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BIRGIT

L1.1 Concepts of 3D Modelling

Lecture Notes

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Summary

This lecture provides the introduction to 3D geographical modelling and is possible to take without previous knowledge of 3D GIS. It starts with several different concepts of 3D visualisation and explains how they differ according to area of usage. The student learns briefly about voxels models and more deeply about creation of reality-mesh models, with real-world examples.

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Learning outcomes

At the end of this lecture, the learner is expected to be able to

- Understand main concepts and different types of 3D geographical modelling
- Understand principles of 3D raster / voxel models
- Describe creation and advantages of reality-mesh models

Expected competences when entering the lecture

Basic knowledge of GIS

Expected workload

10 slides with learning content, approximately 2 hours

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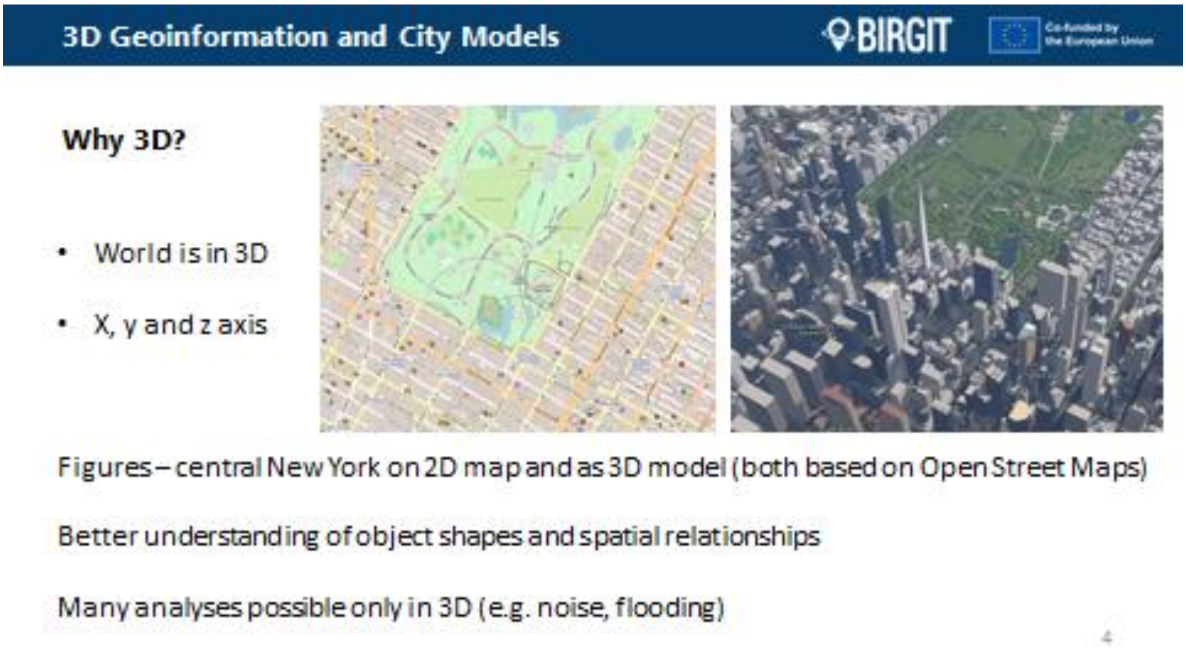


Why 3D?

