CONSTRUCTION 3D URBAN MODEL FROM LIDAR AND IMAGE SEQUENCE

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ABSTRACT :

This paper describes an algorithm framework for building recognition in urban area with laser scanned data (LIDAR) and image sequence. Three image sequences, two oblique photography to buildings' walls and one vertical photography to building's roof, and DSM from LIDAR data are used as sources of information. Classification and segmentation can be processed by combined multispectral information which is provided by color aerial image and geometric information from a laser scanned DSM . A homologue line matching, based on geometry constraint, is applied for automatically getting the corresponding line features in multi target images. We also discuss a intergrate step to 3-D model reconstruction by multiple data source based on Probabilistic approach.

KEY WORDS: LIDAR , Extraction, Matching, Modeling, Sequences Image, City

1. INTRODUCTION

The reconstruction of houses and other man-made objects in 3D is currently a very active research area and an issue of high importance to many users of geodesy, including urban planners , architects,and telecommunication engineers. Manual 3D processing of aerial images is time consuming and requires the expertise of highly qualified persons.

Fully automatic systems working with aerial images are not considered for practical use (Brenner 2001), although tremendous progress has been made. Commercial utility collect 3D models relyies almost exclusively on manual data acquisition .So an efficient and at least semi-automatic procedure to reconstruct virtual city models is a valuable research topic.

2. PREVIOUS WORK

Significant progress has been made in recent years in the goal of extraction building models by means of automatic or semi-automatic ways.

In the ETH's project AMOBE [Henricsson etc 96] , they use the strategy of mutual interaction of 2-D and 3-D procedures at all levels of Processing ,since neither 2-D nor 3-D procedures alone are sufficient to solve the problems.Three-dimensional information ,such as Digital Surface Models and 3-D edges, should be drive as soon as possible.

Baillard and Zisserman [C.Baillard 2000]use a plane-sweep strategy for the automatically reconstructing a 3D piecewise planar model from multiple images.Only a single 3D line with a textur neighbourhood is required to generate a plane hypothesis without any user intervention at any stage .

Scholze use a probabilistic approach to roof extraction and reconstruction[S.Scholze] The 3D line segments are grouped into planes by means of a Bayesian model selection procedure.

Gruen and Wang provide a semi-automated methodology and a commercial Implementation[Grun 1998] .Given the primary data as point clouds measured on analytical Plotters or digital stations ,a generic topology generator fit the plannar structures.

3. WORKING FRAMEWORK

Maas use of invariant moments applied to laser scanning data for the Determination of roof parameters of simple building types .[Maas 99].Using only first and second order invariant moment, a number of basic parameters of a building(position , orientation ,length ,width , height ,roof type and roof steepness) can be determined as closed solutions.

In our procedure ,there are three steps in the generation of 3-D building models, namely: (1)data acquisition and aerial triangulation, (2) feature extraction and stereo-model measurement, and (3) model reconstruction.

3.1 data source

It is generally acknowledged that good data is the most valuable and the most needed componets , prior to computer hardware , software and user interface. [Henricsson etc 96].

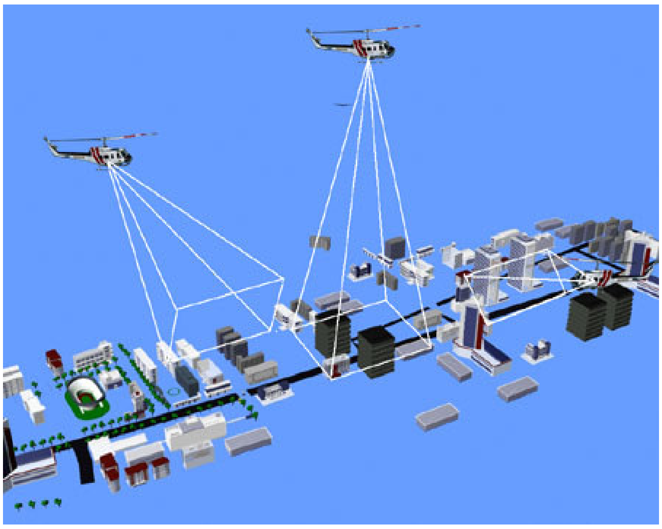

Figure 1. Three Flying Routes

In principle ,the use of aerial images alone for automatic reconstruction of buildings should be sufficient. However ,it is difficult to separate the useful information from irrelevant details. Also useful information for the reconstruction task can be lost because of occlusion ,low contrast, and bad perspective.

So high-resolution,multiple-overlap color images,plus Lidar data provide enough redundant information to reduce human interaction in the process of modelling. There are totally three image sequences, one with optical axes looking downward to get the images for roofs and roads, other two sequences with oblique view-angles of about 45 degree to acquire the texture of walls of buildings. The image in the first sequence is nearly level and the others in the sequences with oblique photography are oblique. Three flying routes are shown in Figure 1 ,and photos are show on Figure 2.

Airborne laser-scanning has become a viable technique for the surveying data during the past few years. As an active technique,it delivers reliable height data without requirements to surface reflectance variations. The inherent 3-D nature of laser-scanning data saves time consuming and reduce potentially erroneous matching techniques and yields a high potential for realtime application if laser ranger data can be fused with GPS/INS data onboard in aircraft.[Maas 99].

