Analysis of classification possibility infrasound signals from different sources based on correlation ability

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Archive of natural infrasound signals

Archive contains five type of the data files:

- Class № 1, “ExplosionTest” (for the 1980 Chinese nuclear test);
- Class № 2, “MAW” (for mountain associated waves);
- Class № 3, “Microbarom” (for microbaroms);
- Class № 4, “VOL” (for volcanic infrasound);
- Class № 5, “AIW” (for auroral infrasonic waves).

Signals were recorded by 3 sensors for class № 1 (ExplosionTest) and by 4 sensors for other four classes.

Each infrasonic data file contains 160 minutes of data. The interval dt = 0.2930 seconds.

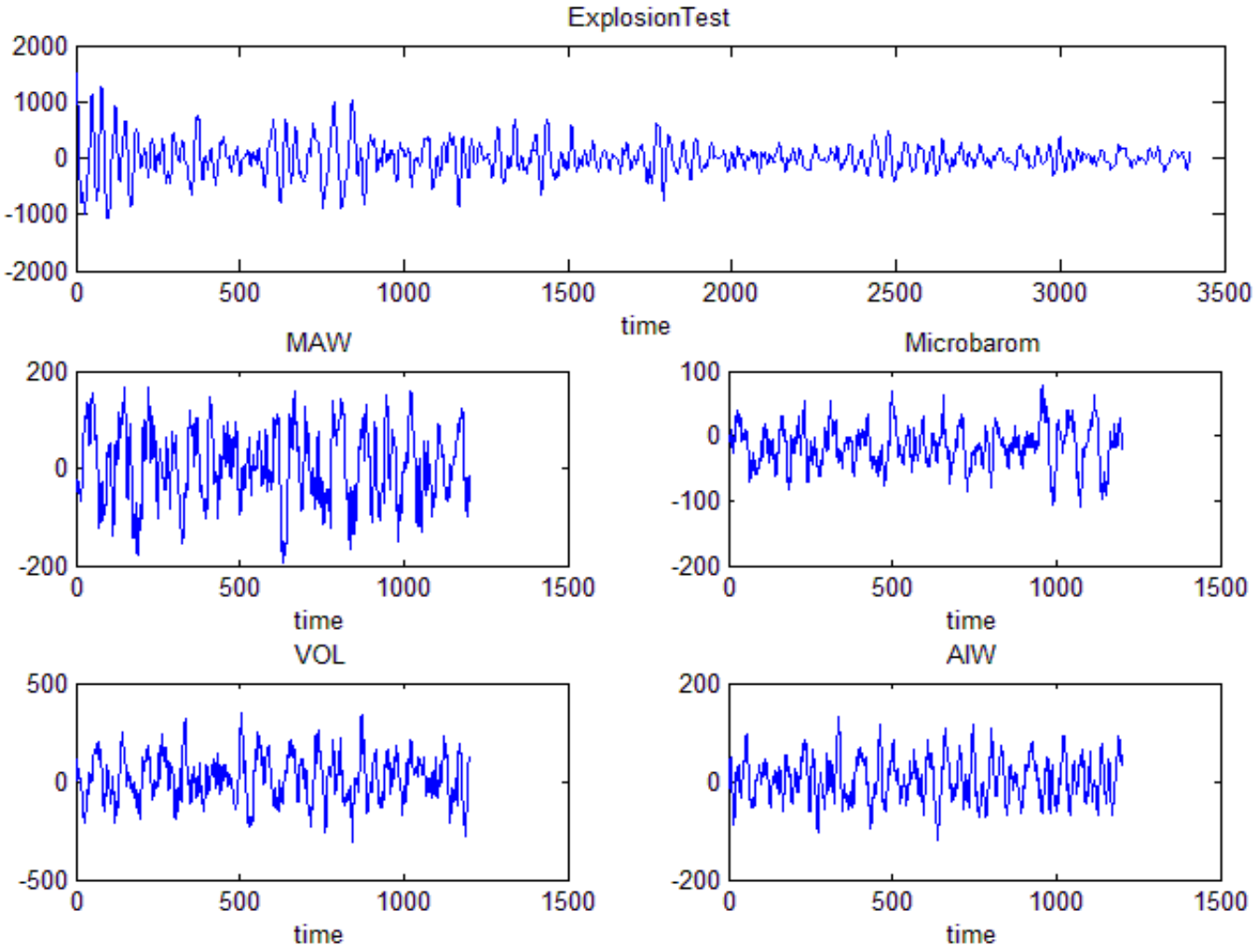
The pressure data were operated at Fairbanks, Alaska and Windless Bight, Antarctica from 1980 to 1983 by the Geophysical Institute of the University of Alaska.

