Real Time Monitoring System for Crag Based on the Adaptive Color's Spatial Information Fusion Algorithm

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Abstract. This paper presented Real time monitoring system for crag based on the Adaptive Color's Spatial Information Fusion Algorithm, which realized real-time monitoring of crag area along the road. Aiming at the problems of missing detection, voids and ghost images in the traditional frame difference algorithm, the Adaptive N Frame Difference Algorithm was proposed. Under different light conditions we select the mix color's spatial with the best detection results. And in this spatial, frame difference algorithm is adaptively selected to optimize the system performance. The edge information of moving object extracted by edge detection is combined with frame difference information by using the Information Fusion Algorithm to get a complete moving object detection result. Experiments show that the algorithm proposed in this paper can identify and track moving targets more accurately. At the same time, it greatly reduces the detection time of the system, and has good robustness and real-time performance.

Overview

In recent years, crag collapses, landslides and other geological disasters have been occurring frequently, especially along the highway and railway lines. These have caused enormous loss of life and property to the world [1]. Therefore, real-time monitoring of crag has become a key research content.

With the development of science and technology, video image processing technology has become relatively mature. We can detect the moving target by analyzing the dynamic image. It can achieve real-time automatic monitoring of crag, obtain the real-time condition of crag, and make corresponding measures in advance to avoid personnel and property losses.

At present, the most frequently used moving target recognition technology is Optical Flow Method, Background Subtraction Method and Frame Difference Method [2-6]. The Optical Flow Method has a large amount of calculation and is not suitable for real-time monitoring systems. The Background Subtraction Method can identify moving targets more accurately, but there would be large error if the external environment and light changes. The Frame Difference Method is relatively simple, efficient in real-time processing, and insensitive to scene changes such as light. However, this method is affected by the velocity and background of the target. The recognition accuracy would be reduced greatly. Combining the advantages and disadvantages of the above identification technology. Adaptive Color's Spatial Information Fusion Algorithm is proposed to identify and track moving objects in this paper. We combine The Color's Spatial Information Fusion Algorithm and Adaptive N Frame Difference Algorithm together for information fusion, and get the target recognition algorithm which is more accurate.

System Design

In the real-time monitoring system for crag, the key is the acquisition and processing of real-time images. With the rapid development of programmable logic device (FPGA), real-time image processing technology has the advantages of high speed and flexibility.
Therefore, choosing FPGA as the system controller can ensure the real-time performance of the system and solve the disadvantages of insufficient power supply in outdoor venues, etc. More important, it can make the real-time monitoring system for crag with low cost, low power consumption and high efficiency [7-8].

The main controller design of FPGA is divided into different modules in accordance with the different functions. The design is shown in Figure 1.

![Figure 1. Internal module of FPGA main controller.](image)

Its workflow is as follows:

1. The analog video signal collected by high-definition infrared camera device is decoded into digital signal through the decoder chip. After that, we collect the images from videos and send the images to the FPGA main controller.

2. The signal received by the main controller of the FPGA is transformed into YCbCr4:2:2 format signal by ITU-R BT.656 standard. YCbCr4:2:2 format signal is converted from interlaced scan to progressive scan data signal by using multi-port SDRAM1 buffer chips.

3. The line-by-line scanning YCbCr4:2:2 format signal is converted into RGB format signal through signal interpolation and serial-parallel conversion, which achieves Color-Space Conversion. Store the required multi frame RGB format data in multi port SDRAM2 cache chip to complete the data cache from videos.

4. The Target Recognition Algorithm is used to track and detect dynamic targets in the cached multiple frames of videos. At the same time, an adjustable threshold can be set to satisfy the environment conditions. When the pixel number of the moving target is larger than the threshold value, there will be large objects moving and may be a risk of crag collapse. Therefore, the alarm is issued, and the alarm information and current scene pictures are uploaded to the background server through the transmission unit.

5. The RGB format data which completes the Target Recognition Algorithm is fed into the encoding chip for digital-to-analog conversion, and the video image is displayed and output by VGA.

**Realization of Target Recognition Algorithm**

**The Basic Idea of Algorithm Design in This Paper**

The Target Recognition Algorithm's Technological Process presented in this paper is shown in Figure 2.

1. The video's image sequence is collected from crag background by HD infrared camera to obtain N frames and video's sequences before and after time point i.