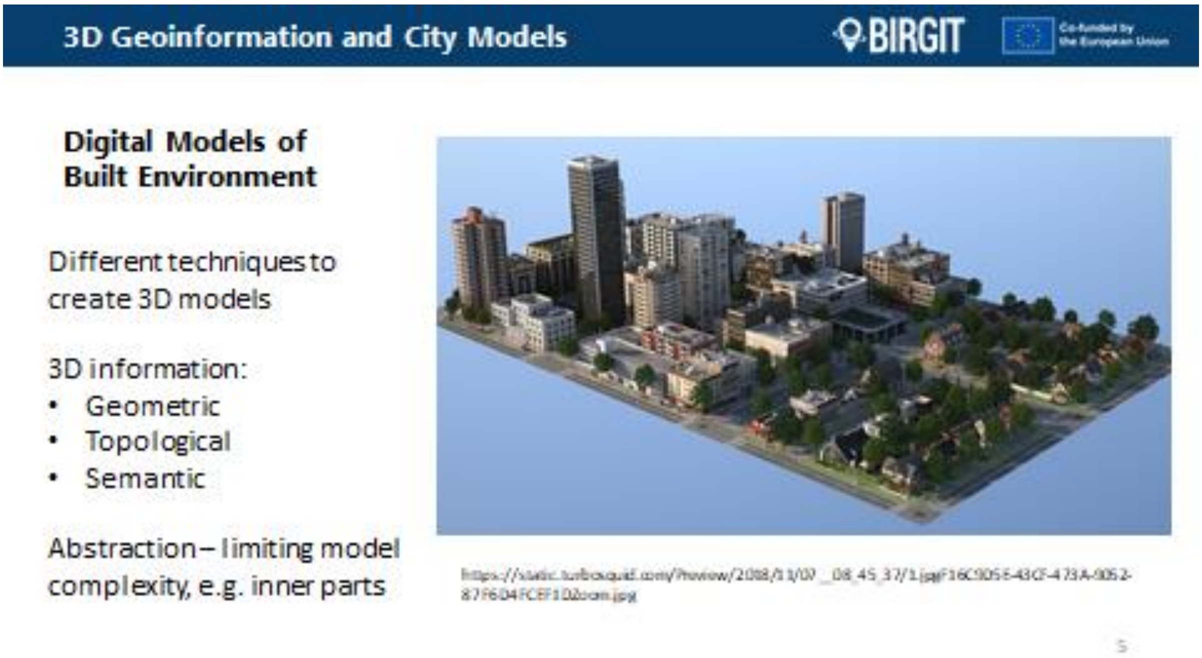
The world is 3D. Thus, 3D model improves visualisation of the real world, compared to 2D map.

We can see the difference on the figures. Both of them show central parts of New York and are based on Open Street Map.

As we know, 2D has x and y-axis. 3D space has a z-axis too, along with x and y-axis. The z-axis shows the height of the object.

Adding this third dimension helps us to better understand the distribution of objects and the spatial relationship among them. Therefore there are many applications possible only in 3D, like noise, shade or flooding analyses.

Buildings, terrains and infrastructure can be 3D modelled. In this course, we will focus on 3D representation of the built environment.



Digital Models of the Built Environment

3D city models can be derived from various acquisition techniques. That's why they can greatly vary in structure, format, and characteristics (as we will see later on).

In any case, the 3D models can combine a mix of geometric, topological and semantic information.

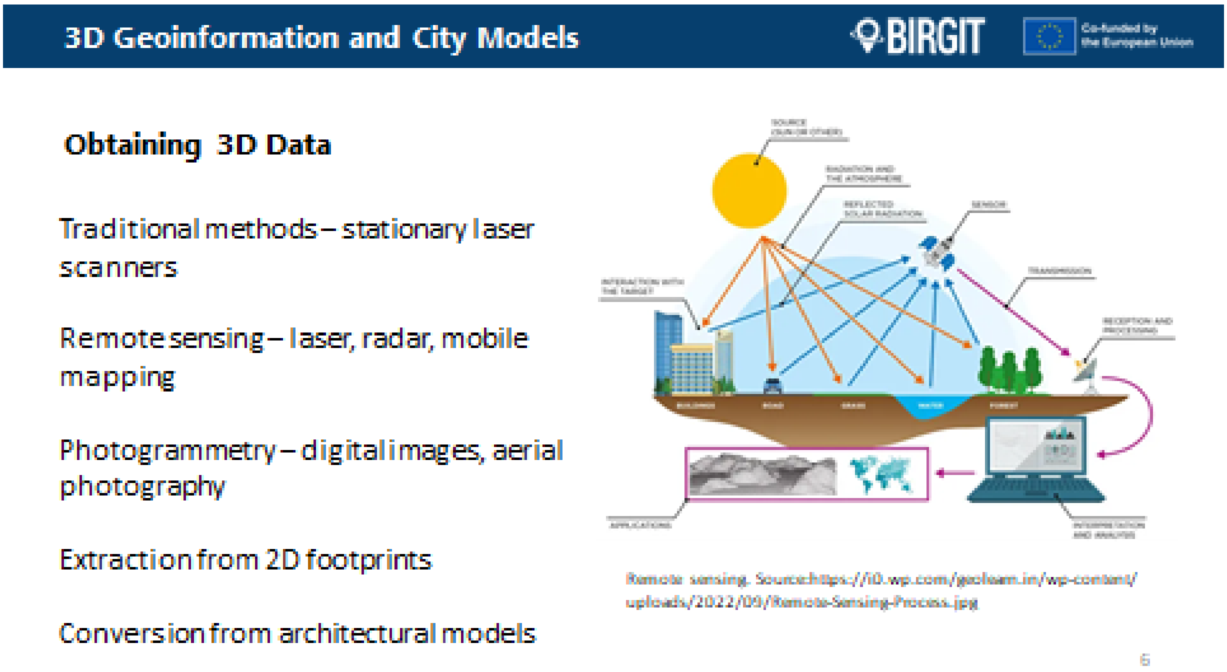
The geometric information is the description of shape.