Task formulation

The task is to construct algorithm for automatic classification of pressure signals in atmosphere on:

- two classes: “ExplosionTest” (class № 1) and “AIW” (class № 2);
- five classes: “ExplosionTest”, “MAW”, “Microbarom”, “VOL”, “AIW”.

Character signal plots



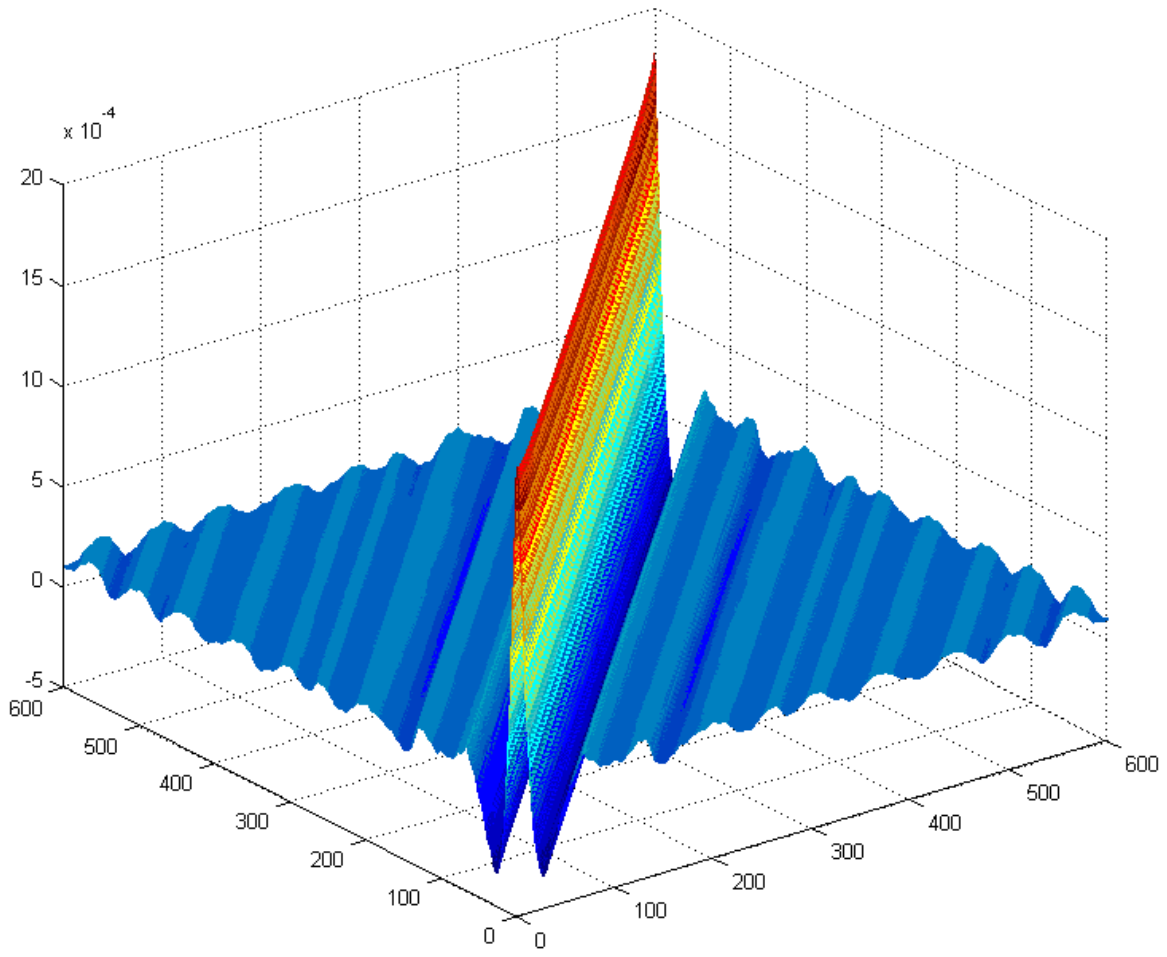
Signal analysis

The analysis of archive data shows:

- Signals expected values is near to null;
- Signals covariance matrix is near to toeplitz matrix.

Then random vectors of different classes can be considered as realization of stationary random process.

