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KNOWLEDGE ACQUISITION ON URBAN LAND COVER FEATURES USING TERRASAR AND QUICKBIRD IMAGES

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ABSTRACT: The aim of this study is to conduct a knowledge acquisition through the analysis of backscattering and reflecting properties of different urban land cover types using TerraSAR X-band data and a multispectral Quickbird image, and propose an appropriate technique for the acquired knowledge representation. The backscatter and reflectance values of different land features are compared on the basis of statistics of signatures of the selected classes. Overall, the study demonstrated that the TerraSAR and Quickbird images can be successfully used for the knowledge acquisition as well as for the investigation of different land surface features based on spectral analysis.

1. INTRODUCTION

Over the years, knowledge-based systems (KBS) have been widely used for automatic image understanding and interpretation. The design and physical implementation of such systems are one of the main tasks of many researchers dealing with digital image processing and analysis. Different types of these systems have been and are being developed depending upon the solutions of the given problems and the structures of knowledge representation. The main task of a KBS is to provide solutions to a problem in a specific domain, utilizing the knowledge and expertise embodied in it. This knowledge is mainly extracted from human experts through a knowledge acquisition process and corresponds to standard knowledge taken from different sources as well as from the results of long experiences in a given field (Amarsaikhan *et al.* 2005). For the RS data sets, a set of knowledge can be acquired from contextual, backscatter, reflective and emissive properties of objects or classes of interest.

In case of microwave data, an automatic interpretation is based on the backscatter properties of the surface features, whilst in case of optical data it is based on the reflective and emissive characteristics of the classes of objects. At SAR wavelengths, three types of scattering such as surface scattering, volume scattering, and double bounce scattering occur, and most radar analyses are based on them. If the surface is homogeneous, then surface scattering will occur and it can be either specular or diffuse, or intermediate depending on the wavelength and surface roughness. If the surface is dielectrically inhomogeneous, then volume scattering where radar penetrates the surface and the return is due to scattering from the underlying materials, will occur. Double bounce scattering occurs, when the right angles are formed between natural and artificial objects (Richards *et al.* 1987, Amarsaikhan and Ganzorig 1999, Amarsaikhan *et al.* 2005). Unlike the microwave data whose interpretation is mainly based on the scattering mechanisms, the analyses of optical data are directly related to the reflected and emitted radiances of the Earth surface features, because the objects reflect and emit different amounts of energy in different portions of the optical spectrum.

The aim of this study is to analyze the backscattering and reflecting characteristics of different urban land cover classes used for knowledge acquisition and describe an appropriate technique for the acquired knowledge representation. For this purpose, 8 different land cover classes have been selected from TerraSAR X-band and multispectral Quickbird images of urban area in Mongolia, and analyzed in relation to the surface and system parameters. For the final analysis, the greylevel values of a group of contextually dependent pixels selected from different parts of the images have been used and compared on the basis of the mean values (M) and standard deviation (SD).

2. TEST SITE

As a test site, Ulaanbaatar, the capital city of Mongolia has been selected. The selected part of the city is characterized by such main classes as building area, ger area (Mongolian traditional dwelling), forest, vegetated surface, soil with high moisture, soil with low moisture and water. The building area includes buildings of different sizes, while ger area includes mainly gers surrounded by fences. The forest class consists of different types of tall and short trees located along the Tuul River. The vegetated surface mainly includes grass, but there are some bush and short trees, too. The soil with high moisture is located along the area which previously was a river valley. The soil with low moisture is mainly distributed along the northern range of the Tuul River. The water class represents the Tuul River located in the southern part of Ulaanbaatar. Figure 1 shows a recent Quickbird image of the test site, and some examples of its land cover.

Figure 1. 2006 Quickbird image of the selected part of Ulaanbaatar. 1-building area, 2-ger area, 3-forest, 4-vegetated surface, 5- soil with high moisture, 6- soil with low moisture, 7-open area, 8-water.The size of the displayed area is about 3.9kmx4.4km.