The topological information shows adjacencies and connectivity.

The semantic one describes attributes and other object properties.

But in practice, it is desirable to limit the complexity to only the aspects that are really needed for the planned applications. An example can be a removal of inner parts of the buildings, when such information is not needed.

This limiting of the complexity is called abstraction.



Obtaining 3D Data

We will have a whole lecture specialised on the acquisition of the 3D data (2. 3D Data processing). But we briefly summarize the methods here:

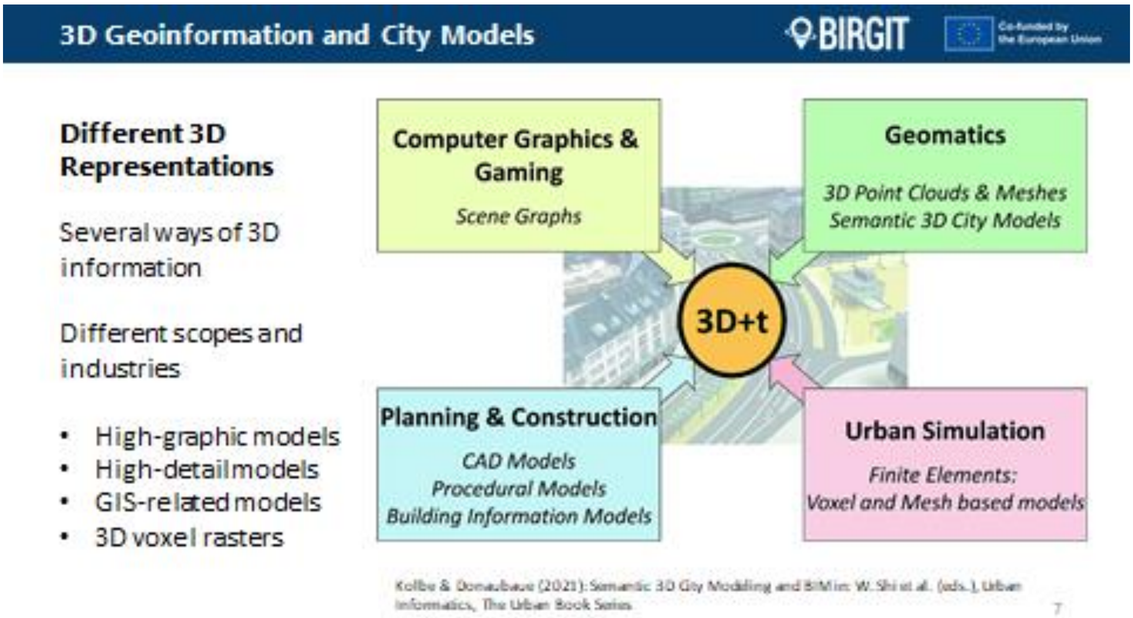
First, there are the traditional measurements, like using stationary laser scanners.

