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Image Exploitation–A Forefront Area for UAV Application

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ABSTRACT

Image exploitation, an innovative image utilisation program uses high revisit multisensor, multiresolution imagery from unmanned air vehicle or other reconnaissance platform for intelligent information gathering. This paper describes the image exploitation system developed at the Aeronautical Development Establishment, Bangalore, for the remotely piloted vehicle (RPV) *Nishant* and highlights two major areas (i) In-flight image exploitation, and (ii) post-flight image exploitation. In-flight image study includes real-time enhancement of image frames during RPV flight, target acquisition, calculation of geo-location of targets, distance and area computation, and image-to-map correspondence. Post-flight image exploitation study includes image restoration, classification of terrain, 3-D depth computation using stereo vision and shape from shading techniques. The paper shows results obtained in each of these areas from actual flight trials.

Keywords: Ground image exploitation system, in-flight image exploitation, perspective correction, image restoration, texture analysis, classification of terrain, shape from shading, stereo vision, post-flight image exploitation, unmanned air vehicles, reconnaissance platform

1. INTRODUCTION

Image exploitation is an interdisciplinary image utilisation program to develop unique breakthrough technologies addressing the broad, deep challenges associated with imaging research. The objective of image exploitation is to develop novel ways to use high revisit multisensor, multiresolution imagery from unmanned air vehicle (UAV) or other reconnaissance platform.

A variety of applications of image exploitation include image enhancement and compression, change detection, site monitoring, activity tracking, airborne, spaceborne, shipboard and ground-based missile warning and situation awareness system, automatic target recognition and identification, image and information fusion technologies for human-in-the-loop and automated systems[1-7].

An image exploitation system provides a total solution of a problem by combining both hardware and software at the system and subsystem level. Imaging sensors used for image exploitation system cover visible, infrared and radar region of the spectrum. Typical sensors often used are: Synthetic aperture radar (SAR), moving target indicator (MTI), infrared (IR) sensor, electro-optical (EO) sensor, laser radar (LR) sensor and multispectral systems.

Major operational goals of image exploitation technology are:

(a) To extract the most intelligence from the glut of available imagery by filtering those which are most likely to produce valuable findings.

(b) To combine classical image/signal processing

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techniques with technologies available in other fields, such as artificial intelligence, neural network, fuzzy set theory, genetic algorithm, parallel processing, cognitive psychology, etc.

The end users of this technology are the intelligence agencies, mainly government and defence sectors, that require the exploitation of a large storehouse of information or imagery gathered from a large variety of sensors.

2. CUSTOMISED IMAGE EXPLOITATION SYSTEM

Most of the existing systems used by the military photographic interpreters and image analysts to extract intelligence are based on films. The rapid growth of advanced technology and availability of low cost sensors emphasises the use of ground exploitation system (GES) which exploits high volume imagery, recorded on tape or other digital media, as the source of intelligence[8-10].

The basic components of a GES are a modular image interpretation workstation, digital image storage, software-based image processing system, report writing, intelligence dissemination and secondary image transmission.

The tools usually provided for image exploitation tasks are:

- Acquisition, storage, retrieval display and conversion of hard copy of imagery
- Automatic histogramming for brightness and contrast adjustment, haze setup, sharpening, rotation and zoom facility
- Image enhancement, preprocessing tools
- Perspective transformations, image mensuration for geopositioning, distance and area computations
- Image annotation tools
- Near-real-time image importing from ground control station (GCS)
- Large image manipulation
- Photogrammetric analysis

3. IMAGE EXPLOITATION

The Aeronautical Development Establishment (ADE) has undertaken research and development activities in an unmanned aerial vehicle for the Armed Forces in India. UAV programme in ADE is a multidepartmental, interdisciplinary project which combines basic and applied research with system design and development, prototyping, and testing and evaluation. Image exploitation program is a part of this activity. Figure 1 shows the ground image exploitation system (GIES) developed at ADE for UAV application. Two primary objectives of this system are:

(a) In-flight image exploitation involves both real-time and near-real-time image exploitation during flight with the objective of using the extracted information for mission planning and navigation.

(b) Post-flight image exploitation involves analysis and interpretation of imagery to build knowledge base of specific areas, to acquire information about strategic targets, and to study the geographic characteristics of a territory to plan actions for future.

