Using Satellite Data for Studying the Urban Environment

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SPACE4U EU law, policies, actions & technology
JEAN MONNET CHAIR

EUSPACE European Union in Space
JEAN MONNET MODULE

Outline

- Introduction
  - Satellite observation of urban areas
  - Role of machine learning and AI
- Case study I
  - Urban vacant land: the URBIS project
- Case study II
  - The IEEE GRSS Data Fusion Contest
- Conclusion

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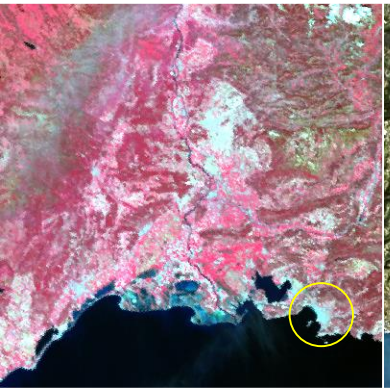
Satellite observation of urban areas

- Earth observation from space
  - Global coverage through satellite optical and radar sensors
  - Very high spatial resolution (VHR; up to 30 cm) and short revisit time (up to 12 h) with recent space missions
- Extraordinary potential for applications to urban areas


Marseille • 500 m

Nice • 30 m

Genoa • 10 m

Venice • 2 m

Madrid • 30 cm

The need for data interpretation

Many applications of satellite observation of urban areas e.g.:	Urban planning, conservation, development, growth patterns	Urban and peri-urban ecology and climatology	Disaster risk prevention and management in urban areas
But how to	use satellite images for these applications?	extract useful info from satellite data?	interpret possibly huge satellite data sets?
Methodological tools provided by	Pattern recognition	Machine learning	Artificial intelligence

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The URBIS project • 2014-2017

- Funded by

European Commission

cip competitiveness and innovation framework programme 2007–2013

- Project team

gisat (Coordinator, CZ)

UNIVERSITÀ DEGLI STUDI DI GENOVA (IT)

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STADTLAND (DE)

adu a Agence de développement et d'urbanisme du Grand Amiénois (FR)

SIRS (FR)

The URBIS project

- Objective
  - Developing services based on satellite imagery to support sustainable city development with focus on vacant urban land
- Why?
  - Annual land take by urbanization is still quite high all over EU.
  - Re-use of urbanized land needs promoting and increasing.
  - Crucial role for sustainable urban development in the future
  - Earth observation provides means for EU-wide monitoring.
  - More and more satellite data available through EU and ESA initiatives: the Copernicus program

