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Emergency Evacuation Guiding System Using Changeable Sound Directivity

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ABSTRACT

This paper introduces a method to design an emergency guiding system which uses changeable directivity based on a speaker array. In general, existing emergency evacuation guiding systems depend on visual techniques like emergency lights or LEDs. Actually people in the case of fire emergency condition may not obtain a range of view because of smoke from the fire. To cope with this problem, the guiding system based on the visual techniques need to be replaced with the systems using sound from a number of speakers proposed in this paper. A fundamental method to implement the sound directivity needs to use a speaker array which consists of many speakers in a line. In this paper, we can obtain the sound directivity using the modified fundamental method which will work in several shaped buildings. We use a modified speaker array system to make a time delay and differential frequency based on Doppler Effect and Haas Effect. For more accurate direction information, a servo motor is used to each speaker of the speaker array to make sound directivity physically. In this case all speakers are serially connected for audio signal transmission in a serial fashion to achieve convenient speaker installation. The system with more accurate direction proposed in this paper has been designed and tested as follows; first, we study to find the appropriate frequency range and sound pressure level in a noisy emergency environment. Second we verify the efficiency of our proposed evacuation guiding system with sample groups of people in a virtual emergency studio environment. As conclusion, the system proposed in this paper has achievements, such as increasing evacuation rate under emergency conditions, and serial transmission of audio signal for easy maintenance and low installation cost.

1. INTRODUCTION

With the increasing natural disasters due to the global warming, people should be more cautious about natural disaster which can be occurred without any notice. Furthermore, there should be development for the disaster prevention technology with the improvement of modern technology.

Looking at recently built building, not only there are lights for the signs but also there is an indicator which tells the distance to the exit [1]. In addition, sensor network systems can be used to watch over the inside the building, especially, it can be very useful in emergency evacuation to help the evacuators by suggesting the safest way out [2]. However, most existing systems are only supporting visual effects and it seems useless when there is a smoke that disturbs the sight.

In this paper, to increase the efficiency of the evacuation system, the sound effect has been added that is designed and adjusted with the hardware to reassure the efficient evacuation.

2. SYSTEM ARCHITECTURE

2.1 Design of the system

As mentioned above, this system is using the sound effect to guide people. Figure 1 shows the concept of making sound directivity by the lined speaker. By using Hass effect and Doppler Effect, the different timing and strength of the sound from each different speaker tells people where to go. Sound directivity system can guide people where to evacuate. Each speaker is connected by the serial transmission technique.

A. Doppler Effect

Doppler Effect means the change in frequency of a wave for an observer moving relative to the source of the wave. It is commonly heard when a vehicle sounding a siren or horn approaches, passes, and recedes from an observer. The received frequency is higher during the approach, it is identical at the instant of passing by, and it is lower during the recession. We adopted this idea in group of speakers in same direction. Each group has different sound frequency that range is between 1.4 KHz and 3.3 KHz. The closest group to exit is got 3.3 KHz and the next close group is got lower frequency

under 0.1 KHz. The speakers in group have sound moving among the 0.1 KHz frequency range like a moving train.

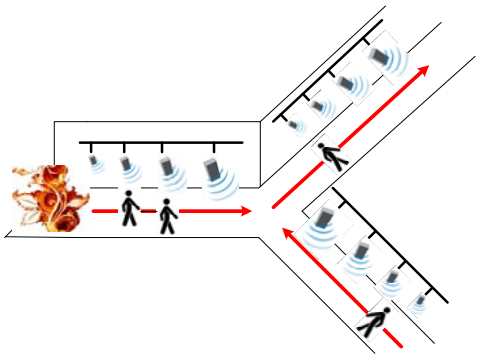

Figure 1. Concept of emergency evacuation guiding system

B. Haas Effect

The Haas effect is a psychoacoustic effect related to a group of auditory phenomena known. These effects, in conjunction with sensory reaction to other physical differences between perceived sounds, are responsible for the ability of listeners with two ears to accurately localize sounds coming from around them. When two identical sounds originate from two sources at different distances from the listener, the sound created at the closest location is heard first.

The Haas effect occurs when arrival times of the sounds differ by up to 30~40 ms. As the arrival time of the two audio sources increasingly differ beyond 40 ms, the sounds will begin to be heard as distinct. The delay time between speakers in a group is 30ms when sounds move to the other speaker in a group. The sound of a speaker more close from the exit is louder as 1.5dB than the speaker before it.

