

Research Article

Noise Data Removal and Image Restoration Based on Partial Differential Equation in Sports Image Recognition Technology

Shi Junmei 

Department of Physical Education, Taiyuan Institute of Technology, Taiyuan, Shanxi 03008, China

Correspondence should be addressed to Shi Junmei; shijunmei@tit.edu.cn

Received 15 October 2021; Revised 1 November 2021; Accepted 5 November 2021; Published 24 November 2021

Academic Editor: Miaochoao Chen

Copyright © 2021 Shi Junmei. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

With the rapid development of image processing technology, the application range of image recognition technology is becoming more and more extensive. Processing, analyzing, and repairing graphics and images through computer and big data technology are the main methods to obtain image data and repair image data in complex environment. Facing the low quality of image information in the process of sports, this paper proposes to remove the noise data and repair the image based on the partial differential equation system in image recognition technology. Firstly, image recognition technology is used to track and obtain the image information in the process of sports, and the fourth-order partial differential equation is used to optimize and process the image. Finally, aiming at the problem of low image quality and blur in the transmission process, denoising is carried out, and image restoration is studied by using the adaptive diffusion function in partial differential equation. The results show that the research content of this paper greatly improves the problems of blurred image and poor quality in the process of sports and realizes the function of automatically tracking the target of sports image. In the image restoration link, it can achieve the standard repair effect and reduce the repair time. The research content of this paper is effective and applicable to image processing and restoration.

1. Introduction

Images have unique use effects and their own significance in various fields [1]. It is the image information stored and obtained by the objective impression in the human brain, that is, an important way for us to know the external information and external changes [2]. If we want to know what we care about and what we observe from the external environment, we will directly obtain it by means of image processing. With the rapid development of science and technology, computer technology is also making continuous progress and improvement [3, 4]. More and more artificial intelligence technology has been applied to our surrounding life, and artificial intelligence equipment has gradually participated in our daily work. Image recognition technology has also begun to be widely used by people in the fields of scientific exploration, medical image processing, military machinery analysis, and so on [5, 6]. The generation of image processing technology is based on the tracking and recognition of pixel changes. In order to improve the image quality

and processing speed, it effectively identifies and completes the tracking task through its own image film technology and computer algorithm. Image processing technology is gradually changing our living environment and lifestyle. For example, this technology can observe astronomical information, intelligently recognize traffic license plates, and carry out face recognition and machine recognition [7, 8].

Image recognition is to process, analyze, and restore graphics and images with the support of computer technology. It is a technology to complete tasks by identifying targets and subjects in different environments [9]. The image processing technology is to further improve the graphics and images by using computer algorithms under the background of recognition technology, mainly focusing on the exchange between images and improving the visual effect of the naked eye [10]. Image processing can further change the blurred image, restore the incomplete image, and improve the image quality. In sports, many images are obtained in dynamic mode and environment [11]. This leads to the problems of difficult tracking and acquisition of image

information, incomplete blur, more impurities, and poor quality [12]. In the definition of sports image features, in order to capture sports images, we also need to distinguish other disturbing features in the scene, which has a great impact on our image acquisition and image processing [13]. In order to solve the above problems, we need to carry out point-to-point detection and synthesis of moving images to form high dynamic image information. Firstly, the tracking difficulty of image acquisition is solved, and then, the image processing technology is used for noise interference removal and image restoration. Therefore, this paper proposes a partial differential equation research method based on image processing to optimize the noise data, image processing, and restoration in sports [14, 15].

This paper creatively studies the partial differential equation based on motion noise data and image processing. The main innovative contributions include the following: (1) It overcomes the interference factors in the image processing technology to remove, repair, and restore the environment, and mainly optimizes the quality problems such as image distortion and blur in the transmission process. (2) Using automatic image tracking and target recognition technology, the pixel sequence structure model composed of images is established, and the feature points are extracted, so that more accurate image data can be obtained. (3) It can be applied to complex environment and dynamic images and is suitable for accurate image processing and image restoration.

The rest of this article is organized as follows: In Section 1, this paper studies and analyzes the development of image recognition technology and the application status of image processing in various countries and puts forward the main content of this paper. In Section 2, the moving image is tracked, and then, the partial differential equation image processing technology is used to remove the noise interference in the moving image. Finally, the partial differential image processing equation is used to repair the moving image as a whole to improve the image quality. In Section 3, the research results of removing moving image noise data by partial differential equation and image restoration are analyzed.

