EndoView: A Phantom Study of a tracked virtual bronchoscopy

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Abstract

Virtual endoscopy can be used for preoperative planning, for training and intraoperatively. Surface rendering displays the inner lumen very well. Volume rendering has to be used if the external structures are of interest. For certain applications, e.g. endoluminal biopsy, it is of great advantage to be able to use both techniques at once. In this work we describe an approach that allows to use these two methods in combination on a low-end standard personal computer. Since image generation is done in a preprocessing step, any high quality volume or polygonal rendering technique can be used and mixed together without any loss in performance at run-time. This work extends a previous image based rendering system for virtual bronchoscopy to include tracking of a rigid or flexible endoscope and finding one's way in the tracheal tree by displaying the endoscope's position in a top-view map of the trachea. Natural landmarks, i.e. bifurcations in the bronchial tree, are used for registration. Properties of the technique are explored on a phantom data set.

Keywords: medical visualization, virtual endoscopy, registration, image based rendering

1 Introduction

In virtual endoscopy a camera is placed inside a data set which is gained from computer tomography (CT) or magnetic resonance tomography (MR). It allows a physician to view the patients inner structures in a similar way as through a real endoscope. As CT or MR scanning become more widespread, virtual endoscopies are nowadays not only used in rare cases for preparation of complicated operations [Doh90], [Hu90], but also for students' training [Hon97], [Hof95] and even intraoperatively. In preoperative planning the simulation has not to be done in real-time and the focus is on giving the surgeon as much information as possible. In training and interoperative computer aided surgery the focus, however, is on providing a simulation as real as possible. This requires registration and also fast feedback on the user's actions. In the registration process virtual objects are aligned with their associated real counterparts. The system must also react realistically on any possible action the user is allowed to perform. In addition the system has to provide a realistic and usual input device for the endoscopist. In the best case this is the endoscope or as tracked version thereof. Virtual endoscopy allows a cost-effective preoperative training, because there is no need for the trainee to work on a patient or corpse.

The methods described in this paper make it possible to do virtual endoscopies on a low-end platform, yet achieving a high grade of realism, precision and fast feedback by using image based rendering and standard tracking techniques. Image based rendering can be used, because the virtual camera is dictated to stay on the central path on the way from entering the trachea to the point of interest. This is a minimal restriction for an endoscopic system but reduces the degrees of freedom to four, resulting in a tremendous reduction of data.

2 Related Work

There are two common ways to render volumetric data gained from CT or MR. Polygonal rendering or volume rendering can be used. Whereas the latter case provides more flexibility and higher image quality, it is way to slow to be done interactively without specialized hardware support. To speed up volume rendering, techniques such as 3D texturing [Pea85] shear-warp factorization [Lac94] and splatting [Lau91] have been developed. These methods are still slow or reduce flexibility considerably. Polygonal rendering requires a preprocessing step where polygonal data is extracted from the data set. This allows to use standard rendering hardware with the tradeoff of loosing a lot of information. As our approach uses image based rendering with images created in a preprocessing step, it is independent of the rendering technique.

Image based rendering [Möl99] takes advantage of the fact that a complex geometry can be pre-rendered into an image that is later on used as a replacement for that geometry. A common technique that falls into this area is texture mapping. In cubic environment mapping [Gre86] the camera is placed in the center of the scene and six images are rendered, projecting the scene onto the sides of a cube. The advantage is that a very complex scene can be reduced to six images in a preprocessing step, which can then be displayed quickly at runtime.

Our previous work EndoWeb [Weg00] uses image based rendering to view virtual endoscopies on a remote station using a web browser. EndoView extends EndoWeb to allow the system to be use intraoperatively, by adding features such as tracking support, displaying position information on a top-view map and defining special locations of interest. Image based rendering for virtual endoscopy has also been used by other groups [Ser01].

Registration deals with finding the counterpart of a virtual object in the real world and vice versa. The problem here is that usually objects in the real world tend to move and deform. Michael Fitzpatrick suggests [Fit99] markers based on artificial landmark points, which have to be bone implanted to be accurate. Our approach uses natural landmark points, which do not harm the patient.

