SLUM MAPPING: MAPS AS INFRASTRUCTURES OR INFRASTRUCTURING MAPPING?

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CONTENT

- Slums, slum dwellers and slum mapping requirements
- Infrastructure
- Slum mapping methods and examples
- Infrastructuring slum mapping?
The nature of slum dwellers and slums

Who are slums dwellers? Urban households lacking at least 1 of the following:

- Adequate water
- Adequate sanitation
- Sufficient living space
- Secure tenure
- Durable housing (quality of structures & environment – hazards)

UN-HABITAT 2002
SLUMS: spatial concentration of slum dwellers - diversity of physical forms and settings

Kampala
Uganda

Cairo
Egypt

Kisumu
Kenya

Ahmedabad
India
How can we define slums spatially and characterize their conditions from aerospace images?

- Emphasis on slum indicator: **durable housing**
- Description of **settlement extent and pattern**
  - Dwelling size and type
  - Roof materials – quality?
  - Orientation of buildings and road network
  - Absence/presence of vegetation
- Identification of **hazardous locations**
  - Natural hazards – requires specialist knowledge and data (e.g., DEM, drainage, rainfall, soil, slope stability, etc.)
  - High-risk zones through mapping of traffic infrastructure and industrial sites – needs knowledge of production processes, waste disposal and good transport routes, volumes etc.
IS IT SO STRAIGHTFORWARD?
COMMON PHASES OF SLUM DEVELOPMENT

- **Infancy**: initial land occupation and construction (bridge-headers)
- **Consolidation**: Bridge-headers expand, improve housing and individual services; increasing subdivision, construction and tenancy
- **Maturity**: private space maximised at expense of public space; total build out, congestion and infrastructure improvement only at expense of demolition

**Formal slum development** result of different process associated with *filtering* and physical decline of buildings and infrastructure
SLUM DEVELOPMENT PROCESS

- Key aspects for mapping purposes
  - Speed of development
  - Level of spatial order (access as well as building layout)

- Other aspects
  - Building type
  - Building size
  - Density
  - Road networks and access

- Changes in the above and more
## The physical nature of slums: possible morphological characteristics of slum areas and planned areas

<table>
<thead>
<tr>
<th>Morphological features</th>
<th>Slums /informal</th>
<th>Formal /planned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>• Small (substandard) building sizes</td>
<td>• Generally larger building sizes</td>
</tr>
</tbody>
</table>
| **Density**            | • High densities (high roof coverage)  
                         • Lack of public spaces within or in the vicinity of residential areas | • Low – moderate density areas  
                         • Provision of public spaces within or in vicinity of residential areas |
| **Pattern**            | • Organic layout structure (disorderly road network and noncompliance with planning standards) | • Regular layout pattern (orderly road network and compliance with planning standards) |
# REQUIREMENTS

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Slum settlement level</th>
<th>City wide level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial level</td>
<td>Building – settlement</td>
<td>Settlement-environs-city</td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>Very high (&lt; 1m)</td>
<td>Medium – Very high</td>
</tr>
<tr>
<td>Temporal resolution</td>
<td>Annual or more frequent e.g. upgrading projects</td>
<td>1-5 years depending on growth rates and capacity</td>
</tr>
<tr>
<td>Spectral resolution etc.</td>
<td>Generally optical (possibly also oblique or terrestrial, LIDAR)</td>
<td>Optical VHR Radar (DLR)</td>
</tr>
<tr>
<td>Applications</td>
<td>Topographic mapping Regularization of tenure Settlement upgrading Vulnerability assessment</td>
<td>Topographic mapping Urban (slum) policy and strategic planning Monitoring (modelling) Urban growth monitoring Vulnerability assessment</td>
</tr>
</tbody>
</table>
WHAT IS INFRASTRUCTURE?

Some definitions

- Oxford Dictionary: A collective term for the subordinate parts of an undertaking; substructure, foundation;

- Larkin: “built networks that facilitate the flow of goods, people or ideas and allow for their exchange over space .... providing the undergirding of modern society, and they generate the ambient environment of everyday life.”

- So are (slum) maps infrastructures? Or can they be conceived of as such? And is there a difference between paper maps and digital maps in this respect?
WHEN IS AN INFRASTRUCTURE?

