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The Compound Police: Idea of a Noise-monitoring Device in Crowded Residences

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ABSTRACT The study conceptualised a noise-monitoring device that could be used by managers of crowded residential areas. The hypothesised noise-monitoring device which operates like compound police is envisaged to replace human presence in noise detection, monitoring, and switching off of noise-making machines that transgress set community noise standards. The device targets loud music or unwanted sound generated by radios and television sets. The intended device could work in places such as hostels, flats, townhouses, dormitories, office buildings and similar residences or workplaces in which the playing of loud music is restricted. The study attempted to demonstrate how the conceptualised device works by providing a theoretical framework on which to base the design of the noise-monitoring machine and the equipment that could be used in the manufacture of the device. Theoretically, the idea provides positive engineering indicators of the possibility of designing the intended noise-monitoring device in South Africa. Directions for future research could focus on laboratory testing of the idea in order to produce and patent such a device.

INTRODUCTION

Noise production by individuals and organisations has received the attention of health monitoring organisations such as the World Health Organisation and the International Labour Organisation (Fuente and Hickson 2011). Noise is harmful to individual well-being and organisational effectiveness (International Labour Organisation 2008). Individuals and organisations should be aware of the need to control the noise they make and they should advise others to reduce noise levels in residence and the workplace (Government Gazette Act 85 1993). In South Africa, the production of noise is governed by statutory instruments which seek to protect individuals, groups, and organisations from occupational health hazards (Government Gazette Act 130 1993).

Noise Production in the Workplace

There could be a great deal of noise production in some of the workplaces in South Africa. Familiar noises in the workplace include noise made by traffic, landing and departing aeroplanes, construction machinery, heavy industrial machines, earth moving and building machinery vibration, ventilation systems, sirens and such other sounds produced by machines operated by employees or machines giving feedback to employees through the industrial human-machine interaction processes (Prashanth and Venugopalachar 2011). In this regard, the role of ergonomists, ecologists, epidemiologists and environmental psychologists is to work towards the minimisation of industrial noise. They monitor and play an advisory role on the levels of community noise that is produced in residential areas (World Health Organisation 2009).

The Production of Community Noise

Community noise is also known as environmental noise, residential noise or domestic noise (Mehravaran et al. 2011). The World Health Organisation guidelines on community noise encompass noise emitted from all sources except noise produced in the workplace (Berglund et al. 1999). The community noise that is commonly produced in crowded residential areas in South Africa is music. The unwanted audio sounds are a form of noise pollution (Atkinson

2011). In halls of residence in colleges and universities, students and wardens often disagree on what loud music is. It is common for university proctors presiding over student disciplinary hearings on “disturbing noise“ to fail to reach a consensus on the degree of music noise that warrants disciplinary action or imposition of a fine. Usually, there is lack of tangible evidence regarding allegations of noise in halls of residence. There is no quantifiable criterion for categorising music played by a student as noise. In fact, telling a neighbour in communal residence that the music they are playing is noisy could be construed as an attack on their personal integrity or privacy.

Effects of Noise on Psychological Well-being

Community noise is associated with adverse health effects on individuals. It is documented by World Health Organisation and environmental psychologists that uncontrolled noise in residential areas places where people live can cause hearing impairment, communication disorders, sleep disorders, sick building syndrome, stress, sexual disorders, cardiovascular and physiological disturbance, emotional disorders, cognitive errors, poor work performance, argumentativeness and social conflict (Berglund 1999; Heslop 2007; Dinno et al. 2011). Noise in residential areas can cause overt individual adjustment behaviours such as the closing of windows, not using the balcony any more, and turning down the volume of a radio or television set. Individuals in crowded residences could increase the volume of their radio or television to louder levels in retaliation to the neighbour‘ s action. Excessive noise production in residential areas could result in residents writing petitions, complaining to authorities and reporting the matter and to the police. Incidents of public violence due to noise are common in crowded residences in South Africa (Morojele et al. 2006). Individuals in noise-polluted environments may show signs of “sanctuary-disturbance“ by moving house. Residents relocate and settle in less noise-polluted areas. Residents in music-polluted environments could report more cases of insomnia, hospital admissions, drug use, accident proneness and mood changes (Berglund 1999). Domestic noise can traumatise animals and birds (Campo et al. 2005). Disturbing music-related noise in residential areas is prohibited by laws that prevent cruelty to animals and birds in South Africa (Government Gazette Act 169 1993).

