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ATR Applications in Military Missions

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Abstract— **While there has been a nominal effort to develop Automatic Target Recognition (ATR) technologies for military systems for the last couple of decades, there have been relatively few significant breakthroughs. At the same time, the evolution of some of our missions has made it more desirable to achieve solutions from this technology to meet some of the escalating operational challenges. This paper is intended to identify and characterize some areas where ATR algorithms might materially improve our operational capability.**

Index Terms—Automatic Target Recognition, Surveillance, Reconnaissance, Strike, Weapon Guidance

EXTENDED SUMMARY

(Invited Paper)

Automatic Target Recognition (ATR) can provide a significant increase in operational capability in three different military missions. These are

> Surveillance and Reconnaissance
> Strike Target Detection and Recognition
> Autonomous Weapon Guidance.

The objective of Surveillance and Reconnaissance is to detect, identify and locate targets of interest, so that subsequent sorties can be prepared and tasked for their destruction or neutralization. When a Strike or Attack sortie is conducted, it is generally necessary for the sensors or pilot on board the aircraft to detect and recognize the target before weapons are released. Because of the risk of fratricide and concern over collateral damage, current rules of engagement (ROE) have become more stringent with regard to confidence of target identification. Extremely effective local defenses have made it necessary to conduct attacks at longer stand-off ranges, some times even beyond the ability of aircraft sensors to do target acquisition. Hence there has been interest in weapons that lock on to the target while in flight, known as LOAL or lock on after launch. As shown in Table 1, the operational challenge and resultant technical requirement is different for each of these three missions. Let us now examine each of these three missions in greater detail while focusing on those mission parameters that drive the ATR solution space that is desired. Starting with the first, Surveillance and Reconnaissance…

The advent of ultra-high resolution surveillance sensors has resulted in the generation of imagery with extremely high data band widths in Surveillance and Reconnaissance missions. . To gain a semi-quantitative feel for the scope of this data, consider a surveillance mission over a 200 mile square area as shown in Figure 1, noting that this is not a particularly large area for a surveillance mission. If the imaging sensor can acquire imagery with a one foot resolution (an appropriate size for recognizing many targets), then this collection process will generate approximately 1.5×10^{12} pixels of data. If photo interpreters examine scenes with as many as 10 million pixels in each image, there would be over 100,000 images to examine. This is an impractical workload and results in a delayed or incomplete assessment of what targets within the 200 mile square should be attacked. Furthermore, the protracted targeting time allows moveable targets to relocate so that they can not be found in subsequent strike missions. This scenario was repeated many times in the Gulf war when attacks against portable short range ballistic missiles (Scuds) were unsuccessful because they had moved between time of surveillance and time of attack. ATR algorithms should be hosted on powerful mainframe computers to expeditiously process large batches of data in significantly shorter times.

Table 1. Missions and Challenges

Mission	Operational Challenge and Requirement
Surveillance and Reconnaissance	Rapid processing of extremely wide bandwidth data Target obscuration
Strike Target Detection and Recognition	Confident Target Cueing or Recognition
Autonomous Weapon Guidance	In-flight Target Detection & Recognition with very Low False Alarm

The second mission, airborne strikes of ground targets, has become an increasingly dangerous operation because of the emergence of improved air defense radars and extremely

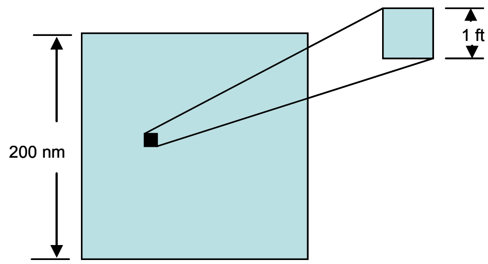

Figure 1. One foot resolution for a 200 nm surveillance area.

deadly area defense missiles and guns.. Even with low observable signatures, aircraft must rely on high speed to complete a quick strike before they are detected by defensive radars. This places a real premium on the aircraft's ability to quickly detect, recognize and launch a weapon on the target before it is detected itself and attacked. Since the attacking aircraft usually ingresses at very low altitude to avoid enroute defenses, the target frequently is not clear of the horizon or other obstructions until the aircraft is within 10 or 20 miles or less. As shown in Figure 2, this is very close to the range that the pilot would like to release his weapon. At a flight speed of Mach .9 the strike aircraft closes on the target at approximately 10 n.m. per minute. So there are precious few seconds available to detect, recognize, designate the target and initialize and launch the weapon. Any reduction in search, acquisition and identification time that could be provided by an ATR algorithm would significantly improve performance and survivability on this strike mission. If automated target recognition is not completely achievable, it would be helpful if ATR algorithms could cue likely targets to reduce the pilot workload and to allow him to quickly assess target validity.

