# Automatic 3D Symbol Mapping Techniques for Construction of 3D Digital Map

Seungyong Park, Jaebin Lee, Kiyun Yu ,Yongil Kim

School of Civil, Urban, and Geosystem Engineering, Seoul National University
(slpak1, dama77, kiyun, yik)@ snu.ac.kr

**ABSTRACT:** Over the years, many researches have been performed to create 3D digital maps. Nevertheless, it is still time-consuming and involves a high cost because a large part of 3D digital mapping is conducted manually. To compensate this limitation, we propose methodologies to represent 3D objects as 3D symbols and locate these symbols into a base map automatically. First of all, we constructed the 3D symbol library to represent 3D objects as 3D symbols. In the 3D symbol library, the attribute and geometry information are stored, which defines factors related to the types of symbols and related to the shapes respectively. These factors were used to match 3D objects and 3D symbols. For automatic mapping of 3D symbols into a base map, we used predefined parameters such as the size, the height, the rotation angle and the center of gravity of 3D objects which are extracted from Light Detection and Ranging (LIDAR) data and 2D digital maps. Finally, the 3D map in urban area was constructed and the mapping results were tested using aerial photos as reference data. Through this research, we can identify that the developed the algorithms can be used as effective techniques for 3D digital cartographic techniques

**KEY WORDS:** 3D object, 3D symbol library, 3D symbol mapping, LIDAR

## 1. INTRODUCTION

The proliferation of digital mapping techniques, computing devices and the Internet has fostered a growing interest in 3D (3 Dimensional) digital map. 3D mapping techniques are augmented continuously in urban planning, LBS (Location Based Service), virtual reality and etc. (MOCT, 2004). The 3D digital mapping is a processing technique to symbolize a real world automatically in a virtual space. Over the years, many related researches have been performed to create 3D digital maps. For example, to improve 3D map's realism, texture mapping with aerial photos is proposed (C. Fruh, 2003). In 2004, Pedro Company developed an optimization program to construct 3D model from simple sketching works (Pedro Company, 2004). It is also proposed that integrate various data sources such as 2D CAD map data, DEM (Digital Elevation Model) and the information of 3D objects to create 3D digital map efficiently (Q. Wu, 2004). These researches can be classified as methodologies to improve the realistic representation of 3D digital maps (G. Sidiropoulos, 2006). However, under these methodologies, it is still time-consuming and is very costly because a large part of 3D digital mapping is conducted manually.

To circumvent this limitation, we propose algorithms to represent 3D objects as 3D symbols and locate these symbols into a base map automatically. First of all, we constructed a 3D symbol library to represent 3D objects as 3D symbols. In the 3D symbol library, the attribute and geometry information are stored. The attribute information defines factors related to the types of symbols and geometry information defines factors related to the shapes. In this study. these factors were used to match 3D objects and 3D symbols. For automatic mapping of 3D symbols into a base map, we used predefined parameters such as the size, the height, the rotation angle and the center of gravity of 3D objects. Then, the factors described above are extracted from LIDAR (Light Detection And Ranging) data and 2D digital maps. By classifying LIDAR data and using the attribute information of 2D digital map, the factors are extracted to search the 3D symbol matching a 3D object in the symbol library. The parameters to locate the 3D symbols into the base map are also extracted by analyzing LIDAR data. Finally, the 3D map in urban area was constructed and the mapping results were tested using aerial photos as reference data.

Through this research, we found that the developed the algorithms can be used as effective techniques for 3D digital cartographic techniques. Now, we are focusing on extracting valuable information from aerial photos for automatic mapping of 3D symbols to compensate developed algorithms.

## 2. ESTABLISHMENT OF SYMBOL LIBRARY

To perform the automatic matching 3D symbol to a 2D base map, the 3D symbol library should be predefined. In this library, the geometry information of 3D symbol which define the shape of symbols and the attribute information which define the class and necessary parameters to be used in automatic matching process are stored. The class attributes define the types of symbols such as apartments, commercial buildings, governmental office, etc. The parameters consist of gravity centers of the objects, translation parameters, rotation parameters and etc. In this study, we constructed a 3D symbol library, only considering buildings which are classified in 1:1,000 2D digital maps. The library are constructed in ARC/GIS commercial GIS software and the automatic matching process are realized using VBA programming language

