Space 4 cities

New Space Economy

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Video

Introduction

- **Welcome!**
- **Today we talk about**
  - Cities
  - Space technology to observe them
- **We will use examples from**
  - Planning
  - Renewable energy

So welcome, my name is Devis Tuia, I am the head of the Environmental Computational Science and Earth Observation Laboratory of EPFL in the Sion Campus in Valais. And today, I'm a host to talk about Space for Cities. And in particular, to discuss with you what is the potential of space data to observe urban areas, cities in general, and also see what is the potential impact to a lot of application from planning to renewable energy consumption.

Notes

Summary

0m 04s

So let's get started. When we study cities, we basically observe that it's an important problem because most of the world population nowadays lives in cities. And cities are becoming more and more complex and if you look at this image of Tokyo, you can see that there are several different aspects at work. That would be human mobility, transportation, the organisation, the planning of the building environment, and all this is very difficult to grasp using only a terrestrial view of the city. And this is not only true for megacities like the one you see in this image, all this complexity can also be observed across geographies.

Notes

Summary

0m 38s

More than half the world population lives in cities.

Cities are highly dynamic and complex environments

They show extreme diversity within the city

- socially
- in urban construct

And between cities

Müller et al., 2020. Misperceptions of predominant slum locations? Spatial analysis of slum locations in terms of topography based on Earth observation data. *Remote Sensing*, 12(15), 2474.

For example, if you compare the image you see on the slide that depict cities of Caracas, Mumbai, and Cape Town, you can see the wonderful diversity that cities are made of where we have very organised and high-rised type of buildings like the example of Caracas on the right and then more of a organic, strangely organised type of built tissue that you can see on the left side in Caracas. And all this complexity live side by side and has strong social consequences or reasons. I mean, we could talk about causality but this is not a topic today. But as you can see, if you get a step back and you observe cities from afar, in our case, from space, we can actually start analysing how cities organise, how they are dynamic, and how the urban tissue organises in space and also in time.

Notes

Summary

1m 26s

So yeah, space is a prime way of observing cities so we have all these sensor satellites that are orbiting over our heads in space and we have many of those of different type, and resolution, and image quality as well. Some of them you can access for free, for some you need to pay, but all in all, observing cities from space allows us to really describe urban areas in a way that can be global, we can observe the dynamics of urban spaces, because we can have time series. Remember, satellites come to the same place at regular intervals. And then we can take also advantage of the fact that different satellites have different resolution so we can look at very local organisation or global organisation of the city and understand the usage of urban areas.

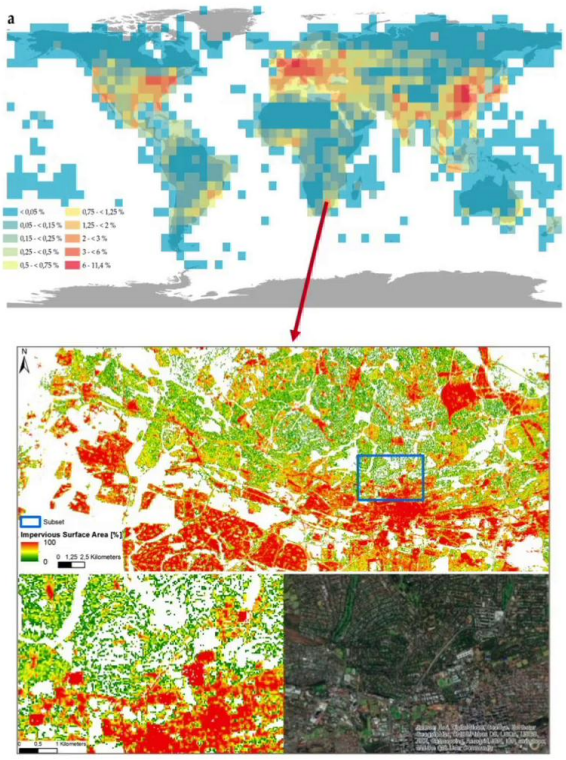
Notes

Summary

2m 22s

Global

- Satellites allow large, global footprints
- They allow extending analysis to many cities
- Global urban footprint products were not possible before
- These products are crucial in Southern countries, e.g. for peace organisations and NGOs



