Enhanced Remote Sensing Based Airport Detection: A Military Detection

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Abstract

Target detection is one of the significant areas of study in remote sensing which is gaining importance in the military field due to its pertinent applications. Airfields are example of one such valuable target having dual usage of civil and military applications. The primary infrastructure at an airport forms the interpretation keys for identification and analysis of this target in remote sensing data which have been deliberated upon in this article. The additional interpretation keys which are specific to a military airbase due to its additional & characteristic infrastructure are listed and considered in view of their inclusion in identification in satellite data. In this paper, the target detection methods are discussed first and then a review on various target-detection methods that have been qualified in identification of airfields have been deliberated upon. The challenges faced in detection of airports have been brought in light of advancements in remote sensing data acquisition.

Introduction

Airports are valuable strategic asset of a nation from economic as well as military viewpoint and are one of the leading forces in the indigenous, provincial, national and international economy. Transportation enables swift and easy movement of material, men and resources which plays a primary role in economic development of a country. The progression of transportation system from shipping, railways, highways and now airways has significant impact

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in terms of financial returns to the economy. Airports form critical national assets thereby also serve as viable targets to disrupt an adversary's economic backbone, in terms of his war fighting capability hampering transport of troops, weapons and equipment and resources. Remote Sensing (RS) makes a decisive contribution to the independent and unbiased analysis of situations and present day combat operations, situational awareness has been extensively impacted by incorporation of RS data. Detection of airports from remote sensing data provides a lucrative target to the adversary that can majorly assist in disrupting enemy operations. All airports are national security assets & most airports are dual in nature (civil & military). In view of thrust on air transportation in present scenario to gain advantage of time, hampering of air operations will have a severe adverse impact on all successive operations. Availability of RS data in large volumes and of higher resolutions has increased the battle field transparency in large quantums and target detection methods based on RS data have also improved manifold. Airports form one such viable target that can be detected in more accurate ways in high resolution imageries based on various computing methods.

Aerodrome, Airport, and Airfield

Aerodrome, airport, and airfields are few nomenclatures that are used interchangeably in parlance of air transport. But these are different in terms of the operations conducted and facilities available. An aerodrome is 'A defined area on land or water including any buildings, installations, and equipment intended to be used either wholly or in part for the arrival, departure, and surface movement of aircraft.[1] An airport is a generalised idiom for aerodromes with supporting facilities like the shops inside the docks, the taxiways for the aircraft, control tower, hangers, terminals, taxi bridges, and aprons, primarily for commercial air transport. The airport facilitating only helicopters is a heliport. An airfield covers all areas of the aerodrome apart from the buildings/ terminals and parking and is also enclosed by the aerodrome perimeter. The airfield particularly refers to the runway and taxiways but it may not necessarily have terminals or paved runways.

