# 5. An Efficient Data Acquisition and Database Design for Urban Landscape Simulation

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[Abstract] Revitalization of the central business districts of Japanese local cities is an urgent social problem. Due to prolonged recession, it is difficult to perform an expensive survey project and 3D-CG contents making. Authers studied a method to create 3D-GIS (geographical information system) of an adequate accuracy for the urban planning, by means of using only existing data.

[Keywords] 3 dimensional geographical information system, input of an automatic map data, texture mapping, parametric processing, database design

## 1 Introduction

Aizuwakamatsu-shi, Fukushima-ken, the subject of this example has a population of 300,000 and is a basin in center of the Aizu district. The town's population is 120,000 and the outside surrounding area of about 13km has about 30,000 buildings. The main industries are lacquer ware and sake brewing, it is also a tourist area but the industry is now in decline and stagnant. Recently, the construction of a new semiconductor factory was postponed for a long period and reduction of the town finances have begun. According to the chamber of commerce, because of the advancement of a car society, the bankruptcy rate of the central six main shopping districts has become 35a common problem for provincial cities in modern Japan. How to revitalize the emptying central city districts is a vital policy problem for the beginning of the 21st century. With the establishment of the "Central city district revitalization bill", over 100 government bodies have started to make plans.

In traditional civil engineering planning studies, in order to handle an area this size, a 1/1000th scale model of this area was made then planning of the city and area started [1]. In recent years, 3D computer graphics (3D-CG) system ratio of price and functionality have greatly improved and instead of models, there are increasing trials in using CG for simulations [2]. Additionally, and when 3D and 3D-GIS systems are used that also have advanced researched in 3D geographical information systems (3D-GIS) in redevelopment projects [3][4].

A: The current situation of the streets is reproduced in cyber space (3D-GIS construction)

B: The appropriate central town area view (3D-GIS data reorganization)

C: Detailed civil engineering and construction works

must be based on these 3 steps. The problem is creating a 3D-GIS model that maintains the accuracy demanded by town planning studies quickly and at low cost.

If it were a time where a large budget was at disposal, self-advantageous road account book could be created spending ample time and the current situation could be precisely measured and a blueprint created. Also the 3D-CG content could be contracted out to a professional. (Current CG contents are handmade with retail software and therefore costly.)

In a metropolitan area, the problem is not building wide roads spanning several tens of meters in the surrounding area or numerous high rise buildings or even creating new housing development areas for living space but rather, the problem lies in creating from those several hundred buildings in the revitalization, an area having an individualistic atmosphere and history. In this case, it is not only the buildings facing the street but the residents of each house in the back streets must have ample respect for others.

## 2 The Objectives and the Newness of the Research

The authors have for the past 4 years worked with the Aizu town planning department, Fukushima prefecture civil engineering department, construction planning association Aizu branch office to reproduce the central town area of Aizu in 3D-CG. Base on the experimets, we propose the new approach the following: possible.

($\alpha$) we use the existing public data such as the heights and the distances of electric poles, to create more precise map

($\beta$) We develop new image processing programs in or-

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der to reduce the time for creating texture mapping images. And we develop a program to create various roof types automatically.
($\gamma$) We sedign a relational databse to cover all necessary data for creating 3D-GIS of an urban area.

## 3 Contents Production Overview

First in 1996, a 3D-CG of Aizu's most traditional "Nanokamachi Dori" was created. This was a contracted survey from the Ministry of Construction. The period was 4 months and there was no budget for creating the contents and so the Ueda Research Center at Aizu University undertook the work as a contribution to the area. There were 150 buildings on both sides of a 1 Km East and West road however, because of the time limit, houses were divided into types such as Japanese 2 story and warehouses into 20 basic forms and 3D shape models were created. Next, town planning members passed in front of all the buildings and took photographs with normal cameras and regular lenses. These analog pictures were scanned and digitally converted. These were used for texture maps of the corresponding buildings. The models with the images laid out on a separate digitized basic map. The results of this were reported as the "Nanoka Machi Shopping district Vitalization Plan".

