TRIZ Innovative Method for Eliminating Fissures in 3D Panorama Image Stitching

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Abstract. roaming splices several photographs taken by the camera into a panoramic image, and then uses computer graphics and image technology to construct panoramic space for the panoramic image. Image stitching will directly affect the user’s roaming experience, but some panoramic images will have obvious color seams after stitching. TRIZ is a knowledge-based, human-oriented inventive problem solving systematic method. Based on TRIZ innovation method, this paper describes, analyses, resolves and evaluates the final problem plan. By using TRIZ innovation method, we can break through the thinking barrier, break the thinking stereotype, and analyze the problem with new vision, and carry out logical and non-logical systematic thinking. The problem of stitching cracks in the process of 3D panorama stitching is solved thoroughly and effectively. Finally, according to the law of technological evolution, the future development trend is predicted, and competitive and innovative products are developed.

1. Introduction

3D panoramic roaming system refers to switching in the panoramic space constructed by panoramic images to browse different scenes. Users can import pictures into the platform according to their own needs. The system intelligently registers and fuses sequence images, automatically generates panoramic tourism system, realizes 360° roaming without dead angle, and can be protected and inconvenient in some places. Scenes that allow users to enter (such as cultural relics, historic sites, museums, tourist attractions, etc.) will realize virtual panoramic roaming through the objective and real scenes, and achieve remote virtual effects through browsers. Users can roam the whole regional scene through matching maps, radar, hot spots, hot spots and other functions, and embedding
background music and scene interpretation in 3D scenes through hot zone functions. Elements such as pictures, animations, videos, text descriptions, etc., realize the functions of user visiting scenic spots and internal scenes of buildings without leaving home [1]. The effect of image stitching will directly affect the effect of panoramic walkthrough. Usually most panoramic images will have obvious color seams after stitching.

TRIZ theory occupies a unique position in the field of global innovation and creativity research because of its good operability, systematisms and practicability [1-3]. After experiencing the internal integration of theoretical creation and theoretical system, TRIZ theory is in the stage of further perfection and development of itself and integration with other advanced innovation theories and methods, especially has become the most effective theoretical and methodological basis for computer-aided innovation technology and innovation problem solving [4]. After more than half a century of development, TRIZ theory has developed into a mature theoretical and methodological system to solve the practical problems of new product development. Its application has also expanded from engineering technology to management and society. The application of TRIZ theory can greatly speed up the process of people's invention and obtain high-quality innovative products [5-8].

Based on TRIZ method, this paper solves the problem of eliminating the stitching cracks of 3D panoramic images in practical teaching and scientific research. Through the solving process of TRIZ method, the existing problems are analyzed and the solutions are obtained. Finally, the scheme is evaluated. It enables TRIZ to systematically analyze the situation of stitching cracks in 3D panoramic images and quickly discover the essence or contradiction of stitching cracks in 3D panoramic images. It can accurately determine the exploration direction of stitching cracks in 3D panoramic images.

2. TRIZ Innovative Method Problem Solving Process
The core idea of TRIZ theory is mainly embodied in three aspects. First, whether it is a simple product or a complex technological system, its core technology follows the objective law of development and evolution, that is, it has the objective law of evolution and mode [9]; secondly, various technical problems, the constant solution of conflicts and contradictions is the driving force to promote this evolutionary process; thirdly, the ideal state of technological system development is to achieve the maximum with the least resources. Objective function [10-11].

The problem solving mode of TRIZ theory is illustrated in Fig.1. Compared with the traditional methods of trial and error and brainstorming, TRIZ theory successfully reveals the inherent laws and principles of invention and creation, and focuses on clarifying and emphasizing the contradictions existing in the system, rather than escaping from contradictions. Its goal is to completely solve the contradictions and get the final ideal solution instead of compromise or compromise. And it is based on the evolution of technology to study the whole design and development process, rather than random behavior. Practice has proved that the application of TRIZ theory can greatly speed up the process of people's invention and obtain high-quality innovative products [12]. TRIZ can help the system to analyze the problem situation and quickly find the essence or contradiction of the problem. It can accurately determine the direction of problem exploration. As shown in Fig.2, it is a TRIZ-based problem solving process in this paper.
3. TRIZ Innovative Method for Eliminating Fissures in 3D Panorama stitching

3.1. Object Description
TRIZ theory itself is the practice of decomposing a system into subsystems, distinguishing useful and harmful functions. These decompositions depend on the problem and environment, and are random in nature [13-14]. Computer software plays a supporting role, but can not completely replace the designer. It is necessary to provide methods and tools for designers dealing with these random problems [15].

