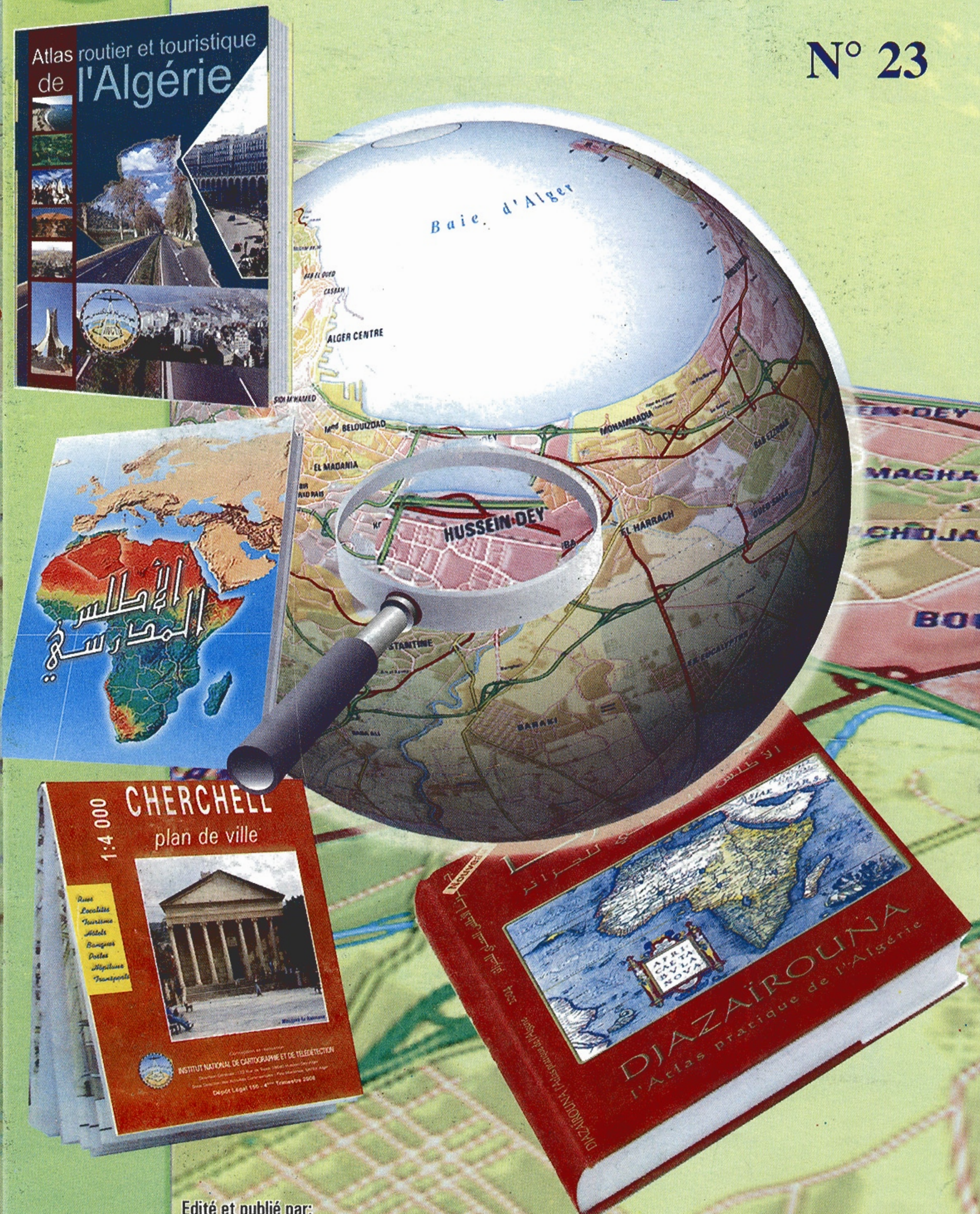
Bulletin des Sciences Géographiques

N° 23

1er Semestre 2009 • 12ème année • Prix 40 DA • Etranger 15 € • ISSN 1112-3745



Edité et publié par:
l'Institut National de Cartographie et de Télédétection

INCT
BULLETIN DES SCIENCES GÉOGRAPHIQUES

N° 23
Septembre 2009

Publication semestrielle, de l'Institut National de Cartographie et de Télédétection (INCT), Algérie.

Fondée en Octobre 1997
N°23 - Septembre 2009
ISSN 1112-3745

Responsable de la revue : INCT

Éditeur : Centre de la Documentation et de la Conservation de l'Information Géographique, INCT, Alger.

Adresse : Bulletin des Sciences Géographiques, INCT, 123, rue de Tripoli Hussein Dey 16040, BP 430, Alger, Algérie.
Tél: (021) 47 09 20
(021) 47 00 30
Fax: (021) 23 43 81
(021) 47 00 29
E-mail : inct99@wissal.dz

Tirage :
500 Exemplaires

Sommaire / Contents

Pages

Pollution organique des eaux de l'Oued Seybouse (Plaine alluviale de Guelma, Nord-Est Algérien)

A. LARABA* ; S. HADJ ZOBIR.
Université Badji Mokhtar, Faculté des Sciences de la Terre,
Laboratoire de Géologie, BP12, 23 000 Annaba, Algérie
E-mail: abdlaraba@yahoo.fr

ملخص : تكون المياه السطحية محملة بالمواد. تشكل كثرة المواد العدوى بالنسبة لمياه الري والمياه الجوفية. يحدث التلوث العضوي لما يدخل في الماء فائض من المواد العضوية مثل الأسمدة الكيماوية أو المياه القذرة . تقع مسطحة قالمة في وسط منطقة فلاحية كبيرة و محاطة بجبال مما يعطيها اسم "مدينة حوض". تستمد خصوبة هذه المنطقة من واد سيبوس و السد الكبير الذي يسقي مساحة كبيرة منها تقدر ب (12000 هكتار). لكن تطور الحركة الصناعية و النمو الديمغرافي أدى إلى تدهور نوعية المياه السطحية و الجوفية. لتقييم أثار تسرب المياه القذرة على نوعية مياه واد سيبوس تم حسب عدة عوامل فيزيائية و كيميائية منتشرة على سبعة نقاط على طول الواد. أوضحت النتائج أن هناك تدهور في نوعية المياه. يتمثل هذا التدهور في نقص تركيز الأكسجين المحلل في الماء و ارتفاع كبير في مؤشرات التلوث.

الكلمات الأساسية : تلوث عضوي، سيبوس، قالمة، الجزائر.

Abstract : The surface waters are often charged in matters. An excess of matter increase the contamination risk for the irrigation and the underground waters. Organic pollution occurs when an excess of organic matter, such as manure or sewage, enters the water. Water pollution also occurs when rain water runoff from urban and industrial areas.
The alluvial plain of Guelma is located in the centre of an agricultural region and is surrounded by mountains what gives it the name of "basin pan city". The Seybouse wadi and the dam assure a vast perimeter of irrigation (12000 ha). However, the very fast development of the industrial activity, accompanied by a very advanced growth of the population dragged a deterioration of surface and underground water quality. In order to study the impact of the waste waters, different physico-chemical parameters have been measured in seven sites distributed along the Seybouse wadi. The study shows a deterioration of the water quality, this result in a decrease of the oxygen content in water and by an important increase of the pollution indicators.

Keywords: Organic pollution, Seybouse, Guelma Algeria.

Résumé : Les eaux de surfaces sont souvent chargées des matières. Un excès de matière présente généralement un risque de contamination pour eaux Les eaux d'irrigation ainsi que pour les eaux souterraines. La pollution organique se produit quand un excès de matière organique, tel qu'engrais ou eaux d'égout, entre dans l'eau. La plaine alluviale de Guelma, se situe au centre d'une grande région agricole, entourée de montagnes ce qui lui donne le nom de « ville cuvette ». Cette région trouve sa fertilité grâce notamment à l'Oued Seybouse et au grand barrage qui assure un vaste périmètre d'irrigation (12000 ha). Cependant, le développement très rapide de l'activité industrielle, accompagné d'une croissance très poussée de la population ont entraîné une dégradation de la qualité des eaux de surfaces et souterraines. Afin d'évaluer l'impact des rejets des eaux usées sur la qualité des eaux de l'oued Seybouse différents paramètres physico-chimiques ont été mesurés en sept sites répartis le long de l'Oued. Les résultats ont montré une nette détérioration de la qualité des eaux. Cette détérioration se traduit par une diminution de la teneur en oxygène dissous dans l'eau et par une augmentation importante des indicateurs de pollution.

Mots-clés : Pollution organique, Seybouse, Guelma, Algérie

1. Introduction

La vallée de la Seybouse et ses principaux affluents constituent des zones de vulnérabilité des eaux de surfaces et de la nappe superficielle de Guelma. La caractéristique hydrographique du bassin est l'absence de grandes rivières, les cours d'eau, formés de rivière et petits oueds, se caractérisent par la faiblesse de leur débit. Situation qui ne favorise pas la dilution de la pollution, associée à une forte densité de la population et d'industrie et le manque d'infrastructure d'épuration et d'évacuation des eaux usées, ce qui explique la médiocre qualité de l'eau de l'oued. L'étude menée sur les sept stations localisées sur le parcours de l'oued Seybouse a permis d'évaluer l'impact des eaux usées sur la qualité des eaux de la Seybouse.

2. Cadre géographique et climatique

La plaine alluviale de Guelma se situe au Nord Est algérien formant une cuvette entourée par les monts de (Haoura, Debagh, Mahouna et Dj Nador), faisant partie du bassin versant de l'Oued Seybouse, elle s'étend le long de la vallée de l'Oued orientée sensiblement Ouest – Est. Le cours d'eau principal, l'Oued Seybouse, est formé par la confluence des oueds Cherf et Bouhamdane au niveau de Medjez Amar drainant la partie sud du bassin imposant ainsi au drainage général une direction sud – nord. Le long de son parcours, l'oued Seybouse reçoit d'autres affluents d'importance inégale en longueur et en quantité d'eau. La « moyenne Seybouse », s'étendant jusqu'au pied du Djebel Nador, occupe les bassins versants des oueds Mellah et Bouhamdane et toute la plaine de Guelma. La région de Guelma soumise à un climat de type méditerranéen, est caractérisée par deux périodes différentes, l'une pluvieuse humide, l'autre sèche. La pluviométrie de 570 mm/an et la température moyenne annuelle est de l'ordre de 18°C La zone d'étude y est marquée par un réseau hydrographique constitué par l'Oued principal Seybouse qui parcoure la plaine, présente l'axe de drainage d'un bassin versant de 6471 Km². Et ses affluents secondaires : Oued Skhoun à l'ouest de la ville de Guelma, Oued Maïz à l'ouest de Belkheir, Oued Zimba à l'est de Belkheir et Oued Bou Sorra à l'ouest de Boumahra Ahmed. La vallée de Guelma est un ancien bassin d'effondrement longtemps fermé où s'est entassé un ensemble varié de sédiments allant du Miocène au Quaternaire. Les mouvements tectoniques du Plio-quaternaire ont joué un rôle important dans la morphogenèse de la région.

3. Contexte géologique

Le bassin versant de la Seybouse fait partie de la chaîne alpine de l'Algérie orientale (Durand Delga, 1969). Cette chaîne est constituée par la superposition de plusieurs unités structurales hétérogènes, dont l'histoire géologique s'étale depuis le Trias jusqu'au Pliocène (Figure.1). Cet édifice complexe est partiellement recouvert par une sédimentation Mio-Pliocène et/ou Quaternaire, surtout continentale (Vila, 1980). La géologie de la région de Guelma peut–être divisée en trois grands ensembles anté-nappe, (ii) un ensemble Mio-Pliocène (continental, du bassin de Guelma) et (iii) un ensemble récent (Pliocène et Quaternaire). La région de Guelma c'est le domaine néritique de Djebel de Debagh, Héliopolis et le sud de Guelma.

Cette unité à faciès carbonaté Jurassique-Crétacé, plus ou moins karstifiée est surmontée par plusieurs nappes de charriages et soumise à de grands accidents tectoniques.

Entre Nador et Medjez Amar, la Seybouse a déposé des alluvions sur son parcours, le Quaternaire occupe le centre de la plaine et correspond au faciès des terrasses on y distingue :

Alluvions anciennes : éboulis et galets formant le remplissage du bassin d'effondrement, et possédant une grande importance hydrogéologique pour la région.

Alluvions récentes : Ces formations sont peu importantes et sont constituées de cailloutis, de graviers, de galets, de calcaires et de limons.

L'Oued Seybouse traverse le bassin de Guelma qui a connu pendant le Pliocène un remplissage avec des manifestations diapiriques intenses du Trias.

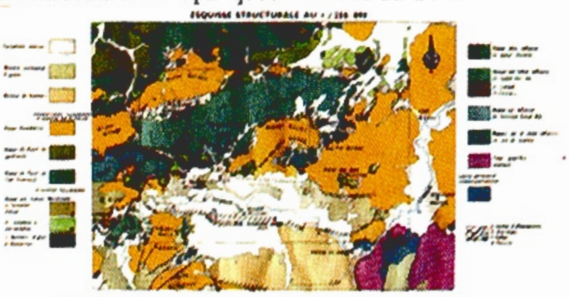


Fig. 1 : Esquisse structurale de la région de Guelma

4. Matériels et méthodes

Deux campagnes de prélèvements ont été effectuées pendant la période des hautes eaux (Mai 2005/2006). Sur chaque échantillon d'eau, les déterminations analytiques ont porté sur les paramètres suivants :

- Température, pH, Conductivité à 20°C, Oxygène dissous,
- Demande chimique en oxygène DCO,
- Paramètres de l'azote : NH4, NO2, NO3
- Phosphore : PO4

La série de données hydrochimique des eaux de la Seybouse réalisée au sein du laboratoire des recherches appliquées (DRA, ISPAT Annaba) a permis de tracer les courbes d'évolution des principaux indicateurs de pollution des eaux. Les eaux sont classées d'après les critères de qualité de la grille établie par l'ANRH (2004) selon les normes internationales et européennes, pour les eaux de surfaces. Les échantillons d'eau ont été prélevés dans des flacons en polyéthylène de 1 litre, transportés au laboratoire dans une glacière à basse température (4°C). Les paramètres physico-chimiques (pH, CE, T°, et l'O2 dissous) sont mesurés in situ en utilisant des appareils de terrain : un pH mètre WTW, un conductimètre de terrain WTW et un oxymètre OXI.

La température est obtenue simultanément avec la mesure du pH, CE et l'oxygène dissous. Les nitrates, nitrites, l'ammonium et les orthophosphates ont été dosés directement dans l'eau filtrée par addition des réactifs.

5. Résultats et discussion

Le réseau de contrôle de la qualité des eaux de surface comprend 07 stations réparties le long de la vallée de la Seybouse dans la région de Guelma (Figure. 2), sur les différents affluents du bassin, et ce de l'amont à l'aval :

à l'amont, cette partie est surtout l'objet d'une activité agricole.

sur les cours des affluents de la Seybouse (O. Skhoun, O. Maiz, O. Zimba, O. Bou sorra) La partie médiane (centre) est exposée à une activité industrielle et ménagère.

- à l'aval dans l'oued Seybouse

Les résultats des analyses sont exposés dans le tableau 1.

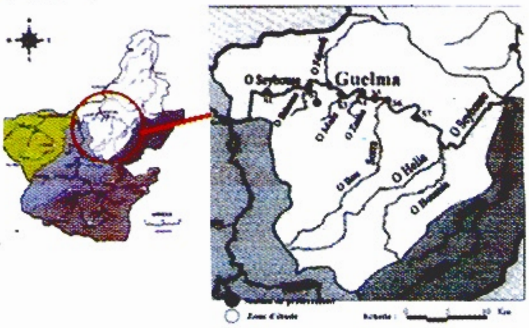


Fig. 2 : Localisation des stations de prélèvement sur l'Oued Sebouse (région de Guelma)

Tableau 1 : Caractéristiques physico-chimiques des affluents de l'oued Seybouse (région de Guelma)

Paramètres	Seybouse amont	Skhoun	Maiz	Zimba	Seybouse centre	Bou Sorra	Seybouse aval
T°C	17,5	20,3	21,3	22	21,5	22	22,5
pH	7,7	7,6	7,3	7,5	7,4	7,1	7,8
O2 (mg/l)	5,75	4,75	4,8	4,6	4,85	6,1	5,3
DCO (mg O2/l)	240	258	250	252	260	284	264
NO3 (mg/l)	30	43	78	48	81	80	60
NH4 (mg/l)	0,09	0,34	0,24	0,12	0,19	0,12	0,08
PO4 (mg/l)	0,12	0,33	0,5	0,09	0,22	0,04	0,6
NO2 (mg/l)	0,3	3	2,2	1,2	1,7	0,3	0,4

Température

La mesure de la température s'effectue dans la rivière au moyen d'un thermomètre approprié. La température exerce son influence sous deux aspects principaux : Elle modifie la solubilité des gaz dans l'eau et modifie la vitesse des réactions chimiques et biochimiques. Lorsque la température s'élève, les bactéries consomment plus de dioxygène, ce qui réduit la quantité disponible pour les autres êtres vivants de l'écosystème. Les températures des eaux des affluents de l'oued varient entre 17,5 °C en amont et 22,5 °C en aval (Tableau.1).

On constate qu'à l'amont les valeurs thermiques sont faibles alors que dans les secteurs centre et aval de la plaine, ces dernières deviennent élevées. Cette variation peut être expliquée par des rejets industriels d'eaux chaudes de rinçage des appareils de production. Ces valeurs de températures répondent bien aux normes algériennes de rejet industriel qui est de 30°C (JORA, 2006). La température élevée des eaux favorise le développement des micro-organismes et induit des odeurs désagréables.

pH

Le pH influence la dissolution des roches et la précipitation de certains sels.

Le pH est important dans les rivières pauvres en carbonates dont le pouvoir tampon est très faible. Elles sont donc plus sensibles aux apports extérieurs d'un pH différent.

Le pH est aussi important dans les rivières déficientes en dioxygène : la dégradation des molécules organiques s'arrête souvent au stade d'acides organiques.

Les eaux de l'oued Seybouse sont caractérisées par un pH relativement neutre à alcalin entre 7,7 en amont et 7,8 en aval. Ceci est probablement lié à la neutralisation par les industries de leurs rejets avant leur déversement dans l'oued. Mais leur pH est compatible avec la vie de la biomasse.

L'oxygène

La teneur en oxygène dissous est déterminante pour la qualité des eaux : Les eaux polluées renferment peu ou pas d'oxygène (O2 dissous) parce que les microorganismes qui font fermenter les déchets organiques consomment cet oxygène massivement. L'oxygène dissous est l'un des paramètres indicateurs de pollution, Les variations de cet élément sont régulières et faibles, comprises entre 4.6 et 6.1 mg/l, (Fig.3), elles définissent une classe de l'eau assez bonne avec une pollution de l'eau modérée. Les faibles valeurs sont observées au niveau des affluents de l'oued Seybouse : oueds Zimba, Maiz et Skhoun et notamment oued Seybouse centre, exprimant une classe médiocre et une pollution nette.

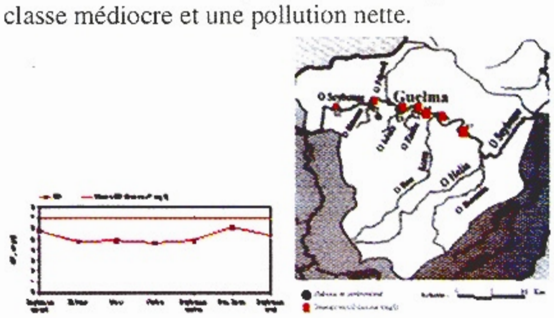


Fig. 3 Variation de l'oxygène dissous O2

La Demande chimique en oxygène DCO

Les eaux résiduaires de l'oued Seybouse présentent des valeurs voisines de 281 mg/ l en demande chimique en oxygène (Tableau1). Les valeurs de DCO pour les eaux des différentes stations étudiées dépassent la valeur de 50 mg d' O2 /l fixée par les normes Algériennes (ANRH 2004) (Tableau 2). Ce qui permet de classer ces eaux comme de très mauvaise qualité, ceci est en rapport avec les déversements des eaux usées des agglomérations et des différentes zones industrielles de la région de Guelma.

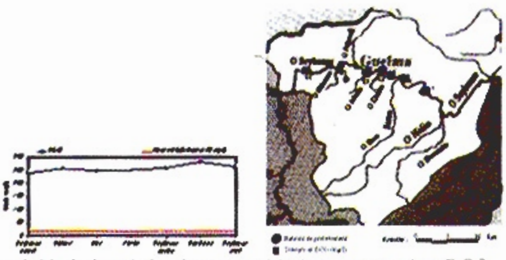


Fig. 4 Variation de la demande chimique en oxygène DCO

Tableau 2 : Classe de qualité des eaux de surfaces (ANRH mai 2004)

	Classe de Qualité			
Paramètres	Bonne	Moyenne	Polluée	Très polluée
DBO5 (mg /l)	≤5	5 à 10	10 à 15	≥15
DCO (mg /l)	≤20	20 à 40	40 à 50	≥50
O2 dissous (mg/l)	≥7	7 à 5	5 à 3	≤3
NH4 (mg/l)	0 à 0,001	0,01 à 0,1	0,1 à 3	≥3
PO4 (mg/l)	0 à 0,001	0,01 à 0,1	0,1 à 3	≥3
NO2 (mg/l)	0 à 0,001	0,01 à 0,1	0,1 à 3	≥3
NO3 (mg/l)	≤10	10 à 20	20 à 40	≥40

Les nitrates

Les résultats des analyses des nitrates montrent que leurs teneurs varient entre 30 mg/l à la station amont et 81 mg/l à la station médiane. La figure. 5, indique une forte teneur en nitrates de l'amont vers l'aval de la plaine de Guelma parallèlement au sens d'écoulement des eaux de l'oued, sans doute à cause des phénomènes de transformation et consommation par les microorganismes (Rodier 1996). Les teneurs en nitrates dans les eaux prélevées dépassent les 40 mg/l proposées par les normes algériennes sauf pour le site amont. Ce qui indique une contamination des eaux de la Seybouse.

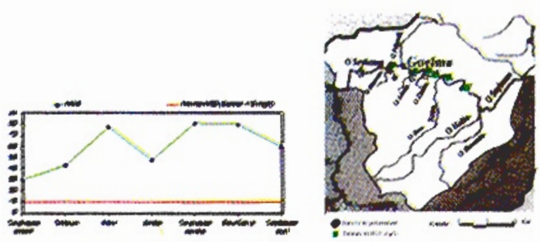


Fig. 5 Variation des nitrates NO3

Les nitrites

Les analyses révèlent que la totalité des sites de prélèvements ont des teneurs en nitrites inférieures aux normes Algériennes de 3 mg/l pour les eaux usées. Les valeurs enregistrent des variations allant de 0.3 à 3 mg/ l (Fig.6). La valeur seuil limitant est observée au niveau de l'affluent de Oued Skhoun où se déversent les rejets des eaux usées non traitées.

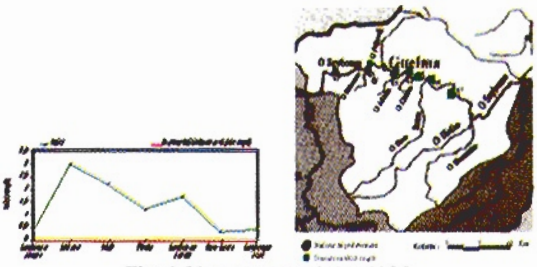


Fig. 6 Variation des nitrites NO2

L'ammonium

L'évolution de la courbe (NH4 ammonium) (Fig.7) montre qu'il y'a de faibles concentrations inférieures à 0,1 mg/l en amont et en aval de l'agglomération de Guelma, ce qui indique une qualité moyenne de l'eau. Les valeurs élevées s'observent sur les sites des oueds Skhoun, Maiz, et Seybouse centre, où les teneurs en NH4 sont respectivement : 0.34 , 0.24 et 0.20 mg/l, indiquant une eau polluée, ceci pourrait être lié aux rejets des eaux usées de la ville de Guelma.

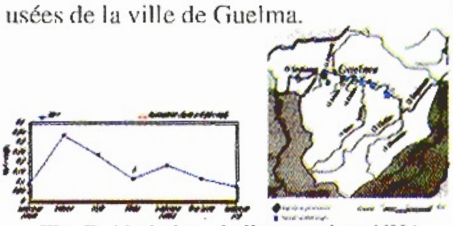


Fig. 7 Variation de l'ammonium NH4

Les phosphates

Le phosphore provient essentiellement des activités domestiques, (rejets organiques des lessives) mais également des industries et de l'agriculture via l'érosion des sols. Des teneurs supérieures à 0.1 mg/l constituent un indice de pollution (Rodier.1996, ANRH.2004). Selon ces normes, les valeurs obtenues des ions orthophosphates (Tableau.1) sont considérées comme élevées pour les stations de : O. Skhoun, O. Maiz, Seybouse Centre et Seybouse Aval (Fig.8). Ces valeurs sont à attribuer aux déversements des eaux usées de la ville de Guelma. La qualité phosphore est mauvaise à l'aval de l'oued Seybouse et de chaque collectivité importante, ceci est dû à l'absence de traitement de cet élément par les stations d'épuration. Dans ces zones, les eaux usées collectées doivent être soumises à un traitement plus rigoureux pour éliminer en particulier azote et phosphore.

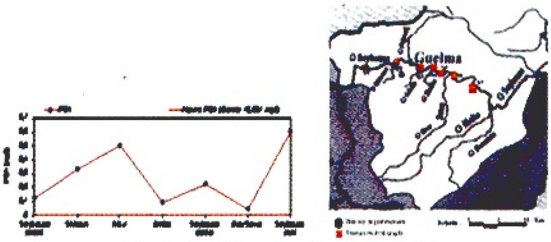


Fig. 8 Variation des phosphates PO4

6. Conclusion

Les résultats obtenus au cours de cette étude témoignent dans leur majorité d'une contamination relative des eaux de l'oued Seybouse par les eaux usées de la région de Guelma. Avec des teneurs maximales de 81 mg/l en nitrates, de 284 mg d'O_2 / l en DCO.

Les eaux de la Seybouse sont classées selon la grille de qualité des eaux de surfaces en Algérie comme étant assez chargées et polluées. Elles constituent une menace pour l'environnement de la région et notamment pour les eaux souterraines. La demande chimique en oxygène (DCO) a des valeurs très élevées, soit 284 mg /l, ce qui reflète bien la quantité importante de matière organique contenue dans les eaux de l'Oued. Elles donnent une indication globale de la contamination organique.

L'évolution des teneurs en ammonium, nitrates et nitrites dans l'oued Seybouse montre une forte concentration de NO3, NO2 et NH4. L'azote est présent dans l'eau sous forme organique ou minérale plus ou moins oxydée et en quantité importante a souvent pour origine des rejets domestiques, agricoles ou industriels. L'abondance du phosphore dans le milieu aquatique conduit à la prolifération des algues. A certains endroits ce phénomène peut- être aggravé par le ralentissement de la dynamique des oueds (sécheresse). La principale source de phosphore est l'agriculture, les rejets domestiques et les rejets industriels.

Le rejet dans l'Oued Seybouse et ses affluents, sans aucun traitement préalable, des eaux usées des villes et des industries se trouvant sur le bassin versant présente un haut potentiel de risque de contamination des eaux souterraines d'autant plus que l'oued traverse sur la presque totalité de son cours des zones très vulnérables. Ce risque est d'autant plus grave que des échanges sont possibles d'une part entre l'oued et la nappe superficielle et d'autre part entre les deux nappes (superficielle et profonde).

La gestion de la qualité d'un oued est donc une responsabilité partagée par tous ses utilisateurs, La qualité de l'eau en aval dépend du souci de protection en amont.

Les cours d'eau pourraient être considérés non plus comme des égouts naturels, mais comme une ressource potentielle d'eau d'irrigation.

Pour des mesures préventives, ces zones à risque doivent être contrôlées, d'une part, par l'utilisation rationnelle des fertilisants et d'autre part, il faudrait aussi prévoir, à l'échelle de tout le bassin versant de la Seybouse, un traitement préalable des eaux usées urbaines et industrielles qui sont rejetées.

La protection des forages de captage par des périmètres de protection est très recommandée

Remerciements

Les auteurs remercient le personnel du laboratoire des recherches appliquées (DRA, ISPAT Annaba, Algérie, le personnel des analyses chimiques, l'ensemble des étudiants hydrogéologues du département de Géologie Annaba, Algérie.

Références

Debieche. T.H. (2002), Evolution de la qualité des eaux (salinité, azote et métaux lourds) sous l'effet de la pollution saline, agricole et industrielle. Application à la basse plaine de la Seybouse N-E Algérien. Thèse pour le grade de docteur de l'université de Franche-Comté. 199p

Djabri L, Hani A, Mania J, Murdy J. (2001). Impact des eaux urbaines sur la qualité des eaux de l'oued seybouse Symposium frontière de la gestion de l'eau urbaine, 18-20 juin 2001 ; marseille

Durand Delga M. (1969). Mise au point sur la structure du Nord-Est de la Berbérie. Bull.Serv.Carte Géol. Algérie, N.S, n°39, 9.89-131, 9 fig., Alger.

JORA, 2006.JournalOfficiel de la République Algérienne. Décret ministériel n°06-141, portant organisation et réglementation des déchets liquides industriels.

Lahondère. J.C. (1987), Les séries ultratelliennes d'Algérie nord-orientale et les formations environnantes dans leur cadre structural. Thèse d'Etat Univ. Paul Sabatier, Toulouse 204p.

Rodier J. (1996). L'analyse de l'eau, eaux naturelles, eaux résiduaires, eau de mer, 7e édition, Dunod, Paris, 1350p.

Vila J.M. (1980). La chaine Alpine d'Algérie orientale et des confins Algéro-Tunisiens. Thèse Doctorat d'état Univ. Pierre et Marie – Curie, Paris VI, 665 p.

Génération d'un Modèle Numérique de Terrain Radar : Application à la région d'Oran, Algérie

HASNI Kamel, TOUAM Saïd , HASSAINE Benali
Division de Géodésie, Centre des Techniques Spatiales,
1, Avenue de la Palestine, B.P.13 Arzew 31 200, Algérie.
Email: hasni_kamel@maktoob.com

ملخّص : نقدّم في هذا العمل المرحلة الكاملة لمعالجة الصوّر لتوليد نماذج أرضية رقمية (MNT) ذات قياس التداخل الضّوئي بإدراج البرنامج الذي أنجزته جامعة Delft (هولندا) ، قصد الحصول على نماذج أرضية رقمية ذات دقة التمييز العالية من خلال زوج من الصوّر الرادارية ERS1/2 . هكذا ، بمجرّد الوصول إلى هذا الهدف ، تطرقنا لتحليل النتائج المحصّل عليها خلال إستعادة التضاريس في منطقة التجربة . تبيّن نتائجنا بأن النماذج الأرضية الرقمية المنجزة والتقنية InSAR تعطي الدقّة الإجمالية لـــ 20 م.