2. Related Work

In image processing, computer technology is used to obtain and process the graphic image and finally achieve the required result image [16]. Image processing can be divided into two parts: one is analog processing and the other is digital graphics and image processing [17, 18]. Most image processing technologies are aimed at digital images, which basically depend on computer technology and software processing. Digital image processing is to solve the problems of poor image quality and many interference factors. The other purpose is to remove the interference noise, restore the original scale graphics image one-to-one, and finally facilitate the artificial intelligence to obtain the feature points directly [19]. Traditional image processing is to extract data through sampling method, mainly with the help of external forces and equipment, that is, cameras and electronic products.

The sampling process also contains a lot of dynamic video data, as well as dynamic images and sounds [20].

Some scholars have a relatively advanced development in the computer field. They have combined computer technology with image processing technology to form a real-time fire alarm system in life [21]. It mainly uses virtual technology equipment combined with image processing to analyze and detect fire, and can obtain the color range of fire from the image. By comparing with the color threshold of fire, the fire situation and the specific location of ignition point can be judged, so as to achieve the purpose of alarm and early warning [22].

In the application field of computer technology and image processing technology, the image category is briefly described through the role of image in application [23]. The restoration of dynamic images according to image technology improves the beautification defects in the process of website design and improves the convenience of users.

The construction of mineral resources is in the process of intelligent development [24]. In order to realize unmanned intelligent transportation, they use obstacle detection as an important means to solve unmanned driving. In order to improve work efficiency and safety, image processing and tracking technology are added to detect and determine the track position. It improves the efficiency and intelligent progress in the working process.

China has intelligentized and improved image processing technology, which has developed rapidly in the medical field. Through the combination of image technology, the efficiency of disease inference and pathological analysis is greatly improved, and it is gradually widely used in provincial and municipal hospitals [25]. In order to realize real-time image processing and analysis, firstly, combine with intelligent image processing technology, optimize medical equipment, and finally, form an important trend in the development of medical field. Based on the above development of image processing technology, we will pay attention to the application of this technology in sports. In the process of image acquisition in sports, this paper mainly uses the target tracking method in image recognition to reconstruct the three-dimensional features and contour of sports image. Then, the fourth-order partial differential equation in image processing is used for moving image denoising data processing. According to the comparison between the removed image and the original image, it is found that the feature points need to be integrated for image restoration.

3. Research on Partial Differential Equation Technology Based on Noise Data and Image Processing and Restoration in Sports

3.1. Research on Sports Image Processing and Noise Data Processing Based on Partial Differential Equation Composite System. Image processing technology is based on the tracking and recognition technology of pixel sequence, combined with computer vision analysis and imaging to form high-quality pictures. There are a lot of dynamic data and dynamic images in sports image acquisition, so the accuracy

of feature acquisition is relatively low, and the dynamic image has great technical requirements for tracking targets. The traditional recognition and tracking technology mainly include feature robust algorithm. In this paper, the point diagonal detection and automatic recognition technology are mainly used. Firstly, the feature points of the image formed in sports are extracted, and the geometric feature set of sports sequence is formed according to the invariant origin, contour, and edge of the feature sequence. According to different sports characteristics, this paper analyzes the key content and information degree in sports activities. By analyzing the sports feature sequence to improve the pixel detection accuracy, the matrix sequence of moving image is constructed as follows:

$$\text{Dif}(C_1, C_2) = \min W(v_i, v_j). \quad (1)$$

In the formula, Dif is the image feature points formed in sports, which is mainly composed of image contour feature values and vectors. Take a sports activity as the acquisition area, and construct the image model according to the distribution of edge motion feature vector, as shown in Figure 1.

As can be seen from Figure 1, we automatically divide the tracking and recognition target into feature vector space. The generated structure can basically coincide with the input data. Finally, the dynamic feature vector position output value within the moving image range is as follows:

$$I(x) = J(x)t(x) + A(1 - t(x)). \quad (2)$$

In the above formula, A represents the image pixel set collected by sports in different environments and places. $t(x)$ is the maximum range pixel area, and $J(x)t(x)$ is the sharpness intensity of the whole image. We compare the image after automatic tracking feature point recognition with the original image, as shown in Figure 2.