Panoramic roaming refers to switching in the panoramic space constructed by panoramic images. Panoramic roaming realizes virtual panoramic roaming through the objective and real scene, achieves the virtual effect of different places through the browser, and realizes the functions of users visiting scenery, scenic spots and internal scenes of buildings without leaving home [16]. Therefore, its technical system can be described as a 3D panoramic roaming system as shown in Fig.3 (this paper takes the panoramic of Shuohuang Railway Training Station as an example for analysis), and its technical system function can be described as roaming and browsing.
3.2. **Working principle of the system**

A panoramic image is composed of 360-degree horizontal and 180-degree vertical photographs taken by the camera. Then the panoramic image is used to construct the panoramic space using computer vision technology. The principle of 3D panoramic roaming is shown in Fig. 4.

3.3. **Description of System Main Problems**

Panorama stitching will directly affect the user's roaming experience. Usually, some panoramic images will have obvious color seams after stitching. These problems are mainly caused by the limited pre-shooting technology, high complexity of algorithm and the high requirement of PS technology in the post-processing of stitching images. The problem of stitching cracks in panoramic images is shown in Fig. 5.
At present, aiming at the stitching cracks of 3D panoramic roaming images, mainly improving image splicing algorithm and subsequent panoramic image processing technology, but it has not solved the problem thoroughly. In this paper, the main work is to effectively eliminate the 3D panorama stitching cracks, improve the reliability of the system. The ultimate ideal result of the technical system is that IFR (Ideal Final Result) can realize smooth and seamless panorama stitching for the panoramic image taken by itself [9].

4. TRIZ Innovative Method to Eliminate Fissures in 3D Panorama stitching

4.1. System analysis and tailoring
Systematic analysis is the abstract "function" angle of technical system to analyze the system, analyze the state of system execution or completion of its functions. Through systematic analysis, the functions of technical system can be defined, the basis for creating schemes can be provided, the relationship between various functions can be fully grasped, and the design ideas for expanding scheme creation can be enlarged. The analysis of the 3D panoramic walkthrough system is shown in Fig.6, in which the rectangle is the component, the rounded rectangle is the object of action, and the hexagon is the supersystem.

![Fig. 6 Analysis of 3D Panoramic Walkthrough System](image)

Some components of the technical system can be cut off, but the useful functions of these components can be retained, and the useful functions of the cut components can be redistributed to reduce the number of components, reduce the cost of the system, optimize the functional structure of the system, rationally lay out the system structure, reflect the functional value, eliminate excessive, harmful and repetitive functions, and improve the idealization of the system.

Through system analysis, it can be concluded that single panorama preprocessing can be tailored. The main function of single panorama preprocessing is to solve the problems of position coordinate change, insufficient overlap rate, noise and color change of single panorama image. The preprocessing function of single panorama can be realized by panoramic image shooting. It can improve the image shooting equipment, increase the number of images, improve the image shooting technology and select the appropriate shooting location. The trimmed model of the 3D panoramic walkthrough system analysis is shown in Fig.7.
Through the above system cutting, we can get the solution one: cutting single panorama preprocessing function. As shown in Table 1, single panorama preprocessing mainly uses image processing software and image denoising enhancement algorithm to obtain panoramas with ideal position coordinates and high overlap rate. By improving image capturing equipment, increasing the number of images captured, improving image capturing technology, and selecting appropriate shooting sites, a single panorama with ideal position coordinates and high overlap rate can be obtained. After cutting, the original problem has not been completely solved.

