# SEMI-AUTOMATIC REGISTRATION BETWEEN VEHICLE-BASED IMAGE SEQUENCE AND 2D VECTOR MAP

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### Abstract

Since the street is a primary component of city, it is very significant for 3D city modeling (3DCM) that how to rapidly realize the 3D visualization of street sight. The acquisition of vehicle-based image sequence for buildings has the characteristics of convenience and rapidness. Moreover, the resolution of textures obtained from vehicle-based sequence is very high. Therefore, it will be aided greatly by the automatic processing of textures from vehicle-based image sequence that the 3D visualization of street sight in 3DCM. To reconstruct 3D texture model from images, the mapping from image space to object space should be acquired. Therefore, in this paper, image sequence and 2D vector map are registered for reconstruction of 3D texture model for urban street.

Firstly, the image sequence is subsected automatically by the histogram of projective difference of corresponding points. Rectification and mosaic process are implemented to generate facade texture. After that, two corresponding point pairs between facade texture and map are selected to calculate the initial transform parameters from image coordinate system to map coordinate system. By those parameters, other corner points on the map are projected into image sequence. The positions of projected corner points, however, are only close to the exact corresponding points in raw images. Accordingly, the problem is how to extract those corresponding points. It is difficult to extract corner points directly from images because corner points may not be distinct features in close-ranged images and occlusion between objects with different range also makes the extraction easier to fail. To solve this problem, vertical lines passing corner points are automatically extracted to intersect out the exact positions of corner points in raw images. Finally, all of the corresponding point pairs acquired are used to compute the precise transform parameters between image sequence and 2D vector map.

## 1 Introduction

Since the street is a primary component of city, it is very significant for 3D city modeling (3DCM) that how to rapidly realize the 3D visualization of street sight. The acquisition of vehicle-based image sequence for buildings has the characteristics of convenience and rapidness. Moreover, the resolution of textures obtained from vehicle-based sequence is very high. Therefore, it will be aided greatly by the automatic processing of textures from vehicle-based image sequence that the 3D visualization of street sight in 3DCM. To reconstruct 3D texture model from images, the mapping from image space to object space should be acquired. However, it’s difficult to acquire with necessary accuracy and robustness only based on image information from close-ranged image sequence. Since 2D vector map is always available, it should be involved to improve the accuracy and robustness.

As we know, image-to-map registration is already wildly used for automatically absolute orientation and change detection of region. In several studies, the registration methods by corresponding the points on the images have been proposed [1, 2], however, it is difficult to detect the points automatically and to obtain stable results. Zuxun Zhang et al. [3] presented an automatic approach for the absolute orientation of aerial imagery by matching extracted road from the image against the corresponding objects of an existing vector road map or a GIS database, which is divided three phases process. In the first phase, a coarse global affine transformation between aerial image and vector road map is carried out by three coarse ground control points. Based on LSB-Snake model and pyramid image strategy, the road net was extracted automatically in the second phase. In the third phase, absolute orientation parameters were recovered by line based space resection with image road lines and their corresponding objects in vector road map. Heiner HILD et al. [4] presented a fully automatic approach for the registration of satellite imagery by matching extracted image segments against the corresponding objects of an existing a GIS data base. Since neither lines nor points allow for the determination of the complete transformation for each pair of corresponding objects, the image-to-map transformation is based on corresponding regions, which are defined by polygons. Yasuharu Yanamura et al. [5] proposed a new method of automatic detection of the damaged areas from the aerial images. The matching method is applied to the edge information of the aerial image and the digital map.

It is essential for approaches presented above that the same features are identified from the image and the reference data. However, as terrestrial close-ranged images as be concerned, the same features in the image and vector map are pretty different owing to posture of camera. As a result, those methods will not be applicable for terrestrial close-ranged images.

