REAL TIME MONITORING OF CULTURAL HERITAGE THROUGH CAMERA PHONE DIGITAL IMAGES

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ABSTRACT:

The paper describes the development of a low-cost and rapid technique, for documentation and monitoring of the cultural heritage, with particular regard to emergency management, anomaly detection and early warning. The technique uses images captured and sent by camera phones. An archive, with several images of selected monuments has been set up. For monitoring purposes, or in case of damages, a not specialized photographer should connect to the dedicated website; the image of the selected monument is shown on the display of his camera phone; he is then requested to take a picture with the (almost) same line of sight, and to upload it. The image processing allows to detect the changes and to activate an early warning procedure. The system, the image processing and the results of a test are described.

1. INTRODUCTION

Since June 11th 1997, when Philippe Kahn made the first public demonstration of a complete seamless cellular phone and camera solution that he had personally built, instantly sharing pictures taken in real time with over 2000 people around the world, the camera phone market has had an impressive growing, and it is foreseen that over 1 billion camera phones will be shipped in 2008.

This device allows to instantly share pictures, but pictures can also be sent to other phones, e-mail recipients and web-shared: for this reason camera phones have had a broad social impact over the past decade. They can also play a significant role in several fields, e.g. journalism and crime prevention: on January 2007, New York City Mayor announced a plan to encourage people to use their camera-phones to capture crimes happening in progress or dangerous situations and send them to emergency responders.

Because they can be used to send and receive images almost in real time, camera-phone can be very useful in case of emergency, and for monitoring and early warning regarding cultural heritage.

At the University of Calabria, Italy, a system has been designed and is being completed, for monitoring the cultural heritage of the region, and for contributing to the civil defense in case of earthquakes, floods or vandalism actions. The system components are an archive of images of several buildings, monuments and works of art, a web site and the software for image processing and change detection. The proposed technique should have further developments for the following reasons:

- the increasing diffusion of the camera phone, will allow the presence of potential *photographers* almost everywhere and in every moment;
- the images can be shared in real time;
- no specialized operators are requested.

In the following, the archive, the web site and the techniques used for image processing and change detection will be described.

2. THE ARCHIVE

For every monument, building or work of art, some images has been acquired, from different points of view, in order to have a complete description.

For every image, several filters have been applied, in order to obtain data useful for future registration of other images, and to allow change detection; in particular:

- Canny filter has been applied, for edge extraction (Canny, J., 1986);
- Harris, Moravec and Forstner operators have been used to obtain corners and interest points, (Harris, C.G., Stephens, M.,1988; Moravec, H.P., 1979; Forstner, W. and Gulch, E., 1987); the used parameters have been recorded;
- Straight lines have been selected;
- Rectifying has been performed, for the almost plane facades;
- The image is partitioned in regions, having homogeneous geometric characteristics (e.g. belonging to the same plane), bounded by linear features previously detected;
- The roughly approximate azimuth of the camera line of sight has been recorded;

After image processing, some straight lines and some interest points are saved. The lines will be useful for camera calibration, while the interest points will be used for performing the registration.

For some monuments, other information are recorded, like the coordinates of the camera and the coordinates of several selected points.

3. THE WEBSITE: HOW THE SYSTEM WORKS

All information regarding the involved cultural heritage (name, city, coordinates, etc..), along with images and data obtained by image processing, have been used to set up a website. An archive with the approximate interior orientation parameters of several diffused camera phone has been set up.

In case of emergency, or for monitoring activities, a person who is close to a monument, can access the website via the cell phone. This person (we call him photographer) need not be a specialized operator; he should know the names of the city and monument; alternatively, he can select among the archived monuments of the city. It is also possible to send the coordinates, if the photographer has a GPS receiver.

The photographer can watch to the display the image of the selected monument; he is then requested to take a picture with the (almost) same line of sight, and to upload it. The procedure should be repeated, if more than one image are archived and the photographer can reach the relevant viewing positions.

Once downloaded, the images are processed and compared with the archived ones. If changes are detected, an alert procedure is activated.

4. THE IMAGE PROCESSING

For the image processing, a computer code has been realized. The main goal is the registration of the new images with the archived ones, and the change detection. For this aim, one has to deal with several issues: camera calibration, registration, change detection.

