Automatic Configuration of Cityscapes

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In this study, Japanese cityscapes in the Tokyo metropolitan district are depicted by using algorithmic computer graphic configurations. A numerical analysis of the three-dimensional configuration is performed to grasp the characteristics of its form. The distributions of the heights of the buildings in the city blocks are observed to be similar to a normal distribution. As random numbers based on a normal distribution can be generated using the mean and variance as parameters, it is possible to generate the forms of cityscapes using computer graphics configurations. The planar shapes of buildings are able to be extracted from map data. Map data indicating the planar forms of buildings throughout Japan are provided by the Geospatial Information Authority of Japan. However, the heights of buildings are not included in the map data. We attempt to generate cityscapes automatically. We reproduced the appearance of a cityscapes using this approach.

Keywords: *computer graphics; cityscape; automatic configurations; map data*

1. INTRODUCTION

The objective of this study is to create cityscapes using algorithmic computer graphic configurations.

In Japanese cities, especially in the multiple city centres of the Tokyo metropolitan district, buildings are distributed diversely. In particular, the heights of the buildings are diverse and apparently random. Such diversity and randomness are observed not only within individual city blocks, but also within entire neighbourhoods, where low-rise and mid-to-high-rise buildings are densely and randomly crowded together. The mixture of these city blocks forms a three-dimensional (3D) cityscape and gives rise to its characteristics (see Figure 1).

The planar shapes of buildings can be extracted from map data. Map data containing the planar forms of buildings throughout Japan are provided by the Geospatial Information Authority of Japan [1]. However, the height data of buildings are not included in the map data. Although there are several ways to survey and determine the heights of buildings, we do not perform a survey in this study, but rather, attempt to generate cityscapes automatically.

2. ANALYSIS

We performed a numerical analysis of the 3D configurations as aggregations of the building volumes in Asakusa (see Figure 2), one of the historical city centres of Tokyo, to confirm the characteristics of the form of the cityscape.

Figure 3 shows the 3D configuration of Asakusa around the Senso-ji temple (the temple is not depicted). This cityscape model was generated by using digital map data, provided by the Geospatial Information Authority of Japan.

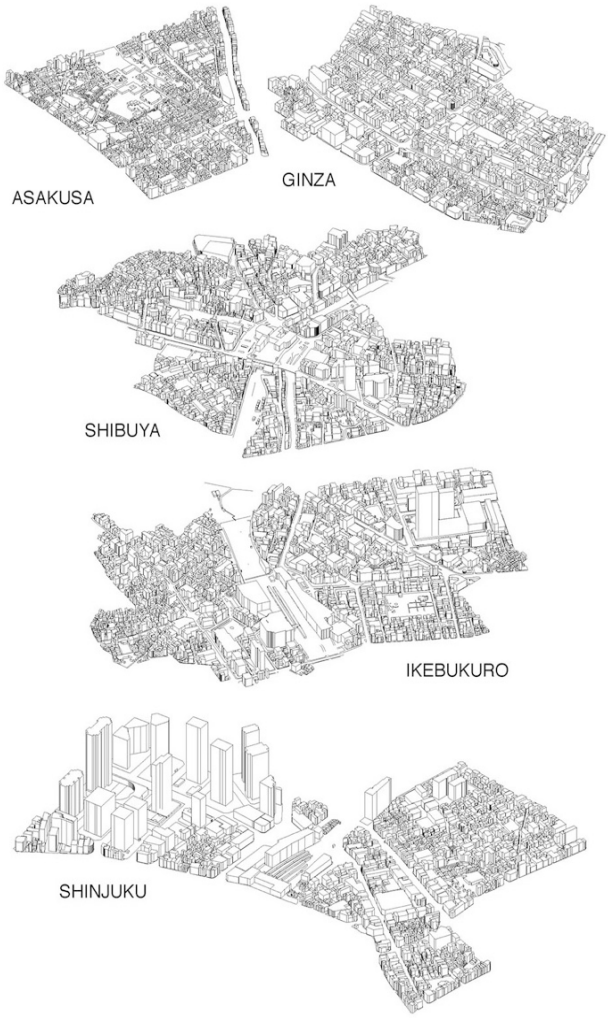

Figure 1. Cityscapes of city centres in Tokyo [2]

