3D SPATIAL OBJECTS MODELING AND VISUALIZATION BASED ON LASER LANGE DATA

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ABSTRACT
The laser technology has been currently brought into photogrammetry and cartography fields as a tool for mapping. The main application of laser scanning systems concerns large-scale and precise topographic DEMs. Automatically interpret range images for extracting geo-spatial features and reconstruction of geo-objects are the main research problems. The objective of this paper is to develop the algorithms and methods for modeling and visualization of 3D spatial data in large scale based by processing laser-scanning data. For processing airborne laser range data, a set of algorithms should be developed. Those algorithms are mainly include: TIN based range image interpolation, MM (Mathematical Morphology) based range image filtering, features extraction and range image segmentation, feature generalization and optimization, 3D objects reconstruction and modeling, CG (Computer Graphic) based visualization and animation of virtual environment.

1 Introduction

Over the past few years, the need for describing larger scale 3D spatial data is continually increasing. These data are used for variety of applications such as region planing, architecture, archaeology, disaster prevention, microclimate investigations or transmitter placement in telecommunication. Many kinds of raster and vector based models for describing, modeling, and visualizing 3D spatial data in large scale have been developed. With the development of laser technology and sensor techniques, several kinds of airborne laser scanners are available for acquisition of high accuracy 3-D spatial data in real or very fast time. The main application of laser scanning systems concerns large-scale and precise topographic DEMs, especially in areas that are difficult for conventional photogrammetry. These are forest areas of total or scattered coverage. As a side product tree heights are obtained. Other interesting applications concern coastal areas, wetland, beaches, dunes etc. As in all successful developments, new applications emerge which had not been anticipated at the beginning.

The purpose of this research is to study and develop the algorithms and methods for modeling 3D spatial objects based on airborne laser range data. For processing airborne laser range data, a set of algorithms should be developed. Those algorithms are mainly include TIN based range image interpolation, MM based range image filtering, features extraction and range image segmentation, feature generalization and optimization, 3D object reconstruction and modeling, CG based visualization and animation of virtual environment. In this research we using laser scanning data of Kyoto Station area simulate 3D reconstruct result.

2 Methodology

The airborne laser scanner reaches area coverage, for instance, by an oscillating deflection of the laser beam perpendicular to the flight direction. The instant angle of deflection has to be known precisely, as the basic geometric principle is maintained of providing position, direction and length of the vector to the ground point, for each shot.

An essential feature of laser scanning is the potentials for almost complete automation. the GPS, INS and laser data being digitally recorded. After the GPS processing and the necessary system calibration the computation of the terrain points, the interpolation of a DEM and the block formation of the DEM is quite straightforward, as far as open terrain is concerned.

It includes following main problems:

- Pre-processing for inputting airborne Laser range data
- Semi-automated extraction of 3D Spatial features
- Methods for 3D-visual modeling
- Generation of virtual reality environments
- Editing & Checking methods

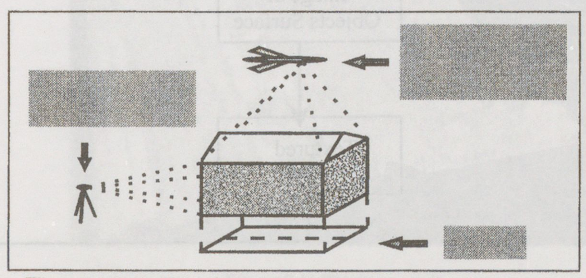

Figure1 Integration of laser range images and existing maps

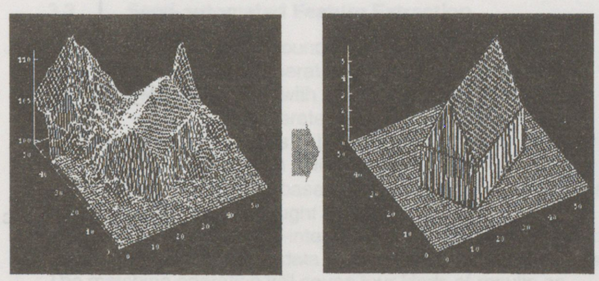

Figure2 3D object reconstruction based on laser range images

3 Procedure

In this paper, laser-scanning system on the ground is a thing that shall be used. In order to map all details of objects, fundamental surveying is brought to data-collected process in terms of data acquisition. After that all data is stored into the proper format, those shall be filtered in order to reduce an error occurring during collecting processes (Baltsavias, 1999). Scene Modeling is a next step to create 3D model, after pass filtering. Triangulation, segmentation, extraction are involved also into Scene Modeling process in terms of mathematics algorithms (Ackermann, 1999). And then all data should be combined as one based on combination modeling to be established for this purpose. The combination process, consisting of algorithms to be used for merging different kinds of data, is conducted to this process. GIS attribute data, aerial photograph, existing map and laser data are the primary data to be combined. The results of work can be shown on 3D modeling as visualization, and also let the user to walk through the visual spatial data (Hala, etc., 1999). Applications for this modeling can be applied in several kind of work.