- Star and Ruhleder take a different view - ethnographic perspective.: “a thing becomes a tool in practice” – when it is used.
- “.. infrastructure is something that emerges for people in practice, connected to activities and structures.”
- So the question is not “what” but “when” and I would argue how?
- “As we learn to rely on electricity for work, our practices and language change, we are “plugged in” and our daily rhythms shift. The nature of scientific and aesthetic problems shift as well.”

- Bateson: “What can be studied is always a relationship or an infinite regress of relationships. Never a ‘thing.”
KEY CHARACTERISTICS OF INFRASTRUCTURE
STAR AND RUHLEDER

- Embeddedness.
- Transparency.
- Reach or scope.
- Learned as part of membership.
- Links with conventions of practice.
- Embodiment of standards
- Built on an installed base.
- Becomes visible upon breakdown.
SOME EXAMPLES OF SLUM MAPPING
Data sources
Platforms: from space to unmanned aerial vehicles, terrestrial including analogue methods.
Trends in geo-spatial technologies
Increasing spatial, spectral and temporal resolutions

- **WorldView 2 - 2009**
  - VNIR: 1.8 m (8 bands)
  - PAN: 0.5 m

- **WorldView 3 - 2014**
  - VNIR: 1.24 m (8 bands)
  - PAN: 0.31 m
  - SWIR: 3.7 m
  - CAVIS: 30 m
Trends in geo-spatial technologies
Ultra-high resolution imagery from UAVs

Source: Caroline Gevaert, Faculty ITC.
Agatare slum, Kigali Rwanda
Trends in geo-spatial technologies
Open data and software

- Increasing availability of open data – e.g. promoted by Group on Earth Observation – many countries now make certain types of images freely available but not VHR images.
- Internet platforms for access to data and maps: OpenStreetMaps, Google Earth/Maps/Map maker, India’s Buhvan server and Wikimapia etc.
- Numerous open source software packages (e.g. QGIS, ILWIS, GRASS, etc.)
- Advanced methods for data fusion, dense image matching, etc. to improve data extraction and quality.
Slum map makers - 4 broad communities

- Professional
  - Public data &
    - Mapping services
- Academic
  - Researchers &
    - New technologies & methods
- NGO/CBO
  - Participation &
    - Empowerment
- Professional
  - Commercial data &
    - Mapping services

How are slums being mapped?
How are slums being mapped? 
Research: object based data extraction

Geographic object based image analysis

Segmentation:
spectral, spatial properties, scale
Classification, cleaning
Object based classification of slums in Pune India

Correctly identified Slums (light blue)

Confusion in Historic city centre area

Source: Kohli et al:2014
Deep learning approach: learn spatial-contextual features from the image instead of extracting "handcrafted features" [1].

SOME PRELIMINARY RESULTS IN DAR ES SALAAM
Participatory slum mapping
NGO/CBO approaches
Informal settlements in Kawempe Division Kampala

KAWEPE: SLUM COVERAGE

- 75% Non-Slum Areas
- 25% Slum Area
KNOW YOUR SLUMS KNOW YOUR CITY

Select a country...
Sharing Available Information through GIS

Manual

How to create a recent map of the area?

Nowadays, the easiest way of creating a map of a certain area is to use a satellite image as a master copy. Satellite images from almost any place in the world can be found on the Internet. These satellite images can be downloaded and saved in an easy-to-use format. Satellite images provide you with very exact information on the layout of an area. They show the real physical situation at a given moment. They are usually quite up-to-date, often not more than a few years old.

How to find satellite images on the internet?

All you need is a computer with an operating system that meets certain specifications (see website for a reference), and an internet connection. Go onto the internet and visit the site: http://earth.google.com. The internet site is in English and Arabic. At this internet address you can download a program called Google Earth. The installation process is quite simple and straightforward. Just follow the instructions on the screen and you will easily manage to install the program on your computer. Once this is done, you can open the program and navigate to any place on the planet you would like to see from a bird’s eye view.

The following section will explain:

- How to create a recent map of the area?
- How to find satellite images on the internet?
- How to obtain a high resolution satellite image of your area?
- How to derive a map of the area from the satellite image?
ACADEMIC RESEARCH

IDENTIFY BUILDINGS, TERRAIN, VEGETATION, OTHER OBJECTS

PhD research: Caroline Gevaert.
Supervisors: Prof. G. Vosselman, C. Persello, R. Sliuzas
FEATURE EXTRACTION FRAMEWORK

- **2D - Orthomosaic**
- **2.5D - DSM**
- **3D - Point Cloud**

Feature Extraction

Classification Algorithm (SVM) using different feature sets

Take highest point
3D FEATURES (POINT CLOUD)

SPATIAL BINNING + PLANAR SEGMENTS + POINT-BASED

- Spatial binning
  - # of points
  - Height difference
  - Height std. dev.

