Automatic Extraction of Planar Projections from Panoramic Range Images

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Abstract

This paper presents a segmentation technique to decompose automatically a panoramic range image into a set of planar projections. It consists of three stages. Firstly, two orthogonal surface orientation histograms are generated. Secondly, from these histograms the major surfaces' orientations are extracted. Finally, a histogram of distances is computed for each one of these orientations; it will be used to define the position of the projection planes as well as the corresponding clipping planes. The original panoramic range image is divided into as many planar projections as main directions in the orientation histograms are extracted. This technique can be used with both indoor and outdoor scenes. Experimental result with a panoramic range image is presented.

1. Introduction

During the past years 3D computer vision has experienced a fast growth. The appearance of new sensors, which allow the obtainment of a huge amount of three-dimensional information in a short time, and the need to process and represent these images efficiently, has given rise to new research topics in the 3D computer vision community. One of these topics is the 3D digital representation that has gained an important place in different fields (e.g. architectural [1], [2], [3], automotive engineering [4], robotics [5], computer animations [6], to mention a few). However, the gap existing between 3D digital representations and the classical planar drawings need to be saved—considering that planar drawings are the "de facto" representations for many applications.

Planar drawings are still nowadays used because of their portability. In industrial environments or building works is not easy to find the appropriate tools to visualize or show 3D digital representations. In this sense, this

paper presents a technique to generate automatically planar projections from 3D panoramic images. Up to our knowledge, [7] is one of the first works taking the problem of panoramic range image decomposition. In [7], panoramic range images of forest scenes have been investigated. In the current work indoor and outdoor scenes, scanned by using the Imager 530 scanner, developed by the Z+F company, have been tested. This sensor allows a scanning rate up to 625,000 points per second with a panoramic field of view in the horizontal direction and a field of view of 135 degrees in the vertical direction (more technical details about the Imager 530 scanner are given at the company's Web page: www.zf-uk.com).

The Imager 530 scanner allows capturing the full geometry of big environments, with a high fidelity, in a short time. The required space to store all this information (images bigger than 500MB) or the CPU power to process all these data are not a problem for the current technology. The only constrain for these panoramic range images appears when it is necessary to print or represent all these 3D data in a single snapshot. The envisaged solution is the segmentation of the original panoramic range image into a set of easy to understand planar representations.

Planar drawings can be used not only as a final representation but they can also be used to define the next position of the sensor. This problem, known in the literature as the *next-best-view* problem [5][8], consists in computing the positions where the range sensor should be placed in order to acquire the surfaces of the objects present in a scene minimizing the total amount of scans. The computed planar representations can be used to detect occluded areas or low resolution areas, defining thus the next position of the sensor.

The proposed technique consists of three stages. Firstly, two surface orientation histograms are computed; they will unveil the major surfaces' orientations of the given panoramic scene. Secondly, main directions are extracted by combining local maximum from the previous
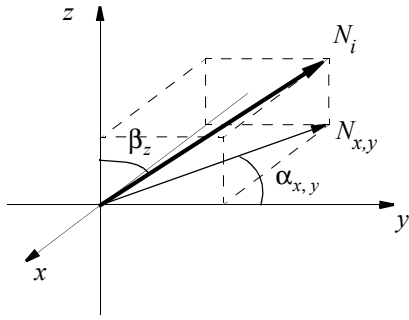
Figure 1. Angles used to compute the horizontal and vertical histograms

Figure 2. (*top*) Illustration of an horizontal orientation histogram and main direction detection. (*bottom*) Vertical orientation histogram.

histograms. Finally, a histogram of distances is computed for each main direction in order to define the position of the projection planes, as well as two clipping planes associated with each projection planes. Section 2 describes the generation of surface orientation histograms and the main directions extraction. Projection planes definition, as well as clipping planes definition, is described at Section 3. Section 4 presents experimental results with an indoor panoramic scene.

2. Surface Orientation Histograms

This section describes the technique used for computing the surface orientation histograms. Let $\mathbf{R}(r, c)$ be a panoramic range image with R rows and C columns, $r \in [0, R)$, $c \in [0, C)$, where each array element is a scalar that represent a surface point of coordinates (x, y, z). From the given range image a trivial triangulation is computed by linking all the points horizontally and vertically, and by dividing the obtained cell choosing one of the diagonals (triangles defined by edges longer than a user defined threshold are discarded, considering that they are linking noisy data or they are linking a surface discontinuity). A unitary normal vector N_i is computed for each one of the obtained triangles assuming that the reference frame is placed at the sensor position. In addition, each triangle has associated its distance to the sensor position δ_i. This triangle distance is computed as the average of the three points defining the triangle.

