26th Asian Conference on Remote Sensing and 2nd Asian Space Conference (ACRS2005)
7-11 November 2005, Hanoi, Vietnam

Knowledge Acquisition in C-band and L-band Radar Frequencies

D.Amarsaikhan
Institute of Informatics and RS, Mongolian Academy of Sciences,
av.Enkhtaivan-54B, Ulaanbaatar-51, Mongolia
amar64@arvis.ac.mn

M.Ganzorig
Institute of Informatics and RS, Mongolian Academy of Sciences,
av.Enkhtaivan-54B, Ulaanbaatar-51, Mongolia
ganzorig@arvis.ac.mn

V.Battsengel
Faculty of Geography
National University of Mongolia, Ulaanbaatar, Mongolia
battsengel@num.edu.mn

Abstract. The aim of this study is to conduct a knowledge acquisition through the analysis of the backscattering characteristics of different earth surface features in Central Mongolia using the C-band and L-band SAR images in relation to the surface characteristics and system parameters. The backscatter values of different land features are compared on the basis of statistics of the signatures of the selected classes. The study demonstrated that the ERS-2 SAR and JERS-1 SAR data can be successfully used for the knowledge acquisition as well as the investigation of different land surface features, however, in order to perform thorough analyses, one should have knowledge about the study area and sufficient ground truth data.

1. Introduction

In recent years, knowledge-based systems (KBS) have been used for automatic image understanding and interpretation. The design and physical implementation of the automatic image interpreter-KBS are one of the main tasks of many researchers dealing with digital image processing. Different types of these systems are being developed depending upon the solutions of the given problems and the structure 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 extracted from human experts through a knowledge acquisition process and corresponds to standard knowledge taken from different sources as well as from results of long experiences in the field. For the RS data sets, a set of knowledge can be acquired from contextual, reflective, emissive and backscattering properties of the objects or classes of interest.

In case of the microwave data, the automatic interpretation is based on the backscatter properties of the surface features and at radar wavelengths, three types of scattering such as surface scattering, volume scattering, and corner reflector-like scattering can occur. 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. Corner reflector-like scattering occurs as a result of the right angles formed between natural and artificial objects (Richards *et al.* 1987, Amarsaikhan and Ganzorig 1999). Moreover, radar interpretations are very much environment or site specific and relative to frequency as well as polarisation, incidence angle, surface properties and the effects of water and soil moisture (Richards *et al.* 1987). The tonal variations on the radar images also depend on the changes of the boundary condition between specular and diffuse scattering. (Amarsaikhan *et al.* 2000). In addition, SAR images are granular in appearance due to speckle formed because of the coherent radiation used for radar systems. The reduction of the speckle is a very important step in further interpretation and analysis and the radar image analysis must be based on the techniques that remove the speckle effects while considering the intrinsic texture of the image frame (Ulaby *et al.* 1986).

The aim of this study is to describe the backscattering characteristics of natural and artificial objects at different radar frequencies that are used for knowledge acquisition and some appropriate techniques for acquired knowledge representation. For this purpose, ERS-2 SAR and JERS-1 SAR data related to different land surface features in Central Mongolia have been selected and analysed in relation to the surface and system parameters. For the study, 8 different land cover classes have been selected on the basis of the availability of the ground truth data and local knowledge about the sites. For the analysis, the backscatter values of a group of contextually dependent pixels selected from different parts of the images presented in digital numbers (DN) have been used and compared on the basis of the mean values and standard deviation (SD).

2. Study area and data sources

As a test site, central part of Mongolia including the capital city of Ulaanbaatar has been selected. The area is situated in between forest-steppe and steppe zones and is characterized by such main classes as forest, shrub, soil with sparse vegetation, agricultural (abandoned) fields, wet soil with sparse vegetation, water, building area and ger (Mongolian national dwelling) area. The total size of the study area is about 35kmx24km.
The data used consisted of ERS-2 SAR image of September 1997 with a spatial resolution of 25m and JERS-1 data of April 1997 with a spatial resolution of 18m. Also, as additional ground truth information a topographic map of 1984, scale 1:50.000, SPOT XS image of June 1997, ASTER image of May 2001 and soil and vegetation maps of scale 1:100.000 were available.

