Algorithm For On-site Estimation Of The Time Of Arrival Of Impulse Phenomena Without The Man In The Loop

S. Vračar and M. Vračar

ITS INFORMATION TECHNOLOGY SCHOOL, Belgrade and Military Technical Institute, Belgrade
stevo5817@its.edu.rs and vracarmiodrag@mts.rs

INTRODUCTION AND MAIN RESULTS

Appearing of such forms of impulses is a consequence of the sudden release of energy at a location in a relatively short time. Estimation of the time of arrival of these signals, on several spatially distributed sensors, enables locating the place where these phenomena occurred, which is of particular importance. An algorithm has been developed that enables the time of arrival of impulse occurrence to be estimated on-site, without a human in the loop, and this has been demonstrated in many cases.

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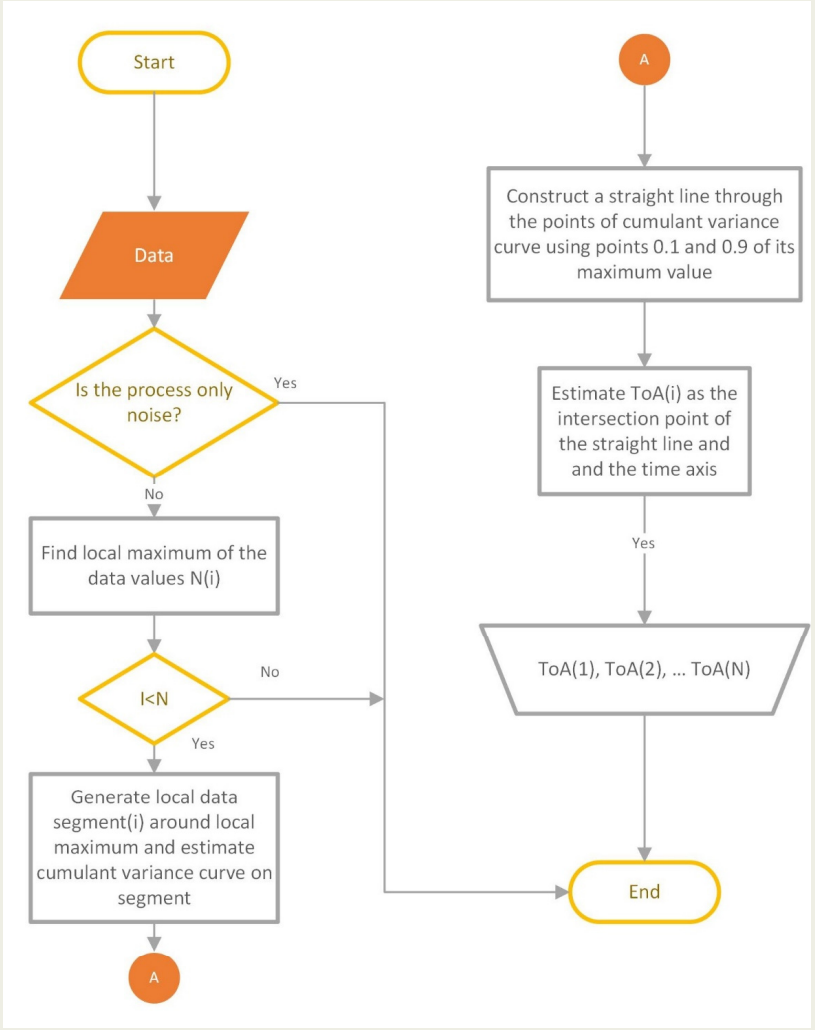
Time of Arrival (ToA)

The essence of the source localization algorithms is time of arrival, ToA, estimation of the relatively short time acoustic perturbation. Differences of estimated ToA values are time delays between sensors, and actually significant number of the methods for acoustic source localization is based on time-delays

The first step of the algorithm is the recognition of such characteristic acoustic events. This is performed by filtration of the raw acoustic data to remove noise and to improve SNR. The best results were obtained by wavelet decomposition and/or using statistical filter method which is based on higher order statistics.

The problem when wavelet decomposition is used is choosing the level of smoothing and type of the wavelet function. It's all resolved in the research phase by strategy, which includes a multi-scale wavelet decomposition of the acoustic signal and improving the signal noise ratio by de-noising process. Such a strategy is accomplished with the Debauchies wavelet coefficient of the seventh order, or "db7" wavelet.

