# POINT CLOUDS REGISTRATION AND GENERATION FROM STEREO IMAGES

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***Abstract**: Registration of 3D point sets is a basic problem in computer vision and 3D modeling. The goal of registration is to transform two or more overlapping point clouds into one common coordinate system. In this paper we discuss point clouds generation from stereo images and registration problem. We also present our realization, we capture object images from different angles with two cameras, then we generate point clouds from these stereo images and merge these point clouds to get 3D model of the object.*

***Keywords**: point clouds, registration, stereovision, ICP, stereo image*

***ACM Classification Keywords:** I.4.4 Image Processing and Computer Vision - Restoration*

## 1. Introduction

Point cloud is a set of points in some coordinate system. Point clouds are typically used to measure physical world surfaces. Point clouds are used for many purposes, including to create 3D CAD models for manufactured parts, and at a multiple of visualization, rendering, animation and mass customization applications. They have applications in robot navigation and perception, depth estimation, stereo vision, visual registration, and in advanced driver assistance systems (ADAS).

There are different ways of getting point clouds, such as, laser scanners, time-of-flight cameras, special 3D cameras, like PrimeSensor or Microsoft Kinect, or stereo cameras. In Section 2 we describe the process of getting point cloud from pair of images taken from two cameras simultaneously that is called stereo image or stereo pair.

For different purposes, such as 3D modeling or 3D scene reconstruction, it is usually needed to merge point clouds from different scenes or partially overlapped point clouds into one common point cloud - this process is called registration. In other words, registration transforms multiple 3D point clouds into the same coordinate system so as to align overlapping components of these sets.

Point clouds registration is very important problem that is used in 3D modeling. In Section 3 we discuss registration problem and different registrations algorithms and in section 4 we present our realization of merging object point clouds from different views to get object 3D model.

## 2. Point cloud generation from stereo pair

Stereovision is a technique that estimates 3D information of a scene from two or more cameras. In the case of two cameras it is usually called binocular stereovision. One of the fundamental problems in stereovision is calculating disparity map which is also known as stereo correspondence problem. Disparity is the distance between correspondence points in the left and right images. The goal of stereo correspondence algorithms is to find correspondent points in the left and right images. There are plenty of stereo correspondence algorithms, good taxonomy and review of stereo correspondence algorithms is at [Sharstein, 2002].

Let us consider simple case (Figure 1): suppose we have two cameras with parallel optical axes, we know geometrical arrangement and internal parameters of the cameras and have disparity map calculated.  So we can compute point's coordinates by triangulation.

The line connecting the cameras lens centers is called the baseline. Let the baseline be perpendicular to the optical axes of the cameras and parallel to x-axis. The distance between cameras is d and cameras have equal focal length f.