The surface orientation histograms—*horizontal* and *vertical*—are two orthogonal histograms generated by considering the $\alpha_{x, y}$ and β_z angels. $\alpha_{x, y} \in [0, 360)$ is used to generate the horizontal histogram; it corresponds to the angle defined by the projection $N_{x, y}$ and the y axis. On the other hand, $\beta_z \in [0, 180)$ is used to generate the vertical histogram and it corresponds to the angle defined by the vector N_i and the z axis. Both angles are considered as integer values for the histogram sampling (Fig. 1 present an illustration of the definition of these
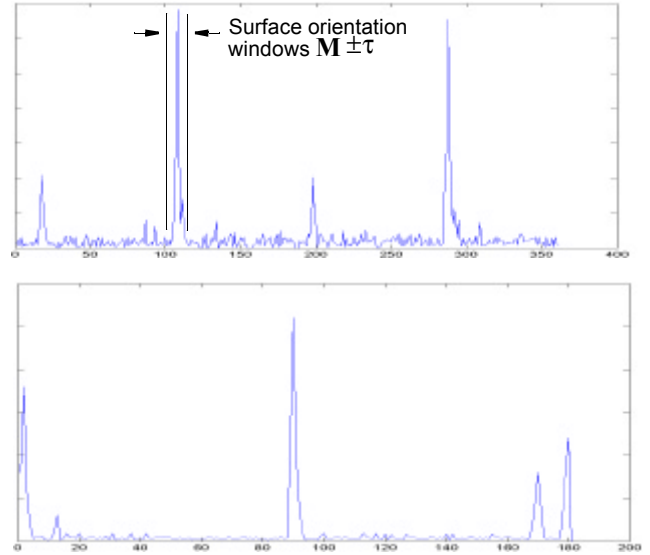
angles). The vertical histogram is used to compute the orientation of the floor, walls and ceiling (when indoor environments are considered; or floor and walls in outdoor environments). On the contrary, the horizontal histogram will present the number and distribution of walls in the given scene.

After computing both histograms (see Fig. 2) the main directions $(M_{\alpha(i)}(i \in \{1, n\}), \; M_{\beta(j)}(j \in \{1, m\}))$ are extracted by using a two steps iterative process. This process is applied separately over each histogram. Firstly, the global maximum $\mathbf{M}$ is detected. That value indicates a predominant direction in the panoramic view. Secondly, from that direction a windows of $\mathbf{M} \pm \tau$ is defined (in the current implementation the threshold τ was set to 10 degrees). All those points contained in that windows are removed from the histogram (see illustration in Fig. 2). The new global maximum $\mathbf{M}$ is computed over the points left in the histogram and the process starts again. This iterative process is applied until the value of the new local maximum is below a user defined threshold or until a predefined number of local maximum has been found (in the example presented at Fig. 5 the second option has been used based on the previous knowledge of the scene's structure—four main directions in the horizontal histogram and three main directions in the vertical histogram were computed).

3. Planar Projections

The outcome of the previous stage is a set of surface orientations $(M_{\alpha(i)}(i \in \{1, n\}), \quad M_{\beta(j)}(j \in \{1, m\}))$.
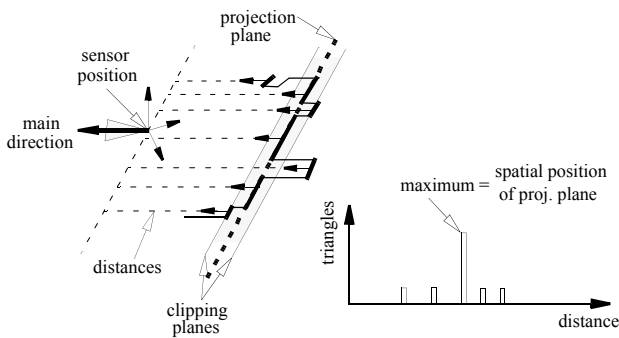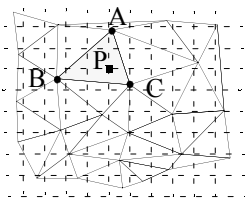
Figure 3. Illustration of a distance histogram.

$$P_x = uA_x + vB_x + wC_x$$
$$P_y = uA_y + vB_y + wC_y$$
$$P_z = uA_z + vB_z + wC_z$$

Figure 4. Triangles projected over the projection plane and the uniform sampling

Assuming that the horizontal histogram corresponds to the second maximum in the vertical histogram (the first correspond to the floor orientation and the last one to the ceiling in those indoor environments), we have a combination of $n+2$ (n horizontal main direction plus the floor and ceiling surfaces) main directions. In other words, at this point we have a set of main directions that describes the structure of the digitized scene. Now it is necessary to define the spatial position of the projection planes—one projection plane for each main direction—as well as two clipping planes associated with each projection plane.

