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S0088
Point Cloud Library (PCL) on CUDA

Radu B. Rusu @ Open Perception
Michael Dixon @ Willow Garage

PRESENTED BY NVIDIA.

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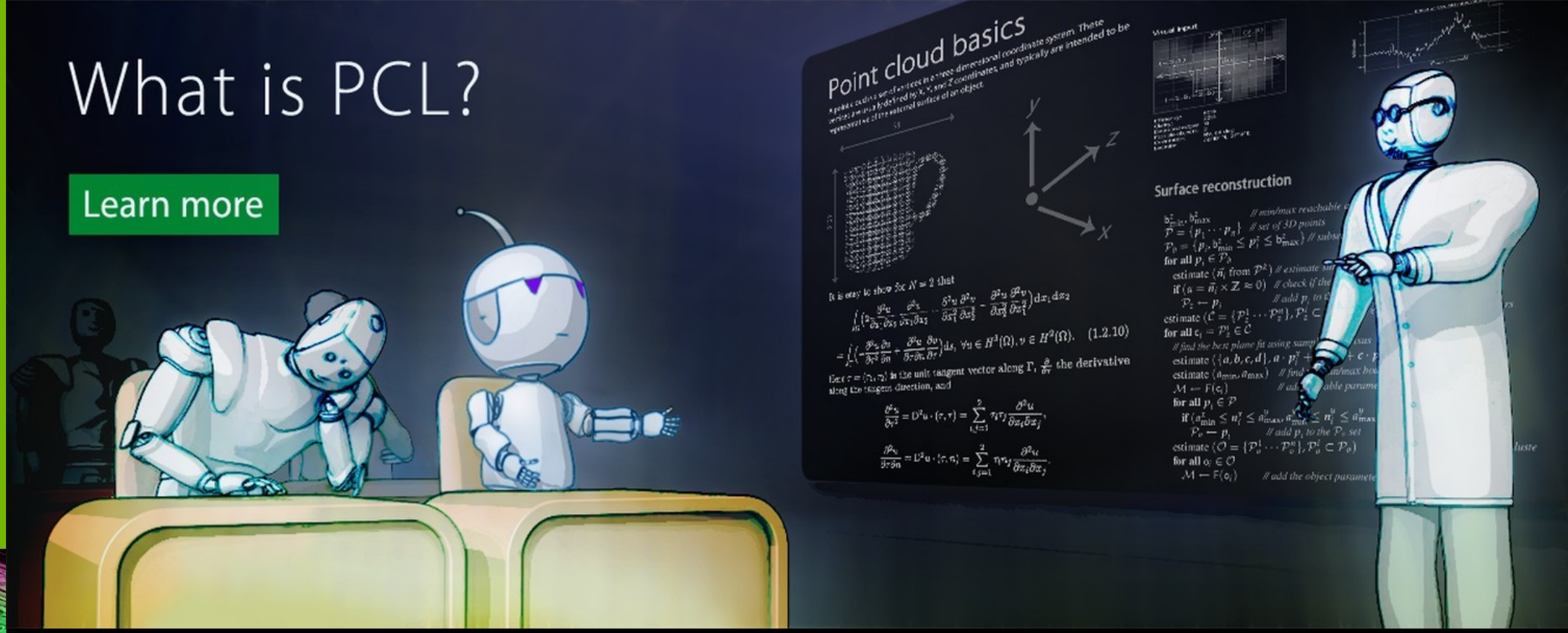
What is PCL?

Learn more



- General overview on PCL – Radu
- CUDA optimizations for KinFu and KinSkel - Michael

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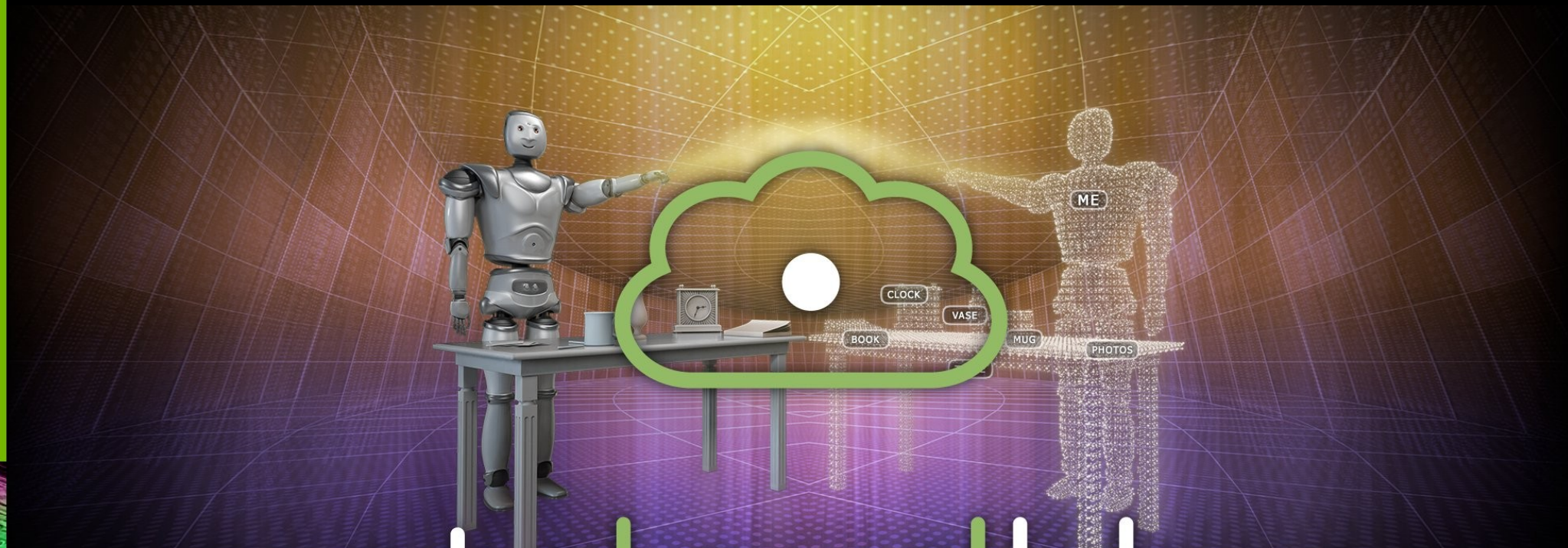

pointcloudlibrary

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Point Cloud Library (PCL)

- large scale, collaborative, open project for 2D/3D processing
- BSD licensing, free for commercial use
- 350 developers and contributors, many thousands of users

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Why 3D?

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Why 3D?

- Because the world is not 2D

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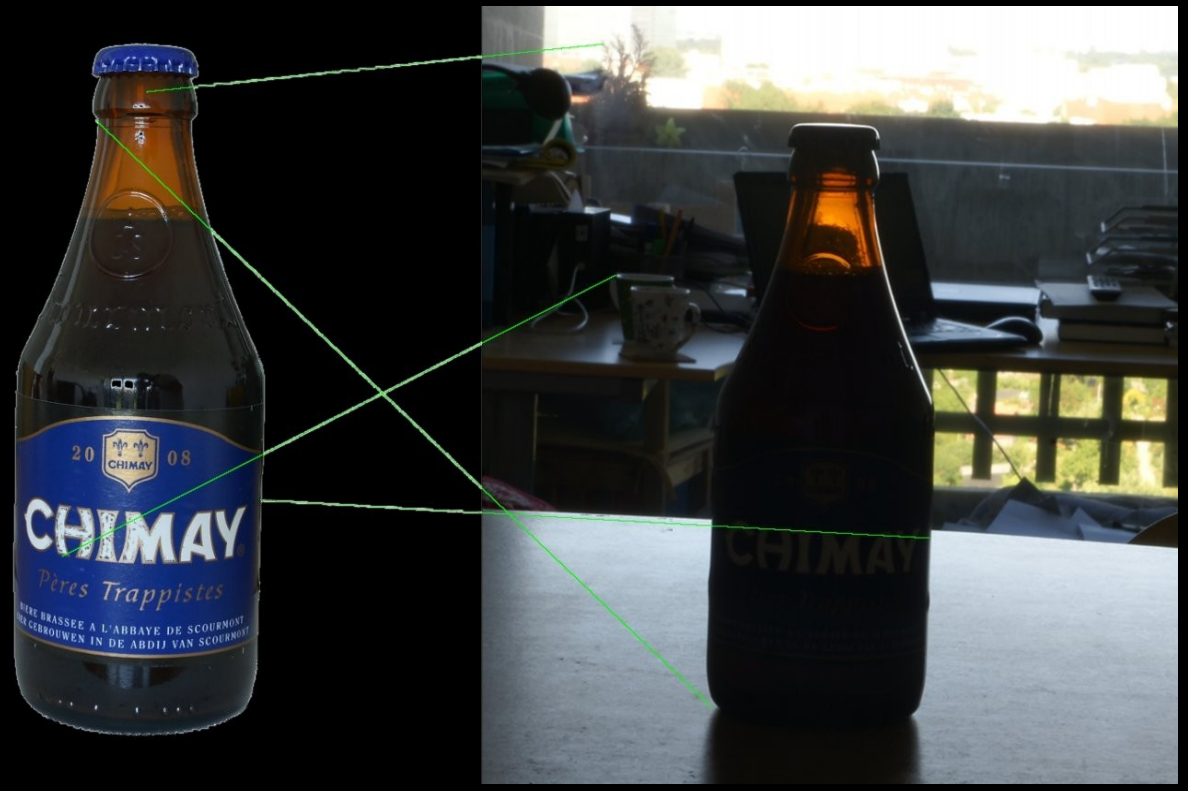
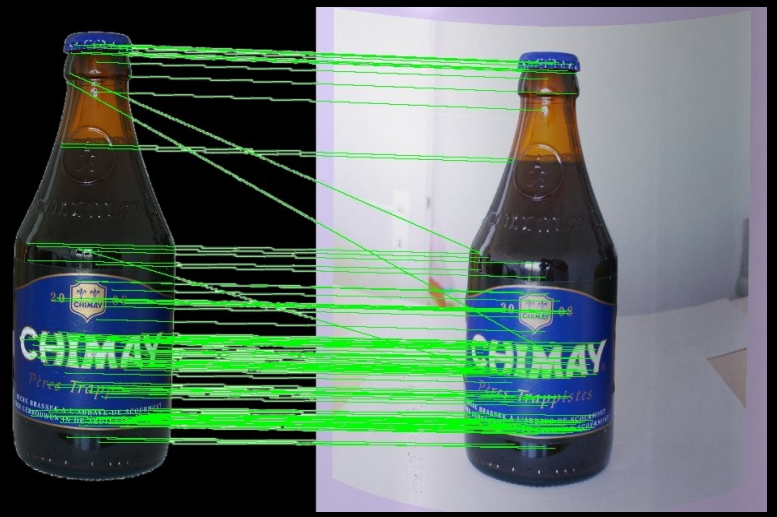
Why 3D?