Camera calibration can be previously performed, if several points of the selected monument are known; otherwise, distorted images have to be registered. Another problem is due to the presence of regions visible in the reference image, and hidden in the new one, or vice versa. For this reasons, the following strategy has been chosen:

- on the new image, edges, corners and interest points are extracted;
- the image is partitioned in regions, corresponding to the sub-images in which the reference image has been partitioned; for this aim, the corners of the contour are matched by means of a cross correlation (the procedure is possible if the lines of sight of the images are close);
- a locally affine (piecewise) registration is performed for every sub-image; to improve the results of this operation, internal interest points are used and the straightness constraint is imposed to the lines of the new image, which are conjugate with the straight lines of the input image;
- after the registration, a change detection procedure is performed.

In case of routine monitoring activities, the new images, and the results of the image processing, are archived. In case of emergency, all data are send to experts (structural engineers, art historians) which collaborate with the civil defence. Experts can be connected with the web server and with the photographer; they can request further images (e.g. close-up) and/or image processing.

4.1 Calibration

Several algorithms have been proposed for automatic camera calibration. Cronk et al. (Cronk, S., 2006) proposed an effective method when a multi-image, convergent camera station geometry is available. In our case, both the interior and exterior orientation parameters are unknown, and we have only one image. Another possibility is to consider non rigid geometrical deformations due to the uncorrected lens distortion; for such a case, Arsigny et al. proposed a general framework to parameterize deformations with a finite number of rigid or affine components, while guaranteeing the reversibility of global deformations (Arsigny, V., 2006). Taking into account the presence of plane surfaces and straight lines, different strategies can be followed. Habib et al. proposed a method for calibration and registration, based on the use of straight lines (Habib, A.S., 2002; Habib, A.S., 2004; Habib, A.S., 2005). We used straight lines just for eliminating the distortion of the lenses.

4.2 Cross correlation

For the identification of the points of the new image, corresponding to the interest points of the archived image, the matching techniques can be used; among these techniques, cross-correlation is simple and effective (Jaehne, B., 1989). Cross-correlation allows getting the correspondence between two digital images, and is based on two assumptions: the images geometrically differ only due to translation and radiometrically differ only due to brightness and contrast.

The precision of cross-correlation decreases rapidly when geometric model is violated, i.e. rotations greater than 20° and/or scale differences greater than 30% are present (Forstner, W., 1984).

In our case we can suppose a rotation of the new image of about 10°. For a such angle, the cross-correlation allows to detect the interest points, but the precision decrement is not negligible. By using the line connecting two interest points, it is possible to obtain the rotation of the portion of image surrounding the same points (targets) respect to the archived ones.

If we use four points, it is possible to perform, with good approximation, the transform of the quadrilateral obtained by connecting them. Two vanishing points can be located and it is possible to build up the projective transformation of the targets images, thus obtaining the view of the targets with the same perspective of the archived image (Artese, G., 2008). In this way, a fine cross-correlation can be performed.

4.3 Registration and change detection

The registration is obtained by spatial transformation from control point pairs. In our case a piecewise registration (locally affine) has been performed. In order to extract the changes, the difference of images is performed. The small differences, due to slightly different radiometric characteristics and subpixel errors of the registration, are removed by applying a threshold.

5. THE TEST

A test has been performed at the University of Calabria. In a first case, a flat facade has been used (Figure 1) and some interest points have been extracted (Figure 2). A crack has been drawn on the image taken from a slightly different line of sight (Figure 3). The radial distortion has been removed by using the straight lines. The cross correlation has been used to find the interest points. It is possible to observe that the results of the correlation are not very accurate, due to a rotation between the images (Figure 4). The image difference shows many regions (Figure 5), and it is not possible to isolate the crack from the other regions.

By using the transformation described above, a precise correlation has been performed, and the difference of the images clearly shows the crack (Figure 6).