A projection plane is orthogonal to a main direction and its spatial position is defined by the maximum in the associated distance histogram. The distance histogram is computed by considering the distances δ_i corresponding to those triangles whose normal vector is contained into the orientation window of a given main direction. For each main direction its corresponding distance histogram is computed and the corresponding global maximum is extracted. These global maximums define the spatial positions of the projection planes. In addition, each projection plane has associated two parallel clipping planes placed at a distance equal to a user defined threshold in front and at the back of the projection plane. Fig. 3 (*right*) illustrates a distance histogram associated with a main direction and surface distribution presented in the section showed in Fig. 3 (*left*) (thick lines correspond to triangles with a normal vector contained into the orientation windows of the main direction).
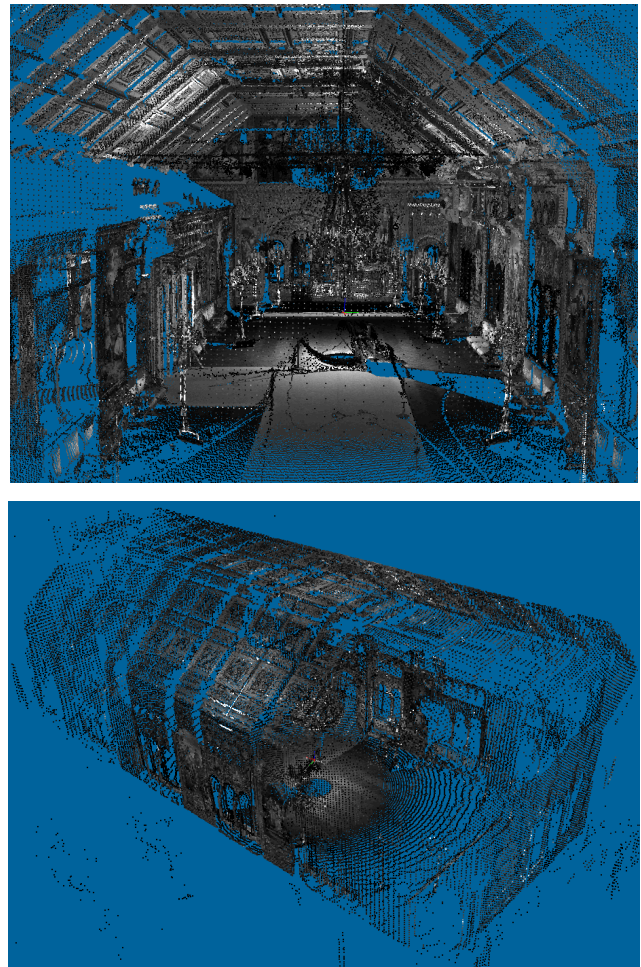

Figure 5. (*top*) Inside view of a panoramic range image. (*bottom*) Overview of a low resolution representation of the previous panoramic range image

After defining the spatial position of a projection plane all those triangles bounded by the corresponding clipping planes are projected over the projection plane. Next, a uniform sampling is computed through that planar projection generating a new range image. The coordinates of each one of the points of that new range image are obtained by a linear interpolation of the three points of the intersecting triangle (see Fig. 4). This process—projection and uniform sampling—is applied over each main direction. The result is a set of range images associated with each one of the computed planar projections.