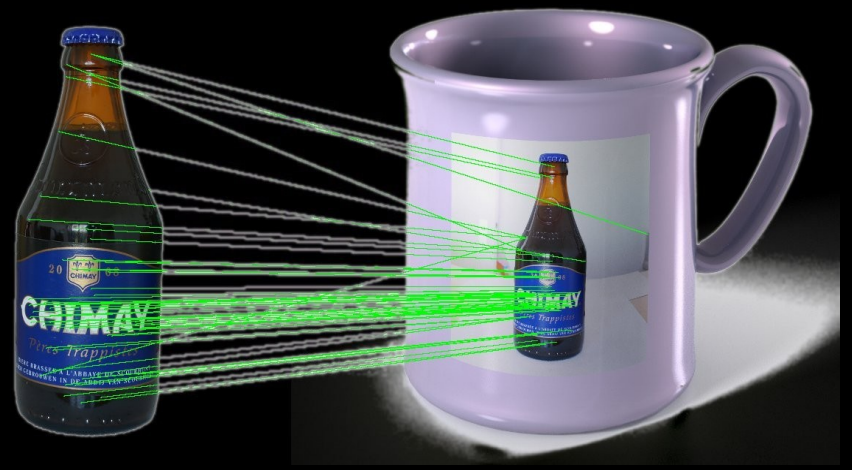
- Because 2D imagery is **useless** in certain conditions

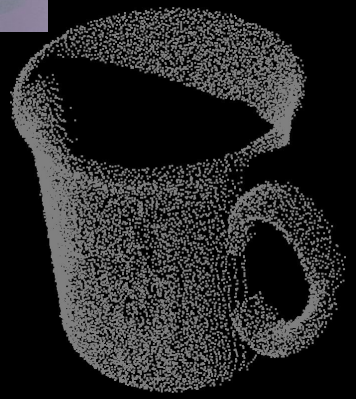


Why 3D?

- Because 2D imagery doesn't always infer good semantics

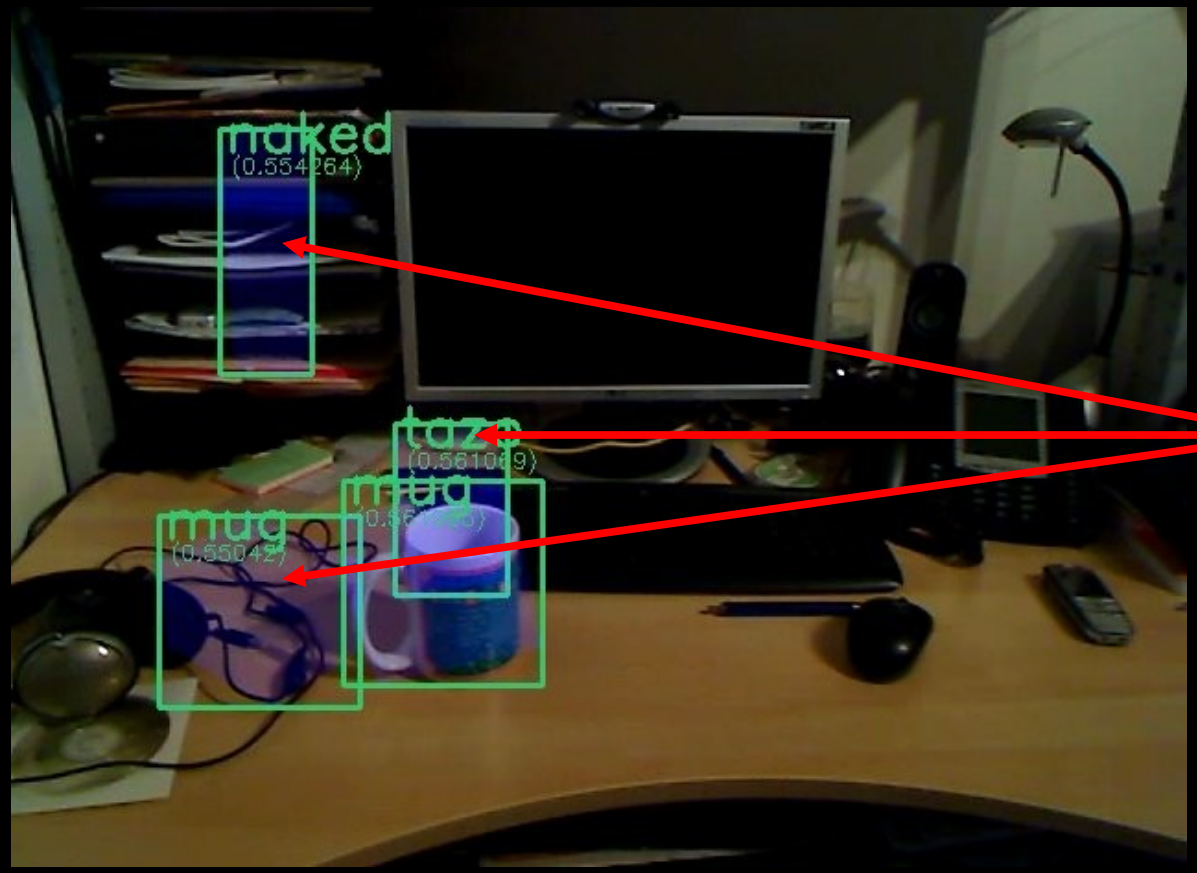






Why 3D?

- Because 2D imagery is just a … 2D projection



2D matching failures

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3D

50% better than 2D

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Three-dimensional data

- Point Cloud = collection of 3D points
  - 3D is really more like nD

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What

can we do with Point Clouds?

