Analysis of City Range Image Using Digital Map

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Abstract In existing research about 3D city map, geometrical information of buildings' facade is derived from video image. In order to improve quality of the geometrical information, range image is used in our research. At first range image of existing buildings is acquired using laser scanners mounted on data acquisition vehicle which runs in the street. After removing obstacles from original range image, edge detection based segmentation can be used to extract range image of different buildings. Through matching patterns from edge map with that from existing 2D digital map, one building's corresponding range image can be determined. Thus precise geometrical information of the building's facade can be obtained from its corresponding range image.

Keyword Range Image, Digital Map, City Range Image, Range Image Segmentation, Canny Edge Detector, DP Matching

1 Introduction

As IT technology and market developed, demand for 3D model of the real world has increased rapidly in recent years. The 3D model representing existing objects or scene is very useful in many fields. [1] In general, 3D model of an object is a numerical model representing its geometric information (shape) and photometric information (color and texture). In this paper, we focus on obtaining geometric model of existing buildings in urban area and generating 3D city map.

In order to make 3D city map, existing 2D digital map can be used to reduce cost, improve productivity and reduce error. One example of 2D digital map is shown in figure 1. [3] One red polygon in the figure means one building. And number of floors of every building is available in this digital map. [3] The derived 3D geometrical model of buildings is shown in figure 2. Now height of buildings and geometric shape of the rooftop of buildings become available by using laser scanners mounted on helicopters or planes, such as in Mapcube. [21] But side faces of buildings in existing 3D map are mainly constructed from video images, precise geometric model of side faces of buildings is still unavailable in 3D map.

Instead of video image, range image of side faces of buildings is used to acquire more precise geometrical information in our research. At first, buildings are scanned by line scan type laser scanners mounted on data acquisition vehicle. After some processing, the range image is matched with 2D digital map using DP pattern matching algorithm, and range image corresponding to one building can be extracted. Precise geometrical model of facade of the buildings can be obtained from their corresponding range image.

Figure 1 Example of digital map [3]

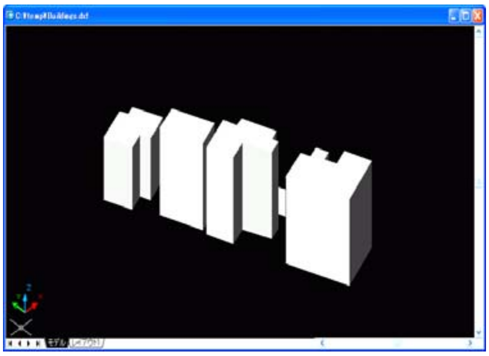

Figure 2 Example of 3D model

In the previous research, both matching between range images and matching between video image and digital map have been studied. Based on these, we concentrate on matching between range image and digital map.

In the following section, some related works are introduced. Our method of analysis of city range image is introduced in section 3. In section 4, our experiment is described. Conclusion of this paper is in section 5.

2 Related Works

Range image is “an array of depth values for points on the object from a particular viewpoint”. Because distance value is recorded directly in range image, geometrical model obtained from range image can be more precise than that derived from video image. So instead of video image, range image is used in our research to realize more precise geometrical model than previous research.

Acquisition of range image of buildings is introduced in subsection 2.1. The reason why data acquisition vehicle is used can be found in this subsection. Analysis of buildings’ range image is introduced in subsection 2.2. In order to extract range image of one building, original street range image should be segmented. So range image segmentation is introduced in subsection 2.3.

2.1 Acquisition of City Range Image

According to position of scanners, methods of acquiring range image of existing buildings can be classified into two kinds: airborne [6,7,8] and ground based[6,9,10,11,12].

In the airborne methods, laser scanners are mounted on helicopters or planes. This kind of methods is good at acquiring information about terrain, rooftop and height of buildings. But their resolution is coarse. In general, this method is not suitable for acquiring information about the lower part of buildings in urban area, because the lower part of buildings is often hidden by other buildings and becomes invisible from the scanners in the air.

In the ground based methods, laser scanners or cameras are mounted on vehicles. This kind of method is good at acquiring information about buildings’ façade and street scenery.

Building façade is our main concern, so the ground based method is chosen.

