From 2D to 3D at Esri

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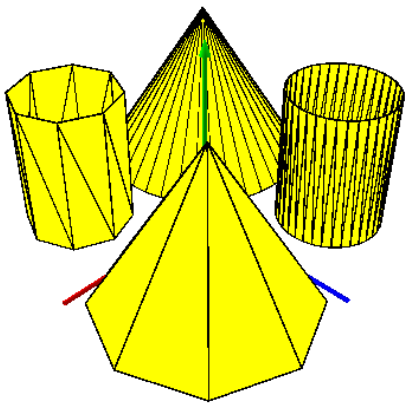
SHORT PAPER

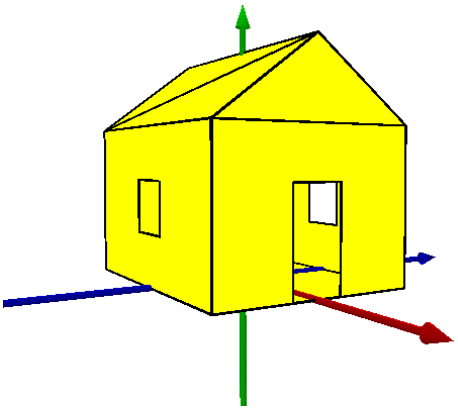
This short paper provides an overview of the 3D capabilities of a modern GIS, illustrated by the Esri ArcGIS system, concentrating on city modelling for National Mapping Agencies (NMAs). We live in a three-dimensional world, so 3D data is increasingly important to NMAs and to their customers – e.g. GIS professionals in flood risk management, or urban planning. 3D is also expected by the younger generation used to realistic 3D computer games. New 3D data sources such as CityGML and LIDAR complement the traditional 2D topographic and terrain data held by NMAs, and together provide the basis for a 3D GIS. New technologies such as rule-based procedural 3D modelling, HTML5 and WebGL underpin powerful dynamic 3D visualisation in the browser or mobile app, opening up new markets for NMA data.

1 3D IN THE GEODATABASE

GIS has traditionally captured, managed, analysed, produced and shared geodata as 2D vector features in a geodatabase. In the past few years, this has been extended to include feature classes of 3D points, lines and areas - symbolised as 3D markers, textured lines and polygons, optionally extruded into volumes. A further important 3D data type in the geodatabase is the 'terrain' which holds XYZ point clouds from LIDAR, elevation models, and faceted surfaces such as TINs. The other vital 3D data type is 'multipatch', which describes volumetric spaces such as 3D buildings, complete with their surface texture, colour, transparency, and lighting vector information. A multipatch is a collection of triangle strips, triangle fans, triangles, and rings.



Multipatch triangle fans and strips

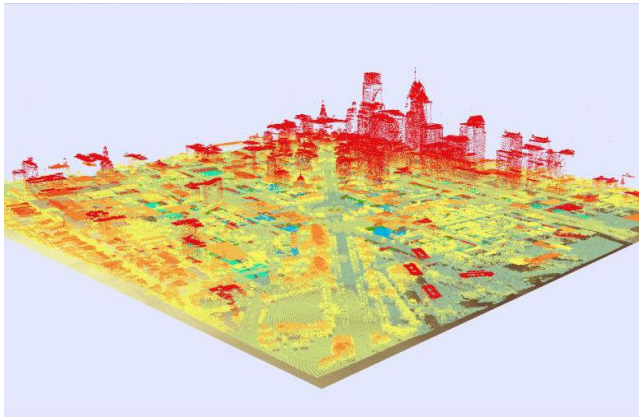


House as triangles and rings

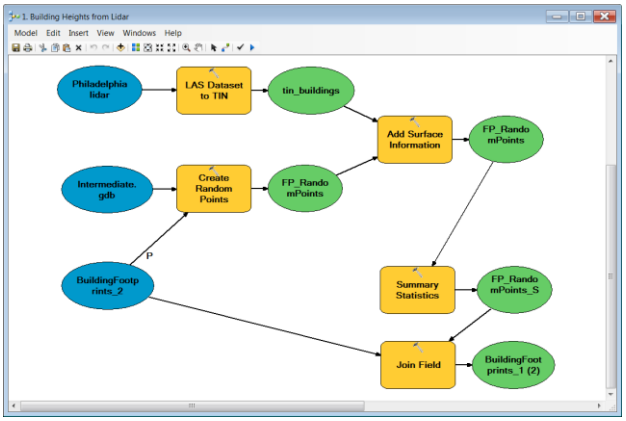
Texture & lighting

2 2D TO 3D

The advent of available LiDAR data and of similar point clouds from oblique imagery stereomatching has made possible automated determination of heights to be associated with existing 2D data held by NMAs. Buildings can be extruded into 3D features; roads and buildings can be aligned to the terrain, or used in 3D spatial analysis.



