# Virtual Endoscopy for Cardio Vascular Exploration

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**Abstract.** With the recent introduction of multi-slice CT which acquire four image slices at the same time (which will increase to 16 image slices in the near future) the possible size of the generated image stack has increased tremendously. Traditional cine mode explorations of the image stack are rendered impractical by the sheer quantity of possible 1000 image slices of the resolution of $512 \times 512$ pixels.

In this paper, we discuss the use of VIVENDI, a virtual endoscopy system applied for the three-dimensional exploration of cardio vascular structures. In particular stenoses of the coronary arteries can be visualized, if depicted by the scan.

**Keywords:** Virtual Endoscopy, Multi-slice CT, Cardio Vascular Visualization, Computer Assisted Diagnosis.

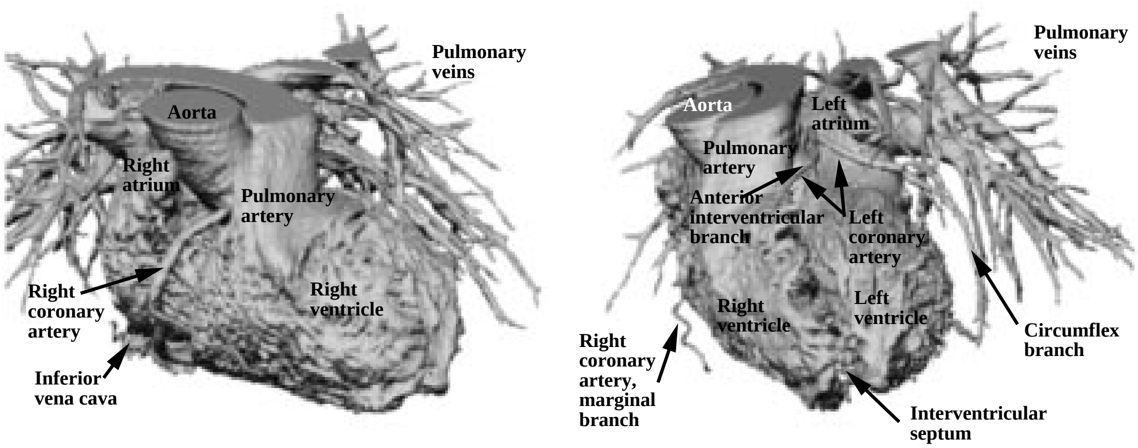
## 1. Purpose

Methods of virtually endoscopy provide a new paradigm for viewing volumetric datasets in the clinical practice. In contrast to the currently used cine examination mode – where image stacks are examined sequentially – it mimics an endoscopic examination of an organ system of interest. Furthermore, it composes a three dimensional image which is not limited by a specific field of view, the fish eye effect, or a limited depth perception, since all these parameters can be modified appropriately to provide the required view, if necessary in stereo. Recently, multi-slice CT as been introduced which provides faster scanning times and a higher resolution than previous, single slice spiral CT [5,8]. Multi-slice CT is used for explorations of a number of different organs. Here, we focus on cardio vascular data which are used for the diagnosis of stenosis or occlusions of the coronary arteries – for bypass planning, or for follow-up examinations after a dilatation of a stenosis – and of the function of the heart itself.

The sheer possible quantity of data from a modern multi-slice CT poses a problem in itself for the traditional cine mode exploration of the image slices. More than 1000 slices of a resolution of $512 \times 512$ are frequently generated which require 3D visualization techniques for an efficient finding process. Here, we discuss the use of VIVENDI [3,4], a flexible, interactive virtual endoscopy system, for the exploration of cardio vascular multi-slice CT data. Specifically, we examine the use of VIVENDI to detect and assess stenosis and occlusion of coronary arteries, and for volumetric measurements of the ventricles of the heart to assess its function.

