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ACOUSTIC SOURCE LOCATION, PRESENT TECHNIQUES AND FUTURE IMPLICATIONS FOR INDUSTRIAL NOISE CONTROL

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1. Introduction

In the past, acoustic source location relied on techniques of a mechanical nature. Directional microphones were used, sometimes with an ellipsoid 'acoustic mirror'. Another method used was the 'acoustic shield', which was progressively advanced across the source region to shield a single non-directional microphone[1]. From this a crude source distribution could be deduced.

More recent techniques exploit the availability of computing power, which is becoming more and more cheaply available. The methods of Polar Correlation[2] and the Acoustic Telescope[3] are based on the use of multiple microphones, and the signals from these undergo considerable computational processing to yield a one-dimensional image of a line of sources. Originally developed to investigate source regions on the axis of a jet engine, this restriction to one dimension was unimportant. For other applications, however, two dimensions are needed, requiring the use of a two dimensional array of microphones. If good resolution is to be obtained, the number of microphones required can get out of hand unless sparse array techniques are used[4,5], or unless the microphones are moved about during the test.

The use of a computer can help in many other ways. Already commercial instruments are available with 'post triggering', so that sounds can be captured over an interval preceding a trigger event. Correlation techniques allow comparison of far-field noise with the signal from a probing near-field microphone. Captured signals can be 'dissected' to analyse the noise level contributions of their component clicks and bangs. With adequate knowledge of likely sources, the computer can even be made to simulate the noise of a machine not yet built.

2. Polar Correlation

As its name implies, the method is based on correlating signals from a pair of microphones. Originally a large number of recordings were made, one microphone remaining fixed whilst for each recording the other was advanced in position around a circular arc. More recently, in order to shorten the test time a large number of microphones are used, one for each required position. As computing power has fallen in price it has been possible to progress from lengthy off-line analysis to the use of a dedicated minicomputer; the result of the computation is a line distribution of sources for any chosen frequency.

Like many other modern source location techniques, the underlying principle has much in common with that of the multi-aerial radio telescope. When two signals are correlated the result is a confused mixture of correlations of the individual sources. If the sources are assumed to be uncorrelated, so that cross correlations are zero, the mixture consists of autocorrelations of all the sources. These are individually shifted according to their position, and according to the separation of the microphones, but positional and spectral features are inextricably mixed. It is only when several correlations are compared, for different microphone separations, that the distribution starts to emerge. As with submarine sonar systems, 'sparse array' techniques allow a given number of microphones to yield a large number of pair separations, giving an improvement in resolution.

3. The Acoustic Telescope

From the outset, the Acoustic Telescope method was based on simultaneous recording or logging from an array of sixteen or so microphones. When analysed in depth[6], the mathematical principles are seen to be remarkably similar to those of Polar Correlation, but a large practical difference arises in the computational process. Analysis takes place largely in the time domain, time shifts being applied to the microphone signals corresponding to each required results point. A distribution of source intensity as a function of position and frequency can be obtained within a few seconds, with the use of a dedicated on-line minicomputer. A particular variant of the sparse array technique, the 'coarse-fine' array, allows the computation to remain simple and swift whilst giving good resolution from as few as eight microphones. Because of its time domain processing, the technique is capable of tracking moving sources, and if the noise is cyclic the analysis can be synchronised with some periodic event.

4. Two Dimensional Methods

At a recent meeting in Cambridge, a paper was presented by a French group[4] who used a two dimensional sparse array to generate two dimensional distributions of industrial noise sources - the examples presented included a compressor and a pneumatic drill. Microphones - sixty or so - were distributed in a random manner on a plane framework reminiscent of a bed-spring. As presented, the method seemed in need of much further development. The basic 'Green's function' (the resulting appearance of a single point source) had numerous sidelobes, and for all but simple localised sources, bogus 'ghosts' were liable to occur. Nevertheless, the method showed great promise.

Work is proceeding in several centres on the extension of coarse-fine techniques to two dimenions, with the potential benefits of economical computation and a well-formed Green's function.

5. The Implications and Future Possibilities for Industrial Use

Much of the development of source location techniques has taken place in connection with aerospace industries, where everything must be 'of the best'. With condenser microphone capsules costing several hundred pounds each, and requiring elaborate amplification techniques to make the best of their puny output, a multimicrophone array has been somewhat restricted in its sphere of application. However, as soon as there is pressure to produce 'budget' arrays, endless possibilities open up. Crystal microphones may lack perfection, but their response can be compensated by the computational process.

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The advent of the microprocessor has halved and halved again the cost of computation, and there is a strong argument for associating a processor with each microphone.

In the main, distance scales will be relatively small and an eight microphone coarse-fine array will be quite compact, perhaps no more than two metres in total length. The possibility then opens for rotating the entire array about a horizontal normal axis, to build up a two dimensional source image by a method similar to that used in the 'body scanner'. With computing based on microprocessors, an economic system can be derived which will produce a two dimensional image in a few minutes of real-time.

As microprocessors become more powerful, the potential will increase for rapid on-line processing and ever more versatile acoustic analysis systems. The development of such systems will require considerable investment of software effort, but if there is quantity demand the price can reflect falling hardware costs - in turn opening up more widespread use and a further increase in demand.

6. Conclusion

In recent years the 'spin off' from high technology aerospace projects has resulted in techniques of wide use and ready availability. This can be no less true of acoustic source location, which has already borrowed from the technologies of sonar and the Radio Telescope. Within a year or two it could be commonplace in the analysis of industrial noise.

7. References

1. SUSAN M. DAMMS 1977 Royal Aircraft Establishment, Farnborough Technical Report 77032. The shielding method for noise source location and a review of alternative methods.

2. M.J. FISHER, M. HARPER-BOURNE and S.A.L. GLEGG 1977 Journal of Sound and Vibration 51, 23-54. Jet engine noise source location: the polar correlation technique.

3. J. BILLINGSLEY and R. KINNS 1976 Journal of Sound and Vibration 48, 485-510. The acoustic telescope.

4. J. JAQUES Imagery of Acoustical Noise Sources. Presented to Institute of Acoustics Meeting Source Location and Active Control of Noise, Cambridge, June 1979.

5. J. BILLINGSLEY The use in the Acoustic Telescope of a Coarse-Fine Array. Presented to Institute of Acoustics Meeting Source Location and Active Control of Noise, Cambridge, June 1979.

6. J. BILLINGSLEY 1978 Journal of Sound and Vibration 61(3), 419-425. A comparison of the source location techniques of the acoustic telescope and polar correlation.