AN INSTANTANEOUS POINT SOURCE DETECTION AND EXTRACTION SYSTEM FOR GEO REMOTE SENSING SATELLITE

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ABSTRACT:

To accomplish the task of detecting the instantaneous point source, an on-board information real-time processing system is designed which can process the point-source detection with reconfigurable function. The system has the algorithm reconfigurable function, which can detect and extract the instantaneous point source from the remote sensing image. By using FPGA programming, the satellite target detection and processing algorithm can be update easily. At the same time, the software can be reconfigured to improve the system's information processing capabilities. The system has been verified by simulating real instantaneous source point target image data to meet the real-time processing requirements of instantaneous point source information detection.

1. INTRODUCTION

The instantaneous point source target detection is one of the most difficult problems in the field of remote sensing. Whether it is in the military field (such as missiles, aircraft, etc.) or in civil geography field (such as volcano eruption, lightning, etc.), it has a very important meaning. The west countries started earlier in the source point detection field, did a lot of effective work, and accumulated a lot of experience. Since the 1950s, the United States has started to carry out the research on various types of target points for detecting instantaneous points based on aviation and aerospace platforms. In 1995, the United States launched the world's first on-board instantaneous lightning detector(OTD), and then launched with its improved Lightning Imaging Sensor (LIS) in 1997. The OTD and LIS have proven that it is feasible to use optical imaging techniques to achieve instantaneous point source observations. However, both satellites are LEO satellites and are unable to perform all-weather observations of a region, while the GEO satellite can perform all-weather observations of a region. It is considered as a target for instantaneous point source observations. Although the United States put forward the plan of using instantaneous orbit satellites to detect instantaneous point sources in the 1980s, the launch plan has not been confirmed for a long time and the plan originally launched in 2014 has been postponed. The FY-4 meteorological satellite launched in China in December 2016 is a GEO satellite. Its instantaneous point source target imager can carry out all-weather continuous observation from the geostationary orbit height to the instantaneous point source targets in the mainland of China and its surrounding areas. This instantaneous point source target imager mainly utilizes four methods of spectral filtering, spatial filtering, time filtering and frame-frame background removal to achieve instantaneous point source signal enhancement and detection.

This article builds a FPGA-based instantaneous point source detection and extraction system. The system can receive the focal plane image data, use the image processing technology to accomplish the real-time detection and extraction of instantaneous point source events, and encode and output the detected instantaneous point source target event information to the data transmission system.

2. PRINCIPLE AND ALGORITHM DESIGN OF INSTANTANEOUS POINT SOURCE DETECTION

The most important task of the instantaneous point source target detection system is to detect the instantaneous point source target events from the high-speed background image. So, each pixel taken by the focal plane imaging circuit in the instantaneous point source imaging target needs to be processed, and then output information such as the position, intensity and background evaluation value of the target instantaneous point source. The basic principle of its work as shown in Figure 1.

