

Comparison of 2D and 3D Input Devices for Virtual Endoscopy

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Abstract:

Within the last few years computer support became essential, since complex systems have substantially influenced the therapy planning. Those systems enable the physician to virtually plan the operation procedure at the patient, already before the real intervention is performed. It is the aim of surgery to avoid the danger of complications and to operate as gently as possible to ensure the quality of the surgical intervention. The computer-assisted surgical intervention planning can help here with optimized interaction techniques and selected input devices. The major application for virtual endoscopy was diagnostics [1] for which a number of efficient visualizations and image analysis techniques has already been developed [2],[3]. In this paper the interaction with 2D and 3D input devices for the planning of endoscopic sinus interventions is examined and evaluated, and for the first time the systematic comparison of different input devices is in the focus. In addition, the possibilities for the control mapping of a single input device and a combination of two different devices to an interaction technique are described. The focus is on the control of the view point that represents the virtual endoscope.

Keywords: virtual endoscopy, intervention planning, interaction techniques

1. Motivation

The possibility to additionally explore patient individual slice image data interactively in 3D via a virtual endoscopy enables physicians to improve the assessment of position, size and connection of the individual anatomical structures, and mentally prepares (even better) for the real intervention. The choice of an input device for this task should be well chosen due to the variety of possible interaction techniques. Within the last few years there were many further developments besides the conventional input mediums, like keyboard or mouse. 3D input devices that were developed for interactions in the three-dimensional space are not often used in the intervention planning yet. In the feedback of the evaluation of this work it turned out that physicians are partly not aware of the technical possibilities. Training period and initial costs are called most as reasons against a new purchase of an input device. This barrier can only be dismantled by clarifying the advantages of the input device towards others. The aim of this work is the development of a system for a possible objective comparison of input devices for certain interaction techniques. Among other things the comparison of conventional input mediums, like mouse and keyboard with alternative input devices like the graphic tray for trackball or spacemouse, is in the focus. The comparison was carried out with the help of the developed evaluation system. Here, the focus lay on the camera control as interaction technique since the exploration of data by a virtual camera is an important method in the intervention planning with a virtual endoscopy.

2. Methods

The interaction shall be examined with 2D and 3D input devices for the intervention planning at the example of nose sinuses, and shall be evaluated by a study. A system shall be developed, which enables us to compare input devices as objectively as possible. The needed training period for the use of the input device is, besides efficiency at use and aspects like price and ergonomics, an important aspect. The choice of the input devices to be examined was carried out in an assessment of the potential suitability for the control of the virtual endoscopy, the clinical availability and the initial costs. Therefore, the following devices were examined: keyboard, mouse, trackball, spaceball and graphic tablet as well as combinations

of them. The implementation of the test environment was done with VTK (<http://www.vtk.org>), which proved favourable for the connection of the device libraries.

The input devices are primarily different in the number of degrees of freedom and the generation of absolute or relative position values. To include these input data in arbitrary combinations, an interface controller was developed providing special information about the evaluation to the analysis modules and data for the camera control of the virtual endoscope. The allocation of the incoming data to the interaction techniques takes place in the interface controller (cp. Figure 1). The simultaneous use of several input devices is carried out by a prioritized queue. The orientation and position of the camera as well as the current modification frequency of these values are recorded to the application of the analysis methods besides the equipment ID.

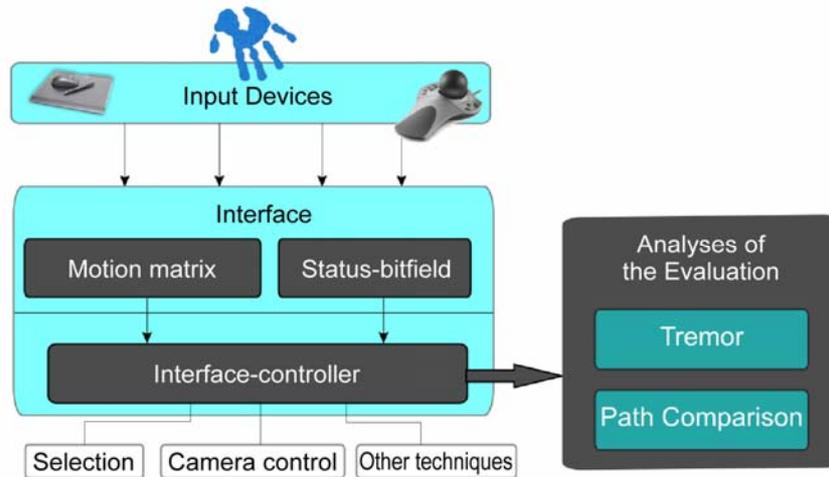


Figure 1: Schematic diagram of the evaluation system and the connection between the input devices, the interface controller and the analysis methods.