3.1 Real-Time Image Exploitation

Real-time image exploitation is done on a pentium PC with dedicated image processing boards consisting of a real-time acquisition board and computation module controllers (CMCs). Computation modules (CMs) are the commonly used image processing routines (such as histogram/ feature extraction processor, median and morphological processor, label and measurement processor, etc.) implemented in hardware boards. A number of CMs, plugged as mezzanine modules on each CMC boards, accelerate the processing capability of the system. Figure 2 (a) shows the user interface on PC screen during actual flight. During flight, the system receives two data streams, one is the video data received at the rate of 25 frames/s and digitised using the image capture board, and the other is the flight data received at the serial port of the PC. At any instant during flight, the target points of interest are selected by a mouse click and a sub-window

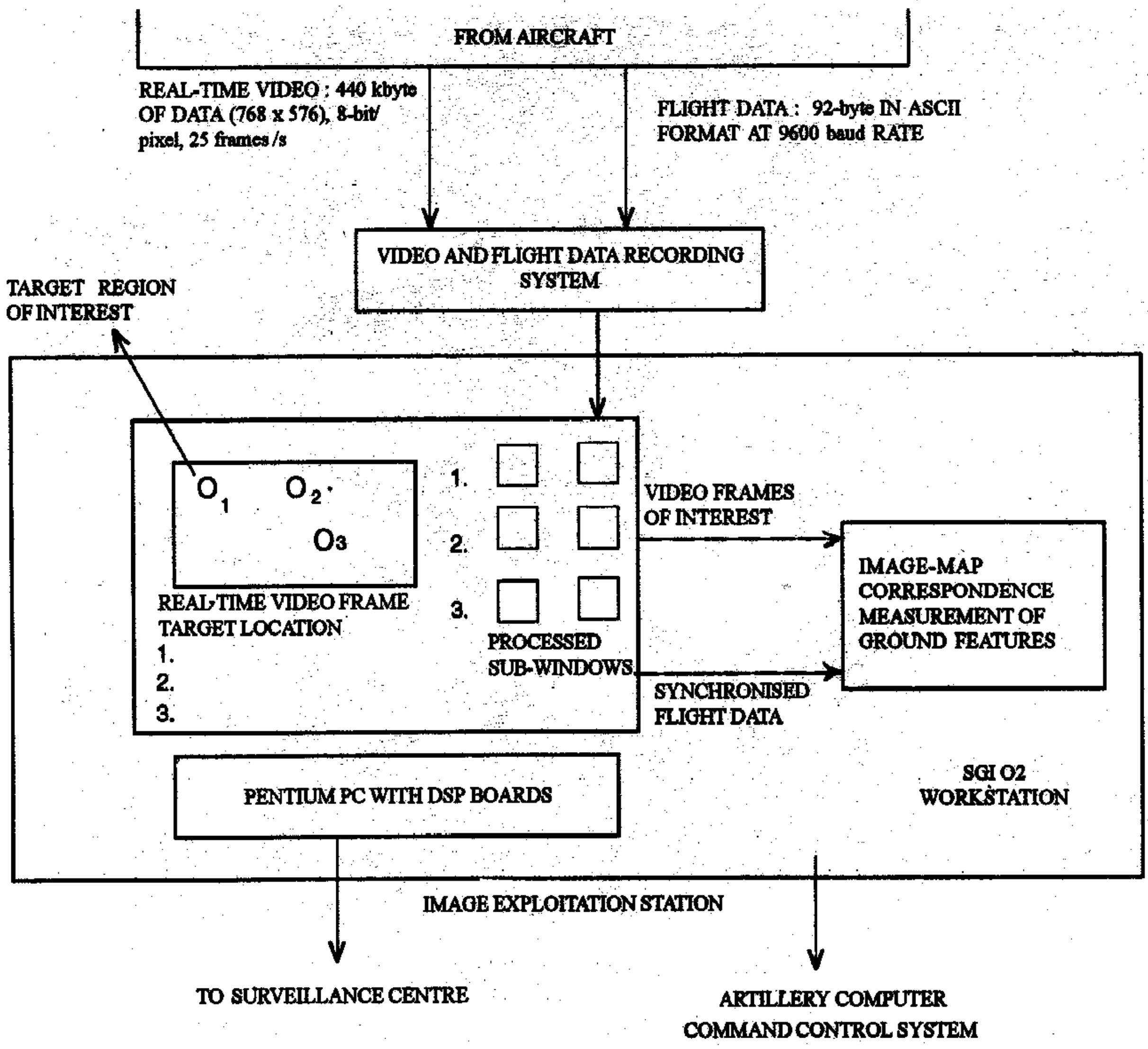


Figure 1. Ground image exploitation system developed at ADE for UAV application

around the target region is preprocessed using image processing routines implemented in hardware of the system [Fig. 2(b)].

3.2 Near-Real-Time Image Exploitation

At any instant during flight, the frames of interest that need further processing are transferred to a silicon graphics workstation using a high speed network. The system acquires and processes specific target points and performs measurement of interesting ground features like width of a road, length of a bridge, area covered by a water body or area inhabited. The system also displays the image frame and the corresponding survey map [Fig. 2(c)]. The information extracted from this exploitation could be used for critical decision-making during flight.

