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Point Clouds Preprocessing for Better Registration

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Abstract

In this article, we review point clouds preprocessing algorithms that enhance the results and performance of point clouds registration. Registration is a problem of merging two or more point clouds into one common. If a point cloud is obtained from a real physical object, it definitely has some noise and outliers. This noise can negatively affect the registration process and often prevent from good results. Point clouds preprocessing reduces noise and helps to get better registration results. Also we present several experiments on real dataset and results.

Keywords: Point clouds, Registration, ICP, SOR filter.

1. Introduction

3D technologies are developing very fast in recent years and are used in many spheres. One of the most commonly used formats in which 3D data is stored is a point cloud. Point cloud is a set of points in some coordinate system. Point cloud can also store some additional information, such as color or surface normals. Point clouds have many applications, and they can be converted to other formats. We can also get a surface from point clouds using one of the surface reconstruction algorithms.

One of the fundamental problems in computer vision and computer graphics is 3D or point clouds registration problem. Registration is the process of merging multiple partially overlapped point clouds from different scenes into one common point cloud. In other words, 3D registration transforms multiple point clouds from different coordinate systems into the same coordinate system so they can be aligned.

Process of getting a point cloud from a real physical object is known as reverse engineering or 3D scanning. There are active and passive methods of 3D scanning. Active methods usually use laser or structured light for getting 3d information. While passive methods don't emit anything, they rely on the detection of reflected ambient radiation. Examples of passive methods are stereovision, structure from motion, structure from shading. All these methods have their props and corns. But whatever method we use for getting a point cloud, it cannot be ideal. Some noise and errors are presented. All these factors negatively affect the process of registration and can prevent for getting good results. Also in case of big data, if point clouds have many points performance of the registration algorithms may be inacceptable. So in this article we review some point clouds preprocessing methods that can enhance the results and performance of registration algorithms.

The article has the following structure: in Section 2 we speak in details about point clouds registration and ICP algorithm, in Section 3 we review some preprocessing algorithms and in Section 4 we present experiments and results.

2. Related Work

Suppose we want to align the source point cloud P $(P = \{p_{1,}, p_2, ..., p_n\})$ with the target point cloud Q $(Q = \{q_{1,}, q_2, ..., q_n\})$. The aim of registration problem is to find such a transformation T (rotation matrix and translation vector) (1) applying which to source point cloud P will bring it to the same coordinate system with Q.

$$T = (R, t) = \begin{pmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \\ 0 & 0 & 0 & 1 \end{pmatrix}. \quad (1)$$

The registration algorithms can be divided into 2 classes: coarse and fine registration. Coarse registration algorithms are usually used for initial alignment and then results are refined with fine registration.

The most popular 3D registration algorithm is Iterative Closest Point (ICP) [1-2] algorithm. ICP is very simple for realization and has good performance. The main idea of ICP algorithm is iteratively register point clouds, trying at each iteration to minimize distance between point clouds. ICP algorithm consists of the following steps:

1) Finding correspondent points between point clouds. The closest point between point clouds are defined as correspondent points.
2) Transformation estimation applying which to source point cloud P will minimize the error E. $E = \frac{1}{N}\sum_{i=1}^{N}\left\|(Rp_i + t) - q_i\right\|^2$, where R - rotation matrix, t - translation vector, p_i and q_i - correspondent points, N - number of points. This error metric is called as point-to-point metric, there are also point-to-plane metrics defined in [2].
3) Apply the transformation to source point cloud P.

The steps 1-3 are executed iteratively until the error is smaller than the given threshold.

Over the years many variants of ICP algorithm are developed, more details about them in [3].

ICP algorithm has a known local minimum issue: if the initial distance between the point clouds is big ICP can give very wrong results. Also noise and outliers can negatively affect the results of the registration. So it will be good to reduce noise before the registration process.

3. Point Clouds Preprocessing

There are several point clouds preprocessing techniques that can be used for different purposes. Let us review some of them.

