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8—9 Multi-Spectral Panoramic Sensor

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Abstract

To reconstruct an environment under 360 degrees with a great accuracy and true color represents an important challenge for motion pictures and multimedia applications. This paper describes a new stereoscopic panoramic sensor to achieve this task. Unlike the existing sensors, it uses four acquisition channels coupled with an additional structured light projector to obtain an accurate 3D panoramic reconstruction with faithful colors. Real experiments demonstrate the feasibility of this new panoramic sensor.

Keywords: Panoramic Sensor, 3D Reconstruction, Linear CCD Camera, Structured light Projector, ICC profile.

1. Introduction

The increasing interest for panoramic imaging over recent years led numerous research laboratories to design original panoramic sensors. They can be grouped into three classes which include all the techniques: mirror system, fish-eye and rotating camera.

Originally, most sensors found their applications in robotics [1] [2] [3] [4] and video surveillance [5], due to their main characteristics, which are a large view angle and a real time acquisition (fish-eye and mirror system).

Nowadays, the 3D reconstruction of real scenes over 360 degrees represents an important challenge for motion pictures and multimedia applications. These applications require for the 3D reconstruction two major features:

- faithful colors restoration
- a great geometrical accuracy over 360°.

Although most panoramic sensors can be used to reconstruct 3D panoramas, no existing sensor matches these two requirements. On the one hand, faithful color acquisition requires rigorous color calibration and light control. On the other hand, the 3D reconstruction of complex scenes is generally time consuming and suffers from matching errors.

We designed a multi-spectral stereoscopic panoramic sensor which satisfies these requirements by separating the color acquisition and the reconstruction. Each camera owns four acquisition channels, three for the colorimetric values and one to retrieve the spatial coordinates of the acquired 3D points.

In this paper we will first present the principle of this new stereoscopic panoramic sensor, then the faithful color acquisition and 3D reconstruction. Finally, experiments show the efficiency of this new sensor to reconstruct accurate panoramas.

2. Sensor principle

The principle of the sensor is based on the rotation around a same vertical axis, of two linear CCD cameras [6] (figure 1) under the control of a stepper motor. Moreover, the axis of rotation passes through the optical centers of the cameras. This important characteristic allows to obtain panoramic images with cylindrical geometry. Indeed, the linear CCD sensors are placed in the focal planes of the lenses, so, the linear CCD arrays describe a vertical cylinder during a 360 degrees rotation.

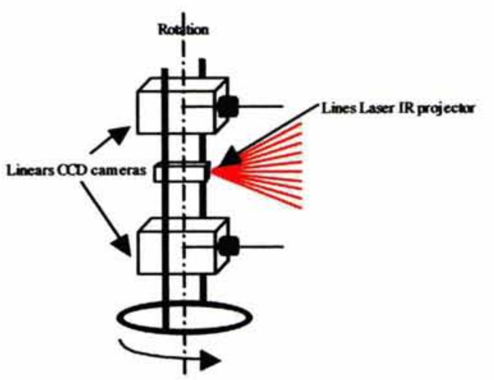

Figure 1: *Sensor principle*

An additional infrared Laser [7] equipped with an optical head (diffractive network) which projects 15 parallel lines from the laser beam, is fixed on the same axis of rotation than the two linear cameras. The position of the laser is fixed close to the middle of the two optical centers of the cameras. The fan angle of the laser is smaller than the view angle of the camera, so that, the latter sees completely the light pattern.

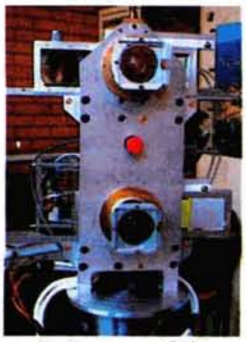

Figure 2: Image of the sensor

3. Four channels acquisition

One originality of our work uses the intrinsic property of CCD sensors to provide multi-spectral acquisition.