Therefore, in this paper, a semi-automatic image-to-map registration method is presented. Before the registration process, several processing is implemented on the raw image sequence. The image sequence is subsected automatically by the histogram of projective difference of corresponding points [6]. Rectification and mosaic process [7] are implemented to generate facade texture. After that, two corresponding point pairs between facade texture and map are selected to calculate the initial transform parameters from image coordinate system to map coordinate system. By those parameters, other corner points on the map are projected into image sequence. The positions of projected corner points, however, are only close to the exact corresponding points in raw images. Accordingly, the problem is how to extract those corresponding points. It is difficult to extract corner points directly from images because corner points may not be distinct features in close-ranged images and occlusion between objects with different range also makes the extraction easier to fail. To solve this problem, vertical lines passing corner points are automatically extracted to intersect out the exact positions of corner points in raw images. Finally, all of the corresponding point pairs acquired are used to compute the precise transform parameters between image sequence and 2D vector map.

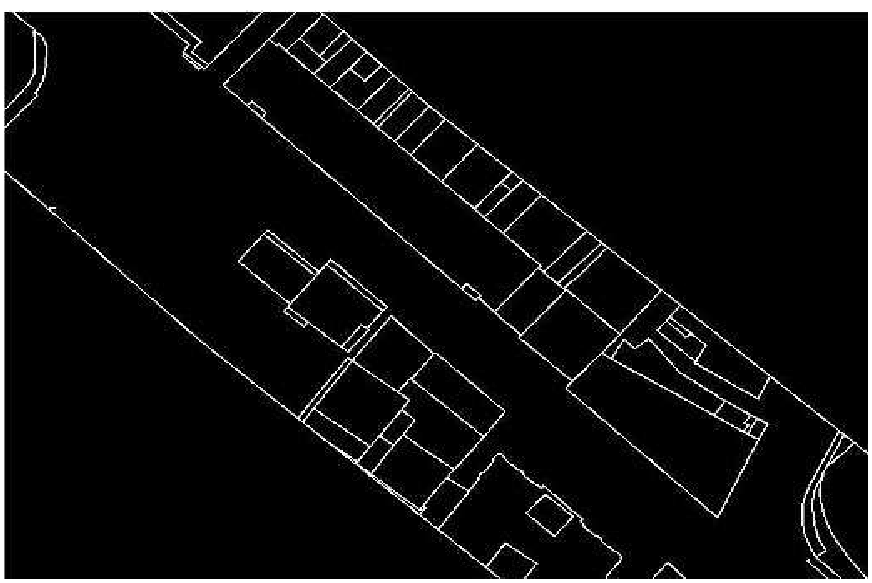


Fig.1 2D vector map

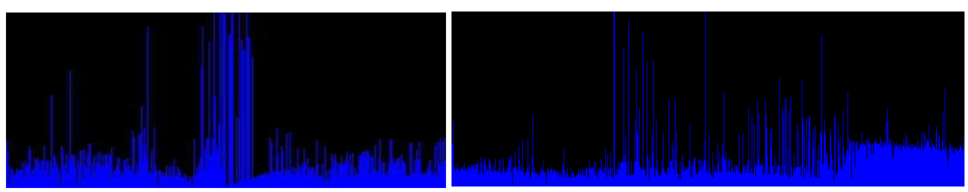
## 2 Preprocessing on raw image sequence

In this paper, registration is implemented on each building because the purpose is to reconstruct the 3D facade models of buildings. Therefore, firstly, the image sequence is subsected into segments corresponding to each building on the map illustrated in Fig.1. Range variance is automatically detected by the histogram of projective difference of corresponding points [6]. As far as corresponding points on facade be concerned, the projective difference should be very small or even ideal zero. Corresponding points in cross-road or on other facades having obviously range variance with common projective plane (Fig.2), however, have large projective difference. Accordingly 1-D histogram along *x*-axis of image coordinate system is drawn to show the distribution of projective difference (Fig.3). Cross-road and facades having large range variance are represented in the histogram by peak areas. Moreover, the 1-D locations of peak areas in the histogram are obviously corresponding to those having large range variance. By histogram of corresponding points, therefore, not only the existence of range variance is detected, but also the location of range variance in image is indicated because it is drawn following the moving direction of vehicle. According to the location indicated, images including cross-road are excluded from image sequence and subsections of image sequence are divided for facades having large variance with each other as well.

