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GIS와 SAR 영상을 연계한 근 실시간 홍수지역 분석

Near Real Time Flood Area Analysis Based on SAR Image and GIS

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Abstract

Accurate classification of water area is a preliminary step to analyze the flooded area and damages caused by flood. This is essential processfor monitoring the region where annually repeating flood is a problem. The accurate estimation of flooded area can ultimately be utilized as a primary source of information for the policy decision. In this paper, flooded areaswas classified using 1:25,000 land use map and a RADARSAT image of Ok-Chun and Bo-Eun located in Chung-Book province taken in 12th of August, 1998. Then we analyzed the flood area based on GIS. A RADARSAT image was used to classify the flooded areas with slope theme generated from digital elevation model. In processing on a RADARSAT image, the geometric correction was performed by a backwardgeocoding method based on ephemeris data and one control pointfor near real time flood area analysis.

Key words : Classification of water area, Flood monitoring, RADARSAT image, Slope theme, GIS

요 지

정확한 수계영역의 분류는 홍수에 의한 피해면적을 분석하는데 핵심적인 과정으로서 매년 홍수가 발생하는 지역을 모니터링 하는데 매우 유용하다. 정확한 홍수지역의 분류는 궁극적으로 정책결정자에게 매우 유용한 정보가 될 수 있다. 본 연구에서는 1:25,000 토지이용도와 1998년 8월 12일 옥천, 보은지역을 촬영한 RADARSAT 영상을 이용하여 홍수지역을 분류하고, GIS와 연계하여 대상지역의 피해상황을 분석하였다. 근 실시간 지형보정을 위해서 천체력자료와 단일기준점을 활용하였으며, 특히, 수계영역 분류시 경사도정보를 이용하여 분류정확도를 향상시키는 기법을 개발하여 적용하였다.

핵심용어 : 수계분류, 홍수모니터링, RADARSAT 영상, GIS

Ⅰ. Introduction

Remote sensing techniques have beenrapidly developed since the last half century and applied to various fields of study, such as the terrain mapping, the environmental management, the urban planning, and etc., using built-in optical sensors. The remotely sensed images based on optical sensors, however, have disadvantages in acquiring images in bad weather condition, since the optical sensor uses the sunlight as an energy source, called passive sensors. Main obstacle in optical sensors is that it is limited to acquire in cloudy condition.

Unlike passive sensors, SAR (Synthetic Aperture Radar), the active sensor, emits radiation from antennae and receives the reflected radiation from a target to acquire the radioactive data. Main advantage is that SAR can obtain data, not affected

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by weather condition or sunlight. The radioactive data can detect additional information on the earth's surface, which could not be detected by the optical sensor.

The applications of SAR are not limited to agriculture, forest management, water resources, maritime management, but to the natural hazard management. Especially, SAR is particularly useful to the flood management since SAR could detect ground features through clouds. Analysis of flood range and distribution of the Yangtze, the north of China, in 1998(Shaoet al., 2000), flood damage mapping in North Korea(Kim, 2002), and determination of inundation areas as well as low drainage areas of the Lesse in Belgium(Ormsby et al., 1985) are good examples using SAR for flood estimation.

Although a RADARSAT image has been useful for flood studies, a RADARSAT image is rather hard to interpret for several reasons. A RADARSAT image critically needs the satellite information in geometric correction, but the information is often not available or incorrect to use (Small et al., 1997). Also, similar to most actively remotely sensed images the radiometric distortion by local terrain relief of a RADARSAT have a great influence on the quality of an image and may cause to mislead the ground information, especially about water areas. Applications on mountainous areas make more difficult due to radiometric distortion by terrain relief when to classify water areas (Sun et al., 2002).