As can be seen from Figure 2, we can accurately judge the position of feature points in the whole frame according to the automatically recognized image. After obtaining the data information of automatic tracking of sports images, we process the images digitally. In digital processing, it is necessary to compare the deformation between digital images. In the camera sensor, the position of light spot within the area is the pixel value, and the lowest pixel value is black and the highest is white. Select an image to set coordinate points, and calculate according to the gray value of coordinate points. The relationship between image and horizontal motion is as follows:

$$x^* = x + u + \frac{\partial u}{\partial x} \Delta x + \frac{\partial u}{\partial y} \Delta y, \quad (3)$$

$$y^* = y + v + \frac{\partial v}{\partial x} \Delta x + \frac{\partial v}{\partial y} \Delta y, \quad (4)$$

wherein u and v are the horizontal positions of the assembly center in the transverse and longitudinal directions, respectively. The correlation is calculated by the minimum coefficient. In order to reduce the amount of calculation, we

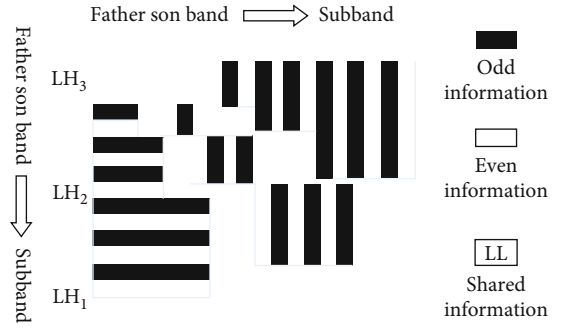


FIGURE 1: Structure diagram of image model.

only determine two values and guess other parameters. The comparison results between the calculated amount before and after calculation by using the correlation coefficient are shown in Figure 3.

As can be seen from Figure 3, with the increase of feature points, using this search technology to determine the minimum correlation coefficient can compare each group of calculated values, greatly reducing the amount of calculation. In this paper, the fourth-order partial differential equation is mainly used in image noise data processing. First, consider the definition of image information space continuously generated within a certain range:

$$E(u) = \int f(|\nabla^2 u|) dx dy, \quad (5)$$

where represents ∇^2 Laplacian and the change of function is increasing. With regard to the horizontal range and function change of the measured image, we define the minimum function:

$$E(u) = \int F(x, y, u, D_1 u, D_2 u, \dots, D_i u, \dots) dx dy. \quad (6)$$

In sports, we have high requirements for image quality, but the corresponding noise data will be generated after image processing and transmission. Therefore, we also need to use partial differential equations to study the image denoising function. At present, the fourth-order partial differential denoising equation is widely used. Based on the traditional anisotropic denoising method, combined with the image processing structure and feature points, this paper introduces the difference calculation. The purpose is to improve the image frequency quality and pixel quality and can save most of the original image appearance. Firstly, the difference calculation is carried out according to the image edge detection method:

$$D = ||u_{\eta\eta}| - |u_{\zeta\zeta}||. \quad (7)$$

In the formula, $u_{\eta\eta}$ and $u_{\zeta\zeta}$ are the derivatives of the moving image in the plane and stage directions, respectively. The unit vector in the direction of plane and phase degrees is as follows:

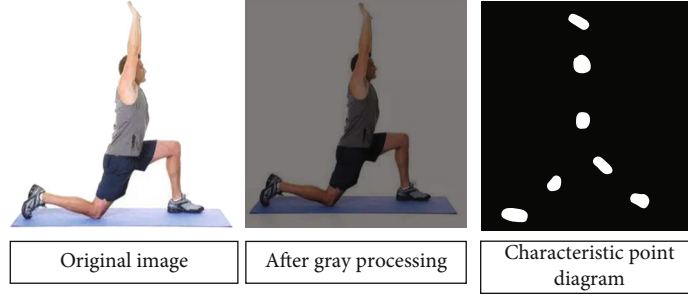


FIGURE 2: Comparison between original image and image after automatic tracking feature point recognition.

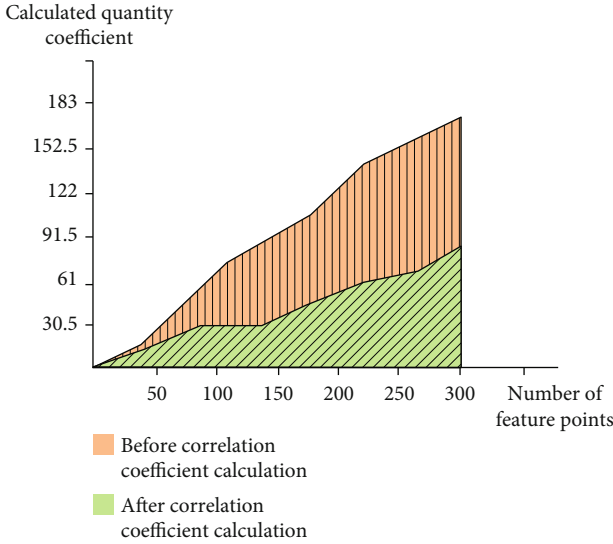


FIGURE 3: Comparison results of calculation amount before and after calculation of correlation coefficient.