3 System Description

EndoView can be use for preoperative planning and intraoperatively as well. Because of a missing wide field study, EndoView is still far away from being used in a hospital intraoperatively. While in preoperative planning the system has to give the user as much freedom, comfort and information as possible, it must react directly and realistically to the actions of the endoscopist during the operation. Because of these contrary requirements, EndoView has a navigation and an online-mode. When the system is in online-mode the position and rotation of the camera is retrieved from the head of the endoscope. In navigation-mode the user can look around and move forward and backward freely. The EndoView application consists of three windows (see *Figure 1*): The endoscopic view on the right, the control window on the top left and the top-view map on the bottom left.

The endoscopic view window can be resized freely to adjust between viewing size and rendering speed on a very slow machine. When in navigation mode the user can look around by dragging the mouse in the endoscopic view. All the navigation and changing of viewing settings is done in the Controls Window. When in navigation mode the user can use a slider to move the virtual endoscope forward and backward, jump to predefined locations of interest or fly through the trachea or intestine. The top-view map shows the body and the tracked endoscope viewed from above.

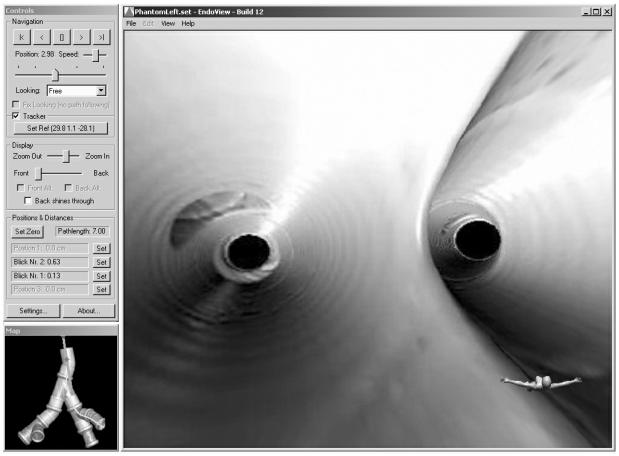

Figure 1: EndoView Screenshot

3.1 Rendering Technique

In a preprocessing step the images for the cubic environment mapping are generated with an external software. The endoscopist defines a path through the body along which he plans to move the endoscope. Next the software renders a cubic environment for every position on the path (See *Figure 2*). Because this is a preprocessing step, time is not critical and any high quality volume rendering techniques can be used. For a more realistic simulation of a real endoscope, the trachea walls can be textured [Shi98] and distance shaded. For every side of the cube a video file is generated which reduces the data size tremendously and allows decoding of the images with hardware support. As an own video format was implemented, resolution changes within the movie are possible, which allows to generate high quality views for locations of special interest.

EndoView can use two independent image layers, which can transport different information. In the usual case the top layer shows the trachea walls and the back layer shows the inner organs. The blending between the layers can be done in real-time at runtime. This way it is possible for the endoscopist to set organ walls transparently (see *Figure 5*) and let the inner organs become visible without loosing orientation inside the tube. For each layer two different representations can be generated, which can be switched at runtime. For the top layer one might generate a usual visualization of the trachea plus a visualization which colorcodes the distance to a point of interest (see *Figure 6*). The back layer switching can be used to show or hide a set of external organs. At runtime the rendering in EndoView is done using OpenGL.

