Sensor Fence: A New Approach To Large-Perimeter Security

By Andrew F. Mazzara, David C. Swanson and Nicholas C. Nicholas

For the past five years, Penn State's Applied Research Laboratory has been building a network of relationships with law enforcement and correctional agencies throughout the United States. These partnerships stem from the increasing interest and use of "smart" technologies, minimal-force approaches and nonlethal devices by these agencies. One example is the Institute for Emerging Defense Technologies' (IEDT), sensor fence — a novel, low-cost, low-maintenance, tensioned wire system that may be used on new or existing fences that results in an improved capability to detect, locate and classify intruders. The sensor fence can be used reliably in large, secure areas such as correctional institutions, airports, military bases, power generation facilities, ports, reservoirs or other large areas typically protected by fences.

Invention and Prototype

The concept for the sensor fence was developed in 1999 through discussions at IEDT, a unit of the university's Applied Research Laboratory. The IEDT team surveyed existing high-tech fences, including microwave, fiber optic and taut wire (strain gauge) systems, and found that these approaches could cost as much as $165 per foot. Such systems would be prohibitively expensive for any large-perimeter facility such as a correctional institution, military base, airport or nuclear power plant.

The team decided to develop its own approach based on the Applied Research Laboratory's expertise in acoustics and signal processing. The IEDT approach uses an inconspicuous, ordinary, tensioned steel wire as an extended sensor. The wire can be attached to any new or existing chain-link or wooden fence. Geophones — inexpensive, rugged, off-the-shelf vibration sensors — are attached to the tensioned wire at about 1,000-foot intervals. The entire system is connected to a dedicated computer that is equipped with software developed at the research laboratory. Essentially, the software analyzes the fence's vibrations, pinpoints disturbances within 50 feet and then determines whether the vibration pattern signals a human intruder as opposed to, say, wind or rain.

With the exception of the computer equipment and a few corner brackets fabricated from 1-inch angle irons, the components — springs, pulleys, clamps and wire — were all available at a local hardware store (see Figure 1). The prototype system was installed covering roughly 1,000 feet of chain-link fence by one of the authors in about six hours and the installation cost approximately $2 per foot, plus about $5,000 for the computer equipment.

During one year of continuous operation, there have been no maintenance requirements on the mechanical or electronic system. However, if the wire in the sensor fence were to be cut or damaged, the system would detect and locate the point of signal disruption as it went "deaf." Repair would consist of simply resplicing the ordinary steel wire.

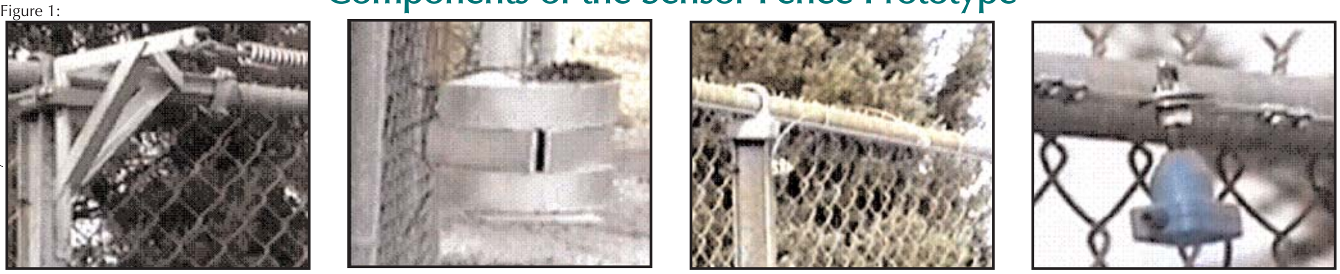
How It Works

The sensor fence works by converting the entire fence into a detector, similar to a spider's web. A spider poised on a web can feel vibrations conducted by the tensioned silk from any point in the network and so can the sensor fence. Vibrations at any point along the fence are transmitted via the tensioned wire to the computer, where they are detected and analyzed by the software. The system software then locates the site of intrusion by monitoring the vibrations in the fence and precisely detecting the time of arrival of signals from two or more locations. Measured differences between the signal's arrival times indicate the location where the intrusion occurred.

The sensor software is basically a passive detector designed to reject environmental noises from wind and rain and detect the types of vibrations produced by someone climbing over, cutting through or otherwise trying to

Components of the Sensor Fence Prototype

Figure 1:



Photos courtesy of IEDT

Spring anchors | Tensioning weights | Tensioned steel wire | Geophone

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defeat the fence. The software is protected by encryption and can operate on common Windows-type PCs, allowing detection information to be automatically routed to desktops using secure communication protocol.

The system identifies different intruders by monitoring changes in loading (weight applied to an area of the fence). For example, even careful climbing by an intruder will change the loading on the fence and signal that a human is present rather than a squirrel. This approach addresses a problem common with typical sensor fences by minimizing false alarms. The sensor fence can distinguish between the vibrations caused by wind or small animals and man-made vibrations from climbing, cutting and digging. However, tree branches and foliage should be cleared away from the fence to avoid impacts with the fence in strong winds, which will likely be detected as intrusion signals. The sensor fence is also being designed into a commercial product that steers cameras to capture images of the detected intrusion area for absolute confirmation.

Applications

While the sensor fence's low cost, low maintenance and low false-alarm rate are obvious advantages, the potential for customization offered by the approach promises even more value. Some advanced concepts envisioned by the team include adding sound, motion, imagery or heat detectors to the fence and using data fusion and fuzzy logic techniques to fuse the output from the multiple detectors into a coherent report.

For example, the team is working with a commercial partner to integrate video cameras into a sensor fence system. Vibrations at any point in the fence system would cue a camera to turn toward that point and record the intrusion. Currently, many pharmaceutical companies monitor their fenced perimeters with video cameras, which record continuously, creating large volumes of tape. Adding sensor fence capability to already existing camera systems will increase sensitivity while greatly reducing the volume of tape that would need to be monitored.

Other advanced concepts IEDT is exploring for integration into sensor fence systems for automated security include using computer-controlled nonlethal weapons such as sting balls, pepper spray and even nets to deter or apprehend an intruder without harm. These systems can be installed at fixed locations or on autonomous ground vehicles for rapid deployment.

Through IEDT, Penn State is working with the Los Angeles Sheriff's Department, the Pennsylvania State Police, the New York City Police Department, the National Institute of Justice and police agencies in the United Kingdom to support law enforcement's need for new approaches and technologies to improve its ability to maintain public order and public safety.

For example, IEDT and the Los Angeles Sheriff's Department conducted the first assessment of less-than-lethal munitions, such as rubber bullets, and found that these projectiles do not approach the accuracy demanded of their lethal counterparts. The report is posted at www.arl.psu.edu/areas/defensetech.html.

Other projects being conducted at IEDT range widely from noise reduction in military armored vehicles to better sensors for detecting toxic chemicals or biological agents potentially used in terrorist attacks.

As for the sensor approach, it enables great efficiencies over the long term for maintaining a robust security presence over large areas. A key role for IEDT is to integrate the sensor fence into appropriate security solutions that can be dynamically controlled by the user to meet specific, unique or complex security needs, and give an instant virtual presence at any points of intrusion.

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