Construction of an Active Triangulation 3D Scanner for Testing a Line Following Strategy

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Abstract: Referring to [1] an active triangulation 3D scanner is developed by the author. The configuration of the system is described first in the paper highlighting the difficulties of the construction. Since one of focuses of the author is the statistical consideration of the noise originating from different sources in the line following algorithm the question of the measurement, distribution, sources of the noise are mentioned. The planned development directions are drafted in the last section. The system plays an important role not only in research but in the education as well.

Keywords: active triangulation scanner, speckle noise, video noise

1 The Configuration of the Scanner

The device is an active triangulation laser scanner using vertical line structured light. The draft of the scanner configuration is shown in *Figure 1* and a photo of the device is shown in *Figure 3*. Main components are the following:

- Object table,

- The light source,

- Matrix camera,

- Frame,

- Software controlling table drive and camera capture and assembling input to 3D objects.

This is a traditional configuration of an active triangulation scanner [4] [5]. The direction of the research is to find more accurate algorithms to extract lines from

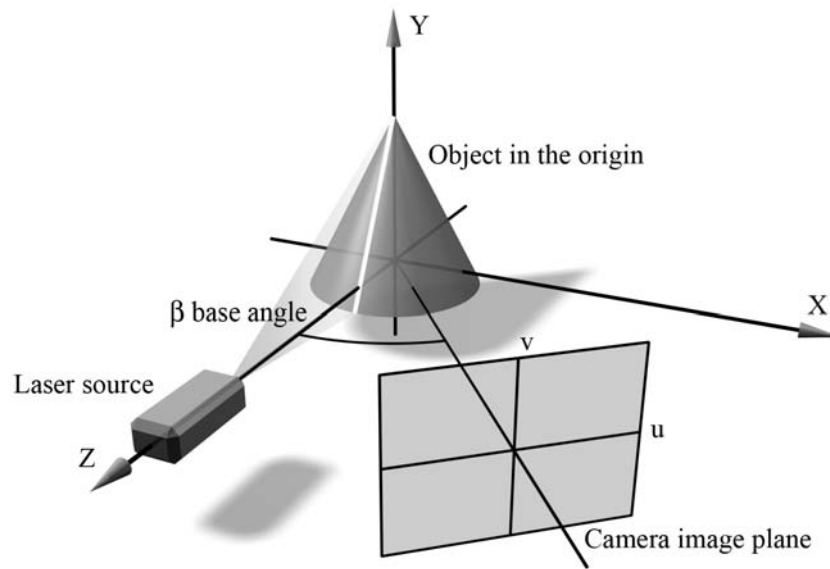the camera images taking into consideration noise of images originating from different sources.

Figure 1

The configuration of the scanner is presented. The light plane is the *YZ* plane, the camera base angle can be set in the *XZ* plane. The rotating axis is the *Y* axis of the basic coordinate system. The camera has its own camera coordinate system with directions *u* and *v*.

The algorithm applied to this hardware is described in detail in papers [1] and [2]. The essence of the strategy is to use a weighted average of image intensities in a previously fixed sized window. The output is a direction defined by an angle like a compass. The anisotrophy is increased by a so called mask matrix that enables pixels into the calculation from a circle not from the squared shape window. The mask matrix is shown in *Figure 2*.

A noise model is set and a connection is derived from this model among the window size, noise parameters (mean and variance) and the accuracy of the calculation of the direction. So under given circumstances (applied hardware, lighting and software parameters, like window size) an estimation of the direction accuracy can be set, or previously defined an accuracy the window size can be chosen.
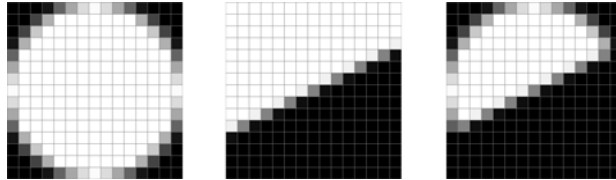
Figure 2

