AlarmLocator: A Software Tool to Facilitate the Installation of Acoustic Warning Devices in Noisy Work Plants

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1. INTRODUCTION

In many workplaces, acoustic warning signals are necessary to promptly alert workers of events that can compromise safety. Unfortunately, the use of warning signals is poorly regulated and submitted to intuitive installation practices with little regard to the many factors contributing to an efficient use. There exists a very complex interaction between the noise characteristics, hearing protector attenuation and hearing status, so that the perception of warning signals for a given workplace by an individual worker or group of workers is difficult to predict without a suitable analysis [1].

A psychoacoustic software tool, *Detectsound*, was developed to determine whether an acoustic warning signal satisfies the constraints for optimal detection and recognition by the attending workers [2]. *Detectsound* is particularly useful when assessing the level and spectrum of existing alarm systems at given workstations. Warning devices, however, are typically installed on walls or on the ceiling at a certain distance from the targeted workstations. In order to design alarm systems for new plants and to forecast modifications to existing systems, the sound transmission path from the warning devices to the workstations must be considered.

This paper presents the development of a complementary software tool, *AlarmLocator*, to automate the process of installing auditory warning devices in a given setting, in terms of the characteristics of the devices to use and their optimal location in the plant. The software tool produces a solution to two practical installation problems: (1) selecting a suitable number of warning devices and their acoustic power for a given work area, and (2) specifying the location of the devices in the plant in such a way that the signals emitted are clearly audible by all workers at all workstations. A solution to the problem of installing warning devices is thus provided in a format that can be easily understood and used in the workplace.

2. GENERAL FRAMEWORK

The general modeling framework proposed for the optimal installation of warning devices is illustrated in Figure 1. The method consists of the integration of two software tools, *Detectsound* and *AlarmLocator*. As shown in Figure 1, the psychoacoustic tool *Detectsound* [2] requires four inputs:

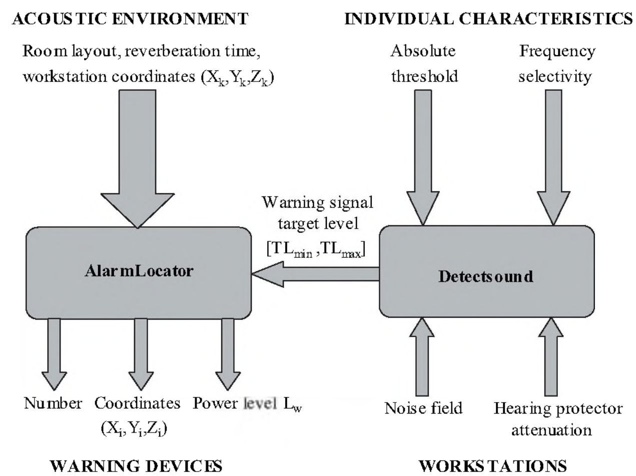

Fig. 1: *AlarmLocator* in interaction with *Detectsound*

(1) The noise field at the workstation;
(2) The attenuation of hearing protectors, if used;
(3) The absolute hearing thresholds of the individual worker attending the workstation;
(4) The frequency selectivity of the worker.

The last 2 inputs can be obtained through clinical measurements or by predictive tools within *Detectsound* [2].

The output of *Detectsound* is the predicted optimal range (Design window) of warning signal levels at each workstation for various frequencies as shown in Figure 2.

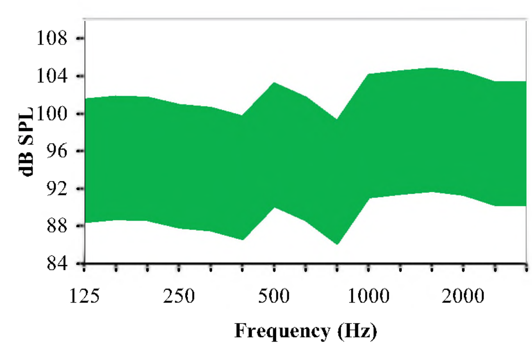

Fig. 2: Example warning signal design window

The left side of Figure 1 represents the model of acoustic propagation in the work plant, *AlarmLocator*. This tool accounts for the sound propagation of warning signals from the physical device location (on walls or ceiling) to the position of individual workers or workstations [3]. The model takes into account the direct field from the alarm devices and the reverberant field due to wall, ceiling, floor and other reflections. Source directivity effects due to alarm placement are computed using the mirror image method by considering the first three orders of room reflections.

