Automated texture mapping for 3D modeling of objects with complex shapes --- a case study of archaeological ruins

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Abstract: Recently, the ground-based laser profiler is used for acquisition of 3D spatial information of archaeological objects. However, it is very difficult to measure complicated objects, because of a relatively low-resolution. On the other hand, texture mapping can be a solution to complement the low resolution, and to generate 3D model with higher fidelity. But, a huge cost is required for the construction of textured 3D model, because huge labor is demanded, and the work depends on editor's experiences and skills. Moreover, the accuracy of data would be lost during the editing works.
In this research, using the laser profiler and a non-calibrated digital camera, a method is proposed for the automatic generation of 3D model by integrating these data. At first, region segmentation is applied to laser range data to extract geometric features of an object in the laser range data. Various information such as normal vectors of planes, distances from a sensor and a sun-direction are used in this processing. Next, an image segmentation is also applied to the digital camera images, which include the same object. Then, geometrical relations are determined by corresponding the features extracted in the laser range data and digital camera's images. By projecting digital camera image onto the surface data reconstructed from laser range image, the 3D texture model was generated automatically.
Keywords: Data integration, Automation of 3D data generation, Texture mapping, Digital Photogrammetry

1. Introduction

Detailed and accurate archaeological investigation survey is very important to reconstruct the original target as completely as possible. Along this track, ground-based laser profilers are used for acquisition of 3D spatial information of archaeological ruins. However, it is very difficult to accurately and completely measure complicated objects due to limited resolution. On the other hand, texture mapping can generate 3D model with high visible fidelity by draping textural information onto reconstructed surfaces from the laser profiler. But, a huge labor cost is required for construction of textured 3D model, and the quality of the product depends on editor's experiences and skills. Moreover, the accuracy of data might be lost during the editing works.

This research aims at integrating automatically the laser profiler and a non-calibrated digital camera for an automatic generation of 3D model.

At first, feature extraction is applied to both digital camera images and laser range data. Various features are extracted such as region segments ,normal vectors of planes, distances from a sensor and a sun-direction. Feature matching is applied to determine the geometric relationships between the digital camera images and laser range data. Approximate matching for determining the initial position is followed by fine matching to improve the accuracy. Then, geometrical relations are calculated by corresponding the features in the laser range data and digital camera's images. Finally, it is possible to generate the 3D texture model with texture mapping. It is expected to reducing labor by using the method.

2.Methodologies

At first, In order to search for the geometry correspondence relation between a CCD image and laser data, features were calculated. Template matching was applied for by using these features in Approximate and fine matching. And the geometry correspondence relation between a CCD image and laser data was searched. Texture mapping was performed after correlation with the coordinates of a CCD image and laser data.
Generally, a picture from which the same subject also differed considerably by the range sensor and the CCD sensor like a digital camera. Therefore, if matched as it is, it will be thought that a big error. Then, first, by Approximate Matching, using the comparatively reliable features the general position of a range sensor and a camera was decided. Next, an accurate position was decided by fine Matching.

1) Approximate matching

Checking sky lines easily in outdoor, it was possible to use this line between target object and sky in Approximate matching. Concretely, for sky color was uniform, it regarded as one domain by the CCD image. So, a boundary line with target object extracted it clearly. Region segmentation was performed in order to extract this boundary.

On the other hand, in laser data, sky part was regarded as No data with intense image. It was possible to distinguish between sky and target object. Approximate matching was performed using these amounts of the features. However, when it was required to reproduce the complex shapes inside target object correctly like archaeological ruins, it was difficult to give Correspondence relation to target object only using sky line.

Therefore, in addition to the above-mentioned technique, extracting the amount of feature was applied with using both point cloud data and intense image which were one of laser data. After that, it matched to each obtained features using the SSDA method (Sequential Similarity Detection Algorithm). The SSDA method was the technique of asking for the position where the difference of templates became the minimum. It was adopted, because it was high-speed processing since operation processing was only using addition and subtraction.

2) Fine matching

The picture obtained if a photograph was taken with a digital camera was created using intense image and geometric form of target object reproduced from a range data. Fine Matching was performed by comparing the imitation picture with an actual digital camera picture. Explaining it as using Fig. 2-1, 2-2.
Attention to the stairs located in the front from point of photography, by the CCD image, the form of stairs can be clearly seen on CCD image.
On the other hand, by laser data, since the reflection of laser light was stronger than a reflection of sunlight, the influence of sunlight didn't almost appear on intense image.
In this research, at first, generating a polygon from point cloud data. Next, calculating a normal vector from this polygon. Finally, taking an inner product with a normal vector and direction vector of the sunlight. An imagination shade picture (CCD image) was created. Furthermore, about a flat portion, a more real false CCD image was created by considering intense image of laser.

After that, fine matching with between the gray scale picture of CCD image and a false CCD image was performed using the SSDA method like approximate matching. Moreover, in order to avoid the mistake of matching, based on the result of approximate matching, fine matching is performed in more narrow region.

