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Generic design of a head-mounted gaze tracker for eye movement studies

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Introduction

Eye movements are a key element for various cognitive studies such as human attention, interaction (human, robots, virtual environments), ARE (Attention Responsive Environment), navigation, reading, painting analysis, etc. The usage of the gaze tracker for such activities requires the acquisition of specific skills such as control of eye movement (dwelling, displacement in precise direction and at giving speed, eyelids blinking at specific time, etc.). A gaze tracker can assist efficiently in understanding the underlying cognitive processes However, all the existing gaze tracker are rather expensive. Therefore, a design of a low cost gaze-tracker is on the progress in the frame of AsTeRICS, FP7 ICT project .

Two realizations of a gaze tracker are investigated: 1) boom arm-based system in front of the eye (direct gaze tracker), and 2) hot mirror-based system with camera on the side of the head (or indirect gaze tracker).

Gaze tracker global parameters

Human parameters: head sizes, distances “eye-camera(s)”, allowed head movements, eye illumination (infra-red (IR) or visible).

Generic design parameters: mono/binocular configuration; adaptability to scene illumination; precision of gaze detection adaptable to targeted application ; interchangeable parts; possibility to add additional sensors (inertial sensors); ease to wear; ease to use.

Optimal realization : minimized cost , minimized weight; fast realization time; reduction of the obtrusiveness of the field of view using the hot-mirror

Boom arm-based design

Figure 1 and figure 2 show stereo (direct) gaze tracker support, which directly acquires images of the eyes and of the observed scene (forehead camera) in visible spectrum. The original adaptive parts are shown in white color .

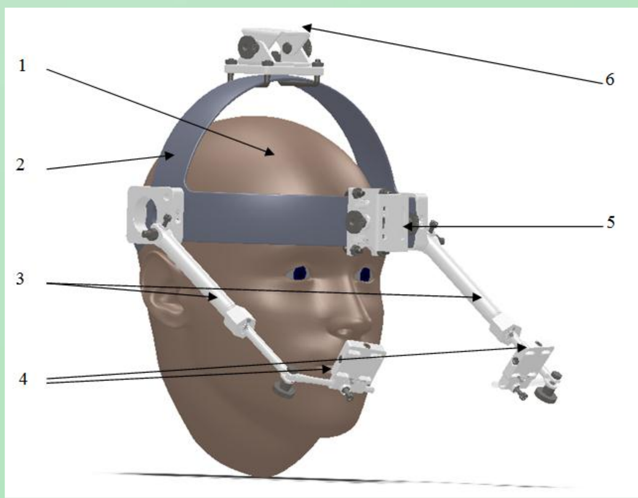

Figure 1. Direct gaze-tracker
(1-head, 2-helmet, 3-camera telescopic boom arms, 4-supports for the eye cameras, 5-support for the scene camera, 6-gaze tracker basic control (and additional sensors))

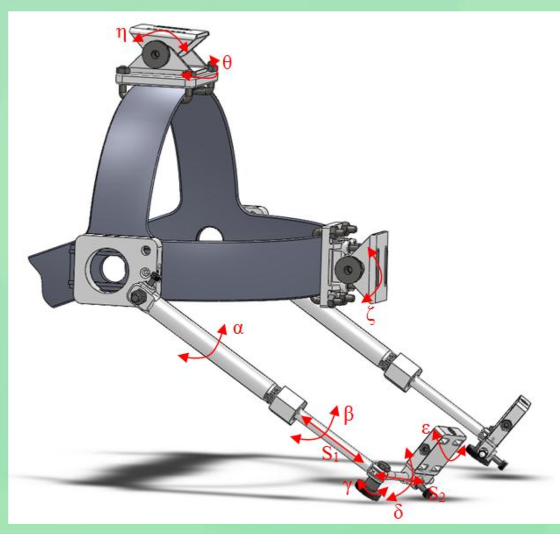

Figure 2. Direct gaze-tracker degrees of freedom (DOF) (generic design parameters)

Mechanical parameters (Figures 1 & 2):
- 4 DOF of the camera telescopic boom arm ;
  ($\alpha = 0 \div 75°$; $\beta = 0 \div 360°$; $\gamma = 0 \div 200°$ and $S_1 = 120 \div 200mm$);
- 3 DOF of support for the scene camera;
  ($\delta = 0 \div 360°$; $\varepsilon = 0 \div 360°$ and $S_2 = 10 \div 30mm$);
- 1 DOF of place for the scene camera;
  ($\zeta = 0 \div 360°$);
- 2 DOF of support for gaze tracker basic control;
  ($\eta = 0 \div 30°$ and $\vartheta = 0 \div 30°$).