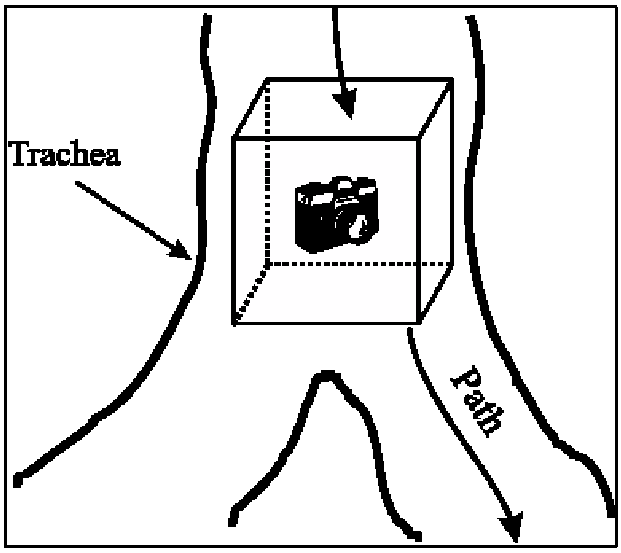

Figure 2: Cubic Environment Mapping

3.2 Registration

Registration in EndoView is done using a magnetic tracking device. An Ascension pcBird is used as the miniBird500, a tracking sensor that is small enough to fit into the working channel of an endoscope, is still not publicly available. Because of the bigger size of the pcBird, a special phantom device was constructed, on which our technique was tested (see *Figure 7 and 9*). A common problem when doing registration in medical visualization is to find good landmark points. A landmark point is a location on the human body which can be

clearly identified on the real body and in the data set. There are natural (anatomical) landmark points such as the bridge of the nose, the nipples or the bellybutton. The problem with those points is that they not only tend to move, but also lie on the outside of the body, which is out of range of the endoscope. To gain a good precision inside the body, landmark points have to be used not only on the front, but also on the back of the body, where they are more difficult to find and use during the endoscopy, since the patient is usually lying on his back.

Many approaches [Glo99] also propose artificial landmark points. Those markers are placed on the body before the MR or CT scan. The main drawback of this method is that the markers must remain attached to the patient throughout all data acquisitions and even have to stay there until the operation. Simple markers which are glued on the skin are often removed by patients. More sophisticated and precise markers require to be implanted to the bone, which reduces the noninvasive character of endoscopies.

The method we use does not need any artificial markers, thus avoiding surgical invasiveness. To register the patient with the data set, all the physician has to do, is to touch the first bifurcation with the endoscope and tell the software to register. Since the part of the trachea until the first bifurcation is rather straight, and the patient lies stretched supine on a table during the endoscopy, the software can then not only calculate the position, but also the rotation of the patient in respect to the tracking system.

The registration precision is better than one centimeter, which is enough for an exact navigation with the endoscope inside the trachea. For a flexible endoscope the tracking must be done at the endoscope's head, which requires a tiny tracking device such as the Ascension miniBird 500, that can be placed inside a working channel. For rigid endoscopes EndoView allows the head's position to be extrapolated from two position values at the part of the endoscope that is not inserted into the body, which results in a higher precision than just using one tracking position plus the rotation of the endoscope. This enables the physician to use large and cheap tracking devices such as the Ascension pcBird.

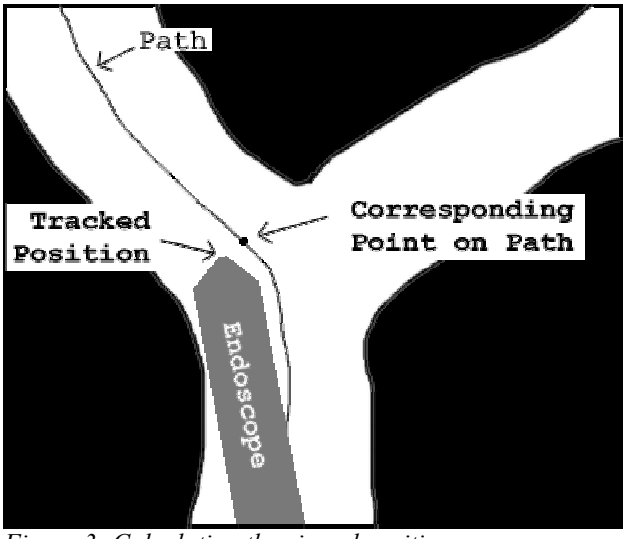

Figure 3: Calculating the viewed position

As only positions on the central path in the trachea can be displayed, the system calculates the nearest position on this path in respect to the endoscope's position. This is simply done running through all the path positions, searching for the one with the smallest Euclidian distance (See *Figure 3*). Since the system can not restrict the user from taking another way at a bifurcation, an alarm is displayed if the smallest distance is above a predefined value.

