Research on the application status of 3D point cloud

ABSTRACT

This paper aims to discuss the application and development trend of 3D point cloud technology in different fields. As an effective means of digitizing the real world, 3D point cloud has been widely used in many fields, including computer-aided design, building information modeling, geographic information systems, robot navigation, autonomous vehicles, and the digitalization of cultural relics. In this paper, the techniques of acquiring 3D point cloud data are summarized, including laser scanning, structured light scanning and time flight measurement. Then, the latest advances in key technologies such as point cloud data preprocessing, feature extraction, model matching and visualization are analyzed. Further, the challenges of 3D point cloud technology are discussed, such as large data volume, slow processing speed and high precision requirements. Finally, this paper looks forward to the future development direction of 3D point cloud technology, especially in the integration of artificial intelligence and machine learning technology application potential. Through this study, we expect to provide researchers and practitioners in related fields with a comprehensive understanding of 3D point cloud technology and promote its application in a wider range of fields.

Keywords:three-dimensional point cloud, application status, point cloud processing

1. INTRODUCTION

With the continuous improvement of the global productivity level, the intelligent factory and intelligent manufacturing with the computer network physical system as the core is leading a profound change. The degree of intelligence of the manufacturing industry has been continuously improved in the manufacturing industry in the world to consolidate and expand the competitive advantage of the manufacturing industry[1]. In such a wave of global manufacturing change, the upgrading and transformation of China's traditional manufacturing industry has become particularly urgent and necessary. With the development and popularity of 3D scanning technology, point cloud data is starting to play an important role in a number of fields such as computer vision, robotics, and mapping. A point cloud consists of a number of three-dimensional points that map the external morphological and structural features of an object. Therefore, point cloud processing technology has become the core technology of point cloud data analysis and utilization. This paper aims to process 3D point cloud data through PCL (point cloud library) technology, and design a spatial curve fitting algorithm for more accurate model reconstruction and feature extraction. The machine vision method can effectively improve the automation level of the production line and reduce the detection error caused by human factors[2]. The application of this technology can not only improve production efficiency, but also ensure the consistency of product quality, especially in the production and quality control of complex components show its unique advantages.

2. DEVELOPMENT OF 3D IMAGE PROCESSING

3D image processing, as an important branch of computer graphics, has received great attention and in-depth research due to the increasing temperature at home and abroad in recent years[3]. With the continuous improvement of computer hardware performance and optimization of algorithms, 3D image processing technology has shown great application potential and value in many fields.

Although the research and application of 3D image processing technology in China started late, in recent years, due to the rapid development of technology and the continuous expansion of application fields, China has made remarkable progress in this field. Many universities and scientific research institutions have invested heavily in research and development, which has promoted the innovation and progress of 3D image processing technology.
Algorithm level: Domestic scientists have proposed many innovative algorithms and methods for the characteristics of 3D images, such as 3D image segmentation based on deep learning and 3D reconstruction based on voxels. These algorithms not only improve the efficiency and accuracy of 3D image processing, but also provide strong support for downstream applications.
Application level: 3D image processing technology has achieved remarkable results in medical, industrial, cultural heritage protection and other fields. For example, in the medical field, 3D image processing technology is widely used in medical image analysis, surgical navigation and other aspects. This can provide doctors with more accurate and intuitive diagnosis and treatment means[4]. In the industrial field, 3D image processing technology is an important application in product quality inspection, product design, etc., which makes the production efficiency and quality of products improve. In addition, three-dimensional image processing plays an important role in the field of cultural heritage protection. It helps experts to carry out accurate records and three-dimensional reconstruction of ancient buildings and cultural relics, providing new solutions for the protection and inheritance of cultural heritage. Through virtual reality and augmented reality technology, 3D image processing can also enhance the public's contact and experience of cultural heritage, making cultural communication more vivid and intuitive. 3D image processing technology is not only widely used in these applications, but also shows its great potential in future development [13-16].
The research and application of 3D image processing technology in foreign countries has been relatively mature. Europe and the United States and other developed countries in the three-dimensional image processing technology has a relatively complete research system and industry chain.
Algorithm level: foreign scholars have proposed many advanced algorithms and methods, such as three-dimensional reconstruction based on point cloud and three-dimensional perception based on depth camera. These algorithms have reached a high level in precision and speed [17,18].
Application level: 3D image processing technology is more widely and deeply applied in foreign countries. In addition to medical, industrial, cultural heritage protection and other fields, 3D image processing technology is also widely used in games, movies and other entertainment industries[5]. In games and film production, 3D image processing technology can create more realistic and vivid virtual scenes and characters, bringing a more immersive experience to the audience. However, although 3D image processing technology has made remarkable progress both at home and abroad, it still faces some challenges and problems [19,20].
(1) Due to the complexity and variability of current application scenarios, it is necessary to update and optimize relevant 3D image algorithms in real time.
(2) The acquisition and processing of 3D image data are still difficult and costly, and more efficient and economical solutions are needed. In addition, with the increasing popularity of 3D image processing technology, the protection of user privacy and data security has become a key issue.
In summary, although 3D image processing technology has been widely studied and applied at home and abroad, it still needs to be continuously optimized and improved in the follow-up research and development. With the passage of time, the performance of computer hardware will continue to improve and the continuous progress of algorithms, I believe that 3D image processing technology will show its huge application potential and value in more fields[6]. At the same time, 3D image processing technology will also have a lot of problems, need to continue to find and solve problems to promote the continuous development and progress of 3D image processing technology.