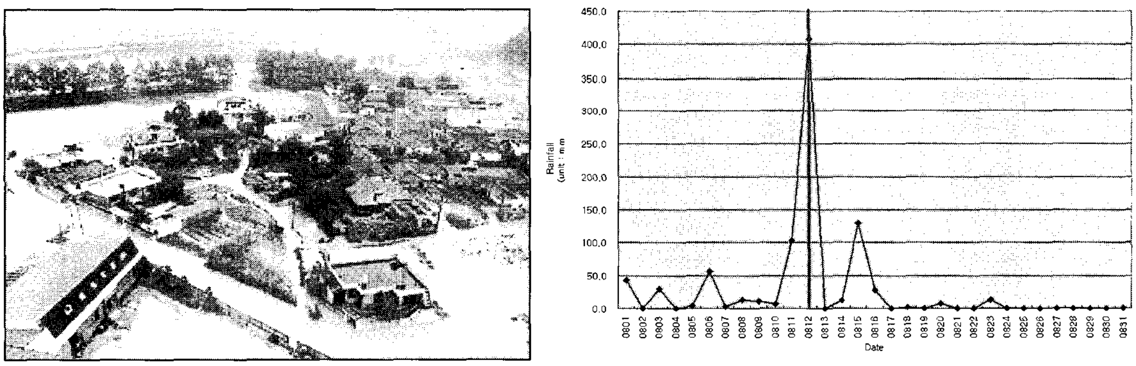
In this study, a RADARSAT image is used to classify the flooded areas with additional information from surfaces, such as a slope image. In processing on a RADARSAT image, the geometric correction was performed by a rapid geocoding technique based on ephemeris data and one control point. We believe that this research can be ultimately applied to the quick estimation of flood damage and policy decision for flood related disaster repeating every year.

2. Study area and datasets

In 1998, a couple of hurricanes, Yanni and Penny, had tragic effects on the middle of Korea, and one of affected areas is Ok-Chun and Bo-Eun urban areas and agricultural lands. Penny had visited this area from August 11th and 12th, 1998 and had particularly caused heavy rainfalls during these days. The areas were inundated by raised levels of the river and were greatly affected on agricultural lands and urban areas (Fig. 1). As shown in Fig. 1(b), daily precipitation record in these areas and the image acquisition time represented by thick line read a sharp peak on August 12, 1998.

The characteristics of topography in these areas are narrow, so flash floods have been frequent. The elevations on these areas are ranged from 28 to 830 m, meaning high relief areas, and the maximum slope is up to 64 degree. The assessment of inundated areas is critical to residents and local governments so that the accurate inundated identification would be only taken by active sensor satellite images.

The datasets in this study are 16 bit SGF (SAR Georeferenced Fine resolution) RADARSAT SAR image of standard beam 6 (August 12, 1998). Fig. 2



(a) (b)

Fig. 1. Cities and farms inundated by the flood(a) and daily precipitation (b)