a. Cross-road

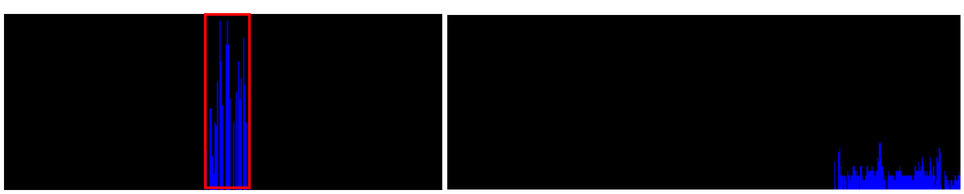
b. Connected buildings with large range variance

Fig.2 Segments with large range variance



a Original

a Original



b After filtering

(1) Cross-road

b After filtering

(2) Connected buildings with large range variance

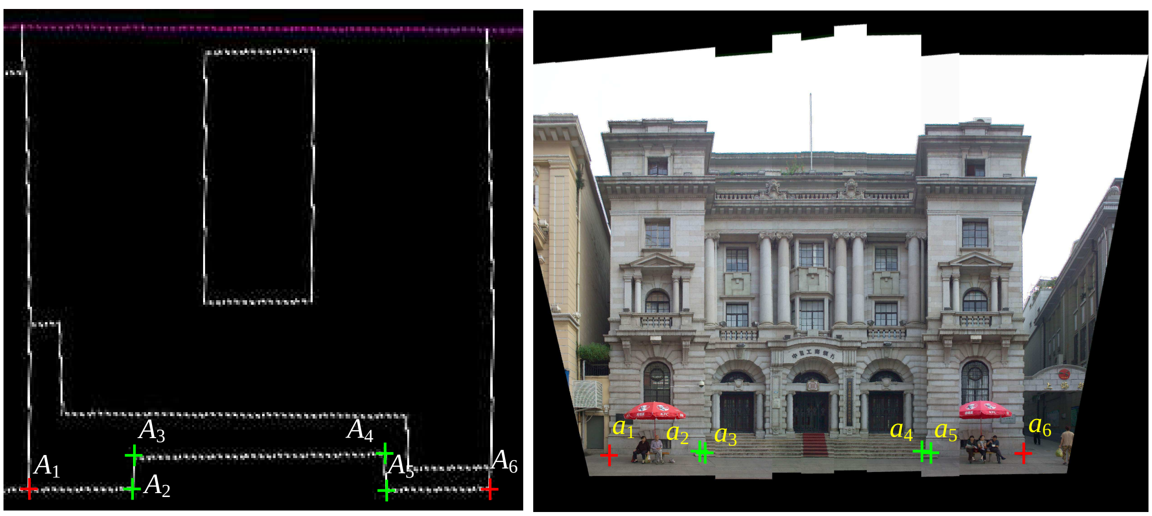
Fig.3 the histogram of projective difference of corresponding points

The raw images are rectified by the algorithm employed the constraint of straight lines bundle and the constraint of known orientation of parallel lines in object space [7] and the whole facade texture is generated for each building by strip method [7] , e.g. Fig.4 and Fig.5(b).

## 3 Image-to-map registration

As Fig.4, if the facade is planar, only two point pairs are enough to correspond facade texture to vector map. However, the facade of a single building or several connected buildings possibly consists of convex or concave parts which are visible in the vector map. As Fig.5, therefore, the corner points (Highlighted in green) on the convex and concave parts of vector map should be corresponded to facade texture except the two corner points highlighted in red.


