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Target Detection New Techniques for Defence Applications

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ABSTRACT

Discusses the machine interpretation of remotely-sensed images in terms of human concepts by combining the techniques of artificial intelligence, pattern recognition and image analysis. Describes the solution to cognitive problem in registration, material classification, region extraction, structural analysis, semantic reasoning and problem solving architecture. The paper also discusses briefly the weapon-borne recognition systems using simulation and prediction models to hypothesise target appearance observed by sensors.

1. INTRODUCTION

Image, namely physical picture is represented by an array of pixels. The processing algorithms convert this array of pixels into logic picture regarded as the model of the real image in terms of picture and relational objects, both consisting of a set of attributes. The logic picture is subjected to a higher level of processing, and semantic labels in terms of human concepts are overlayed on the physical picture. The algorithms proceed through many transitions, like pixel-to-region vector representation, spectral-to-spatial and structural model-based pattern analysis, numeric-to-symbolic computation, procedural-to-declarative programming, and domain independent-to-knowledge-based interpretation model. The power and effectiveness of a few prototype systems built in early 1980[1] by combining artificial intelligence, pattern recognition and image analysis techniques failed to meet the expectations. Most research papers popularised automatic target recognition (ATR) and others, like computational image interpretation model or knowledge-based target recognition system or knowledge-based expert system. The systems performed low due to many deficiencies. Simple forward chaining rules were used in the absence of a mechanism to validate the antecedent condition. No feedback loop was used to indicate which algorithm worked well under what condition. Assumption on initial classification label as always correct provided no evidential reasoning. The knowledge-based system functioned as a back-end processor and provided no control on low-level algorithms. The auxiliary information on maps, weather, time of day, season were the least utilised. Finally, the test sets used for software development were very limited.

The present and future weapons systems are increasingly autonomous. They address two distinct requirements. One, the automated system on the ground with inputs from satellites/airborne platforms, maps and other sources, and output as description of target area annotated with object names and geometrical dimensions. The performance level needed is better in relation to human. The second system is weapon-borne, like missile payload for use in terminal phase, remotely piloted vehicle (RPV) or aircraft. The system performance is decided by the number of false alarms per observation frame. This paper discusses machine cognitive system replicating how humans assimilate facts, articulate descriptions and perform reasoning. It also discusses a weapon-borne recognition system using model-based prediction to hypothesise target appearance observed by sensors.

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MACHINE COGNITION SYSTEM

For interpretation of remotely-sensed imagery and to describe a target area, the algorithms are conceptually grouped into three levels[2] as low, mid and high. At each level of processing, it is the information that passes through different levels of abstraction or domain of representation. The processing starts from image domain, which is spatial variation of intensity. The final product is in world domain consisting of physical objects modelled in three-dimensional space with surface geometry/material, relation between objects and significant structures annotated. In the last twenty years, sufficient number of software packages are claimed to have been developed with little concern shown for validation, evaluation of capabilities/limitations and usefulness in real world situation. The problems, solutions and approaches used in machine cognition have been described here.

2. Registration

Most algorithms offer multiplatform and multisensor data registration using ground control points. The selection of control points is manual, difficult and inaccurate, specifically for the data belonging to high terrain and desert area. Matching structures (intersection, joint) using templates or invariant moments do not offer desired inputs to make the process automatic. The need is to reduce dependency on GCPs. One option is to use Swath model[3] or sensor attitude model[4]. The sensor attitude parameters are determined comparing two images one as reference or image and its ground truths. The parameters are assumed to remain valid for all successive image frames over the path. Further, a target may lie between adjacent paths corresponding to different sensors with different spatial and temporal resolution. Gray level balancing using first and second order regression curve fitting algorithm is seen to provide consistency in the combined product generated.

2.2 Classification

The classical multispectral classification algorithms are of two types - supervised and unsupervised. For clustering, supervised method uses training sets and unsupervised method uses global statistics. Both the classification techniques have problems. The spatial information loss is more in the unsupervised classification, but for supervised clustering the availability of training sets of unknown territory is difficult and not possible to obtain. The consistency in the regions formed and flagged with material type is poor because reflectance conditions are not stable. Synthesised rule-based classification techniques[5,6] offer robust solution. Rules are universal and are formed once only. Concatenation and expansion of rules is possible for the system to accept complex class definitions. The algorithm first divides the image into primary classes and then subdivides into secondary classes and then finally composes to represent five or six material types on ground.