Fig.2-1 Digital camera image

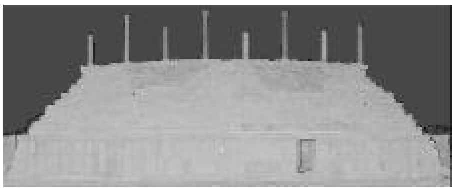

Fig.2-2 Laser intense image

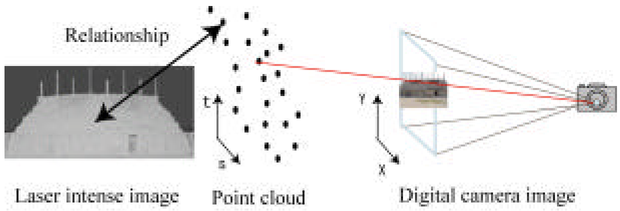

Fig.2-3 Collinearity condition

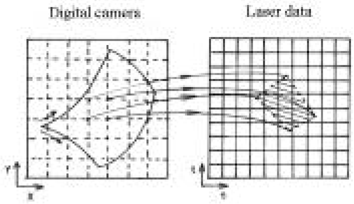

Fig.2-4 Resampling image

3) Texture mapping

In order to do texture mapping from a CCD image to TIN calculated from laser data, coordinates conversion was needed to be possible between the coordinates of a CCD image and the coordinates of laser data. For that purpose, it was necessary to ask for point of photography of CCD image and the rotation which were an unknown from collinearity equation. (Fig.2-3)
Since the CCD image photography position coordinates and the rotation angle which were an unknown were calculated from collinearity equation. It was possible to do coordinates conversion between the coordinates of a CCD image and the coordinates of laser data. Therefore, texture mapping became possible at the points matched by performing resampling which was adapted the nearest neighbor method. (Fig.2-4)

3.Experiments

1) Study area

A study area is Tyre, Lebanon. Tyre was originally developed as one of cities of ancient Phoenicia in B.C. 700. Archaeological ruins have overridden on each another and form a layer. It is very meaningful to record ruins for every layer in 3D form (See, Fig-3-1, 3-2). Authors focused on Roman stepped stand, which is one of world heritages.

2) Sensors

We used Riegl LMS-Z210i, the three-dimensional laser scanner of RIEGL Laser Measurement Systems

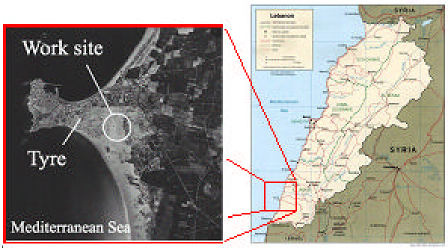

Fig.3-1 Study Area

Fig.3-2 a stepped stand

Table.3-1 Technical data for Riegl and image

for natural targets, 80%	up to 400 m
for natural targets, 10%	up to 120 m
Minimum range	4 m
Measurement accuracy	typ. 15 mm (averaged)
	typ. 25 mm (single shot)
Measurement resolution	5 mm
Measurement rate	up to 12 000 pts/sec @ low
	(oscillating mirror)
	up to 8 000 pts/sec @ high
	(rotating mirror)
Laser wavelength	near infrared
Beam divergence	3 mrad

GmbH. (Table.3-1) This provide three-dimensional point clouds data by operation from notebook PC and then Riegl sends the data into notebook PC.

4.Preliminary Results

The result of this research was shown below. In this space, since uneven of surface form couldn't be expressed, if the results of whole target object was displayed. It displayed as a preliminary result of texture mapping when a corresponding point was found. (Fig. 4-1) In addition, the result was showed depended on the sensor (Cyrax2500) which acquired point cloud data with density deeper than Riegl data. (The result of the whole is shown at the time of presentation) Riegl data was created TIN from point cloud, performed Texture mapping. On the other hand, in the case of using Cyrax data, as the density of point cloud was high, the color was added to the point cloud. (Fig.4-2)

5.Discussions

When template matching was applied by using SSDA

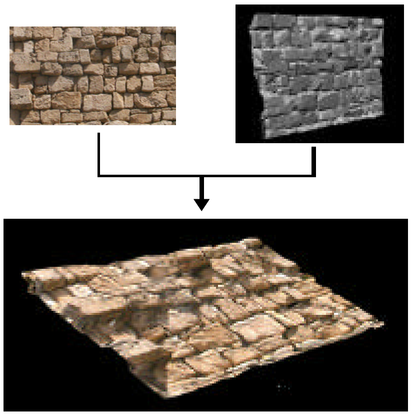

Fig.4-1 Preliminary Results

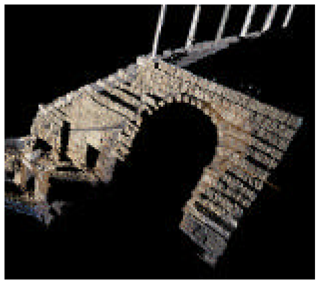

Fig.4-2 Results of using other point cloud

method, although such as narrowing down the reference range, mistake matching occasionally occur near the stairs of the stand. However, it became to perform texture mapping in short time, by using fine matching after using approximate matching.

6. Conclusions

A conclusions was the following two points.

1. As fine matching was applied after approximate matching, it was possible to reduce the amount of work.
2. For using features made from CCD image, laser intense image, and point cloud, it was possible to perform texture mapping to complex shape object.

Future works is not only in outdoors using the feature of sky lines but also in the interior of a room using other features. In addition, it is necessary to consider the application in point cloud data acquired using different sensors.

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