### Table 1. Panorama stitching problem solution (scheme 1)

| Method                                | Chart |
|---------------------------------------|-------|
| Improvement of image capturing equipment | ![Image](chart1.png) |
| Increase the number of images shot     | ![Image](chart2.png) |
| Improving image capturing technology   | ![Image](chart3.png) |
| Choose the appropriate shooting location| ![Image](chart4.png) |

#### 4.2. Causality Analysis
There are a series of causal relationships between the root causes and the results of technical system problems, which constitute one or more causal chains. By constructing causal chains, the causes and results of events are pointed out, so that the root causes of problems are found, and the "weak points" in the chain of problems generation and development are found. Finally, the starting point for solving problems is found. As shown in Fig.8, the causal analysis of the stitching cracks in 3D panoramic images is presented.
According to the above causal analysis, the main reasons for the stitching cracks of 3D panoramic images are imperfect follow-up processing of the completed panoramic images, incomplete image matrix transformation and splicing process, inadequate image matching accuracy, and inadequate quality of single panoramic images. Further analysis shows that the fundamental reasons are the unstable application level of panoramic image processor software, the inadequate performance of image processing software, the unstable performance of image projection transformation method, the unstable performance of feature detection algorithm, the unstable performance of error matching point removal algorithm, the unstable application level of panoramic image processor software, the inadequate performance of image processing software, translation vector. Inadequate estimation of quantity error, unstable performance of image projection transformation method, insufficient number of panoramic images, uneven shooting location, lack of feature information of shooting scene, inadequate panoramic image shooting equipment, unstable use of technical level of shooting personnel and equipment, etc.

4.3. Resource Analysis

The ideal system needs resources. In order to achieve any goal, the system inevitably chooses the most effective method. Necessary resources need to be found or created, and when needed, the system will be able to use all common sense and the surrounding environment to select the right resources.
Usually available system resources play an important role. The closer the solution to the ideal solution, the more important the system resources are.

4.3.1. Resource Analysis I. The shortage of panoramic images is analyzed as shown in Fig.9. Its information resources include shooting speed, shooting angle and so on. Through analysis, we can use supersystem and subsystem to shoot speed and reduce shooting rotation angle. As shown in Table 2, scheme 2 can increase the number of panoramic images taken per unit time by improving shooting equipment and shooting methods in the scene space. It can be solved by choosing multi-lens panoramic camera, automatic panoramic shooting platform and reducing shooting rotation angle.

![Fig. 9 Analysis of insufficient resources for panoramic image shooting](image)

| Method                        | Chart       |
|-------------------------------|-------------|
| Multi-lens panoramic camera   | ![Chart]   |
| Automatic panoramic photography platform | ![Chart] |
| Reducing the rotation angle of shooting | ![Chart] |

4.3.2. Resource Analysis II. As shown in Fig.10, the resource analysis of the unstable performance of feature detection algorithm is carried out. Its information resources include: algorithm parameters, panoramic image content, number of features and other resources. Through analysis, the number of features in supersystem and subsystem can be used to get scheme 3. In feature detection software, the number of feature points can be adaptively detected to improve the accuracy of image matching and make the stitching panoramic image smooth and seamless (the number of feature points increases, the time of image matching increases). It can be solved by adjusting the contrast of panoramic image and removing the mismatched points.
Table 3. Solution of Fissure Problem in 3D Panorama stitching (Scheme 3)

| Method                              | Chart |
|-------------------------------------|-------|
| Adjust the contrast of the image    | ![Chart](chart1.png) |
| Parameter modification of mismatched point removal algorithm | ![Chart](chart2.png) |

5. TRIZ Innovative Method to Eliminate Fissures in 3D Panorama stitching

5.1. Technical Contradiction Analysis

Technical contradiction is the conflict between two or more parameters in a technical system. By striving to improve one parameter in a product or process, another parameter may be problematic.

5.1.1. Technical Contradictions I. Causal analysis shows that there is a lack of feature information in shooting scenes. At present, the solution is that the original scene has less information, and the feature information can be added appropriately in the scene, but the useless feature information increases, which makes the post-modification of panoramic image more difficult and image processing more difficult. Further analysis shows that the improvement parameters are adaptability and versatility, and the deterioration parameters are harmful factors acting on objects. By looking for the TRIZ contradiction matrix, we can see that the innovative principle can be used as follows: 35. physical or chemical parameters change; 11. precaution; 32. color change; 31. porous material.

