DESIGN, DEVELOPMENT AND VALIDATION OF EXPERT SYSTEM FOR COMMUNITY NOISE POLLUTION

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Abstract

Community Noise Pollution (CNP) in residential areas involves the use of quantitative data along with qualitative judgment of an expert. The Expert System (ES) designed, developed, described and discussed in this paper integrated the qualitative analysis and quantitative aspects of CNP. It is designed to assist in identifying noise causes, levels, effects, life quality index related to noise and suggest probable mitigation measures. Four experts from the Department of Environment (DOE) and Institute of Noise and Vibration (INV) in Kuala Lumpur, Malaysia were involved as domain experts. The quantitative measurements were taken to identify the existing noise levels and its causes. C Language Integrated Production System (CLIPS) is the tool used to develop the system. Guidelines on validation of expert systems given in the literature were applied on validation of ES for the CNP (ESCNP). Results showed that the system is able to identify noise causes, levels and potential impacts. It is also heuristically make recommendations on noise problem using certainty factor and fuzzy logic techniques.

Key Words: Expert system, Community, Noise, Validation

Introduction

The objectives of developing an ESCNP are to propose a flexible system that can be easily used and extended. This means that the system can be changed at the imlementation level is more easily accomplished without requiring changes to the system design itself (Muhana, 1993) The accuracy of the system is also an important part i.e. the ability of a system to function well in a problem area where there is uncertainty and ambiguity involved in noise judgments. As such, an expert system designed and developed here integrates both quantitative data and qualitative judgments of an expert. It is developed in the form of a rule-based structure to assist in identifying and characterizing CNP. It involves the use of quantitative information from fieldwork and qualitative information from domain experts and textual sources. The quantitative information have been widely used in predictive modeling in expert system to predict future results and outcomes based on given knowledge (Frenzel, 1987; Durkin, 1994; Settito and Dillon, 1994; Ables, 1997; Ridingger *et al.*, 2000).

The ES approach aims at providing a concrete full-scale analysis of the CNP and

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suggesting probable solutions to the problem domain (Missikoff and Widerhold, 1984; O'keefe *et al.,* 1987; Medsker, 1993; Patterson, 1990). The system allows for additional information to be incorporated into the analysis when needed before the decision on the problem sub-module is complete.

CNP problem domain is suitable for the development of expert system, as its solvable problem, does not change quickly, well bounded and the qualitative knowledge required by the problem is heuristic and uncertain. A study conducted by the DOE in 1993 in Kuala Lumpur, Malaysia showed that noise levels in terms of equivalent sound level (L_{eq}) reached up to 87dBA. These levels exceeded the 55dBA level recommended by the World Health Organization (WHO). As such, the literature reflects that noise pollution was ranked as a third pollution problem in Malaysia following air and water pollution (DOE, 1995). To curb such a problem, a concrete full-scale ESCNP is needed.

Once the CNPES is designed and developed, it must be validated. Validation is often considered the cornerstone of expert systems evaluation (Stachowitz and Combs, 1987; Stunder, 1990). Validating and expert systems has, however, turned out to be a difficult task as the expert system is often both a piece of software and a model (back, 1994). Validation is an important part of designing, developing and implementing an expert system (O'keefe *et al.*, 1987; O'leary, 1987). The validation of a system can be accomplished through construct validity (emphasis on the existence of a theory on which the system is based), content validity (can be assessed through direct examination of the system by expert, by a system test against human expert and by a system test against other models.) It can also be achieved through criterion validation, which involves a definition of the level of expertise of the system. This involves demonstrating the system to selected experts in order to elicit their comments about the system performance in terms of functionality. Validation can also be accomplished through sub-system validation, face validation and predictive validation (Back, 1994). It is an interactive process that takes place throughout the development of the system (O'keefe *et al.*, 1987). Validation in the early stages consists of a demonstration of the prototype that can be used in simple cases. Once the knowledge base is expanded, the evaluation process continues to include more complex cases and feedback from experts.