3.3 The Phantom Device

In order to test the EndoView's support for flexible endoscopes without having an Ascension miniBird 500 that would fit into a real endoscope, we built a phantom device (see *Figure 7*), that resembles an enlarged trachea. The phantom device has a size of 34x35x16 centimeters and is build out of drain pipes. Because of an inner radius of 5 centimeters it is possible to insert large standard tracking devices into the "trachea".

4 Results

In our tests the system precision lied between 3 millimeters and 1 centimeter depending on the accuracy during registering at the first bifurcation and the distance of the tracker to this bifurcation. As the runtime 3D scene consists only of 12 quadratic polygons and the video decoding takes hardly any CPU time, the viewing speed depends primarily on the graphics card's fill rate and bus speed for uploading the textures. Practical experience shows that any current low cost 3D accelerator is sufficient to maintain update rates of about 30 to 60 Hz.

5 Conclusion and Future Work

The EndoView project demonstrates a simple approach for virtual endoscopy on a low end pc suitable for preoperative planning as well as interoperative usage, which can easily be implemented on other systems too. The speed of the system depends primarily on the graphics card in use and the size of the textures. A video demonstrating EndoView in action can be found at http://www.cg.tuwien.ac.at/research/vis/vismed/endoview.
In the near future a wider clinical study is planned. The next step will be to work on overlaying the calculated image with the real image from the endoscope. This requires high precision and correction for lens distortion in real time, which can also be done image based. The data set of the phantom device is free for use and can be found at http://www.cg.tuwien.ac.at/research/vis/vismed/endoview/phantom.zip.

6 Acknowledgements

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References

[Doh90]: Dohi, T. , Ohta, Y. , Suzuki, M., et al., „Computer Aided Surgery System (CAS): Development Of Surgical Simulation And Planning System With Three Dimensional Graphic Reconstruction“, In Proceedings of the First Conference on Visualization in Biomedical Computing. (pp. 458-462). Los Alamitos, CA: IEEE, 1990

[Fit99]: J. Michael Fitzpatrick, Jay B. West, Calvin R. Maurer Jr, “Predicting Error in Rigid-body, Point-based Registration”, IEEE Transaction on Medical Imaging, pp. 694-702, March 7, 1999,

[Glo99]: N. Glossop, R. Hu, , G. Dix, Y. Behairy, “Registration Methods for Percutaneous Image Guided Spine Surgery”, Computer Assisted Radiology and Surgery, proceedings of the 13th international congress and exhibition, pp. 746-755, Paris, France, June 23-26, 1999

[Gre86]: Ned Greene, “Environment Mapping and Other Applications of World Projections”, IEEE Computer Graphics and Applications, Vol.6, No. 11, pp. 21-29, Nov. 1986

[Hof95]: Hoffman, HM, A Irwin, R Ligon, M Murray, & C Tohsaku (1995). Virtual Reality-Multimedia Synthesis: Next-generation Learning Environments for Medical Education. Journal of Biocommunications, Vol 22 No 3, pp. 2-7, 1995.

[Hon97] L. Hong, S. Muraki, A. Kaufman, D. Bartz, T. He, "Virtual Voyage: Interactive Navigation in the Human Colon", in Computer Graphics (Proceedings of Siggraph'97), pp. 27-34, Los Angeles, 1997

[Hu90]: Hu, X. P., Tan, K. K., Levin, D. N., et al., „Three-Dimensional Magnetic Resonance Images Of The Brain: Application To Neurosurgical Planning“, Journal of Neurosurgery, 72 (3), 433-440, 1990

[Lac94] Philippe Lacroute, Marc Levoy, “Fast Volume Rendering Using a Shear-Warp Factorization of the Viewing Transformation”, Proc. SIGGRAPH '94, Orlando, Florida, July, 1994, pp. 451-458.

