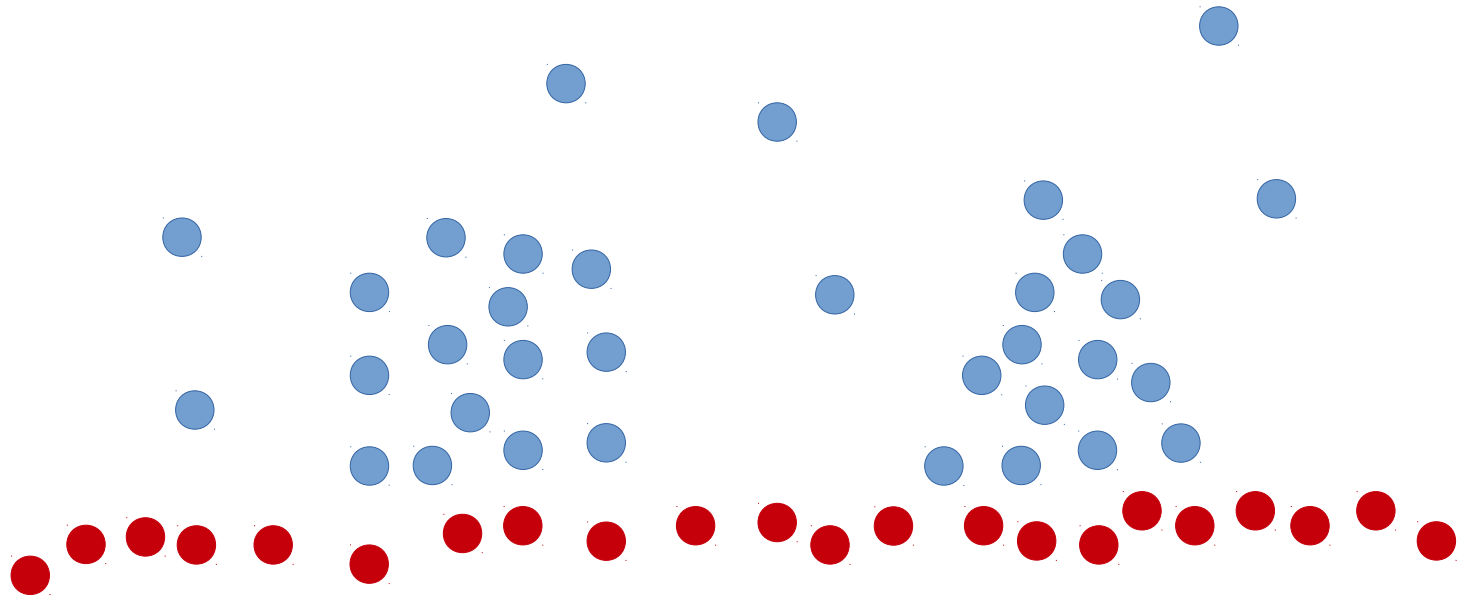
<https://www.youtube.com/watch?v=tasdvsnGCH0>

# Cluster Extraction

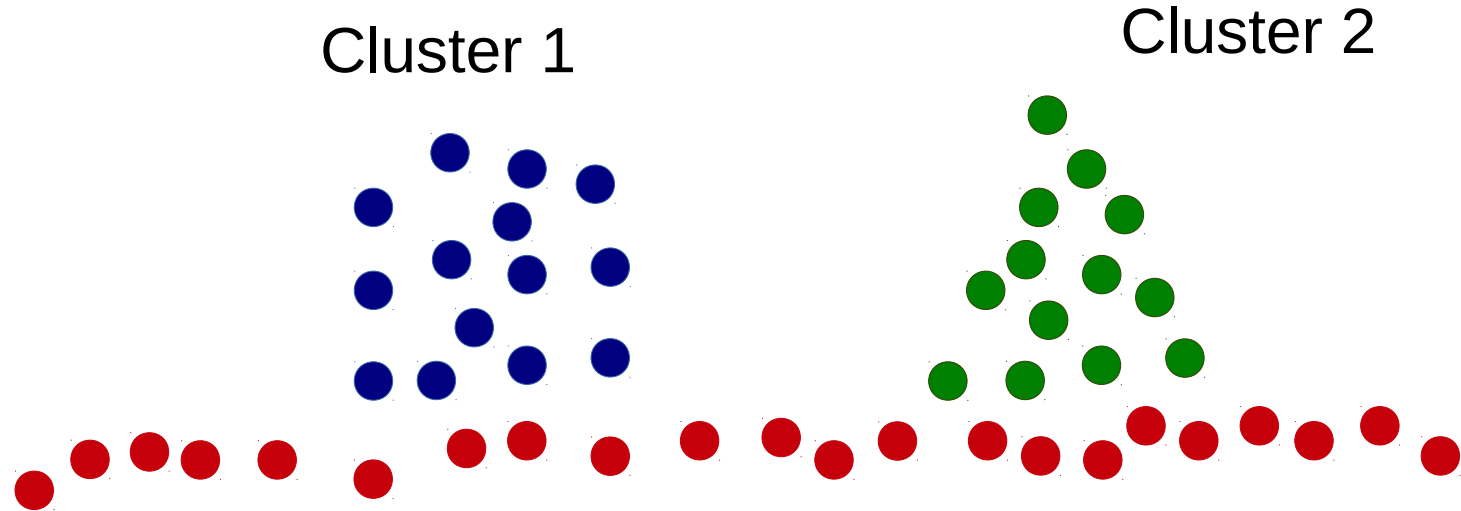




# Cluster Extraction



# Cluster Extraction



# Cluster Extraction in PCL

- Code example

# Further Applications

- Obstacle Detection:
  - <https://www.youtube.com/watch?v=jHKzBMKk4hY>
- Tracking 3D objects:
  - <https://www.youtube.com/watch?v=NzRME9ZEOnY>

# Resources

- Main website: <https://ointclouds.org>
- Tutorials:  
<http://pointclouds.org/documentation/tutorials/>
- API: <http://docs.pointclouds.org/1.7.2/>
- Blog: <http://pointclouds.org/blog/>





THE END



