High speed and low latency eye direction measurement camera system and saccade prediction algorithm

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Abstract Eye direction measurement is expected to have wide application area, including user interface and psychological analysis. The saccade, a rapid eye motion, is also expected to be applicable for a new type of interaction technique, however, it is impossible to measure and track the saccade in real-time by using the conventional eye direction measurement system. In this paper, we describe the high frame, 500[Hz], and low processing latency eye tracking camera system using high speed camera and FPGA, are described. We also discuss on the saccade destination prediction algorithm enabling to predict the saccade destination at early step of saccade, before the saccade ends.

Key words Line-of-sight, Eye tracking, Saccade, Prediction of Saccade Destination, High-speed Camera, Low Latency, Image sensor

1. Introduction

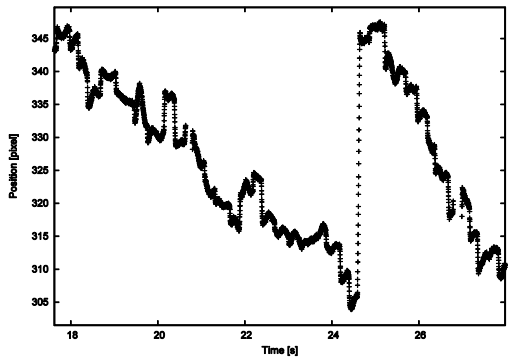
Eye direction measurement is expected as user interfaces, and have been researched for psychological analysis and drive assist[1][2], and so on. There are a lot of commercial products available on eye tracking cameras at a low price [3].

The eyeball often moves very rapidly regardless of our intention, which is called as “saccade”, however, real-time tracking of saccade is difficult with the conventional image processing systems for their long processing time and latency against the speed of saccade. In this paper, we describe the eye tracking camera system, which is high speed and low latency, employing column-parallel architecture suitable for one chip eye tracking camera implementation. We also describe the prediction algorithm of saccade destination.

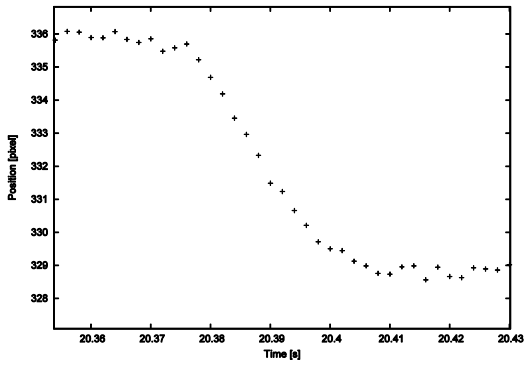
2. Eye tracking camera system using high-speed camera and FPGA, and CMOS image sensor

The eye direction can be calculated from the position of the pupil in the infrared image of the user’s eye, which is observed as a black area. In order to realize the real-time saccade tracking including the saccade prediction, it is important in tracking system with high resolution, high frame rate, and low latency. We employed a column parallel architecture for integrated CMOS camera with eye tracking implementation enabling both high resolution and high speed. We developed the high-speed and low latency eye tracking camera system using the high-speed camera and the FPGA to observe eye movement including saccade in order to emulate the processing capability.

3. Capability of saccade tracking



(a)



(b)

Figure 1. (a)Pupil X position and (b)its magnified part.

Figure 1 shows an example of the measured horizontal eye motion during reading horizontal Japanese sentence. The saccade is observed as the step motion in Figure 1 (a), whose detailed process is captured by the developed camera system.

4. Prediction of saccade destination

We extracted the saccade motion from the measured eye motion data, and measured the saccade speed and the saccade travel distance. The relation of the saccade speed and the saccade travel distance is shown in Figure 2, which indicates a linear relationship between the saccade speed and the saccade travel distance.

Figure 3 shows an example of the predicted saccade destination based on the measured saccade speed at the 3 points from saccade beginning, with the liner relation in Figure 2, where the circle in Figure 3 indicates the saccade destination. The measured mean prediction, error

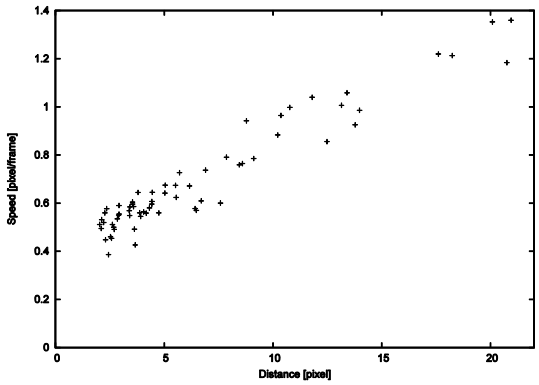


Figure 2. Saccade speed and saccade distance.

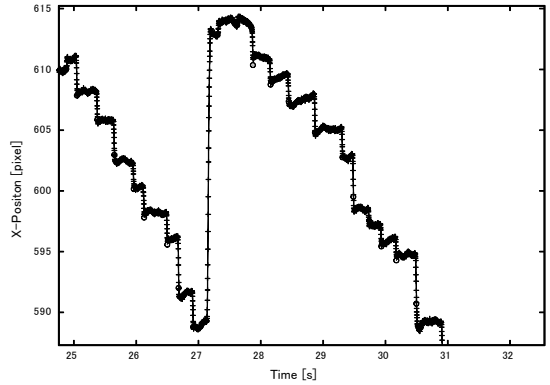


Figure 3. Pupil position and predicted saccade position.

is -0.47[pixel], with standard deviation of 0.96[pixel].

5. Conclusion

In this paper, we described the high-speed and low latency eye tracking camera system, and the eye tracking experiments. We also described the saccade destination prediction algorithm and prediction result. We can predict the saccade destination within 1[pixel] error.

6. References

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