



Ten years of remote sensing advancement <u>&</u> the research outcome of the CRC-AGIP Lab

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CRC-AGIP

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1. Remote Sensing Advancement

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力	
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ノ		Sp	atial resolution	Swath (km)	Year of		
LINIR	Optical satellite	Pan*		MS*			launch
UND			VNIR*	SWIR*	TIR*		
	Landsat 7	15	30 (4)	30 (2)	60 (1)	185	1999
	CBERS 1 and 2	20	20 (4)			113	1999, 2003
A	Ikonos 2	1	4 (4)			11	1999
	Terra/ASTER		15 (3)	30 (6)	90 (5)	60	1999
	KOMPSAT-1	6.6				17	1999
	EROS A1	1.9				14	2000
LINE COLUMN TO STREET	Quickbird 2	0.61	2.44 (4)			16	2001
1	SPOT 5	2.5–5	10 (3)	20 (1)		60	2002
	IRS-P6 / ResourceSat-1	6	6 (3), 23.5 (3)			24, 70, 140	2003
Ontical earth	DMC-AlSat1		32 (3)			600	2002
optical cartin	DMC-BILSAT-1	12	28 (4)			25, 55	2003
observation	DMC-NigeriaSat 1		32 (3)			600	2003
satellites	UK-DMC		32 (3)			600	2003
	OrbView-3	1	4 (4)			8	2003
	DMC-Beijing-1	4	32 (3)			24, 600	2005
	TopSat	2.5	5 (3)			25	2005
	KOMPSAT-2	1	4 (4)			15	2006
and the second	IRS-P5/CartoSat-1	2.5				30	2006
	ALOS	2.5	10 (4)			35, 70	2006
Contraction of the second	Resurs DK-1	1	3 (3)			28.3	2006
	WorldView-1	0.5				17.5	2007
	RazakSat	2.5	5 (4)			20	2008
	RapidEye A–E	6.5	6.5 (5)			78	2008
[Zhang and	GeoEye-1	0.41	1.64 (4)			15	2008
Kerle, 2007;	EROS B – C	0.7	2.8			16	2009
Stoney, 2008]	WorldView-2	0.46	1.84 (8)			16	2009
	Plèiades-1 and 2	0.7	2.8 (4)			20	2010, 2011
THE REAL PROPERTY.	CBERS 3 and 4	5	20 (4), 40	40 (2)	80	60, 120	2009, 2011

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Airborne digital cameras/sensors



Brand	Name	Date of update	Weight [kg]	# of lenses	# of CCD ^a chips	# of pixels across track	# of pixels along track	Spectral bands ^b
Applanix	DSS 422	2007	7kg	1	1	5,436	4,092	R,G,B or NIR,R,G
	DSS 439	2007	24kg	1	1	7,216	5,412	R,G,B or NIR,R,G
DIMAC	DiMAC 2.0	2006	100kg	2 to 4	2 to 4	10,500	7,200	R,G,B, NIR
IGI	DigiCAM- H/39	2007	1.8kg	1	1	7,216 or 5,412	5,412 or 7,216	R,G,B, or NIR
	DigiCAM- H/70	2008	3.6kg	2	2	13,500 or 10,000	10,000 or 13,500	R,G,B, or NIR
Intergraph	DMC	2003	88kg	8	8	13,824	7,680	Pan, R,G,B, NIR
Jena	JAS 150s	2007	65kg	1	9	12,000/line	Unlimited	Pan, R,G,B, NIR
Leica	ADS40	2006	61-65kg	1	8 or 12	12,000/line	Unlimited	Pan, R,G,B, NIR
RolleiMetric	AIC x1	2004	1.4kg	1	1	5,440 or 4,080	7,228 or 5,428	RGB or IR
	AIC x2	2007	12kg no lenses	2	2	10,227 or 4,080	13,588 or 5,428	RGB and IR / RGB or IR
	AIC x4	2008	38kg	4	4	10,227 or 7,670	13,588 or 10,204	RGB and IR / RGB or IR
Vexcel	UltraCam X	2006	54kg	8	13	14,430 (pan)	9,420 (pan)	Pan, R, G, B, NIR
Wehrli	3-0C-1	2006	25kg	3	3	8,002/line	Unlimited	R,G,B

