

M6X00945 Remote Sensing & Imaging Part 1 & 2

by Christopher Budden

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Part 1 – Remote Sensor Platforms

Introduction

There is a new request from the U.K. defence company; QinetiQ, to gain an updated geographical data set for an urban area within the U.K. The requirement is to gain topographical imagery to which is above the neap lowest astronomical tide chart datum. The imagery includes the topographical layer of the Earth's terrain, local structures & access ways within 250m of the mean sea level. The required resolution is 15cm.

This paper will assess the practicalities of obtaining the required imagery data, with the investigation into which types of remote sensing platforms are suited for the task in hand. The various remote sensing platforms will be defined under their methods for obtaining the data set & analytically accessed for their applicability based on the cost, performance, reliability & ease of implementation. A final assessment will be made, based on the comparison of each platform capabilities & a recommendation will be finalised as to which method for obtaining the topographical data is suited for the requested employer.

The recommended remote sensing platform will then be descriptively addressed as to how the gained topographical data set will be processed to georeference the data to 1:1250 Ordnance Survey scale & generate a digital terrain relief model to the same scale.

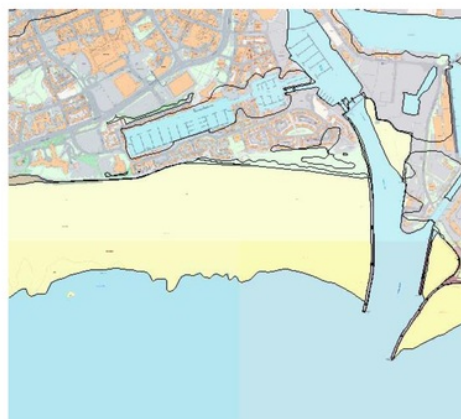


Figure 1

**MapInfo™ 1:1000 MasterMap & OS Terrain DTM Layers;
Swansea Bay Beach**

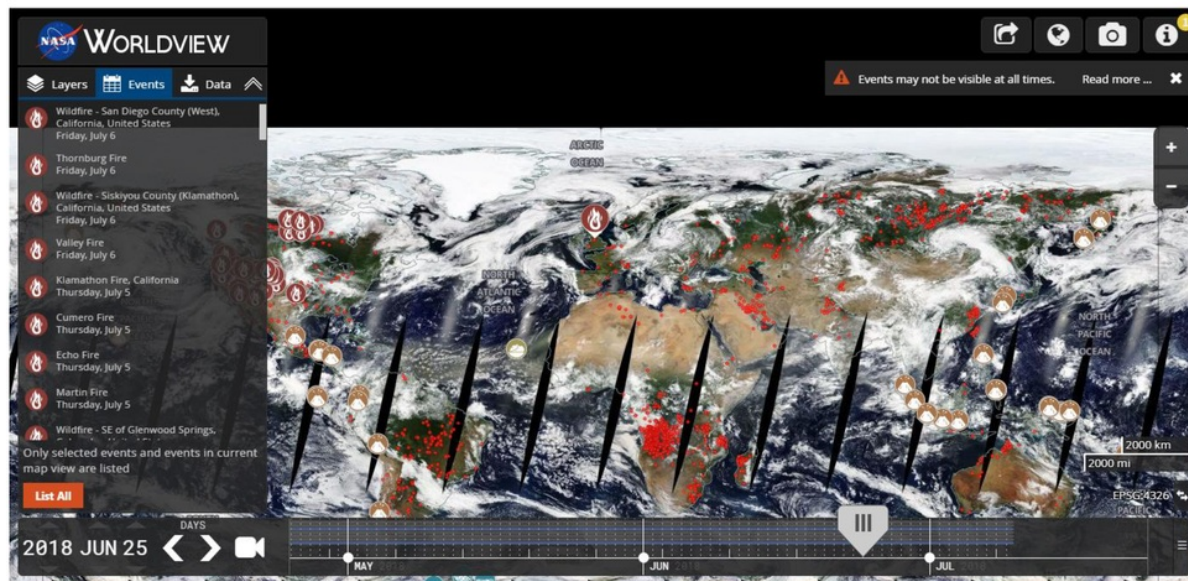


Section A

Sensor Platforms

1. Orbital Satellite Imaging

Satellite imagery is one of the best methods for obtaining geographical images, because of the instantaneous demand for the imagery [1]. Satellite imagery has played a vital role in remotely observing any location on the Earth's surface, from studying climate change, i.e. observing the deterioration of the polar ice caps, gathering hostile activity intelligence, as well as monitoring the weather, i.e. cloud movement & thunderstorms/ hurricanes. Pictured below in Figure 3, Page 3 is the satellite imagery captured by Landsat 8 on the Saddleworth Moor fire, located in the Peak District, UK, June/ July 2018 [2]. Satellite imagery also provides live updates of the current fires on the globe (Figure 2).



NASA World View Fire Events

Figure 2



Figure 3

***Saddleworth Moor fire, Peak District Landsat 8 Image Close-up,
Source: NASA Landsat Image Gallery [2]***

These satellites are in constant orbit of the Earth, therefore, constantly capturing data using such sensors as; Operational Land Imagers (OLI) & Thermal Infrared Sensors (TRIS) to capture different bands within the emitted radiation spectrum, from visible to infrared [3]. However, there is a caveat to having a remote sensing platform that constantly supplies updates of the Earth's terrain, which everyone around the world with internet access can view, hours after the satellite has uploaded its imagery data to the ground station, and that is the repeat time, is 16 days for Landsat 8, as an example [4].