Fig.4 Facade considered as a plane




a Vector map

b Facade texture

Fig.5 Building with convex or concave parts

### *3.1 Corner point extraction*

At first, two corresponding convex point pairs $A_1$ and $a_1$, $A_6$ and $a_6$ are selected in vector map and facade texture respectively as shown in Fig.5. The transformation parameters between texture coordinate system and ground coordinate system are computed with these two corresponding point pairs. The computation formula is as below.

$$\left.\begin{aligned} \lambda^2 &= \frac{(X_{A_2}{}^2 - X_{A_1}{}^2) + (Y_{A_2}{}^2 - Y_{A_1}{}^2)}{(x_{a_2}{}^2 - x_{a_1}{}^2) + (x_{a_2}{}^2 - y_{a_1}{}^2)} \\ \theta &= \arctan\frac{Y_{A_2} - Y_{A_1}}{X_{A_2} - X_{A_1}} \end{aligned}\right\} \tag{1}$$

Where, $\lambda$ : the scale factor;

$\theta$: the rotation angle;

($x_{a_i}$, $y_{a_i}$): the texture coordinates of corner point $a_i$, $i$ = 1,2;

($X_{A_i}$, $Y_{A_i}$): the ground coordinates of corner point $A_i$, $i$ = 1,2.

The green corner points are projected onto facade texture according to $\lambda$ and $\theta$ as point $a_i$ ($i$ = 2,…,5) in Fig.5(b). Afterwards, those points are projected onto raw image sequence. For instance, in Fig.6, projective points in raw images of point $a_5$ are around the actual corners. However, corner points may not be distinct features in close-ranged images and occlusion between objects with different range also makes the extraction easier to fail. It can be found from Fig.6 and 7 that there is always a long vertical line passing the corner of wall and the corner point of interest must lie on this vertical line. The searching for corner point is thereby limited on the vertical line. To extract the vertical line, raw images are firstly rectified onto vertical projective plane and then an image strip, which width is 60 pixels and center is the projective point, is taken out. Consequently, vertical line extraction is implemented in this image strip. As Fig.7, although there might be several vertical lines extracted, the longest line is most likely on the corner of wall. As a result, the longest line highlighted in red is picked out to search the actual corner point. As image III and IV as be concerned, the vertical lines, extracted from planes with different range, are close to each other so that only the line length is possibly not enough to determine the right line passing corner point.


Fig.6 The projective points of corner point in raw image sequence

To tackle this problem, a strategy to eliminate false accepted line is implemented based on the relative spatial relationship of image sequence. As Fig.7, vertical lines are firstly extracted from the raw image (e.g. I) in which the geometric difference between planes with variant range values is most significant since it is most likely to pick up the right vertical line from this image. In this image, the longest vertical line is selected and projected onto other adjacent images according to the relative spatial relationship of image sequence. As Fig.8, the projective line in image IV is highlighted in blue and can be used as predicted position of the right vertical line. As a result, an image strip, which width is narrowed to 40 pixels and center point is the center of projective line, is taken out for vertical line extraction. Although the predicted position is close to the actual vertical line, as Fig.7, the distance is only 6 pixels between the green line and actual red line in the while rectangle and moreover the green line is long as well. Under this circumstance, the green line is possibly to be falsely accepted. Therefore, the selected line is projected into image I. As Fig.9, the distance is still small between the right projective line from image IV (highlighted in blue) and the actual line in image I (highlighted in red). The distance, however, becomes large between the false line in green and the actual red line. Obviously, the falsely accepted line can be eliminated by this strategy.


Fig.7 Vertical lines extracted

After the extraction of vertical lines passing corner points, the line between corner points $a_1$, $a_6$ in Fig.5 is projected into raw images and the actual corner points are the intersected points between extracted vertical lines and projective line of $a_1a_6$ in corresponding raw image.

## 3.2 Iterative process

Since the scale factor $\lambda$ and rotation angle $\theta$ are computed with the two red corresponding point pairs shown in Fig.5, the farther the green points on the convex and concave parts in vector map away from the red corner points, the larger deviation is between projective and actual points in facade texture. The iterative strategy is thereupon employed to tackle this problem.

