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</table>
The following links describe a set of basic PCL tutorials. Please note that their source codes may already be provided as part of the PCL regular releases, so check there before you start copy & pasting the code. The list of tutorials below is automatically generated from reST files located in our git repository.

**Note:** Before you start reading, please make sure that you go through the higher-level overview documentation at http://www.pointclouds.org/documentation/, under Getting Started. Thank you.

As always, we would be happy to hear your comments and receive your contributions on any tutorial.
BASIC USAGE

• walkthrough

| Title: PCL Functionality Walkthrough  
| Author: Razvan G. Mihalyi  
| Compatibility: > PCL 1.6  
| Takes the reader through all of the PCL modules and offers basic explanations on their functionalities. |

• basic_structures

| Title: Getting Started / Basic Structures  
| Author: Radu B. Rusu  
| Compatibility: > PCL 1.0  
| Presents the basic data structures in PCL and discusses their usage with a simple code example. |

• using pcl_pcl_config

| Title: Using PCL in your own project  
| Author: Nizar Sallem  
| Compatibility: > PCL 1.0  
| In this tutorial, we will learn how to link your own project to PCL using cmake. |

• compiling_pcl_posix

| Title: Compiling PCL from source on POSIX compliant systems  
| Author: Victor Lamoine  
| Compatibility: > PCL 1.0  
| In this tutorial, we will explain how to compile PCL from sources on POSIX/Unix systems. |

• building_pcl
In this tutorial, we will explain the basic PCL cmake options, and ways to tweak them to fit your project.

- compiling_pcl_dependencies_windows

In this tutorial, we will explain how to compile PCL's 3rd party dependencies from source on Microsoft Windows.

- compiling_pcl_windows

In this tutorial, we will explain how to compile PCL on Microsoft Windows.

- compiling_pcl_macosx

This tutorial explains how to build the Point Cloud Library from MacPorts and source on Mac OS X platforms.

- installing_homebrew

This tutorial explains how to install the Point Cloud Library on Mac OS X using Homebrew. Both direct installation and compiling PCL from source are explained.
• using pcl with eclipse

Title: **Using Eclipse as your PCL editor**  
Author: *Koen Buys*  
Compatibility: PCL git master  
This tutorial shows you how to get your PCL as a project in Eclipse.

• generate_local_doc

Title: **Generate a local documentation for PCL**  
Author: *Victor Lamoine*  
Compatibility: PCL > 1.0  
This tutorial shows you how to generate and use a local documentation for PCL.

• matrix_transform

Title: **Using matrixes to transform a point cloud**  
Author: *Victor Lamoine*  
Compatibility: > PCL 1.5  
This tutorial shows you how to transform a point cloud using a matrix.
ADDITIONAL USAGE

• adding_custom_ptype

  Title: Adding your own custom PointT point type
  Author: Radu B. Rusu
  Compatibility: > PCL 0.9, < PCL 2.0
  This document explains what templated point types are in PCL, why do they exist, and how to create and use your own PointT point type.

• writing_new_classes

  Title: Writing a new PCL class
  Author: Radu B. Rusu, Luca Penasa
  Compatibility: > PCL 0.9, < PCL 2.0
  This short guide is to serve as both a HowTo and a FAQ for writing new PCL classes, either from scratch, or by adapting old code.
CHAPTER THREE

FEATURES

• how_3d_features_work

Title: How 3D features work
Author: Radu B. Rusu
Compatibility: > PCL 1.0
This document presents a basic introduction to the 3D feature estimation methodologies in PCL.

• normal_estimation

Title: Estimating Surface Normals in a PointCloud
Author: Radu B. Rusu
Compatibility: > PCL 1.0
This tutorial discusses the theoretical and implementation details of the surface normal estimation module in PCL.

• normal_estimation_using_integral_images

Title: Normal Estimation Using Integral Images
Author: Stefan Holzer
Compatibility: > PCL 1.0
In this tutorial we will learn how to compute normals for an organized point cloud using integral images.

