GENERATING ROAD SURFACE ORTHOPHOTO FROM IMAGES OF MOBILE MAPPING VEHICLES

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ABSTRACT: Orthophoto of road surface is a valuable data source for extracting road features and 3D road modeling. Road surface orthophoto were traditionally generated using aerial photographs or satellite imagery. However, road surface maybe obscured or sheltered by vegetation or manmade structures from aerial perspective. Images acquired from perspective of a ground vehicle would provide a higher resolution and free of obscuration photograph, and higher data update rate. For maintaining the flexibility of using consumer cameras or camcorders as image acquisition sensors, the interior and exterior orientation parameters are assumed unknown, only rough GPS coordinates are used in this proposed procedure. The lower half of the image within a front facing camera mounted on a vehicle is the area where road surface is present, these areas are use to perform this procedure. The transformation between two images of a flat surface in the object space can be represented by homography matrices. By utilizing this property, two consecutive image of a set of image sequence can stitch their road surface together using the homography matrix between the two images. All images along the same road segment can be stitched and forming a trapezoid shaped image. Pavement markings such as dashed lines and pedestrian crossing can be used to detect the two set of perpendicular vanishing lines, and these two vanishing points correspond to the vanishing lines can be used to rectify the stitched road surface image. After rectification, this road surface image is without the correct scale. The scale can be estimated using the actual dimensions of the pavement markings since the dimensions are fixed with regulations. Based on our preliminary results, the generated road surface orthophoto is useful for presentation purpose after removing the discolorations caused by stitching multiple images.

1. INTRODUCTION

Road is one of the major component in 3D city model. Most of the 3D city models focused their effort on the buildings, left the road surface areas with the untreated satellite imagery or aerial orthophoto. Road surface issue is one of the reasons that a 3D city model seemed unrealistic. In rural areas, accurately registered satellite imagery or aerial orthophoto may be visually sound for road surface texture, however in urban areas, due to the existence of high-rise buildings, relief displacement of satellite imagery and lack of true-ortho of the aerial orthophoto may result in problematic road surface textures. High-rise buildings and trees on the sidewalk may easily obstruct the view of road surface from the angle of satellite/aerial imagery. In this research, we propose a procedure to generate road surface orthophoto from images acquired by mobile mapping systems (MMS). Since the vehicle based MMS acquired the images while driving on the road, the obstruction issue should be at the minimum and the image resolution of road surface would be better than satellite and aerial images.

There are two types of image acquisition platform that we have examine during the development. First is the stereo camera setup, the other is the single camera/camcorder setup. All of the cameras are facing forward, and the stereo cameras are capable of acquiring images simultaneously. In this research, we focus on the single camera scenario for the possible use on any dashboard camera/event data recorder for road surface orthophoto generation.

The rectification algorithm is the key process for the proposed procedure. The rectification procedure is based on the dual conic theory described in Hartley and Zisserman (2004), and can be divided in to two phases, affine rectification and ortho (metric) rectification. In order to perform affine rectification, two vanishing points is needed to be derived. While performing ortho rectification, two sets of orthogonal line pairs are needed (Hartley and Zisserman, 2004). It is difficult to find two sets of orthogonal line pairs on the road surface within one image, hence, it is not possible to generating an orthophoto for each of the MMS image. The solution we proposed is stitch the road surface image for several consecutive MMS images, and then use the pavement markings to find the vanishing points and orthogonal line pairs.

2. METHODOLOGY

The data source used in this research is an images sequence acquired while the vehicle is moving forward. Figure 1 shows and example of the image use by this research. The procedure for the road surface orthophoto generation from MMS images consists of six steps. First, feature point extraction and matching. Next, homography calculation between image pairs of consecutive image sequences. Then, image stitching of the road surface. Forth, road markings extraction. Fifth, ortho rectification of the stitched road surface image. Lastly, scale determination and image resampling. The detailed description is been discussed in the latter sections.

2.1 Feature Point Extraction and Matching

Corresponding points of the consecutive images within the image sequence are needed to be estimated. In this research, Scale-invariant feature transform (SIFT) algorithm (Lowe, 1999) is used to extract and establish corresponding point pairs. Since the percentage of the corresponding point pairs matched correctly is pretty low using SIFT, around 30% in our current experiments, robust estimation procedure is needed to remove the blunders (Brown and Lowe, 2003). Next step will be handling the robust estimation and calculate the homography matrix.