Because of size of buildings and urban scene, it is impossible to cover all in one scan. There exist two solutions for this problem: one is stop-and-go scanning and the other is continuous scanning. [10]

In stop-and-go scanning, scanners scan buildings from fixed points. The scanners move to next points after finishing scanning from current points. High resolution can be achieved, but long scanning time is necessary in stop-and-go scanning. [12]

In continuous scanning, scanners are mounted on vehicles. When the scanners scan buildings, the vehicle remains moving. [6, 9, 10, 11] Because of this continuous movement, resolution is low. The main advantage of continuous scanning is that wide area can be scanned quickly.

In order to make 3D city map, we need to acquire range image in wide area. Stop-and-go scanning becomes impractical because too long scanning time is needed. So continuous scanning is used.

2.2 Range Image Analysis

As stated in the previous subsection, range image of buildings can be acquired by stop-and-go scanning or continuous scanning. In stop-and-go scanning, 3D laser scanners, such as Cyrax scanner, can be used. [12] But in continuous scanning, very high scanning speed is needed, and line scan type laser scanner should be used. Different types of scanners result in different type of range image. So analysis of range image is different for stop-and-go scanning and continuous scanning.

In stop-and-go scanning, range images of the same buildings can be acquired from different viewpoints. All these range images can be registered to generate a geometrical model of the entire buildings. [12]

In continuous scanning, the scanner scans vertically when the scanner moves on the road. [6, 9]In general, there exist no range images of one building from different viewpoints, and no registration can be performed to generate geometrical model of entire buildings. Only facade model of the building can be obtained. [6, 9, 13]

Because our main concern is facade of buildings, continuous scanning is sufficient.

2.3 Range Image Segmentation

One range image can be divided into range images for some objects by segmentation. Methods of range image segmentation can be classified into region based [12] and edge based [15]. Region based methods group pixels into regions according to homogeneity measures. It suffers the problem of complex control and difficulty to implement. On the other hand edge based method locates the boundaries of the region by edge detection. It suffers problem of unconnected boundary. Edge based segmentation is adopted in our research.

The edge model used in edge based segmentation is illustrated in figure 3. [15] For a pixel at position x0, the left and the right side can be modeled by local line equation f1 and f2 respectively. If f1(x0)!= f2(x0), i.e. h>0, there exists an step edge at x0. If f1(x0) ==f2(x0), and k1!=k2, there exists an crease edge at x0. If f1(x0) ==f2(x0), and k1==k2, there is no edge at x0.

Edge detector for color image can be directly applied to step edge model of range image.

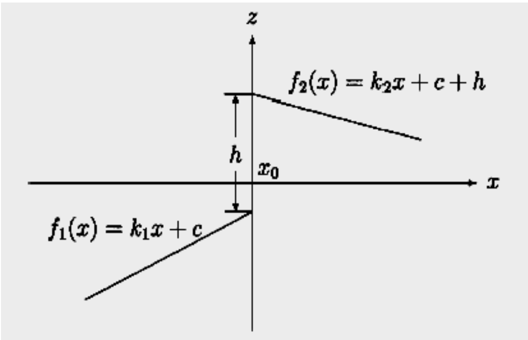

Figure 3 Range image edge model [15]

3. Analysis of City Range Image

Overall flow of our city range image analysis is illustrated in figure 4. More detailed information is available in the following subsections.

3.1 Removing Obstacles

City range image is captured when data acquisition vehicle moves on the road. The objects between laser scanner and the buildings, such as trees, cars, pedestrian, are recorded in the range image. These obstacles should be removed from the range image before other processing.

Because buildings are not transparent, obstacles in range image must be in front of the building. In our experiment, the data acquisition vehicle tried to move in a line parallel to the road, so the distance value between the building façade and the laser scanner remains almost the same. If the range image is divided by a distance value just smaller than the distance value of the building façade, the range image can be divided into a part of buildings and a part of obstacles.

Histogram of a range image is shown in figure 5. The horizontal coordinate value corresponding to the maximum vertical coordinate value is the distance value of the building facade. If the range image is divided at the red line shown in figure 5, the right part is the buildings.