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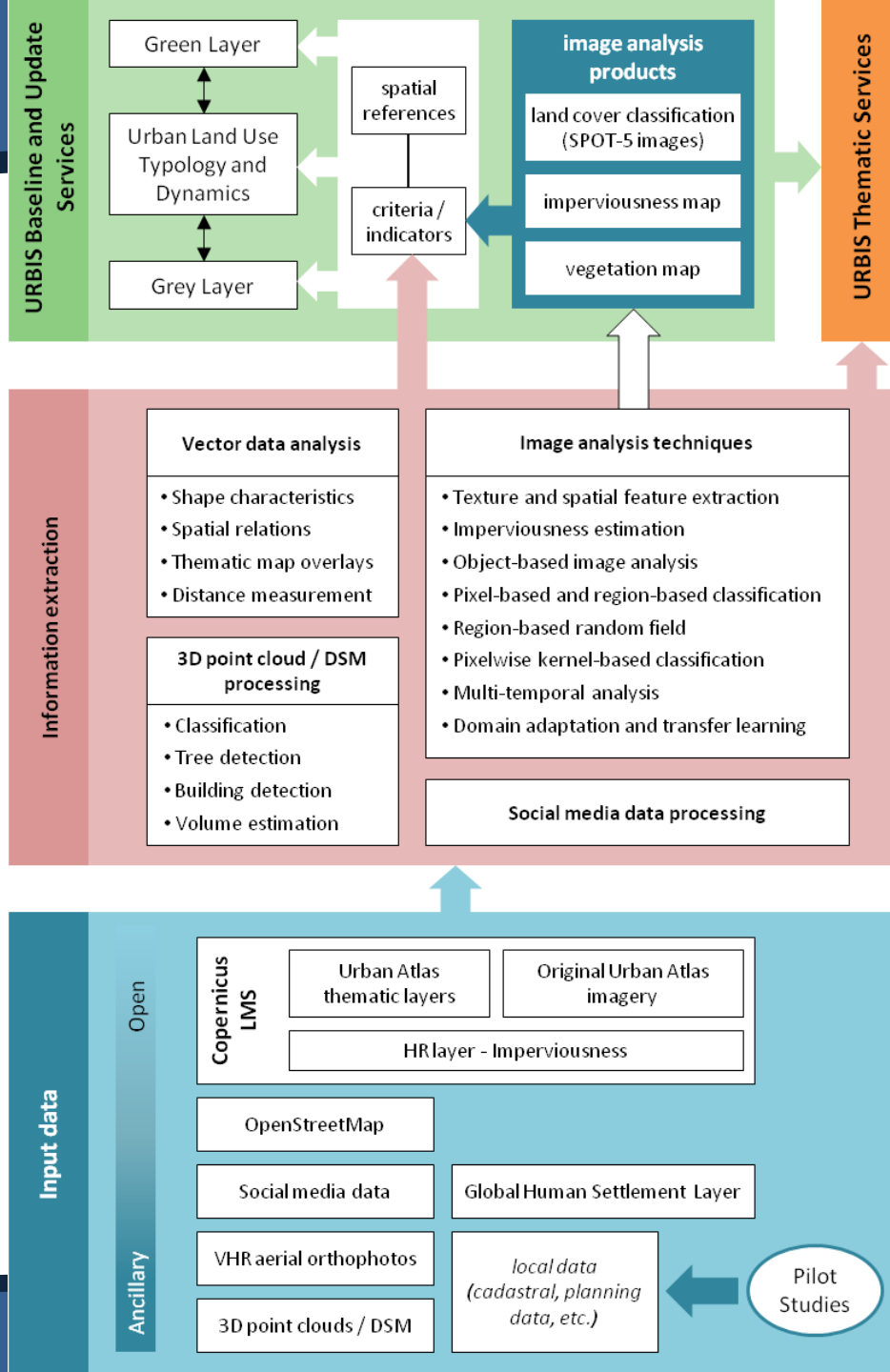
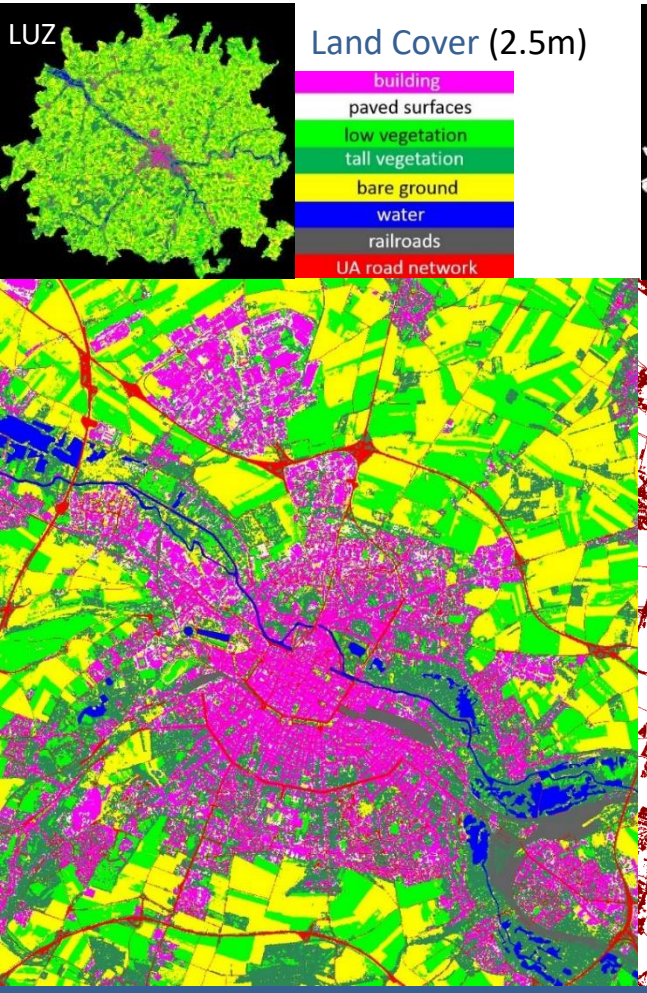
Overall project idea

