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A novel approach to the low cost real time eye mouse

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ABSTRACT

The PCCR (Pupil Center Corneal Reflection) method became dominant for finding human's diverse eye gaze directions through the research on the eye tracking technology that has been done for a very long period of time. The initial studies on the eye tracking technology were related to the general human interface for operating equipment and devices, then it has been promoted to the field of various purposes such as a market research in a recent study analyzing customer's behaviors. In particular, a real time eye gaze tracking system is most important for many HCI applications including stereoscopic synthesis, intend extraction, behavior analysis and etc. In order to make an eye gaze tracking system to be real time, the system must have an efficient pupil detection algorithm and ambience-independent image processing as well as reduced complexity, small size and number of circuit components. This paper proposes a method for getting clean images compared to the previous systems to reduce image processing overhead. Because it also helps reducing the number of image frames to be dropped during the image processing, the proposed method can provide a sufficient performance even on a low cost hardware system by reducing the transmission traffic.

1. Introduction

The number of ALS (amyotrophic lateral sclerosis, also known as Lou Gehrig's disease) patients in Korea is estimated to be about 1200 and over 2,000,000 physically disabled people in the whole world. ALS begins with irregular limb weakness, body-wide tremors and/or speech difficulty. Unfortunately, ALS patients, sometimes within months, lose the ability to move, eat, drink, speak and breathe. Their life can sometimes be prolonged through the use of a feeding tube and respirator. The term 'ALS' can be expressed what is called 'life in a glass coffin', which means death comes within 2 to 4 years. Particularly, ALS strikes anyone, anywhere and anytime without warning. Fifteen new cases are diagnosed each day in the United States alone, the same are diagnosed with multiple sclerosis. However, ALS patients die usually within a few years [1].

This rapidly progressive disease attacks motor neurons in the spinal cord and brain, and there is no known cure for it at this time. The combined number of patients difficult to move their body by accident or illness is getting bigger. Therefore, a potential demand of the input pointing devices utilizing the eyes is increasing because they can be used instead of their hands, speech or other methods to interact. Around 30,000 potential patients just in Japan use computer with specially designed input devices and, of course, their economic circumstances are also all different depending on the individuals. In case of the commercially used eye-based mouse for example, it is difficult for many people to try because of its expensive cost.

To resolve above problem, this paper introduces a missionary project called Low Cost Real-time Eye Gaze System, a hardware-based pointing device framework for ALS patients that is composed of a remote type eye mouse hardware and firmware, a HID (Human Interface Device) driver software for the operating system and an application software suit. This hardware-based pointing device framework can be implemented with low cost materials via a convenient-to-deploy assembling environment. This framework was designed as a result of the VOC (Voice of Customers) from the ALS patients including potential candidates, as well as analytical needs and desktop research results. The implemented system was proved that it can excellently provide functionality of a conventional pointing device through a practical usability test. It is expected that this system can provide an IT experience even for ALS patients so that they can interact with the world, which was not achievable before (Fig. 1).

The implemented eye mouse has a performance adorable harmonized software and hardware. In this paper, we broadly handle the system organization, and focus on the reduced complexity of the system for a low cost real time system.

2. The eye gaze tracking system

2.1. The gaze tracking system

Gaze-tracking has been used in studies dating as far back as 1935 and 1967. During these early days of eye tracking, systems were cumbersome, invasive and not very accurate. However, with recent advancements in eye tracking technology, we can have a system that is remove, non-encumbering, non-invasive and accurate to within 0.5–2.0°

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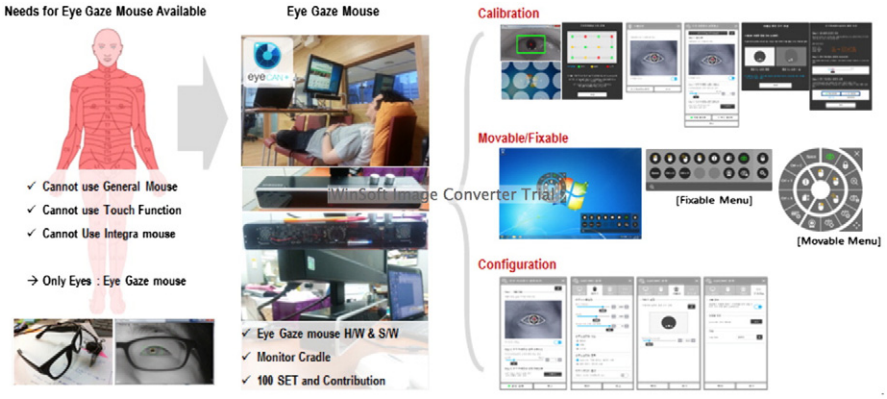

Fig. 1. Hardware-based pointing device framework for the ALS patients.

accuracy but expensive. It has been focused for a very long period, in the Initiated approach was the recognition of human's interests and then recently, the focus is getting moved to the searching purposes and behaviors for various fields such as marketing research, detecting of napping at driver's seat, and etc [2–6].