Flow chart of the algorithm for time of arrival estimation on-site and without men in the loop



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The significance of the ToA value

The TOA parameter is scientifically significant across multiple disciplines due to its role in quantifying temporal information about events or signals. Its importance stems from enabling:

- Fundamental Measurements in Physics
- Particle Physics: TOA of particles in detectors (e.g., at CERN) helps reconstruct particle trajectories, identify decay chains, and measure velocities.
- Quantum Mechanics: TOA distributions probe wave-function collapse and tunneling times, addressing foundational questions about measurement.
- Astrophysics: Precision TOA of pulsar radio pulses tests general relativity and gravitational waves (e.g., pulsar timing arrays).
- Signal Processing & Communications Localization: TOA-based techniques (e.g., trilateration) underpin GPS, radar, and sonar systems. Accuracy in TOA directly, and etc.

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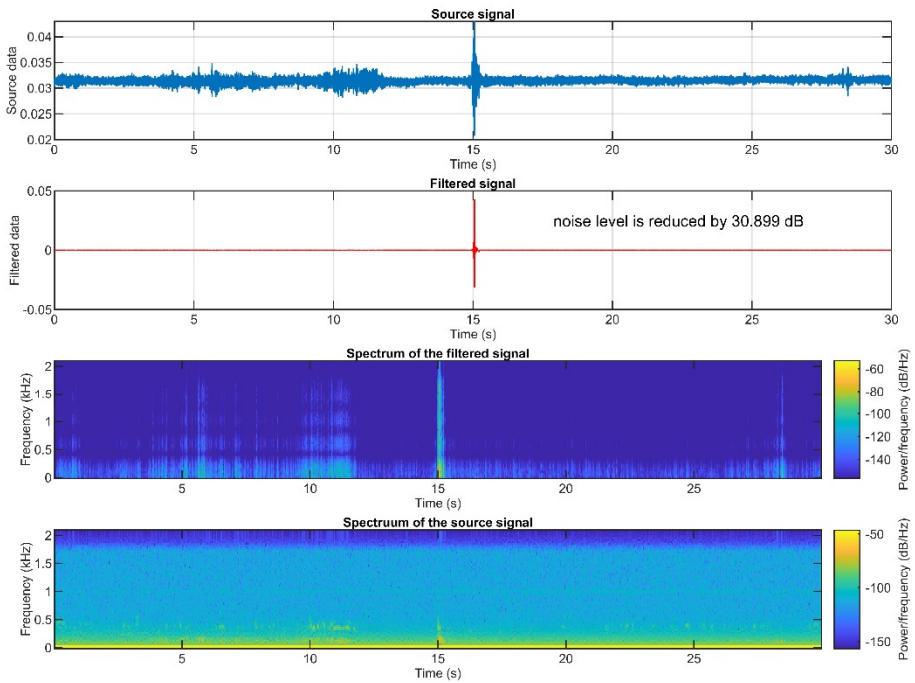
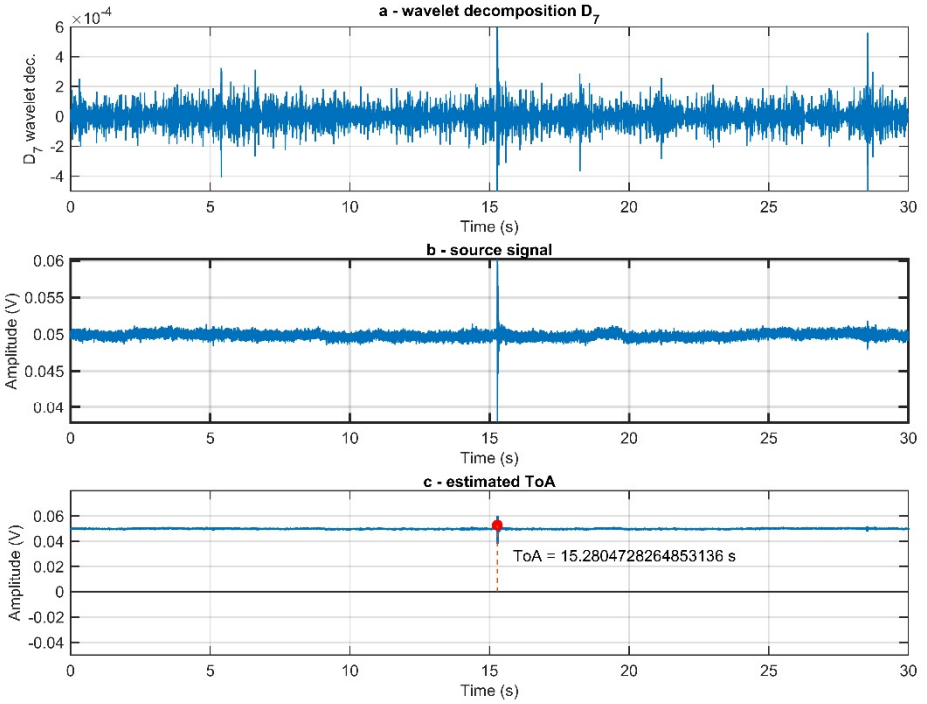
ToA value estimated starting from relatively noisy signal

Raw noisy signal, filtered signal by statistical filter and spectra of the filtered and raw signal.