2.2 Homography Calculations between Image Pairs of Consecutive Image Sequence

The principle of robust estimation for point pair correspondence is by fitting a transformation function. The transformation between two consecutive images of an image sequence acquired by a front facing camera is usually a relative orientation / essential matrix transformation (Mikhail, 2001). The transformation of a surface between an image pair is a homography transformation. Since road surface area is our only concern in this research, putative corresponding point within the lower half of the image (where the road surface are present) is used to estimate a homography matrix using RANdom SAmple Consensus (RANSAC) algorithm (Fischler and Bolles, 1981). After RANSAC process, putative corresponding points that do not satisfy the estimated homography matrix are removed from the corresponding point list. The estimated homography matrix is the transformation function of road surface area between the images.

2.3 Image Stitching of the Road Surface Area

In the scenario of images acquired by a single forward facing camera while the vehicle moving forward, the images acquired earlier can be stitched to the next consecutive image within the road surface area. In a consecutive image pair, the homography matrix is used to transform the first image into the perspective of the second image, and the second image is then paste onto the transformed image.

2.4 Pavement Marking Detection

The information within the pavement markings is used to evaluate vanishing points and two orthogonal line pairs. The marking of pedestrian crossing is ideal to evaluate two vanishing points and one orthogonal line pair, furthermore, it can be easily found at road intersection. The second set of orthogonal line pair is truly the issue that bothers us. The second pair of orthogonal line cannot be perpendicular to the first set, which will result in a degenerated condition while solving the dual conic function. It is difficult to find the second pair of orthogonal line using pedestrian crossing, hence, the lane markings, turn lane arrows and painted characters are used to provide the second constraint. Since these pavement markings are having dimension regulations, these known dimensions can be used to find the orthogonal line pair or length ratios providing the constraint to resolve the dual conic.

This research is currently still in the development stage, the auto detection of pavement markings have not been implemented yet. The corner points of pavement marking is been manually identified and measured.

2.5 Ortho-rectification of the Stitched Road Surface Image

In this research, the first vanishing point is estimated using the rectangles of the pedestrian crossing. The longer side of the rectangle point to one vanishing point, and the shorter side point to the other vanishing point. The vanishing point can be estimated by intersecting two perpendicular lines, then the line at infinity can be calculated by connecting these two vanishing points.

The second step is providing the orthogonal line pairs. The rectangles of the pedestrian crossing can provide one set of orthogonal line pair. Another orthogonal line pair from other sources is needed. In this research, we provide two type of pavement markings that can be used for the second orthogonal line pair. First type is the Chinese characters for lane indication. Second type is finding a square within the pedestrian crossing by knowing the dimension of the markings. The latter solution is used in our experiment.

2.6 Scale Determination

The last step of the procedure is to determine the scale for all image patches in order to generate an image with uniform resolution. For example, if we define the spatial resolution of the finished orthophoto to be 1 cm, each of the image patch need to calculate the exact scale and resample the image. The scale can be estimated using the pavement marking dimensions described in the regulation by department of transportation and compare against the pixel distance measured from the image. This scale factor is used to resample these image patches for latter image mosaicking if necessary.

3. EXPERIMENT

The data sources used in this experiment is acquired by Sunrise geomatics MMS. This vehicle equipped with 8 cameras, however, only the forward facing camera mounted on the left side of the vehicle is used. This data set is acquired at Zhongxiao East Road, Taipei City, Taiwan. Four consecutive images from a set of image sequence are used. Figure 1 depicts three of the four images. Figure 2 shows the result of the stitched image from the four images. Figure 3 shows the ortho-rectified road surface image.

Figure 1. Three consecutive images used in this experiment from a set of image sequence.

