The Realisation of Satellite Remote Sensing

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Abstract: *In this paper are presented the realisations of remote sensing from the last years. In general, are treated the aspects regarding the satellite missions and the main satellites as well as the kind of images takes with this satellites and the features of this. There are makes reference, also, to the fields in which the satellites images can be used in view of spatial and multispectral resolution.*

Keywords: *remote sensing, satellite missions, images, spatial and multispectral resolution.*

1. General aspects

Satellite remote sensing is a dynamic instrument in full development, useful for several activity fields and offering the possibility of tracking details and phenomena on a large space on the terrestrial surface. Mainly, on a global scale, it has become an important means in studying natural resources and in monitoring the environment. Realising such applications assumes the well-knowing of the spectral features of the details being recorded, as well as the work manner of the satellite sensors (Lillesland, Kiefer, 1987, 1994). At the same time, the introduction of new technologies in remote sensing also involves a change both in the style and in the managerial structures of the sectors they are applicable in. Consequently, remote sensing information serve especially for drafting theme maps necessary in view of performing activities in different fields. The great number of remote sensing satellites illustrates the interest for data collection to be used in modern cartography, by facilitating the fast drafting of the maps and the highlighting of a certain country's economy sectors.

The collection techniques of the remote sensing data used in the sectors of interest are undergoing a continuous improvement, which leads to obtaining some qualitative recordings, superior under all aspects. The creation of new sensors the satellites are fitted with makes possible capturing images with a high spatial and spectral resolution. This leads to the decrease of the pixel from 80 x 80 m in 1972 (Landsat 1) to *0.61 m* nowadays for *Quickbird* images and to *0.50 m* for *Worldview-1* recordings, values hard to imagine two or three centuries ago. Thus, using satellite images in knowing the natural resources imposes itself more and more. Together with the high spatial resolution satellite images show nowadays, the spectral resolution must not be neglected, because a certain value of it allows a clear separation of details and highlighting some of their features.

2. Satellite missions and satellite sensors

Satellite missions have become nowadays important image sources holding great information and practically forming a distinct information class. The systems' features, as *great terrestrial coverage, regular cycle, multispectral scanning sensors*, turn them useful in different fields, in the study of different processes and phenomena appearing on different scales. The results obtained are conditioned in a decisive way by the sensors the satellite image recording equipment is fitted with, respectively by the resolution they can ensure.

A complete inventory of the satellite missions – together with the equipment and with the main features of the recordings, aiming at inventorying the Earth's natural resources and the changes encountered – is impossible to draft. Thus, the most common inventories are mentioned and commented from bibliographic materials – part of them being used in our country in several activity sectors (Table 1).

Apart from the traditional spatial programmes of the advanced countries, there appeared some programmes initiated by countries having a more reduced tradition in the field, like *China, India, Brazil,* and *Russia*. This way, an important stage in acquiring satellite images pertains to *Aster* satellites, which capture 15-metre resolution images, to *IRS* satellites – launched by India –, having a 2,5-metre spatial resolution (Cartosat 1), and to *SPIN 2* satellites – launched by Russia –, having a very high spatial resolution, of 1 metre.

Improving image recording sensors is imposed in view of reaching this goal, as a major tendency as to increasing resolution power, respectively reducing the dimensions of the pixel, as the elementary surface unit. From this point of view, it is concluded that:

- nadir *spatial resolution* has importantly improved, reaching *0.61 m* for *Quickbird 2* images and *0.50 m* for *WorldView 1* images, both in panchromatic, performances that have been unimaginable for long. Furthermore, the creation of satellite sensors to ensure a spatial resolution over the most optimistic provisions – of *0.40 m* and *0.25 m*, for the civil sector – is forecasted and awaited;
- *spectral resolution* relates to the increase in the number of bands by narrowing their interval, idea that leads to the appearance of *hyperspectral sensors*. These allow the data processing in tens or even hundreds of spectral bands, which ensure an easier detail recognition based on the spectral signal, as well as classifications performed for several groups or classes;
- *temporal resolution* records the same scene at a shorter time interval, by increasing the number of satellites of by capturing side images;
- *radiometric resolution* is improved once with new collection sensors by means of the increase from *7* to *8 bits* in the case of *Landsat TM* and *Landsat ETM+* images, and to *11 bits* for *Ikonos 2, Quickbird,* and *WorldView 1* images. This increase assumes that every recorded pixel from the image is found in a greater string of values on the grey scale or on the colour shades, which allows a better separability of the recorded field's details.

