Design of a Communication-Aid Circuit to Detect Eye-Gazed Patterns

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Abstract: A communication-aid circuit to detect eye-gazed patterns is proposed in this paper. The circuit is an analog-digital mixed system. By determining the direction of eye-gazed pattern, the circuit detects an eye-gazed pattern from 2-dimensional arrayed patterns on a syllabary. Different from conventional systems, the syllabary is moved to overlap the eye-gazed pattern with the center coordinate of screen. Thus, the proposed circuit can avoid a complex calculation of the distance between the eye-gazed point and the center coordinate. Furthermore, an economical size of hardware can be provided since no full-adders are required by employing floating-gate MOSFET's. The validity of the circuit design is confirmed by computer simulations. Furthermore, to implement onto an IC chip, the layout design is performed by using a CAD tool, MAGIC.

1. Introduction

In the fields of engineering and medical science, the electronic devices to support patients have been becoming important. Many support systems have been proposed, for example, hearing-aid systems, walking support systems, and so on [1]-[6]. Among others, communication-aid systems for the patients suffering from a paralysis of body attract many researchers' attention [7]-[10]. Several methods have already been proposed for the realization of the communication-aid systems. By detecting the blink of patient, Kanou et al.'s system judges whether the patient intents *Yes* or *No* [8],[9]. From 1-dimensional arrayed characters on a syllabary, Yamada et al's system detects the eye-gazed character by calculating distance and direction [10]. However, most of these communication-aid systems are realized by software systems on digital computers. For this reason, these systems are very large and heavy.

In this paper, a communication-aid circuit to detect eye-gazed patterns is proposed. The aim of this work is a development of a vision chip to incorporate into a HMD (Head Mount Display). To implement onto an IC chip, a small size and a simple algorithm for the pattern detection are required. Therefore, we focused on an analog-digital mixed circuit.

By determining the direction of eye-gazed pattern, the proposed circuit detects an eye-gazed pattern from 2-dimensional arrayed patterns on a syllabary. Different from the conventional systems, the syllabary is moved to overlap the eye-gazed pattern with the center coordinate of screen. Thus, the proposed circuit can avoid a complex calculation of the distance between the eye-gazed point and the center coordinate. Furthermore, an economical size of hardware can be provided since no full-adders are required by employing floating-gate MOSFET's. The validity of circuit design and algorithm is confirmed by computer simulations. Furthermore, to implement onto an IC chip, the layout design is performed by using a CAD tool, MAGIC.

2. Architecture

Figure 1 shows a block diagram of the proposed circuit. The circuit shown in Fig.1 consists of a digital block and an analog block. Figure 2 shows the block diagram of the digital block.

Firstly, in the digital block, an input image $I^t(i,j)$ ($i \in \{1,\ldots,m\}$, $j \in \{1,\ldots,n\}$) is given by a CCD camera. Here, $I^t(i,j)$ denotes the value of (i,j) pixel when the time is t and $I^0(i,j)$ denotes the initial value of (i,j) pixel when a patient gazes at the center coordinate of screen. From the input image, a binary image $f^t(i,j)$ ($f^t(i,j) \in \{0,1\}$) is calculated by the comparator in the digital block.

Secondly, from the binary image $f^t(i,j)$, $p \times q$ image $g^t(k,l)$ ($k \in \{1,\ldots,p\}$, $l \in \{1,\ldots,q\}$) is extracted by the extractor in the digital block. The extracted image

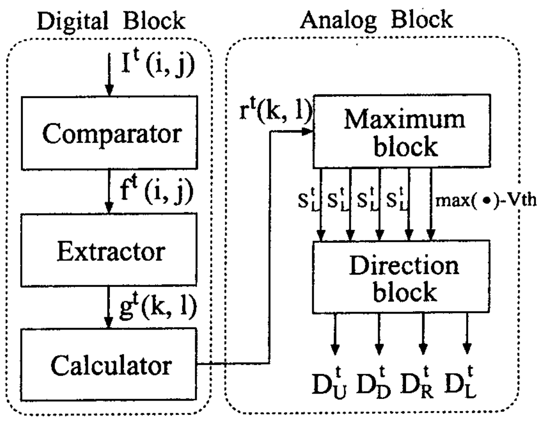


Fig.1 Block diagram of the proposed circuit.