Aerial LiDAR to provide heights

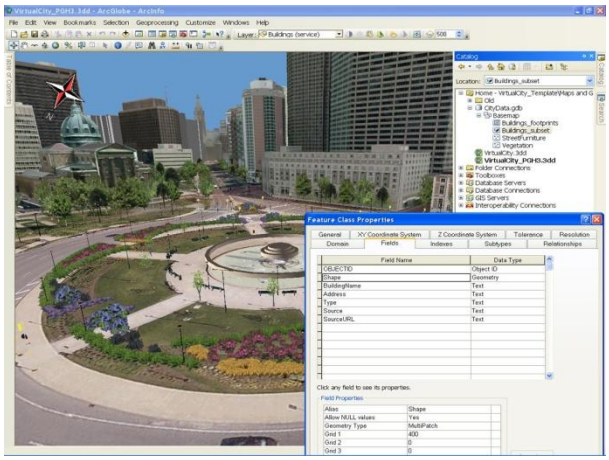


Geoprocessing model to automate heights

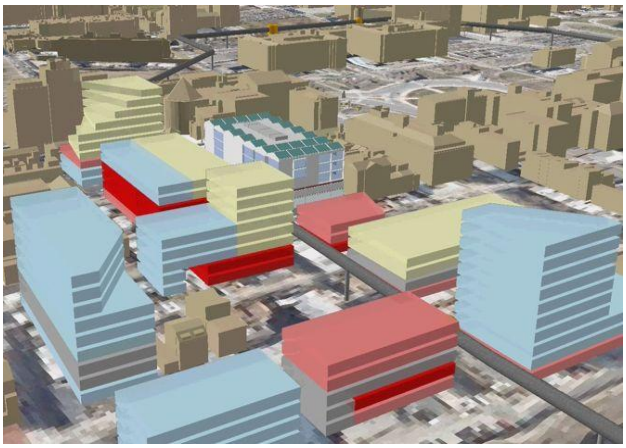
The illustrations above show typical aerial LiDAR data for a city superimposed on the 2D features, and a geoprocessing model which runs a set of tools to deduce the maximum height inside each building and assign it as an attribute. Esri publishes a set of best practice 3D workflows, complete with example models and sample data, available at http://resources.arcgis.com/en/communities/city-engine/, and at http://resources.arcgis.com/en/communities/3d/.

3 3D VISUALISATION AND EDITING

ArcGIS Desktop includes two applications for 3D edit and visualization – ArcScene and ArcGlobe.



3D Virtual City Philadelphia - ArcGlobe

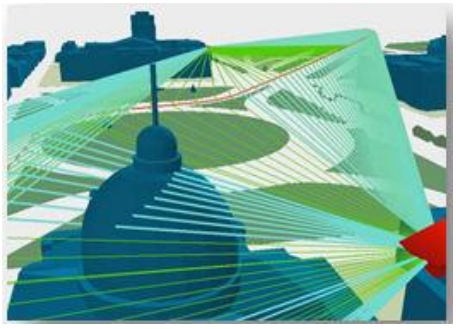


3D land use planning - ArcScene

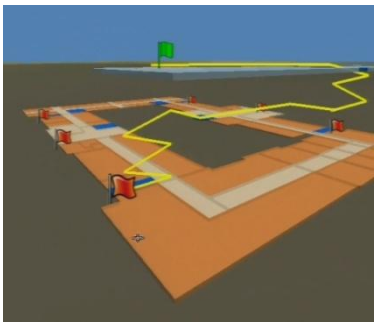
ArcScene brings a high level of precision to 3D views and allows use of native coordinate systems. ArcGlobe provides a 3D globe surface and allows quick navigation from a global to local extent. In addition, ArcGIS Explorer is a free desktop viewer for globe views.