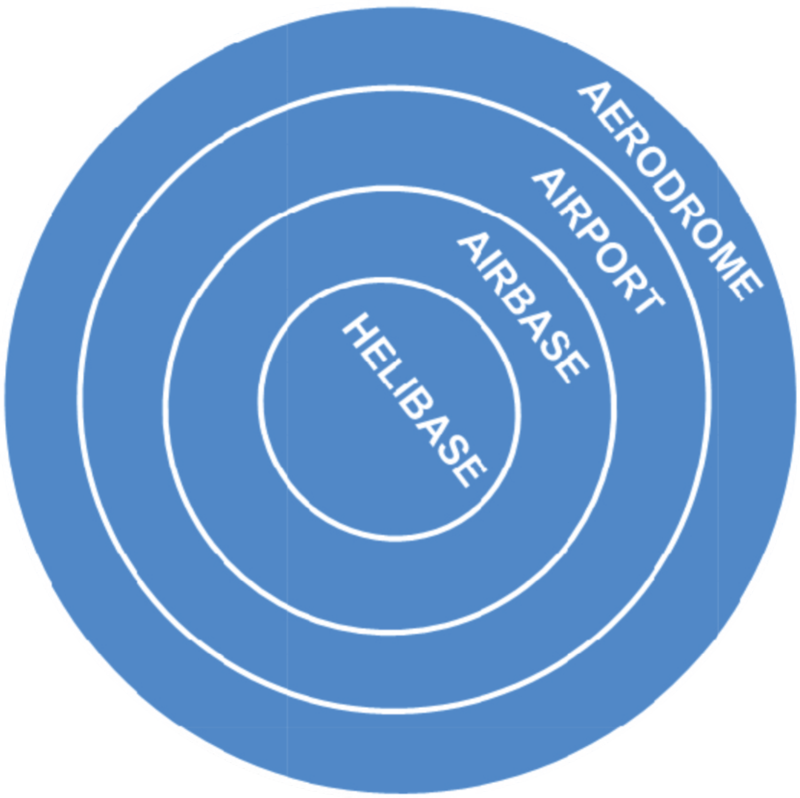

Figure 1 : Size-wise Aviation Facilities

Airport is a complex infrastructure that has to accommodate aircrafts, passengers, cargo and ground vehicles. The layout of an airport is built according to the aviation authority norms / guidelines which include; topography of the area, physical facilities in an airport (aviation / non-aviation), dimensions, safety standards etc. Few other factors that are in consideration while planning the layout of an airport include; access requirements of an airport, effects on environment, development of land use around the airport, etc. The primary components of an airport include; runway for the landing or take-off of aircrafts, taxiway: a path for linking runways with aprons, hangars, terminals and other facilities, apron for parking the aircrafts, terminal building for all administration purposes and the passenger wait area, Air Traffic Control (ATC) for managing the movement of the aircraft, and hangers for aircraft parking and maintenance. The escalating demand for air travel and concomitant need for large transport aircraft also brings in the allied extensive

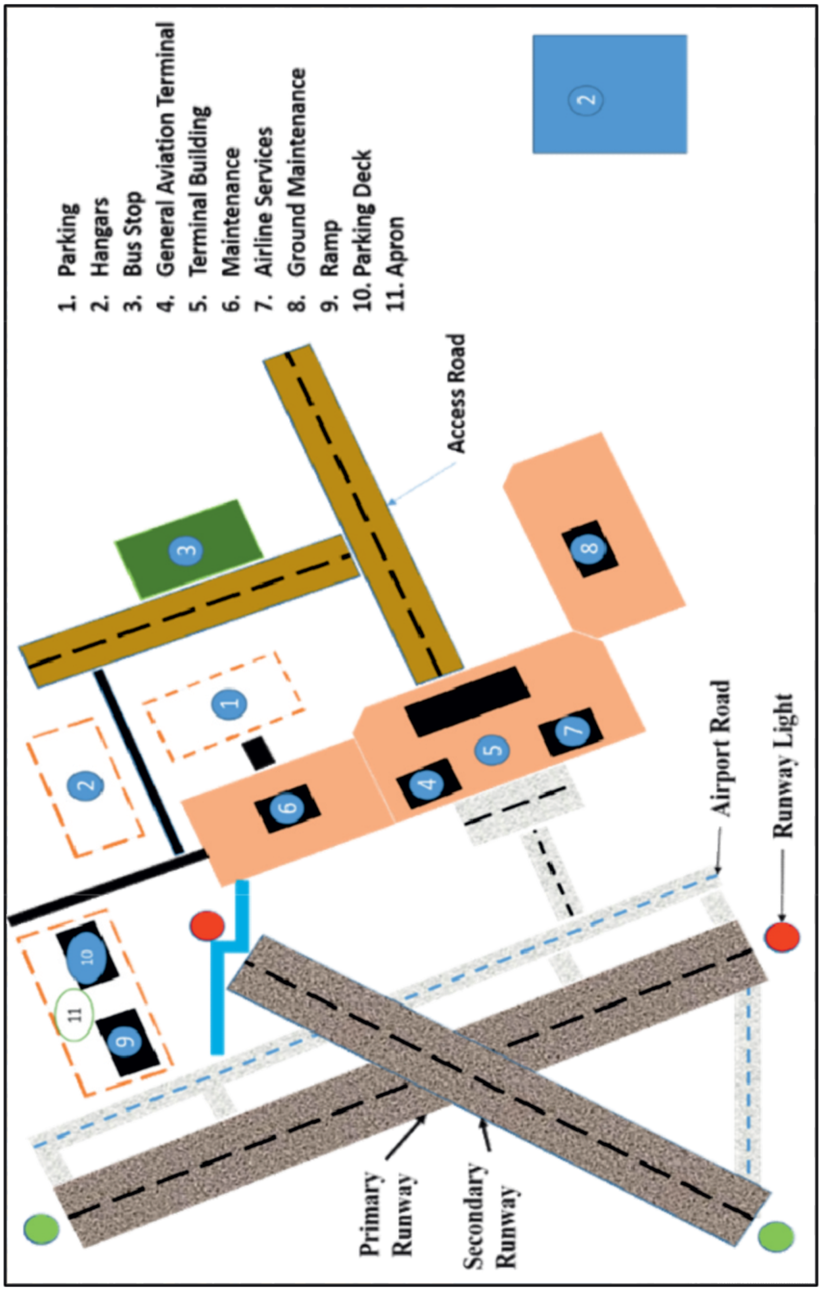

Figure 2 : Layout and Basic Components of an Airport

ground facilities, requisite runways, taxiways, fire-fighting and rescue services, passenger- and cargo-handling facilities, access to car parking, public transport, lighting, navigational approach aids, and a range of support facilities such as catering, meteorology, and governmental inspection and so on.[2]