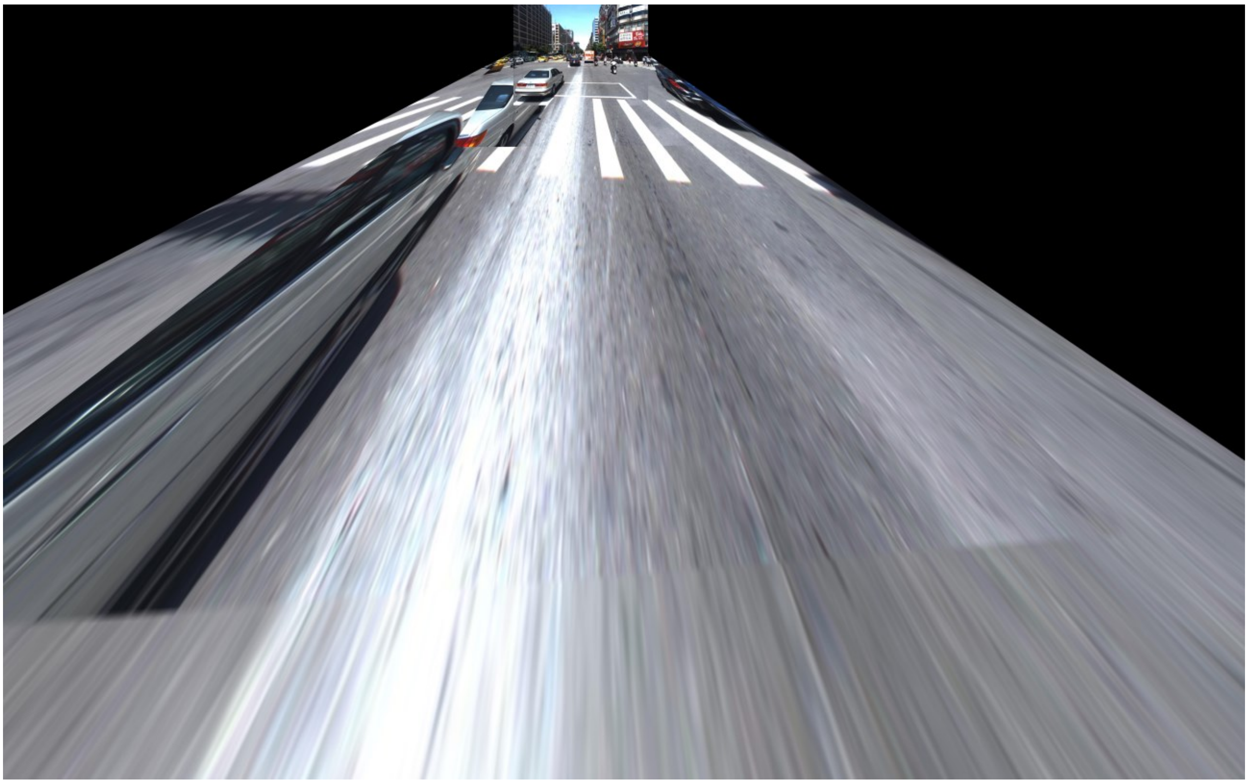

Figure 2. Three consecutive images stitched to the fourth image.

Figure 3. Ortho-rectified road surface image

4. CONCLUSIONS

The experiment shows the preliminary result of the proposed procedure, it can only handles a very small section of the road surface. Form this experiment we have identify the potential of this procedure and also the issues needed to be resolved before the procedure can be applied to practical use. This research proposed a procedure to generate road surface orthophoto, can be used as textures of 3D city model. However, the completeness of this procedure is still in a very rough shape, efforts is needed to be put into solving the issues. These issues are: 1. the autonomous pavement markings detection algorithm. 2. In figure 3, there are deformed vehicles on the ortho-rectified image. Algorithm for removing objects which is not on the road surface is needed. 3. The ability for stitching the entire image sequence is needed. At present, only 3 to 5 consecutive images can be stitched together and generate the orthophoto. The reasonable number for handling the consecutive images is around 20-100 images, in order to cover the entire block of road pavement.

References:

Brown, M., & Lowe, D. G., 2003. Recognising panoramas. In: International Conference on Computer Vision, Vol. 3, p. 1218.

Fischler, M. A., & Bolles, R. C., 1981. Random sample consensus: a paradigm for model fitting with applications to image analysis and automated cartography. Communications of the ACM 24(6), pp. 381-395.

Hartley, R., & Zisserman, A., 2004. Multiple view geometry in computer vision. Cambridge university press.

Lowe, D. G., 1999. Object recognition from local scale-invariant features. In: Computer vision, 1999. The proceedings of the seventh IEEE international conference on, Vol. 2, pp. 1150-1157.

Mikhail, E. M., Bethel, J. S., & McGlone, J. C., 2001. Introduction to modern photogrammetry (Vol. 1). John Wiley & Sons, New York.