WorldView-4 Satellite

The most recent & highest spatial resolution satellite currently in operational service is the WorldView-4, with a 31cm resolution at an orbital height of 617km. The advantages & disadvantages for using a comparable satellite for capturing observational data are listed in Table 1 below:

Advantages	Disadvantages
Obtain data within 24hrs of capture	Cost \$835M to produce & implement
680,000 km ² area coverage per day	Resolution limited to 31cm at 617km (Panchromatic)
Gather 4 Multispectral Passive Radiation Bands: Red, Blue, Green & Infrared	Service life 5-10 years
Gain geographical data from any location on Earth	Repeat time: 16 days (Sun-synchronous)

Table 1

[5]



2. Aerial Imaging

Fixed Wing Airborne Photography

The disadvantage to fixed wing aircraft for remote sensing is that the flight mission requires a permit & Aerial Application Certificate (AAC) from the Civil Aviation Authority (CAA), especially to fly within areas such as forestry or horticulture areas [6], this is apparent to areas of high aviation traffic, such as commercial airliners near or on the approach to airports. The other restriction that affects the procedure of such data collection is restricted areas, or 'No Fly Zones'. These areas include MoD airbases & firing ranges. All major firing range facilities, such as MoD Shoeburyness, activities are governed by range control, to whom issue the air traffic authorities & Civil Aviation Authority (CAA) a

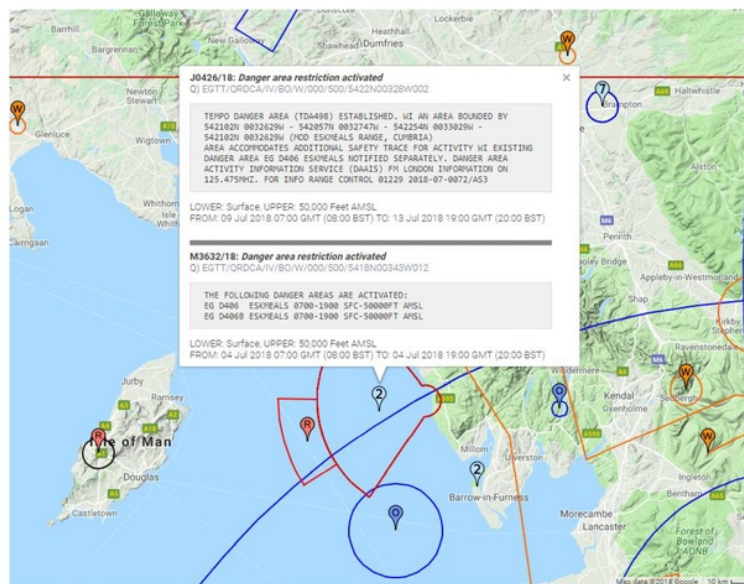


Figure 4

MoD Eskmeals 50,000ft NOTAM Weapon Danger Area, Source: NOTAM Info U.K.

Notice to Airmen (NOTAM) that indicates the weapon danger area. This danger area, in terms of aviation, affects altitude, as ricochets or high velocity fragments are a major hazard to civilian aircraft. The MoD QinetiQ firing range in Eskmeals, Cumbria, issues a NOTAM every firing day, which typically covers an altitude of 50,000ft, Above Mean Sea Level (AMSL) [7]. Figure 4 above illustrates the live danger area coverage & the extended weapon danger area. The advantage of using fixed wing aircraft is the overall cost & effectiveness of mounting such remote sensing equipment. Light aircraft, such as a Cessna 404, can have the internal fuselage modified to mount the remote sensing



equipment. Light, fixed wing aircraft, such as a specially modified Cessna 404 can also be rented for such one off tasks to reduce costs. The effectiveness and speed of deploying the light twin-propeller aircraft is far quicker to gather data than such methods like satellite or hot air balloon.



Figure 5

Cessna 404 (G-MIND) & 406 (G-LEAF) Capturing LiDAR Data

3. UAV/ Drone

UAV's & Drones are becoming more popular with hobbyists & aerial surveyors. As the battery technology is ever improving to output more energy per weight ratio, Lithium Polymer (Li-Po) batteries are making drones smaller, lighter and cheaper to purchase. [8]

Mid-range professional hobby drones, such as the DJI Phantom 3 Professional, can be purchased for under £1000 RRP, features a slight time of 23 minutes & has a gimbal mounted 4K resolution 12.4MPixel camera. [9]. As drones are becoming more popular and more affordable for the general public consumer market, there are new restrictions & by-laws brought out to control the uses of these. One of the issues with using drones to capture geographical data, are the privacy terms. Flying a hobby drone near or around active airports is an offence to the Civil Aviation Authority [10].



Figure 6

DJI Phantom 3 Professional with 4K 12.4M Pixel Camera



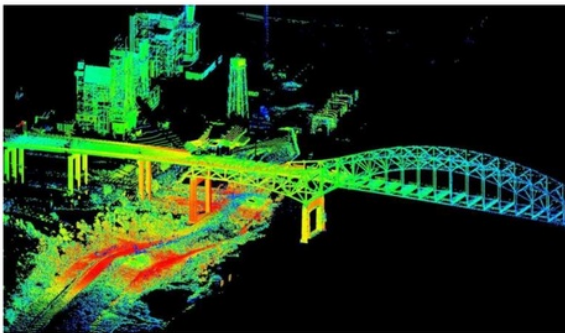
4. Ground based LiDAR (Light Detection And Ranging)

Topographic/ Terrestrial LiDAR

Ground based LiDAR, more commonly known as terrestrial LiDAR is a portable fixed piece of equipment that is mostly mounted to surveying tripods. These terrestrial LiDAR systems are deployed at a vantage point & scan a swathe of an area. Terrestrial LiDAR's is an affordable method of 3-D mapping an environment that produces a highly detailed terrain map. They include a GPS receiver, coupled with an IMU (inertial measuring unit) that synchronises every scanned plot with its respective GPS co-ordinate.