Global urban footprint: globally and of Johannesburg.
From: Esch et al. 2018. Where we live – a summary of the achievements and planned evolution of the Global Urban Footprint, *Remote sensing*. 10, 895

I will now go through these four points one by one and give you some examples, hoping that this will inspire you to pursue, research, or business in one of these areas. So I talked about being global in observing cities and as you can imagine, satellites orbit around the Earth so they observe the different urban areas all over the world at regular intervals. And this allows us to have analysis that can go across several cities. As you can see on the image on the top, we can have actually a view of the density of organisation globally, thanks to satellites. And this is something that is now available through global products like global urban footprint, for example, and not only we can see the ensemble of the planet in terms of urbanisation, but then we can zoom-in like in the example below of Johannesburg, where actually, we can analyse at a very local scale how much of the urban space is actually occupied by imperview services, let it be buildings, asphalts, roads, and the like. And this is information that we could not have before because we didn't have this satellite coming back at regular intervals. And this is crucial information, especially in Southern countries. Imagine planners, peace organisation, non-governmental organisations, this information is and must be accessible to everyone.

Notes

Summary

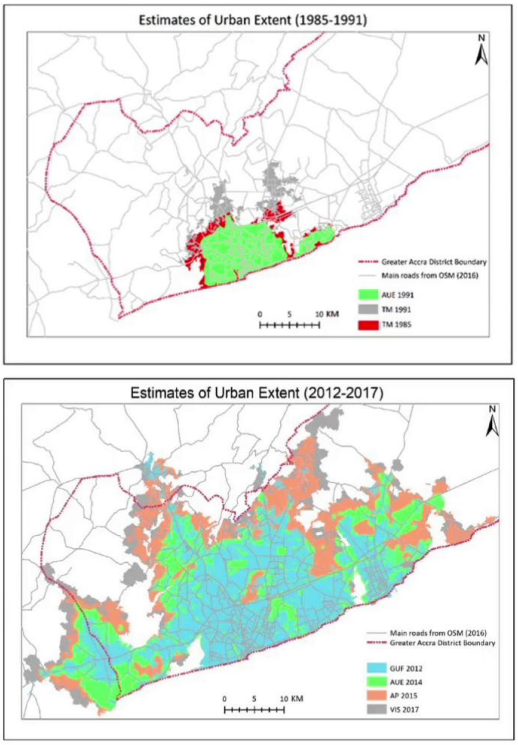
3m 13s

Dynamic

- Satellite images are regularly acquired (clouds permitting)
  - Landsat (30m), every two weeks
  - Sentinel 2 (10m), every five days
  - Planet Doves (3m), ~ every day

  we can build time series and analyse urban trends

- Several products already exist, they can be compared.



Urban expansion in Accra, Ghana.
Source: Moller-Jensen, L., Allotey, A. N., Kofie, R. Y., Yankson, P. W. K. 2020. A comparison of satellite-based estimates of urban agglomeration size for the Accra Area. *ISPRS Int. J. Geo-Inf.*, 9, 79.

The view of the city we have is not only a point in time. Remember that satellites come back to the same place every two weeks, five days, every day, depending on the sensor that you use. And this allow you to basically monitor how cities evolve in time. You can imagine that as like a heartbeat of a city where you can basically know how the city moves in space. And as in the example, you can see here on the right where researchers studied the urban expansion in Accra, Ghana, they've used existing products that were able to trace back the growth of Accra from the 80s and then at a more fine grain scale when using new generation sensors that helped having a footprint of the city almost every year. And of course, this needs technology to come to this maps of urban growth but this is basically a potential use of satellite data that you could have if you're a planner and you want to know in almost real-time what's going on in a urban area.