In the following year of 1997, "Oomachi Dori" which is perpendicular to "Nanoka Machi Dori" to the North and South (1.3 Km in its entire length) was created in about one year. (Approximately 250 buildings) This was contracted to the construction planning organization Aizu branch by the Fukushima prefecture civil engineering department as a survey to "Preserve Historic Streets". Ueda research was in charge of the overall CG creation. The planning organization members selected 30 from about 100 candidates of houses for preservation (buildings of and after the Meiji era). ('96) These measurements were summarized into volumes in '97. At that time, there were only 1 or 2 design offices that could purchase retail construction CAD software for use. (This is the reality of Aizu) In order to allow cooperation in the work, free 2D CAD construction software was used as a common tool and flat diagrams of 1/100th scale models of 30 buildings were made. (This was to be used as a construction map in the future by Aizu when giving aid for repairs.) Next, this 2D data was converted to the DFX format, the industry standard for 2D CAD data. Additionally, it was entered into the University's retail construction 3D CAD software. The members then divided this and with this CAD, created 3D-CG data (shape models and texture). (Even after getting used to use, it took 3 days for 1 building.) The intersection of "Nanoka Machi Dori" running East to West and "Oo Machi Dori" running North to South is the traditional center of Aizu, however only 6 of the selected houses exist in the area around this intersection and the overall street cannot be simulated from this. For this reason, the Aizu University team created the approximately 240 buildings that make up this street in the same method as "Nanoka Machi Dori".

In order to merge the data created by the construction planning organization and the CG data created by the University team on a basic map, data from both sides are being currently converted to the current industry standard Wavefront format and being merged. The final results can be seen in the report to the prefecture "Creation of a Historic Aizu Town" or on the Homepages of the Construction orgainization (http//www.hechima.co.jp)[5].

## 4 The Data Set to Create 3D-GIS

In order to construct the 3D geographical information (3D-GIS) database, the data used this time as explained below:.
(i) 1:2500 City planning map 1 set (Provided by the Aizu City Planning Department)
(ii) 3D buildings specified for preservation were built by local carpenters and contractors some 10s of years ago and there were no blueprints remaining.
(iii) The data of heights and distances of poles along the street (Provided by Tohoku Power Electric Co.Ltd)
All data other than the above and necessary work to create 3D-CG data were done by the Aizu University team.
(a) Setting for accuracy to withstand use as 3D-GIS (building spacing, height). [for the objective ($\alpha$)]
(b-1) Gathering and editing of digital images for texture mapping.
(b-2) Develop a program to create various roof types automatically. programming. [for the objective ($\beta$)]
(e) Design of the overall database. [for the objective ($\gamma$)]

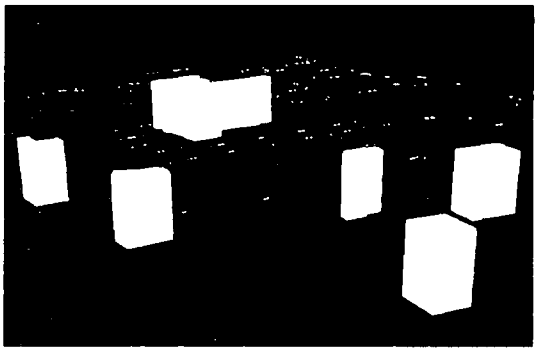


Figure 1: 3D digital base map

## 5 Creating the Digital Base Map

In general, automatic recognition of a design sheet is difficult. But automatic recognition of a street map at a scale of 1:2,500 is the easiest target, because there are only lines representing street boundaries and block boundaries [6]. First, we scan the map with a scanner at a resolution of 400 dpi, raster data elements that are obtained are well separated from each other. When we do a transformation from raster data to vector data, we can recognize a closed polygon (a set of short vectors) as a candidate for a house. Roads and rivers are understood as long lines. An A1-sized map is converted to raster data of about 6 Mega bytes. Then finally converted into vector data of about 400 KB in size. Other line segments should be candidates for houses. On one map, there are about 93,000 candidates for houses and buildings. Using a specific area as a threshold value, we distinguish non-buildings such as playgrounds and parks from housing lots. In total, we read ca.8,700 closed polygons as building or house sites. Those three files of 2D DXF file formats are converted to Wavefront formats with their Z value 0 in order to use the data in 3D-CG. The field survey reveals that due to quick devastation in the central business district, polygons on a map do not match the actual building site at times. When we can not derive the situation clearly from the map, we visit the site ourselves and to determine the correct position of a building.