$$\zeta = \frac{[-u_y, u_x]}{\sqrt{u_x^2 + u_y^2}}, \quad (8)$$

$$\eta = \frac{[u_x, u_y]}{\sqrt{u_x^2 + u_y^2}}, \quad (9)$$

of which

$$u_x(ij) = \frac{u_{i+1j} - u_{i-1j}}{2}, \quad (10)$$

$$u_y(ij) = \frac{u_{ij+1} - u_{ij-1}}{2}. \quad (11)$$

In the formula, u_{ij} represents the specific value of the function at node (ij) . The definition function $u_x(ij)$ represents the calculated value of the phase derivative. In this paper, the diffusion coefficient is proposed as follows by using differential calculation and molecular stage properties:

$$g(u, d, v) = \frac{1}{1 + (|G_\sigma \cdot (u + d)|^v / k)^2}. \quad (12)$$

Finally, according to the above calculation results, the adaptive formula related to the local range is extracted as follows:

$$v = 1 + \frac{\sigma_{x,y}^2 - \min(\sigma_{x,y}^2)}{10 \times \max(\sigma_{x,y}^2)}. \quad (13)$$

In the formula, v and $\sigma_{x,y}^2$ are the calculated mean and local calculated variance of noise image, respectively. In the process of image noise removal, the second-order partial differential equation denoising can also be applied. The second-order partial differential equation model can mainly protect the edge contour of the picture, but there will be stage effect. The fourth-order partial differential calculation model can suppress the stage effect caused by the second-order partial differential equation. We also propose the optimized combined image denoising data model on the basis of the fourth order and define the model formula as follows:

$$\min \beta \iint_{\Omega} f(|\nabla^2 u|) dx dy + \iint_{\Omega} |\nabla^2 u| dx dy + \frac{\lambda}{2} \iint_{\Omega} (u - z)^2 dx dy. \quad (14)$$

In the formula, when $f(|\nabla^2 u|)$ satisfies the function property, there is an optimal numerical solution in the whole solution set. We assume that it satisfies the following:

$$f(|\nabla^2 u|) = (|\nabla^2 u|)^2 = (\nabla^2 u)^2. \quad (15)$$

If Equation (15) is satisfied, the whole function converges downward. In the specific experimental process, we control the gray value of the moving image. In order to compare the effects of denoising models in different stages, we add the white noise with the calculated mean value of 0 to the original sports image. With the increase of pixels in the experimental image, the smaller the error value, the better the denoising effect. The comparison results of second-order partial differential equation, fourth-order partial differential equation, and optimized fourth-order partial differential equation are shown in Figure 4.

As can be seen from Figure 4, the error coefficient is the noise ratio of the image peak signal. With the increase of image pixels, the error coefficient of the second-order partial

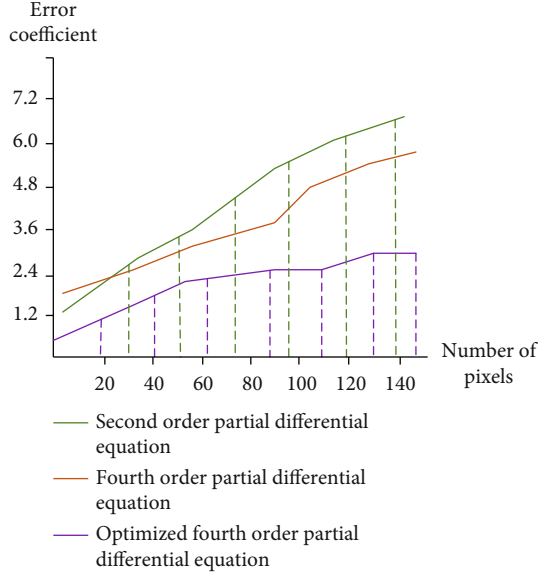


FIGURE 4: Comparison of error coefficients of second-order partial differential equation, fourth-order partial differential equation, and optimized fourth-order partial differential equation.

differential equation is the largest, and the optimized fourth-order partial differential equation can reduce the error coefficient below the mean value. Therefore, the optimized fourth-order partial differential equation can restore the original image to the greatest extent.

3.2. *Research on Sports Image Denoising Model Diffusion and Image Restoration Based on Partial Differential Equation.* The image noise increases with the number of iterations, and the image quality decreases with the number of iterations. The average filtering will reduce the image quality. The same result can be obtained by recalculating the reconstructed image with Utah. It shows that noise affects the calculation of image quality, and noise filtering will cause the calculation error of the optimal image. Accurate estimation of noise and effective filtering will obtain the truly optimal iterative image.

