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Study on real time 3D imaging of streak tube lidar based on LabVIEW

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ABSTRACT

This paper introduces a streak tube imaging lidar (STIL) used for real-time 3D range imaging. Based on the LabVIEW platform, this system realized system control, image acquisition, data processing and image display through PC. Long distance target imaging experiments have been carried out with our self-designed system. The frame rate of raw image processing is up to 100 Hz, and the real-time display of the intensity image and range image is realized. For a specific target with a distance of 2000 m away, the experimental results show that our system has realized spatial resolution up to 0.1 m and the range resolution up to 0.18 m, which can be further improved. Compared with the traditional STIL system using FPGA, DSP and other hardware control and processing methods, our system has the advantages of short design cycle, low cost and high flexibility.

1. Introduction

The streak tube imaging lidar (STIL) system is an efficient means for 3D data acquisition, which has the advantages of high range resolution, wide field of view and high frame rate [1–3]. The STIL has attracted a lot of attentions in recent years and has been widely used in terrain mapping, power transmission line monitoring, engineering building modeling, underwater target detection [4,5] and other fields.

Using linear scanning voltage, the difference in the time-of-flight in a beam line is transformed into different spatial locations on the screen. By processing the raw image, the 3D information of the target can be obtained [6,7]. Currently, high-speed real-time image processing usually uses FPGA, DSP etc., hardware processing methods [8,9], which have advantages of high-speed processing. However, they have shortcomings of complex structure, long design cycle and poor flexibility. With the rapid development of computer technology and data processing software in recent years, the use of PC to perform the STIL system control and high-speed image acquisition and processing has gradually become possible [10,11].

This paper adopts LabVIEW for system control and image data processing, and develops a high frame rate STIL system, which can cover remote imaging distance up to 10 km. This system has been put into experiment for high resolution 3D scanning and high-speed image processing of a particular target up to 2000 m away. The experimental results show that the LabVIEW program used for system control can also achieve high frame rate of real-time processing together with display of raw STIL image concurrently. This has proved the feasibility of the method. Compared with the traditional way of the hardware approach, the system development needs less effort, and it is flexible to do algorithm integration and system parameter changes.

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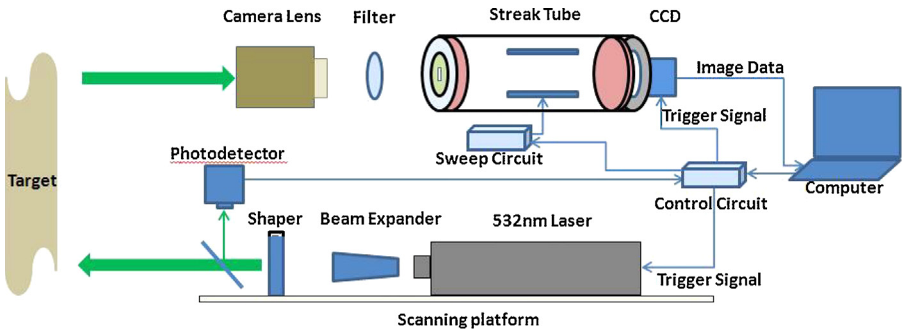

Fig. 1. General schematic diagram of the experimental setup of STIL system.

2. System structure

The STIL system is mainly composed of 4 parts, emission sub system, receiving sub system, optical sub system and control and data processing sub system. The working principle of the system is shown in Fig. 1, in which the emission sub system uses Nd:YAG pulse laser, with wavelength of 532 nm, pulse width of 8ns and the highest frequency of 150 Hz. The optical sub system is further divided into emission optical sub system and receiving optical sub system. The emission optical sub system uses beam expander to adjust the divergent angle, and the outgoing laser is transformed into a linear beam by a cylindrical lens and a Cassegrain lens is used for the receiving optical sub system. In order to reduce the interference of background light, an optical filter is installed with a center wavelength of 532 nm. For receiving and acquisition of the laser signal, the receiving sub system is mainly composed of streak tube, light cone, image intensifier and CCD. For the purpose of realizing the overall control of the system, the control and data processing sub system is mainly composed of a PC, a signal generating card and a precise delay device.

The STIL uses LabVIEW software on the PC to control signal generating card to send frequency, delay time, scanning speed and other system control commands. A laser beam splitter will be used to divide the light into two light beams of different intensities. The stronger beam is shaped into line beam, by using a collimation telescope and a cylindrical mirror, and then the line beam is used to scan the target. The weaker one is received by a light detector, and the signal then is used as the time reference of a delay generator. The set delay time is output to the streak tube deflection circuit, so as to ensure that the reflection signal with a predetermined detection distance lies inside the range gate of the streak tube.

After the laser beam has irradiated a target, an echo signal is received by the receiving sub system, and then the signal is converged to the streak tube photocathode. A light cone will be used to couple the streak tube image to the image intensifier, and then, the enhanced image is captured by the CCD and its data will be processed by the computer.

The LabVIEW software is used to acquire the CCD images, and at the same time, image data processing is being carried out. A reconstruction algorithm is used to achieve real-time display of the target intensity image and range image.

3. System control and data processing

Image processing and system control of the STIL is realized by the LabVIEW, which is a kind of graphical virtual instrument development platform, with a variety of control and computing nodes and rich visual function modules [12,13], and therefore, the LabVIEW platform has been widely used in industrial manufacturing and other fields.

3.1. Graphical software control interface

The operation interface of STIL is shown in Fig. 2, which is mainly composed of control part and display part. The control part mainly carries out the adjustment of system parameters, including CCD settings, imaging frequency control, and scanning speed regulation, etc. The CCD settings can be used to achieve the parameter settings of exposure time, gain, and contrast, etc. The "Frequency" slide bar is for adjusting the laser trigger signal and CCD signal acquisition control. The "Motor speed" text area for controlling the speed of the scanning motor, when combined with the "Frequency" slide bar, can achieve different resolutions of the target imaging.

The image display part is mainly for the real-time display of the raw images, the intensity images, the range images and the 3D images. The raw image, displayed on the upper left panel, is a streak image acquired by a laser beam, while the other images, displayed on the remaining three panels respectively, are real-time synthetic images. The intensity image shows the reflection characteristics of the target by a single color and the range image uses pseudo color to display the distance information of the target. The 3-D target information, residing on the lower left panel, is real-time displayed.