An omnidirectional image unwrapping approach

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Abstract—**Omnidirectional vision has received a particular interest in many computer vision applications such as video-conference, video surveillance and Robotic navigation. Omnidirectional vision systems can provide images with 360° as field of view. In various applications, it is useful to unwrap the obtained images to panoramic images which are more adapted to human visual system. The unwrapped images can be obtained by converting polar coordinates to Cartesian coordinates. However, this technique affects the size and the resolution of the output image. As effect, the image quality is degraded. To overcome this problem we present an improvement of this technique using nearest-neighbor interpolation method. Experimental results indicate that the proposed approach is effective to enhance the quality of unwrapped panoramic images.**

Keywords-component; Omnidirectional vision, Catadioptric image unwrapping, Nearest-neighbor interpolation.

I. INTRODUCTION

The omnidirectional camera system is given increasing interest by researchers working in computer vision, because it can capture large part of a surrounding scene with an angle that can reach 360°. Many applications such as robotics, video surveillance, video-conference and virtual reality representations have found a great interest in using this system.

There are many ways to enhance this field of view and obtain a large one, such as replacing classical optics of the camera by a very short focal length lens called fisheye lens [1], multiple-camera devices [2-4] and the rotating camera system [5]. All these systems have some advantages in typical applications and are limited in others [6].

Among all ways to enlarge the field of view the catadioptric system mounting by combining a perspective camera with a revolution mirror (Fig. 1) is one of the most frequently used to acquire an omnidirectional image. However, the mirror geometry provides important radial distortions on the obtained image. Moreover, the image sampling combined with the distortion brought by the mirror leads to a non-uniform resolution all over the image. The image resolution is lower at the center than at the periphery. Such phenomena complicate the omnidirectional image unwrapping process.

In various applications, the unwrapping process is necessary to obtain panoramic images which are more adapted to human visual system because of concentric annular distortion. The unwrapped image can be obtained by converting polar coordinates to Cartesian coordinates. However, this technique affects the size and the resolution of the output image due to non-uniform resolution. Consequently, the image quality is degraded.

In this paper, we present an improvement of the unwrapping technique using nearest-neighbor interpolation method. After presenting an omnidirectional vision system used in this study, we describe the proposed mapping technique conversion from polar to Cartesian coordinates in section 2. In section 3, experimental results are commented and compared to those obtained by the former one.

II. OMNIDIRECTIONAL VISION SYSTEM

A vision system is the richest source of information but the narrow field of view offered by standard cameras limits the range of possible applications. The catadioptric sensor can solve this problem and it is a useful way for omnidirectional images acquisition. For this study a catadioptric camera has been mounted in our LETS laboratory (Fig. 1) to acquire the omnidirectional images.

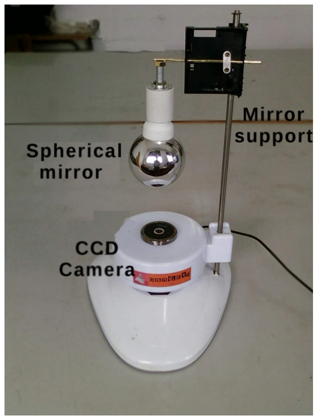

Fig. 1 Catadioptric-camera.

The sensor is mounted by combining a CCD camera with a spherical mirror. The optical axis of the camera and the mirror are aligned (Fig. 1). Sensor has the following specifications.

- The spherical mirror has a radius of 3.5 cm.
- The focal distance is variable.
- The resolution is 640x480.
- The interface is USB 2.0.
- The ratio of the video stream is 30 fps.
- The color depth is 24 bit.

The omnidirectional catadioptric vision systems intercepts the scene surrounding into a polar form (Fig. 2.a). For many applications it is useful to transform the acquired image onto panoramic form (Fig. 2.b). The method consist to remap the pixels. This process is often called "unwrapping" (Fig. 3).