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Applications of Point Clouds

- Point clouds enable very cool applications
- We are trying to solve extremely hard problems

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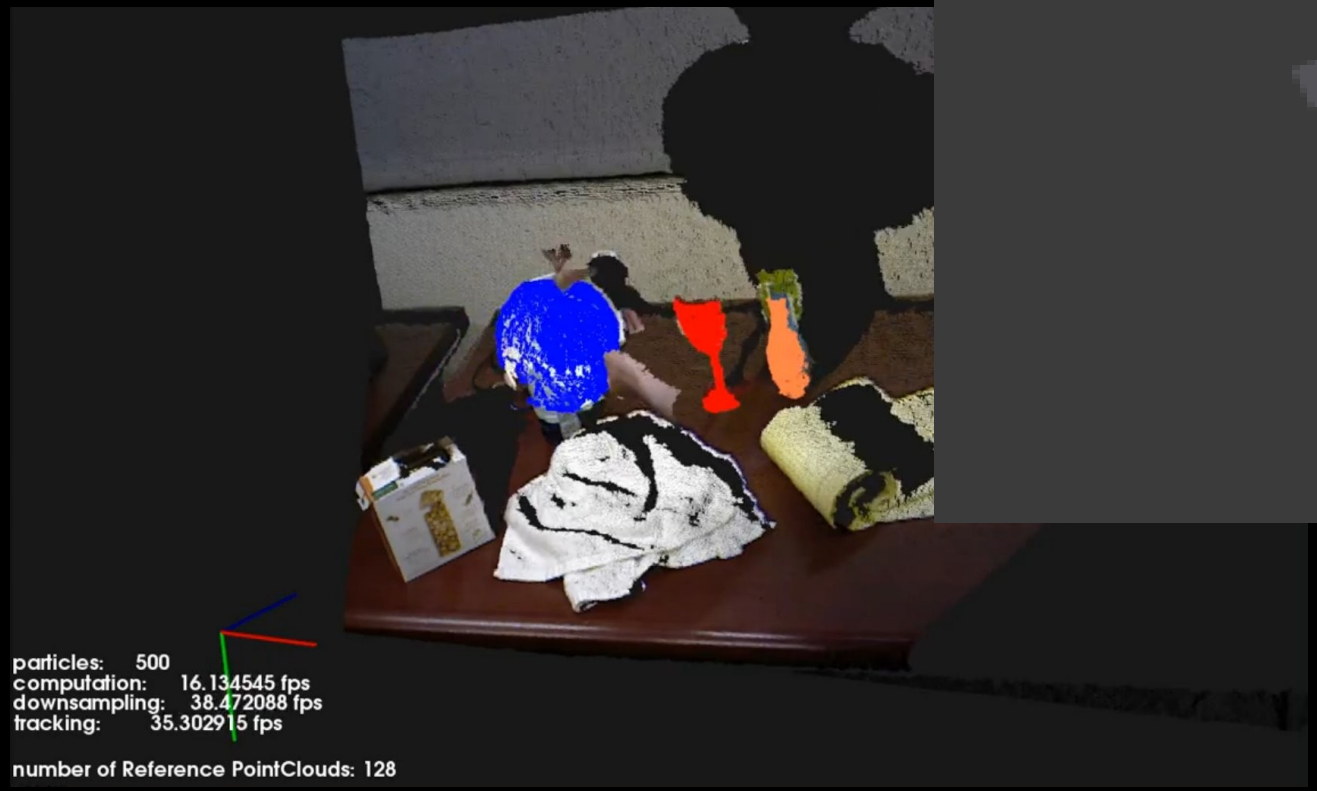

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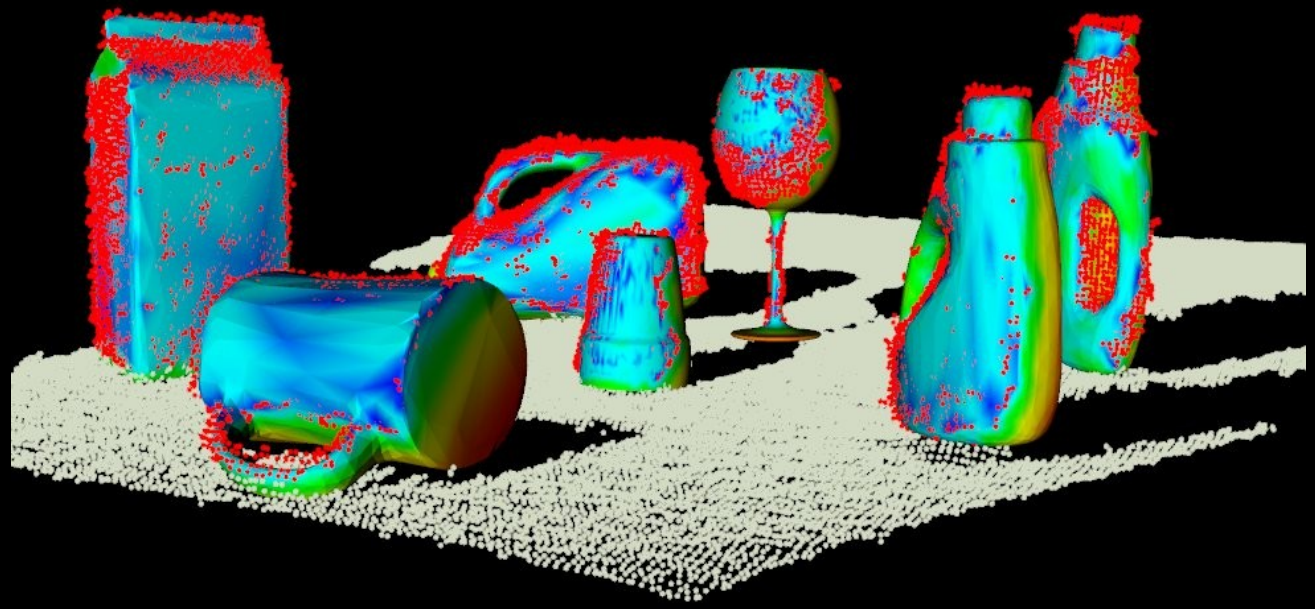

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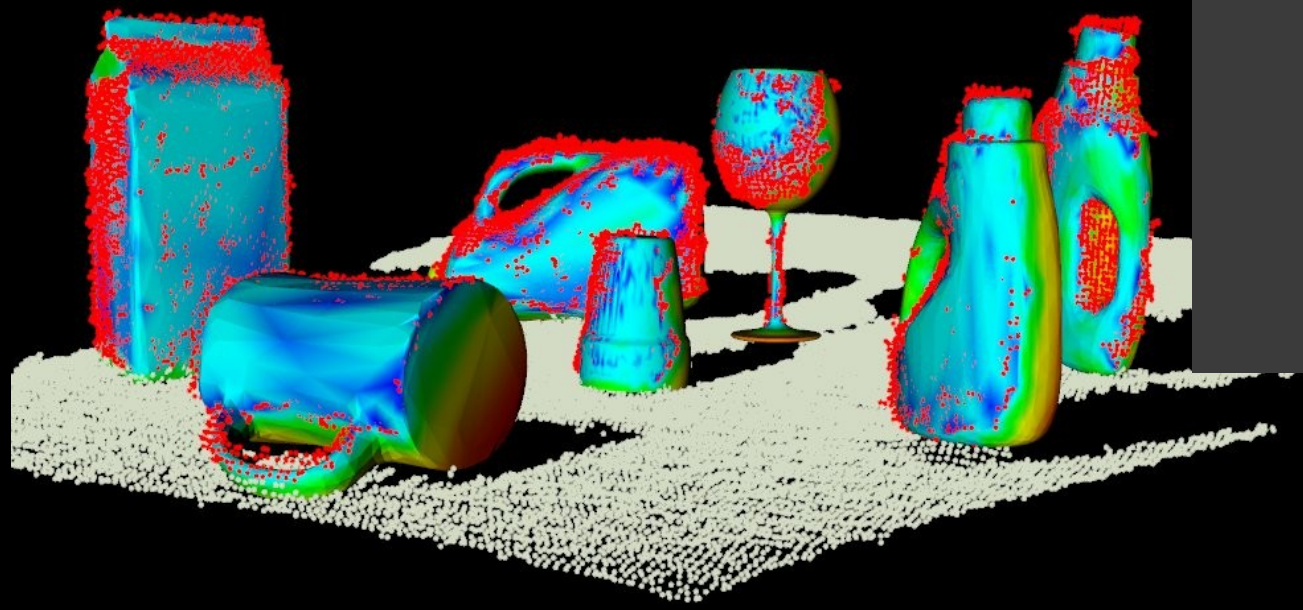