The objectives of this article are:

1. To study existing CNP in Kuala Lumpur, Malaysia.
2. To develop a knowledge base for CNP.
3. To design, develop and validate ESCNP to assist in CNP identification, characterization and curbing.

Methods (Knowledge Acquisition)

Knowledge acquisition is a major bottleneck in the production of expert system (Kidd, 1987). It involves eliciting, analyzing, interpreting, organizing and codifying knowledge. The knowledge acquisition in this study was based on manual acquisition techniques that include:

Quantitative Method

The purpose of the quantitative method is to get a sufficient data on the major factors that probably contribute to the CNP. These represent a problem sub-module (causes sub-module). As such, motorbikes, cars, heavy trucks and buses were counted using a tally counter.

On the other hand, the existing noise levels (Level sub-module) in terms of L_{eq} and background noise level (L_{90}) were measured using a modular precession Sound Level Meter (SLM) type 1 plus statistical analyzer module. The SLM was posted at a height of 130cm and a distance of 1200cm from the main road at Brickfield area in Kuala Lumpur, Malaysia. The measurements were taken for day and night (24hours) with an interval of ten minutes and measurement lasting for five minutes. The causes and levels sub-modules are important as the other sub-modules of the proposed expert system are largely related to these sub-modules and to some extent depend on the accuracy of the knowledge and information related to them. These sub-modules are shown in Figure 1.

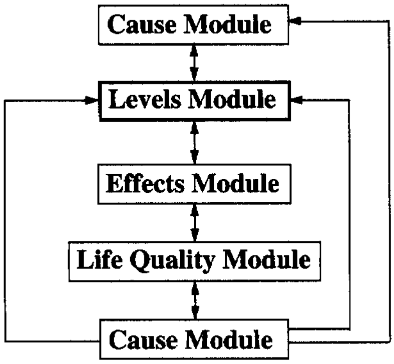

Figure1: CNPES Problem Sub-modules

The Figure indicates that five modules present CNP problem domain. These are noise causes, levels, effects, life quality and management. Each of these has it's own sub-division and characteristics.

Qualitative Techniques

The qualitative method aims at extracting knowledge from related textual sources and selected domain experts. As such, structured and unstructured interviews as a basic knowledge elicitation mechanism (Durkin, 1994) were conducted with domain experts. These were done through normal dialogue with experts relating to the conceptual model of the problem, problem sub-modules and general strategies used by the experts to curb such a problem.

The information and knowledge collected through both qualitative and quantitative techniques were stored in a database of the ESCNP. The knowledge has been gathered in the form of Object-Attribute-Value (OAV). A sample form of knowledge acquisition process is shown in Table 1.

The domain experts were asked to rate the factors that cause noise based on its contribution to the problem. The noise intensity was determined based on the existing noise levels. As such, noise causes and levels modules determine noise effects and other problem sub-modules.

ESCNP Design and Development

ESCNP is designed to utilize the ES shell that runs under windows, which combines the rules and procedures. Thus, any button or value box added to the system's interface could also be programmed with a function. As such, the ESCNP captures the problem solving expertise of an expert in well-defined problem such as CNP. It incorporated facts and knowledge, which include heuristic knowledge, rule of thumb, procedures or rule of solving the problem (Arockiasany, 1993). The four experts from the Department of Environment and Institutes of Noise and Vibration participated in the design of the rules for the expert system were interviewed to determine the methods and approaches use to identify, characterize and solve the problem of CNP. Their approaches were partially examined at the field in order to observe them in practice. The procedures for working

Table 1. Knowledge acquisition on CNP in the form of OAV.

