ANALYSIS OF BIOMEDICAL SIGNALS AND IMAGES

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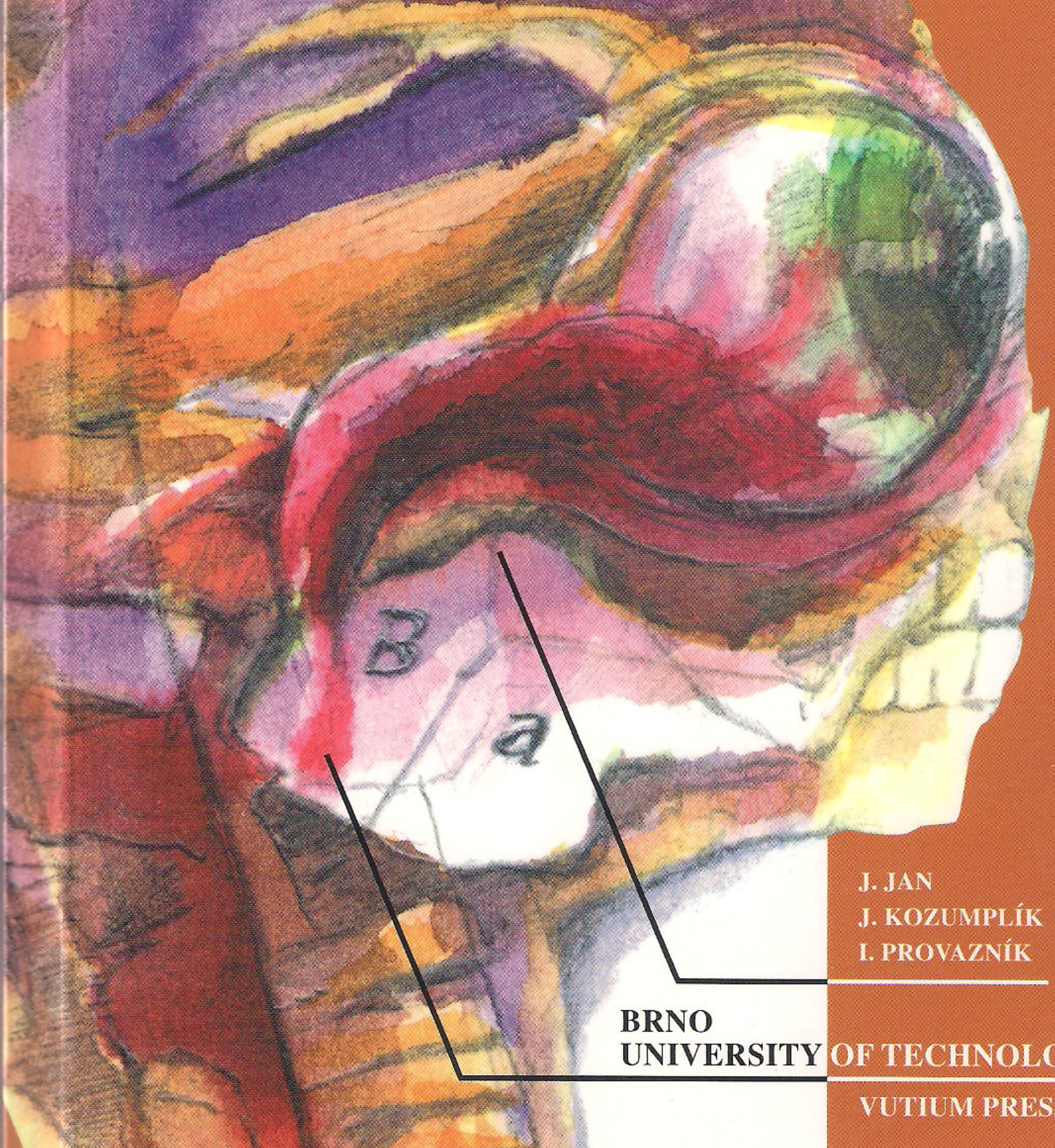

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Tetraoptical Camera System for Medical Navigation

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Abstract. *An accurate medical navigation system and precise patient positioning is essential for optimal medical therapy during biopsy, interstitial brachytherapy and radiotherapy. This paper describes an infrared based four camera-system, which in contrast to a binocular system has a number of advantages.*

1 Introduction

Biopsy needles are used for intracorporal irradiation of tumors. They are positioned under control of computer tomography into tumor tissue and supplied with a radioactive source, e.g. Ir^{192}. When applying extracorporal irradiation, the patient has to be positioned in the same position with respect to the LINAC as supposed for the irradiation planning system. During irradiation the patient's movement, involuntarily or by extensive breathing, should be controlled to gain the best therapeutical success with minimal damage of healthy tissue.