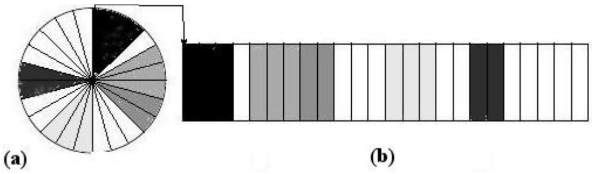

Fig. 2 (a) Original omnidirectional form (b) unwrapped form

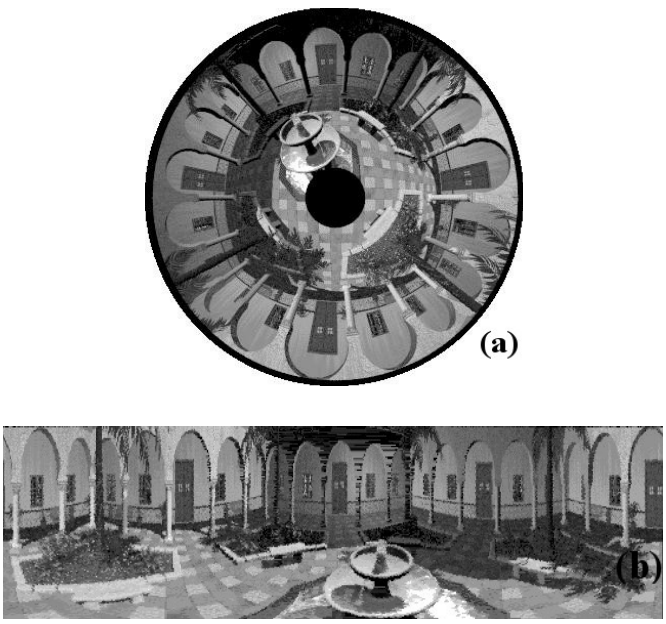

Fig. 3 (a) Original synthetic omnidirectional form (b) unwrapped form.

III. UNWRAPPING APPROACH

The proposed method is based on a direct transformation from omnidirectional images to panoramic ones.

The first step consist to translate the origin of coordinates system of the omnidirectional image toward its center. Initially, each point is identified by its coordinates *(x, y)*. After this translation, the new coordinates are *(x', y')*. The coordinates x' and y' *are:* $x'=x-x_c$ and $y=y-y_c$. Where x_c and y_c are the coordinates of the image center. The polar coordinates for each image pixel (ρ, θ) are given by following equations:

$$\rho=\sqrt{\left(x'^2+y'^2\right)} \quad (1)$$

$$\theta=\arctan\left(x'/y'\right) \quad (2)$$

The coordinates of a point in the rectangular image can be obtained according to (3):

$$\left(\alpha.\left(R_{max}-\rho\right), \beta.\left(\rho.\theta\right)\right) \quad (3)$$

Where R_{max} is the radius of the omnidirectional image, α and β are scaling factors acting on the resolution and the ratio of the output image.

$$\alpha, \beta \in \left[0,1\right]$$

When the two parameters α and β are equal to 1, the output image will have a maximum resolution that can be given by (4).

$$\left(R_{max}-R_{min}, 2.\pi.R_{max}\right) \quad (4)$$

The second step of the proposed method is to process the unwrapping image. From (Fig. 4.b), it can be seen that the unwrapped image has a rectangular form but the observed scene is deformed. As shown in (Fig 4.a) the omnidirectional image can be considered as a set of concentric circles. Circles with a courtyard perimeter cannot be spread along the rectangle. This problem can be overcome by replacing $\rho.\theta$ with $R_{max}.\theta$ in (3).

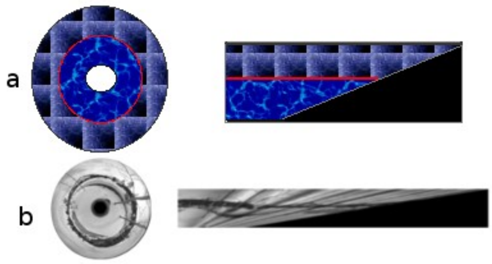

Fig. 4 Example of unwrapping process using equation 3. (a) a synthetic image. (b) a real image.