3. DATA SOURCES

In the present study, for the urban land cover studies, a Quickbird image of March 2006 and a TerraSAR-X image of March 2008 have been used. The Quickbird data has four multispectral bands (B1: 0.45–0.52µm, B2: 0.52–0.60µm, B3: 0.63–0.69µm, B4: 0.76–0.90µm) and one panchromatic band (Pan: 0.45-0.9µm). The spatial resolution is 0.61 m for the panchromatic image, while it is 2.4 m for the multispectral bands. The high spatial resolution of the panchromatic image can distinguish most small elements at an object level which multispectral bands cannot fully resolve. Therefore, a combination of panchromatic and multispectral bands gives a real colour view of a scene. In the current study, a pan-sharpened image has been used (Pohl and van Genderen,1998). TerraSAR-X is a German Earth observation satellite carrying a cloud-piercing, night-vision radar which is designed to create the most precise maps and images ever produced by a civilian space radar system. It images the Earth's surface at a rate of one million square km a day and provides information at various spatial resolutions. The characteristics of the TerraSAR-X data used in the current study are shown in Table 1 and the image of the test area is shown in Figure 2.

Table 1. The characteristics of the TerraSAR-X data.

Parameter	X-band
Polarization	HH and VV
Frequency	9.6 GHz
Wavelength	3.1cm
Spatial resolution	1.0m

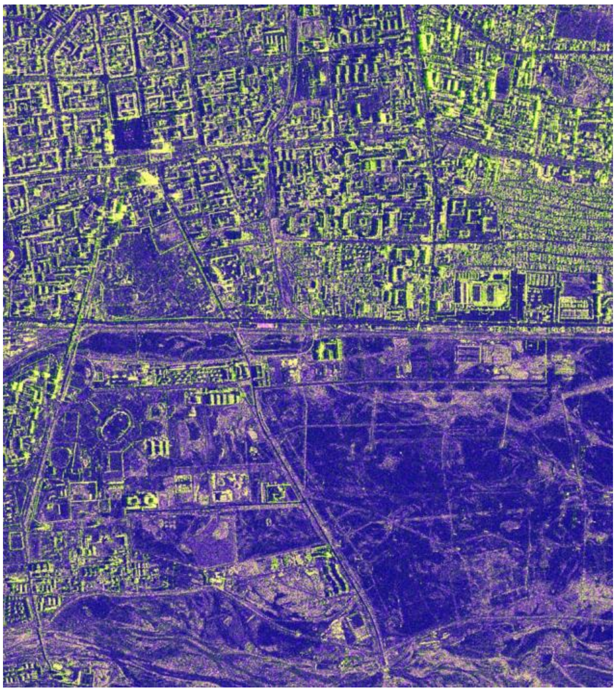

Figure 2. 2008 TerraSAR-X image of the selected part of Ulaanbaatar.
(Red=HH, Green=VV, Blue=HH-VV).

4. KNOWLEDGE ACQUISITION

In general, knowledge acquisition is used for an initial intelligent guess of the spectral values of selected classes and it is important for selection of the reliable features as well as for definition of reliable spatial and spectral thresholds. In the present study, knowledge acquisition has been conducted based on the theory of backscattering mechanisms and reflecting properties of each class available within the selected image frame.

Initially, from different parts of the TerraSAR and Quickbird images, polygons representing the selected land cover types have been selected using local knowledge. Then, the polygons were transformed into primary signatures (ENVI 1999, ERDAS 1999) of the representative classes. As the images have a very high spatial resolution, the final signatures included about 932-51714 pixels. The plot of the mean values for the chosen training samples selected from the integrated images is shown in Figure 3 and the actual mean and SD values are shown in table 1.

