DETECTION AND IDENTIFICATION OF OBJECTS IN APPLICATIONS OF GIS

Konrad Maj, Paweł Pabisiak, Grzegorz Stępień

Miliatary University of Technology

Kaliskiego Str, 2,

00-908, Warsaw, Poland

gelo79se@o2.pl

Key words: Imagery Intelligence, resolution, interpretation key, GIS.

Abstract

The topic of the publication is the description of the methods and techniques of using satellite imageries for the applications of GIS. The article introduces the specificity of detection, identification and technical description of objects in the context of using high-resolution imageries data. The special attention is paid to image resolution and image information content, connected with that. The article depicts the results of the American geospatial intelligence experts' work connected with image resolution and possibilities of its analytic use. Later, analyzing the factors influencing an informative content of image and our own conclusions supported with examples are presented. In the final part of the publication, interpretation keys and comparative models are described, showing the whole process from detection to technical description of an object for the GIS needs. The attention is also paid to a possibility of hyperspectral imagery use. The introduced conclusions present the continually increasing role of the use of contemporary raster images for interpretative aims in the context of using GIS software.

Introduction

Nowadays GIS becomes a basic tool in crisis and military management, provided that the system is integrated, updated and modernized. It helps managing, forecasting and assessing the crisis situations. Generally it can be assumed that all dangerous events, especially in a warfare zone, are of spatial character, therefore it is necessary to have cartographic knowledge to define and prevent them.

Nowadays, all the applications of GIS require description of the objects presented on a map. In order to make it possible, to describe the object we need to detect and identify it, using imagery data. Solution to this kind of problem leads to the analysis of factors influencing the informative content of an image through the image resolution, supported with interpretation keys. All of these factors determine a level of details in the object description and it is also a base of efficient use of GIS tools.

Detection and identification of objects

In recent years the American Intelligence conducted the sequence of analyses of accessible images, on the basis of which they introduced the interpretative possibilities of objects from images in resolution function. Considering the data shown below "one meter" resolution of image (pixel size) seems to be sufficient for general identification e.g. station of rockets launcher, however, bearing in mind photo 1b or 1c the question occurs: how many pixels we need in fact to say if there is a tower in the photograph. If you look at the image 1c (about 300 pixels) you only know that something is visible but if you look at the image 1b it is still hard to guess what it is actually. Apart from suitable resolution we need to know what the character of analyzed objects is and what we are looking at and searching for. It is also important who is looking at the imagery. Only those familiar with harbour infrastructure can immediately recognise a patrol boat, a tugboat and towers, just because they know where and what to look for (Maj K., Pabisiak P., Stepień G., Wysota R., 2007). Another thing is what type of tugboat or boat it is, which can be important from the military point of view. This is when interpretation keys and comparative standards are useful. The table shown below also proves that even larger resolution is required for the precise technical analysis of most military objects.

Target	Detection	General ID	Precise ID	Description	Technical Analysis
Bridges	6	4.5	1.5	1	.3
Communications					
Radar	3	1	.3	.15	.015
Radio	3	1.5	.3	.15	.015
Supply Dumps	1.5-3	.6	.3	.03	.03
Troop Units (in bivouac or on road)	6	2	1.2	.3	.15
Airfield Facilities	6	4.5	3	.3	.15
Rockets and Artillery	1	.6	.15	.05	.045
Aircraft	4.5	1.5	1	.15	.045
Command and Control Headquarters	3	1.5	1	.15	.09
Missile Sites (SSM/SAM)	3.	1.5	.6	.3	.045
Surface Ships	7.5-15	4.5	.6	.3	.045
Nuclear Weapons Components	2.5	1.5	.3	.03	.015
Vehicles	1.5	.6	.3	.06	.045
Minefields	3-9	6	1	.03	–
Ports and Harbors	30	15	6	3	.3
Coasts, Landing Beaches	15-30	4.5	3	1.5	.15
Railroad Yards & Shops	15-30	15	6	1.5	.4
Roads	6-9	6	1.8	.6	.4
Urban Areas	60	30	3	3	.75
Terrain	–	90	4.5	1.5	.75

Fig 2. Target identification in ground resolution (meters). According to STANAG 3769 (Standarization Agreement):

***Detection**: the discovering of the existence of an object but without recognition of the object.*
***Recognition**: the ability to fix the identity of a feature or object on imagery within a group type, ie, tank, aircraft.*
***Identification**: the ability to place the identity of a feature or object on imagery as a precise type, ie, T-54 tank, MIG-21J.*
***Technical Analysis**: the ability to describe precisely a feature, object or component imaged on film.*