Image Interpretation Keys: Airport

All objects have a particular reflectance which is captured in RS data in particular ways based on the category and calibration of sensors. The basic infrastructure or components of an airport will also have these reflectance patterns and thus these components act as the image interpretation keys for airport identification in a satellite data. RS data based attributes that can be exploited to analyse these infrastructure as interpretation keys are discussed below.

Runways. Shape is the most distinct and primary interpretation key for identification of runways. Its significant dark texture reflected by the tarmac surface is another characteristic that can be analysed in optical imageries with regards to its high pixel values and or exploiting the thermal bands for its comparatively hot signatures as compared to background features. A linear feature of dimensional restrictions beyond a particular width and height, absence of curves, based on a flat terrain with open spaces around are additional attributes that can be added in the target detection model to narrow the search amongst features in spatial domain.

Taxiways. This component of the airport which has similar reflectance of a runway is shorter in length and appears like a connecting path ejecting from the runway either towards the parking space or interconnecting with other adjoining runway. Shorter length than of runways, curves in this feature, lighter pixel values than of a runway and wider than standard runway width are differentiation aspects that can be incorporated in computing models for better interpretation.

Apron. This part of an airport appears like a wider squarish or rectangular extension in satellite imagery mostly situated towards the exit area from flying spaces towards administrative areas of an airport. Signatures of parked aircrafts are the most remarkable interpretation cue for identifying an apron.

Hangar. Hangars give away the signatures of large asphalt or concrete material rooftops that are predominantly ridge-roofed or flat roofs with distinct heights. These structures are located in close vicinity of the runway preferably at either of the ends and connected with taxiways. Temporal analysis of satellite imageries giving away entry / exit of aircrafts into these structures can be identification cue in interpretation of hangers.

Air Traffic Control. The most prominent identification signatures of the ATC in RS data, is its height as it is one of the tallest structure in an airbase and also centrally location in the overall airport region. The shadow becomes a strong interpretation key due to the height of ATC.

Distinctive Image Interpretation Keys: Military Airfield

A military airfield has certain variations and additional facilities as compared to a civilian airport. Distinctive image interpretation keys for the military airfields are as mentioned below:

Runways. Presence of multiple (cross or parallel runways) and longer runway signatures can be seen military airfields, probably due to the redundancy and contingency hence acting as a prominent identification key. The Hyperspectral imageries can be utilised to detect any variations in the spectral signatures in the region for camouflage detection.

Blast pen. (Fig 2 (a))These protective shelters for housing / safeguarding the aircrafts,are generally made of concrete hard structures over or underground. These structures can be studied with reference to different satellite sensors adding the factors of their proximity to the runway, connected via taxiways in a singular direction for effective detection. Presence of shadow at the mouth of the structure is another attribute that can be studied in the satellite imagery. As these structures are huge, it can be detected in the coarser resolution imageries where they are in the open.

Bomb dumps. (Fig 2(b)) These storage structures give away the signatures of symmetrical layout of buildings within a confined space with restricted access. The confined space housing group of building like structures similar in shape and size placed at considerable distance (equidistant at few locations) with absence of multi-floored structures co-located with some water signatures

Figure 2: Components of a Military Airport (a) Blast Pen (b) Ammunition Storage Site (c) Dummy Target and (d) Missile Launch Pad near an Airstrip

and comparatively more vegetation signatures than adjoining areas are cues for its interpretation keys.

Missile sites. (Fig 2 (d)) These sites reflect a pattern of hard standing bases of particular dimensions which are equidistant from each other and standardised in shape. Identification of such features can be clubbed with their proximity to airbases, radar signatures in Synthetic Aperture Radar (SAR) images and road connectivity with an administrative setup in vicinity.

