Modeling Middle Urban Population Density With Remote Sensing Imagery

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Key words: population density, least square principle, remote sensing imagery

Abstract: A new land use density method is proposed based on least square principle after analyzing usual remote estimation methods. The main idea is: First, habitation types is defined in the study region; and the boundaries of every habitation types are lined out based on remote sensing imagery and the area of every habitation types are calculated; then mathematical models according to the population data of every sub-region are established; the best population density estimation of every habitation types are calculated with the least square principle when sub-regions number (m) is more than the number (n) of habitation types. The population estimation of any new region can be calculated since the population density of every habitation types are known as well.

1 INTRODUCTION

Population data is very important to stipulate for decision-making for governments. Census is carried out every decades. Though the precision is very high, the cycle is long and the cost is high. So every kinds of population estimation method with low cost and short cycle is worthy studied. People estimated population using remote sensing since 1960 and obtained some results. Wang H H (1990) estimated population in Gulou district in Nanjing in 1990 with land using density method . The sampled region is difficult to select in this method. Wang Faceng (1990) pointed out a method for estimation urban population using multispectral imagery. The land using density algorithm is used in the paper as well. Langford et al. (1991) derived population with LandSat TM imagery. The results were encouraging, but failed in globally applying the regionally derived model. Otherwise, Flowerdew and Green (1992) estimated population density using areal interpolation. Sautton P (1998) modeled population density with night-time satellite imagery and GIS. Langford et al (1994) and LIN Z J et al (2001) modeled population density by means of GIS. The land using density method is used in practice when modeling urban population density. The key of land using density method is the accurate represent of sampled region. The error of population estimation will be notable if sampled region is not correct. In fact, selection sampled regions is very difficult. There is still different between sampled regions and real regions. So errors of population estimation is inevitably. This paper tries to estimate population density of every kind of habitation types avoiding selecting sampled regions. So, usual methods of population estimation is overviewed.

2 Traditional methods for estimation population

In recent decades, scientists have done a lot of works in modeling population density in cities with remote sensing imagery. The main study results are habitation element method, land using density algorithm and built region area method, and so on.

2.1 Inhabitation unit method

The formula of inhabitation unit method is

$$P=N_1F_1+N_2F_2+\ldots+N_nF_n \qquad (1)$$

P is total population, N is average population of every family, F is the count of family, 1…n are inhabitation types.

The distribution and instruction feature of buildings is analyzed with big scale remote sensing imagery. First, Inhabitation area and other building area is distinguished. Then, the type of inhabitation is distinguished and the inhabitation sum of every type is counted. The average population of every family

obtained from sample. This method is fit for big scale remote sensing imagery and the precise of inhabitation count is 99%. The inhabitation is disperse in county. It is easy to count the inhabitation. So this method is fit for county.

2.2 Land use density method

In city, the population density is different from with every kind of land use types. The relation of population and land use type is

$$P=\sum_{i=1}^{n}(A_iD_i) \qquad (2)$$

A_1、A_2…A_n are the area of every land use type. D_1、D_2…D_n are the population density of every land use type, P is total population.

The land use type is obtained from the different of population density. The flow of this method is: first, the inhabitation and the non-inhabitation is distinguished with remote sensing imagery. Every kind of inhabitation type is distinguished in inhabitation area. The boundary of every kind of inhabitation is draw out. Then, the area of every kind of inhabitation is measured. The area of every kind of inhabitation type multiplying corresponding population density from sample is the estimation population of every kind of inhabitation type. The total sum of every kind of inhabitation type is the total population in study area.

3 Land use density method based on least square principle

The excellence of the land use density method is it's idea and calculation is simple; the disadvantage of the method is that the selection of sampled region is much more difficult. Is there a method the population density of every habitation type is estimated but the sampled region need not be selected. In some region, there is mathematical relation among the area, the population density and it's total population of every habitation type. The population density of every habitation type can be estimated via the mathematical relations.

Suppose there are j regions which the population is known, j=1,2…m. The population sum of every region is P_j. There are i kinds of habitation types, i=1,2…n. The population density of every habitation type is D_i, then

$$P_j=\sum_{i=1}^{n}(A_{ji}D_i) \qquad (3)$$

the quantity of (3) is

$P_1=A_{11}D_1+A_{12}D_2+...+A_{1n}D_n$

$P_2=A_{21}D_1+A_{22}D_2+...+A_{2n}D_n$

$P_m=A_{m1}D_1+A_{m2}D_2+...+A_{mn}D_n$

the matrix of (3) is

$$P=AD \qquad (4)$$

$$P=\begin{bmatrix}P_1\\P_2\\...\\P_m\end{bmatrix} \qquad A=\begin{bmatrix}a_{11}\ a_{12}...a_{1n}\\a_{21}\ a_{22}...a_{2n}\\...\\a_{m1}\ a_{m2}...a_{mn}\end{bmatrix}$$