Table 1 The Heights and Distances of Poles

| Pole ID | Height (m) | Distance from the pole before (m) |
|---|---|---|
| Nakamachi 51 | 13.5 | — |
| 52 | 13.5 | 29.0 |
| 53 | 15.0 | 26.0 |
| 54 | 13.5 | 30.0 |
| 55 | 15.0 | 31.0 |
| 56 | 13.5 | 28.0 |
| 57 | 13.5 | 34.0 |
| 58 | 13.5 | 17.0 |
| 59 | 13.5 | 39.0 |
| 60 | 13.5 | 21.0 |
| 61 | 13.5 | 18.0 |
| 62 | 12.5 | 24.0 |
| Nakamachi 63 | 14.0 | 33.0 |
| NanokaMachi45 | 13.5 | — |
| Ohmachi9 | 12.3 | — |

## 6 The Criteria for Building Heights

We have beautifully re-created the urban walk-through images [7][8]. However, when we think of the actual application for urban planning, the 3D-CG models must have the preciseness that the urban planner demands. The horizontal distance between buildings are adjusted by the field check. As for obtaining more accurate building heights efficiently and economically, we utilize the data for distances and heights of electric poles along the street which are property of Tohoku Electric Power Company. The Tohoku Electric Power Company personnel in charge says the distances have a ca.± 1m margin of error and the heights have ca.± 10 cm in accuracy. This means that the accuracy is ca.± 10

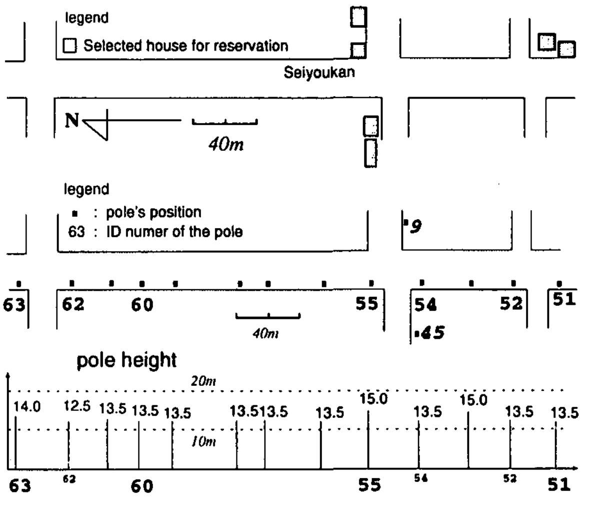


Figure 2: The Plan View of the Poles along Ohmachi

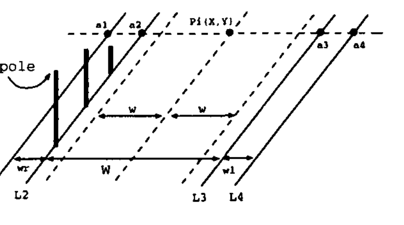


Figure 3: A Map of Poles and Buidings

In the poles' inter-relationship shown in Figure 2 and 3, we state how to estimate a building height based on a photogrametrical method using the known pole's height. First, to get a better acuracy, a photo must include two poles. Assume the scale of photo s is $s = \sum_{k=1}^{n} l'_k / \sum_{k=1}^{n} l_k$ (n means more than 2 poles): where the actual height of poles is $l_k$ and the nominal height in the photo is $l'_k$.