This new mapping (5) disperses the pixels along the rectangle but introduces an additional distortion as shown in (Fig. 5).

$$\left(\alpha.\left(R_{max}-\rho\right), \beta.\left(R_{max}.\theta\right)\right) \quad (5)$$

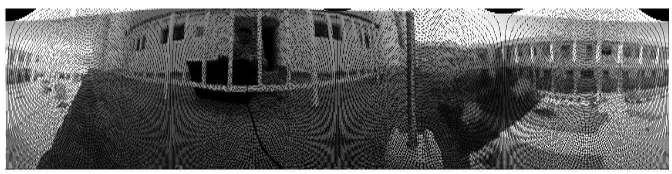

Fig. 5 Distorted image due to the unwrapping process.

In the following we show that this issue can be resolved by performing nearest neighbor interpolation which requires the least processing time of all the interpolation algorithms. The method consist to select the value of the nearest point, and ignore those of other neighboring points at all, yielding a piecewise-constant interpolate.

IV. EXPERIMENTAL RESULTS

The simulation is done on Laptop computer with following specifications:

TABLE I. COMPUTER SPECIFICATIONS

Simulation platform	Matlab 7.10.0.499 (R2010a 32bit)
Processor	Intel Celeron CPU 2.26 GHz
RAM	2Gb DDR2
Operating System	Ubuntu 10.10
Reset Time (reboot time of the computer)	~35s

Some experiments have been taken on several omnidirectional images to evaluate the proposed approach. In this work,we have just reported two cases.

Two omnidirectional images have been taken by our omnidirectional camera in this experimentation (Figs. 6 and 9). The unwrapping method was implemented and applied to different images.

The coordinates center, the maximum and minimum radius of all these images, can be detected manually by mouse or automatically if the image has a centered square shape. These parameters are used in the first step of the algorithm.

(Fig. 6) shows the omnidirectional image used to test the processing time for different resolutions. Table 2 illustrates the execution time. It can be noted that this approach is relatively faster.

Fig. 6 The input omnidirectional image acquired with the catadioptric camera.

TABLE II. RESULTS OF EXPERIMENTS

Input image resolution	**Scaling factors (α, β)**	**Output image resolution**	**Execution time**
64 X 64	(1, 0.5)	17 X 100	16,021 ms
128 X 128	(1, 0.5)	35 X 204	62,509 ms
256 X 256	(1, 0.5)	67 X 409	240,115 ms
473 X 482	(1, 0.5)	130 X 769	944,725 ms
1683 X 1689	(1, 0.5)	669 X 2642	19.781 s

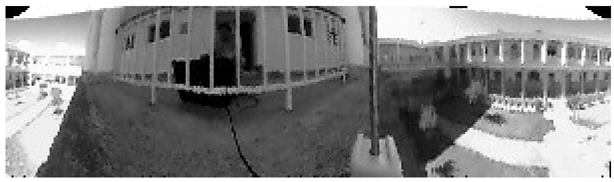

Fig. 7 Unwrapped image without interpolation. Resolution : (86x303, α=0.7, β=0.2)

Fig. 8 Unwrapped image with interpolation. Resolution : (122x749, α=1, β=0.5)

(a)

(b)

Fig. 9 Images acquired by the omnidirectional vision system. (a) Image acquired using the spherical mirror; (b) A Panoramic image created by the proposed approach.

From this experimentation it is easy to see that the objectsConclusion in the acquired images have low resolution near the center of the mirror. Additionnaly, the unwrapping process using direct pixels remapping of these images introduce some discontinuity of pixels mapping (Fig. 5). A basic technique consisting of reducing the size of the unwrapped image by decreasing the values of the scaling factors α and β followed by a filtering step can be used to overcome this discontinuity (Fig.7). It can be seen from (Fig. 7) and (Fig. 8) that our approach is offering a way to avoid the degradation of resolution without filtering process and leads to a fast processing speed.

V. CONCLUSION

This article presented an unwrapping approach. The omnidirectional images are acquired by a catadioptric sensor mounted in our laboratory. The experimental results and the comparison of this method with the former one show some improvement in the resolution and processing speed. In the future, we will extend this work to video unwrapping process.

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