A Self-adaptive and Real-time Panoramic Video Mosaicing System

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Abstract—**In real-time monitoring process, resolution must be set against field vision. There are two problems in the real-time monitoring procedures, which are: the field vision is too small to capture the target completely and a larger field vision with low resolution . In order to solve these problems, a new type of real-time panoramic monitoring systems becomes necessary. In this paper, we proposed a new adaptive video mosaicing algorithm based on SIFT algorithm and template matching method. By real-time adjusting and updating the mosaicing position of adjacent two images to establish the optimal mosaic line, we can both made full use of the accuracy of feature matching and the simplicity of template matching. Experimental results show our algorithm not only has good matching rate but also reduces the time complexity, which make it very suitable for the application which requests high real-time performance.**

Index Terms—**Video mosaicing, panoramic, SIFT, real-time**

I. Introduction

Traditional video monitoring system has limited filed vision, and there is a difficult problem on monitoring all events in 360 degree range at the same time, which all make the monitoring blind area, is necessary to the monitoring system improvement. The generation of panoramic video is one of the key methods. There are mainly three methods to generate panorama video based on three kinds of panoramic camera currently:

One kind is composed of single cameras equipped with fish eye lens. But fisheye lens has poor average resolution and irreversibility distortion on close range images. The inconsistency of viewpoint on various parts of image may lead to the difficulties of post process.

The second kind panoramic camera is to change the lights come into it by the principle of light refraction and light reflection, such as FullView [1] [2].It constructed a multilateral body with plane mirror, which make multiple camera view mirror overlap at one point virtually, this method effective constructs a panoramic and virtual camera that can capture the image video frame rate. Its filming image has high resolution, good effect and can achieve the video frame rate, makes it applicable to sports complex environment. With the help of adjusting exposure and brightness of the camera, it can form panorama video without post algorithm processing. It is the best way to establish real-time panoramic video mosaicing system, but the necessary auxiliary optical components require strict accuracy, the modeling procedures are quite tedious and time-consuming, at the meantime, the cost is high.

The finally kind panoramic camera is by the help of multiple cameras with different directions, for example, Flycam panoramic camera system [3]. This plan can capture different images on different angles and different spaces by multiple fixed position cameras and then to mosaic the scenes to get the panoramic images. It can also provide a higher resolution and just need ordinary camera to capture images. It can make any shape without any special equipment. But because of the inconsistent camera viewpoint, especially in the overlapping area of adjacent images existing long shot and close shot simultaneously, the ghost [5] it is hard to avoid.

Panoramic video mosaicing systems used for monitoring have the higher requirement of real-time and resolution, our system based on the third kind of panoramic camera motioned above, it is small in size and easy to installation and maintenance, and at the same time it can adjust the size of mosaicing area adaptively with high resolution by our Self-adaptive optimal mosaic line matching algorithm.

II. Related work

Panorama image generation mosaicing is one of the key methods to generate panorama image, by combining multiple overlapping image about the same scene into a panoramic images. A classic example panorama application is QuickTimer commercial software [6] by

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Apple Company. It generates cylinder panorama image in some key point positions, and, on each key positions, it can realize the eye-gaze continuous variation and achieve scene roaming by the jump between key points positions.

Kyung and others advances an effective algorithm to build cylinder panoramic image mosaicing. By equidistance matching the images horizontal photographed by cameras, they generate the cylinder panoramic image based on horizontal motion model, and they can effectively Estimated the focal length of used cameras by dichotomy algorithm. It is the most commonly used methods currently. And our paper uses it as a foundation. Shum and Szeliksi [7] put forward a panoramic image mosaicing algorithm, using image construct a complete panoramic image mosaicing system, this is the typical representative of image mosaicing technique.