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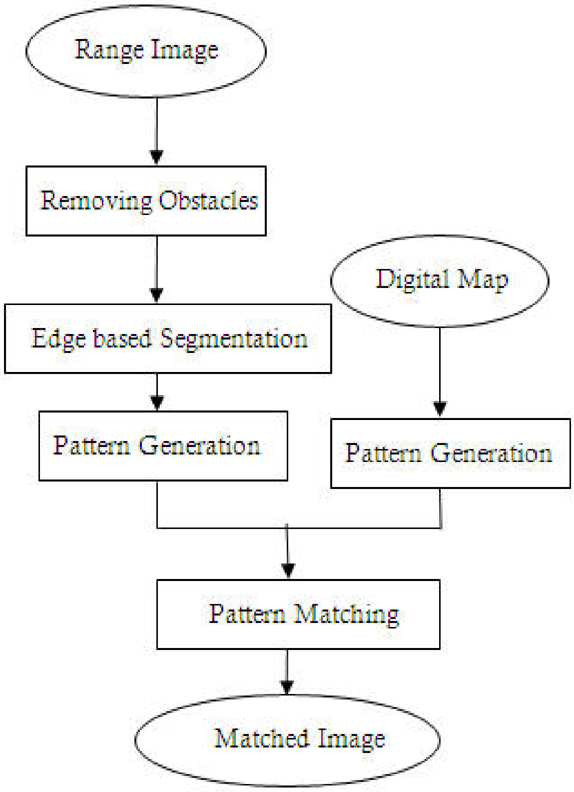

Figure 4 Analysis flow

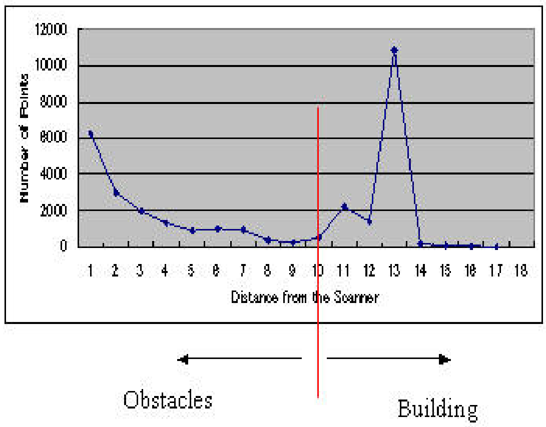

Figure 5 Removing obstacle using histogram

3.2 Edge Detection

Range image of all buildings should be farther divided into range images of single building by segmentation.

Our main concern is boundaries of the building.

Because there is space between two adjacent buildings and there exists big distance difference between parallel planes of one building in our range image, the boundaries of the buildings can exist as an edge in the range image. So we prefer edge based segmentation.

For the boundaries of buildings, one side is inside the building and the other side is out of the building, the value of h in figure 3 must be not zero. So step edge model is used in our analysis.

After a lot of try of different edge detectors, we prefer output result of Canny edge detector. There are a lot of edges made from windows or doors, and these edges are weak compared with edges from the boundaries of buildings. It is easy to erase some of these weak edges by adjusting the threshold of Canny edge detector.

Range image of some buildings can be segmented easily just using the edge detection based segmentation. But range image of some buildings can not be extracted, and need to be determined by matching between the range image and the digital map.

3.3 Matching with Digital Map

In order to know which part of range image corresponds to which building, range image is matched with existing 2D digital map. At the same time, undivided range image of some buildings can be segmented. By using digital map, error accumulation can be reduced.

DP matching algorithm was used to match video image with 2D digital map in previous research. [11, 14] We adopt this algorithm to match range image with 2D digital map.

As stated in the previous subsection, we assume all vertical boundary lines of buildings can be captured and can be represented as vertical edge in edge map. Then we divide the range image by determining which vertical edge belongs to which building using the digital map.

Not all edges can be identified easily from the edge map generated in edge detection segmentation of subsection 3.2. We make histogram of the edge map along direction of the data acquisition vehicle's moving direction, and generate one pattern line from one local maximum value as shown in figure 6.

Next we make pattern from the digital map by making projection from visible corner point of buildings on the moving path of the data acquisition vehicle. One projection point means one pattern line. This is shown in figure 7. The black line represents the moving line of the scanner.

Then DP matching algorithm is used to match the pattern from the range image with that from the digital map. According to matched pattern, the edges in range image can be divided into different buildings, thus scan lines in range image can be divided into different buildings. Thus range image of every building can be extracted, and correspondence between the range image and the building can be determined.

