Research on denoising algorithm of 3D point cloud data based on curvature change

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Abstract. This paper focuses on the algorithm of denoising for 3D point cloud data in 3D modelling technology. Through the problem that it is difficult to retain the feature points of traditional 3D point cloud data denoising and the denoising amplitude is too large, taking the change of Gaussian curvature value of sampling points as the basis of region division, an improved denoising algorithm based on the combination of median denoising algorithm and bilateral denoising algorithm is proposed. The algorithm is implemented and simulated by pseudo code. The simulation results show that the 3D point cloud data denoising algorithm based on curvature change not only has a higher ability in denoising effect and feature retention effect, but also has a greater advantage in the execution time of the denoising algorithm.

1. Introduction

In the process of the development of human society, the cognition of space has become one of the most extensive and basic systems. Human beings are always enjoying the experience of the three-dimensional world. In the process of gradual cognition, human beings rely on some basic clues, such as image, perspective, texture, shadow, etc., to fully realize the perception of three-dimensional objects. At present, with the continuous progress of computer technology and the development of multimedia technology, there are more and more improvement and expansion technologies based on 3D vision, and the visual feast based on 3D model is constantly unfolding. In this context, 3D modelling technology has become the most popular research topic. It involves not only classic fields such as automation and geometry, but also new disciplines such as image processing and graphics. Such technology has great application potential in virtual reality, 3D entertainment, reverse engineering, artificial intelligence and many other industries. At present, the means of 3D modelling technology are becoming more and more abundant. 3D point cloud modelling technology is becoming the most popular means of 3D modelling. The core process of using 3D point cloud model to realize modelling is shown in Figure 1. The main links involved include obtaining modelling object determination, obtaining point cloud data, point cloud data registration, typical feature mining, and establishing digital model [1].

In the process of 3D point cloud modelling, the acquisition of point cloud data is a crucial link. Currently, based on the 3D scanning hardware, the realization of 3D point cloud modelling has a higher accuracy. However, due to the influence of many objective or subjective factors, the acquisition of 3D point cloud data is not perfect. Most of the obtained 3D point cloud data have some noise, which makes the denoising of 3D point cloud data become very important in the process of 3D modelling.
2. 3D point cloud data denoising target

In most 3D point cloud models, the generation of noise is not directly related to the surface of the actual object. It is always generated for reasons other than the object. These noises greatly affect the representation of 3D point cloud model on the object, and even change the most essential characteristics of the object. However, in the process of 3D modeling, it is necessary to retain the essential characteristics of the modeling object, and the generation and existence of noise have a great impact on the retention of the characteristics of the modeling object. Traditional denoising methods are difficult to effectively define the noise points of the modeling object, which often makes the process of denoising become the process of the disappearance of the characteristics of the object, with prominent contradictions [2]. In view of this reason, this paper puts forward the main target of 3D point cloud data denoising as follows:

To denoise the 3D point cloud data acquired in the process of 3D modeling, it is not only necessary to realize the smooth and smooth of the discrete surface, but also need not destroy the original feature points of the modeling object, such as the size of the model changes or the surface is too smooth and so on. Therefore, for the denoising algorithm of 3D point cloud data, the most basic goal is to remove noise and retain features [3]. At present, there are many de-noising algorithms for 3D point cloud data, most of which are proposed from the perspective of digital geometry, but these de-noising algorithms are basically difficult to achieve the goal of both de-noising and fidelity. Therefore, based on the traditional denoising algorithm, the author proposes a three-dimensional point cloud denoising algorithm based on the curvature feature change information.

3. Denoising algorithm of 3D point cloud data under different curvature conditions

3.1. Basic idea of denoising algorithm

The denoising algorithm of 3D point cloud data under different curvature conditions is a kind of denoising algorithm based on the curvature value in the adjacent areas of acquisition points. The core idea is as follows: firstly, according to the average Gaussian curvature value in the adjacent areas of acquisition points, compared with the Gaussian curvature value of each point, some areas whose Gaussian curvature value is less than the average Gaussian curvature value are used in the other part of the region, the dynamic parameter bilateral denoising algorithm is used to denoise and retain the features of 3D point cloud model, so as to achieve the effect of flow field smoothing. Thus, the idea of denoising algorithm in this paper is shown in Figure 2.

3.2. Division of high curvature area and low curvature area

According to the previous analysis of the denoising algorithm, the denoising algorithm proposed in this paper is a combination of two algorithms. Based on the characteristics of different curvature changes, different denoising algorithms are adopted to achieve the goal of denoising and fidelity. Therefore, in this paper, the average Gauss curvature value is taken as the basic region judgment standard, and the Gauss curvature value of each sampling point is calculated, and then compared with the average Gauss curvature value, so as to divide the high curvature value region and the low curvature value region, providing the basis for selecting different algorithms.

Figure 1. Process of 3D point cloud model
If the selected sampling point is \( t \), the calculation formula of the mean Gaussian curvature value of the adjacent region to \( t \) can be expressed as follows:

\[
\bar{T} = \frac{1}{t} \sum_{i=1}^{t} | T_i |
\]

In the above formula, \( T_i \) represents the Gaussian curvature of each point in the region adjacent to the sampling point \( t \). According to the above formula, the average Gauss curvature value is obtained, and then other specific points are compared with the average Gauss curvature value. All points with the Gauss curvature value greater than \( \bar{T} \) are divided into points with high curvature area, and all points with the Gauss curvature value less than \( \bar{T} \) are divided into points with low curvature area.

3.3. Algorithm selection of different curvature value regions

After dividing the high curvature region and the low curvature region, we can select and execute the specific algorithm according to the basic idea of the algorithm given above.

