The Esri 3D city information model

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Abstract. With residential and commercial space becoming increasingly scarce, cities are going vertical. Managing the urban environments in 3D is an increasingly important and complex undertaking. To help solving this problem, Esri has released the ArcGIS for 3D Cities solution. The ArcGIS for 3D Cities solution provides the information model, tools and apps for creating, analyzing and maintaining a 3D city using the ArcGIS platform. This paper presents an overview of the 3D City Information Model and some sample use cases.

1. Introduction

Managing built environments together with their legal framework and the natural surroundings in 3D gains importance with the on-going densification and urbanization. The 3D City Information Model (3DCIM) simplifies the creation, maintenance and usage of 3D cities for GIS users. It covers a wide range of themes, including the built environment, the legal environment and the natural environment. At the same time it is complementary and not replacing existing GIS data model.
The 3DCIM is designed to be compact and simple in its structure, making the core of the model easy to understand and to populate with data. At the same time, it is compatible to important exchange formats and standards such as CityGML [1]. Furthermore, it can be extended and localized with minor effort. In addition to these qualities, it is also expressive enough so that maps and applications can be built on it.

2. Background

There is an increasing need for 3D city models for different application areas like 3D cadastre, geodesign, urban planning, facility management, simulation, and analysis.
Whereas earlier 3D City models were almost exclusively used for visualization and had in turn relaxed requirements regarding accuracy and semantics, today's applications ask for spatial information models that are general enough to serve a wide range of use cases beyond visualization. Several standardization efforts are under the way such as CityGML, INSPIRE [2] or FGDC-STD-003 [3] which specify semantic-rich information models. They not only cover the 3D representation of constructions and their spatial attributes but also the natural environment and sub-surface structures. The 3DCIM is complementary to the Esri's well established Local Government Information Model [4] and the Building Information Model BISDM [5].

3. The 3D City Information Model

A 3D city is in general a vast a collection of features, networks and surfaces, and there are many approaches how to model it for purposes of processing, analysis and visualization. The approach we chose is driven by use cases that specifically benefit from 3D GIS. A design goal of the 3DCIM is to

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At the same time, the model is required to be compatible to exchange formats and (de-facto) standards such as CityGML and the ArcGIS Local Government Model. The 3DCIM has several in-built extension points and can be localized by utilizing File Geodatabase features and tools that are delivered with the information model. For building custom applications, it maintains a high expressiveness.

Content-wise, the 3DCIM is organized into basic themes: the *built environment*, *the legal environment*, and the *natural environment*. Each of these themes shares some common attributes and traits, which are described below.

3.1 The Built Environment

The *built environment* is comprised of features and networks that are created or actively managed by humans. These features include: structures (buildings, bridges, tunnels), utility networks, multimodal transportation networks (interior & exterior), installations (e.g., street furniture, sensors), and street trees.

