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# Local feature based automatic target recognition for future 3D active homing seeker missiles

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ABSTRACT

We propose an architecture appropriate for future Light Detection and Ranging (LIDAR) active homing seeker missiles with Automatic Target Recognition (ATR) capabilities. Our proposal enhances military targeting performance by extending ATR into the 3rd dimension. From a military and aerospace industry point of view, this is appealing as weapon effectiveness against camouflage, concealment and deception techniques can be substantially improved.

Specifically, we present a missile seeker 3D ATR architecture that relies on the 3D local feature based SHOT descriptor and a dual-role pipeline with a number of pre and post-processing operations. We evaluate our architecture on a number of missile engagement scenarios in various environmental setups with the missile being under various altitudes, obliquities, distances to the target and scene resolutions. Under these demanding conditions, the recognition performance gained is highly promising. Even in the extreme case of reducing the database entries to a single template per target, our interchangeable ATR architecture still provides a highly acceptable performance.

Although we focus on future intelligent missile systems, our approach can be implemented to a great range of time-critical complex systems for space, air and ground environments for military, law-enforcement, commercial and research purposes.





## 1. Introduction

Automatic target recognition (ATR) for military applications has been extensively investigated during the last decades seeking reduction of collateral damage and fratricide targeting. Investigation involved numerous spatial and data domains such as 2D infrared (IR) [1], [2] and radar exploiting the high-resolution range profile [3], 2D Synthetic Aperture Radar (SAR) [4], [5] or Inverse SAR (ISAR) [6]. Latest trends include 3D laser based solutions [7–11] exploiting a Light Detection and Ranging (LIDAR) device. Object recognition in 3D is an active research area as it offers numerous advantages over its 2D counterpart. Indicatively, 3D data take advantage of the geometric properties and the underlying structure of an object. These are more informative compared to 2D image information [12]. Also, features extracted from the 3D domain are less affected by illumination variation and target pose changes [11], [13].

Current and upcoming missile seeker ATR algorithms [1] operate in the IR domain taking advantage of the target's thermal fingerprint. These approaches have a number of disadvantages such as, the thermal signature of the target may vary [14] and is affected by the history of the target and the time of day [15]. The former is related to whether the target is still hot or has cooled down, while the latter to the thermal difference between the environment and the target. Finally, current camouflage [16] and countermeasure techniques affect ATR performance [17].

With respect to future LIDAR based missiles, 3D ATR can improve weapon effectiveness against camouflage, concealment and deception techniques because the laser beam has a small spot size, which enables penetration of sparse structures. In addition, the short wavelength in which laser scanners operate provides high-resolution data and the capability to acquire details of the target reinforcing recognition applications. These appealing features can enhance the probability of detection and reduce the false alarm rate of future LIDAR seeker missiles with ATR capabilities.

Driven by the appealing advantages of 3D ATR, we propose a missile seeker architecture based on a dual role pipeline that incorporates extensive pre and post-processing operations combined with the Signatures of Histograms (SHOT) descriptor [18]. Since real military data are classified, we apply SHOT on a number of simulated but highly credible air-to-ground and maritime missile

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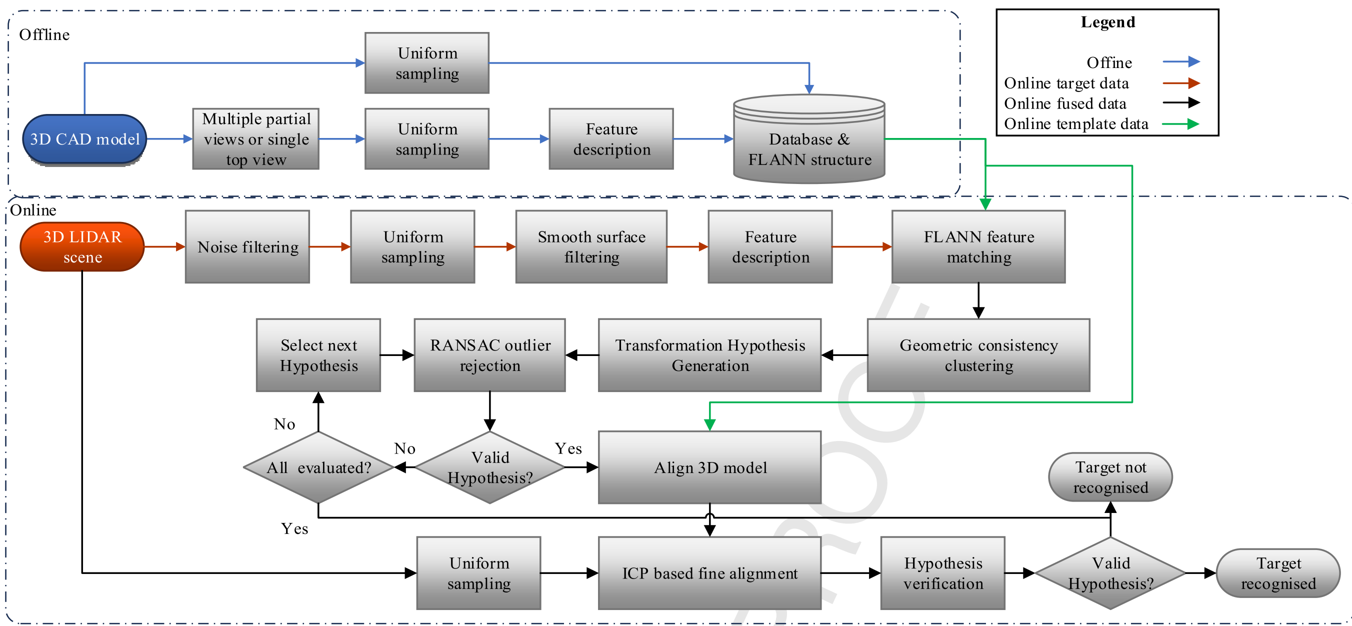