Hyperspectral sensors quantify energy in more spectral bands than the multispectral sensors; thus, their number can surpass 200, even reaching 242 (Hyperion). Spectral bands have a width of *1.3 – 12 nm*, according to the sensor type and to the band number, allowing a continuous recording in the electromagnetic spectrum interval of *0.4-2.5 μm* and being more sensitive to the reflected energy's variations. These sensors can detect the light modifications in the leaf and soil humidity content, the stress provoked to plants due to nutrients or to other environment factors. The small width of the bands allows *HIS* (Hyperspectral Imaging) multispectral image capturing devices to make the difference between the plant species, the tree species, and the vegetation type, having a very close spectral behaviour. In this sense, if the multispectral images can be used for making maps of the forest covered areas, the hyperspectral images can be used for identifying and making maps of the species inside the forest. Furthermore, *CHRIS* (Compact High Resolution Imaging Spectrometer) sensor, different from the other hyperspectral satellite sensors through high spatial and spectral resolution, allows the obtaining – in the case of every scene – of five images from different angles (55°, -36°, 0°, 36°, and 55°), captured within 2.5 minutes and representing a great advantage.

Due to the advantages it brings along, remote sensing using hyperspectral sensors has become popular among herbalists, in agriculture, sylviculture, and geology, proving to be a very good instrument for studying plant physiology and productivity, for detecting the plants' state of health, and for vegetation map making. Hyperspectral image processing and analysis is different from that of images captured with multispectral sensors, leading to the usage of special programmes and instruments or assuming the existence of processing models within the programmes used in the case of multispectral images.

The main satellite missions and the characteristic of the sensors

Table 1

Missions	Sensor	Nr. spectr. bands	VIS 0,35-0,70 μm	NIR 0,7-1,5 μm	MIR 1,5 - 2,3 μm	TIR 3 - 14 μm	MW 1-100 cm	Spatial resolution	The side look	The size of scene	Date of launch / finish	
1	2	3	4	5	6	7	8	9	10	11	12	13
A. THE MAIN SATELLITE MISSIONS												
LANDSAT												
Landsat 1	RBV MSS	3 4	* *	* *				80 m	N N	185x185 km	1972	1978
Landsat 2	RBV MSS	3 4	* *	* *				80 m	N N	185x185 km	1975	1982
Landsat 3	RBV MSS	1 4+1	* *	 *		 *		40 m 80 m (120m TIR)	N N	185x185 km	1978	1983
Landsat 4	MSS TM	4 7	* *	* *	 *	 *		80 m 30m (120 m TIR)	N N	185x185 km	1982	1987
Landsat 5	MSS TM	4 7	* *	* *	 *	 *		80 m 30 m (120 m TIR)	N N	185x185 km	1985	Oper. TM
Landsat 7	ETM+	7 + 1	*	*	*	*		30 m (60 m TIR) (15 m PAN)	Y (PAN)	185x185 km	1999	Oper.
SPOT												
SPOT 1	HRV	3 + 1	*	*				20 m (10 m PAN)	Y	60x60 km (nadir)	1986	1990
SPOT 2	HRV	3 + 1	*	*				20 m (10 m PAN)	Y	60x80 km	1990	
SPOT 3	HRV	3 + 1	*	*				20 m (10 m PAN)	Y	(side view)	1993	
SPOT 3	HRV	3 + 1	*	*				20 m (10 m PAN)	Y		1993	1996
SPOT 4	HRVIR VEGETATION	4 + 1 4	* *	* *	* *			20 m (10 m PAN) 1000 m (nadir)	Y N		1998	
SPOT 5	HRG VEGETATION	4 + 1 4	* *	* *	* *			10 m (5 m PAN) 1000 m (nadir)	Y N	60x60 km at 80km at nadir	2002	
NOAA												
NOAA 15	AMSU-A AMSU-B AVHRR 13 HRPT	10 3 5						40 km 15 km 0,5 km (visible) 1000m (infrared)		2240 km 2240 km 2940 km	1998	
NOAA 16	AMSU-A AMSU-B AVHRR 13 HRPT	10 3 5						40 km 15 km 0,5 km (visible) 1000m (infrared)		2240 km 2240 km 2940 km	2001	
ASTER												
Aster (Terra Platform)	VNIR	3	*	*				15m		60x60 km	1999	
	SWIR	6			*			30m		60x60 km	1999	
	TIR	5				*		90m		60x60 km	1999	
ORBVIEW												
OrbView 1	PAN	1	*					10000 m		1300x1300 km	1995	
OrbView 2	MULTISPEC	8	*	*				1100 m		2800x2800 km	1997	
OrbView 3	PAN MULTISPEC	1 4	* *	 *				1 m 4 m		8x8 km	2003	
IKONOS												
Ikonos 2 (Geoeye)	PAN MULTISPEC	1 4	* *	 *				0,82 m (at nadir) 1m (at 26° off n) 3,2 m (at nadir) 4 m(at 26° off n)		11,3x11,3 km (at nadir) 13,8x13,8 km (at 26° off n)	1999	

