Initial Approach

Single scan pick up for standing pellets

a) Divide levels with laser scan data.

b)No of pellets in each level = Total no of points in that level / no of points in each pellet.

(Rounded off- to nearest integer)

c)Run the code in a loop for each level as per number of pellets in that level

d)Laser integration with image data

e)Find the centre of standing pellets from image data using hough circle.

f) Pick up centre of circle from laser data with heuristic (left most, bottom most pellet in xy plane)

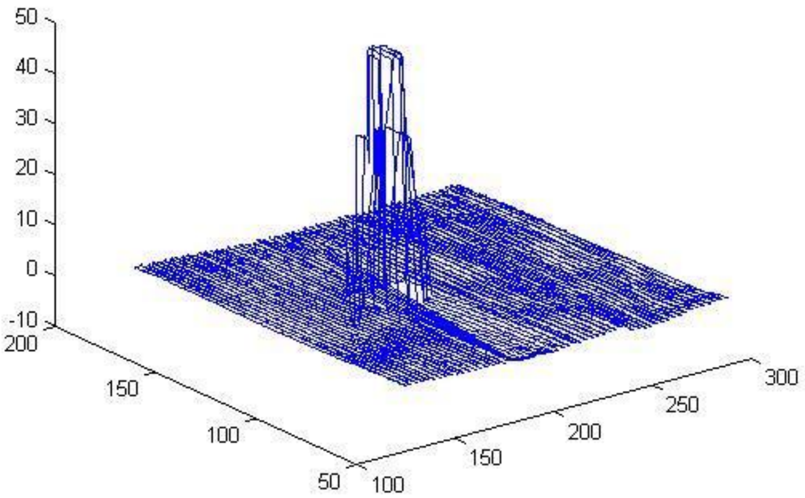
g)Find the circle from image data whose centre is closest to the value given by laser data.

h)take xy co-ordinates from image data and z co-ordinate from laser data for the corresponding point.

Photograph

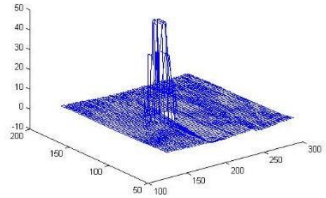
The pellets are kept in a pile, lacking any specific order.

Depth Scan

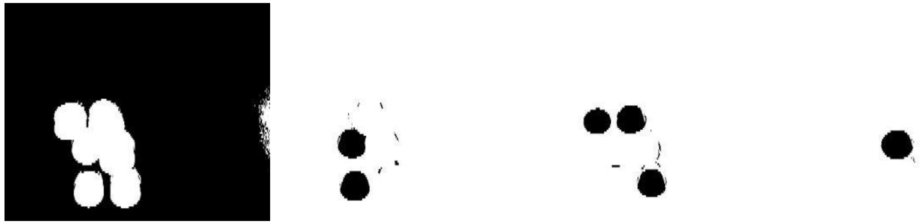


A 3D map of the pile is created using the laser scanner.

Vertical Segmentation



The pile is now segmented vertically at various levels.



Level 1 – Ground lvl Level 2 Level 3 Level 4

These images provide us a floor by floor map of the pellets

Pellet Detection

Using image processing in OpenCV the cross section of pellets (Circular, rectangular- 2D) is detected.

The center of each individual cross section is calculated by averaging.
The center of desired pellet is further relayed to KUKA for picking.

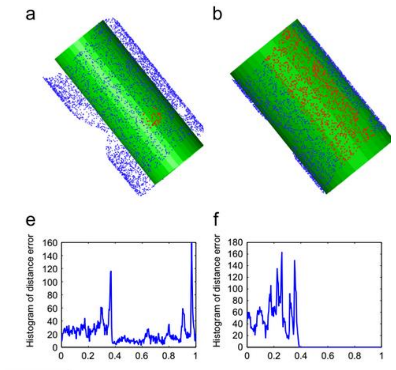
This method is independent of pellets size and shape and position. It does assume basic uniformity among all the pellet being used at a given instance.

Mayank Roy
Susobhit Sen

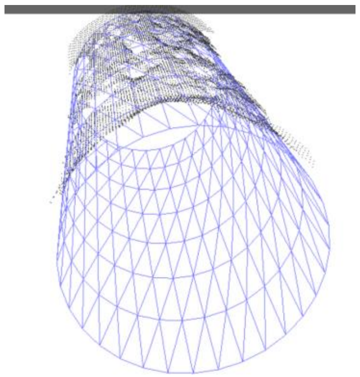
Research Survey

3D Point Cloud processing and object identification

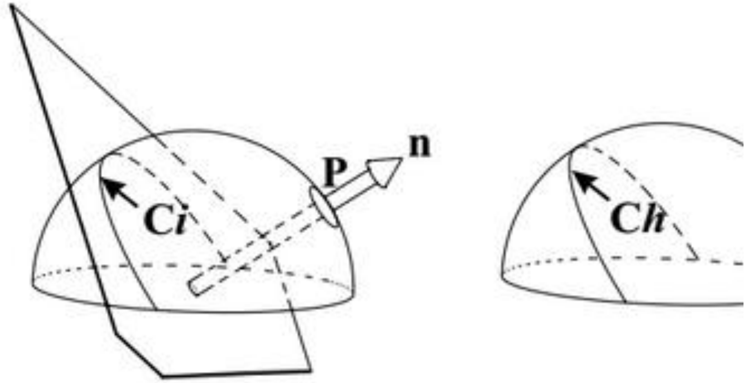
there are two predominant methods in consideration