$$D=\begin{bmatrix}D_1\\D_2\\...\\D_n\end{bmatrix}$$

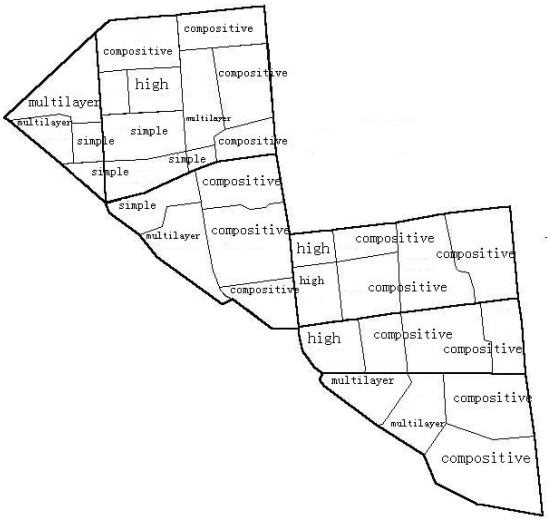
When m>n, that is, the region count known population is more than habitation type count. The least square principle is used to calculate the best population density estimation of every kind of habitation which the errors of statistical population is least.

$$D=[A^TA]^{-1}A^TP \qquad (5)$$

General speaking, the more that m being bigger than n, the more the quality of population density estimation. The population estimation of any region can be calculated since the population density of every habitation types are known as well.

4 Experiment and analysis

There are 6 region which their population known including fengsheglu, daguanzhuang, xihoujie, beidajie, ronghejie and lingyuanxi, etc. The experiment data include 1:10000 remote sensing imagery(1995).



4.1 Habitation types and their area

There are 4 kinds of habitations in the study region: high building, multilayer building, simple building and compositive building. The high building indicates a building with more than 7 layers. The multilayer building indicates a building with from 3 to 6 layers. The simple building indicate a building with less than 3 layers. The compositive building indicate a building which used for business and habitation.

First, habitation region is distinguished from other types. Every kind of habitation is distinguished in habitation region(Fig.1). Then, the boundary of every kind of habitation is drawn out and the area of every kind of habitation is measured(Tab.1)

Fig.1 study region and its habitation types

Tab.1 The area and estimation population density

region	Total area (k m^2)	Habitation type	Area (k m^2)	Estimation density (person/km^2)	Estimation population	total	Statistical population	Relatively error（%）
Fengsheglu	0.09384	multilayer building simple building	0.06945 0.02439	14810 4394	1028 107	1135	1192	-4.7
Daguan zhuang	0.31318	high building multilayer building simple building compositive building	0.02663 0.04028 0.09269 0.15358	49014 14810 4394 1784	1305 596 407 274	2582	2173	18
xihoujie	0.21977	multilayer building simple building compositive building	0.07363 0.03141 0.11473	14810 4394 1784	1090 138 205	1432	1572	-8.9
beidajie	0.23179	high building compositive building	0.04578 0.18601	49014 1784	2243 331	2574	2621	-1.7
yonghejie	0.15311	high building multilayer building compositive building	0.0329 0.02792 0.09229	49014 14810 1784	1612 413 165	2190	2260	-3
lingyuanxi	0.21567	multilayer building compositive building	0.03282 0.18285	14810 1784	486 326	812	889	-8.6
total	1.22736					10725	10707	-0.1

4.2 Models calculation and error analysis

There are 4 kinds of habitation types and 6 sub-region with known population. 6 equations can be listed from formula (3)

$$P_1=A_{11}D_1+A_{12}D_2+A_{13}D_3+A_{14}D_4$$

$$P_2=A_{21}D_1+A_{22}D_2+A_{23}D_3+A_{24}D_4$$

…

$$P_6=A_{61}D_1+A_{62}D_2+A_{63}D_3+A_{64}D_4$$

$P_1 \ldots P_6$ indicate the statistical population. D_1、D_2、D_3、D_4 indicate the population density of high building, multilayer building, simple building and compositive building, respectively. Indicate the area of high building, multilayer building, simple building and compositive building in fenshenglu region, etc(Tab.1).

There is 6 equations and 4 unknown. The best population density estimation of every habitation types are calculated with the least square principle(Tab.1). The precise of population estimation can be calculated using formula 3(Tab.1).

Population of any other new region can be calculated since the population density of every kind of habitation type is known. The experiment result is shown in table 2.

Tab. 2　population estimation of new unknown region

region	Total area (k m^2)	Habitation type	Area (k m^2)	Estimation density (person/km^2)	Estimation population	total	Statistical population	Relatively error（%）
qiliyan	0.30611	high building multilayer building simple building compositive building	0.03364 0.05426 0.04273 0.17548	49014 14810 4394 1784	1648 803 187 313	2951	2773	-6.4
dongshun jie	0.31078	multilayer building simple building compositive building	0.14124 0.02431 0.14523	14810 4394 1784	2091 106 259	2456	2572	4.5
jianshelu	0.2509	high building compositive building	0.05738 0.19352	49014 1784	2812 345	3157	2896	-9.0

5 CONCLUTION

This paper pointed out a new land using density method based on least square principle. The method need not sample the population density of every habitation types. The estimation workload of population density of every habitation type is low. The mathematical models is not influenced by random error of sample. The main idea is: (1) habitation types is defined in the study region; (2) the boundaries of every habitation types are lined out based on remote sensing imagery and the area of every habitation types are calculated; (3) mathematical models according to the population data of every sub-region are established; (4)the best population density estimation of every habitation types are calculated with the least square principle when sub-regions number (m) is more than the number (n) of habitation types. (5)The population estimation of any region can be calculated since the population density of every habitation types are known as well.

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