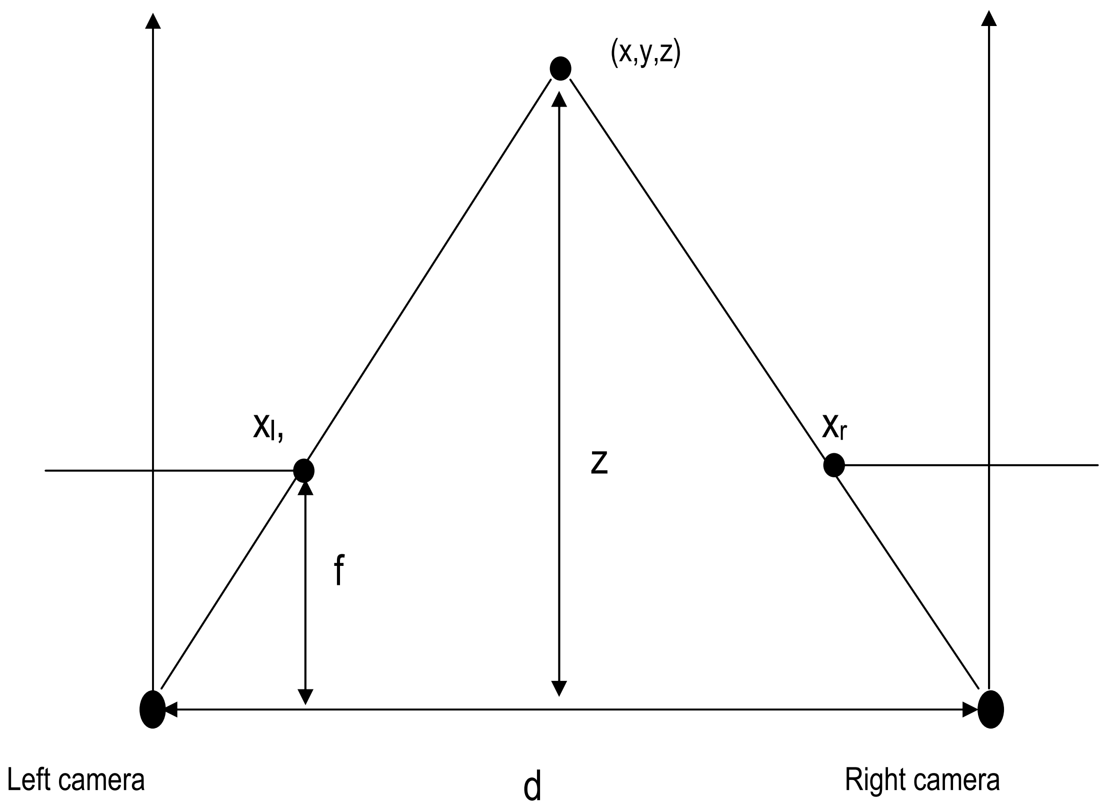


Figure 1. Two cameras with parallel optical axes

Consider (x, y, z) are coordinates of a point in three-dimensional world, where z is a depth. Let this point have (xl, yl) and (xr, yr) coordinates in the left and right image planes of the respective cameras. Then from the similar triangles we have:

$$\frac{z}{d} = \frac{f}{x_l - x_r} \Rightarrow z = \frac{df}{x_l - x_r},$$

where $x_l - x_r$ is disparity. Thus, the depth at various scene points may be recovered by knowing the disparities of the corresponding image points.

Also we can compute:

$$x = \frac{d\left(x_l + x_r\right)}{2\left(x_l - x_r\right)}, \quad y = \frac{d\left(y_l + y_r\right)}{2\left(x_l - x_r\right)}.$$

So having these coordinates we can construct point cloud. In more details how to compute depth from stereo images is described at [Bagga, 2013], [Mahammed, 2013].

## 3. Registration

As it was mentioned, 3D registration is problem of merging overlapping point clouds and bringing them into one common coordinate system. There are two types of registration algorithms that uses rigid and non-rigid transformations. Rigid algorithms assume that point clouds may differ only by rotation and translation but preserve the distance between every pair of points, which means that transformation can be modeled using only 6 Degrees of Freedom (DOF). On the other hand, non-rigid approaches are able to cope with articulated objects or soft bodies that change shape over time.

Both rigid and non-rigid algorithms can be also classified as pairwise registration and multi-view registration methods. Pairwise registration algorithms calculate a rigid transformation between two subsequent point clouds while the multi-view registration process takes multiple point clouds into account to obtain better results.

Rigid transformations algorithms are usually divided into 2 classes: feature-based registration algorithms and iterative registration algorithms.

Feature-based registration algorithms use geometric features of the objects for registration. Usually consists of the following steps:

1) estimate the associated descriptors of the point clouds
2) correspondence calculation
3) reject bad correspondences
4) transformation estimation

Iterative algorithms that are Iterative Closest Point(ICP) algorithm and it's variants iteratively register points clouds, trying at each iteration minimize distance between point clouds. In contrast to feature-based registration, iterative registration algorithms do not match salient feature descriptors in order to find correspondences between source and target point clouds, but instead search for closest points and align the found point pairs. ICP algorithm consists of the following steps:

1) Selection subsets of two point clouds
2) Matching corresponding pairs
3) Weighting the corresponding pairs appropriately
4) Rejecting certain pairs based on looking at each pair individually or considering the entire set of pairs
5) Compute an error metric based on the point pairs
6) Minimizing the error metric

ICP algorithm needs aligned point clouds to have small rotation degree and to be near each other to achieve good results, it is also called fine registration. So it is frequently combined with feature-based registration algorithms, feature-based registration is used for initial alignment and then alignment is improved with ICP. More about ICP and its variants at [Besl, 1992], [Rusinkiewicz, 2001], [Johnson, 1997].