[GIM International, 2008]

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Radar earth observation satellites

Satellite	Sensor	Year of launch	Band	Wavelengt h (cm)	Polarizatio n	Resolution range (m)	Resolutio n azim. (m)	Scene width (km)
ERS-1	AMI	1991	С	5.7	VV	26	28	100
JERS-1	SAR	1992	L	23.5	НН	18	18	75
ERS-2	AMI	1995	С	5.7	VV	26	28	100
Radarsat-1	SAR	1995	С	5.7	НН	10 - 100	9 – 100	45 – 500
Envisat	ASAR	2002	С	5.7	HH/VV	30 - 150	30 – 150	56 – 400
Alos	PALSAR	2006	L	23.5	Alla	7 – 100	7 – 100	40 – 350
Radarsat-2	SAR	2007	С	5.7	All	3 – 100	3 - 100	50 – 500
TerraSAR-X	TSX-1	2007	Х	3	All	1-16	1-16	5 – 100
Cosmo/SkyMe d 1, 2, 3, 4	SAR- 2000	2007, 2007, 2008, 2010	Х	3	HH/VV	1 - 100	1 – 100	10 - 200
TerraSAR-L	SAR	2008 (plan)	L	23.5	All	5 – 50	5 – 50	20 - 200
TanDEM-X ^b	TSX-SAR	2010	Х	3	HH/VV	1.7-3.5	18.5	100

[Zhang and Kerle, 2007; Düring et al., 2008]



Airborne LiDAR sensors



Brand	Name	Date of update	Weight [kg]	Wave- length [nm]	Elevation precision at 1km [cm]	Overall planimetric precision [cm]	Max. # of points/m ²
<u>Airborne</u>	Dragon	2008	25kg	1,000	GPS/INS	GPS/INS Pending	50 @ 150m, 300kHz, 20m/s
<u>Hydro-</u>	Eye				Pending		
graphy AB	Hawk Eye	2006/	95kg	532	Bathy<50	Bathy<5m	Bathy 1/m ² , topo 10/m ²
	II	2008		/1,064	Topo<30	Topo<1m	
Leica Geo-	ALS60	2008	38.5kg	1,064	14 - 16	20 - 26	91 @ 150km/h, 200m, 15
<u>systems</u>							
	ALTM	2006	23.4kg	1,064	< 10	1/11000	
Optech	Gemini						
	ALTM	2008	27kg	1,064	< 10	1/5500	
	Orion						
	RIEGL	2008	11.5kg	1,550	< 15	< 10	50 @ 50km/h, 150m, 60
<u>RIEGL</u>	VQ-480						
	RIEGL	2008	16kg	1,550	< 15	< 10	4 @ 200km/h, 500m, 60
	LMS-Q560						66 @ 50km/h, 150m, 60
	RIEGL	2009	17.5kg	1,550	< 15	< 10	5 @ 200km/h, 500m, 60
	LMS-Q680						
	Harrier	2008	42kg	1,550	< 15	< 10	4 @ 200km/h, 500 m, 60
TopoSys	56/G4		_				66 @ 50km/h, 150m, 60
	Harrier	2009	N/A	1,550	< 15	< 10	5 @ 200km/h, 500m, 60
	68/G1						
	Falcon II	2000 / 2008	41kg	1,560	< 15	< 10	12 @ 200km/h, 500m, 14.3

[GIM International, 2009]

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2. AGIP Lab Technologies

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2.a. Image Fusion

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Popular IHS Technique for IKONOS Fusion



IKONOS 4m Multispectral





IHS Fused 1m IKONOS Image



Significant Colour Distortion

IKONOS 1m Panchromatic 11/8/2010 © CRC-Laboratory in Advanced Geomatics Image Processing, UNB, Canada



QuickBird 60-cm natural color image (www.DigitalGlobe.com) Brussels, Belgium, June 2, 2002