Figure 3(a) shows the user interface in silicon graphics workstation. The survey map of the entire territory covering UAV mission path is loaded in the system. The software calculates the geo-location of the frame centre and selects the appropriate area of the survey map to be displayed. The window marked 1 in Fig. 3(a) displays the geo-location of the GCSs, window marked 2 displays the flight data associated with the frame and the window marked 3 displays the geo-location at the centre point of the frame.

Figure 3(b) shows the accuracy in calculation of geo-location and feature measurement. Both calculation and surveyed result for geo-location of the target launcher in runway and measurement

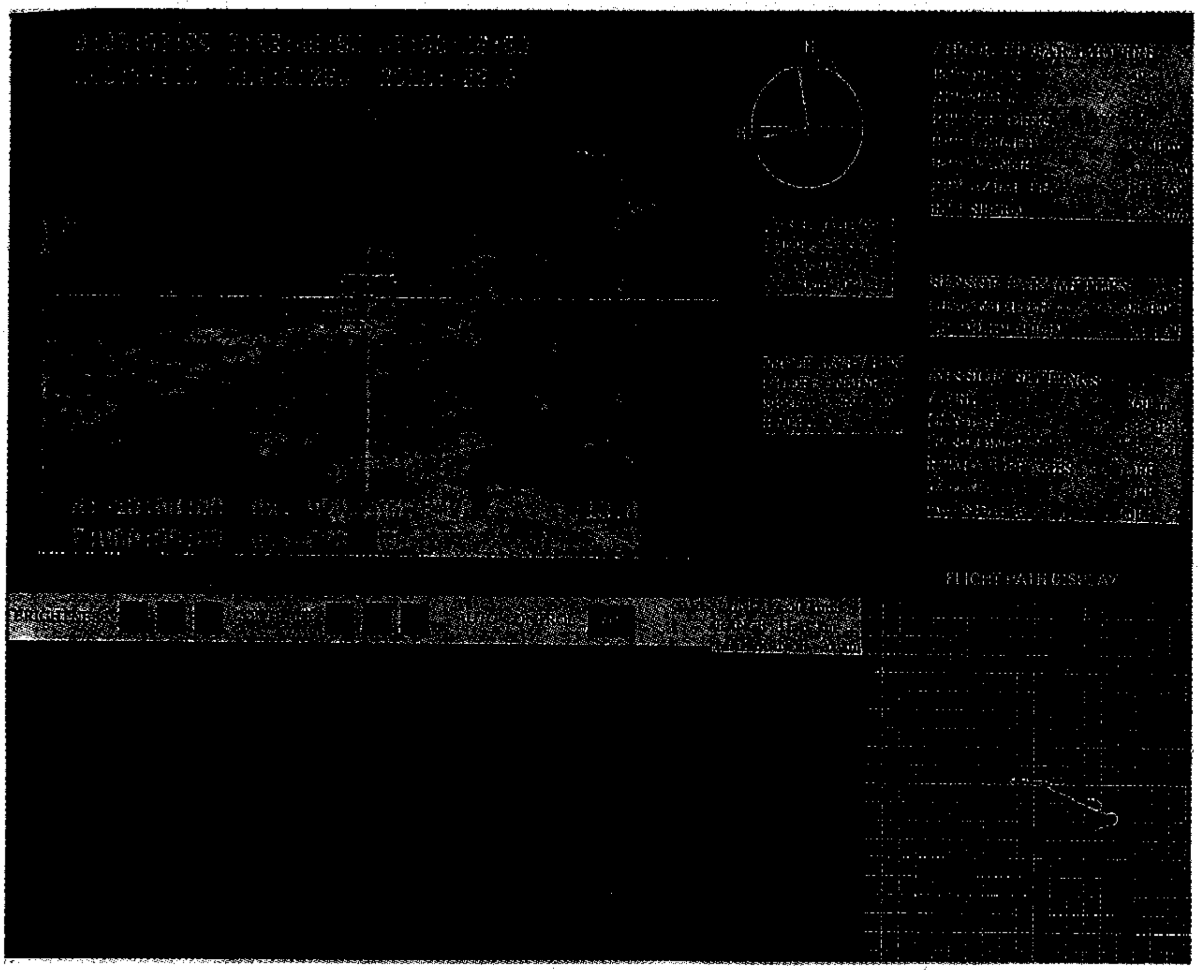


Figure 2 (a). Real-time image exploitation – user interface on PC

of width of the runway is shown in the table in Fig. 3(b). Figure 3(c) shows the image-to-map correspondence, where the target crossroad in both the image and the map is marked with a circle.