For the evaluation, a test scenario with a 3D representation of the nose sinuses was developed. As an analysis method we used the evaluation of the movement itself and the number of changes per metering rate on a path comparison. For this, a movement path which corresponds to a typical endoscopy of the nose sinuses was provided. During the study, the subjects had the task to pass checkpoint markers and therefore to follow the 3D path (see Fig. 2 left). For the evaluation the predefined path was provided with spheres and the differences to the recorded path of the subject were measured. Therefore, the algorithm can be parameterized with the radius and distance value to adjust the degree of sensibility (Fig. 2 right).

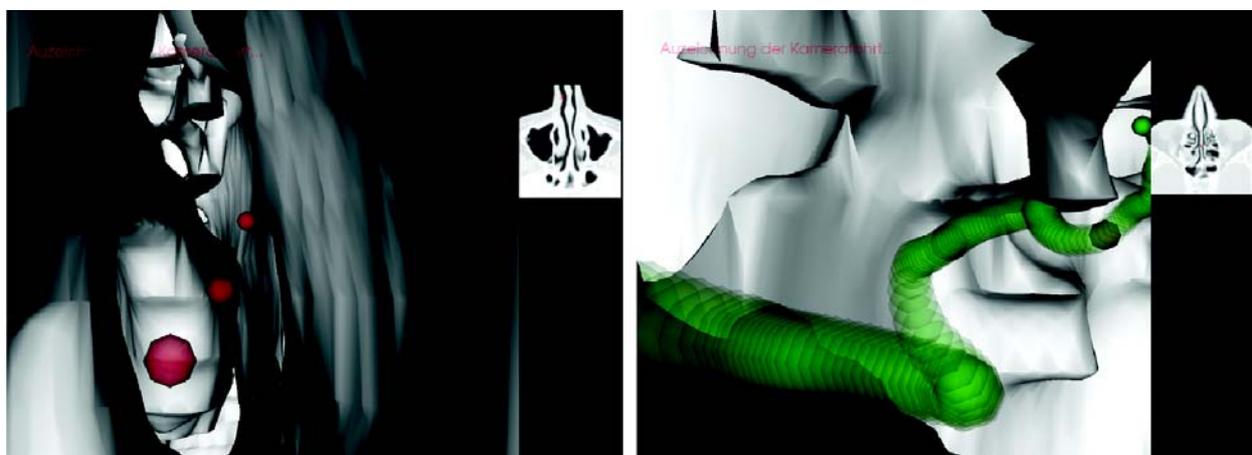


Figure 2: Left: test scenario with spherical checkpoints; right: visualization of a recorded path, symbolized with transparent green spheres

For the second analysis - the evaluation of the "trembling" of the input data - the timed position and orientation data were evaluated. The task of performing a camera movement along a path in the intervention planning usually consists of a purposeful movement to a concrete place of the nose sinuses. A high movement change frequency (tremor) should have an appropriately negative effect on a steady camera movement (Fig. 3).

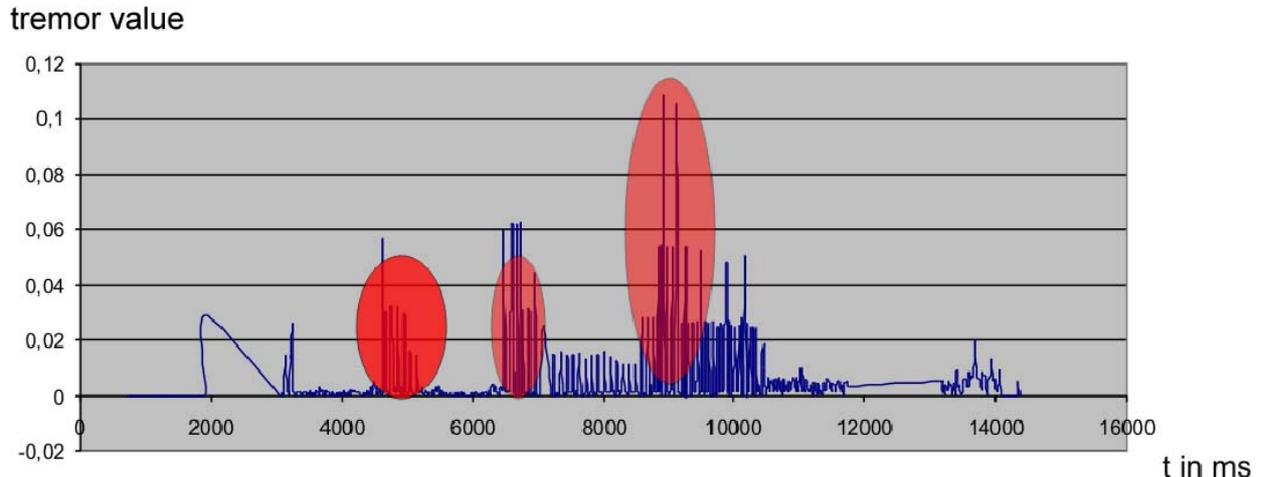


Figure 3: Movement change frequency over time. The red elliptical areas suggest stronger movements in a short amount of time. Usually this indicates an unwanted movement or a correction during the direction of the camera.