QUICKBIRD												
Quickbird (Digital Globe)	PAN	1	*					0,61 m (at nadir) 0,72m(at 25° off n)		16,5x16,5 km at nadir	2001	
	MULTISPEC	4	*	*				2,44m (at nadir) 2,88m (at 25° offn)				
WORLDVIEW												
Worldview 1(Digital Globe)	PAN	1	*					0,5 m (at nadir) 0,55m(at 20° off n)		17,6x14 km at nadir	2007	

B. OTHER SATELLITE MISSIONS												
CANADA												
Radarsat	SAR	*					*	10 m (fine) 30 m (standard) 30 m (wide) 50m (scan.narrow) 100 m (scan. wide) 25 m (extend.high) 35 m (extend. low)	Y	50x50 km 100x100 km 150x150 km 300x300 km 500x500 km 75x75 km 170x170 km	1995	
INDIA												
IRS 1-C	PAN	1	*					< 10 m	Y	70x70 km	1995	
	LISS-III	4	*	*	*			23,5 - 70,5 m	N	141x141km		
IRS 1-C	WiFS	1	*	*				188 m	N	806x806 km		
IRS P2	LISS-II	4	*	*				36,25 m	N		1995	
IRS 1d	PAN	1	*					< 10 m	Y		1997	
	LISS-III	4	*	*	*			23,5 - 70,5 m	N			
	WiFS	2	*	*				188 m	N			
IRS	Cartosat-1	2	*					2,5 m	N	30x30 km	2005	
JAPONIA												
JERS - 1	OPS	8	*	*	*			18 X 24 m	N	75x75 km	1992	
	SAR	1					*	18 m (band L)	N			
ESA, NAS and JAPONIA												
ERS - 1	AMI SAR	3					*	10 m, 30 m, 50 m	N	100x100km	1991	2000
	ATSR	4	*	*	*	*		1000 m	N	5x5 km		
	MWR											
	RA	1						0,1 m				
ERS - 2	AMI SAR	1					*	30 m (band C)	Y		1995	
	ATSR - 2	8	*	*	*	*		1000 m (at nadir)				
ADEOS	POLDER	8	*	*				6 x 7 km (at nadir)	Y		1996	
	AVNIR	5	*	*				8 - 16 m	N			
Envisat- 1	MERIS	15	*	*				300 - 1200 m	N		1998	
	ASAR	1					*	(at nadir)				
	AATSR	8	*	*	*	*		30 - 1000 m				
								1000 m	Y			
EOS-AM 1	MISR	4	*	*				240 m (at nadir)			1998	
BRAZILIA SI CHINA												
CBERS - 1	CBERS - 1	2	*	*				20 - 260 m			2001	
CBERS - 2	CBERS - 2	2	*	*				20 - 260 m			2003	
TAIWAN												
Formosat-2	PAN	*						2 m	N		2004	
	MULTISPEC	*	*					8 m				
C. THE MISSIONS WITH HIPERSPECTRAL SENSORS												
EOS-AM 1	MODIS	36	*	*	*	*		250 m, 1000 m	N		1998	
PROBA	CHRIS	63	*	*	*	*			Y		2001	
EO-1	ALI PAN	1	*					10 PAN	N	37x37 km		
	HYPERSPECT	10	*	*	*			30 m				
	Hyperion	242	*	*	*	*		30 m	N	7,7x42 km	2007	
	AC	256		*	*			250 m	N	185x185 km		
D. THE FUTURE SATELLITE MISSIONS												
Geoeye – 1 (GeoEye)	PAN	1	*					0,41 m	N	15,2x15,2 km	2008	
	MULTISPEC	4	*	*				1,65 m				
Worldview 2(Digital	PAN	1	*					0,5 m (at nadir) 0,55m(at 20° off n)		17,6x14 km at nadir	2009	