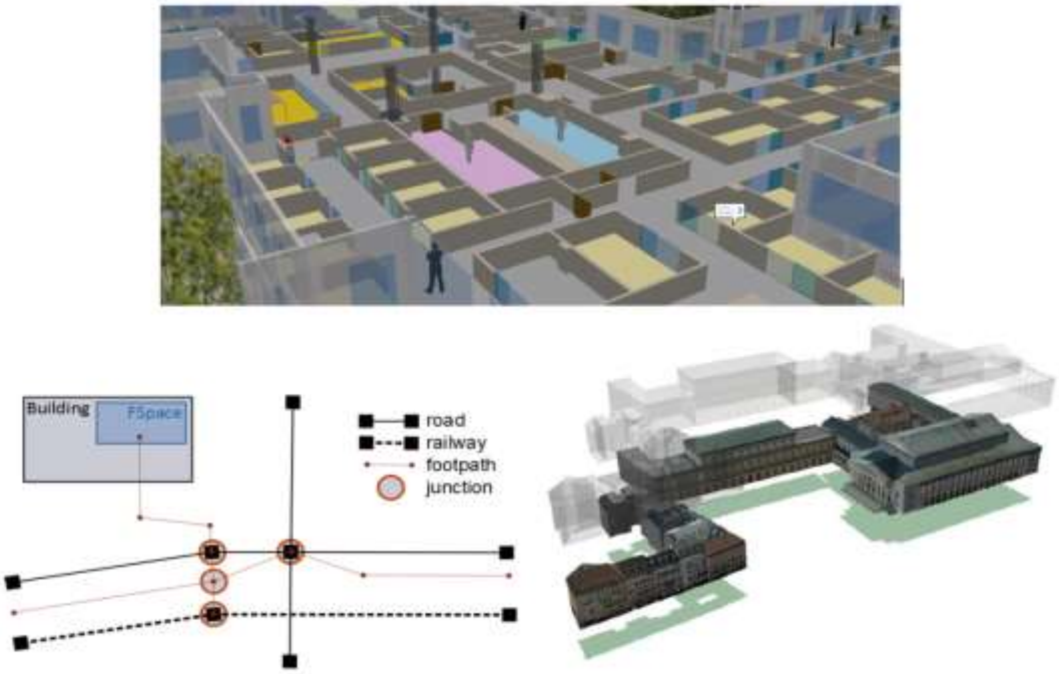

Figure 1. Examples of built environment: interiors (top); transportation networks (left); structures (right).

3.2 The Legal Environment

Features in the *legal environment* define land use plans and regulations and property ownership boundaries. These include land use zones, which can have a nested structure (zones that are within and override the regulations of larger zones), and may have both 2D and 3D dimensional attributes, like maximum buildable heights. These regulations are typically stored as tables and may also apply to Parcel (ownership) boundaries.

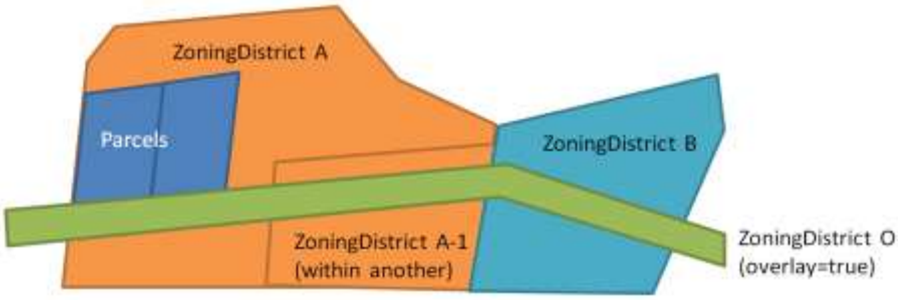

Figure 2. Example of legal environment with overlapping zoning regulations.

3.3 The Natural Environment

The *natural environment* is comprised of all naturally occurring features on, above, or below the earth's surface. This can include the land cover (wilderness areas, biomes, water bodies), but also surface/subsurface geologic structure and above-earth atmosphere, climate, and weather.

Figure 3. Example of natural environment.

3.4 3D City Information Model Structure

Within these three themes a set of feature classes (FC) and object classes (OC) describe the model in detail, as summarized in Figure 4.

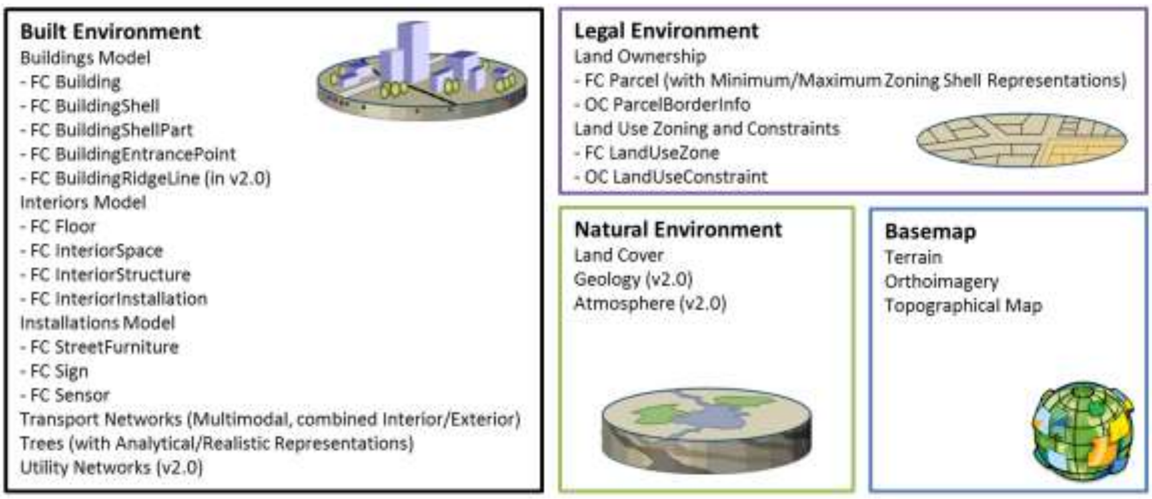

Figure 4. An overview of the 3D City Information Model structure.