- Planar segments
  - # of points
  - Avg. residual
  - Inclination angle
  - Max. height difference to surrounding points

- Point-based
  - Planarity, linearity, scattering, etc. of local neighborhood
FEATURE EXTRACTION - RESULTS

COMPARISON SETTLEMENTS IN RWANDA AND URUGUAY

<table>
<thead>
<tr>
<th>RGB image</th>
<th>2D</th>
<th>2D + DSM</th>
<th>2D + 3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rwanda</td>
<td><img src="image1" alt="RGB image" /></td>
<td><img src="image2" alt="2D" /></td>
<td><img src="image3" alt="2D + DSM" /></td>
</tr>
<tr>
<td>Uruguay</td>
<td><img src="image5" alt="RGB image" /></td>
<td><img src="image6" alt="2D" /></td>
<td><img src="image7" alt="2D + DSM" /></td>
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</tbody>
</table>

- Buildings
- Vegetation
- Terrain
- Structures
- Clutter
### FEATURE EXTRACTION - RESULTS

#### QUANTITATIVE EVALUATION

<table>
<thead>
<tr>
<th>Input</th>
<th>Feature set</th>
<th>N</th>
<th>Overall Accuracy (%)</th>
<th>5-class</th>
<th>10-class</th>
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</thead>
<tbody>
<tr>
<td>Orthomosaic</td>
<td>Radiometric</td>
<td>7</td>
<td>81.0</td>
<td>71.3</td>
<td></td>
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<tr>
<td></td>
<td>Radiometric + Texture</td>
<td>75</td>
<td>78.6</td>
<td>62.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Radiometric + Texture over segments</td>
<td>82</td>
<td>90.8</td>
<td>81.8</td>
<td></td>
</tr>
<tr>
<td>Orthomosaic + DSM</td>
<td>Radiometric + DSM Tophat filters</td>
<td>20</td>
<td>86.9</td>
<td>77.7</td>
<td></td>
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<tr>
<td>Orthomosaic + Point cloud</td>
<td>Radiometric + Texture and 3D over segments</td>
<td>103</td>
<td>91.5</td>
<td>84.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Radiometric + Texture and 3D over segments + Feature selection</td>
<td>34</td>
<td>91.1</td>
<td>82.9</td>
<td></td>
</tr>
</tbody>
</table>
5.2% improvement over single-kernel SVM and 4.1% over random forests.
CLASSIFICATION RESULTS

EXTENDED STUDY AREA (KIGALI, RWANDA)
REFLECTIONS ON INFRASTRUCTURING SLUM MAPPING
Most slum mapping is done on a snapshot basis – time-series may or may not be made depending on context, user needs and long term commitment (organizational capacity)

The process of slum mapping is both socially and technically defined and therefore contextually bound

- Which areas are mapped and which not and why?
- Who decides how slums are defined?
- What mapping technologies and approaches are used – images, terrestrial?
- Who maps, how and what?
- What quality and precision requirements are used – do they meet official standards?
- Who has access to the data?
- How is the data used?
- etc.
SOME IMPLICATIONS OF KEY CHARACTERISTICS OF INFRASTRUCTURE

- Embeddedness – slum mapping often not a structural component of mapping and related processes.
- Transparency – distinction between bottom up and top-down approaches
- Reach or scope – specific slums more likely than city-wide, regular updating may be unlikely.
- Learned as part of membership – bottom-up more inclusive and community learning: various aspects – site, place in the city, mapping methods.
SOME IMPLICATIONS OF KEY CHARACTERISTICS OF INFRASTRUCTURE

- Links with conventions of practice: community participation approaches shapes the bottom-up approach while professional practice conventional mapping but both draw on scientific developments related to new Geo-spatial technologies.
- Embodiment of standards: wide use of space images, UAV images and access to GI and EO software allows bottom up approaches to meet local standards but there may be conflicting views of mapping requirements related to content and accuracy.
- Built on an installed base – must adapt to existing standards, fit to other local initiatives e.g. resident saving schemes, immunization programmes, land tenure registration.
- Becomes visible upon breakdown: subject to intermittent power supplies, need for regular updating to maintain usefulness.
SOME REFERENCES


THANKS FOR YOUR ATTENTION