4 3D ANALYSIS

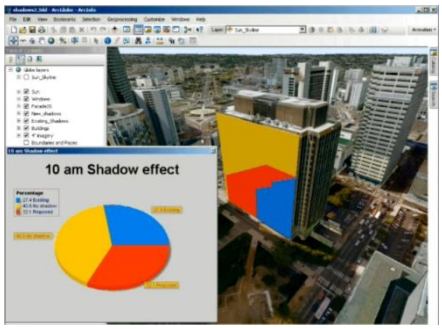
A GIS does much more than visualization - 3D analysis capabilities include intervisibility, skylines, shadows, 3D routing, and much more. ArcGIS provides a rich set of 3D spatial analysis tools, such as Buffer 3D, Intersect 3D, Near 3D and Union 3D, so that the relationships between 3D entities can be explored and processed.



Security camera coverage



3D Routing



Shadow analysis

5 3D IMPORT AND EXPORT

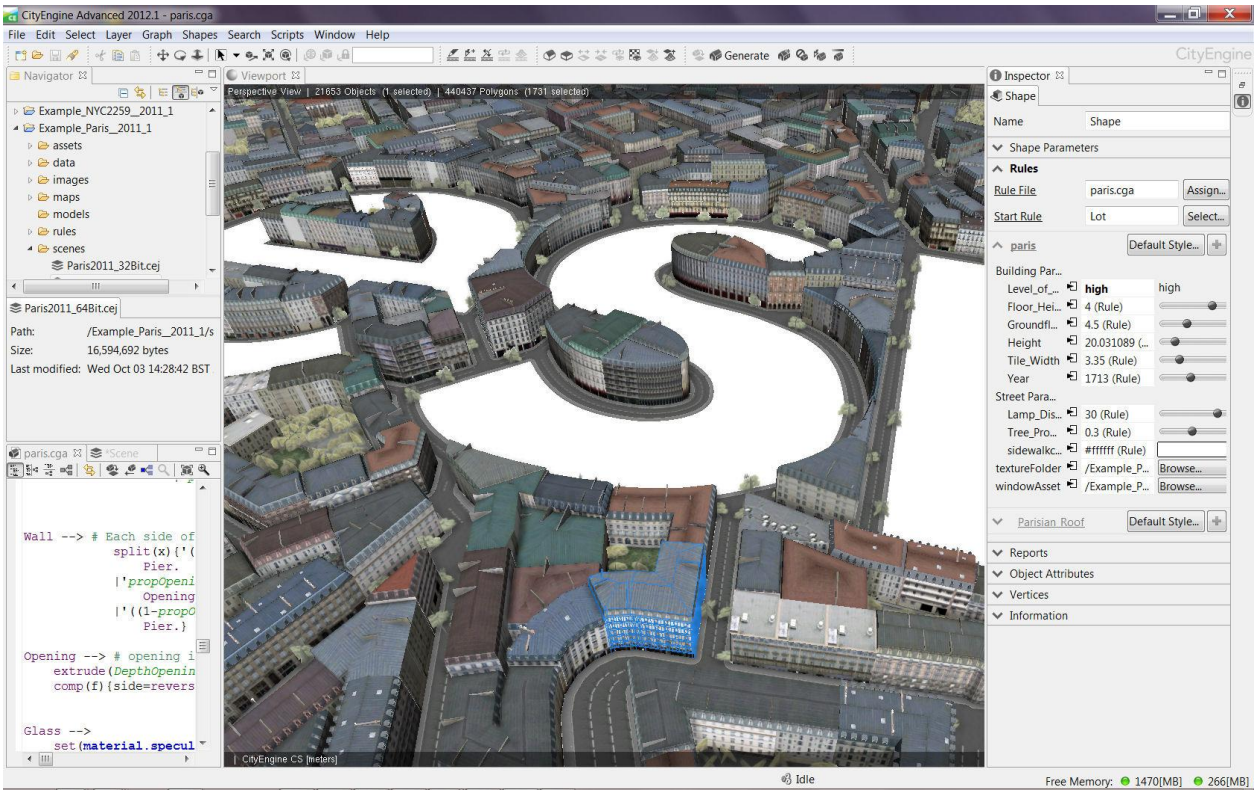
As well as reading and writing CityGML and other 3D vector formats such as DXF, KML or IFC via its Data Interoperability Extension, ArcGIS can directly import textured 3D building data in a variety of formats - 3D Studio Max, VRML/GeoVRML, SketchUp, OpenFlight, and COLLADA. It can also directly export VRML and COLLADA, and import other formats via Data Interoperability.

