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QUALITY OF SOFTWARE PRODUCTS FOR THE PREDICTION OF SOUND IMMISSION - STANDARDIZATION EFFORTS IN GERMANY

U.J. Kurze

Müller-BBM GmbH, Robert-Koch-Str.11, D-82152, Planegg, Germany

Tel.: +49 89 85 60 22 35 / Fax: +49 89 85 60 21 11 / Email: ku@mbbm.de

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ABSTRACT
As an extension of ISO / IEC 12119 for quality requirements and testing of software packages a German standard has been drafted for software products designed for noise mapping and related tasks of environmental noise control. The most important aspects are related to the definition and testing of software precision and to an interface suitable for the data exchange between various programmes. In a first step the consistency of the software calculation procedures with standardised procedures is checked by test cases. Since switches can be set in most programs to accelerate calculation procedures for complex and extended situations, a second step is required to control the precision obtainable by the user for his special application. This is proposed on a statistical basis, which will be described.

1 - INTRODUCTION
ISO/IEC 12119 [1] for quality requirements and testing of software packages has been issued in 1995 when activities were first started in Germany on such standardization for special software products for the prediction of outdoor sound immission. By that time a number of programs were on the market, most of them not to handle without special training, requiring different sets of input data and providing sometimes rather different results. In addition, official procedures had been specified for traffic noise to avoid artificial precision with numerous decimal places by limiting the display of results to integer values of decibels. It should be clear to every engineer that the last digit of a rounded number is uncertain by 1. But computer specialists and many administrative people have not been content with a precision of 1 dB. Neglecting the experience from acoustical measurements, which relates 1 dB to laboratory quality, they are aiming at an error margin of 0.1 dB or less. Test cases have been developed for the validation of the required precision. Frequently, such procedures are taken as substitutes for the quality assessment of software packages. In this paper some more general aspects will be addressed.

2 - WHAT THE MANUFACTURER OFFERS
The software manufacturer takes the relevant standard, e.g. ISO 9613-2 [2], looks at the required input parameters and calculation procedures, adds some requirements from his potential customers and tries to come up with a procedure which is well organized, easy to handle, consistent with the specified regulations and fast in computation. The first things he finds out are inconsistencies, contradictions and open questions in the standard or regulation. He sees the need to amend, extrapolate or extend the rules. The next thing he realizes are limitations in data handling and efficiency. He will try to reduce the effort without substantial loss of precision. Finally, to improve upon his product, he will add special features reflecting his personal experience or understanding of physics, acoustical planning and engineering application.

So far, the manufacturer has done his best without taking ISO/IEC 12119 into consideration. This is the state-of-the-art. In the future – according to the standardization efforts – the general quality criteria for software packages should be observed, tailored to the needs of sound immission prediction. This implies clear statements about the referred standard and the section applied, distinctions between modeling of specified rules and of additional features, descriptions of procedures applied which are necessary to use the model but are not normative parts of the standard, and explanations of special calculation procedures not contained in the standard. The information should be given in the product description (for potential customers) and consistently in the user documentation as part of the product. Validation procedures should be made available. Benchmark testing is considered as an important part [3], but not exclusively. For this purpose, German manufacturers have agreed to provide with the software a complete set of official test cases and a common interface for data exchange with software packages from other manufacturers of qualified products. The test cases are run in a reference mode which supports the manufacturer's declaration of conformity with relevant standards and allows for the user's verification of such a statement. Furthermore, by providing the possibility for a comparison of results obtained from applications of the software on actual cases in the reference mode and in a simplified operational mode selected by the user, the manufacturer shall offer the opportunity for the user to determine the precision of his calculation for a complex situation. Of course, such a procedure is restricted to situations where standardized calculation procedures provide the basis for a clear reference mode.

3 - WHAT THE USER SHOULD KNOW

A variety of factors determines the precision of the results obtained from a software program. This includes input data (data on sound sources and transmission paths), simplifying relations specified in the relevant standards (e.g. straight line sources instead of curved roads), simplified or wrong assessments of complex situations by the software manufacturer, and inappropriate applications of the software by the user. In many cases, uncertainties about input data are most important. They are independent of the software quality but may determine the operational mode selected by the user. Similarly, the simplifications contained in the standards, which may result in differences between calculated and measured data, cannot be attributed to the quality of the software product. The responsibility for the remaining factors (complex situations and inappropriate applications) is shared between the manufacturer and the user. The manufacturer has to provide sufficient guidance through the program and its interconnections as well as supporting tools for checks on procedures and on the precision of calculated data. The user is responsible for his selection of the operational mode and the subsequent deviation from standardized procedures. As long as the effect of the selected mode of operation on the precision can be determined, the software quality is not impaired.

From checking the official test cases in the reference mode, the user can make himself familiar with a software program and its potential precision. But very often, the overall precision is limited in practical cases by uncertain input data and simplifying calculation procedures. Therefore, the user should tailor his application of the software program to the actual situation. He should consider the overall situation when making a statement on the precision of his calculation which he may derive from permissible ranges of results for test cases and from differences between results obtained in a reference mode and in a simplified mode of calculation. E.g., when the type of a road surface and the traffic density and composition are not sufficiently specified to determine the sound creation within a standard deviation of 2 dB, a calculation carried out for the neighborhood with a precision better than 1 dB may not be very meaningful.

It must be emphasized that a high precision alone is not a sufficient qualification criteria for a software program. Precision is a threshold for complying with the standard test cases. But real situations almost always require the setting of switches to leave the reference mode and to enter into a special mode of operation. Quality is related to the ability of a program (and the user) to distinguish between situations, which have a reference to a standard and thus allow for a clear baseline, from other situations without such a reference for which a precision thus cannot be defined.