A graphic representation of the mask matrix. White pixels denote values of 1, black pixels have value of 0 and in-between grey pixels have values between 0 and 1.
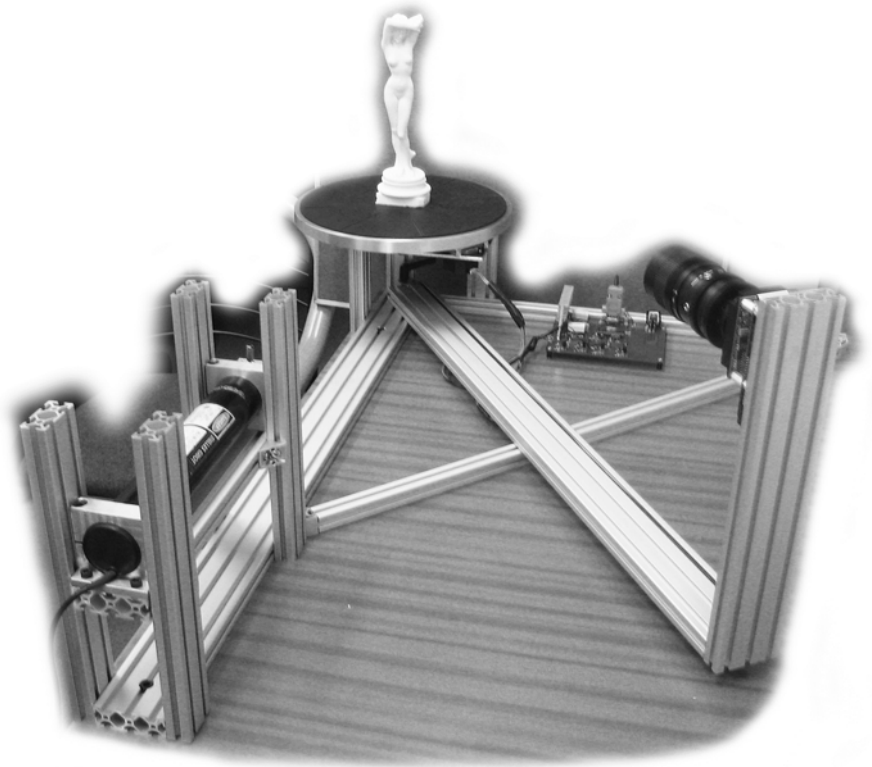

Figure 3

Photo of the scanner. The software can handle rotating and sliding tables as well, however, at the moment only the rotational object table is installed. The frame is fixed onto a robust table to avoid unwanted resonance or inaccuracy. Elements of the frame are modular, so it is easy to change the camera distance, the position of the light source or a number of configurational parameters.

1.1 Object Table

The object is set onto a rotating table in order to creating vertical sections of the object. The table is driven by a stepping motor connected to the table item by an XL timing belt. The gear ratio is approx. 1:20, the minimal step of the motor is 1.8 degree. The control of the motor is designed based on a microcontroller that handles coils of the motor and the reset sensor (an infra gate).

The firmware of the controlling card receives commands from the host computer via serial connection. An elemental rotating command is divided to three parts because of the safe and accurate rotating of an object: an acceleration phase, constant velocity phase, deceleration phase.

The table can be set to the initial position with the signal of the reset sensor. It is important, because the camera calibration object has to be fixed onto the table, and during the calibration it has to be located and oriented in a well-defined position.

It is planned to build a sliding object table as well in medium term (*Figure 4*). The application using this hardware is prepared to handle transformations in connection with translational scanning method.
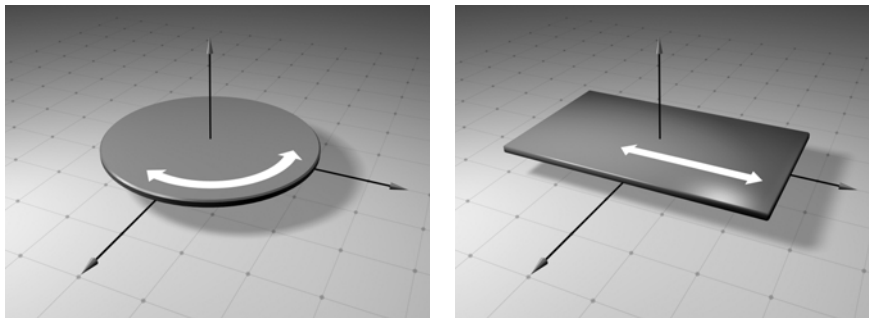