2. The Sobel Operator is used to extract the edge of the N frame image sequence processed in step 1 to ensure the detection of a more complete contour information of moving targets.
(3) For the N frame image sequence processed in step 1, we use Color's Spatial Fusion Algorithm, combined with the influence of external environment (such as light, etc.), to achieve that the best color components can be adaptively selected for recombination under different environmental conditions. Thus, different mix color's spatial suitable for motion detection under different environmental factors can be obtained, and the accuracy of moving object detection can be improved.

(4) In order to ensure the accuracy and real-time of the system, different Frame Difference Algorithms are selected in different states by analyzing the state of moving objects. In the mix-color-space obtained in step 3, the best color components of different frames are used to achieve the best moving object detection by adaptive N Frame Difference Algorithm.

(5) The images obtained in step 2 and step 4 are fused, to increase the amount of information fusion and improve the integrity of motion detection.

(6) The moving cartoon obtained by step 5 is processed by morphological filtering to eliminate the outliers of the boundary and smooth the boundary of the image can obtain a clear moving target detection result.

Color's Spatial Information Fusion Algorithm

There are many classifications of colors. People often use RGB, YUV, YIQ and so on. Color's spatial can be transformed into different space according to the corresponding formula. If some pixels in the image move, some of the changes in color components are not significant. But there are always some color components that may change significantly. Therefore, the fusing of different color components will achieve better detection results. Specific algorithm technological process diagram shown in Figure 3.
(1) Selecting the current frame and background frame image sequence, the RGB color's spatial of the two frames is converted by the color's spatial conversion formula to obtain the YUV and YIQ color's spatial.

(2) The color channels of each color's spatial in the two frames are processed differently, and different thresholds are used to judge the color channels. The binary images of each channel are obtained after the difference. It is shown in Figure 4.

![Figure 4](image)

Figure 4. Single channel detection results.

(3) The results of each color channel are selectively fused. Different color's spatial are fused, and the results are very different. So by comparing the fusion results of different color channels, we can find the best color channel to reconstruct and get the mix color's spatial suitable for the motion detection of this system.

Figure 5 is the result of the fusion of each channel. From Figure 6(a) we could observe that the detected target contour is clearly described, and the internal filling is substantial, no voids, no ghost, and basically no noise effect. (b) and (c)'s target contour has burrs, and there is a bigger noise. Therefore, we choose the Y channel and R channel to recombine to get the mix color's spatial model YR.

![Figure 5](image)

Figure 5. Result of the fusion of each channel.

(4) The background frame image is updated in time [9], and the steps (3) are executed under different illumination conditions to obtain different mix color's spatial suitable for different illumination conditions, so as to improve the accuracy of moving object detection.

**Adaptive N Frame Difference Algorithm**

The traditional inter frame difference algorithm is easy to implement and has strong adaptability to the dynamic environment. However, the algorithm is sensitive to the moving speed of the target. When the moving speed of the target is too slow, the region of the two frames changes little, and the extracted moving target often appears "voids" phenomenon, which has a greater impact on the detection results. In order to reduce the rate of miss detection and error detection of traditional Inter-Frame Difference Algorithm, Multi-Frame Difference Algorithm comes out. It is used to track and detect the target by making full use of the correlation information between video frames. In this paper, the traditional Inter-Frame Difference Algorithm is improved, and an Adaptive N Frame Difference Algorithm is proposed, N=2,...,5. The specific algorithm technological process is as follows:

(1) Based on the I frame image, the sequential N frame image sequence of I frame image is extracted, N=2,..., 5.

(2) In the reconstructed mix color's spatial, N Frame Difference Algorithm is used to track and detect moving objects. The N Frame Difference Algorithm technological process is shown in the Figure 6.
Figure 6. N Frames Difference Algorithm.

\[
D_{13} = \begin{cases} 
1, & |f_i(x, y) - f_{i-2}(x, y)| > T \\
0, & |f_i(x, y) - f_{i-2}(x, y)| \leq T
\end{cases} \quad (1)
\]

\[
D_{23} = \begin{cases} 
1, & |f_i(x,y) - f_{i-1}(x, y)| > T \\
0, & |f_i(x,y) - f_{i-1}(x, y)| \leq T
\end{cases} \quad (2)
\]

\[
D_{34} = \begin{cases} 
1, & |f_i(x,y) - f_{i+1}(x, y)| > T \\
0, & |f_i(x,y) - f_{i+1}(x, y)| \leq T
\end{cases} \quad (3)
\]

\[
D_{35} = \begin{cases} 
1, & |f_i(x,y) - f_{i+2}(x, y)| > T \\
0, & |f_i(x,y) - f_{i+2}(x, y)| \leq T
\end{cases} \quad (4)
\]

\[
D_{45} = \begin{cases} 
1, & |f_{i+1}(x,y) - f_{i+2}(x, y)| > T \\
0, & |f_{i+1}(x,y) - f_{i+2}(x, y)| \leq T
\end{cases} \quad (5)
\]