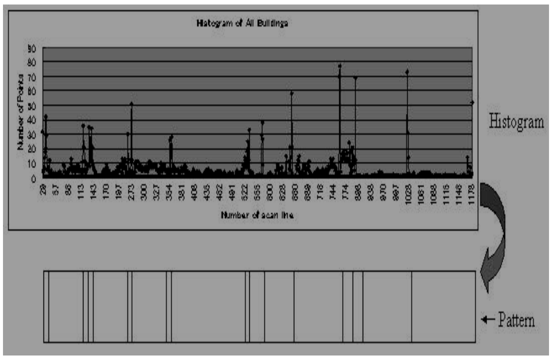

Figure 6 Pattern generation from edge map

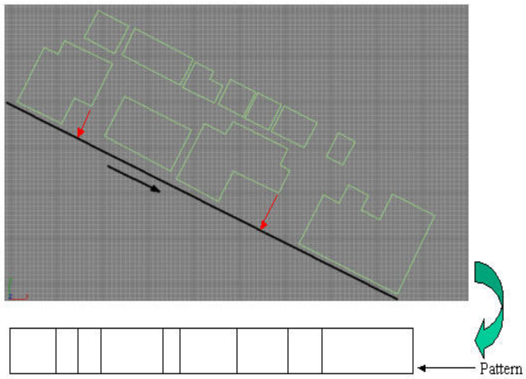

Figure 7 Pattern generation from digital map

4. Experiment

We have acquired range images of some streets using data acquisition vehicle shown in figure 8. Because very high scanning speed is need in continuous scanning, SICK LMS200 scanners are used in our research. SICK LMS200 scanners made line scan at frequency of 75 Hz in our experiment. The laser scanners are mounted on the top of the data acquisition vehicle.

In our experiment, we tried to make the vehicle run in a line parallel to the direction of the road at a constant speed less than 30 kmph. When the vehicle moved on the road, the scanner scanned buildings along the road. We used range image acquired by range scanner whose scan plane is vertically perpendicular to the vehicle's moving direction.

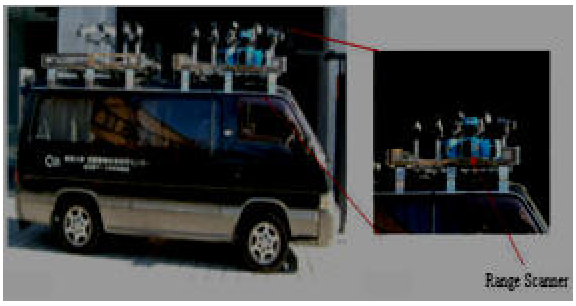

Figure 8 Data acquisition vehicle

Path and result of DP matching between the range image of a street and the digital map are shown in figure 9 and figure 10 respectively. In figures 10, the vertical line segments in the upper and the lower part represent the pattern generated from the range image and from the digital map respectively. The matching path is the line segments in the middle part connecting the matched vertical line segments in the upper and the lower part. There exist some unmatched patterns because of existence of change of data acquisition vehicle's speed and direction and existence of noise such as electric post. As mentioned in [11], more effective range image segmentation may possibly reduce this error. Based on this result, the range image corresponding to the façade of one specific building can be extracted.

Processing of the street's range image is shown from figure 11 to figure 14. Figure 11 is a part of the original rang image of the street. Figure 12 is a part of the range image after removing obstacles. The part of range image lower than 3 meters is removed to reduce influence of noise, such as pedestrian and cars. In fact all buildings in the street are higher than 3 meters, so this will not affect analysis result. Figure 13 is edge map of the entire street generated by Canny edge detector. Figure 14 is extracted range image of one building's façade after matching between the range image and the digital map. The vertical space in the middle of the image results from an electrical post.