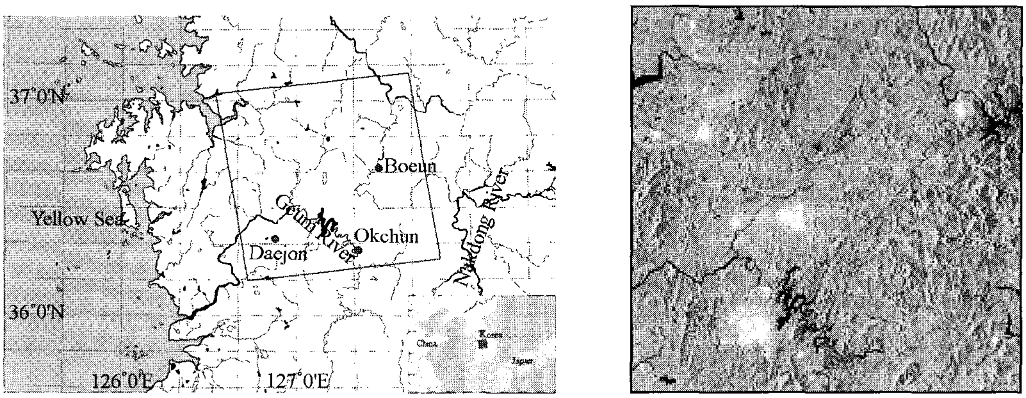


Fig. 2. Study area and RADARSAT SAR image

Table 1. Characteristics of RADARSAT-1 SAR image

Beam Mode	Standard 6 (41° ~ 46°)
Polarization	HH
Wavelength	C-band (5.6cm)
Orbit	14461-ascending
Product Type	Path image (SGF)
Size	8630 lines, 8724 pixel
Image nominal size	100km × 100km
# of Looks(range × azimuth) (m)	1 × 4
pixel spacing	12.5m

is showing the target area and SAR amplitude image used in this study. The characteristics of RADARSAT image used this study are listed above Table 1.

Several commercial software packages, ENVI (Environment for Visualizing Images) by Research Systems, Inc., Imagine 8.4 by ERDAS, ArcView 3.3by ESRI for Windows, and MFC (Microsoft Foundation Class) 6.0, were used for all preprocessed procedures and water classifications.

3. Near Real time geocoding and water area classification

3.1 Geocoding using a single control point

The orbit data for RADARSAT is not as accurate as for ERS, hence it is necessary to refine the orbit datato allow for these possible errors. Any attempt to refine the relationship between map and image space need great number of good quality GCPs with dense and appropriate spatial distribution, which is generally impractical and cost-expensive, Further-more, the quality of provided GCPs is not always reliable due to speckle, poor illumination of features appearing in SAR images, mapping accuracy, and scale.

In this study, we determined initial satellite orbit parameters using ephemeris data in header information to reduce the number of GCPs required for geocoding. Systematic error is occurred if initial orbit parameters from only header information are used for geocoding process (Chen and Dowman, 2001). Therefore, only accurate a single control point can correct this systematic shift error in geocoded SAR image. Fig. 3 is the procedure of backward geocoding method by a single control point processing and Fig. 4 is geocoded image by the method. The geometric accuracies for 16 check points are 1.5 pixels for range direction and 1.8 pixels for azimuth direction, respectively.

3.2 Water area classification using slope theme

Although SAR imagery with its own energy source is very sensitive to the water area, its shadow effect similar to the reflectance of the water area should be carefully checked before accurate classification. Especially, when we want to identify