3D	**Reduce the problem to 2D**
use curvature and normal information	by projection on a plane or sphere
Literature: **a)Extraction of cylinders and estimation of their parameters from point clouds** Trung-Thien Tran n , Van-Toan Cao, Denis Laurendeau **Methods Summary** : 1.Select a point lying on cylinder(based on curvature) 2.Define a neighbourhood(based on object) 3.Find axis - vector perp to most of the points 4.Fit a cylinder 5.Confirm by fitting cylinder on projection **Why it won't work for us** : 1.Assumes completeness in data(CAD model) 2.Works better on sparse cyllinders  **b)Fitting 3D Data with a Cylinder** David Eberly **Methods Summary** : 1.Fits data to cylinder equation using least square error minimization.	**Literature**: **a)EFFICIENT HOUGH TRANSFORM FOR AUTOMATIC DETECTION OF CYLINDERS IN POINT** **CLOUDS** Tahir Rabbani and Frank van den Heuvel **Methods Summary** : 1.Select a point lying on cylinder(based on curvature) 2.Define a neighbourhood(based on object) 3.Define a base point and Gaussian sphere around it 4.Create normal projections on sphere using plane passing through origin. 5.Apply hough circles to detect these circles in the spherical coordinates. 6.With this as axis now project all points to an orthogonal plane. Detect a circle and find centre of the cylinder **Why it won't work for us** : 1.The presence of multiple cylinders of different radii along one orientation can lead to failure. 2. Only works well in scattered cylinders 3. Very slow

Why it won’t work for us :
1.Assumes only one cylinder in scope.



c)**Plane Detection in Point Cloud Data**
Michael Ying Yang
Methods Summary :
1.Applies RANSAC for plane.
2.Fits data to plane equation using given by any random 3 points least square error minimization.
Why it won’t work for us :
1.works well for planes
2.Too slow for multiple surfaces.
3. Modelling generalised eqn. for cylinder will not. be this easy and fruitful.



b)**3D Vision Systems for Industrial Bin-Picking Applications**
Ales Pochyly * , Tomas Kubela ** , Vladislav Singule *** and Petr Cihak †
Methods Summary :
1.Talks more about the whole process ID , picker design etc
Why it won’t work for us :
1.Not much focus on ID

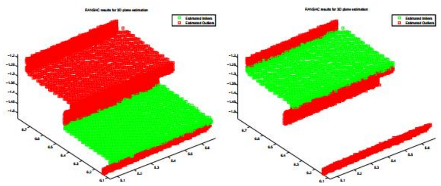


Figure 1.5: **Left**: First plane detected in one block of stair (Fig. 1.3).
Right: Second plane detected.

d)**Efficient Organized Point Cloud Segmentation with Connected Components**
Alexander J. B. Trevor, Suat Gedikli, Radu B. Rusu, Henrik I. Christensen

Methods Summary :
1.Characterizes each pixel with position, depth, colour and normal information.
2.Clustering based on contrast in above characteristics.
3.Finding surface and object in these cluster based on curvature manainance and colour gradient.

Why it won't work for us :
1.Works great on flat surfaces and well calliberated colour images.
2.needs sensor integration.
3.Relies a lot on RGB data for contrast.
4.Not much work on depth edge detection and curvature classification.

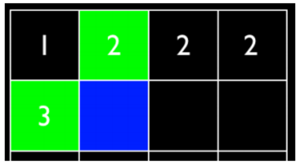


Fig. 2. An example where two labels must be merged, if the pixel highlighted in blue matches both the neighbor above and to the left, shown in green. Merging is performed in a second pass using the union-find algorithm.

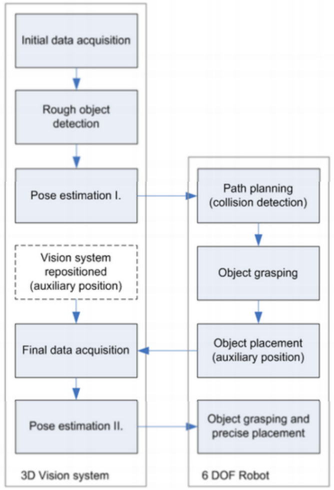


Figure 6. A general bin-picking methodology

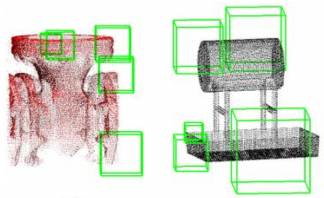
c)*F. Tombari and L. Di Stefano:* "**Object recognition in 3D scenes with occlusions and clutter by Hough voting**", 4th Pacific-Rim Symposium on Image and Video Technology, 2010.

e)**Fast object localization and pose estimation in heavy clutter for robotic bin picking**
Ming-Yu Liu, Oncel Tuzel, Ashok Veeraraghavan, Yuichi Taguchi, Tim K Marks and Rama Chellappa

(a) Flash from right (b) Flash from left (c) Depth edges (d) Canny edges

f)*H. Chen and B. Bhanu:* **"3D free-form object recognition in range images using local surface patches**", Pattern Recognition Letters, vol. 28, no. 10, pp. 1252-1262, 2007.

g)**Training-based Object Recognition in Cluttered 3D Point Clouds**
Guan Pang
Methods Summary :
1.Training method for pattern recognition.
2.Based on detecting and combining primitives..
Why it won't work for us :
1.Amazing future scope and versatility.
2.We don't need something so powerfull.