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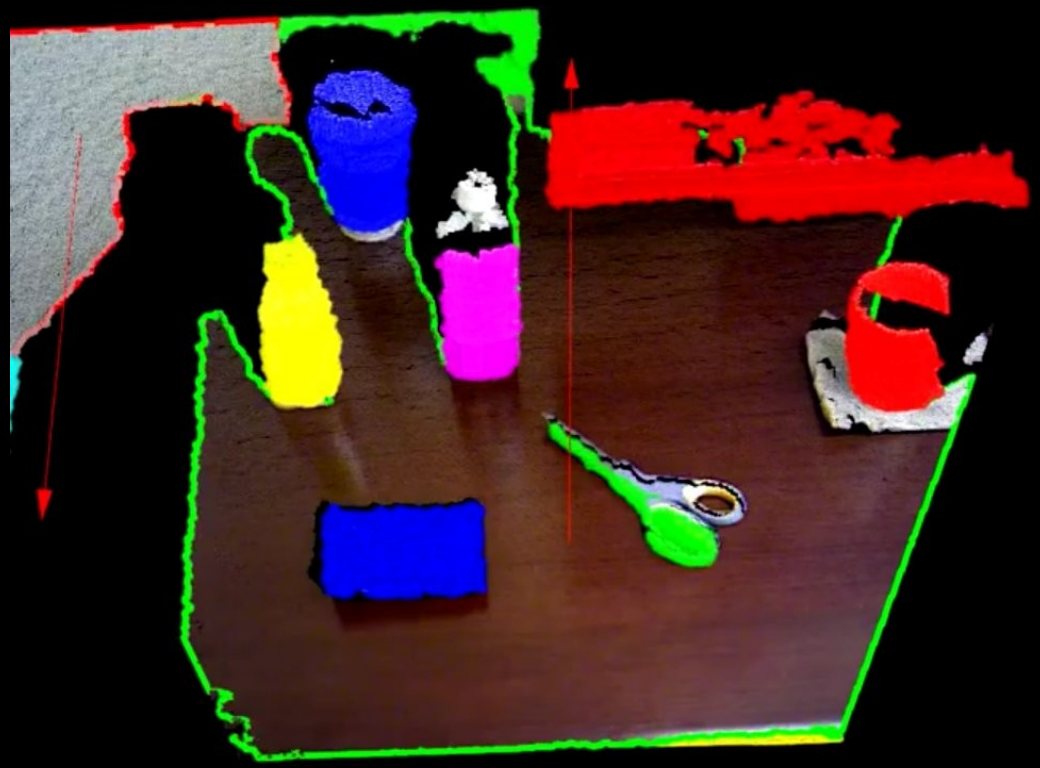

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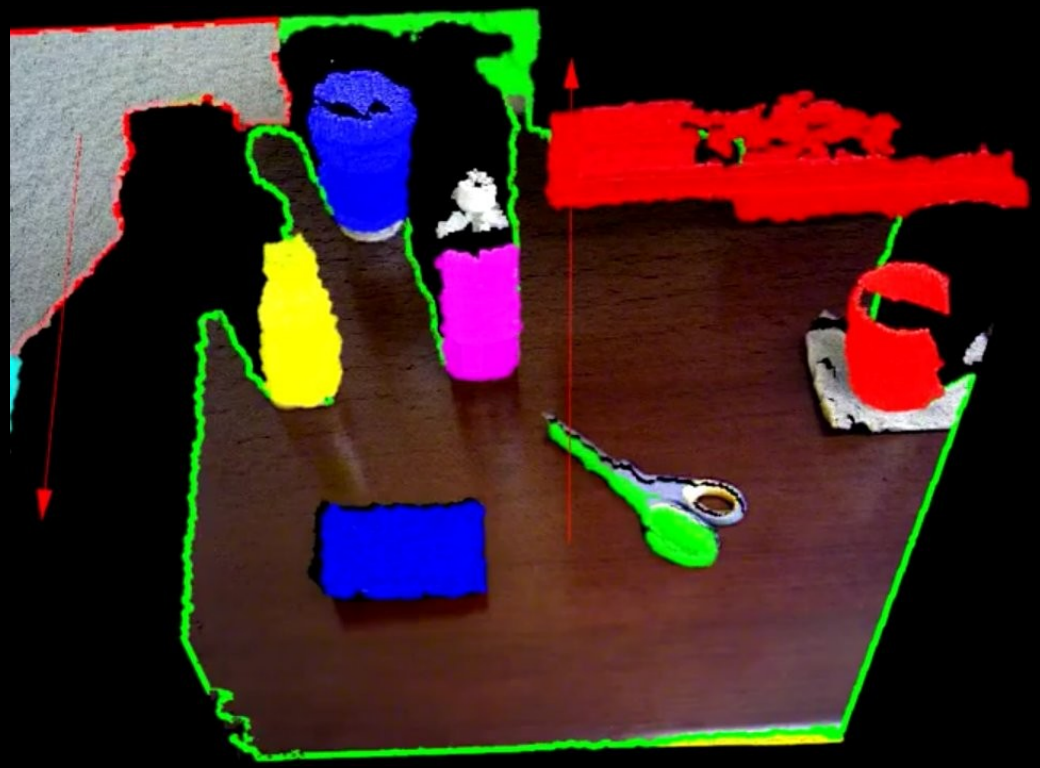

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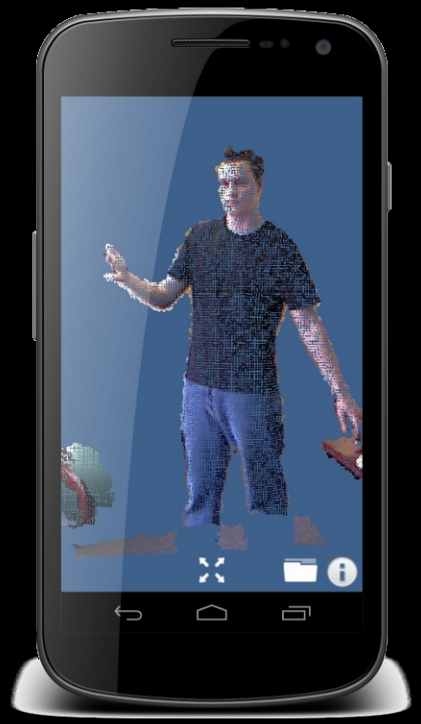

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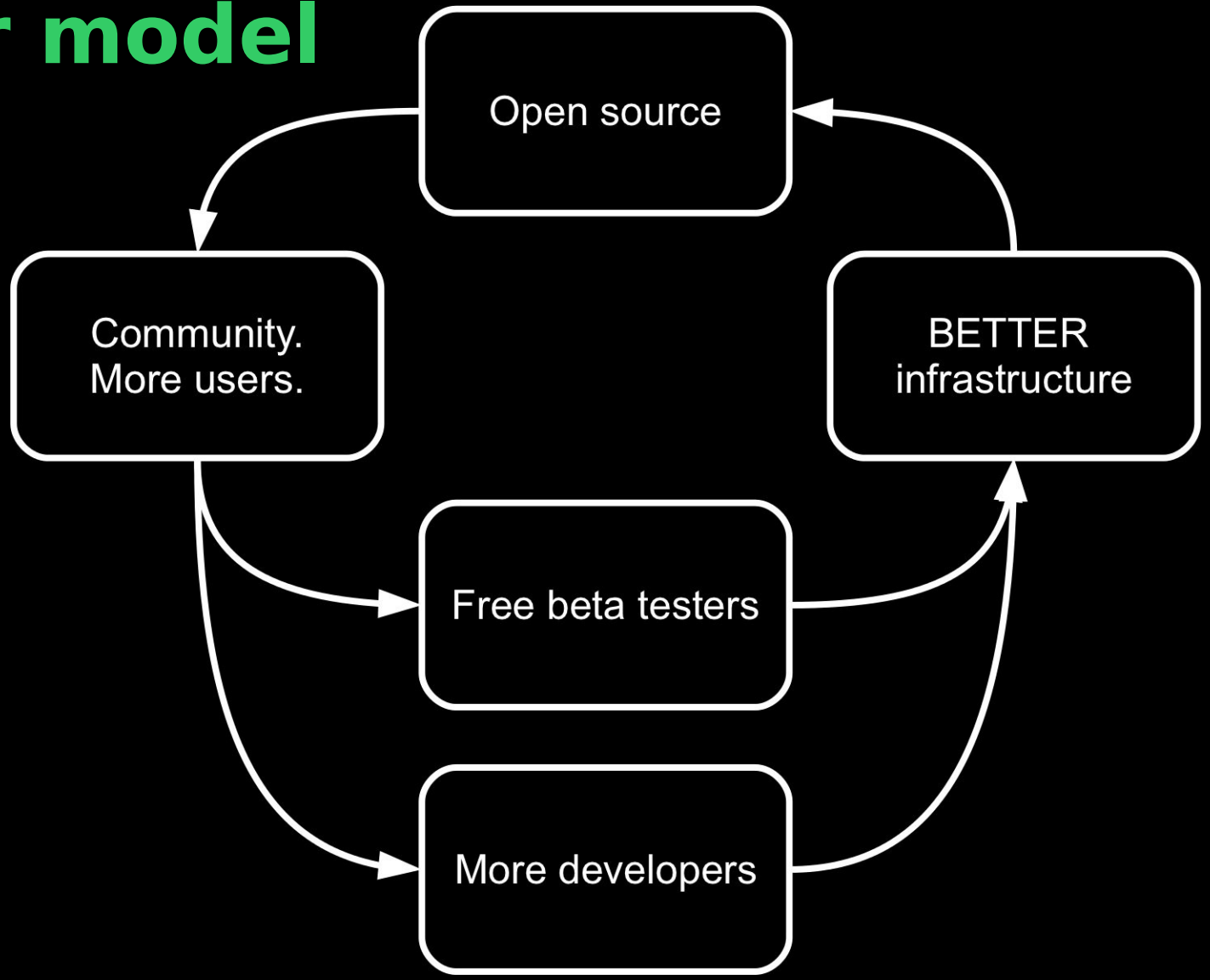
Our model