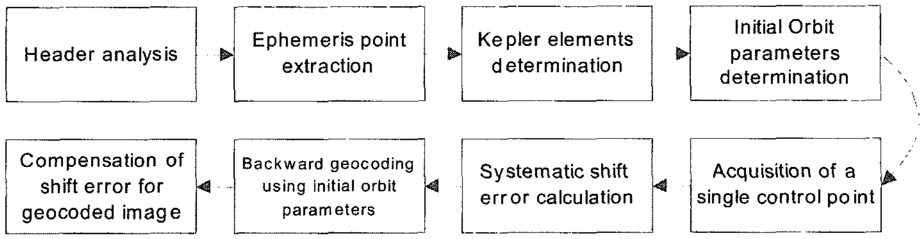


Fig. 3. Geocoding method using a single control point

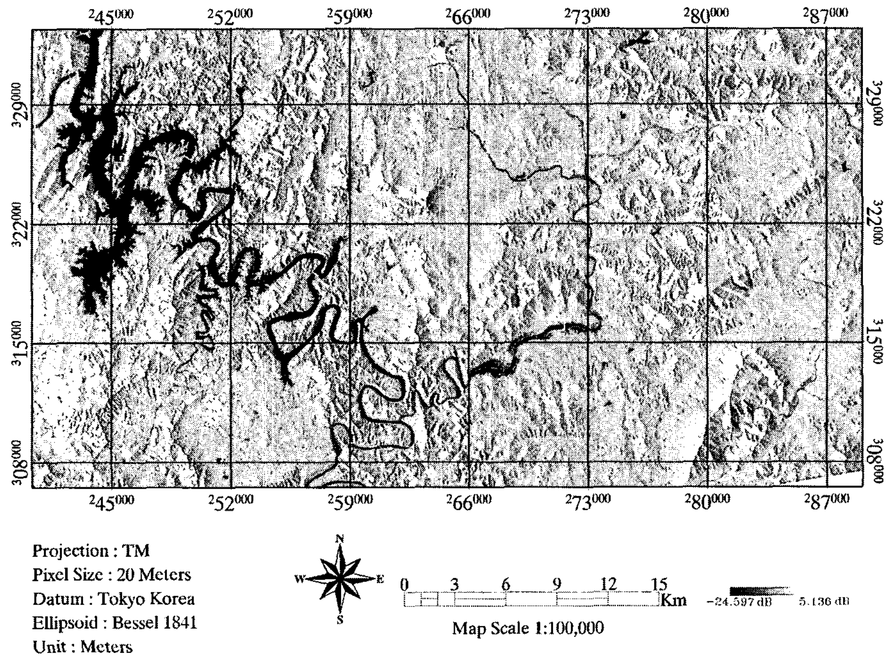


Fig. 4. RADARSAT image geocoded by a single control point

small water flood area with mountainous environment, the step for compensating radiometric distortion by local terrain relief turns to be essential. It is very complicated and time consuming process to correct radiometric distortion caused by the terrain relief to improve the classification accuracy of the water area.

Terrain information is used to improve the classification accuracy simply, and the most commonly used theme is DEM (Digital Elevation Model). DEM, however,could not be fully resolved in rugged terrain, particularly (Goering et al,. 1995, Goyal et al., 1998, Sun et al., 2002), but contains the slope rates, which may be essential information on water flows particularly the time in floods.

DEM can be generated by two stereo images using the image matching technique, or LIDAR data, SAR interferogram, radargrammetry, paper maps, or digital map could be possible sources for DEM. In this study, DEM was generated from 1:5,000 digital maps,and the spatial resolution of DEM is 20 m. Digital maps contain several layers about ground objects, and the elevation layer (x and y coordinates) and the point layer (z value) were employed. These layers were to construct TIN (triangulated irregular network) and then TIN was converted into raster DEM. The total counts of maps used here are 200 digital maps. The formats of digital maps are listed in table 2 and the generated DEM is shown in Fig. 5.

The slope theme was simply calculated from DEM and has the same resolution as DEM. This study ran the 3×3 minimum filter on the slope theme to increase flow accumulation possibilities. Figs. 6 (a) and 6(b) illustrate these result maps. Dark areas represent low slope, light areas represent higher slope.

Table 2. Characteristics of digital topographic map

Ellipsoid	Bessel
Datum	Tokyo Korea
Longitude of central meridian	38 degree
Latitude of origin of projection	127 degree
False easting	200,000m
False northing	500,000m
Scale	1/5,000
Projection Type	Transverse Mercator

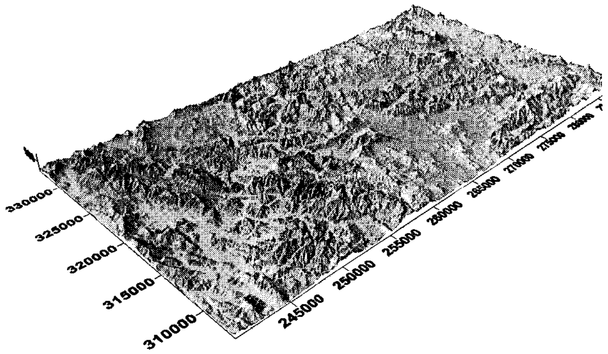
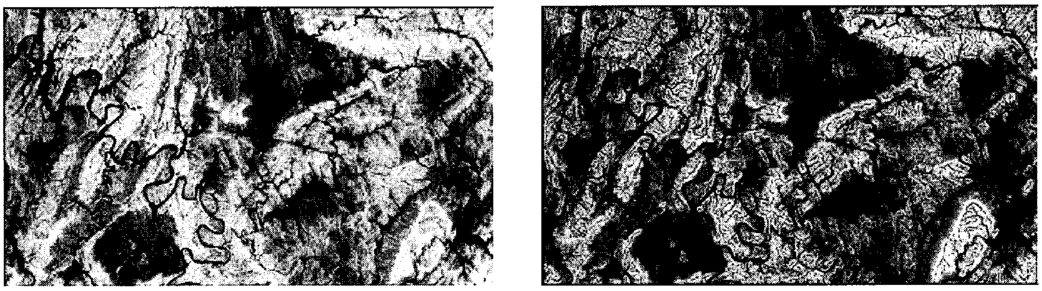