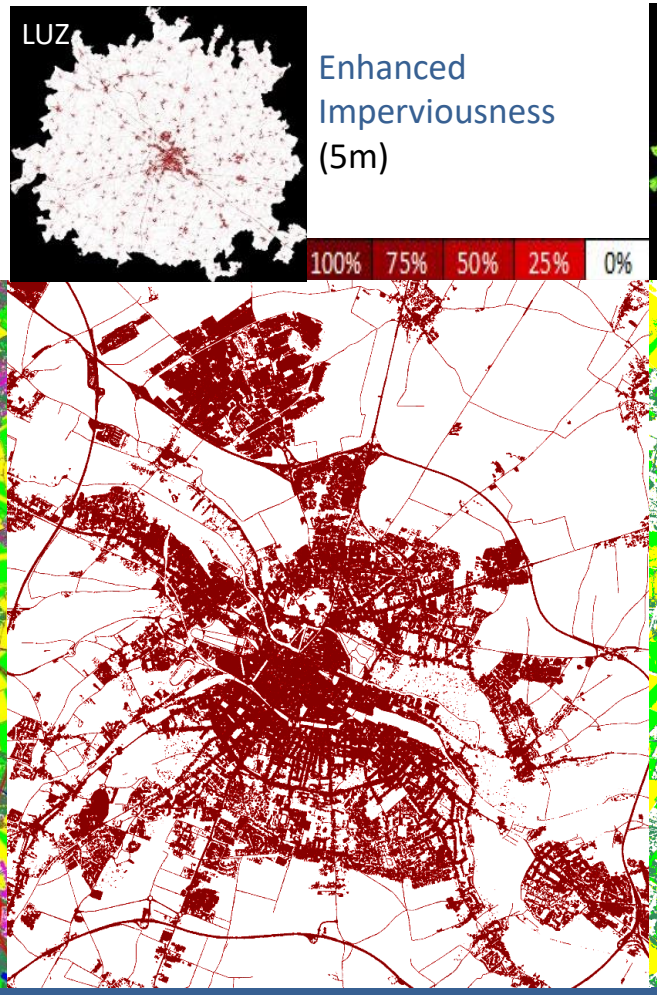
- Complex processing chain
  - Machine learning for satellite image analysis ▶ our lab at U Genoa
  - GIScience (geographic information science)
- Using both
  - satellite data
  - and pre-existing urban mapping databases (Copernicus Urban Atlas)
- To map
  - green areas
  - built-up areas and imperviousness
  - land use typology and dynamics
- Over European large urban zones (LUZs)
  - 50K+ inhabitants
  - 3 pilot sites: Amiens (FR), Ostrava (CZ), Osnabrueck (DE)