Difference from traditional video surveillance system，panoramic video surveillance system can provide viewers with a complete 360o view． MA Li，ZHANG Mao-jun，XU Wei, etal.[8]designed KD-PVS ，one embedded high resolution panoramic video surveillance system ． They introduces the multiple-camera configuration and video mosaicing algorithm to stitch the video data from multiple camera sources into the panoramic video．KD-PVS system is very convenient for various situations，warehouses，prisons，mobile monitoring ， etc ， especially useful for indoor monitoring． ZHAO Hui and others [9]presented an improved fully-automatic image mosaic algorithm is．By sorting the unordered image sequence and roughly computing the translation offset between adjacent images to speeds up corner match procedure and improves matching stability ,and then using RANSAC algorithm to eliminate outliers to ensure effectiveness of the matched corner pairs， finally using a multi-band blending technique to generate the final panorama．It has less blur or ghost effect after blending，especially when there are noise， moving objects，repeated texture and small overlaps presented in the images．

YIN Run-min，LI Bo-hu, etal. [10] constructed a cylindrical panoramas view of a scene from an image sequence by using multiple image matching algorithms according to self-relation variant after precise focal lens searching adaptively to redraw the accurate overlapping image horizontally and vertically． In order to improve the visual field of photos，FENG Yu-ping，DAI Ming， SUN Li-yue [11] presented an optimized algorithm of automatic image mosaic based on frequency and time domains．By adopting the frequency phase correlation to sort the unordered image sequence and to estimate the overlapping area firstly, and then using the bidirectional greatest correlative coefficient to obtain the initial feature point pairs，and combining the image mean with the linear weight function to implement image mosaic finally, it can efficiently solve the difficulty in confirming corresponding points and achieves the desired visual effect in mosaic images with notable illumination difference

Multiple static cameras or PTZ(Pan-Tilt — Zoom)cameras are often used to monitor activities over a wide area in video surveillance system Miao Li-gang[12] studies the video compositing algorithm of multiple static cameras and video mosaicing algorithm to proposes a key frame based video mosaicing approach for PTZ cameras．these frames are selected based on the amount of overlap and abundance of the texture information．All frames are matched to their latest neighbor key frames， and then back-ground model parameters are updated for the overlapping regions．Key frames have very high alignment accuracy，so it can create accurate background image of the scenes that the moving object has traversed．

From these priors' researches mentioned above, we propose our self-adaptive optimal mosaic line matching algorithm to adjust the size of mosaicing area adaptively with high resolution for real-time monitoring system.

III. DESCRIPTION OF REAL-TIME PANORAMIC VIDEO MOSAICING

Our real-time panoramic video mosaicing system is comprised of three modules: Video Acquisition Module, Images Process Module, and Real-time Update Module. The framework of our system is shown as Fig.1.

The establishment of our system based on the problems we meet on our process of prior images mosaic, the mainly problems are shown as following:(1) Because of the oversize of our cameras' volume, there are external geometric distortions caused by the lack of coincidence in physics amongst each camera viewpoint; (2) Because of the oversize of our cameras' angle and the short-focus, there are internal geometric distortions;(3) Because of the lack of same projection plane amongst the images taken by multiple camera arrays, mosaicing them directly will destroy the visual consistency of actual scenery;(4) Because of the existence of long shot and close shot, there will be ghosts generated for the reason of depth of a field in the real –time process of mosaicing the overlap areas between the adjacent images; (5) Because of the automatic adjust brightness function of camera when meeting inconsistent brightness scenes; there are external optical output image distortions of output image after mosaicing for the different brightness of images taken by the different cameras.

Video Acquisition Module is comprised of 8 camera arrays to get the 360 degree panorama, This camera array put scheme as shown in Fig 1, the height of it is 11cm, by configuring it as octagon with its sides is 10cm, and the angle between each camera is 45°. The focal length of each camera's lens is 3mm, and the each visible angle of these cameras is 90 °. In order to reduce the influence of the size of the camera, we choose common pinhole camera and make our best effort to keep the light heart consistent (as close as possible) and all the cameras in the same horizontal as far as possible.