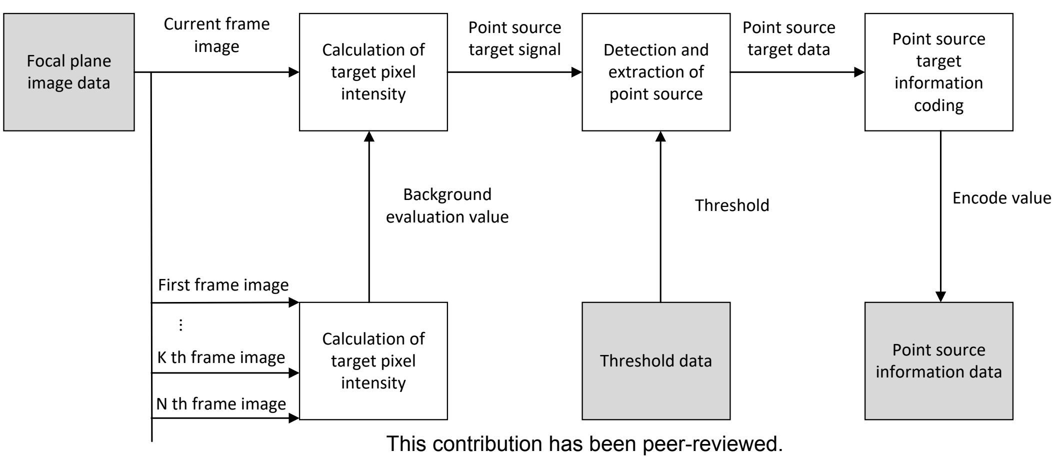

Figure 1. Principle of instantaneous point source target detection system

Where the background signal is the weighted average of the previous k background frames (k = 6); In average, the newest frame has a greater weight than its previous frames. It performs the function of the time-domain low-pass filter by the combination of background signal evaluator, background signal remover and instantaneous point source target signal recognition device. The focal plane image signal is sent to an external buffer, and the current image signal frame is weighted averagely with the previous N buffered frames to obtain a background evaluation value. The obtained background evaluation value and the corresponding focal plane output signal are sent to a background signal remover and a instantaneous point source signal recognizer to determine the instantaneous point source signal. The formula is:

$$Y_i(0) = H(0) * X_i(0) + H(1) * X_i(1) + \cdots + H(k-1) * X_i(k-1) + H(k) * X_i(k)$$
$$S_i = X_i(0) - Y_i(0) \quad (1)$$

Where $X_i(k)$ is the signal of the i pixel of the previous k frames ($k = 6$), and $X_i(k-1)$ is the signal of the i pixel of the previous $k-1$ frames. $X_i(1)$ is the i pixel of the previous one frame, and $X_i(0)$ is the i pixel of the current frame. $Y_i(0)$ is the evaluation background of the i pixel of the current frame. S_i is the i pixel of the current frame after removing the evaluation background. If S_i is greater than 0, it is indicated that S_i may be the instantaneous point source target signal, and then S_i is sent to the instantaneous point source target recognizer unit for further identification. Conversely, it is considered not instantaneous point source target signal, and directly outputs data 0 . The instantaneous point source target recognizer receives the input S_i, and compares S_i with the threshold T corresponding to the background evaluation value. If S_i is greater than the threshold T, it considers the signal to be instantaneous point source target signal, otherwise, the output data is 0.

$$H(0) = \alpha/b,$$
$$H(1) = (1-\alpha)/b,$$
$$H(2) = (1-\alpha)^2/b,$$
$$H(k) = (1-\alpha)^k/b,$$
$$b = \alpha + (1-\alpha) + (1-\alpha)^2 + \cdots + (1-\alpha)^k \quad (2)$$

The b is the sum of all the coefficients, and α is the gain coefficient, and α are determined by the relative prior knowledge.

3. DESIGN AND IMPLEMENTATION OF AN INSTANTANEOUS POINT SOURCE TARGET DETECTION SYSTEM

3.1 Systems Analysis

The system receives the data from the focal plane, and needs to complete the detection and extraction of the instantaneous point source target event within each frame cycle. The target event of a instantaneous point source is defined as a pixel that radiated over the background threshold in a frame period. To achieve the function of instantaneous point source target event detection, we need to design the hardware system that can accomplish the task according to the functional requirements of the system. With the instantaneous point source target detection and recognition software, we can detect and identify instantaneous point source events. The main difficulties of the detection and recognition system of the instantaneous point source target event lie in:

1) It needs to real-time receive and process the high-speed image data which is transferred from focal plane in real time;
2) It needs to store and process 7 background frames data;
3) It needs to recognize and encode signal of instantaneous point source;
4) It needs to complete the reconfigurable design of algorithm software of instantaneous point source.

According to the instantaneous point source target detection and data processing requirements, the article propose a reconfigurable method of FPGA software, and gives the system hardware design scheme. Secondly, the article designs a instantaneous point source target detection real-time processing algorithm software which can complete the target detection and encoding, to accomplish the real time fast processing of instantaneous point source target event. The system can achieve the reconfigurable processing of the on-board FPGA software through uploading the instantaneous point source target detection algorithm, and it can expand the system information processing capabilities by configuring different instantaneous point source target detection algorithm programs for FPGA..

3.2 System Hardware Design

The hardware block diagram of the instantaneous point source target detection system mainly includes data routing circuit, detection and extraction circuit, upload refresh circuit. It is shown in Figure 2.

