With Gaze Tracking Towards Noninvasive Eye Cancer Treatment

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Introduction

Uveal Melanomas are the most frequent primary intraocular tumors (cancer of the eye). Untreated, they may lead to blindness and to death, caused by metastasis. Nowadays, such tumors can be treated successfully with proton radiation while conserving the eye and frequently preserving the eye function. Despite its successful outcome, **the main limitation of the state-of-the-art method is that it requires an invasive patient preparation**. The surgeon sutures radio-opaque clips to the outer surface of the eyeball around the tumor periphery in order to define the tumor location within the eye and to be able to target the tumor during radiation therapy. Two orthogonal X-ray units and a motorized chair are integral parts of the treatment facility. X-rays are used to localize the clips, enabling an iterative alignment of the eye for the actual therapy.

Our objective is to make the entire workflow noninvasive (i.e. without clip surgery), using a suitable gaze tracker to predict a patients eye position.

Gaze Tracker

The present **gaze tracker hardware** (Fig. 1) consists of:

- an industry camera
- a 50 mm lens with an infrared pass filter
- two infrared LEDs and a battery pack
- a frame (optomechanical and 3D printed components)
- a hot mirror (reflects infrared light and transmits visible light)

The **gaze tracking software** consists of:

- 3D gaze tracking model
  ⇒ To determine eye position
- Coordinate system transformation chain
  ⇒ To transform the gaze tracking coordinates into the world coordinate system of the treatment device

Figure 1: Gaze tracking hardware

Integration I

For the gaze tracker integration, **we introduced a hot mirror to overcome the limited available physical space in the treatment facility**. The hot mirror deflects the infrared rays and enables us to place the gaze tracker close to the eye without hindering the sight of the patient and any other components required for the treatment.

Additionally, the gaze tracker can be rotated around the proton beam axis to guarantee an optimal view onto the eye of interest. Figure 2 illustrates the situation.

Integration II

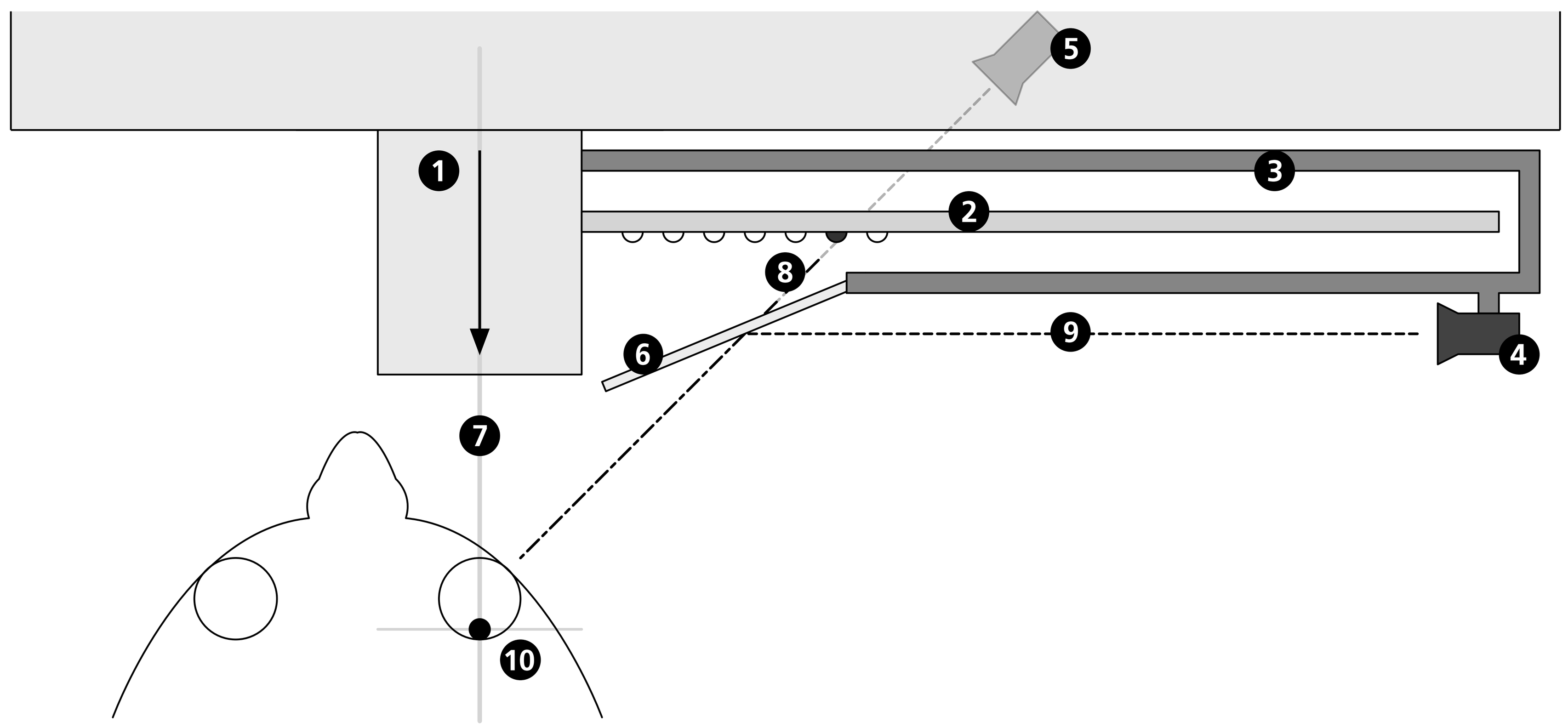

Figure 2: Situation plan (caudal view)