IKONOS UNB Fusion (UNB PanSharp)



IKONOS 4m Multispectral





New 1 mIKONOS Fusion Image



Minimized Colour Distortion

IKONOS 1m Panchromatic



Landsat 7 ETM+ Image Fusion (Bands 1, 2 and 3)





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15m UNB Fusion Result

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Landsat 7 ETM+ Image Fusion (Bands 2, 3 and 4)







15m UNB Fusion Result

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QuickBird 2.8m MS

QuickBird 0.7m Pan

Courtesy Digital Globe

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QuickBird 0.7m MS, UNB Fusion

QuickBird 0.7m MS, UNB Fusion & Color Enhancement

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QuickBird 2.4m MS

U

QuickBird 0.6m MS, UNB Fusion



GeoEye-1, MS 1, 2 and 3, 2m



"Ling"

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and the second s

GeoEye-1, UNB-PanSharp, 0.5m

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And the second s

GeoEye-1, GeoEye-Pansharp, 0.5m

113 47 B

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A CADA







GeoEye-1, UNB-PanSharp, 0.5m







Conclusions UNB Fusion — UNB-Pansharp

(1) Fully automated, one step process.

(2) All the fusions have shown a perfect result with:

- maximum detail increasing,
- minimum colour distortion, and
- natural colour and feature integration.








GigitalGlobe's employees waiting for QuickBird, Boulder, CO

Photography: Yun Zhang,

GigitalGlobe's employees thank QuickBird image users, Boulder, CO







254 BKP

Dr. Y. Zhang helping DG install UNB-Pansparp

OCT 10 2003







• Being used worldwide, including NASA, Google, and US and Canadian national security.

• One of 9 Canadian successful research achievements for the "<u>Technology Transfer</u> <u>Works: 100 Cases from Research to Realization</u>", by the Association of University Technology Managers 2006.

• Other universities being selected into the 100 Cases include: <u>MIT</u>, <u>Yale</u>, <u>Stanford</u>, <u>Columbia</u> and <u>Brown</u> Universities.





2.b. Adjustable SAR-MS Fusion

UNB-ASMF

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Adjustable SAR-MS Fusion

Radarsat, SAR (8m) – Landsat TM, MS (30m)

For display purpose, the same standard linear image stretching is applied to all the images.

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Original Landsat, MS 123 (30m)

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UNB Adjustable SAR-MS Fusion, Level 2

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Original Landsat, MS 234 (30m)

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UNB Adjustable SAR-MS Fusion, Level 2

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and the second states of the

Original Landsat, MS 345 (30m)

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Adjustable SAR-MS Fusion

Radarsat, SAR (12.5m) – Ikonos, MS (4m)

For display purpose, the same standard linear image stretching is applied to all the images.

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Original Radarsat, SAR (12.5m)

(No image stretching is applied)

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UNB Adjustable SAR-MS Fusion, Level 1

(No image stretching is applied)

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UNB Adjustable SAR-MS Fusion, Level 2

(No image stretching is applied)

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2.c. Moving Target Detection

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QuickBird Pan

~1.55







QuickBird MS

~ 1.554





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Parallax

QuickBird Pan-MS arrays alignment





P -> parallax Hae -> ellipsoidal height D -> focal plane distance F -> focal length

θ -> off nadir angle



Reference:

8 June 20040/4910

Padwick, C., 2004. Pan Sharpening of High Resolution Satellite Imagery, ASPRS Annual Conference, June 8, 2004





Moving targets









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Table 5: Coordinates, speed, and azimuth angle of moving targets