The entire software, developed using multitasking and multithreading concept, is written in visual C++ with windows SDK tools. The image processing software runs in the hardware boards. The software in silicon graphics interface workstation is developed using C in Unix and the graphical user interface is developed using open GL. The system works using menu-driven operation.

3.3 Post-Flight Image Exploitation

The post-flight image exploitation consists of analysing the images and interpreting the results to extract useful information, such as restoration of degraded images, classification of terrain, calculation of terrain height using shape from shading and stereo vision.

3.3.1. *Image Restoration*

Restoration[11-12] is a technique that restores the original image from the observed degraded image. The first step for image restoration is to obtain the presence of edges in the image using a suitable edge detector. The extent of blur is calculated using the spread function at points in the centre of the image. The frequency response of the deblurring function is then calculated and used in designing the filter which is applied to the blurred image for restoration. Figure 4 (a) shows the input blurred image of 512 × 512 pixels. The output restored image after six iterations is shown in Fig. 4 (b).

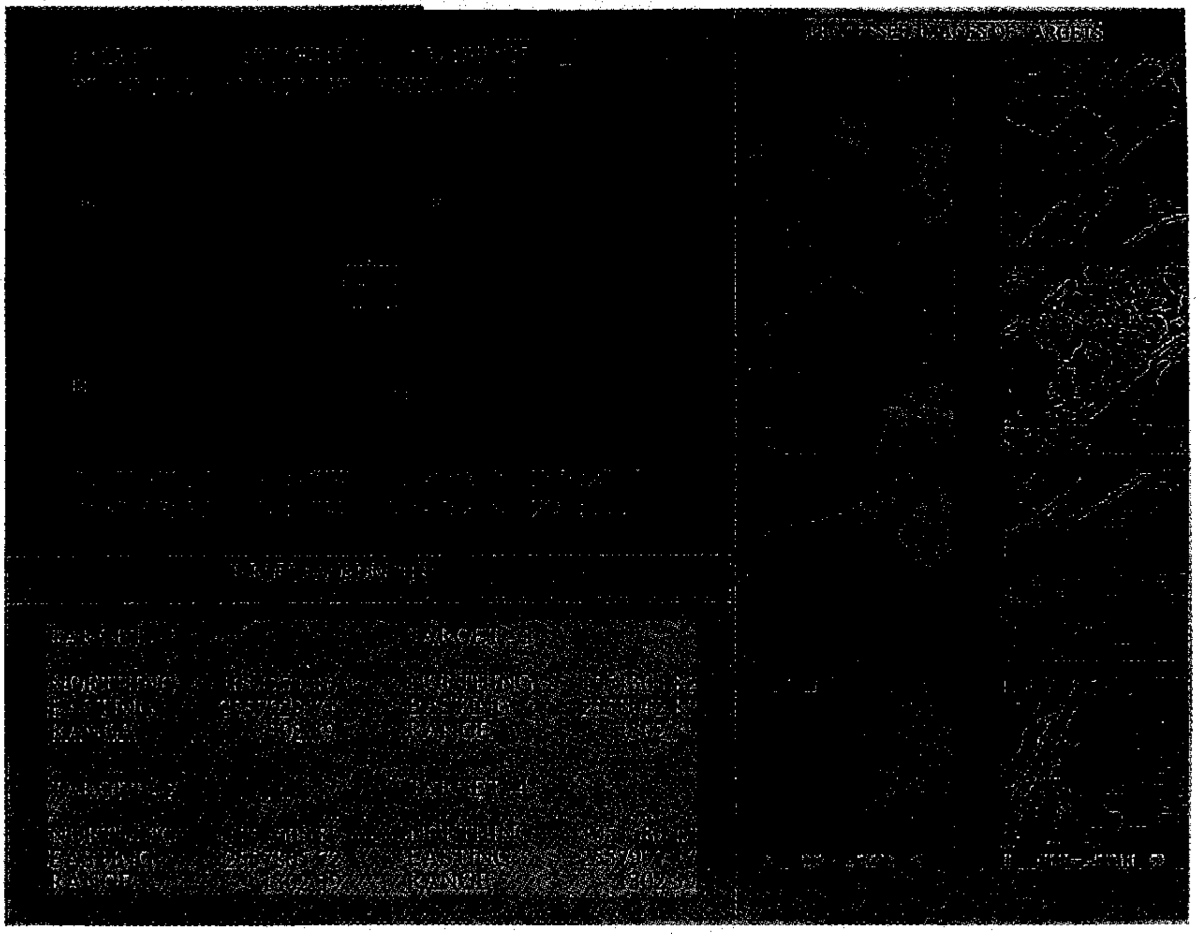


Figure 2 (b). Real-time image exploitation – calculation of target location

3.3.2 *Terrain Classification Using Texture*

The goal of texture analysis[13-14] is to produce a segmentation of the input image, where each region is identified by the texture class it belongs to. In this study, important features in the images, viz., water bodies, bare land, forest and grassy areas are classified based