The Seventeenth International Symposium on Artificial Life and Robotics 2012 (AROB 17th '12),
B-Con Plaza, Beppu, Oita, Japan, January 19-21, 2012

Simple system for detecting sound localization based on the biological auditory system

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Abstract: In this study, we proposed and fabricated the simple system for detecting sound localization based on the biological auditory system. The proposed system is constructed with the simple circuit for detecting sound localization, two microphones, the photodiode, the motor and the rotation table. The test system was fabricated by the simple circuit for detecting sound localization by using the simple circuit constructed with discrete metal oxide semiconductor (MOS) transistors on the breadboard. The experimental results of the test system showed that the proposed system can detect the position of the sound of the target. We can realize novel target tracking system by applying the proposed system based on the biological auditory system.

Keywords: sound localization, auditory system, tracking system, analog circuit, digital circuit

1 INTRODUCTION

It is necessary for robotics vision, monitoring system and collision avoidance system to capture quickly the target in the visual field. However, it is difficult for the systems based on only the vision system to capture quickly the target in the visual field since the system cannot detect the position of the target when the target is not existed on the visual field. On the other hand, the animal can capture quickly the target in the visual field by using other functions such as the auditory system. The biological auditory system can process the sound information of the target and detects the position of the sound, even if the target is not existed on the visual field.

Recently, many researchers proposed and fabricated the simple system for target tracking based on the biological vision system [1]-[5]. These systems can track the target by using the motion signals. These systems are characterized by simple structure, low power consumption and high speed processing. However, these systems could not track the target when the target was not projected on the input parts since the systems were proposed by mimicking only the vision system. If the system based on the vision system is connected with the system based on the auditory system, it is able to track the target in various situations.

L. A. Jeffress proposed the model for detecting sound localization based on the biological auditory system [6]. Because the model is constructed with the delay line and the comparator, the model is simple structure. We proposed the simple analog-digital circuit for detecting sound localization based on the model by Jeffress [7]. The proposed circuits were constructed with the current mode delay line and the NOR circuits. The proposed unit circuit of delay line was constructed with 9 metal oxide semiconductor (MOS) transistors and 1 capacitor. The NOR circuit used as the comparator was constructed with 4 MOS transistors. Therefore, the proposed circuit is simple structure. We showed that the circuit can detect the position of the sound of the target. It is necessary to fabricate the system for detecting the position of the target (sound) by using the proposed simple circuit.

In this study, we tried to propose and fabricate the system for detecting sound localization. The proposed system is constructed with the circuit for detecting sound localization, two microphones, the photodiode, the motor and the rotation table. The test system was fabricated by using test circuit for detecting sound localization constructed with discrete MOS transistors on the breadboard. The experimental results of the test system showed that the proposed system can detect the position of the sound, and capture the target in the visual field.

2 MODEL AND CIRCUIT

2.1 A model

Figure 1 shows the model for detecting sound localization proposed by Jeffress [6]. The model is constructed with the delay line constructed with the delay neuron D and the comparator C. The Unit is constructed two delay neurons and one comparator, as shown in Fig.1.

I_{left} is input signal for delay line (left) generated by the left ear. I_{left} transmits the delay line (left) from D_1 to D_n. I_{right} is input signal for delay line (right) generated by the right ear. I_{right} transmits the delay line (right) from D_n to D_1. Therefore, delay neurons output the signal sequentially.

When the sound of the target is large, I_{right} and I_{left} become large. Inversely, I_{right} and I_{left} become small when the sound of the target is small. When I_{right} (I_{left}) is large, I_{right} (I_{left}) transmits the delay line quickly. When I_{right} (I_{left}) is small, the I_{right} (I_{left}) transmits the delay line slowly.

The output signals of delay neurons are input to the comparator. When both delay neurons in the Unit output the signal, the comparator outputs the signal.

When the sound of the target located on the right side, the Unit located on the left side outputs the signal. When the sound of the target located on the left side, the Unit located on the right side outputs the signal. When the positions of the sound of the target differ, the different comparator outputs the signal. Therefore, the Jeffress model can detect the position of the sound.