Image information will be affected by noise data in imaging state and processing, which will lead to image quality damage. Therefore, after establishing the partial differential equation denoising model, we need to study the edge diffusion of the image to analyze the diffusion influencing factors of the denoising model. In the collection of sports images, the noise interference of external equipment and environment will lead to image degradation. Partial differential equation denoising is to study the method model of accurate image retention. The edge diffusion of the model can enhance the denoising effect in one step. This paper mainly studies the anisotropic diffusion model PM to correspond to the quantitative value in the diffusion equation. The structural equation formula is as follows:

$$\frac{\partial I}{\partial t} = v(D\nabla I). \quad (16)$$

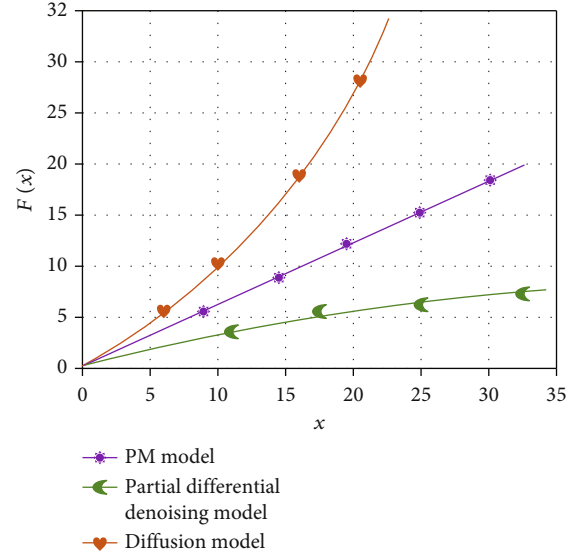


FIGURE 5: Comparison of PM model, partial differential denoising model, and diffusion model function.

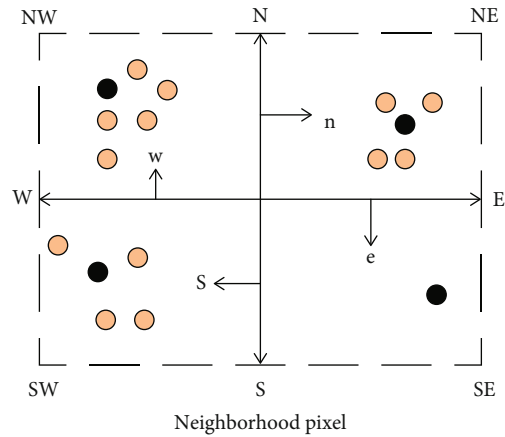


FIGURE 6: Process diagram of pixel increase in adjacent area.

Now, decompose the diffusion value of the model. Because it is a symmetric matrix type, it is necessary to define the unit eigenvector. The defined feature vector has a maximum value, which can provide simulation data for the image in the horizontal direction. After calculating the model output data, we compare the PM model with partial differential denoising model and diffusion model, as shown in Figure 5.

As can be seen from Figure 5, the independent variables of function values in the three models are gradient values. All models are monotonically increasing, and the denoising algorithm will fail if it is not an increasing function. The diffusion model function is a quadratic function, and the others are close to a quadratic function. Finally, according to the denoising effect, we need to establish an image restoration model and use the contour information around the damaged moving image to determine the diffusion direction and position to judge the damaged area. At present, image restoration technology is mainly composed of texture restoration

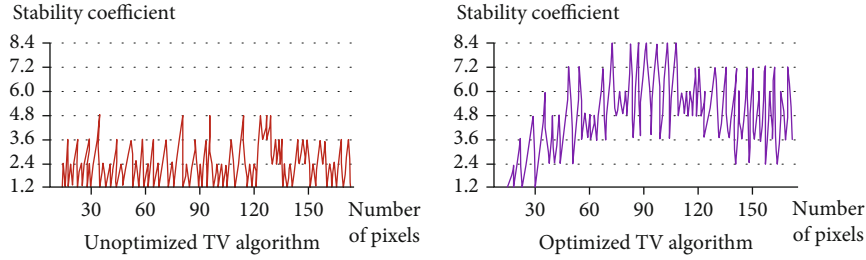


FIGURE 7: Comparison of TV algorithm without optimization and TV algorithm after optimization.

and nontexture restoration. The repair method based on partial differential equation is composed of curvature-driven diffusion (CDD) algorithm and total variation (TV) repair method. However, TV repair cannot meet the needle patching effect, which will produce visual error. It can only be applied to areas with small damage, and the problem of sports dynamic image restoration cannot be solved perfectly. In order to further optimize the repair algorithm, this paper proposes to introduce the gradient value as the diffusion function to optimize the TV repair algorithm, which can enhance the horizontal radian of the image, reduce environmental interference factors, and protect the edge information of the moving image. Firstly, it is necessary to discretize the original repair equation, artificially increase the number of pixels in the adjacent area, and build a higher stage difference formula, as shown in Figure 6.