1) N=2, two frames difference results \(D_{diff,2}\):

\[
D_{diff,2} = D_{23} \quad (6)
\]

2) N=3, three frames difference results \(D_{diff,3}\):

\[
D_{diff,3} = D_{23} \cap D_{34} \quad (7)
\]

3) N=4, four frames difference results \(D_{diff,4}\):

\[
D_{diff,4} = D_{23} \cap D_{45} \quad (8)
\]

4) N=5, five frames difference results \(D_{diff,5}\):

\[
D_{diff,5} = (D_{13} \cap D_{35}) \cup (D_{23} \cap D_{34}) \quad (9)
\]

The higher the number of frames, the higher the detection rate of moving pixels, and the longer the detection time. Because the system requires high precision and real-time detection, in order to ensure the optimal detection effect, it is necessary to analyze the state of the moving pixels. Set the threshold T. When the number of pixels detected moving is less than the threshold T, it shows that there is no large moving target, and the image sequence is processed in real-time by Two Frame Difference method to ensure the real-time requirement of the system. When the number of moving pixels is greater than the threshold T, the suspected crag collapse is generated, and the Five Frame Difference method is used to detect the moving target to ensure the accuracy of the system.

**Information Fusion and Morphology Processing**

Adaptive N Frame Difference Algorithm can get the correlation information between video frames. Target Edge Detection Algorithm can get the feature information of image edge contour. The fusing of the two can improve the effective information contained in the detection results.
Binary images obtained by Adaptive N Frame Difference Algorithm often contain many isolated points, small gaps and holes. In order to solve the problems that may exist in the fused image, morphological filtering is used to eliminate the interference of small particle noise effectively, so as to reduce the misjudgment and missed judgment as far as possible, and get a complete and clear moving target detection results. Figure 7 is the final detection result.

![Figure 7. Final detection result](image)

Experiments show that the fusing of N Frame Differential Information and Edge Information can improve the effective information contained in the test results, reduce the impact of noise, and increase the accuracy of detection results.

**Experimental Results and Analysis**

Figure 8 is an effect diagram of the system's recognition and tracking of moving objects. Choose outside slope environment as the experimental site, roll a basketball to simulate rolling rock, set up system equipment at a distance of 10 meters to carry out system function test.

![Figure 8. An effect diagram of the system's recognition and tracking of moving objects.](image)

The red rectangle region in Figure 11 is the result of system algorithm recognition and tracking. Even though the proportion of basketball area in the overall image is small, the system can effectively recognize and track the rolling objects, and has achieved good detection results. It can be seen from the experiment that the hardware platform of the system can work normally. It can achieve real-time image acquisition and display, and mark out moving objects on the display screen, and achieve real-time recognition, tracking and monitoring of moving objects. When the movement occurs, the alarm information and the scene pictures are uploaded to the back-end server in time, which is convenient for the relevant departments to consult and confirms the correct choice of using FPGA to complete the design requirements.

**Summary**

In this paper, a real-time monitoring system for crag which can run for a long time in crag zone is designed. The system uses Adaptive Color's Spatial Information Fusion Algorithm to achieve recognition and tracking of moving objects. The Color's Spatial Information Fusion Algorithm is added to reduce the influence of external environment factors on the detection results and improve the observability and detection accuracy of the recognition results. At the same time, by analyzing the state of the moving pixels and combining with the Adaptive N Frame Difference Algorithm, the detection time of the system is greatly reduced, and the accuracy and real-time of the detection results are guaranteed.

The experimental results show that the system can run quickly and stably. It can also identify the moving targets accurately, upload the alarm information and the current scene pictures to the background server in time, and achieve the real-time monitoring of dangerous rock areas to meet
the system performance requirements. At the same time, the system doesn't need too much power, which is suitable for the special situation of insufficient power supply and unstable network coverage in the field, and has value in practice in the field of intelligence monitoring.

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