As CCD sensors have a spectral response from 300 nm to 1100 nm, a set of four filters, whose spectral band are depicted on figure 3, can provide four acquisitions channels per camera. The first three channels composed by Red, Green and Blue primary filters allow to acquire color panoramas. The fourth channel composed by a cold filter allows infrared light pattern acquisition.

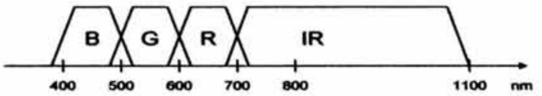

Figure 3: *Four filters bandwidth principle*

The filters are mounted on a motorized stage. Between two acquisitions, the stage moves automatically and places the filter which corresponds to the programmed acquisition channel.

Three acquisition over 360° are needed to obtain a RGB image. A last acquisition, combined with the infrared light, is needed to obtain the infrared image from the fourth channel.

4. Faithful color

Another originality of our sensor relies in its capability to acquire high quality color stereoscopic panoramas.

In most linear color CCD cameras, the three channels are obtained by using three linear photo-detectors arrays. So, a 3D point of the scene is acquired from three different lines of sight due to the array pitch. However, color algorithms are based on the fact that the three color components of a point are obtained from the same line of sight. So, some errors are introduced on the real values of the color image channels.

To acquire faithful colors, two steps must be respected: the first is to make sure that each 3D point of the scene is acquired with the same line of sight for all channels while the second represents the reduction of the defaults in the color acquisition process.

To guarantee that there is a single line of sight for each 3D point, we used for each camera a set of three Red, Green and Blue primary filters and a single black and white CCD linear array as described above in section 3.

So, the three color components of the 3D point are obtained following the same perspective projection.

To decrease the defaults in color acquisition, the filters are set between the output of the lens and the CCD linear sensor of each camera. This original position of the filters reduces the chromatic aberration. An additional hot filter is used in conjunction with the three RGB filters to exclude UV and IR spectral band. By these ways, we can ensure that the color acquisition process is made with minimum errors and only on the visible spectral band.

5. Color calibration

To make sure that each camera sees the real colors, we must calibrate the sensor space of colors and make color corrections. We developed a new calibration method which is inspired by the scanner calibration methods. We have used light sources whose spectral characteristics are close to the day light (at 5400°K) and an IT8.7/2 chart [9] whose values are known in the Lab space. From the image of the chart illuminated by the day light source, it is possible, to retrieve the ICC (International Color Consortium) profiles of the two cameras. For that, a color acquisition over 360° of an RGB image including a chart was done. By extracting the chart out of the image, the ICC profile of each camera was computed. The application of this profile generates images with their true color in the Lab space as shown in figure 4.

Figure 4: Up and low color images

6. Reconstruction 3D

Two major issues in 3D reconstruction are the processing time and the matching errors. Most matching algorithms are very time consuming and their errors number increase dramatically for complex images. To overcome this problem, we use the cold filter (fourth channel) combined with the structured light projector which projects lines from the laser beam into the scene. The structured light allows to obtain in all cases (any complex scene) the same number of characteristics points.

The patterns obtained by the two cameras on the IR channel (figure 5), were extracted column by column. By matching these patterns, the metric information of the light projected into the scene can be easily retrieved (figure 6 and 7). A specific algorithm based on the cross-correlation has been developed to perform this task. By this way, we obtain an accurate 3D reconstruction of the light pattern and the processing time is dramatically decreased.

Figure 5: IR images

From the 3D points and color image data, we can map texture on the 3D representation to make a textured color 3D reconstruction. A specific algorithm based on Delaunay triangulation and VRML functions makes the 3D texture color representation file. The latter can be seen with an additional viewer plug-in, as cosmo player [10], under Netscape or Internet Explorer.

7. Experiments

A prototype has been built and used to reconstruct 3D color panoramas. Systematic error on 3D reconstruction measured at 3m is 8%. This error decreases quickly when objects are close to the stereoscopic sensor.

