Medical Applications enabled by a motion-robust optical 3D sensor

S. Ettl*, S. Fouladi-Movahed**, S. Bauer***, O. Arold*, F. Willomitzer*, F. Huber*, S. Rampp**, H. Stefan**, J. Hornegger***/****, G. Häusler*

*Institute of Optics, Information and Photonics
**Epilepsy Center, University Hospital of Neurology
***Pattern Recognition Lab, Department of Computer Science
****Erlangen Graduate School in Advanced Optical Technologies
Friedrich-Alexander-University Erlangen-Nuremberg, Germany

mailto:svenja.ettl@physik.uni-erlangen.de

In the medical field, the demand for motion-robust 3D data acquisition is steadily growing, e.g. for capturing limbs to construct prostheses. For this purpose, an optical 3D sensor is required which enables a flexible and comfortable 3D capturing of body parts. A “Flying Triangulation” sensor enables such tasks. Two exemplary applications, one in epilepsy surgery and one in radiation therapy, are presented.

1 Introduction

In the medical field, the demand for motion-robust, 3D data acquisition is steadily growing, e.g. for capturing limbs to construct prostheses. For this purpose, an optical 3D sensor is required which enables a flexible and comfortable 3D capturing of body parts.

The measurement principle “Flying Triangulation” [1] enables such measurement tasks. The sensor, based on light sectioning, can be freely moved around the object while capturing sparse 3D data with each single shot. The data is aligned and displayed in real time and after a few seconds a dense 3D model of the object is generated. The sensor is scalable and hence enables the measurement of a wide range of objects (see Fig. 1).

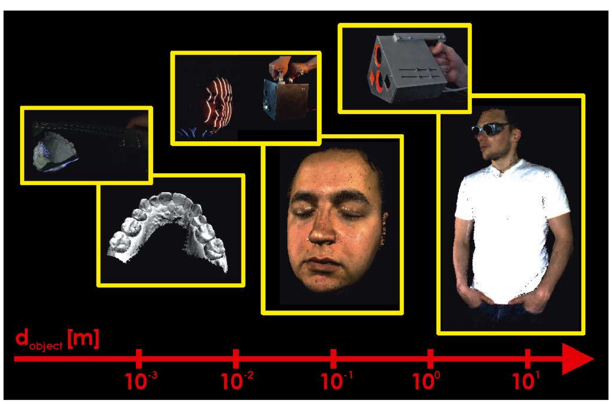

Fig. 1 *The measurement principle Flying Triangulation enables a motion-robust 3D acquisition of a wide range of objects.*

As representative medical applications, we show two examples: an application in epilepsy surgery and another application in radiation therapy. In epilepsy surgery, the goal is to locate and remove brain regions responsible for epilepsy by combining functional and anatomic data. For the co-registration of the two data sets, Flying Triangulation can be employed. In radiation therapy, the patient position must be known for accurate dose delivery. It is captured employing Flying Triangulation. We present measurement results and discuss further fields of applications.

2 Application in epilepsy surgery

In epilepsy surgery, brain regions responsible for epilepsy have to be detected and removed by combining functional and anatomic data. The following information can be used (see Fig. 2):

- functional electroencephalography (EEG) data
- 3D positions of EEG electrodes
- anatomical magnetic resonance imaging (MRI) data

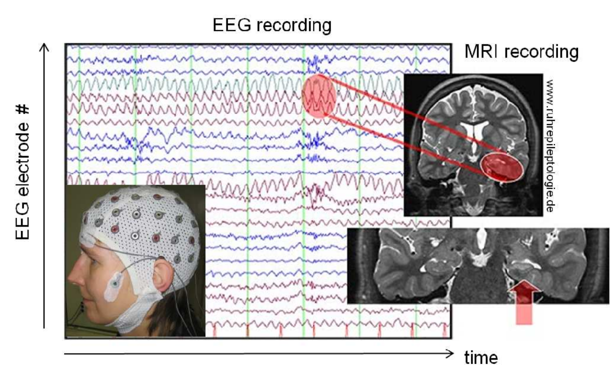

Fig. 2 *Center: Part of an EEG measurement. Bottom left: The employed EEG cap. Right: Exemplary MRI data with a localized brain region.*

Preserving healthy brain tissue requires, among other things, an accurate localization of the electrode positions. The localization method should also be simple, fast, and automatable. The current method [2] uses a hand-held stylus (Polhemus) which has several drawbacks, such as a strong user-dependence. Instead, we propose to employ a Flying Triangulation sensor for this task.