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Commercial partnerships

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Current sponsors

Willow Garage

NVIDIA

Google Summer of Code 2012

Trimble

TOYOTA

Urban Robotics

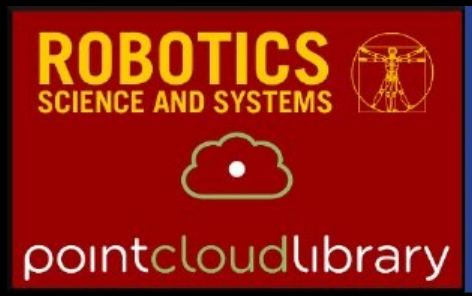
Sandia National Laboratories

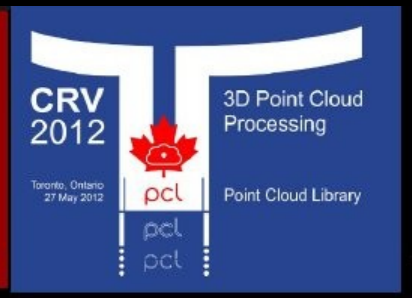
NASA

HRI

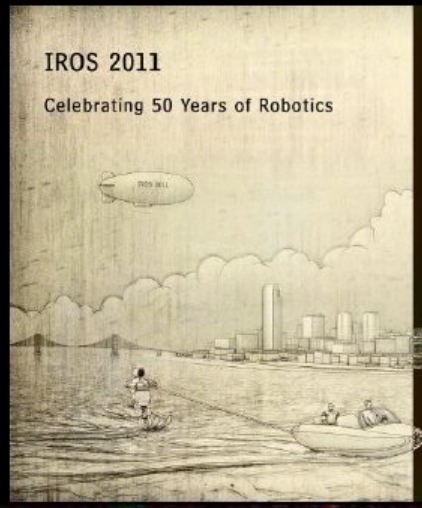
http://pointclouds.org/blog

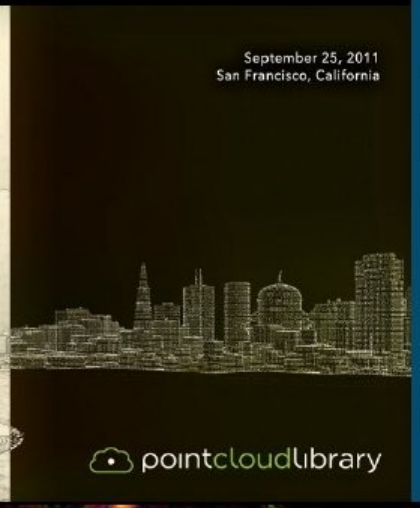
Tutorials

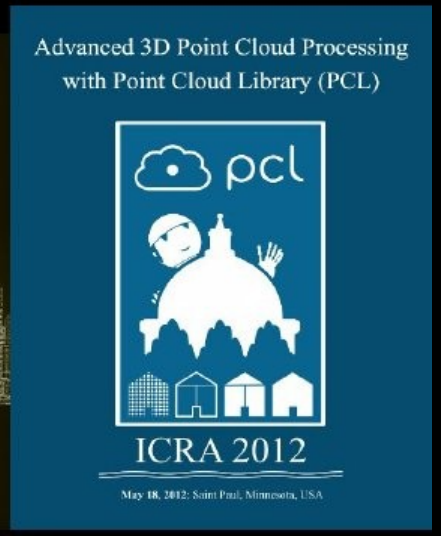




Advanced 3D Image Processing
with Point Cloud Library







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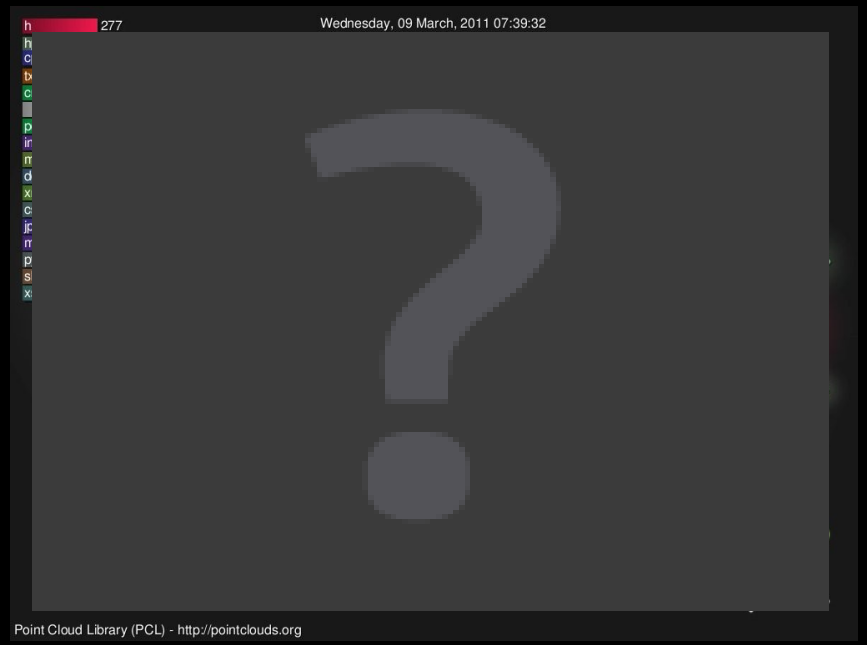
OSS 2011 challenge first prize

24/7 development



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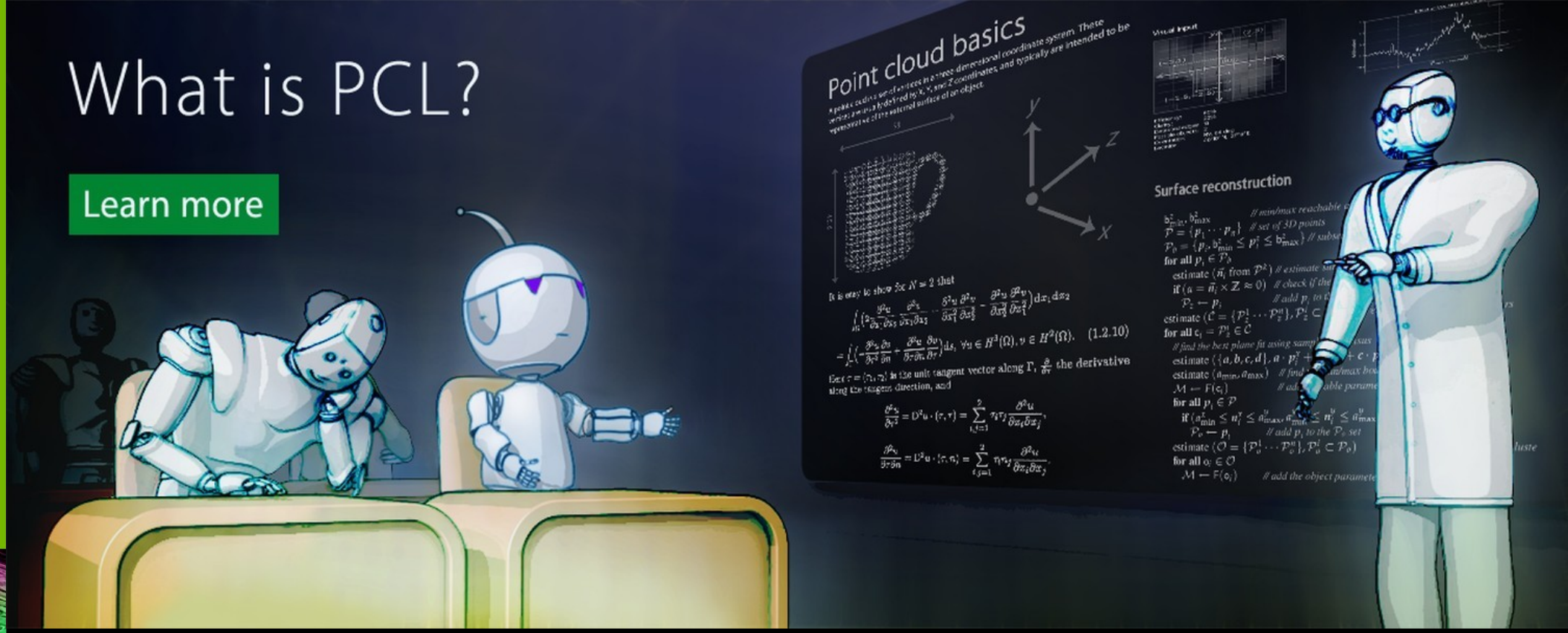
What is PCL?