Fig. 5. Digital Elevation Model



(a) Slope theme (b) Slope theme after minimum filter

Fig. 6. Slope theme

In a RADARSAT image, the high probable water areas show the characteristics of low steep areas and low radar backscatter coefficients. It means that slope information is critical to estimate whereto water flows or where water resides (손홍규 등., 2004). Therefore the geocoded RADARSAT image is combined with slope theme for reducing terrain effect instead of correcting topographic effects such as shadow.For an image combination with terrain information, SAR image was assigned to a green band, DSM to a red band, a blank layer that has constant value to a blue band, respectively. Fig. 7 is the pseudo color composite image to classify water area.

The method used here to classify water area from composite image is the maximum likelihood method, the most commonly used. The rationale of this method here is that the distribution of the RADARSAT image became the normal distribution when the radiometric processes were applied. The supervised classification of the maximum likelihood method was performed with 22 training sites. Table 3 shows characteristics of training site used for image classification. The training sites for water and non-water areas are 12 and 10 sites over an image, respectively.

By reason that this study is merely interested in either water or non-water areas, water areas accumulated in various terrain areas, such as high slopes or moderate slopes or flat areas, were

Fig. 7. The composite image of RADARSAT image and slope theme

Table 3. Characteristics of training sites

	Water areas				Non-water areas			
	Min.	Max.	Mean	Std.	Min.	Max.	Mean	Std.
Gray value	674	15700	2885	674	1069	10696	11682	7092
Slope (degree)	0.00	11.34	0.43	0.91	0.00	39.56	10.31	9.99
Num. Total samples	10191				47595			

carefully selected over the region. Flooded water tends to accumulate relatively lower areas and rivers, so it means that water would inundate to lower and flatter areas than surrounding regions.

Fig. 8 shows the classification result by the maximum likelihood method. Dark areas mean water area during a flood, bright is non water area. For accuracy estimation, ground truth ROI (Region of Interest) was generated from land use map and Annual Disaster Report (1998) from NDPCH (National Disaster and Prevention and Counter-measure Headquarters) and an error matrix was constructed. As a result, overall accuracy is 99.26 and kappa coefficient is 0.98.

4. Results and discussions

We purposed to analyze flooded area using land use map of 1:25,000 and classification results from RADARSAT SAR image acquired during a flood. For this process, extracted water area was converted

Fig. 8. Classification results

to image format (*.bil) of ArcView and it was reconverted to GRID format. Vector data that represents outline of water area during a flood is generated by converting GRID format into SHAPE format in ARC/VIEW. To analyze the geographical position and the land use condition of the estimated flood area, we overlaid water vector data with land use map (Fig. 9). In Fig. 9, red lines mean outline of water area during a flood, and A region is serious damaged areas where are Shin-mae, Chang-We of Ok-Chun county.

To analyze land use condition within inundated areas, the land use map is cut by water area vector data and geo-processed to dissolve polygons with same properties into one polygon. After adding to AREA property into property table, and then areas according to land use condition was calculated by Query Builder operator. Fig. 10 is showing status of damage area within inundated area according to land use. As shown in this figure, the majority of the inundated area is not a zone of life but areas composed of mountainous area, a vacant lot. Also, we can know that the flood gave damages to roads, factory sites, farms and residential areas.