Our goal towards to reconstruct large-scale 3D spatial objects byusing the laser range images (airborne or on the ground) and existing maps or image. The Principe is shown in Figure 1 and Figure 2. Laser range images can be thinking as a kind of high-resolution digital terrain models (DTMs) or digital surface models (DSMs). The reconstruction of 3D objects from laser range images can be simply thought as the 3D raster-vector conversions from a noisy DTM to parametric CAD formatted 3D vector data. Due to the limited resolutions and noisy, the existed low lever processing methods for reconstruction of 3D objects from laser range images generally can not fit to real application needs. Urban planning maps sever as set of well-organized high lever data source interpreted and generalized by human operators would be a kind of useful knowledge for 3D object reconstruction and recognition. Therefore, we set the algorithm of 3D reconstruction into below major steps for our approach(see the Figure3)

- Pre-Processing
- Laser range image filtering and segmentation;
- Extraction of 3D spatial objects
- Reconstruction of 3D objects as a 3D GIS needed format.
- Visual Texture mapping
- Generation of VR environments

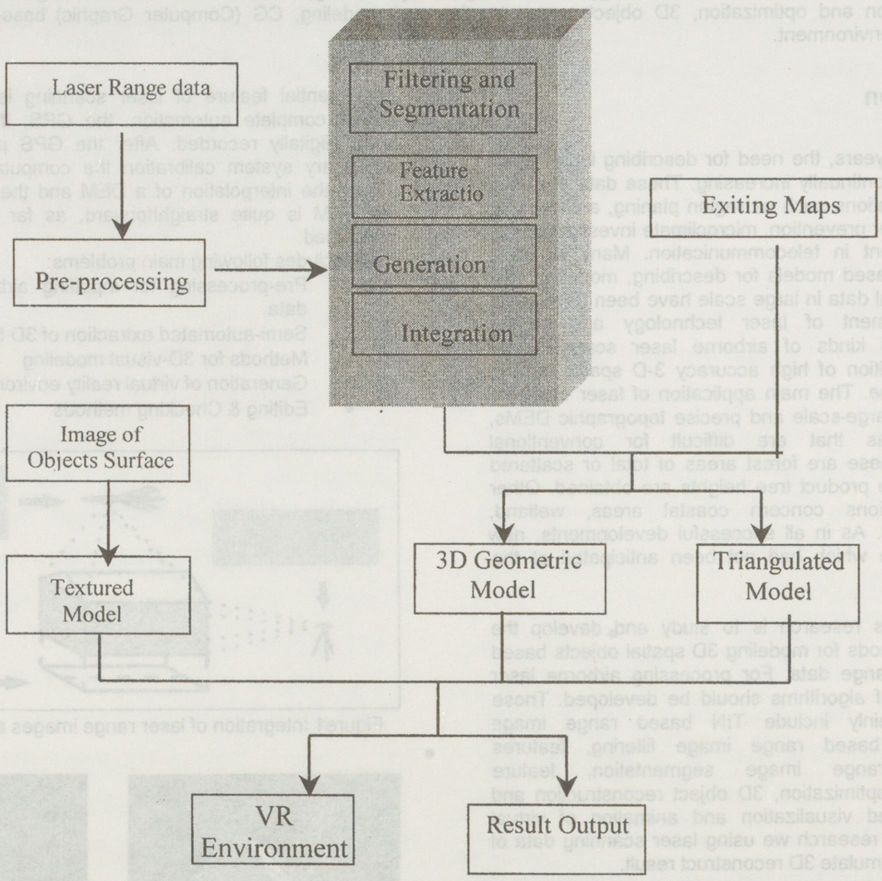

Figure3 The basic procedure of this research

3.1 Laser Range Data Imputing and Pre-Processing

In the first step, we need translate the raw data got by the laser ranger to the file format that SoftImage|3D can read. Generally, there are two ways for this transformation. First one is generating SoftImage|3D graphic file based on raw laser range data directly. Second is translating DXF file (generated by MicroStation or AUTO-CAD) into SoftImage|3D. We have try these two methods for imputing laser range data and it will be useful for different laser range hardware (such as airborne or ground-type machines). Another important problem is to convert the raw data from their local coordinate system to the global one. The processing can be realized by making C program for 3D coordinate transformation based on given parameters.