11 mg		Pan				
No	X(m)	Y(m)	H(m)	Speed(km/h)	Azimuth(degree)	
1	694447.8621	5079066.252	29.539007	118.522133	133.830994	
2	694485.7676	5079025.978	30.392731	109.926338	150.191025	On alour land
3	694524.2158	5079028.594	30.532267	68.152657	323.130402	On slow lane
4	694021.1658	5079358.151	18.099633	133.697861	126.339523	1 2
5	693929.825	5079424.877	15.421739	93.154297	306.870209	
6	693917.1496	5079406.324	15.740675	23.862312	◆ 74.054672	- On road side
7	695493.5569	5077424.519	30.564808	135.721359	317.726593	
8	<u>695349.1159</u>	5077532.095	30.622373	113.871544	152.488144	
9	695370.0456	5077506.848	30.630486	149.73671	134.356384	and the second second
10	695185.9368	5077759.267	30.330296	107.45369	150.191025	
11	695206.4002	5077792.369	30.298069	145.642273	337.50769	On high speed lane,
12	695203.0379	5077735.757	30.372644	145.450485	146.192184	will pass over 13
13	695209.0495	5077724.515	30.388153	83.820351	164.745041	
14	698168.0609	5077339.579	37.840326	71.232735	52.957577	Big truck
15	698551.6409	5077532.603	43.529508	120.406052	254.578079	
16	698525.3102	5077484.445	43.616787	162.604324	74.188698	vviii pass over 17
17	698553.9627	5077496.88	44.048217	127.154083	75.379196	
18	698465.6076	5077497.859	42.224455	150.211761	4249.145782	Just passed over 15
19	699557.0058	5078000.132	42.423995	144.731583	243.904816	
20	699597.5814	5077989.308	42.318242	143.545547	68.198654	
21	700452.3905	5079682.306	27.973226	96.366844	4.39871	1 0 0 7 N 1 1 1 1 1 1 1
22	700445.0516	5079628.63	28.158358	138.395966	11.228902	
23	700441.445	5079599.551	28.268832	100.277542	10.35333	
24	700404.1849	5079558.529	28.569551	77.596268	183.252106	



Speed and direction of moving target:





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Speed and direction of moving target:



- ASPRS John I. Davidson President's Award for Practical Paper, 2009, with my PhD student Z. Xiong







2.d. Image Matching

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Problems with the Existing Solutions



Ambiguity in smooth (low texture) areas, such as forest, grass, water, highway surfaces, building roofs, etc.






UNB Image Matching



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UNB Image Matching

Right image rotates 315

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UNB Image Matching

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2.e. Image Segmentation

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Problem in object-oriented classification

Segmentation in eCognition[™]

The operator must use his/her experience and a trial-and-error method to find the appropriate segmentation parameters:

- Scale = ?
- Shape weight (factor) = ?
- Smoothness = ?

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Existing object-oriented classification (eCognition)

Step 1: Segmentation at various scales

Step 2: Classification of image objects

- Perform Preliminary Segmentation
- Parameters used:
 Scale = 25
 Shape weight = 0.1
 Smoothness = 0.1
 weight

(1) Initial Segmentation

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• Train the system by selecting appropriate subobjects that comprise the object of interest

• Start iterative process to determine appropriate segmentation parameters

(2) Segmentation Training

- Convergence in 4 iterations
- Solution parameters:
 Scale = 120
 Shape weight = 0.410

Smoothness = 0.868 weight

(3) Automatically finding optimal segmentation parameters

Re-segmentation Results and Comparison

Trial and error approach (State-of-the-art) UNB approach (UNB solution)

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Re-segmentation Results and Comparison

Trial and error approach

UNB approach

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Re-segmentation Results

(UNB result)

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Segmentation Parameters Segmentation Parameters Segmentation Parameters Compactness: 0 Compactness: 241.72 Target Object Information Texture: 29.55 Stability: 127.34 Brightness: 241.72 Area: 1652 Rectangular Fit: 0.8836 Compactness: 7.775 SubObjects Information Subjects Information Mage: Sag Object Information Mage: Sag Object Information Sag Object Information <th>Ope</th> <th>en:</th> <th></th> <th></th> <th></th> <th>Select Folder</th>	Ope	en:				Select Folder	
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2.f. InSAR DEM Reconstruction

11/8/2010

for DEM generation

Fig. 1: Interferogram and sections of corresponding DEM of Upper Bavaria.

