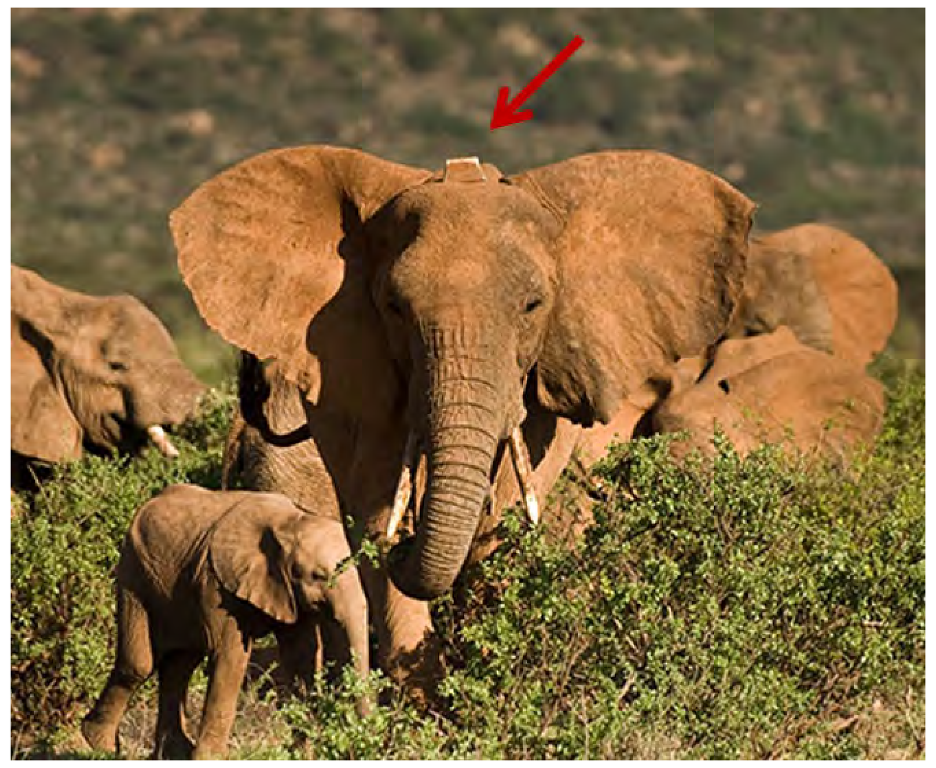
Animal-Borne Acoustic Gunshot Detector

György Kalmár[1], George Wittemyer[3], Péter Völgyesi[2], Henrik B. Rassmussen[4], Miklós Maróti[1], Ákos Lédeczi[2]
[1] University of Szeged [2] Vanderbilt University [3] Colorado State University [4] Savannah Tracking Ltd.

Animal Tracking



The aim is to integrate an acoustic shockwave detector into existing GPS tracking collars and send geo-tagged real-time alerts when a gunshot is detected near an elephant herd. The objective is to notify authorities so that they can catch the perpetrators. Given the remoteness of the typical deployment areas, the current poaching event cannot be prevented unfortunately.

The work focuses on the two main technical challenges: power consumption and gunshot classification accuracy.

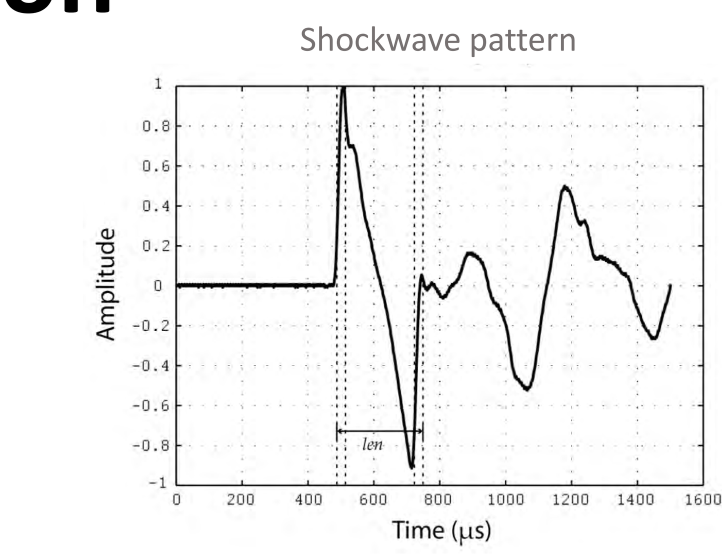
The device needs to last two years on a single charge while continuously listening for shots.