In South Africa, if a neighbour is making excessive noise in their room or house, the law allows the complainant to file a lawsuit against the neighbour or call the police to enforce municipal by-laws governing community noise. If a neighbour intends to have a party in which loud music is played; they are required by law to seek approval from all the members of the residential complex. It is a requirement that they obtain a police clearance certificate which allows them to hold such a function. It will be stated in the police clearance certificate that the people hosting the party will ensure that they monitor the music-related noise to acceptable levels. If the party organisers fail to control the noise made by the sound system and people at the party, the police will respond by closing down the function and asking patrons to leave by force to maintain public law and order (Government Gazette Act 200 1993).

In view of the inconvenience caused to residents by loud music in residential areas, this paper sought to investigate the possibility of designing a noise-monitoring device suited to South African conditions that could be used by managers of hostel residences, university and college residences, building complexes, townhouses, dormitories, office buildings, and such other crowded living or working spaces that could be affected by the playing of loud music.

The Idea of a Noise-monitoring Device

This paper presents a hypothetical device that can be used in monitoring music-related noise. The idea of a noise-monitoring device is of interest to researchers with a special focus on the impact of loud music on health and safety (Voegel et al. 2007). The idea could be applied to control engineering, communication system design, and human-machine interaction systems.

The envisaged device will not be the first device to be made in the area of noise-monitoring. The new device will complement existing technologies in noise-monitoring and it will provide consumer variety in the selection of noise-monitoring machines. There are related devices that are patented all the time the world over (Atmoko et al. 2008). This proposed noise-controlling device is only conceptualised as a feasible idea. However, there could be problems encountered in the implementation of the idea in terms of device manufacture or it could be found that related work has been done but not in the exact manner described in this study or a related gadget could have been made but not precisely using the materials and design described in this study. The world today is abuzz with new ideas, experimentation, and inventions and so the does not claim to be above the rest. The intended device can stimulate research on the provision of machines that can control the high level of domestic noise that is currently experienced in South Africa (Morojele et al. 2008). At the moment, the police, managing agents of communal residences and residence managers of universities and colleges do not have noise-monitoring devices to control domestic noise. While most of the noise-controlling devices reported in the literature survey seem to have the capacity to detect noise signals, they fail to detect, monitor and switch off the gadget producing the undesirable noise. The envisaged device should be able to go a step further by warning noise makers through flashing lights before shutting off the noise-making machine.

Aim of the Study

The study aimed to provide a hypothetical representation of a noise-monitoring device. The intended device should detect noise and shut off the device that makes the noise. The device should be able to imitate the behaviour of a compound policeman or policewoman. The compound police monitor the level of noise in crowded residential areas.

METHOD

Research Design

A hypothetical framework of a noise-monitoring device is presented. The study did not involve the making of such a device in physical terms; it provided a theoretical framework that could be used by technologists to make such as device. This study describes the method of making a machine that can detect, monitor and control noise in the absence of humans.

Instruments and Materials

Microphones: The project will need four microphones to detect the direction and distance of the noise- making radio. Microphones are used because they are cheap and cost-effective. They are also the simplest method of detecting sound. While more sophisticated sensors may exist elsewhere in the world, in South Africa, microphones could be the starting point in the design of the intended device.

Microprocessor: Microprocessors and their advanced processing versions, that is, microcontrollers, are electronic devices that can easily be coupled to electrical sensors. Their key advantage is the ease of signal processing since they digitise sensor signals thus enabling logical sequences to be performed digitally. Hence, a procedure such as “check if this sound is higher than a certain limit“ can easily be done in software by comparing the digitised sound with a pre-programmed threshold. If the sound is above the set threshold then the microprocessor can easily determine that the radio sound is “noise“. The microprocessor can distinguish between pleasant music and disturbing music-related noise as agreed to in the residence. Similarly, microprocessors can act as switches. They can switch off the mains of offending residential units. However, residence managers and unit owners in residential complexes will have to agree on noise standards without violating human rights and ethical standards of providing electronic devices to consumers.

Buzzers: These are simple warning devices that are commonly used for attention and warnings. They use low level sound signals.