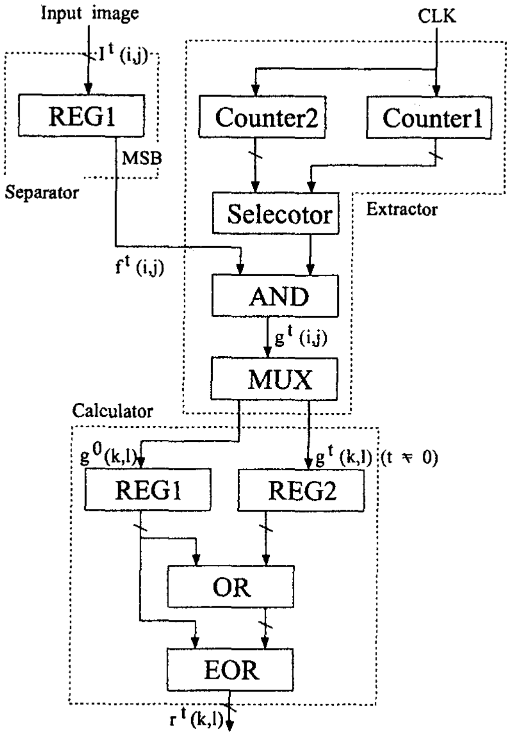


Fig.2 Digital block.

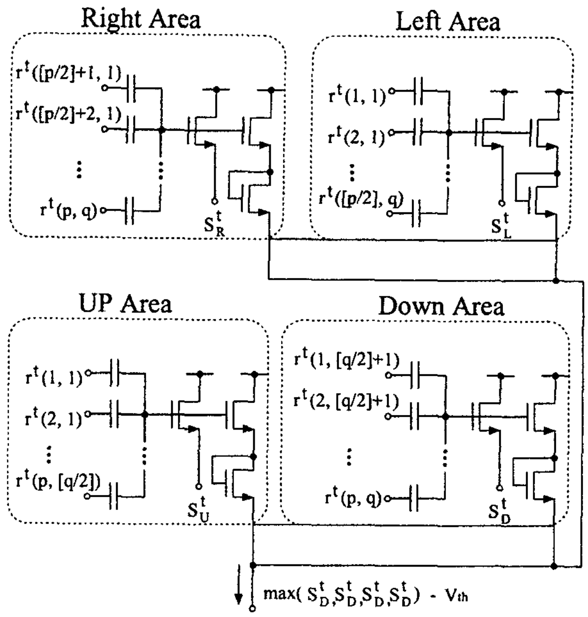


Fig.3 Maximum block.

$g^t(k,l)$ satisfies

$$\begin{aligned} g^t(k,l) &= f^t(c_1 \times k, c_2 \times l) \\ \text{and } c_1 \times p &\leq m \\ \text{and } c_2 \times q &\leq n, \end{aligned} \tag{1}$$

where c_1 and c_2 are integer parameters.

Next, from the extracted images, $g^0(k,l)$ and $g^t(k,l)$, the differential image $r^t(k,l)$ is obtained by the calculator in the digital block. The differential image $r^t(k,l)$ is given by

$$r^t(k,l) = g^0(k,l) \oplus (g^0(k,l) \cup g^t(k,l)). \tag{2}$$

The output of the digital block is given as an input of the analog block.

In the analog block, the direction of eye-gazed pattern is determined from $r^t(k,l)$. This block functions as

$$\begin{aligned} D_U^t &= S_U^t \ominus \{\max(S_U^t, S_D^t, S_R^t, S_L^t) - V_{th}\}, \\ D_D^t &= S_D^t \ominus \{\max(S_U^t, S_D^t, S_R^t, S_L^t) - V_{th}\}, \\ D_R^t &= S_R^t \ominus \{\max(S_U^t, S_D^t, S_R^t, S_L^t) - V_{th}\}, \\ D_L^t &= S_L^t \ominus \{\max(S_U^t, S_D^t, S_R^t, S_L^t) - V_{th}\}, \end{aligned} \tag{3}$$

where

$$\begin{aligned} S_U^t &= \sum_{k=1}^{p} \sum_{l=1}^{[q/2]} r^t(k,l), \\ S_D^t &= \sum_{k=1}^{p} \sum_{l=[q/2]+1}^{q} r^t(k,l), \\ S_R^t &= \sum_{k=[p/2]+1}^{p} \sum_{l=1}^{q} r^t(k,l), \\ \text{and} \quad S_L^t &= \sum_{k=1}^{[p/2]} \sum_{l=1}^{q} r^t(k,l). \end{aligned} \tag{4}$$

In Eq.(3), $\ominus$ is the bounded-difference operator defined as

$$x \ominus y \triangleq \begin{cases} x - y & \text{if } x > y \\ 0 & \text{if } x \leq y \end{cases}$$

and $\max(\cdot)$ denotes the maximum operation. The operation of Eq.(4) is realized in the maximum block shown in Fig.3. The circuit shown in Fig.3 is designed by using floating-gate MOSFET's. In this block, the maximum operation $\max(\cdot)$ in Eq.(3) is realized by the diode-connected MOSFET's. The parameter V_{th} in Eq.(3) denotes the threshold value of diode-connected MOSFET's in Fig.3.