• pfh_estimation
This tutorial introduces a family of 3D feature descriptors called PFH (Point Feature Histograms) and discusses their implementation details from PCL’s perspective.

• fpfh_estimation

This tutorial introduces the FPFH (Fast Point Feature Histograms) 3D descriptor and discusses their implementation details from PCL’s perspective.

• vfh_estimation

This document describes the Viewpoint Feature Histogram (VFH) descriptor, a novel representation for point clusters for the problem of Cluster (e.g., Object) Recognition and 6DOF Pose Estimation.

• narf_feature_extraction

In this tutorial, we will learn how to extract NARF features from a range image.

• moment_of_inertia

In this tutorial we will learn how to compute moment of inertia and eccentricity of the cloud. In addition to this we will learn how to extract AABB and OBB.

• rops_feature
| Title: **RoPs (Rotational Projection Statistics) feature**  
| Author: *Sergey Ushakov*  
| Compatibility: > PCL 1.7  
| In this tutorial we will learn how to compute RoPS feature.

- gasd_estimation

| Title: **Globally Aligned Spatial Distribution (GASD) descriptors**  
| Author: *Joao Paulo Lima*  
| Compatibility: >= PCL 1.9  
| This document describes the Globally Aligned Spatial Distribution (GASD) global descriptor to be used for efficient object recognition and pose estimation. |
CHAPTER FOUR

FILTERING

• passthrough

Title: Filtering a PointCloud using a PassThrough filter  
Author: Radu B. Rusu  
Compatibility: > PCL 1.0  
In this tutorial, we will learn how to remove points whose values fall inside/outside a user given interval along a specified dimension.

• voxelgrid

Title: Downsampling a PointCloud using a VoxelGrid filter  
Author: Radu B. Rusu  
Compatibility: > PCL 1.0  
In this tutorial, we will learn how to downsample (i.e., reduce the number of points) a Point Cloud.

• statistical_outlier_removal

Title: Removing sparse outliers using StatisticalOutlierRemoval  
Author: Radu B. Rusu  
Compatibility: > PCL 1.0  
In this tutorial, we will learn how to remove sparse outliers from noisy data, using StatisticalRemoval.

• project_inliers

Title: Projecting points using a parametric model  
Author: Radu B. Rusu  
Compatibility: > PCL 1.0  
In this tutorial, we will learn how to project points to a parametric model (i.e., plane).
### extract_indices

Title: **Extracting indices from a PointCloud**  
Author: *Radu B. Rusu*  
Compatibility: > PCL 1.0  
In this tutorial, we will learn how to extract a set of indices given by a segmentation algorithm.

### remove_outliers

Title: **Removing outliers using a Conditional or RadiusOutlier removal**  
Author: *Gabe O’Leary*  
Compatibility: > PCL 1.0  
In this tutorial, we will learn how to remove outliers from noisy data, using ConditionalRemoval, RadiusOutlierRemoval.
CHAPTER FIVE

I/O

• pcd_file_format

<table>
<thead>
<tr>
<th>Title: The PCD (Point Cloud Data) file format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author: Radu B. Rusu</td>
</tr>
<tr>
<td>Compatibility: &gt; PCL 0.9</td>
</tr>
<tr>
<td>This document describes the PCD file format, and the way it is used inside PCL.</td>
</tr>
</tbody>
</table>

• reading_pcd

<table>
<thead>
<tr>
<th>Title: Reading Point Cloud data from PCD files</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author: Radu B. Rusu</td>
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<tr>
<td>Compatibility: &gt; PCL 1.0</td>
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<tr>
<td>In this tutorial, we will learn how to read a Point Cloud from a PCD file.</td>
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• writing_pcd

<table>
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<tr>
<th>Title: Writing Point Cloud data to PCD files</th>
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<tbody>
<tr>
<td>Author: Radu B. Rusu</td>
</tr>
<tr>
<td>Compatibility: &gt; PCL 1.0</td>
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<tr>
<td>In this tutorial, we will learn how to write a Point Cloud to a PCD file.</td>
</tr>
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</table>