According to the principle of prior precaution (11) and color change (32), as shown in Fig.11, scheme four is adopted. If the information in the original scene is small, the focus of the camera will be less. Before the shooting, we can add colorful information or color blocks to the local area (blank) of the scene, so that the original scene information volume and focus will be increased, and the panorama quality will be improved. Single treatment is enough. For example, color information rich pictures or color blocks can be added to the blanks of the original scene to support the subsequent image stitching s.
5.1.2. **Technical Contradictions II.** Causal analysis shows that there is a problem of uneven shooting location. At present, the solution is that the ground of the original scene is uneven and the tripod is adjusted appropriately in the scene, but the equipment adjustment consumes more time and the shooting difficulty is increased. Further analysis shows that the improvement parameters are harmful factors and the deterioration parameters are productivity. By finding the TRIZ contradiction matrix, we can see that the innovative principle can be used as follows: 22., change the harm into profit; 35., change the physical or chemical parameters; 13., reverse the effect; 24., with the help of intermediaries. With the help of the mediator principle (24), as shown in FIG.12, scheme five is adopted. If the location of the original scene is uneven, resulting in an increased workload, the relevant intermediaries can be appropriately enhanced in the scene to ensure the smoothness of the location. For example, acrylic rotating plates can be placed in uneven places on the ground, with the help of flat acrylic plates to reduce the difficulty of equipment construction.

5.1.3. **Technical Contradictions III.** Causal analysis shows that there is an excessive complexity of feature information in panoramic images. At present, the solution is to avoid the complex information as a splicing gap in the shooting process, but with the increase of equipment adjustment time, some complex information pictures cannot be avoided. Further analysis shows that the improvement parameters are complexity and the deterioration parameters are convenience of operation process. By looking for the TRIZ contradiction matrix, we can see that the innovative principles can be used as follows: 27. cheap alternatives; 9. counteraction; 26. replication; 24., with intermediaries. According to the inspiration of replication principle (26), as shown in Fig.13, scheme six is adopted. If the complexity of information in the original scene leads to the complexity of panorama stitching process, and then leads to the appearance of stitching cracks, the images of multiple complex regions can be photographed, and the fusion of multi-source panoramic images and the splicing of Gai Shansan's panoramic images will be carried out. For example, it can take multiple images in complex areas and fuse them to improve the image quality of complex areas.
5.2. Analysis of Physical Contradictions
When the engineering parameters of a technical system have opposite demands, there will be physical contradictions, such as requiring that a certain parameter of the system not only exist, but also be high and low, or both large and small, etc.

5.2.1. Physical Contradictions I. In the process of panorama stitching, the lack of panoramic image information and the lack of feature points make it impossible to do the follow-up stitching work. The panoramic image is rich in information and has many feature points, which easily leads to panorama stitching cracks. In order to get a smooth seamless panoramic image, the number of feature points is not only small (panoramic image with abundant information), but also large (lack of panoramic image with abundant information). The conditional separation method can be applied, while the innovation principle of conditional separation recommendation is as follows: 1. homogeneity principle, 2. phase transformation principle, 3. thermal expansion principle, 4. change color, mimicry principle, 5. accelerated oxidation principle and more than 6 usability principle.

As shown in Table 3, we apply the principle of multipurpose (6) to get the scheme seven: by setting up a single panoramic image to extract the number threshold of feature points theta, when theta "T1", we use algorithm 1 (such as SIFT algorithm) for feature detection. When theta "T2", we use algorithm 2 (such as ORB algorithm) to perform feature detection [17], where "T1" and "T2" are the minimum and maximum values of detecting feature points. When the panoramic image is lack of information or abundant in feature detection, an appropriate number of feature points can be obtained, namely "t1", "theta", "t2". For example, formula 1:

\[
F = \begin{cases} 
\text{Algorithm 1} & \theta < t1 \\
\text{Algorithm 2} & \theta > t2 
\end{cases}
\]

(1)

| Table 4. Number of Characteristic Points and Solution of Physical Contradictions (Scheme 7) |
|---|
| Project | Chart | Appropriate number of feature points t1 < θ < t2 |
| Many feature points θ > t2 | ![Image] | ![Image] |
| Letter feature points θ < t1 | ![Image] | ![Image] |