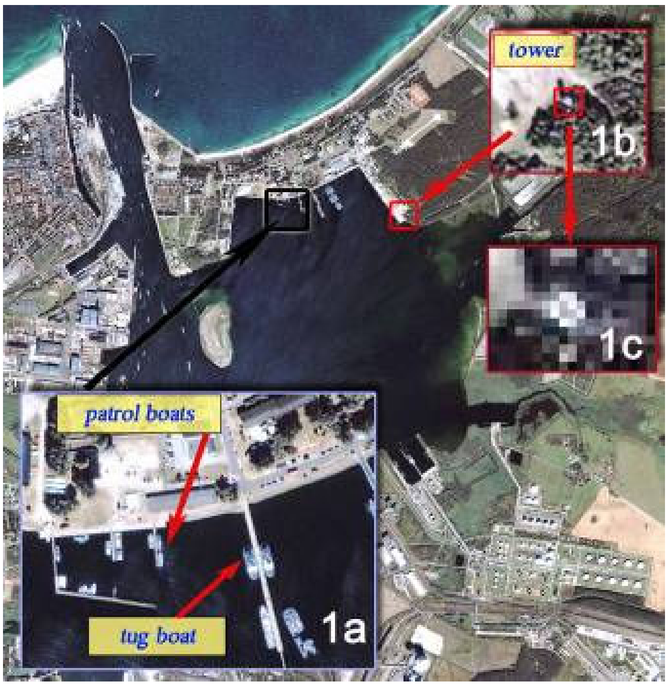

Fig 1. A part of a harbour in Rostock..

Geometrical accuracy

Geometrical accuracy is influenced by many factors connected with registration imagery process, placing of photo-points or methods of geometrical correction of the imagery, and the received data are distorted by curvature of the Earth as well as defects of used sensors. The reading off imagery co-ordinates can considerably differ from these measured in terrain, and can achieve errors of several pixels. Hardly ever has it the essential meaning for interpretation, it does not change mutual - relational localization of terrain objects. Therefore we will pay attention to checking the accuracy of internal geometry of objects, not to the accuracy of their spatial location. We conducted a small experiment using imagery taken from QuickBird.

We measured width and length of the two groups of Corimec dwelling containers, used in Iraq and in Afghanistan by the coalition forces and located to each other at approximately right angles, which means that they are disposed relatively in horizontally - vertically arrangement of pixels also under azimuth different on 90^0 value. We measured in every groups – 40 width, length and areas. Results turned out to be a bit surprising (tab. below)

CORIMEC Contener					
Measurements	**Width [m]**	**Length * [m]**	**mean error** - *apparent*	**mean error** - *real*	**Azimuth** (of measurement)
group I	2,176	6,176	0,38 0,38*	0,20 0,37*	124^0,24 211^0,30*
group II	2,623	5,796	0,23 0,36*	0,23 0,30*	35^0,53 126^0,92*
real value [m]	2,50 [±5 cm]	6,00 [±5 cm]	-	-	-

Values with added sign - „" refer to the column – Length.*

According to the table above the location of an object in relation to arrangement of pixels (the Column Azimuth) is important. However this arrangement generates the mean error (real) in the frames of half value of pixel size, and the extreme differences of received values between the groups do not exceed the whole pixels' size. It is similar with mean error of a individual observation calculated for a value of apparent errors. These values are even smaller, which proves the accuracy of measurements, meaning that deviation between measured values and average measurement value (small dispersion of measurements values) is small. The measurements were executed without special care, in scale (zoom) approximately 1:500. Therefore it could be expected, that during determination of characteristics (sizes) of objects an error for linear object measuring is the half of length (width) of pixel. It is true for surface objects with a surface of at least (a dozen or so) pixels (Maj K., Pabisiak P., Stepień G., Wysota R., 2007). Later we will show how the situation for "punctual" objects, smaller than pixel size, looks like through the analysis of different types of resolution.

Resolution vs. interpretation

In order to provide the correct digital imagery characteristic it is essential to define the dependence between the notion of picture resolution and its informative content. Resolution understood as a level of data precision allows self - characterization of imageries with the help of its four kinds: spectral, spatial, radiometric and temporal, which have the decisive meaning in analysed images interpretation (Maj K., Pabisiak P., Stepień G., Wysota R., 2007).