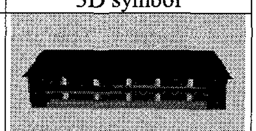
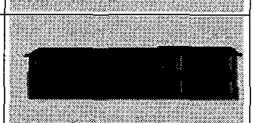
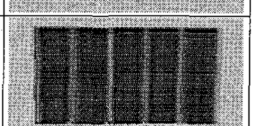
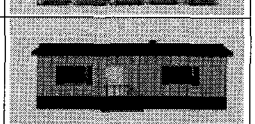
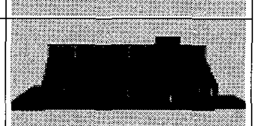
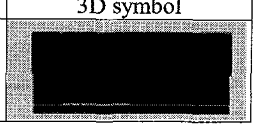
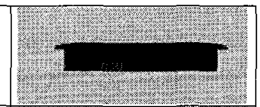
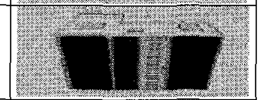
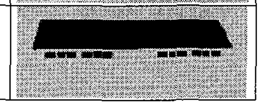
### 2.1 Geometry information of 3D symbols

To construct the geometry information of the 3D symbol library, we used the classification defined in 1:1,000 national digital maps. Table 1 shows the classification criteria used in the paper and Table 2 shows some examples of the library constructed in ARC/GIS software

Table 1. Example of classifications used in the library

| Class code | Class name | Object type |
|---|---|---|
| AAA001 | General houses | Polygon |
| AAA002 | Public houses | Polygon |
| AAA003 | Apartments | Polygon |
| AAA004 | Buildings | Polygon |
| AAA005 | Green houses | Polygon |
| AAA006 | Buildings under construction | Polygon |
| AAA007 | Unauthorized Buildings | Polygon |
| AAA008 | Commercial buildings | Polygon |
| AAA999 | Unclassified buildings | Polygon |

Table 2. Examples of 3D symbol library

| Class code | Class name | 3D symbol |
|---|---|---|
| AAA001 | General Houses |  |
| AAA002 | Public Houses |  |
| AAA003 | Apartments |  |
| AAA004 | Buildings |  |
| AAA005 | Green houses |  |
| Class code | Class name | 3D symbol |
| AAA006 | 공사중건물 |  |
| AAA007 | Unauthorized Buildings |  |
| AAA008 | Commercial building |  |
| AAA999 | Unclassified buidings |  |

### 2.2 Attributes information of symbol library

To define the shape of symbols and match symbols to 2D base map automatically, various kinds of information are necessary. In this paper, the following definitions were used.

**2.2.1 Class ID**: To find the appropriate 3D symbols from the constructed library, the common information between a 2D base map and a symbol library are necessary. Generally, the attributes such as unique IDs, primary keys, object names and classification ID are employed. In this paper, we defined class codes from digital map as Class IDs and used this attribute to search the appropriate symbol in the library.

**2.2.2 Symbol shape parameter; X and Y**: These parameters define the shape of each symbol. The attribute X means the length of a symbol in the X-direction and Y means the length of a symbol in the Y-direction. When creating a library, these values are determined by default values. Then, they are modified when mapped onto the 2D base maps.

**2.2.3 Symbol shape parameter; Z**: This parameter also defines the shape of each symbol. The attribute Z means the height of a symbol in the Z-direction. This value is determined by a default value when creating a library. Then, it is obtained automatically from LIDAR (Light Detection and Ranging) data which are co-registered with 2D digital maps (see equation (1)).

$$Z = \frac{1}{n}\sum_{i=1}^{n} GH_i \qquad (1)$$

Where $GH_i$ is the height value of a LIDAR point grouped by a polygon in 2D digital map and $n$ is the number of points in the group.

**2.2.4 Mapping parameters; $x_t$ , $y_t$ and rotation angle ($\theta$):** These parameters are used for automatic symbol mapping. To find the locations of which symbols are placed, gravity centers of objects in 2D digital maps are used. The values of x_t and y_t mean the gravity center of objects to be mapped. They were computed with equations 2 and 3.

$$x_t = \frac{1}{6A}\sum_{i=0}^{N-1}(x_i + x_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \tag{2}$$

$$y_t = \frac{1}{6A}\sum_{i=0}^{N-1}(y_i + y_{i+1})(x_i y_{i+1} - x_{i+1} y_i) \tag{3}$$

Where, $x_t$ and $y_t$ are coordinates of vertices of a polygon and $A$ is the area of a polygon. The values of $\theta$ are rotation angles of objects according to Z-direction which are obtained from 2D polygons on 2D digital maps. Fig. 1 shows the parameters defined in the paper and constructed in the library.