Down sampling:

Down sampling filter decreases the number of points in a point cloud data set. The aim of down sampling is to reduce the number of points in point cloud while still preserving the object and scene it represents. Down sampling filter is generally used on big data set to increase the performance of the algorithms working with point clouds.

Each point is described by a voxel and its centroid. Voxel is a box with a specific size in the space, and centroid is a point the coordinates of which are the mean value of coordinates of all points in the voxel.

There are two ways of down sampling: "voxel grid" and "uniform sampling". The first way replaces all points in the voxel with the centroid of that voxel, and the second one replaces with the nearest existing point to centroid. In the voxel grid approach a new point is generated, while in the uniform sampling no new point is inserted into the point cloud. The uniform sampling method is a bit slower than the voxel grid, but it represents the underlying surface more accurately.

Pass-through filter:

Pass through filter is used for cutting of values that are either inside or outside the given range. It can be used, for example, if we want to remove points that are deeper than some threshold. Pass through filter checks for every point if its field (coordinate) is in the given interval or not.

Radius outlier removal filter:

Radius outlier removal filter for each point examines a circle with the given radius and with center in that point. If the number of points in that circle is less than the given threshold k, then this point is specified as an outlier and removed from the point cloud.

In Figure 1 we can see an example of radius outlier removal filter, if k = 1, the yellow point will be removed, if k =2, the green and yellow points will be removed.

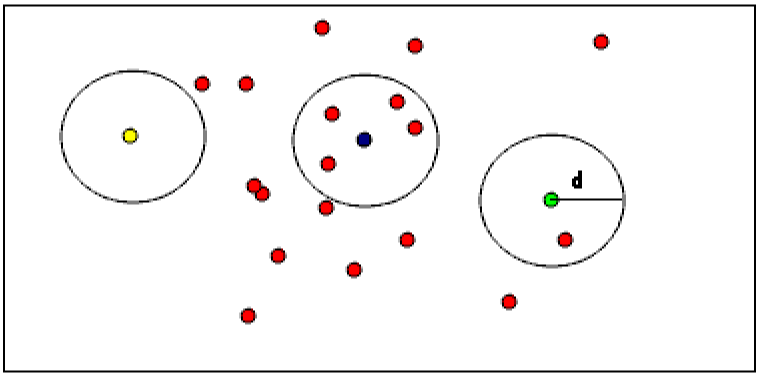

Fig. 1. Example of radius outlier removal filter [8].

Statistical outlier removal filter (SOR):

Statistical outlier removal filter removes points depending on their local neighborhood. For each point the mean distance from it to its k nearest neighbors is computed. By assuming that the resulted distribution is Gaussian with a mean and a standard deviation, all points the mean distances of which are greater than the global distances mean plus standard deviation with some coefficient are defined as outliers and removed from dataset. Point is specified as an outlier if its mean distance of its nearest k neighbors is bigger than M, where M is defined as:

$$M = avg + nSigma * \sigma,$$

where avg is the average distance, $nSigma$ – the number of times the standard deviation (user-defined parameter), σ – the standard deviation.

An example of statistical outlier removal filter is shown in Figure 2.

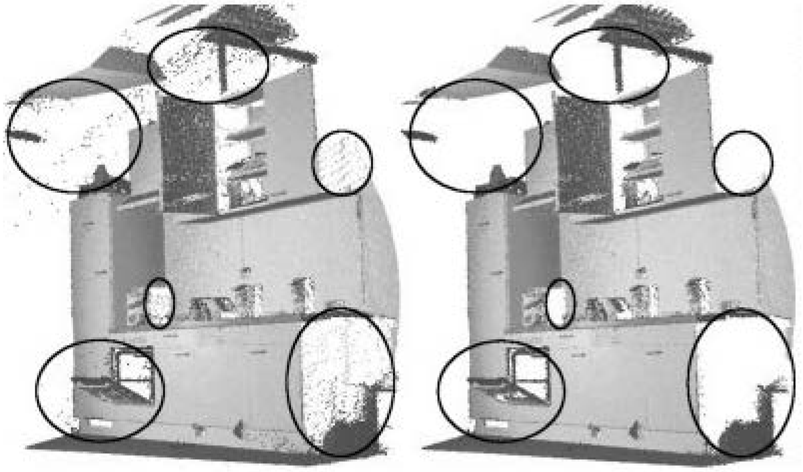

Fig. 2. Example of statistical outlier removal filter.