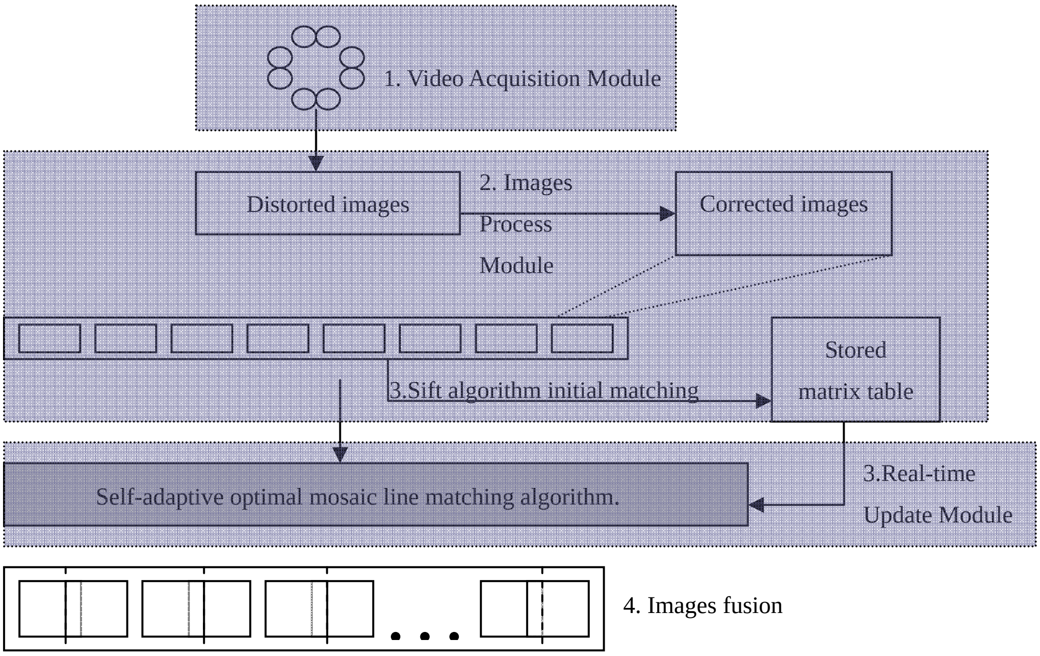

Figure 1. The Framework of Real-time panoramic video mosaicing system

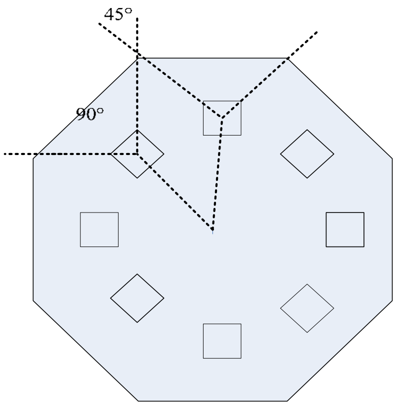

Figure 2. camera arrays

Images Correction Module is used to cylindrical transform the images captured by acquisition module; there are mainly two tasks (or two sub-modules) in this module. The first one is to correct the inconsistent amongst these images caused by some of the cameras' parameters, such as the internal image distortions caused by the oversize view angle of our pinhole cameras.the unprocessed and corrected images are shown as Fig.3 and Fig.4 separately.

This problem must be solved before mosaicing process. Our system adopted the camera calibration deformation correction method mentioned in [13] by Liansheng Sui, Haitao Wang and Jiulong Zhang,etal. The second one is to achieve image pre-matching by SIFT (Scale Invariant Feature Transform) algorithm [14]. In our system, this task is used as initialization stage to process our images. For SIFT algorithm is a mature method, the details of it do not have to be further mentioned in our paper.

The last module is Real-time update module, it is used as real-time image mosaicing stage compared with the SIFT process sub-module. It is designed to improve the defects of unchanged mosaicing line, by the instruction of real-time updating of the mosaicing line, it can resolve the mosaic ghost generated by the inconsistent viewpoint of camera arrays totally. As it is the most important module in our system, we will have a detailed discussion about this module in the next section.