Globe)	MULTISPEC	8	*	*				1,8m (at nadir) 2,4m(at 20^o off n)		17,6x14 km at nadir		
Geoeye – 2 (GeoEye)	PAN MULTISPEC	1 4	* *	 *				0,25 m	N	15,2x15,2 km	2011	

In the case of RADAR remote sensing system with a synthetic opening currently under focus, there are two development directions:

- *polarmetric radars* offering a decimetric or even a subdecimetric spatial resolution when recording more complex images and high precision structural determinations over recorded details;
- *interferometric radars*, also allowing high spatial resolution data collection.

Radar sensors are diversified and appreciated due to the fact that they capture images irrespective of weather conditions and scene illumination. Due to the fact that the recordings in this system lead to side images – different from the spectral perspectives obtained through satellite recordings –, the correction and processing procedures differ as well. Consequently, international preoccupations are focused on setting up these recordings' software processing systems.

Planned satellite missions for the future bear in mind the use of satellite sensors allowing the capture of images having very high spatial resolution. Satellites *GeoEye-1* and *GeoEye-2* (GeoEye) can be mentioned here, to be launched in 2008 and 2011, and satellite *WorldView-2* (Digitalglobe), to be launched in 2009. Images to be captured by these satellite sensors will have a spatial resolution of *0.41 m* and *0.25 m* in panchromatic and of *1.8 m*, respectively *1.65 m,* in multispectral (Table 1), values hard to imagine being reached in 1972, when launching the first *Landsat* satellite*.* Also, *11-bit* spectral resolution allows recording details with a higher accuracy in relation to grey tones and colour shades, while temporal resolution will be improved, that is, the same field surface is more often revisited (less than 3 days). These new developments of satellite sensors will allow daily image collection on hundreds of thousands of square kilometres, to be used in different projects from several activity sectors. It is obvious that the quality and the spatial resolution of them lead to a very high price (even a prohibitive one for many countries), that is why these assets will be used by sectors having a great financial force.

Companies trading satellite images are also continuously adapting to new requirements. Thus, we should mention the fact that *GeoEye* company is new on the market, being set up in 2006, subsequent to the purchase of *Space Imaging* company by *ORBIMAGE*. Also, the satellite sensors planned to be launched, *GeoEye-1* and *GeoEye-2*, actually pertain to *Orbview* satellite series. Other companies on the market of satellite image trading – competitors of *GeoEye* – are *Digital Globe* and *Spot Image*.

In processing satellite images, as basis for their interpretation is the attention given to diversifying the existing programmes by creating new software as close as possible to the user, cheap and easier to operate. Thus, the GIS software specialised in remote sensing, *Erdas, ErMapper, ENVI, Spans, GRASS*, more and more performant, has all modules incorporated, allowing satellite image preparing and processing, classifying their content, obtaining the field's digital model, etc. In order to obtain a classification of the fields as precise as possible, new software specialised in remote sensing of large use appeared. Thus, the German company *Definiens Imaging* has realized the "*eCognition*" programme based on "*object classification*" as an alternative to "*pixel classification*" which uses – apart from the *spectral signature* of the objects –, their *texture, vicinity, form,* and *context.* Also, the viewers' diversification is observed, allowing suggestive visuals of satellite images referring to certain contrast improvement and image operation procedures.