## 2. Methods

Datasets are acquired using a Siemens SOMATOM Volume Zoom, which enables a high data resolution and a short scanning time. To reduce motion artifacts while scanning the heart, the scanning procedure is synchronized with the ECG signal, which indicates an appropriate phase of the heart cycle [1].




(a) (b)

Figure 1. Reconstructed heart; (a) anterior view, (b) sinister view.

For the endoscopic assessment of the heart, we use the VIVENDI virtual endoscopy system, developed at the WSI/GRIS of the University of Tübingen. VIVENDI provides a flexible framework for intuitive navigation and interactive visualization of large medical data. The patient volume dataset is first segmented using a simple threshold/3D volume growing algorithm. Subsequently, the isosurface – which describes the material interface between the contrast agent enhanced, blood filled cavities of the heart (i.e., ventricles, atria, coronary arteries) and the surrounding tissue – is extracted (see Fig. 1), based on an octree decomposition of the volume [2]. This decomposition is later used to cull parts of the geometry of the datasets which are not visible to accelerate the isosurface rendering. Finally, distance fields are generated based on the segmentation of the heart, to provide guidance for the intuitive navigation system, and to implement a collision avoidance scheme. The overall pre-processing step takes about 10-20 minutes, depending on the size of the dataset [3].

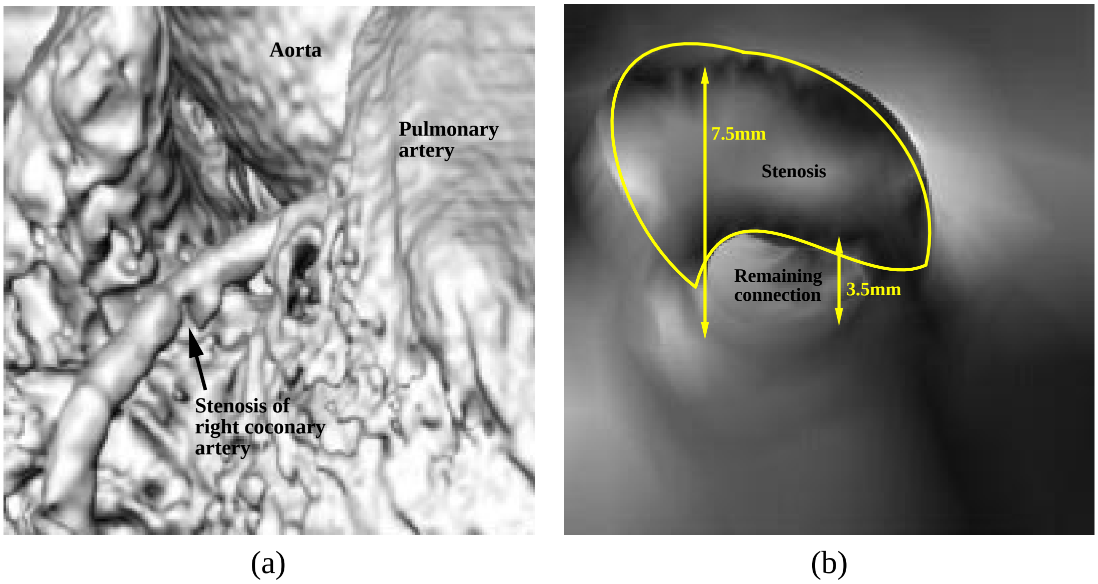



Figure 2. Stenosis of the right coronary artery; (a) exterior view, (b) endoscopic view.