As can be seen from Figure 6, new discrete pixels are added near the original pixel distribution area. It can improve the accuracy and stability of numerical results. The pixel value of the repaired image in the pixel center coordinate can also be calculated by Gaussian function. Finally, we analyze the stability of the discrete equation repair model and compare it with the original unoptimized TV algorithm, as shown in Figure 7.

As can be seen from Figure 7, the TV algorithm without optimization has poor stability. With the increase of the number of pixels, the optimized TV model can accurately repair the damaged image and find the damaged location.

4. Analysis of Research Results of Partial Differential Equation Technology Based on Noise Data and Image Processing and Restoration in Sports

4.1. Analysis of Research Results of Sports Image Processing and Noise Data Processing Based on Partial Differential Equation. Because it is difficult to obtain sports images, many dynamic data need to be collected by image automatic tracking and recognition arithmetic. We study the sequential automatic punctuation technology in image processing technology, which can extract the pixels in the feature area and realize the automatic tracking of moving images. The image contour data is reconstructed by matching the sample data. After intelligently detecting the image contour, the performance of automatic recognition is improved. We test the processing speed of traditional method and image sequence

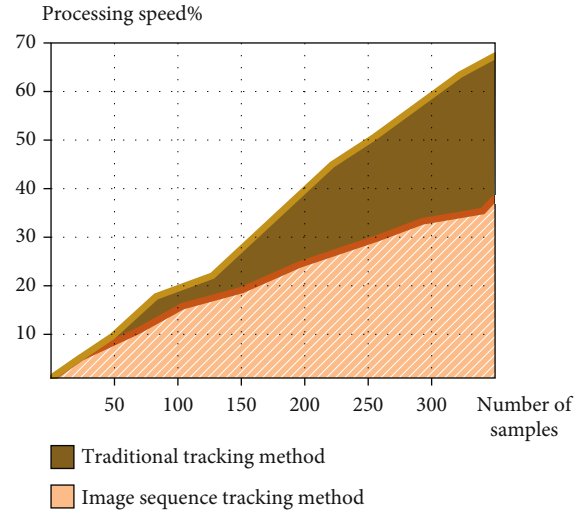


FIGURE 8: Comparison of processing speed between traditional method and image sequence tracking method.

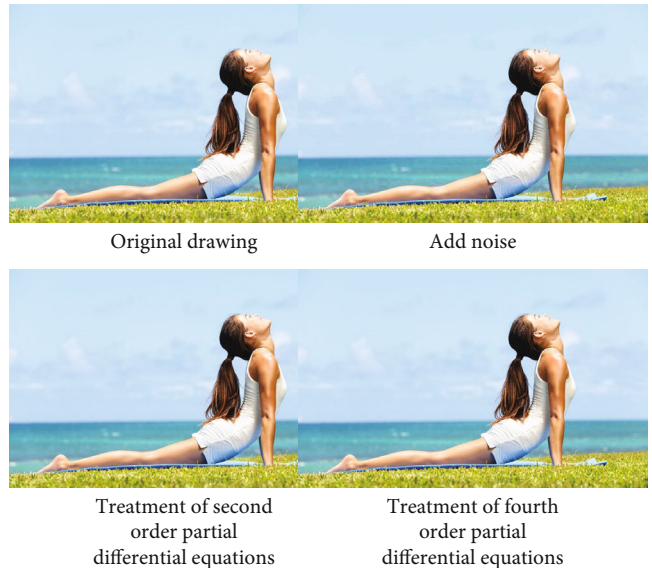


FIGURE 9: Comparison of image processing effects between second-order partial differential equation and fourth-order partial differential equation.

tracking method in moving target tracking, and the comparison results are shown in Figure 8.

As can be seen from Figure 8, the image processing algorithm combined with computer technology can realize the

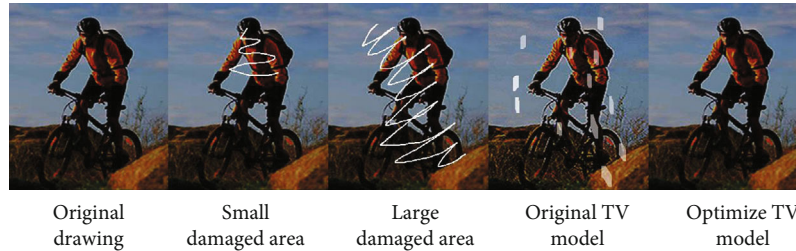


FIGURE 10: Comparison effect between original TV repair model and optimized TV repair model.

automatic tracking behavior of sports image acquisition and improve the speed and effectiveness of image acquisition. Then, the noise removal effect of the collected sports image is tested. In this paper, the information of image size averaging is used as the test data to analyze the effect of second-order partial differential equation and fourth-order partial differential equation in image processing, as shown in Figure 9.

