Integration of classification errors in the AUV driving for ATR

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General problem

The aim of this PhD thesis is to define an acquisition process of a target by a HRR (High Range Resolution) radar, such as a Synthetic Aperture Radar carried by a UAV (Unmanned Aerial vehicles), such as those operated by the Fraunhoffer Institute (Miranda35 or Miranda94 for example).

This application of target recognition has, naturally, applications in the field of the defence but also in that of safety and security (survey, traffic supervision, detection of intrusion by sea or land). The underlying idea of this thesis is that a "good" data acquisition, even if these data are processed by a simple algorithm of target recognition, will always lead to results better to those obtained from an "average" acquisition with sophisticated (and sometimes extremely complex) algorithms. Indeed, our experience shows that, the more complex an algorithm is, (with different steps in the recognition process e.g. learning, extractions of primitive/ point scatterer, in other words the Scattering centre», research in a dictionary ...), the less it is adapted to operational situations for which a robust and rapid classification is necessary. This heuristic (of good acquisition) is now made possible by the appearance of UAV able of carrying synthetic aperture radars, (even if they use frequency bands higher than those currently used, e.g. X or C band, and for which the ATR algorithm have been derived) and for which, an acquisition configuration can be defined in near real time.

Thus, the main purpose of this PhD is to define what is a "good" acquisition for the point of view of the ATR or in other words for the recognition as well as the localization, in a 3-D space, of point scatterers taking into account, in particular, the limitation of the UAV (detailed below) in order to perform this "good" acquisition in an acceptable time for the operator.

The final objective of the UAV driving algorithm is to perform one or more additional acquisitions to reconstruct the target elements into 3-D, in order to have the finest possible reconstruction of the target for the purpose of target Recognition/Identification.

PhD program

The starting point of our research is that an object, representing a potential danger to the sensor (against measure EM/destruction ...), has been detected. A first attempt to recognise is then performed thus providing a first set of possible backscattering centres as well as the type of associated target (see below). We assume that this recognition is based on:

1) The frequency instability of the scatterer response (i.e., variations of the pulse envelope). This instability of frequency response with respect to particular waveforms, for example "Chirp" or "step frequency" can be used to characterize the type of scatterer [1] [2].

2) The angle of observation with respect to the axis of symmetry of a point scatterer. (In other words the incidence/backscattring angle of the electromagnetic wave on the scatterer).

3) A scatterer height estimate when it is possibl using multipath backscattering in marine environment for instance [3]

Finally, although it is not (generally) useful to discriminate among the possible targets, the sensor must also estimate the Doppler generated by the possible displacement of the target, with the UAV displacement capabilities (relative to the target to be identified) to be considered in defining the data acquisition and target reconstruction algorithm.

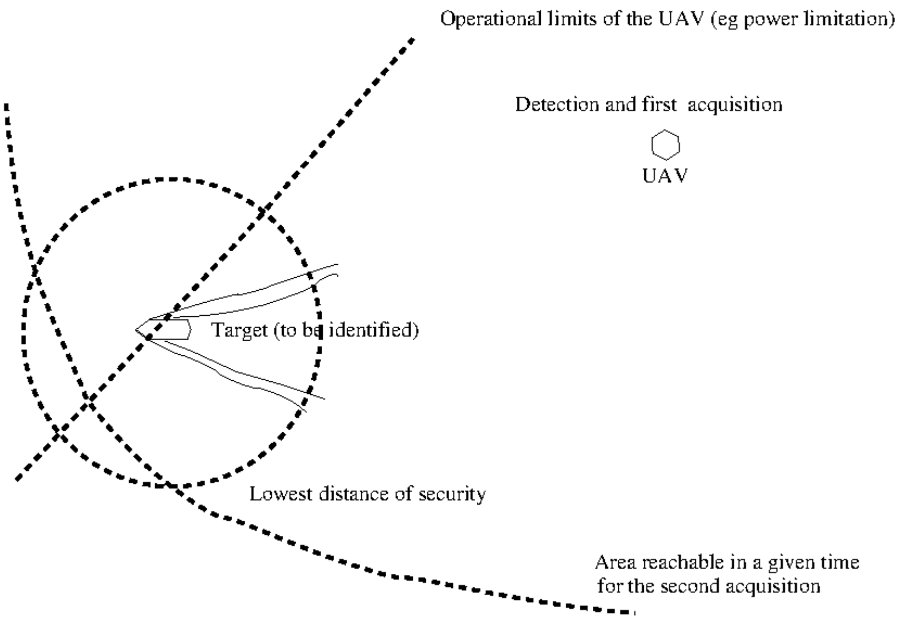


Fig 1: Operational scenario for target recognition by successive acquisition (with possible limitations)