3.2 MM Filtering and 3D object segmentation

For the purposes of range image filtering and related object segmentation, here we used Mathematical Morphology (MM) based approaches (Haralick et.al, 1987; chem., 1991). Generally, MM operators (such as dilation, erosion, opening, closing, hit or miss, thinning...) can be described as a kind of combination of shift and logic operations. Shifting operations are controlled by the given structuring elements (SEs) whose size, shape and orientation can be changed by the different applications. Different MM operators according for the different purposes organize logic operations.

MM filtering is one of the most successful tools for MM applications. For range image processing, we used the opening filter to remove dirty voxels and small-connected volumes. We also used the closing filter to fill the small holes within surfaces and to link short gaps among objects. Here, the key problem is how to select suitable SEs, since the spatial features in range images are very dense in most cases, the direction-oriented SEs are suitable for many applications. How to select the parameters and algorithms for segmentation processing is highly dependent on different applications. Generally, before the real processing of whole large images we can process several selected typical small testing areas to find the suitable parameters and optimal processing procedures. We also can generate simple knowledge bases based on these selected parameters and procedures using for other range image processing.

3D object segmentation is also based on open processing. In this case, the size of SEs should be a little larger than the segmented objects, the shape of SEs can be a simple convex object, such as a cubic box in 3D space or a rectangular area in the 2D horizontal plain. The basic idea of MM based object segmentation is firstly filtering all the parts smaller than the given SEs, then segmenting the objects by the logic difference operations between the original 3D data set and the filtered 3D data set. Since MM based filtering with a small SE in the first step processing also will damage the detail object features, a feature recovering is better to be added in the object segment procedure. The feature-recovering algorithm is based on the conditional dilation operations, in which the segmented object parts sever as the dilation seeds and the original 3D data set serves as the masking field for limiting dilated ranges. Weidner and Foerstner (1995) have also used the similar MM based methods for filtering and segmentation of 3D spatial objects from small scale DSMs.

In large-scale laser range image processing, we think it is better to add the feature recovering procedures during segmentation of spatial objects for protecting the detail object structures. When we integrally using the 2D map data for range image processing, a feature protected filtering based on the conditional masking volumes generated by the 2D boundary lines of building or roads also can be realized. Figure 4 shows a simple procedure of MM filtering and object segmentation. Figure 5 and Figure 6 are MM Filtering and H result Filtering result of Kyoto train way station area.

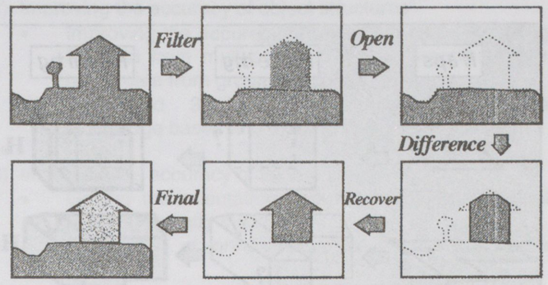

Figure4 3D MM filtering and object segmentation in a 3D space

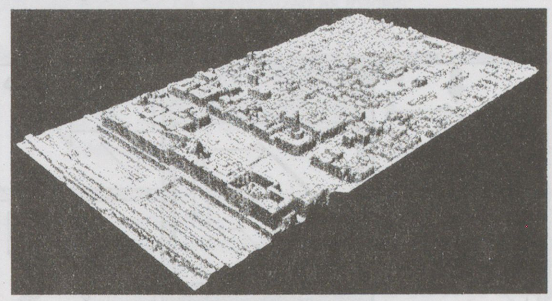

Figure5 MM Filtering

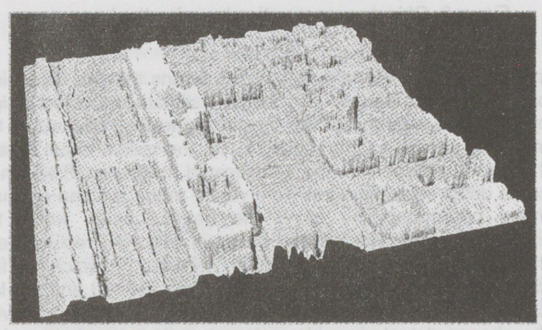

Figure6 H filtering result

3.3 Semi-automated Feature Extraction

Based on the extracted ground truth data from 2D existing maps/images, we can generate the parametric or prismatic building and road models with the unknown heights firstly. In this way, we can also generate a little detail object features, such as the roof structures of buildings by using the vectored feature lines. Then we can estimate the height parameters of generated spatial objects based on the processed laser range images, which can be thought as a kind of model based matching between the pre-interpreted models (generated from 2D vectors) and objected data sets (processed range images). The matching operation will cause four kinds of results as described following:

A pre-interpreted model matched a object with almost different heights;
A pre-interpreted model can not match the object on the given range image;
An object on the given range image can not match the pre-interpreted object on the map.

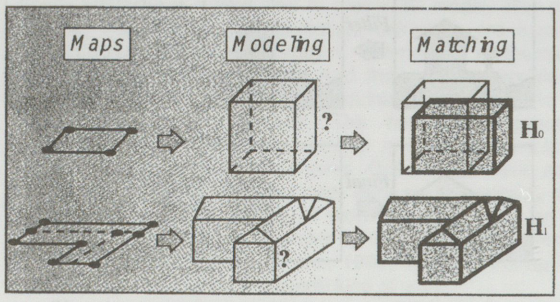

Figure7 Matching between models and range image objects

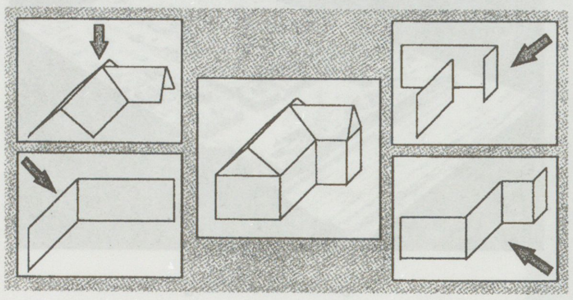

Figure8 Object reconstruction by using the laser range

In the first case, the matching result means that the object is a prismatic object and we can simply estimate the object height by using the average or the maximum height value within the matching region. In the second case, the match result means the object may be with the complicated structures. If we know some detail object features from vector maps, we can estimate these parameters by using the height values within the matching region. The last two cases of matching results mean that the object changes have been detected, in which the first case means that the old object has been deleted and the last case means that a new object has been created. For solving the change detected problems in our system now is based on semi-automated editing, i.e. the computer automated searching the changed places and operators modify these change places with manual editing. Figure 7 shows a basic matching procedure between map models and range image objects.

If not only airborne laser range images but also ground laser range image in the different view points are available, above presented methods can be extended for reconstruction of high accurate 3D spatial objects with their detail features. The basic idea is to extract different DSMs from the different view points (as Figure 8). After that we can integrate these DSMs to generating whole 3D spatial objects by using the data fusion methods. In this case, the information got from 2D vector maps also can partially serve as a useful data source for estimating the vertical surfaces. Surface interpolation algorithms also should be extended for generating invisible object parts.

3.4 3D visual Modeling

There are several areas in urban system whose design and management can be considerably improved with the help of 2D or 3D visual modeling. Among these needs are traditional mapping, infrastructure design, urban planning and environment. Since there is not a clearly defined terminology for various types of 3D city models, we may simply call a 3D city model as a special computer representation of all fixed 3D spatial objects (buildings, vegetation, traffic- and waterways) within a urban area.

For different purposes and applications, such as GIS related 3D spatial management and analyzing, simulation and visualization of urban planning, and building design and construction, there are several kinds of 3D city models existed now. In these models the 3D spatial objects in urban areas are described as the different detail of their structures. Ranzinger and Gleixner have summarized four kinds of 3D city models mainly for simulation and visualization (Ranzinger and Gleixner, 1996.) The 3D spatial objects are called the prismatic model, in which the building is represented whither as a cubic box with the fixed parameters or as an object with the plain polygon adding the same height. The 3D spatial objects are called the parametric model, in which the building is represented with its roof structures. Other two kinds of 3D spatial objects show the complicated 3D object and with added surface 2D or 3D image textures.

Our target is to generation of complicated 3D object and with added surface 2D image textures from air photos. By using SoftImage|3D system, we need generate the 3D spatial objects based on extracted spatial lines and surfaces. Here, the following kinds of 3D objects have been used for 3D city modeling in our system:

- Polygon Mesh object: using for modeling grid DTM or surfaces
- NURBS curves: using for modeling line objects
- Patch and NURBS surface: using for modeling smoothing un-form surface objects
- 3D TIN objects: using for modeling un-form surface objects
- Boolean object: using for modeling and generating complicated objects

3.5 Generation of Virtual Reality Environments

One of main task for generation of Virtual Reality environment is to put the real image textures on generated 3D spatial objects.