| FID | AREA | PERIME | MAX_LEN | MINLEN | HEIGHT_ | CENRO_X | CENTRO_Y | ANGLE |
|---|---|---|---|---|---|---|---|---|
| 20 | 912,998919 | 176,58928 | 76,309500 | 11,964420 | 82,153390 | 233653,716221 | 317905,535148 | 0,070838 |
| 49 | 888,190904 | 177,08122 | 77,009526 | 11,533520 | 81,931368 | 233654,032538 | 317957,523358 | 0,038703 |
| 2 | 878,906030 | 176,82972 | 77,079683 | 11,402564 | 81,254812 | 233653,924516 | 317853,391408 | 0,374638 |
| 98 | 630,223442 | 128,03579 | 51,993660 | 12,121159 | 80,947093 | 233736,482013 | 318072,938985 | 1,109384 |
| 77 | 904,294139 | 177,77922 | 77,209756 | 11,712174 | 79,912101 | 233657,449228 | 318009,52821 | 1,024404 |
| 99 | 1014,779986 | 201,44869 | 89,146392 | 11,383298 | 79,457331 | 233659,876998 | 318073,22738 | 0,043834 |
| 116 | 883,724002 | 172,54264 | 74,125497 | 11,921998 | 79,370996 | 233751,965341 | 318125,376937 | 0,007485 |
| 115 | 1023,846765 | 200,88438 | 89,038438 | 11,498930 | 78,419198 | 233659,877273 | 318125,025268 | 0,007485 |
| 179 | 416,499548 | 96,989241 | 34,725309 | 11,994121 | 78,041624 | 233632,764228 | 318281,680361 | 0,783736 |
| 178 | 636,799165 | 133,58042 | 52,157683 | 12,209115 | 77,972101 | 233682,277234 | 318281,610756 | 0,097654 |
| 180 | 431,197677 | 98,042227 | 34,870782 | 12,365587 | 77,872724 | 233731,760323 | 318284,728569 | 1,352348 |
| 135 | 774,595745 | 159,45773 | 66,999587 | 11,561202 | 77,769516 | 233752,668811 | 318179,839042 | 0,734629 |
| 101 | 773,300560 | 111,63627 | 28,459827 | 27,161159 | 77,539923 | 233832,004139 | 318066,684287 | 0,437383 |
| 151 | 1044,422330 | 204,95391 | 89,259521 | 11,700963 | 76,482342 | 233659,904701 | 318229,146106 | 0,793639 |
| 219 | 881,747428 | 175,94512 | 21,150955 | 41,688303 | 76,164486 | 233754,458141 | 318371,727451 | 0,963527 |
| 85 | 978,803626 | 143,41409 | 39,631358 | 24,697706 | 76,071086 | 233841,264398 | 318005,400908 | 0,393733 |
| 152 | 773,978519 | 159,75522 | 67,098635 | 11,534937 | 75,957284 | 233752,729289 | 318232,277746 | 0,876364 |

Figure 1. Examples of attributes of constructed library

# 3. EXPERIMENT AND ANALYSIS

## 3.1 Data description and target Area

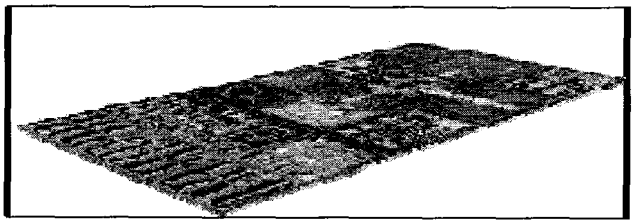
The target area for this study was Daejon, South Korea where there are mainly apartments and commercial buildings. Fig. 3 shows LIDAR data, aerial photos and 2D digital maps to be used in the study. LIDAR data was captured using a high-end airborne laser system which is developed by Optech company. The specification of LIDAR data is presented in Table 3.

Table 3. Specification of LIDAR dataset

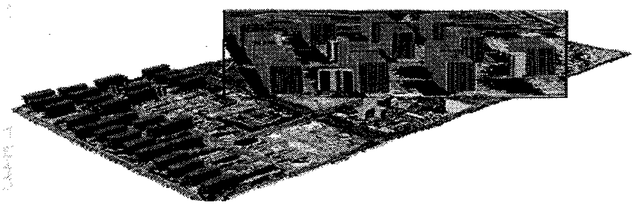
| | |
|---|---|
| Altitude | 200~3000m |
| Vertical accuracy | <15cm (flying height is less than 1200m)<br>35cm (flying height is 3000m) |
| Horizontal accuracy | 1/2000 * flying height |
| Transmission angle | 0~50° |
| Reflection angle | 12bit |
| Multi returns | 1~4th range |

## 3.2 Construction of the 3D digital map

The general goal of a 3D digital map is realistic visualization and database construction of a real world. For the realistic visualization, we used the 3D base map using aerial photos in the study. This map was constructed based on co-registration techniques between LIDAR data and aerial photos. Then, by using the 3D symbol library and 2D digital map, the 3D symbol mapping was conducted. In this process, the pre-defined parameters were used. Fig. 2 shows the processing flow of the 3D symbol mapping graphically.