A terrain relief model can then be mapped, shown below in Figure 7, however, the downside to this is that in order to capture 3-D LiDAR cloud points of a wide urban area, the vantage point would have to be constantly moved due to buildings & objects restricting the lasers FOV (field of view).

An example of an affordable Terrestrial 3-D LiDAR scanner is the Leica ScanStation P40, shown below in Figure 8, this particular LiDAR scanner can scan up to a range of 270m with 34% reflectivity & 0.4m minimum scan distance. Accuracy is 6mm at 100m, scan rate is 1 Million points/ second [11].



3-D LiDAR model of New Orleans 510 interstate bridge
Source: USGS

Figure 7

[12]



Figure 8

Leica ScanStation P40 Terrestrial LiDAR Scanner



Bathymetric LiDAR

Bathymetric Lidar is similar to Topographic/ Terrestrial Lidar in the way it operates and plots the gathered returned signal data, but is airborne & solely used to scan areas such as the seabed. Bathymetric Lidar can penetrate the water column as the Laser scanner operates on 532nm wavelength [13]. The advantage this system has is that it can scan the seafloor far more effectively, taking less time to gather the same area data than SoNAR, a study by Bryan Costa et al, in their paper '*Comparative evaluation of airborne LiDAR and ship-based multibeam SoNAR bathymetry and intensity for mapping coral reef ecosystems*', found that comparing LiDAR to SoNAR, specifically, the Multi-Beam Echo Sounder, (MBES), requires 40 hours less time to collect data from the same study area as the MBES SoNAR, with 4 x 5km & 4 x 500m areas that were scanned. The airborne Bathymetric LiDAR is also 6.6% cheaper compared with the MBES SoNAR system [14].

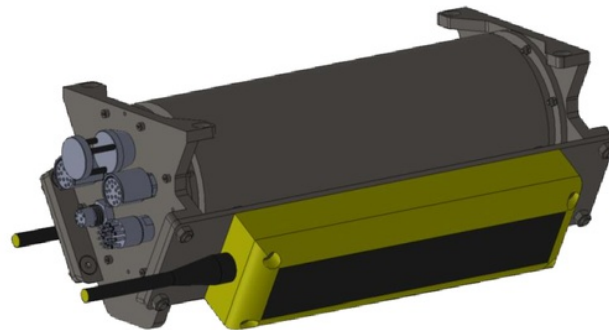


Figure 9

NautiKaris Bathyswath-2 MBES SoNAR

The disadvantage that Bathymetric LiDAR entails when compared to the MBES system is that the system is limited in the depth & resolution that it can scan to. The NautiKaris Bathyswath-2 can scan at a maximum slant range depth of 350m when emitting 117 kHz pulses, down to a resolution of 12mm [15].



The Leica HawkEye III offers:

2 Bathymetric channels;

- 10kHz, for scanning deep water depths down to 50m, density of 0.4 points/ m² at 400-600m AGL (Above Ground Level)
- 35kHz, for shallow water & costal mapping down to 2m depth, density of 1.5 points/ m² at 400-600m AGL (Above Ground Level)

1 Topographic channel

- 500kHz, for topographic land mass modelling, density of 12 points/ m² up to 1,600m AGL (Above Ground Level)

[16]



Figure 10

Leica HawkEye III Bathymetric & Topographic Airborne LiDAR



Section B

Platform Methodology Selection

The ideal remote sensing platform for obtaining topographical data at a resolution of 15cm would be the age old fashioned fixed wing aircraft with the Leica HawkEye III & Hi-Res camera system. Drones/ UAV's would be the 2nd choice, but is trumped by the limited weight of the sensors they can carry, not able to carry LiDAR scanner & the Civil Aviation Authority (CAA) restrictions, giving airspace priority to fixed wing aircrafts. Satellite remote sensing would not be cost effective for the limited use of capturing DTM (Digital Terrain Model) & Topographic data & will not fulfil the requirement for its resolution of 15cm and ability to give a DTM from LiDAR.

Satellite Vs Fixed Wing Aircraft

Fixed wing aircraft is best suited for the task in hand when compared with satellite imaging based on these reasons;

- Satellites cost millions (\$835M *WorldView-4*) to manufacture & launch into space
- Satellites take years to develop, once the satellite is finalized, the sensor technology has already evolved & improved
- Satellite failures are critical, once it's in orbit, repairs are near impossible
- Fixed wing aircraft are abundant & can even be rented for temporary use [17]
- Satellite LiDAR doesn't offer same geospatial accuracy as airborne LiDAR [18]

Drones/ UAV's Vs Fixed Wing Aircraft

Below is a comparison table of the two preferred remote sensor platforms, thus a suitable method will be apparent through this table;

Drones/ UAV's		Fixed Wing Aircraft	
Advantages	Disadvantages	Advantages	Disadvantages
Low cost, <£1000 for professional amateur variant	Limited range & height	Mount various sensors (Hi Res cameras/ LiDAR)	Higher cost of purchasing/ renting aircraft, sensors/ scanners & storage than drones
Quick deployment, lightweight & easy to transport	Prohibited from high traffic areas	Higher spatial resolution due to versatility of mountable sensors	Requires Air Traffic Control authorisation



Easy to fly & capture aerial footage/ images	Limited weight capability for different sensors	Wider area of scanning coverage	Limited minimum altitude
No additional costs for flying & capturing	Cannot fly in treacherous weather/ high winds	More stable flight than drones	Aircraft requires strict maintenance & pre-flight test procedures

Table 2

Section C

OS Survey 1:1250 Georeferencing

The Topographical Raster imagery obtained by the aerial photography, to which after the sensor platform has flown its mission, is considered as 'Raw data'. Because the imagery has no references within the data yet, correlation & correction needs to be applied to the 'Raw' Raster imagery before they are scaled to 1:1250 OS Survey mapping.