Learn more



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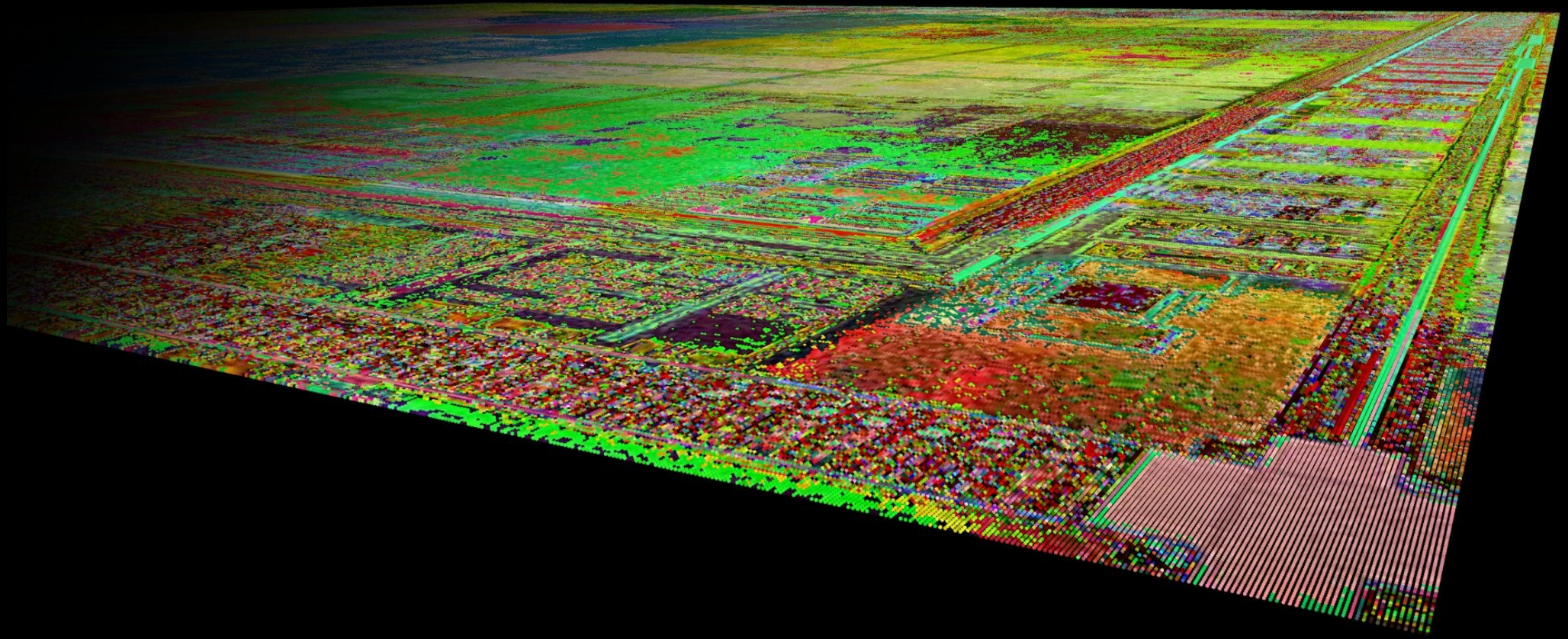

- Extremely large speedups with CUDA processing!
  - depth to cloud assembly: 10x
  - 3D feature estimation: 50-500x
- We are enabling research otherwise not possible!

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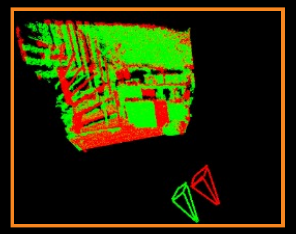
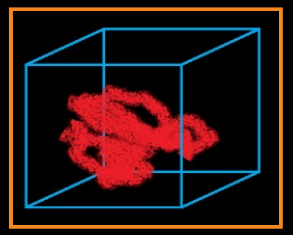
Kinect Fusion

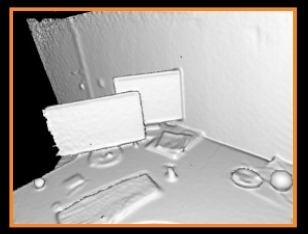
first open source implementation

Cloud & Normals → Camera tracking (frame-to-model) → Volumetric integration → Ray casting



model





References:

– R.Newcombe at all, “Kinectfusion: Real-time dense surface mapping and tracking”. In ISMAR, IEEE, 2011.

Kinect Fusion – camera tracking ICP

- Want to compute: α, β, ϒ, tx, ty, tz
- At each iteration
  - Find matching points between two frames in parallel
  - Cost: Sum of point-to-plane distances for all matching pixels

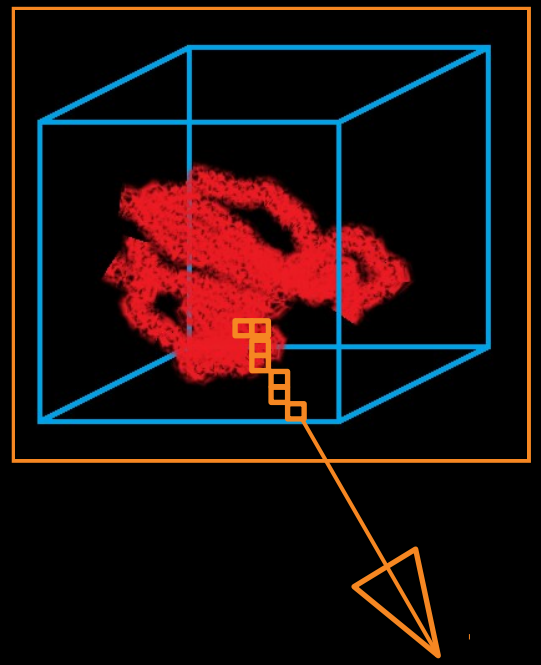
  - Lest squares problem Ax = b (6x6)
  - Coefficients are computed using standard GPU reduction
  - over 640x480 pixels, next linear system is solved on CPU

Kinect Fusion – volume integration

- Voxel grid 512x512x512 (voxels contain avg. distance to surface)

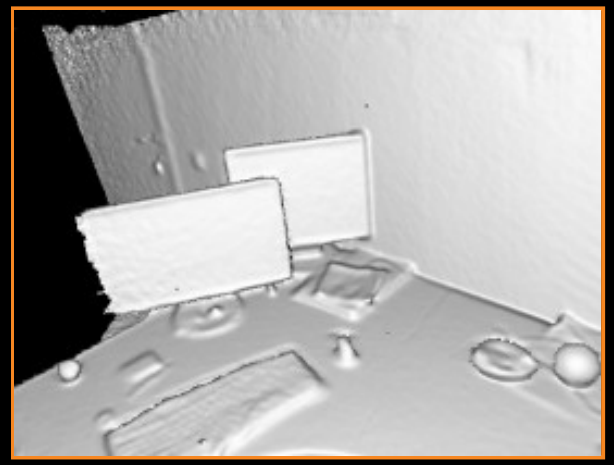
Know current distance measurements
- for all voxels in camera frustum

- For each voxel in parallel on GPU
  - Project voxel to Kinect image
  - Get depth from pixel and update voxel value (using running average)