Spectral resolution - defines the range (interval) of the wavelength a sensor is able to distinguish. The high resolution satellite sensors record in the first place in the modes: multispectral (MS) - visible band (channels: blue, green, red) range 400-700 nm, band of near infrared (NIR) 700-1200 nm and panchromatic (PAN) including the average value of reflex energy in range 450-900 nm. Systems displaying in blue, green, red and infra-red band, make it possible to generate imagery in true colours (R,G,B), spectral (R,G,NIR) or in multispectral (R,G,B,NIR), characterised for the largest interpretative values.

The distinctive feature essential for the interpretative possibilities of panchromatic imagery is the hue of image which depends on the lighting conditions. The different spectral profiles of displayed, objects e.g.: concrete runway, grass, open grounds, trees, metallic constructions covering airplanes, decide about their detectionand identification possibilities. In the case of colourful (MS) display, in infrared, the distinctive feature is colour and propriety of spectral infrared radiation, what in comparison with panchromatic image e.g. aircraft surfaces, we get better possibilities of detection of concrete surface, field ground movement, structures and disperse halting places on a green background, at the same time attenuating object's masking proprieties.

Spatial resolution – as a size of the smallest object, which is possible to be distinguishes by a sensor, is identified with area on surface of the ground (Earth) represented by pixel.

The definition "one meter system" means the system with field dimension of pixel GSD (Ground Sampling Distance) close to 1m. The standard rule, conditioned by the construction of imaging systems, is fact that recorded in panchromatic bands images can be characterized with four times higher spatial resolution in comparison to multispectral images. Publications often use images being combination of PAN and MS imageries giving the colourful, pan-sharpened picture, characterized by the size of pixel recorded in PAN mode and informatively "enriched " by colours of the MS mode. Taking into consideration optical system (resolution of a lens) we should rather speak about IFOV *(Instantaneous Field of View)* - temporarily angular field of vision of detector, what with a certain approximation may be presented as a spatial size of a pixel (GSD).

Fig.3. Taxi way lights marked with white circles on images with resolution: 1 m (on the top), 2,5 m and 5 m.

How to explain the fact that a few decimetres taxiway light is visible in 2,5 – meter (resolution) imagery but an experienced interpreter would find it in already 5 meter (resolution) imagery? It is connected with the radiometric resolution and also the contrast between an object and background. Let's imagine that the contrast is large – background is dark and light is bright (as presented in our example). Therefore it is suffice for the detector (from matrix of detectors) "accumulating light" e.g. from area about 6,25 m^2 to get from a lit lamp (taxiway light) a sufficient amount of the energy "to go over " a few levels towards brighter pixels in scale of the recorded levels of greyness. This example shows that in a specific lighting conditions with a suitable contrast elements much smaller than spatial pixels' size can be "seen". To achieve that a suitable radiometric resolution is necessary, meaning the sensitivity to distinguish very close levels of brightness (greyness).

Radiometric resolution - defines so-called dynamics of the range, i.e. the maximum value of data in every band. It is defined by the number of bits of the divided energy. For example, for 8-bits data the data value for every pixel is in the range 0-255, and for 11-bits data in the range 0-2047. The imagery characterized by dynamic 11-bits range informatively prevails the imagery received in 8-bits range. The mentioned 2048 possible brightness pixels' levels allows to register much more details in shadowy or foggy regions.

Temporal resolution - defines frequency a sensor records image from definite area. During imagery interpretation process this parameter can decide about choice of satellite data for researches on change detection. On the one hand long revisit time can make it impossible to detect an intensive movement in region of military bases, on the other hand it allows the detection of new building constructions. During observation and interpretation of the newly built objects of the infrastructure e.g. atomic power stations, the series of short revisit time images are used, comparing both adjacent time distant images, creating rich and varied regarding the resolution library of images.

Interprtation keys

The interpretation objects with regard to their shapes were already made in aerial photographs and had a great input during both Ist and IInd World War. Pieces of information about military objects (e.g. ships, vehicles) were gathered in catalogues and lexicons like Jane's Book and are in use for reconnaissance and objects' detection also today. Information gathered in this way are not only schemes, diagrams or pictures, but also precise information about dimensions, sizes, loaded draught, height, capacity, technical ability (speed, carrying capacity, using) of all kind of military units. Because the similarities of recorded objects on the surface of the Earth (species of trees, roofs, water, soil) appear in both shape and a kind of components they were built from, during the interpretation process special interpretative keys started to be used to provide systematization of certain qualities characteristic for definite objects. The applied interpretative keys concern both shape and length of wave of recorded by sensor and complement each other.