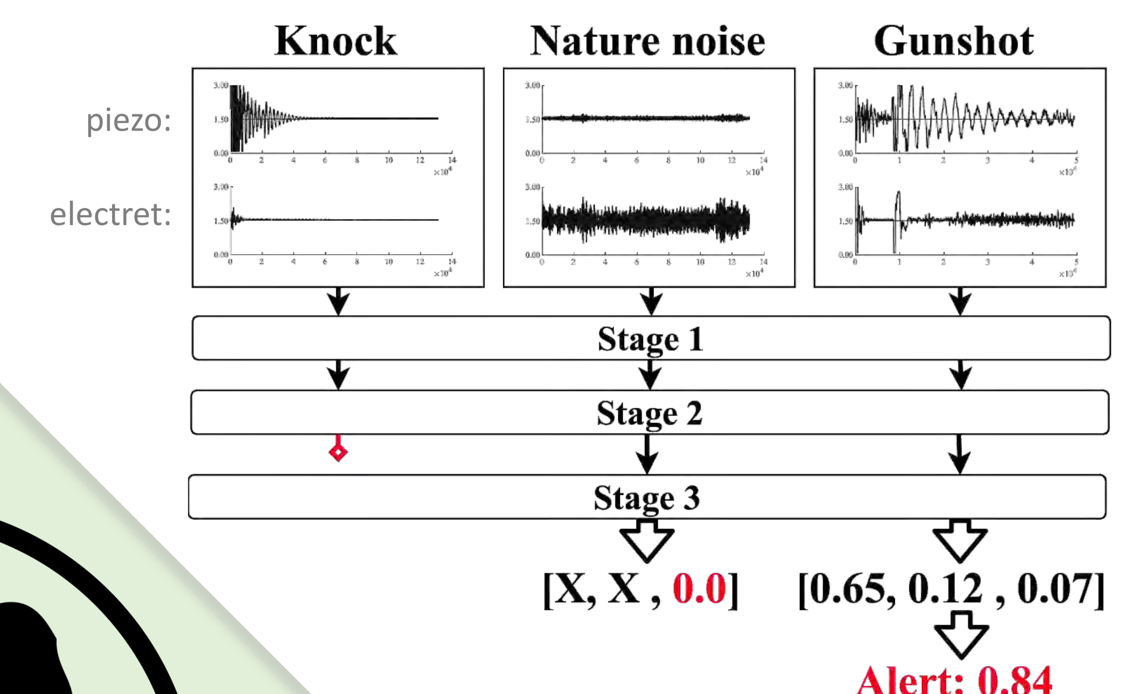
Law enforcement response in remote areas are resource intensive, so false detection rate must be kept at an absolute minimum.

Gunshot Classification

Gunshot classification is based on the detection of ballistic shockwaves - the unique, *N*-shaped sound signatures of supersonic bullets (right). Preserving the signal shape of this event is essential to build a reliable classifier.

The analysis of the possible shockwave patterns is based on the well-known shape and symmetry properties of the *N*-wave. Our method extracts ten features and produces an output in the interval [0,1] to represent the probability of a shockwave in the signal.