A first geometry of the object can then be deduced. Especially for each detected point scatterer, the first three characteristics defined above (instability of the envelope, angle, Doppler being used to define the trajectory) can be estimated.

A second step in the algorithm will be the search in a dictionary, this research leading, then, thanks to a metric to be defined, to select the pairs (type of points scatterer, angle) the most likely. A list of backscatters is thus made up by decreasing metrics (most likely to the least likely). Two cases may then occur

-Either the point scatterer is clearly identified (large metrics difference between the first type and second type of point scatterer)

-Several point scatterers are possible (close metrics).

The algorithm that we want to design involves finding the new position of an acquisition allowing discarding or confirming the possible kinds of point scatterers as well as the orientation for all scatterers not clearly identified. It is obvious that several solutions, optimal for each point, will be to be combined in an algorithm that will lead to an optimal first solution, taking into account the trajectory constraints detailed below. This algorithm should in particular determine the number of views required and the duration of the UAV movement for a robust estimate of the target structure. When possible, the optimal place searching could be also combine with the optimal waveform when waveform diversity is available for the considered radar [6].

As mentioned above, UAV movement controls must take into account:

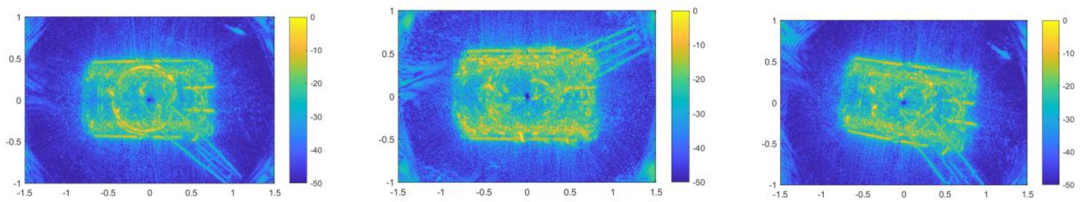
-UAV operational constraints, communication, operability and battery.

-Target displacement (partially achieved through target Doppler estimate) relative to the position and speed of the carrier.

-Security constraints, minimum distance from the target, for example.

-Travelling time to reach the new data acquisition position(s).

In the case of terrestrial targets, the masking effects of the target could also be taken into account, but also the effects of (sea/land) clutter in order to define the best possible acquisitions.



Example of SAR images of T64 for different configurations

Plan of the works

The works of the PhD will have be made up of five steps

Step 1: Definition of a set (dictionary) of point scatterers (trihedral, dihedral, cylinder ...) with along their electromagnetic response at the central frequency of the carrier (35 or 94 GHz by example) with bandwidths leading to the usual (high) resolutions and different incident angles.

Step 2: Simulation of simple scenes, from several objects with their dimension, orientation [5], speed, and these objects being described by a set of point scatterers with possibly one or two point scatterers not in the dictionary (defined in the step 1), in order to evaluate the effects of a possible lack within the dictionary.

Step 3: Definition/choice of a metric for point scatterer identification, for example distance of Fourier transform of the EM response, Wigner Ville transform or RANSAC approaches [1], [2], [4]

Step 4: Definition of a utility function taking into account the discrimination constraints of the possible point scatterers and trajectory constraints described above. This utility function will be introduced for the sake of the UAV mission definition. In particular, the algorithm will have to define whether one or more additional acquisitions are necessary (conflict of position for discrimination of different detected point scatterers).

Step 5: Optimization of the trajectory (if several acquisitions are required) and finally 3-D target reconstruction

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