Based on the method presented above, points $a_2$, $a_5$ (Fig.5) closest to red corner points are firstly extracted from raw images and then $\lambda$ and $\theta$ are recalculated combined with extracted points and selected red color points. According to the transformation parameters recalculated, point $a_3$ and $a_4$ are extracted. This iterative process repeats till all corner points are extracted.

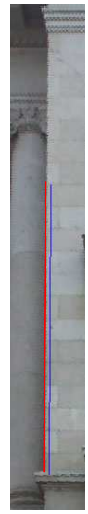


Fig.8 Line prediction

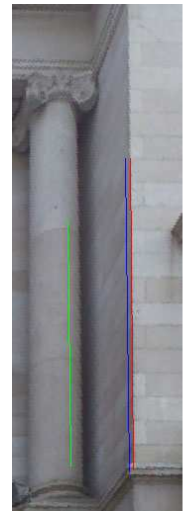
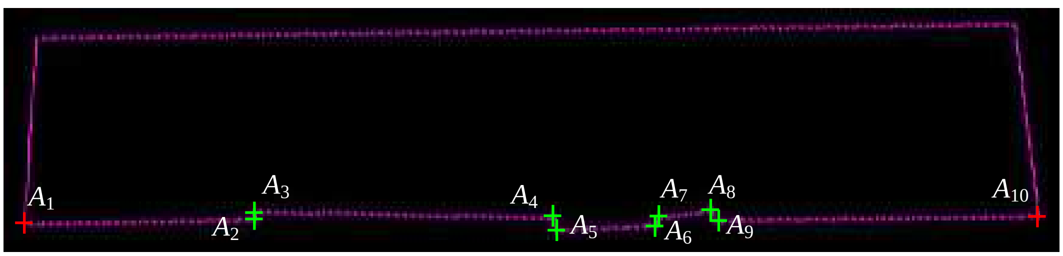
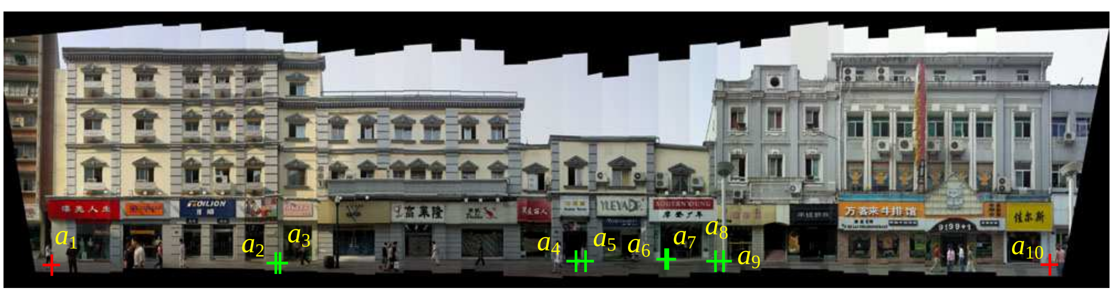


Fig.9 Elimination of error line




*a* Vector map



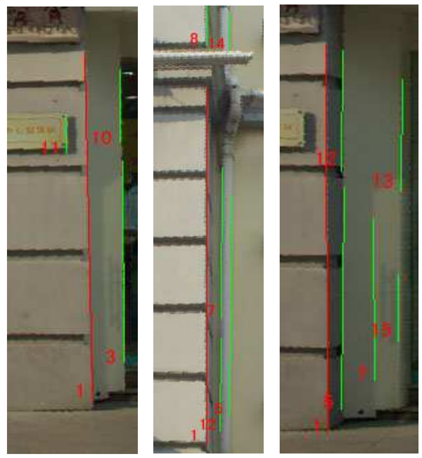

*b* Facade texture

Fig.10 Connected buildings

# 4 Experimental results

To verify the presented method, experiments are implemented on the terrestrial image sequence taken by digital camera KODAK PROFESSIONAL DCS Pro SLR/n along the pedestrian street. The image size is 4500 pixels$\times$3000 pixels and the distance between photographic center and building is about 10m.

