Measurement of Head and Eye in vHIT

PRODUCT INSIGHTS

author:
Enrico Armato, Dr.

This document provides a comprehensive overview of how to perform the video Head Impulse Test, starting from the physiological bases up to daily diagnostics. SYNAPSYS VHIT is a unique system that represents a fundamental step forward in the evaluation of the vestibular system. It does not require the patient to wear any goggles; all results are obtained from the analysis of the patient's head and eye movements, recorded by a remote camera.

HEAD POSE ESTIMATION AND PUPIL TRACKING

The remote camera-based vHIT system captures the patient's face and identifies the pupils and then measures the two key elements for the calculation of the VOR gain: head velocity and eyes velocity. A device of this type belongs to the family of Eye-Gaze Tracking Systems but differs from the latter as it has additional functionality, as we shall see shortly.

EYE-GAZE TRACKING SYSTEMS (EGT)

EGT systems are able of determining and following the position of the eyes over time, calculating the coordinates of the point observed by the subject. First used in the 19th century in academic settings to better understand the mechanisms underlying visual perception, they were quickly developed mainly for medical purposes: ophthalmology, neurology, psychology, oculomotor skills and to study the relationship between these areas and cognitive and mental capacity in general.

EGT systems are video-oculographs (VOG) that use infrared (IR) technology, thanks to which it is possible to obtain a better contrast for the pupil recognition. They can be distinguished into wearable (Head-Mounted) and remote devices.

THE VHIT AS AN EVOLVED FORM OF EGT

The vHIT must necessarily have the function of calculating the position of the eyes in space; therefore, it belongs to the EGT family of technologies. In particular, the Natus vHIT ICS Impulse and the Interacoustics EyeSeeCam are gaze detection systems IR-VOG Head-Mounted, while the Inventis vHIT Ulmer is a remote IR-VOG. Unlike EGTs, however, the vHIT must be able to calculate not only the position of the eyes but also that of the head.

While v-HITs with wearable masks use the information from the accelerometric sensor to determine the position of the head in space, devices with remote cameras must perform this operation based only on the recorded images.

A remote vHIT must therefore determine both the position of the eyes and the head starting from the video-acquired sequence.

In both cases it is a matter of calculating, or rather estimating, the position of a target in three-dimensional space starting from the representation in the two-dimensional space of the image taken by a camera.

In the literature, the two problems of estimating eye and head position are named **Pupil Tracking** and **Head Pose Estimation** respectively, which therefore represent the two sequential analysis steps necessary to determine the position of a generic target in three-dimensional space.

TRACKING

This is a technique for the monitoring of one or more moving objects by means of a camera. It is necessary to identify the exact location of the target and create the correct corresponding points in consecutive frames (or, as you would say in jargon, to "identify and lock onto the target").

The operations of a tracking algorithm are as follows:

1. Identification and representation of the targets; the latter in turn includes edge detection and shape recognition;
2. Filtering and association: this is a statistical estimate of the target's position in the image using movement patterns; that is, constraints on the possible configurations of the target.

POSE ESTIMATION

While tracking identifies the location of the target of the image that is taken from the camera in two-dimensional space, pose estimation converts this to the location position of the target within actual three-dimensional space. It is therefore a technique for estimating the spatial arrangement of one or more objects captured by a camera system. However, the vHIT remote only uses only one camera: pose estimation in this case will then become a mathematically undetermined problem, since with a single camera it is not possible to understand whether the target of the image is a small object that is nearby or a large one that is far away.

The easiest solution is to use a second camera to be able to integrate information coming from the two views, unambiguously determining the position of the target in space. This technique is named camera triangulation and does no more than mimicking the binocular system with which nature has endowed human beings and all animals that have stereoscopic vision, through which we can see in 3D.

However, with a single camera it is not possible to use the triangulation method: we must therefore take advantage of mathematical models which allow us to estimate through statistics the most likely position of the target in each frame. Shown below are two examples of such mathematical models: the first is used for the eye (it is a parametric model as it uses an analytical formulation of shapes, characterized by certain parameters that are to be determined), and the second is used for the head (consisting instead of a series of polygonal finite elements which together form a 3D mesh):

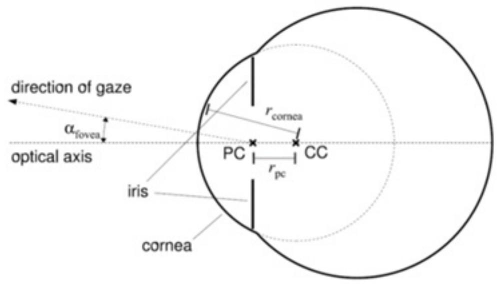

Figure 1: 3D Model of the eye

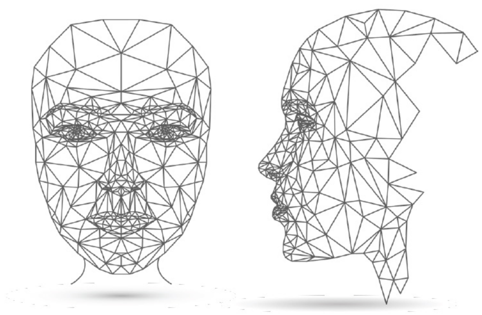

Figure 2: 3D model of the face

The mathematical model is usually constructed off-line, determining the structure (that is, a set of equations that combine the measurements from the camera with the estimation of position by means of a series of parameters) and by then performing the training on a dataset, to define the ranges for the parameters and the constraints a priori. To obtain a more statistically accurate estimate of the target's position in 3D space, the measurements taken are then submitted to the model in real time. In the case of video Head Impulse Test Ulmer from Synapsys, the algorithms for pose estimation used guarantee an accuracy of 0.1° for the estimation of head and eye position, of 0.4° for the estimation of gaze direction and 0.08 for the calculation of VOR gain.

INVENTIS S.r.l.
CORSO STATI UNITI, 1/3
35127 PADOVA – ITALIA
TEL: +39.049.8962 844
FAX: +39.049.8966 343
info@inventis.it
www.inventis.it