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Figure 2. Photos of Senso-ji temple and its surroundings in Asakusa (left) and the cityscape of Tokyo near Asakusa (right)

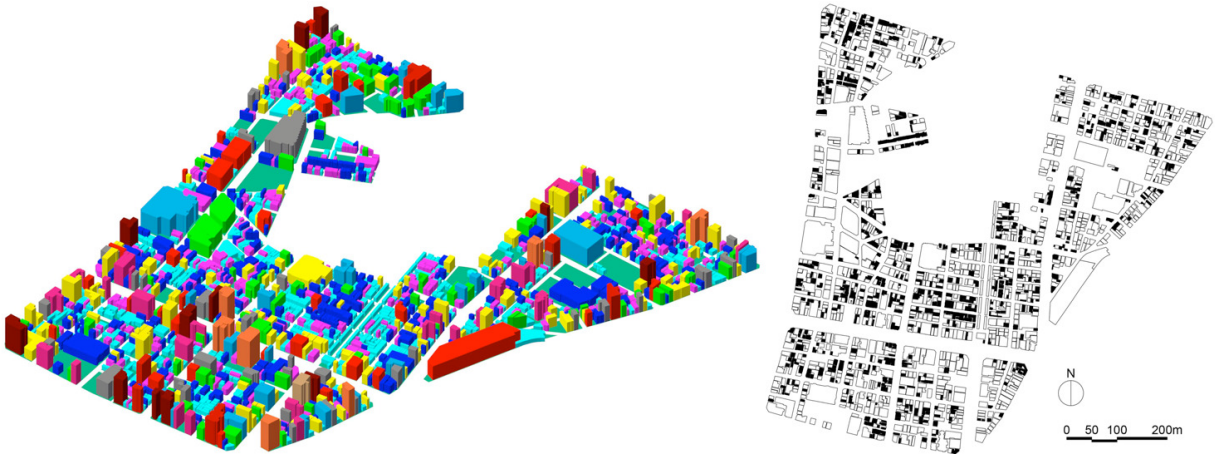

Figure 3. 3D configuration of Asakkusa (left) and the arrangement of small buildings (right)

The planar shapes of buildings can be extracted from the map data. However, the heights of buildings are not included in the map data. Thus, we referred to a commercially available map (ZENRIN [3]), which shows the number of floors of buildings, and inferred the heights of the buildings from this information.

In this area, 2,068 buildings having 1 to 15 floors are arranged. Table 1 shows, by the number of floors, the average building area, and the total area of small buildings (the building area is less than 50m^2, shown with black colour in Figure 3), and middle buildings (the building area is between 50m^2 and 200m^2), large buildings (the building area is more than 200m^2). And Figure 4 shows their distribution.

The correlation ratio between the building areas and the numbers of floors was 0.30. Thus, we could not observe the relationship between them.

In Asakusa, the total proportion of the number of the small buildings was 49.2%. Almost half of the total number of low-rise buildings (1 to 4 floors) were in this category. Although, recently in this area, mid-to-high-rise buildings had been developed, many small, old houses remain.

This area is designated as a "Commercial Area" by local authorities. For this area, the building coverage ratio (planer area / site area) is limited to 80%, and the floor-area ratio (total floor area / site area) is limited to 500-700%. According to the aforementioned data, the actual building coverage was 67.6%, and the actual floor-area ratio was 338.9%.