• concatenate_clouds

<table>
<thead>
<tr>
<th>Title: Concatenate the fields or points of two Point Clouds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author: Gabe O’Leary / Radu B. Rusu</td>
</tr>
<tr>
<td>Compatibility: &gt; PCL 1.0</td>
</tr>
<tr>
<td>In this tutorial, we will learn how to concatenate both the fields and the point data of two Point Clouds. When concatenating fields, one PointClouds contains only XYZ data, and the other contains Surface Normal information.</td>
</tr>
</tbody>
</table>
In this tutorial, we will learn how to acquire point cloud data from an OpenNI camera.

In this tutorial, we will learn how to acquire point cloud data from a Velodyne HDL.

In this tutorial, we will learn how to acquire point cloud data from a Dinast camera.

In this tutorial, we will learn how to acquire point cloud data from an IDS-Imaging Ensenso camera.

In this tutorial, we will learn how to acquire point cloud or mesh data from a davidSDK scanner.
Title: Grabbing point clouds from DepthSense cameras
Author: Sergey Alexandrov
Compatibility: >= PCL 1.8.0

In this tutorial we will learn how to setup and use DepthSense cameras within PCL on both Linux and Windows platforms.
CHAPTER SIX

KEYPOINTS

• narf_keypoint_extraction

Title: How to extract NARF keypoints from a range image
Author: Bastian Steder
Compatibility: > 1.3
In this tutorial, we will learn how to extract NARF keypoints from a range image.
In this tutorial, we will learn how to search using the nearest neighbor method for k-d trees.
CHAPTER EIGHT

OCTREE

• octree_compression

Title: Point cloud compression
Author: Julius Kammerl
Compatibility: > PCL 1.0
In this tutorial, we will learn how to compress a single point cloud and streams of point clouds.

• octree_search

Title: Octrees for spatial partitioning and neighbor search
Author: Julius Kammerl
Compatibility: > PCL 1.0
In this tutorial, we will learn how to use octrees for spatial partitioning and nearest neighbor search.

• octree_change_detection

Title: Spatial change detection on unorganized point cloud data
Author: Julius Kammerl
Compatibility: > PCL 1.0
In this tutorial, we will learn how to use octrees for detecting spatial changes within point clouds.
Range Images

• range_image_creation

Title: Creating Range Images from Point Clouds
Author: Bastian Steder
Compatibility: > PCL 1.0
This tutorial demonstrates how to create a range image from a point cloud and a given sensor position.

• range_image_border_extraction

Title: Extracting borders from Range Images
Author: Bastian Steder
Compatibility: > PCL 1.3
This tutorial demonstrates how to extract borders (traversals from foreground to background) from a range image.
CHAPTER
TEN

RECOGNITION

• correspondence_grouping

**Title:** The PCL Recognition API  
**Author:** Tommaso Cavallari, Federico Tombari  
**Compatibility:** > PCL 1.6  
This tutorial aims at explaining how to perform 3D Object Recognition based on the pcl_recognition module.

• implicit_shape_model

**Title:** Implicit Shape Model  
**Author:** Sergey Ushakov  
**Compatibility:** > PCL 1.7  
In this tutorial we will learn how the Implicit Shape Model algorithm works and how to use it for finding objects centers.

• global_hypothesis_verification

**Title:** Hypothesis Verification for 3D Object Recognition  
**Author:** Daniele De Gregorio, Federico Tombari  
**Compatibility:** > PCL 1.7  
This tutorial aims at explaining how to do 3D object recognition in clutter by verifying model hypotheses in cluttered and heavily occluded 3D scenes.
CHAPTER ELEVEN

REGISTRATION

• registration_api

Title: The PCL Registration API
Author: Dirk Holz, Radu B. Rusu, Jochen Sprickerhof
Compatibility: > PCL 1.5
In this document, we describe the point cloud registration API and its modules: the estimation and rejection of point correspondences, and the estimation of rigid transformations.