 (a) (b) Figure 4. The first 5 features selected by the Adaboost training procedure. (a) For the T-junction object; (b) For the oil tank object.	
Conclusion	**Conclusion**
Mathematical constructs a)Normals b)Curvature c)Depth edge detection using gradient d)Inliers/outliers besides fitting methods	**Mathematical constructs** a)Hough space b)Gaussian sphere c)Projection besides fitting methods
Limitations a)Incomplete point cloud Data(point of view) b)Scan resolution c)Scan speed is inversely proportional to resolution	**Limitations** a)Works for low density of objects b)High computation requirement. c)More relevant on feature detection in 2D
Advantages a)Currently work in progress b)Has a lot of future scope(versatility)	**Advantages** a)Lot of existing work
Approach Comment We will mostly stick to point cloud in 3D, its more suited and adaptable and faster	**Approach Comment** The problem when required can be interpreted in 2D and verified for the purpose of accuracy and confirmation

Task at hand : recognition of multiple(max possible) cylindrical pellets from a given 3D point cloud data.

Assumptions :

the pellets are uniformly sized and cylindrical in shape
kept in a predefined zone
not in any specific order or orientation
no specific texture

Challenge description:

Scan frequency.
Scan speed.
Detection of all unoccluded pellets in one scan.
Position estimation.
Pose estimation.
Conversion to machine base or world coordinates from sensor coordinates. Done
Pick up by Kuka.
Delivery by Kuka.

Routes

Option 1 use literature a,b,c,d. They are generalised(Height and radii) algorithms for cylinders. We can combine parts of their approach.	**Option 2** Do our own math. The code will be developed keeping in mind the radii and eight of our cylinders hence will be faster.	**Option 3** Use generalised form feature detection using localised surface patches as explained in literature e,f.
Basic Steps 1.Find normals 2.Find Curvature 3.Detect edges given	**Basic Steps** 1.Find normals 2.Find Curvature 3.Create equivalence classes of points -with	**Basic Steps** 1.Find normals 2.Find Curvature 3.Create surface patches

curvature(Planes,Cylinders). 4.Localise the problem 5.Try fitting cylinders(RANSAC, lse others) 6.Identify Cylinders	normals in the same direction -at same height in the direction of normal -curvature rating of the point 4.Localise the problem 5.Consider equivalence classes in the given region -If circles found: assume standing pellet and pick -If curvature found: -- find nearest equivalence class -- find intersection of the two planes defined by the class -- accept if distance of intersection ~ r -- repeat for all classes in the region -- enough votes found means cylinder with given axis and position. 6.Pick pellet delete used points from point cloud.	4.Characterise the to be found body(Pellets) using the above techniques. 4.Localise the problem 5.Try matching pattern 6.Identify Cylinders The approach is non specific hence not optimised for cylinders.
Comments Patching up required in multiple techniques. 4-5 weeks. Low accuracy Medium speed Medium versatility	**Comments** Maths will have to be figured out Optimal code to be written 7-8 weeks High accuracy High speed Low versatility	**Comments** Parametrization to be done complete new to what we are currently doing not much of customizability(at level of algo and maths) 3-4 weeks Medium accuracy Low speed High versatility

Pellet ID in 3D point cloud cluster

Step A. Localisation of the problem(Divide and rule)

Find Surface patch consistent with shape of pellet and ignore rest of the point cloud.

1.Find normals

2.Find Curvature

3.Using curvature classification differentiate plane and cylindrical surface.

Further Classify surface belonging to pellet or not based on size of object.

4.Create surface patches using depth edge, curvature info and pellet characterization

Step B. Rough cylinder fitting.

Step C. Exact Fitting

3.Create equivalence classes of points -with normals in the same direction

-at same height in the direction of normal

-curvature rating of the point

4.Localise the problem

5.Consider equivalence classes in the given region

-If circles found: assume standing pellet and pick

-If curvature found:

-- find nearest equivalence class

-- find intersection of the two planes defined by the class

-- accept if distance of intersection ~ r

-- repeat for all classes in the region

-- enough votes found means cylinder with given axis and position.

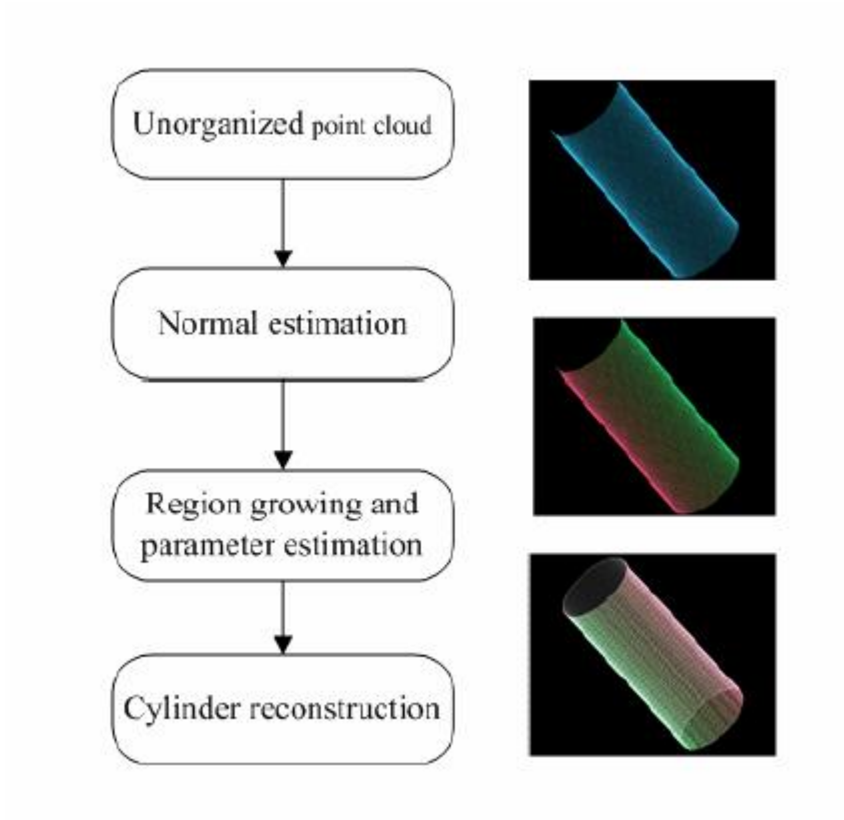
6.Pick pellet delete used points from point cloud.