2.3 Region Extraction

It is an abstraction process and the algorithms form part of mid-level processing. The input is in image domain, a set of pixels which are isolated points. The connected set of pixels is composed to a higher level of abstraction called primitives (point, line, curve, boundary, and area). Based on intuitive appeal, thresholds are set to examine the properties, like uniform density, similarity, proximity and continuity to detect primitives with no relevance to context, knowledge or expectation of scene domain. To avoid this problem it is necessary, first to increase the domain of representation with no loss of information, including pixel inheritance and then assign labels to indicate primitives. Even an isolated pixel is represented. A four-element vector[7] (x, y, z, r) to indicate position, gray value and radius of uniformity can be used for this purpose. The radius varies between 0-3 to include a maximum block size of 49 pixels. The vector is then further processed for higher level of abstraction and description. The algorithms are implemented in dynamic structure as shown in Fig. 1.

2.4 Structural Information

Finding global information shape attributes, hierarchical decomposition, quantitative membership values to shape classes and shape representation algorithms are of concern to spatial analysis for the extraction of structural information. An integrated look[8] of these algorithms is shown in Fig. 2. Interior-based analysis is sufficient to assign global attribute labels and generic classes as 'natural'. Since man-made objects are recognised on the basis of parts, a boundary-based approach is also necessary. For