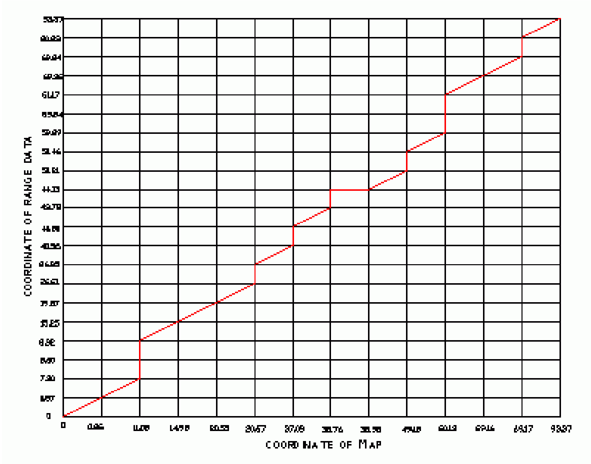

Figure 9 Path of DP matching

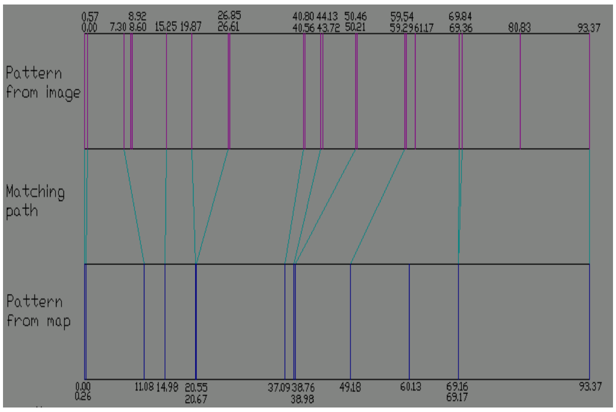

Figure 10 Result of DP matching

5. Conclusion

In order to realize more precise geometrical model of buildings' façade in 3D map effectively, ground based continuously scanned range image is used to record geometrical information of buildings. The problem of matching between the range image and digital map is discussed. After removing obstacles and edge detection based segmentation, the range image is mapped with existing 2D digital map using DP matching. Range image of one specific building can be extracted, and more precise 3D model of the buildings can be realized.

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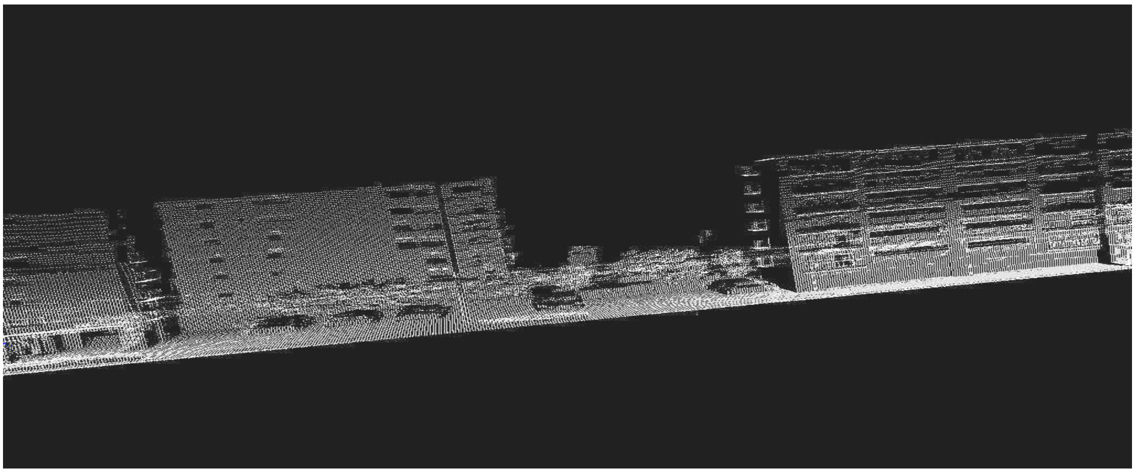