Object	Attributes	Values
Noise levels	Low	<55 dBA
	Moderate	55-65 dBA
	High	>65 dBA
Noise causes	Cars (unit)	<200, 200-400, 401-600, 601-800, 801-1000, >1000
	Motorbikes (unit)	<100, 101-200,201-300, 301-400, 401-500, >500
	Trucks &buses (unit)	<50, 51-100, 101-150, 151-200, 201-250. 251-300, >300
	Distance (meters)	<10, 10.1-20, 20.1-30, 30.1-40, 40.1-50, >50
	Unsatisfactory planning decision	Present/ not present
Noise effects	Hearing danger	Low, moderate, high
Parameters	Sleep disturbance	Low, moderate, high
	Speech interference	Low, moderate, high
	Task performance	Low, moderate, high

with expert and stages of a system development were divided into three phases. The advantages of using the phases were that the phases provide framework for incorporating the knowledge of multiple experts into the system. As such, phase 1 consists of the development of a prototype and initial consultation with the first expert. During phase 11 the second and third experts were consulted. The fourth expert was consulted in the final phase of the ESCNP development. Changes were made by any of the experts brought to other for revision until the consensus among all the experts is reached.

Framework of the Expert System

The identification and characterization of CNP and the probing analysis were made by the experts based on the problem sub-modules as shown in Figure 1. Knowledge obtained is used to develop the proposed EXCNP, which includes the steps shown hereafter (Figure 2)

the facts and data obtained from user during a particular session. The knowledge base for the EXCNP is designed as an individual unit as shown in Table 2. The advantage of individual units is that it facilitates the processes of updating, changing and revising when they are needed.

The rules for EXCNP are organized using CLIPS ES shell. They are programmed in form of ***If....Then*** structure that logically relates the information on the antecedents part with the action or conclusion part. Through using If < condition>, Then <action> i.e. if the condition or premise in the if part of the rule is satisfied by the data supplied by the user during a particular session, the then part of the rule (action) is executed. These processes were done through matching pattern techniques. That is to say matching the current facts against domain knowledge. If more than one rule are satisfied the system performs the rule with a high priorities (conflict resolution). This is done through assigning specific number to a rule that

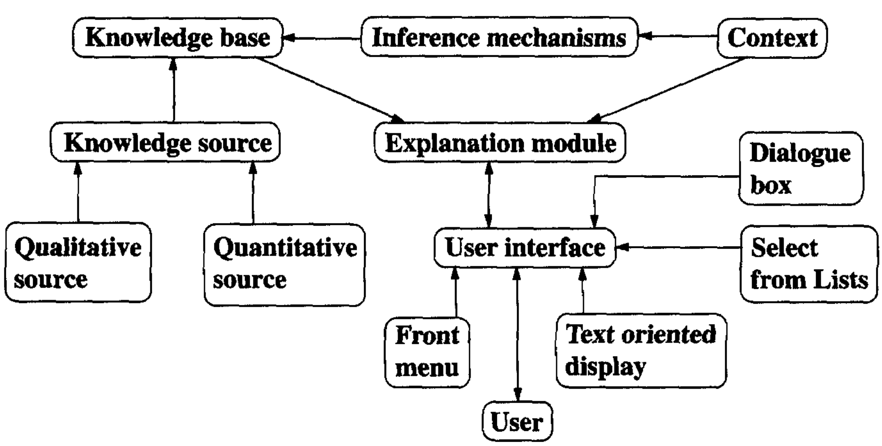

Figure 2. ESCNP Components

Results and Discussion

Knowledge Base Structure and Rules Format

Knowledge base is the collection of domain knowledge related to the problem domain. It contains working memory and rule of thumb of a problem domain. The working memory stores

presents its priorities and certainty factor (CF) was attached to reflect the degree of believes in the rule.

ESCNP uses forward *changing* mechanism to link the rules together as the reasoning strategy is formed. As such, the system arrives at an action by following a series of conditions given as input. For example

If The area is a noise (Leq >65 dBA)

Table 2. Example of Knowledge base Structure of the EXCNP

Rule No.	Variable	Parameter	Value	Fuzzy logic	CF
101	Noise causes	Truck and buses	<50 unit	Small	0.90
			201-250 unit	Moderate	0.80
			>300 unit	Big	0.78
103	Noise causes	Distance (receiver-source)	< 10 m	Near	0.90
			10.1-20 m	Not far	0.60
			> 50 m	Far	0.80
201	Noise levels	L_{eq}	<55 dBA	Low	0.90
			55-65 dBA	Medium	0.80
			>65 dBA	High	0.70
....	....	....	....	....	....

