Modeling population density by integrated analysis of Kompsat-1 images and census data

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Abstract: In this paper the use of panchromatic KOMPSAT-1 imagery is proposed to provide detailed information on built-up areas in suburban regions. In order to derive this information a texture analysis is utilized. In the next processing step census data are incorporated in order to perform refined demographic analysis. Assuming that the population lives in settlements rather than in agricultural areas, the census data are assigned to the actual residential areas within each census unit. Using this information a number of questions can be addressed which cannot be answered by statistical data alone.
Keywords: Kompsat, texture analysis, human settlements, demographic analysis.

1. Introduction

Large cities and their surrounding areas are faced with the trend of increasing suburbanization. City and regional planners are called upon to provide concepts for these developments and thus need data on which to base their models. Until now, detailed information has in general only been available for large cities, rarely going beyond the city limits. Basic information, such as census data, is of course available, but usually only on a census unit basis, with no additional more detailed spatial reference. While in urban areas the size of the census units is small enough to estimate the actual spatial distribution of the population, in rural areas the size of the census units is much larger thus giving no indication where the people actually live, i.e. where the settlements are.

In this paper the use of panchromatic KOMPSAT-1 imagery is proposed to provide detailed information on built-up areas in suburban regions. Assuming that the population lives in settlements rather than in agricultural areas, census data are assigned to the actual residential areas within each census unit. Using this information a number of questions can be addressed which cannot be answered by statistical data alone.

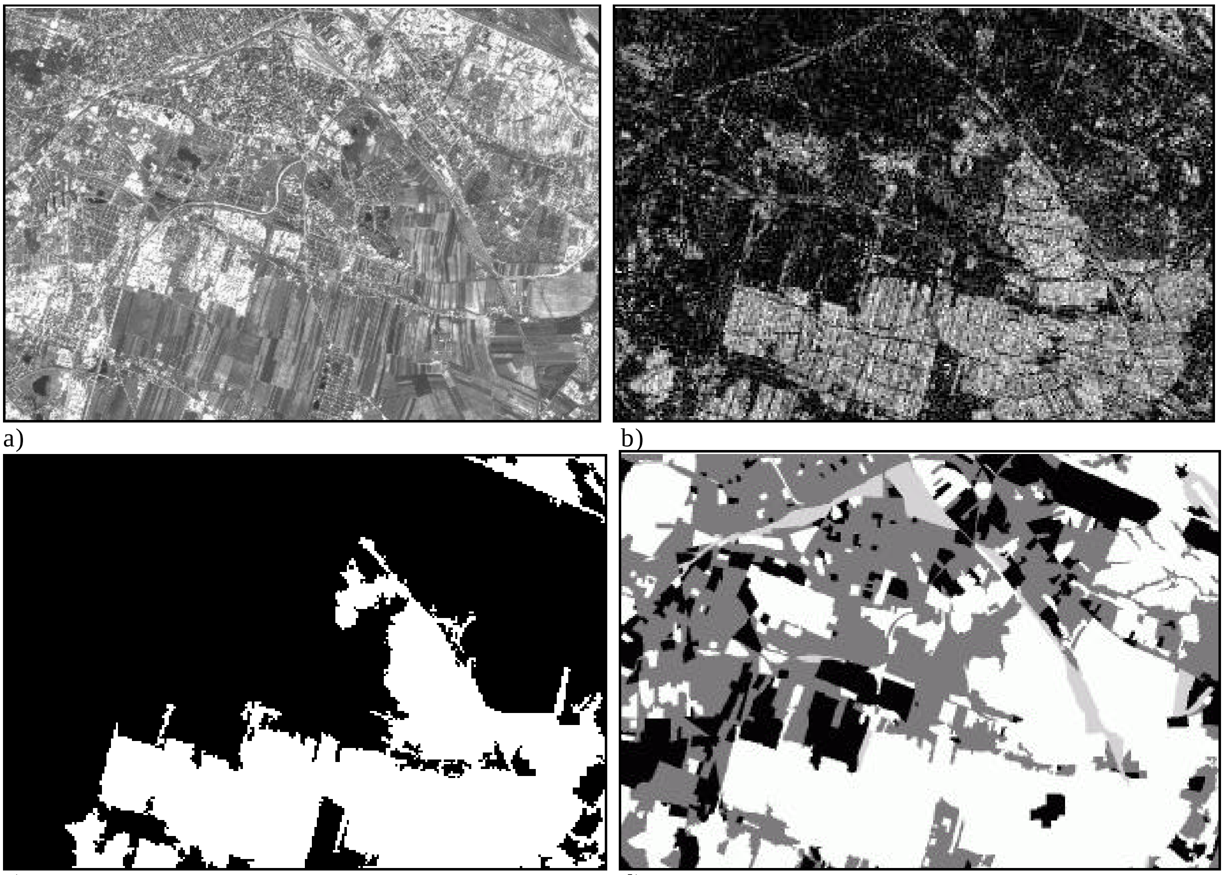
2. Texture Analysis

High spatial resolution satellite images as acquired by KOMPSAT-1 contain a large number of objects. In order to recognize them the human visual system does not only rely on the intensity of single pixels but also, among others, on the spatial variations of these intensities, in general called texture. The method used here to derive textural features uses gray-level co-occurrence (GLC) matrices [1]. The GLC matrix contains estimates for the transition probabilities of the gray-level of two neighboring pixels. In order to obtain a texture feature image the texture is calculated in a moving window for each pixel. The result is a digital image where the single pixel values represent the degree of texture in the local neighborhood.