4. Experiments and Results

In this section we present some experiments and results with different datasets and preprocessing algorithms. For our realization we use Point Cloud Library (PCL) [6] - the biggest library for point clouds processing, viewing and manipulation. A registration with PCL is described in [7].

Let us review some experiments of point clouds preprocessing steps.

Experiment 1:

In this experiment we want to show how the downsample filter can affect the performance of registration algorithms, especially if point clouds have many points. We take two point clouds from Stanford Bunny dataset [4] - each point cloud has 40256 points. We downsample these point clouds with the voxel of size 0.01. Then we compare the performance of ICP registration algorithm of original point clouds and these point clouds after down sample filter is applied. The results were shown in Table 1.

Table 1:

Point clouds	Number of points	ICP (time)
Original point clouds	40256	32.91
Downsampled point clouds	394	0.1

As it is seen downsampling greatly affects the performance, while results in this case are almost the same.

Experiment 2:

In the second experiment we use our dataset of bear object. The point clouds in this dataset were generated from 2 web cameras by stereovision techniques. Stereovision is a technique that estimates 3D information of a scene from two or more cameras. 3D information is obtained as a depth map, then the depth map can be converted into a point cloud. More about stereovision -in [5,10]. We scan the bear from different views and get a point cloud for each view.

In this experiment we want to remove background to have a point cloud only of bear object. Figure 3 shows the point cloud of whole scene.

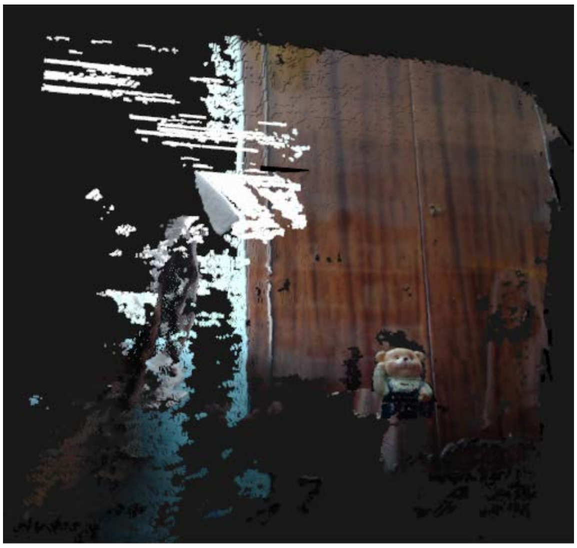

Fig. 3. The whole scene.

We segment our bear object from the scene using pass through filter, filtering by X, Y and Z coordinates. The result is shown in Figure 4:

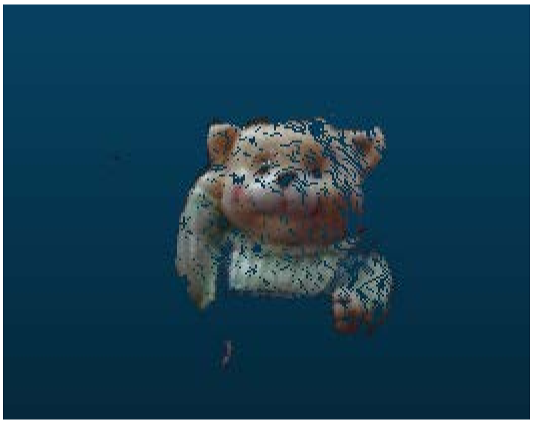

Fig. 4. Segmented point cloud.