❶ Part of the treatment device with proton beam. ❷ LED bar with activated fixation light, can be rotated around proton beam axis. ❸ Holder for gaze tracker, can be rotated around proton beam axis. ❹ Infrared camera and illumination (gaze tracker). ❺ Virtual gaze tracker position. ❻ Hot mirror reflecting infrared wavelengths, while letting through visible wavelength. ❼ Proton beam and rotation axis. ❽ Patient's line of sight, fixating activated LED. ❾ Infrared rays, imaging the eye. ❿ Patient with target eye tumor in focus at isocenter of treatment device.

Results

Experimental setup: We examined ten healthy volunteers and recorded 2× 12 different calibration points per volunteer. One part of the data was used to calibrate the subject-specific parameters, the remaining data was used to test the point of gaze accuracy (Fig. 3).

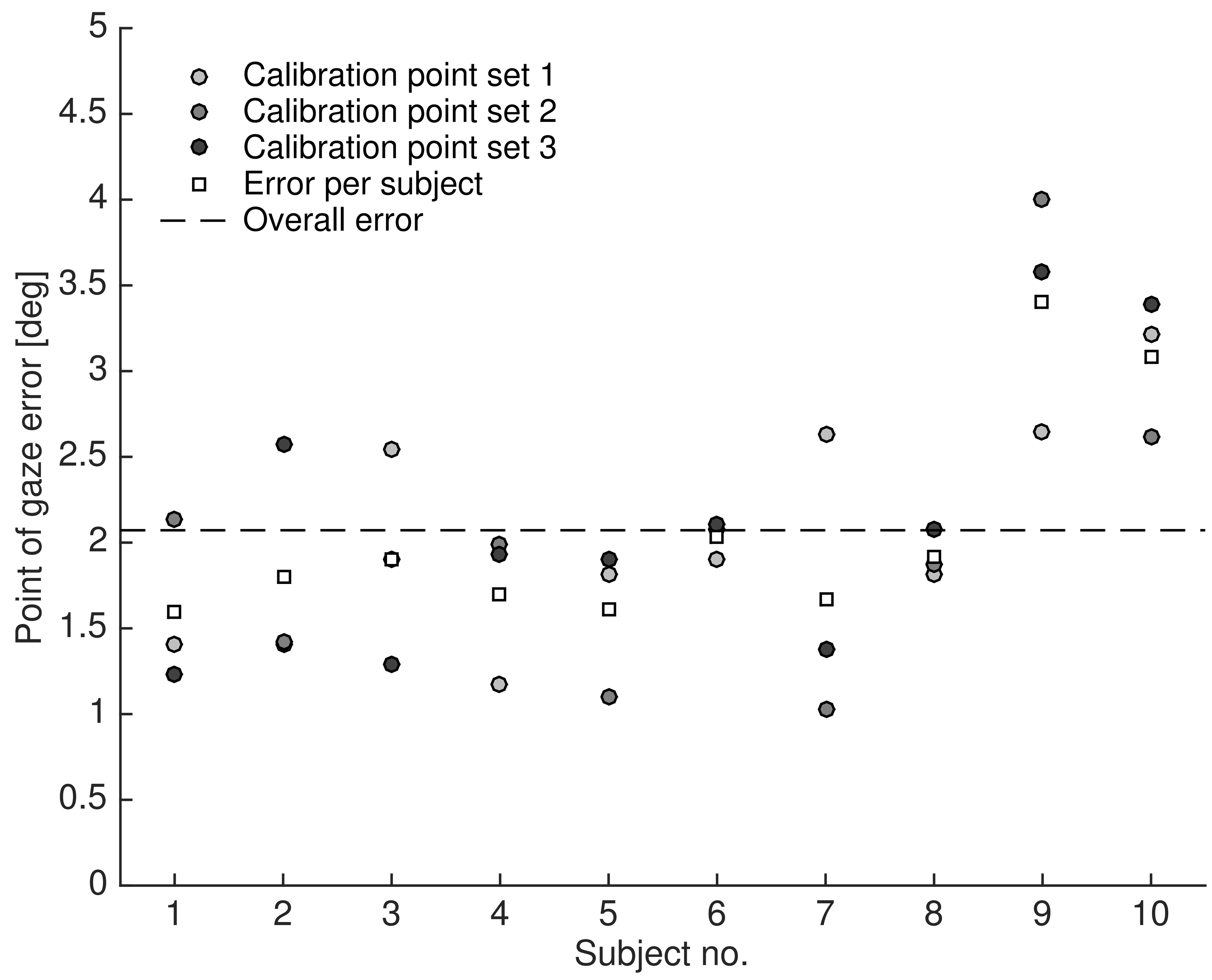

Figure 3: Average point of gaze errors

Mean distance between estimated points of gaze and true calibration points, **the accuracy of the gaze tracker:** 2.07°. An error estimate on the retina's depth (and thus tumor position): 0.59 mm.

Discussion

Next step: The prediction of certain points of the 3D model can not easily be verified, since the points are within the eyeball. Therefor, we suggest a testing stage with an artificial eye at a known position. This enables us to verify the accuracy of the required points.