C. Serial transmission technique for audio signal

Figure 2 is the block diagram of the serial transmission technique for audio signal. When many channels receive a sound source, ADC & Channel Encoding Block abstracts the data and relocates and sends it to the receiver through the serial connecter. When the receiver gets the data it restores the data to sound source by using DAC & Channel Decoding from each receiver. Left side of the Figure 2 represents transmitter, and the right side of the Figure 2 represents receiver. Serial method is used for the sound transferring between this two systems and the audio data format is I^2S [3].

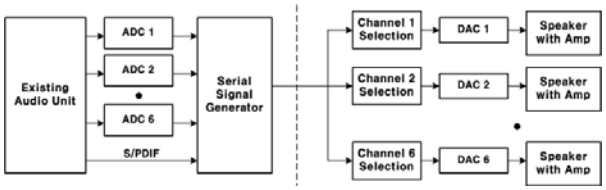

Figure 2. Block diagram of serial transmission technique

2.2 Design of Emergency evacuation guiding system

Figure 3 is a prototype board for sound signal by serial transmission technique. XILINX's spartan3 equivalent 200,000 gates FPGA has been used. For transmission of long distance of audio data and clock, three of RS-485 transceiver is used. Main clock frequency of the system is 22.5792MHz. Frequency 44.1 KHz is transmitted from the main board to a server board. It is multiplied as 512 times to 22.5792MHz by PLL of DAC in the server board. Frequency 22.5792 MHz is Main clock frequency of the server board.

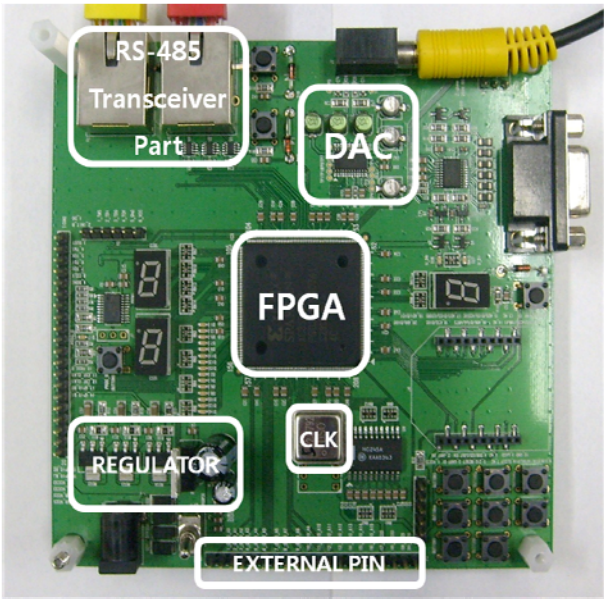

Figure 3. Prototype board of system

The server board receives sound sources from RS-485 transceiver and collects the compatible sound sources. A speaker controls the time and volume of the sound by order of priority.

Figure 4 shows a group of emergency evacuation guiding system. That has one main board and three server board. Each server board has speakers with servo motor. Figure 5 shows speakers with servo motor that has 0 to 300 degree moving angle.

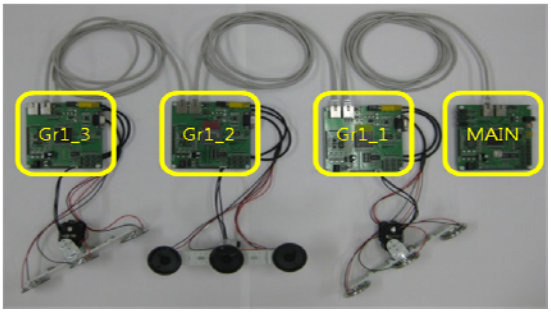

Figure 4. A group of emergency evacuation guiding system

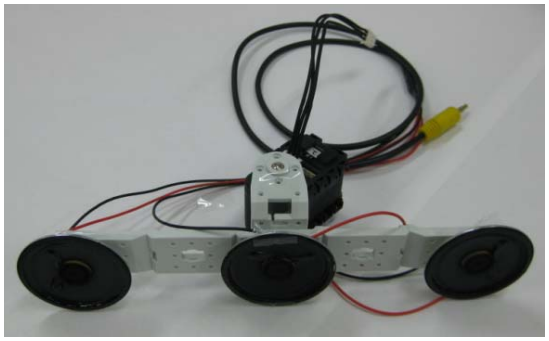

Figure 5. Speaker array with servo motor

3. EXPERIMENT

3.1 Experiment Method

The Experiment was conducted in T-shaped corridor[4]. According to the Figure 6 in T-shaped corridor there are 3 groups to guide to the closest exit. Basically the group which is near the exit gets higher priority and higher sound frequency. Situation Figure 7 shows the evacuation from the each side to the exit and Figure 8 shows the evacuation from left to the right. To make this experiment more convincible for the hearing effect, experiment has been conducted in two situations, one with the visual and one without the visual by using eyepatch. In this experiment, we did not inform the people of the exit and make a time limit. The one with the visual got 30 sec to escape and the other one had 2min to escape due to no visual. Additionally we experiment that the situation of speakers is controlled by servo motors to improve the sound directivity. Then the time limit is 2min in the use of eyepatch.