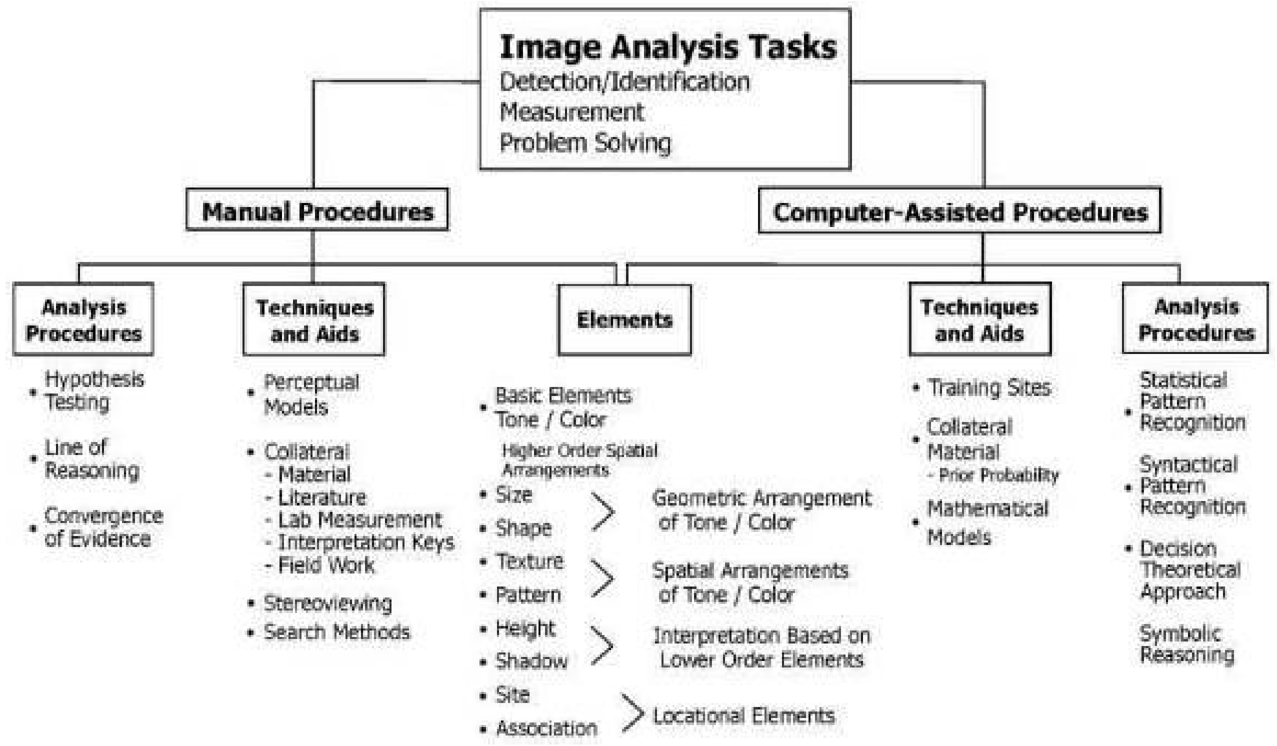

Fig 4. Diagram of analysis and interpretation of the image
Source: http://www.geog.ucsb.edu/~jeff/115a/lectures/elements_aids_and_techniques.html

As shown above the solution for the tasks used for detection and identification of objects in GIS leads to the analysis of the following elements: tone (colour), shape, size, shadow, height, texture. The key meaning in interpretation of an object has its colour (tone) or colour of individual components in the case of objects with complex structure. Hue (colour) enables detection, but for the analysis we need: size, shape, and texture of an object. Height, shade, pattern as well as placing and interrelationship between neighbouring objects are also important. We can also add to these elements trace (movement) of the object, which is particularly well visible on the water, in the case of moving "motor boats" or afloat submarines.

The level of the details of analysis depends on resolution of objects. However, with low radiometric resolution even with small pixel sizes we would not be able to describe something in details. Temporal resolutions are necessary in this case. Without knowledge of these elements it is difficult to determine the possibilities of analytic use of an image. Unfortunately fig. 1. does not take into consideration these elements, only spatial resolution comes into account, we even do not know whether the point of analyses is multispectral or the panchromatic imagery.

On the other hand, we may think why we need high resolution since nowadays almost all kinds of objects are presented in tabular form. The resolution enhancement will surely increase the effectiveness, reliability and completeness of imagery intelligence and will shorten the time required for collecting information. However, fig 1. makes sense in non-standard situations, during the unknown (not tabularised) objects analysis. There is an example of a key for interpretation of forest species in Japan, worked out by Japanese Forest Association. This key takes into account shape of a trees' head, tone, shade and a shape of individual tree, pattern and texture.