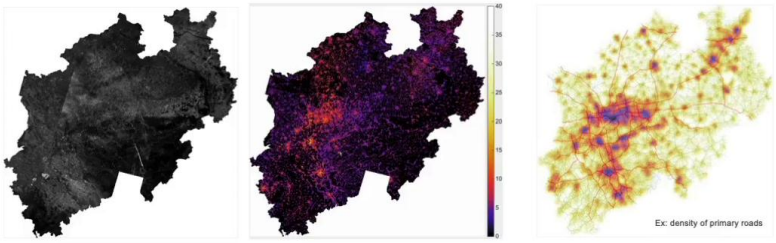
Notes

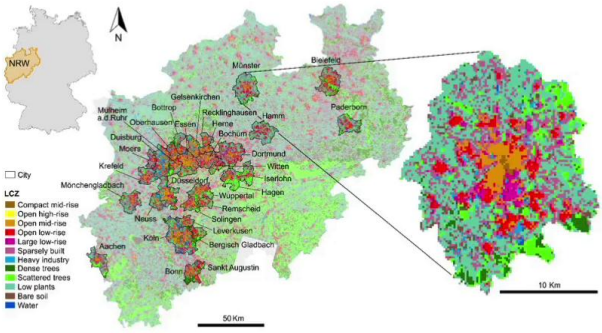
Summary

4m 39s

Dynamic

- Also in the sensors sense
- With height data (e.g. LiDAR), GIS, social media, we can
  - Understand typologies of neighborhoods
  - Assess quality of life
  - Improve the city experience





Quality of life and city networks in North Rhine Westfalia, Germany.
From (modified): Sapena et al., 2021. Estimating quality of life dimensions from urban spatial metrics. *Comp. Env. Urb. Sys., 85, 101549.*

It's not only about urban footprint themselves, but we can also start working on understanding what is the topologies that are occurring on the city. If you cross different type of images like the one you see on the top of these slides, you could use at the same time satellite images, height model, maybe information from social media, and nightlife information. So all the sensor data that are nowadays available to us in order to understand locally what is the construct of the city and how the different neighbourhoods are being used. As you can see in the map at the bottom in this study, we were able to characterise at a hectare resolution which was the density and potential use of every little 100 X 100 metres region in terms of density of the construct, the height, and then we can understand if it was a commercial business administrators, a residential area of low or high density.

Notes

Summary

5m 45s

Dynamic

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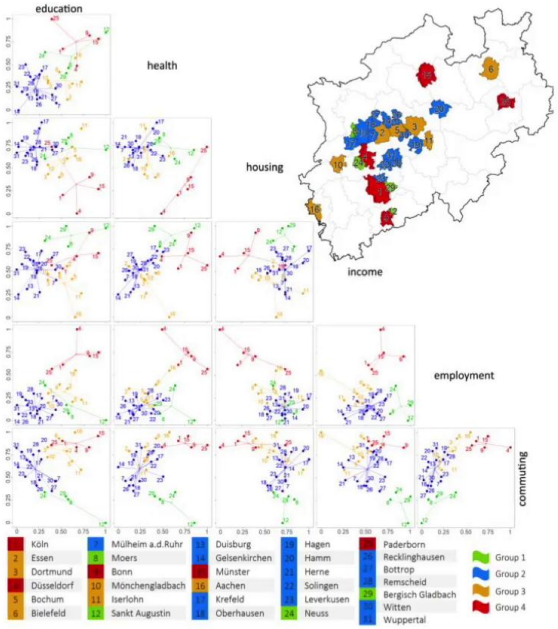


Quality of life and city networks in North Rhine Westfalia, Germany.
From: Sapena et al., 2021. Estimating quality of life dimensions from urban spatial metrics. *Comp. Env. Urb. Sys., 85, 101549.*

And when we have this information, this is basically very useful because we can cross it with all kind of socioeconomic data. So for example, the access to education, or health facility, or statistics about housing and this allows us to understand the network of cities, in this case, in Northern Germany, and to see if there are dynamics like cities that are more where people sleep or cities that are more where people go to work and then understand fluxes of people, socioeconomic dynamics, and the like. So it's a kind of a door to assess the quality of life that you can see in urban areas.