Raw data signal, it's wavelet decomposition D7 Debauchies coefficient and statistical filtered signal and estimated ToA value.



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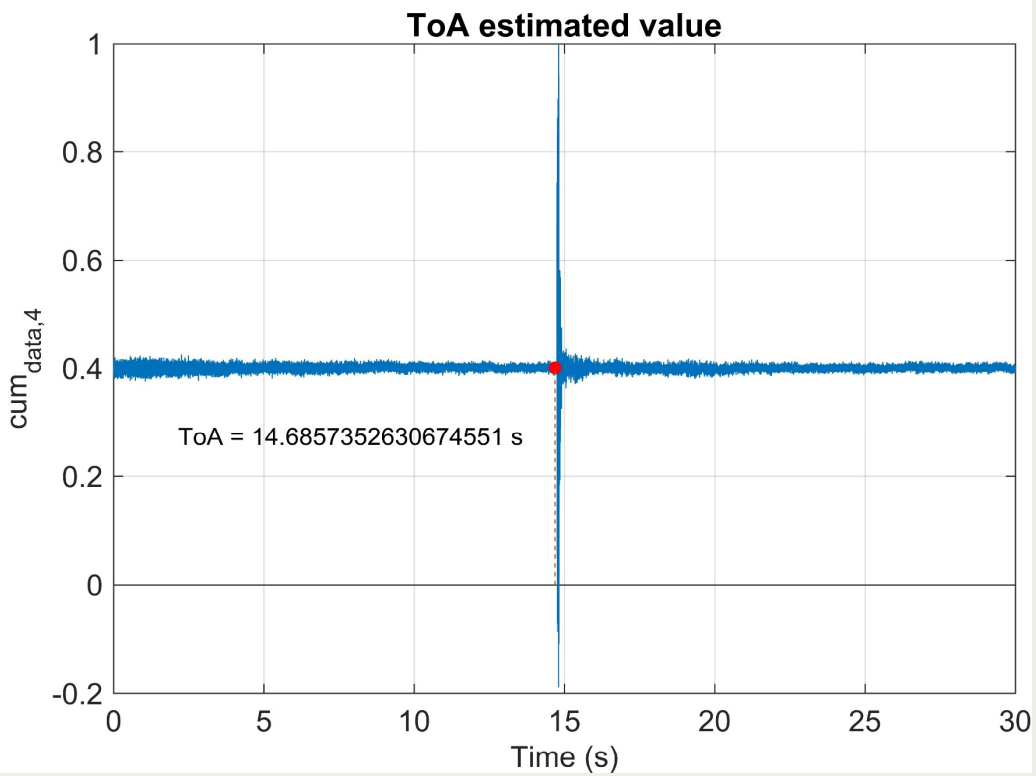
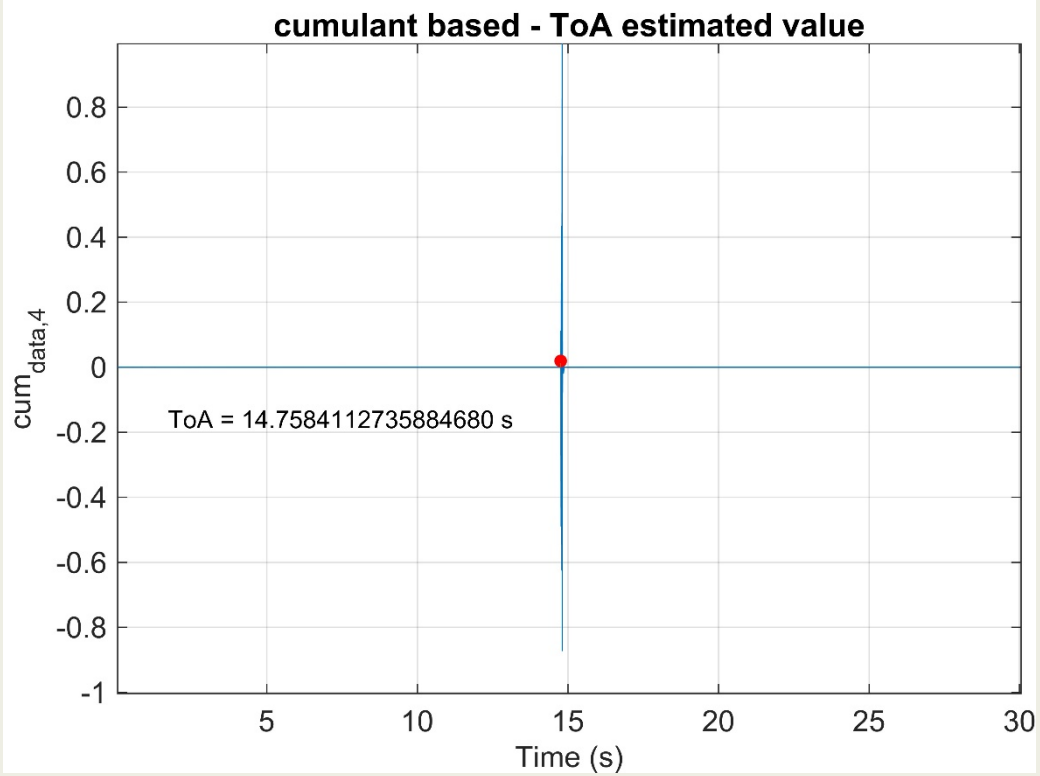
Single explosion