Kinect Fusion – parallel raycasting

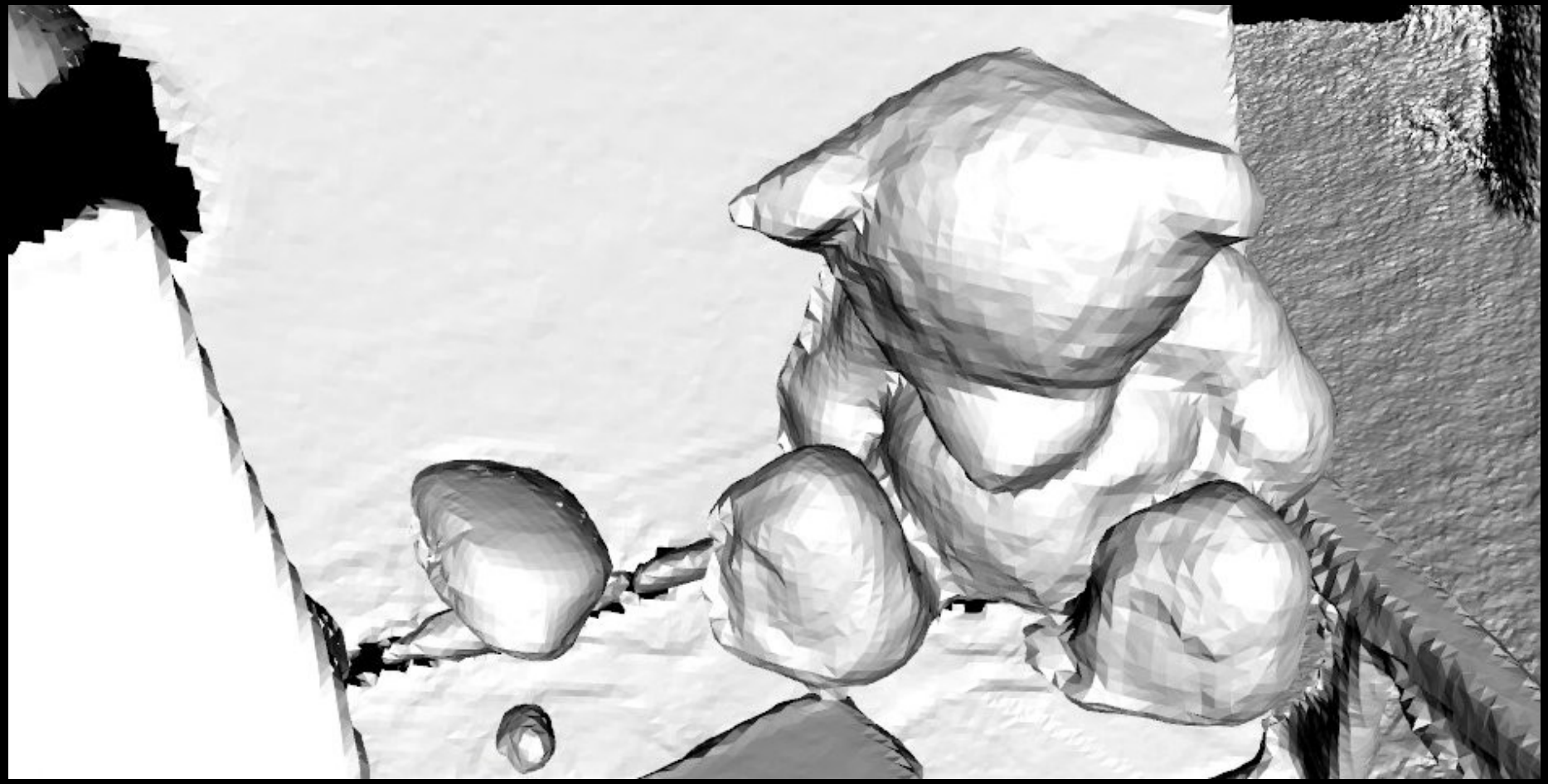
- Want to measure exact distance to surface for each pixel from current camera position.



- For each pixel in parallel on GPU
- Ray is traced through integration volume
  – until surface intersection

Output is noise-less and much more precise than frame from Kinect (because volume contains averaged data from different positions)

Kinect Fusion – demo



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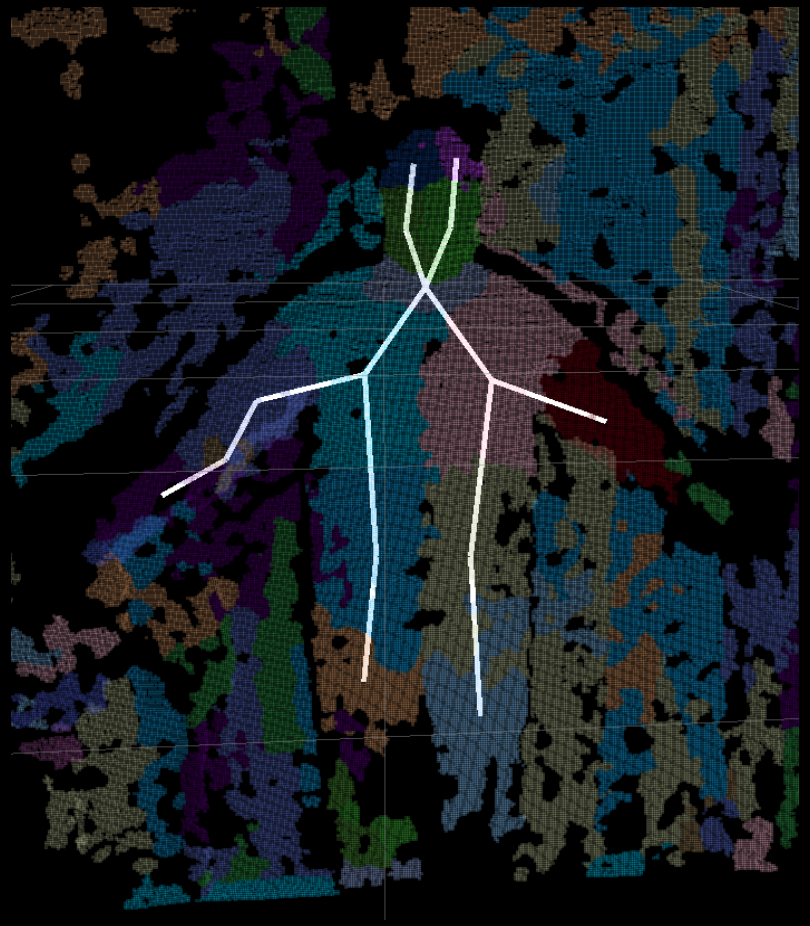
Kinect Skeleton Tracking

first open source implementation



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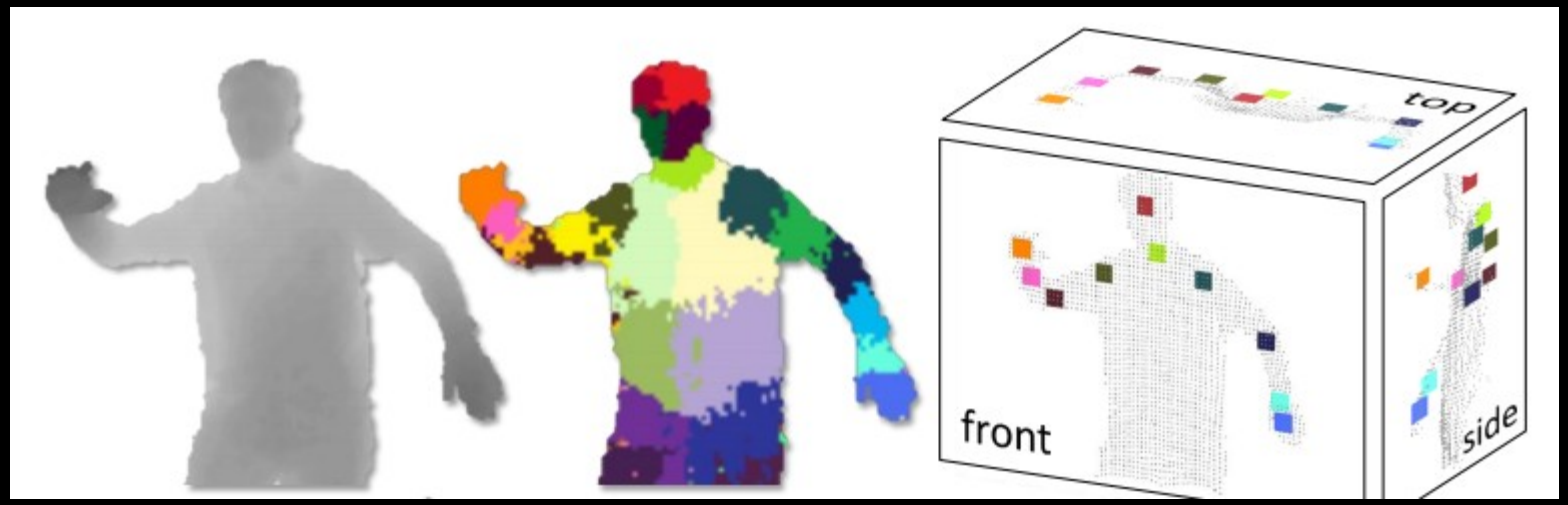
Algorithm overview

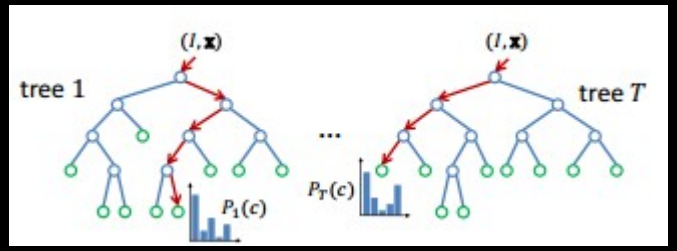
Given a depth image...

