Urban Extraction Using Sentinel-1 SAR & Sentinel-2 MSI Dense Time Series with Google Earth Engine

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Where do we stand on Earth Observation?

- Thanks to the fast growth of satellite technology we are moving forward into a new era of Earth Observation Big Data.
- Both National and International space agencies and innovative companies are supporting various EO programs acquiring huge amounts of data every day.
Earth Observation Big Data: Opportunities & Challenges

- **Opportunities**
  - Near-real time monitoring of phenomena affecting built and natural environment
  - Dense time series for analysis of global environmental changes
  - New possibility to deploy operational and reliable services

- **Challenges**
  - Exploit innovative computing infrastructure to handle, store and process the data
    - ESA Thematic Exploitation Platform
    - Copernicus Data and Information Access Services (DIAS)
    - Google Earth Engine
  - Develop new methods and algorithms to extract valuable information combining different sensors (i.e. Sentinels 1 & 2) and products (i.e. DSMs, Land Cover Maps)
  - Integrate the analysis of the EO imagery with other geospatial big data (i.e. social media, ground sensors (i.e. GNSS), crowdsourced data)
Research Objectives

- **Why Urban Mapping?**
  - Today, 54% of the world’s population lives in urban areas.
  - By 2050, the world is expected to add an additional 2.5 billion urban dwellers.
  - Nearly 90 percent of the increase is concentrated in Asia and Africa.
  - Urbanization has a significant impact on the environment.

- **The objective** is to evaluate Sentinel-1 SAR and Sentinel-2 MSI dense time series for developing a global approach to continuously extract urban footprints to support smart and sustainable urban development.

- Follow-up of the EO4Urban Project Funded by the European Space Agency
Existing Urban Dataset:

- **DLR Global Urban Footprints (GUF):**
  - Global coverage derived from TerraSAR-X data (90% of the data acquired in 2011-2012)

- **JRC Global Human Settlement Layer (GHSL):**

- **JRC GHS Built-Up:**
  - Global coverage derived from Sentinel-1 data (2016 beta version)

- **Urban Layer in GlobeLand30:**
  - Global coverage derived from Landsat data

- **Atlas of Urban Expansion (NYU):**
  - 200 cities global, derived from Landsat data
Google Earth Engine (GEE) is a computing platform released by Google “for petabyte-scale scientific analysis and visualization of geospatial datasets”:

- GEE enables researchers to access geospatial information and satellite imagery, for global and large scale remote sensing applications (over than two petabytes of geospatial data)

- GEE can be used to perform geospatial analysis, exploiting a dedicated HPC infrastructure, also running user-developed software through the GEE API
We developed a GEE App to compute the Urban Footprint using S1 & S2

- Totally automatic workflow
- Selection of the AOI and the sensing period (i.e. Jan 2016 to June 2016)
- Fast processing exploiting the GEE potentialities (around 5/10 minutes for a city)
- Combine use of Sentinel-1 SAR and Sentinel-2 MSI data
- Free and open source software (first release expected June 2019)
We applied the method on subsequent periods with a time span between 6-12 months.

We automatically generate consistent urban footprint time series.
Validation Dataset

- Six cities investigated characterized by different morphology, climate and terrain
- > 10000 of validation points for each city (acquired in the ESA EO4Urban project)
- Comparison with available global datasets:
  - DLF GUF - Global Urban Footprint TerraSAR-X data acquired between 2011-2012
  - JRC GHS (Global Human Settlement)
## Accuracy Assessment Beijing

<table>
<thead>
<tr>
<th>Dataset (start date)</th>
<th>Producers Accuracy (%)</th>
<th>Users Accuracy (%)</th>
<th>Overall Accuracy (%)</th>
<th>Kappa Coefficient</th>
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GEE 2016-01-01
GEE 2016-04-01
GEE 2016-07-01
GEE 2016-10-01
GEE 2017-01-01
GEE 2017-04-01
GEE 2017-07-01

Kappa Coefficient

*2019 DRAGON 4 SYMPOSIUM
24–28 June 2019 | Ljubljana, Slovenia*
Beijing Results
Beijing Results: Issues

KTH GEE UE results 2017

GUF results (2011-2012)
Beijing Results: Changes

KTH GEE UE results 2017

GUF results (2011-2012)
### Accuracy Assessment Stockholm

<table>
<thead>
<tr>
<th>Dataset (start date)</th>
<th>Producers Accuracy (%)</th>
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![Kappa Coefficient Graph](chart.png)
Stockholm Results
Stockholm Results

KTH GEE UE results 2016

GUF results (2011-2012)
Stockholm Results: Urban Changes

KTH GEE UE results 2017

GUF results (2011-2012)
### Accuracy Assessment Milano

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<th>Dataset (start date)</th>
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## Accuracy Assessment Mexico City

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![Kappa Coefficient Graph](image)
Conclusions & Future Prospects

The developed method is able to:

- achieved good results ($k > 80\%$) in the different tested cities
- exploiting the fusion of S1 & S2 data
- produce urban footprint time series exploiting the processing capabilities of GEE

Next steps:

- Applied the method for large scale urban mapping and improve the accuracy assessment using other reference data
- Investigate the generated urban footprint time series to track the changes and improve the overall accuracy