الكلمات الأساسية : ردار ، كاشوف (ردار) الفتحات الصنعية SAR ، نماذج أرضية رقمية MNT ، ردار قياس التداخل الضّوئي ، طور .

Resumé : Dans ce travail, nous présentons un processus complet de traitement d'images pour la génération d'un Modèle Numérique de Terrain (MNT) interférométrique en incluant le logiciel développé par l'Université de Delft (Pays Bas), avec pour finalité l'obtention d'un MNT haute résolution à partir d'un couple d'images radar ERS1/2.
Ainsi, une fois cet objectif atteint, nous avons été amenés à analyser les résultats obtenus lors de la restitution du relief d'un site test. Nos résultats montrent que le MNT réalisé avec la technique de l'InSAR donne une précision globale de 20 m.

Mots-clés : Radar, SAR, MNT, interférométrie radar, phase.

Abstract : In this work, we present a complete image processing for the generation of an interferometric Digital Terrain Model (D T M) including software developed by the University of Delft (Netherlands), with the aim of obtaining a high resolution D T M from a couple of ERS1/2 radar images.
Thus, once achieved, we have been conducted to analyze the results of the restitution of a relief in a test area. Our results showed that the D T M achieved with the InSAR technique gives an overall accuracy of 20 m.

Key words : Radar, SAR, DTM, radar interferometry, phase.

1. Introduction

La restitution du relief par stéréoscopie depuis l'espace est une discipline relativement ancienne avec notamment la photogrammétrie. Bien qu'accédant à de bons résultats, les difficultés de survols inhérentes aux conditions météorologiques la rendent toutefois limitée. Les capteurs optiques embarqués sur des satellites peuvent atteindre des précision décamétriques mais demeurent dépendants des phénomènes atmosphériques. A ce titre, en s'affranchissant en partie de ces phénomènes, l'imagerie radar permet des exploitations intéressantes pour la réalisation de MNT.

2. PRINCIPE DE L'InSAR

L'interférométrie radar (InSAR : Interferometric Synthetic Aperture Radar) est une technique de télédétection utilisant deux images SAR acquises avec un décalage dans l'espace et (ou) dans le temps, appelé base, afin d'extraire l'information sur l'altitude (MNT) ou le mouvement de la surface terrestre (déformation).
L'InSAR appliquée au calcul de MNT a été décrite par Graham en 1974 et mise en application pour la première fois en 1986 sur des capteurs aéroportés [Bamler R., 1997]. Depuis, pour des raisons de stabilité orbitale, la technique satellitale du radar à ouverture de synthèse est la plus employée.

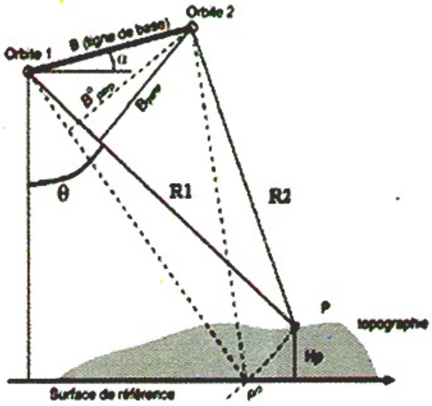


Fig. 1: principe géométrique de l'InSAR

A la différence des données optiques où on utilise la stéréoscopie, dans la technique de l'InSAR, la phase du signal est utilisée (équation 1). Nous calculons la différence de phase de deux images de la même zone, prises en deux passages (figure 1).

$$\Delta\varphi = \varphi_2 - \varphi_1 = \frac{4\pi}{\lambda}(R_2 - R_1) \quad \text{..................(1)}$$

Avec :

λ : Longueur d'onde.

R1, R2 : Distances obliques radar-cible.

Le terme $\Delta\varphi$ est appelé « interférogramme ». Il est composé de trois termes :

Un terme de terre plate, qui est dû à l'existence d'une base. Il se traduit sur l'interférogramme en la présence de franges parallèles.

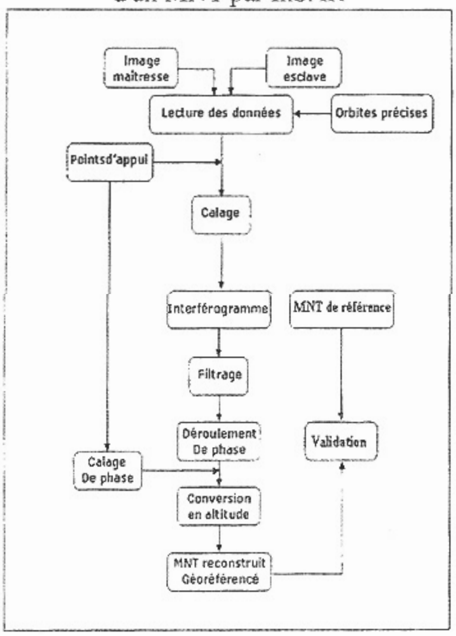
Un terme de topographie, correspondant à la différence de phase causée par l'altitude de la surface observée par rapport à une surface de référence (ellipsoïde, géoïde,...).

Un terme d'erreur.

3. Algorithme pour la réalisation d'un MNT Radar :

Pour la réalisation du MNT, nous avons utilisé le logiciel DORIS (Delft Object-oriented Radar Interferometric Software) [Kampes B. & Usai S., 1999], avec l'algorithme de la figure 2 suivante :

Fig. 2 Méthodologie générale de réalisation d'un MNT par InSAR



3.1 Calage

Un pixel d'une image doit correspondre exactement à un pixel dans une autre image.

Recaler les deux images de la même scène permetimage « maîtresse ». Par opposition, l'autre image est appelée image « esclave ».

3.2. Génération de l'interférogramme

La multiplication complexe est utilisée pour extraire l'information de phase, comme il est présenté dans l'équation 2.

$$I(i_1,i_2) = U_1(i_1,i_2) \cdot U_2^*(i_1,i_2) = |U_1| \cdot |U_2| \cdot e^{(j(\varphi_1-\varphi_2))} \quad \text{.......(2)}$$

Avec :

$U_k(i_1,i_2)$ Valeur l'interférogramme pour le pixel (i_1,i_2)

$I(i_1,i_2)$: Valeur complexe $(k=2)$ pixel (i_1,i_2) de la scéne maitresse $(k=1)$ ou esclave

3.3 Calcul de la cohérence :

La cohérence est une mesure de la fiabilité de la phase dans le voisinage d'un pixel. Elle est définie par l'équation 3 :

$$\rho = \frac{E\{U_1 \cdot U_2^*\}}{\sqrt{E\{U_1 \cdot U_1^*\} \cdot E\{U_2 \cdot U_2^*\}}} \quad \text{.............................(3)}$$

Avec :

U_1, U_2 : Valeur moyenne dans la zone prédéfinie .

ρ : Les signaux complexes.

Ou « * » dénote le conjugué complexe. La valeur réelle de la cohérence est $\gamma = |\rho|$ et sa valeur déterminé la qualité de l' nme dans cette région.

3.4 Calcul et soustraction du terme de la terre plate

Ce terme de phase causé par l'existence d'une base est calculé par rapport à une surface de référence (l'ellipsoïde WGS84) puis il est soustrait de l'interférogramme brut. Cet interférogramme ne contient maintenant que les franges topographiques, dont chaque frange représente une altitude dite «altitude d'ambiguïté», défini par Massonnet et Rabot (1993) [Massonnet D. & Feigl K., 1998] par l'équation 4 :

$$h_a = \frac{\lambda R_S \sin i_M}{2B_\perp} \quad \text{..................................(4)}$$

Avec :

R_s : Distance oblique de l'image esclave.

i_M : Angle d'incidence de l'image maitresse.

$B_\perp$: Base perpendiculaire du couple.

3.5 Filtrage de la phase

Selon l'altitude d'ambiguïté employée, l'interférogramme peut contenir un bruit excessif, notamment dans les zones montagneuses, susceptibles de gêner son exploitation puisque les franges se retrouvent masquées.

Une étape de filtrage est nécessaire pour éliminer le bruit qui s'ajoute au signal exploitable. La difficulté du filtrage consiste à nettoyer le bruit sans dégrader l'information de phase. Ce bruit d'origine spatiale ou temporelle n'est pas toujours réversible. Seulement, une partie non négligeable du bruit affectant les interférogrammes peut être éliminée, ce qui conduit à une information de phase nettoyée laquelle garantit un déroulement de phase plus robuste et une information finale non bruitée.

3.6 Déroulement de phase

C'est une étape critique dans le processus interférométrique. Dans un interférogramme, la phase est seulement connue à modulo 2π . Il est donc nécessaire de déterminer le multiple de 2π à additionner à la phase mesurée sur chaque point pour obtenir une estimation de la phase réelle. Donc, la phase ambiguë dans l'intervalle $[-\pi,\pi]$t être convertie en une valeur non ambiguë (continue) qui peut être n'importe quel nombre réel. Le déroulement de phase consiste donc à redistribuer à chaque pixel sa phase absolue. Deux contraintes grèvent cette procédure :
La surface doit être relativement régulière ; à ce titre, il est préférable qu'elle soit préalablement lissée.
La variation absolue entre deux pixels voisins doit être inférieure à π. Les discontinuités dues à l'occultation en zone de basculement ou d'ombre rendent alors la procédure particulièrement délicate.

3.7 Conversion des phases en altitudes

Cette étape permet de transformer la phase ainsi déroulée en hauteurs dans la géométrie radar ; l'utilisation de points d'appui permet de corriger les paramètres orbitaux de l'image maîtresse pour un calcul plus précis de la base, ce qui permet un bon géoréférencement du MNT résultant et pour déterminer les altitudes réelles.

3.8 Géoréférencement

Il s'agit de la transformation du système de l'interférogramme (ligne, pixel, phase) en un système de coordonnées géographiques (λ,φ,h).

4. Test resultats

Notre étude d'interférométrie porte sur une zone située au sud-est de la région d'Oran (Algérie), s'étalant sur 47 kmx47 km . Cette zone est relativement montagneuse avec un relief très marqué (figure 3). L'existence de zones plates au nord-ouest et au sud-ouest devrait induire des distorsions géométriques sur les deux images, en particulier le phénomène d'ombre et de basculement.

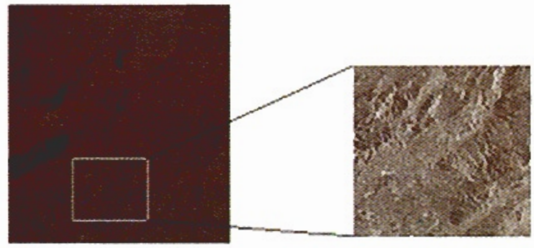


Fig. 3 Amplitude de l'image maîtresse (gauche) et zone de test (droite)

4.1 Donnée initiales

Nous disposons d'un couple interférométrique issu des observations du satellite ERS1 et de sa doublure ERS2 en orbite circulaire.

Tab. 1 Le couple ERS1-ERS2

Couple	Date	Angle d'incidence au centre	Orbite	Temps d'acquisition
Image 1	10/01/1996	23,164°	descendante	10:42:43
Image 2	09/01/1996	23,290°	descendante	10:42:33

Couple Date Angle d'incidence au centre Orbite Temps d'acquisition
Image 1 10/01/1996 23,164° descendante 10:42:43
Image 2 09/01/1996 23,290° descendante 10:42:33
Tab.1 : Le couple ERS1-ERS2
Ce couple d'images est acquis en mission tandem (décalage d'observation de 1 jours), ce qui permet de minimiser les problèmes de décorrélation temporelle. La longueur de base de 123.5 m induit une altitude d'ambiguïté de 83.5 m (équation 4). Cette valeur devrait conduire à une précision altimétrique correcte, tout en évitant la formation de bruit sur l'interférogramme.

4.2 Réalisation du MNT

L'application de l'algorithme précédent permettra d'extraire à partir du couple considéré un MNT de notre région.

4.2.1 Calage

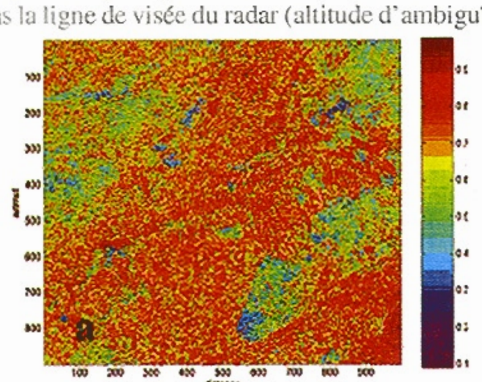
Le calage a été sur la base des orbites précises délivrées par l'Université de Delft [Scharroo R. & Visser P., 1998]. Doris fournit une première approche, utilisant les orbites pour calculer la corrélation entre les deux images. Cette étape donne une idée grossière sur les paramètres de calage (un décalage de 196 lignes et de 194), elle permet de caler les images avec la précision de 30 pixels [Kampes B., 1999].

Puis une deuxième étape permet de calculer localement la corrélation entre les deux images d'amplitudes, cela permet d'arriver à une précision de calage de 1 pixel. Finalement, une étape plus précise permet de calculer le décalage entre un pixel dans une image et son homologue sur l'autre image. Ceci donne une précision de calage d'un 1/10eme ce qui permet de superposer l'image esclave sur l'image maîtresse. Le résultat de cette étape est un décalage de 194 en lignes et de -94 en colonnes. Finalement, l'image esclave est interpolée sur la même grille de l'image maîtresse pour qu'elles puissent être superposables.

Durant le calage, deux étapes de filtrage peuvent être introduites dans le traitement. Le premier est un filtrage en azimut des deux images afin de supprimer les portions de spectre non chevauchées, puisque le traitement SAR des deux images a été effectué avec différent doppler centroïdes. Un deuxième filtrage est effectué en distance à cause du non chevauchement complet des deux scènes après le premier filtrage, qui est dû à une légère différence entre les angles de visée des deux capteurs se qui permet de réduire ce bruit.

4.2.2 Produit interférométrique

Le produit interférométrique de DORIS est constitué de deux images : une image de phase ou interférogramme et une image de cohérence (figure 4). Pour la réalisation de l'interférogramme un facteur de multivue de 5 en azimut et de 1 en distance a été utilisé afin de minimiser le bruit. La cohérence est automatiquement calculée après la création de l'interférogramme en utilisant l'équation 3, un facteur de multivue de (2,2) est utilisé pour réduire le bruit. La figure 4-b présente l'interférogramme nettoyé des franges orbitales (terme de terre plate). Ce terme de phase causé par l'existence d'une base, est calculé par rapport à une surface de référence (l'ellipsoïde WGS84) puis il est soustrait de l'interférogramme brut. L'interférogramme ne contient maintenant que les franges topographiques. Chaque frange représente une altitude de 83.5 m dans la ligne de visée du radar (altitude d'ambiguïté).



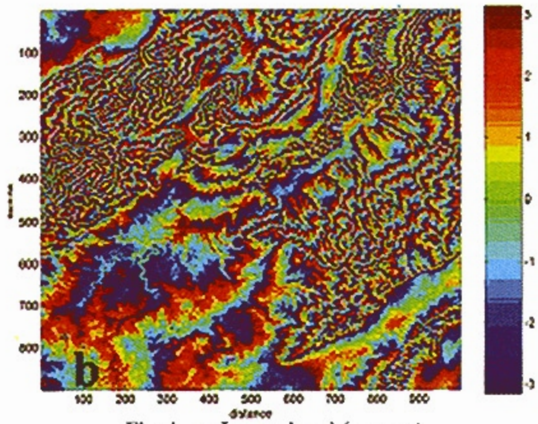


Fig. 4 a : Image de cohérence et b : Interférogramme

4.2.3 Filtrage de phase

Le logiciel DORIS offre deux possibilité de filtrage : La première est une convolution spatiale et la deuxième est le filtrage de Goldstien décrit dans [Goldstein R. M. & Werner C. L., 1998]. Pour notre travail, nous avons choisi le filtre de Goldstein puisqu'il est plus commode pour les zones présentant une variation rapide de la phase [Tsay J. & Chen H., 2001].

Le filtre de Goldstein est basé sur le principe de diviser l'interférogramme en parties dont on calcul la transformée de fourrier de chacun deux [Goldstein R. M & Werner C. L., 1997] et les spectres sont transformés en nouveaux spectres suivant la formule:

$$Z' = |Z|^{\alpha} Z \quad \text{.................................(5)}$$

Avec :

Z : Lancien spectre.

Z' : Le nouveau spectre.

α : Paramétre du filtre.

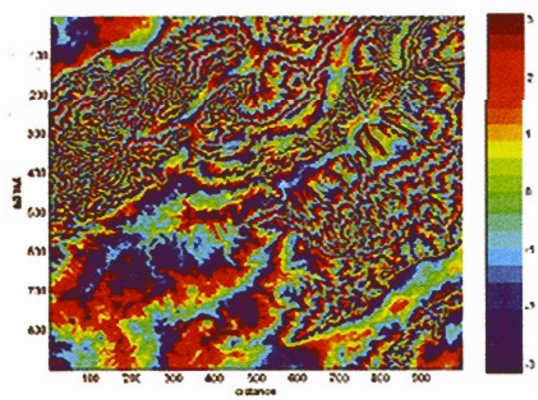


Fig.5 : Interférogramme filtré

4.2.4 Déroulement de phase

L'étape de déroulement de phase a été réalisée avec le programme « SNAPHU » [Chen C. W. & Zebker H., 2001].

La figure 6 présente l'interférogramme déroulé de notre zone. Nous pouvons remarquer des trous dans l'image qui représentent des zones non déroulées, qui est dû au manque de cohérence dans ces zones. Ce sont principalement des zones montagneuses avec une végétation dense.

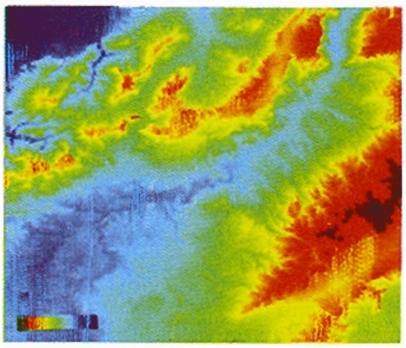


Fig. 6 : Interférogramme déroulé

4.2.5 Conversion de la phase en altitude :

Comme étape finale, les altitudes peuvent être déterminées en utilisant plusieurs méthodes qui sont intégrés dans DORIS, qui permettent de convertir les phases en altitudes. Avant de réaliser cette étape, nous avons dû affiner la géométrie du couple pour une nouvelle estimation de la base interférométrique ; pour cella, des points de contrôle ont été utilisés. DORIS utilise un seul point de contrôle dont il calcule les coordonnées maître et esclave déroulée, mais cette information n'est utilisée dans aucune étape du processus, elle peut être introduite par l'utilisateur pour calculer la constante de phase à additionner à l'interférogramme déroulé, car quoique l'interférométrie radar soit une technique très précise, elle demeure néanmoins relative puisque le déroulement de phase s'effectue par rapport à un pixel de référence.

Nous avons utilisé des cartes de 1/50.000 pour choisir soigneusement 33 points qui ont une précision de 10 m. Les coordonnées des points ont été transformées de leur système d'origine, le système UTM Clarke 1880 au système WGS84. La figure 7 présente le MNT résultant du traitement.

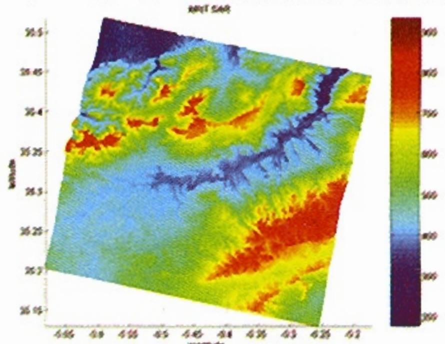


Fig. 7 : MNT résultant

5. Validation :

Afin d'évaluer la qualité du MNT réalisé dans ce test, nous l'avons comparé au MNT global SR T M. La mission SRTM qui a été lancée le 11 Février 2000 et a duré 11 jours avait pour but de réaliser une base de donnée topographique numérique complète de la terre (Ramirez E., 2005]. Les prévisions des précisions horizontales et verticales sont approximativement de 20 m et 16 m [Bridget S. & Sandwell D., 2003]. En absence de données meilleures, nous avons opté pour le MNT SRTM en supposant qu'il n'y avait pas de déformations significatives de la surface durant la période qui sépare l'acquisition de nos images et l'émission SRTM qui est de quatre ans.

La comparaison des courbes de niveaux des deux MNT révèle un rapprochement entre eux, surtout dans les régions montagneuses. Mais, dans la zone plate, un décalage est visible au sud-ouest de la zone dans la figure 8.

La comparaison des deux MNT a révélé un nombre de points communs s'évaluant à 796672, couvrant la zone d'étude. Elle montre que la moyenne de la différence d'altitude entre les deux MNT SR T M et SAR notée $dH=H_{srtm}-H_{SAR}$ est de 2.56 m. L'erreur moyenne quadratique (EMQ) de la différence est approximativement 20.15 m sur toute la zone (figure 9).

Entre les points communs des deux MNT; nous avons un pourcentage de 70.58 % correspondant à un écart altimétrique $|dH| \leq 20$ m qui sont principalement réparties dans les région montagneuses.

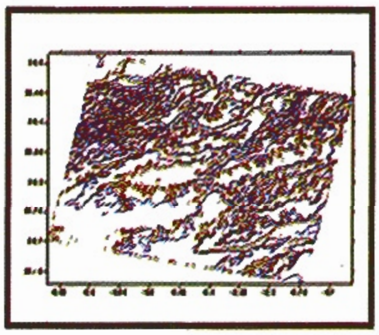


Fig. 8: Courbes de niveaux des deux MNT: SRTM (marron) et SAR (bleu)

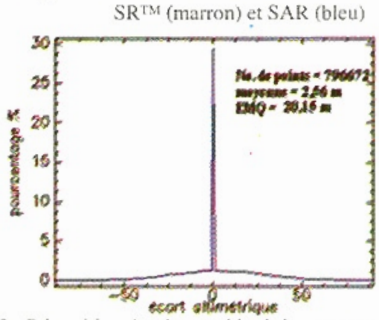


Fig. 9: Répartition des écarts altimétriques entre les MNT SR T M et SAR

6. Conclusion :

La génération d'un MNT précis avec la technique de l'interférométrie tandem d'ERS a été validée sur une grande surface où la topographie a des variations significatives par un traitement précis et accentué. Les résultats de notre travail, montrent que le MNT réalisé avec l'InSAR à une précision altimétrique de 20m approximativement dans les zone montagneuses, qui présente une cohérence moyenne.

Références:

Bamler R.: Digital terrain models from radar interferometry. Photogrametric Week 1997.

2- Bridget S. & Sandwell D.: "Accuracy and resolution of shuttle radar topography mission data," Geophysical Research Letters, Vol. 30, No. 9, 1467, 2003.

3- Chen C. W. & Zebker H.: Two-dimensional phase unwrapping with use of statistical models for cost functions in nonlinear optimization. Journal of Optical Society of America. Vol.18, No.2, February 2001.

4- Goldstein R. M. and Werner C. L.: Radar ice motion interferometry. 3rd ERS ESA Symposium Proceedings. http://www.ers-symposium.org/data Goldstein. Florence, Italy. 1997.

5- Goldstein R. M. and Werner C. L.: Radar interferogram filtering for geophysical applications. Geophysical Research Letters 25(21), 4035–4038. November 1998.

6- Kampes B. & Usai S.: DORIS: the Delft Object-oriented Radar Interferometric Software. 2nd International Symposium on Operationalization of Remote Sensing. Enschede, The Netherlands. 16-20, August 1999.

7- Kampes B.: Delft Object-oriented Radar Interferometric Software, user's manual and technical documentation. TU Delft, 1999.

8- Massonnet D. & Feigl K., Novembre1998. Radar Interferometry and its application to changes in the earth's surface, Reviews of Geophysics, Vol 36, p441-500.

9- Ramirez E.: Shuttle Radar Topography Mission. The Mission to Map the World JPL website URL: http://www2.jpl.nasa.gov/srtm Jet Propulsion Laboratory California Institute of Technology, California.

10- Scharroo, R. and P. Visser (1998). Precise orbit determination and gravity field improvement for the ERS satellites. Journal of Geophysical Research 103(C4), 8113–8127.

11- Tsay J. & Chen H.: DEM generation in Taiwan by using InSAR an and ERS data. 22nd Asian. Conference on Remote Sensing, Singapore. 5-9 November 2001.

High-Sensitivity GPS – an Availability, Reliability and Accuracy Test

Volker Schwieger
Institut für Anwendungen der Geodäsie im Bauwesen
Universität Stuttgart, Geschwister-School-Str. 24 D-70174 Stuttgart, Germany
Tel. : (+49) 711-685-84064 Fax : (+49) 711-685-84044
Email : Volker.schwieger@iagb.uni-stuttgart.de

ملخَص : يعود رصد أجهزة الإستقبال GPS ذات دقّة عالية للمواقع في المناطق المضلّلة كما داخل البنايات إلى دقّتها فيما يخص إشارة GPS بنسبة أدنى من 150 dBm− . يشرح المقال مقارنة ثلاثة أجهزة إستقبال GPS ذات دقّة عالية مستعملة على وضع سكوني تخص التوفّرية ، المصداقية و الدقة في المناطق الأفقية و المضلّلة كما في الداخل . تبيين الإستقصاءات بأن نسبة التوفّرية تدل على أكثر من 90% بالنسبة للمناطق المضلّلة . داخل البنايات المنخفضة وفي الغرف ذات نوافذ تكون التوفّرية ما بين أكثر من 70% و 18% حسب نوع جهاز الإستقبال . بالنسبة للشروط الأفقية يسجّل الإنحراف المعياري قيم ما بين 3.75 م و 7.33 م . خُفّف تدريجيا الإنحراف المعياري الخاص بداخل البنايات بأكثر من80 م . أكثر من داخل البنايات ، مثلاً. في غرفة دون نافذة أو في قبْو ، لايمكن الحصول على أي إشارة من أجهزة تحديد المواقع GPS .
زيادة على ذلك تمّ إنجازقياسات مبحث حركة الأجسام . بلغت التوفّرية قيَم في حوالي 97 % بالنسبة لطرق بما في ذلك المناطق المضلّلة و النفق . يسجّل الإنحراف المعياري قيَم مابين 4.92 م و 12.22 م بالتأكيد تعَد نتائج مبحث حركة الأجسام صحيحة أكثر من النتائج السكونية ، بسبب مراقبة المواقع التي تستعمل نموذج الحركة .

الكلمات الأساسية : أجهزة تحديد المواقع GPS ، GPS ذات دقّة عالية ، تقنيات منخفضة الكلفة

Résumé: Les récepteurs GPS à Haute sensibilité observeront les positions dans les zones ombragées aussi bien qu'à l'intérieur de bâtiments dû à leur sensibilité en ce qui concerne les signaux GPS à un rapport au-dessous de -150 dBm. L'article presente une comparaison de trois récepteurs GPS à haute sensibilité utiliser en mode statique concernant la disponibilité, fiabilité et la précision dans les zones à horizon libre, dans les zones ombragées aussi bien qu'à l'intérieur. Les investigations montrent que le taux de disponibilité indique plus de 90% pour les zones ombragées. À l'intérieur de bâtiments à basse atténuation et dans les pièces avec des fenêtres la disponibilité est entre plus de 70% et 18% selon le type de récepteur. Pour les conditions à horizon libre la déviation standard indique des valeurs entre 3.75 m et 7.33 m. À l'intérieur de bâtiments la déviation standard respective est dégradée de plus de 80 m. Plus qu'à l'intérieur du bâtiment, par exemple dans une pièce sans fenêtre ou une cave, aucuns signaux GPS ne sont reçus.

En outre les mesures cinématiques ont été réalisées. Ici la disponibilité atteint des valeurs au environ de 97% pour la route y compris les zones ombragées et les tunnels. La déviation standard indique des valeurs entre 4.92 m et 12.22 m. Évidemment les résultats cinématiques sont plus exacts que les résultats statiques, dû à un filtre pour les positions qui utilisent un modèle de mouvement.

Mots-clés : GPS, GPS à Haute sensibilité, techniques à bas coûts.

Summary : High-Sensitivity GPS receivers shall deliver positions in shadowed areas as well as inside buildings due to their sensitivity with respect to GPS signals with a power ratio below -150 dBm. The paper shows a comparison for three high-sensitivity GPS receivers used in static mode regarding availability, reliability and accuracy in areas with free horizon, in shadowed areas as well as indoor. The investigations show that the availability rate indicates more than 90 % for shadowed areas. Inside buildings with low attenuation and in rooms with windows the availability ranges between more than 70 % and 18 % depending on the receicer type.

For free horizon conditions the reproducability standard deviation shows values between 3.75 m and 7.33 m. Inside buildings the respective standard deviation is degraded to more than 80 m. More inside the building, e.g. in a windowless room or a cellar, no GPS signals are received.

Additionally kinematic measurements were carried through too. Here the availability reaches values of around 97 % for the track including shadowed areas and even tunnels. The reproducability standard deviation indicates values between 4.92 m and 12.22 m. Obviously the kinematic results are more accurate than static results, due to a filter for the positions using a movement model.

This paper has been originally prepared and presented at the FIG Working Week in Stockholm, Sweden, 14-19 June 2008.

1. Motivation

Satellite-based positioning has been developed and is still developing towards a general tool for surveyors all over the globe. But still the restrictions have to be mentioned: free line-of-sight to minimum four satellites. For real time solutions requiring phase data even five satellites have to be tracked. The dream of each surveyor would be to avoid these problems and have something like indoor GPS or GNSS.

Since some years the so called High-Sensitivity (HS) GPS receivers are on the market. They show a higher sensitivity with respect to weak GPS signals. In general the possibility to track signals inside forests, cars and even buildings is given. But this ability is restricted to the use of non-line-of-sight signals that may be reflected and attenuated. Thus leading to decrease of accuracy and reliability. In this paper the author has investigated the availability, the reliability and the accuracy of three HS GPS receivers in static and kinematic scenarios. An insight into the possibilities to use the technology for indoor positioning as well as for trajectory determination for vehicles in urban canyons is given. Positioning for surveying tasks that require mm to dm accuracy level will not be treated in this paper.