The bounded-difference operation in Eq.(3) is realized by the direction block shown in Fig.4. The direction block of Fig.4 compares $\max(S_U^t, S_D^t, S_R^t, S_L^t) - V_{th}$ and $S_U^t, S_D^t, S_R^t, S_L^t$. From the outputs of the direction block, $D_U^t, D_D^t, D_R^t, D_L^t$, the direction of eye-gazed pat-

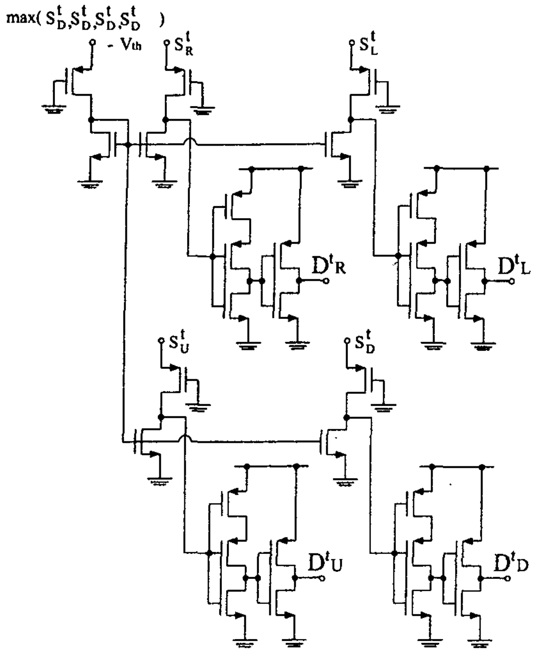
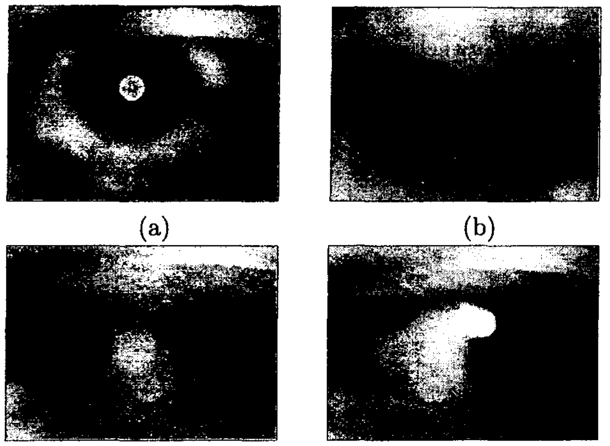


Fig.4 Direction block.



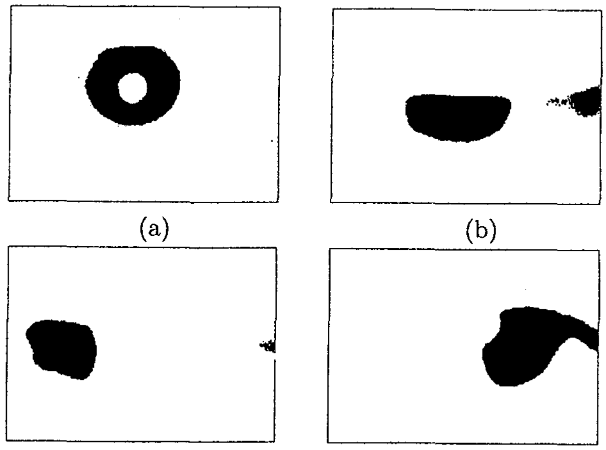
(a) (b) (c) (d)

Fig.5 Input images $I^t(i,j)$. (a) Up. (b) Down. (c) Right. (d) Left.

tern is determined as

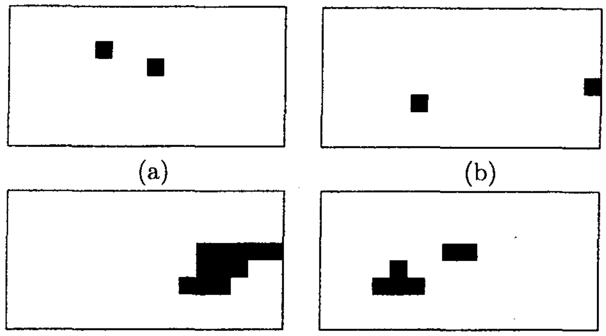
$$D^t = \begin{cases} \textbf{Up} & \text{if } D_U^t = 1 \text{ and } D_R^t = 0 \\ & \quad \text{and } D_D^t = 0 \text{ and } D_L^t = 0, \\ \textbf{Right} & \text{if } D_U^t = 0 \text{ and } D_R^t = 1 \\ & \quad \text{and } D_D^t = 0 \text{ and } D_L^t = 0, \\ \textbf{Down} & \text{if } D_U^t = 0 \text{ and } D_R^t = 0 \\ & \quad \text{and } D_D^t = 1 \text{ and } D_L^t = 0, \\ \textbf{Left} & \text{if } D_U^t = 0 \text{ and } D_R^t = 0 \\ & \quad \text{and } D_D^t = 0 \text{ and } D_L^t = 1, \\ \mathbf{0} & \text{if } D_U^t = 0 \text{ and } D_R^t = 0 \\ & \quad \text{and } D_D^t = 0 \text{ and } D_L^t = 0. \end{cases} \quad (5)$$

The syllabary is moved to the opposite direction of the eye-gazed point. The pattern detection is over when $D^t = \mathbf{0}$.