In summary, georeferencing is the art of correlating datum points in the Raster image to known physical fixed surveyed points within that image. The process consists of image transformation, due to the tilt of the camera & rotation of the Earth, as well as relief displacement [19].

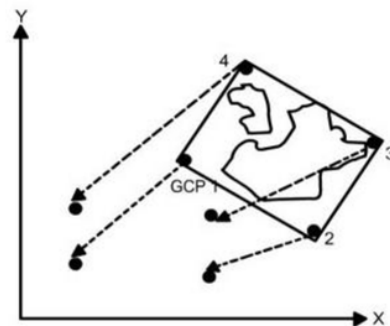


Figure 11

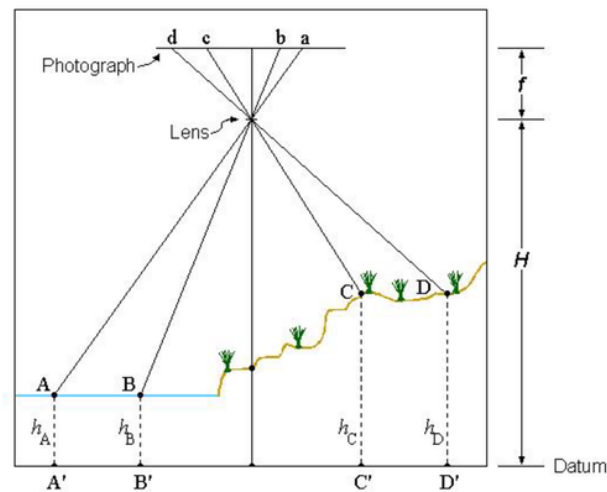
Georeferencing with Geographic Data & Ground Control Points (GCP)

Figure 11 above is a basic illustration of the georeferencing principle, at least 3 Ground Control Points, (GCP) are needed to project the geographical Raster image onto the coordinate system, i.e. map projections, such as;



- Cylindrical (Straight Parallel Coordinate Lines)
- Conic (Cone Constant, Angular Distance Between Meridians)
- Azimuthal (Geodesic Arcs)
- Space Oblique Mercator (Satellite Elliptical Orbit Projection) [20][21]

The more GCP used over the Raster spatial image, the less distortion & inaccuracies will be apparent during the image correction stage. Relief displacement occurs during aerial photography when elevations in the Earth's surface, such as mountainous terrain, alter the actual ground distance. This is due to the camera's focal length & the distance of the terrain from the Nadir point.



Relief Displacement Error

Figure 12

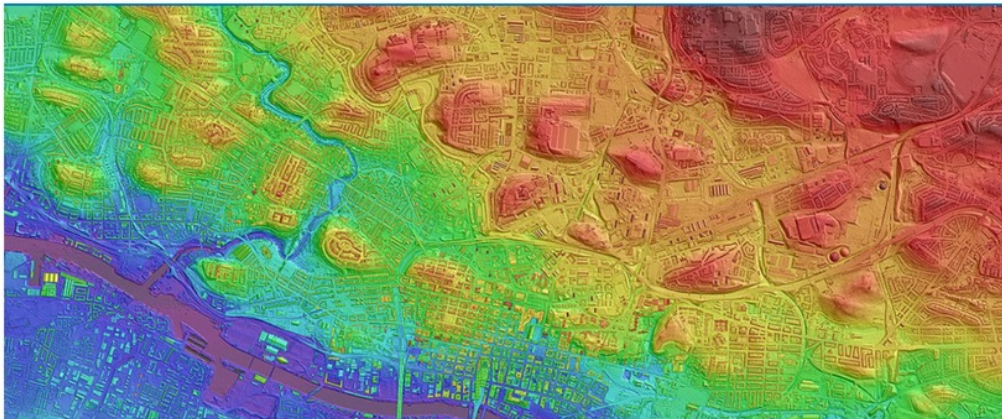
Figure 12 above illustrates this effect, because points A & B are on a flat surface, the distance shift can be corrected easily, as the surface is flat and linear. Points C & D are exact ground distances as A & B, but due to the change in elevation, the slope distance from the focal length is shorter, creating more image distortion that's harder to correct. This is because the camera & lens cannot determine variations in ground height & sees the terrain as a flat image.



Post-processing & O.S. Scale Modelling

The digital terrain relief modelling of the littoral zone of interest will need to be created from the gathered LiDAR data, as LiDAR measures distance of the terrain around it. When the LiDAR data is downloaded and extracted, the next stage is to create a DTM (Digital Terrain Model), or a DSM (Digital Surface Model). However, in order for this data to be Georeferenced to the 1:1250 OS Topographic data, a GPS device coupled with an IMU (Inertial Measuring Unit) will need to be used, so that the plotted LiDAR data points are referenced to a coordinate [22].