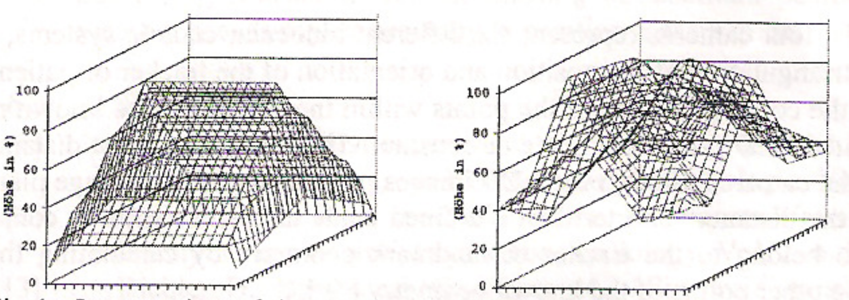

Fig.1 : Intersection of the overlapping supervised cameras (2 cameras left vs. 4 cameras right)

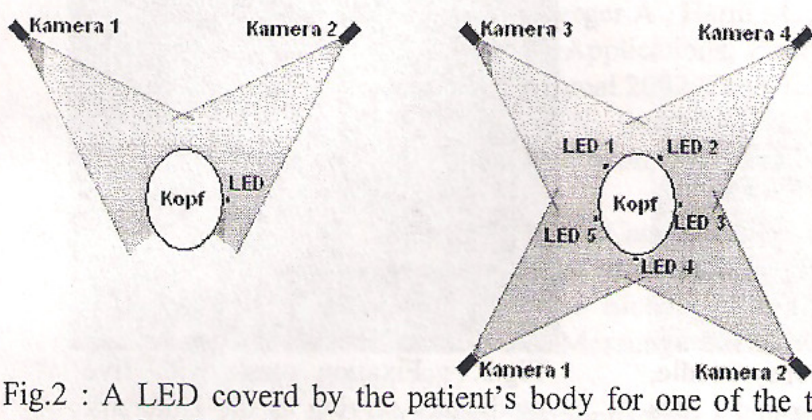

Fig.2 : A LED coverd by the patient's body for one of the two cameras of a binocular system (left). All LEDs are seen at least with two of the four cameras (right). [Kopf : head]

Different techniques may be used for navigating biopsy needles or for patient's repositioning, such as mechanical, electromagnetic, optical infrared or laser guided systems [1,2,3]. For infrared guided navigation active or passive landmarks are used. The advantage of optical navigation systems is that infrared light is not harmful, the independence of electromagnetic disturbances and the lack of discomfort for the patient [4]. However, disadvantages of binocular camera systems are the narrow bounded intersection of the two overlapping supervised volumes of the cameras (Fig.1), the limited orientation of the biopsy needle trackers with respect to the direction of vision and the possibility to cover the camera's view to the landmarks by the moving therapist or by the patient's body itself (Fig.2).

2 Tetraoptical System

We used four standard CCD video cameras mounted at the corners of a rectangular frame. The length at its edge was about 100 cm. The frame was positioned 120 cm above the CT table. The incident light was filtered by optical longpass filters with cut-off frequency of 830 nm (Fig.3). The cameras were externally synchronized to guarantee the time coincidence of the video frames. According to the applied mathematical model of the cameras, values for pixel aspect ratios, coefficients describing the radial symmetric distortion of the lenses, the orientation of the optical axes and the positions of the cameras are acquired during a calibration process [5]. We tested both a single plane [6,7] and a multiplane method [8] for calibration as well. The tracker is equipped with five IR light emitting diodes (LEDs) with wavelength of 890 ± 45 nm. Their spatial positions serve as the tracker geometry (Fig.4). Five landmarks, equipped with LEDs, were also fixed to the patient's body. The positions of these landmarks are segmented within the computer tomogram DICOM dataset by 3D image processing and serve as the landmark geometry (Fig.5). The LEDs of the tracker and those in the landmarks may be switched on and off mutually by the analyzing computer program.