4. Experimental Results

Several panoramic range images have been tested (both indoors and outdoors) showing good results. Fig. 6 presents the six planar projections obtained by processing the
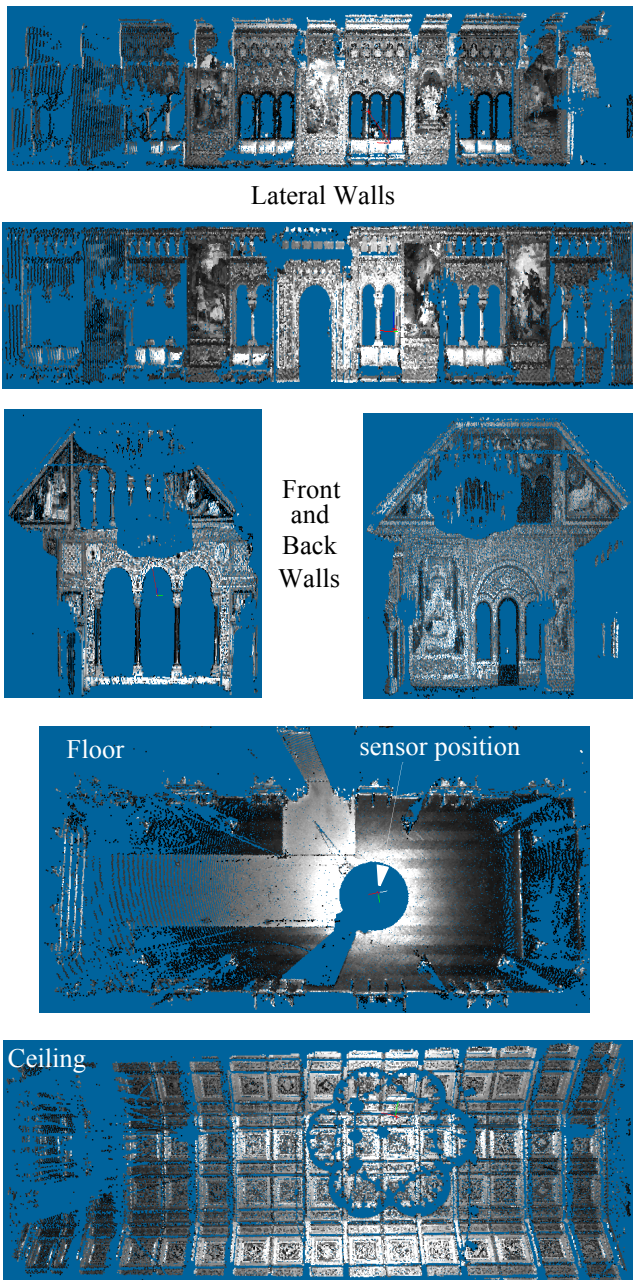
Figure 6. Set of planar projections automatically obtained from the panoramic range image presented in Fig. 5

5. Conclusions and Further Improvements

This paper presents a fast technique to break down the world into a set of planar projections. It works automatically without any parameters tuning (except the distances between the clipping planes). It can be used for indoor as well as outdoor scenes. It is useful not only to show the scanned surfaces of a panoramic range image but also to define the next sensor position or detect occluded areas.

Immediate work will consist of the introduction of spherical discretization maps [8] to compute the surface orientation histograms. Further work will include the study of point density as well as occluded areas detection in order to compute the positions where the range sensor should be placed at the next scan.

6. References

[1] A.Sappa and M. Devy, Efficient Contour Extraction in Range Image Segmentation for Building Modelling, *Int. Symposium on Virtual and Augmented Architecture*, Dublin, Ireland, June 2001.

[2] A.Sappa and M. Devy, Fast Range Image Segmentation by an Edge Detection Strategy, *IEEE Int. Conf. on 3-D Digital Imaging and Modeling*, Quebec City, Canada, May/June 2001.

[3] Y. Cho, C. Hass, K. Liapi and S. Sreenivasan, Rapid Visualization of Geometric Information in a Construction Environment, *IEEE Fifth Int. Conf. on Information Visualisation 2001*.

[4] R. Luo, J Tzou and Y. Chang, The Integration of 3D Digitizing and LCD Panel Display Based Rapid Prototyping System for Manufacturing Automation, *IEEE IECON 2000*, October 2000, pp. 1255-1260 vol. 2.

[5] M. Reed and P. Allen, A Robotic System for 3-D Model Acquisition from Multiple Range Images, *IEEE Int. Conf. on Robotics and Automation*, Albuquerque, New Mexico, USA, April 1997. (pp. 2509-2514 vol. 3).

[6] F. Di Fiore and F. Van Reeth, Employing Approximate 3D Models to Enrich Traditional Computer Assisted Animation, *IEEE Proceedings of Computer Animation 2002*, Geneva, Switzerland, June 2002. (pp 183-190).

[7] J. Huang, A. Lee and D. Mumford, Statistics of Range Images, *IEEE Int. Conf. on Computer Vision and Pattern Recognition*, South Carolina, USA, June 2000.

[8] M. A. García, S. Velázquez and A. Sappa, A Two-Stage Algorithm for Planning the Next View From Range Images, *The Ninth British Machine Vision Conference*, Southampton, UK, September 1998.

panoramic range image presented in Fig. 4. Notice that the density of points decrease with the distance to the sensor position (floor, ceiling, and lateral walls). The density of points is almost uniform in the front and back walls. By studying occluded areas, the next sensor position can be easily defined (left part of the ceiling and floor show a low density of points; in addition, front and back walls show areas occluded by the chandeliers that need further scan).