2. High-Sensitivy GPS

2.1 Basics

The GPS Interface Control Document (ARINC, 2000) defines the minimum GPS signal strength for a user on the earth surface. For C/A-code this is defined with -130 dBm. This value may be reached only, if no attenuation occurs. In reality the GPS signals are attenuated e.g. by the atmosphere, trees, buildings.

According to WIESER & HARTINGER (2006) the attenuation may reach values about 5 dB in cars, up to 20 dB in buildings and more that 25 dB in subterranean garages. EISSFELLER et al. (2006) indicate attenuation values for building materials (see table 1). They complement the ones given before. These attenuation values lead to the problems occuring with the acquisition of GPS signals inside buildings. "Normal" GPS receivers, especially GPS receivers for geodetic applications, do not work indoor, because the sensitivity is not sufficient to track signals with low dBm values. The HS GPS receivers acquire signals below -150 dBm assured by a longer integration time, non-coherent integration and a high number of parallelly working correlators. Further information may be found e.g. in WIESER & HARTINGER (2006).

Tab 1. Attenuation for different building material for 1 500 MHz (Eissfeller et al. 2006).

material	attenuation [dB]
dry wall	1
plywood	1 - 3
glass	1 - 4
shaded glass	10
construction timber	2 - 9
steel fabric mats	2 - 11
brick	5 - 31
concrete	12 - 43
reinforced concrete	29 - 33

2.2 Exemplary Receivers

In 2006 the Institute for Applications of Geodesy to Engineering (IAGB) has procured three HS GPS receivers reflecting the latest technologic developments: u-blox LEA-4T, SiRFstarIII and Fastrax iTrax03-S. These receivers showed the highest sensitivity at the time of purchase. Table 2 shows the different characteristics of the three receivers and figure 1 presents the hardware including receiver, antenna, cables and boxes indicating that the investigations have been made with the evaluation kit delivered by the respective companies. The table has been compiled using information of the producers (U-BLOX 2007, SIRF 2007, FASTRAX 2007).

Intermediate results for real time navigation solutions for these receivers regarding static code measurements were presented in SCHWIEGER (2006). In this paper results of static as well as kinematic measurements are reported. Since the procurement of the three receivers the technologic development has been gone further ; e.g. the company u-blox has developed ublox 5 chips having a sensitivity of 160 dBm, so that a further improvement of availability is expected (U-BLOX 2008). Nevertheless the comparison of the three receivers will give a good insight into the performance of HS GPS.

As to be seen in table 2 all receivers support the output format NMEA developed by the National Marine Electronics Association. This is the standard for navigation applications. Additionally proprietary formats of the producers are supported. For the investigations the NMEA strings (NMEA 2007) are used for SiRF and u-blox. The coordinates are extracted of the GPGGA string.

The values for the sensitivity differ between - 159 dBm for the SirFstarIII and 156 dBm for the Fastrax iTrax03-S. All receivers use the phase observable L1 and the C/A code for real time positioning. The u-blox receiver has two advantages: the number of channels allowing to track more satellites simultaneously, and the possibility to store the phase data on a computer, a PDA or even a data logger. The second feature is important for the post-processing precise positioning task (e.g. SCHWIEGER, WANNINGER 2006) currently investigated at IAGB. This research is beyond the scope of this paper.

Tab 2. Characteristics of investigated HS GPS receivers.

Receiver	**u-blox LEA-4T**	**SiRFstarIII**	**Fastrax iTrax03-S**
Tracking-Sensitivity	-158 dBm	-159 dBm	-156 dBm
Signals	L1, C/A Code	L1, C/A Code	L1, C/A Code
Cold Start	34 s	35 s	40 s
Warm Start	34 s	15 s	33 s
Hot Start	< 3.5 s	< 1 s	4 s
Number of channels	16	12	12
Output of phase data	yes	only with special agreement of SiRF	no
Protocoll	NMEA, UBX Binary, RTCM	NMEA, SiRF Binary	NMEA, iTalk Binary

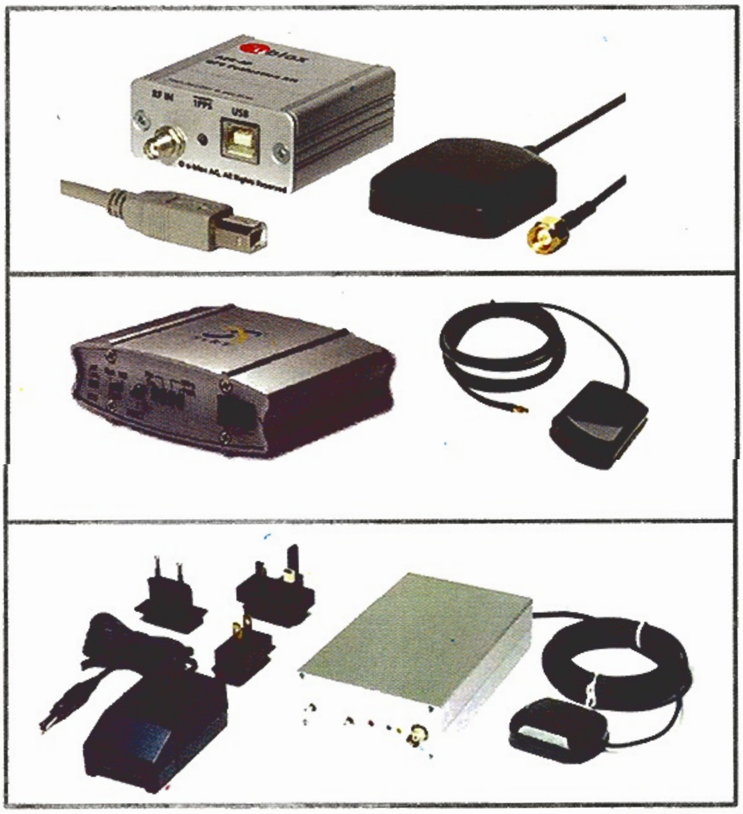


Fig. 1 Investigated high-sensitivity GPS receivers (top down: u-blox, SiRF, Fastrax).

This string includes e.g. information regarding the sort of the solution (not valid, GPS or DGPS), and the accuracy criteria "Horizontal Dilution of Precision" (HDOP) as well as the number of satellites in view, if a free horizon is assumed. These additional information may be used to analyse the solutions and find e.g. reasons for outliers or bad quality data in general. Additionally the GPGSA and the GPGSV strings are stored. The first delivers information about the satellites really used for the determination of the coordinates. The excluded satellites may be shadowed by obstructions like buildings, or the quality of the data is so bad that the internal algorithms eliminate the data. The second string provides for each satellite the azimuths and elevations as well as the signal-to-noise-ratios (SNR) as a second quality criteria. For the Fastrax receiver the propriety format is used and the required information is extracted by matlab-files provided by the producer.

3. Static Positiong

3.1 Measurement Concept and Realisation

Main topic of the investigation is the determination of the availability of the HS GPS receivers in shadowed and strong multipath areas as well as indoor environments. The study of reliability and accuracy of the coordinates is of importance too. For this reason sites were chosen to cover different attenuation values and different shadowing effects. Figure 2 shows the location of the sites outdoor and indoor. The building sketched in figure 2 is built using concrete leading to attenuation values of 12 to 43 dB (compare table 1).

Figure 3 presents the adapter used for the measurements, and figures 4 to 6 show the different environments. The adapter guaranties that the receivers may measure simultaneously almost at the same place. The position difference is at the 10 cm level and therefore negligible for the accuracy levels discussed in this paper.

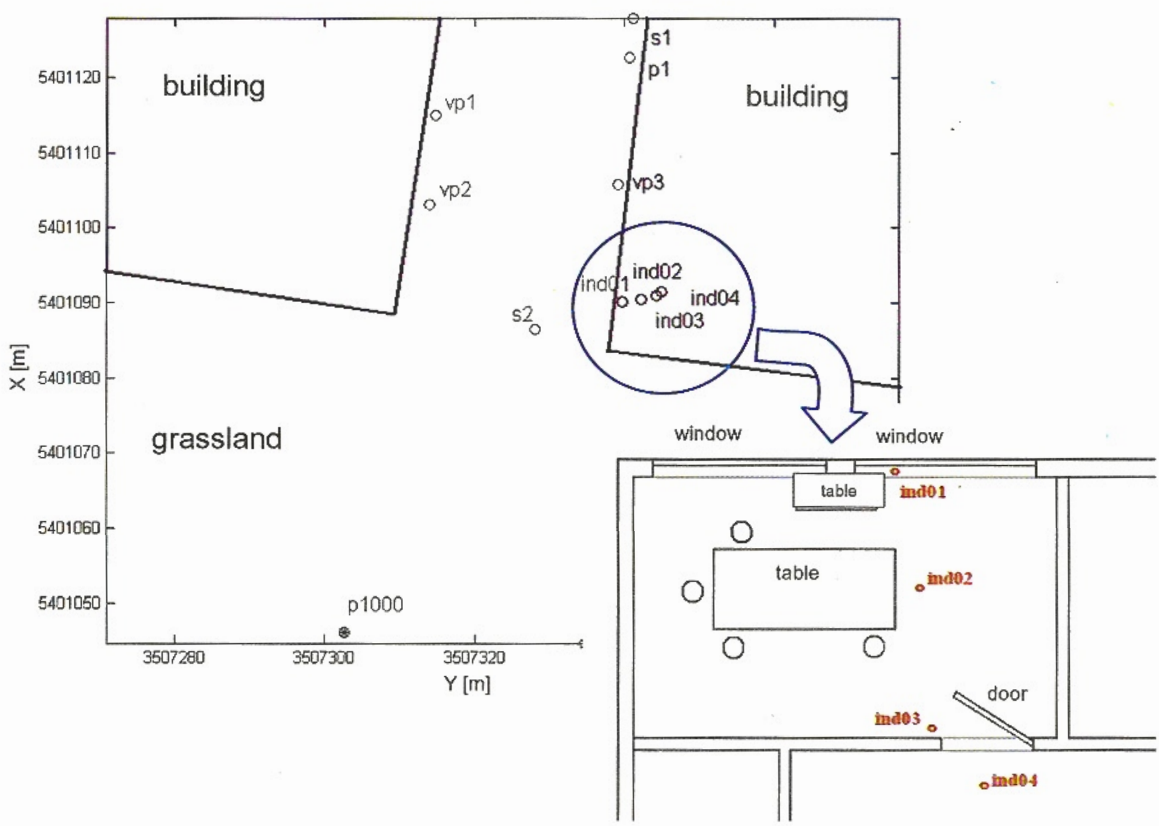


Fig. 2 Sketch of measurement sites.

For reliability and accuracy analysis the coordinates of all measurement sites have to be known with superior accuracy. For this task all sites presented in figure 2 are measured using geodetic GPS receivers and a tachymeter. The accuracy is around the cm level (compare SCHWIEGER 2006).

All site occupations were carried through in 30 minutes and were repeated a second time to get to an affordable extend independence from the satellite configuration. The sampling interval was set to 1 second.

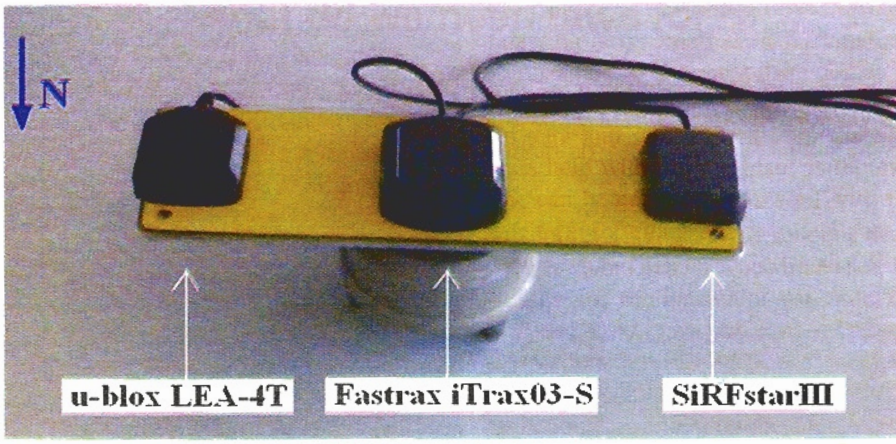


Fig. 3 Adapter for HS GPS receivers.

Fig. 4 Site with free horizon (p1000 / left) and shadowed site (vp1 / right).

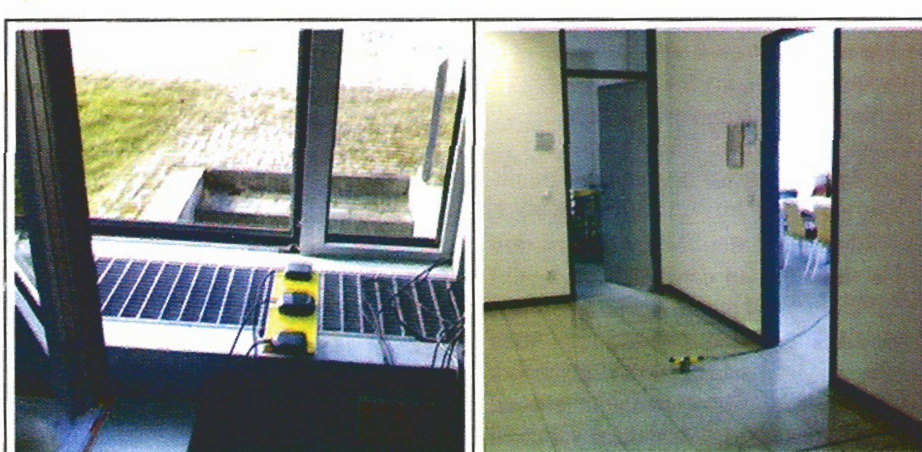


Fig. 5 Indoor sites (left: at window / ind01, right: windowless room / ind04).

Fig. 6 Cellar sites (left: staircase point / s1. right: inside cellar / p1).

3.2 Quality Criteria and Parameters

In general the paper aims at the quality appraisal and comparison of the three different HS GPS receivers. The quality criteria relevant for geodetic and navigation issues are availability, reliability and accuracy. Reliability may be called correctness, too. Availability is the probability or the measure that a system delivers a specified complete information at the right time. Here are the three dimensional coordinates delivered with a sampling rate of 1 second are this information. The availability quality parameter is the availability rate in percentage :

$$A[\%] = \frac{T_t - T_n}{T_t} \cdot 100, \qquad (1)$$

with T_t total measurement time,
T_n measurement time without coordinates.

Correctness or reliability describes the ability of a system to deliver information corresponding to the reality. Here the deviations between measured and given coordinates should not exceed a limit specified to three times the standard deviation. The reliability quality parameter is the reliability rate in percentage, whereby the percentage value is referred to the number of available measurements n_a taken within the time $T_a = T_t - T_n$:

$$R[\%] = \frac{n_{3\sigma}}{n_a} \cdot 100, \qquad (2)$$

with $n_{3\sigma}$ number of observations within the $3 \cdot \sigma$ limit.

Accuracy describes the random difference between measured and given values. Here the standard deviation of the measured coordinates is determined. The repeatability standard deviation sin is related to the average, and the reproducibility standard deviation s_{in} is related to the average, and the reproducibility standard deviation s_{ou} is related to the given true coordinates. Thus the latter includes systematic (described by the reliability too) and random errors (described by the repeatability standard deviation too). Both parameters are computed using $n_{3\sigma}$ measurements and are given in the following equations :

$$s_{in} = \sqrt{\frac{1}{n_{3\sigma} - 1} \cdot \sum_{i=1}^{n_{3\sigma}} (x_i - \bar{x})^2}, \qquad (3)$$

$$s_{ou} = \sqrt{\frac{1}{n_{3\sigma}} \cdot \sum_{i=1}^{n_{3\sigma}} (x_i - \mu_x)^2}, \qquad (4)$$

with x_i single measurement value (here: coordinate),
$\bar{x}$ average,
μ_x expexted value of observation.

3.3 Results of Investigations

The three quality criteria are separated with respect to three categories: free horizon, shadowing and indoor (compare table 3). The results of the single points are averaged to get an overall picture of the investigations. The cellar sites shown in figure 6 could not be measured due to high attenuation values. They are not included in the following analysis.

Tab 3. Environment categories and allocated point numbers for static measurements.

category	point numbers	remarks
free horizon	p1000, p1001	p1001 not visible in figure 2
shadowed area	s1, p1, vp1, vp2	includes almost shadowed points as well as multipath environments
indoor	ind01, ind02, ind03, ind04	ascending point numbers with longer distances from window

Tab 4. Availability rates for static measurements.

availability rate [%]	SiRF	u-blox	Fastrax
free horizon	100	100	99.5
shadowed area	99.6	92.6	93.6
indoor	71.6	42.2	18.1

Table 4 shows the availability rate for three dimensional coordinates. For the two dimensional case a slight increase of the rate is obtained (MAO 2007), but the general statements of the analysis are not different, so that these results are not presented here. The availability rate shows values of more or less 100 % for free horizon and higher than 90 % for shadowed areas. For the second environment the SiRF receiver outclasses the two other ones. This is even more valid for the indoor case. The SiRF receiver performs much better than the other two: more than 70 % availability in relation to around 40 % or even 16 % for the Fastrax receiver.

Table 5 shows that the reliability rate, with other words the ability to protect against outliers, is excellent even under bad GPS conditions. For all scenarios the values are larger than 98.7 %, meaning that 98.7 % of all measurements are within a sphere around the reference point coordinates. The differences among the receivers are negligible.

Tab 5. Reliability rates for static measurements.

reliability rate [%]	SiRF	u-blox	Fastrax
free horizon	100	99	99.8
shadowed area	100	100	99.9
indoor	99.4	99.5	98.7

Tab 6. Repeatability and reproducibility standard deviations for exemplary sites.

standard deviations [m]	SiRF		u-blox		Fastrax	
	repeat	**reproduce**	**repeat**	**reproduce**	**repeat**	**reproduce**
free horizon	2.74	7.33	2.65	5.17	1.70	3.75
shadowed area	7.41	34.69	17.42	36.69	16.80	36.78
indoor near window	18.37	41.36	36.54	48.30	33.49	51.86
indoor room middle	54.54	88.11	37.21	60.90	-	-

Table 6 presents the repeatability and reproducibility standard deviations for selected sites p1000, vp02, ind01, ind02. Due to the fact that the repeatability standard deviations contain random effects only and therefore are too optimistic, the reproducibility standard deviations will be discussed here only. In any case the general trend is the same. The standard deviations for free horizon environment are between 3.75 m and 7.33 m. They correspond to the values given in literature for HS GPS receivers (WIESER et al. 2005) as well as for "normal" navigation receivers (e.g. RAMM, SCHWIEGER 2004). The Fastrax receiver delivers the best results, due to the low sensitivity preserving him from tracking signals of low strength and, probable, low quality. In contradiction the SiRF receiver tracks signal of low strength.

This increases the availability (see table 4), but degrades the accuracy due to low quality signals used for positioning. If shadowed areas or even indoor environments are investigated, the standard deviations rapidly decrease to values of 30 m up to more than 80 m. These standard deviation are better than the ones reported by Collin et al. (2003), but they are approximately at the same level. Figure 7 shows typical positions (blue) around the given reference coordinate (red cross) for the point vp2, shadowed and disturbed by multipath effects. Obviously the position average does not coincide with the true value indicated by the red cross. The Fastrax receiver do not track any satellite inside the room. The only indoor position was determined near the window.

Due to the fact that reliability and accuracy dependent on each other, the very good values for the reliability rates do not need to attach importance. The bad standard deviations are one reason for the good reliability rates.

No reproducible influence of the HDOP value, the number of tracked satellites, or the minimum elevation of the tracked satellites on the position quality can be shown. But a low mini-mum SNR results in a low position quality for most of considered cases. More details may be found in MAO (2007).

Altogether it may be summarized that obviously positioning near or inside buildings is possible but not with a high accuracy. Room-accurate positioning by GPS is impossible using current technology.

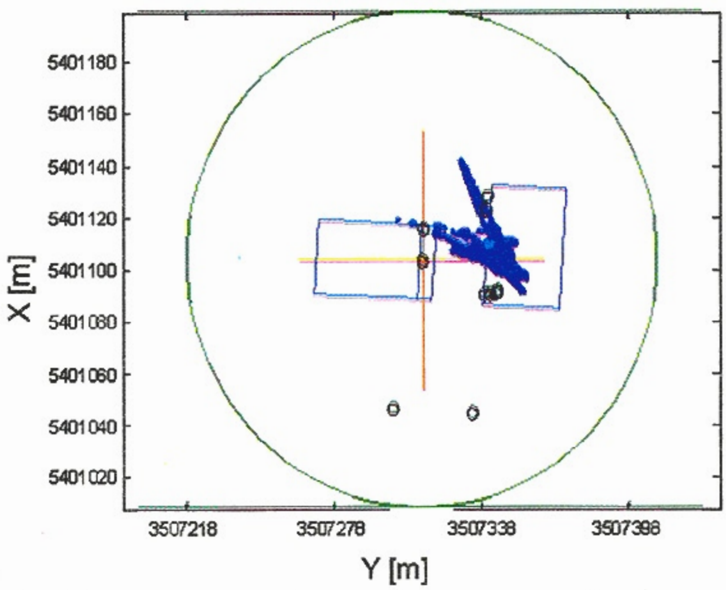


Fig. 7 Measured positions (blue) and true position (red) for point vp2 in shadowed area.

4. Kinematic Positioning

4.1 Measurement Concept and Realisation

In a second step the quality of moving receivers should be investigated. For this purpose the three HS GPS receivers are mounted on the IAGB measurement vehicle, a Mercedes Sprinter. The sampling rate was chosen to 1 second again. Additionally a Leica SR530 receiver was mounted on the top of the vehicle. The geometric differences between the four receivers are of no importance for the determination of the quality parameters.

The Leica receiver was used for determining the reference trajectories, if available. The availability of the Leica solution is strongly reduced, since phase signals of high quality are required. Therefore two different standard deviations have to be determined (see section 4.2) for evaluating the accuracy.

The investigation scenarios cover different environments typical for kinematic drives: free horizon, city centre (urban canyons), forest, narrow curves, underpasses and tunnels. Figure 8 shows the whole track and the most important environments.

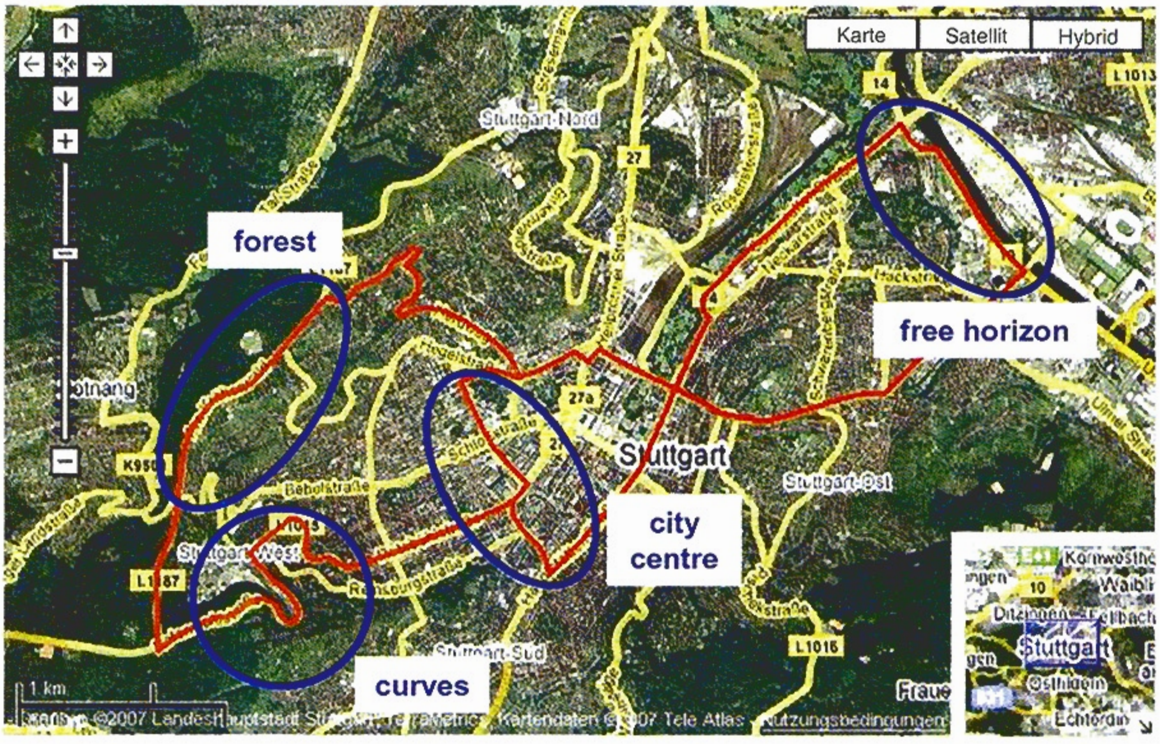


Fig. 8 Kinematic track and different environments.

4.2 Quality Criteria and Parameters

The availability and the reliability rates are determined as described in section 3.2, equations (1) and (2). For the reliability one has to take into account that reference trajectories are available for a part of the total time only (for concrete value see table 7).

The repeatability accuracy according to section 3.2 cannot be computed, since averages cannot be determined. Regarding reproducibility accuracy equation (4) is used for time periods where the reference trajectory is available. For time periods without reference trajectories, which is clearly more than half of the time, a standard deviation is computed using double differences :

$$s = \sqrt{\frac{1}{2n} \cdot \sum_{i=1}^{n} (x_i^1 - x_i^2)^2}, \qquad (5)$$

with
- n number of measurements,
- x_i^1 single measurement of receiver 1,
- x_i^2 single measurement of receiver 2,
- both measurements simultanously.

Due to the fact that no reference values exist, a clear statement regarding repeatability or reproducibility conditions cannot be given, since it remains unknown, whether systematic errors are included in the accuracy measure.

If the different HS GPS receivers have different systematic errors, the standard deviation would be a reproducibility value. If they show the same systematic effects, the result would be a repeatability standard deviation. In any case by this way standard deviation for three receiver combinations could be determined. This may give hints concerning best and worst receiver.

4.3 Results of Investigations

The track has been driven two times for all the scenarios. The information in the following tables is based on an average of the respective two drives. The table showing the availability rate is enlarged by the values for the Leica reference receiver thus indicating the large difference between a geodetic GPS receiver and a HS GPS receiver. The GPS reference receiver shows an availability rate of around 20 % for the total track. In contradiction all HS GPS receivers deliver values better than 97 %.

These values include tunnel and underpasses, so that almost 100 % is reached for areas where GPS signals are receivable. The difference gets even larger, if the two curve drives are analysed. These drives are carried through in a shadowed area. The three different HS GPS receivers show no significant differences.

Tab. 7 Availability rates for kinematic measurements.

availability rate [%]	Leica	SiRF	u-blox	Fastrax
total track	20.5	97.4	97.6	97.1
curves (slow drive)	10.2	100	100	100
curves (fast drive)	0	100	100	99.8

Tab. 8 Reliability rates for kinematic measurements.

reliability rate in %	SiRF	u-blox	Fastrax
total track	100	100	99.5
curves (slow drive)	100	100	100

The reliability rate is again, as for the static case, excellent. Please keep in mina that these values are determined for the time periods, where the reference trajectory is available. This means that the quality of the signals is very good by this way allowing accurate and reliable code solutions of the HS GPS receivers too. Due to this reason the good results should not be overrated. For the fast curve drive reliability cannot be computed, since no reference trajectories are available (see table 7).

As written in 4.2 the author distinguishes between standard deviation calculated versus reference trajectory and using double differences. Due to the fact that the reference trajectory is estimated using phase observations, it shows an accuracy of cm to dmlevel. Therefore it may be used as reference. For thcsc accuracy parameters the u-blox receiver obviously has the best accuracy and, if compared to 3.3 the standard deviations, are even better than for the static measurements. For this purpose two reasons are given in the following. One is that only time periods with good data quality are compared, since phase data solutions with Leica receivers are possible. On the other hand it can be assumed that kinematic measurements are supported by a filter algorithm working correctly only in the case of movement. This assumption can be exemplarily verified, if typical trajectories at an intersection including a stationary phase are presented. Figure 9 shows this behaviour exemplarily for the SiRF receiver. The Same could be shown for the Fastrax and with less influence for the u-blox receiver. Additionally it is visible that the trajectories are very smooth. There is no shape difference with respect to the reference trajectory.

Tab 9. Reproducibility stand. Dev. For kinematic measurements (using reference trajectories).

standard deviation [m]	SiRF	u-blox	Fastrax
total track	7.85	4.92	6.31

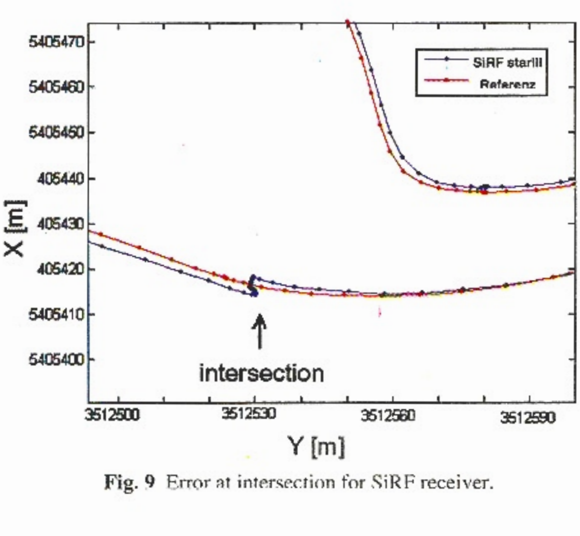


Fig. 9 Error at intersection for SiRF receiver.

The standard deviations using double differences are worst than those using the reference trajectories. This is caused by the lower quality of the data showed up by the fact that no phase solutions for the Leica receivers were possible. Nevertheless the standard deviations are still better than in the shadowed static case (compare table 6). This is even true for the very shadowed drive through the curves.

The fast drive through the curves pruduces worst results caused again by different filter models for the motion. Figure 10 shows e.g. a curve where SiRF and u-blox receiver positions fit together and the Fastrax positions deviate obviously. But for the total track no obvious difference among the receivers can be outlined. This is valid for the curve tracks too.

