Algorithm of radar pattern clustering in passive radar systems

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*Abstract*—

Keywords—

# Introduction

Target recognition in airspace is one of the priority areas of radar. Radar information processing is an important range of tasks solved with the help of radar stations (radars) or complexes. The purpose of processing - to prepare for delivery in the required form complete, reliable and up-to-date information for the user about the state of air situation, appearance and location of air objects, parameters of their movement, possible variants of development of dynamics of change of air-interference situation. A typical example of radar information processing is the task of aircraft detection and estimation of their belonging to a certain class or type. The problem is similar to the well-known task of clustering and subsequent classification [1], it is necessary to select from a set of single marks a few grouping centers, which correspond to the targets to be detected.

In most systems, clustering is performed using semi-empirical methods, the efficiency of which is low. This leads, on the one hand, to missing some of the marks and reducing the energy in deciding on the presence of targets, as well as multiplying marks from large targets and producing false targets. On the other hand, if the clustering threshold is too high, the reflections from different nearby targets may be combined into one cluster, resulting in missed targets and poor target trajectory accuracy. The implementation of effective mark clustering will further allow adequate formation of target group trajectories, which will lead to energy gains and reduce the number of false traces by an order of magnitude [2].

At present, the number of works, where the problem of radar pulse clustering is solved using different methods, is growing. For example, the recognition of dynamic objects in radar space using k-means and fuzzy c-means clustering algorithms on navigation parameters [3], the scale mixture model of normal distributions for classification and clustering of radar emitters [4], automatic classification method using p-value calculation network to test hypotheses about the types of emitters, where the clustering algorithm is based on a trained vector clustering method [5], density-based radar scanning clustering algorithms [6], apply and neural network apparatus, namely deep recurrent neural networks (RNN) for classification and coarse clustering of different groups of pulses hierarchically with respect to their sequential structures [7].

The aim of the work is to develop and study an algorithm for clustering the sequence of radar pulses in passive radar complexes.

In this work we consider the possibility of improving the efficiency of information processing in passive radar systems by identifying signals with targets by clustering the received radio pulses by DBSCAN algorithm [8-9]. In turn, this algorithm does not require to determine the number of clusters in advance and takes into account the emissions (noise) in the radar data. It is important to note, in this paper the clustering problem is not set for single pulses, but for the processing of a sequence of pulses, called a pattern. Such a formulation complicates the classical clustering problem, because it is necessary to isolate in one cluster not simple single pulses, but a sequence (pattern or complex signal) from the observed target. In this regard, in addition to the DBSCAN algorithm, heuristic rules for screening out false signals were implemented.

# Problem statement

Let the passive radar system receives simple signals (pulses or marks) in a discrete observation period equal to N cycles. The state vector describing a simple signal at the k-th time moment is written in the following form:

|  |  |
| --- | --- |
|  | (1) |

where  - time of pulse arrival, - pulse carrier frequency, - pulse duration, - period between k-th and (k-1)-th pulses.

At the same time in the observed realization of pulses the following signal sequences (patterns or complex signals), described by the following state matrices, are encountered:

|  |  |
| --- | --- |
| , | (2) |

where the number of columns in both matrices shows the size of these signal sequences.

The other signals in the implementation will be considered interference, and their state vector will be written as that of a single pulse:

|  |  |
| --- | --- |
|  | (3) |

The entire received pulse realization on an observation period equal to N is written by the following equation:

|  |  |
| --- | --- |
|  | (4) |

where is the state matrix of the whole pulse realization of dimension , is the matrix of additive white Gaussian noises with zero mean and finite dispersion of dimension .

The task is to cluster, i.e. to separate into separate groups (clusters), all occurring patterns of types A and B on the background of the received pulse realization .

As a criterion of solution efficiency we will use the following metrics:

1) Pattern recognition accuracy (in %):

|  |  |
| --- | --- |
|  | (5) |

where - the number of true clusters containing the sought patterns, - the number of true patterns in a cluster,  - an estimate of the number of true patterns in a cluster.

2) False detection of patterns (in %):

|  |  |
| --- | --- |
|  | (6) |

where  - estimate of the number of true clusters containing the patterns sought,  - estimate of the number of true patterns in the cluster,  - estimate of the number of incorrect patterns in the cluster.

3) Skip (in %):

|  |  |
| --- | --- |
|  | (7) |

where skip takes discrete values of 0 and 1 (1 - skip cluster with sought patterns, 0 - cluster with sought patterns recognized),  - number of true clusters containing sought patterns.

4) Estimation of number of true clusters .

# Modeling

# Conclusion

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