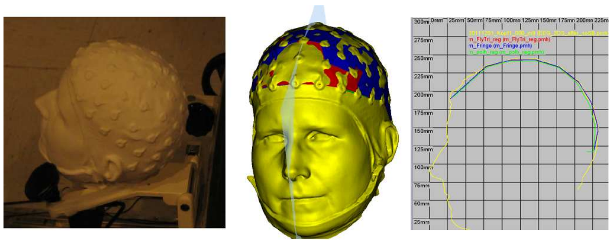

Fig. 3 *Left: Realized head model. Middle: 3D data of head model. Right: Cross-section of determined electrode positions.*

In order to compare both methods, a realistic head model with known electrode positions is generated and measured with a Flying Triangulation sensor (see Fig. 3). The resulting positions are compared to those obtained using the Polhemus stylus. As a result, the new method is more accurate, by a factor of 3.5, see Tab. 1 for further information.

	Polhemus	FlyTri
Accuracy	3.39 mm	0.97 mm
Acquisition procedure	stop & go	continuous
Acquisition time	15-20 min	< 1 min
Automatable	no	yes

Tab. 1 *Comparison of results for Polhemus and Flying Triangulation sensors*

3 Application in radiation therapy

In radiation therapy, prior to each treatment fraction, the patient must be aligned with respect to planning data. The underlying workflow is depicted in Fig. 4.

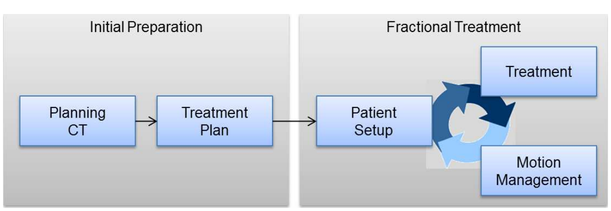

Fig. 4 *Flowchart of the clinical workflow in fractionated radiation therapy. Reproducible patient setup is essential for accurate dose delivery.*

Using a ceiling-mounted stationary Flying Triangulation sensor in combination with the steerable treatment table (Fig. 5), a dense and accurate model of the patient can be recovered from a series of sparse 3D measurements. This patient model can be employed for automatic patient positioning, c.f. [3].

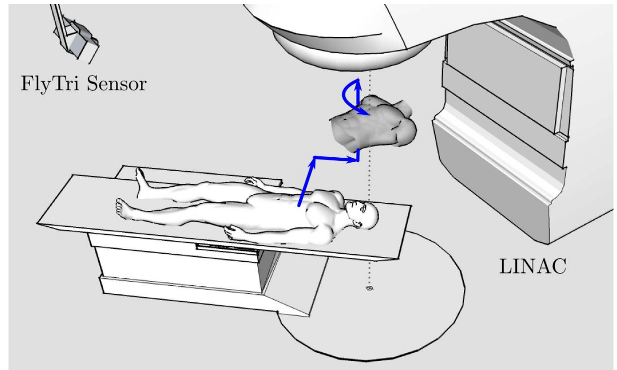

Fig. 5 *Patient positioning with respect to pre-fractionally acquired planning data, using a Flying Triangulation (FlyTri) sensor.*

In an experimental study, we have acquired dense 3D body models from healthy volunteers (Fig. 6, left) using a body-scale Flying Triangulation sensor with a measurement uncertainty of less than 1.1 mm over the entire measurement volume of $800 \times 800 \times 550\ \mathrm{mm}^3$ [4]. Further applications of the Flying Triangulation principle in radiation therapy include respiratory motion management (Fig. 6, right).

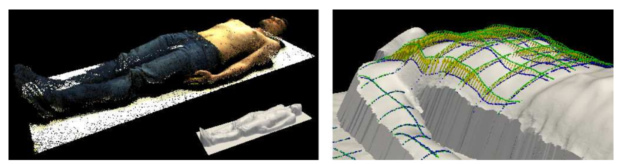

Fig. 6 *Left: 3D patient body model acquired using Flying Triangulation. Right: Tracking of non-rigid torso deformations for motion compensation.*

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