Mapping Urban Population Distribution Based on Remote Sensing and GIS  
— A Case of Jing'an District, Shanghai

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1. Introduction
2. Methods and Data sets
3. Land use classification
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1. Introduction

1.1 Background

- Population is a key element exposed to natural disasters.
- Urban population distribution is very complex and dynamic. It keeps changing with seasons and holidays, between working days and weekends, days and nights.
- Census data can not indicate spatio-temporal population distribution. In contrast, population mapping based on remote sensing and GIS may provided more actual distribution in urban areas.
1.2 Study area

- Jing'an District, located at the CBD of Shanghai, has a total area of 7.6 km²
- 5 sub-districts, and 71 communities.
- The total resident population is about 304 thousand people according to 2010 census.
2.1 Methods

- Population distribution in a working day was mapped, using dasymetric mapping based on land use.
- A detailed land use classification system was developed for mapping urban population distribution, and
- A detailed land-use in the study area was interpreted from high-resolution aerial photographs.
According to the urban resident activities, we divided a working day into four time periods.

Several models were used for simulating the spatial distribution of population in the four time periods in our study area.

<table>
<thead>
<tr>
<th>Time</th>
<th>Behavior</th>
<th>Population concentration places</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:00-12:00</td>
<td>Working hours</td>
<td>residential land, commercial land, industrial land, public management and public service land</td>
</tr>
<tr>
<td>12:00-13:00</td>
<td>Midday break</td>
<td>residential land, commercial land, green space and square land</td>
</tr>
<tr>
<td>13:00-18:00</td>
<td>Working hours</td>
<td>residential land, commercial land, industrial land, public management and public service land</td>
</tr>
<tr>
<td>18:00-08:00</td>
<td>Nighttime</td>
<td>residential land, commercial land, green space and square land</td>
</tr>
</tbody>
</table>
2.2 Data sets

- Aerial photographs with resolution of 0.25 m in 2012
- The sixth census data of Shanghai in 2010
- Demographic data from Shanghai Civil Affairs Bureau in 2013
- The second economic census data in 2008
- Shanghai administrative division data, and
- In-situ survey data
3.1 Land use classification system for mapping urban population distribution

- Referring to the “Standard of Urban Land Use Classification and Land Use of Planning and Construction (GB50137-2012)” in China and the land use classification system from HAZUS, and
- According to the land use characteristics in Shanghai CBD, a land use classification system was proposed for mapping urban population distribution.
## Jingan district land use classification system

<table>
<thead>
<tr>
<th>Category code</th>
<th>Category name/layer name</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>Residential land</td>
</tr>
<tr>
<td>R11</td>
<td>Low-rise residential</td>
</tr>
<tr>
<td>R12</td>
<td>multi-story residential</td>
</tr>
<tr>
<td>R13</td>
<td>mid high-rise residential</td>
</tr>
<tr>
<td>R14</td>
<td>high-rise residential</td>
</tr>
<tr>
<td>R2</td>
<td>mobile housing</td>
</tr>
<tr>
<td>R3</td>
<td>agencies hostels</td>
</tr>
<tr>
<td>R31</td>
<td>student domitory</td>
</tr>
<tr>
<td>R32</td>
<td>amy domitory</td>
</tr>
<tr>
<td>R33</td>
<td>prison</td>
</tr>
<tr>
<td>R4</td>
<td>community welfare homes</td>
</tr>
<tr>
<td>R5</td>
<td>commercial mixed housing</td>
</tr>
<tr>
<td>R6</td>
<td>other mixed-residential</td>
</tr>
<tr>
<td>B1</td>
<td>commercial facilities</td>
</tr>
<tr>
<td>B11</td>
<td>retail business</td>
</tr>
<tr>
<td>B12</td>
<td>wholesale market</td>
</tr>
<tr>
<td>B13</td>
<td>catering</td>
</tr>
<tr>
<td>B14</td>
<td>hotel</td>
</tr>
<tr>
<td>B15</td>
<td>shopping Centre</td>
</tr>
<tr>
<td>B2</td>
<td>business facilities</td>
</tr>
<tr>
<td>B21</td>
<td>finance and insurance</td>
</tr>
<tr>
<td>B22</td>
<td>arts and media</td>
</tr>
<tr>
<td>B23</td>
<td>other business facilities</td>
</tr>
<tr>
<td>B3</td>
<td>entertainment, leisure and sports facilities</td>
</tr>
<tr>
<td>B31</td>
<td>entertainment</td>
</tr>
<tr>
<td>B32</td>
<td>leisure</td>
</tr>
<tr>
<td>B33</td>
<td>sports facilities</td>
</tr>
<tr>
<td>B4</td>
<td>public management and public service</td>
</tr>
<tr>
<td>B41</td>
<td>administrative Office</td>
</tr>
<tr>
<td>B42</td>
<td>green</td>
</tr>
<tr>
<td>B5</td>
<td>mixed public services</td>
</tr>
<tr>
<td>B51</td>
<td>foreign Affairs</td>
</tr>
<tr>
<td>B52</td>
<td>religious Facilities</td>
</tr>
<tr>
<td>B53</td>
<td>other mixed public services</td>
</tr>
<tr>
<td>B54</td>
<td>mixed public services</td>
</tr>
<tr>
<td>B6</td>
<td>cultural relics and historic sites</td>
</tr>
<tr>
<td>B61</td>
<td>green</td>
</tr>
<tr>
<td>B62</td>
<td>square</td>
</tr>
<tr>
<td>B63</td>
<td>other land use</td>
</tr>
<tr>
<td>B64</td>
<td>waters</td>
</tr>
</tbody>
</table>