Figure 2 . Image from different view angles

3.1 Automatic Aerial Triangulation

Traditional aerial photographs overlapped about 60 percent in a strip. While image sequences taken with digital video camera has the advantages of high overlapping and redundancy of corresponding features, which has a well potential for automatic 3D reconstruction.

Automatic Aerial Triangulation (AAT) technique can be adopted to acquire initial values of camera parameters. The three image sequences are processed with VirtuoZo AAT software as single strip separately. Two images near the beginning and end part of the image sequences are selected. Then some control points are selected from the vector data and LIDAR data, and their corresponding image points are given interactively in the selected images. Thus camera parameters of the two selected images can be obtained with space resection. Then all parameters of the strip can be transformed into world coordinates system. The pass points are also calculated, which will be used in hybrid point-line photogrammetry to ensure the stability of bundle adjustment.

3.2 Preprocess in DSM

The first step in the processing of the laser scanning data is a segmentation of the range data.. In the beginning, we compute an approximation of the topographic surface by mathematical morphological filtering .To reduce noise caused by small objects such as antennae or chimneys on roofs ,the median filter was used .

. Segmentation process suggested a pyramid-linking algorithm as an effective implementation of a combined segmentation and feature computation algorithm
finds connected components without preliminary threshold, It is an iterative algorithm:

1. Computation of the Gaussian pyramid.
2. Segmentation by pyramid-linking.
3. Averaging of linked pixels.

Steps 2 and 3 are repeated iteratively until a stable segmentation result is reached.

As soon as all the borders have been retrieved from the image, the shape representation can be further compressed. Polygonal approximation is to find and keep only the dominant points,that is, points where the local maximums of curvature absolute value are located on the digital curve, stored in the chain code or in another direct representation format.

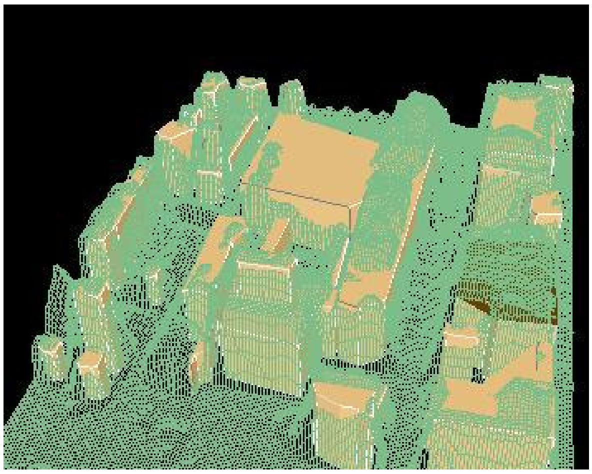

Figure 3 . Image segmentation and initial build blob

As a result , the initial 3D blobs, i.e. possible building has been detected. To Separate the building from other blobs ,such as trees , classification can be processed by combined multispectral information which is provided by color aerial image and geometric information from a laser scanned DSM .

3.3 Linear Feature Extraction and Matching

The extraction of line feature on images is only performed in the neighbourhood of projected initial segmentation of the building blob. The main purpose is to gain the long line feature. Common steps of line extraction are edge detection, edge tracing and edge fitting. Although the image line features, extracted in this stage, are not so good in geometry precision, it’s still good enough for line intersection and space forward intersection to improve the roof geometry model. After the roof geometry model is improved with the adjustment of space forward intersection later, the line extraction algorithm based on Least Squares Template Matching-LSTM to a narrow rectangle image can be applied to gain the final line feature.

Some Constraint are imposed to get exactly right match result.

1. epipolar constraint :

The match for a line segment in one view must lie at least partially within a quadrilateral defined by the epipolar geometry and the 3D height constraints.A particular height in the world coordinate system corresponds to a particular point in the epipolarline. So the Lidar point in DSM can reduce the search space to the segment on each epipolar line .

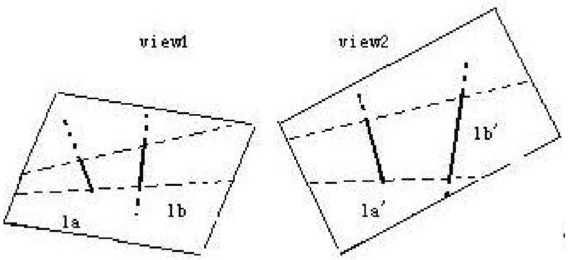

Figure 4: epipolar constraint

2. Orthogonality Constraint

Given a junction match , we can compute the 3D angle between the lines forming it(from the knowledge of the matching lines). This angle is required to be nearly orthogonal in 3D if we are looking for rectilinear structures only.

3. trifocal constraint

For some difficult situation such as dense buildings and building with double edges, it is possible to produce some misidentification. A homologue line matching, based on three-view geometry constraint, is applied for automatically getting the corresponding line features in all target images.