The LiDAR DTM itself would need to be georeferenced, the same as Topographic & 1:1250 OS master map Raster images to a base map. As the different sets of data are essentially layers, displaying various types of information within that layer, i.e. elevation levels, & objects & boundaries for Topographic, a DEM (Digital Elevation Model) from ALM (Airborne Laser Scanning) would have to be used, as this is the correct projection for mapping. Ground based LiDAR is intended to create a 3D mapped environment, giving millimetre precision [23]. Aerial based LiDAR typically requires the aircraft to cruise at an altitude of 1000m AMSL (Above Mean Sea Level). The raw LiDAR data then needs to be 'Devegged' in order to remove unwanted objects, such as trees & street lamps.



LiDAR Height Data, Source: BlueSky



Conclusion

It has come to the conclusion that the fixed wing aerial sensor platform is best suited, based on cost Vs performance. Although drones are the obvious and cheapest alternative, this doesn't offer the flexibility to provide high level detail & accuracy for obtaining the resolution & terrain height measuring that is required, drones are only capable of remotely sensing small spatial areas at a time. Satellites are of course the best choice if an area of the world is hard to access & rapid data collection is needed from thousands of miles away, however, the cost impedes this.



Part 2 – MATLAB Image Processing

Introduction

An experimental task is carried out to obtain high resolution imagery on man-made scale structures, to access the pre & post 'event' with the aid of image machine vision processing, using a mathematical software tool: MATLAB, to generate segmented morphological images.

Man-made scale sand structures were fabricated on Swansea bay beach, Coordinates; 51°36'48.1"N 3°55'54.1"W. These scaled structures included features such as turrets, moats, fortifications & bridges, to simulate a hostile military base. A DJI Phantom 3 Pro™ is employed to capture 4K resolution video imagery by the bird's eye perspective of the man-made structure. Video data is captured prior & post catastrophic event to part of the structure.

The two images, pre & post event, were imported into MATLAB via frame grab script at a specified time interval of interest. A second script is then run to convert the raw video frame capture, to which the image is made up of; Red, Green & Blue (RGB) channels, to a grey-scale image for it to be morphologically processed to transform the grey-scale image to a structured matrix element, so that image processing parameters can be adjusted; Strel size, Opening disc size, Dilation & Pixel radius for the algorithm of marker controlled water shed segmentation to be overlaid over the original grey-scale image.

The final outcome is to extract the maximum number of valid whole features from the original image through the image filtering parameters in the morphological transformation process & compare the two processed images to ascertain the damages & effects within the image.



Figure 14

DJI Phantom 3 Professional with 12.4M Pixel 4K Camera



Section D

MATLAB Image Processing Methods

Video imagery is obtained by a 4K resolution 12.6M Pixel camera of the aerial footage. The video files were then saved as a .mov format in preparation for the image processing.

MATLAB R2016a software is used for the image segmentation of the footage. In order to process the site aerial footage, frame grabs are employed in MATLAB at particular frame instances. The purpose of using segmentation machine vision process, is so that objects or shape outlines can be transformed from a raw image, that appears as a flat dimensionless picture to a computer, that only has contrast & colour to distinguish objects within the picture, to an image that a machine can define the depth, size, outline & separate objects within that image, a process that us humans are constantly carrying out when viewing objects.



Sand Castle Fortification Site: 51°36'48.1"N 3°55'54.1"W

Figure 15

Figure 15, pictured above is the aerial drone footage of the site section that is of interest. This section of the scale sand fortification is chosen as the turrets on the fortification wall are of discrete shapes that are distinguishable from the other features around it. This is also the section that an



'event' will occur, 'event' being a targeted attack to this area. The segmentation image machine vision process will show the before & after event images, so that MATLAB overlay & outline watershed lines from the raw image shapes, for the fortification castle turrets.

GrabVideoFrame.m

The script, GrabVideoFrame.m, is used purely to take a video frame image from the video recording, taken from the DJI Phantom 3 drone. The script is as follows;

```
1 function [ I ] = GrabVideoFrame( videofile, time )
2 %GrabVideoFrame takes a frame of 'videofile' at a time 'time' and converts
3 %it to a greyscale image I.
4
5 v = VideoReader(videofile);
6 v.CurrentTime = time;
7 rgb = readFrame(v);
8 I = imresize(rgb2gray(rgb),0.25);
9
10 end
```

MATLAB 'GrabVideoFrame' Script

Figure 16

In summary, what the task that this script carries out is;

The '**segmentation.m**' MATLAB script uses the '**GrabVideoFrame.m**' to work from the selected .mov file in the MATLAB current folder directory, it then takes a frame at time= η , η being the calculated video frame time in seconds from the start of the video. The '**GrabVideoFrame.m**' then stores that frame image as rgb (Red, Green, Blue) pixels, shown in line 7, Figure 16, then resizes the 4K image to $\frac{1}{4}$ of the original size (0.25), this is done as the original resolution is in excess of that MATLAB can process. Then converts this scaled image to a grey-scale image (rgb2gray(rgb)), shown on line 8. Then it stores this gray-scaled image as a variable; [I], Lines 1 & 8.

Segmentation.m

This script is where the image processing is undertaken, as mentioned in the previous section; '**GrabVideoFrame.m**', the video file name is manually typed in; i.e. 'videofile = 'DJI_0018.MOV';' & the calculated frame time, i.e. 'time = 315; ' so that '**GrabVideoFrame.m**' can carry out this task of fetching the frame image.