Finally, to make the mosaic area smooth and to enhance image quality, we used a linear weighted fusing method to avoid the intensity disparity and color disparity on the mosaicing line. By adding the image pixel values of the areas' points with a certain weight values, it generates a new image on the overlapping area.

Figure 3. uncorrected image

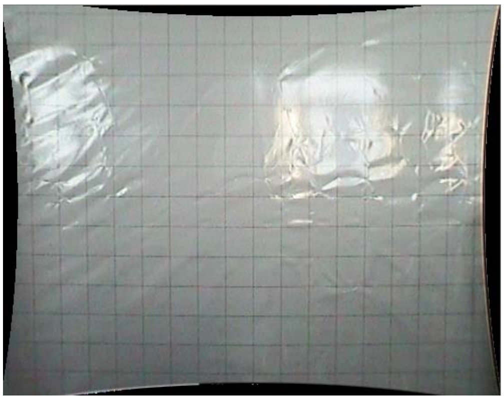

Figure 4. corrected image

IV. SELF-ADAPTIVE OPTIMAL MOSAICING ALGORITHM

A. Significance and Procedures

Theoretically, if all cameras of a video collection system can overlap in a single point of view, the panoramic images mosaicing is just needed in the initial process, i.e., using video collection system to collect the first frame image. Once the geometry parameters amongst the images collected by each camera is computed, and if it is in conformity with the parameters computed in the initial process, the subsequent part can take some mosaics transformation directly.

But there are lots of problems in application, take FlyCam system [4] for an example, for the parameters of the image mosaicing is computed only one time, it can realize real-time images processing speed. But at the same, it will lead to very serious ghost [4] phenomenon. Because of the volume of the camera itself, and for the keep changing distance among cameras and the scenes or objects it takes, it will make the images' geometry parameters constantly change finally. With this in mind, it is necessary to adopt a self-adaptive real-time adjusting algorithm in the process of subsequent video frame mosaicing, which has to consider the mosaic precision and real-time capability at the same time.

After considering various image matching algorithm, we advances a new type of self-adaptive optimal mosaicing algorithm. As mentioned in the section 3, there are two phases on image matching process, the first one is initial matching phase using SIFT algorithm, the second one is real-time image mosaicing stage using self-adaptive optimal mosaicing algorithm, the latter algorithm belongs to one of template matching algorithms .so we can give consideration to both the precision of SIFT algorithm and the simplicity of template matching algorithm.

There are mainly four steps in the initialization process of our system. Firstly, we cylindrical transform the images collected by video acquisition array module to solve the inconsistent visual in the process of image mosaicing. Secondly, we extract the images' SIFT feature points and match them by RANSAC algorithm. Then, we mathematical operate the matched feature points by singular value decomposition to product preliminary affine matrix (short for H matrix) of adjacent images. Finally, we refine H matrix by ML algorithm to calculate the image mosaicing line at this time. So far, the initialization process is finished.

Now the initial matched results amongst adjacent images already are for sure. For image acquisition system with fixed camera, through optical imaging principle and large number of experiments, it is shown that, there is no change on vertical offset of cylindrical image overlapping areas, which means they can be determined by the initial matched results; on the other hand, the horizontal offsets are keeping changing. Therefore, our system uses template matching algorithm, for it has the small amount of calculation, to real-time match and adjust the horizontal offset of image overlapping areas.

B．Algorithm designing

Theoretically, if the camera viewpoint is consistent, the overlap area between adjacent cameras is shown as Fig.5. In this circumstance, long shot or close shot, the overlapping areas have the same proportion of the two adjacent images. It only takes one time to pre-match the two images to make sure the overlapping area between them. But, for there are multiple cameras in our Video Acquisition Module , the problem of inconsistent viewpoint is unavoidable ,shown as Fig.6.Right now, the overlap range is decided the shot are long or close shot, close shot with a narrower overlapping area, long shot with a wider overlapping area, vice versa. There is blind spots existing if the camera is little too close. In the real-time process, for the kept changing overlapping areas, it is necessary to use the self-adaptive mosaicing method to get the new mosaicing area. In this section, we will discuss the designing of our algorithm to real-time self-adaptive optimal mosaicing video stream.