Then, there are the methods based on remote sensing, that's to say on reflections of electromagnetic waves, including laser scanning (also called LiDAR), radar or mobile mapping systems (like Google cars with LiDAR scanners).

Third common technique is photogrammetry, that's to say reconstruction from digital images.

These 'raw' measurements are then processed and assembled to create more complex 3D objects.

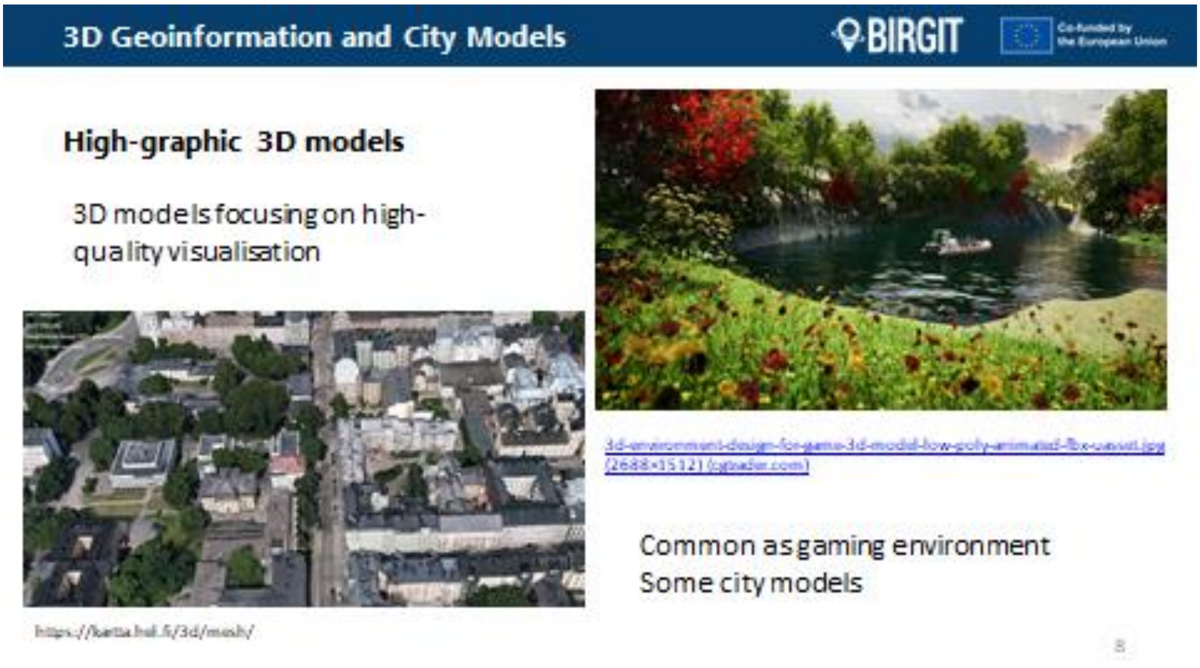
Further, 3D city models can be extracted from 2D footprints or converted from architectural drawings.



Different 3D representations

3D buildings and cities has been approached in several ways. These ways differ in focus, model structure as well as exchange format, as summarized in the figure.

We can see that there are visual models with highly advanced graphics, highly-detailed models from AEC (Architecture, Engineering and Construction) industry, GIS-related models as well as 3D rasters.



High-graphic 3D models

We can first take a look at high-graphic visual 3D models. They aim at very high-quality 3D visualization, but do no divide the environment into individual objects and, as such, provide no information on object properties.

Such models are often developed and used in computer graphics and gaming.

Real-world examples of visual models are some of the city models, for instance mesh model of Helsinki, or models of Berlin, Stockholm etc. We come back to these city models later in the course.

AEC industry models

Models from AEC Industry (Architecture, Engineering and Construction) are also highly –graphical, but their main focus is on details and on individual objects. They also provide highly detailed information about object geometry and properties, which is necessary for planning and construction goals.