• iterative_closest_point

Title: How to use iterative closest point algorithm
Author: Gabe O’Leary
Compatibility: > PCL 1.0
This tutorial gives an example of how to use the iterative closest point algorithm to see if one PointCloud is just a rigid transformation of another PointCloud.

• pairwise_incremental_registration

Title: How to incrementally register pairs of clouds
Author: Raphael Favier
Compatibility: > PCL 1.4
This document demonstrates using the Iterative Closest Point algorithm in order to incrementally register a series of point clouds two by two.

• interactive_icp

Title: Interactive ICP
Author: Victor Lamoine
Compatibility: > PCL 1.5
This tutorial will teach you how to build an interactive ICP program.

• normal_distributions_transform
Title: **How to use the Normal Distributions Transform algorithm**  
Author: *Brian Okorn*  
Compatibility: > PCL 1.6  
This document demonstrates using the Normal Distributions Transform algorithm to register two large point clouds.

- **in_hand_scanner**

Title: **How to use the In-hand scanner for small objects**  
Author: *Martin Saelzle*  
Compatibility: >= PCL 1.7  
This document shows how to use the In-hand scanner applications to obtain colored models of small objects with RGB-D cameras.

- **alignment_prerejective**

Title: **Robust pose estimation of rigid objects**  
Author: *Anders Glent Buch*  
Compatibility: >= PCL 1.7  
In this tutorial, we show how to find the alignment pose of a rigid object in a scene with clutter and occlusions.
SAMPLE CONSENSUS

• random_sample_consensus

Title: How to use Random Sample Consensus model
Author: Gabe O’Leary
Compatibility: > PCL 1.0
In this tutorial we learn how to use a RandomSampleConsensus with a plane model to obtain the cloud fitting to this model.
• planar_segmentation

Title: Plane model segmentation  
Author: Radu B. Rusu  
Compatibility: > PCL 1.3  
In this tutorial, we will learn how to segment arbitrary plane models from a given point cloud dataset.

• cylinder_segmentation

Title: Cylinder model segmentation  
Author: Radu B. Rusu  
Compatibility: > PCL 1.3  
In this tutorial, we will learn how to segment arbitrary cylindrical models from a given point cloud dataset.

• cluster_extraction

Title: Euclidean Cluster Extraction  
Author: Serkan Tuerker  
Compatibility: > PCL 1.3  
In this tutorial we will learn how to extract Euclidean clusters with the pcl::EuclideanClusterExtraction class.

• region_growing_segmentation
In this tutorial we will learn how to use region growing segmentation algorithm.

- **region_growing_rgb_segmentation**

In this tutorial we will learn how to use color-based region growing segmentation algorithm.

- **min_cut_segmentation**

In this tutorial we will learn how to use min-cut based segmentation algorithm.

- **conditional_euclidean_clustering**

This tutorial describes how to use the Conditional Euclidean Clustering class in PCL: A segmentation algorithm that clusters points based on Euclidean distance and a user-customizable condition that needs to hold.

- **don_segmentation**

In this tutorial we will learn how to use the difference of normals feature for segmentation.

- **supervoxel_clustering**
• **Supervoxel Clustering**
  
  **Title:** Supervoxel Clustering  
  **Author:** Jeremie Papon  
  **Compatibility:** >= PCL 1.8  
  In this tutorial, we show to break a pointcloud into the mid-level supervoxel representation.

• **Progressive Morphological Filtering**
  
  **Title:** Progressive Morphological Filtering  
  **Author:** Brad Chambers  
  **Compatibility:** >= PCL 1.8  
  In this tutorial, we show how to segment a point cloud into ground and non-ground returns.

• **Model outlier removal**
  
  **Title:** Model outlier removal  
  **Author:** Timo Häckel  
  **Compatibility:** >= PCL 1.7.2  
  This tutorial describes how to extract points from a point cloud using SAC models.
CHAPTER
FOURTEEN

SURFACE

• moving_least_squares

Title: Smoothing and normal estimation based on polynomial reconstruction
Author: Zoltan-Csaba Marton, Alexandru E. Ichim
Compatibility: > PCL 1.6
In this tutorial, we will learn how to construct and run a Moving Least Squares (MLS) algorithm to obtain smoothed XYZ coordinates and normals.