The object's attributes described so far, which were the basis for the interpretation process, were enriched with information contained in recorded electromagnetic wavelength bands. On that basis additional standards were worked out describing objects which allowed to find out information about materials which were used to build or make these objects of interest. The basic kind of displays used for this sort of interpretation are multispectral imageries, however, the success would be achieving hyperspectral imageries where dozens or a few hundreds of spectral channels can be recorded on. This way of recording enables getting data connected with object's structure, ingredients of soil or other natural elements.

Hyperspectral imageries

In descriptions of the applied of hyperspectral imageries, most often we come across the example of detection (distinguish) of two minerals, kaolinite and alunite, with very similar spectral profiles, distinguishing of which is possible only in the exact and very narrow spectral ranges. But there are also more spectacular applications.

A project in Sydney, provides another example of material identification and mapping. In this application, hyperspectral imagery was used to identify roofs susceptible to hail damage (Shippert P., 2004). The spectral differences in roofing materials with different hailstone resistances are very subtle, precluding the use of multispectral sensors for their identification. However, imagery from the hyperspectral Hymap sensor was used to detect the overall shape of the spectral curve and the position and strength of distinguishing absorption features in these roofing materials. These spectral characteristics were used to identify locations that were more susceptible to hail damage.

Hyperspectral images provide ample spectral information to identify and distinguish between spectrally similar (but unique) materials. Consequently, hyperspectral imagery provides the potential for more accurate and detailed information extraction than it is possible with other types of remotely sensed data. About their usefulness states not a number of spectral bands, but their dense distribution (quasi - continuous) and the narrow ranges of registration of electromagnetic spectra.

Hyperspectral images are sometimes referred to as “image cubes” because they have a additional spectral dimension as well as two spatial dimensions. Similarly to radar images, nowadays they provide the interesting widening potential of object interpretation and recognition which is difficult to detect using other methods of action. The detection potential makes it possible to detect masked military objects or identify the environment pollution quickly (e.g. oil films on a sea surface). Extending the scale of recording the number of greyness levels as well as the number of spectral ranges allows to forecast the quick dissemination of this type of solutions and to increase the possibilities of detection and objects identification using satellite imagery data.

Conclusions

Taking into consideration the fact that the access to the satellite images in the age of the Internet and to many services offering the possibilities to observe territories of different states from the space becomes more and more common, objections related to security and protection of important objects from the defence point of view appear.

Schedule introduced by American experts (Fig.2. - STANAG 3769), do not consider differences in informative content between panchromatic and multispectral images. It also skips the influence of contrast on the level of image interpretation, radiometric and spectral resolution. Additionally, considering the fact that GSD and IFOV are not the same and moreover in many currently constructed matrixes of pixels, arrangement of photodetectors is not identical with pixels arrangement, we should be aware that what pixel represents is the result of multi-level interpolation, which combined with weak contrast can give completely wrong terrain imaging. On the other hand, using interpretative keys, excluding technical analysis, basically “2,5-metres” pictures are enough for us to read almost everything.

Detection and identification can be very quick and almost identical when we have the database of symbols and descriptions at our disposal. Satellite imageries, enabling informative advantage, can be used for assessment of economical and military potential, including the assessment of weapons of mass destruction development, industry and arms production, the monitoring of army's movements but also for the assessment of condition and type of equipment and for the monitoring the development of new technologies (Czaban A., 2007). This variety of possible applications, combined with more and more common access to satellite data and also tabular and characteristics of different kinds of infrastructure and equipment causes the constant increase of the role of GIS as a tool integrating vectorial and raster spatial data. It enables to carry out analyses and conclusions based not only on the descriptive and vectorial data, but also creates new perspectives for application of GIS with the use of raster data.

References:

1. http://www.geog.ucsb.edu/~jeff/115a/lectures/elements_aids_and_techniques.html

2. Why use hyperspectral imageries? – Peg Shippert - Photogrammetric Engineering & Remote sensing – kwiecień 2004.

3. Detekcja a identyfikacja – od wykrywania do analizy technicznej – Maj K., Pabisiak P., Stępień G., Wysota R. – GEODETA, Wrzesień 2007.

4. Rozpoznanie obrazowe i jego rola w obronności kraju - Anatol Czaban - II Konferencja naukowo-techniczna, Wykorzystanie współczesnych zobrazowań satelitarnych, lotniczych i naziemnych dla potrzeb obronności kraju i gospodarki narodowej, VII Konferencja użytkowników oprogramowania ERDAS Imagine i Leica Photogrammetry Suite – Podlesice, 2007.