Mayank Roy
Shraddha Chowdhury

Chosen Approach

Pellet ID in 3D point cloud cluster :

Approach overview



Step A. Localisation of the problem(Divide and rule)

Find Surface patch consistent with shape of pellet and ignore rest of the point cloud.

1.Find normals -

using plane fitting on neighbourhood points.

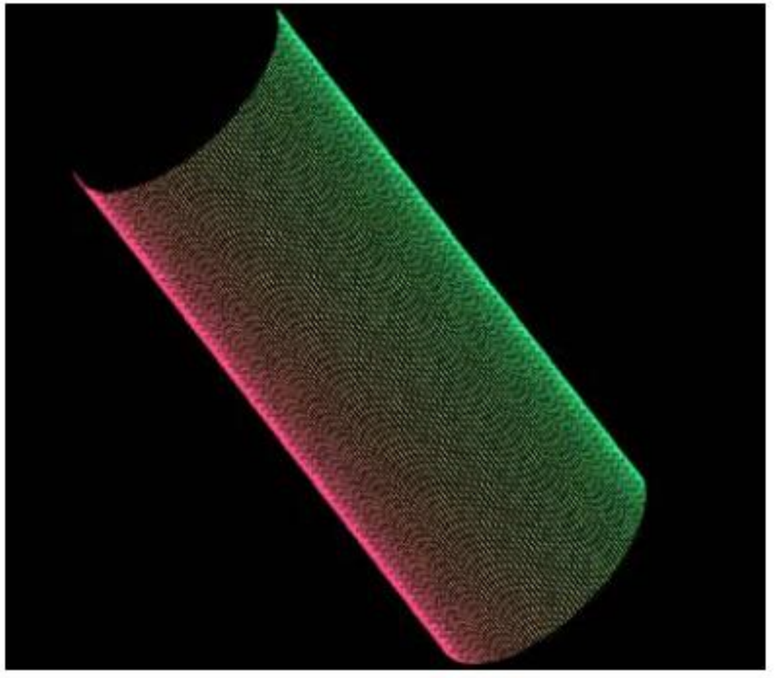


Figure 1. Normal estimation of the cylinder.(pseudo color)

PCA least eigenvector corresponding to least eigenvalue.

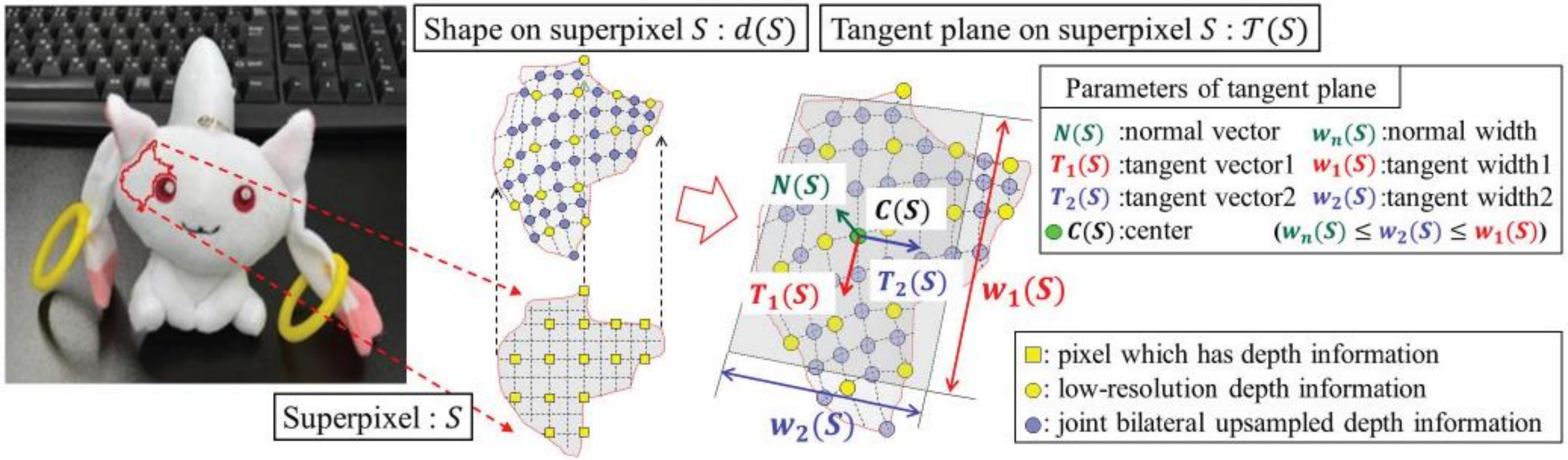


Figure 4. Tangent plane on a superpixel. Tangent plane on a superpixel is calculated using Principal Component Analysis of the shape on the superpixel that is defined by joint bilateral upsampled depth information.

