Acoustic localization techniques

Time Difference of Arrival (TDOA)

TDOA works by measuring the differences in arrival times of a sound at multiple microphones. Using these differences, the location of the sound source can be estimated geometrically. Specifically, when the positions of each receiver are known, the time difference measurement reflects a variation in distances from the two receivers to the unknown object.

To determine possible locations of the object with use of 2 mics we can use the following formula:

quicklatex.com

x, y, z – position of object  
x1, y1, z1 - position of mic 1  
x2, y2, z2 - position of mic 2  
t1 - t2  - difference in time of sound arrival  
c – speed of sound

With the use of multiple pairs of microphones, we can estimate the location more precisely.

Beamforming

Beamforming works by focusing on microphone array’s sensitivity in a concrete direction. In the most basic form, it combines signals from all microphones using time delays.

More specifically, microphones in array receive the sound at slightly different times, then those signals are appropriately delayed and summed, in a way that constructive interference of waves occurs from the direction, where sound came from. And vice versa from the other sides signal fades away. By scanning all possible directions, it is possible to find the source of the sound.

In other words, after some object emits sound, the microphones capture it at a slightly different times. Then we slide one microphone’s signal in time relative to the other and see how well they match. The amount of shift (delay) that gives the best match tells us from which direction sound came from.