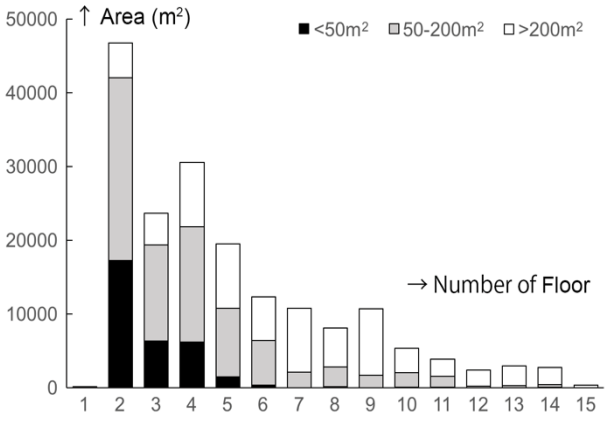

Figure 4. Distribution of building floors

Table 1. List of the average area and the total area of buildings by the number of floors

Floor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Num	2	898	373	383	153	77	33	40	29	28	1	8	11	11	1	2068
Area Avg (m)^2	61.4	52.1	63.4	79.8	101.6	160.3	327.8	202.6	370.6	190.9	185.4	305.1	273.7	249.2	389.8	84.3
<50 m^2	21	17277	6365	6208	1481	354	31	145	46	92	88	19	0	91	0	32218
50-200 m^2	123	24723	13041	15639	9292	6079	2121	2725	1682	1948	1471	218	280	358	0	79700
>200 m^2	0	4769	4236	8721	8725	5909	8665	5233	9020	3305	2334	2205	2731	2292	390	68534

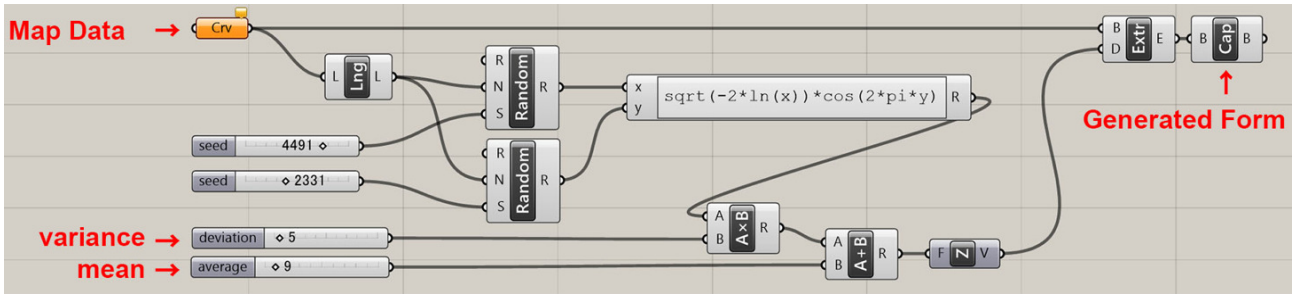

Figure 5. Algorithm used to generate 3D forms

3. CONFIGURATION: ASAKUSA

Generally, the planar shapes of buildings are given in the map data, but the building heights are unknown. Then, how can we generate the cityscape?

We used an algorithmic method to generate the heights of the buildings. The algorithm was described by Grasshopper [4], which is a plug-in for Rhinoceros [5] (3D modelling application). With Grasshopper, an algorithm is visually composed by arranging the components on a graphic screen. A screenshot of the algorithm in Grasshopper is shown in Figure 5.

In this algorithm, the planer shapes of the map data are entered into the "Crv (curves)" component, then the heights are generated by a calculation, and the planer shapes were extruded in the perpendicular direction with the calculated heights. Figure 6 represents a real cityscape (same as Figure 2), and an automatic configuration, which is generated by using this algorithmic method.