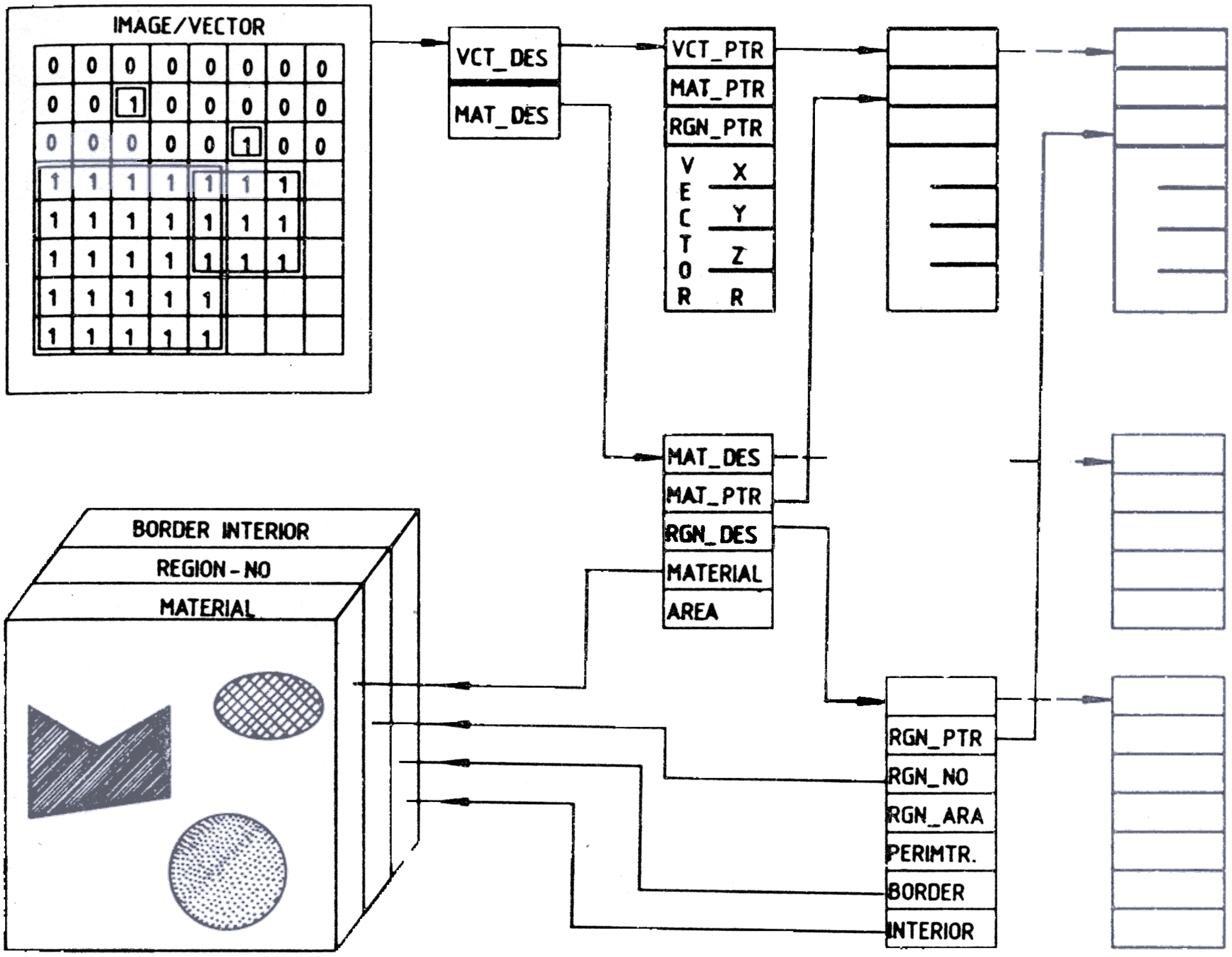

Figure 1. Region description.

polygonal approximation, simple iterative line fit algorithm can be used. In shape decomposition, all convex shapes are considered primitive, and concavity is a measure of complexity. The decomposition process is recursive which minimises the concavity, finding valid dividing line between vertices. To store context information, the spatial relations considered are nearby, connected-to and adjacent-to. For representation, a hierarchical frame structure or a semantic net can be used depending on the recognition strategy to be followed in the final inferencing.

2.5 Semantic Reasoning

To assign labels of human concept to the significant structures, in a target area, the domain knowledge comes from human. Generally, the knowledge passed is vague and difficult to define crisply. Further, the input image data goes through a series of low- and mid-level processing steps, and some amount of impreciseness is incurred. It is true that attribute values obtained after mid-level processing are numeric but then the search for exact match is not proper and an inexact match is desired to cope with the practical situation. The reasoning system[9-10] must respond to inherent human Fuzzy concept, imprecise information, matching of similar rather than identical observation, and differing expert opinion or conflict. A block schematic for the reasoning system is shown in Fig. 3.

2.6 Problem Solver

The algorithms and the processes discussed conceptualised a few specific independent knowledge sources. Each source has different kinds of knowledge and different mechanisms to function within it. For problem solving, one or more knowledge sources are required to communicate, share hypothesis/information