Figure 4
Rotating table for creating cylindrical sections and sliding table for producing linearly distributed sections

1.2 Light Source

The light source is a He-Ne laser with additional optics [6]. The light beam is to be dispersed to a vertical line by a cylindrical lens. The quality of the line is enhanced by a collimating system constructed by two lenses with focal length of 37.2 mm shown in *Figure 5*. This telescope is used near to the common focus plane a light cutter is applied to cut scattered light increasing the contrast of the line. A temporal coherence reducing element can be inserted into this optical unit

in order to deflate the disturbance of the speckle noise characterizing laser systems.
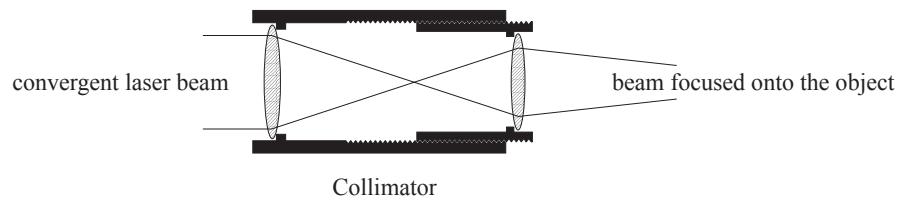

Collimator

Figure 5

The collimator is a small telescope but it is used not in the way to set to infinity but set to the object focusing convergent beam onto the object

1.3   Image Sensor

The image sensor is a Lumenera 130C camera head connected via USB to the host computer. The CCD has 1.3 megapixel. The system is ideal for programming because a lot of low-level functions can be reached and the native pixel flow can be got from the CCD. A C++ based driver was created with a C# interface, because the host application is coded in C# .NET environment.

Zoom, focus and aperture can be set manually.

1.4   Frame

The frame is constructed of aluminium alloy partially based on ITEM type standard elements. The mechanical design is focused on the freedom of the development. So the position of light source, camera can be set, the base angle of the triangulation can be defined coaxially with the rotating axis of the table. In order to reduce the unwanted reflections by the elements of the frame all of the element will be eloxed to black.

1.5   Software

The low level parts of the driver application cooperating with the scanner is developed in C++. Camera driver and the serial port controller of the motor are encoded in this way. The higher level functionality of the system is implemented in .NET C#. The visualisation module is constructed using DirectX.

The hardware is a computer with 3GHz P4, 512MB RAM, under Windows XP operation system.

2   The Noise

2.1   Definition

The image of the line is composed of two effects:

- The noiseless image of the line. All *u*-directed sections are Gaussian (in the camera coordinate system), only the amplitude and the variance are varying. Directions *u* and *v* are defined in *Figure 1*.

- The noise of the imaging system. It is described as an independent, Gaussian distribution zero mean additive noise (random variable), with variance σ_N. In this model the noise is independent from the intensity and from the frame buffer position as well.

2.2   Sources of the Noise

With this device two sources of noise will be taken into consideration.

- Noise of the imaging system cumulated into the image matrix transferred to the software (noise of the CCD element, analogue circuits, optical elements). It is a time-dependent random noise.

- Speckle noise of the laser source, that is a mostly time-independent noise pattern on the surface of the object depending on the quality of the surface.

3   Conclusion, Planned Activities

At the time of this paper the hardware will be almost finished. The next phase will be the fine tuning of the hardware and the development of the software.

One of targets is to analyse the noise of the camera subsystem [3] [7] [8]:

- What is the distribution of the noise,

- What is the dependence of the distribution from the intensity,

- What is the dependence of the distribution from the position on the image surface,

- How can be characterised the interaction between pixels.

Another target of the research is that how the speckle noise of the laser source can be used or eliminated in the workflow. Maybe it can be used to extract the microstructure of the surface.

Some practical enhancement is planned to do. For instance in order to rotate the object table smoother a micro stepping motor control will be elaborated. In this way resonance of the frame will be suppressed and the accuracy of the table rotation can be higher.

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