In the second case, the image of a building has been archived, with different plane surfaces (Figure 7). The archived image has been partitioned in some flat zones, delimited by known interest points. On the image taken from a different line of sight (Figure 8), it is possible to observe the delimitation of two flat zones. The above described procedure has been repeated, and the image difference has been performed for every flat zone. In this way, a piecewise registration is performed, and the zones which are not present in both sent and archived images are not compared.

Figure 1. The Land Planning Dept. facade

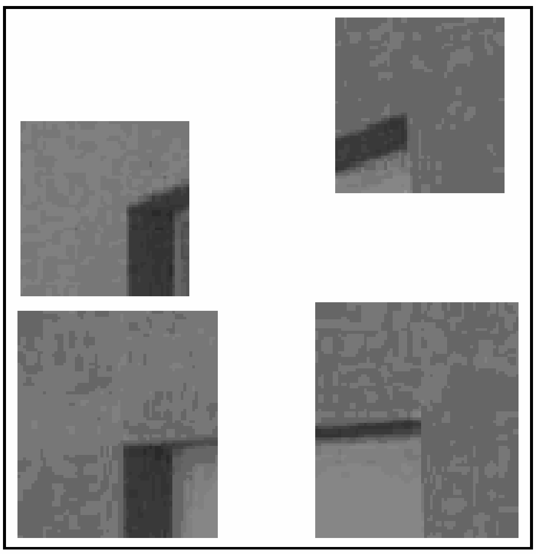

Figure 2. Interest points

Figure 3. A different view of the Land Planning Dept. facade

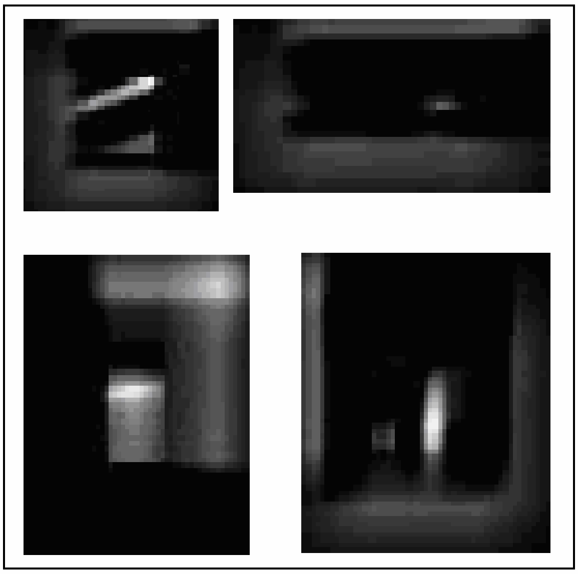

Figure 4. Cross correlation results for the interest points

Figure 5. Images difference: the crack is not isolated

Figure 6. Images difference after precise cross-correlation: the crack is isolated