As can be seen from Figure 9, we first add noise data to the original moving image for interference and then observe the image information of the two processing methods, respectively. Although the second-order partial equation can improve the horizontal plane, there are some impurity spots in the processed image information. This is mainly because the second-order partial equation cannot solve the gradient effect problem, resulting in poor noise removal effect. Finally, by observing the fourth-order partial differential equation studied in this paper, it is found that the image basically restores the original image information. The speckle in the processed image is reduced, and the image quality is improved.

4.2. Analysis of Research Results of Sports Image Denoising Model Diffusion and Image Restoration Based on Partial Differential Equation. In this paper, the diffusion equation formula has been studied. In addition to proving the formula of minimum pixel function, the problems of image gradient direction and vertical direction angle have also been analyzed. When acquiring sports image, if there is noise data in the image, the diffusion equation will be calculated directly according to the above calculation formula. The calculated results will have the phenomenon of uneven horizontal plane. We need to study the diffusion of the uneven image edge and get the diffusion speed and diffusion direction. Because the calculation method of image noise coefficient is the ratio of peak value to noise data, if the coefficient decreases all the time, it shows that the diffusion model has a certain effect. When the diffusion speed and trend of the image edge are significantly greater than that across the edge region, the effect of image noise removal is also better. The above results can prove that the overall quality of the image will not decline after acquisition. If we face the information obtained in sports, there are problems of fuzziness and low quality. We also need image restoration based on partial differential equations. In this paper, the gray image is used for comparative experiment. Firstly, the image is set for small area scratch, and then, the large area scratch

is set to explore the effects of the original TV repair model and the optimized TV repair model, as shown in Figure 10.

As can be seen from Figure 10, the algorithm in this paper not only has obvious restoration effect for small area damaged images. In the face of damaged images in large areas, more than 90% can still be repaired. The traditional TV repair model cannot meet the purpose of supplementing visual effect, and the effect is poor in large area repair.

5. Conclusion

It is very difficult for human beings to recognize things and complex environment in the real world, so we need to use computer image processing technology for complex graphics and image recognition. In the face of static and simple image information, image recognition technology can maintain a certain accuracy and efficiency. However, for complex environment and dynamic images, it is necessary to remove, repair, and restore the interference factors in the environment through image processing technology. Therefore, this paper studies the partial differential equation system based on noise data and image processing in sports. Firstly, the sports image acquisition adopts the image automatic tracking and target recognition technology, which can establish the pixel serialization structure model composed of the image, extract the feature points, and then obtain the accurate image data. Then, the image data is optimized, which mainly aims at the quality problems such as image distortion and blur in the transmission process. The image noise data is removed by optimizing the fourth-order partial differential equation to improve the image quality. The experimental results show that compared with the second-order partial differential equation, the optimized fourth-order partial differential equation can improve the image processing speed and improve the image quality. Finally, this paper also explores the comparative effect of TV model in partial differential equation and optimized TV model in image restoration. The results show that the image restoration technology after model optimization can not only solve the problem of small area restoration but also repair large area targets. Compared with the original image information, the restored image restoration proportion reaches 90%. Therefore, the content of this paper has effectiveness and applicability for image accurate processing and image restoration. However, the proposed partial differential equation TV model and optimization model are not simulated in this paper. Therefore, more data need to be combined in future research.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares there are no conflicts of interest.

Acknowledgments

The study was supported by the 2017 General Project of 13th Five Year Plan Project of Educational Science in Shanxi Province (Grant No. 17072) and the teaching reform and innovation project of Shanxi Provincial Department of Education (No. Px_1021550).