[Lau91]: D.Laur, P.Hanrahan, “Hierarchical Splatting: a progressive refinement algorithm for volume rendering”, ACM Computer Graphics (Proceedings of SIGGRAPH ’91), 25(4), 1991, pp. 285 -288

[Möl99]: Tomas Möller and Eric Haines. “Real-Time Rendering“. A K Peters Ltd, 1999.

[Pea85]: D. R. Peachey: Solid Texturing of complex surfaces, Proceedings of SIGGRAPH'85, pp. 279--286, 1985

[Ser01]: I.W.O. Serlie, F.M. Vos, R.E. van Gelder, J. Stoker, R. Truyen, Y. Nio, F.H. Post, "Improved Visualization in virtual colonscopy using image based rendering", to appear at Joint Eurographics-IEEE TCVG Symposium on Visualization (VisSym01), Ascona, Switzerland, 28-30 May 2001

[Shi98]: O. Shibolet and D. Cohen-Or, “Coloring Internal Cavities for Virtual Endoscopy”, The 1998 Symposium on Volume Visualization, 15--22, October 1998. (VolVis98)

[Weg00]: Rainer Wegenkittl, Anna Vilanova, Balint Hegedus, Daniel Wagner, Martin C. Freund, Eduard Gröller, „Mastering Interactive Virtual Bronchioscopy on a Low-End PC“, IEEE Visualization 2000, pp. 461-464, 2000

