147th ASA Meeting, New York, NY

A Shot in the City:
Locating a sound source in an urban environment

(http://www.crrel.usace.army.mil/sid/ASA/SoundSource.htm)

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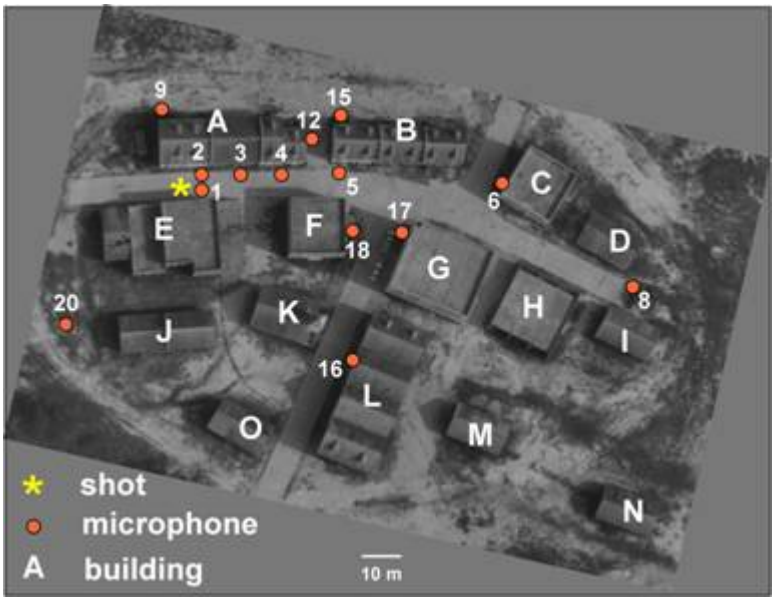
Gunshot noise measurements in an urban area.
(Photo J. Aguiar, USA ATC)

Sound propagation in an urban environment is complicated by the presence of buildings. The sound waves reflect from building walls and diffract (or bend) around corners. Because of the many diffractions and echoes, it is difficult for a listener to locate the source of the sound waves, especially when the source is not directly visible. (Where is that ambulance siren coming from?)

At the last Acoustical Society of America Meeting, we discussed measurements of these effects made in an artificial urban setting (a full scale model village used for training) and a method of mathematically simulating these sounds on a PC. In this paper, we apply a technique called time reversal processing to locate sound sources in urban areas. This method has been previously used in medical imaging and treatment, underwater communication, and other applications, and a short course on this method was taught at the last ASA Meeting by ASA Fellows Mathias Fink and William Kuperman. We are applying it to urban sound propagation for the first time.



Aerial photo of the training village where measurements were made. Most of the buildings are two stories high and made of concrete blocks. The distance from the shot to microphone No. 8 is 100 m.

How does it work? In the time reversal method, a network of simple, low-resolution sensors in the urban area detects sound waves. These signals are complicated, since they include all the many echoes

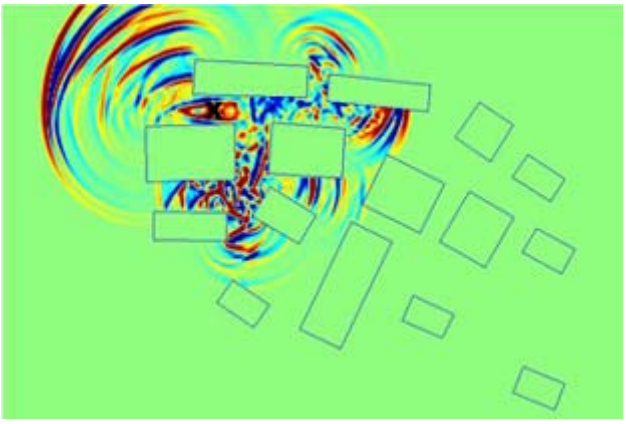
and other arrivals from the wave "bouncing" around amongst the buildings. We then turn completely to a computer. It receives the sound signals from the sensors, and we use it to generate a backwards version of the detected sound waves. Then, using a model of sound propagation in the urban area, we rebroadcast the sound waves in a virtual urban environment. The waves eventually return and focus at the original source point, enabling us to pinpoint the location of a sound, such as an explosion or gunshot! By having a few microphones somewhere in the village, we can use the computer model and the time reversal technique to locate the sound source.

Equipment used in recording the sounds of the shot.

By measuring the sound at a few locations in the village and using the computer model to propagate them back from the receiver locations, a focus of sound energy occurs at the original source location.

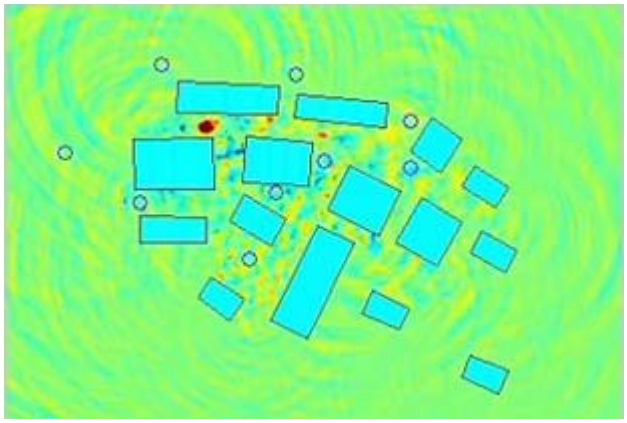
The time reversal model shows that the sound waves emanate from the various speakers, bounce off of the buildings, and concentrate (red blob, image below, right) at the approximate source of the original shot, ("**X**" in the image below, left). This model run shows that the correct source location is found from just a few sensors, all of them being shielded from the view of the source location. With further development this method has the potential of improving sound source (sniper) detection and other sensor systems.

Forward: Sound from the shot



Computer simulation showing sound waves from a shot (the black "**X**") bouncing off buildings in the village. Movie of the propagation of the sound waves is available at: http://www.crrel.usace.army.mil/sid/ASA/SoundSource.htm

Reverse: Locating the shot



The result of modeling the sounds using the Time Reversal Method. Notice the concentration of sound waves (red blob) indicating the source location of the original shot sound. Movie of the model run is available at: http://www.crrel.usace.army.mil/sid/ASA/SoundSource.htm

In the ASA short course, Drs. Fink and Kuperman showed that time-reversal procedure also works if you physically rebroadcast the sounds into the actual environment, such as an underwater minefield, or a kidney-stone patient's body. They gave many examples of applications in the medical, communication, and signal processing fields.

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