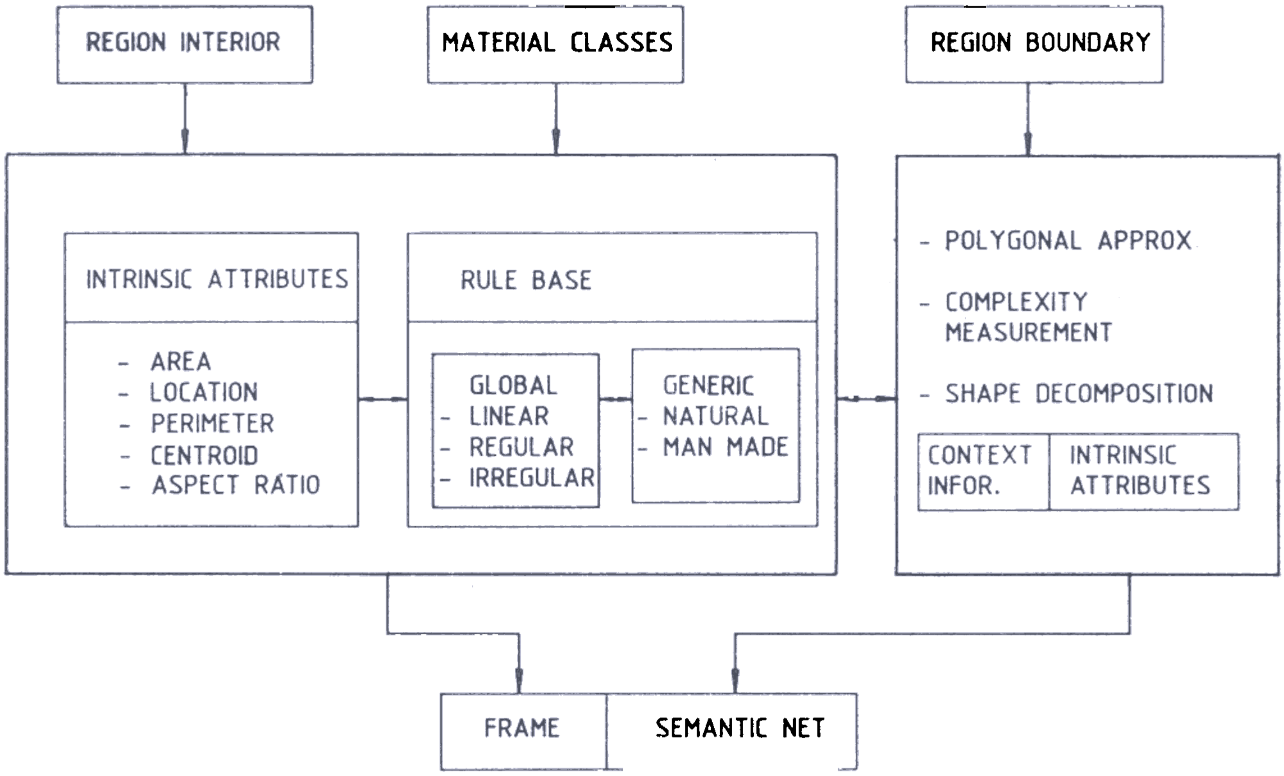

Figure 2. Structure analysis.

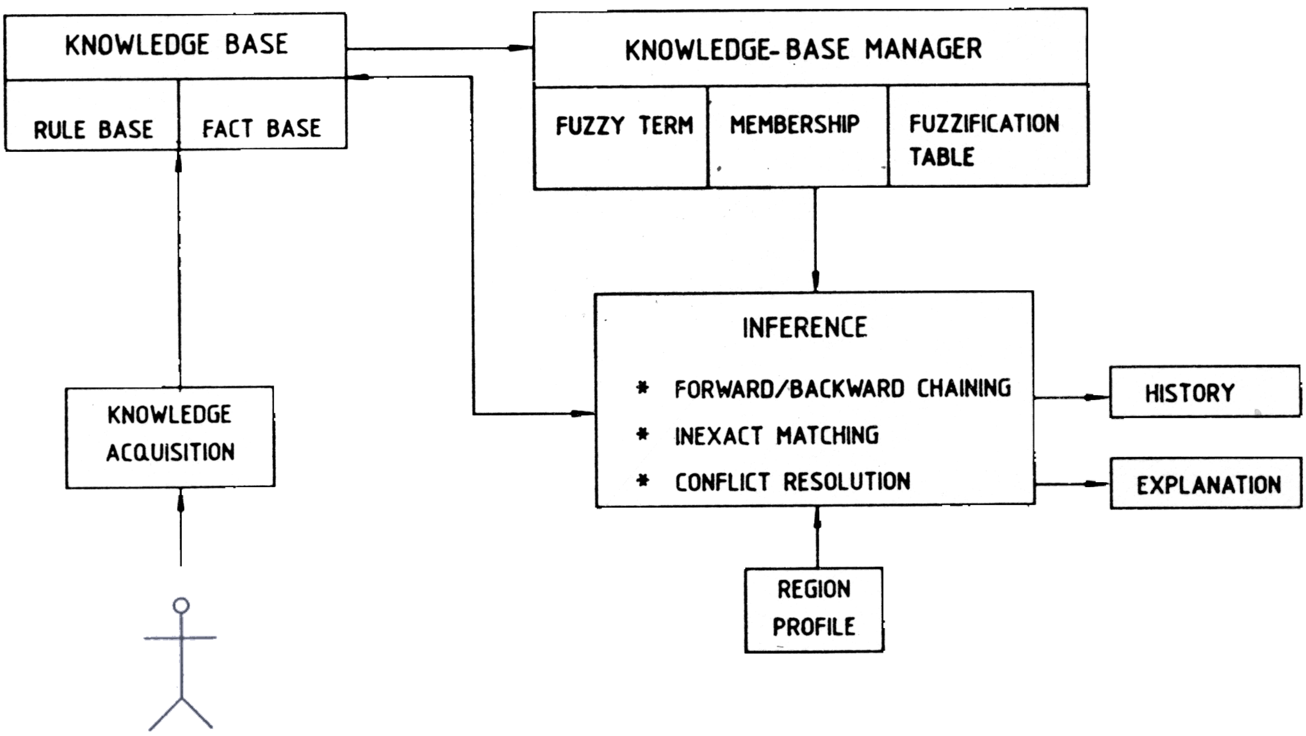

Figure 3. Reasoning system.