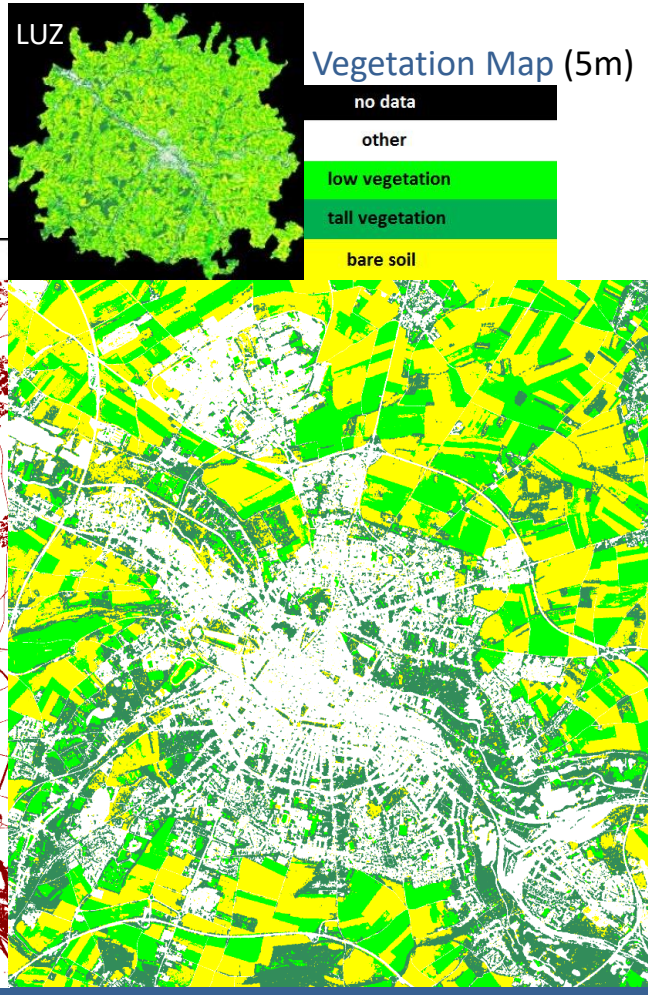


Examples of results

Land cover, imperviousness, and vegetation maps generated through the application of ensemble learning methods of our lab to satellite images and to Urban Atlas data of the entire LUZ of Amiens