Experiment 3:
In this experiment, we want to show how the noise can negatively affect the registration process. We take segmented point clouds from the previous experiment and merge these point clouds without applying any filter and after applying a statistical outlier removal filter. The results are shown in Figures 5:

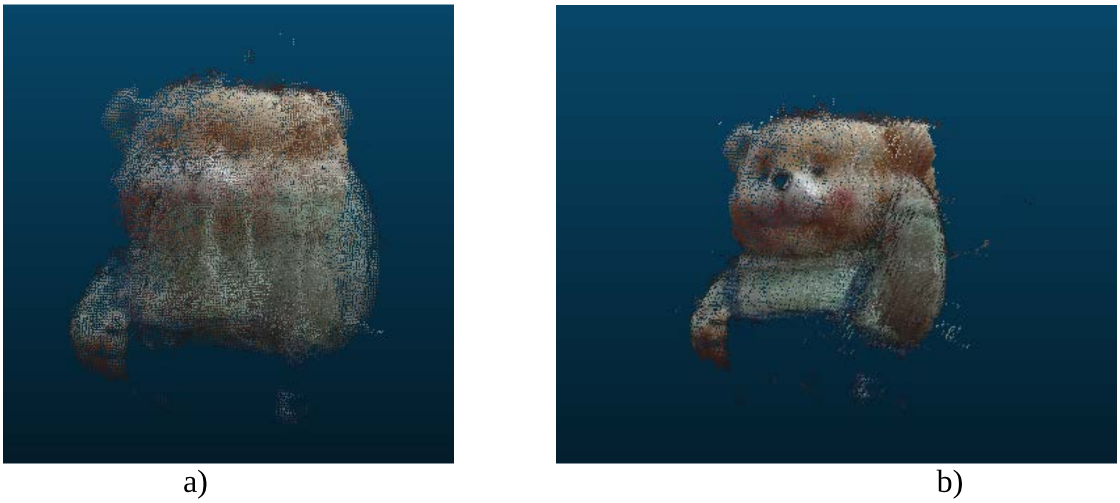

Fig. 5. The result of merging 10 point clouds with ICP algorithm. a) - range point clouds, b) - after applying statistical outlier removal filter.

As we can see from the figures, the noise and outliers in original point clouds negatively affect the registration process bringing to an absolutely wrong result. But after applying the SOR filter, we can get a good result.

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Կետերի ամպերի մշակում գրանցման արդյունքները բարելավելու նպատակով

Ա. Գևորգյան

Ամփոփում

Սույն հոդվածում ներկայացված են կետերի ամպերի մշակման ալգորիթմներ, որոնք բարելավում են կետերի ամպերի գրանցման (registration) արդյունքները և արդյունավետությունը։ Գրանցման խնդիրը կայանում է երկու կամ ավելի կետերի ամպ միաձուլելու մեջ։ Եթե կետերի ամպը ստացված է իսկական ֆիզիկական օբյեկտից, այն պարունակում է աղմուկ, որը կարող է բացասական ազդեցություն ունենալ գրանցման գործընթացի վրա և խոչնդոտել ստանալ լավ արդյունքներ։ Կետերի ամպերի նախամշակումը նվազեցնում է աղմուկը և օգնում է ստանալ ավելի լավ գրանցման արդյունքներ։ Սույն հոդվածում ներկայացված են նաև մի քանի փորձերի արդյունքներ իրական տվյալների վրա։

Обработка облаков точек для лучшей регистрации

А. Геворкян

Аннотация

В данной статье представлены алгоритмы обработки облаков точек, которые улучшают результаты и эффективность регистрации облаков точек. Регистрация - это задача соединения двух или более облаков точек. Если облако точек получено от реального физического объекта, то в нем присутствует шум. Данный шум отрицательно влияет на процесс регистрации и часто мешает получить хороший результат. Предварительная обработка облаков точек уменьшает шум и помогает получить лучший результат регистрации. В данной статье, также представлены результаты нескольких экспериментов на реальных данных.