(a) (b) (c) (d)

Fig.6 Binary images $f^t(i,j)$. (a) Up. (b) Down. (c) Right. (d) Left.



(a) (b) (c) (d)

Fig.7 Differential images $r^t(k,l)$. (a) Up. (b) Down. (c) Right. (d) Left.

3. Simulation

Concerning input images shown in Fig.5, computer simulations were performed to confirm the validity of algorithm. The simulated circuit was designed by assuming a 1.2 μm process produced by On-Semiconductor. Figures 6 and 7 show the simulated binary images $f^t(i,j)$'s and differential images $r^t(k,l)$'s. Figure 8 shows the simulated output, $D_U^t, D_D^t, D_R^t, D_L^t$, for the images $r^t(k,l)$'s. The computer simulations were performed under the conditions that supply voltage V_{dd} = 5V and capacitor C = 1pF. As Fig.8 shows, the simulated output, $D_U^t, D_D^t, D_R^t, D_L^t$, express the direction of the eye-gazed point of Fig.5.

4. Layout

To fabricate the VLSI chip, the layout of the proposed circuit was performed by using an analog CAD tool, MAGIC. Figure 9 shows the layout pattern designed by a 1.2 μm CMOS process. The VLSI chip shown in Fig.9 was fabricated in the chip fabrication program of VLSI Design and Education Center(VDEC), the University of Tokyo with the collaboration by On-Semiconductor. The size of the fabricated IC designed

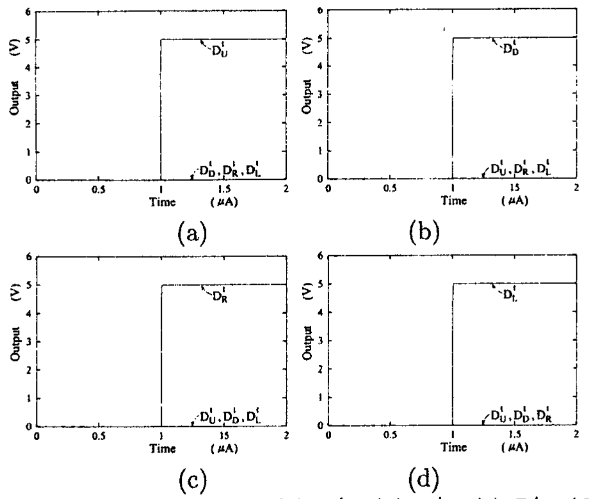


Fig.8 Simulated outputs. (a) D_U^t. (b) D_D^t. (c) D_R^t. (d) D_L^t.

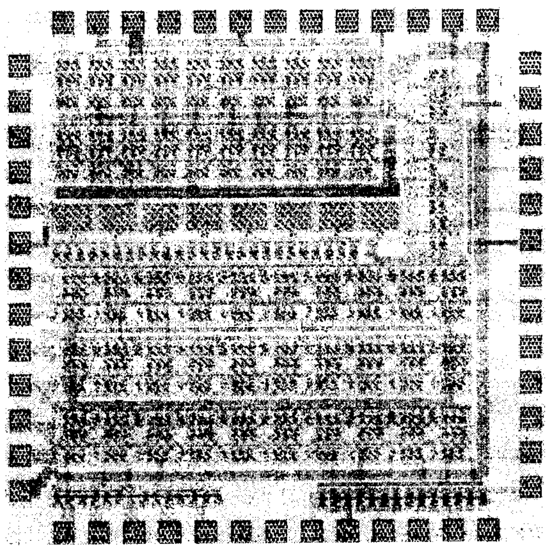


Fig.9 Layout pattern.

by a 1.2 μm CMOS process is 2.3mm × 2.3mm.

5. Conclusion

A vision circuit to detect eye-gazed patterns has been proposed. The results of the simulations showed the following results: 1. The proposed circuit can detect the direction of eye-gazed point. 2. The proposed CMOS circuit can be compatible with a standard IC technology.

The HMD incorporating the proposed circuit will help the patients suffering from a speech impediment. as well as a paralysis of body.

The improvement of the algorithm is left to the future study.

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