More about registration algorithms and their survey is given in [Bellekens, 2015].

## 4. Realization

We reconstruct object 3D model from the set of stereo pair images taken from the left and right cameras (see examples on Figure 2 and Figure 3). We realize our project in C++ using OpenCV [OpenCV], [Bradski, 2008] – the biggest image processing library for calculating disparity map and generating point clouds and Point Cloud Library (PCL) [PCL] – point clouds processing and viewing library for 3D registration.

We try our realization with image sets captured from two Logitech HD Pro Webcam C920 web cameras and Minoru 3D stereo camera [Minoru]. We place an object at about 40-50 cm in front of the cameras and rotate it at small degrees capturing images for each rotation.

Then for each stereo pair we calculate disparity map using Stereo-Global Matching (SBM) algorithm [Hirschmuller, 2005] that is one of the best stereo correspondence algorithms combining speed and accuracy. From disparity maps we generate point clouds and segment our object from the scene to have point cloud only of the object.

Then we register these point clouds. We perform pairwise registration with ICP. At first step we take the first point cloud as a global model. Then at each next step we take the next consecutive point cloud and merge it to the global model with ICP registration algorithm, transforming it to the global model's coordinates and adding to it. . We also try to combine ICP with feature-based registration algorithms, but it didn't give good results in our case.

