An optical head-pose tracking sensor for pointing devices using IR-LED based markers and a low-cost camera

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***Abstract*—In this paper, we present a head-mounted pointing device (i.e. "Head-mouse") which consists of an optical sensor based on a small CMOS-camera with the IR blocking filter replaced by an IR-bandpass filter and IR LEDs (850nm wavelength) as markers. The advantage of our sensor compared to other head-mouse systems and eye-gaze systems is that the proposed sensor results in an absolute positioning of the mouse cursor and does not require laborious recalibration as the user changes his position. Furthermore, the sensor has a larger operating area and allows seamless control of multiple devices.**

***Index Terms*—optical sensor, head-pose tracking, pointing device**

I. Introduction

In this paper, we present a head-mounted pointing device (i.e. "Head-mouse") which consists of an optical sensor based on a small CMOS-camera with the IR blocking filter replaced by an IR-bandpass filter and IR LEDs (850nm wavelength) as markers. The device is targeted at people with limited hand/arm movement or control. The position of the mouse cursor is estimated by using a homography matrix which is estimated using the Direct Linear Transformation (DLT) algorithm [1]. This algorithm requires at least 4 detected marker-coordinates in the camera image and their corresponding coordinates in the world coordinate system. The advantage of our sensor compared to other head-mouse systems and eye-gaze systems, as discussed in section II, is that the proposed sensor results in an absolute positioning of the mouse cursor and does not require laborious recalibration as the user changes his position. Furthermore, the sensor has a larger operating area and allows seamless control of multiple devices. The static accuracy of the system is discussed in section III-A, and accuracy and speed of use by untrained users of the system are discussed in section III-B, leading to results that are comparable to other head-mouse applications and other alternatives like eye-gaze systems, and can be further improved by implementing tremor suppression filters.

II. Head-mounted pointing device

The current main alternative pointing devices for people with disabilities [2] can be classified as (1) switch or joystick oriented, (2) head tracking (single marker), (3) head pose tracking (multiple markers), and (4) gaze tracking. While stating all pro's and con's is not in scope of this article, the main issues in the field of pointing devices can be summarized as follows. Switch or joystick oriented systems generally have low throughput; single marker head tracking requires frequent recalibration; current head pose tracking systems require high processing power, and eye-gaze systems either require expensive hardware or high processing power and lack consistent accuracy. None of these systems have the ability to control multiple devices (using a single sensor). For a detailed discussion of these issues we refer the reader to reference [2]. The proposed system, which uses IR LEDs as markers and a cheap IR sensitive camera, as described in more detail in [3], allows for a calibration-less pointing device which is able to control multiple devices using low-cost hardware while maintaining a similar performance as current state-of-the-art systems. The positions of the markers relative to the screen coordinates must be known. The cursor location is estimated by translating the center of the camera to screen coordinates using the homography matrix which is estimated from the marker locations in camera coordinates.

$$P_{l,W} = H \cdot P_{l,C} \tag{1}$$

with $P_{l,W} = \begin{pmatrix} u & v & 1 \end{pmatrix}^T$ the marker coordinates in the world coordinate system, $P_{l,C} = \begin{pmatrix} x & y & 1 \end{pmatrix}^T$ the detected marker coordinates in the camera coordinate system, and H the homography matrix.

An estimation of the homography matrix $\widetilde{H}$ can be found using the Direct Linear Transformation (DLT) algorithm [1], leading to

$$P_{i,W} = \widetilde{H} \cdot P_{c,C} \tag{2}$$

with $P_{i,W}$ the calculated cursor position, and $P_{c,C}$ the center

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