In Addition to the four themes, the 3DCIM also supports generic *3D annotations*, *associations*, and a *general attribute container*.

4. Application Scenarios

Application scenarios are the central driver for the design of the information model – compared to CityGML, the 3DCIM is not primarily an exchange format, but rather a platform for different kinds of applications. In this section, a few scenarios that have been used among many others to develop the 3DCIM are presented.

4.1 Communicating complex decisions

Mr. Hartsch is mayor of a mid-sized German city which has been having a difficult time in communicating recent improvements to the traffic routing in the inner city. The inner city is characterized by a lot of road tunnels and bridges and a lack of space, severely limiting options to add lanes to improve on the traditionally difficult situation. Recent changes at some critical places led to a huge uprising of complaints and heated discussions in the city council. For this reason, the mayor has decided to use the existing 3DCIM to provide an information tool to both the public and to policy makers. It was straightforward for his IT staff to extend the online application templates that were provided with ArcGIS for 3D Cities. Today he presents the application, which is available both on-line and on a large multi-touch table in the foyer of the city hall to a public audience.

After a short introduction, he shows how this tool allows non-experts to interactively explore options such as adding a lane or changing its purpose, and to directly see the consequences such as traffic jams or a higher rate of accidents of these alternatives. A time slider allows visualizing the impact of a change during the course of a typical day. The 3D presentation uses specific 3D symbology to allow seeing both a local situation such as a single crossing, but also the impacts on larger areas.

4.2 Urban Growth Simulation

A larger Asian city expects an increase in population of 500'000 people until 2050 due to the economic growth in the region. Because living in the city center is already expensive today, many people seek a new home in the surroundings of the city generating substantial urban sprawl and increased traffic congestions during rush hours. The city council wants to evaluate different development scenarios based on the existing 3DCIM of the area.

One scenario is based on a newly built public transportation system with densified zones near the public transportation stations. An initial network is laid out along the coastline and the DTM from the *natural environment* of the 3DCIM helps optimizing the routes and minimizing the costs of artificial structures like bridges and tunnels in the hilly terrain by modifying the *built environment* of the 3DCIM. A walkability analysis along the network together with electro-scooter drive time polygons provides hints for the placement of the stations. Different zoning rules are evaluated in the *legal environment* of the 3DCIM to find the right balance between multifamily versus single family housing and the necessary infrastructure and green space. Out of many scenarios, the council selects the most promising ones and presents them online to the public for commenting and voting.

4.3 Cumulative Energy Balance

Mrs. Syngh works in a large construction company. Among her responsibilities is to calculate the energy a proposed building will receive from its surroundings by means of direct sunlight and reflected heat to optimize shielding, insulation, the usage of renewable energy and the required air conditioning. For this purpose, she exports a model of her new building from the CAD and goes to a website provided by the local government which uses the 3DCIM for representing its GIS data. The local government has been very supportive of energy-optimized buildings and offers a set of web applications. At this website, she uploads the file, positions I correctly in a 3D view of the surroundings. When the initial calculation has finished, she can use the 3D view to preview the result, with the façade cells now color-coded according to the energy input received in the current hour. She can use a date/time selector to go to any other time or time range, such as a full month or even a full year. An information tool allows her to pick any location on her building to get detailed data.

Finally, she goes to the export options and selects three results – the hour with the highest energy input, the hour with the lowest energy input and the overall energy input for each month. The system calculates these and provides them as CAD files, based on the input geometry, but annotated with the calculation results.

5. Conclusion

Today's 3D needs beyond visualization such as 3D cadastre, geodesign, urban planning, facility management, simulation, and analysis ask for a common, semantic rich model. This paper gives a very high-level overview of Esri's 3D City Information Model. The design of the model is driven by ease of use, simplicity, extensibility, and compatibility. While it interplays with various 3D city data formats, it is mainly its implementation in the ArcGIS for 3D Cities solution that makes the 3DCIM a platform ready to use for many applications.

Although numerous applications can be realized today with the current implementation of the 3DCIM, some extensions are already planned in the area of utility networks, geology, and atmosphere. We expect further requirements from our users as well as input from academia to broaden the use of the 3DCIM. We are looking forward to a whole new range of 3D City applications in the near future.

References

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