1 The road width (one lane is w) W
2 The sidewalk width Wr, Wl is constant.
3 Poles and buildings run paralle to each other along the street.
4 Any point $P_i$(X,Y) in Figure 3 can be decided by the corresponding point $p_i$(x,y) in the photo. X = f (x), Y = f (y) where the function f is the scale s.

Figure 4: A Photo Look at the Pole 59 from the 61

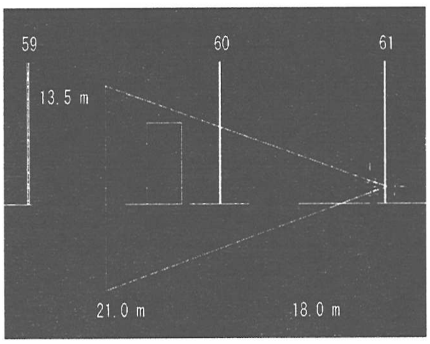


Figure 5: Calculation by 3D-CG

5 The point $a_j$ which vertically crossing against the roda can be read by the point $p_i$(x,y) in the photo.
6 We calculate the building actual height $H_j$ which locates at the point $a_1$ based on the nominal height $h_j$ in the photo. $H_j = (1/s)\ h_j$

As an example, we set a camera at the mid-point on the road at the pole 61 and take a photo toward south (Figure 4), then estimate the building height based on the known height of the pole 59. We use a camera of focus length 24 mm positioned at 1.5 m in height. A commercial 3D-CG software can set its virtual camera's lense focus length as we wish. We allocate the poles according to their actual spatial relationship in the virtual space. Array buildings as boxe shapes in the virtual space (Figure 5). We modify the location of the virtual building in the virtual space manually and find out the better position which can match the real condition. In the case of the central building in Figure 5, its height is estimated at about 8 m. This estimated value matches the height measured by the architectural designer.

## 7 Creating a Building Models

In this paper, we categorize building models into

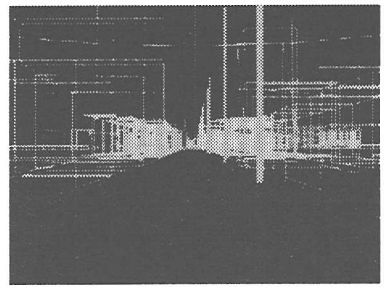

Figure 6: 3D-CG based on the Calculation

three groups, based on their detail and data size.

**level 1:** the most detailed Building Model such a few such as landmark buildings in Aizu, shown in Figure 7.
more than 1Mb planes and and a few Mb texture mapping images.)

**level 2:** a Building Model Mostly from Texture Mapping shown in Figure 8 [9][10][11].
categorized shapes consists of planes (less than 1Kb) and has 1 or 2 texture mapping images per building (2Mb).

**level 3:** The Simplest House Models shown in Figure 9.
the model consists of planes (less than 1Kb)

### 7-3-1 level 1: the Most Detailed Building Model

In creating a CG model of buildings which are designated to be preserved, the detail of doors and windows are made from polygons and not as texture images. This is because the CG data may be used as a blue print for the maintenance work in future. It contains a large number of polygons so that the size of the data is ca. 1 MB in a type of Wavefront format. Only roofs and walls are texture-mapped. The size of image data is about 1 Mb in a the JPEG format. So altogether, the size for data of a building is ca. 2 Mb. Currently, it is a common practice to create 3D CG data in OpenGL format. However, our example consists of different data types; I.e., data created manually using commercial CG software and data created using a program in batch mode.