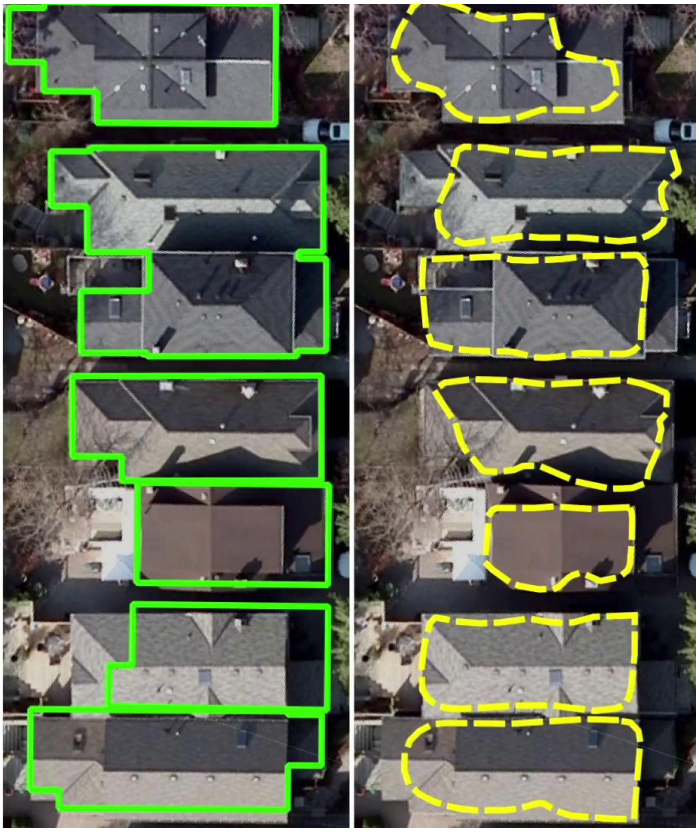
Notes

Summary

6m 47s

Fine grained

- Very high resolution satellites
  (e.g. Maxar's Worldviews, Planet Doves, aerial imaging from swisstopo)
- We can generate information about
  - Buildings geometry
  - Buildings usage,
  - Energy consumption,
  - Solar potential
- Crossing with auxiliary data, e.g.:
  - Ground-based pictures
  - 3D models
  - GIS-based sun trajectory



Detailed building footprints in Toronto from aerial imagery.
From: Marcos et al., 2018. Learning deep structure active contours end to end, Computer vision and pattern recognition, 2018.

But it's not only about looking from really afar and having very large footprints. We can also look at city at a very fine grained way. So in this case, we start mostly to consider very high resolution satellites. They can be metric, or submetric, to less than a metre resolution. And there is a number of sensor that provide this type of data. They're usually commercial but they basically help you zoom in and look at single buildings, for example, and they allow to understand the building geometry as you can see here in the example on the right, where it was possible to delineate buildings quite precisely analysing the aerial image in this case.

Notes

Summary

7m 22s

Fine grained

- Very high resolution satellites
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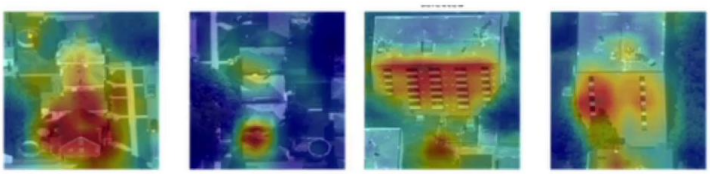
Detecting the number of building floors from oblique images

Aggregation	Top-1 Error (%)	Macro f1
hard voting	39.39	0.660
soft voting	18.52	0.810
lowest entropy	**16.16**	**0.830**



Number of floors estimation from oblique images
From: T. Dong. Building attribute extraction with deep learning models from aerial imagery
EPFL master thesis (CVLAB – M. Salzman, AXA GETD – P. Jayet)

Images courtesy from AXA

Or in this example, where colleagues at AXA, they were building models to basically estimate the height of the building from oblique images taken from space. And this is pretty interesting because it's the kind of information that seems very simple to grasp. So if you look at the buildings, you will immediately know how many floors you have. But when you have to scale this up at the level of an entire city and you have to go each building one by one, it's very good to have sensor data that basically allow you to do that automatically with the model. And in this master study jointly supervised by AXA and the CV Lab of EPFL well, researchers could estimate the number of floors with a 15% error which is a pretty interesting result and also to pinpoint which parts of the image were important for the model to get to the estimation. This is a typical example on how space data can help you together with some machine learning to extract information at scale.

