Abstract

Impulsive sound source localization has received a lot of interest in the past few decades due to its potential applications in various fields like underwater acoustics, battlefield acoustics, etc. In this work, the localization of the point of explosion of an explosive sound source over a range of (0.5-2500) m is addressed by using the time difference of arrival based multilateration approach. Firstly, a set of governing nonlinear hyperbolic equations is formulated. A novel modified Levenberg-Marquardt algorithm (MLMA) is proposed here to solve the nonlinear equations using an optimization strategy. The method employs four exclusive update steps in each iteration to achieve both global convergence and faster computing. The inclusion of a constraint in the objective function improves the positioning accuracy by improving the global convergence property even if a random initial guess is taken, not necessarily close enough. The stability of the proposed algorithm is demonstrated by employing the trust region method. The proposed MLMA can identify planar and spatial sound source positions accurately over a wide range of distances by utilizing random microphone array configurations. Several field experiments and simulation studies are conducted to demonstrate the performance of the proposed method over existing methods.

The simulation studies consider different source and microphone positions by varying ratio between microphone spacing and source range (k) from 0.05 to 3. The numerical simulation results demonstrate that the MLMA outperforms the existing methods in terms of accuracy and computational speed at both lower and higher noise thresholds. The effect of the number of microphones and k on the positioning accuracy is also studied for source location beyond 2 km from reference microphone. Based on results, this work proposes that five microphones in an array are enough to locate near sources, whereas a six-microphone array is enough to identify a distant source position with an accuracy of 97% at lower noise thresholds (Signal-to-noise ratio (SNR): (6 to 20) dB) and an accuracy of 95% at higher noise thresholds (SNR: −6 to 0 dB). From the results, it is concluded that the microphone spacing should be at least 0.3 times of the source range for accurate localization of distant sound sources at both higher and lower noise levels.

The source localisation experiments are conducted in a reverberant indoor environment to localise an omnidirectional sound source ($k \geq 1$). The outdoor source localization experiments are conducted to determine the position of a "chocolate bomb" ($0.1 < k < 2$) and an artillery shell ($k < 0.004$). The results show that the MLMA iterative approach outperforms the existing well-known source localisation approaches (geometric, maximum likelihood estimator, weighted spherical interpolation, gradient descent, hybrid optimisation algorithm, Levenberg-Marquardt algorithm) in terms of positional accuracy and computational complexity (at least ten times faster than other methods globally). For localization of sound source in indoor environment, the accuracy falls within 98% by employing five or six microphones. For outdoor low explosive sound source localization problem ($0.1 < k < 2$), the accuracy lies between 92%-98%, whereas, for outdoor high explosive sound source localization problem ($k < 0.004$), the accuracy is decreased to approximately 80%-91%. In addition, the impact of the number of microphones and the selection of reference microphones on positioning accuracy is explored. The experimental study concludes that employing more microphones in an array for distant source positioning is always preferable.

Keywords*:* Artillery, Impulsive sound source, Microphone spacing, Modified Levenberg-Marquardt algorithm, Multilateration, Optimization, Reverberation, SNR, Time Delay.