Flashing Lights: These are generally used as flashing robots to attract easily the attention of machine users or people playing loud music. They are cheap and readily available in South Africa.

Function Description of the 3-D Stereo Sound and Noise Detector

The challenge in the design of this type of noise-detection and monitoring device lies in the determination of the exact noise source in a community of sound producers such as student residences or town-house complexes. There could be many radios producing music-related noise at the same time. The solution is via four unidirectional microphones and geometrical triangulation to determine the source of the noise (Atmoko et al. 2008).

OBSERVATIONS AND DISCUSSION

The first primary goal is to determine the sound power and consequently deduce thresholds for what noise is in the residence. The acceptable level of noise as per World Health Organisation ISO Standard 1999/ (ISO 1990) is noise levels below 70dB to avoid damage to the eardrums of children and adults in residence (Berglund et al. 1999). Specifically, 30 dB LAeg inside bedrooms, 45 dB LAmax for noisy events and 55 dB LAeq for outdoor living areas are desirable levels. The second and foremost goal is to locate spatially the source of the noise with good accuracy within the presence of obstacles whose presence may generate reflections. So, rightly called, the task is to design a system that can determine the spatial location of a sound source as well as the sound levels at the sound source.

The detection or sensing of sound is accomplished easily by a number of general purpose microphones that convert or sense sound or acoustic signal to an electrical voltage or current signal. Different types of microphones such as the condenser, dynamic, carbon, piezoelectric, laser, and liquid can be used. Over and above this, there are general groupings such as omni-directional, unidirectional and bi-directional microphones, depending on the polar pattern of determining how much a microphone is sensitive to determining acoustics emanating from different directions.

Typical frequency magnitude and phase response curves show that the voltage to sound frequency response of typical microphones is good for audio frequencies up to about 15 kHz (Shure User Guide Model SM58 2009). In addition, it should be noted that, generally, for a microphone, the greater the sound the greater the output voltage signal.

Designing of the noise-monitoring device requires knowledge of determining the distance of the sound source from the microphone. This can be accomplished by analysing the attenuation of sound in air. Stoke’s law and more especially a special variation of Stoke’s Law namely Navier-Stoke‘ s Equation, determines the attenuation of sound in a compressible fluid (Temkin 1998). In this case, air is a typical compressible fluid. Thus, with knowledge of the attenuation of sound and use of a directional microphone, the distance of the sound source can be determined to be a locus of a sphere whose radius is the distance from the microphone. If only a transverse plane is used then the microphone identifies a circular locus of radius the distance of the sound source from the microphone.

Lastly, geometrical analysis is used to solve the spatial source location problem. Triangulation with re-sectioning is used to identify the exact location of the sound source using three microphones for planar sound source location and four microphones for a full three-dimensional sound source location. Three parameters are thus identified of the sound source location with four microphones; the distance, the azimuthal angle, and the angle of elevation from a particular point of reference. This procedure can easily determine the three-dimensional location of a sound source from a particular reference using four microphones.

It can be hypothesised that, all things being equal or held constant in the design of the noise-monitoring device, the original problem of determining the spatial location of the sound source as well as the sound levels at the sound source can be identified. When that is done the solution can be found through the following procedures. With four microphones two specific parameters can now be determined. These are the location of the sound source and the sound level at the source. It therefore follows that using four microphones can detect where sound is coming from and also how much sound is being produced. This determines the direction of sound and whether or not the sound is at noise level as programmed on the device.

Once the noise source and level are determined, the noise-monitoring device can automatically switch off the noise-generating residential unit’s mains utility power at the electrical distribution board. This method is effortless and is less likely to cause social conflict in crowded residences. The presence of the compound police will not be required. Residents will not interfere with their neighbour’s private life by constantly asking them to lower the volume of their radios. The switch-off can remind the noise-making resident of the need to abide by residence rules and municipal by-laws. The diagrammatic representation of the noise-monitoring device as a “compound police“ is illustrated in Figure 1.

Triangulation-based Noise Detection

The three-dimensional triangulation-based noise detection diagram (Figure 1) shows noise determination. This is represented as x1, the radial distance to sensor S1 with noise power P1 and similarly x2 and P2 for sensor S2 and also for S3 and S4. The sensors S1, S2, S3 and S4 are shown to be non-co-linear as required in the above method and using S1 and S2, the circular locus of possible noise source location is depicted. An additional sensor S3 gives points A and B as possible noise source location. Finally, the sensor S4 clearly locates the source of the noise to be at point A and at distances x1, x2, x3 and x4 from the various sensors S1, S2, S3 and S4 respectively.