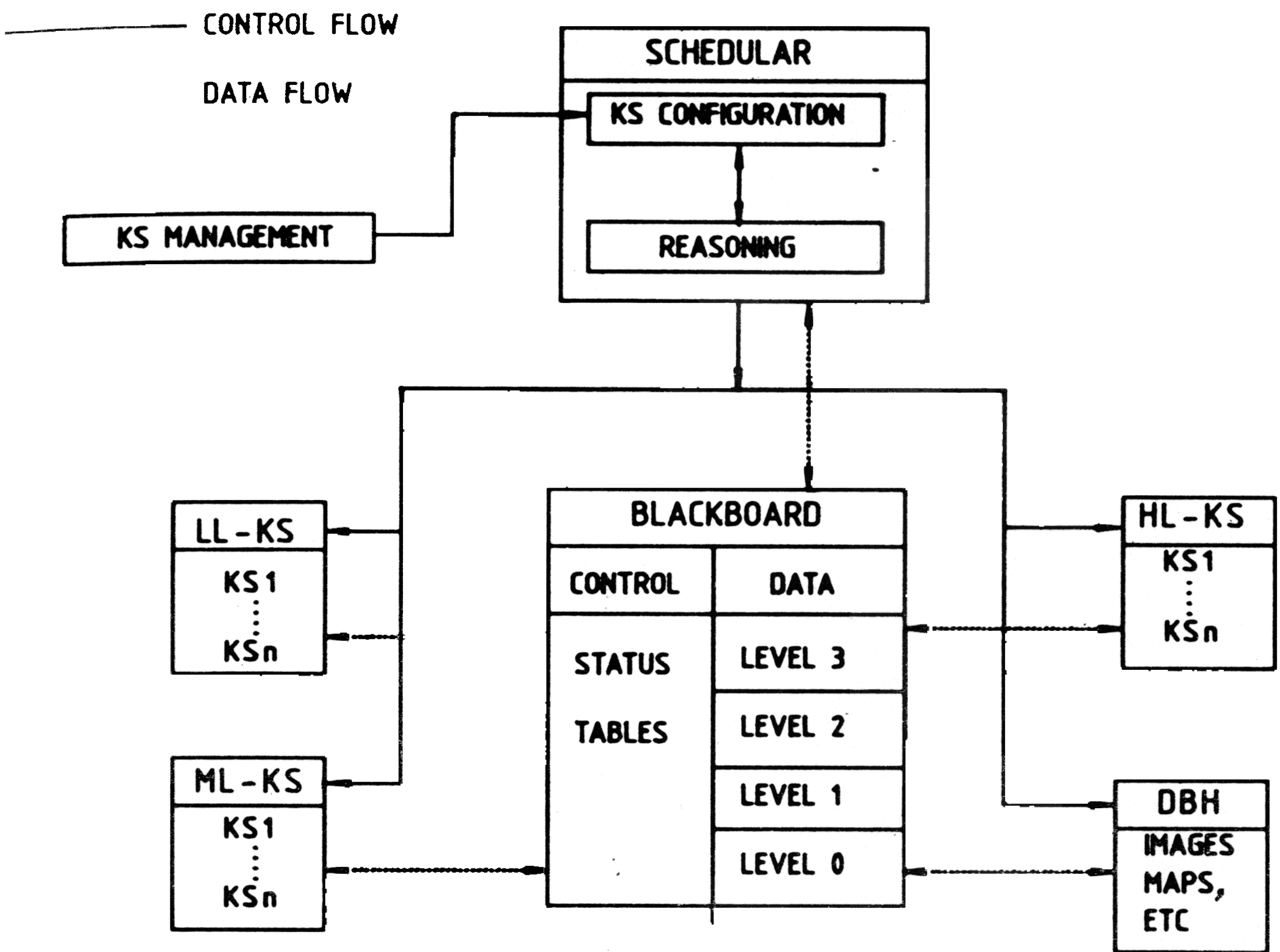

Figure 4. Integration of knowledge sources.