Covariance matrix for ExplosionTest signal



Signal model

For each class

- The informational signal parts are separated
- Signals are combined:

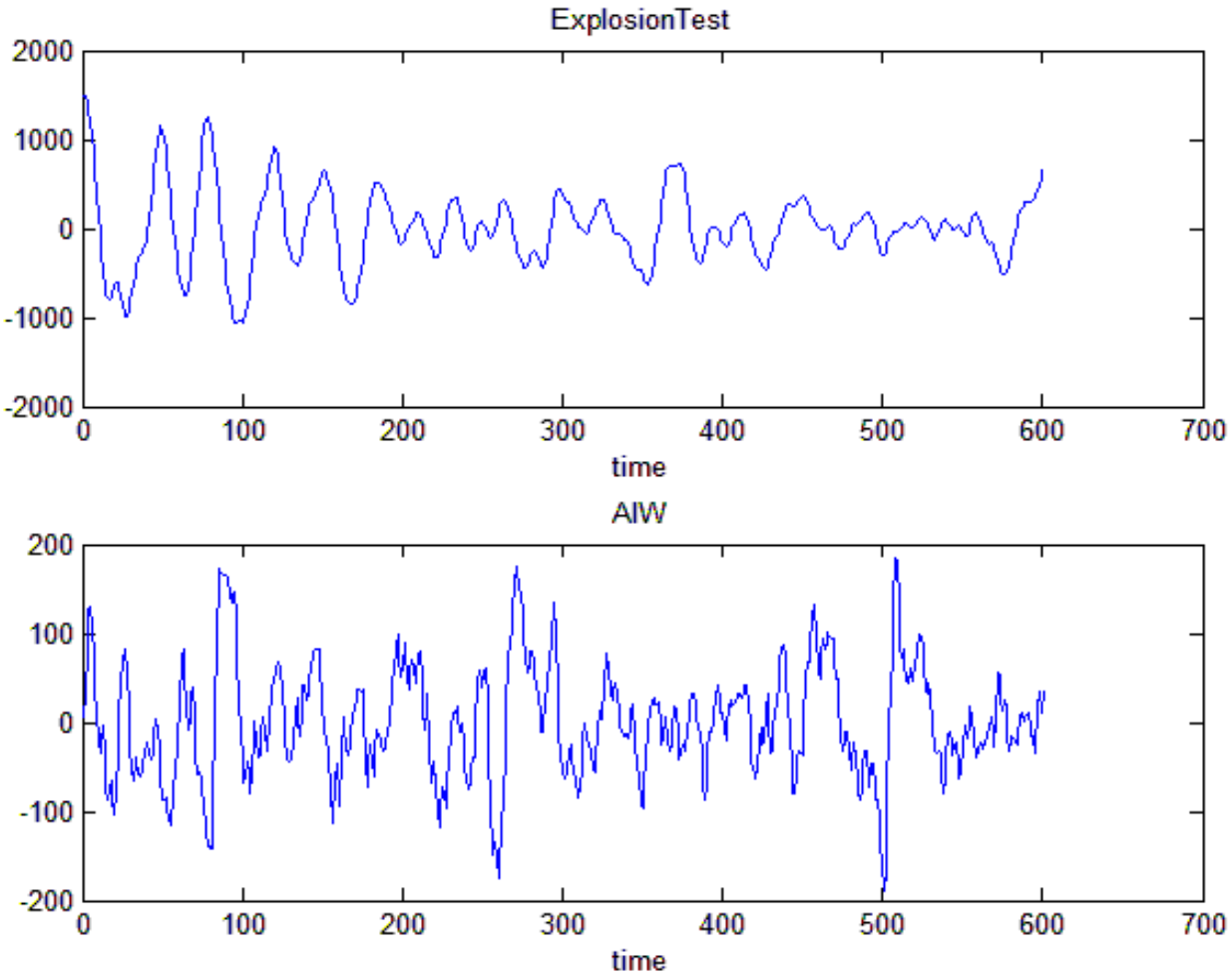
$$X_1 = \begin{pmatrix} x_1^1 \\ x_2^1 \\ \vdots \\ x_n^1 \end{pmatrix}, \quad X_2 = \begin{pmatrix} x_1^2 \\ x_2^2 \\ \vdots \\ x_n^2 \end{pmatrix}, \quad X = \begin{pmatrix} x_1^1 \\ x_2^1 \\ \vdots \\ x_n^1 \\ x_1^2 \\ x_2^2 \\ \vdots \\ x_n^2 \end{pmatrix} = \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \end{pmatrix}.$$