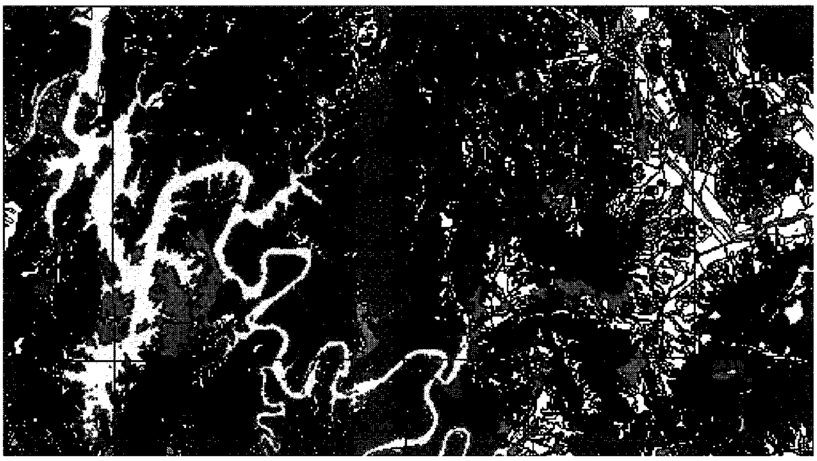
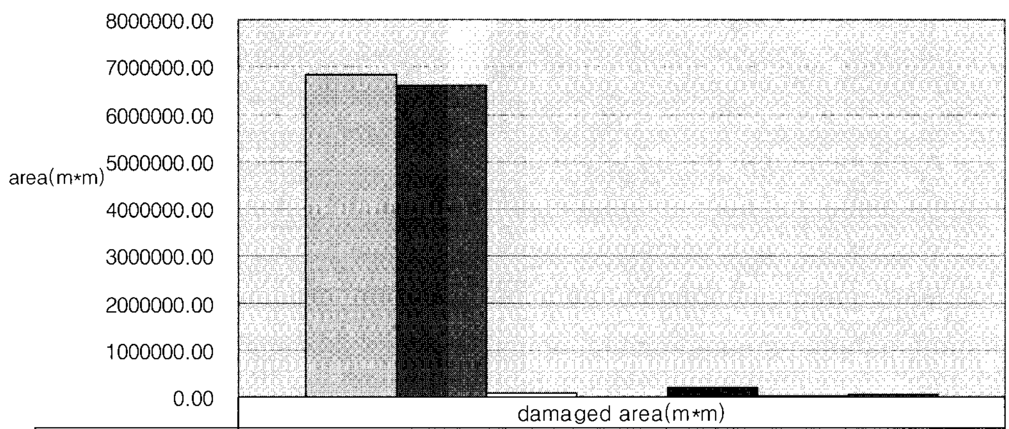


Fig. 9. Overlay of the water vector data with land use map



	damaged area(m*m)
agricultual area	6838813.76
forestry area	6617855.05
residential area	73711.73
commercial area	8816.55
road	211683.60
factory area	19348.51
et cetera	68879.44

Fig. 10. Areas damaged by the flood according to land use

5. Conclusions

After classifying the water area and monitoring the flood area of Ok-Chun and Bo-eun using RADARSAT SAR image and land use map, we are reached the following conclusions.

1. We successfully identified the flood area from the water area of the RADARSAT image by overlapping them with the land use map. We also observed the fact that serious damage occurred around the Dae-Chung Dam and the farm lands along the Bo-Chung River, the upper stream of the Dae-Chung Dam.
2. In such a mountainous area like KOREA, the water area classification using SAR imagery can be substantially improved by slope theme, and this combination of a radar image and slope theme is more time and effort efficient in classification processes.
3. We applied the new method to determine the orbit model required for the rapidly accurate geometric-correction with a single control point and ephemeris data in header information. This method is possible for us to real time SAR processing when needed to analyze for rapid flood monitoring.

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