Notes

Summary

8m 03s

Related to usage

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  (e.g. Maxar's Worldviews, Planet Doves, aerial imaging from swisstopo)

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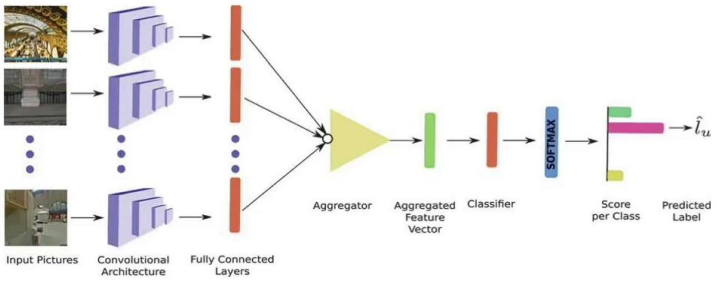

Building usage characterization with ground-based pictures and AI
From: Srivastava et al., 2020. Fine-grained landuse characterization using ground-based pictures A deep learning solution based on globally available data. *Int. J. GIS*. 34(6), 1117-1136.

But it's not only about geometry, you can also then make the step to usage. And for example, to understand for each building in the city, what is this being used for? So it can be a residential house, but it can also be a shop, or a bank, maybe a museum. And in this specific study, we used together with the space data, also terrestrial images, google street view type of images, or social media based, they could help us by looking at the facade of the building to basically understand better what the building was used.

Notes

Summary

9m 05s

Related to usage

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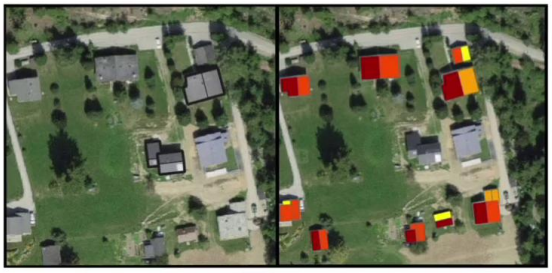

Images source: picterra.ch

The GROUP-IT project, powered by Picterra
From: Solar Panels in Switzerland brought to the next level with Picterra
https://picterra.ch/blog/solar-panels-switzerland/

Last but not least, I promised you an example in renewable energy and this is an example provided to us by their colleagues at Picterra. And in this specific study, they were assessing the potential for solar panel to be installed on the roof of the buildings. And using some machine learning models that I won't detail here, and some height information, it was possible to understand for each roof where we could put the solar panels and which location were the most interesting with respect to the solar expedition of the single building.

Notes

Summary

9m 36s

Summary

- **Space technology is powerful to observe cities**
- **We can monitor**
  - the built environment
  - green spaces
- **And assess (improve?) citizens quality of life**
- **But the information is not readily available (yet). Skills in machine learning are necessary**…(but this is another story)

So in conclusion, I hope you have appreciated how much space technology is important for observing cities for the future development and that you have now an idea on which sensors you can use and what are the interesting applications to observe, monitor, and plan better cities. Of course, this doesn't limit itself only to the built environment even though I presented mostly examples about buildings and the impervious surfaces but you can also use all this technology to analyse green spaces and the interaction between the construct and the non-construct spaces. In all this example I presented you today, there was also a heavy involvement of image processing and machine learning techniques. Of course, I didn't detail that today because it was not a topic, but this is also important that you get some training in that because it will allow you to make read the link between the sensor data and the final product you want to have. But this is another story for another course and I invite you to continue your journey to better understand cities with space data.

Notes

Summary

10m 12s