**Fig. 1.** 3D ATR pipeline.

engagement scenarios. It should be noted that although SHOT is a high performing descriptor, the dataset we use is very challenging as it is highly realistic, cluttered, occluded, and incorporates sensor noise while the target scene is generated under various obliquities (viewing angles) and resolutions. The difficulty to achieve a successful ATR is such that just applying the SHOT algorithm on its own is ineffective and thus the proposed architecture has a very important contribution to the overall ATR performance.

From a military and aerospace industry point of view, we consider our contribution as highly appealing. Indeed this paper demonstrates that an existing 3D descriptor from the computer vision domain, after properly processing the data obtained from a LIDAR sensor and refining the matching process, can provide an appealing military ATR solution. In addition, the military dataset exploited is much more challenging compared to the ones used in the current open source literature because ours combines more parameters.

The rest of the paper is organized as follows: Section 2 presents a literature review of the existing 3D ATR algorithms in a military context. Section 3 refers to the proposed ATR architecture while Section 4 to the scenario generation and evaluation. Section 5 evaluates our pipeline on seven highly challenging military scenarios. Section 6 exploits the proposed pipeline with a single template scheme and finally, Section 7 concludes this paper.

## 2. Related work

The battlefield is a noisy, highly cluttered and occluded, dynamically changing environment. These demanding features require implementing robust object recognition techniques capable to fulfill the needs of a missile platform with ATR capabilities.

To the best of our knowledge, open source military oriented ATR algorithms are based on Spin Images [8], geometric fitting [10], multi-hypothesis sequential testing [9], the Baseline Processing Pipeline (BPP) [7], the Probabilistic oriented algorithm [19] and the SPR [11]. The Spin Image descriptor accumulates the points enclosed within each bin of a rectangular grid that is rotated around a local reference axis. The latter is aligned to the normal calculated from the neighboring vertices of the keypoint to be encoded. Even though the Spin Image performs well, its performance has been tested only in top-down viewing situations, which are not always the case during a missile–target engagement scenario. In addition, as the target becomes sparse or noisy, the Spin Image based algorithm performance degrades [20]. Geometric fitting decomposes the scene into a number of rectangle-based regions, based on the assumption that manmade objects are such. Decomposition is performed iteratively by minimizing the area that encloses the scene's vertices after being projected on the planes of a manually established Global Reference Frame (GRF). The rectangles created are filtered based on simple geometric comparisons with the templates. Finally, template matching relies on comparing the vertices of the remaining rectangles against vertices belonging to the target's CAD model. Although this technique performs well for simplistic shaped targets, this assumption is not always valid, and additionally its iterative nature imposes a large computational time. The probabilistic oriented solution relies on Bayesian decision theory. Disadvantages are its limited robustness to noisy environments and the assumptions that the ground in the scene has already been discarded. Multi-hypothesis sequential testing deals with multi-hypothesis sequential probability ratio tests motivated by Bayesian settings. Although this method is computationally efficient, the ATR performance achieved is moderate. The BPP clusters the vertices above a planar ground level into volumes of interest that are refined based on their physical dimensions. The remaining volumes are described by mapping their height based on a user defined grid size. BPP is constrained to planar ground scenes that include un-occluded targets. Finally, the SPR algorithm projects the scene on the planes of a GRF, set at the missile seeker, and applies the 2D SURF [21] descriptor. Despite this being a computationally efficient solution, it has not been tested in complex scenarios.

Although current military oriented 3D ATR proposals have interesting features, these do not pose an overall optimum solution meeting the performance and processing requirements of current battlefield scenarios. Thus, we propose a solution based on the local 3D descriptor SHOT which combines high quality recognition performance with an appealing low processing time [18], [22], [23].

## 3. Proposed recognition pipeline

The algorithm consists of an online and an offline phase as presented in Fig. 1.