3. Analyses

3.1. Speckle suppression

As the SAR images have granular appearance due to speckle formed because of the coherent radiation used for radar systems, in most cases the reduction of the speckle is a very important step in further analysis. The analysis of the radar images must be based on the techniques that remove the speckle effects while considering the intrinsic texture of the image frame (Ulaby *et al.* 1986) and nowadays, a number of filtering techniques are available for this purpose. Detailed descriptions and applications of such filters (eg, leesigma, gammamap, lee, local region and frost filters) are given in ERDAS (1999). In this study, for the speckle suppression of both images a 3x3 size Frost filter has been used. In the output images speckle noise was significantly reduced with low degradation of the textural information.

3.2. Backscatter analysis and signature evaluation

Initially, in each image frame, polygons representing the selected land cover types have been selected. Then, the polygons were transformed into primary signatures of the representative classes. The final signatures included about 232-651 pixels. The statistics of the signatures representing different cover types is shown in table 1.

Table 1. The mean backscatter values of the selected land cover classes and their variations in the original and speckle suppressed SAR images

No	Classes	Original 16bit ERS-2 image		3x3 Frost filtered ERS-2 image		Original 16bit JERS-1 image		3x3 Frost filtered JERS-1 image	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	Forest	357.7	103.8	255.3	54.0	1075.2	349.0	769.4	156.7
2	Shrub	319.2	80.6	226.8	38.4	852.7	318.6	612.2	154.7
3	Soil with sparse vegetation	148.7	45.9	104.6	24.2	361.4	104.8	257.2	43.6
4	Agricultural (abandoned) fields	228.1	87.0	163.4	51.0	453.2	145.7	319.5	63.3
5	Wet soil with sparse vegetation	436.0	134.1	310.0	67.4	577.2	192.5	409.3	84.5
6	Water	72.0	18.8	50.9	7.9	325.3	96.2	233.8	42.8
7	Ger	398.0	164.8	282.8	90.7	1349.5	503.3	960.1	239.5
7’	Ger individual pixels	2256				5660			
8	Buildings	625.2	682.5	461.6	438.6	3591.4	4091.8	2632.8	2514.7

8’	Building individual pixels	6744				32767			

As seen from table 1, on both images forest and shrub have higher average backscatter values than some other classes and display higher variations. There are some distinctions of these classes on the JERS-1 image, but on the ERS-2 image the two classes almost overlap. In the case of these classes, at L-band frequency the wavelength will penetrate to the forest canopy and will cause volume scattering to be derived from multiple-path reflections among twigs, branches, trunks and ground, while at C-band frequency only volume scattering from the top layer can be expected, because the wavelength is too short to penetrate to the forest layer (Richards *et al.* 1987, Amarsaikhan and Ganzorig 1999). Comparing the backscatter values in both images, one can observe that at L-band frequency volume scattering in forest area is stronger than in shrub, because of the increased interaction among different scattering mechanisms that contributed to the overall backscatter return.

There are three soil-related (dominated) classes having different average backscatter values. As seen, they can be differentiated at both C-band and L-band frequencies, despite some overlaps on the edges of the signature distributions. Here, soil with sparse vegetation and agricultural (abandoned) fields form more compact signatures but wet soil with sparse vegetation forms a scattered cluster, however, after speckle suppression variations of all signatures have been significantly decreased. 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. 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 sparse vegetation and agricultural (abandoned) fields have lower values in comparison with all other classes, excluding water. This indicates low backscatter intensities caused by specular reflection due to lack of some surface features, low roughness properties and low dielectric constant of the soil. At both frequencies, wet soil with sparse vegetation gives high backscatter return compared to the most of the classes because of the soil moisture content and increase of dielectric constant.