2.Create Curvature classification measure difference in normal directions.

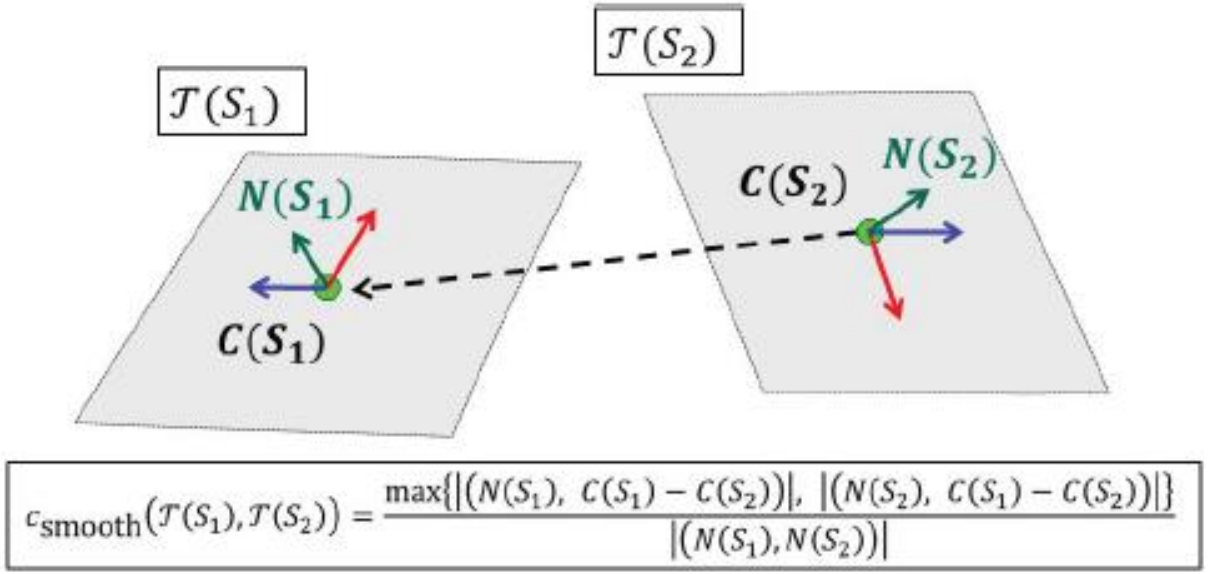


Figure 6. Characteristic value of smooth connectivity between two tangent planes.

3.Using curvature classification differentiate plane and cylindrical surface.

Further Classify surface belonging to pellet or not based on size of object.

4.Create surface patches using depth edge, curvature info and pellet characterization ad region growing to find connected component or surface patch.

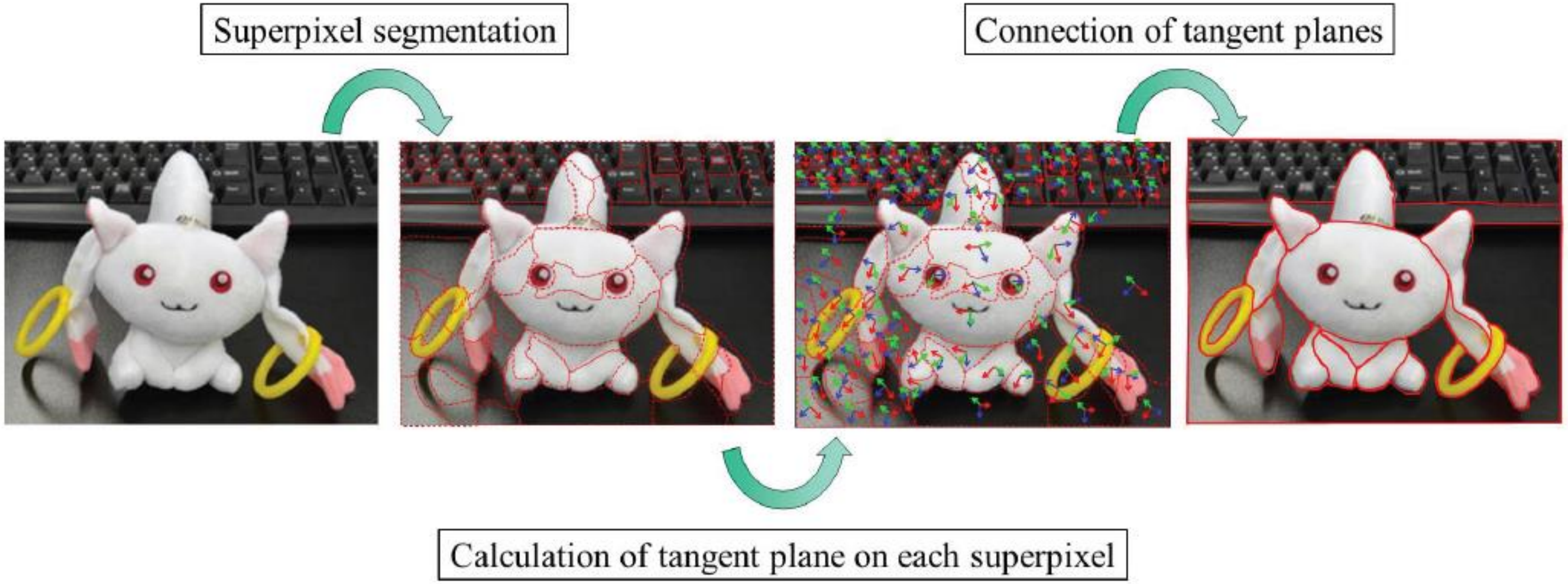


Figure 3. Overview of the processing flow of our smooth surface segmentation.