As Fig.10, several connected buildings are considered as a whole building because the range difference between each facade plane is small. As presented in Section 3.1, point pair $A_1$ and $a_1$, $A_{10}$ and $a_{10}$ are selected from facade texture and vector map respectively. Two transformation parameters were computed with these two point pairs as: $\lambda = 0.0102$ (m/pixel) and $\theta = 2.397$ (rad). Other corner points were projected onto facade texture with $\lambda$ and $\theta$ as Fig.10(b). The projections of point $a_2$, $a_3$, $a_8$, $a_9$ are close to the actual points because they are the closest points to selected point $a_1$ and $a_{10}$. However, the projections of other points obviously deviate the actual points since they are far away from selected points. The iterative process presented in Section 3.2 was implemented to tackle this problem. At first, vertical lines (Highlighted in red) were extracted in raw images for corner point $a_2$ and $a_9$ as Fig.11.



a Point $a_2$

b Point $a_9$

Fig. 11 Vertical lines extracted

And then two transformation parameters were recalculated according to the extracted point $a_2$, $a_9$ and selected point $a_1$, $a_{10}$ as: $\lambda = 0.0105$ (m/pixel) and $\theta = 2.386$ (rad). Corner points were reprojected onto facade texture with the recalculated parameters as Fig.12. Obviously, the deviated projective points are close to actual points after reprojection.

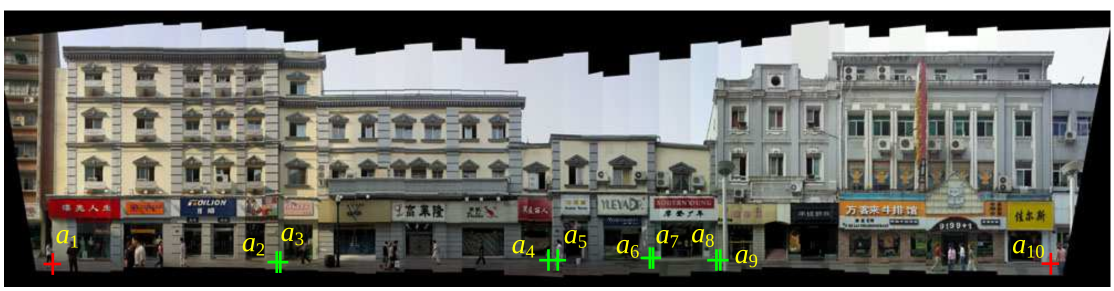



Fig.12 Reprojection result

Vertical lines (Highlighted in red) were extracted in raw images for those corner points (e.g. point $a_5$ and $a_6$) as Fig.13.


a Point $a_5$


b Point $a_6$

Fig.13 Vertical line extraction after reprojection

After the registration between image sequence and 2D vector map, the 3D facade texture models were reconstructed as Fig.14.

Fig.14 3D facade models

## 5 Conclusions

In this paper, a semi-automatic method of image-to-map registration was presented. Before registration, raw image sequence is subsected into segments corresponding to each building because the purpose is to reconstruct the 3D facade models of buildings. This process can be automatically implemented using the histogram of projective difference of corresponding points. Corner points may not be distinct features in close-ranged images and occlusion between objects with different range also makes the extraction easier to fail. Because there is always a long vertical line passing the corner of wall and the corner point of interest must lie on this vertical line. Therefore, the searching for corner point is thereby limited on the vertical line. Since the scale factor $\lambda$ and rotation angle $\theta$ are computed with two selected corresponding point pairs, the farther other points away from the selected corner points, the larger deviation is between projective and actual points in facade texture. It is proved by experiments that the iterative strategy can be used to tackle this problem.

## References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