Raw data signal



Statistical filtered signal and estimated ToA value



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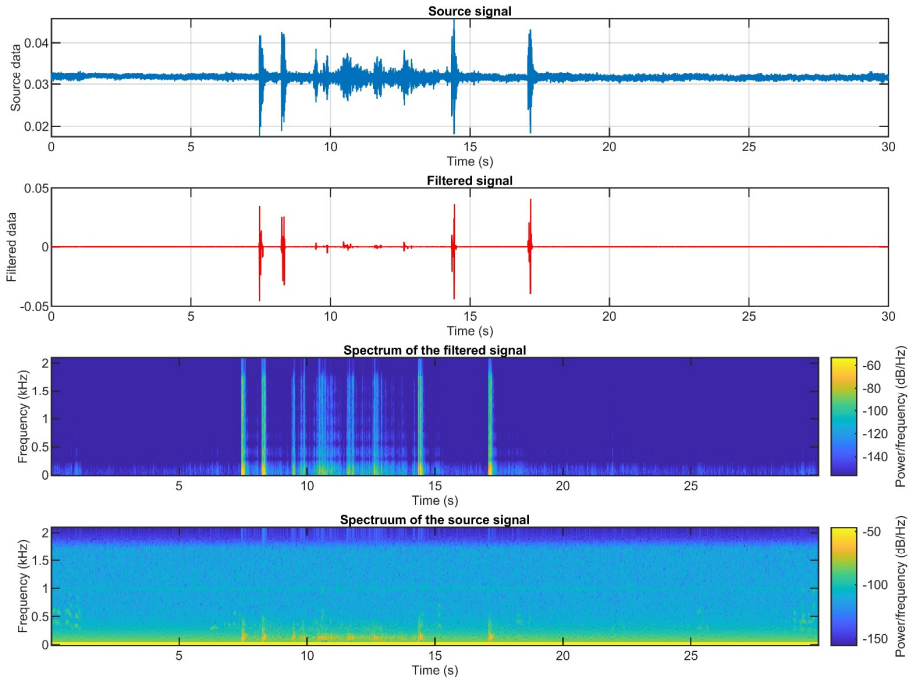
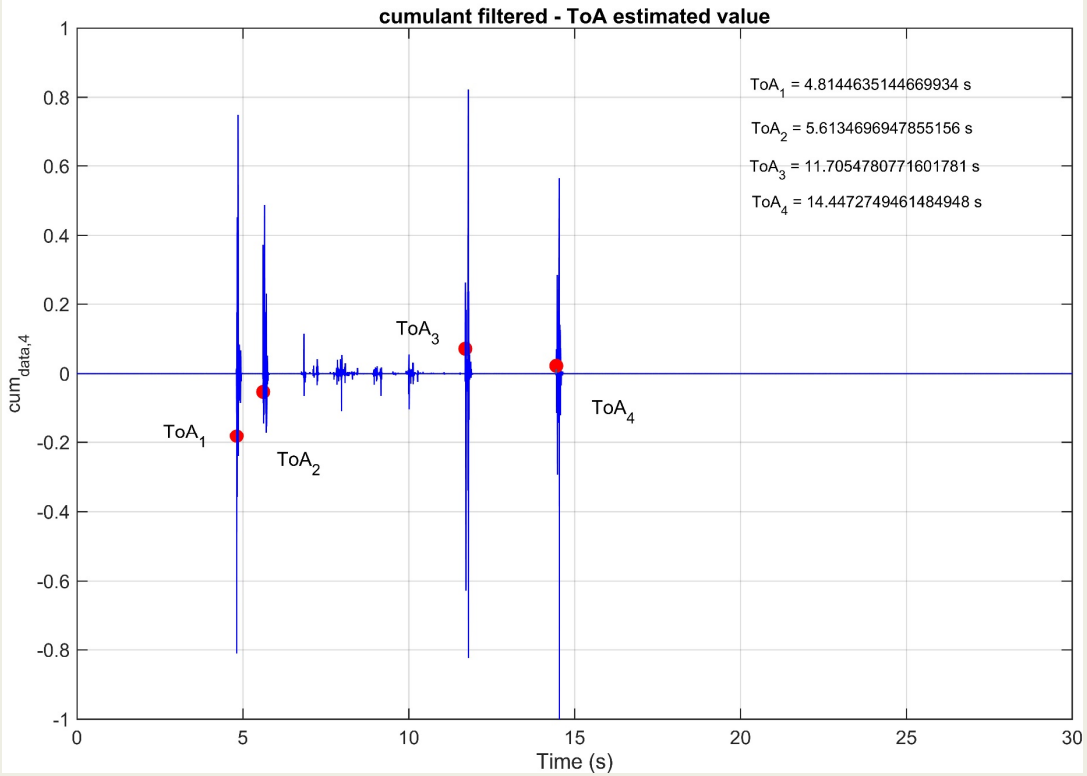
Four explosions in noisy environment