The frame time is to be entered in seconds, from T0 (Time Zero), T0 being the start of the recording. A simple conversion from mm:ss (minutes & seconds) is calculated by multiplying the minute duration by 60, then adding the remaining seconds;

$$5m\ 15s = 5m \times 60 = 300s + 15s = 315s$$

Image Processing Parameters & Morphological Image Processing

Once the video frame time that is of interest is chosen & frame time calculated, the segmentation image machine vision processing is carried out using the following script commands:

Strel Size

Strel, by definition is a structuring element, there are two types, one of which is a flat dimension; 'A *flat structuring element* is a binary valued neighbourhood, either 2-D or multidimensional, in which the true pixels are included in the morphological computation, and the false pixels are not' [24]. It is illustrated below in Figure 17.

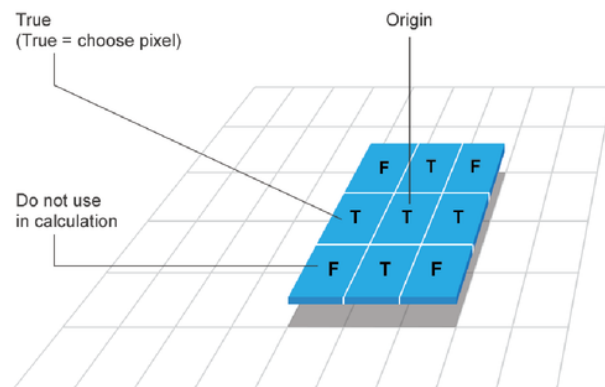
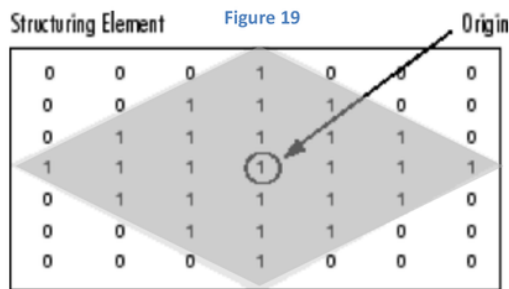


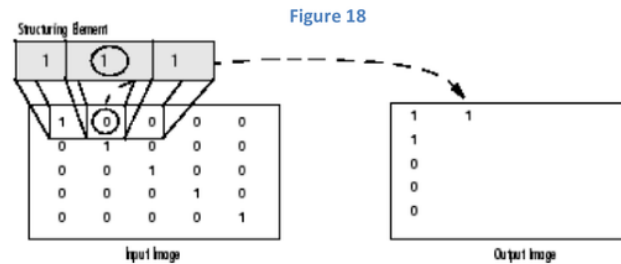
Figure 17



The 'Strel' function creates an output image structure that is digital, 1's & 0's to which is morphologically processed from a grey-scale input range image. It takes an origin pixel, and compares it with the neighbouring pixels around it, and from this, can generate a binary matrix table



Diamond-shaped Origin Structuring Element



Morphological Dilation Output Matrix

from a flat dimension grey-scale. The size of the 'Strel' is the radius of the processed pixels from the origin, or in other words, depending on how many neighbouring 'True' value pixels compared with the Strel size, can dilate or erode. Figure 19 above, shows a flat grey-scale structuring element with the diamond shape around the origin. The 'Strel' size should be best fitted to the same size as the shape to be morphologically processed [25].

Opening Disc Size

The function; `'se = strel('disk', OpeningdiscSize);'` creates a disk shape for the reconstructed image pixels. The disk size refers to the radius of the disc, measured in pixels. It is a post processing relation to the 'Strel' function.

Dilate Size

By definition, the dilation function is; *'The morphological dilation operation expands or thickens foreground objects in an image.'* [26]

numPixels

'Maximum number of pixels in objects, specified as a nonnegative, integer-valued, numeric scalar.'

Example: `BW2 = bwareaopen(BW, 50);` [27]



```

1  clear vars;
2
3
4  videofile = 'DJI_0018.MOV';
5  time = 315;
6
7  StrelSize = 4;
8  OpeningdiscSize = 4;
9  dilateSize = 7;
10 numPixels = 10;
11
12 I = GrabVideoFrame( videofile, time );
13 I = imadjust(I,stretchlim(I),[]);
14 hy = fspecial('sobel');
15 hx = hy';
16 Iy = imfilter(double(I), hy, 'replicate');
17 Ix = imfilter(double(I), hx, 'replicate');
18 gradmag = sqrt(Ix.^2 + Iy.^2);
19
20 se = strel('disk', OpeningdiscSize);
21 Io = imopen(I, se);
22
23 Ie = imerode(I, se);
24 Iobr = imreconstruct(Ie, I);
25 Ioc = imclose(Io, se);
26
27 Iobrd = imdilate(Iobr, se);
28 Iobrcbr = imreconstruct(imcomplement(Iobrd), imcomplement(Iobr));
29 Iobrcbr = imcomplement(Iobrcbr);
30
31 fgm = imregionalmax(Iobrcbr);
32
33 I2 = I;
34 I2(fgm) = 255;
35
36 se2 = strel(ones(StrelSize,StrelSize));
37 fgm2 = imclose(fgm, se2);
38 fgm3 = imerode(fgm2, se2);
39
40 fgm4 = bwareaopen(fgm3, numPixels);
41 I3 = I;
42 I3(fgm4) = 255;
43
44 bw = imbinarize(Iobrcbr);
45
46 D = bwdist(bw);
47 DL = watershed(D);
48 bgm = DL == 0;
49
50 gradmag2 = imimposemin(gradmag, bgm | fgm4);
51 L = watershed(gradmag2);
52
53 I4 = I;
54 I4(imdilate(L == 0, ones(dilateSize, dilateSize)) | bgm | fgm4) = 255;
55
56 Lrgb = label2rgb(L, 'jet', 'w', 'shuffle');
57
58 figure
59 subplot(2,1,1);
60 imshow(I)
61 hold on
62 himage = imshow(Lrgb);
63 himage.AlphaData = 0.3;
64 %title('Lrgb superimposed transparently on original image')
65 subplot(2,1,2);
66 imshow(Lrgb);

