HOG: A New Model Representation for 3D Acquisition and Planning

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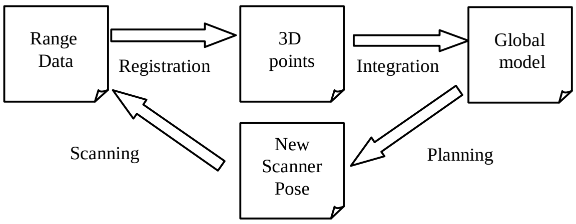
3D acquisition

Digital acquisition of 3D objects is a process in which a computer model of a physical object is constructed. This process is extremely popular nowadays as the resulting computer models have many applications. The acquisition process can be decomposed into four stages which have to be repeated until a satisfying model is obtained. Those four stages are scanning, registration, integration and planning [1].

The planning stage is needed because an object cannot be modeled from a single scan. It is necessary to measure the object from various points of view to obtain a complete model.

Currently, there is no system that can automatically scan an unknown object. Hence, a highly trained operator is needed to control the scanning device. The operator must select poses for the scanner such that the number of scans required to completely scan the object is kept reasonably small.

We present a novel representation for the model: the Hierarchical Occupancy Grid (HOG). This representation can be used for the integration and planning stage of the 3D acquisition pipeline.



The four stages of the acquisition pipeline are iterated until the object is completely scanned.

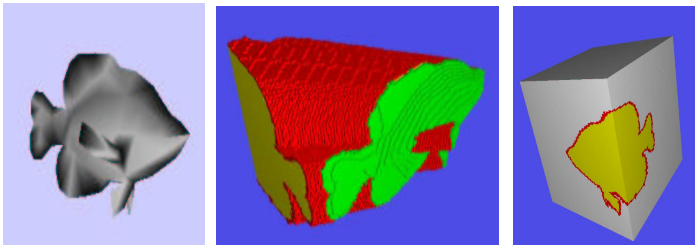
Hierarchical Occupancy Grid (HOG)

The occupancy grid is a partition of the working volume of the scanner into cells. Each cell can have one of four different states: unseen, skin, empty and full. The state of a cell is computed by comparing the cell to the samples obtained from the range scanner. The cell can be in front of a surface, intersecting the surface or behind the surface, the corresponding states are respectively empty, full and unseen. A cell is classified as a skin cell when it is partially empty and unseen but does not intersect the surface. Skin cells correspond to occlusion edges in the range scan.

The partition of the working volume into cells is done hierarchically. By only subdividing full and skin cells we obtain a tight representation that conforms to object complexity. This permits us to use high resolution for the full and skin nodes without excessive memory and computing requirements.

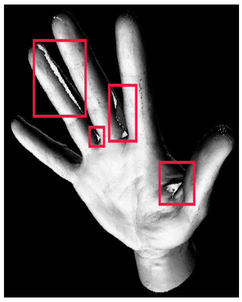
Integration

The *HOG* is updated after every scan. The update is done by a hierarchical traversal of the data structure. We compare the old state of each cell with the state in the new 3D scan. We follow simple transition rules to find the new state of the node: unseen -> skin -> empty -> full. This allow us to process the cells that are visible in the current scan and use previous information when it is more reliable than the current one. The hierarchical approach allows us to merge new scans at interactive rate even for very large models.



Using the range scan (left) we partition the working volume into full (green), empty (white), unseen (yellow) and skin (hole) cells.

3D scanning without skin detection leads to missing data in the final model (scans performed by an expert operator).

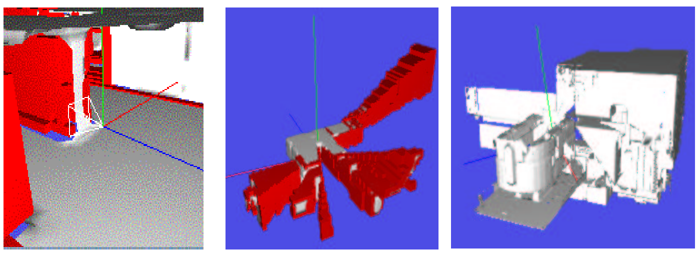


Surface extraction

The *HOG* can also be used to extract a surface from the full nodes, as we know that the full nodes intersect the surface of the object. We use the Surface Nets [2] algorithm to extract triangles from neighbouring full cells. We perform this operation at interactive rate because of the hierarchical nature of the HOG.

Planning

Skin nodes represent area of the model that have not been correctly scanned yet. The HOG is used to estimate how many skin cells can potentially be seen from any viewpoint. This is achieved by rendering the full and skin cells and measuring the area covered by skin nodes. As this evaluation is very fast due to graphics hardware we can efficiently find an promising next pose for the scanning device in little time.



Integration and planning for an extremely large scene. The surface net algorithm allows fast surface extraction even for large models.

References

[1] W.R. Scott, G. Roth, and J.F. Rivest. View planning for automated three-dimensional object reconstruction and inspection. ACM Computing Surveys, pp. 64-96, volume 35, 2003.

[2] S. F. Gibson, Constrained Elastic Surface Nets: Generating Smooth Surfaces from Binary Segmented Data Source. Proc. Conference on Medical Image Computing and Computer-Assisted Intervention, pp. 888-898, 1998, Springer-Verlag.