2.2 Circuits

Figure 2 shows the unit circuit of the delay line [5]. The unit circuit is constructed with 9 MOS transistors and 1 capacitor. The input current I_{in} flows into the capacitor C_n. Then, the voltage V_C is increased. The circuit transmits I_{in} to the neighboring unit circuit and outputs the output voltage V_o to the comparator.

When I_{in} is large, V_C is increased quickly. Then, the unit circuit outputs V_o quickly. When I_{in} is small, V_C is increased slowly. Then, the unit circuit outputs V_o slowly. The voltage V_{th} is the constant voltage. The voltage V_r is utilized to reset V_C.

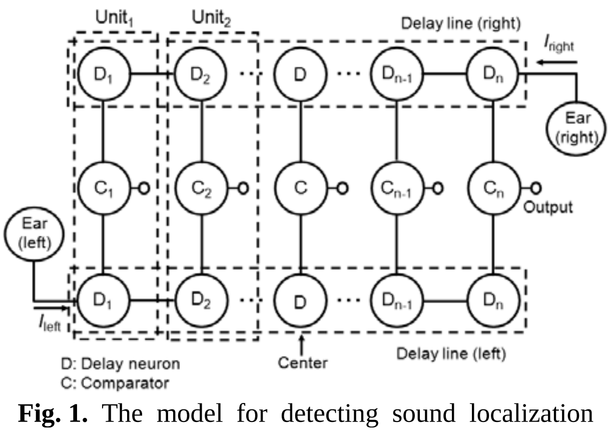


Fig. 1. The model for detecting sound localization

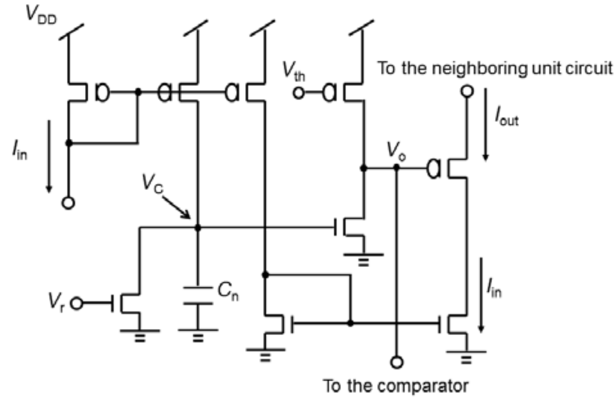


Fig. 2. The unit circuit of delay line

Figure 3 shows the NOR circuit used as the comparator. The NOR circuit is constructed with 4 MOS transistors. Therefore, the circuit is simple structure.

3 SYSTEM CONSTRUCTION

Figure 4 shows the proposed simple system for detecting sound localization. The proposed system is constructed with the simple circuit for detecting sound localization, two microphones, the photodiode, the motor and the rotation table. The output terminals of neighboring Units are connected each other. For example, the output terminals of Unit1 and Unit2 are connected, as shown in Fig.4. All of the terminals are connected with the capacitor and Reset line. The Reset line is connected with the terminals of V_r in Fig.2. When the voltage of the Reset line becomes supply voltage V_{DD}, the circuits are reset.

The voltage V_{right} is generated by connecting the output terminals of Units located on the left side. The voltage V_{left} is generated by connecting the output terminals of Units located on the right side. The output terminals of the Units located on the center are connected with the Reset line.