on texture segmentation result. The factors on which success in texture analysis depend are the choice of textural features that can discriminate one region from the other, selection of appropriate window size for computing textural features and finding a reliable texture boundary. In this study, textural features are calculated using statistics of geometrical attributes of connected regions in a stack of binary images obtained from the textured image. An intensity-based image segmentation scheme which uses a multiresolution pyramid and a refined edge map is employed to improve the texture segmentation result. The individual regions are classified using a database generated from known samples of actual terrain. Figures 5 (a) and (b) show the input image of a terrain and its output image after classification, respectively.

3.3.3 *Shapes from Shading*

The process of extracting the local slope information from the local shading variation is known as shapes from shading[15-18]. The basic approach of SFS is to model the observed image intensity in terms of surface orientation. Using the terrain slopes, terrain heights can be calculated. The shape from shading problem is usually cast as a problem of cost minimisation with a regularisation term to make the problem well-posed. The minimisation of the cost function leads to a set of Euler equations. The quality of the shapes from shading result depends on the parameters chosen

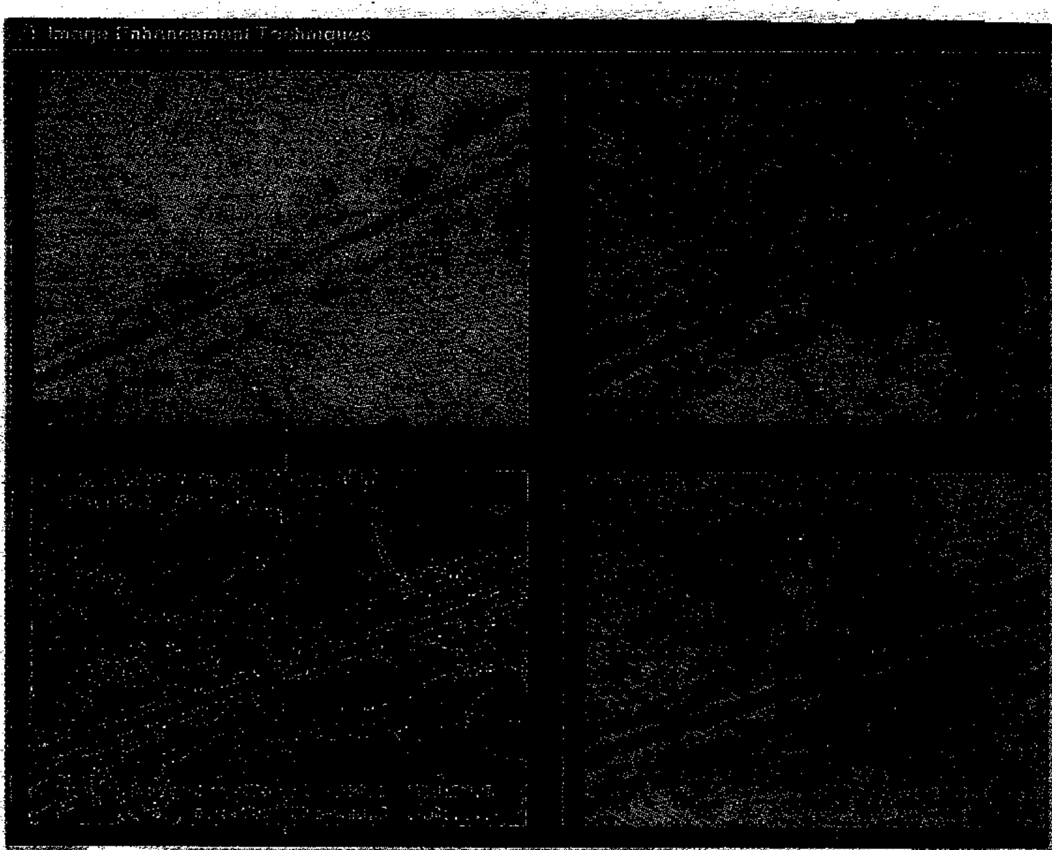


Figure 2 (c). Real-time image exploitation – full frame processing on real-time video

in the cost function and also on the choice of the numerical method. Figures 6 (a) and 6 (b) show the input satellite image and the calculated depth map using shapes from shading method.