Water has the lowest backscatter values at both frequencies creating the most compact signatures. This is due to the specular reflection of water that causes less reflection towards the radar antenna. At C-band frequency, it can be differentiated from all other classes, but at L-band frequency there are some overlap between this class and soil with sparse vegetation. The reasons could have been the fact that at the higher frequency the water caused more specular reflection, however, at the lower frequency both classes caused similar reflection.

There are two classes (ger area and buildings) selected from urban areas, having high mean backscatter values and SD at both frequencies. Specifically, the building class created highly scattered signatures which made it impossible to distinguish from many other classes. In urban areas, the backscatter would contain information about street alignment, building size, density, roofing material, its orientation, vegetation and soil, i.e., it would contain all kinds of scattering. Roads and buildings 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 very bright appearance and non-aligned areas will have a more dark appearance in the resulting image. Volume and surface scattering will also play an important role in the response from urban areas (Richards *et al.* 1987, Amarsaikhan and Ganzorig 1999). To form the signatures of ger area and building classes, the polygons representing these classes were selected from more homogeneous parts of the images. Because of the above scattering reason, the average backscatter values for these classes are somewhat lower (specifically in C-band) after averaging the selected pixels. However, the investigation of the individual pixels indicated that those objects aligned at right angles gave extremely high backscatter values. For example, the backscatter values in ger area reached up to 2256 and 6744 in C-band and L-band respectively, while in building area they reached up to 5660 and 32767 in C-band and L-band accordingly. Moreover, as seen from table 1, at C-band frequency ger area almost overlaps with wet soil with sparse vegetation, but at L-band frequency the two classes are completely separable. This is most probably due to the fact that soil moisture is more saturated at the upper 5cm-6cm (penetrating capability of C-band) of the soil causing high backscatter return at C-band frequency, while at the depth of 23cm-24cm (penetrating capability of L-band) the soil surface condition is more homogeneous causing moderate backscatter return at L-band frequency.

Furthermore, as can be seen from table 1, after speckle suppression the mean values of the signatures are shifted forming more compact clusters. It is related with the fact that due to speckle suppression very high and low backscatter values are eliminated thus forming less scattered signatures with decreased mean values.

For development of a proper KBS used for the automatic interpretation of radar images, the above knowledge about backscatter properties of different natural and artificial objects should be represented in a most efficient way, for example, 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 forward chaining principle.

4. Conclusions

The study on knowledge acquisition through the analysis of the backscattering characteristics of different earth surface features in Central Mongolia using the C-band and L-band SAR images in relation to the surface characteristics and system parameters was carried out. Overall, the research demonstrated that the C-band ERS-2 SAR and L-band JERS-1 SAR data can be successfully used for the knowledge acquisition as well as the investigation of different land surface features, however, in order to perform thorough analyses, one should have knowledge about the study area and sufficient ground truth data.

5. References

1. Amarsaikhan, D., and Ganzorig, M., 1999, Interpretation and comparison of AirSAR quad-polarised radar images. Proceedings of the 20th Asian Conference on RS, Hong Kong, China, 22-26 November 1999, 695-700.
2. Amarsaikhan, D., 2000, Application of Spectral and Scattering Knowledge for Interpretation of Active and Passive Sensor Data. Institute of Informatics and RS, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia.
3. ERDAS, 1999, Field guide, Fifth Edition, ERDAS, Inc. Atlanta, Georgia.
4. Manual of Remote Sensing, 1999, 3rd Edition, Volume 3, American Society of Photogrammetry.
5. Richards, J.A., Milne, A.K., and Forster, B.C., 1987, Remote sensing with synthetic aperture radar. Centre for Remote Sensing, UNSW, Sydney, Australia.
6. Ulaby, F.T., Kouyate, F., Brisco, B., and Williams, T.H.L., 1986, Textural information in SAR images. IEEE Transactions on Geoscience and Remote Sensing, 24, 235-245.