Remote sensing data integration into geographic information systems (GIS), together with the digital photogrammetry and GPS techniques, obviously represent major preoccupations for different fields which are more and more interested in new performant technical achievements, to improve necessary information's quantity and quality. Integration of data recorded by satellite missions in geographic information systems implemented in the natural resource management systems help mainly in relation to arrangement, development, and impact scenery realization over the environment. Remote sensing project examination and GIS from different countries show that a lot of them lead to forecasted results, while the others find it difficult to transfer technology and scientific development autonomy to host countries.

As a general tendency in developing satellite systems, there are new high performance satellite images capturing programmes. These are satellites fitted with *Ikonos 2*, *Quickbird 2*, *Orbview 3*, and *WorldView 1* sensors, able to capture special quality recordings. Do not forget that high spatial resolution of *0.50* m of *WorldView 1* images cannot replace for now air photograms having a resolution of *0.10 – 0.20* m. By successfully launching satellite *WorldView 1* (Digitalglobe), the difference between satellite image resolution and air photograms is reduced; the latter might be replaced according to the immediate progresses to be performed. Nowadays, high spectral resolution and using temporal resolution in the case of *Ikonos, Quickbird, WorldView* images, the great coverage area, and the ability of capturing images from any surface, including the areas planes cannot fly in, can represent major advantages in using remote sensing recordings in comparison with air photograms.

Apart from these, there is a tendency of creating *sensors capturing stereo images* (Precision Stereo 4m CE90 Ikonos, SPOT) for the same surface, thus ensuring the possibility of realising the stereoscopic model according to satellites and obtaining the field digital model.

3. Conclusions

Performing new satellite missions by launching satellites fitted with more and more performant satellite sensors, as well as continuing the current satellite missions by also using satellite sensors having improved technical features is a continuous issue of the companies in the field.

Each satellite mission having functional satellites, as well as the new planned missions *launch their satellites in different purposes*, thus *issues have to be perceived from this point of view.* That is why *NOAA* missions having satellites which capture images with the spatial resolution of *1x1 km* do not assume that the satellites have not improved, but the main purpose of launching them is to collect meteorological data, reason for which this resolution ensures reaching this purpose. Furthermore, these satellites and others from other satellite missions, having a small spatial resolution, collect data from large and very large surfaces, without needing a detailed recording of the objects on Earth. Implicitly, each satellite mission, together with the satellite sensors used, collects data referring to diverse phenomena (meteorological, pollution, fires), natural resources, waters, frozen areas, rainforests, deserts, urban areas, etc., which also leads to the adaptation of the satellites’ features, in view of highlighting the necessary information.

Generally, the goal of trying to obtain images as clear as possible turns spatial and spectral resolution into key-factors in relation to assessing satellite registration. Continuous improvement of the satellite images’ resolution has allowed realizing several applications in different sectors, data fusion with photograms and the digital models of the field, as well as the cartographic data’s integration with GIS data. The *1 m* resolution of *Ikonos* images, that of *0.61 m* of *Quickbird* images and that of *0.50 m* of *WorldView* recordings allows data collection that reduces the difference between the satellite recordings and the photogrammetric ones. In the closest future, the latter could be replaced for certain applications, according to the resolution and to the accuracy claimed by the new satellites to be launched, *GeoEye 1* and *GeoEye 2*, whose spatial resolution will reach, in panchromatic, *0.41 m* and *0.25 m*. The high spatial resolution of *Ikonos, Quickbird*, and *WorldView* images on the market, their high temporal resolution, the large coverage area, and the ability of these sensors of capturing images from any surface, especially in the areas planes cannot reach, becoming great advantages in using these images in comparison with the air photograms.

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