(a) 3D base map



(b) 3D digital map

Figure 2. The process of 3D symbol mapping

## 3.3 Analysis

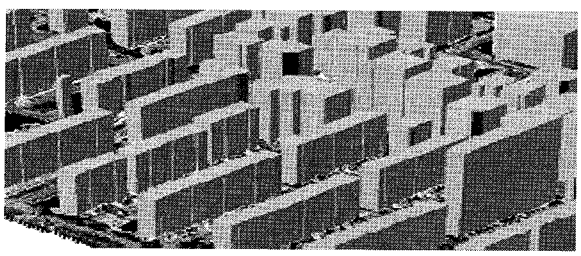
The assessments of mapping results were conducted in several ways. To investigate the accuracy of mapping results, we compared the area, perimeter and the degree of matching of the classes between the 2D base map and the 3D digital map. The area ratio and perimeter ratio of objects were calculated using Eqs. 1 and 2. Table 4 shows the mapping results from the accuracy test.

Table 4. The accuracy test of mapping results

| Class codes | The number of objects | The matching accuracy (%) | Area ratio (%) | Perimeter ratio (%) |
|---|---|---|---|---|
| AAA001 | 10 | 10 (100%) | 110 | 114 |
| AAA002 | 0 | 0 (100%) | 110 | 107 |
| AAA003 | 30 | 30 (100%) | 110 | 99.3 |
| AAA006 | 4 | 4 (100%) | 110 | 95.0 |
| AAA007 | 12 | 12 (100%) | 110 | 93.1 |

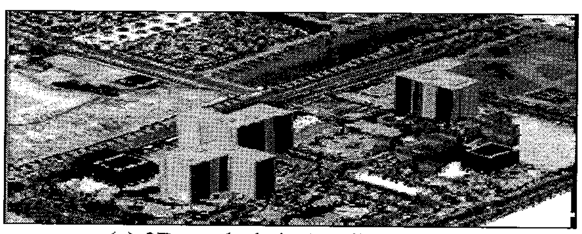
| | | | | |
|---|---|---|---|---|
| AAA008 | 19 | 19 (100%) | 110 | 102 |
| $\sum$ | 75 | 75 (100%) | 110 | 101.73 |

From table 4, we can see that there is no error in the automatic class matching process between the classes of 2D map objects and the classes of the 3D symbol library. The area ratio shows that the area of the symbols increases after the symbol mapping. This is normal because we set up the safety coefficient as 1.1 to cover all of the objects in 2D maps with symbols [as much as possible-??]. The perimeter ratio is also increased a little bit due to the fact that the complex 2D objects were replaced by relatively simple 3D symbols. However, this ratio does not affect the location accuracy of objects. Fig. 3 shows the final product constructed using proposed methodologies. From this figure, we can identify that the relatively large objects such as apartments and commercial buildings can be represented well with symbols. However, it is hard to represent the small ones such as general houses and public houses with symbols because their shapes are so diverse. Therefore, various symbols and classification of objects are necessary and in more detail.



(a) 3D visualization with 2D polygons

(b) 3D visualization with 3D symbols



(c) 3D symbols in 3D digital maps

Figure 3. 3D symbol digital map

## 4. CONCLUSIONS AND FUTURE WORKS

In this paper, we presented a methodology to construct 3D digital maps automatically using 3D symbols. The algorithm explicitly formulates step-by-step methodologies. First of all, we created a 3D symbol library consisting of geometry information and attribute information of 3D symbols. Then, by using LIDAR data and 2D digital maps, the parameters to be used for mapping were extracted. The results clearly demonstrate that this approach can be applied to construct 3D digital maps. However, in the proposed algorithm, we only consider the simple objects of which shapes are rectangular or perfect square for 3D symbol mapping. This limits applicability of the developed methodologies. Thus, we are now focusing on developing the algorithms dealing with the complex objects such as circles and multi-polygons. Also, to increase the efficiency of updating 3D symbol maps, we are developing the classification algorithms of objects using LIDAR data

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