Tab 10. Standard deviations for kinematic measurements (using double differences).

standard deviation [m]	SiRF / u-blox	u-blox / Fastrax	Fastrax / SiRF
total track	10.67	10.83	12.22
curves (slow drive)	10.37	15.46	13.43
curves (fast drive)	13.93	19.34	25.10

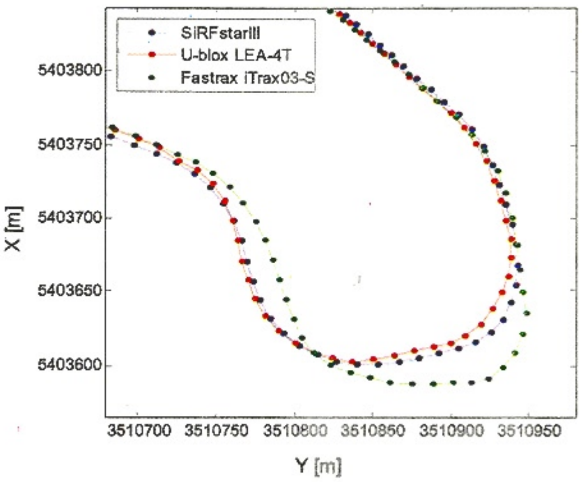


Fig. 10 Different movement models for curve drives.

The correlation of the position quality with possible input parameters like number of satellites, HDOP value, signal-to-noise ratio (SNR) do dot deliver any obvious result. The SNR is the only indicator : a low SNR will in a lot of, but not in all, cases lead to bad accuracy of the position. For further details the author refers to MAO (2007).

5. Conclusion

The paper clearly shows that the new generation of HS GPS receivers shows standard deviations from 3.75 m to 7.33 m in free horizon environment. The accuracy strongly decreases up to 88 m, if shadowed areas or even indoor measurements are analysed. This shows that roomaccurate positioning is not possible for the time being. The author concludes that the way towards indoor positioning using GPS respectively GNSS is still a long one.

On the other hand it could be presented that for shadowed areas more than 92 % availability rates and reliability rates higher than 99.9 % are determined. The availability decreases for indoor measurements, but the SiRF receiver still tracks satellites. This receiver has a clear plus in static applications, especially regarding availability. Discussing the kinematic measurements the u-blox receiver outperforms the other two especially with respect to accuracy. Concerning reliability and availability the three receivers are comparable.

An important result of the analysis is the fact that the receivers are designed for kinematic applications. All three seem to include a movement model respective a filter algorithm as a black-box model not known to the user. This fact is not reported to the user, but could be shown by some examples as well as by an statistical overview showing that the kinematic standard deviations are smaller that the static ones for comparable environments.

Regarding precise positioning at the cm level a diploma thesis at IAGB is on the way to investigate the use of phase observations of the u-blox receiver. Due to the fact that the use of phase data falsified by multipath and attenuation effects for indoor positioning with geodetic accuracy is even not visible at the horizon, the research is restricted for non-indoor measurements under "normal" geodetic conditions. First results show encouraging accuracies. For the future more field tests using the respective latest technology should be performed. The author encourage other research groups to contribute to these investigations.

Achnowledegements

The author thanks Ms. Junyu Mao for preparing, realising and analysing the measurements within her study thesis at IAGB, University Stuttgart.

References

Arinc Research Cooperation (2003): Navstar GPS Space Segment, Navigation User Interfaces. Interface Control Document ICD-GPS-200 Revision IRN-200C-004, El Segundo, California.

Collin, J., Kuusniemi, H., Mezentsev, O., Macgougan, G., Lachapelle, G. (2003): HSGPS under Heavy Signal Masking – Accuracy and Availability Analysis. Proceedings on 6th Nordic Navigation Conference and Exhibition, Stockholm – Helsinki, 2003.

Lachapelle, G. (2004): GNSS Indoor Location Technologies. The 2004 International Symposium on GNSS/GPS, Sidney, Australïa, 6-8 December 2004.

Mao, Junyu (2007): Qualitätsanalyse aktueller High-Sensitivity GPS-Empfänger. Study thesis at IAGB ; University Stuttgart (not published).

Ramm, K., Schwieger, V. (2004): Low-Cost GPS Empfänger für Anwendungen im Forstbereich. Flächenmanagement und Bodenordnung, Vol. 66, No. 4.

Schwieger, V. (2007): High-Sensitivity GPS – the low cost future of GNSS?!. Proceedings on FIG Working Week, Hongkong SAR, 13.-17. 05. 2007.

Wieser, A., GAGGL, M., HARTINGER, H. (2005): Improved Positioing Accuracy with High-Sensitivity GNSS Receivers and SNR Aided Integrity Monitoring of Pseudo-Range Observations. ION GNSS, 18th International Technical Meeting of the Satellite Division, 13-16 September, 2005, Long Beach, California, USA.

Wieser, A., HARTINGER, H. (2006): High-Sensitivity GPS: Technologie und Anwendungen. In: GPS und Galileo. Beiträge zum 66. DVW-Seminar am 21. und 22. Februar 2006 in Darmstadt, Wißner Verlag, Augsburg, 2006.

FASTRAX (2007): http://www.fastrax.fi/.

NMEA (2007): http://www.nmea.de/.

SIRF (2007): http://www.sirf.com/products/gps_chip.html.

U-BLOX (2007): http://www.u-blox.com/products/lea_4t.html.

U-BLOX (2008): http://www.u-blox.com/products/ublox5/technology/sensitivity.html.

Biographical Notes

1983 – 1989 Study of Geodesy in Hannover.

1989 Dipl.-Ing. in Geodesy (University Hannover).

1998 Dr.-Ing. in Geodesy (University Hannover).

2003 Head of Department "Positioning and Measurement Techniques" at Institute for Applications of Geodesy to Engineering, University Stuttgart.

2004 Habilitation (University Stuttgart).

What do we need laws for?

Laila Aslesen
Head of Legal Service, Norwegian Mapping and Cadastre Authority Norway
laila.aslesen@statkart.no

ملخَص : لاحظنا في مملكة النرويج بأن وضع أسُس بناء ذات معطيات فضائية SDI على أساس طوعي قد سارت بطريقة جيّدة. لا نحتاج حتى الآن إلى إقامة إطار قانوني ، في شكل تشريع جديد أو بدلا للتشريع الحالي . نضمّت الحكومة نشاطاتها و إنضم إليها مشاركين طواعيةً ، مع مراعاة مصالحهم .
في أوروبا طبّق الإتحاد الأوروبي قانون مختلف . وضع أسُس بناء ذات معطيات فضائية SDI في إطار قانوني ، وتعليمة مستوحاة من الأنظمة التكميلية كمكمّل للقطاع الخاص ، يملك الإتحاد الأوروبي تعليمة توجيهية PSI (لإعادة الإستعمال) .
مهم أن تقارن هذه القوانين مع إحتياجات و إستعمال الإطار القانوني لوضع أسُس بناء ذات معطيات فضائية . مهم أيضا أن نرى ما يحدث عندما يعوّض حل طوعي بإصلاح قانوني .
تعَد القوانين و الأنظمة وسائل لبلوغ هدف ما وليست النهاية في حد ذاتها . والسؤال يكمن في ما إذا كان القانون التنظيمي مفيد مقارنة بالوسائل الأخرى .هي تجربة عامة ينوي التشريع المباشرة في الإصلاح على نطاق واسع في بعضِ المناطق ،و المتابعة الصارمة لمدة طويلة للعمل كما هو متوقع . يهم دور القطاع العمومي في دراسة كيفية وضع أسُس بناء ذات معطيات فضائية . في هذا السياق ، لايمكننا تجنّب مسألة التمويل و الدراسة حول ما إذا كان تداول الأموال بين المنظمات يصلح لهدف ما .
من وجهة نظر شاملة من المهم التبصر إلى كيفما يسري التشريع و التعاون في مدن أخرى . هناك مدن وضعت معطيات وخدمات تعمل في إطار تكنولوجي حديث جدّ مهم من أسُس بناء ذات معطيات فضائية ، لأن أسُس بناء ذات معطيات فضائية تحتاج إلى معطيات و خدمات المعطيات كشبكة الطرق التى تحتاج إلى وجود طرق و لوحات الإشارة . يجب الأخد بعين الإعتبار التتوّق إلى أسُس بناء ذات معطيات فضائية كما هي محددة حتى الآن، يجب أن يعاد النظر فيها طبقا لوسائل تطبيق أسُس بناء ذات معطيات فضائية .

Résumé : En Norvège nous avons constaté que l'établissement d'un SDI sur une base volontaire a bien fonctionné. Nous n'avons jusqu'ici aucun besoin à instaurer un cadre légal, en forme de nouvelle législation ou en changement à législation existante. Le gouvernement règle ses propres activités et autres participants ont joint volontairement, en voyant leurs avantages.
En Europe une loi différente est utilisée par l'Union européenne. Un SDI est instauré dans un cadre légal, avec une instruction inspirée des règlements Complémentaires. En tant que complément aux besoins du secteur privé, l'UE disposa une instruction PSI (réemploi).
C'est intéressant de comparer ces lois en analysant le besoin et l'usage du cadre légal pour établir un SDI. C'est aussi intéressant de voir ce qui se passe quand une solution volontaire est prête à être remplacée par une réforme de la loi.
Les lois et les règlements sont que des moyens pour arriver au but mais pas une fin en soi. La question est si une loi réglementaire est utile que les autres moyens. C'est aussi une expérience générale pour la législation qui a l'intention d'entamer une réforme assez grande dans certaine région, suivi vigoureux pour travailler comme attendu.
Le rôle du secteur public est important dans l'étude de la question de l'établissement d'un SDI. Dans ce contexte, on ne peut pas éviter la question de financement et d'étude si la circulation d'argent entre organisations public sert à un but.
Dans une perspective globale il est intéressant de considérer comment ces deux lois, législation ou coopération fonctionneront dans d'autres villes. Il y a des villes où établir les données et les services qui fonctionneront dans un environnement technologique moderne sont plus important qu'un SDI, parce qu'un SDI a besoin des données et des services des données comme le réseau de la route qui a besoin des routes et des panneaux de signalisation. Il faut tenir compte que certaines ambitions concernant un SDI comme ils ont été définis jusqu'à maintenant, devrait être reconsidéré vu les moyens de mise en œuvre d'un SDI.

Abstract : In Norway we have found that establishing an SDI on a voluntary basis have worked well. We have had no need so far to establish a legal framework, in the form of new legislation or changes to existing legislation. The government regulates its own activities and other stakeholders have voluntarily joined in, seeing the advantages for themselves.
For Europe a different approach is used by the European Union. An SDI is being established with the use of a legal framework, the INSPIRE directive with supplementing regulations. As a supplement for the needs of the private sector, EU has the PSI (re-use) directive.
It is interesting to compare these approaches by analysing the need and use of a legal framework for establishing an SDI. It is also interesting to look at what happens when a voluntary solution is about to be replaced by a law reform.
Laws and regulations are tools for a purpose and not an end in itself. The question is whether a regulatory approach helps in a way that other tools can not. It is

also a general experience that legislation meant to initiate a fairly large reform in a certain area, needs vigorous follow up for a long time in order to work as expected.

The role of the public sector is important in the discussion of how to establish and SDI. In this context, one can not avoid the issue of funding and the discussion on whether the moving around of money between public organisations serves a purpose.

In a global perspective it is interesting to consider how these two approaches, legislation or cooperation will work in other places. There are places where establishing data and services that will work in a modern technological environment are more important than an SDI, because an SDI needs data and data services like a road network needs the roads and the road signs. It is also a consideration that some of the ambitions of an SDI as they have been defined up to now, should be reconsidered when considering the tools for implementing an SDI.

1. Introduction

I am only discussing the kind of reforms that do not necessarily involve law, i.e. reforms which does not impact on the citizens rights and obligations as such, but involves how government and society are organised and how one approach the tasks that it is given. In these cases one can really make a choice whether to apply legislation as a tool or not, whereas if one must use legislation, there is no point in discussing voluntary solutions.

Separation between law and regulation is difficult to make on a global and even on a European basis. To simplify I have applied the Norwegian legal starting point. A law is passed by the Parliament according to the Constitution, while regulations are passed according to and under the authority of a law. Simply put, anything pertaining to the rights and obligation of citizens must be handled under a law, but Parliament can apply law to other types of regulations if they find it useful. An EU directive needs to be passed by law if the Constitution requires it.

In order to discuss a legal framework for an SDI one needs to start with what an SDI is. For this paper I start with the following concept of an SDI (taken from SDI cookbook 2004, page 8).

- An SDI includes the technologies, policies and institutional arrangements to facilitate the availability of and access to spatial data.
- "Infrastructure" is used to promote the concept of a reliable, supporting environment, analogous to a road or telecommunications network, that facilitates access to spatial data using a minimum set of standard practices, protocols, and specifications.
- It should as a minimum include in addition to the data sets, metadata and means to discover, visualise and evaluate the data.
- It must include organisation agreements to coordinate and administer the SDI.

From this one can itemize some important factors that must be a part of an SDI reform, whether done by law or voluntary co-operation :

1. An infrastructure must be in place and the responsibilities for it must be agreed upon.
2. The construction of the infrastructure and responsibilities for those involved in this must be agreed upon (Technology and standards):
   - Metadata.
   - Specifications.
   - Means to discover, visualise and evaluate (network services).
3. The financing of the infrastructure must be agreed upon and provided for:
   - Governmental responsibilities and funding.
   - User payment – equivalent to toll roads.
   - Access pay on a regular basis (membership).
   - A combination of the above.
4. The use of the infrastructure must be agreed upon.
   - Restricted to certain purposes or for everyone who needs it. Could be a question of quality – "motorways" for members only.
   - Restrictions based on other legal requirements.

E-government issues will be an important part of the discussion for any SDI law reform. The OECD definition is simple: *The use of information and communication technologies, and particularly the Internet, as a tool to achieve better government*[1]. EU has set some goals for e-government (eEurope 2005) which includes:

- Broadband connection for all public administrations.
- Interoperability framework to support the delivery of pan-European e-government services to citizens and enterprises.
- Interactive public services, including access for people with special needs, such as persons with disabilities or the elderly.
- Public procurement to be carried out electronically.
- Public Internet Access Points (PIAPs) for all citizens preferably with broadband connections.

[1] http://webdomino1.oecd.org/COMNET/PUM/egovproweb.nsf

It is easy to see that these goals will have great benefits for establishing an SDI. First issue to consider is what benefits and challenges the use of legislation has, then how this can be applied to the list above. From there I will be discussing the content and scope of an SDI reform, go into the two examples and finally add a global perspective on the issues discussed and some conclusions.

2. Benefits and challenges with using legislation

Legislation is slow in the making and not easily adaptable. It tends to lag behind the technological development. This has become an even more serious problem than before, because of the speed of technological development[2]. The obvious solution is to make it technology independent, but alarmingly often this does not happen, often as a result of political compromises and lobbying from those with a vested technological interest.

A reform carried out by law can walk into many traps.

E-government has become an important word in many countries, denoting the governments wish to become "modern" and use modern technology to improve its operations and image. In this context it becomes even more tempting to formulate law with technology in mind. This is nearly always a mistake, as one rarely has the ability to foresee accurately what technology will be the best solution even in a very near future. Another issue for e-government is that the government must depend on the citizens will and ability to use the technology, and the appeal of a technology may be very different to a citizen and someone in charge of acquiring technology for the government.

It is therefore preferable to define the content of a reform in a technology neutral manner, and leave the definition of technology to regulations that are meant to handle technology in general. In our example, leave the technology out of the law that defines what the SDI should be and provide, and give regulations on the government's general use of technology for all government activities, subject to easier change as things move ahead. Alternatively, if general regulations do not exist or are not feasible at the time, one can save the technology issues for regulations and internal governmental instructions.

Laws can have beneficial effects on activities that are considered important but not presently given the necessary focus. In many European countries there is a widespread demand that INSPIRE is being used to give the country a proper "geodata law" where this is not yet in place.

The use of law to make changes in a society requires the right amount of regulation and extensive follow-up. In many cases one will regret just doing the bare minimum to make the necessary legal changes happen, as this means the issues has not been thought properly through and one is forever chasing behind new issues that needs solving. On the other hand a law reform of some scale requires a lot of resources and needs to be considered only if it will give good results. A law aiming at a large reform will simply not work by itself, no matter how good the intentions are and how thorough a work is done with drafting the law.

A voluntary solution has many advantages that reforming by law do not have. It ensures that the stakeholders not only do what is required to make the solution work, but have a vested interest in its success. It ensures that the solutions are workable because everyone involved has had their chance to influence it and it will be largely based on what already has been proven to work.

And it creates an atmosphere and a platform for further work and development which ensures the long term success of the reform.

On the downside is the time and resources needed to work with the stakeholders to ensure that they are all on board for this. Above all things one needs to establish trust and a sense of having a common goal that can only be achieved by working together. The human factor is always vital in such work, which makes lengthy, difficult and vulnerable to personnel changes.

In Norway the establishing of Norway digital is the result of more than 15 years of previous work to make the stakeholders see the common interest in working together towards a common goal.

But once that was established, the selling of rather wide reaching new ideas was much easier than it would have been without the years of hard work gone before it.

A law reform will rarely take that many years, although this can also be a long winded process, particularly since it involves at least getting the politicians of the present government on board. An important factor in both cases is to be able to provide the technological solutions that will make the SDI easy and relatively inexpensive to the users, and to enable people to use them.

3. Legislation or not for the SDI reform

Generally one can compare the use of law and regulations, and the totally voluntary solution. Law is required if you need to put legal restrictions or requirements, on stakeholders that can not be

[2] A good example is the InfoSoc directive, where one totally failed to foresee the extensive use of handheld onlineconsumer devises as well as the need to establish working online services in a global perspective.

instructed to do it otherwise, i.e. are legally independent from the government on these issues. Law is also a way to get a focus on the issues, and agree generally on the principles that the government wants to apply. Regulations must be based on existing law and are usually meant to give the practical details that are not appropriate in a law. Based on the list above and these considerations, one can make an overview of the use of legislation versus no legislation.

Factors	Law	Regulation	No legislation
Infrastructure required	Useful because of its general nature and the importance of such a policy decision	If law already have a platform for such a regulation	Requires that stakeholders agree on this requirement
Construction	Responsibilities. General principles for laws and standards.	Technology and standards – Metadata and specifications, services	Requires to make all agree on a common standard and technology
Financing	If funds are required from legally independent stakeholders[3]	Detailed requirements if necessary	Requires that stakeholders are willing to provide the resources
Use	If data is required from legally independent stakeholders Adapting to already existing regulations[4]	Detailed requirements if necessary	Requires that stakeholders are willing to make data available and can agree on sharing agreements

4. Special challenges for an SDI reform

To ensure the full support not only of the present government, but also among those who may come into power, is a critical factor for an SDI law reform. This is because the extensive followup required will need funds for a long period. A look at the INSPIRE Work Programme[5] should be sufficient to document this, and INSPIRE only includes public use for environmental purposes. A change in government may kill the reform even if you have established a law that is not being changed. In the case of INSPIRE one has the added strength of this being a European initiative and therefore difficult to “ditch”, but the lack of willingness to fund the necessary task can render a reform more or less useless for a long time.

Even if one is to be careful about regulating technology, this is typically a reform where certain technological platforms have to be available to make the reform work. This will apply to the law reform as well as the voluntary approach. In this context it is fair to say that the technological developments have provided the tools that can make the ambitions of a SDI much easier to fulfil. The use of Internet services (WMS/WFS), the widespread access to Internet by the public, and the increasing cheapness of hardware and storage facilities for the undou-btedly large amount of information that is required.

Another critical factor is to ensure co-operation and sympathy for the reform, because an SDI requires a lot of stakeholders to work together, many who are not under any obligation to follow government policies. It is fair to conclude that even if one chooses a legal approach rather than a voluntary approach this will require a voluntary component or at least a willingness to do more than what is specifically stated in the law. It is important to make the stakeholder see beyond their own responsibilities and towards a long term common goal. In doing this one should emphasise on how this will give more efficient use of funds and be able to demonstrate that by giving a little, you get a lot.

5. The role of the public sector

The public sector often gets a particular focus when talking about an SDI. There are several reasons for this. When you talk about an infrastructure, it is natural to see this as a public sector responsibility. If not to actually make it, at least to ensure that it exists. For an SDI, the basic data required will very often come from the public sector. Full coverage mapping for a country is a costly and rarely commercially viable investment, while the government will have a need for such coverage for important public tasks. Traditionally it is mostly for taxation or warfare, but today for an increasing amount of everyday public tasks. Traditionally it is mostly for

3 Example: in Norway the local communities are independent and needs to be instructed by law, while governmentorganisations and government owned companies can be required to provide funds without a law present.

4 Data protection, security, etc.

5 http://www.ec-gis.org/inspire/reports/transposition/INSPIRE_IR_WP2007_2009_en.pdf

taxation or warfare, but today for an increasing amount of everyday public tasks. Another important factor is that a lot of the thematic data that can be used for public as well as commercial purposes are produced by the public sector. Important examples are road information, property information and land coverage. It is therefore fair to say that any SDI has to start with organising the public sector.

And last but not least, the public sector themselves will have a strong interest in making use of such an infrastructure. It will give more efficient use of public funds and allow the public bodies to focus on their core activity rather than the gathering of the information required to do it.

There are many ways of looking at how to administrate the relations between public sector bodies. In Norway a principle is applied which has become quite common in many countries, although others oppose it strongly. The idea is that any public body is given the money needed for their task, and anything they need which they do not already have ; they need to buy, including buying it from other public sector bodies. The idea with this is that it will demonstrate more clearly what certain activities costs, and give each organisation a motivation to ensure that their activities are carried out as economically as possible. The critics argue that this moving around of public funds is a process that requires a lot of public resources without demonstrating clearly its benefits. The main concern with spatial data is, as has been mentioned earlier, the costliness of establishing and maintaining these data. Experience shows that public funding is a fickle thing indeed, and without a regular demand from "paying customers", it is easy to cut these funds because the long term consequences are too long term to concern most politicians. This is also another argument for the "moving around money" policy – it focuses what is important to the government, under the assumption that if it is important for your activities ; you are also willing to pay for it.

6. From voluntary solution to law reform

Very often when a law reform is introduced, there are already in place some sort of co-operation or administration aiming at similar goals. In Europe, many countries already have an SDI of some sort, and now it is to be wholly or partly replaces by INSPIRE. Fortunately, in many countries one has already looked to the principles of INSPIRE when establishing the SDI.

However, when something is to be a matter for politicians and political interest, one needs to ensure that this comes harmoniously together and do not create the need to start from scratch.

It is very important to preserve as much as possible the voluntary elements that are already working. Still it is probable that harmonisation towards other countries in the same region may require changes, and this can be more rewarding in the long run than the cost of making these changes.

If a lot of factors are already in place, it is very tempting to try a minimum solution for the lawmakers. This is as mentioned above, a possible trap that may prove costly in the long run. The necessary legal basis for the existing solutions will not be in place. Any changes down the line will require new, scattered regulations, rather than a holistic and thorough approach to the long term solutions and the effects of these on society.

One need to take a step back and consider the fact that an SDI is meant to create a solution that is more than a collection of activities and servers, and which will give benefits way beyond a more efficient use of public funds. As an example of this one can mention the European Commissions assessment for Europe in the first draft for an INSPIRE directive (page 5)[6]: "The required investment of the preferred option - *a focused framework backed by an EU framework Directive* - will to a large extent be borne by the public sector and is estimated at an average of €3.6–5.4 million per annum per EU Member State (EU25). This would represent only 1% of the total expenditure on spatial information.

The benefits include environmental gains, wider social benefits and gains by the private sector. Only the environmental benefits have been quantified. The average annual benefits per Member State (EU25) amount to €27-42 million. Knowing that these elements only represent a partial view of the whole picture, the conclusion is that the benefits outweigh the investment requirements by a considerable amount." The public sector bodies involved in Norway digital has experienced that the costs of acquiring data becomes predictable and reasonable and the benefits increase.

7. A reform in whose interest?

The ultimate goal of an SDI as defined above is to provide access to spatial data. It is hardly possible to underestimate the importance that spatial data has come to have in a modern society.

The development of an information society depends on having the information needed available. Early on in the development of the widespread technologies of today, an undue importance was given to factors which seemed easier to understand from a traditional perspective, such as hardware and software developments. The importance of cheap and efficient hardware and software solutions are of course not to

6 http://www.ec-gis.org/inspire/proposal/EN.pdf

be underestimated, but it is vital to understand that in the information age, information and intellectual property has acquired an even more important role in many contexts than the traditional "material" values. An interesting example is the fact that intellectual property law is suddenly becoming an interesting issue to politicians. Why is that? Because people suddenly have a very acute daily interest in the use of such material, because of the now widespread use of consumer electronics that requires information for its purpose, such as mobile phones, portable music players and navigations systems. They demand easy access and fewer restrictions. Where voters go, politicians will follow.

This has for a long time also applied to businesses in the private sector. They are the ones who provide the products for the public, as well as assisting the public sector in developing their systems and tools. Again in comparison to the road network, an SDI is an infrastructure which is equally important to everyone in the society.

However, a successful reform has to have priorities as well as long term goals. One of the things that INSPIRE and Norway digital has in common is that the focus is mainly on improving the use of spatial data in the public sector. This is partially a result of the fact that most spatial data are created in the public sector, and that the private sectors are mostly users, not data providers. To accommodate the users one needs to get the data providers organised first. Another reason is that it is easier to get the necessary political backing for a more limited approach.

So far one has left the access for the private sector to public spatial data to other laws based on the EU directive on Public Sector Information (PSI). It is however clear that improved services and exchange within the public sector will improve the public sectors abilities to provide spatial data in a timely, cost-efficient and more user-friendly manner than before. Servicing the citizen is at the bottom of everything, but first one must aim to make public sector more efficient.

8. Examples of establishing SDI with or without legislation

8.1 Norway digital

From the Norwegian standpoint we have found that establishing an SDI have worked best by getting the stakeholders together and co-operating voluntarily. We have never had a geodata-law or other overall regulations on public sector spatial data ; it has however been regularly discussed and many stakeholders think it is a necessity in the long run.

Our experience is that one needs to accommodate the stakeholders need to feel that they have control over the data they use resources to establish, and that the use of their data by others gives a reward of interest to them. After a while the stakeholders see the benefits and are willing to discuss simpler rules and more expedient ways of exchanging data.

It has been done by establishing a vertical co-operation rather than going via the horizontal reporting chain. But political support from up the chains is also necessary. You need political support for your aims even if you are not aiming for a law regulated reform. It has therefore been a priority to include and interest the most important ministries involved in spatial data and e-government to ensure that the right politics are being implemented for the government authorities involved. The Ministry of Environment made a Green Paper on the issues and submitted them to the Parliament in 2003. The Parliament approved of the goals and methods to be applied, and this was the formal starting point for the co-operation[7].

A great help here has been the ability to offer the technology that will allow this. A great deal of resources has been devoted to technology development over many years, which is considered an important success factor for Norway digital.

In connection with the elements mentioned above, the following solutions can be mentioned :

- The Green Paper and the Ministry has decided it should be established and co-ordinated by the Norwegian Mapping and Cadastre Authority.
- The long term co-operation on establishing basic information (GEOVEKST) and collecting and co-ordinating thematic data (AREALIS) for the public sector, together with a national standard (SOSI), are the basis for the construction of the SDI named Norway digital. In addition WMS services are established to further the aims of the co-operation.
- Financing is a bottle party, as we call it in Norway: everyone brings their own bottle. Everyone provide the data they have and pay for usage according to what they have provided and what they need to use. The administration is funded by the Ministry of Environment.
- Norway Digital membership are restricted to public bodies, organisations with public tasks (for the public tasks only) and organisations which establish and provide data of national interest (for the purpose of this activity only). It is restricted to certain types of use and all commercial exploitation is excluded.

7 http://www.statkart.no/Norge_digitalt/Engelsk/About_Norway_Digital/

8.2 Inspire

In Europe we are trying to establish an SDI for public sector needs with the INSPIRE directive and supplementing regulations. As a supplement for the needs of the private sector, we have the PSI (re-use) directive. It has been an important issue all through the INSPIRE process to take care of what is already there.

One thing that is clearly demonstrated with INSPIRE is how the need for political backing will change the original goals. INSPIRE came from an initiative meant to encompass all use of spatial data. To get a directive adopted it was necessary to limit it to what could be politically supported. A lot of aspects of a complete SDI will therefore still be a matter for getting people to work voluntarily.

INSPIRE regulates quite meticulously requirements for :

- Metadata and free metadata services.
- Data Specifications for harmonisation of datasets.
- Network services to discover, view, visualise and download data as well as invoking other services.
- Data and service sharing – access, usage and elimination of obstacles INSPIRE is a framework directive. One problem that some countries, like Norway, encounter with this is that we do not give framework laws. This means that implementing the directive without at least some of the regulations in the Implementation Rules, will be a potentially difficult exercise.

The relations between INSPIRE and other directives are also sources of difficulty and confusion. The grounds for an SDI for public sector information have to be clear, consistent rules for how to disseminate public information. A lot depends here on how the various countries have implemented the PSI directive and how this influences the outcome of implementing INSPIRE.

9. A global perspective

Taking a global view, it is interesting to consider how INSPIRE or Norway digital could work in other places. The first thing that comes up is that such a reform is largely based on what is already there and what is needed. Therefore in many countries where the existing situation is different, one should approach the reform with different priorities in mind. Sharing data requires data to share. Establishing an SDI without having a solid data foundation will therefore require a focus on this rather than on the sharing which will come later. However, a co-operation early on with the people you eventually will share with, may work out very well for establishing the data.

Critical voices have been raised towards the aim of amassing large amounts of information in the form of metadata as a prerequisite for an SDI. Google Maps have sailed up as an alternative method. Get the data and give access immediately, and let the users help with the metadata as things move along. One can be come too obsessed with perfection and long term solutions, and forget the fact that needs are pressing today. A large collection of metadata also requires a lot of resources in updating. Many experience that in the case of emergency, any available data can be useful and certainly more useful than no data and you do not really have the time to check the metadata anyway. It is therefore a question whether metadata should be a big priority in a reform until more pressing issues are dealt with, such as having completed the data to make the metadata for.

For the professional working on tasks requiring very accurate results, metadata is of course important. But for services to the general public it may be something they will not have any interest in at all and therefore largely be a waste of resources. The important thing is that the provider of the information has made sure the information is reliable and can provide information if needed.

Of course one can argue that one needs to educate the public in the necessity of checking accuracy of information, but this is a general issue for the information age, and a matter for schools, parents and e-government authorities to deal with.

INSPIRE has a long list of services that should be available to the public, and it is a question whether these can not be reduced to two services only, especially if one needs to make priorities. What one needs is a service that discovers and view in the same, like a long range of on-line services do today. The other thing you need is a download service, for those who are entitled to access or wants to buy.

The technological platform needed for an SDI may not necessarily be there for everyone. One can of course always make law reforms based on what is not already there with the ambition to have it in the future, but not without being willing to apply the resources necessary to ensure that it will be in a reasonably near future.