Figure 6 and 7 show the images with IR points put in correspondence and the 3D representation of the same points. The best way to visualize this 3D color reconstruction is to use VRML language. An example can be viewed on the web of the LIS at the URL: www.lis.jussieu.fr/~camint.

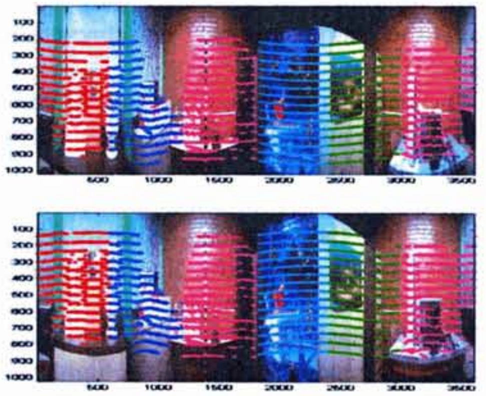

Figure 6: Color images with IR structured lights.

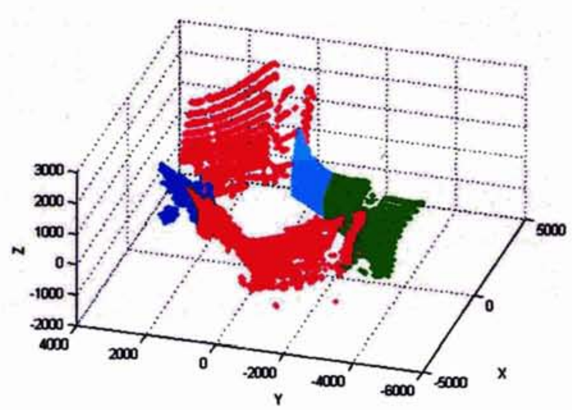

Figure 7: 3D reconstruction of the characteristic points

8. Conclusion

We have introduced in this paper a new stereoscopic panoramic sensor. Thanks to an original four channels acquisition, it enables the fast creation of 3D constructions with faithful color texture and a great accuracy.

A prototype setup has been built. Experimental results confirm that the sensor provides an efficient way to retrieve accurate metrics and faithful colors.

9. Acknowledgements

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10. References

[1].Y. Yagi, S. Kawato and S. Tsuji, *"Real-Time Omnidirectional Image Sensor (COPIS) for Vision-Guided Navigation, IEE Transactions on Robotics and Automation, Vol.10, NO. 1, February 1994.*

[2].C. Pégard and M. Mouaddib, *"A mobile robot using a panoramic view", Proceeding of the 1996 IEEE International Conference on Robotics and Automation, Mineapolis, Minnesota, April 1996.*

[3].R.A. Jarvis and J.C. Byrne, *"An Automated Guided Vehicle with Map Building and Path Finding Capabilities".*

[4].H. Ishiguro, T. Maeda, T. Miyashita and S. Tsuji, *"A Strategy for Acquiring an Environmental Model With Panoramic Sensing by a Mobile Robot", Proc IEEE International Conference on Robotic and Automation, 724-729, 1994.*

[5].V.N. Peri and S.K. Nayar, *"Generation of Perspective and Panoramic Video from Omni directional Video", Proceeding of DARPA Image Understanding Workshop, New Orleans, May 1997.*

[6].T. Manière, R. Benosman, J. Devars and C. Gastaud, *" Vision System dedicated to Panoramic Scene Reconstruction ", journal of Electronic imaging 7(3), 672-676 (July 1998).*

[7].Laser line Projector DLS500/SLH515. Commercial Product of LASIRIS Inc.

[8].Dichroic Coherent Filter, Primary Blue, Red and Green. Hot and Cold Coherent Filter.

[9].IT8.7/2 AGFA charter.

[10].Cosmo Player 2.1 plug-in. You can download in http://cosmos.sgi.com/