5.2.2. Physical Contradictions II. In panoramic image shooting, many panoramic images need to be taken because of the equipment, space and the maximum preservation of scene information. In the process of stitching, every stitching of panoramic images may lead to the appearance of panorama stitching cracks. In order to obtain a panoramic image with rich scene information and smooth seamless, the number of panoramic images is both large (in the process of panoramic image shooting) and large number of panoramic images. Less (panoramic image stitching process). Time separation can be applied, while the principle of time separation recommendation is as follows: 1. the principle of
dynamic characteristics, the principle of 2. pre action, the principle of 3. periodic actions, 4. the time principle of reducing harmful effects, and 5. the principle of counteraction in advance.

As shown in Fig.14, we apply the 3 periodic motion principle to get the plan: we can work periodically for the panoramic image. First we will stitch the panorama after shooting. If there are stitching cracks, we will take the large scene images of the stitching cracks. If there are no stitching cracks, then we can continue the panorama stitching.

![Fig. 14](image1)

**Fig. 14** How many panoramic images are taken and how many physical contradictions are solved (Scheme 8)

5.3. Material Field Analysis

Material field model is an important analysis tool of TRIZ theory. It is used to analyze model problems related to existing technology. The function of all technical systems is to achieve a certain function. All systems can be decomposed into three basic components: two substances (S1, S2) and one field (F).

5.3.1. Field Analysis I. According to the result of causal analysis, it is found that the information complexity of panoramic image is excessive, which leads to the excessive number of feature points in the image. The object field model of feature detection as shown in Fig.15 is established.

![Fig. 15](image2)

**Fig. 15** Field model with excessive information complexity in panoramic images

Using standard solution 4.1.1 to replace detection or measurement with system changes, scheme 9 shown in FIG.16 can be obtained. Without extracting feature points, one block in the overlapping area of an image is used as a template, and the matching block most similar to this template is searched in another image. For example, the middle picture is an image block, and the first one is the picture where the image block is located. The image block can be found and matched in Fig.2.

![Fig. 16](image3)

**Fig. 16** Over-field analysis of panoramic image information complexity (Scheme 9)
5.3.2. Field Analysis II. According to the result of causal analysis, it is found that the erroneous estimation of translation vector is uncontrollable, which results in the inaccuracy of panoramic image matching. The object field model of translation vector estimation is established as shown in Fig. 17.

![Material Field Model of Shift Vector Estimation](image)

**Fig. 17** Material Field Model of Shift Vector Estimation

By using the standard solution 2.1.1 chain object field model, scheme 10 as shown in Table 4 can be obtained. By increasing the overlap ratio of local panoramic images, the erroneous estimation of translation vectors can be reduced, and the accurate registration of panoramic images can be realized. For example, the matching of two images can be improved to the matching of three-spoke images, thus increasing the overlap ratio of panoramic images.

**Table 5.** Analysis of Uncontrolled Object Field by Error Estimation of Shift Vector (Scheme 10)

| Photo | Original map | Stitching image |
|-------|--------------|-----------------|
| The two picture | ![Original Map](image) | ![Stitching Result](image) |
| The three picture | ![Original Map](image) | ![Stitching Result](image) |

5.4. Evolutionary Analysis

As shown in Table 6, the above ten schemes are analyzed and divided into two categories: A panoramic image shooting class and B feature registration algorithm class. There are:

**Table 6.** Analysis and classification of existing solutions

| Serial | Classification basis | Taxonomy |
|--------|----------------------|----------|
| A      | Panoramic image shooting | 1: Improve the shooting quality of single panorama  
2: Increase the number of panoramic images taken  
5: Add ground equipment to improve the quality of single panoramic image shooting  
8: Periodic shooting and stitching  
10: Increase the number of images taken and the proportion of overlapping images |
| B      | Feature matching algorithm | 3: Number control of feature points in stitching process  
4: Adding local feature information to panoramic images  
6: Image fusion improves local image quality  
7: Adaptive Image Feature Detection Algorithms  
8: Periodic shooting and stitching  
9: Image Block Stitching Algorithms |
A further summary of category B schemes can be as follows:

| Number control of feature points in stitching process |
| Adapative image feature detection algorithm |
| Adding local feature information to panoramic images |
| Image fusion to improve local image quality |
| Periodic shooting and stitching |
| Image block mosaic algorithms |