In many countries one would also need to work with existing laws to update them towards the information age. Public internet services giving access to spatial data should be available and easy to use, but then it is a question of how the data can be abused and what steps one need to take to deal with this. It is a question of data protection (privacy), public security, secrecy, etc. Lastly, priorities should be made as to where the reform is aiming in the short term and in the long term. To get the data collectors and providers organised must be the first task. One should be careful handling out rights to the public that one is not able to fulfil later, and providing data to the private sector has little interest if you do not have a private sector to speak of.

10. Conclusions

Although one has managed to define what an SDI is for global use, it is difficult to define a common standard for what is the necessary tools and priorities for making this type of reform.

It is necessary to learn from and apply what has been experienced in establishing reforms based on voluntary co-operation, and what is pre-existing in your own country.

In each case it is a matter of what is existing data and services, how does the public sector function today and what resources one has for such a reform. On the legal side the existence of other laws and regulations are important, as well as how far the government has come in defining its policies for things like dissemination in the digital age, e-government and protection of sensitive information.

As in many other cases, it is important not to be blended by possibilities, but rather have a pragmatic approach both to the SDI and possibilities of law making.

Generally, a sound basis for a reform is that some steps already have been taken in this direction voluntarily, and that one has used the time and resources to motivate before one starts to tell people what they must do.

It is important to remember that regulations are tools for a purpose and not an end in itself. In establishing laws, administrative rules and regulations it is important to ensure that at the end of the day, the data needed is available, even if one needs to sacrifice a few principles that looks good on paper. It is useful to have freely available geodata for both public and private use. But it is even more important to actually have the data.

So do we need laws? I think the answer might be that they could come in handy, but there are alternatives, and one needs to approach any SDI reform with care and consideration.

References

Douglas D. Nebert (Editor), 2004, Developing Spatial Data Infrastructures: The SDI Cookbook, version 2.0
(http://www.gsdi.org/gsdicookbookindex.asp)

eEurope 2005: An information society for all - An Action Plan to be presented in view of the Sevilla European Council, 21/22 June 2002.
(http://ec.europa.
eu/information_society/eeurope/2005/all_about/
action_plan/index_en.htm)

A Framework for the Generalization of 3D City Models

Richard Guercke and Claus Brenner
Institute of Cartography and Geoinformatics, Leibniz University Hanover, Germany
Appelstr. 9A, 30167 Hannover
{richard.guercke, claus.brenner}@ikg.uni-hannover.de

ملخّص : مع إزدياد توفُرية نماذج المدن الكبرى الثلاثية الأبعاد 3D المفصّلة ، ستقدم طلبات كثيرة لتعميم هذه النماذج . و لتأسيس نظام مناسب لتعميم توفُرية نماذج المدن الكبرى الثلاثية الأبعاد 3D الجدّ مفصّلة ، من المهم إعطاء الفرصة للمستعمل لتحديد ملائمة المميزات على أساس دلالي . يتطلب هذا الأخير مستوى عالي من المعلومة الدلالية التي غالبا فاتكون غير موجودة في النماذج الحالية و إسترتيجيات التعميم القابلة لتكيّف إلى أبعد حد و التي تسمح للخوارزمية و المتغيرات المختلفة أن تستعمل في نفس النموذج . للإجابة على هذه المتطلبات ، نقترح هيكل بناء لتعميم نماذج المدن الكبرى الثلاثية الأبعاد 3D التي تدعم تحديد تسلسل المميزات و خوارزمية التعميم و تقدم مميزات محددة مسبقا و مقاييس التناسب لتعميم التي يمكن إستعمالها عندما يسمح التطبيق .

Résumé : Avec la disponibilité croissante des modèles de ville 3D détaillés, une demande accrue pour la généralisation de ces modèles va survenir. Afin de créer un système utile pour la généralisation des modèles de ville 3D très détaillés, il est nécessaire de donner à l'utilisateur l'occasion de définir la pertinence de caractéristiques sur une base sémantique. Cela exige un haut niveau d'information sémantique qui n'est pas souvent présent dans les modèles existants et les stratégies de généralisation extrêmement flexibles qui permettent aux différents algorithmes et paramètres d'être utilisés dans le même modèle. Pour répondre à ces exigences, nous proposons une structure pour la généralisation des modèles de ville 3D qui soutient la définition d'hiérarchies de caractéristiques et les algorithmes de généralisation et offre des caractéris-tiques prédéfinis par défaut et les modules de généralisation qui peuvent être utilisés quand l'application le permet.

Abstract : With a growing availability of detailed 3D city models, an increased demand for the generalization of these models is going to arise. In order to build a useful system for the generalization of highly detailed 3D city models, it is necessary to give the user the opportunity to define the relevance of features on a semantic basis. This requires a high level of semantic information that is often not present in existing models and extremely flexible generalization strategies that allow different algo- rithms with different parameters to be used for the same model. In order to meet these requirements, we propose a framework for the generalization of 3 D city models that supports the definition of custom feature hierarchies and generalization algorithms and offers predefined default features and generalization modules that can be used where the application allows it.

1. Introduction

At the current state, most 3D city models are created for special tasks like noise emission simulations or for navigation systems. Therefore, there has been little demand for generalization. With a growing availability of highly detailed 3D city models, the demand for the generalization of such models is going to increase when the models are used for purposes beyond those they were created for.

The generalization of 2D models for visualization (cartographic generalization) has been researched extensively, and there are several different tools for automatic cartographic generalization as well as a set of generally accepted generalization operators. The successful generalization of 3D city models, however, requires a higher degree of semantic information to be present in the model and more specialized (up to task-specific) generalization procedures.

In this paper, a framework for the generalization of 3D city models is presented. Within this framework, default generalization tools for the most common features like buildings, roofs etc. are provided. It is also possible to replace standard features with application-specific models and to define custom generalization strategies for different (constellations of) features.

Because the required semantic information is frequently not given explicitly in existing models, the extraction of such information is often done within the generalization procedure – in many cases implicitly. Due to this fact, many generalization approaches consist in greater parts of feature detection. Therefore, we propose a stricter dis-tinction between feature extraction and genera-lization in order to be able to define more transparent generalization algorithms and reuse existing feature extraction algorithms. To make this possible, gene ralization algorithms are required to explicitly state within their interfaces what kind of features they operate on and – if these features are not part of the default set of features – how they can be extracted from a data set.

2. Related Work

While there has been a lot of research concerning the generalization of 2D models (cartographic generalization), the generalization of 3D city models has not received the same level of attention yet. In the CityGML (Kolbe et al., 2005) specification, four distinct levels of detail (LoD) are defined and several approaches concerning the automatic derivation of less detailed models from models with a higher LoD have been presented. The focus this paper, however, is on continuous generalization of city models.

Döllner and Buchholz (2005) introduce the concept of Continuous-Level-of-Quality buildings that allows the user to model buildings with custom granularity according to the task at hand. They do, however, not provide concepts for the automatic generalization of such models. The concepts for generalization introduced in Buchholz (2006) are mostly concerned with visualization issues, especially the treatment of textures.

In his PhD thesis, Lal (2005) addresses the necessity of a stronger separation of the processes of feature extraction and generalization; his focus is on feature recognition and aggregation. Thiemann and Sester (2004) derive a CSG representation by cutting off smaller parts of a building and treating them as additions. In the approach of Kada (2007), a building complex is first divided into its wings (cells) using the main lines of its footprint. The borders of these cells are then used to form the walls of the generalized model. For the generalization of the roof shapes, the feature detection is done explicitly by instancing roof shape primitives for each cell and selecting the best-fitting one.

3. 3D City Models and their Generalization

3.1 Features as Semantic Entities

Features represent entities of the real world and are the central part of the model. For the scope of this paper, the term *semantics* refers to a feature's type and application-specific data.

In the 2-dimensional case, it is often possible to use purely geometric algorithms for the generalization of a shape in the real world ; streets and canals may, for example, be simplified by similar algorithms for line simplification. The semantics of the objects are often introduced by using different algorithms or parameter sets for different feature types; only in rare cases is semantic information used in the algorithms themselves. In the 3-dimensional case, however, the semantics are often of vital importance for the generalization of a feature because there are several constraints that depend strongly on a feature's semantics : A wall surface should, for example, stand (more or less) perpendicular to the ground while a roof surface should not. If the process of generalization is intended to transform a valid model into another less detailed but also valid model, it is therefore necessary to take the semantics of a feature into account in the algorithm itself.

The problem of this approach is that it requires specific algorithms for each feature type and potentially even different algorithms for features of the same type with different parameters. This problem can be alleviated by defining parameterized generalization algorithms and using geometric simplification methods in appropriate cases. A system for the generalization of 3D city models should, however, offer the possibility to introduce specific, application-dependent generalization operators for all features.

Most modeling systems (such as the one underlying the CityGML data format) use a hierarchical approach with different layers to represent the features in the real world. The different layers in such a model represent different domains. In the case of CityGML these are, for example, water bodies, buildings, traffic objects and vegetation.
The hierarchies within the domains usually indicate "part-of" relations. A roof object, for example, is usually part of a building object and will therefore usually appear as a child object of a building feature.

In order to make the model extensible, the concept of inheritance is often introduced as well: This way, it is possible to introduce new types of features that can replace features of a known type in the hierarchy; for example, a "gabled roof" feature type could be introduced as a specialization of the "roof" feature type.

3.2 Parametric and Explicit Models

An important criterion for the distinction of 3D city modeling systems is whether they use explicit or parametric representations of the underlying geometry. In explicit models, the geometry is stored with the feature, for example as a set of polygons that represents the roof surfaces of (a part of) a building.

In a parametric model, the geometry is implicitly given through the parameters of the feature : The shape of a symmetric gabled roof, for example, is given by its eaves and ridge heights in combination with the width and depth of the building on which it is built.

Explicit models have the advantage that the geometry of the model can be reconstructed from the model without knowledge of the semantics. This means that the model can be visualized and interpreted in many respects using only a limited set of concepts like geometric primitives; visualization and purely geometric calculations can be done independent of the semantics. For this reason, the explicit approach is used especially in formats for the exchange of models. The CityGML model, for example, uses the explicit GML format to represent geometry. The disadvantage of this approach is that in many cases, semantic information has to be stored redundantly. In the CityGML format, for example, it is possible to explicitly label a roof as a gabled roof; the geometry associated with the roof may, however, form an entirely different shape.

In a parametric model, the features are represented by instantiating feature classes. The values of special data fields (parameters) determine the geometry of the object. The advantage of this approach is that a wide range of internal constraints can be assured implicitly and (for example generalization) algorithms can work on a higher level of abstraction. Additionally, parametric representations are often considerably more compact than explicit ones because the type information and some parameters can define highly complex models. For these reasons, the default model of the generalization framework uses a parametric modeling approach. In concept, however, the framework is able to work with both geometry representations. The problem with parametric representations is that in order to read a data set, the underlying model's semantics have to be known. If necessary semantic information is contained in explicit geometric data, it has to be extracted from that data.

3.3 Generalization and Feature Extraction

Generalization and feature extraction are closely related : Most generalization algorithms require semantic information that is usually not explicitly given in a model. For this reason, heuristics are defined to deal with the lack of relevant information or it is extracted from the model for the purpose of the algorithm.

A common case are models in which buildings are given as a set of surfaces in which roof and wall surfaces are not labeled. If a generalization algorithm uses such information, it must be extracted from the model. Thiemann and Sester (2004), for example, consider smaller parts of a building that appear on its outside to be additions and therefore geometrically less relevant than the basic shape. The consequence of this observation is to cut off all parts of a feature with an extent of less than the target resolution. As in many other generalization algorithms, a major part of the effort is directed towards the extraction of the features instead of the generalization itself. For this reason, it is sensible to separate the feature extraction and generalization steps explicitly. This way, it is possible to reuse both the feature extraction and generalization algorithms in different combinations.

An additional improvement of the separation of the steps is the fact that existing feature extraction solution could be used. Milde (2008) and Ripperda (2008), for example, present projects concerned with the extraction of detailed roof and façade structures from mostly geometric data. Models provided by these approaches contain a high level of semantic information and are therefore promising for semantics-based generalization.

4. The Underlying City Model

4.1 Features

In the framework presented in this paper, the central modeling element is the concept of features. For the modeling of the default features, a parametric approach was chosen because it is often easier to define generalization operators in terms of characteristic parameters and parametric models can ensure many constraints implicitly. Additionally, explicit models are usually less flexible and occupy more space in memory.

These features are structured in trees that represent containment hierarchies: For example, a roof as part of a building that is part of a building block which is a part of a quarter of a city which is part of a district (and so on). The hierarchy is extensible in all directions: Features representing finer details like bricks can be introduced as well as features that model large structures as whole countries. It is also possible to define application-specific features that can be used instead of or in addition to the features in the default hierarchy. The children of these features may be of types from the default hierarchy. This makes it possible to introduce application-specific feature classes without having to re-implement existing ones.

As in a scene graph, individual transformations can be defined for each feature in the hierarchy.

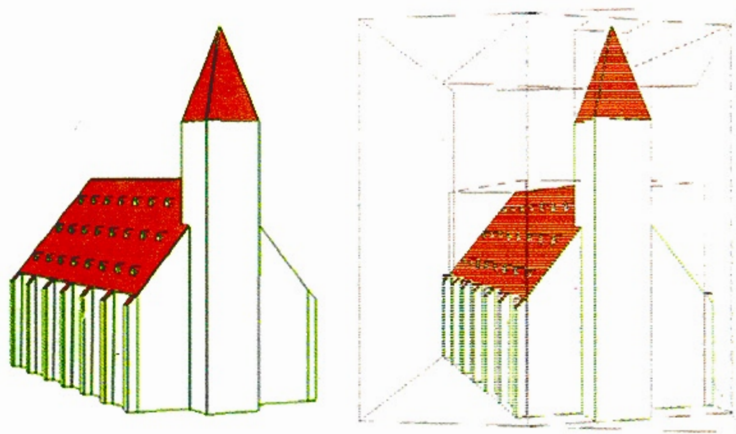


Fig. 1 Model of a church with (right) and without (left) the bounding boxes of its parts.

Using these transformations, local coordinates can be used in the modeling of the features. An additional advantage of these transformations is that they can be used to alleviate the problem of locally different distortions that arise from the transformations used in most coordinate systems.

Because the feature hierarchy represents containment relations, it can be also used as a search structure similar to the R-Tree. This is made possible by defining bounding boxes (or domains of more suitable shape) for all features (in their local coordinates) that are updated automatically when new child features are attached. This can be extremely helpful, especially if geographic queries on large models have to be evaluated. Figure 1 shows a model of a simple church with and without the bounding boxes of the features from which it was built.

Due to the modular structure of the model, it is also possible to define specific feature models that use explicit modeling of geometry. If one wants to use, for example, the approach of Kada (2007) to generalize building complexes for which no parametric model could be found, it is possible to define a feature type like ComplexBuilding that can be inserted in the feature tree in places where buildings may appear.

A generalization module that is able to handle models that contain such complex buildings has to provide a method that is called when such a building is encountered in the generalization process. Such a method may, for example, implement the approach of Kada (2007) for the generalization of the building model.

Figure 2 shows a UML diagram of the feature classes used in the first prototype. The attributes in the *Feature and LinkFeature* classes are properties : In the *BuildingPart* class, for example, the *roof* and *body* attributes are also part of the *children* list, and the *roof* and *wall* of a *Gable* are its *clients*.

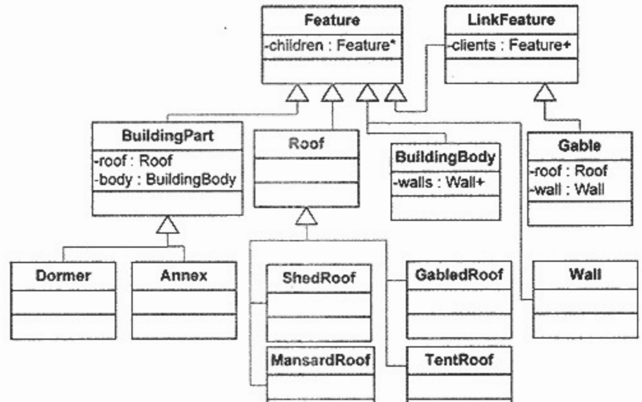


Fig. 2 Feature classes in the prototype.

4.2 Group Features

Group features represent groups of similar features, often arranged in a pattern. Such features are interesting in the context of generalization in two respects: They provide a means to reduce the amount of memory that is needed to store a feature and they are necessary for generalization operators like typification.

The reduction of memory used to describe a constellation of features is possible because only one default feature, the pattern the features are arranged in and the deviations of features from the pattern or shape of the default feature have to be stored.

For the purpose of generalization, group features are of special importance because they are necessary for generalization operators like typification in which a mostly regular pattern of similar features is replaced by a similar pattern (usually the same) with less – usually enlarged – features. This generalization operator makes it possible to keep the characteristic pattern of features even if the target resolution does not allow the individual features to be retained.

The most important group features in the context of generalization are features grouped in regular (matrix-like) patterns. These are especially suitable for typification because the reduction of the number of features is easily done by reducing the number of features in the different dimensions. By using the same ratio of reduction for all dimensions, it is also possible to achieve a homogenous degree of reduction in all parts of the region covered by the feature group.

In order to be able to extract group features from a data set in which they are not labeled, it is necessary to define strategies to determine how a constellation of more or less similar features can be allocated to different groups of features in such a way that the resulting model is best suited for generalization. An approach to detect group features from laser scanning data is, for example, introduced in Bokeloh (2009).

4.3 Link Features

Link features are features that represent relations between different features. Additionally, they may also represent tangible objects in the real world. A gable, for example, is a link between a roof and the walls below. Such a gable can, for example, be represented as a feature that is attached to a wall feature as an addition. When in the course of a generalization process the roof changes its shape, the gable is also changed and the affected wall can be notified automatically through the gable feature.

Such links can, however, also be of a more abstract nature. In the model of the church in Figure 1, a feature may be introduced that indicates that both sides of the church are symmetric or that all windows should have the same size. Such features would not necessarily be part of the general feature hierarchy. They offer, however, valuable information that can be used in the generalization process.

Additionally, link features can also be used to model intersections of features. This can be useful to model features located on the intersection of other features or complex intersections of (possibly) multiple features like many intersecting roofs or a terrain intersection curve (TIC).

4.4 Creating Geometry

Because a parametric model is used for the standard features, information about the geometry of the features is not present directly in the model. This makes it possible to develop different ways of deriving geometric representations of a feature.

For the process of generalization, information about the exact geometry of features is necessary in many cases but often it is not needed directly because custom generalization algorithms can adjust the parameters of a model to a target scale without using a geometric representation of the features.

If an explicit representation of a feature's geometry is needed, it has to be reconstructed from the parameters of the feature. This is done in a separate component of the system in which different modules are defined for the reconstruction of the geometry of each feature. This way, it is possible to adjust the generation of the geometry to the task at hand. If, for example, the thickness of a wall is given in the parametric model but some algorithm for which the geometry is intended works with walls that are represented as single surfaces, it is possible to create the geometry accordingly to return a single surface.

5. The Generalisation Component

5.1 Generalization of Parameterized Models

As indicated in the preceding chapters, the generalization of a parameterized model requires individual generalization modules for all feature classes. Additionally, scaling methods should be available because they are required for operations like emphasis and typification.

Generalization operations can, in principle, be defined for any constellation of features. They transform these features into a new set of features that is valid at the target scale. Usually, such algorithms are defined for small constellations in the feature hierarchy, for example for a building part with a certain roof shape.

The generalization module for a feature class basically provides a function with a signature get_generalization(Feature+, Resoultion) : Feature* that returns a new (possibly empty) set of features that is a generalized version of the input at the given resolution. This means that in principle, the module is responsible for the generalization of all features below the given one(s) in the feature tree. In most cases, the different modules will only cover a depth of about one to three levels in the feature tree and let the central control unit decide how to deal with sub-features that are outside its scope.

This usually leads to a recursive approach : A typification module for group features, for example, may first request generalized versions of the features it contains. This process may again trigger different generalization modules. The process stops when a leaf feature is reached – in this context, a leaf feature is a feature for which the generalization returns an empty set. Once the generalized features are collected, the typification algorithm determines how many features fit into its domain and chooses the parameters of the pattern accordingly. A possible criterion for the scaling of the features is to require the diameter of their bounding box to be greater than the resolution.

An example of a generic generalization operator is the typification operator for group features: If the target resolution does not allow the individual features in the pattern to be retained, the features are emphasized in such a way that they can be represented at the target scale. If the emphasized features cause conflicts, the number of individual features is reduced while the general pattern is retained. In Figure 3, the church model from Figure 1 is displayed at different levels of detail. The second model was derived using typification: The three rows of eight dormers each were replaced by two rows with five dormers; the seven support poles on the sides were replaced by five.

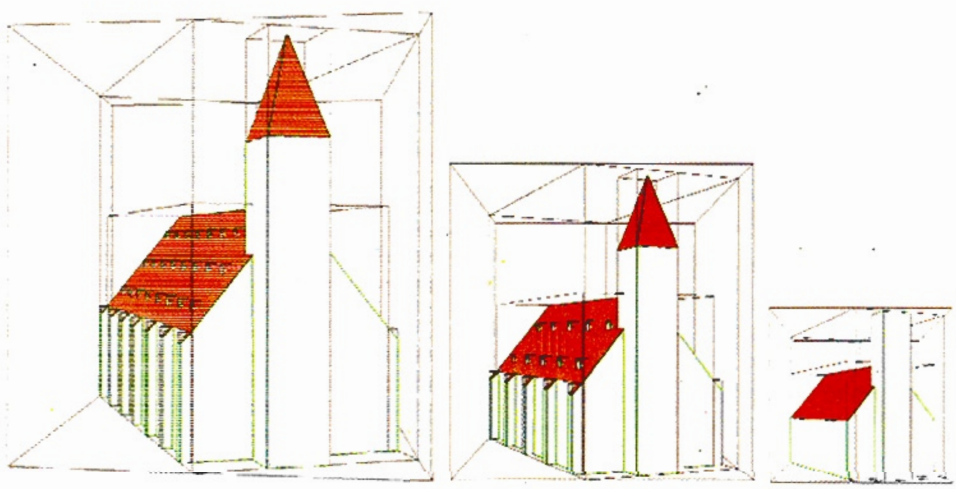


Fig. 3 Generalization sequence for the church model.

5.2 Coordination : A Modular Automaton

The most complex problem with the generalization of city models is how conflicts are resolved. Conflicts arise when either different generalization modules can be chosen in a given situation or if a generalization operation produces result feature sets that violate constraints (for example overlapping features).

While, in principle, the current generalization module is responsible for the resolution of conflicts within its scope, it is useful to have a global instance to which requests for the generalization of feature outside the algorithm's scope can be directed.

For the resolution of conflicts, different models can be chosen. For the first prototype, a simple rulebased approach is being implemented. Later solutions can use blackboard techniques, randomized optimization strategies or analogies from physics like spring models or weak primitives.

Figure 4 shows a possible delegation of responsibility among different generalization modules : The generalization of the building delegates the generalization of details on a wall to a specialized façade generalization module. The central generalization control module can be used by the building generalization to find the appropriate module for the generalization of facades. This way, the building generalization does not have to know all features that may appear in its scope but only those it needs.

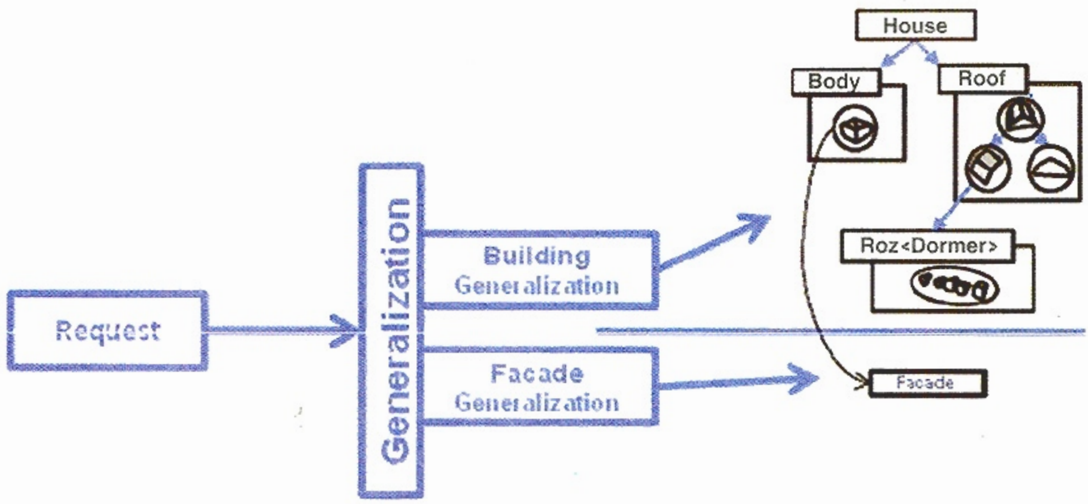


Fig. 4 Modularized Generalization.

6. Conclusion and Outlook

In this paper, a framework for the generalization of 3D city models has been proposed. Within this framework, custom feature types and generalization algorithms can be defined. In a first prototype, a small hierarchy for the modeling of buildings has been developed together with modules for generalization.

Further work is needed to enhance the prototype of the framework in different respects: The feature model is going to be extended, a control module with different conflict resolution strategies for the generalization model has to be implemented, and algorithms will be developed for the generalization of different feature constellations. The prototype is also going to be extended by the possibility to generate data sets with non-uniform user-defined resolutions.

Acknowledgenent

This work was funded by the German Ministry of Education and Science (BMBF) in the context of the GDI Grid project.

Bibliography

M. Bokeloh, A. Berner, M. Wand, H.-P. Seidel, A. Schilling, 2009: Symmetry Detection Using Line Features, Computer Graphics Forum (Proceedings of Eurographics), to appear.

H. Buchholz, 2006: Real-time Visualization of 3D City Models, PhD thesis, Universität Potsdam.

J. Döllner andH. Buchholz, 2005 : Continuous Level-of-Detail Modeling of Buildings in 3D City Models. In GIS '05: Proceedings of the 13th annual ACM international workshop on Geographic information systems, ACMPress, New York, NY, USA, 173–181.

M. Kada, 2007: 3D Building Generalisation by Roof Simplification and Typification. In: Proceedings of the 23th International Cartographic Conference, Moscow, Russian Federation.

T. H. Kolbe, G. Gröger and L. Plümer, 2005. CityGML: Interoperable access to 3D city models. In: First International Symposium on Geo-Information for Disaster Management GI4DM.

J. Milde, Y. Zhang, C. Brenner, L. Plümer and M. Sester, 2008: Building Reconstruction Using a Structural Description Based on a Formal Grammar, International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XXXVII, Beijing, China.

J. Lal, 2005: Recognition of 3D Settlement Structure for Generalization, PhD thesis, Technische Universität München, 2005.

N. Ripperda, 2008: Determination of Facade Attributes for Facade Reconstruction, International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. 37, no. B3a, p. 285-290.

F. Thiemann and M. Sester, 2004: *Segmentation of Buildings for 3D-Generalisation,* Proceedings of the ICA Workshop on generalisation and multiple representation, Leicester, UK.

Automated 3D Modeling of Urban Environments

Ioannis Stamos
Department of Computer Science Hunter College, City University of New York
695 Park Avenue, New York NY10065
istamos@hunter.cuny.edu
http://www.cs.hunter.cuny.edu/~ioannis

ملخّص : تتطلب نمذجة صورّ المناظر ذات مقياس كبير ، تماماً مثل هياكل البناء الحضرية ، اندماج تكنولوجيا الكشف عن بعد و الصورة الرقمية التقليدية . يلخّص هذا المقال المساهمات التي قام بها فريقنا في هذه المنطقة . نقدّم نظام يدمج تقنيات الكشف 3D- في 3D-و 2D- في 3D الآلية ، مع الهندسة المتعددة المشهد لنمذجة صورّ المناظر الحضرية . يكشف التمشيط عن بعد 3D بإستعمال طريقتنا في الكشف 3D- في 3D الآلية الذي يطابق المميزات 3D ، (الخطية أو الدائرية) للصور عن بعد .

تُصفَ حينئذ مجموعة دونيّة لصوّر 2D مع النموذج 3D الذي يستعمل خوارزمية الكشف 2D- في 3D الآلية الذي يطابق المميزات الخطية بين التمشيط عن بعد و الصوّر. أخيراً ، تستعمل الصوّر 2D لتوّليد نموذج ثاني 3D للمنظر المتمثل في نقاط غائمة متباعدة 3D، بتطبيق خوارزمية الهندسة المتعددة المشهد (بنية الحركة) مباشرة في الوحدة التصورية للصوّر 2D .

تمّ إنجاز خوارزمية جديدة للإسترجاع الدوران ، المقياس و التفسير الذي يصفَ بطريقة أحسن النماذج الكثيفة و المتباعدة . يعدّ هذا الصفّ ضروري حتى ترسم الصوّر على النموذج الكثيف . أخيراً نقدّم تقسيم و نمذجة الخوارزمية للمناظر الحضرية. ندمج في هذا العمل فوائد الهندسة المتعددة المشهد مع الكشف الآلي لتمشيط عن بعد 3D للإنتاج نماذج الصور بتفاعل بشري صغير . نقدّم نتائج التجارب في المناظر الحضرية ذات مقياس كبير .

الكلمات الأساسية : ليدار ، نمذجة ثلاثية الأبعاد 3D ، مناظر حضرية

Résumé : La modélisation photoréaliste de scènes à grande échelle, telle que structures urbaines, exige la fusion de technologie de détection à distance et la photographie numérique traditionnelle.

Cet article résume les contributions de notre groupe sur cette surface. Nous présentons un système qui intègre les techniques de repérage 3D-à-3D et 2D-à-3D automatisé, avec la géométrie de multivue pour la modélisation photoréaliste de scènes urbaines.

Les scannages à distance 3D sont repérés en utilisant notre méthode de repérage 3D-à-3D automatisé qui adapte les caractéristiques 3D, (linéaire ou circulaire) dans les images à distance.

Un sous-ensemble de photographies 2D est alors aligné avec le modèle 3D qui utilise notre algorithme de repérage 2D-à-3D automatisé qui adapte les caractéristiques linéaires entre les scannages à distance et les photographies.

Finalement, les photographies 2D sont utilisées pour générer un second modèle 3D de la scène qui consiste en un nuage de points 3D clairsemé, produit en appliquant l'algorithme de la géométrie de multivue (structure-de-mouvement) directement sur une séquence de photographies 2D.