```

The image processing & segmentation algorithm is shown here in Figure 20, from lines 1 to 66. As we know that lines 7-10 are the filtering parameters as described in the section above & what they do, they are stored as variables & used in the next stages of the processing, which starts from line 12. 'GrabVideoFrame' is also used as a sub-routine within the scripts algorithms.

'hy = fspecial('sobel');' creates a high pass filter & applies this filter to the Y axis of the image.

Line 12, as just mentioned, grabs the video file for the RGB frame the specified time. 'Imadjust' stretches the grey-scale contrast of the image to a binary format of 0-255 decimal value.

lobr is Image opening by reconstruction, which by definition is; *'opening is the dilation of the erosion of a set A by a structuring element B:'*

$$A \circ B = (A \ominus B) \oplus B,$$

[28]

'himage.AlphaData = 0.3;' This function holds the image (himage) & sets the transparency to 30%, of which the reconstructed image is overlaid over the original grey-scale image.

Figure 20



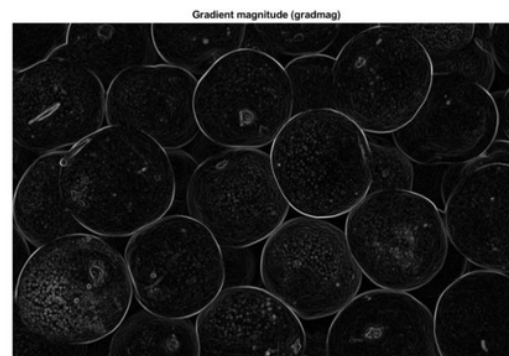
Marker Controlled Watershed Segmentation

Watershed Segmentation is the process of defining ridgelines and boundaries, much like rivers that separate land. The function separates touching objects by creating 'watershed ridgelines', through treating light pixels as high from the surface, and dark pixels as low [29].

By definition; '*Marker based watershed transformation make use of specific marker positions which have been either explicitly defined by the user or determined automatically with morphological operators*' [30].

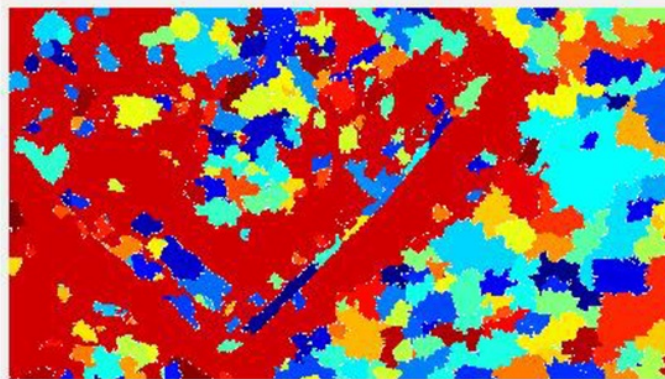
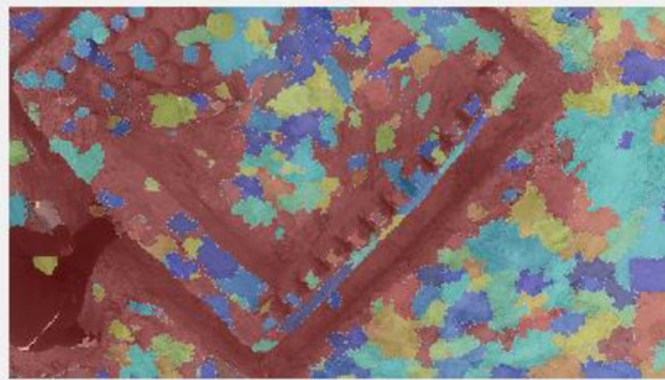


Image courtesy of Corbis



Segmented Watershed Transformation

Figure 21



Segmented Image: 'DJI_0018.mov' at 270 seconds

Figure 22

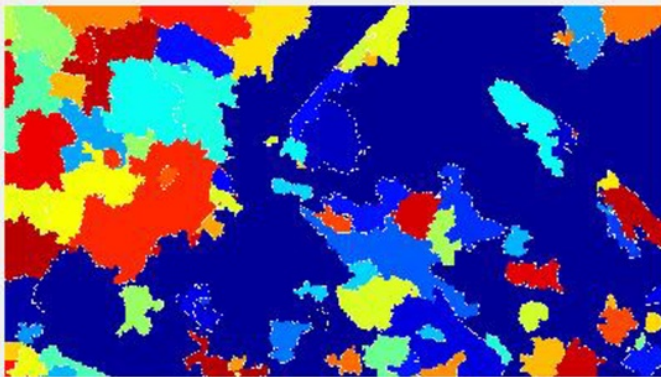
with some of the turret features that are almost recognisable when compared with the original grey-scale image.

The video file; 'DJI_0018.mov' is chosen to proceed the image segmentation upon. Upon analysis of the video footage, the time of 270 seconds was chosen as of particular interest. This was based upon the close in view & directly over the top of the castle turrets of the fortification to be targeted.