3. RESEARCH PROGRESS OF 3D POINT CLOUD DATA PROCESSING

As an important tool for data processing, point cloud database has been widely used and studied at home and abroad. Point cloud library not only provides rich algorithms and functions, but also provides convenience for users to process and analyze point cloud data[7].
There are some similarities in the use of point cloud libraries at home and abroad. For example, when preprocessing point cloud data, domestic and foreign users will preprocess the point cloud data in the point cloud library, including filtering, de-noising, adjustment, etc., to improve the accuracy and stability of the subsequent curve fitting algorithm. In addition, the users of the point cloud database know the spatial curve fitting algorithm, and the spatial curve fitting and modeling of three-dimensional point cloud data is an important research field. Domestic researchers have developed a variety of curve fitting algorithms, such as straight line fitting, arc fitting, spline curve fitting, etc., combined with the corresponding functions in PCL library to model and analyze complex three-dimensional curves. From the application field, these algorithms are widely used in robot navigation, industrial inspection, geological survey and other fields. Researchers at home and abroad have combined 3D point cloud processing in PCL library with spatial curve fitting algorithm to provide a more effective means for data processing and analysis in these fields. Domestic and foreign point cloud library users have also achieved fruitful results in the development of 3D point cloud data processing and spatial curve fitting algorithms

based on PCL, making important contributions to the development of related fields[8]. Their research results are not only of great significance to academic research, but also play an important role in industrial applications.

Although there are similarities in the use and research of point cloud libraries at home and abroad, there are some differences in the research of PCL based point cloud processing at home and abroad to some extent, which involve the research direction, application field, algorithm improvement and practical application.

In foreign countries, the research on PCL point cloud processing is more focused on cutting-edge technologies and innovative applications in academia and industry. Researchers continue to innovate in the field of 3D image processing technology, focusing on the development of advanced algorithms capable of processing complex point cloud data. Their research focuses on key techniques such as feature extraction, registration and target recognition to ensure the applicability and accuracy of the algorithm in different application scenarios. In order to improve the robustness and generalization ability of the algorithm, researchers often conduct rigorous tests and optimize the algorithm for its performance in real-world environments. These research results not only promote the progress of science and technology, but also provide solid technical support for industry applications. Research results are often published in international journals and professional conferences for peer review and industry sharing, driving development and innovation across the field.

It is worth mentioning that, with the rapid development of artificial intelligence technology and deep learning, the field of point cloud processing has also begun to explore the combination of these technologies. Foreign researchers have made remarkable achievements in feature extraction and classification recognition of point cloud data by using deep learning algorithms. The integration of these technologies has brought new ideas and directions for point cloud processing.

In contrast, domestic research is more focused on the application of PCL point cloud processing technology to practical projects to a certain extent, especially in the field of industrial production and intelligent manufacturing. Domestic researchers may pay more attention to translating advanced algorithms and technologies into actual products and solutions to promote the development of related industries[9]. In addition, domestic research may also pay more attention to the needs and characteristics of localization to adapt to specific domestic application scenarios and environments.

4. POINT CLOUD DATA PREPROCESSING

Due to the inevitable irrelevant effects of equipment factors, human factors and operational experience when obtaining closed point cloud data, there will be some irrelevant points, such as noise points, outlier points, etc., which greatly increases the number of points in the point cloud. Therefore, it is necessary to pre-process the obtained point cloud data before formal processing[10]. The preprocessing of point cloud data can reduce the number of points in the point cloud, thus making the subsequent algorithm processing more efficient and simpler.