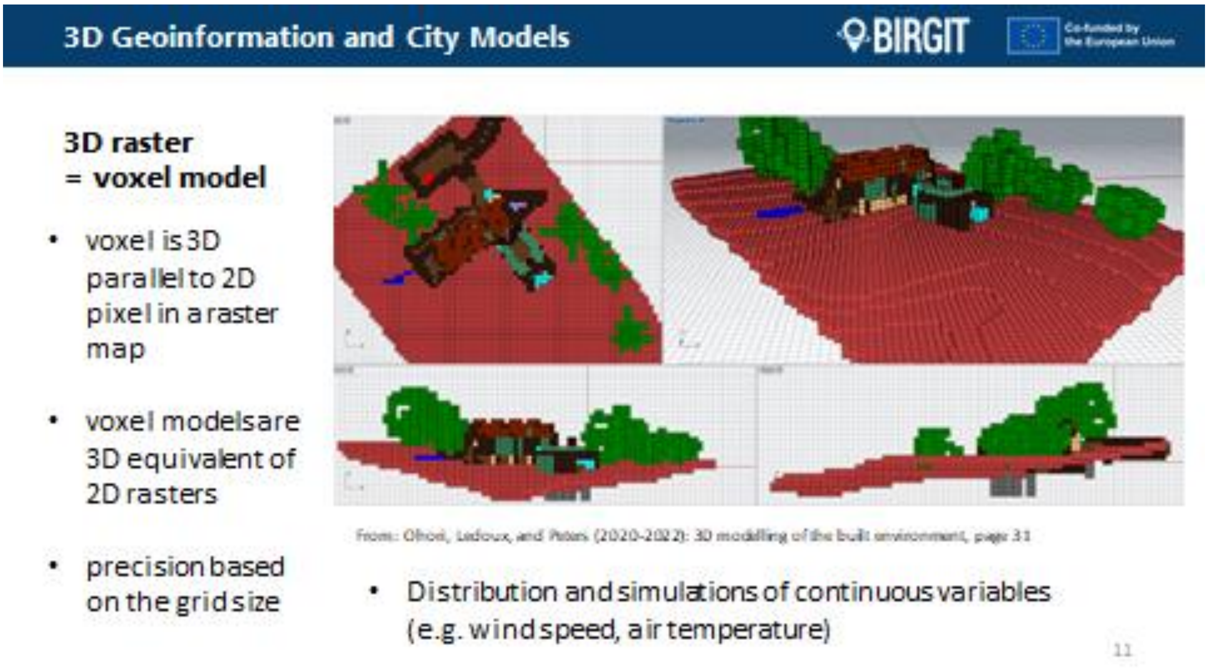
Building information modelling (BIM, left on the slide) belongs to this category and is targeted in our separate course-module (Introduction to BIM). Right on the slide, there is also a CAD (Computer Aided Design) model. Though CAD is still used in AEC, BIM is the state-of-the-art technology nowadays.

Geomatic / GIS-related 3D models

The third domain of 3D modelling is the GIS related one.

It includes the typical 3D city models, visualizing the 3D geometry, 3D topology and, in the best case, even thematic attributes and logical interrelationships among the objects. If these attributes, that's to say the semantic information, are included, the models are referred to as semantic 3D city models. The semantic models are the main focus of this course-block.

To learn more about photogrammetry, laser-scanning and 3D point clouds, see the second block of this course, called 3D data processing.



3D raster = voxel model

Last on our list of different 3D representation is 3D raster, also called voxel model.