Then Check the number of heavy vehicles and buses
If < 50 units
Then check the number of motorbikes
If <200 unit
Then measure the distance
If the distance is < 50 meter
Then The existing noise level is neither an outcome of traffic flow nor the effects of short distance (source- receiver). It is most probably an outcome of unsatisfactory planning decision **CF 0.90**

In CLIPS format this rule was written as follows:

```
(If (and (L_eq? Level ">65 = noisy =")
Then
(bind? Number (get choice "please insert trucks and buses number")
(mv-append "1" Trucks<50)
(get choice " please insert motorbikes number)
(mv-append "2 " Motorbikes <200)
(get choice "please insert distance)
(mv-append "2" distance >50)
( get choice "else1")
(Then "The existing noise level is neither an out come of heavy trucks/ buses/ motorbikes nor of the effects of the short distance between the main road and the receivers. It is most probably outcome of unsatisfactory planning decision).
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When the user supplies the information that satisfy more than one rule, the ESCNP performed the rule with a high priority for example,

Rule 301 930

If Noise level is > 65 dBA
And Mitigation measures are needed
Then Build wall to reduce noise by 3-6 dBA **CF 0.90.**

Rule 310 1050

If Noise level is > 65 dBA
And Mitigation measures are needed
Then Cultivate tree belts to reduce noise by 3-6 dBA **CF 0.90.**

As such, the working memory contains information such as noise level is >65 dBA and mitigation measures are needed as supplied by the user, which means that all conditions part of rule 301 and 310 are satisfied. However, only rule 310 was fired since the ESCNP uses priority mechanism to resolve the conflict.

User-System Interface Mechanism

As show in Figure 2 the user interfacing is a curcial part of ESCNP. As such the easy accessibility of the system especially user interface mechanism was considered. As such, the user inter with the system through three interaction mechanisms:

1. Front menu as the main menu (program menu) where four menus were made.
2. Program function menu where interface can be done through text oriented display and dialogue box.
3. Select from list.

The system asks the user to select from a given list until the final conclusion reached as using forward chaining mechanism.

Validation of ESCNP

Verification and validation of an expert system is quite a complicated task (Addison *et al.*, 1983; Back, 1994). Verification is a demonstration of consistency, completeness and correctness of the software at each stage and between each stage of development cycle. Meanwhile, validation is considered as a cornerstone of expert system. As such, validation is the demonstration of the correctness of the final program or the software produced from a development project with respect to user needs and requirements. Validation ensures that the capabilities that have been specified in the expert system requirements have been exercised and meet acceptable level to user. In this respects, validation is objective validation in terms of its performance and subjective in comparison with experts (Back, 1994). Validation is extremely important because the implementation of an invalid expert system is useless. Thus, an expert system value can be determined through verification, validation and usability evaluation. Validation is important in the process of designing and implementing an expert system because it included in the decision-making success of the system (O'keefe *et al.*, 1987).

Once the development of ESCNP is completed, validation on sub-system modules and overall system performance was conducted. The valid ation focuses on whether the right system has been built, does the system include the knowledge needed?; and does the system perform at an acceptable level in terms of its completeness, accuracy and consistency.

The ESCNP was validated against known results and expert performance. In the former case, the user provides the system with existing noise levels (> 90 dBA), duration of exposure to such levels (10-12 hours/ day for the period of 8-10 years). The system concluded th at such levels would certainly cause temporal hearing loss, speech interference and sleeping disturbance. Similar Results were found in a paper presented by the experts of WHO in 2000.