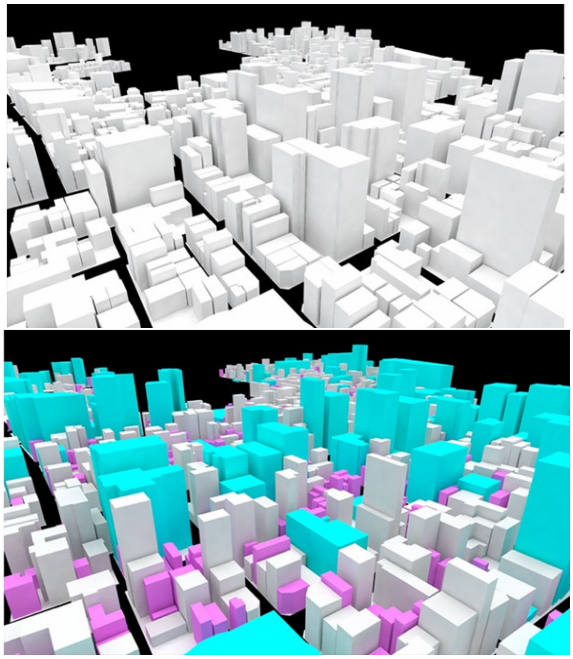

Figure 6. Cityscape of Asakusa: generated using actual heig–hts (top figure) and by automatic configuration (bottom figure)

The most significant part of the automatic configuration is how to calculate the heights. As is self-apparent, the distribution of heights does not follow a uniform random number. We generated the heights by using a random number of the normal distribution with the mean and the variance.

By applying the algorithmic method, we payed attention to the three categories of the buildings according to their planar area - small (< 50m^2), middle (50 to 200m^2), and large (>200m^2). The actual average and standard deviation of the number of floors are shown in Table 2.

Figure 7. Map data of Shinjuku

As we considered that large buildings will have a lot of ups and downs, we used the corrected value shown in Figure 2. When the floor heights are assumed to be 3.5m, the heights in each category were; small - mean 10.5m, variance 3.5m; middle - mean 17.5m, variance 7m; large - mean 31.5m, variance 14m.

Table 2. Averages and standard deviations of heights

	Actual value		Corrected value	
Plane Area	mean	variance	mean	variance
Small - 50 m^2	2.9	1.4	3	1
Middle 50 m^2 - 200 m^2	4.2	2.2	5	2
Large 200m^2	7.1	3.3	9	4

4. CONFIGURATION: SHINJUKU

Figure 7 shows the map data of Shinjuku (west side of the Shinjuku railway station), which is one of the major city centers in Tokyo with skyscrapers, including Tokyo metropolitan city hall.