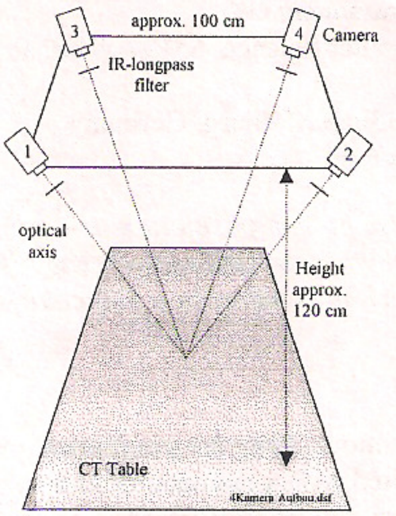

Fig.3 : Mechanical layout of the tetraoptical system

All combinations of the four cameras represent six different binocular camera systems, all of which are chosen for triangulation of the position and orientation of the tracker or patient's body as well. Neither is the correspondence of the points within the stereo images known nor is the number of segmented LED points complete or constant. Therefore all closest distances of projection rays from the cameras through the LED images passing the virtual image planes are calculated. From all the distances shorter than a defined value the center point is considered to belong or not to belong to the tracker or landmark geometry by calculating their Euclidean distances to the other points of the known geometry [9].

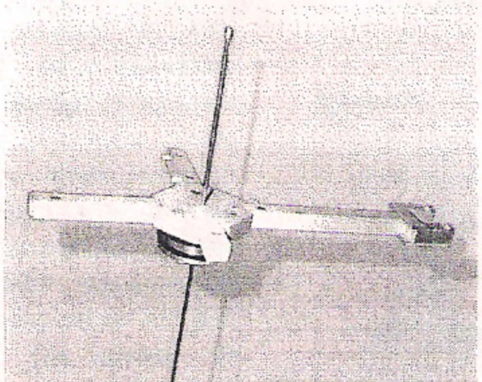

Fig.4 : Tracker with biopsy needle, force- and torque sensor and LEDs serving as the tracker geometry

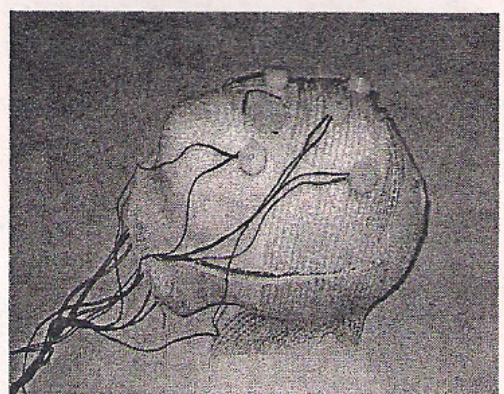

Fig.5. : Fixation mask with five landmarks serving as the landmark geometry

3 Results

The tetraoptical system was able to recognize and to reconstruct all tracker and landmark geometries which we tested in the laboratory, as far as all LEDs were registered by at least any two out of the four cameras. The range of the allowed orientation of the tracker was between vertical and horizontal direction and around 360° with respect to the vertical axis, depending on the momentary position. Repeated position measurements of the same position and orientation of tracker or landmark geometries could be reproduced better than 0.5 mm. Measurements of absolute preciseness are difficult to carry out and are still in progress. The repetition rate of the measurements is 12.5 Hz, sufficient for medical applications.

4 Discussion

We have shown that the analysis of the four images with unknown correspondences of the points of the tracker geometry or landmark geometry respectively and a varying number of points within the individual images, could be performed within the 40 ms of a video frame. This allows the navigation of the tracker online and the supervision of the patient's slow movements. Efforts still have to be made to evaluate the absolute preciseness of the system.

5 Conclusions

In this paper the use of a tetraoptical camera system is presented. The results have verified the advantages as opposed to binocular systems. The main advantages are

- the significant extent of the inspection volume,
- the robustness against the occlusion of the camera's view towards the LEDs, which gives the therapist much more freedom to move around the patient,
- the extended domain in which the orientation of the tracker is visible, giving the therapist more supervised access paths to critical regions of the patient's body and
- decreasing restrictions for the chosing of landmark positions on the patient's body, which achieves higher accuracy in position measurement.

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