Active-pulse television measuring systems images space-time filtration by range

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Abstract. The paper proposes an approach for visualizing objects on images obtained with active-pulse television measuring systems (AP TMS) by range. The calculation of the AP TMS active vision area shape allows getting data of the light energy distribution inside the active vision area. To distinguish the object of interest on the video frame, an inter-frame difference of several frames obtained with different gating delays can be found. The equation of inter-frame difference for three frames is proposed. The difference simulation for three active vision areas was performed. To test the method of images space-time filtration by range, we used images obtained as a result of experimental studies conducted using large aerosol chamber of the V.E. Zuev Institute of Atmospheric Optics of Siberian Branch of the Russian Academy of Science (IAO SB RAS). In order to conduct the experiment video frames obtained under conditions of normal transparency of the propagation medium at different gating delays of the image intensifier tube (IIT) were taken. During the experiment, an image of the measuring table located at a distance of 15 m was distinguished, and the remaining objects located in the system's field of view were successfully removed using space-time filtration. Removing of the "unwanted" information from images will increase the compression ratio and speed up the algorithms for further processing.The results obtained in this paper contribute to a more efficient use of the AP TMS for the purpose of detection and recognition of the objects under various conditions of visibility.

1. Introduction

Active-pulse television measuring systems (AP TMS) are designed for visual detection and identification of objects in difficult weather conditions and in low light.

Difficult visibility conditions, such as fog, haze, dust, snowfall or rain, significantly limit the range of detection and recognition of objects. The main reason for limiting the range of detection and recognition of objects in difficult weather conditions is the scattering of light radiation by aerosols of the propagation medium. Scattering occurs in all directions, including the direction towards the observer, which leads to a significant decrease in the contrast of the observed objects [1].

The AP TMS operation principle allows eliminating the backscatter noise and significantly reduce the intensity of natural or artificial light interference.The operation principle of the AP TMS is based on the pulsed illumination of the observed objects and the time gating of a photodetector equipped with a fast shutter.As a high-speed electronic shutter and image brightness amplifier, an AP TMS uses an image intensifier tube (IIT). In order to receive a video signal, the image intensifier tube is compatible with a television camera. As a backlight device for AP TMS, illuminators based on lasers or LEDs operating in a pulsed mode are used.The pulse mode of the system allows forming an active vision area and excluding everything that is beyond [2].

Observation range control is carried out by changing the delay time of the photodetector shutter opening relative to the backlight pulse (gating delay). Figure 1 shows a structural diagram of AP TMS.

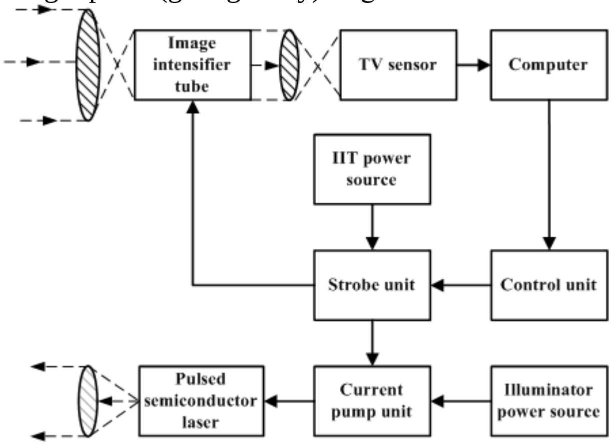

Figure 1. Structural diagram of AP TMS.

2. Active Vision Area of the AP TMS

The active vision area is the illuminated space in which the photons reflected from objects of this area will be received during the open state of the "shutter". Photodetector gating delay control allows adjustment of the observation distance. By adjusting the pulse duration of the light source and the gating delay of the photodetector, one can control the depth and shape of the active vision area.

The active vision area shape in general case will be the result of convolution of the illumination pulse with the gating pulse of the IIT [3, 4]. In practice, it is rather difficult to obtain the rectangular pulses with short duration and high amplitude. In addition, when the light propagates through the atmosphere, the attenuation of its intensity is determined by two factors, one of which is inversely proportional to the square of the distance to the object, and the second contains a negative exponent [5]. Therefore, the active vision area shape of a real AP TMS will be look like a Gaussian function.

In addition to the direct effect on the backlight and IIT gating pulses duration, the depth and shape of the active vision area can be controlled by the processing operations with the images obtained using AP TMS. Since AP TMS images are usually black and white, the resulting video sequence can be written as a three-dimensional array.

Example of the three-dimensional system is shown on Figure 2. Let the x (n_1, n_2, n_3) – represents three-dimensional signal, where n_1, n_2 – space coordinates, n_3 – number of the frame (Figure 2).