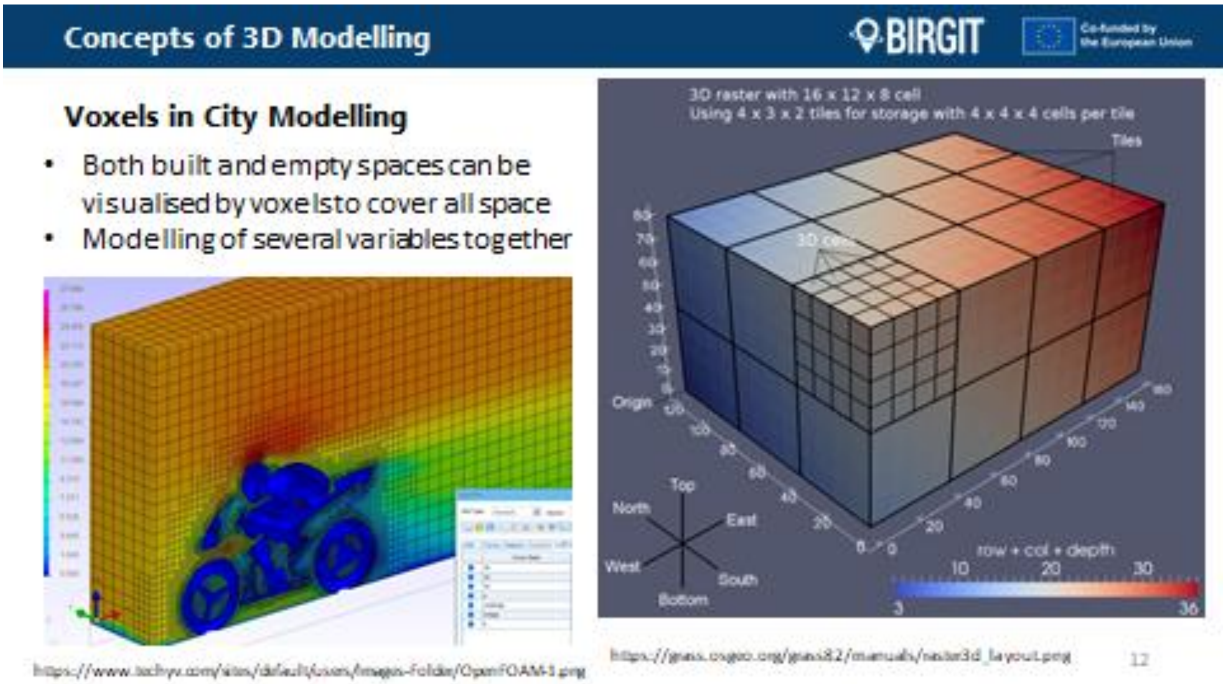
A voxel is the 3D parallel to 2D pixel in a 2D raster map. Voxel models are the 3D equivalent of 2D rasters.

And similarly to 2D rasters, the 3D voxel models are limited in precision based on the grid size. Decreasing the grid size will increase the precision, but also grow to very large sizes in terms of memory.

The voxelisation is based on decompositions of the urban space into finite elements. We can imagine it as dividing the whole space into equivalent cubes of a given volume.

Voxel models are easy to create and understand, compared to e.g. mesh or semantic 3D models. Even computations using voxels are much simpler than those using other representations.

Another important advantage of voxels is that they can represent three-dimensional distribution of continuous variables. (It means quantitative variables that can take on any value within a certain range or interval). As examples we can name wind speed, soil moisture, air pollution, water salinity etc.