Finally, after noise source location has been performed by locating the source of the sound, the sound level is compared to the tolerable threshold and if the sound is above the threshold then this is determined to be noise. Various approaches can be taken depending on the set noise level thresholds from simple warning for minor noise infringements to switching off the mains reticulation of the offender at the electricity distribution board. This can easily be accomplished by use of simple 220Volts trip or relay switches. A warning can be sent to the household from which the sound originates by simple flash lights or buzzer installed in each household.

Further recording of the noise as measured from the various sensors can be done and stored on recording media such as compact discs or digital versatile discs for future reference and proof of noise making. Since simple microphones are used as sensors these can be installed on a computing platform such as a micro-controller thus automating the entire process of three dimensional sound location, determination of noise, warning and switching off functions. A micro-controller can easily perform the supplementary functionality such as recording of the noise, handling additional household units that may need to be connected to this automatic noise-detection and control mechanism.

CONCLUSION

On a theoretical level, the idea of designing a noise-monitoring device could offer good

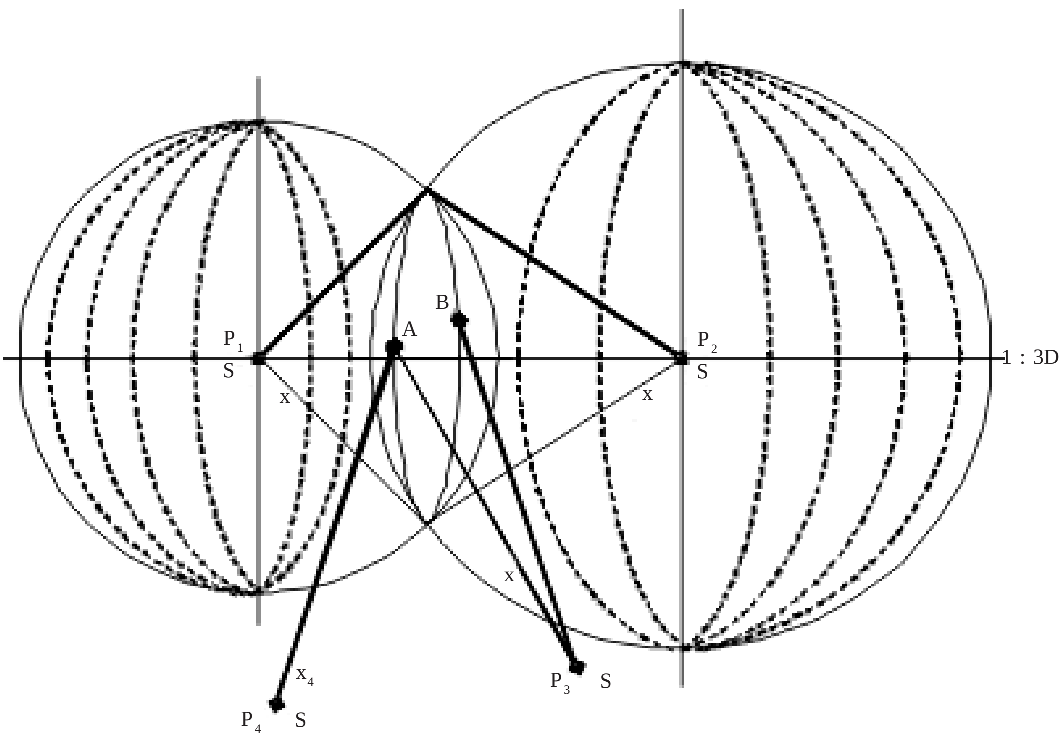

Fig. 1. Triangulation-based Noise Detection

prospects for replacing human presence with machines in noise detection, monitoring and control. Noise produced by radios, television sets and other sound-making machines has been proven to affect the well-being of individuals, communities and workgroups. The idea of producing devices that could control noise may prompt researchers to focus on the need to promote human welfare, psychological health, and quality of life in the workplace and at home through noise management.

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