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RECOGNIZING DRONES TO MAINTAIN AIRSPACE SAFETY AROUND AIRPORTS

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Abstract

This article presents the resolution of drones among other means (airborne and ground) captured by an auxiliary airport radar system. The principle of targets recognition uses a novel signal and data processing for preservation information about detected targets and machine learning methods, which are applied to real measurement of different targets. The direction of the design and the methods used are chosen with a view to make it as simple as possible to implement to specific radar systems.

Keywords

Drone, signal processing, recognition of target, classification

1 INTRODUCTION

Recently, it is very popular to use small drones, respectively UAV (Unmanned Aerial Vehicles) or RPAS (Remotely Piloted Aircraft Systems) because of the different needs of their users. Little knowledge of legislation and the irresponsibility of mainly hobby users of drones increase the risk of a serious accident with a lot of aircrafts around airports. Most aircraft are at risk of landing, take-off and low flight manoeuvres. According to German air traffic control, 15 drones broke the airspace of airports in 2015, see [1]. In 2016 it was even 64 drones and 88 drones in 2017. It seems the tendency increases in a scary amount every year.

Drones are very small in Radar Cross Section (RCS) [2], [3] and cannot be detected by conventional radars. The radar must have a high sensitivity. However, if the radar is sensitive enough, it also detects more ground clutter, jammers, and fair no-interest targets at the airport or its surroundings (cars, trains, wind turbines, etc.). These no-interest targets need to be recognized and suppressed because it creates very complicated environment around airport. This environment and birds greatly reduce the reliability of drones of recognition.

2 A NOVEL SIGNAL AND DATA PROCESSING

A typical structure of signal processing in primary pulse-Doppler radar works primarily and mostly only with signal amplitude, see [4]. Doppler processing is primarily used to suppress ground

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and volume clutters. Because of the computational difficulty, single Doppler channels are merged or switched before extraction, see [5].

However, to get the most information, it is necessary to keep the output of Doppler processing itself for further calculations and subsequent classification of targets. The extension of the common signal processing structure is shown in fig. 1 in dotted, along with the completed classifier.

A prerequisite for detecting targets with a very small RPAS reflecting surface is a highly sensitive system setting and minimization of any losses that may occur during processing.

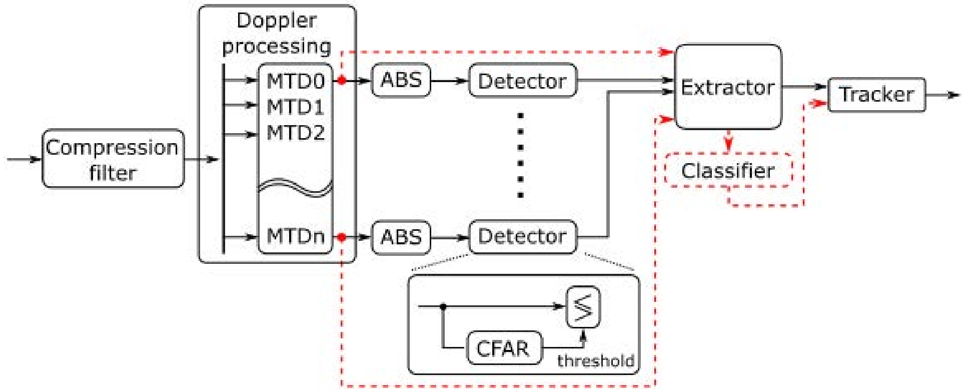

Fig. 1 A novel signal and data processing structure

3 TARGETS ANALYSIS

An important prerequisite for distinguishing targets is a thorough analysis of the specific features of specific types of targets. A large amount of information can be obtained from spectral properties using Doppler MTD processing.

With this technique, it is possible, as with the simpler MTI method, to distinguish the reflection of a moving object from ground clutter. Additionally, it is possible to get an overview of the speeds that the object moves. Characteristic features are also rotating elements of monitored objects (automobile wheels, helicopter rotors, wind turbine rotors, etc.). Under certain conditions, using the microprocessor effect, see [6], it is possible to distinguish the reflections of the radar signal from RPAS target rotating elements and differentiate them primarily from birds.

Of a large number of measurements and analyzes, for example for car type targets the specific expression is reflection from the wheels. This can be seen on fig. 2, which shows the virtually always present reflection from ground clutter - GC (such as road, causeway, trees), the car bodywork itself and the reflection from the wheels (seen in certain directions of rotation - the specific side lobes of the main reflection from the car bodywork).

4 DISCRIMINATORS

From the results of various analyzes carried out above the radar signal, it is necessary to define the so-called discriminators. These are parameters that describe the identical properties of each target type.