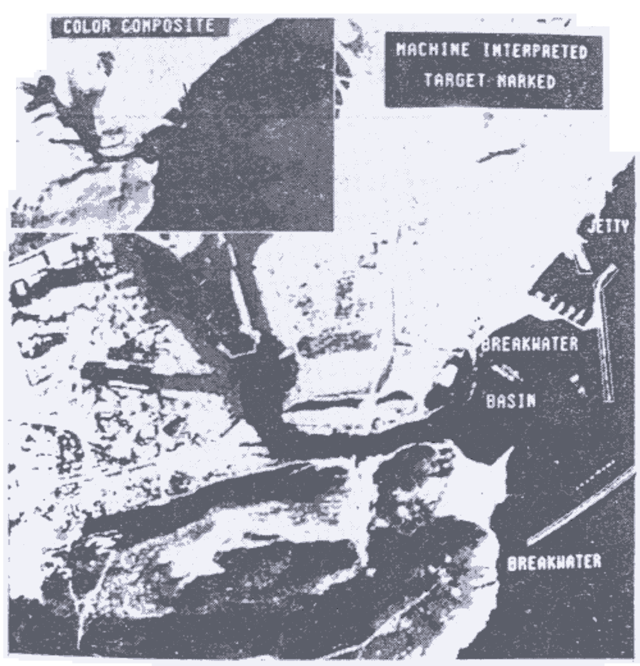

Figure 5. Machine-interpreted satellite imagery.

and adopt a synchronised strategy of operation. These are better done in a blackboard frame[11-12]; and problem solving models based on this architecture are increasingly in use. The block schematic shown (Fig. 4) indicates a typical solver where the knowledge sources are integrated under this architecture. An example of machine-interpreted satellite imagery is shown in Fig. 5.

3. WEAPON-BORNE RECOGNITION SYSTEM

Autonomous vehicle mission involves the determination of objects in natural scene in different weather conditions in the presence of countermeasures and battlefield contaminants. The systems respond in real-time and are required to adopt the dynamic situations, like sensor platform at varying altitudes and distances from the target area producing different imaging geometries. The system includes target acquisition, identification and tracking. It functions in two space, one, creation of scene in image space and then processing/recognition in decision space. Model prediction for hypothesised target appearance can be considered as preparation of knowledge base of the target area. The comparison between hypothesised target and that observed by the weapon-borne sensor is the process of recognition. The sensors used are restricted to one or two types only. Earlier, FLIR sensors were mostly used. Presently, microwave sensors are becoming popular because of increased resolution and all-weather capabilities. Even synthetic aperture radars are used for this purpose.

3.1 Simulation Models

The knowledge base of the target area is generated using ground-based recognition system discussed in Sec.2 with all resources available and data from satellite-based platforms. The weapon-borne sensors are different from those used for generating the knowledge base. A series of simulation and prediction models accepts input from the knowledge base and creates an output similar to that obtained by weapon-borne sensors in its wavelength geometry and resolution.

3.2 Hypothesised Targets

The dynamics of environment[14] affect the appearance of the target. For example, appearance of petroleum tanks seen by thermal sensors changes during the course of day. In the morning, a single tank appears in three pieces: the cover, liquid containing portion and empty portion. In the afternoon, the cover blends into the empty portion of the tank. These target-specific dynamics are included to hypothesise the target.

3.3 Recognition

Matching is done for each successive frame acquired by the weapon sensors during its flight time. Feature matching or area correlation techniques are used for matching. The processing and decision space indicates in real-time confidence factor in target recognition.

4. CONCLUSION

Machine annotation in terms of human concepts and geometrical values in remotely-sensed imagery is a complex task. Researchers are able to produce promising results and more efforts are required to validate the results and remove ambiguities. It is difficult to extract knowledge from domain expert and model the objects. With the availability of increased resolution and intelligence gathering mechanism, a target recognition system will be able to provide information on the potential threat movements for tactical needs.

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