Figure 11 Example of original range image

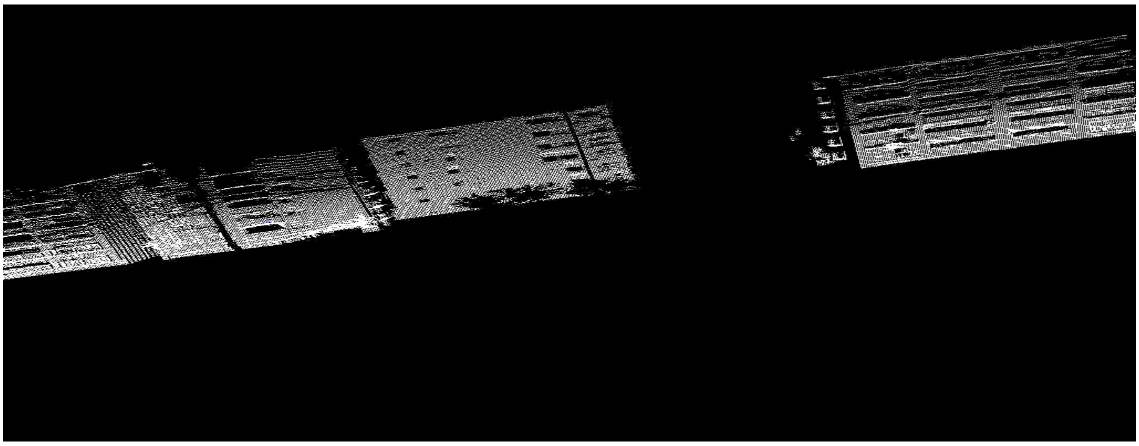

Figure 12 Example of range image after removing obstacles

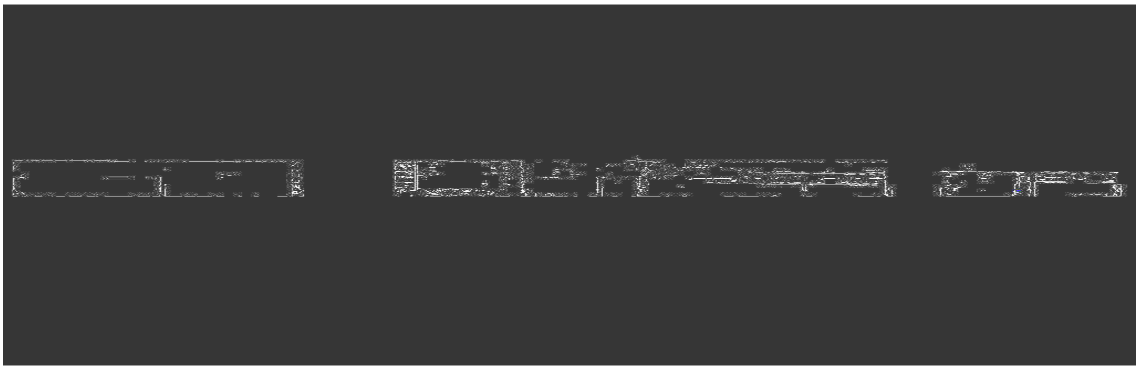

Figure 13 Example of edge map generated by Canny edge detector

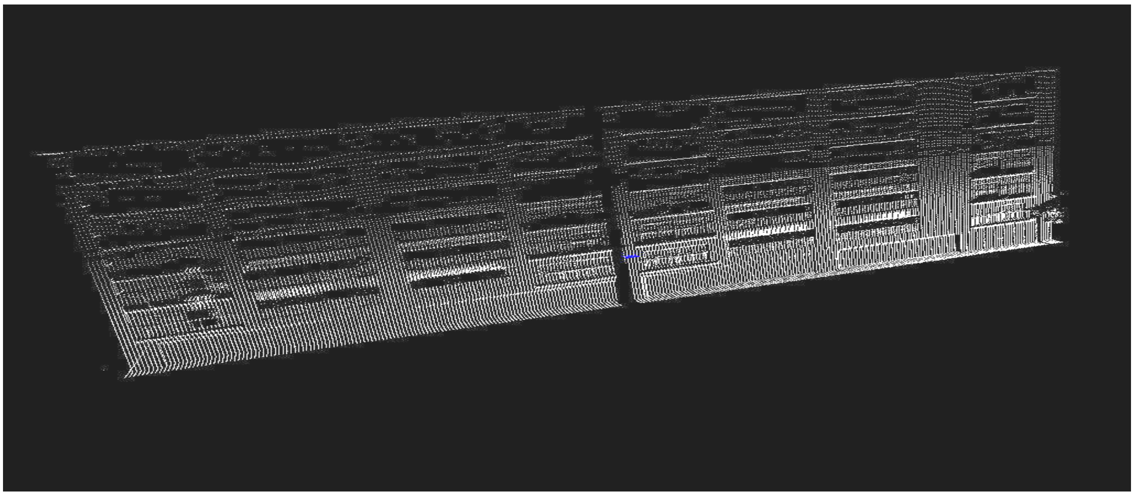

Figure 14 Example of extracted range image of one building