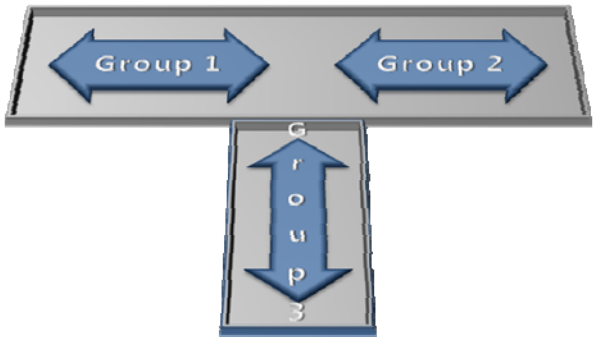

Figure 6. Studio of emergency experiment

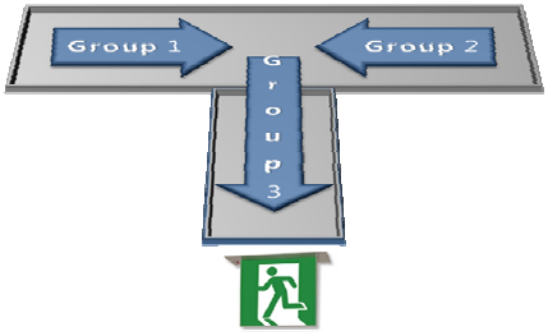

Figure 7. Virtual emergency situation 1

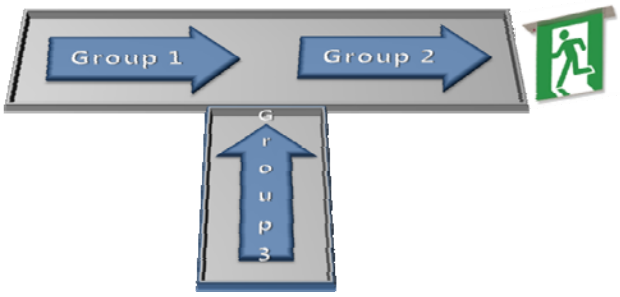

Figure 8. Virtual emergency situation 2

3.2 Experiment Result

The result was like the Figure 9. Most of the people who got the visual escaped. Some of them failed to escape due to the time limit; however, they all got escaped in 1min.

The other group showed a huge difference in terms of speed of walking due to the eyepatch. And also, when there were a corner people had difficulty in finding the way which took more time to find the exit. And we found the increase of escape rate when we controlled speaker angle to make sound directivity.

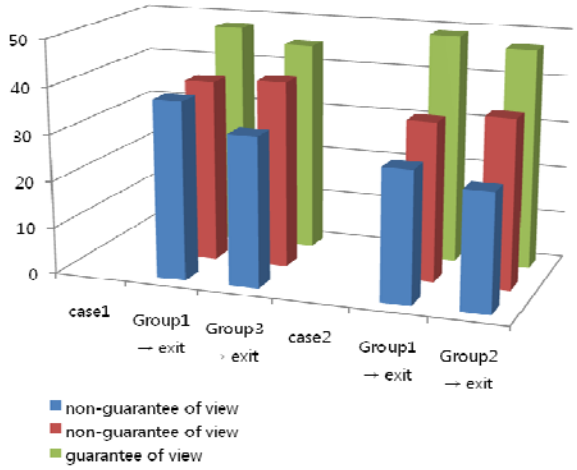

Figure 9. Experiment result

4. CONCLUSION

Existing evacuation systems are only depending on visual effect which means it is useless if there is no visual. This experiment shows that the sound effects increased efficiency in evacuation even when there is no visual. Thus, by adding sound effect to the existing evacuation system, it can increase the efficiency even more. And we improve the sound directivity using servo motors. The system use the existing speaker in the building that decreases the installation fee and it also gives extra efficiency on the connection with the central broad casting system.

5. REFERENCES

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