An Adaptive Structured Light Pattern for the 3D Profiling of Colored Objects

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Abstract

Coded structured light is a fast and reliable technique to acquire the geometry of a measuring surface since the pattern codification might solve the correspondence problem in a single shot. Colored patterns reduce pattern segmentation complexity but their efficiency decreases in the presence of colored surfaces.

We propose a color coded pattern which is automatically adapted depending on the color of the measured surface, which is a topic not completely solved in literature. In 1, Caspi showed that the projection of colored patterns on a saturated object is possible to get the 3D geometry of the surface but the surface color was not acquired and so the pattern lacks of an automatically adaptation. Hence, an accurate color calibration of the structured light system is required, which has been based on 2: Nayar's radiometric calibration computes the non-linear relationships between camera and projector. Then, the system identifies the color of the surface and the projected colors might change with the aim of making easy the pattern segmentation and the labeling.

Introduction

There exists several 3D reconstruction techniques indexed in 3. We use a system with color coded structured light. In our case, coding is used at two aims:
- to differentiate the projected patterns and thus to allow the reconstruction of 3D objects by triangulation;
- to determine the color of each reconstructed point.

We want to measure both 3D and color information of a scene with a tri-CCD camera and a LCD projector. It is initially necessary to gauge color the complete system. The goal is to adapt the color of projection to the color of the scene. It is thus necessary to project, detect and decode the color coded structured light. The principal advantage of our technique is the 3D and color reconstruction of an observed scene, and to find the best pattern whose will thus allow an optimal detection for the best possible color 3D reconstruction. The major disadvantage is the adaptation, which thus implies several projections and the objects must be static during the time of projection.

We will see first how to treat the output images from a tri-CCD camera. It is initially necessary to remove various noises and interfering signals. Then the crosstalk between the three channels must be processed. To check the model described is coherent, we will reconstruct the scene color. We will thus show that the model is faithful and can determine the color of the scene precisely. We will finish by the presentation of some result and a conclusion.

Color Images Preprocessing

System Color

We use a preprocessing described in 4 for a multispectral camera based on interference filters. In this case, this preprocessing is of primary importance. We applied the corrections evoked above for a tri-CCD camera. Although the image obtained from a tri-CCD camera can be used directly, the taking into account of the interfering signals and other noises leads to images much cleaner. Indeed, the pixels do not react in the same way to same illuminant: it is one of the characteristics of CCD sensors.

Crosstalk between the 3 Channels of a tri-CCD Camera

Following that, we can calculate the crosstalk matrix between the three channels of the tri-CCD camera, pixel by pixel. Let us recall that a crosstalk matrix is necessary for the camera calibration in order to describe the parasitic superimposition between the three components at sensor output. Once calibration carried out, we can correct each image acquired to give the color of the observed object.

We will use the radiometric calibration method of 5 to characterize the non-linearities of the three channels of our tri-CCD camera. This information, stored in a LUT, allows a first correction of the camera images. Then, contrary to the method described in 1, we chose to calculate the crosstalk matrix pixel by pixel. Moreover, we want a method which is free from the use of a spectrophotometer.

It should be noted that the geometrical calibration is done by the pinhole model. We carried out it in a way presented in 6.

Color Projection

System

The system used is made up with a tri-CCD camera and a LCD projector. The camera acquires a picture of the scene with the coded pattern projected by the LCD projector. We used a camera Sony Dxc-9100P. The scene used to calibrate is the color rendition chart Macbeth ColorChecker® A4 format with 24 patches. All these calculations are made pixel by pixel.

The calibration process allows, from a projected image by the video-projector, to calculate which is really projected on the scene and from the camera image, the input signal of the camera.

Using the color calibration process we can accurately determine the color of each point of the scene. This permits us in the same way to choose the color of projection of each point.

Principle of the method

The goal is to project a color coded structured light but on a colored scene. 3 shows various possible codes to make 3D reconstruction. The work led to University of Girona led the use of a De Bruijn code, 7. The use of a De Bruijn code on scenes of uniform and not very strong colors allows an optimal matching. In our case, i.e. colored scenes, this type of code does not give interesting results. Indeed, in the case of colored objects, the colors recovered by the camera are the product of the reflectance spectrum of the object by the projection spectrum. Matching is not thus obvious any more. To eliminate this problem, we used a De Bruijn colored pattern which circulates in front of each point of the camera. We currently have tools allowing us to check and show the feasibility of the method.

Obviously, usually De Bruijn method requires only one projection. In our case, it is necessary several projections but the two information 3D and color both is extracted into only once.

Initially we calibrated the system geometrically. This stage enables us to rectify the pair of image from the camera and from the projector. According to the epipolar conditions, a point in the camera image is on the same line in the projector image. There is thus no uncertainty on the line index for the mapping. We project a set of vertical lines, of different color according to three projections in first time, for example. For example with three projected pattern. It acquired by the camera. In the camera image we will analyze a point. This point has several possible points for matching in the first projected pattern. We can thus write the following equation:

$$\begin{pmatrix} \mathbf{C_{R1}} \\ \mathbf{C_{G1}} \\ \mathbf{C_{B1}} \end{pmatrix} = \begin{pmatrix} \mathbf{R} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{G} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{B} \end{pmatrix} . \begin{pmatrix} \mathbf{P_{R1}} \\ \mathbf{P_{G1}} \\ \mathbf{P_{B1}} \end{pmatrix} \qquad (1)$$

The same thing can be written for all the candidates with matching. We choose the best possible by retaining the color point which the weakest correlation rate. We use an iterative process. In fact, the method is based on a control color.

The equation (1) comes from the equation in 3:

$$\mathbf{C} = \mathbf{A}.\mathbf{K}.\mathbf{Q}.\mathbf{P} \qquad (2)$$

A is the crosstalk matrix of size 3x3. For first experimentations, A is fixed to unity matrix. K is the scene reflectance, is a diagonal matrix of size 3x3. Q is the vector of size 3 of the projector characteristics. For first experimentations, the projector is linear. P and C are size 3 vectors, respectively, projector and camera colors.

Conclusion

The method used to correct the multispectral images can apply perfectly to images color RVB. The goal of this handling was to show that if the images resulting from a tri-CCD camera are pretreated, the calculation of the crosstalk is much more reliable. Moreover, while using a color coded structured light in several projections we can raise ambiguity in the case of colored scenes.

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Biography

Alexandra Lathuilière graduated in electronic optic in ISTASE in University of Saint Etienne in France in 2003. She received the DEA degree in Images in 2003 too. She joined the Laboratory of Electronic, Computer Science and Image for her thesis in Automatic adaptation of pattern for the 3D reconstruction scenes for a stereoscopic system of active vision since December 2003. She joined the Computer Vision and Robotics Group in the University of Girona for a period training.