- Sampling covariance matrix is constructed by caterpillar method:

$$V = \begin{pmatrix} x_1 & x_2 & \dots & x_{N-K} \\ x_2 & x_3 & \dots & x_{N-K+1} \\ \dots & \dots & \dots & \dots \\ x_K & x_{K+1} & \dots & x_N \end{pmatrix}.$$

for K=600

Plots of signal part for construction sampling covariance matrix



Statistical hypothesis testing

Algorithm:

- The signal is decomposed on vectors ξ_j.
- Vectors ξ_j are viewed as random with normal distribution, expected values equal null.
- Classes are defined as covariance matrix V_1, V_2, V_3, V_4, V_5.
- The null-hypothesis: vector $\xi_j \sim N(0, V_j)$ – random vector ξ_j is normal distribution with covariance matrix V_i (is in class i).
- The alternative hypothesis: vector $\xi_j \sim N(0, W_i)$ – random vector ξ_j isn't normal distribution with covariance matrix V_i (isn't in class i).

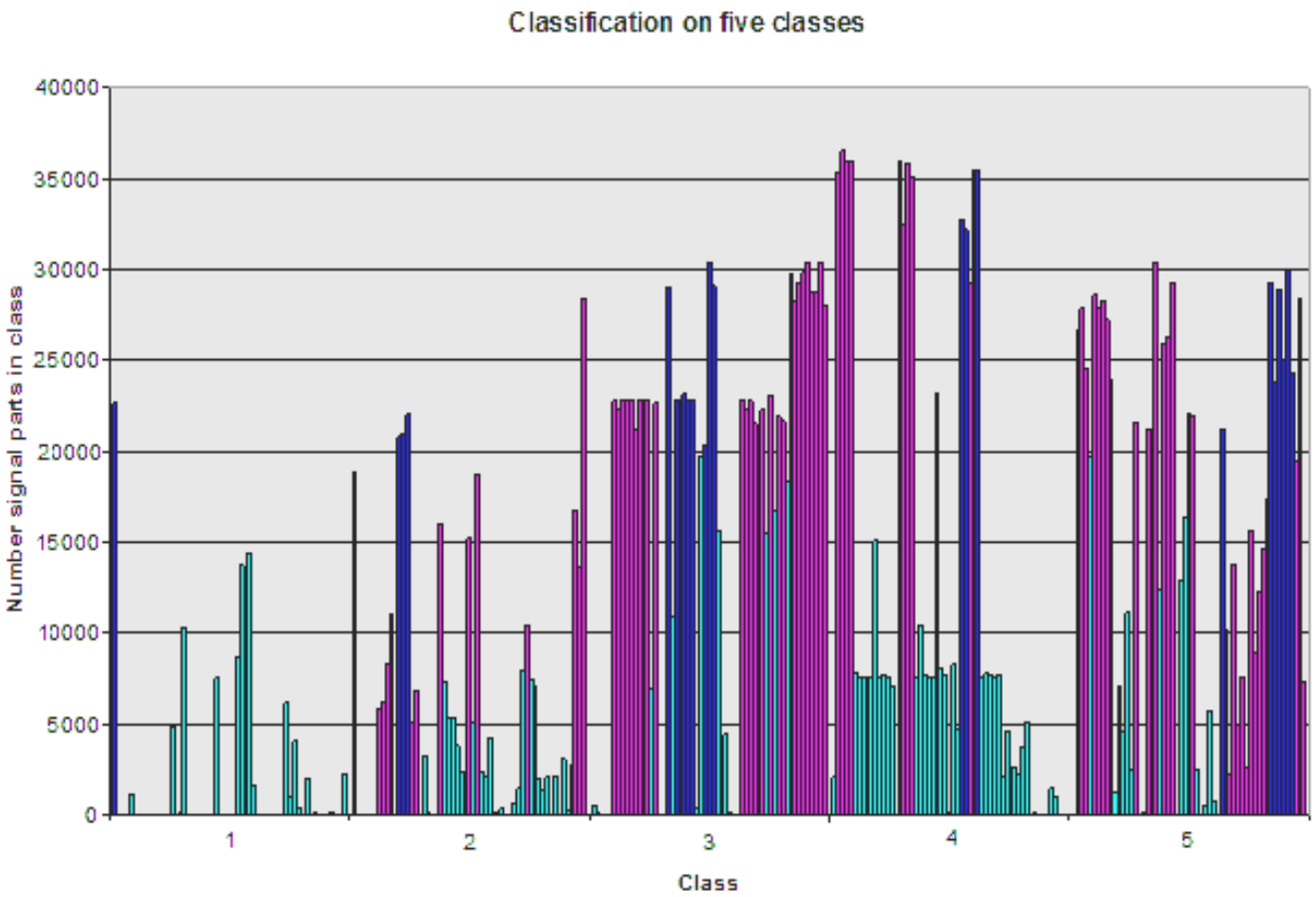
$$W_i = \frac{1}{4}\sum_{j \neq i} V_j.$$

- The critical region of a hypothesis test is $S = \left\{ x \in R^n : \quad (x, V_i^{-1} x) - (x, W_i^{-1} x) \leq c_i \right\}$

where c_i is hypothesis level (determined empirically). If $\xi_j \in S_i$, signal part is in class № i. In other case signal part isn't in class № i.