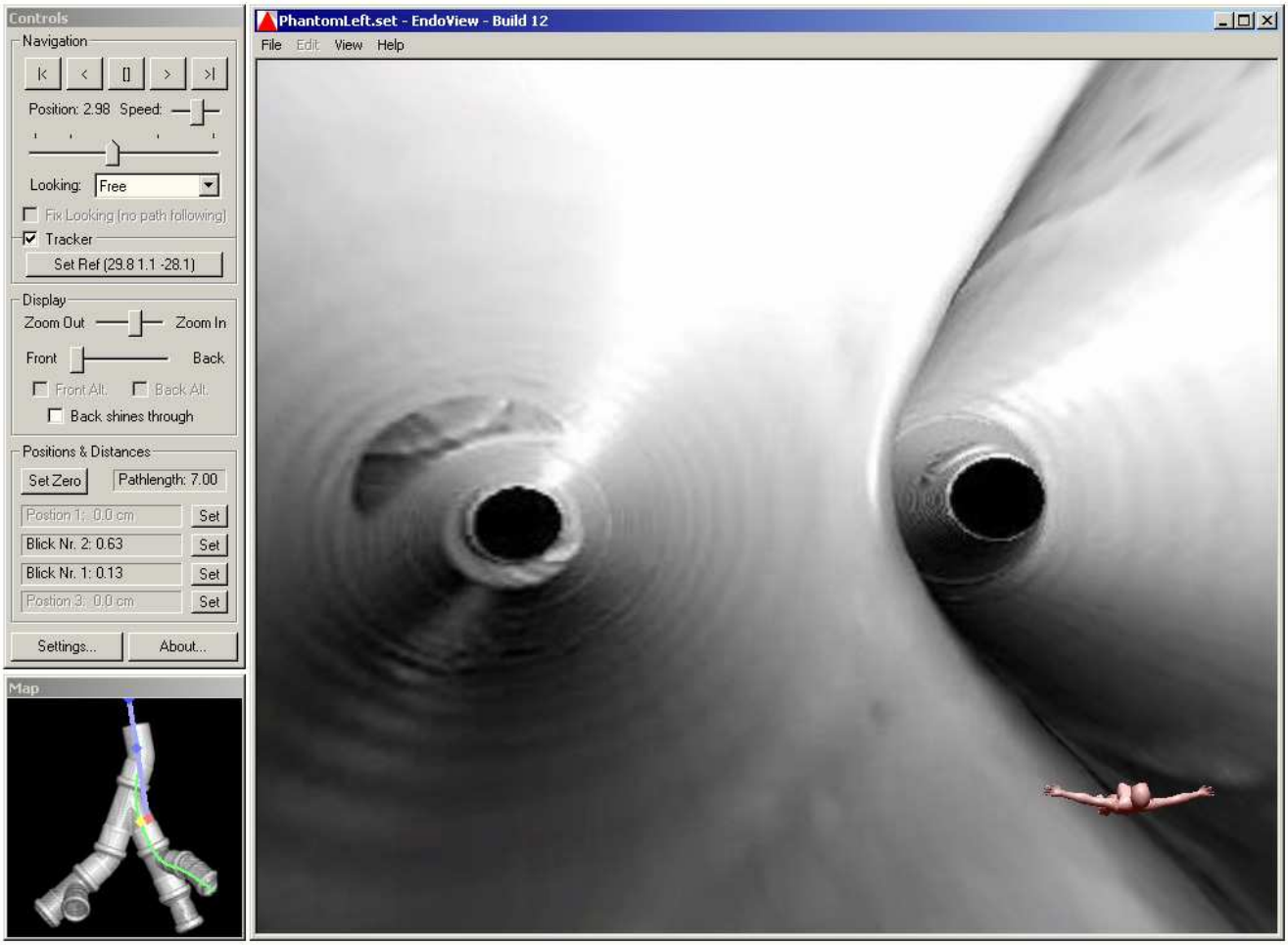

Figure 4: The Endoview Application

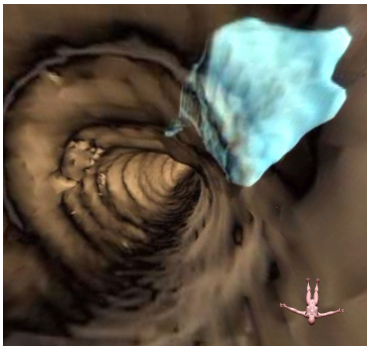

Figure 5: Transparent trachea walls

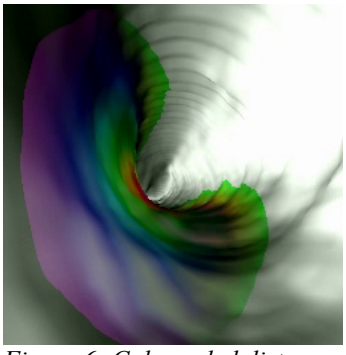

Figure 6: Colorcoded distance to a location of interest

Figure 7: The Phantom Device

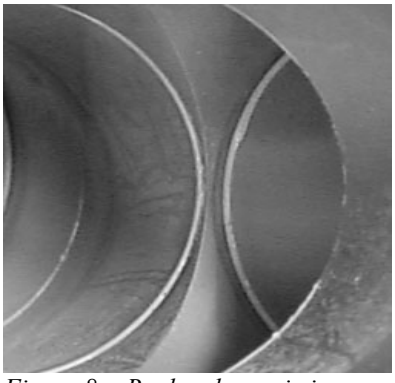

Figure 8a: Real endoscopic image

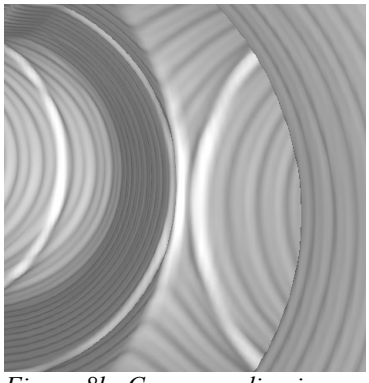

Figure 8b: Corresponding image in EndoView

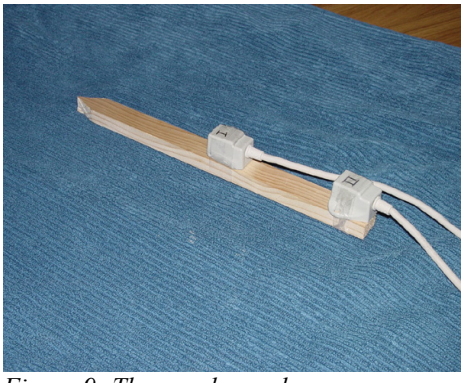

Figure 9: The wooden endoscope