### Public management and public service
- A1: administrative Office
  - A11: general Administrative Office
  - A12: emergency response agencies

### Cultural facilities
- A2: cultural facilities
  - A21: book and exhibition facilities
  - A22: cultural activities and other facilities

### Education and research
- A3: education and research
  - A31: inst of higher learning, secondary schools
  - A32: primary and secondary schools
  - A33: school physical education
  - A34: special education
  - A35: scientific research

### Medical and health
- A4: medical and health
  - A41: sports venues
  - A42: sports training
  - A43: medical and health
  - A44: hospital
  - A45: health and epidemic prevention
  - A46: special medical
  - A47: other medical and health

### Other public services
- A5: other public services
  - A51: foreign Affairs
  - A52: religious facilities
  - A53: mixed public services
  - A54: mixed public services

### Cultural relics and historic sites
- A6: cultural relics and historic sites
  - A61: green
  - A62: square
  - A63: other land use
  - A64: waters
3.2 Principles and methods of urban land use classification

- Residential land
- Commercial land
- Industrial land
- Public management and public service land
- Green space and square land
- Water land
- Unutilized land
3.3 Land use in Jing’an District

Legend
- Residential land
- Commercial
- Public management-service
- Industrial
- Piazza and green space
- Waters
- Unused
- Affiliated sites

Area statistics of the land use
- Residential land (R): 47%
- Commercial (B): 22%
- Public management-service (A): 12%
- Industrial (M): 10%
- Piazza and green space (G): 6%
- Waters (E): 2%
- Unused (D): 1%
- Affiliated sites: 1%
Residential land classification and distribution
Commercial land classification and distribution
Public management and public service land classification and distribution
Industrial land classification and distribution
Green space and square land classification and distribution
4.1 Nighttime population distribution model

\[ BP_i = BA_i \times BH_i \left( \frac{CP}{\sum_{k=1}^{n} BA_k \times BH_k} \right) \]

where \( BP_i \) is the population of building \( i \), \( CP \), the census tract population, \( BA_i \), the footprint area of building \( i \), \( BH_i \), the average height of building \( i \), \( i, k \), summation indices, and \( n \), the number of buildings.
4.2 Results of nighttime population distribution

Legend
Night-time population distribution
- Low
- Relatively low
- Medium
- Relatively High
- High

Nighttime population distribution
- Low: 19%
- Lower: 6%
- Medium: 4%
- Higher: 3%
- High: 1%
4.3 Population distribution in residential land during daytime

\[ P_Y = P_n \times \alpha \]

where \( P_Y \) is the population of residential land during the daytime, \( P_n \), the population of residential land at night, \( \alpha \) = the percentage of infants and aged people.
4.4 Population distribution in nonresidential land during daytime

\[ P_d = \frac{A_m}{\sum A_m} \times P_s \times k_m \]

where \( P_d \) = the population of rest type land during the day, \( A_m \) = the area of rest type land, \( P_s \) = the population of working and students, \( k_m \) = the attracting ratio of every type land.

In situ survey for \( k_m \) of 20 sub-categories was carried out at 163 sites.
Daytime population distribution during working hours

Legend
Work in the day time population distribution
- Low
- Relatively low
- Medium
- Relatively high
- High

The proportion of the population distribution during the day time

- Low: 11%
- Lower: 20%
- Medium: 24%
- Relatively high: 21%
- High: 24%
4.5 Population distribution during midday break

\[ f_h(x) = \frac{1}{Nh} \sum_{i=1}^{N} K \left( \frac{x - x_i}{h} \right) \]

\[ K(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}x^2} \]

where \( K(x) \) is a Kernel density, \( h \), the distance of scope, \( n \), the number of dots in the scope.
4.6 The green and square land population distribution during the day

\[ P_g = \sum \frac{P_i}{A_i} \times \frac{1}{n} \times A_g \]

where \( P_g \) is the population of green and square land, \( P_i \), the population of survey, \( A_i \), the area of survey, \( n \), the number of survey places, \( A_g \), the total area of green and square land.

<table>
<thead>
<tr>
<th>Time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:45-13:00</td>
<td></td>
</tr>
<tr>
<td>12:30-12:45</td>
<td></td>
</tr>
<tr>
<td>12:15-12:30</td>
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<tr>
<td>12:00-12:15</td>
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<tr>
<td>18:45-19:00</td>
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<tr>
<td>18:30-18:45</td>
<td></td>
</tr>
<tr>
<td>18:15-18:30</td>
<td></td>
</tr>
<tr>
<td>18:00-18:15</td>
<td></td>
</tr>
</tbody>
</table>
4.7 Gridded population density during nighttime
4.8 Gridded population density during daytime

Population distribution in residential land during daytime
Population distribution during working hours
5. Concluding remarks

- We developed a land use classification system for mapping urban population distribution, and interpreted detailed land-use in the study area using high-resolution aerial photographs. We simulated urban population spatial distribution in four time periods in a routine working day.

- However, urban population movement is complex in reality, especially dynamically changes on holidays, with different seasons.

- We didn’t consider population attributes closely related to social vulnerability, such as aged, children, female, disabled, and more efforts should be made in further study.
Thanks!