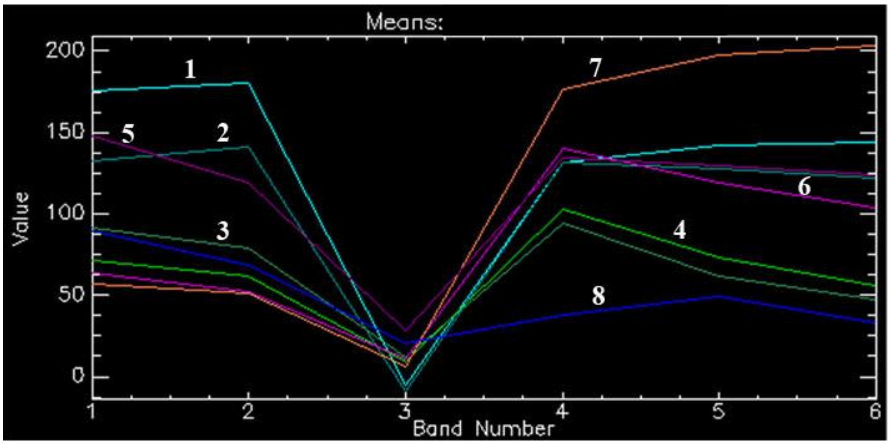

Fig. 3. The plot of the mean values for the available classes.
Along the X-axes: TerraSAR and Quickbird bands. 1-building area, 2-ger area, 3-forest, 4-vegetated surface, 5- soil with high moisture, 6- soil with low moisture, 7-open area, 8-water.

As seen from table 1, the building area has the highest mean values in all bands and it is statistically separable from most classes, whereas the ger area might easily have some overlaps with other classes (*eg,* soil classes) unless accurate spectral threshold values are selected. The backscatter from urban areas should contain information about street alignment, building size, density, roofing material, its orientation as well as vegetation and soil, thus resulting in all kinds of scattering. Roads and buildings in urban areas can reflect a larger component of radiation, if they are aligned at right angles to the incident radiation. Here, the intersection of a road and a building tends to act as a corner reflector. The amount of backscatter is very sensitive to street alignment. The areas of streets and buildings aligned at right angles to the incident radiation will have a saturated very bright appearance and non-aligned areas will have a bright/dark appearance in the resulting image. Volume and surface scattering will also play an important role in the response from many of the urban features (Richards *et al.* 1987, Manual of Remote Sensing 1999). Using Rayleigh's criterion of surface roughness, for the TerraSAR X (3.1cm) band data, the boundary between the diffuse and specular reflection can be determined as being between .38cm and 1.45cm, depending on the incident angles. Many urban surfaces have variations that are just greater or less than these values. In the optical range, it is clear that these two classes should have high reflectance values, because the objects forming these classes are made of materials that reflect much of the incoming solar energy.

In case of forest, at X-band frequency, canopy scattering and attenuation will be caused primarily by leaves and needles, because the wavelength is too short to penetrate into the forest layer. As seen from table 1, the forest has moderate backscatter return and it has some statistical overlaps with the vegetated surface. The vegetated surface will act as mixtures of small bush, grass and soil and the backscatter will depend on the volume of either of them (Richards *et al.* 1987, Amarsaikhan and Ganzorig 1999). Although plant geometry, density and water content are the main factors influencing the backscatter coming from the vegetation cover, ground truth information revealed that the contribution of vegetation is not very significant during this time of the year. Comparing the mean values of these two classes, one can observe that they are more separable at radar bands due to stronger volume scattering in the forest area. However, they have a high statistical overlap in the optical range, because, in March the green vegetation is not yet green in Mongolia. Thus, the forest gives a similar reflectance as the other vegetated surfaces.

There are two soil classes having different mean values. As seen, they can be differentiated at all bands (except the red band), despite some overlap on the edges of the signature distributions. Here, the soil with low moisture forms more compact signatures, whereas the soil with high moisture forms scattered clusters. The backscatter of soil depends on the surface roughness, texture, existing surface patterns, moisture content, as well as wavelength and incident angle. The presence of water strongly affects the microwave emissivity and reflectivity of a soil layer. At low moisture levels there is a low increase in the dielectric constant. Above a critical amount, the dielectric constant rises rapidly. This increase occurs when moisture begins to operate in a free space and the capacity of a soil to hold and retain moisture is directly related to the texture and structure of the soil (Richards *et al.* 1987, Amarsaikhan and Ganzorig 1999). As it can be seen from table 1, soil with low moisture has lower values in comparison with all other classes, except the open area. This indicates lower backscatter intensities caused by specular reflection due to lack of some surface features, low roughness properties and low dielectric constant of the dry soil. In contrast to the soil with low moisture, wet soil gives high backscatter return compared to the most of the classes because of the soil moisture content and increased dielectric constant. In the optical range, both soil classes give high reflectance values. This is due to a fact that the (brighter) soils should have increased spectral reflectance, when wavelength increases from visible to near infrared ranges.