References for region growing characterisation:

Depth Interpolation via Smooth Surface Segmentation using Tangent Planes Based on the Superpixels of a Color Image
Kiyoshi Matsuo and Yoshimitsu Aoki
ICCV IEEE - 2013

A New Method of Cylinder Reconstruction Based on Unorganized Point Cloud
Li Yan, Hong Xie, Zhan Zhao
Geoinformatics, 2010 18th International Conference

Once we have local points of interest we can then -

Step B. Rough cylinder fitting.

1. Normal cross product for axis - orientation.
2. Normal cross using line and plane fitting.
   - If circles found: assume standing pellet and pick
   - If curvature found:
     - find nearest equivalence class
     - find intersection of the two planes defined by the class

Step C. Exact Fitting

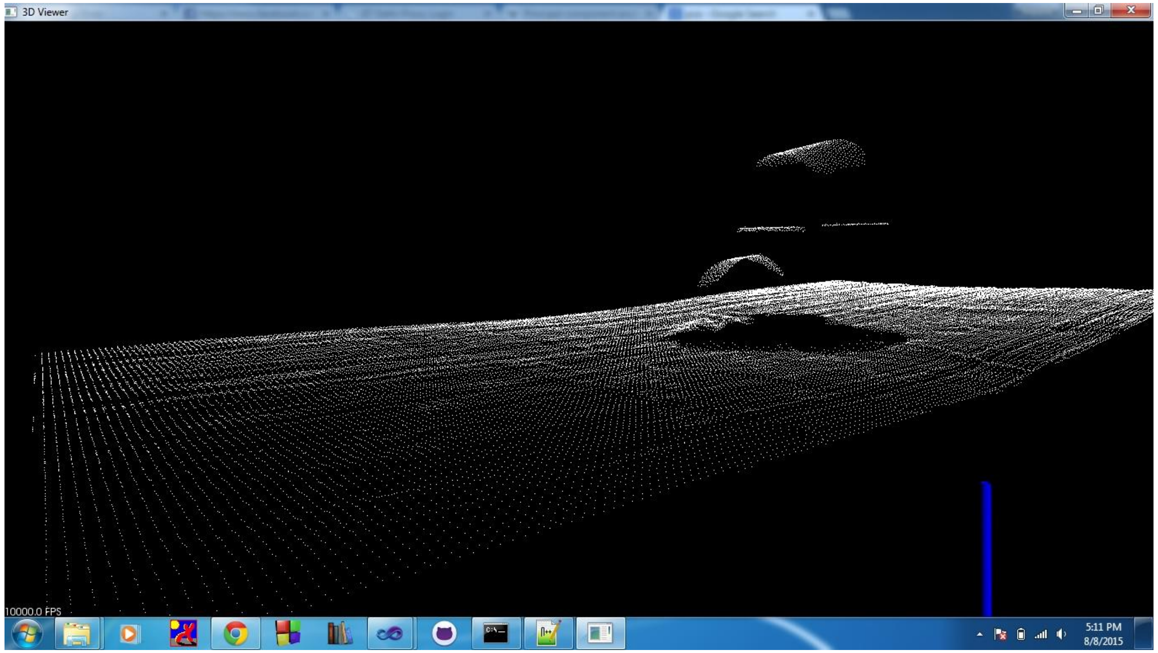
1. RANSAC - parametric fitting
2. Projection and Hough Fitting
3. plane intersection radii verification and vote
   - accept if distance of intersection ~ r
   - repeat for all classes in the region
   - enough votes found means cylinder with given axis and position.

Step D. Pick pellet delete associated points from point cloud.