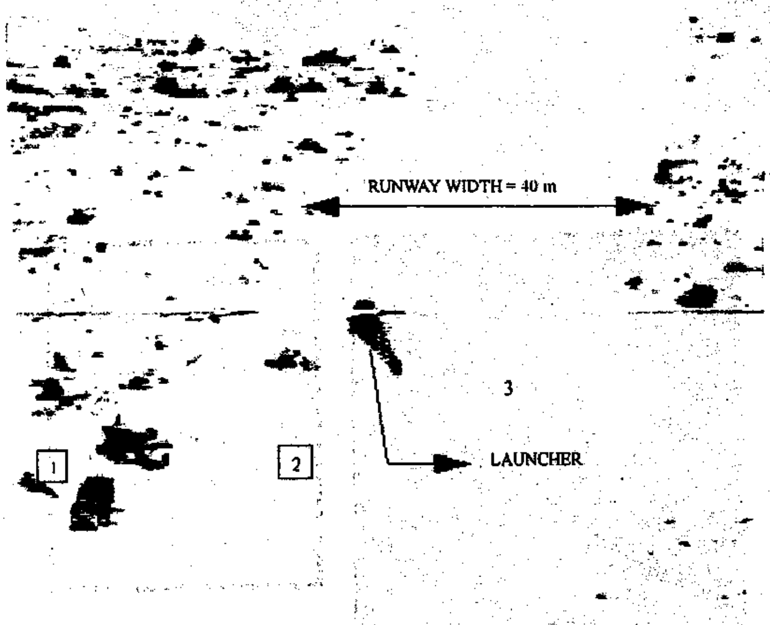
3.3.4 *Shapes from Stereo Vision*

The goal of stereo vision[19-23] is to recover 3-D depth from the images taken from different view points. In this study, the stereo pair of images are formed from the sequence of video images obtained during the flight. The images are preprocessed, aligned and both the edge and the region are used as the primitive features for matching. The pyramids of successively higher and lower resolutions of the original image are used for calculating disparity. The information from area-based and edge-based approaches are merged to get the final disparity map. Depth is calculated from disparity using geometry of the imaging system. Dense depth map is computed by suitable merging and interpolation. The proposed approach is novel, since it uses pyramids of higher and lower resolutions and extract benefits from both. Figures 7 (a) and 7 (b) show a pair of input images and Fig. 7 (c) shows the final depth plot.

4. FUTURE OF IMAGE EXPLOITATION RESEARCH

The image exploitation system will expand the visual range of UAVs by acquiring detailed information about territory without compromising on the safety of soldiers. An image exploitation system would deal with the factors that impair surveillance system, such as darkness, fog, smog, overcast weather, and result in an increase in the detection range.Image understanding algorithms, the key tools used in image exploitation study, will fulfil the requirements of battlefield awareness. The existing image understanding algorithms are too categoric, inflexible and unreliable to cope with the intricacy and the complexity of the real-world scenario. Their reliability barrier is not likely to be broken through incremental improvement of known algorithms. Instead, researchers should develop new

Figure 3 (a). Near-real-time image exploitation – user interface on silicon graphics workstation



LAUNCHER		
	BY CALCULATION	BY SURVEY
LOCATION OF THE TARGET (LAT-LONG)	13-11-11 78-09-58	13-11-11 78-09-57
RUNWAY WIDTH	40 M	44 M

Figure 3 (b). Near-real-time image exploitation – measurement on image – target launcher in runway