The recording of subjective statements of potential users was carried out via the preparation of questionnaires which covered aspects like the training period for the use of the input device, the efficiency, and the fulfilment of expectations towards the control.

3. Results

To be able to assess the learning progress of an input method, each of the 11 subjects had to solve the provided task of the path following repeatedly. Some interesting trends arose from the evaluation of the explorative first part from the measuring of path comparison and tremor. The built theses were checked in the confirmative part of the evaluation. Here, the 15 subjects were primarily physicians and medical engineering experts (Fig. 4).

It proved that two-handed interaction [4],[5], e.g. with keyboard and mouse, is accepted in general and provides good results, also by means of the execution of the provided interaction task. However, beginners have difficulties with coordination. The trackball has the advantage of lower space requirements in comparison to the mouse and was judged subjectively to be better to handle. A disadvantage of this device is the tremor sensitivity that results in noticeable constant oversteer and rapid direction changes of the camera (similar to the Results in [6]). The graphic tablet represents a relatively exotic interaction method for this application area; however it offers many degrees of freedom and furthermore permits simultaneous interaction with two inclination sensitive pens. The evaluation showed that the tablet can be used for the navigation over the pen inclination; however, precision improvements are still necessary for the adjustment of this interaction technique. Here, the learn curve was pleasantly high so that the approach is promising for future research. The spaceball has the highest acceptance from the users, and it also delivers the most exact values at the path following and a low tremor. Furthermore, the learning curve is very steep here; that was expected due to the direct mapping of the camera control.

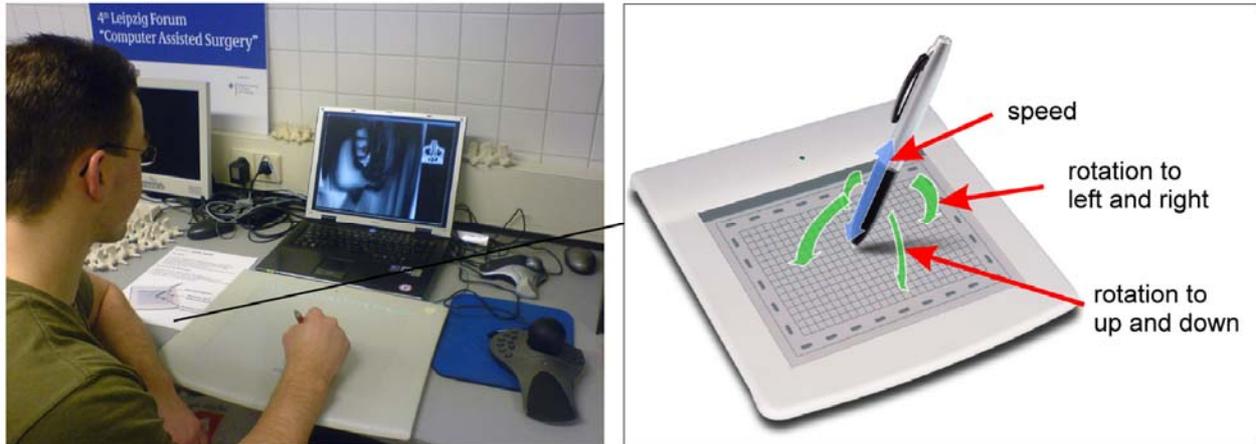


Figure 4: Evaluation setup at the Innovation Center Computer Assisted Surgery (ICCAS) in Leipzig. Each interaction technique was introduced and explained to the subject through a short illustrated instruction sheet.

4. Conclusion and Outlook

The comparison of different input devices for the use in virtual endoscopy showed that differences consist in the acceptance and suitability. For the occasional use (e.g. planning) the spaceball is the input device of choice, but combined with higher initial costs. Keyboard and mouse are also suitable, but they require a certain training period or a more frequent use. In this case the trackball can replace the mouse. This minimises the space requirements. The graphic tablet, which approximately offers a very large potential (e.g. for annotations), can also be used after a corresponding further development of the here used interaction technique.

At present, the developed interface controller is integrated into an operation planning system for nose sinuses and refines already developed techniques for haptic feedback [2]. Therefore, the endoscopy system is controllable with a variety of input devices in the future and can be used depending on preferences of the user or the existing equipment of the clinic.

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