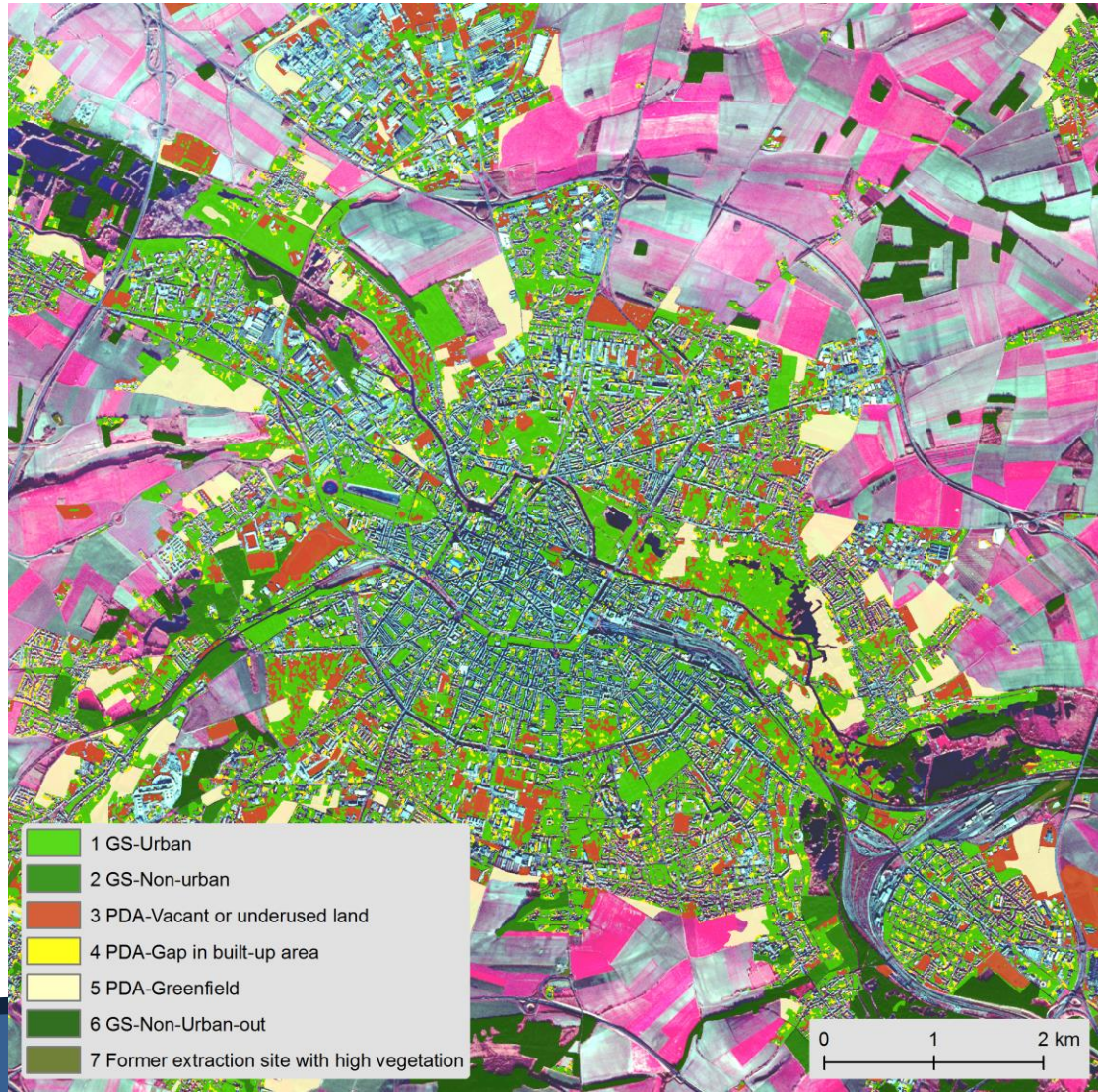




Examples of results

Green and open space layer, generated over Amiens at 5m resolution:

- It identifies green areas, vacant and underused land, gaps in the urban fabric, etc. (potential development areas, PDAs).
- Crucial role of the synergy between machine learning for satellite data analysis and GIScience for ancillary data integration



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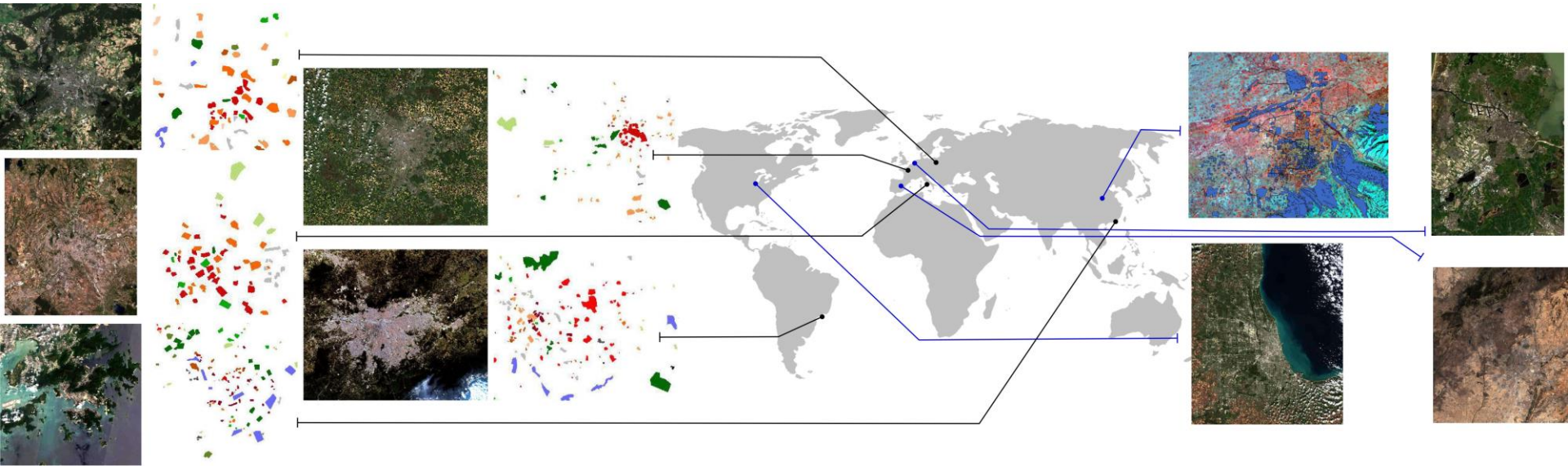
IEEE GRSS Data Fusion Contest