References

- [1] Y. Liu, A. Wang, H. Zhou, and P. Jia, "Single nighttime image dehazing based on image decomposition," *Scientific and Technological Innovation and Application*, vol. 183, no. 24, p. 107986, 2021.
- [2] H. Wanru and L. Guocheng, "Research on fire detection and alarm system based on image processing," *China Equipment Engineering*, vol. 16, pp. 71-72, 2021.
- [3] H. Kai, Z. Wei, W. Xiaozhong, W. Yi, and A. Yunzhu, "UV image detection method of partial discharge on insulator surface of transmission line," *Shandong Electric Power Technology*, vol. 48, no. 8, pp. 54-60, 2021.
- [4] L. Rui, "Research on pattern recognition and its application in image processing," *Popular Standardization*, vol. 16, pp. 122-124, 2021.
- [5] Y. Xiaoyan, "Packaging surface defect detection based on image processing technology," *Microcomputer Application*, vol. 37, no. 8, pp. 63-66, 2021.
- [6] P. Wang, "Visual Design of Web Interface Based on Computer Image Processing Technology," *Journal of Physics: Conference Series*, vol. 1915, no. 2, article 022030, 2021.
- [7] Y. Qianxiang and Z. Yuansheng, "Intelligent recognition technology of underground electric locomotive track obstacle image processing method," *Metal Mine*, vol. 8, pp. 150-157, 2021.
- [8] G. Jifeng, L. Xing, P. Zhiqi, S. Jiayou, and Y. Ming, "Research on custom fuzzy logic and Gan in image highlight processing," *Small Microcomputer System*, vol. 42, no. 8, pp. 1715-1719, 2021.
- [9] E. Gültekin, H. İ. Çelik, S. Nohut, and S. K. Elma, "Predicting air permeability and porosity of nonwovens with image processing and artificial intelligence methods," *The Journal of the Textile Institute*, vol. 111, no. 11, pp. 1641-1651, 2020.
- [10] Z. Zhenghao and C. Bing, "Overview of military application of image target recognition and tracking technology," *Application of Electronic Technology*, vol. 47, no. 8, pp. 26-29 + 33, 2021.
- [11] Y. Li, R. Fischer, R. Zboray et al., "Laser-engraved textiles for engineering capillary flow and application in microfluidics," *ACS Applied Materials and Interfaces*, vol. 12, no. 26, pp. 29908-29916, 2020.
- [12] M. Mamatov and X. Alimov, "Differential Games and Methods of Digital Image Processing," *Journal of Physics: Conference Series*, vol. 1646, no. 1, article 012020, 2020.
- [13] H. Qianwei, Z. Tuanshan, Z. Ling, T. Feng, and L. Lele, "Digital printing defect detection system based on color image processing and edlines," *Light Industry Machinery*, vol. 39, no. 4, pp. 74-79, 2021.
- [14] W. Xinlong, "Research on improved methods of association feature data mining based on partial differential equations," *Modern Electronic Technology*, vol. 44, no. 18, pp. 111-113, 2021.
- [15] H. Wang, A. Ma'aruf Nass, and Z. Zou, "Lie symmetry analysis of partial differential equations," *Advances in Mathematical Physics*, vol. 2021, Article ID 9113423, 7 pages, 2021.
- [16] Z. Dan, F. Qin, and C. Zhenjie, "Inclusive control of partial differential multi-agent systems based on iterative learning algorithm," *Journal of Mathematical Physics*, vol. 41, no. 4, pp. 1111-1123, 2021.
- [17] B. Chan, J. F. Rudan, P. Mousavi, and M. Kunz, "Intraoperative integration of structured light scanning for automatic tissue classification: a feasibility study," *International Journal of Computer Assisted Radiology and Surgery*, vol. 15, no. 4, pp. 641-649, 2020.
- [18] C. Yanan, "Image denoising method based on partial differential equation," *Information and Computer (Theoretical Edition)*, vol. 33, no. 10, pp. 22-23, 2021.
- [19] Y. Suya and T. Quan, "Adaptive image denoising model based on partial differential equation," *Science and Technology Bulletin*, vol. 37, no. 4, pp. 83-87, 2021.
- [20] J. Shuxiang, "Research on digital image processing based on partial differential equation," *Electronic Technology and Software Engineering*, vol. 14, pp. 143-144, 2020.
- [21] H. Yu, "Discussion on directional diffusion and its application in partial differential equation denoising model," *Journal of Ningxia Normal University*, vol. 41, no. 4, pp. 11-17 + 35, 2020.
- [22] W. Wei, "Research on digital image processing based on partial differential equation," *Journal of Taiyuan University (Natural Science Edition)*, vol. 38, no. 1, pp. 34-40, 2020.
- [23] T. R. Oliveira and M. Krstic, "Extremum seeking feedback with wave partial differential equation compensation," *Journal of Dynamic Systems, Measurement, and Control*, vol. 143, no. 4, article 041002, 2021.
- [24] Y. Ying, "Remote sensing imaging radar range image classification method based on partial differential equation," *Journal of Jilin University (Science Edition)*, vol. 57, no. 6, pp. 1472-1478, 2019.
- [25] G. Lin and M. Xudong, "Image denoising algorithm based on partial differential equation and multiscale analysis," *Journal of Jilin University (Science Edition)*, vol. 57, no. 4, pp. 882-888, 2019.