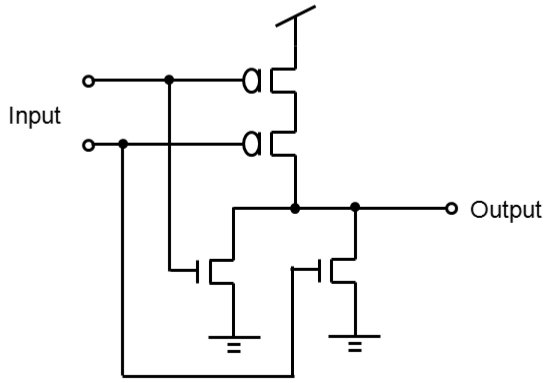


Fig. 3. The construction of NOR circuit

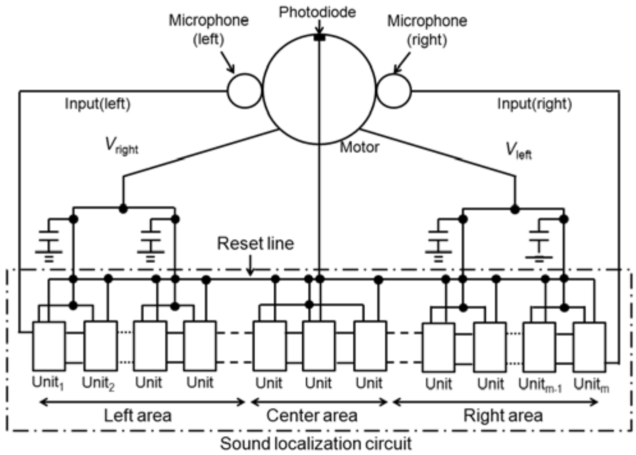


Fig. 4. Simple system for detecting sound localization

The microphones generate the input signal of the system. When the sound of the target is large, the signal of the microphone is large. When the sound of the target is small, the signal of the target is small.

The photodiode is connected with the Reset line. The photodiode is utilized as the visual sensor. When the target is projected on the photodiode, the signal of the photodiode becomes V_{DD}.

The terminal of V_{left} and V_{right} are connected to the motor driver. When V_{left} becomes V_{DD}, the motor rotates the rotation table from center to left. Inversely, the motor rotates the rotation table from center to right when V_{right} becomes V_{DD}. When both of the terminals of V_{left} and V_{right} are 0 V or $V_{DD,}$ the motor does not rotate. The time of rotation was changed by the capacitance.

When the sound of the target is located on the right, the input signal of the right is larger than input signal of the left. Then, the output terminals of Units located on the left area becomes V_{DD}. V_{right} and the voltage of the Reset line become V_{DD}. Then, the motor rotates the rotation table from center to right. After that, the circuits were reset.

When the sound of the target is located on the left, the output terminals of the Units located on the right area becomes V_{DD}. Then, V_{left} and the voltage of the Reset line become V_{DD}. The motor rotates the rotation table from center to left.

When the sound of the target is located on the center, the terminal located on the center area becomes V_{DD}. Then, the system is reset by the voltage of the Reset line becomes V_{DD}.

When the target is projected on the photodiode, the system is reset by using the signal of the photodiode. Therefore, the proposed system can detect the position of the sound and can capture the target in the visual field.

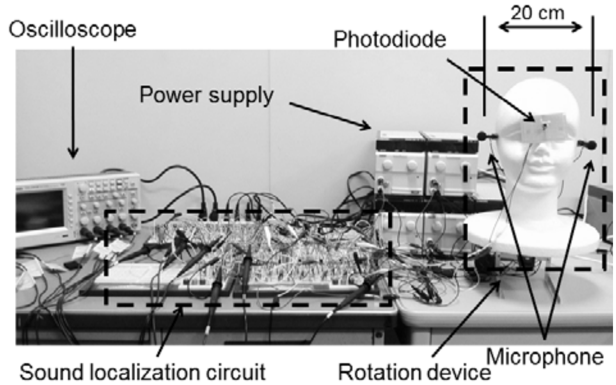


Fig. 5. The photograph of test system for detecting sound localization

4 EXPERIMENTAL RESULTS

We tried to fabricate the test system for detecting sound localization. Figure 5 shows the photograph of the fabricated test system for detecting sound localization. The test circuit was fabricated by discrete MOS transistors (nMOS: 2SK1398, pMOS: 2SJ184, NEC) on the breadboard. The test circuit for sound localization was constructed with 7 Units. Unit1 and Unit2 were connected