Let *P', P* and *P''* be the projection matrix of left, middle and right images respectively. There is a perspective transformation to *P', P* and *P''* resulting in;

$$P' = [A \mid a] \qquad P = [I \mid 0] \qquad P'' = [B \mid b]$$

where *A* and *B* are 3 x 3 matrix, *a* and *b* are 3 x 1 vector. Let a_i and b_i be the *i*th (*i*=1,2,3,4) column for projection matrix *P'* and *P''*; $l'(l_1', l_2', l_3')$, $l(l_1, l_2, l_3)$ and $l''(l_1'', l_2'', l_3'')$ be corresponding image line feature for space line L in left, middle and right image.Then

$$l_i = l'^T (a_i b^T) l'' - l'^T (a b_i^T) l''$$

Let matrix

$$T = [\ T_1\ T_2\ T_3\ ],\quad T_i = a_i b^T - a b_i^T$$

Then, the 3D tensor *T* should fit [Mendon, 1998],[Zhang Z 03]:

$$l = l'^T\, T\, l''$$

Based on three-view geometry constraint,the projective ambiguity could be reduced dramatically.

3.4 Model Primitives

Building models can be categorized into three classes according to their geometry and structure, namely the . *parameterized models, Prismatic models,*and *compound Polyhedral models.*

Parameterized models are suitable for describing the most common building types, such as gable roofs, flat roofs, hip roofs, lean-to roofs,etc. The topology of such models is fixed, while the geometry is variable. The changing of parameters will cause the building's size as well as its position and orientation to vary.

Prismatic models describe complex building with arbitrary polygonal ground plans and vertical walls, but are restricted to flat roofs only.

Compound Polyhedral models describe complex buildings with a polygonal ground plan, it can be generalized using a combination of several Prismatic models or Parameterized models . For the process simplism we constrained that the lowest level of model must be a prismatic models.

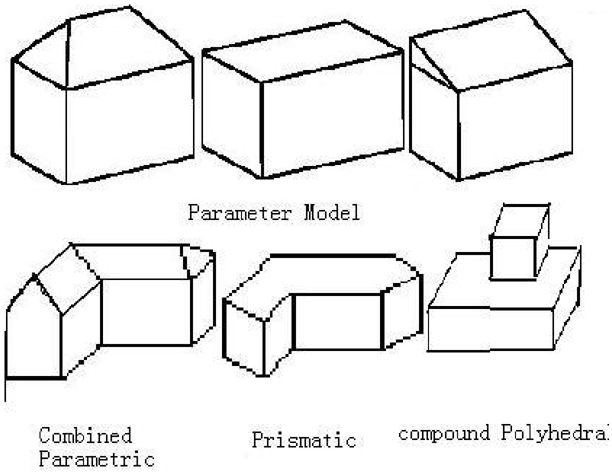

Figure 5 . Model primitives

3.5 Hypothesis Verification

We introduce a semi-automatic framework to complete the procedure of model reconstruction.In the reconstruction stage, an operator is responsible for selecting the initial and possible model primitives. By means a multi-algorithm strategy, the system can build the topology of a roof patch . In the case of failure, human intervention becomes necessary to complete the modeling tasks.

The 3D line segments are grouped into planes by means of a Bayesian model selection procedure.

The plane model which best represents the data x is the one which maximizes the posterior model probability

$P(m \mid x) \rightarrow \max$;

By means of Bayes' theorem , this probability can be expressed by the likelihood and the prior of the model .

$$P(m \mid x, e) = \frac{p(x \mid m, e)\, p(m \mid e)}{P(x \mid e)}$$

To deal with the unknown model parameters , $P(m \mid x, e)$ can be expressed as marginal density computed over θ .[S.Scholze 2002] :

Measurement xi can represent the distance for the plane. Assume they are sampled from a Normal distribution with parameters. $\theta\{\mu(\theta), \sigma\}$

$$P(\mathrm{m}|\, x, e) \propto \frac{1}{M(\mu_{\max}-\mu_{\min})^M} \int_{\theta_{\min}}^{\theta_{\max}} \exp(-\frac{1}{2}\sum_{j}^{M}\sum_{i}(\mu_j - x_i)^2 z_{ij}) d\theta$$

When a model primitive type is choosed , the plane number is determined and the only unknown parameter is θ . To set up plane hypothses ,reconstructed 3D line segments in the patch neighbourhood are considered.The DSM could be used to determined the initial angle range { $\theta_{\min}, \theta_{\max}$ }.The max posterior model probabilities be choosed as the estimated parameter value.

3.6 3D Representation

When all buildings are successfully reconstructed, we can provide a simple back-projection of the reconstructed 3D building to the aerial image. The corresponding image patch for each visible plane of a building is available and can be used for texture mapping.

A 3-D visualization tool was developed for displaying the generated building models with level of detail models.

4. RESULT

Reconstructed buildings are merged into textured ground generated from DSM and orthoimages. These 3D models are visualized realistically as shown in Figure 6.

Figure 6 . Experiments result

5. CONCLUTION

This paper describes an algorithm framework for building recognition in urban area with laser scanned data (LIDAR) and image sequence. With the framework presented in this paper we can construct 3D urban models in a more efficient and reliable way.

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