Un nouvel algorithme pour retrouver automatiquement la rotation, l'échelle et la traduction qui aligne mieux les modèles denses et clairsemés a été développé. Cet alignement est nécessaire pour permettre aux photographies d'être dressées optimalement sur le modèle dense. Finalement, nous présentons une segmentation et une modélisation d'algorithme pour les scènes urbaines.

Ce travail fusionne les avantages de la géométrie de multivue avec repérage automatisé des scannages à distance 3D pour produire des modèles photoréalistes avec interaction humaine minime.

Nous présentons des résultats d'expériences dans des scènes urbaines à grande échelle.

Mots-Cles : LIDAR, modélisation 3D, scènes urbaines.

This paper has been originally prepared and presented at the FIG Working Week in Stockholm, Sweden, 14-19 June 2008.

Abstract : The photorealistic modeling of large-scale scenes, such as urban structures, requires a fusion of range sensing technology and traditional digital photography. This paper summarizes the contributions of our group in that area. We present a system that integrates automated 3D-to-3D and 2D-to-3D registration techniques, with multiview geometry for the photorealistic modeling of urban scenes. The 3D range scans are registered using our automated 3D-to-3D registration method that matches 3D features (linear or circular) in the range images. A subset of the 2D photographs are then aligned with the 3D model using our automated 2D-to-3D registration algorithm that matches linear features between the range scans and the photographs. Finally, the 2D photographs are used to generate a second 3D model of the scene that consists of a sparse 3D point cloud, produced by applying a multiview geometry (structure-from-motion) algorithm directly on a sequence of 2D photographs. A novel algorithm for automatically recovering the rotation, scale, and translation that best aligns the dense and sparse models has been developed. This alignment is necessary to enable the photographs to be optimally texture mapped onto the dense model. Finally, we present a segmentation and modeling algorithm for urban scenes. The contribution of this work is that it merges the benefits of multiview geometry with automated registration of 3D range scans to produce photorealistic models with minimal human interaction. We present results from experiments in large-scale urban scenes.

Key words : LIDAR, 3D Modeling, Urban Scenes.

1. Introduction

The photorealistic modeling of large-scale scenes, such as urban structures, can be achieved by a combination of range sensing technology with traditional digital photography. Laser range scanners can produce highly-detailed geometry whereas color digital cameras can produce highly-detailed photometric images of objects. Our main focus is the geometric and photorealistic reconstruction of individual buildings or large urban areas using a variety of acquisition methods and interpretation techniques, such as ground-base laser sensing, air-borne laser sensing, and ground and air-borne image sensing. The ultimate goal is the reconstruction of detailed models of urban sites, i.e. digital cities, by the effi-cient combination of all possible sources of information. The creation of digital cities drives other areas of research as well: visualization of very large data sets, creation of model databases for GIS (Geographical Information Systems) and combination of reconstructed areas with existing digital maps. Recently, intense commercial interest for photorealistic reconstruction of city models is eminent in systems such as Google Earth, or Microsoft Virtual Earth.

3D models of cities can be acquired by various techniques such as aerial imagery, ground-based laser range-scanning, existing architectural CAD modeling, and traditional photogrammetry. Aerial-based methods produce crude box-like models, whereas groundbased laser range-scanning methods produce highly accurate models. The latter models though consist of irregular and heavy ge-ometry. On the other hand purely image-based approaches have presented significant progress, and are now able to produce impressive 3D models (Pollefeys et al., 2008, Seitz et al., 2006), that are still inferior to laser-based models. Finally, web-based platforms (such as Google Earth or Microsoft Virtual Earth), are able to receive and display light-weight 3D models of urban objects, whereas rapid-prototyping machines are able to build such models. Therefore, the generation of photorealistic 3D content of urban sites at various resolutions and from various sensors is a very important current problem. Some of the systems that combine 3D range and 2D image sensing for 3D urban modeling include the following : (Früh and Zakhor, 2003, Sequeira and Concalves, 2002, NRC, 2008, Zhao and Shibasaki, 2003, Stamos and Allen, 2002, Zhao et al., 2005).

The framework of our system is shown in Fig. 1. Each of the framework elements listed below, is a distinct system module in Fig. 1.

- A set of 3D range scans of the scene is acquired and coregistered to produce a dense 3D point cloud in a common reference frame.
- An independent sequence of 2D images is gathered, taken from various viewpoints that do not necessarily coincide with those of the range scanner. A sparse 3D point cloud is reconstructed from these images by using a structure-from-motion (SfM) algorithm.
- A *subset* of the 2D images are automatically registered with the dense 3D point cloud acquired from the range scanner.
- The *complete* set of 2D images is automatically aligned with the dense 3D point cloud. This last step provides an integration of all the 2D and 3D data in the same frame of reference. It also provides the transformation that aligns the models gathered via range sensing and computed via structure from motion.
- Finally, segmentation and modeling of the 3D point clouds follows.

2. 3D Modeling Pipeline

In this section we present the status of our 3D modeling system: 3D-to-3D Registration (Sec. 2.1). 2D-to-3D registration (Sec. 2.2), and 3D modeling (Sec. 2.3). More details can be found on some of our papers: (Stamos et al., 2008, Liu and Stamos, 2007, Chao and Stamos, 2007, Liu et al., 2006, Yu et al., 2008).

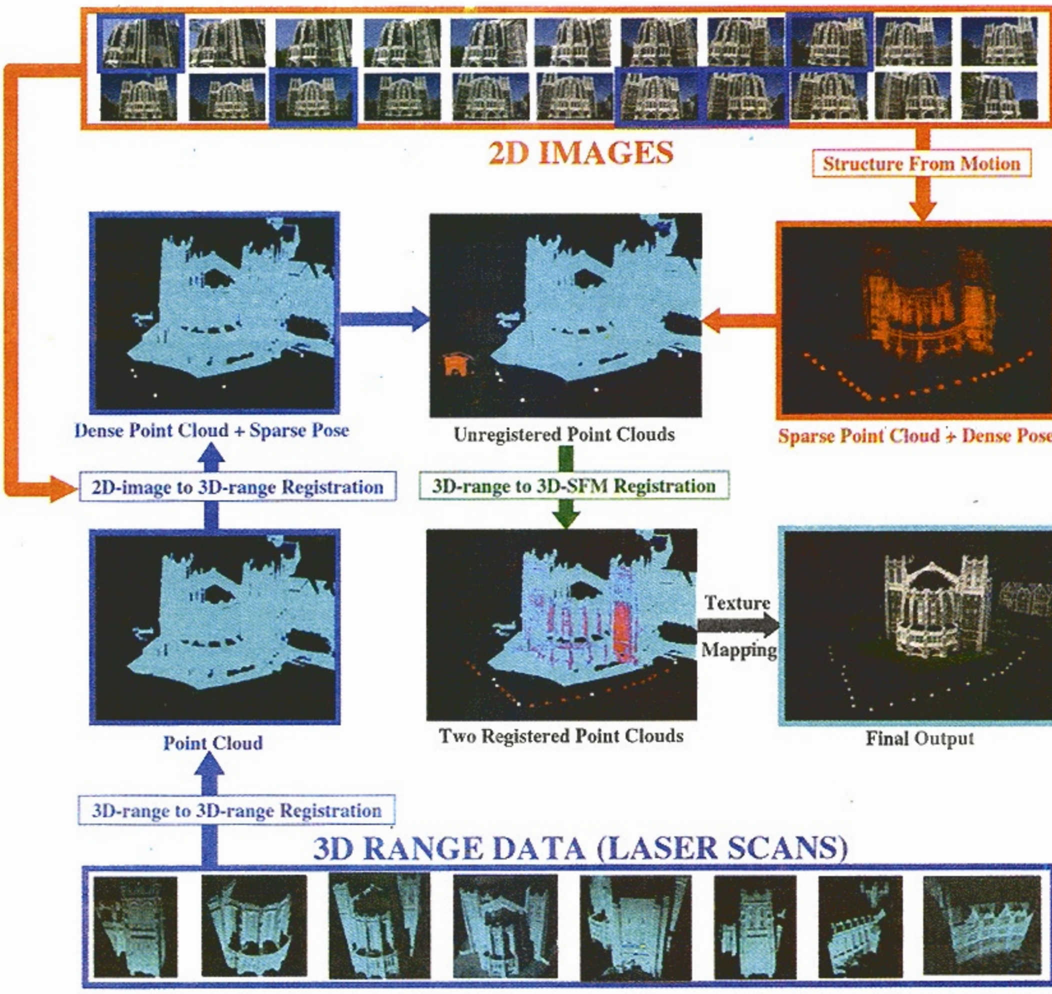


Fig. 1 System framework (Stamos et al., 2008). Several registered range scans of Shepard Hall (CCNY) constitute a dense 3D point cloud model M_{range} shown in the leftmost column. The five white dots correspond to the locations of five of the 26 color images (shown as thumbnails on top row) that are independently registered with the model M_{range} via a 2D-to-3D image-to-range registration algorithm. The rightmost image of the second row depicts the 3D model M_{sfm} produced by SFM. The points of M_{sfm} as well as all the recovered camera positions for the sequence of 2D images that produced M_{sfm} are shown as red dots in the figure. Since SFM does not recover scale, M_{range} and M_{sfm} are not registered when brought to the same coordinate system, as shown in the second row. The 3D range model M_{range} overlaid with the 3D model M_{sfm} is shown in the third row of the figure after a 3D-range to 3D-SFM registration module aligns them together. The recovered camera positions from SFM can now be used to project the26 color images onto M_{range}, which now properly sits in the M_{sfm} coordinate system, to produce the richly textured 3D model (Final Output) shown in the right column.

2.1 3D-to-3D Range Registration

Our 3D registration techniques are based on automated matching of features (lines, planes, and circles) that are extracted from range images. We have applied our automated methods for registration of scans of landmark buildings. In particular we have acquired and registered: interior scans of Grand Central Terminal in NYC, Great Hall at City College of New York (CCNY), as well as exterior scans of St. Pierre Cathedral in Beauvais (France), Shepard Hall at CCNY, Thomas Hunter building at Hunter College, and Cooper Union building (NYC). As a result, all range scans of each building are registered with respect to one selected pivot scan. The set of registered 3D points from the K scans is called M_{range} (Fig. 1).

2.2 2D-to-3D Image-to-Range Registration

We present our automated 2D-to-3D image-to-range registration method used for the automated calibration and registration of a single 2D image I_n with the 3D range model M_{range}. The computation of the rotational transformation between I_n and M_{range} is achieved by matching at least two vanishing points computed from I_n with major scene directions computed from clustering the linear features extracted from M_{range}. The method is based on the assumption that the 3D scene contains a cluster of vertical and horizontal lines. This is a valid assumption in urban scene settings.

With this method, a few 2D images can be independently registered with the model M_{range}. The algorithm will fail to produce satisfactory results in parts of the scene where there is a lack of 2D and 3D features for matching. Also, since each 2D image is independently registered with the 3D model, valuable information that can be extracted from relationships between the 2D images (SfM) is not utilized. In order to solve the aforementioned problems, an SfM module final alignment module (Stamos et al., 2008, Liu et al., 2006) has been added into the system. These two modules increase the robustness of the reconstructed model, and improve the accuracy of the final texture mapping results. Therefore, the 2D-to-3D image-to-range registration algorithm is used in order to register a few 2D images (five shown in Fig. 1) that produce results of high quality. The final registration of the 2D image sequence with the range model M_{range} is performed after SfM is utilized.

Our recent contributions (Stamos et al., 2008, Liu and Stamos, 2007, Liu, 2007) with respect to 2D-to-3D registration can be summarized as follows :

- We have developed a working system that is able to independently register 2D images to 3D models at interactive rates. This system requires minimal user interaction. Note that after a few 2D images are registered to the 3D model the multiview geometry approach (SfM) is utilized for registering all images with the 3D range model.
- The whole space of possible matches between 3D and 2D linear features is explored efficiently. That improves the possibility of convergence of our algorithm.
- Our method utilizes 3D and 2D linear features for matching without significant grouping. This increases the generality of our algorithm since we make fewer assumptions about the 3D scene. Scenes with various layers of planar facades, or without clear major facades can thus be handled.

2.3 Modeling

We have developed novel algorithms (Yu et al., 2008, Chao and Stamos, 2007, Chen, 2007) for extracting planar, smooth nonplanar, and non-smooth connected segments, and then merging all these extracted segments from a set of overlapping range images. Our input is a collection of registered range images. Our output is a number of segments that describe urban entities (e.g. facades, windows, ceilings, architectural details). In this work we detect different segments, but we do not yet identify (or recognize) them. A flowchart of our current technique can be seen in Fig. 2.

In addition to segmenting each individual scan, our methods also merge registered segmented images. The merging results in coherent segments that correspond to urban objects (e.g. facades, windows, ceilings) of a complete large scale urban scene. Based on this, we generate a different mesh for each object. In a modeling framework, higher order processes can thus manipulate, alter, or replace individual segments. In an object recognition framework, these segments can be invaluable for detecting and recognizing different elements of urban scenes. Results of our segmentation and modeling algorithms can be seen at Fig. 3.

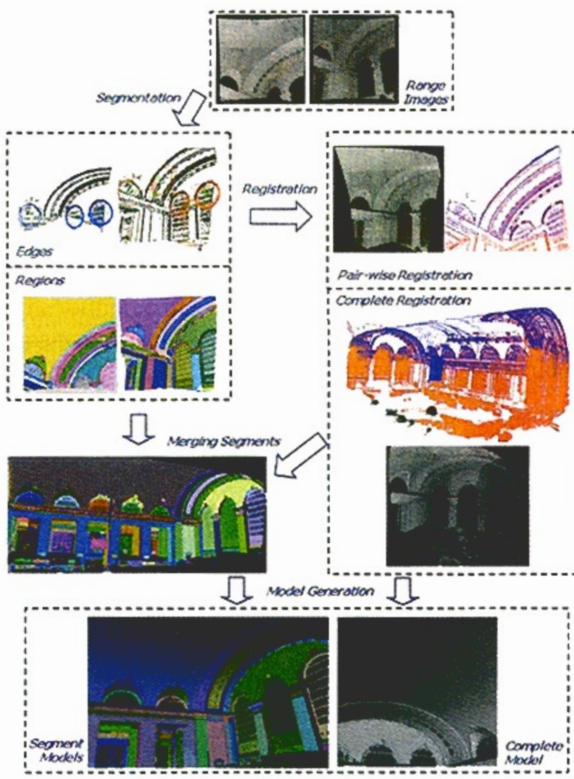
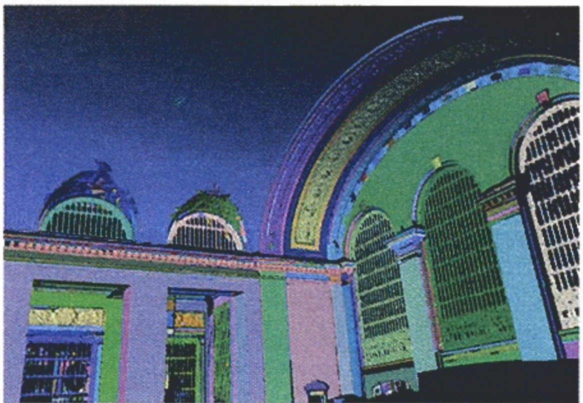


Fig. 2 Our segmentation and modeling framework (Chen and Stamos, 2005, Chao and Stamos, 2007, Chen, 2007).



(a)

(b)

Fig. 3 (a) Segmentation and modeling result : 15 range images of Grand Central Terminal dataset. Different colors correspond to different segments that have been automatically extracted and modeled via the Ball Pivoting algorithm (Bernardini and Rushmeier, 2002). Cylindrical ceiling, planar facades, as well as other more complex areas (windows, etc.) have been correctly segmented. (b) Segmentation and modeling result of Cooper Union dataset: 10 range images (one facade is shown). Planar facades, and complex window and arch elements have been correctly segmented. Note, that in both (a) and (b) each segment is represented as a dense triangular mesh.

3. Future work

The generated 3D models are complex triangular meshes. Mesh simplification is thus important. Unfortunately, simplification approaches suffer from the fact that their input is a complicated mesh. A mesh is a low-level heavy collection of triangles that does not take into account the high-level abstraction of urban structures. A high-level model should identify facades, doors, windows, and other urban entities. An important avenue of exploration is an automated high-level representation of the final 3D urban model.

Acknowledgements

This work was supported in part by the following grants: NSF CAREER IIS-02-37878, NSF MRI/RUI EIA-0215962, and NSF CNS-0821384.

References

Bernardini, F. and Rushmeier, H., 2002. The 3D model acquisition pipeline. Computer Graphics Forum 21(2), pp. 149–172.

Chao, C. and Stamos, I., 2007. Range image segmentation for modeling and object detection in urban scenes. In: The 6th International Conference on 3-D Digital Imaging and Modeling, Montreal, Canada.

Chen, C., 2007. Range Segmentation and Registration for 3D Modeling of Large-Scale Urban Scenes. PhD thesis, City University of New York.

Chen, C. and Stamos, I., 2005. Semi-automatic range to range registration: A feature-based method. In: The 5th International Conference on 3-D Digital Imaging and Modeling, Ottawa, pp. 254–261.

Früh, C. and Zakhor, A., 2003. Constructing 3D city models by merging aerial and ground views. Computer Graphics and Applications 23(6), pp. 52–11.

Liu, L., 2007. Automated Registration of 2D Images with 3D Range Data in a Photorealistic Modeling System of Urban Scenes. PhD thesis, City University of.New York.

Liu, L. and Stamos, I., 2007. A systematic approach for 2D-image to 3D-range registration in urban environments. In: VRML Workshop, 11th International Conference on Computer Vision, Rio de Janeiro, Brasil.

Liu, L., Stamos, I., Yu, G., Wolberg, G. and Zokai, S., 2006. Multiview geometry for texture mapping 2D images onto 3D range data. In: IEEE Conf. Computer Vision and Pattern Recognition, Vol. II, New York City, pp. 2293–2300.

NRC, 2008. Visual Information Technology Group, National Research Council, Canada. http://iit-iti.nrc-cnrc.gc.ca/about-sujet/vit-tiv_e.html.

Pollefeys, M., Nistr, D. and etal., 2008. Detailed real-time urban 3d reconstruction from video. International Journal of Computer Vision 78(2–3), pp. 143–167.

Seitz, S. M., Curless, B., Diebel, J., Scharstein, D. and Szeliski, R., 2006. A comparison and evaluation of multi-view stereo reconstruction algorithms. In: IEEE Conference on Computer Vision and Pattern Recognition, Vol. 1, pp. 519–526.

Sequeira, V. and Concalves, J., 2002. 3D reality modeling: Photo-realistic 3D models of real world scenes. In: Intl. Symposium on 3D Data Processing, Visualization and Transmission, pp.776-783.

Stamos, I. and Allen, P. K., 2002. Geometry and texture recovery of scenes of large scale. Journal of Computer Vision and Image Understanding 88(2), pp. 94–118.

Stamos, I., Liu, L., Chao, C., Wolberg, G., Yu, G. and Zokai, S., 2008. Integrating automated range registration with multiview geometry for the photorealistic modeling of large-scale scenes. International Journal of Computer Vision 78(2–3), pp. 237–260.

Yu, G., Grossberg, M., Wolberg, G., Stamos, I. and Zokai, S., 2008. Think globally, cluster locally: A unified framework for range segmentation. In: Fourth International Symposium on 3D Data Processing, Visualization and Transmission, Georgia Institute of Technology, Atlanta, GA.

Zhao, H. and Shibasaki, R., 2003. Reconstructing a textured CAD model of an urban environment using vehicle-borne laser range scanners and line cameras. Machine Vision and Applications 14(1), pp. 35–41.

Zhao, W., Nister, D. and Hsu, S., 2005. Alignment of continuous video onto 3D point clouds. IEEE Transactions on Pattern Analysis and Machine Intelligence 27(8), pp. 1305–1318.

Using Geo-informatics for Development of Rural Roads Under Pradhan Mantri Gram Sadak Yojna

[1] K. K. Mishra and [2] Naresh Thakral
[1] State Nodal Officer (IT & GIS), PWD Rajasthan, Jaipur
rj-itno@nic.in
[2] Executive Engineer, PWD Rajasthan, Jaipur
E-mail: nkthakral@gmail.com

1. Introduction

The development of any country depends on the infrastructural facilities available therein. Good road network facilities plays major role here. The developed countries have good road infrastructure not because of the fact that they are wealthy; instead they become developed because of good road infrastructure. Realizing this fact an ambitious and biggest ever infrastructure development project in India (expected cost of $26 billion) named as Pradhan Mantri Gram Sadak Yojna (PMGSY) under ministry of Rural Development was conceptualized and launched on 25th December, 2000. The objective was to provide basic access by way of all weather roads to the all habitations having population "250 or above in desert and tribal areas" and "500 or above for the rest of habitations" by year 2007 in phased manner.

The role of Rural Roads is very important in a country like India where majority of the population resides in rural areas and the main source of their earning is based on agriculture products. Rural roads provide the access to basic amenities and means of transporting agricultural products to nearest market centers. The Rural Roads can be classified as Other District Roads (ODR) and Village Roads (VR). ODR are those roads which connects the rural areas to market centers, Block, tehsil/taluka HQ or main roads while VR are those roads which connects villages and group of villages and each other or to the market place or with the nearest road of higher category (Operation Manual, 2005).

PMGSY scheme is becoming very popular among rural areas because of the specifications and quality aspect adopted for construction of roads. Although it is a Rural Road Connectivity Project but it has well designed working system, clear guidelines and stream lined efficient monitoring and execution strategy.

2. Salient Features of PMGSY scheme

The planning and execution of PMGSY roads are unique in many aspects i.e. planning, execution and quality of work (PMGSY, 2004)

- Planning of PMGSY roads are based on the Core network: All roads under PMGSY have been prioritized out of the Core Network.
- Roads are properly designed based on climatic and traffic conditions Roads and built as per the specifications given in Rural Roads Manual published by the Indian Roads Congress (IRC:SP20: 2002).
- Each state has designated a State Level Autonomous Agency to maintain financial and work execution matters. The District Programme Implementation Units (DPIUs) headed by Superintending Engineers who execute the road works in accordance with the programme guidelines.
- A 3-tier quality control system has been envisaged to enforce the quality of construction of roads. Contractors are bounded to set up a field laboratory at the work site. DPIU functions as the first tier of the quality supervisor, these DPIU are further supervised by the State Quality Monitor and National Quality Monitors.
- The complete programme is monitored, planned using Online monitoring System called as Online Management, Monitoring and Accounting System (OMMAS).
- The use of Geographical Information System (GIS) for monitoring, management and building transparency in programme implemented in two pilot states i.e. Rajasthan and Himachal Pradesh.

3. Need of using Geo-informatics in planning, monitoring & management

Implementation of PMGSY scheme poses major challenges in front of nodal executing agency i.e. National Rural Road Development Authority (NRRDA). It was very difficult and hard to manage this giant project using traditional methods of project management as these methods are not only tedious and time consuming but also difficult to retrieve the desired information. To overcome these difficulties Geo-informatics is being used for planning, decision making and monitoring of PMGSY scheme. Geo-informatics is a advance technology and science which emerged very strongly in past 10-15 years , it includes Geographic information System (GIS), Remote Sensing, Global Positioning System, Communication, programming, statistics, geo processing, image processing, digital photogrametry etc..

GIS is a key component of geo-informatics is a computer assisted system for capturing, storing, checking, integrating, manipulating, analyzing and displaying, data which are spatially referenced to the Earth for solving complex planning, decision making and management problems. GIS is a powerful mapping tool that links information found in databases to geographic locations found on colorful map displays in order to make analysis for decision making clearer. GIS allows us to manipulate and display geographical knowledge in a new and exciting ways. GIS integrates spatial and other kinds of information in a single system like spatial information and its attribute information within a single system. Similar to other information system, GIS also depends on the information content input in computer but this information system requires special processing.

Development of database for GIS involved different stages in a sequence. The database preparation part of GIS development is very important and time consuming because all the out come of GIS is based on the quality, completeness, relevancy and accuracy of data. The following stages are involved in development of GIS data base :

- Data input
  - Entering the spatial data
  - Entering the attribute data
  - Linking the spatial and non-spatial data
- Data correction and verification
- Topology creation
- Spatial analysis
- Data output

The creation of GIS data base requires spatial data and the corresponding attribute data of the spatial features. The Spatial data used here includes various layers of habitations, DRRP, Core network and various boundaries maps etc. while all attribute data is being stored in OMMAS. To implement use of GIS for development of rural roads and creation of GIS data base Rajasthan and Himachal Pradesh are chosen as pilot state.

4. Online Management, Monitoring and Accounting System (OMMAS)

Computerized data has the advantage of reliable storage, easy retrieval, immediate processing and complicated calculation ability which is useful in generating the high level abstract information for use of management. The advantage of a centralized database is that the range of comparison is not only vertical in terms of the time period but also horizontal in terms of geographic spread across districts and states (Operation Manual, 2005).

The online Management, Monitoring and Accounting System (OMMAS) have been designed as an online web-based system with centralized database.

The OMMAS is developed to provide features which were not used earlier. The data entry is being done at the point where the data are generated i.e. at the Programme Implementation Unit (PIU) level for project data and at the State Technical Agency/State Rural Roads Development Agency and National Rural Roads Development Agency level where their intervention contributes to value addition to the data. The data entry is for near real time to enable outputs to be useful for management as well as monitoring.

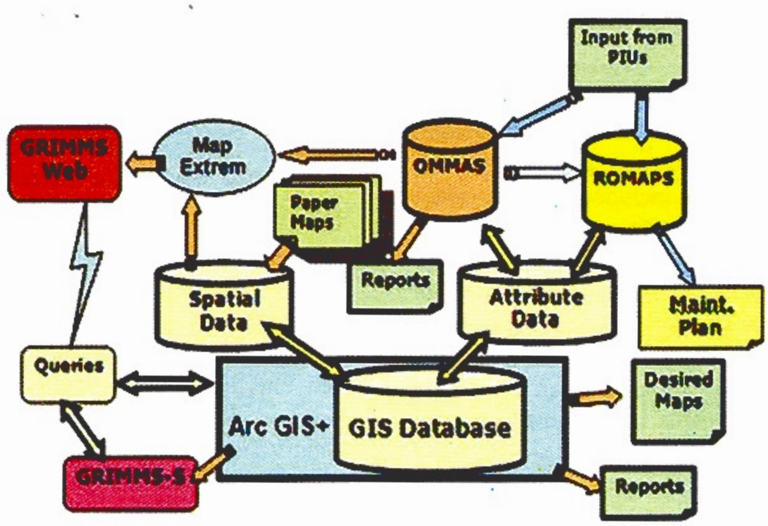


Fig. 1 Data flow & relationship chart.

The huge database and various reports related with habitations, roads, works etc can be accessed at http://omms.nic.in The full power of the software is brought to bear to generate outputs useful at all levels i.e. monitoring and management output at PIU levels, progress management and management-by-exception outputs at SRRDA level and NRRDA and abstracted and analyzed information policy and over all information for use in NRRDA. Transparency is inbuilt in the system enabling abstracted data to be drilled down to basic data, generally up to 'road' or 'Habitation'.

5. Input to GIS database

The spatial data for PMGSY consists of several layers which includes DRRP, Core Network roads, habitations, block and district head quarters, tourist places, queries, boundaries of zones, circles, division, block, districts, forest area etc. The District Rural Road Plan (DRRP) is a long term plan of road network in a district showing the existing road network of all categories, the habitation of various population size and road proposed for connecting the yet connected habitations to already connected habitations by all weather roads in an economical and efficient manner. The Rural Road network required for providing the basic access to all habitations/villages to term as the Core Network. Basic access is defined as one all weather road access from each habitation to the nearest market Centre and essential social and economic services. A Core network comprises of through route and Link Routes. Through routes are the roads which collect traffic from several links and lead it to the market centre or higher category roads. Link routes are the roads connecting to a single habitation or a group of habitations to through route or district road leading to market centre (Operation Manual, 2005).

The maps created by SoI at the scale of 50,000 are used as base map for creating DRRP and Core net work maps. These maps are overlapped on digital maps received from SoI. The Core Network maps are subset of DRRP maps with an additional layer of network of Through Route and link routes. The following features were included in the maps District, Block, MLA constituency, MP constituency, Divisional boundary and Circle Boundary. All category of roads i.e. NH, State Highway, Major District Roads, Other District Roads, Villages roads and other roads are included. All habitations, town and cities, religious/tourist places, quarries, market places, river or major streams, bridges and CD works are mapped. These maps were scanned and digitized to form vector data. Separate layers were created for different categories of roads. These digital maps were then Geo-referenced (a process by which the features on the maps are assigned real world coordinates).

The attribute data belonging to spatial feature are entered through the Online Management, Monitoring and Accounting System (OMMAS) which is being developed programmatically with assistance of Center for Development of Advance Computing (C-DAC), Pune. The data entry in OMMAS is being done by officials of respective state agencies from their own place through internet. The distributed data entry now resulted into massive information bank (User Manual, 2005).

5.1 Linking Data and Quality Checking

Creation of data base for GIS linking of spatial data i.e. maps to non spatial data i.e. OMMAS requires common linking Ids and total number of feature represented in map should match with corresponding attribute data. The cleaning of spatial feature also takes place at this stage. The linking of spatial and non spatial data is done using ARC GIS software. The completeness and accuracy of data is being checked at this stage as these factors decide the usability of data in this decision support system.

5.2 Manipulating and Analyzing Data for Decision Making

To make the database ready for analysis some operations has to be performed at this stage. One of these operations is topology creation. Topology creation develops the location relationship among the geographic feature besides cleaning of the map. Creating topology checks geometry of the features and removes errors by deleting short objects, clustering the nodes etc. To analyze the roads, network topology has to be created. This operation develops relation among roads and its spatial relation with other features e.g. adjacency, disjoint, crossing etc. Once the topology is build successfully the data is ready for analysis and various reports, different queries can be made which can be further used for decision making. The GIS database created this way now makes enable the users to perform several GIS analysis.

The database developed under this project involves huge cost and requires the optimal use by the users. The operation of GIS software requires special training and methods to use it, therefore a customized interface which enabled novice users to use complex functionality with ease was developed using VB.net, Arc GIS, Arc Objects etc. and several common analysis task put to single button commands. The stand alone GIS Enabled Road Inventory

Monitoring and Management System (GRIMMS-S) was developed for this purpose. it is a stand alone GIS software designed for PIUs to use at their office to perform various queries and analysis for their day to day work. The stand alone GRIMMS-S enabled field staffs to perform various analytical GIS processing with ease.