**Fig. 18** B Summary of Schemes

According to the mobility evolution route of TRIZ, scheme 11 shown in Fig.18 can be used to directly stitch the captured images without any operation between them. Then the captured panoramic images and the directly stitched panoramic images can be fused by multi-source data. It has the advantages of convenience, rapidity and keeping the original information to the greatest extent. At present, multi-source image fusion technology is becoming more mature, which has a good inhibition effect on stitching cracks, so this scheme is feasible.

**Fig. 19** Mobility Evolution Path (Scheme 11)

6. Evaluation of TRIZ Innovative Method for Eliminating Fissures in 3D Panorama stitching

From the analysis of the advantages, disadvantages, technological advancement and current feasibility of the eleven schemes, 7 are shown as follows:

**Table 7. Evaluation of Fissure Problem Scheme for Panorama stitching**

| Serial | Name | Advantage | Shortcoming | Advancement | Implementability |
|--------|------|-----------|-------------|-------------|-----------------|
| 1      | Improving the shooting quality of single panorama | Inhibiting stitching cracks from the beginning | Increasing shooting time and labor costs | ★★★★★ | ★★★★★ |
| 2      | Increase the Effective | Increasing | ★★★★★ | ★★★★★ |
|   | number of panoramic images taken | restraint of high complexity panoramic stitching cracks | shooting time and labor costs |   |
|---|---------------------------------|-------------------------------------------------------|------------------------------|---|
| 3 | Number control of feature points in stitching process | Reliability improvement | To a certain extent, increase the time of feature point selection and processing | ★★★☆☆ | ★★★★☆ |
| 4 | Adding feature information locally to panoramic images | Adding feature information of shooting scene | Increase manufacturing costs and shooting time | ★★★★☆ | ★★★★☆ |
| 5 | Incorporating Ground Equipment to Improve the Quality of Single Panoramic Image | Improving the overall stability of image shooting | Increase manufacturing costs and shooting time | ★★★☆☆ | ★☆☆☆☆ |
| 6 | Image fusion to improve local image quality | Reducing stitching cracks caused by complexity of feature information in panoramic images | Increase image processing time and labor cost | ★★★★☆ | ★★★★☆ |
| 7 | Adaptive image feature detection algorithm | Great improvement of reliability | To a certain extent, the extraction time of feature points is increased | ★★★★☆ | ★★★☆☆ |
| 8 | Periodic shooting and stitching | It directly suppresses the errors and uncontrollable factors of scene information in shooting. | Increasing manufacturing costs, increasing shooting time and labor costs | ★★★★☆ | ★☆☆☆☆ |
According to the above analysis, the main execution schemes are to control the number of feature points (scheme 3), add feature information (scheme 4), improve local image quality (scheme 6), adaptive image feature detection algorithm (scheme 7), image block image stitching algorithm (scheme 9) and panoramic image integral fusion (scheme 11).

|   |   |   |   |   |
|---|---|---|---|---|
| 9 | Image block stitching algorithms | Reducing the instability of feature detection algorithms | Image block size needs to be adapted to increase search time to a certain extent. | ★★★★★ | ★★★☆☆ |
| 10 | Increasing the number of images taken and the proportion of local image overlap | Effective restraint of panoramic stitching cracks | Increasing the time of image shooting and processing, adjusting the image proportion and increasing the labor cost in the later stage | ★★★☆☆ | ★★★★☆ |
| 11 | Integral Fusion of Panoramic Images | Suppression of panoramic stitching cracks to a higher level | Increase the time of image fusion to a certain extent | ★★★★★ | ★★★★★ |

7. Conclusion
The quality of panorama stitching will affect user's roaming experience. This paper describes, analyses, solves and evaluates the final problem of color seam in partial panorama stitching by TRIZ innovation method, and effectively solves the problem of stitching cracks in the process of 3D panorama stitching. The next step of this paper is to further explore TRIZ innovative methods to solve practical problems in the field of virtual reality, and to use the scheme in the following 3D image stitching process.

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