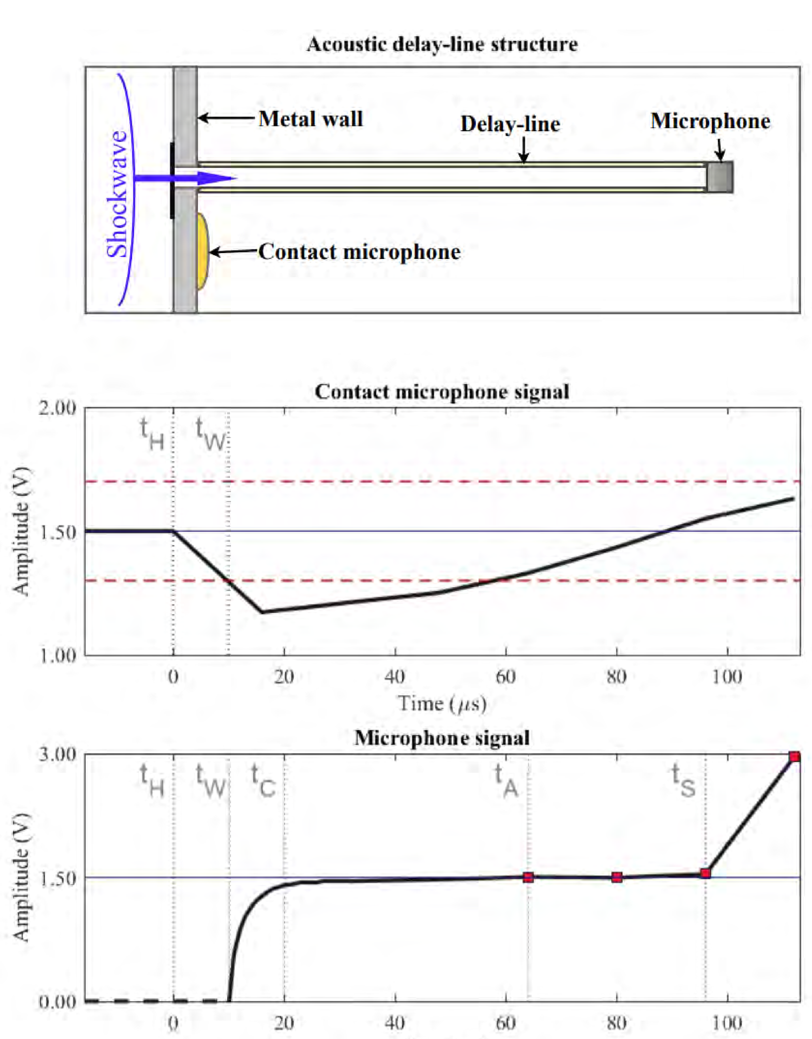


The detector runs on the MCU in near in real-time. It has a hierarchical structure where the consecutive stages filter out more and more complex false events.

Stage 1: filters out false wake-up events using a simple thresholding method.
Stage 2: correlates the two microphones' signals to filter out events caused by mechanical impacts on the metal enclosure.
Stage 3: runs the shockwave classifier and other processing steps.

WIPER

Power Management: Wake-up



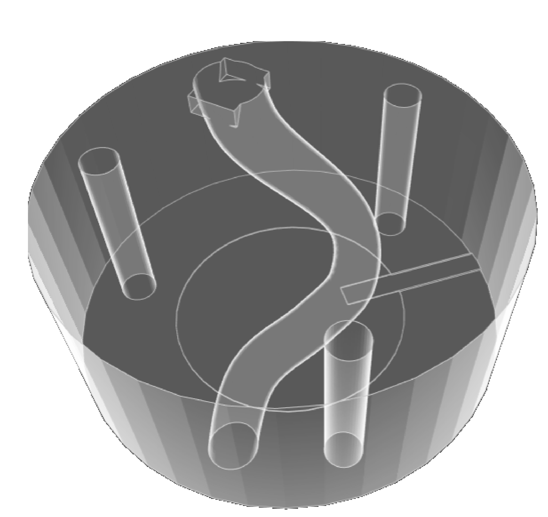
In the top row, the structure of the delay line and the propagation of a shockwave from left to right are shown. Below that, the microphones' signals synchronized to the shockwave's progress are plotted. Timing: t_H - the shockwave hits the wall; t_W - wake-up signals are generated by the contact microphone; t_C - CPU and microphone switch to active mode; t_A - the first ADC sample is collected; t_S - the shockwave reaches the microphone.

To reduce the power consumption, a novel wake-up mechanism was introduced. It utilizes two microphones: a contact (piezo) pickup and a traditional electret microphone.

A 3 cm long tube, an *acoustic delay line*, delays the incoming sound waves to provide enough time for the electret microphone and the corresponding data acquisition MCU to wake up from deep sleep mode. The wake-up trigger is generated by the piezo pickup, which does not consume energy, and the rest of the system is only activated when acoustic events are being detected.

The proposed structure enables the recording of acoustic events without information loss, which is important to maximize gunshot detection accuracy.

The curved tube inside the holder guides the sound to the microphone delaying it just enough to wake up the sensor board before it gets there.