Since the use of stand alone system was constrained to the limited number of users because of the stand alone installation and high cost of the parent GIS software, it was decided to launch Web version of customized GIS e.g. GRIMMS-Web. It overcame the drawbacks of stand alone system and enabled common person/citizens to operate and view information in an interactive and exciting way on the map with related attributes without any specific hardware and software installation. The web based GIS allows transparency to PMGSY programme and disseminate the related spatial as well as attribute information related to progress and status of PMGSY roads in user friendly manner to all those person who even don't have heard about GIS (Baliga, 2005). GRIMMS-Web can be accessed at http://omms.nic.in/grimms

6. Data updating

The quality and usability of data is largely depends on the age of data and it requires constant updating. The data updating requires field verification and input from field for newly created features e.g. roads, building etc. Global Positioning System (GPS) can greatly help here. GPS is an advance method of positioning which assist in positional data collection/updating of spatial information (maps). This technology uses special signals broadcasted by satellites and uses the information contained in to calculate the position of the GPS receiver. The accuracy of this positioning system varies from 50 m to 1 mm depending on the type of the receiver and the processing of data (Guo et al, 1995). The Differential processing (DGPS) can provide very accurate spatial coordinate and can be used for updating of maps in an efficient and cost effective manner.

7. Applications of Geo-informatics for rural roads

The database prepared through above mentioned processes is being used for decision making and planning. GIS can answer following questions and thus helps in decision making.

- Location (what is at ...?)
- Condition (where is it....?)
- Trends (what has changed since....?)
- Pattern (what spatial pattern exist...?) see figure 3
- Modeling (what if....?)

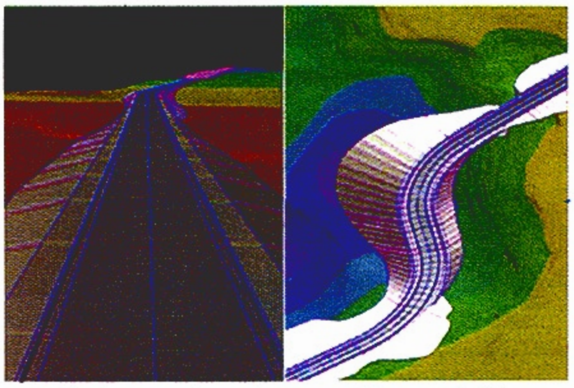


Fig. 2 Design of road for optimal E/W using 3D GIS.

The usage of Geo-informatics is application based ; some of the main usages are as follows :

- Preparing new information based on the existing information.
- Performing various queries to reach to make decisions e.g. which roads are renewed before 10 years and Pavement Condition Index(PCI) is equal to or less than 2 for preparing the maintenance plan.
- Knowing pattern to make policies or launch new scheme like (see figure 3 & 4) using different symbolization methods.
- Various status reports demanded from time to time e.g. during assembly season can be prepared in a effective and time saving manner.
- Study of development along the road or encroachment along the road way.
- Design of road with optimal alignment and grade to save the cost of earth work using 3D GIS. (See figure 2).
- Preparing customized maps/reports which shows the features and area of interest.
- Network analysis to find the shortest route or alignment.
- Flood analysis to find out the which part of the road is likely to fall under submergence in case of flood takes place.
- Preparing Comprehensive New Connectivity Priority List (CNCPL) proposals based on the predefined conditions e.g. Population range: 500 - 999 and Connectivity status as on 2007 is No and then preparing the detailed report of these selected roads to prepare Detailed Project reports.
- Preparing Comprehensive Up-gradation Priority List (CUPL) proposals e.g. Road Category belonging to Village Roads or Other District Roads and PCI Index = 2 and year of Construction of road more than 10 years old.

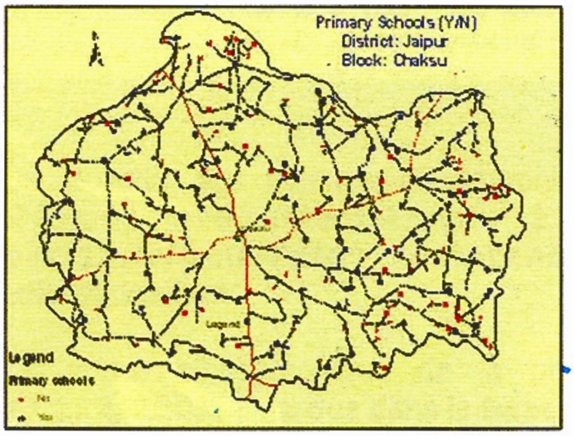


Fig. 3 Spatial Distribution of Primary schools.

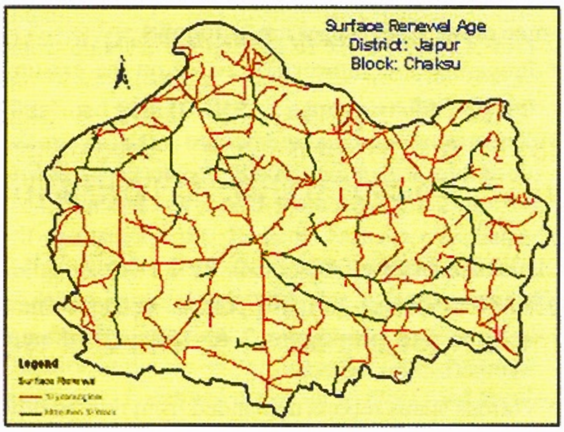


Fig. 4 Symbolizing surface renewal age.

8. Conclusion

The effective planning, monitoring and decision making of any developmental activity mainly depends on the reliable, updated and relevant information system. The GIS over came the drawback of time consuming and tedious traditional methods of planning. Incorporation of Geo-informatics into planning, implementation and monitoring process of PMGSY scheme is changing the whole concept of execution of rural road plan. An authentic database for Rural Road developed using GIS which immensely helped in the planning and monitoring process by maintaining the information in an effective and easily updatable manner. Database prepared this way will also allow the data sharing among different government department which will reduce the cost of duplication. Considering all these aspects and potential of Geo-informatics, this technology is being used for monitoring, management and implementation of PMGSY scheme in India. The performance of Rajasthan state in implementing PMGSY scheme has proved it. Future applications of GIS are beyond imagination and almost all development projects will use this technology.

References

A. M. Rao, Durai B.K., Jain P.K. & Sikdar P.K. (2004): Geographical Information System for Planning and Management of Rural Roads, March 2004, GIS Development, Noida.

B.Guo, Poling A.D. & Poppe M.J. (1995): GIS/GPS in Transportation, Real World Experiences.

PMGSY, Impact Assesment of Pradhan Mantri Gram Sadak Yojna, (2004): Government of India, Mistry of Rural Development, New Delhi.

Operation Manual (2005): Pradhan Mantri Gram Sadal Yojna, NRRDA, MoRD, New Delhi.

Sushant Baliga (2005): A Geographical Information System for PMGSY, Grameen Sampark, Vol.1 No.3, July-Sep 2005, NRRDA, New Delhi.

User Manual, Version 1.0 (2005): Online Management, Monitoring and Accounting System, PMGSY, C-DAC, Pune.

High Resolution DTM Process to generate accurate River Network for Efficient Water Resource Management

[1] G. Prasad Babu, [2] B. Srinivas, [3] Farhat Rafique, [4] Edida Rajesh
RMSI, India
[1] prasad.babu@rmsi.com, [2] b.srinivas@rmsi.com,
[3] farhat.rafique@rmsi.com, [4] edida.rajesh@rmsi.com

ملخّص : بلغ إستخلاص المميزة الهيدرولوجيّة الألية التي تستعمل نماذج أرضية رقمية **MNT** شعبية بتوّفر معطيات الكشف عن بعد ذات دقة التمييز العالية . ليست المميزات الهيدرولوجيّة لنماذج الأرضية الرقمية وحدها صحيحة لكنها تعجّل أيضاً سرعة معالجة نمذجة المشاريع كتسيير المورد المائي و خطر الفيضان . هناك عدّة تطبيقات هيدرولوجيّة تحتاج إلى المعلومة ذات مميزة هيدرولوجيّة جدّ صحيحة. هناك مشاكل خطيرة في النماذج الأرضية الرقمية ذات دقة التمييز العالية . إنها أشياء و منخفضات يتزايد عددها و أثارت قبلاً مشاكل مع دقة التمييز لنماذج الأرضية الرقمية المتطورة . ثانيا تستهلك النماذج الأرضية الرقمية ذات دقة التمييز العالية الكثير من الوقت والموارد ، خاصة عندما يتعلّق الأمر بالأشياء و المنخفضات. تعدّ الأشياء من بناء الإنسان في الجانب الآخر للأنهار وتبين تغلّبها في الأماكن الحضرية. تلعب المنخفضات الطبيعية كالمغارات ، و المنخفضات الشبه دائرية المسطحة دوراً أكبر ، خاصةً في تحويل المميزات الهيدرولوجيّة كشبكة النهر و الحوض الهيدروغرافي . يشكّل وجود الأشياء منخفضات شبه دائرية مسطحة ثانوية تؤدي إلى تعقيدات إضافية . تغيّر المشاكل المذكورة أعلاه المميزات الهيدرولوجيّة من مواقعها الجغرافية الحقيقية وتستهلك الكثير من الموارد والوقت لمعالجتها . بالتّالي تعطي نماذج الإنتاج نتائج غير صحيحة . يبيّن هذا المقال واقع الأشياء و المنخفضات و تأثيرها على شبكة النهر المشتقة . يصف أيضا التقنيات التي تحاول أن توّجه / تحل مثل هذه المشاكل ، بتركيز خاص على النماذج الأرضية الرقمية ذات دقة التمييز العالية .

Résumé: L'extraction de caractéristique hydrologique automatisée qui utilise le modèle numérique de terrain MNT atteint une popularité avec la disponibilité de données de télédétection à haute résolution. Les caractéristiques hydrologiques dérivés du MNT ne sont seulement pas exactes mais accélèrent aussi la vitesse du traitement de la modélisation des projets comme la gestion de la ressource de l'eau et le risque de l'inondation. Y compris la modélisation il y a plusieurs applications hydrologiques qui ont besoin d'information de caractéristique hydrologique très exacte. Il y a des problèmes sérieux qui existent dans le MNT à haute résolution. Elles sont des objets et des dépressions qui augmentent en nombre et exacerbent déjà des problèmes existants avec la résolution MNT croissante. Deuxièmement, le MNT à haute résolution consomme beaucoup de temps et de ressources, surtout quand on a affaire à des objets et des dépressions. et leur influence sur le réseau de rivière dérivé. Il décrit aussi les techniques qui essaient d'adresser / résoudre de tels problèmes, avec concentration spéciale sur le MNT à haute résolution.

Abstract : Automated hydrological feature extra-ction using DTM is gaining popularity with the availability of high resolution remote sensing data. The derived hydrological features from DTM are not only accurate but also accelerate the processing speed of modeling of projects like water resource management and flood risk modeling. Including modeling there are various hydrological application that needs very accurate hydrological feature information. There are serious problems that exist in the high resolution DTM. They are artifacts and depressions, which increase in number and exacerbate already existing problems with increasing DTM resolution. Secondly, high resolution DTM consumes lot of processing time and resources, especially while dealing with artifacts and depressions. Artifacts are man made constructions across the rivers and show their dominance in urban location. The natural depressions like pot-holes, sinks-holes play a major role, especially in the derivation of hydrological features like river network and watershed. The presences of artifacts are also create secondary sinks which again lead to further complications. The above mentioned problems are shift the hydrological features spatially from their actual geographical locations and it also consume lot of resources and time to process. Consequently, the output models give inaccurate results. This paper demonstrates occurrence of artifacts and depressions and their influence over derived river network. It also describes the techniques attempting to address/resolve such problems, with special focus on high resolution DTMs.

1. Introduction

The purpose of paper is to demonstrate the extraction of hydrological feature using high resolution Digital Terrain Model (DTM) and address the artifacts and sinks which are two key issues one must consider while deriving hydrological features.

In recent years high resolution DTM have been widely used in automated hydrological analysis. The sources of high resolution DTM are immense due to advan-cement of remote sensing techniques. The derived hydrological feature information is of great help in many hydrological models, some of them are in estimate flood extent and timing, surface water runoff calculations, predict stream discharges.

All hydrologic models ultimately rely on some form of overland flow simulation to define drainage courses and watershed structure. To create a completely connected and labelled drainage network and watershed divide, water outflow at each cell in the DTM has to be routed to the outlet at the edge of the DTM.

The degree of uncertainty in DTM increases with the increase in resolution. The uncertainties that influence the derivation of hydrological features include DTM errors, topographic parameters, the effect of DTM scale as imposed by grid cell resolution, DTM interpolation, and terrain surface modification used to generate hydrologically-viable DTM surfaces (S. Wechsler, 2006). Provided the preprocessing of DTM is perfect, artifacts and sinks are only key elements to treat. In general, the influence of artifacts and sinks is high on derived hydro-features.

The surface depressions (sinks) and spatially structured elevations (artifacts) in DTM are treated as nuisance features in hydrologic modeling. The common practice is to locate and remove these features in the DTM at the very first step of hydrologic analysis.

2. Artifacts and Sinks in DTM

Artifacts, i.e., spatially structured errors of a systematic nature, are often associated with the production of DEMs. The interpolation of DEMs from contour line maps, for example, can produce several kinds of artifacts (Carrara et al., 1997), an example of which is that of contour line "ghosts in USGS Level 2 DEMs (Guth, 1999). But in high resolution DTM spatially structured elevations not only generated from errors but also due to man made constructions like bridges, weirs, culverts, dams, roadways. Artifact removal or breaching lowers the elevation of DTM cells along a stream. This is analogous to creating a trench through the " dam" or obstacle in front of the depression. The result is a breached DTM whose cell elevation values are either the same or lower than the original DTM, never higher.

Sink filling and breaching represent two opposite approaches, and several techniques have been established to independently deal with sinks and artifacts. We have gone for holistic approach to treat both artifacts and sinks in high resolution DTM.

A sink is an area surrounded by higher elevation values, and is also referred to as a depression or pit. This is an area of internal drainage. Some of these may be natural, particularly in glacial or karst areas (Mark, 1988), although many sinks are imperfections in the DTM. These are more commonly natural features, and are less detrimental to the calculation of flow direction. The frequent presence of surface depressions in the DTM prevents simulated water flow from draining into outlets, result in disconnected stream-flow patterns and spurious interior sub-watersheds pouring into these depressions.

The number of sinks, normally higher for coarser resolution DTM as compare to lower resolution DTM. Another common cause of sinks results from storing the elevation data as an integer. This can be particularly troublesome in areas of low relief and urban centres.

3. Methodology

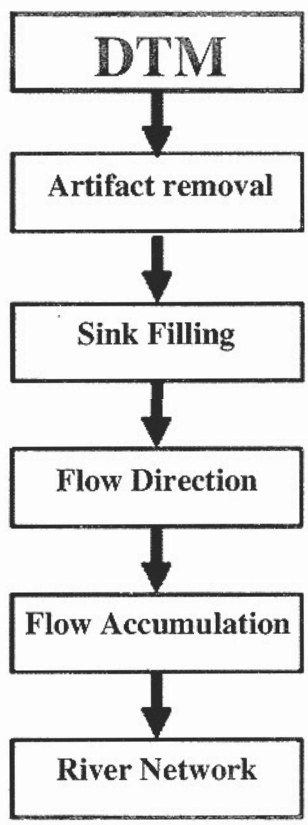


Fig. 1 Methodology followed in current study.

Determining flow direction in low resolution DTM is quite simple if there are less pre-processing errors but while handling high resolution DTM one should exercise more caution.

At RMSI, Spatial Modeling Department, use various resolutions of DTM data. In the present study high resolution DTM of 10 meter was used. We found there were numerous artifacts and sinks which obstruct the water flow. The present methodology explains comprehensively to deal artifacts and sinks in an effective manner without appreciatively altering the original elevation values of DTM. The Hydrology analysis functions in ArcGIS 9X not address the problem of artifact removal. A tool to remove artifacts in systematic manner was thus developed. The Figure-1 depicts the working methodology of present study. All terminologies are subsequently explained.

3.1 Artifact removal

Artifacts are elevation peaks obstruct the water flow in DTM. Removals of such peaks are cumbersome especially if many urban centers in study area. A graphic polygon is drawn over identified artifact (Figure) taking care to place the vertices of the polygon on pixels of lower elevation values. Verification is done through Google Earth and other high resolution remote sensing images.

Artifacts have shown in DTM with high elevation comparatively values of upstream and low stream (Fig.2a). In order to remove obstacle (higher elevation pixel values) draw the graphics around the artifact by carefully placing the all the nodes in lower elevations. This means nodes should be placed in both upstream and lower stream of river valley. We develop a tool to pick up the elevations underlying each node and interpolate all elevation values within graphical element using inverse distance weighted interpolation technique.

3.2 Sink fill

Fill function works to derive depression less DTM. Depression filling has become by far the most widely used approach and several different algorithms have been developed to fill depressions. (Marks, D., Dozier, J. and Frew, J., 1984; O'Callaghan and Mark, 1984; Jenson and Domingue, 1988; Martz and Jong 1988; Planchon an Darboux, 2001; L. Wang and H.Liu 2006). Amongst Jenson and Domingue, 1988, method is best known and widely used in many GIS software packages for sink filling.

The best know method (Jenson and Domingue, 1988) is time intensive method as compared to all latest methods but most of the GIS packages equipped with this technique. For example, the widely used package ArcGIS have utilized of this method. It takes humongous time to fill the sinks, especially in case of high resolution DTM. L. Wang and H. Liu 2006 has been innovated a new method, which is in handling surface depressions as compare to all above methods. It's based on two concepts, termed as cornerstones of the method. They are 1) introduction of a novel concept of spill elevation, and 2) the progressive building of optimal spill paths based on priority queue and least-cost search techniques. The need to introduce fast and accurate sink filling methods in current GIS packages is of utmost importance.

3.3 Flow direction

One of the keys to deriving hydrologic characteristics about a surface is the ability to determine the direction of flow from every cell in the raster. This is done with the Flow Direction function. This function takes a conditioned or depression less DTM as input and outputs a raster showing the direction of flow out of each cell. There are eight valid output directions, relating to the eight adjacent cells into which flow could travel. This approach is commonly referred to as a D8 (eight direction) flow model and follows the approach presented by Jensen and Domingue, 1988. The direction of flow is determined by finding the direction of steepest descent, or maximum drop, from each cell.

3.4 Flow accumulation

The Flow Accumulation function calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster. If no weight raster is provided, a weight of one is applied to each cell, and the value of cells in the output raster will be the number of cells that flow into each cell.

Cells with a high flow accumulation are areas of concentrated flow and may be used to identify stream channels. Cells with a flow accumulation of zero are local topographic highs and may be used to identify ridges.

3.5 River network delineation

Flow accumulation in its simplest form is the number of upslope cells that flow into each cell. By applying a threshold value to the results of Flow Accumulation using Map Algebra, a stream network can be delineated.

4. Results

4.1 River network delineation from DTM : Before Artifact Removal

The study window has been clipped from 10 meter DTM. The total area of window is 3.2424 Sq.Km and comprise of 32424 pixels (10m x 10m). We analyze the number of sinks formed, impact of artifacts and behavior of derived river network at three stages. 1. shows the sinks formed at at the very onset prior to any DTM reconditioning 2) shows sinks formed due to D8 method, terrain properties and mainly presence of artifacts. And derivation of river network, 3) shows the advantages of filling sinks after removal of artifacts, and derived river network.

In the first step, the "Sink" (ArcGIS/Spatial Analyst/Hydrology/Sink) tool is run to find out the number of sinks in the study window. A total of 424 pixels as sinks, which constitutes 1.3076% of total area. The sink function of ArcGIS calculates the number of sinks based on D8 method. In the second step, the original DTM is sink filled is calculated. This area is next matched with initial sinks and a remarkable difference is observed. Because sink is not a single cell rather it is combination cells. So, the filling is worked out in an iterative manner. The function calculates the single lower elevation pixel in 3 x 3 window and then extended to whole DTM. Then next phase it again search for the single lower elevate pixel in 3 x 3 window and process continues till DTM satisfy hydrological conditions. It means, filling takes longer time and alters original elevation cells. This is the case of natural terrain and deepest valley do not consist any obstacles.

ut in case of high resolution DTM secondary sinks form due to obstacles (artifacts) across the water flow as shown in the figure (Fig.2b). This is like artificial reservoir between two obstacles. The increase of sink filled area in the figure (Fig.2c) is clearly evident due to artifacts. The sink filled area before artifact removal is more than 27% of study area. Large percent of filling mainly observed in between two marked artifacts (Fig.2b). It is very clear, derived river network falls other than falling in to the deepest valley of DTM (Fig.2d). The deepest valley of the DTM is actual position of river network.

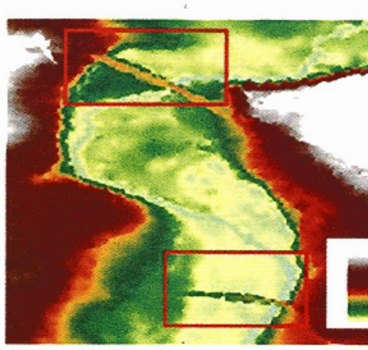


Fig. 2a. Marking shows the artifact with are across deepest valley of DTM

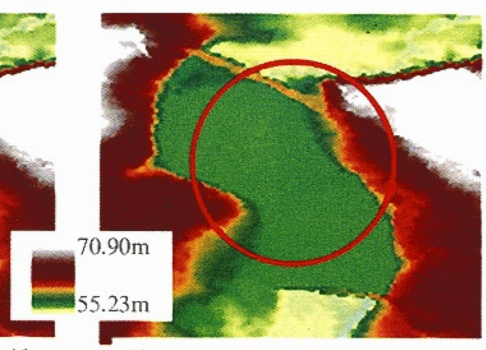


Fig. 2b. Marking shows large area filled between 2 artificats before artifact removal

Fig. 2c. Area under fill before removal of artifacts

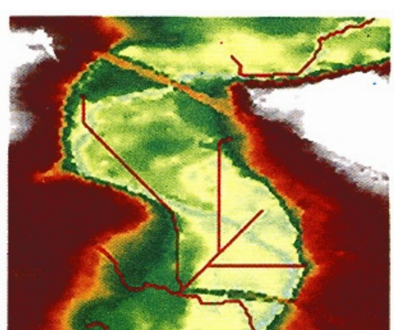


Fig. 2d. Delineated Rivers shows the shift from deepest valley in DTM

Fig. 2 Show the presence of artifacts forms sinks and shifts are river network.

4.2 River network delineation from DTM: After Artifact Removal

The third step in the procedure is artifact removal. The purpose is to provide a passage for unobstructed flow of water (Fig.3a). This method did not alter the major area DTM. This not only allows water to flow but also effectively reduce the area under sink filling and iterative processes. This is clearly demonstrated in figure (Fig.3b and 3c). The total calculate area under sink filling is found to be around 11% of the total area. Nearly 16 % of fill area is reduced due to artifact removal (Fig.4a). The derived river network after artifact removal match very well with the deepest valley of the DTM (Fig.3d).

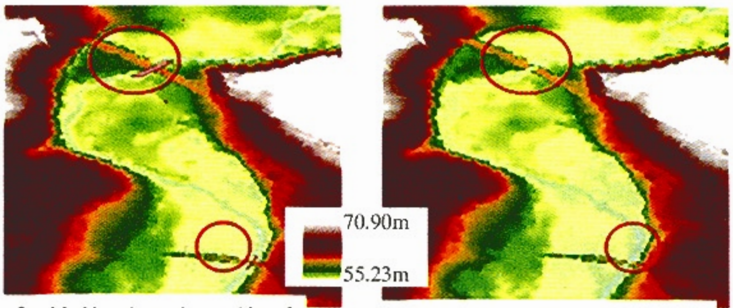


Fig. 3a. Marking shows the graphics of proposed places to remove the artifacts

Fig. 3b. Encircled portion - passage of water flow after artifact removal

Fig. 3c. Sink Fill area after removal of artifacts

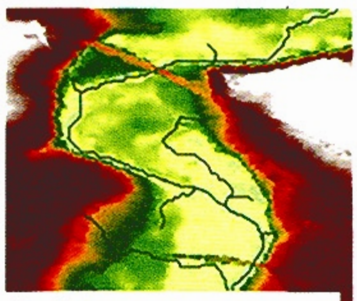


Fig. 3d. Delineated river network fits in to the deepest valley of DTM

Fig. 3 Show the how delineated river network fits in to the deepest valley of DTM and the same is actual path on the ground.

Results depend on many factors such as, DTM resolution, terrain characteristics. Natural sinks have greater occurrence in glacial terrain, krast, topography and low relief areas. But secondary forms more in urban morphologies. The figure (Fig.4b) shows clearly the difference in derived river network before and after artifact removals. The table (Table2 and Graph1) indicates clearly effects of artifacts on high resolution DTMs. The present study shows the advantages artifact removal and river network derivation. The current authors recommend usage of more popular GIS packages which incorporate accurate and fast methods of artifact removal as well as sink filling.

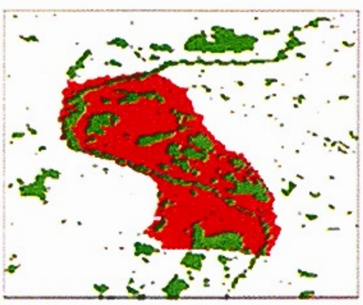


Fig. 4a. Shows the difference of area under fill before and after

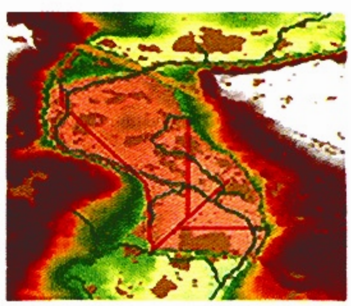


Fig. 4b. Difference of delineated river network before and after

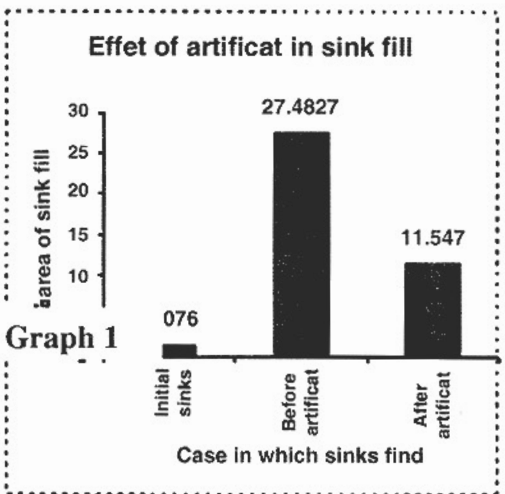
Fig. 4 Show the difference in filling and river networks- before and after removal of artifacts.

Graph1 shows the area under sink fill for three different cases.

Case 1: where there are initial sinks formed about 1. 3% of total area under D 8 method.

Case 2: shows area under sink fill just before artifact removal. This is very, covers more than 27% of total area.

Case 3: Sink area falls down drastically from 27 to 11 % after removing artifacts.



Graph 1

5. Conclusions

Accurate river network derivation is crucial for water resource management and for any hydrological or flood modeling. The nature of high resolution DTM is complex and need to condition. The artifacts are not only structural errors (aberrations) in DTMs but at the same time reflections of man made structures across water courses. Artifacts in DTM increase the sinks and consequently shift the river network from its actual position. Therefore, the need of artifact removal and sink filling is utmost important while deriving river network. There is no need to remove entire portion of artifact rather an outlet is drilled to allow easy passage of water. The sinks formed due to artifacts are called secondary sinks and their impact river network derivation. The exercise of artifact removal and sink fill not only provides accurate river network but saves both resource and time. Unfortunately till date, none of the available GIS packages have incorporated a fast and accurate sink fill method.

Acknowledgements

Foremost, the current author expresses his sincere thanks to everyone in Flood Team for their support and valuable suggestions. And special thanks is due to Ms. Soma Muhuri for proof reading and inserting corrections wherever appropriate. Lastly, the author expresses gratitude to RMSI for providing requisite opportunity and resources.

Reference

Jenson S. K. and J. O. Domingue. 1988. Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis, Photogrammetric Engineering and Remote Sensing. Vol. 54, No. 11, November 1988, pp. 1593-1600.

Mark, D.M., 1983, Automatic detection of drainage networks from digital elevation models. Cartographica, 21, pp. 168–178.

Marks, D., Dozier, J. and FREW, J., 1984, Automated basin delineation from digital elevation data. Geo-Processing, 2, pp. 299–311.

O'callaghan, J.F. and MARK, D.M., 1984, The extraction of drainage networks from digital elevation data. Computer Vision, Graphics and Image Processing, 28, pp. 323–344.

Planchon, O. and DARBOUX, F., 2001, A fast, simple and versatile algorithm to fill the depressions of digital elevation models. Catena, 46, pp. 159–176.

Tarboton, D., 1997, A new method for the determination of flow directions and contributing areas in grid digital elevation models. Water Resources Research, 33, pp. 309–319.

Tarboton, D., Bras, R. and RODRIGUEZ-ITURBE, I., 1991, On the extraction of channel networks from digital elevation data. Hydrological Processes, 5, pp. 81–100.

Wang.L and H.Liu. 2006., An efficient method for identifying and filling surface depressions in digital elevation models for hydrologic analysis and modeling, International Journal of Geographical Information Science. Vol.20, No.2, February 2006, 193-213.

Wechsler.S. 2006. Uncertainties associated with digital elevation models for hydrologic applications: a review, Hydrol. Earth Syst. Sci. Discuss., 3, 2343-2384.

TerraSAR-X and TanDEM-X: Revolution in Spaceborne Radar

Frank Hensler & Marco Weber
Infoterra GmbH, Claude-Dornier-Strasse, 88090 Immenstaad, Germany
frank.hensler@infoterra-global.com
www.infoterra.de

ملخّص : مازالت وستبقى الصوّر الجاهزة تجارياً ضرورية للمنظمات المدنية و العسكرية التي تجمع عدة أنواع من المعلومة الجغرافية الفضائية . يعدّ الوصول إلى معطيات الكشف عن بعد ذات دقة التمييز العالية قاعدة أساسية للإتخاذ القرار، خاصّة في الأوقات الحرجة. إذا تمّت مراعاة الإتفاقيات الدوّلية، إنشاء وحدات عسكرية للحفاظ على السلام الدوّلي أو المهام البشرية ، أو القيام بتمارين تقنية مشتركة مع دوّل أخرى .
في الوقت الحاضر، تحتاج عادة المنظمات إلى اللجوء إلى المعطيات ذات دقة التمييز العالية المكتسبة بالكاشف البصري – غالبا في عملية طويلة. يمهّد القمر الإصطناعي الراداريTerraSAR-X ، في مرحلة لاحقة مع TanDEM-X بسعته للإقتناء المعطيات المتممة تقريبا صحيحة للإستعمال التام لمجموعة المعطيات في المدار للإحتياجات الخرائطية في الأوقات الحرجة.