Manually adjusting the filtering parameters, the values were entered that gave the maximum possible valid whole features of the turrets;

```
StrelSize = 7;  
OpeningdiscSize = 7;  
dilateSize = 2;  
numPixels = 1;
```

Pictured here in Figure 22 (Top left) is the original grey-scale image with the segmented image superimposed over the top, with a transparency of 30%. Figure 22 (Bottom left) is the segmented machine vision image, as you can see, there is a noticeable outline of the outer wall of the fortification,



Segmented Image: 'DJI_0019.mov' at 9 seconds

Figure 23

Figure 23, shown here (Left), is the segmented image of video file; 'DJI_0019.mov' at 9 seconds.

This segmentation was harder to implement compared to the pre-event image, as the image processing algorithms took considerably more time to produce adequate segmented results.

The segmentation values used are as follows;

```
StrelSize = 6;  
OpeningdiscSize = 9;  
dilateSize = 5;  
numPixels = 5;
```

The bottom left segmented image in Figure 23 is harder to distinguish the fortification turrets, partly because of the collateral damage to the other turrets along the fortification wall.

Another factor is the angle at which the camera is positioned over the features. In the pre-event image, the drone was directly over the top of the fortification turrets, which made it easier to segment the discrete outlines. However, the post-event image is at a slight angle from the Nadir point, and in a different position as that of the pre-event image.



Section E

Image Processing Accuracy Factors

There are accuracy factors to consider when comparing before & after morphologically processed images. Physical factors such as consistency of the images that are taken, as the drone has taken the first image from a specific 3-dimensional position, offset, setback & height, the filtering parameters that are used to extract as many valid features as possible are 'tailored' for that image of instance. For example, the pre-event image; 'DJI_0018.mov' at 270 seconds, used the filtering parameters as follows;

```
StrelSize = 7;  
OpeningdiscSize = 7;  
dilateSize = 2;  
numPixels = 1;
```

These filtering figures are manually adjusted as stated. However, there is an underlying issue with the drone footage that was captured. The pre & post images that were extracted in MATLAB from the drone footage shows that both images were not taken in the exact 3-dimensional location, thus causing variations by factors such as; size of the ground objects/ shapes, contrast, rotation of the image, etc. What could have been implemented was the addition of the GPS co-ordinates of the drone position when the footage was captured. Further video editing would be needed to be carried out to gain a better accuracy of the two images.

During the image processing of the two images, it was clear that different values had to be used to extract the most segmented features within the pictures. As stated above, the image processing values differ to that of the second video frame capture; 'DJI_0019.mov' at 9 seconds;

```
StrelSize = 6;  
OpeningdiscSize = 9;  
dilateSize = 5;  
numPixels = 5;
```



As the filtering values differ, coupled with the variation in image capture position & rotation, a subtraction of the two images cannot be undertaken to leave the remainder of the changes within the image, i.e. the destruction to the fortification.

Other factors that will affect the accuracy of the image processing are the resolution that the frame grab images were stored within MATLAB. Upon further investigation at the time of the image processing, the reduced resolution from the original image, from 4K to 1K, made the segmentation process extremely difficult to pick out valid features due to reduced definition. To overcome this, the original resolution was kept when the '*GrabVideoFrame.m*' script is run. This ultimately prolonged the processing time of MATLAB, but the level of detail was adequate to then process the images.

It was found that difficulties arose during the image processing, in that, gaining sensible watershed segmentations, due to the ground surface being the same material & colour as the features within the images. This only gave the algorithms a limited range in grey-scale contrast to work from.

Section F

Impact & Uses of Processed Images

These morphologically processed machine images have many uses, depending on the application of interest. In terms of remote sensing for reconnaissance aerial imagery, MATLAB can calculate; i.e. how many fighter jets an enemy airbase has. Although one aerial image can determine this, a second or succeeding aerial image capture can determine the addition or subtraction of fighter jets, by using the image subtraction function;

```
X= imread('I4'); J= imread('I5');  
K= imsubtract(X,J);
```

[31]

For geological use, satellite imagery is used to determine the effects of global warming on the polar ice caps [32].

Image segmentation processing is now widely adapted into A.I. (Artificial Intelligence) machines. This segmentation image process is the fundamental for transforming a raw image that the contents within that image doesn't represent anything I'm machine language, and being able to identify



objects from the A.I.'s database. This technological advance is being implemented into A.I. robotics [33].

The impact that the task in hand has upon usefulness, is determine the extent of the destruction of the structural changes for the hostile fortification.

Conclusion

The use of morphological image processing & watershed image segmentation gives the ability of machine vision, to where these two techniques can separate an image into shapes, to which firstly appeared as a spectral array of red, green & blue pixels. The factors that affect the machine vision process, when comparing two images of the same scene is grossly affected by the change in light (or contrast), object size & field of view depth. This is because there are variations from the two images, i.e. the same object reflecting more light on the second image when compared with the first.



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RESEARCH-INFORMED LITERATURE



A very good range of reference material cited.

6.5

KNOWLEDGE AND UNDERSTANDING



Very good, detailed descriptions of the algorithm functions and their application in the segmentation process.

17

ANALYSIS



Evidence of logical thinking and a good analysis of the segmentation process

20.4

PRACTICAL APPLICATION AND DEP.



A good application of the methods although it would have been good to see the two images side by side

7.2

SKILLS FOR PROFESSIONAL PRAC.



A well presented report, coherent and well structured.

6.5