### 7-3-2 level 2: a Building Model Mostly from Texture Mapping

Recently, many publications reveal how to create an urban landscape using 3D-CG technology from aesthetical viewpoint [9][10][11]. Their major approach is representing the building walls with many windows by texture mapping. This method is valid for large cities where along the wide roads, most of the buildings are reinforced concrete building with flat wall surfaces. However, it is difficult to apply the

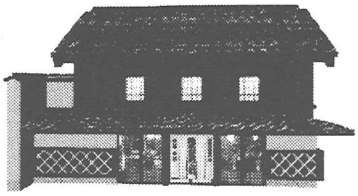

Figure 7: the most detailed building

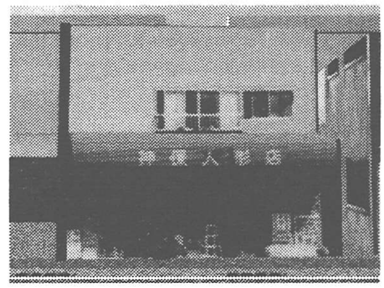

Figure 8: the texture mapped building model

same approach in rural towns where along the narrow streets most of buildings are traditional wooden houses. In the Western towns, residential houses have simpler shapes with shallow eaves or with no eaves so that it is possible to represent houses by fewer texture mapping images. To the contrary, Japanese houses in Monsoon Asia have deeper eaves so that they themselves cast long shadows on the walls. This makes it very difficult to create a texture map image out of a photograph. It takes more than 30 minutes per photo to retouch and remove the shadow effects using commercial painting software. In order to create hundreds of houses and buildings, the retouching work will take several hundred hours. To solve this retouching shadow problem, we developed a series of image processing programs. (1) Geometrical correction: Due to narrow roads, it is difficult to take a photo by setting the camera just in front of the house so we must set the camera at oblique angles. (The width of a one-lane street is ca. 3 m and the width of a two-lane street is ca. 7 m including the sidewalk.) We make geometric corrections by designating four points on the photo. (2) In an image, we designate number of small squares. By referencing the RGB values in those areas, we create tone difference between bright area and shadow area. (3) Building elements such as windows, doors, and pillars have special characteristics, with edges that are either horizontal or vertical. We emphasize these through image processing. (4) When we emphasize the vertical-ness and horizontal-ness, we lose the curved elements such as letters on a signboard. Thus, before the emphasizing process for verticals and horizontals, we temporally remove the areas such as signboards into a memory buffer. After the emphasizing process, we recall the stored image back and overwrite them onto the emphasized image. In this way, we can preserve the curved elements while emphasizing the vertical-ness and horizontal-ness in the building surfaces. (5) By using the same method stated at item 4, we can remove electric poles. On the whole, we can reduce the retouching time to less than 3 minutes per photo [12][13]. We match the coordinates of a side of a house along the street with the edge in the image processed.

**7-2-3 level 3: The Simplest House Models**

The objective of this paper is to visualize houses and buildings along the main street so that we can make the house data simpler, what to locate behind the main street, in order to reduce the total database size and make it as small as possible. On the other hand, the simplified house models should keep the minimum preciseness necessary to enable them to be used for urban planning. As we can not field check all houses in the city (ca. 30,000), we made sampling field survey based on 20 mesh areas covering the whole city. The total sample number was 600 houses. We checked the roof type and the height of a house or a building. This sampling field survey tells that the distribution of building heights is a function of the street widths (lanes) where the houses and buildings are located.

We make a program to create different roof shape models representing the roofs observed in Japan [14], parametrically (Figure 4). As shown in Figure 5, we designate any one of 20 basic roof types and give the values of their parameters. Then the program create a 3D-CG shape model which consists of only planes. The base of the house model is a rectangle plane. The data size of a house model is less than 1 Kb [15]. This materializes our objetct ($\gamma$).

