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


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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 3D data acquisition is steadily growing, e.g. for capturing limbs to construct prostheses. Often, the range of motion during such an acquisition is restricted and the patient might be bedridden and unable to be positioned in a certain way. 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).

1.1 Application in epilepsy surgery

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

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 (Fastrak by Polhemus) which has several drawbacks, such as a strong user-dependence. Instead, we propose to employ a Flying Triangulation sensor for this task.

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.

<table>
<thead>
<tr>
<th></th>
<th>Polhemus</th>
<th>FlyTri</th>
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<tr>
<td>Accuracy</td>
<td>3.39 mm</td>
<td>0.97 mm</td>
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<tr>
<td>Acquisition procedure</td>
<td>stop &amp; go</td>
<td>continuous</td>
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<td>Acquisition time</td>
<td>15-20 min</td>
<td>&lt; 1 min</td>
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<td>Automatable</td>
<td>no</td>
<td>yes</td>
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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.

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].

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 $800 \times 800 \times 550$ mm$^3$ [4]. Further applications of the Flying Triangulation principle in radiation therapy include respiratory motion management (Fig. 6, right).

3 References