- **Segment** the person from the background
- **Label** each pixel with a body part
- **Cluster** part labels to locate skeletal joints

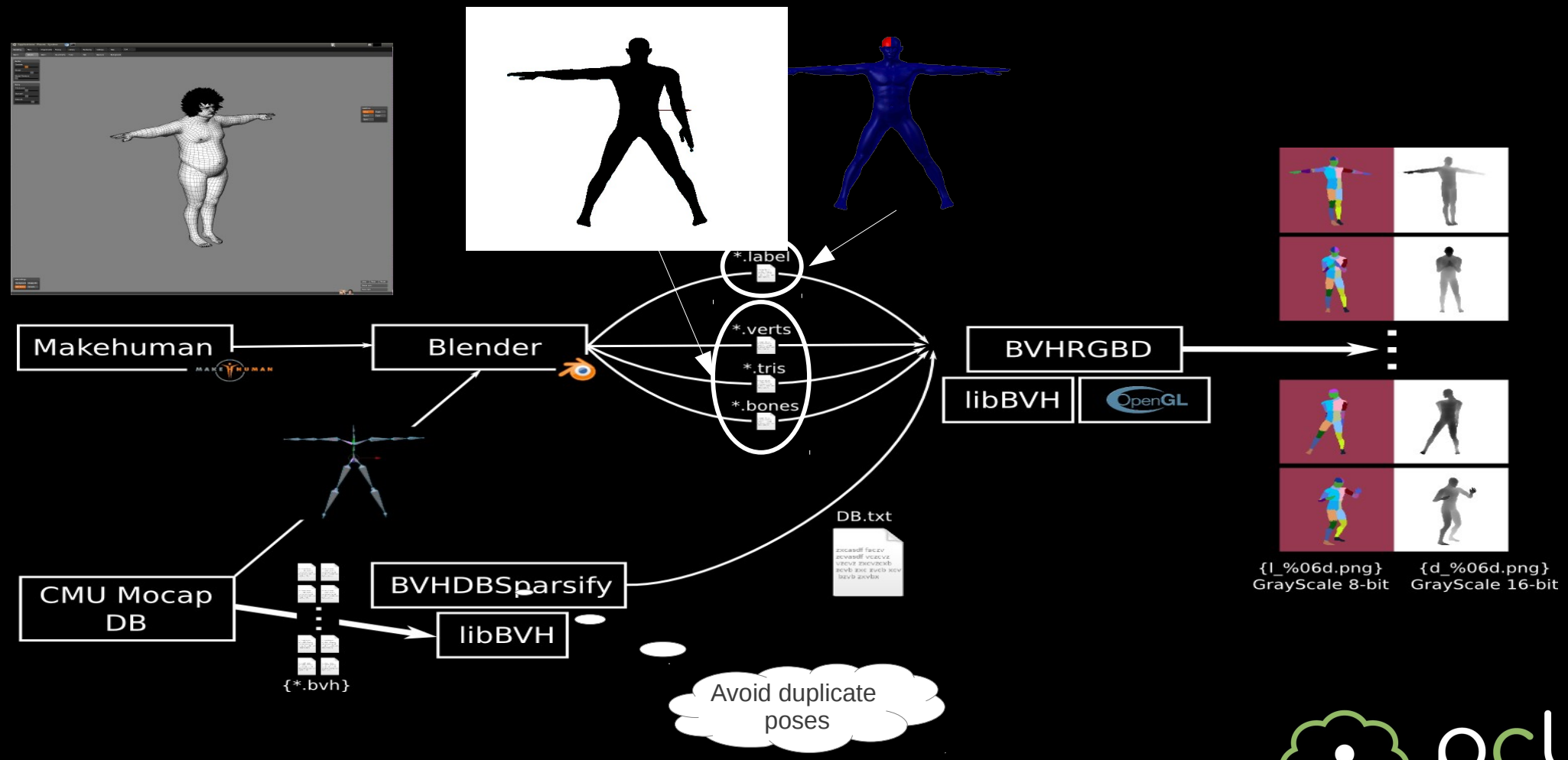


Part labeling

- Use a “forest” of decision trees to classify each pixel
- Train these decision trees using **lots** of synthetic data



Synthesizing training data

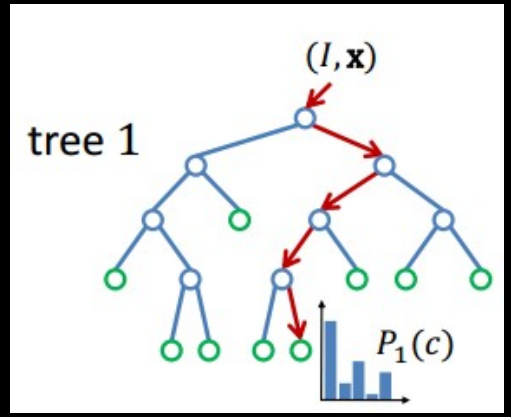


Training data

- Use virtual body to render lots of depth maps and labels
- Sample lots of small patches from each image
- Train decision trees to predict the label for each patch

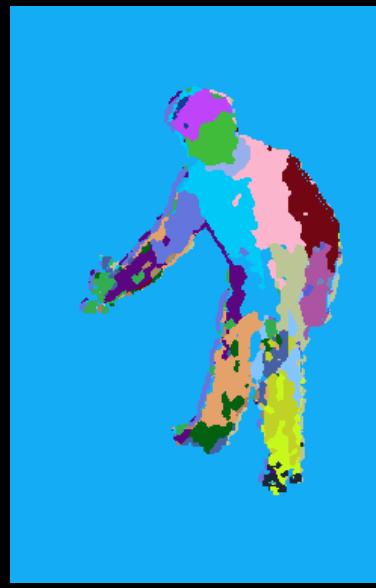
Decision tree structure

- Each node evaluates a simple local feature based on two pixel locations and a threshold (chosen during training)
- To evaluate: subtract the depth values at the given pair of pixels and compare to the difference to the given threshold
- If less than the threshold branch left, otherwise branch right
- Recurse until it reaches a leaf node
  - Leaf node contains the probability distribution of each body part label



Skeleton tracking

- Remove the background
- Use each tree in the forest to label each pixel
  - Highly parallel
- Average the outputs from each tree into one label image
- Cluster each part label to find the joint position



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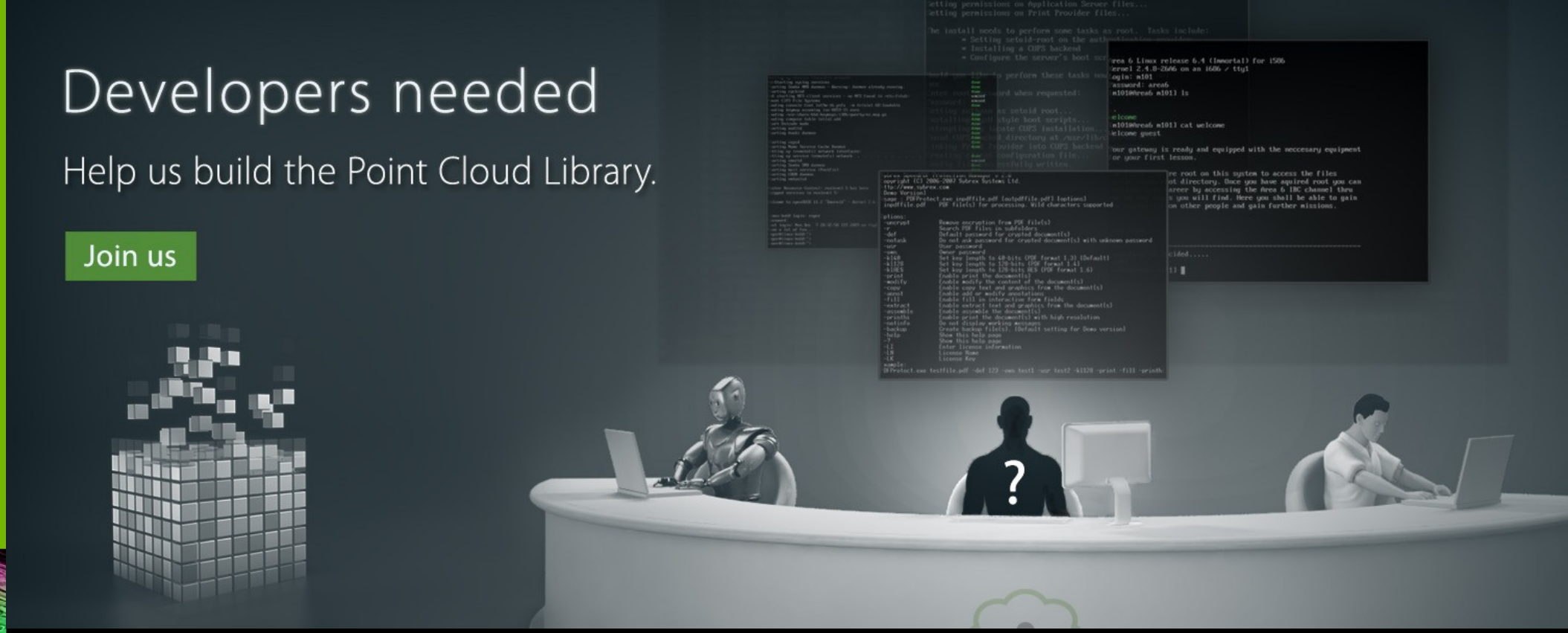

Thanks to our amazing developer community!

(Aitor, Alex^2, Anatoly, Caroline, Francisco, Julius, Koen, Pat, Raphael, Raymond, Ryohei, Suat, Walter)

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