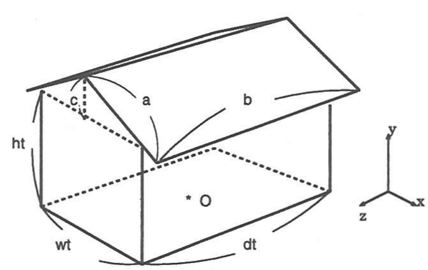


Figure 9: Paramers Representing a Gable Type Roof House

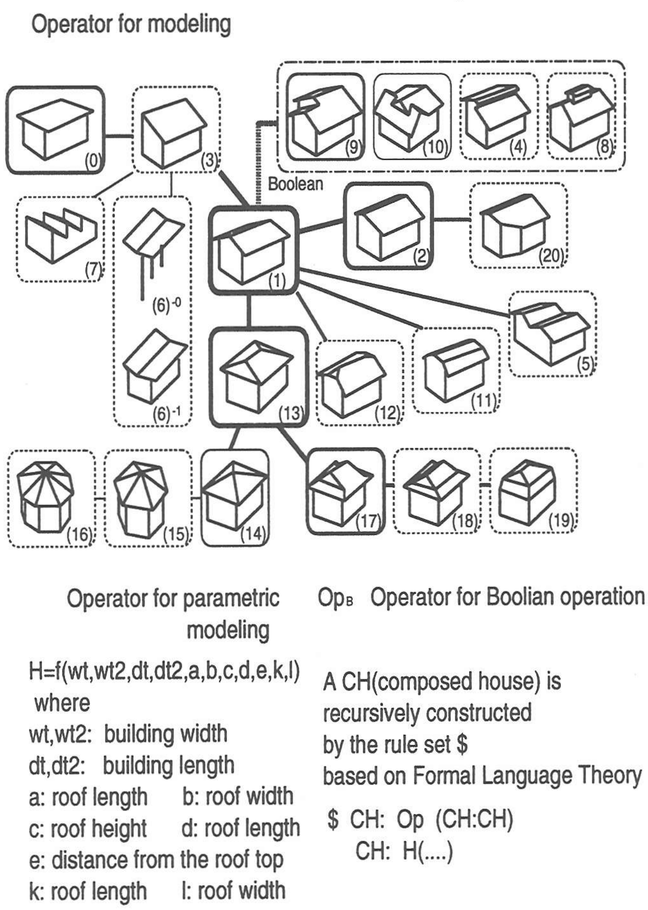


Figure 10: An Outline of Parameters for Various Roof Types

Figure 11: The Simplest House Model

## 8 Database Design

We adopt Wavefront data formats for three different building models in common. The reason is that there is no established database format for 3D-GIS yet. Among many database style, we try to use a relational database using the building number as the main key for easer maintenance sake. Here, we call each data table as directry, naming like from Dir.1 to Dir. 13. Figure 12 shows the relationship of thirteen tables (directries). We have to create those tables manually. Some 3D-CG content creating private companies in Tokyo answer that they are so busy for creating the content itself that they can not think how to create a better database.

```
Dir.1 Closed polygon data representing
      buildings
      (The total number 8,700 in a A1 size
       1:2,500 sheet)
field-1 Building ID (use this as the master key)
field-2 address
        (ASCII text file, up to 50 characters)

Dir. 2  The size of a closed polygon
field-1 Building ID
field-2 assume the left lower corner in a map
        point of the polygon as (x1, y1). the
        distance from the original point
        in the map.
        (ASCII, integer long)
field-3 coordinate values of each polygon
        edge (xn,yn) measured from (x1,y1)
        (ASCII, integer short)
field-9 (x8,y8) we assume a building
         site
         consists of up to 8 edges.

Dir. 3  Heights of buildings
field-1 Building ID
field-2 height data
        (ASCII, integer short)
field-3 the floor numbers.

Dir. 4  Detail level
field-1 Building ID
field-2 which detailed models
        (7-3-1,7-3-2,7-3-3)

Dir. 5  Roof type
      (at Dir.
 4 , value of field-2 is 7-3-1)
field-1 Building ID
field-2 open Dir.12 for visualization
        calculation.

Dir. 6   Roof type
        (in Dir.4, the value of
         field-2 is 7-2-2 or 7-2-3)
field-1 Building ID
field-2 the index representing each
        roof type (Figure 5)
        (e.g., 1: gable、2: hip roof etc)
        (ASCII, integer short)
```

```
        (in case of two floor building, the roof
         type of the second floor is the type)
If we have a field surveyed actual data,
we use it. If not, we assign a nominal
data based on statistics.)

Dir. 7   Roof type model file
       (gives each model planes data designated
         in Dir.4 as Wavefront data formats)
field-1   1: a gable roof
             (text file)
field-20   (up to field-20)

Dir. 8   Texture mapping image data
field-1 Building ID
field-2 ID of each texture iamges
         (e.g., 0 value in case of no texture)
        image data itself is so large that
        we store them in Dir. 13.

Dir. 9   Road file
field-1 Road ID
field-2 width
(alley, one lane, two lanes, 4 lanes)
         (ASCII, integer short)
field-3 the coordinate values of two end
         points. (the distance from the
         original point in the map.)

Dir.10   A file tells the relationship of
         each building and the road along
field-1 building ID
field-2 road ID   where that building faces.
        (When we assign the value using Dir.6
          field-2 statistically. we assign an
          estimated value
          based on our field survey.)

Dir.11   A file of closed polygon which
         is not building sites.
         (such as playground, parks)
field-1 polygon ID
field-2 assume the left lower coner point
         coordinate as (x1,y1),
         give the distance value from the
         original point in the map.
        (ASCII, integer long)
field-3 the coordinate values of each edge
         (x2,y2) distance from the point
         (x1,y1). (ASCII, integer short)
  ......
field-32   (x33,y33)
            In Aizu, the largest edge number
            is 33.

Dir.12 Shape data described in Dir.5.
Dir.13 Image data itself described in Dir.8.
```