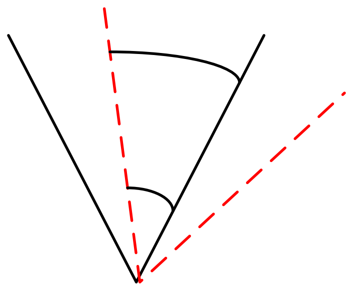

Figure 5. overlap area of consistent viewpoint

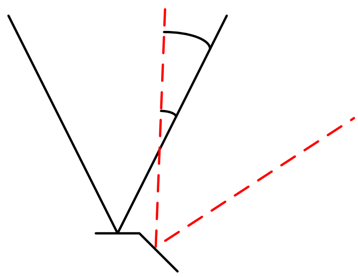

Figure 6. overlap area of inconsistent viewpoint

Algorithm: Self-adaptive optimal mosaicing Algorithm

Input: video streams
Output: the optimal panoramic mosaicing video
1: Correcting images collected by camera arrays
2: Initial image matching stage
  2.1 feature values of the images=SIFT(images)
  2.2 H matrix=RANSAC(feature values of the images)

$$H = \begin{Bmatrix} m_0 & m_1 & m_2 \\ m_3 & m_4 & m_5 \\ m_6 & m_7 & m_8 \end{Bmatrix}$$

  2.3 IML (Initial Mosaicing Line)= Perspective Transformation (H)

$$\begin{cases} x' = \dfrac{m_0 x + m_1 y + m_2}{m_6 x + m_7 y + m_8} \\ y' = \dfrac{m_3 x + m_4 y + m_5}{m_6 x + m_7 y + m_8} \end{cases} \left| \begin{array}{l} x, y: \textit{pixel values of Point}_{(x,y)} \textit{on the first images} \\ x', y': \textit{pixel values of Point}_{(x,y)} \textit{ mapped on the second images} \end{array} \right.$$

  2.4 Serializing the table of IML: <L_1,…L_7> to the disk
3: Inputting two images
4:Self-adaptive image matching stage
  4.1 taking one line of IML L_1 as the template baseline
    (L_1 in the left images of the two adjacent ones)
  4.2 setting the (IMT)Initial Matching Template based on L_1
  4.3 taking the line of IML L_2 as the matching area baseline
    (L_2 in the right images nearest to L_1')
  4.4 setting the TMA (template matching area)based on L_2
    TMA =(L_2-△x, L_2+△x);
  4.5 for(int i=0;i++;i<10)
  4.6   Similarity (x_i)=Similarity(IMT, TMA) ;

$$similarity(IMT, TMA) = \frac{\sum_x \sum_y [f(x,y) - \overline{f}][w(x,y) - \overline{w}]}{\{\sum_x \sum_y [f(x,y) - \overline{f}]^2 \sum_x \sum_y [w(x,y) - \overline{w}]^2\}^{1/2}}$$

$$f(x,y): \textit{ pixel values of point}_{(x,y)} \textit{ on IMT } \overline{f} = Avg(\sum_{(xi,yi)\in IMT} f(x_i, y_i))$$

$$w(x,y): \textit{ pixel values of point}_{(x,y)} \textit{ on TMA } \overline{w} = Avg(\sum_{(xi,yi)\in TMA} w(x_i, y_i))$$

