Calculation of sound pressure level distribution and reverberation in street canyons using the image source method

This program calculates sound level distribution and reverberation in rectangular urban streets canyons with geometrically reflecting boundaries. The program is based on the image source method. Using the program the effects of basic street parameters can be analysed.

For both sound level and reverberation calculation, the program allows the following inputs:
(1) Street length (x), width (y) and height (z).
(2) Sound source position.
(3) The height of a horizontal receiver plane, where there are 10 (width) x 10 (length) calculation points.
(4) Sound absorption coefficient of facades and ground. Air absorption (Np/m) can also be input. Typical air absorption values can be selected.
(5) For sound pressure level calculation, source pressure level at 1m from the source.

Algorithm of the program

For more information, see

Kang, J. Sound propagation in canyon streets: Comparison between diffusely and geometrically reflecting boundaries. The Journal of the Acoustical Society of America, ***107*** *(2000).*

With geometrically reflecting boundaries, the sound propagation in a street canyon can be calculated using the image source method. Consider an idealized street as shown in Fig. 1. Figure 2 illustrates the distribution of image sources in the street, where the street length, width and height are L, W and H, respectively. For calculation convenience, the image sources are divided into four groups, namely A1, A2, B1 and B2. Groups A1 and A2 correspond with the reflections between two façades, and groups B1 and B2 include the reflection from the street ground. Assume there is a sound source S at (S_x, S_y, S_z). With reference to Fig. 2, the energy from an image source to a receiver R at (R_x, R_y, R_z) can be easily determined. First consider an image source i ($i = 1...\infty$) in group A1. For odd values of i the energy to the receiver is

$$E_i(t) = \frac{1}{4\pi d_i^2}(1-\alpha_A)^{(i+1)/2}(1-\alpha_B)^{(i-1)/2}e^{-Md_i} \qquad (t = \frac{d_i}{c}) \qquad (1)$$

where α_A and α_B are the absorption coefficient of façades A and B, respectively. t is the time. M is the air absorption in Np/m. d_i is the distance from the image source i to the receiver:

$$d_i^2 = (S_x - R_x)^2 + [(i-1)W + S_y + R_y]^2 + (S_z - R_z)^2 \tag{2}$$

For even i,

$$E_i(t) = \frac{1}{4\pi d_i^2}(1-\alpha_A)^{i/2}(1-\alpha_B)^{i/2} e^{-Md_i} \qquad (t = \frac{d_i}{c}) \tag{3}$$

with

$$d_i^2 = (S_x - R_x)^2 + (iW - S_y + R_y)^2 + (S_z - R_z)^2 \tag{4}$$

For an image source i ($i = 1 \ldots \infty$) in group A2, with odd values of i the sound energy to the receiver is

$$E_i(t) = \frac{1}{4\pi d_i^2}(1-\alpha_A)^{(i-1)/2}(1-\alpha_B)^{(i+1)/2} e^{-Md_i} \qquad (t = \frac{d_i}{c}) \tag{5}$$

with

$$d_i^2 = (S_x - R_x)^2 + [(i+1)W - S_y - R_y]^2 + (S_z - R_z)^2 \tag{6}$$

For even i,

$$E_i(t) = \frac{1}{4\pi d_i^2}(1-\alpha_A)^{i/2}(1-\alpha_B)^{i/2} e^{-Md_i} \qquad (t = \frac{d_i}{c}) \tag{7}$$

with

$$d_i^2 = (S_x - R_x)^2 + (iW + S_y - R_y)^2 + (S_z - R_z)^2 \quad (8)$$

For groups B1 and B2, the energy from the image sources to the receiver can be determined using Eqs. (1) to (6) but replacing the term $S_z - R_z$ with $S_z + R_z$ and also, considering the ground absorption α_G. By summing the energy from all the image sources in groups A1, A2, B1 and B2, and taking direct sound transfer into account, the energy response at the receiver can be obtained. Consequently, the acoustic indices such as EDT (early decay time), RT (reverberation time) and steady-state SPL, can be determined.