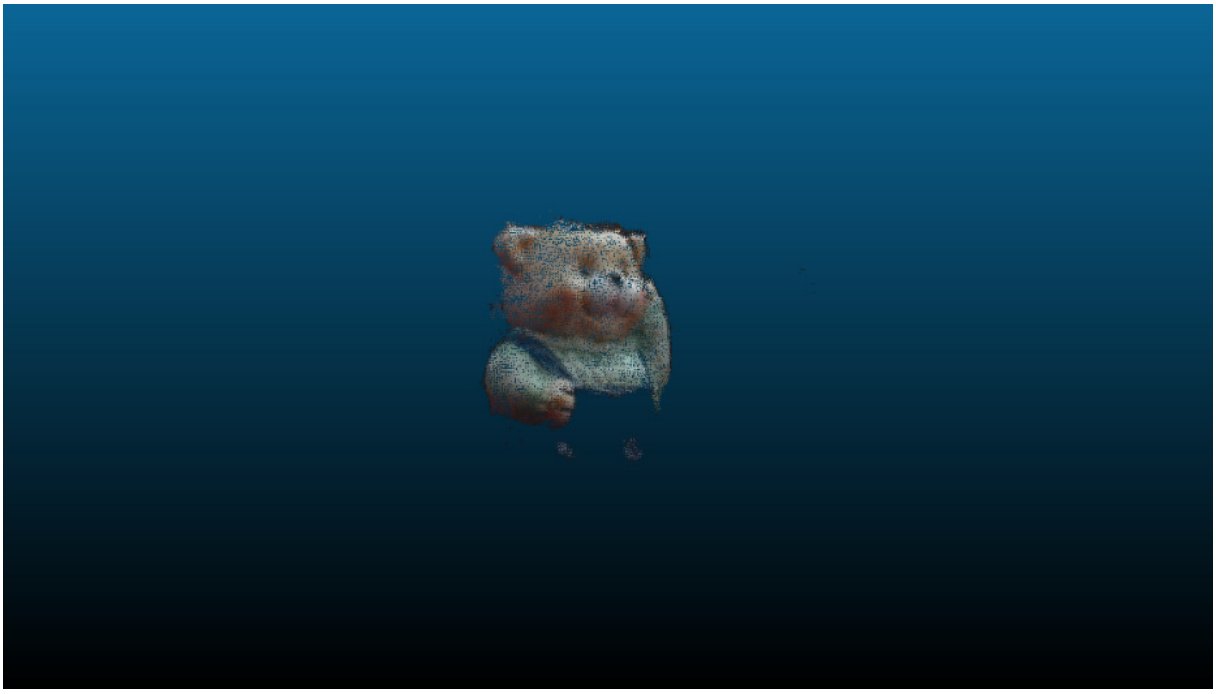

**Figure 2. Reconstructed 3D model from different angles - example 1**

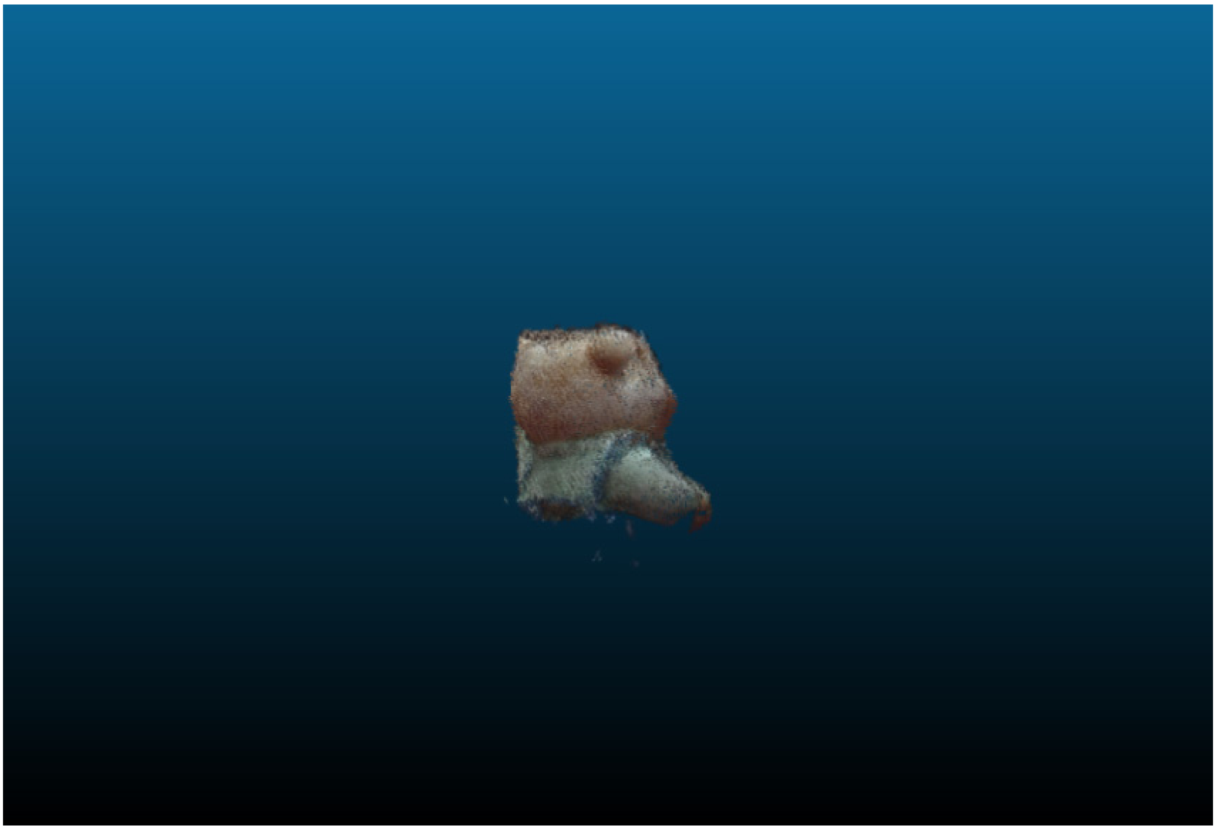

**Figure 3. Reconstructed 3D model from different angles - example 2**

## 5. Conclusion

At this paper we discuss point clouds registration problem and registration algorithms. We show how point clouds can be generated from stereo images using stereovision. And we present our realization, we construct object's 3D model from the set of stereo images. For each stereo image pair we generate point cloud and then merge these point clouds with ICP algorithm.

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***Major Fields of Scientific Research****: Computer Vision, Stereo Vision, 3D reconstruction*