Initial studies of the eye tracking are starting from the interface for operating the equipment and devices, and then, it has been promoted in the field of various purposes. More recently, the movement has been trying to apply to the personal device such as a PC, mobile devices, TV, tablet and etc. Thus, this kind of trend has come out and showed off the UX as an eye tracking technology at CES2012 by Microsoft Company.

Most modern approaches, including remote gaze estimation, are based on the analysis of eye features, head features extracted from video frames. The most common approach to remote POG (Point of Gaze) uses the estimates of the centers of the pupil and on or more corneal reflection. It is called PCCR (Pupil center corneal reflection) system, it uses the corneal reflection image, generally called from 1st to 4th purkinje image or pupil and glint image, in other words, virtual images of the pair of the light source in front of surface of the cornea [7].

When light falls on the eye, part of it is reflected back, through the pupil, in a very narrow bean pointing towards light source. If a light source is located very close to a camera optical axis, a very bright pupil is grabbing, otherwise dark pupil does. If this two grabbed image is subtracted, these two images of subtraction are left by the pupil and glints.

2.2. The PCCR eye gaze tracking prototype system

The proposed PCCR eye gaze tracking prototype system is shown in Fig. 2, it is a prototype model for several experimental setting to find the optimum images. This system is composed of various parts in the camera, and experiments were carried out by configuring the system to match the optimum distance through the experiment by placing on both sides of the reflected light LED. Eye-tracking systems use the difference vector (P-CR) between the pupil position (P) and the corneal reflection (CR) to determine the gaze vector [8,9].

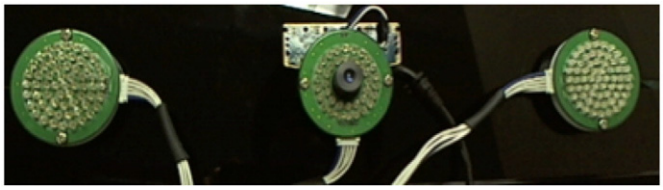

Fig. 2. Hardware components of the system.

It is important that setting up the eye camera and performing a good calibration routine are just as important as the design of the system for the disabled [10]. In this paper, to obtain POG direction, this system uses photometric InfraLED reflections on the surface of the cornea. In appropriate situation, one or more glint lights (dark pupil) and full reflection light (bright pupil) from retina by illuminated light near the optical axis of the eyes. It is an important performance parameter to get clear images from PCCR system because it depends on fast and exact calculation of each image by stable clear image grabbing.

The proposed system uses a CMOS digital imaging sensor and a PC for the image processing instead of standalone FPGA. It processes 640 × 480 progressive scan frames at a 60 frame for second rate. Any CPU based implementation of real-time image-processing algorithm has two major bottlenecks, that is a data transfer bandwidth and sequential data processing rate. After a frame is grabbed and moved to memory, the CPU can sequentially process the pixels. Instead of FPGA, we used note PC and then USB port that bandwidth is limited between Image capturing device and the PC.

2.3. Performance factors for PCCR system

One of the important criteria using eye tracking system in the most input devices is the accuracy of the eye gaze. There are several affecting accuracy factors when using these operations with their eyes, but the operation performance of the human eye depends on the tracking resolution of the eye-tracker, the size of the display, resolution, distance, UI/UX design and etc. For example, the head motion eye has the disadvantage of close relationship with the human face and person. When the object on the LCD screen moves quickly, eye tracking offset occurs. Thus, eye tracking system is the expansion of the freedom of movement, but there is actually a limit to the resolution of the camera and FOV of the eye tracking system. To resolve this problem, we need the most appropriate system configuration depending on the purpose of the eye tracking system.

In a view of the price, the remote stationary eye mouse is around 8 k–40 k US dollars for physically disabled people. This type of mouse is used as an input device for people suffering from ALS, however, despite expensive price, the stationary remote eye mouse is used in the specific field because it is difficult to use and control by practice. In other words, when people use their eyes as a means of access information by eye gaze tracking, there is some discrepancy in the usability surface. It means that the eyes must be used not only getting information but also controlling some devices or equipment. As people use other parts of your body, ALS patient uses their eyes instead of their hands or bodies because there is no better function to replace.

Thus, the performance factors for eye gaze tracking as shown in Fig. 2 are very important to the ALS patient because they cannot communicate with others without the eye gaze tracking system