- If more signal parts is in class № i, then all signal is in this class.

Results classification on five classes



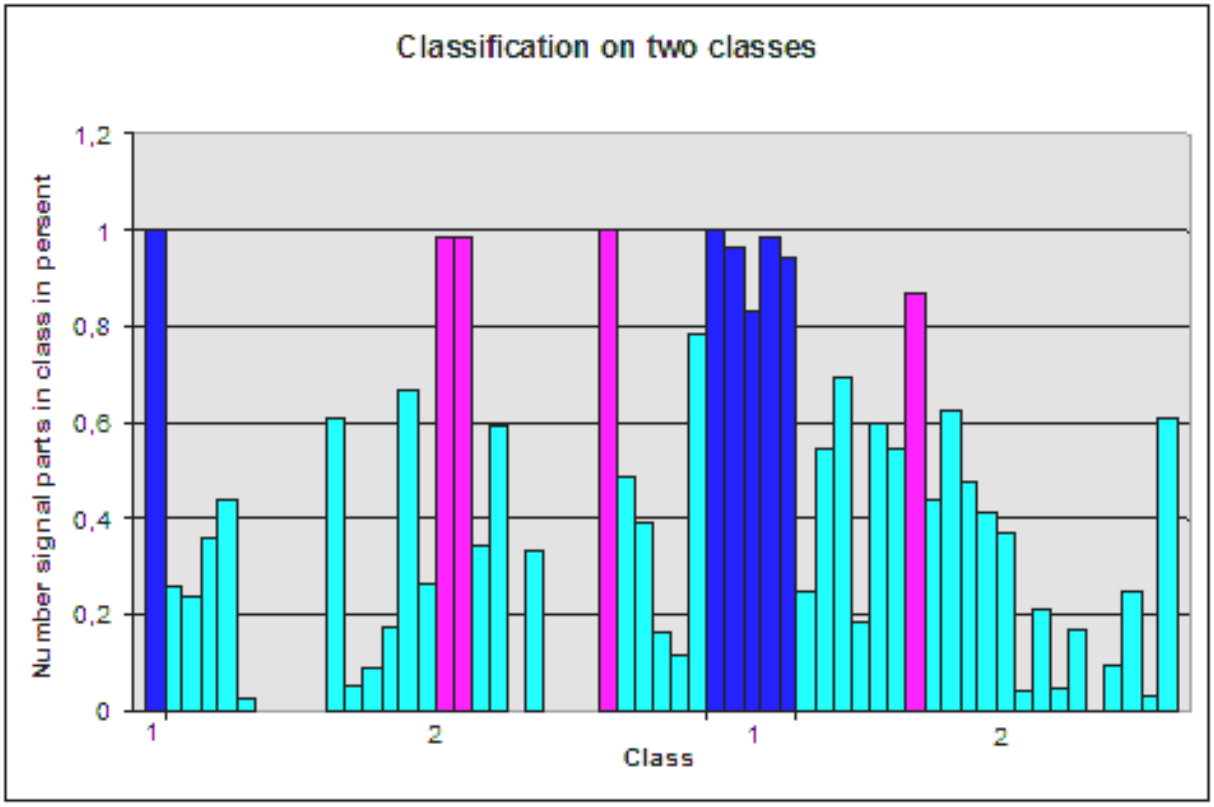
Color symbols:

True classification (signal is in class)

True classification (signal isn't in class)

False classification

Results classification on two classes



Color symbols:

True classification (signal is in class)

True classification (signal isn't in class)

False classification

Resume

- This method can’t classificate archive signals on five classes.
- This method can classificate signals on two subclasses:
  - subclass № 1: signals for volcanic, infrasound and the nuclear test;
  - subclass № 2: signals for auroral infrasonic waves, mountain associated waves and microbaroms.

- All the 6 signals from subclass № 2 were classificated true.
- The 47 signals from subclass № 1 were classificated true.
- The 4 signals form subclass № 1 were false classificated as signals from subclass № 2.