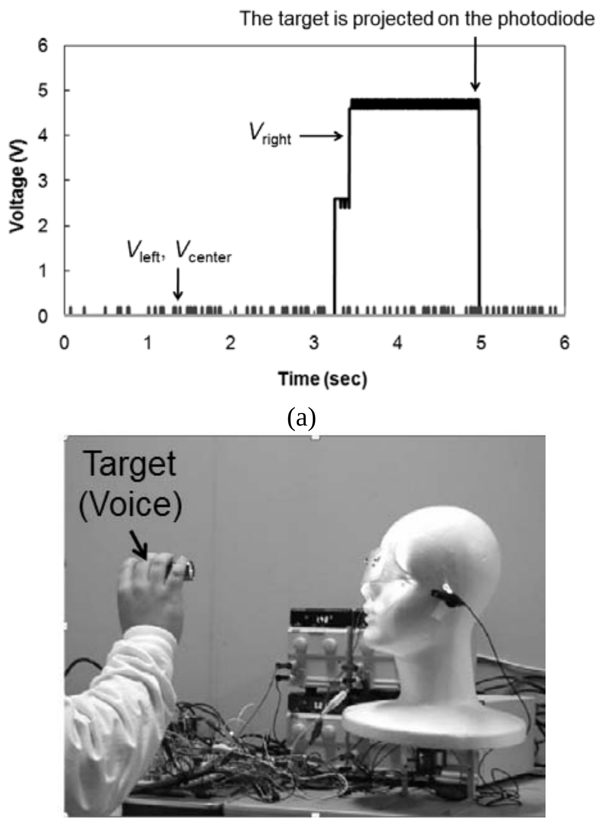


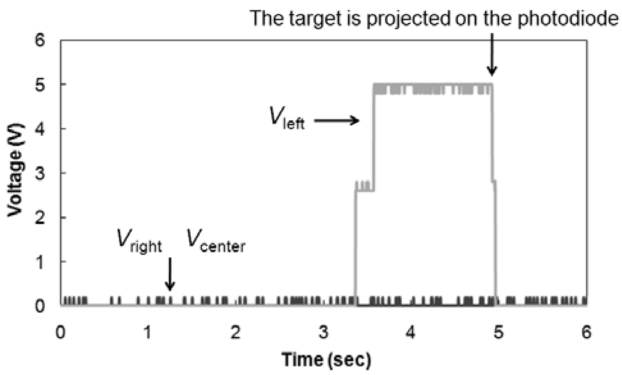
Fig. 6. The experimental result of the test system when the target located on the right side. (a) Output voltage of the test circuit. (b) The measured results of the test system when the system captures the target.

with the terminal of V_{right}. Unit3, Unit4 and Unit5 were connected with the terminal of V_{center}. Unit6 and Unit7 were connected with the terminal of V_{left}. The voice was utilized as the target. The microphones (ECM-C115, SONY) and the photodiode were attached to a mannequin.

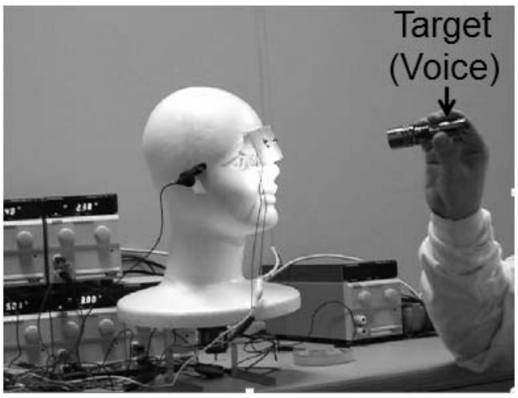
Figure 6 shows the experimental results when the sound located on the right side. When the sound located on the right side, V_{right} become about 5 V, as shown in Fig.6 (a). Then, the motor was rotated from center to right. The motor stopped when the target was projected on the photodiode, as shown in Fig.6 (b).

Figure 7 shows the experimental results when the sound located on the left side. V_{left} become about 5 V, as shown in Fig.7 (a). The motor was rotated from center to left, as shown in Fig.7 (b). The motor stopped when the target was projected on the photodiode.

Therefore, the proposed system can detect the position of the sound of the target.



(a)



(b)

Fig. 7. The experimental result of the test system when the target located on the left side. (a) Output voltage of the test circuit. (b) The measured results of the test system when the system captures the target.

5 CONCLUSION

In this study, we proposed and fabricated the simple system for detecting sound localization based on the model by Jeffress. The system is constructed with the simple circuit for detecting sound localization, two microphones, the photodiode, the motor and the rotation table. The experimental results of the test system showed that the proposed system can detect the position of the sound of the target and can capture the target in the visual field. We can realize novel target tracking system by applying the proposed system based on the biological auditory system.

ACKNOWLEDGEMENT

This work was partially supported by Japan Society for the Promotion of Science, Grant-in-Aid for Young Scientists (B), 23700222.

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