4.1 Point cloud visualization

The visualization of point cloud is the process of graphically displaying the number of discrete point sets in three-dimensional space, which is very important for understanding and analyzing three-dimensional scenes. During visualization, point cloud data is usually presented in the form of points, lines, or surfaces. By adjusting attributes such as color, size, and transparency of a point, you can highlight specific areas or features in a point cloud. In addition, the use of different rendering techniques and visual effects, such as lighting models, texture mapping, and shadow processing, can further enhance the visualization of the point cloud, making it more realistic and easy to understand. It not only helps people intuitively perceive the three-dimensional scene, but also provides convenience for the subsequent data processing and analysis. Through the interactive operation of the point cloud after visualization, such as rotation and translation, users can observe and analyze the point cloud data from different angles and levels. At the same time, combined with other data processing technologies, such as filtering, segmentation and registration, useful information in the point cloud can be further extracted to provide support for practical applications[11].

4.2 Point cloud filtering

The purpose of point cloud filtering is to improve the quality and reliability of high point cloud data. The collected point cloud data may contain noise, outliers, or other types of errors that may result from defects in the acquisition equipment, environmental interference, or other factors. If point cloud data is not filtered, subsequent processing and analysis results may be inaccurate. Point cloud filtering can remove noise in point cloud data and improve the smoothness and continuity of data. Outliers in point cloud data can be detected and removed to improve the reliability and accuracy of data. Gaps in point cloud data can also be filled to improve data density and continuity. The filtered point cloud data can provide more accurate input for subsequent processing and analysis, thus improving the reliability of the final results. In short, point cloud filtering is an important step to improve the quality and reliability of high point cloud data, and has an important impact on the subsequent processing and analysis results.

(1) Conditional filtering: by setting conditional objects to filter and process to achieve accurate control and optimization of data. Points outside the specified region of the point cloud data are removed by setting ranges on the x, y, and z axes (that is, taking specific regions in the three axes).

(2) Statistical filtering: by calculating the average distance and standard deviation of all points in the neighborhood of each point in the point cloud to that point. Then, a threshold, usually related to the standard deviation, is set to determine

whether the point is a noise point. If the average distance of a point exceeds a set threshold, it is considered a noise point and filtered out.
(3) Radius filtering: calculate the distance between the point and other points within a certain radius around it. If there are not a sufficient number of points within this range (that is, the number of points falls below a set threshold), then the point is considered an isolated or noisy point and is filtered out. Conversely, if the number of points in the neighborhood reaches or exceeds the threshold, the point is considered valid and will remain in the point cloud.
(4) pass-through filtering: The function of pass-through filtering in point cloud processing is mainly to eliminate points that do not meet the requirements of a specific dimension range. By setting the value range for x, y, and z axes, and retaining the point cloud data within or outside the set range, a large number of irrelevant point clouds can be removed, which is very simple and efficient. For example, you can set an X-axis range in three-dimensional space, keeping only points within this range, and removing other points that are not within this set range[12]. Such operations help to quickly reduce the amount of data and focus on areas of interest, thereby improving processing efficiency and analysis accuracy.

4.3 Point Cloud Streamlining

3D point cloud often contains a lot of redundant data, and point cloud reduction is a key step in the pre-processing of point cloud. Due to the large amount of data, limited computing resources, high algorithmic computational complexity, data noise and redundant information, limited storage space, difficult data transmission and real-time processing and interaction requirements. With point cloud streamlining, you can reduce data volume, increase computing speed, improve data visualization, optimize point cloud models, and reduce storage costs. Point cloud streamlining can improve data processing and analysis efficiency, reduce storage and maintenance costs, improve data visualization and analysis results, optimize the quality of point cloud models, and meet real-time processing and interaction needs. In short, point cloud streamlining is an important step to increase the efficiency of high cloud data processing and analysis, reduce costs, and improve data quality.

5.CONCLUSION

This paper reviews the application status of 3D point cloud technology in many fields, and points out its key role in data acquisition, processing and analysis. Although there are challenges such as large data volume and complex processing, with the improvement of computing power and the integration of artificial intelligence technology, three-dimensional point cloud technology has shown great development potential and application prospects. In the future, further optimization of algorithms, improvement of processing efficiency and expansion of application scenarios will be an important direction to promote the development of this technology.

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