We store the necessary data in this database. The simplest models (4-2-3) are created by a C language program in batch mode. We make a program which can convert Wavefront data format to OpenGL data format or other way around. As for very detailed model, it is economical to use a commertial architectural 3D-CAD system which provides the interface to create Wavefront data format.

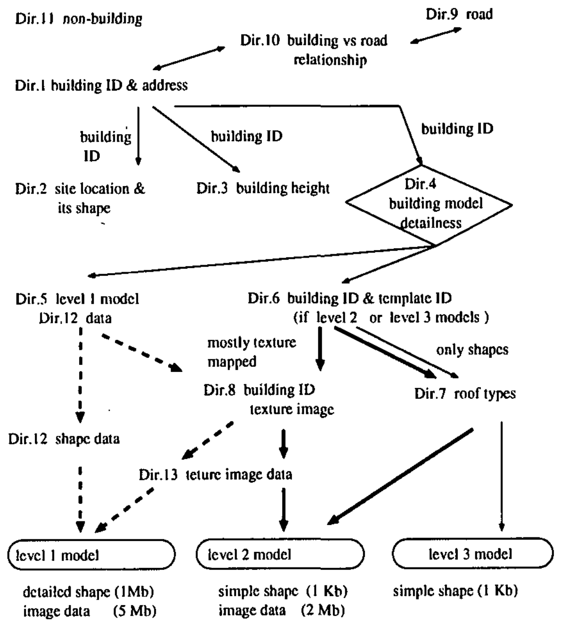


Figure 12: Relationship among 13 directries

## 9 Conclusion and the Future Study

This case study represents an interdisplinary study areas who are the traditional urban planning in the civil enginnering and 3D computer graphics science. We have to deal with several hundreds or several thousands of building and house in an area of several square kilometers in a traditional Japanese local city.

As the total number survey of more than several thousands of building, we propose a mixed method: i.e., we make detailed models manually and simpler models automatically and we integrate them in the same data format.

We materialize the newness proposed in the section 2. First, utilizing an existing data provided by the local power company, we estimate the building height by means of photogrametrical method based on the known heights and distances of electric poles. The estimated values of heights on several landmark buildings are well matched to the values measured by the local architectural designers. [the objective ($\alpha$)].

We make working time smaller to create texture mapping images by means of new image processing programs. [the objective ($\beta$)].

We create simpler building models by means of parametric method. We design a relational database able to integrate different data types so that the visualization program can be independent from the database. [the objective ($\gamma$)].

There are many items to be pursued as for creating 3D-GIS of Japanese cities. We would like to continue our study in order to clarify those future study items such as what to do 3D map simbols for 3D maps [16].

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