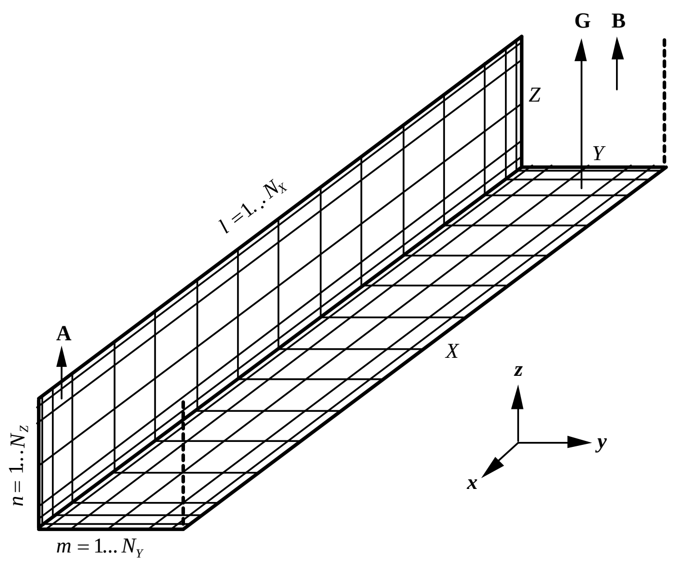

FIG. 1. Three-dimensional projection of an idealised street.

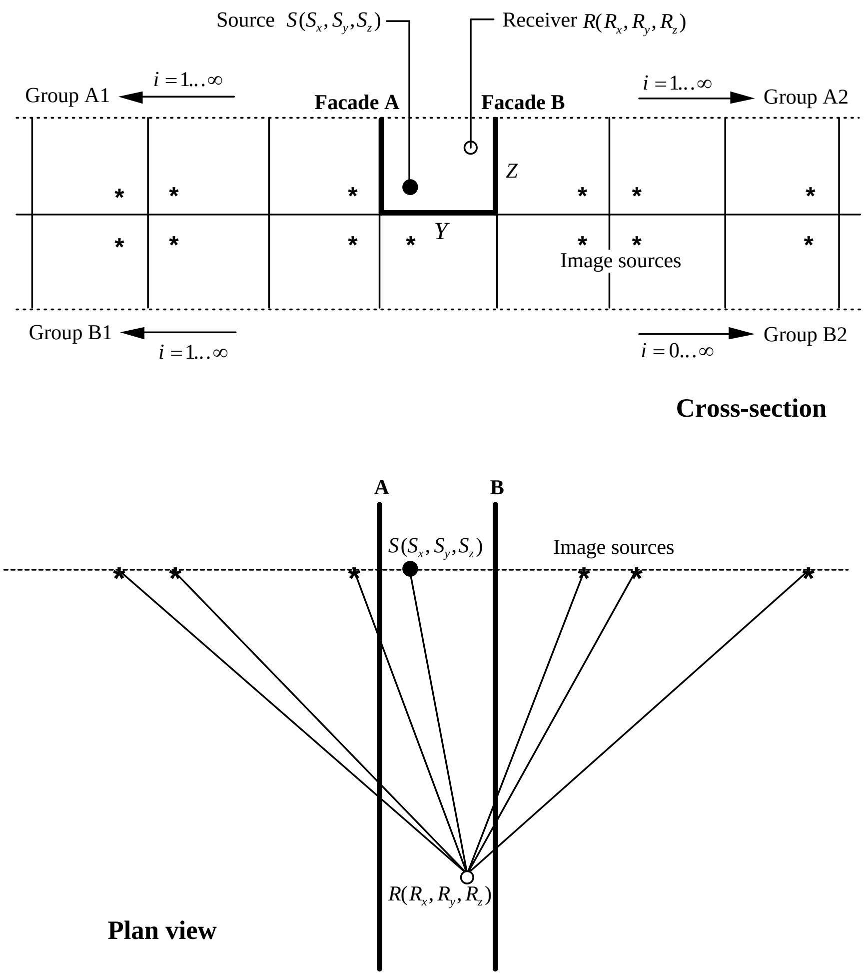

FIG. 2. Distribution of the image sources in a rectangular street canyon.