Because the Gaussian curvature values of all sampling points in the low curvature region are smaller than the average Gaussian curvature values, and the overall Gaussian curvature changes little, so it is reasonable to use the median denoising algorithm. Fundamentally speaking, the median denoising algorithm is an important technology to deal with noise based on the sorting statistics theory. The algorithm can achieve the removal of noise within a small error range, especially for some random impulse noise, with good effect. At the same time, the median denoising algorithm can relatively well retain some details of the modelling object [4]. When using the median denoising algorithm for 3D point cloud data, it is different from the traditional denoising method for 2D data, so the 3D depth coordinate should be considered. Using the median denoising algorithm to denoise the 3D point cloud data is only to change the depth coordinate of the sampling point, but it will affect the position of the sampling point and the relevant curvature, resulting in the sampling point drift. For this reason, the author improves the traditional median denoising algorithm, sets the range of sliding...
window of sampling point, and replaces the original change to the depth coordinate value with the projection value of the corresponding point normal vector [5]. The improved median denoising algorithm is as follows:

1. The number \( t \) of adjacent points of the sampling point is initialized;
2. The projection value \( P \) of the normal vector of the adjacent points of \( t \) number of each sampling point is calculated;
3. Each projection value \( P \) is sequenced to produce the permutation of projection value \( P \) from large to small;
4. Select the median value in the projection value \( P \) arrangement, the value of \( t/2 \) shall prevail, and save the median value as \( m \);
5. When the sampling point \( s \) is displaced along the direction of normal vector, the resulting distance should be the size of the median value;
6. Calculate the position of sampling point \( s \) after displacement.

For another kind of area, that is, the sampling points in the high curvature area, because the corresponding Gaussian curvature value is relatively high, it contains most of the characteristics of the three-dimensional point cloud model, so this paper chooses the dynamic parameter bilateral denoising algorithm for this part of the area. The bilateral denoising algorithm is based on the bilateral denoising function, which is a three-dimensional point cloud data denoising algorithm evolved from the traditional two-dimensional plane image denoising [6]. Specifically, the denoising algorithm is implemented based on anisotropic mechanism, which can better retain the eigenvalues of modelling objects when applied to 3D point cloud data. In fact, the bilateral denoising algorithm belongs to non-linear, non-global, non-iterative algorithm [7]. The main process of applying bilateral denoising algorithm to 3D point cloud data denoising is as follows: firstly, according to the domain of the sampling point, set the tangent plane passing through the sampling point, and take the depth of 3D point cloud model as the vertical distance between adjacent points and tangent plane, while the distance between adjacent points and sampling points represents the pixel distance in 3D point cloud model; secondly, according to the values of the vertical distance and similar distance between adjacent points and sampling points are weighted average to obtain the new coordinates after denoising [8]. For the sampling points of 3D point cloud data, for the position after displacement, the following formula can be used.

\[
 t' = t + \alpha n
\]

In the above formula, \( T \) represents the original position of the sampling point in the region of high curvature, while \( t' \) represents the position of the same sampling point after displacement, \( \alpha \) represents the bilateral de-noising factor, which is the main factor affecting the displacement of sampling points along the direction of normal vector, and \( n \) represents the normal vector of sampling points.

4. Algorithm simulation and analysis

4.1. Simulation environment

This paper proposes a denoising algorithm for 3D point cloud data, which is based on the different curvature characteristics of 3D point cloud data. In order to verify the feasibility and efficiency of the denoising algorithm, the author carried out a simulation experiment. The operating system selected in the experiment is Microsoft Windows system, and the simulation language is Visual C++.

4.2. Simulation process and analysis

In the simulation process of 3D point cloud data denoising algorithm based on curvature change, it is necessary to determine the neighborhood size of 3D point cloud model first, which will affect the denoising effect and simulation efficiency to a certain extent. Too small neighborhood range determination and too large neighborhood range determination will produce adverse results. After many experiments, the author found that the neighborhood of 3D point cloud model in the range of 15-30 has relatively good denoising effect, and has a high operating efficiency. Therefore, the field range value selected in this simulation is 20.
In order to verify the denoising effect of this algorithm, the author designed two kinds of denoising simulation objects, one is bunny rabbit, the other is ordinary desktop experiment object. For these two different types of denoising objects, the single median denoising algorithm, the single bilateral denoising algorithm and the simulation experiment of the algorithm in this paper are implemented, and the results are shown in Figure 3.

![Figure 3. Experimental results of different denoising algorithms](image)

From the results of bunny rabbit simulation experiment, it is not difficult to find that the three-dimensional point cloud model effects obtained by different denoising algorithms are different. Overall, the algorithm in this paper is better than the single use of median denoising algorithm and single use of bilateral denoising algorithm in terms of smoothness and fluency.

In addition, for different denoising algorithms, the time spent for the above two groups of experiments is totally different, as shown in Figure 4. Through the comparison, it is found that in the process of simulation experiment, the experimental running time of the algorithm in this paper is the shortest, and the other two kinds of time are relatively high, which shows that the algorithm based on the curvature change of 3D point cloud data denoising in this paper has more advantages in execution efficiency.

5. Conclusion

As we all know, 3D modelling technology has a very important application in reverse engineering, 3D animation and other industries. As one of the hot issues in the field of 3D modelling, the denoising of 3D point cloud data involves complex computer algorithm and operation process. This paper proposes a new algorithm based on median denoising algorithm and bilateral denoising algorithm, which can effectively achieve the denoising of 3D point cloud data, maintain the smoothness of the model, but also ensure the retention of the basic feature points of 3D point cloud model objects, with large Rationality and availability of. However, in the algorithm mentioned in this paper, the process of sampling points moving along the normal vector is involved, which puts forward higher requirements for the accuracy of normal vector calculation, which also becomes an important direction of future research.
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