Figure 7. Building with different plane surfaces

Figure 8. A different view of the building of figure 7

Figure 9. Transformation of figure 8 for the first zone

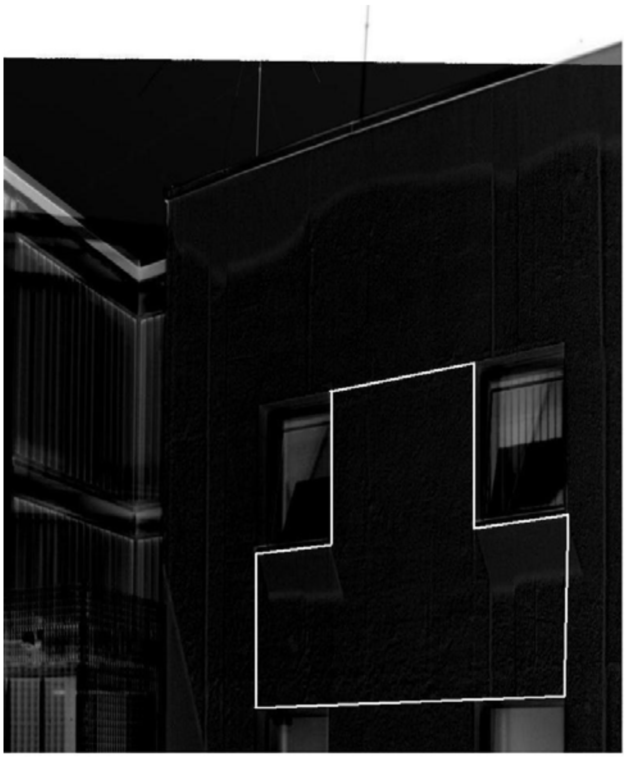

Figure 10. Images difference for the first zone

Figure 11. Transformation of figure 8 for the second zone

Figure 9 shows the transformation of figure 8 for the first zone, and the results of the comparison is shown in figure 10. It is possible to observe that in correspondence of the windows, the differences are noticeable; same consideration can be done for the surfaces with different orientation. Figure 11 shows the transformation of figure 8 for the second zone, with the crack; while the results of the comparison is shown in figure 12. It is possible to observe the crack, along with other differences; by applying a threshold, the crack can be easily isolated, as shown in Figure 13.

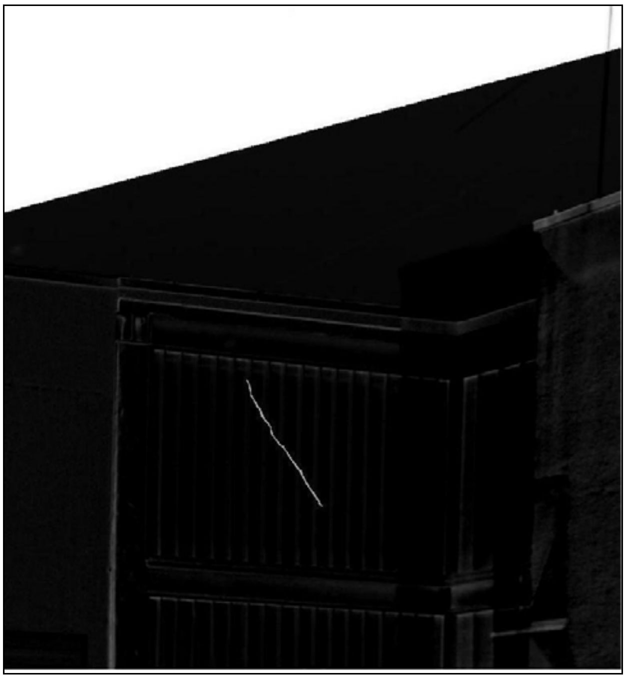

Figure 12. Images difference for the second zone

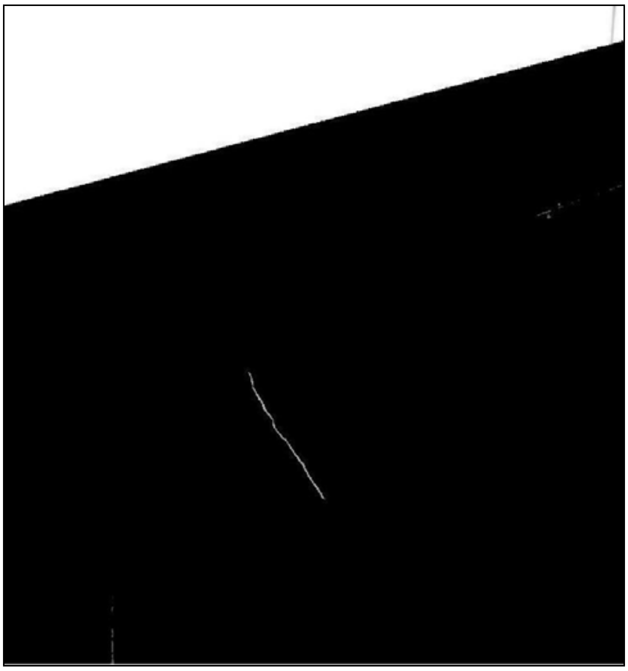

Figure 13. Images difference for the second zone after threshold application

6. CONCLUSIONS

The development of a low-cost and rapid technique, for documentation and monitoring of the cultural heritage, with particular regard to emergency management, anomaly detection and early warning has been described. The technique uses images captured and sent by camera phones. After calibration, the cross correlation has been used for the registration of camera phone images with the archived ones. The results of a test show are promising and demonstrate good performances

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