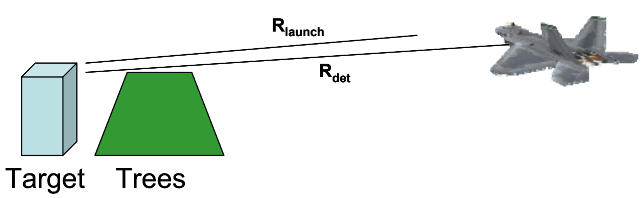

Figure 2. Ground target Strike

The increased risk while penetrating and locating a target to be attacked has motivated military system engineers to search for new weapons capable of stand-off launch with LOAL, the last of the three missions we are evaluating. In addition to stand-off LOAL weapons, there is also interest in loitering Unattended Air Vehicles (UAV's) which would be orbited above the adversary and persistently available to attack transient targets as they are exposed or move into position. Radars, missile launchers and aircraft on runways are examples of this transient target. In either case, the weapon would be required to autonomously detect, recognize and track the target of interest as shown in Figure 3. A variety of ATR techniques ranging from cross correlation to 2-D and 3-D algorithms based on abstracted target characteristics have been proposed and tested with mixed results. The vehicle, propulsion and navigation technologies for such a weapon have been fairly well proven. Thus, a robust ATR concept is all that is needed to enable the development of this desirable autonomous weapon.

Figure 3. Stand-off LOAL missile

We have now identified and characterized three military missions that would realize significant operational benefit from ATR algorithms that are capable of reliably detecting and identifying targets. The missions are listed in Table 2 with a delineation of the unique operational and technical challenge that each of them presents.

Table 2. Operational and Technical Challenge

Mission	Key Characteristics	Human Aid	False Alarm	Algorithm Complexity
Surveillance and Recce	Extremely Fast Processing of Hi Bandwidth Data	Yes	Moderate	Complex
Attack	Rapid, Flexible Target Detection & Recognition Moderate BW	Yes/No	Moderate	Moderate
Autonomous Missile	Autonomous Possible Target Reference	No	Very Low	Simple

First, the ATR algorithms to facilitate Surveillance and Reconnaissance should enable very rapid processing of enormous amounts of data. Since the target interpretation process is conducted on the ground, a large mainframe computer would host the software and provide very large throughputs to expedite the analysis. Because photo-interpreters are available to confirm the validity of designated targets, a reasonable level of false alarms would be tolerable.

Next, ATR algorithms could accelerate a strike aircraft pilot's ability to detect and identify ground targets and thereby serve to enhance aircraft survival and mission success rate. While it is reasonable to expect some target attributes (or even images) to be available from mission planning, it would be desirable for the ATR algorithm to be capable of processing a full range of military targets without the need for reference imagery.. This flexibility would enable the system to be effective when targets are provided by voice from a forward observer. The algorithms should be capable of being hosted on an aircraft computer, with throughputs of XX GHz and a YY GB hard drive.

The ATR algorithms for a LOAL weapon should be capable of robust autonomous operation. Unlike the previous two missions, it should be capable of operating without human participation. As a result, there is compelling need for a very low false alarm rate. However, target reference imagery or characteristics may be available as an aid to the ATR. Additionally, despite dramatic electronic technological advances, the computing capacity on board a weapon is limited in capability due to size, weight and cost constraints. Consequently, simpler algorithms are needed in this application.

The unique attributes of three military missions that can be improved by appropriate ATR algorithms have been described. I hope that it will serve to stimulate and challenge the innovative spirit of some of you to create the novel concepts necessary to improve our military's operational capability.