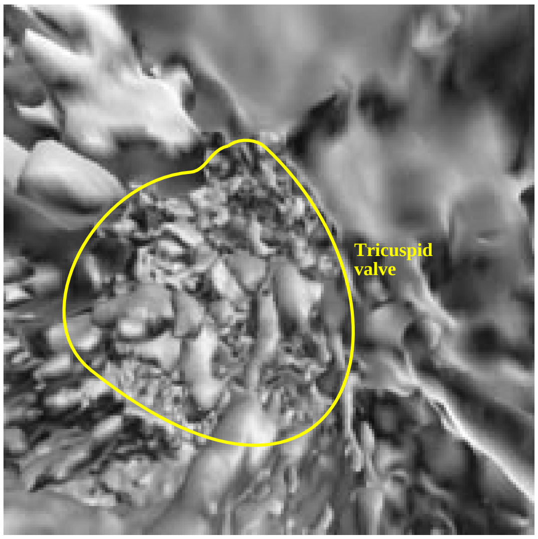
After the pre-processing, the heart geometry is assessed using VIVENDI. Here, the contrast agent filled cavities of the heart are examined from an endoscopic point of view. Measurements based on the volume data can be performed to calculate the diameter of sections of coronary arteries which contain an occlusion or a stenosis. Other measurements include the volume of the ventricles – to assess the heart function –, or the quantification of calcifications.

VIVENDI employs a visibility driven rendering algorithm which removes geometry from the rendering which is not visible from the current viewpoint. The visibility test is based on the elements of the octree decomposition generated in the pre-process and provides an interactive framerate on a PC using the fx6 graphics accelerator of Hewlett Packard [3,10], depending on the dataset.

## 3. Results

We examined several multi-slice CT patient datasets using VIVENDI. Specifically in dataset patient A, we discovered a stenosis of the right coronary artery. The regular diameter of the blood vessel of 7.5 mm was reduced to 3.5 mm at the stenotic segment (Fig. 2a), which was also visible from the outside of the reconstructed, contrast agent filled cavities (Fig. 2b). In our experiments, we also measured the volume of the left ventricle, which resulted in an estimated volume of $240cm^3$. The measurement basically counts the voxels which were classified as interior of the ventricle. The classification is based on the specific threshold of the contrast agent, whereas the selection is limited by planar clip discs that remove the connection between the surrounding cavities which are also filled with the contrast agent, such as the left atrium and the pulmonary artery.

One of the problems of the image acquisition is beam hardening due to the injected contrast agent, which can lead to severe artifacts in the right atrium (Fig. 3a/b). These artifacts overshadow all relevant information in this specific area of the heart, in particular if the calculation of the volume of the right atrium is required (Fig. 3a).




(a)

(b)

Figure 3. Artifacts in the right atrium due to beam hardening; (a) from an endoscopic view (yellow line marks the approximate position of the tricuspid valve) and (b) in a CT image slice (yellow line marks the right atrium).

## 4. Conclusion

We applied VIVENDI, a virtual endoscopy system, for the assessment of multi-slice CT datasets. Important anatomical features such as coronary arteries and stenosis of the arteries could be identified. Furthermore, the three dimensional representation enables volumetric and distance measurements which give quantitative information on the function of the heart, or of the quality of a stenosis. The large number of potentially more than 1000 image slices (not necessarily for cardio angiography) represent a significant problem for the traditional cine mode examination of the volume dataset. High level, three dimensional techniques provide more overview for an efficient finding process.

The quality of the visualization strongly depends in the quality of the reconstructed volume dataset. Artifacts due to motion or beam hardening in areas with a high contrast agent density can reduce the visual quality significantly. It is however, usually limited to the right atrium of the heart which is less important for the assessment of the coronary arteries.

Isosurface algorithm like Marching Cubes [6] are particular sensitive to artifacts, since they compute the accurate isosurface, based on an isovalue. Direct volume rendering approaches have an inherent additional filtering step if the transfer functions do not use perpendicular rising edges at the isovalues which reduces the noise caused by the volume artifacts. However, direct volume rendering do either not provide sufficient interactive performance (software volume rendering), lack visual quality (texture mapping) [7], or do not provide a perspective view (VolumePro volume rendering board [9]) which is required for endoscopic examinations.

Currently, the specification of the planar clip discs to limit the volume measurements can be quite time consuming. Future work will therefore focus on the user-friendly specification of non-planar clip geometry which approximates the target shape, ie. the shape of the left ventricle.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