# Comparison between two Three-Dimensional Edge Operators applied in a 3D Navigation Approach.

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**Abstract**
*This paper will compare two 3D surface detection and normal estimation operators applied on a rough voxel database. These approaches can be applied as virtual endoscopy for the exploriation of 3D medical image volumes. The data context will be first explained, the two methodologies will be then described and evaluated on a 3D model data.*
**Keywords** - Surface detector, normal estimator, 3D moment operator, virtual endoscopy.

## 1. Introduction.

The visualization of 3D data acquired on medical devices (Magnetic Resonance Imaging - MRI-, Computed Tomography -CT-, etc.) can be enhanced by the use of 3D navigation approaches[1] These approaches can be applied as virtual endoscopy exploring the several structures of the image volume. Generally navigation is performed on segmented data (extraction and polygonal modeling of the Surfaces of Interest), however the constraint chosen in[1] allows a direct investigation on the original information acquired by the devices. Since the organization of a volume as a spatial sequence of images constitutes the only hypothesis, the volume contains all the original data but in counterpart the information of interest (i.e. the anatomical surfaces) must be detected and extracted by the visualization function. The several elements characterizing virtual endoscopy are the following :
(1) the virtual sensor is modeled as a video-endoscope. Its position, orientation and physical principle are controlled by the user. The confinement of the observation area (the sensor is very close to the structures) leads to a wide viewing angle. This and the resolution differences between the final images and the 3D data imply undersampling conditions.
(2) the visualization function. According to the data description and the objects to render, the Ray Casting technique seems the most appropriate for this application[2]. The process of surface visualization can be divided in i) extraction of information along a ray, ii) surface detection and iii) shading computation (using the estimation of the normal to the surface. According to the no preprocessing hypothesis and the undersampling condition described in[1], the main difficulty in this Ray Casting remains the surface detection. This paper will present and evaluate two different methods for the detection and the description of a surface in a volume data

## 2. Surface detection operators.

In a medical volume data, the objects (and even more the surfaces) are not explicitly described. Only some physical measurements related to the objects and sampled uniformly in the 3D space (on voxels) are available. This induces the formal definition of a surface in the 3D space which will characterize the surface detection model.

### 2.1 Oversampled iso-value detection[1]

Usually, an object could be defined by a region of connected voxels with close attributes (values on the voxel). A surface is a border between two objects; going from an object A to another object B, values will change from the one characterizing A to that characterizing B. A surface element can thus be seen as a 3D point having a value between the values corresponding to objects A and B and a surface can be defined as a set of iso-value points in the 3D space. In the more usual cases, these iso-values can be simply detected by thresholding.
If we sample spatially a ray through the 3D data, the values on this samples can be compared to the threshold and a surface can be roughly estimated. This traversal can be refined at a higher resolution (typically 1/10 voxel),.computing the value of each sample from the eight neighbor voxels surrounding it by using trilinear interpolation. The iso-value (and the surface point location) is searched along this high resolution traversal. Once each surface point is located, the 3D normal is estimated by trilinear interpolation (3D generalization of Phong's smoothing process) of the 3D gradients computed at the eight neighbor voxels.

### 2.2 Moment based edge operator[3]

A surface in the neighborhood of a specific point is here defined as a plane which divides the space into two regions with values a and b respectively. This plane is characterized by its orientation and its distance from the specific point. The parameters of a surface in the volume data are estimated by identification between the geometrical moment computed on the surface model and from the gray value on the volume data. In a first step, the surface detection is roughly performed by a simple threshold, then, the surface model parameters are estimated using the 3D moment. Finally, the refine intersection between the ray and the surface model is computed analytically.

## 3. Evaluation of the surface detection operators.

An evaluation of the moment operator has already been presented in[3] but not under undersampling conditions. The two detection methods have been tested on a synthetic object : a hollow cone with value 0 inside and 200 outside. This analytical cone has been discretized on a 3D voxel volume. Partial volume effect has been taken into account by a 1/10 subvoxel sampling. From a specific camera position, for each method, the surface detected points and the estimated surface normal have been compared to the analytical form. The results are errors in surface detection measured along the ray and in surface orientation estimation. Figure 1-2 show the histograms of surface detection and orientation estimation errors respectively. We can see that the oversampled iso-surface operator gives better results for surface detection but the moment operator is more accurate for the surface orientation estimation. However if we have a look to the final shaded results (Figure 3), the planar surface hypothesis of the moment operator is clearly perceptible. The planar structure of the moment operator is enhanced by the non continuity in space of its normal estimation. A second pass of Gouraud's or Phong's shading has certainly to be processed in 2D in order to smooth the surface appearance.

## 4. Conclusion

A first comparison of two 3D surface and normal detectors has been presented. The results of both operators seem to be complementary. Such an low level evaluation find its place in a more global quality evaluation in medical visualization[4]. An accurate surface estimation is also essential for further processes. However, such methodologies have to be tested in other conditions (several structures, robustness to noise, etc.).

## References

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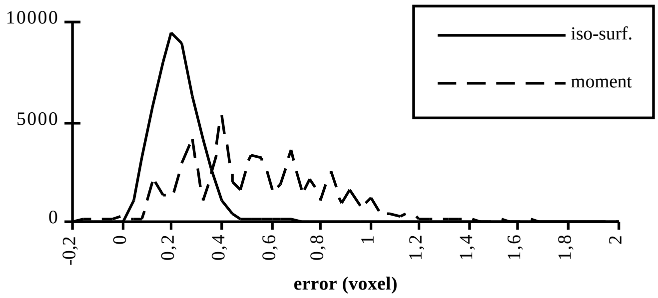


Figure 1 : Surface detection error (in voxel)

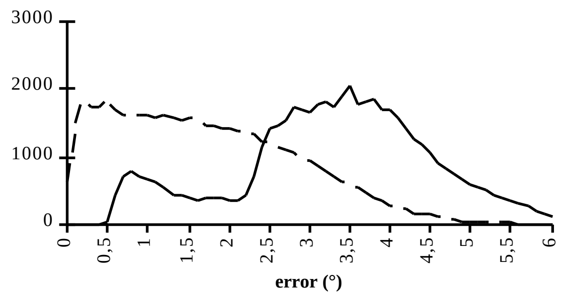


Figure 2 : Surface normal estimation error in (degree)

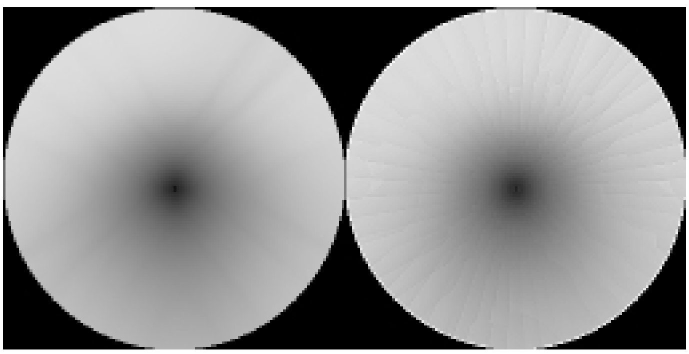

Figure 3 : Surface rendering of the inner part of the cone: iso-value and interpolated 3D gradient (left) and moment operator(right)