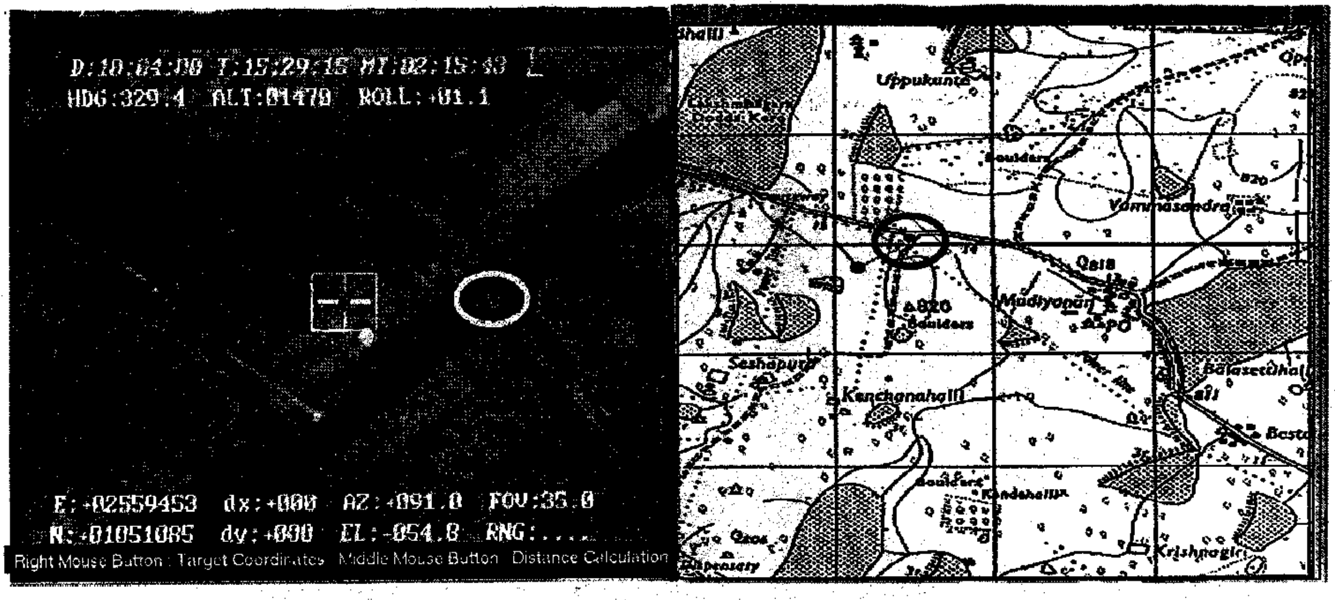


Figure 3 (c). Near-real-time image exploitation – image-to-map correspondence – target crossroad

Figure 4. Post-flight image exploitation – restoration of degraded image (a) input image, and (b) output image

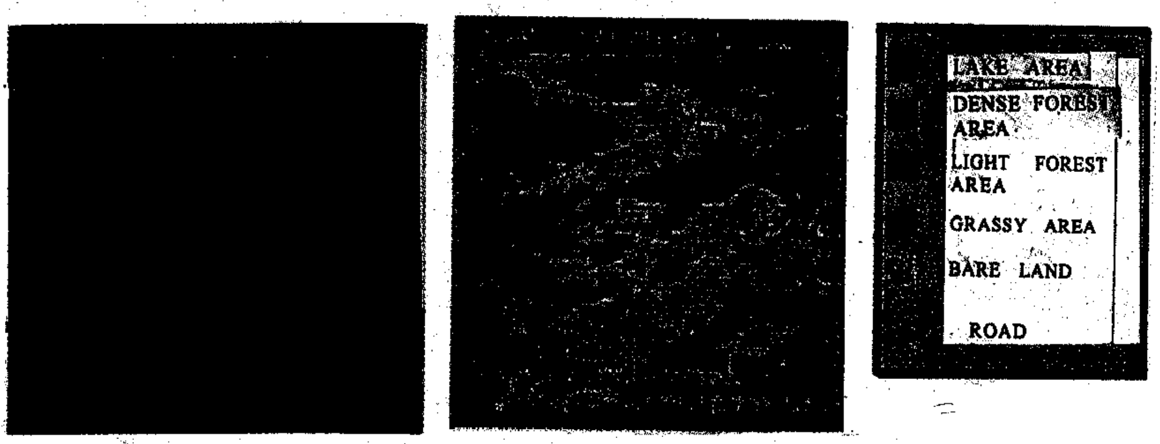


Figure 5. Post-flight image exploitation – classification of terrain using texture (a) input image, and (b) output image

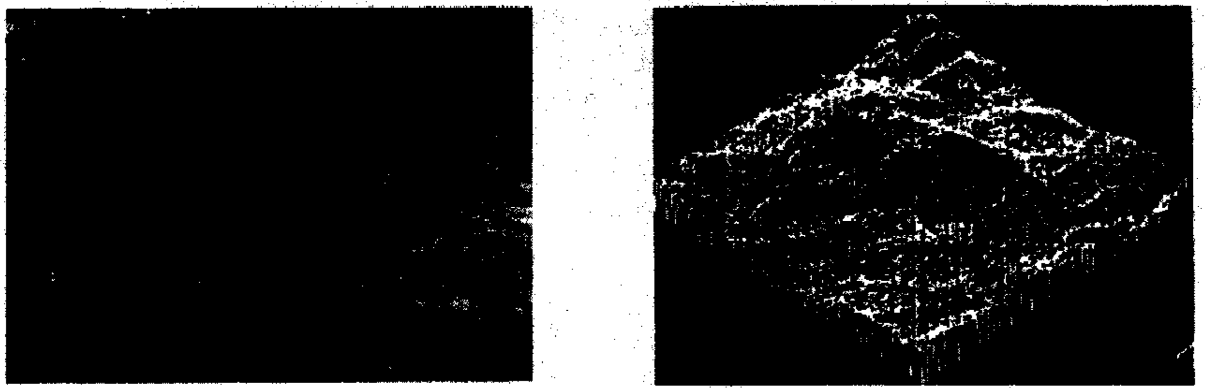


Figure 6. Post-flight image exploitation – shape from shading (a) input image, and (b) output depth map

image understanding algorithms that are tolerant to imprecision, uncertainty and partial truth to achieve tractability and robustness. Comprehensive battlefield awareness will provide military forces a decisive advantage in future military action. The aim of this study is to use imagery collected from UAV or other reconnaissance platform and satellite imagery, a more responsive source to provide battlefield commander with dominant battlefield awareness and a real-time battlefield visualisation for critical decision-making. The future battlefield should be characterised by a rapidly expanding suite of sensors and sensing modalities to collect volumes of imagery from ground, air and spaceborne platforms.