As shown in Figure 1, *AlarmLocator* has 2 major inputs:

(1) The target warning sound levels ([TL_{min}, TL_{max}]) at each workstation produced by *Detectsound*;

(2) The characteristics of the work area (room layout, reverberation time or sound absorption, number and location of workstations in the room).

The objective of *AlarmLocator* is to search for warning device configurations that will globally satisfy the design window produced by *Detectsound* at all workstations.

The outputs produced by *AlarmLocator* are the following:

(1) The minimum number of warning devices needed;

(2) The optimum location of the warning devices;

(3) The optimum sound power level for each device.

Together, these three outputs constitute a complete solution to the problem of installing acoustic warning devices in the workplace. The "minimum number of warning devices" and the "optimum power level for each device" specifications are required at the purchasing phase, while the "optimal location of each device" specification is needed during the installation phase.

3. CASE STUDY

A case study in a hypothetical work area illustrates the use of *AlarmLocator*. The work area is 14m×21m×8m (W×L×H) and it includes 5 workstations (W1-W5). The spatial coordinates of the workstations are presented in Table 1, together with the target warning sound levels from *Detectsound* after an analysis of the noise field in the room and the hearing characteristic of the individual workers [2]. The reverberation time in the room is assumed to be 0.9 s.

Table 1: Workstation spatial coordinates and target levels ([TL_{min},TL_{max}]) in the work area (Z Coor = 1.5 m).

Workstation Index	X Coor [m]	Y Coor [m]	TL_{min} [dB]	TL_{max} [dB]
1	5.0	5.0	69.0	82.0
2	8.0	2.0	73.0	86.0
3	3.0	7.0	75.0	88.0
4	13.0	19.0	82.0	95.0
5	2.0	3.0	81.0	94.0

Using *AlarmLocator*, a set of possible solutions for installing warning devices can be found. Each solution describes the number, locations and power levels of the necessary warning device(s). For this example, 163 possible solutions are found involving two alarm devices (D_1 and D_2). One of the solutions is shown in Table 2. All the other solutions have the same power level requirements, but they differ in alarm location.

Table 2: One possible solution of alarm configuration.

Alarm Index	XCoor [m]	Y Coor [m]	ZCoor [m]	Power Level [dB]
1	10.0	21.0	8.0	90.0
2	0.0	0.0	8.0	100.0

The warning sound level distribution in the work area can be constructed for each solution at any desired height level (Z coordinate) in the room. A representation of the warning sound distribution for the solution in Table 2, intended at a height of 1.5 m (ear level) in the room, is shown in Figure 3.

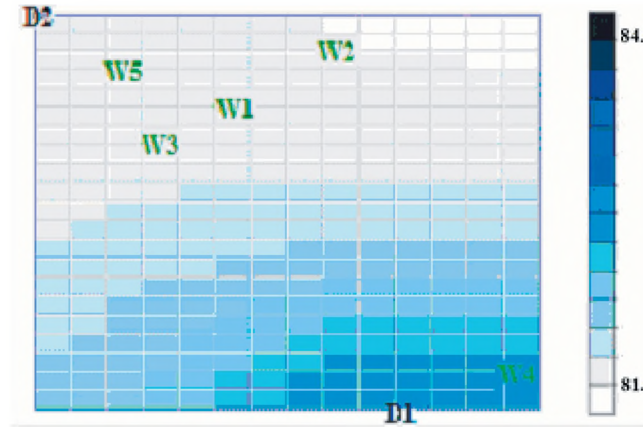

Fig. 3: Noise map for the solution presented in Table 2. "D" represents the alarm devices. "W" represents the workstations.

4. DISCUSSION

A new optimization tool, *AlarmLocator*, was introduced to facilitate the process of installing acoustic warning devices in a given setting. Integrated with *Detectsound*, this new tool provides an optimized possible solution to the complex problem of installing warning devices in a noisy work plant. More specifically, this research revealed a new method for predicting the optimum number, location and sound power of acoustic warning devices. Our goal is to achieve more valid and accurate solutions for the installation of warning devices in the workplace. [Work was funded by a research grant provided by the Workplace Safety and Insurance Board (Ontario)].

REFERENCES

[1] ISO 7731-2003: Ergonomics: Danger signals for public and work areas-Auditory danger signals (Int. Org. for Standardization).

[2] Zheng Y., Giguère, C., Laroche C. et al. (2006). "A psychoacoustic model for specifying the level and spectrum of acoustic warning signals in the workplace". *J. Occup. Environ. Hyg.* (in press).

[3] Al Osman, R., Giguère, C. & Laroche, C. (2006). "Optimal installation of acoustic warning devices in the workplace", IEA 16th World Congress on Ergonomics, Maastricht, Netherlands.