Presence of Precision Radars, Training Areas, Dummy Aircrafts (Fig 2 (c)), and fuel storage tanks can also be analysed with respect to their spectral reflectance patterns, heat signatures and spatial extents in SAR / Hyperspectral Imagery (HSI) / Multispectral RS data as best suited in desired computing models.

Advance Computing Techniques for Satellite Data based Airbase Detection

The advances in computing technologies have enhanced the target detection accuracy in all domains, RS being one of them. In recent years, Machine Learning (ML) algorithms, Artificial Intelligence (AI), Deep Learning techniques pertinent to target detection have made a great progress resulting in faster outputs with higher accuracy rates and requiring minimal human interface. Few broad heads of this computing domain are being discussed that can be modelled and styled based on input data characteristics which is RS data here.

Machine Learning Algorithms. Supervised and unsupervised learning, ensemble learning, neural networks form the major framework in ML algorithms. Naive Bayes and Support Vector Machine are common in supervised learning techniques whereas K-Nearest Neighbour and Principal Component Analysis (PCA) are predominant in unsupervised learning techniques. Object detection, Convolutional Neural Network (CNN), Logistic Regression, You Only Look Once (YOLO) and Single Shot Multi Box Detection (SSD) are mostly used in neural network zones etc.

Spectral Signature Mapping. Databank of spectral signatures generated as the interpretation keys can be exploited using different classifiers like Nearest Neighbourhood, Maximum Likelihood, CNN etc. These classifiers can be trained to classify the features based of the spectral range of the features. Spectral Signatures can be varying due to numerous factors and it is preferable to club this with additional information to derive at conclusive results.

Texture Based Approach.Texture analysis mainly deals with four main issues[3] which are a) texture classification b) texture segmentation c) texture synthesis and d) texture shape. A statistical method of examining texture that considers the spatial relationship of pixels is the gray-level co-occurrence matrix (GLCM), also known as the gray-level spatial dependence matrix. Such matrices drawn for all requisite interpretation keys of an airport will be helpful in mapping.

Shape Based (Geometric) Approach. The shape of an object is denoted by its outer contour, which assists in providing information about that object and classification. Thus, studies have been made to pick features which can provide shape information for successful classification. Conventional maximum likelihood classifies each individual pixel, and object-based image analysis has aimed to move beyond pixels to objects comprised of many pixels (e.g., roads, buildings, parks). The approach starts with pixel classes, segments images based on pixel classes (e.g., grouping by polygon shape), and then conducts object classification based on the spectral characteristics of the object.[4]

Deep Learning with Satellite Imageries. Machine learning feature extraction is done manually and classification is done by machine. However, in deep learning both the feature extraction and the classification are done by machine as given. Different types of deep learning methods include Auto-Encoders, Stacked Auto-Encoder, Restricted Boltzmann machine, Deep Belief Network, Deep CNN models.[5]

Challenges & Possibilities

The primary challenges in advance automated detection of an airfield based on RS data is selecting the correct feature or features that will be tested for its identification in a particular imagery. Runways are predominantly selected for automated airfield detection. But, airport runways different size and appearance in different imaging sensors, which cause challenges to automated systems. Apart from these aspects, the appearance of a runway during an approach and landing is intensely affected by perspective.[6,7,8,9] There are other predominant features in the airfield which need to be exploited for specific and accurate outputs. Another major challenge is creating voluminous training datasets with clear demarcation of target and also considering the atmospheric and climatic changes in the area.

Multi- Sensor fusion is another domain to be explored; hyperspectral, SAR, thermal data with optical imageries could be utilised in combination in the available systems for higher accuracy rate of target detection.

Conclusion

Conventional interpretation methods of identification of targets in RS data are being replaced by automated and semi-automated target detection methods and these can be utilised for detection of valuable targets like airports. Identification of correct and suitable infrastructure that can serve as robust interpretation keys in classifying of objects in RS data is a daunting task. At a progressive level, identification of interpretation keys that can identify category of an airport in terms of its operational parameters will further add to the prioritisation of its usage in military domain. Incorporation and exploitation of multi-sensor data and developing the match of appropriate sensor for analysis of appropriate target will be an achievement that will immensely affect the accuracy results of target detection. The mapping of runways based on advanced computing methods will be useful during crisis to detect airbases created at short notices in vicinity of international borders in times of crisis. Upgradation of interpreting skills combined with employment of specialised minimal human interface will be an efficacious derivative of implementing target detection techniques in the military arena. Gradual, continuous and increasing adoption of target detection techniques will be a stepping stone towards realisation of a fully automated modern army.

Endnotes

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