  4.7   argMax (△x_i)=Max(Similarity),
  4.8   Return △x_i
  4.9 L_2= L_2+△x_i
  4.10Return L2
5: Return to the step 3 to take the next two images.
6: Getting the optimal mosaicing line of the adjacent images as IML<L1',…L7' >
7: Setting the OMA (optimal matching area) based on the optimal IML
8: Fusing Image:

$$\begin{bmatrix} r_{(x'',y'')} \\ g_{(x'',y'')} \\ b_{(x'',y'')} \end{bmatrix} = d \begin{bmatrix} r_{(x',y')} \\ g_{(x',y')} \\ b_{(x',y')} \end{bmatrix} + (1-d) \begin{bmatrix} r_{(x,y)} \\ g_{(x,y)} \\ b_{(x,y)} \end{bmatrix} \textit{ where } d \in (0,1) \textit{ and } \left| \begin{array}{l} (r_{(x,y)}, g_{(x,y)}, b_{(x,y)}): \textit{RGB of Point}_{(x,y)} \textit{on IMT}, \\ (r_{(x',y')}, g_{(x',y')}, b_{(x',y')}): \textit{RGB of Point}_{(x',y')} \textit{ on TMA}, \\ (r_{(x'',y'')}, g_{(x'',y'')}, b_{(x'',y'')}): \textit{RGB of Point}_{(x'',y'')} \textit{ on OMA}, \end{array} \right.$$

9: Return optimal mosaicing images
10: Taking the next frame of the input video streams
11: Iterating the step3 to step 9 to the last frame of the video streams

There is another problem about our proposed algorithm. At line 4.5 of the algorithm description, we actually search along the horizontal direction(that is x-direction). However, the most generic case is to search along the line L2, which is defined by perspective transformation (its formula is at line 2.3). In other words, in most general case, the line L2 is not necessary horizontal, so only searching along horizontal direction will sometimes fail to find correspondence. In a sum, my algorithm is only suitable for the specific case that only translation exists between adjacent images and rotation between them is not allowed.

However, there is no scaling and rotation relationship amongst output images of our cameras cluster in our system, it is suitable for the plan of engineering design, although not comprehensive enough in terms of theory

V. RESULTS

Experiments are conducted on a computer with Pentium 4, 2.4GHz CPU, 1GB RAM based on VC 6.0 program, and eight pinhole cameras cluster. By taking eight primary images with the resolution of 480*260, we can get the panoramic mosaicing image with the resolution of 3580*480 at the mosaicing speed of 25fps.

By the SIFT algorithm, we can get the geometric relationship between the adjacent cameras, which is shown as Tab.1. <m0,…, m8> are the parameters of the H matrix. The content under ‘The i-th camera’ means the values of number i camera in our panoramic camera cluster, the range of i is from 1 to 7, for the values of 8-th camera can be determined by the former seven cameras. The x-offset is horizontal offset between the adjacent images. The Y-offset is vertical offset between the adjacent images.Fig.7 is the picture of our panoramic camera cluster. The panoramic mosaicing images are shown as Fig.8, Fig.8 and Fig.10; they are the 20-th, 150-th and 320-th frame of the panoramic mosaicing video streams separately.

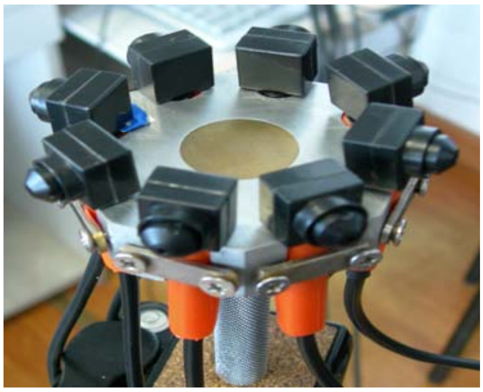

Figure 7. Panoramic camera cluster

Table.I Geometric relationship between the adjacent cameras

H	The i-th camera						
matrix	1	2	3	4	5	6	7
m0	0.988	0.978	0.953	0.8960	0.931	0.971	0.8356
m1	-0.026	0.071	-0.031	-0.018	-0.021	-0.018	-0.0328
m2	-244.033	-318.886	-336.569	-308.124	-342。178	-331.481	-271.874
m3	-0.023	-0.004	-0.059	-0，031	-0.045	-0.061	-0.046
m4	0，987	0.796	0.930	0.951	0.871	0.894	0.9713
m5	-10.749	1.966	-25.312	-23.418	-21.596	1.851	-15.6478
m6	0	-0.000	0	-0.0001	0	-0.0001	0
m7	0	0	0	0	0	0	0
m8	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
X-offset	239	150	127	122	104	134	129
Y-offset	1	1	-2	0	-1	0	1