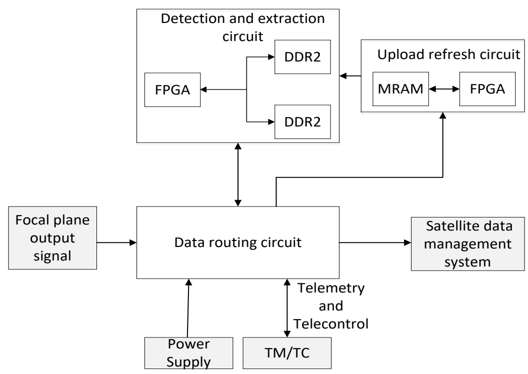

Figure 2. System schematic of instantaneous point source target detection

The data routing circuit is used to receive and transfer image data into detection and extraction circuit, meantime it controls the upload refresh circuit by sent control commands. The detection and extraction circuit is used to complete instantaneous point source target detection and extraction by FPGA program, and the DDR2 is used to store 7 background frames data by ping-pong operation. The upload refresh circuit is used to complete upload function and reconfiguration of FPGA.

The system has three work modes, including target detection mode, landmark observation mode and FPGA program upload mode. In the target detection mode, the system receives the digital signal output from the focal plane, carries out real-time target event detection, and encodes the target signal data of each frame and the background signal data of local area, and transmits to the data management system. In the landmark observation mode, the system receives the digital signal output from the focal plane, and chooses one frame of background signal periodically, then transmits to the data management system. In the FPGA program upload mode, the system stops the two work modes above, and receives the upload FPGA program by packet from ground station to complete the reconfiguration of FPGA.

3.3 Update of FPGA Program for Instantaneous Point Source Target Detection Processing

When image processing control FPGA receives the control instruction of program uploading, it stores the new uploading FPGA program of the instantaneous point source target detection processing to MRAM. First, the image processing control FPGA receives the control instruction and carries on the instruction parse to judge whether it is the uploading program data. If not, it will continue to receive a control instruction; if the judgment is on program data, it will receive the data to have a EDAC check. Secondly, judging the EDAC check the results, if the check result is correct, start to write program data to program storage MRAM of instantaneous point target detection FPGA, and then complete the FPGA reconfiguration; if the verification result is not correct, do not have a write operation. Finally, program update operation is complete after program data uploading. The specific implementation process is shown in Figure 3.

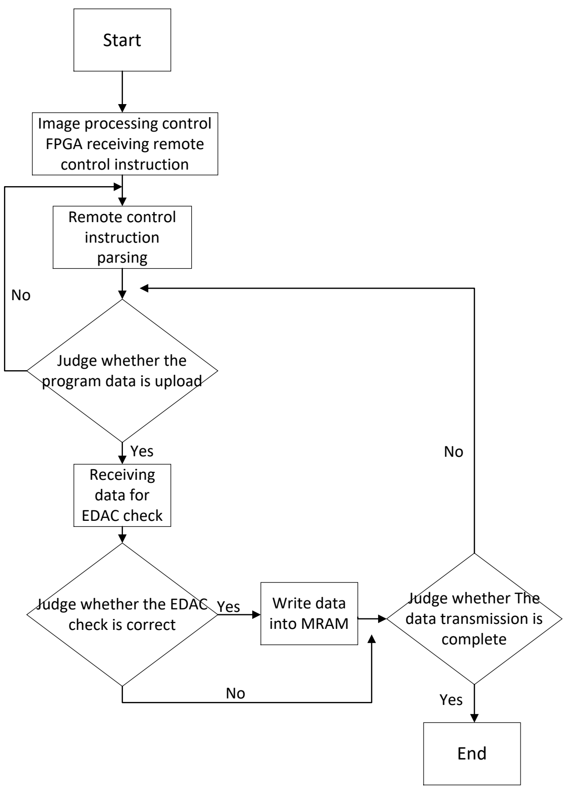

Figure 3. Program data update diagram of FPGA

4. EXPERIMENTAL RESULTS AND ANALYSIS

After completing the hardware and software design of the instantaneous point source target detection system, we need to test the system to see if it can accomplish the task of instantaneous point source target detection. The related test equipment is configured according to the test needs, and the test principle diagram is shown in Figure 4.