Sample Profile of Selected Channel(s)

- ASPRS Talbert Abrams Grand Award

- Used by Intermap Technologies Inc.

2.g. Online 3D

11/8/2010

Glasses-free 2D and 3D monitors

Sharp, Philips, Toshiba

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3D display in Kunming airport, China

Web-I-3D, 3D satellite image

Web-I-3D, 3D satellite image

Web-I-3D, 3D satellite image

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2.h. Generic RPC sensor model refinement

11/8/2010


Accuracy comparison between the Bias method and Generic RPC Refinement Method





Figure 7: Accuracy comparison between the Bias Compensation method and the Generic RPC Refinement Method developed in CRC-AGIP using Ikonos images (narrow field of view) in 3 cases (all with small sensor position and attitude errors) (Note: RMSE = Root Mean Square Error; Row = Row direction of image; Col. = Column direction of image; Generic = Generic RPC Refinement Method; Bias = Bias Compensation method).

11/8/2010



Figure 8: Accuracy comparison between the Bias Compensation method and Generic RPC Refinement Method using simulated SPOT-5 data with 9 different magnitudes of errors and using 1 GCP as ground control and 36 check points for accuracy assessment. (Case 2: the sensor position error is 100m in x, y and z directions, and the sensor attitude error is 0.01 radian about the three axes; Case 3: position error is 1000m in x, y, z, and attitude error is 0.1 radian about the three axes; Case 8: position error is 0, and attitude error is 0.01 radian; Case 9: position error is 0, and attitude error is 0.1 radian; and Cases 1, 4, 5, 6, and 7: the sensor position error varies from 10m to 1000m in x, y, z, and attitude error varies from 0.0 to 0.001 radian.)

11/8/2010



Accuracy comparison between the Bias method and Generic RPC Refinement Method





Figure 9: Accuracy comparison between the Bias Compensation method and Generic RPC Refinement Method using simulated SPOT-5 data with 9 different magnitudes of errors and using 3 GCP as ground control and 34 check points for accuracy assessment. (The magnitudes of errors of the 9 cases are the same as in Figure 8.)





Technology transfer and commercialization:

1)Image fusion (UNB-PanSharp), to PCI Geomatics (2002), resulting in the best image fusion software and industry standard, used by end users globally, developer: Y. Zhang.

2)Image fusion technology, to DigitalGlobe (2003), for producing all pansharpened QuickBird imagery and now WorldView-2 imagery for worldwide distribution, developer: Y. Zhang.

3)Radar image colourization technology, to Intermap Technology (2005), for value added production of SAR images, developers: G. Hong (my PhD student) and Y. Zhang.

4)Colour enhancement technique, to PCI Geomatics (2006), developer: Y. Zhang.

5)Adjustable SAR image colourization, to PCI Geomatics (2008), developer: Y. Zhang.

6)Image fusion technology, to a US company, for security and intelligence (2008), Y. Zhang.





(1) US Patent (7,379,590): Method for Generating Natural Colour Satellite Images, 2008, Zhang.

(2) US Patent (7,340,099): System and method for image fusion, 2008, Zhang.

(3) Canadian Patent (2,491,794):Method for Generating Natural Colour Satellite Images, 2009. Zhang.

(4) US Patent Application (11/656,950): Method of Image Segmentation, 2007, with student Maxwell.

(5) US Patent Application (12/775,240): Method of Interest Point Matching for Images, 2010, with student Xiong.

(6) Canadian Patent Application (61/175,934): Method of Interest Point Matching for Images, 2010, with student Xiong.

(7) US Patent Application (12/775,259): Method for RPC Refinement Using Ground Control Information, 2010, with student Xiong.

(8) Canadian Patent Application (61/175,944): Method for RPC Refinement Using Ground Control Information, 2010, with student Xiong.

(9) US Patent Application: Dual Video Camera System and Method, 2010, Zhang.

11/8/2010







(CRC-Laboratory in Advanced Geomatics Image Processing)



(Azienda Generale Italiana Petroli) established in 1926.

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Thank you!

11/8/2010