Figure 8. The 20-th frame of the panoramic mosaicing video streams

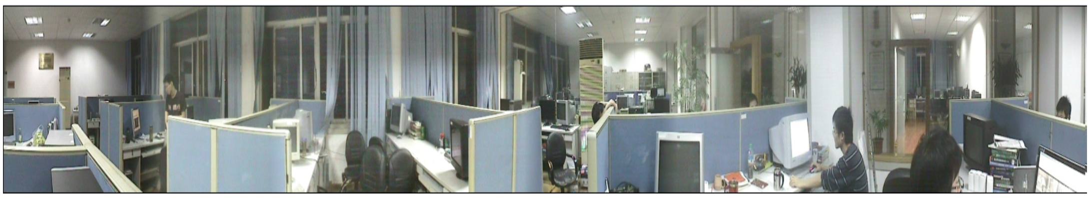

Figure 9. The 150-th frame of the panoramic mosaicing video streams

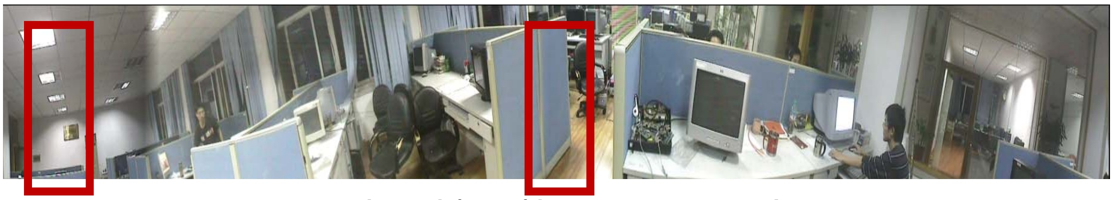

Figure 10. The 320-th frame of the panoramic mosaicing video streams

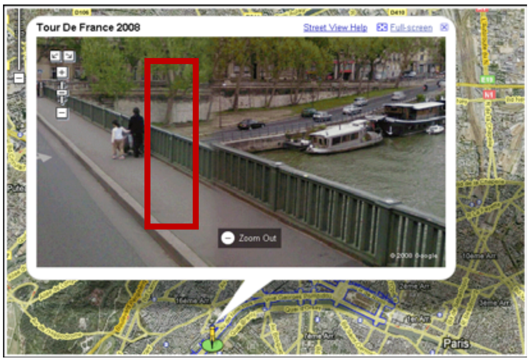

Figure 11. The Point Grey's LadyBug2

The Fig.11 is an image outputted form designed method by Point Grey's LadyBug2 Cop., the technology of which is used by GoogleMap panoramic image mosacing. By the comparison of blurring upon zooming into the red boxes in Fig.11 and Fig.10, ghost in the former one and nonexistent in the other one, we can draw a conclusion that our method has better performance in panoramic image mosacing.

VI. Conclusion

To solve the problems in the real-time monitoring systems, such as the field vision is too small to capture, etal. We designed this real-time panoramic monitoring system, which can output the panoramic video signals in a range of 360 degree. Firstly, we use the improved SIFT algorithm to compute the geometric relationship between the adjacent cameras for pre-matching. Facing the problem of inconsistent viewpoint, we take the self-adaptive template matching method to adjust the images matching at every stage or moment, which make our system very suitable for the application which requests high real-time performance.

Our algorithm can settle the ghost phenomenon caused by the constantly changing depth of a field, and with the help of linear weighted fusing method, we can eliminate the intensity disparity resulted from the different cameras. The entire above-mentioned designing make our system has the characteristics of good real-time, high resolution and ideal effect of video mosaicing.

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