- Annual international image analysis competition (since 2006)
  - Organized by
    - Image Analysis and Data Fusion Technical Committee of
    - Geoscience and Remote Sensing Society of
    - Institute of Electrical and Electronics Engineers
  - Aims at promoting progress on methods for the interpretation of multisource satellite data
- Latest editions
  - Focus on satellite observation of urban areas
  - Hundreds of submissions from 50+ countries
  - IADF was (co)chaired by our lab from 2013 to 2017

2017 Contest • Open Data for Global Multimodal Land Use Classification

- Participants were supposed to develop methods to:
  - Learn to determine land use at 100m from satellite imagery and ancillary info of Rome, Paris, Berlin, Hong Kong, Sao Paulo
  - Map land use over Madrid, Amsterdam, Chicago, Xi'an
- Ground truth was available on the former cities (for learning) and totally undisclosed on the latter cities (for testing).



The winners

Built types						Land cover types					
#	class		#	class		#	class		#	class	
1	Compact high-rise		6	Open low-rise		101	Dense trees		106	Bare soil / sand	
2	Compact midrise		7	Light low-rise		102	Scattered trees		107	Water	
3	Compact low-rise		8	Large low-rise		103	Bush, scrub				
4	Open high-rise		9	Sparsely built		104	Low plants				
5	Open midrise		10	Heavy industry		105	Bare rock / paved				