In order to use image as a texture of surface, objects will be taken as photographs in several parts and after that will be merged on surfaces (Dorffner, L.; Forkert, G., 1998). However, the photographs, 2D texture-map, represented the objects might be mathematically transformed to the orthophoto, differential rectification, because the projection of photographs represent in central projection (Zhizhuo, 1990). At the other points within the segment, there still exist distortions due to relief displacements, and in the case of the indirect projection mode, distortions due to tilt displacements also exist. If we leave these displacements uncorrected, they will give rise to errors and hence effect the quality of the orthophoto (Gruen, 1999).

To generate computer models that are visually realistic, texture is applied to the reconstructed surfaces to make the models appear rich and complex. This be achieved by texturing the 3D triangulated surfaces from the laser scan with the appearance camera. Segments of 3D scene structure may appear in several different images. This may be caused, for example, by overlapping in the image mosaic generated by the camera, or images taken from radically different views. There is also the case where the camera has zoomed to get very high-resolution data for a particularly important scene feature.

The availability of multiple texture sources for a single triangle necessitates additional consideration. To decide which texture source to use, we make use of the label map obtained during hidden texture removal to provide the number of pixels in the corresponding image that would be used to texture map any given model triangle. All that is required is to sum the number of instances of the triangle in the label map. This is done for each triangle in every image and the image contributing the largest number of pixels is used as the texture source. Such that all those triangles sharing a common texture source are grouped together.

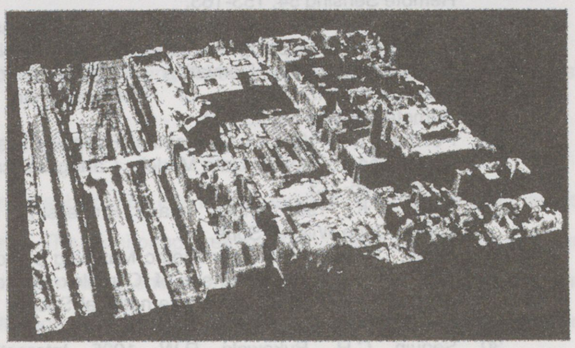

Figure9 Texture mapping Result of Kyoto Train way Station area

This work was finished by using Softimage|3D system. We summary the main procedure is shown as follows(The result is shown in Figure9):

- Surface segmentation for 2D texture mapping
- Generation of texture images by 2D affined transformation
- Imputing texture images into Softimage|3D (TIFF to PIC)
- Object oriented texture mapping based on Softimage|3D
- Defining parameters for animation (color, camera, light, material and so on)
- Visualization 3D virtual environments based on Softimage|3D
- Output 3D results from Softimage|3D to TIFF images

3.6 Spatial Object Editing

After generation of 3D visual models or VR environments, we should check the result based on exiting air photos of maps. The task was finished base on the 3D editing environment of Softimage|3D system. We should make the procedure for sequentially highlighting 3D objects on a 2D base map and image environment. The checking are semi-automatically done by operator's mouse processing. If we find the problem, we can lock this object and modify it based on different 3D editing tools.

3.7 Problem and Future Application Plan

According to our research result, we can find the following problems that should make feather research in the future:

1). The accuracy and density of laser range data
- The distance between random points is too far.
- Some site has no 3D data
- The accuracy is lower for extraction buildings with high densities

2). Improving the accuracy of object structures
- Improving the accuracy of object structures by using 3D data from multi-sources (mobile mapping, laser range data from ground stations)
- Automated 3D feature extraction based on knowledge bases and existing GIS

3). Improving the accuracy of texture images
- Getting the orientation parameters by using digital photogrammetry system
- Generation of ortho-photos for accurately texture mapping

3.8 Application Plan

Our future works can be summarized as follows:

1). Multi-sensor integration
- Airborne laser range data processing
- Ground laser range data processing
- Mobile mapping data processing
- Integration

2). Improvement of digital photogrammetry system for structure feature extraction
- Automated extraction of roads and buildings based on DSM and laser range data
- Automated extraction of roads and buildings based on existing GIS
- 3D environment for editing 3D spatial objects

3). 3D GIS and virtual environment
- Generation of 3D spatial information systems
- Generation of virtual environments for visualization and simulation
- Different applications

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