Résumé : Les images disponibles commercialement sont et resteront indispensable pour les organisations civiles et militaires qui collectent plusieurs types d'information géo spatiale. L'accès fiable aux données de télédétection à haute résolution est une base essentielle pour une prise de décision bien informée, en particulier dans les situations à temps critique. Si on respecte les accords internationaux, fournir des contingents militaires pour le maintien de la paix internationale ou missions humanitaires, ou mener des exercices techniques joignent avec les autres pays.
Aujourd'hui, les organisations ont besoin de recourir habituellement aux données à haute résolution acquises par les détecteurs optiques – souvent une longue opération. Le satellite radar TerraSAR-X, et dans une étape ultérieure avec TanDEM-X avec ces capacités d'acquisition des données complémentaires à temps presque réel, offre une nouvelle approche entière à l'usage d'ensemble de données en orbite pour les besoins de cartographie dans les situations à temps critique.

Abstract : Commercially available imagery is and will remain indispensable to civilian and military organizations gathering various types of geo-spatial information. Whether fulfilling international agreements, providing military contingents in international peacekeeping or humanitarian missions, or conducting joint technical exercises with other countries – a reliable access to timely, high resolution remote sensing data is an essential basis for well-informed decision making, particularly in time-critical situations.
Today, organizations with those needs customarily resort to high resolution data acquired by optical sensors – often a lengthy operation. The radar satellite TerraSAR-X, and at a later stage together with TanDEM-X with it's complementary near-real time data acquisition capabilities, offer a whole new approach to the use of space-borne datasets for mapping purposes in time-critical situations.

1. Introduction

Due after the commissioning phase since January 2008, EADS Astrium's new radar satellite TerraSAR-X provides Earth observation data of unprecedented quality, with a resolution of up to one metre, for increasingly diversified commercial as well as for scientific applications. Its scheduled lifetime will be 5 years. However, the whole SAR programme will last more than 10 years.

Commercial users require detailed data adapted to their individual requirements, available quickly and reliably, independent of daylight and weather conditions. The design and performance of TerraSAR-X will exactly meet these requirements. The Synthetic Aperture Radar (SAR) instruments of the spacecraft supply extremely detailed radar images, day and night, under all weather conditions. The acquired data is the basis for a wide variety of products and services, such as highly sophisticated client-specific image interpretation, topographic maps up to a scale of 1:10,000, geo-spatial databases and terrain analysis much in demand for a wide scope of applications. Other application sectors include environmental planning, land cover and natural resource exploration, regional and urban development, catastrophe response and relief, insurance and risk assessment as well as applications in border control, security and defence.

New-quality data records, as provided by TerraSAR-X, will also offer a vast number of new research incentives, for instance in forestry, ecology,

Images originales : http://www.infoterra.de/image-gallery/images.html geology, hydrology and oceanography. The smallest movements of the Earth's surface due to plate tectonics, volcanism, earthquakes, and land slides are further challenging fields of application of TerraSAR-X interferometry.

The space mission TerraSAR-X is the first German space project implemented under a Public Private Partnership (PPP). Cooperation partners are the German Aerospace Centre (DLR) and EADS Astrium. Under this construct DLR will be responsible for the scientific use of the TerraSAR-X data, whereas commercial marketing will be undertaken exclusively by Infoterra GmbH, a wholly-owned EADS Astrium subsidiary specialising in the collection, processing, and distribution of air- and spaceborne imagery and value-added products.

2. Demand for High resolution data

Commercially available imagery is and will remain indispensable to organizations gathering intelligence information. Whether fulfilling international agreements, providing contingents in international peacekeeping or humanitarian missions, or conducting joint exercises with other countries – a reliable access to timely, high resolution remote sensing data is an essential basis for well-informed decision making, particularly in time-critical situations.

Today, organizations with those needs customarily resort to high resolution data acquired by optical sensors with which huge area coverage can only be accomplished with large temporal offsets. TerraSAR-X, with it's complementary near-real time data acquisition capabilities, offers a whole new approach to the use of space-borne datasets in time-critical situations.

The spacecraft TerraSAR-X delivers unique, novel quality SAR satellite image data with a resolution of up to one metre, which can significantly augment the capabilities of armed forces, homeland security, and intelligence agencies, creating both tactical and strategic advantages. Reduced image speckle through multilooking and the presence of radar shadows of man made objects are important features of the high resolution TerraSAR-X images which will by far enhance the image interpretability over that of medium resolution SAR systems.

Besides of updated high resolution imagery of the Earth's surface, the availability of precise information on terrain evaluation is strongly requested by users of geo-spatial data. Currently most areas in the world are covered by an elevation grid of poor quality in terms of point density and height accuracy (ERS-1/2 Tandem, SIR-C/X-SAR, SRTM, GTOPO30). In order to close this gap of information towards the third dimension TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurements) is a German program for a new generation SAR satellite operating at X-band in single pass SAR interferometry. The single pass SAR interferometric constellation, comparable to stereoscopic survey missions, is realized by two independent X-band satellites, TerraSAR-X together with TanDEM-X, flying in a close formation, quite often less than 1 km. The mission goal is to deliver a global digital elevation model characterized by a height accuracy of better than 2 m. The additional spacecraft TanDEM-X is already financed through a PPP agreement between DLR and EADS Astrium and will be launched in 2009.

The increasing demand of sophisticated geospatial data sets requires appropriate and precise planning documents in all the three dimensions. However, a continuous and up-to-date acquisition by optical sensors or airborne platforms is strongly limited either by unfavourable weather conditions or inefficient mission scenarios. Therefore, the easy access to the high-resolution radar missions TerraSAR-X and TanDEM-X gives the global remote sensing community the possibility to participate in one of the most ambitious space programs.

The System TerraSAR-X will deliver high resolution SAR images with a ground sampling distance up to 1m, in combination with unique satellite agility: The electronically steered antenna allows acquiring physically separated areas of interest within seconds without rolling the whole satellite. The satellite is mainly described by:

- TerraSAR-X is operated at X-band at 9.65 GHz. Even pure visual interpretation will profit from the fact that the short wavelength shows more spatial detail than longer wavelengths.
- The chirp bandwidth, an indicator of the spatial accuracy level, is with 300 MHz the best performance currently in space.
- Single, dual and quadruple polarizations allow for a more complex description of the areas and objects on the ground. Their availability depends on the imaging mode and always is a trade-off with the spatial coverage and swath width.
- Radiometrically calibrated data allow for an easy comparison between scenes.
- TerraSAR-X is both, daylight and weather independent, i.e. the system can record data at night and through clouds or dense smoke cover.
- The system features a quick site access time of 2.5 days to any point on Earth at 95% probability.

- TerraSAR-X features a unique agility: it is possible to switch between its three different imaging modes and various polarisations within only 1 to 3 seconds, corresponding to surface acquisition offsets of only 7 to 20 kilometres.
- Time-critical data can be downloaded within seconds after acquisition to mobile ground stations on-scene, thus enabling near-real time data processing.
- Anonymous and encrypted processes guarantee an unobjectionable confidentiality.
- Furthermore, the satellite's very high resolution of up to 1 m and its high radiometric accuracy, make TerraSAR-X an ideal sensor to support sensitive decision-making in time-critical situations.
- Satellite Tasking twice a day and priority settings for the ordered data takes allow for quick turnaround times in data delivery and late order changes.

TanDEM-X will be an almost identically constructed system with some slight modifications for the necessary synchronization link between both satellites.

3. Image Modes and Products

In the standard operating mode (so-called single receive antenna) image data in three different imaging modes can be acquired: SpotLight, StripMap and ScanSAR:

- **SpotLight** with up to 1 m resolution (10 km (width) x 5 km (length) image size) – the most sophisticated radar imagery available on the market: In flight direction, the radar beam can be steered like a veritable spotlight, illuminating a particular ground scene for the longest time period possible, thus achieving a 1 metre class resolution as well.
- **StripMap** with up to 3 m resolution (30 km x 50 km standard scene size, extendable up to < 4,000 km acquisition length) – the ground swath is illuminated with continuous sequence of pulses while the antenna beam is fixed in elevation and azimuth. This results in an image strip with a continuous image quality (in flight direction). Besides dual polarization StripMap images will even be available as quadruple polarisation data, which allows for a more complete statistical description of the observed scene.
- **ScanSAR** with up to 16 m resolution (100 km x 150 km standard scene size, extendable up to < 4,000 km acquisition length) – Areas up to 400,000 km² anywhere on the globe can be covered in this image mode within only one orbit.

  In the ScanSAR mode, a swath width of 100 km (and even more) will be achieved by scanning four adjacent ground sub-swaths with quasi-simultaneous beams, each with different incidence angle.

The Basic Image Products generated from these three imaging modes are:

- Single Look Slant Range Complex (SSC) with amplitude and phase information in slant range geometry.
- Multilook Ground Range Detected (MGD) corrected to WGS84 with an average terrain height for slant range to ground range projection.
- Geocoded Ellipsoid Corrected (GEC) corrected to WGS84 with an average terrain height.
- Enhanced Ellipsoid Corrected (EEC) corrected to WGS84 with a digital elevation model (DEM).

These products are available as CEOS Level 1b data sets, can be absolutely radiometrically calibrated using the accompanied information and can be delivered as either a radiometrically or a spatially enhanced product. The spatial extent corresponds to the area accessible by the TerraSAR-X standard scene.

In addition to these basic products, a set of value-added products is available, which are spatially oriented at the users region of interest which can be larger than a satellite scene.

The Orthorectified Image (ORISAR) is a geocoded image with highly precise terrain correction included. All those terrain distortions inherent in satellite imagery, particularly in areas with rough terrain have been removed. The orthorectification process uses high precision digital elevation models, so that the pixel location accuracy in comparison to EEC product is increased.

The orthorectified image is also available as an image mosaic (MCSAR) or a customer defined area of interest, i.e. a subsetted image product which covers a predefined geographical area.

Fig. 1 OM^{SAR} OrthoMap Customized map sheet layout.

Radiometric correction and normalization methods improve the orthoimage even more: The RANSAR product provides calibrated backscattering values which are necessary for quantitative analysis methods on the orthorectified images.

Ascending/Descending Merge (ADMSAR) Typical charac-teristics of SAR images are the radar shadows which are usually visible and may not be a helpful attribute because they obscure parts of the area under investigation. If the combination of SAR images from ascending and descending right looking orbits is used for image analysis, a reduction of the impact of layover, and radar shadow effects can be achieved. The ADMSAR product includes this orbit merge. Mosaics (MCSAR) or Oriented Images (OISAR) are optionally available as ADMSAR. The ADMSAR is of particular interest for area with steep mountainous terrain, where shadow and layover can disturb the analysis.

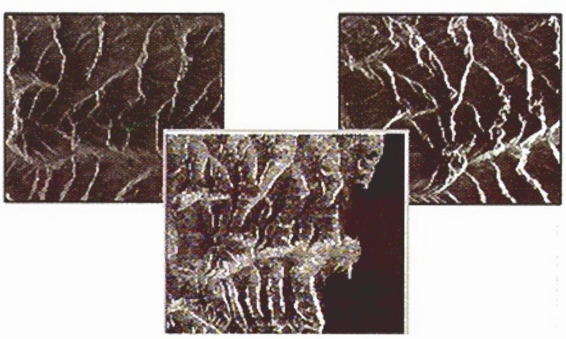


Fig. 2 ADM^{SAR} Ascending/Descending Merge sample product (middle) through combination of ascending (left) and descending orbits (right).

4. The Subsidence Map (SUB^{SAR})

provides information on long-term surface displace-ment in urban areas and settlements. Such vertical surface dis-place-ment may be caused e.g. by tec-tonics, subsurface mining, earthquakes. The resulting maps can be used for risk diagnostics. The displacement is calculated from image pairs using Differential Interferometric SAR (DInSAR) or Persistent Scatterer Interferometric SAR (PSInSAR). These are images of the same area observed under a slightly different squint angle. TerraSAR-X can acquire these image pairs with repeat pass interferometry with a temporal off-set of 2.5 to 11 days depending on the geographical location of the area of interest. The longest time interval will be reached at the equator, the shortest the closer the location is to the poles. The detectible difference in height is related to the wavelength and thus in case of TerraSAR-X is a fraction of approx. 3cm.

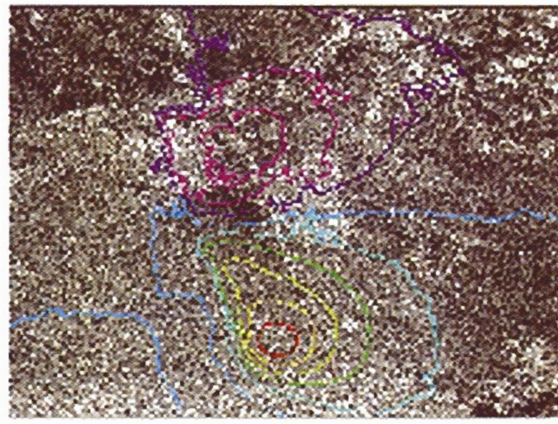


Fig. 3 CDM^{SAR} Change Detection Map - Earthquake.

5. Change Detection Map (CDM^{SAR})

can provide information on long-term Land use/Land cover changes e.g. in surface sealing and urban sprawl. Such information can be used e.g. for urban/construction monitoring, urban planning appli-cations or topographic map up-dates. It is generated from repeat pass inter-ferometric image pairs over an area of interest in which image coherence changes are detected. Changes are mapped of a period of time long enough to be significant for the phenomenon to be mapped, i.e. the period depends on the mapping topic of interest and is defined by the customer. The product is generated from StripMap or SpotLight images.

Fig. 4 CDM^{SAR} Change Detection Map - Airfield.construction

6. Time-Critical Applications

Image interpreters may get into analyzing capacity problems e.g. in case of crises. Infoterra GmbH offers additional products and services that can be adjusted according to customers needs in order to support image interpreters during peak work loads. For example, the customer can define the depth and quality of the image interpretation of the ordered product.

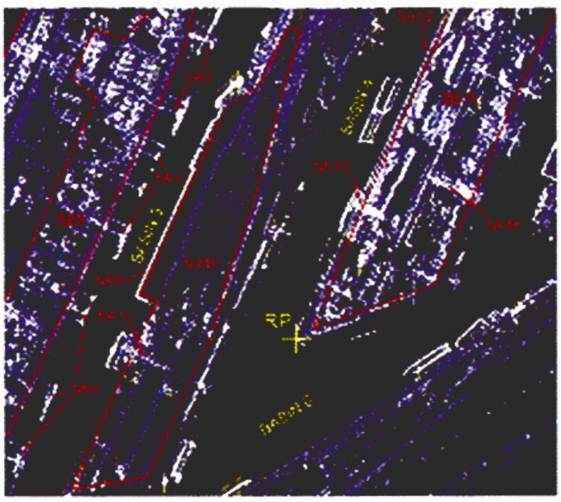


Fig. 5 Annotated dual polarisation SAR image. Harbour of Duisburg, Germany.

- Clearly defined objects or infrastructure characteristics are highlighted and (pre-) interpreted.
- Interpretation keys could follow the NATO Standardization Agreement (STANAG) or others.
- Legends and map styles are adjusted to customers needs.

Thus, decision makers are relived from certain steps in the image analysis process and will gain support for their strategic decisions.

Other options for fast object extractions to create GIS layers are: Line elements (e.g. roads, power transmission lines, railways) through line detection and context evaluation or single man-made objects (e.g. bridges, storage tanks, lattice masts) through fast screening methods.

7. Digital Elevation Height

The TanDEM-X mission aims at generating a global Digital Elevation Model (DEM) with an extremely high accuracy corresponding to HRTI-3 specifications defined by the U.S. National Geospatial-Intelligence Agency (NGA). This goal will be achieved by means of a second SAR satellite TanDEM-X flying in a combined orbit with TerraSAR-X. Thus SAR image and DEM data will synchronously be available for the same site.

Commercial exploitation of TanDEM-X will benefit mainly from the global high quality DEM product, the associated update services, and the generation of topographic base data (image and contour line maps). Further applications with commercial potential will be implemented, based on the applications research results (e.g. moving target detection, super resolution, differential InSAR based monitoring).

The DEM quality domain that the TanDEM-X mission can provide is today dominated by offers based on airborne campaigns. There is currently no system or process available to provide a global service for HRTI-3 (z-accuracy better than 2 m) and in specific cases HRTI-4 (z-accuracy better than 1 m) DEMs with short response time. Those requirements of the important geospatial markets can only be fulfilled by globally operating a space-borne SAR system. Optical systems require cloud free weather conditions and therefore often fail to fulfil the global response time demand. Airborne systems lack in global mapping capability.

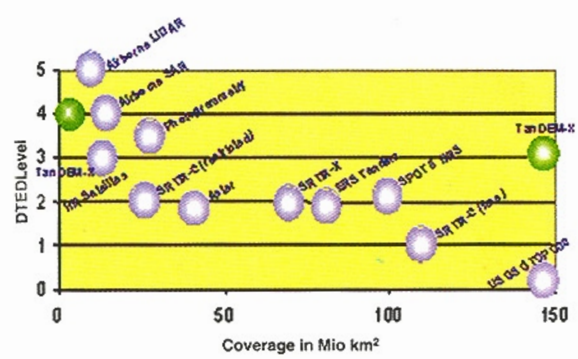


Fig. 3 Overview of available sensors and their digital elevation standard.

8. Geo-Information Service

8.1 Conpany profile

Launched in January 2001, Infoterra GmbH is a 100% owned subsidiary of EADS Astrium, Europe's leading space company. Infoterra was founded to prepare and conduct the commercial exploitation of TerraSAR-X and TanDEM-X data services as well as system capacities.

Infoterra was formed by spinning-off the 'Earth Observation Services' division of the former EADS Astrium GmbH, Germany, re-branding of the UK-based National Remote Sensing Centre Ltd., and the French ISTAR S.A. Infoterra has a 200-strong team of highly skilled staff, including experts in cartography, photogrammetry, forestry, agriculture, geological exploration, environmental management, and telecommunications planning. In addition, Infoterra's staff is skilled in the development of systems software specific to the manage-ment of geographic data. Such a strong market-oriented positioning facilitates a prompt and flexible response to all enquiries within the geo-information community.

Infoterra is serving and supporting both public and private customers with geo-information on cartography, land use/ land cover, and forestry as well as with a focus on TerraSAR-X, GMES (Global Monitoring for Environment and Security), and thematic mapping services. Infoterra is ISO9001: 2000 and ISO 14001 certified and guarantees that all activities are performed according to internationally accepted quality and environmental standards.

8.2 Service Implementation

The TerraSAR-X as well as the TanDEM-X implementation will be carried out in a PPP frame (Public Private Partnership) between EADS Astrium GmbH and DLR. The observation capacity of TanDEM-X will be 50% for InSAR operations and 50% for compensating the TerraSAR-X capacity contributions to the InSAR mission. Through this capacity swap the nominal TerraSAR-X line can be maintained at committed service capacities. Infoterra GmbH will exploit the commercial mission part and sell the products and services globally, capitalizing on the customer base and sales network established for the TerraSAR-X based portfolio.

9. Summary

TerraSAR-X and TanDEM-X data and services will be a major component in many applications related the geospatial information. In the basic application TerraSAR-X will contribute to topographic mapping, time-critical reconnaissance, and land cover surveys which provide the core elements for any presentation or analysis of geographic information. In addition TanDEM-X will provide the third dimension in a new quality.

Depending on the information depth of the requested information categories, the derivation from SAR data might be very complex in specific cases. Based on the profound experience of the Germany-based Infoterra and its distribution and production partners TerraSAR-X / TanDEM-X data and services will be delivered globally and with the highest standard of accuracy, quality, reliability; and sustainability.

Started arly 2008, TerraSAR-X supports the use of other Earth observation data through its multi-scale, multi-temporal and multi-frequency/polarization observations of remote areas that were formerly almost impossible to map. TanDEM-X will follow in 2009.

Reference

Figure 1 - 3 : courtesy of Joanneum, Research, Austria.


الجمهورية الجزائرية الديمقراطية الشعبية
وزارة الدفاع الوطني
أركان الجيش الوطني الشعبي
مصلحة الجغرافيا و الكشف عن بعد
للجيش الوطني الشعبي
REPUBLIQUE ALGERIENNE
DEMOCRATIQUE ET POPULAIRE
MINISTERE DE LA DEFENSE NATIONALE
ETAT-MAJOR DE L'ARMEE NATIONALE POPULAIRE
SERVICE GEOGRAPHIQUE ET DE TELEDETECTION
DE L'ARMEE NATIONALE POPULAIRE
PEOPLE'S DEMOCRATIC
REPUBLIC OF ALGERIA
MINISTRY OF NATIONAL DEFENCE
STAFF OF THE PEOPLE'S NATIONAL ARMY
GEOGRAPHICAL AND REMOTE SENSING SERVICE
OF THE PEOPLE'S NATIONAL ARMY
ملتقى حول توحيد أنظمة الجيوديزيا
لبلدان مبادرة "5+5 دفاع"
Seminar on the unification
of geodetic systems
of "5+5 Defence" initiative countries
Séminaire sur l'unification
des systèmes géodésiques
des pays de l'initiative "5+5 Défense"
5 + 5
DEFENSE
Alger, 23-24 juin 2009
Algiers, June 23-24 2009

Séminaire sur l'Unification des Systèmes Géodésiques des Pays de l'Initiative "5+5 Défense"

Equipe en charge de l'élaboration du projet d'Unification des Systèmes Géodésiques des Pays de l'Initiative "5+5 Défense"

Un système unifié des systèmes géodésiques reliant les pays de la rive nord avec ceux de la rive sud de la Méditerranée était en débat à l'occasion du séminaire des pays membres de l'initiative "5+5 Défense" organisé par l'Algérie du 23 au 24 juin 2009.

Le nouveau référentiel géodésique uniforme - initiative "5+5 Défense" permettra non seulement d'asseoir la cartographie des pays concernés par cette initiative mais aussi la planification et la gestion d'applications de défense, la compréhension des phénomènes liés aux sciences de la Terre et autres domaines porteurs de progrès social.

En effet, la mise en place de ce référentiel géodésique aura plusieurs retombées notamment dans les domaines liés à l'édition de cartes adaptées aux besoins (cartes marines, topographiques, etc.), l'exécution de projets frontaliers (tracés des frontières, etc.), le déminage des terrains, les opérations de maintien de la paix, les opérations de secours et de sauvetage, la planification en cas de catastrophes naturelles et les mesures de réhabilitation, la gestion de la sécurité et des ressources environnementales, la santé et l'hygiène, etc.

En plus des avantages pour la géodésie, Le référentiel géodésique unifié fournira aux utilisateurs des pays de l'initiative "5+5 Défense" des données géodésiques de référence fondamentales et fiables pour la gestion des ressources naturelles et les projets de développement. Le transfert vers l'Afrique des compétences nécessaires pour mettre en œuvre un projet de cette nature et pour créer un large réservoir de géodésiens, de géomètres, de spécialistes des NTIC et des domaines qui y sont liés, est d'une importance vitale pour la réussite de projets similaires au niveau local, national, régional ou continental.

Le projet de mise en place d'un référentiel géodésique unifié pour la région "5+5 Défense" pourra être réalisé selon la démarche suivante :

- la création d'un ensemble de stations GPS de référence de très grande précision (GPS permanent et/ou semi permanent) dans toute la région,
- la densification du réseau de stations GPS de référence par des campagnes de mesures GPS traditionnelles,
- l'élaboration d'un modèle régional affiné de géoïde gravimétrique pour la région,
- l'élaboration d'un système commun de référence verticale.

En l'absence des deux derniers éléments, les avantages des systèmes de positionnement GNSS en tant qu'outil de positionnement en cartographie, planification, ingénierie et autres applications à caractère régional, sous-régional et transfrontalier seront considérablement limités.

En plus des modalités pratiques pour la mise en œuvre de l'unification des systèmes géodésiques, le séminaire a recommandé de profiter de l'expérience acquise dans le domaine de l'unification des systèmes pour sa généralisation à l'ensemble des pays de l'initiative.

Aussi et en vue des objectifs visés par la mise en place du référentiel unifié pour notre région, les participants ont également proposé d'encourager des formations sur les techniques de géodésie spatiale et physique pour permettre à l'ensemble des pays de l'initiative "5+5 Défense" de bénéficier du développement technologique et des expertises dans ce domaine.

Pour soumettre un article...

Vous souhaitez proposer un article pour le Bulletin des Sciences Géographiques.

Pour faciliter votre démarche, nous vous adressons quelques recommandations :

- Ce Bulletin est un espace scientifique, consacré aux sciences géographiques.

- **NATURE DES ARTICLES :** Les articles adressés pour publication doivent traiter des sujets se rapportant aux Sciences Géographiques.
  Les articles se repartissent en deux rubriques:
  - Recherche - développement
  - Synthèse.

  LES ARTICLES DE RECHERCHE - DÉVELOPPEMENT : portent soit sur des travaux ayant une originalité et une contribution novatrice aidant au développement des sciences géographiques, soit sur des réalisations et études concrètes qui pressentent un intérêt dans la maîtrise des concepts des sciences géographiques.

  LES ARTICLES DE SYNTHÈSES : ont pour but de faire ressortir, les théories, les méthodes, les techniques ou les procédés liés aux sciences géographiques, avec notamment des cas précis d'application.

- **LANGUES :** Les articles paraissent principalement, en Arabe, Français et Anglais.

- **CRITÈRES DE PUBLICATION :** Toute communication presentant de l'intérêt sera diffusée, quelle que soit son origine; l'appartenance de son auteur à l'INCT n'est pas exigée.
  Les articles doivent être fournis au format WORD ou équivalent, en colonnes et dans un format A4 en double interlignes, avec une marge de 2,5 cm au maximum sur chacun des quatre côtés.
  Chaque communication doit comporter un titre, qui doit être bref et informatif.

- **LE RESUMÉ :** Chaque article doit comporter un résumé en arabe accompagné d'un autre résumé en français et un autre en anglais de 100 à 200 mots.

- **MOTS CLÉS :** Citer 5 à 6 mots clés.

- **BIBLIOGRAPHIE :** Les références doivent être complètes et présentées dans l'ordre alphabétique des noms d'auteurs. La référence doit mentionner le nom et le prénom de l'auteur suivis de l'année d'édition, du titre de l'ouvrage, de l'éditeur et du lieu d'édition. Toute référence doit être clairement mentionnée dans le texte par le nom et prénom de l'auteur suivie des deux derniers chiffres de l'année de publication.

- **MODALITÉ DE PUBLICATION :** Tout article présenté pour publication est soumis à l'évaluation de deux membres du comité de lecture, en cas d'avis contraire, il est soumis à un troisième membre. Les articles non retenus ne sont pas retournés, à moins d'une demande de la part de l'auteur.
  Deux exemplaires seront fournis gratuitement à chaque auteur ; d'autres seront fournis à la demande, dans la limite du stock.

- **DATES DE PARUTION :** Le Bulletin parait deux fois par an, à la fin du mois d'octobre et du mois d'avril.

- **ENVOI DES MANUSCRITS :** Envoyer un courrier à **inct99@wissal.dz**

Avis aux Auteurs

Le **B**ulletin des **S**ciences **G**éographiques est indexé dans la **Bibliographie Géographique Internationale** à l'adresse suivante : http://prodig.univ-paris1.fr/umr/Poles_comptence/Pole_Documentation%20et%20 valorisation.htm

La notice bibliographique de la publication figure dans le volume annuel **n° 112, 2007**, ainsi que dans la **base de données FRANCIS-Géographie du CNRS** interrogeable sur les serveurs internationaux Questel.Orbit, OCLC/PICA, RLG et sur CD-ROM (Service payants), et dans la **BGI** publié par l'UMR PRODIG qui parait tout les ans http://prodig.univ-paris1.fr/umr/publications_documentaires/bgi_papier.htm

Elle a aussi été mentionnée dans la rubrique Publications du site **Infogéo** consultable sur Internet à l'adresse suivante : http://prodig.univ-paris1.fr/infogéo/Fichiers/Ouvrages.htm La rubrique est actualisée régulièrement.

Le **B**ulletin des **S**ciences **G**éographiques est diffusé sur Internet, sur le site portail des revues scientifiques dénommé http://www.webreview.dz conçu et administré par le Centre de Recherche sur l'Information Scientifique et Technique (CERIST).

INSTITUT NATIONAL DE CARTOGRAPHIE ET DE TELEDETECTION
Crée par ordonnance 211 67 du 17/10/1967 modifiée par les ordonances 84.68 du 23/04/1968 et 73.23 du 05/06/1973 et le décret présidentiel n°98.337 du 29/10/1998.
Siège: 123, rue de Tripoli - BP430 - Hussein Dey - 16040 - Alger
Tél: 213 021 47 09 20 & 021 47 00 30 **Fax:** 213 021 47 00 29 & 021 23 43 81
e-mail: inct99@wissal.dz

Bulletin d'abonnement

Tarif d'abonnement pour une année (comprenant deux numéros):

- ☐ Etudiant: 70 DA
- ☐ Particulier: 80 DA
- ☐ Etranger: 15 Euro

Prévoir en sus pour les frais d'expédition:

- ☐ Envoi Recommandé en Algérie : 400 DA
- ☐ Pour l'étranger: 10 Euro

Mode de règlement :

Pour l'Algérie :

- ☐ Par virement CCP N° 1552.04
- ☐ Par virement bancaire : CPA N° 101 401 78505 1
  BEA N° Q 22 61 570

Pour l'étranger :

- ☐ Par virement bancaire: Banque Deutsche Bank AG Munich
  Compte Nr, 85 960 BLZ: 700 700 I0

Nom et prénom / raison sociale :..

Fonction :..

Adresse complète :...

....

N°Tél :.................................... N°Fax :.................................... Email :..................

Date Signature

Retourner ce bulletin d'abonnement accompagné du règlement à Monsieur le Directeur Général de l'Institut National de Cartographie et de Télédétection

123, rue de Tripoli- BP 430, Hussein Dey- 16040 Alger.
Tél: 213 021 47 09 20 & 021 47 00 30 Fax: 213 021 47 00 29 & 021 23 43 81
E-mail: inct99@wissal.dz,

ou ANT Vertriebs GmbH Fuerstenrieder Str. 166-81377 Munich R.F.A
Fax: 0049 89 71039 449

Bulletin des Sciences Géographiques
Institut National de Cartographie et Télédétection
123, Rue de Tripoli, BP 430, Hussein Dey - 16040 Alger.
Tél: (213) 021 47 09 20 & 021 47 00 30
Fax: (213) 021 47 00 29 & 021 23 43 81
E-mail: inct99@wissal.dz