The latter one reflects content validity as well as criterion validity. It focuses on demonstrating the system to selected experts in order to elicit their comments and opinion about how the system performs in terms of its functionality, accuracy and completeness. The errors detected were divided into input error (meant an item/ variable has no natural correspondence in the system), output error (meant that an important result was not written out or some items were missing in the final reports) and performance error (meant that the system produced false results). In this case the ESCNP had been tested, if missing knowledge and error were detected, the knowledge were added to the system and the error corrected. This cycle was repeated for three times; until nothing was found to be wrong in input question, output results or performance of the system. As such, the results produced by the system were similar to the results obtained by other experts and results found in textbooks such as DOE 1993: and Noise and Society.

Conclusions

The design, development and validation of ESCNP comprises the knowledge base on noise causes characterization, noise levels identification, potential impacts of noise pollution and probable mitigation measures for noise problem. The system fires when interfacing process activated. It accepts user inputs queries and responds to questions through the input/ output interface. The system uses rule production format and the facts stored in the knowledge base coupled with the inference mechanism and using of forward changing strategy to come out with a solution to the problem of CNP. The system can be used for decisions support especially for determining noise causes, levels, life quality index related to existing noise levels. It can also identify the potential impacts and suggest the probable mitigation measures. The performance and outcome given by the system were validated using face, subsystem and blind performance validation.

References

Ables, G. (1997). Predictive Modeling for nonstatistician. *J. of Target Marketing* Vol. 20 (3). North America Publishing Co.

Addison, W. R., Brandstad, M. A. and Cherniavsky, J. C. (1982). Validation, Verification and Testing of Computer Software. *J. of Management Information System* Vol. 14 (4).

Arockiasamy, M. (1993). Expert Systems Applications for Structural, Transportation and Environmental Engineering. CRC Press. Tokyo, London.

Back, B. (1994). Validating and Expert System for Financial Statement Planning. *J. of Management Information systems* Vol. 10(3):157-177.

Department of Environment (DOE). (1993). Malaysian Environmental Quality Report. DOE. Malaysia.

Department of Environment (DOE). (1995). Malaysian Environmental Quality Report. DOE. Malaysia.

Durkin, J. (1994). Expert System: Design and Development. Prentice Hall, New Jersey.

Frenzel, J. (1987). Understanding Expert System. Howard W. SAMS and Co. USA.

Kidd, A. (1987). Knowledge Acquisition for Expert Systems: A practical Handbook. Plenum Press. New York and London.

Medsker, T. (1993). Design and Development of Expert Systems and Neural Networks. Macmillan. New York.

Missikoff, M. and Widerhold, G. (1984). Towards a unified Approach for Expert Systems and Database System In: Kerschberg, L. (ed), (1986) Expert Database Systems. Proceeding from the first International Workshop, Kiawab Island. USA.

Muhana, W. (1993). An Object-Oriented Framework for Model Management and DSS Development. *Decision Support Systems.* Vol. 9(1):409-430.

O'keefe, M., Blacijo, M., Smith, E. (1987). Validating Expert System performance. . Plenum, London.

O'leary, D. (1987). Validation of Expert Systems. With Applications to Auditing and Accounting Expert *Systems. Decision Sciences,* Vol. 18(3).72-79.

Patterson, D. (1990). Introduction to Artificial Intelligence and Expert System. Prentice-Hall, INC. New Jersey.

Ridingger, M., Rice, H., Jeffery, J. (2000). Predictive Modeling points Way to Future Risk Status. *J. of Health Management Technology.* Vol. 21(2). Nelson Publishing Co.

Sestitio, S. and Dillon, T. (1994). Automated Knowledge Acquisition. Prentice Hall of Australia Pty LTD.

Stachhowtiz, R., and Combs, J. (1987). Validation of of Expert System. International Conference on System Science, Vol. (1): 686-695.

Stunder, M. (1990). Validation and Verification of Environmental Expert Systems. American Chemical Society. USA.

WHO. (2000). Guidelines for Community Noise. Paper Presented to 6th Congress on Environmental Health, OSLO. Norway.