Hot mirror-based design

Figure 3 and figure 4 show (IR) indirect gaze tracker (the adaptive original parts are shown in white color). The IR camera and associated illumination (IR LED, on/off optical axis) are mounted on a side plate (close to the ears). The IR camera films eye image on the hot (transparent) mirror located in the front of the eye ; the hot mirror reflected non-visible IR light illuminates the eye.

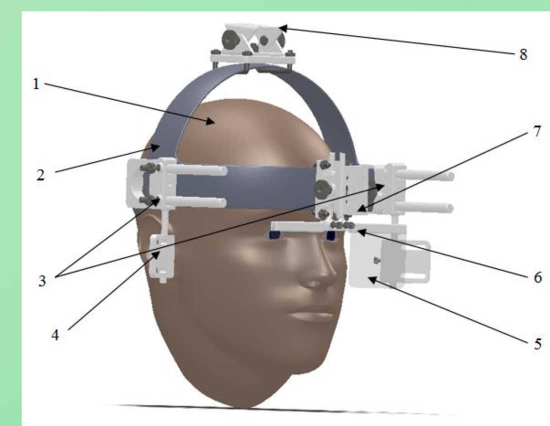

Figure 3. Indirect gaze-tracker
(1-head, 2-helmet, 3- 4 sliding plate for IR camera & LED, 5-6 hot mirror and its arm, 7-support for the scene camera, 8-gaze tracker basic control (and additional sensors).

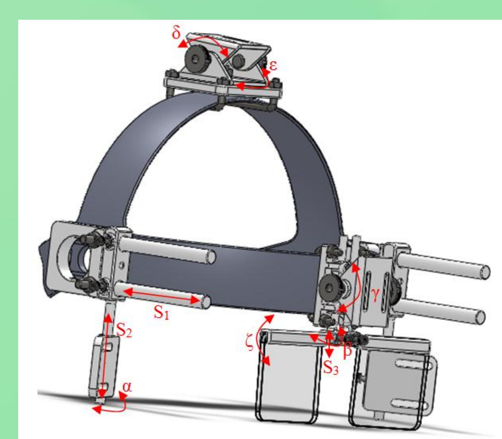

Figure 4. Indirect gaze-tracker degrees of freedom (DOF) (generic design parameters)

Mechanical parameters (Figure 3 & 4):
- 1 DOF of IR camera arm ($S_1 = 0 \div 60mm$);
- 2 DOF of side camera mounting plate;
  ($\alpha = 0 \div 200°$ and $S_2 = 0 \div 35mm$);
- 3 DOF of hot mirror arms;
  ($\beta = 0 \div 90°$; $S_3 = 0 \div 25mm$ and $\zeta = 0 \div 90°$);
- 1 DOF of place for the scene camera ($\gamma = 0 \div 30°$);
- 2 DOF of support for gaze tracker basic control;
  ($\delta = 0 \div 30°$ and $\varepsilon = 0 \div 30°$).

Discussion and future works

Through its 10 DOF, the direct gaze-tracker can adapt to a wide selection of low cost CCD cameras and associated optics, and to large variations of morphological and perceptual capability of the end-users. In visible spectrum, the gaze-tracker can be used in indoor and outdoor environments .

Through its 9 DOF, the indirect gaze-tracker can adapt to a wide selection of low cost IR cameras, wide hot mirror sizes and shapes, wide selection of the associated side camera optics and to various capability (morphological/perceptual) of the end-users.

The direct gaze-tracker configuration can be used with any spectrum subject to an adaptation to final application requirements. Equipped with cameras the system allows acquiring eye images, tracking the eye movements and computing visual gaze mapping via *e.g.* feature based algorithms (such as IR pupil tracking combined with regression).

The proposed adaptable systems and associated software will allow gathering gaze scan paths for detailed human eyes behavior registration when performing different cognitive tasks (such as navigation, reading, human-human interaction, human-robot interaction , etc.).

Future works :
- Tests of the gaze-tracker technical performances (speed and accuracy of the gaze tracking)
- Tests of the designed system with end-users in an application based on human gaze behavior (*e.g.* human attention analysis and modeling through acquired scan paths during the navigation in real scenarios).

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AsTeRICS

SEVENTH FRAMEWORK PROGRAMME