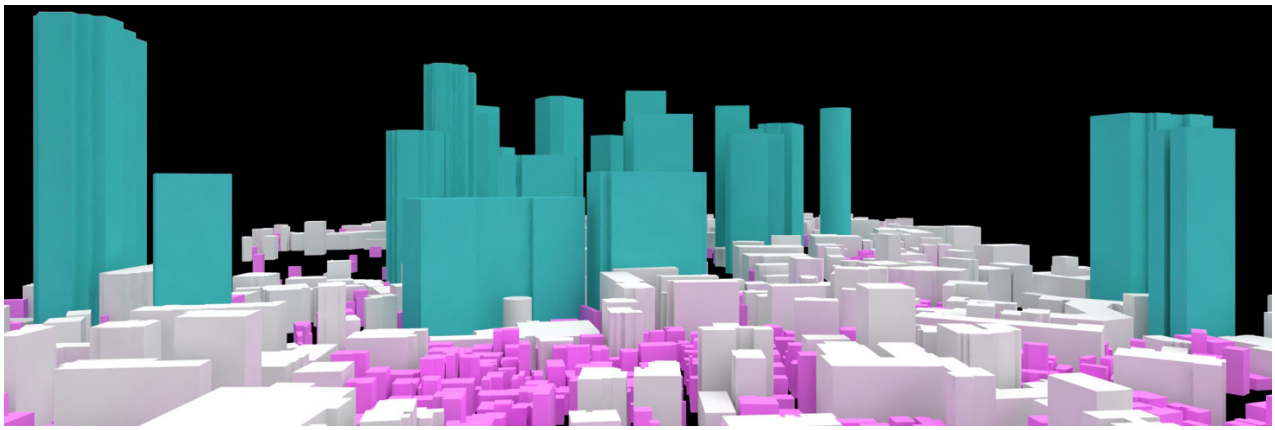

Figure 8. Cityscape of Shinjuku generated by automatic configuration

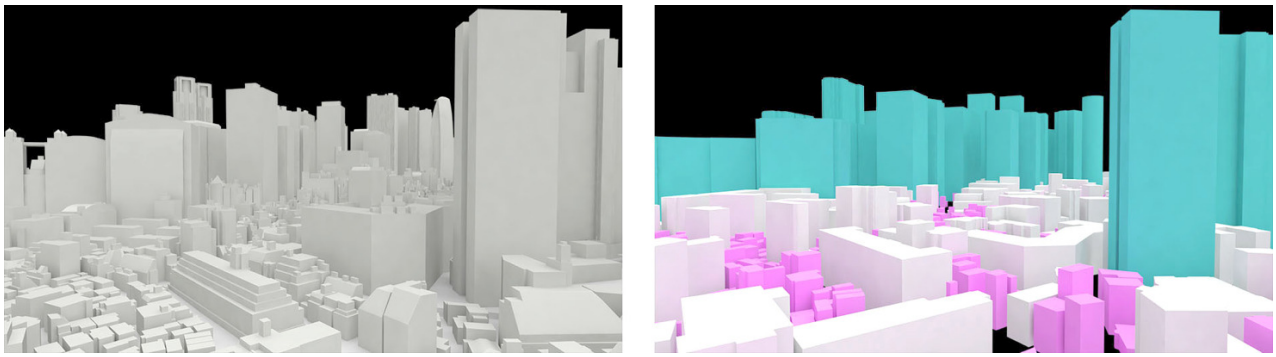

Figure 9. Cityscapes of Shinjuku: actual height (left), and automatic configuration (right)

While Asakusa is a historic city center, Shinjuku is a modern complex city center. Small houses are few, offi–ces, commercial buildings and condominiums are dominant.

In this case study, we categorized the buildings into three: high-rise buildings with over 100m in heights; middle buildings (<200m^2); and large buildings (>200m^2). Figure 8 shows the generated cityscape. While the heights of the high-rise buildings were generated according to their real heights, the heights of the middle and large buildings were generated by a normally distributed random variable with the mean and the variance: middle - mean 15m, variance 5m; large - mean 40m, variance 20m.

Figure 9 compares the actual cityscapes with the automatically configured cityscape.

5. CONCLUSION

For a case study, two Japanese cityscapes, Asakusa and Shinjuku, were depicted by the simple method, using the map data and the automatic configuration of the building heights. Categorization of buildings by their planer areas and usage of the normal distribution for generating building heights were considered to be effective.

As a matter of fact, the automatic configuration is nothing more than a rough prediction. However, its appearance is considered to expresses the image of the cityscape.

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АУТОМАТСКА КОНФИГУРАЦИЈА УРБАНИХ ПЕЈЗАЖА

Н. Андо

Рад приказује јапанске урбане пејзаже у велеградском подручју Токија коришћењем алгоритамских рачунарских графичких конфигу–рација. Извршена је нумеричка анализа тродимен–зионалне конфигурације да би се добиле карак–теристике њеног облика. Утврђено је да су дистрибуције висина зграда у стамбеним блоковима сличне нормалној дистрибуцији. Како се случајни бројеви засновани на нормалној дистрибуцији могу генерисати коришћењем средње вредности и варијансе као параметара, могуће је генерисати облике урбаних пејзажа применом рачунарских графичких конфигурација. Равне облике зграда

могуће је добити из мапа података. Подаци из мапа који показују равне облике зграда широм Јапана су добијени од Управе за геопросторне информације Јапана. Међутим, подаци о висинама зграда не налазе се на мапама. Покушали смо да генеришемо урбане пејзаже аутоматски. Направили смо репродукцију изгледа урбаних пејзажа применом овог приступа.