• hull_2d

Title: Construct a concave or convex hull polygon for a plane model
Author: Gabe O’Leary, Radu B. Rusu
Compatibility: > PCL 1.0
In this tutorial we will learn how to calculate a simple 2D concave or convex hull polygon for a set of points supported by a plane.

• greedy_triangulation

Title: Fast triangulation of unordered point clouds
Author: Zoltan-Csaba Marton
Compatibility: > PCL 1.0
In this tutorial we will learn how to run a greedy triangulation algorithm on a Point-Cloud with normals to obtain a triangle mesh based on projections of the local neighborhood.

• bspline_fitting

Title: Fitting trimmed B-splines to unordered point clouds
Author: Thomas Mörwald
Compatibility: > PCL 1.7
In this tutorial we will learn how to reconstruct a smooth surface from an unordered point-cloud by fitting trimmed B-splines.
CHAPTER
FIFTEEN

VISUALIZATION

• cloud_viewer

Title: Visualizing Point Clouds
Author: Ethan Rublee
Compatibility: > PCL 1.0
This tutorial demonstrates how to use the pcl visualization tools.

• range_image_visualization

Title: Visualizing Range Images
Author: Bastian Steder
Compatibility: > PCL 1.3
This tutorial demonstrates how to use the pcl visualization tools for range images.

• pcl_visualizer

Title: PCLVisualizer
Author: Geoffrey Biggs
Compatibility: > PCL 1.3
This tutorial demonstrates how to use the PCLVisualizer class for powerful visualization of point clouds and related data.

• pcl_plotter
This tutorial demonstrates how to use the PCLPlotter class for powerful visualisation of plots, charts and histograms of raw data and explicit functions.

- visualization

This tutorial will give an overview on the usage of the PCL visualization tools.

- qt_visualizer

This tutorial shows you how to create a PCL visualizer within a Qt application.

- qt_colorize_cloud

This tutorial shows you how to color point clouds within a Qt application.
CHAPTER
SIXTEEN

APPLICATIONS

• template_alignment

Title: **Aligning object templates to a point cloud**  
Author: Michael Dixon  
Compatibility: > PCL 1.3  
This tutorial gives an example of how some of the tools covered in the previous tutorials can be combined to solve a higher level problem — aligning a previously captured model of an object to some newly captured data.

• vfh_recognition

Title: **Cluster Recognition and 6DOF Pose Estimation using VFH descriptors**  
Author: Radu B. Rusu  
Compatibility: > PCL 0.8  
In this tutorial we show how the Viewpoint Feature Histogram (VFH) descriptor can be used to recognize similar clusters in terms of their geometry.

• mobile_streaming

Title: **Point Cloud Streaming to Mobile Devices with Real-time Visualization**  
Author: Pat Marion  
Compatibility: > PCL 1.3  
This tutorial describes how to send point cloud data over the network from a desktop server to a client running on a mobile device.

• ground_based_rgbd_people_detection

Title: **Detecting people on a ground plane with RGB-D data**  
Author: Matteo Munaro  
Compatibility: >= PCL 1.7  
This tutorial presents a method for detecting people on a ground plane with RGB-D data.
CHAPTER

SEVENTEEN

GPU

• gpu_install

Title: GPU Installation
Author: Koen Buys
Compatibility: PCL git master
This tutorial explains how to configure PCL to use with a Nvidia GPU

• using_kinfu_large_scale

Title: Using KinFu Large Scale to generate a textured mesh
Author: Francisco Heredia and Raphael Favier
Compatibility: PCL git master
This tutorial demonstrates how to use KinFu Large Scale to produce a mesh from a room, and apply texture information in post-processing for a more appealing visual result.

• gpu_people

Title: People Detection
Author: Koen Buys
Compatibility: PCL git master
This tutorial presents a method for people and pose detection.