The choice of discriminators is primarily based on the principle of use. For example, the amplitude of the signal cannot be used since it is dependent on the distance in which the target is being observed. For this reason, it is advisable to standardize some parameters. One of the appropriate parameters is the effective reflective area of the RSC target. Apart from the principle selection, it is important that the selected parameters are statistically significant among the target groups, there was no need for them and thus the classifier did not succeed.

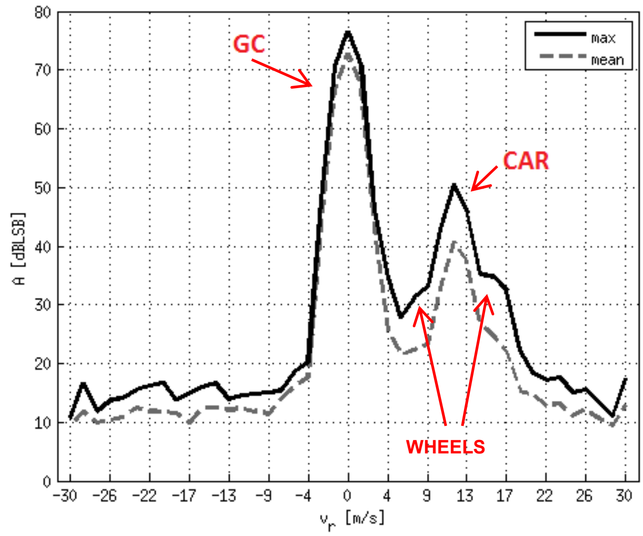

Fig. 2 Spectrum of a car in the general direction

As a suitable discriminant, the bandwidth that the target occupies in Doppler frequency spectrum is shown. It can be defined for different basic frequency components, such as zero frequency, maximum or a certain range of interesting frequencies. Likewise, RCS and so on can often be judged.

Significant discriminators then create a training set of correctly classified targets. These data are used to construct the prediction model, respectively decision rule.

5 CLASSIFICATION

The classification task can be addressed by different approaches to machine learning. With regard to the training set considered, it is appropriate to choose one of the teaching methods with the teacher. For ease of implementation in the target radar system, a discriminatory analysis (DA) seems to be appropriate. The analysis can be solved by the trainer's properties by means of a linear (LDA) or quadratic (QDA) function.

Fig. 3 shows the situation of resolving targets of type RPAS and car using QDA for selected discriminators BW_0 (signal bandwidth for zero Doppler processing component) and BW_{fast} (bandwidth for a certain selection of non-zero frequency components).

RPAS destination training data is shown as dots. Trainer data for the car group is marked with crosses here. The new measured data (test) for the RPAS group is marked with wheels, and the measured data for the car group as squares. Using the QDA, a curve - decision boundary was proposed based on the training data. Based on this decision criterion, new test objects are then assigned to specific groups.

To determine a model error, it is advisable to perform a cross-validation (kloss) or also resubstitution (rloss) error. In this case, errors are not greater than 1%.

In order to assess the overall accuracy of the model, it is also necessary to make matrix confusion.

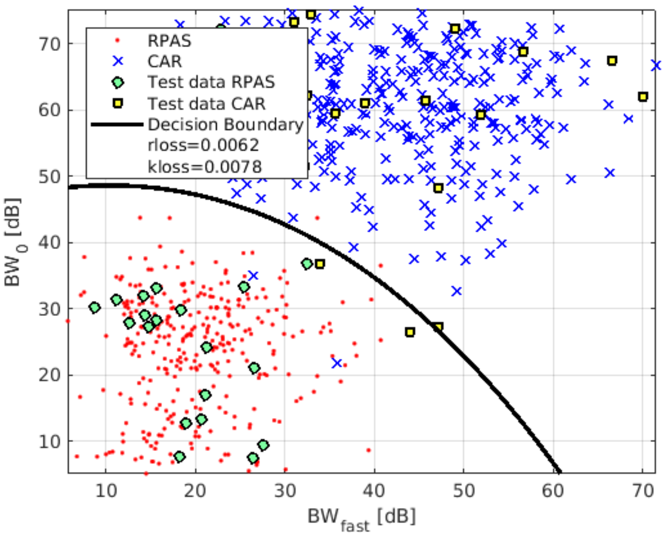

Fig. 3 Recognition RPAS and car targets by QDA

6 CONCLUSION

The article presents a way to recognition the different targets detected by the primary radar and thus to distinguish the target from other objects in the monitored area e.g. the drone in the area of the airport and adjacent surroundings. The basic idea is to get maximum information from a radar signal about a particular target using a new approach in signal processing. This information is central to solving a class problem using machine learning methods. Target recognition can be applied, for example, to protect different areas from espionage, to increase security against terrorist attacks, or to improve the features of existing radar systems in general.

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