Research Paper

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Construction of Virtual Low-Noise Space in Noisy Agricultural Facility for Safety and Comfort

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Abstract

Many types of agricultural facilities have been constructed at many places around the world. Although most of the operations are mechanized at these facilities, high noise from mechanical systems often prevents operators from discharging their duties efficiently and results in an unsafe environment. Virtual low-noise space is defined as the space required by operators in order to smoothly communicate in a high-noise environment, i.e., they feel as though they are working in a low-noise environment. The virtual low-noise space has three functions: to reduce the noise around the operators' ears, to communicate by speech without noise, to recreate the audio image on the basis of the operators' mutual positions. In this research, virtual low-noise space was constructed using noise-canceling headphones, microphones, a TV camera, and computers.

[Keywords] noise, machine vision, spectral signal subtraction, wireless LAN, virtual space

I Introduction

There are many types of agricultural facilities for grains, fruits, nuts, and vegetables; in these facilities mechanized and automated systems are employed. Although most of the operations are mechanized, high noise from the mechanical systems often prevents operators from discharging their duties efficiently and results in an unsafe environment at these agricultural facilities. It is not unusual to find that the noise level is over the permissible range officially determined for operators under noisy conditions: 8 h under 85 dB (A), 4 h under 88 dB (A), 2 h under 91 dB (A), 1 h under 94 dB (A), and 0.5 h under 97 dB (A). For example, in a leek preprocessing and grading facility where the noise level is in the range 80–105 dB (A), which is equivalent to a tractor noise of 90 dB (A), the operators often work for 7 h or so.

It is stated that long working hours under such conditions may result in health problems such as hypacusis, circulatory deficit, and visceral diseases. In addition, it may cause errors during operation thereby resulting in injuries from accidents; the operators could suffer from fatigue and lose concentration. To prevent such situations, the operators sometimes use earplugs; however, this hampers mutual communication between the operators, thus rendering them vulnerable to accidents.

Some researches on active noise control around an operator in order to reduce noise have been reported (Peng et al., 1995). Recently, noise-canceling headphones that can act as hearing-assisting devices were commercialized and they are actually used in subway trains and airplanes. The noise reduction using ANC (active noise canceling) is sufficient at high frequencies, and the shielding method cannot reduce low-frequency noise. The noise-canceling headphone was used in this system because both high- and low-frequency noises are reduced by the headset shielding and its ANC.

The objectives of this research were to reduce noise around the operators' ears to facilitate mutual communication between the operators, and to increase safety under noisy conditions for improving the operators' working environment. In this study, we aim to construct a system to create a low-noise space that not only reduces the noise around the operators' ears but also facilitates communication among them. In the low-noise space, operators feel as though they are in a low-noise environment due to the sound images created on the basis of the operators' mutual positions. In this paper, we describe the newly created virtual low-noise space with the noise-canceling headphones, microphones, a TV camera, a host computer through wireless LAN; we also

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describe a machine vision system that measures the distances between the operators.

II Experimental method

1. Grading facilities and noise measurement methods

Noise was measured to investigate the noise level and frequency characteristics in several fruit grading facilities before designing the system to create a virtual low-noise space. An eggplant fruit grading facility (JA Okayama, Okayama Prefecture, Japan), a leek preprocessing and grading facility (JA Tottoriseibu, Yonago, Tottori Prefecture, Japan), a tomato fruit grading system in a large-scale tomato production greenhouse (Serasaien Co., Ltd., Sera-cho Hiroshima Prefecture, Japan), and a citrus fruit grading facility (JA Uwaseika, Uwajima, Ehime Prefecture, Japan) were selected as sample facilities and the noise in these facilities was measured. In this paper, these grading facilities are denoted as No.1, No.2, No.3, and No.4, respectively. The noise levels were measured by a noise level meter (Rion Co., Ltd., NA-20) at approximately 100 points in the selected facilities, and contour maps of the noise level were created. It was observed that the noise originated from many machines working in these facilities. The noise near the main noise sources was saved for a minute as wave files by an IC sound recorder (Roland Co., Ltd., Edirol R-09). The noise frequency was analyzed by FFT (fast Fourier transformation).

2. Method of constructing virtual low-noise space

2-1. Outline of virtual low-noise space

Virtual low-noise space is defined as the space required by operators in order to smoothly communicate in a high-noise environment, i.e., they feel as though they are working in a low-noise environment. The virtual low-noise space has three functions: to reduce the noise around the operators' ears, to communicate by speech with no noise, and to recreate the audio image on the basis of the operators' mutual positions. An audio image is an image that can enable a human to understand the orientation and the level of sound source due to the difference in the sound volume and phase between both the ears. It is believed that the operators can communicate more smoothly by recreating audio images. Virtual low-noise space requires the corresponding technologies: headphones with the ANC function to reduce the noise around the operators' ears, techniques on speech communication and noise reduction in the original speech signal to communicate through speech without noise, and the operator location detecting method to recreate audio images. In this research, a virtual low-noise space was created with noise-canceling headphones, microphones, a TV camera, and computers.

2-2. Virtual low-noise space construction system

Figure 1 shows a system that creates a low-noise space under high-noise conditions. An operator wears a headphone with ANC function so that most of the noise is reduced by providing an inverse phase of the noise. The operator's (speaker) speech signal was collected by a microphone (Mic.1 (Audio-technica Co., Ltd., AT9642)); however, the speech signal contained noise signals. Another microphone (Mic.2) was set near the speaker's ear to collect the noise signal, and this signal was used as the background signal to subtract the noise from the mixture of the speech signal and the noise. The subtraction was performed by the speaker's note PC and the speech signal was sent to another operator's (listener) note PC through wireless LAN (Buffalo Co., Ltd., WHR-G54S).

The operators' positions on the floor were determined by a TV camera (CIS Co., Ltd., VCC-8350SLT) installed on the ceiling of the building. A PC-based machine vision system processed the acquired images and calculated the decrease rate of sound on the basis of the operators' two-dimensional positions and orientations on the floor. The machine vision system sent the decrease rate to the listener's note PC through wireless LAN. The listener's note PC generated stereo signals so that the listener could hear the speaker's speech. This system creates a virtual low-noise space where the operators can hear the other operators' speech with reduced noise according to their distance and orientation.

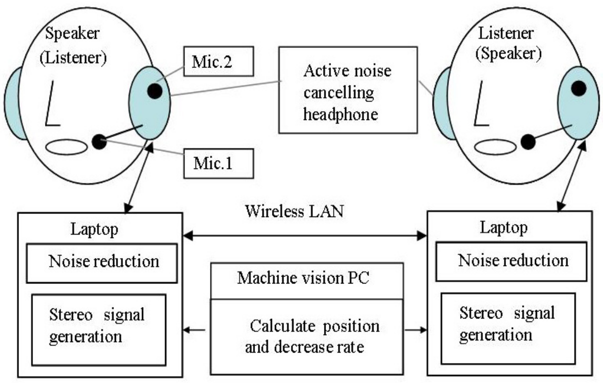

Figure 1. System for construction of virtual low-noise space.

2-3. Spectral subtraction

The speaker's speech signals collected by Mic.1 also contain noise signals. Mic.2 set near the speaker's ear collects only noises. It is fundamentally possible to obtain only the speech signals by subtracting the signals of Mic.2 from the signals of Mic.1. Spectral subtraction (Nomura et al., 2004), as described below, was performed in this research. The signal from Mic.1 is expressed by equation (1).