Considering the different texture features available, the directions and distances that can be used and the variability of the size of the moving window, a huge number of texture feature images can be derived from a single original image. However, for most applications this can be reduced to a reasonable number of images. In terms of directions a minimum number of four is recommended, as they cover all distances that occur in a 3 x 3 neighborhood (horizontal, vertical and the two diagonals).

In addition an appropriate window size has to be chosen. The minimum size of 3 x 3 has a similar effect as a directed edge detection filter. As with all neighborhood algorithms the results will become smoother as the window size increases. At the same time the computational effort will increase exponentially. Considering high resolution panchromatic images as acquired by KOMPSAT-1 window sizes between 7 x 7 and 11 x 11 have given good results.

In order to create a rotation invariant texture image which differentiates between homogenous and heteroge-



a) b) c) d)

Fig. 1. Texture analysis of KOMPSAT-1 panchromatic imagery. a) original KOMPSAT-1 image, b) texture image, c) texture mask, d) refined settlement mask

neous objects, the maximum difference of the different orthogonal texture features is first calculated. If this is subtracted from an average texture image, calculated from all four texture images, rotation invariant objects are preserved, while edges are removed. A detailed description of this method is given in [2].

When applying the above described method to a panchromatic KOMPSAT-1 image (Fig. 1a) the resulting rotation invariant texture image will represent built-up areas as highly textured (Fig. 1b). Using a threshold procedure will lead to a binary mask that can be generalized to eliminate small features. The result is a settlement mask that separates built-up areas from all other land cover types (Fig. 1c).

By visual interpretation the built-up areas are further subdivided into residential, industrial/commercial, transport, administration, water and artificial green areas (parks). In order to allow a visualization the classes for administration and transport were combined to a class called other sealed surfaces. Fig. 1d shows the resulting refined settlement mask. Residential areas are marked in dark gray, industry in black and other sealed areas in light gray. Artificial green areas and water are not shown.

3. Integration of census data

Incorporating census data in the settlement mask allows to perform refined demographic analysis. Assuming that the population lives in settlements rather than in agricultural areas, the census data can be assigned to the actual residential areas within each census unit. Using this information a number of questions can be addressed which cannot be answered by statistical data alone [3].

Comparing the increase of population with the growth of the settlements allows for the derivation of density measures, such as the development of land use per capita. These measures are an indicator for population pressure and also for excessive use of land for building activities. This kind of analysis is of interest on a local planning level (e.g. individual towns) but also on a regional level, indicating different types of population development.

4. Case study

Texture analysis was applied to a panchromatic KOMPSAT-1 image of the surroundings of Vienna, Austria [4], acquired on 1 March 2001, and to a satellite

Fig. 2. Settlement development of the municipality of Vösendorf (light grey indicates built-up areas in 1968, dark grey shows the increase until 2001, black lines are municipality borders)

image taken by the CORONA system on 26 March 1968 [5]. This resulted in settlement masks showing the extent of all built-up areas in the analyzed region and its development between 1968 and 2001. By visual interpretation the settlements were reclassified into residential, industrial/commercial, and transport areas. Based on these data sets it was possible to analyze where building activities have taken place and whether these changes have been due to residential or other developments. Figure 2 shows, as an example, the settlement development of the municipality of Vösendorf, situated in the South of Vienna.

Intersecting the refined settlement mask with the administrative borders results in the assignment of actual settlement areas to the single municipalities. A data base can be generated including residential, industrial/commercial, and transport areas for 1968 and 2001 for each municipality. Population data, available for 1971 and 2001 on a municipality level, is added to the data base as well. Calculating the ratio between residential area and population gives the land consumption per capita and its development over time, a valuable indicator for regional planning activities.

Table 1 shows the results of this analysis for the municipality of Vösendorf. From 1968 to 2001 the size of the residential area has increased from 109 ha to 179 ha. At the same time the population has grown from 3781 to 4913 inhabitants. Looking at the relative growth this equals 64% more residential areas for 30% more people. In other words, today's population needs 74m^2 more space per capita compared to 1971. This is a result of the suburbanization processes that took place during the last 30 years.

Table 1. Development of residential areas, population and land use per capita in the municipality of Vösendorf.

	Absolute values	Difference absolute	Difference relative
Pop 71	3781		
Pop 01	4913	1132	30 %
Res 68	109 ha		
Res 01	179 ha	70 ha	64 %
LU/cap 71	288 m^2		
LU/cap 01	364 m^2	74 m^2	26 %

5. Conclusions

In this study a texture analysis was applied to panchromatic satellite images in order to create settlement masks. Using the proposed method this information can be derived fast and, due to the semi-automatic nature of the procedure, with consistent results across the scene. In a case study two satellite images from 1968 (Corona) and 2001 (KOMPSAT-1) of the surroundings of Vienna, Austria, were analyzed in order to create settlement masks for both dates. By visual analysis the masks were further subdivided into different classes (residential, commercial/industry, transport, water and artificial green areas).

Based on this data set numerous questions can be addressed. They start with the basic question of where and to what extent have building activities taken place. However, by integrating the masks with statistical data much more differentiated information can be derived. As an example the change of population in respect to built up areas was examined and the development of land use per capita estimated. Using a GIS any kind of socio-economic data can be integrated with the settlement mask, giving a better picture not only of what but also of where something is happening, at a spatial scale usually not available outside of large cities.

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