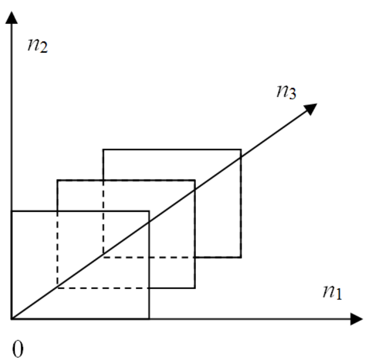

Figure 2. Example of the three-dimensional system.

Using shifting of the photodetector gating delay for the each next frame by a certain value relatively to the previous one, using calculation of the inter-frame difference, one can reduce the depth of the active vision area.

The equation of the inter-frame difference for three frames can be written as follows, $y(n_1,n_2,n_3)=x(n_1,n_2,n_3)-x(n_1,n_2,n_3-1)-x(n_1,n_2,n_3+1)$ [6].

Figure 3 shows the calculation result of the difference between the three active vision areas at normal transparency of the propagation medium, shifted by 5 m (33.3 ns) relative to each other. The value of the backlight and gating pulses durations is constant in each area τ_L= 40 ns, τ_g= 60 ns, gating delay was 100 ns for the first area, 133.3 ns for the secondand 166.7 ns for the third.

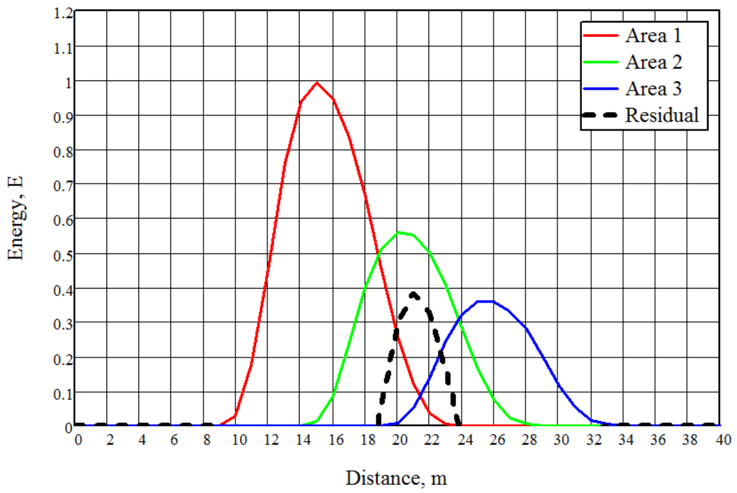

Figure 3. The difference model of the 3 active vision areas.

As can be seen from Figure 3, the depth of each area individually is 15 m, and the result of calculating the difference reduces the depth of the active vision area to 5 m. In addition to reducing the depth of the active vision area, this method also allows subtraction of the background radiation, since it will be present in each area regardless of the IIT gating delay.

3. Experimental Studies

An experiment to test the method of the images space-time filtration by range was carried out using AP TMS laboratory prototype, the appearance of which is shown on Figure 4.

Figure4. Appearance of AP TMS laboratory prototype.

System vision range is about 180 m, vision angle of the system is limited by 12 deg., there is 842 nm wavelength infrared highlight illumination, the durations of highlight and IIT gating pulses are changing in range from 30 ns to 120 ns, wherein highlight pulse repetition rate can be from 50 Hz to 5000 Hz.

To test the method of the images space-time filtration by range, we used images obtained as a result of experimental studies using a large aerosol chamber (LHC). Video frames obtained under conditions of normal transparency of the propagation medium at different IIT gating delays were taken. The objective of the experiment is to highlight the image of the measuring tables located at a distance of 15 m and subtracting the remaining objects located in the field of view of the system (Figure 5).

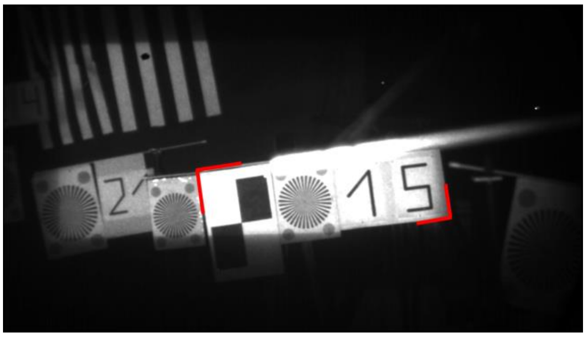

Figure 5. Object of interest, measuring tables at a distance of 15 m.

On figures 6 and 7 shows AP TMS video sequence frames, obtained with IIT gating delays of 60 and 140 ns respectively, backlight pulse duration τ_L=40 ns and IIT gating pulse duration τ_g=60 ns.