Four explosions in the noisy environment due to thunder and strong wind



Four ToA values estimated by algorithm on site



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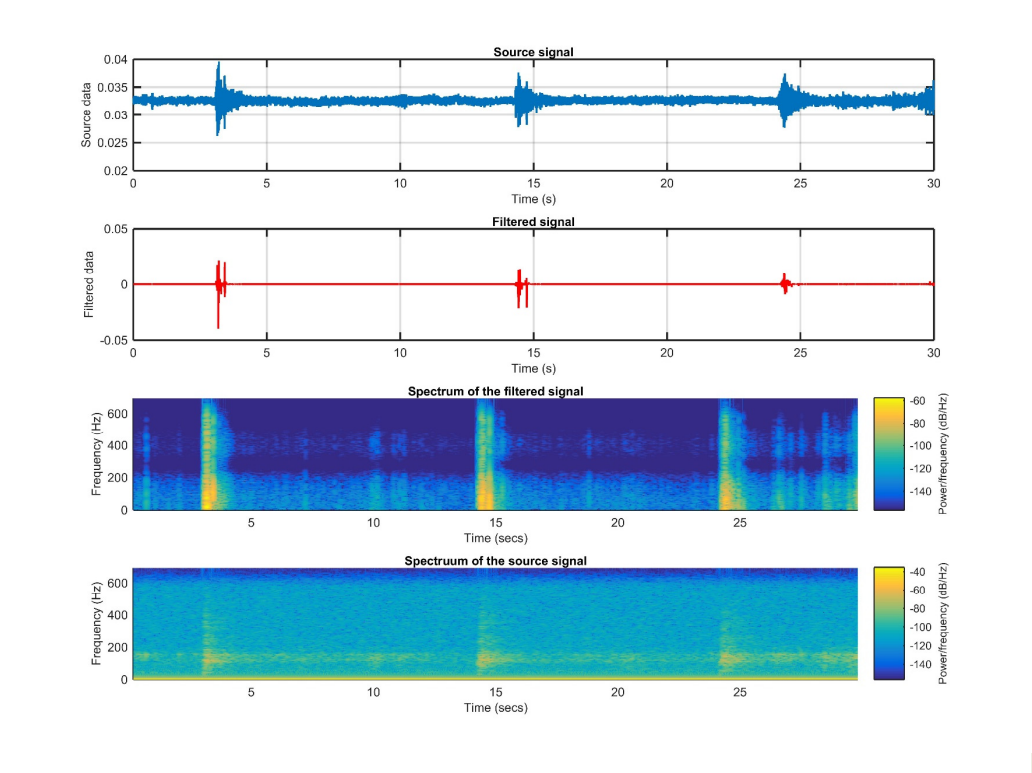
Three explosions

Raw noisy signal, filtrated signal by statistical filter and spectra of the filtered and raw signal



On-site estimated three ToA values by algorithm