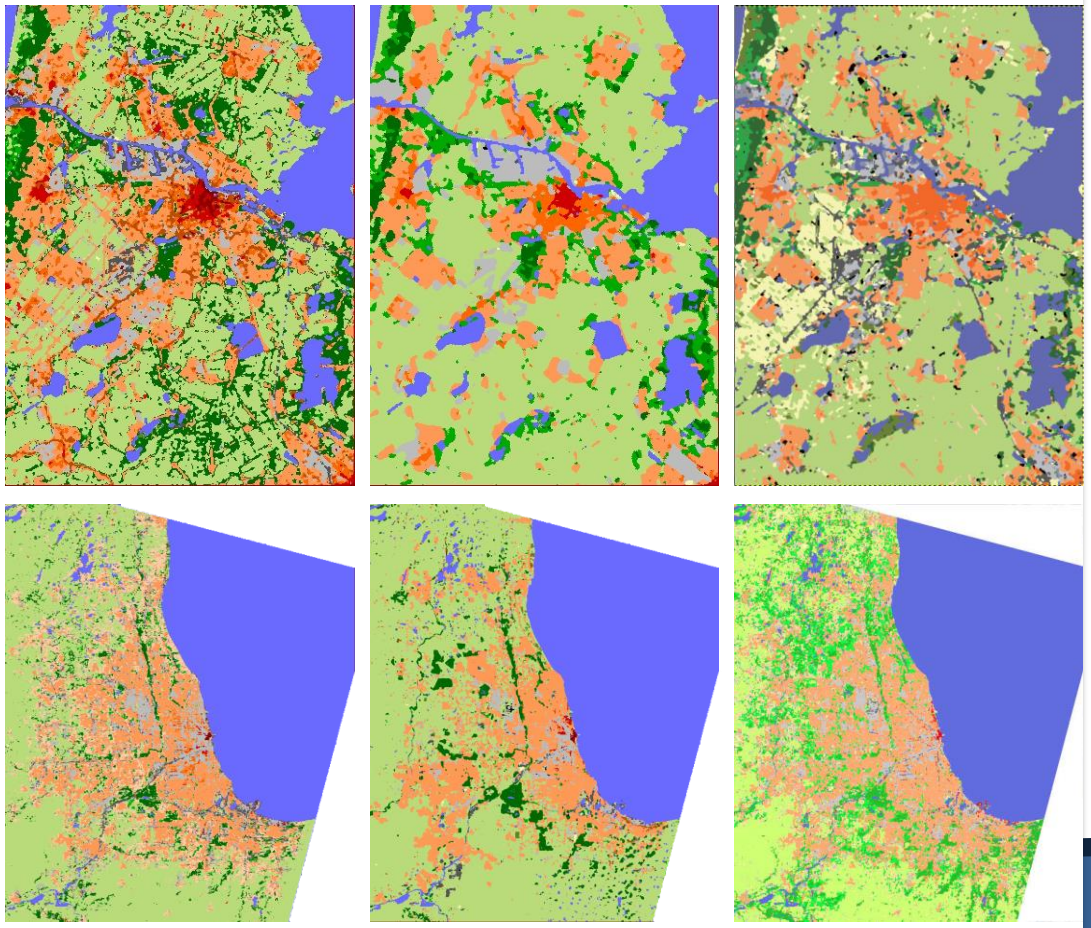
1st place
U Tokyo & DLR

2nd place
AGT International

3rd place
Brazilian Air Force

Amsterdam

Chicago



Highly challenging competition

- Learn a complex relation between satellite data and land use and export it across cities all over the globe
- Addressed by the participants by combining advanced learning approaches: ensemble learning, deep learning, etc.
- Reached satisfactory accuracy (75%) in spite of a very challenging task

2016 Contest • Very High Temporal Resolution from Space

Images and video from space (Vancouver)

- Satellite images, March and May 2015, 1m and 4m resolution
- Video taken by a camera onboard the International Space Station, 30 s, 3 frame/s, 1m resolution

Paper submissions

- Participants were supposed to propose novel methods to analyze these data.
- Papers were ranked by a committee.

3 frames from the video

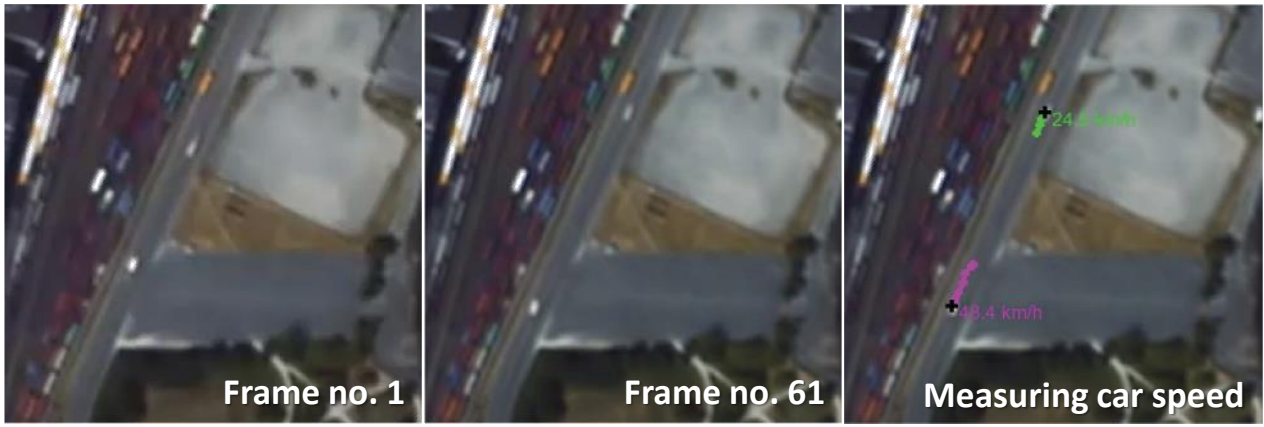
The winners

urban vegetation harbour river

1st place (DLR, Munich): land cover mapping, temporal activity analysis, object tracking from space

Topical case study exploring the potential of a highly novel type of data, video from space

- Opens the possibility to new applications to activity analysis, tracking, population modeling, etc.
- Methodological contributions mixing advanced machine learning and video processing



Zoom on the activity analysis and tracking result, including the measurement of the speed of individual objects (cars)

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Conclusion

- Wealth of satellite data together with advanced machine learning: big potential for urban area applications
  - From global scale across multiple continents to local scale at very high temporal resolution
  - From widely investigated land cover mapping to very new applications to activity analysis
  - As a support to urban planning, monitoring, and sustainability
- Need for the development of accurate, fast, and effective machine learning methods to extract useful info from satellite data with higher and higher spatial and temporal resolution

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