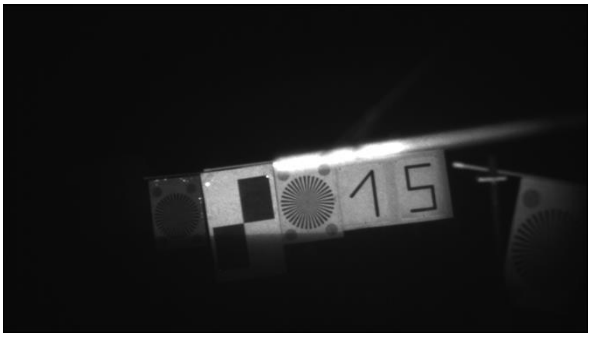

Figure 6. Gating delay60 ns.

Figure 7. Gating delay140 ns.

Figure 8 shows the inter-frame difference modeling result. The most suitable for the purpose of the experiment were frames with IIT gating delays of 60, 110 and 140 ns. In order to highlight an object of interest with acceptable energy losses the coefficients a_1, a_2 and a_3 were introduced into the difference equation which are necessary to equalize the brightness of the experimental frames. The coefficient values were selected experimentally. The difference curve obtained from the simulation results shows the 4 m depth region with a maximum energy at a distance of 15m, which corresponds with the distance to the object of interest location.

Difference equation for distinguishing the object of interest: $y(n_1,n_2,n_3)=a_1x(n_1,n_2,n_3)-a_2x(n_1,n_2,n_3-1)-a_3x(n_1,n_2,n_3+1)$, if a_1=2, a_2=0.33, a_3=4.

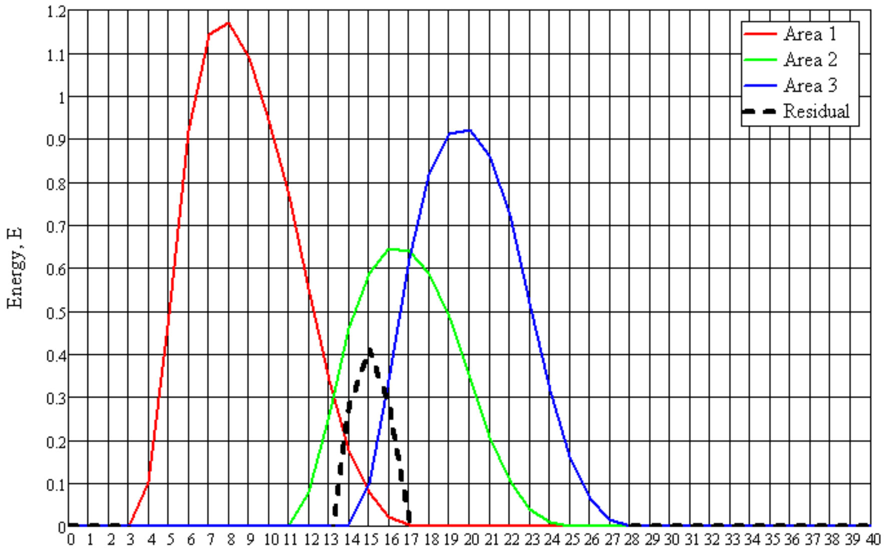

Figure 8. Modeling of inter-frame difference.

Figure 9 shows the modeling result of the AP TMS inter-frame difference distinguishing. As can be seen from this figure, object of interest was successfully distinguished with some loss of brightness, and the rest of the scene objects are suppressed.

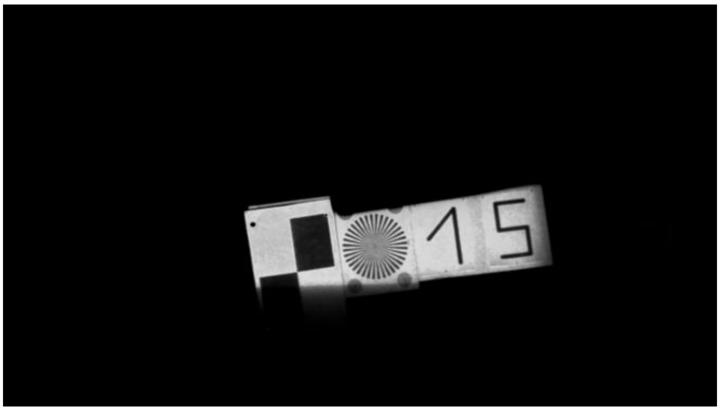

Figure 9. Object of interest distinguishing result

4. Conclusion

Methods of the AP TMS images space-time filtration by range have been tested. As a result of the experiment it was found, that even with relatively deep active vision area the images of objects of interest can be successfully distinguished by range with acceptable energy losses. Removing of the "unwanted" information from images will increasethe compression ratio and speed up the algorithms for further processing of the image. The results obtained in this paper contribute to a more efficient use of the AP TMS for the purpose of detection and recognition of the objects under various conditions of visibility.

Acknowledgements

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