Even for well specified situations, the precision of calculated results may not be meaningful without further information. One important aspect is the spatial gradient of sound pressure level in the sound field. Small variations in space combined with strong gradients may result in large variations in level. Such situations typical for the immediate vicinity of sound sources and for sound shadow boundaries should be excluded from precision analysis by qualified programs.

4 - A STATISTICAL APPROACH TOWARD PRECISION

Noise maps have become a useful tool for the public and for authorities to discuss the problems of environmental sound impact and to focus the attention on essential aspects. Ever increasing computer capabilities lead to more and more sophistication in the prediction of sound propagation outdoors between buildings, over barriers and earth mounds, downwind and upwind, and over terrain of various shape and ground cover. The calculations are no longer traceable in detail. The results are given in terms of contours of equal equivalent levels. Neglecting errors of input data, what is the precision of the information given with such a noise map?

The answer depends on the position. In principle, level contours derived from interpolation of data calculated for grid points may be affected by errors of the grid point data (due to simplified calculation procedures), interpolation errors (e.g., due to missing grid points at positions inside buildings), and the spacing between adjacent level contours. The software manufacturers prefer to concentrate on the first type and to claim zero errors for calculations carried out for grid points in the reference mode for test cases. The user would like to have interpolation errors identified from comparison of calculations in the reference mode both for grid points and for arbitrary points in between. However, this would require the option of an additional run of the program for selected test points, which is presently not offered by the manufacturers. In addition, some users would also like to account for the uncertainty due to the spacing ΔL between two adjacent level contours L_1 and L_2, which − for a random distribution of levels − results from the mean value $L_1 + \Delta L/2$ and the standard deviation $\Delta L/\left(2\sqrt{3}\right)$. The software manufacturers are afraid this uncertainty could be attributed to the quality of their product instead of to the mode of operation or data presentation chosen by the user. From an engineering point of view, there should be no doubt about the correct handling of these questions. However, software products are also sold to customers who may have a particularly high expectation of computer capabilities. This requires sensitive considerations.

A statistical procedure for the general case of arbitrary test points in a test area GP has been proposed as follows. The test area should be a sufficiently small part of the total area GG under consideration in order to allow for sound level calculations at selected or statistically chosen test points in the reference mode as applied for all the relevant test cases. Test points inside buildings are invalid. Test points close to sources and obstacles in the propagation path should be omitted to avoid effects of strong gradients. For the selected test points, the computer program is run in two modes, the reference mode and a simplified mode. Computations in the reference mode are restricted to sources and propagation conditions in a partial area GA, which contains the test area GP and its acoustically relevant vicinity (see the scheme in Figure 1). The results for a (small) number of n test points may be labeled $L_{\rm r1}$, $L_{\rm r2}$,...$L_{\rm rn}$. Computations in the simplified mode are first carried out under consideration of the same partial area GA with the results $L_{\rm sA1}$, $L_{\rm sA2}$,...$L_{\rm sAn}$ for the test points. The level differences $L_{\rm r1}$-$L_{\rm sA1}$, $L_{\rm r2}$ -$L_{\rm sA2}$,... $L_{\rm rn}$-$L_{\rm sAn}$ are evaluated in terms of their mean value m_1 and their standard deviation s_1. A second computation with the simplified mode is applied for consideration of effects (sources and propagation paths) from the total area GG on the test area. This results at the test points in levels $L_{\rm sG1}$, $L_{\rm sG2}$,...$L_{\rm sGn}$ and in level differences $L_{\rm sG1}$-$L_{\rm sA1}$, $L_{\rm sG2}$ -$L_{\rm sA2}$,... $L_{\rm sGn}$-$L_{\rm sAn}$ with mean value m_2 and standard deviation s_2. Obviously, the partial area GA is appropriately chosen and the effect of the remaining area on the test area GP is small if $m_1^2 > m_2^2$ and $s_1^2 > s_2^2$. Otherwise, a larger or shifted partial area GA needs to be chosen by the user.

As a result characterising the precision of the approximate procedure obtained in the test area GP, the software package should provide the level difference

$$D = \sqrt{m_1^2 + m_2^2 + \left(s_1^2 + s_2^2\right) \frac{\chi^2_{\nu-1;1-\alpha}}{\nu}} \tag{1}$$

where $\chi^2_{\nu-1;1-\alpha}$ denotes a factor depending on the confidence level α.

5 - FUTURE DEVELOPMENTS

At present, it is not the task of the German standards group to develop new test cases. But for the future, this group will be involved in the necessary consensus about the type and the correct results of further test cases. This will especially apply to complex situations requiring statistical evaluation procedures.

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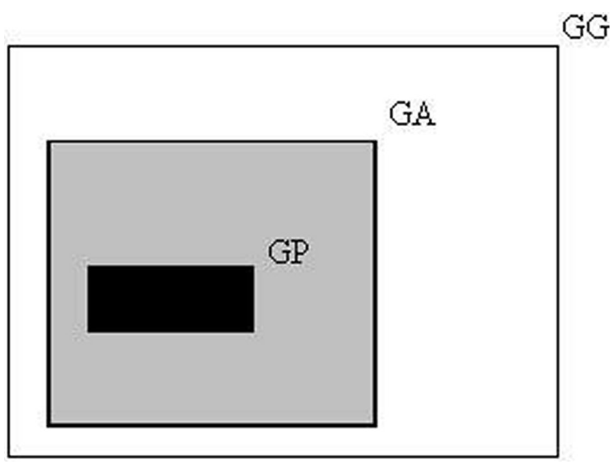

Figure 1: Partitioning of a large total area for calculation of sound immission (schematic); GG: total area with information about sound sources and propagation conditions, GA: partial area where sources and propagation conditions are taken into account, GP: test area with immission points.