6 CITYENGINE - PROCEDURAL MODELLING

Many users would like to go 3D but they only have 2D Data. Esri CityEngine integrates closely into ArcGIS and allows the user to take their existing geodata and apply procedural rules to automatically generate high quality 3D content. Starting with existing spatial data such as parcels or road centrelines, CityEngine takes the GIS geometries and attributes, and uses them to apply parametric rules to automatically create 3D urban content such as 3D buildings and 3D streets, including realistic textures and ornaments.

The example below shows a procedural model for a hypothetical city in the style of Paris, using just street centrelines as starting point. From these roads are generated the land polygons (Lots), and from those, the buildings with (random) heights and styles from a range of years. From the

buildings are generated the walls and roofs, and from them the frontages with windows, ornaments, and textures. If actual information such as heights or years were available as attributes, then they could be used to make the model more precise. Specific important building models can be imported via formats such as COLLADA. The result is a realistic model in a short time with minimum human effort.

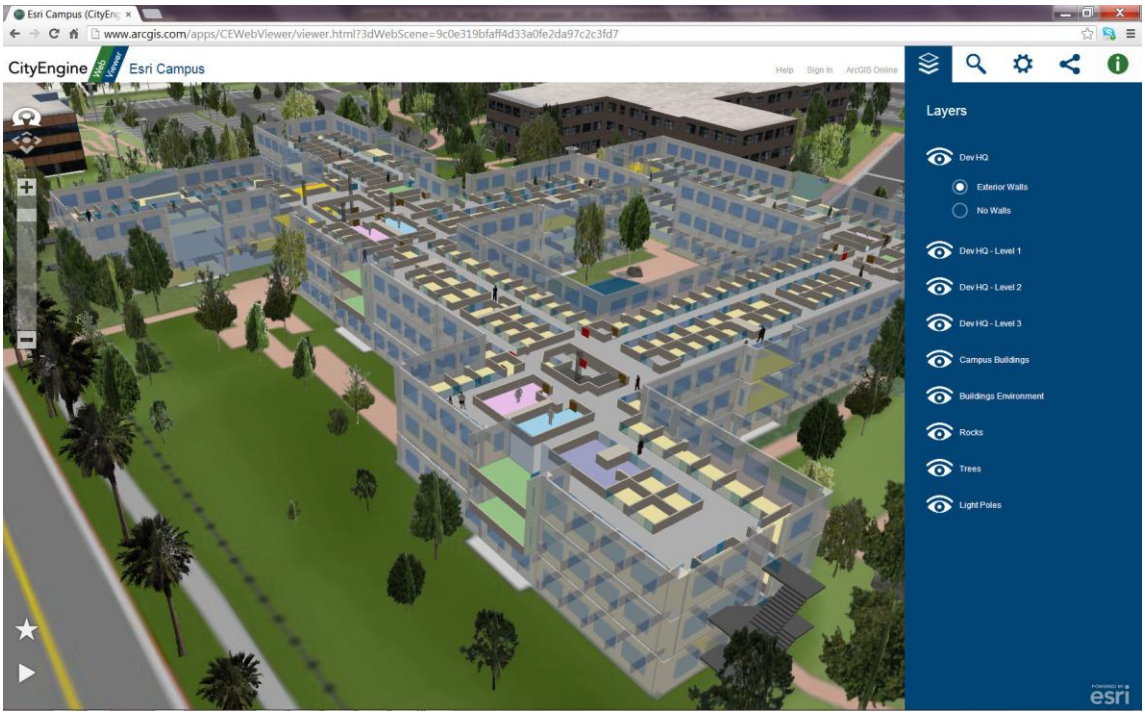


CityEngine – procedural model rules

7 WEB AND MOBILE VIEWING

Once generated in CityEngine, such 3D models can be exported as a CityEngine Web View, which can be read into a modern WebGL-capable browser, and dynamically explored. The view below is of Esri's development headquarters. Within the browser one can turn on and off the walls, interrogate the attributes of features, swipe between layers to see what is behind, add lighting and shadows, etc. – all without installing specialist software.

Such CityEngine Web views can be uploaded to ArcGIS Online (http://ArcGIS.com/), where they can be catalogued and accessed for easy sharing, along with associated map and feature services.



CityEngine Web View – WebGL in a browser

8 CONCLUSIONS

ArcGIS has evolved from a 2D GIS to a true 3D environment, which provides a rich set of tools for collection, management, visualisation, analysis, and sharing of 3D data such as city models. As such it allows NMAs to add value to their legacy 2D data and create and deploy vibrant 3D city models.

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