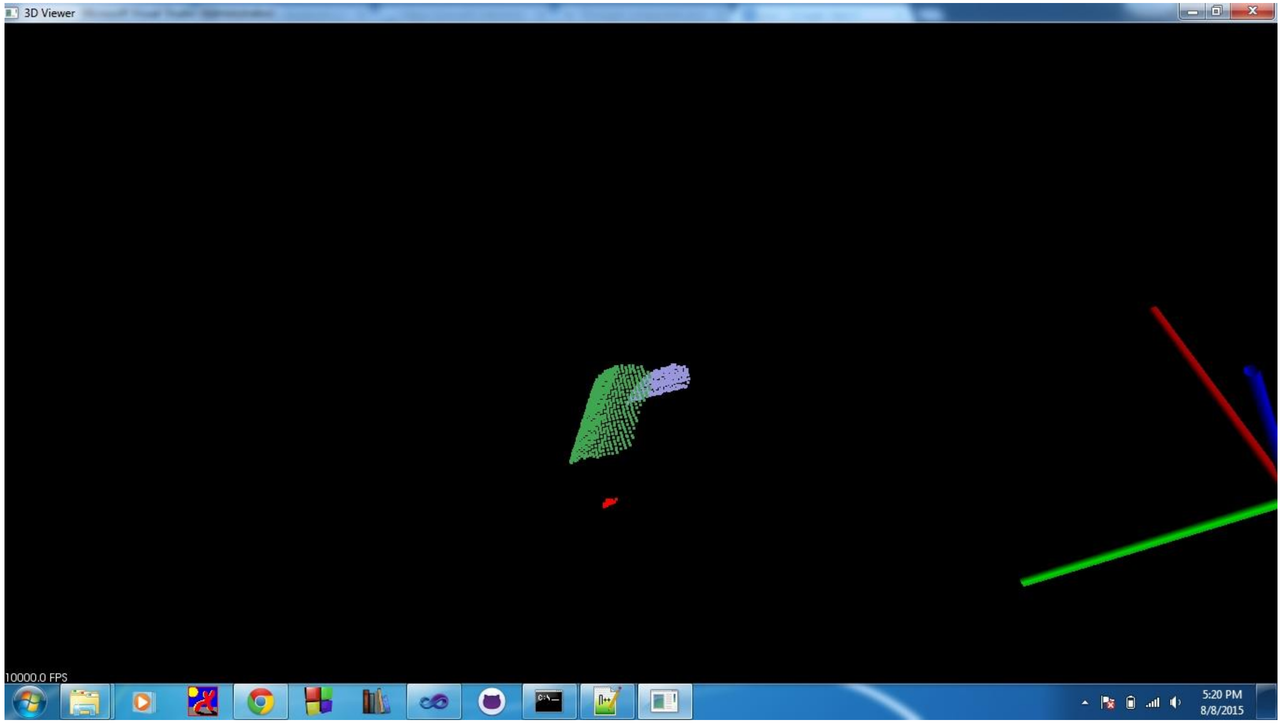
Mayank Roy

Implementation

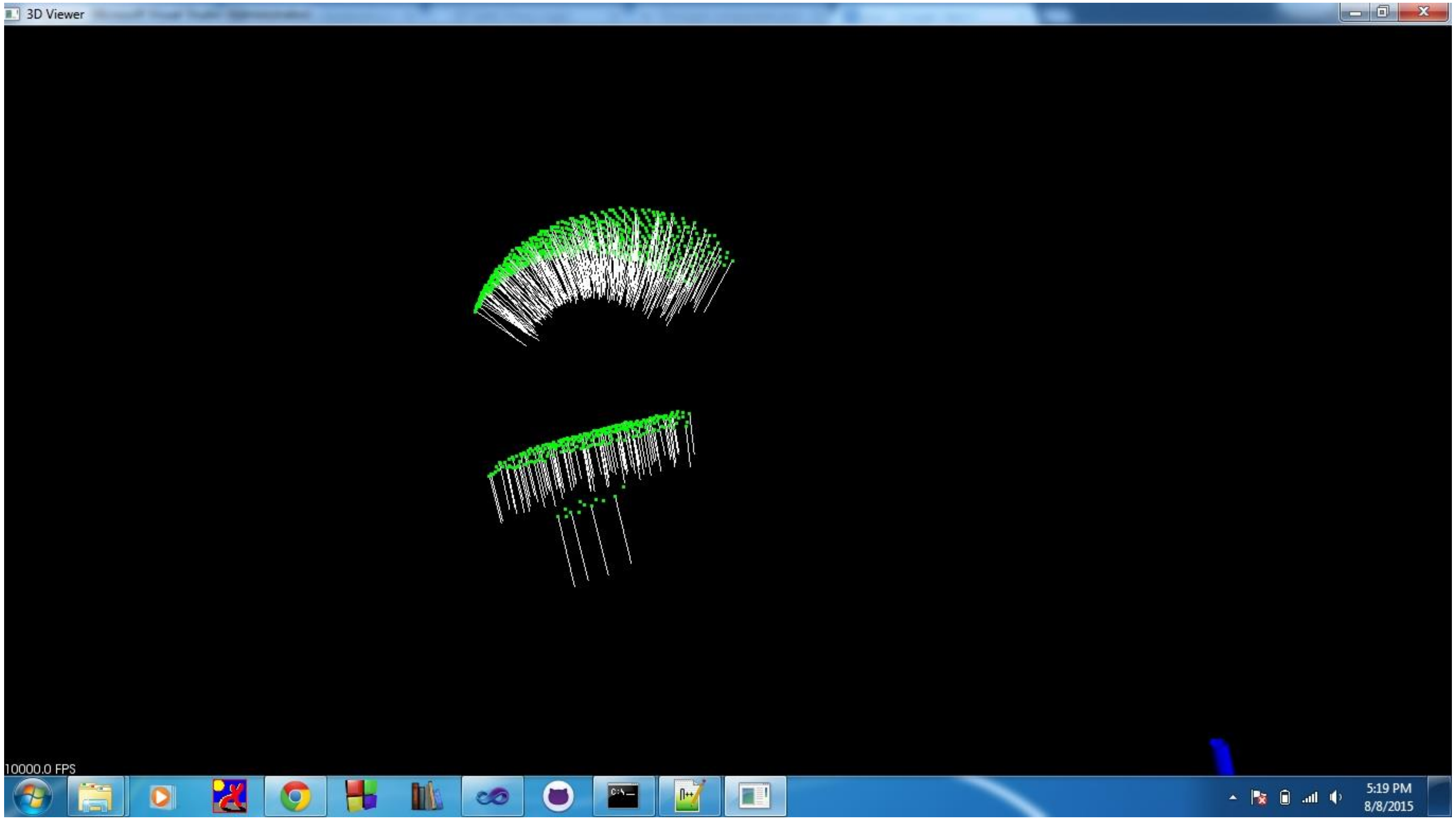
- Downsampling to create data consistency(averaging and aspect ratio)
- Filtering of lonely or stray points