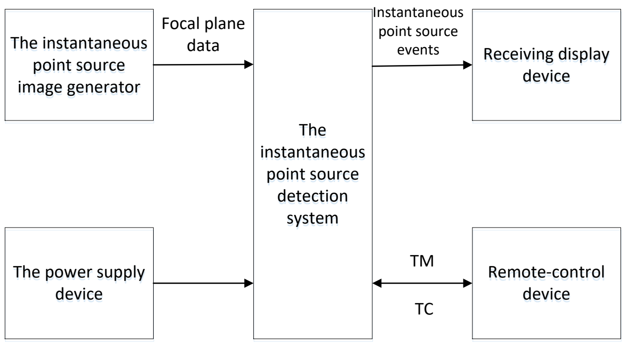

Figure 4. Test hardware diagram of the system

In the figure, the instantaneous point source image generator used to simulate the focal plane imaging, and output image data according to specified format. Receiving display device receives the instantaneous point source target image data storage and display. The power supply device supplies for instantaneous point source target detection system; The remote-control device for the instantaneous point source target detection system sends the remote instruction and receiving the returned telemetry status information.

To verify the function of the system, two types of images are used as the test images: the simulated image and the real image of the instantaneous point source. Figure 5 is the effect of the US LIS satellite on the lightning. We can use the real image data captured by the satellite to do the instantaneous point source target recognition, and the instantaneous point source target event identified by the instantaneous point source target detection device is shown in Figure 6.

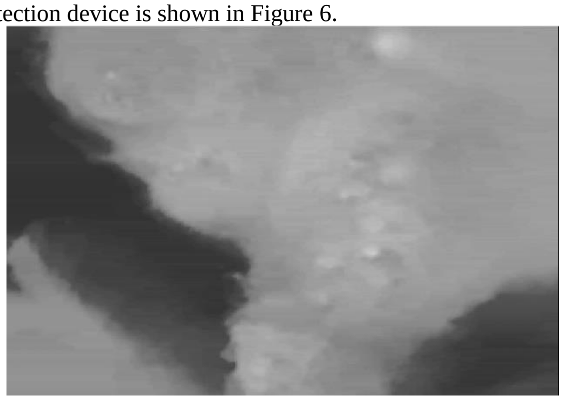

Figure 5. US LIS satellite lighting image

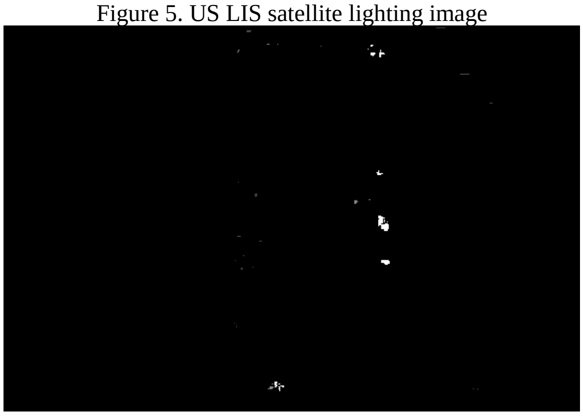

Figure 6. Detection result of the system designed

5. CONCLUSION

In this paper, a instantaneous point source target detection system which can recognize the target event of instantaneous point source is designed. The system is based on FPGA technology, using two DDR2 chips to store 7 consecutive frames of background image; and is based on the water design technology, designed for the instantaneous point source target recognition and encoding algorithm in FPGA to achieve the real-time processing. To verify the function of the system, an experimental verification platform was built, and the actual instantaneous point source target images captured by the US LIS satellite were verified by experiments. The experimental results show that the instantaneous point source target detection system designed in this paper can detect the real-time instantaneous point source target detection for the focal plane image. And it can be used in the geography field and some military field.

REFERENCES

Fuxiang Huang, Junbo Guo, Xiaohu Feng. Simulation and calculation of false alarm rate and detection rate of lightning imager. 2009, 38(12), pp. 3116-3120.

Wei Chen, Shulong Bao. Research on FPGA design of real-time processor for FY-4 blitz imager. Spaceflight return and remote sensing, 2005, 26(3): 31-37.

Douglas M M, HUGH J C, Richard J B, et al. Performance assessment of the optical transient detect and lighting sensor, 2007, 112(d09210).

Duo Chen. Research on the data processing method of lightning signal model and lightning instrument. Changchun, Jilin, 2011, pp. 201-205.

Shengbo Chen, Yin Yang, Tengfei Cui. Study on the influence of cloud detection of geostationary satellite lightning. Journal of Geophysics, 2012. 55(3): 797-803.