Voxels in city modelling

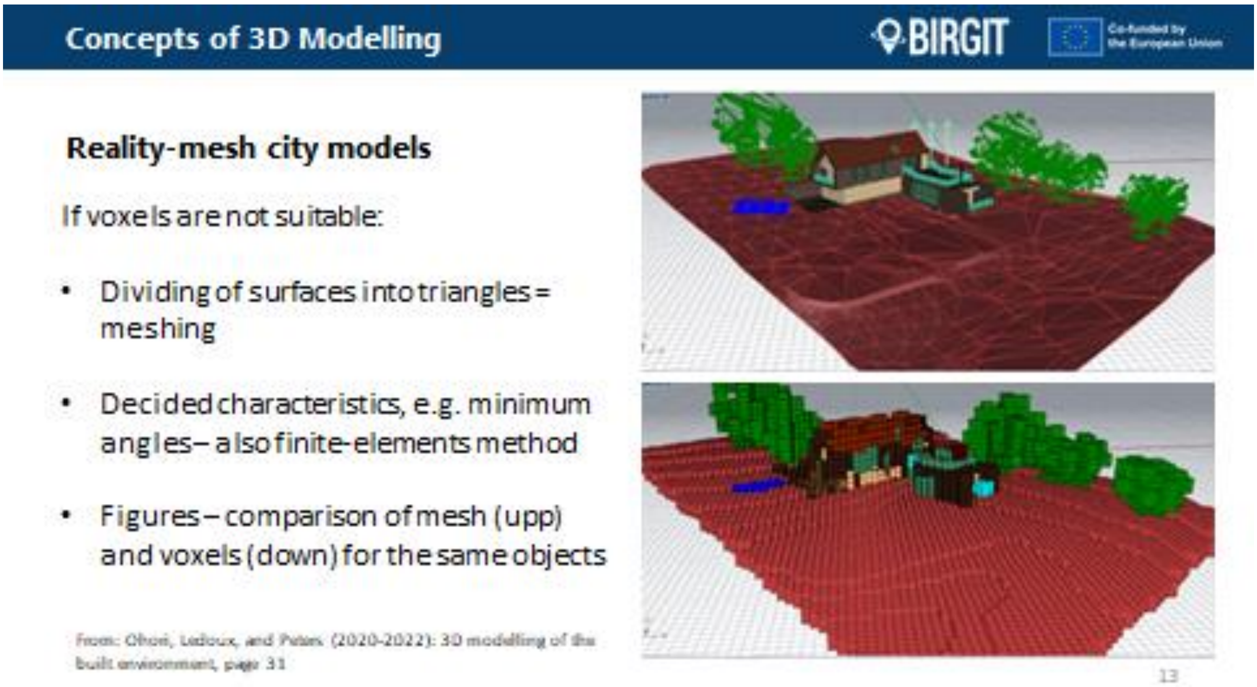
All urban features i.e. both built and surrounding spaces, can be represented by voxels.

Values of multiple variables (both qualitative and quantitative, https://www.mygreatlearning.com/blog/types-of-data/) can be defines for each pixel and used in computations.

An example of such simulation can be modelling of pollution dispersion. All voxels representing the urban air space have a parameter vector for wind direction, wind speed, air temperature, and concentrations of specific pollutants.

Another example is simulation of building heat-energy demand. Building voxels provide information about e.g. usage type and about building physics like the wall, roof and window insulation. And these can be combined with air-space properties around the building.

And even temporal units can be used, so that it is possible to simulate the 3D raster in different times.



Reality-mesh city models I

For certain simulations the voxel model is not optimal and it is better to use highly detailed geometric and photorealistic models.

Such models are based on aerial photos, LiDAR point-clouds or a combination of these two. The data is put together into the city model using specialised software.

The roof, walls and other surfaces can then be divided into triangles in a process called meshing. The figures show a comparison between a voxel and a mesh-based model.

One can decide certain characteristics of the division, such as minimum angles. Therefore, meshing is also counted as a finite-elements method.

Reality-mesh city models II

This abstraction of surfaces into triangular meshes is fast and cost-effective. It is possible to create such geometric and photorealistic models for whole cities in an automatized way.

Mesh-based models are available for many cities and can usually be navigated freely through the city webpages. Even Google Earth uses mesh models, also freely available.

We can say that the first generation of 3D city models were reality-mesh models. However, many applications do not just need data about the 3D geometry of surfaces and their graphical characteristics (as in a mesh model).

For many applications, it is necessary to divide the model into individual objects. For instance, to define: this is a house and this is another house, and this is a tree.

Such models, where real-world things are characterised as individual objects, are called “semantic”. In best case, the objects in the semantic models even have specific properties and defined interrelationships. And these semantic models are topic of the next lecture.

References

Ken Arroyo Ohori, Hugo Ledoux, and Ravi Peters (2020-2022): 3D modelling of the built environment

The latest version of this book can be downloaded in PDF at https://github.com/tudelft3d/3dbook/releases

Thomas H. Kolbe and Andreas Donaubaue (2021): Semantic 3D City Modeling and BIM in: W. Shi et al. (eds.), Urban Informatics, The Urban Book Series