CALIBRATION-FREE GAZE TRACKING

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ABSTRACT

The application of gaze tracking is well established in user behavior studies and human computer interface for some applications such as amyotrophic lateral sclerosis patients. However, those application of gaze tracking is still limited in other domains due to various challenges. One of the challenges is the cumbersome calibration process that requires the user to gaze at calibration points on an object, typically a monitor screen. This process is necessary to estimate the subject specific eye parameters, which are essential to model the eye in 3D and to estimate the gaze accurately. In this thesis, we focus on improving the calibration process by eliminating the need for explicit calibration. This improvement simplifies the use by reducing the user's effort for calibration. This is particularly important for three reasons. First, the calibration process tends to discourage the user from using the technology and influences the user's state of mind in a user behavior study. Second, it prevents the development of a fully automatic and natural eye tracking system. Third, the system cannot estimate the user's gaze accurately when the user is uncooperative, which is particularly true if the user is an infant or a criminal. In this thesis, we take two approaches to solve this problem.

First, we extend and improve an existing stereo eye tracking approach that does not require explicit personal calibration. This approach eliminates the need for explicit calibration by exploiting the binocular constraint that assumes visual axes of the two eye intersects at the gaze point. However, this approach, being very susceptible to image noise, is neither robust nor accurate enough for practical applications. To alleviate this problem, we propose to enhance this method with two additional constraints: the screen constraint and the eye parameter constraint. While the former limits the scope of the eye gaze, the latter limits the range of the eye parameters. Experiments show that the proposed enhancements improve both the gaze estimation accuracy and robustness, as well as simplify its use.

Second, we study the feasibility of performing calibration-free eye gaze tracking from a monocular camera. Compared to the stereo eye gaze tracking, the monocular eye tracking allows larger head movement. In order to realize this approach, we systematically develop a mathematical model that for the first time establishes a concise analytic relationship between the optical axis, the visual axis and the personal eye parameters. Using this mathematical model, we show that a measurement matrix resulting from a collection of optical axes can be constructed, and furthermore we show that the measurement matrix can be factorized into the product of two matrices- one is composed of the visual axes and another composed of the personal parameters only. Based on this, we propose a factorization procedure that can recover the personal parameters (up to a rotation matrix) by factorizing the measurement matrix through singular value decomposition. Further research is needed to estimate the rotational matrix and to validate the method.