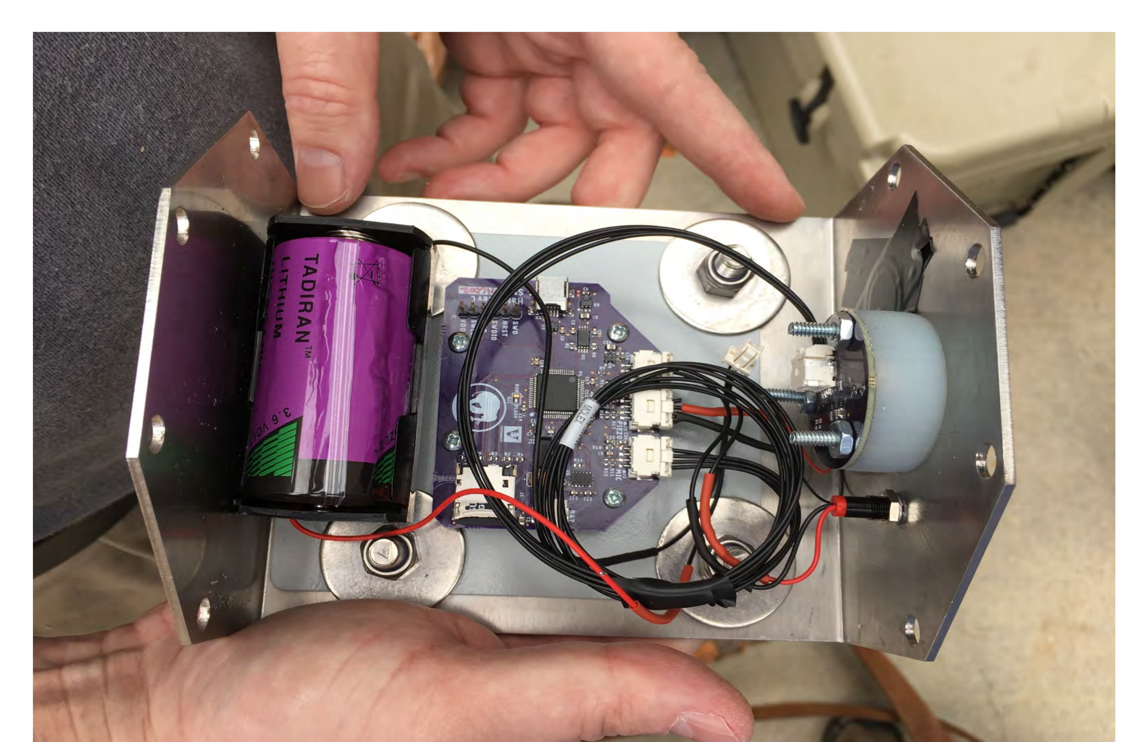


Results

The delay line wake-up mechanism offers ultra-low power consumption and full shockwave recordings to maximize detection accuracy.

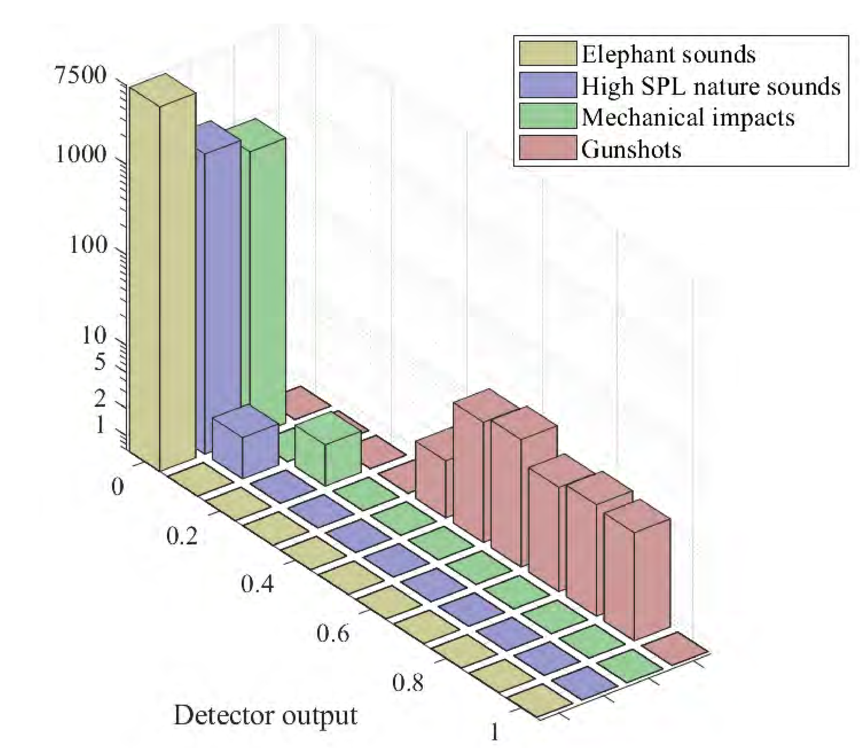
Average power consumption is ≈100 μA. Estimated lifetime is ≈8 years.

Our first prototype has been deployed on a wild elephant in Kenya.



Gunshot detector prototype integrated into the enclosure of a commercial GPS collar from Savannah Tracking. The single D-cell lithium battery supplies 3.5V and is rated at 20 Ah.

Animal-borne tests were performed to collect real-world data. The device was worn by a cow and by zoo elephants. To evaluate the detector algorithm with representative data, a set of additional impulsive sound effects have been collected. A live fire test on a shooting range was also carried out. The detector reliably distinguished gunshots from various other noises



Output histograms of each subgroup of the evaluation dataset. A clear separation between the various sounds and gunshots can be observed. Note that all acoustic events analyzed were recorded with the actual sensor.

Supported by the Vodafone Americas Foundation and Vanderbilt University