The basic requirements of battlefield awareness are change detecting, site monitoring and activity tracking. Unlike the conventional method of change detection, the image exploitation tool for change detection would develop models to detect the general patterns of changes associated with certain

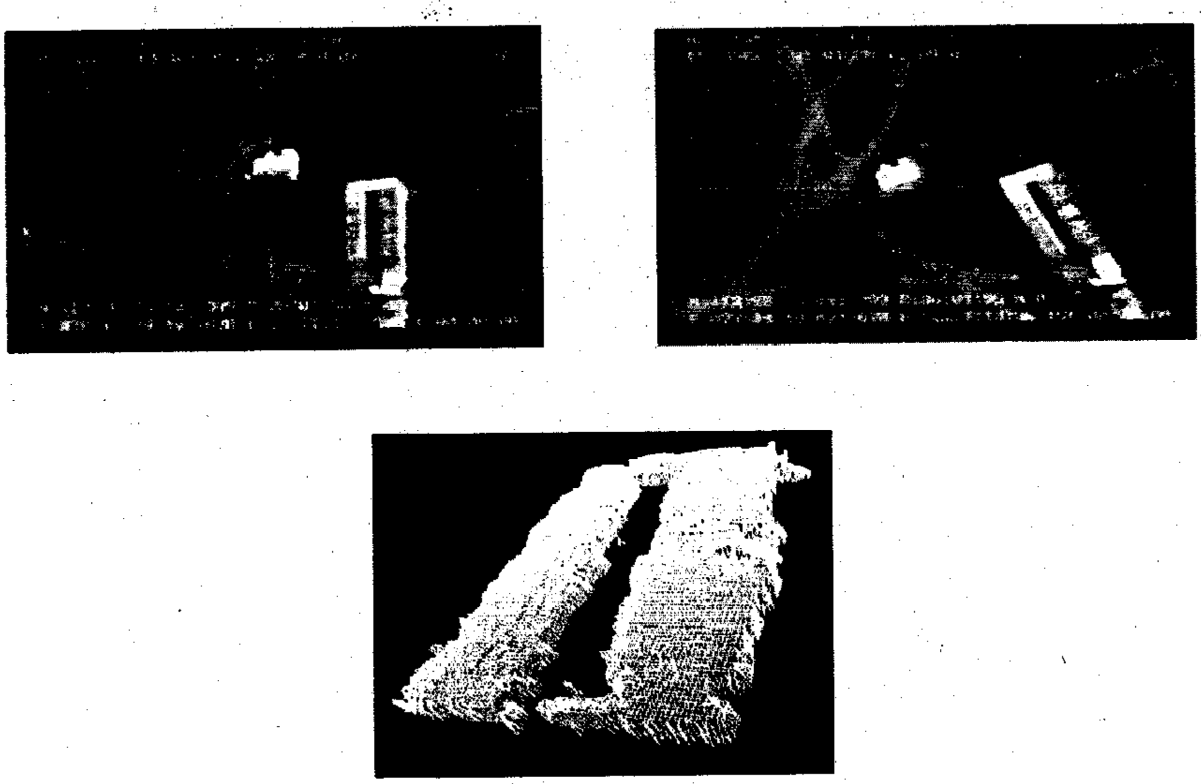


Figure 7. Post-flight image exploitation – depth recovery using pair of UAV images (a) & (b) a pair of input images, and (c) final depth plot.

specified activities, such as construction work, strategic treaty compliance, deforestation, etc. The user-defined model of change would take care of uncertainty in time (due to a change in construction schedule) and space (size and shape of the activity). Special care will have to be taken to monitor areas where weather (e.g. cloud or snowcover) is a factor to depict change.

The technical objective of site monitoring and activity tracking is cooperative surveillance by multiple ground and airborne video sensors to monitor site activity and seamlessly track moving targets. The visual, geometric and symbolic sensor observations together with scene level representation of targets and their environment will be integrated to recognise interactions between human beings, vehicles and buildings and infer whether their actions pose a threat. Successful execution of this activity would enable the commander patrolling long perimeters (strategic borders), detect military activities (movement of important military vehicles, of troops and target activities) in potential battlefield.

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