- Voxel Grid : Creating parametric restriction
- Normal Estimation
- Region growing based on roundness info & Curvature Info

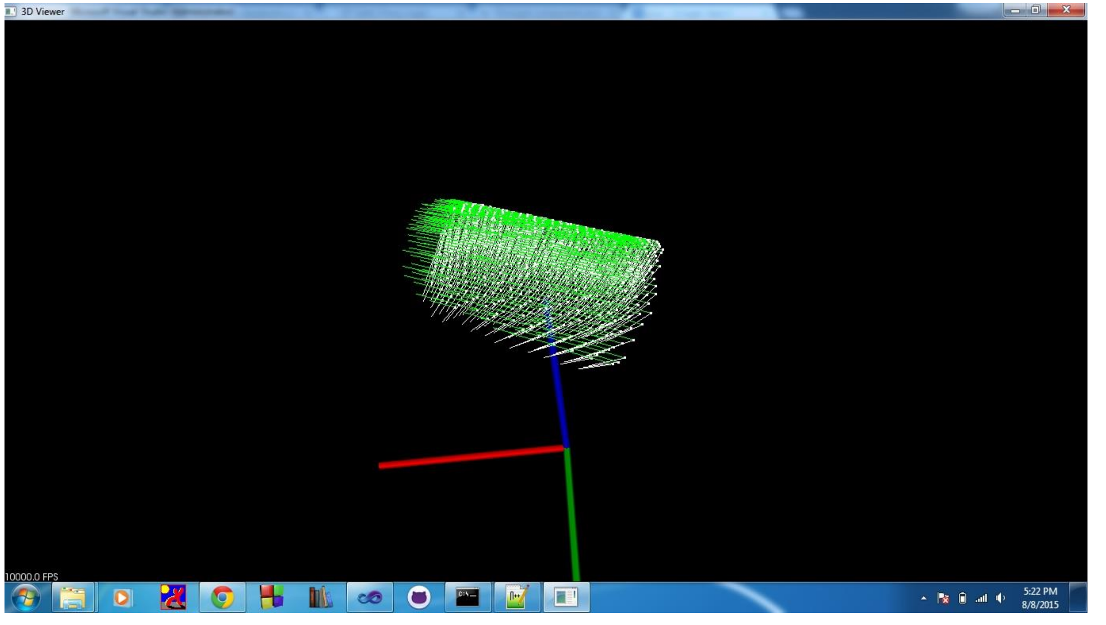


- Cluster Segregation
- Principal Curvature :



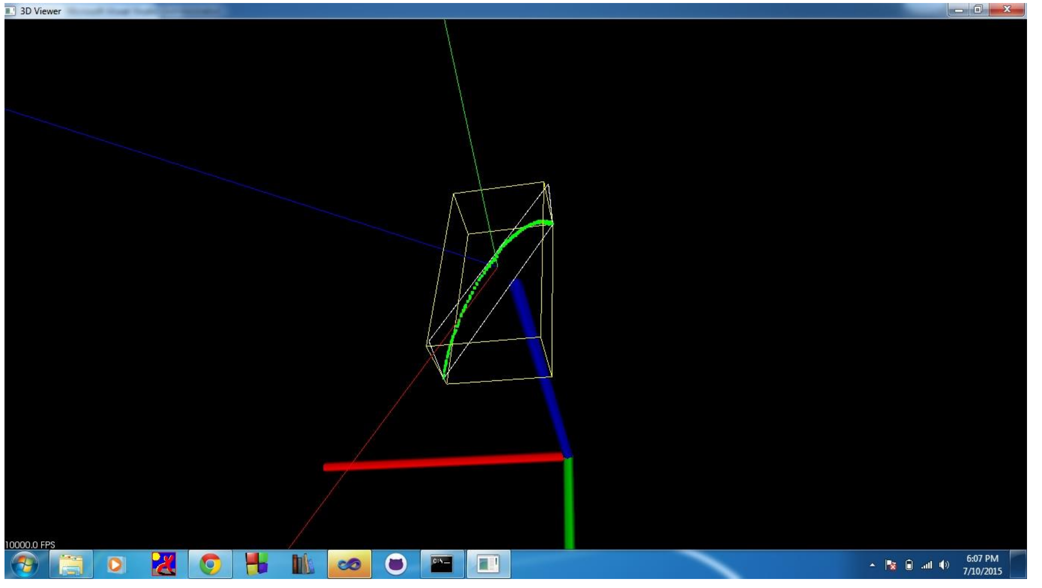
-
- Cross Product
- Reorient all the axis in same direction(parallel - anti parallel) based on max component alignment

- average out the axis value, averaging of multiple samples of the same variable to improve consistency and reliability in results
- find dot product of all points with the axis for creation of local reference frame
- find mean and min, max deviation - filter results based on expected height of the cylinder



- reduce centred patch by making axis component zero
- apply pca on these points
- find mean and deviation in the axis of direction 2
- mean is the centre of the cylinder , find min and max deviation

- again cross verify pellet dia and filter results
- orientation of pick up is given by the cross product between axis & direction 2.



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Shraddha Chowdhury