Table 1. The mean backscatter values of the selected land cover classes and their variations in the TerraSAR and Quickbird bands.

		HH		VV		HH-VV		Red		Green		Blue	
No	Classes	M	SD	M	M	M	SD	M	SD	M	SD	M	SD
1	Building area	175.2	71.3	180.4	71.4	-5.1	40.6	141.2	74.3	142.1	75.7	145.1	74.5
2	Ger area	132.2	64.4	140.9	70.2	-8.6	49.9	131.1	66.1	127.4	67.5	122.3	67.1
3	Forest	90.9	42.1	78.9	37.4	11.9	30.1	94.3	29.1	61.9	29.4	47.8	28.5
4	Vegetated surface	71.4	28.3	62.1	24.9	9.2	24.72	103.2	23.9	73.5	25.6	56.3	26.2
5	Soil with high moisture	147.3	50.2	119.1	45.5	28.2	49.1	134.1	16.4	129.9	16.8	123.9	16.9
6	Soil with low moisture	63.2	21.1	52.5	18.3	10.7	18.4	140.2	15.6	119.2	15.1	104.1	16.0
7	Open area	57.1	17.5	50.7	15.6	6.3	18.2	176.1	24.3	197.1	22.2	204.1	23.2
8	Water	89.1	29.1	68.4	22.8	20.6	23.3	37.7	8.0	49.5	6.3	33.1	8.4

In most cases, open area will behave as a specular reflector, but at some specific conditions where sufficient surface roughness is observed, it will have some components of diffuse scattering. As seen from table 1, at radar wavelengths the open area has very low average backscatter return and it has a high statistical overlap with soil with low moisture. Nevertheless, it has very high reflectance values in the optical range, because most of the objects related to this class are made of concrete materials.

Generally, in an urban environment, most of the available water resources will have specular reflection and should appear very dark on images for all incident angles except 0. To obtain some backscatter from a water surface, it must by some mechanism, be made rough. The principal mechanism for the roughening the water surface is the generation of waves and in reality the waves can be generated by strong wind. However, in the given case, there is contextual influence of vegetation and small bush (from both sides of the river) due to which there is increased backscatter return. As seen from table 1, water has the lowest reflectance in the optical range, although there are some contextual influences. It is clear that, water should have decreased reflectance values along the optical range (Mather 1999).

5. THE PROPOSED KNOWLEDGE REPRESENTATION

For development of a proper KBS used for the automatic interpretation of such integrated SAR and optical images, the above knowledge about backscattering and reflecting properties of different natural and artificial objects can be represented in a most efficient way, for example, using a rule-based approach. It is one of the most commonly used knowledge representation technique, in which different rules mainly containing the constraints on expert-defined variables, spatial objects, external programs and other spatial models are constructed and used for the hypothesis evaluation (Amarsaikhan, 2007). Thus, different parameters to be required might be formulated as a set of 'IF THEN' rules and the actual image processing can be done on the basis of a forward chaining principle.

6. CONCLUSIONS

The study on knowledge acquisition through the analysis of the backscattering and reflecting properties of the urban land cover features in Mongolia using the TerraSAR X-band and multispectral Quickbird images, was carried out. Within the framework of the study, an appropriate technique, that is a rule-based approach for the acquired knowledge representation was proposed. Overall, the research demonstrated that the integrated very high resolution TerraSAR and Quickbird images could be successfully used for the knowledge acquisition as well as for the investigation of different urban land surface features.

7. ACKNOWLEDGEMENT

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8. REFERENCES

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