CityEngine for Archaeology

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Mini conference: 3D GIS for mapping the Via Appia
VU University Amsterdam, 19 April 2013

Universiteit Leiden
The Netherlands

Outline

-Introduction

- 3D urban reconstruction at the ancient city of Koroneia

- Procedural modeling with CityEngine

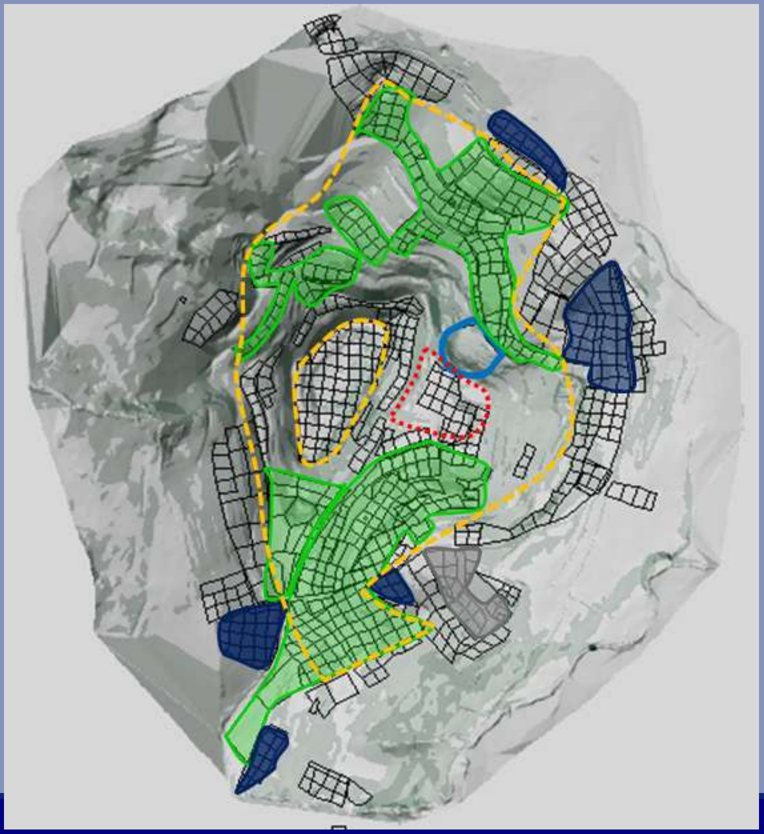
- Procedural modeling approach
- CityEngine's functionalities
- Overview of archaeological projects
- 'Transparent' 3D models in archaeology

- Discussion

Koroneia, Greece

In 2006 Leiden University has started to survey the ancient city of Koroneia (Boeotia, Greece).

The integration of the preliminary results from pottery and architectural survey gives a preliminary functional zoning of the ancient city



Koroneia, Greece

Aims of the 3D visualisation project:

- Combine all the available data (e.g. pottery and architectural survey results, geophysical analysis) in 3D to visualise Koroneia's development over time

- Test reconstruction hypotheses on the ancient city layout in the virtual environment

- Evaluate available software packages to find the best solution for 3D modeling of (archaeological) urban environments

- Online and on site navigation for heritage education of local communities

Koroneia's 3D visualisation project

Challenges:

- The survey/study is still ongoing: data are constantly updated by fieldwork results, the 3D model should change accordingly to the most updated state of the knowledge of the ancient city

- Combination of heterogeneous sources; need of a 3D modeling software that interfaces well with GIS based data

- Reconstructing an entire ancient city → large scale virtual environment: need of low poly modeling for online access/real time interaction

Koroneia’s 3D visualisation project

Challenges:

- Parts of ancient Koroneia are only superficially known from archaeological and historical sources: need of a 3D modeling approach that allows to “fill in” this missing information in a controlled, documented yet fast way

- Clear distinction between archaeologically documented data and hypotheses - intellectually transparent, London Charter compliant 3D visualisation

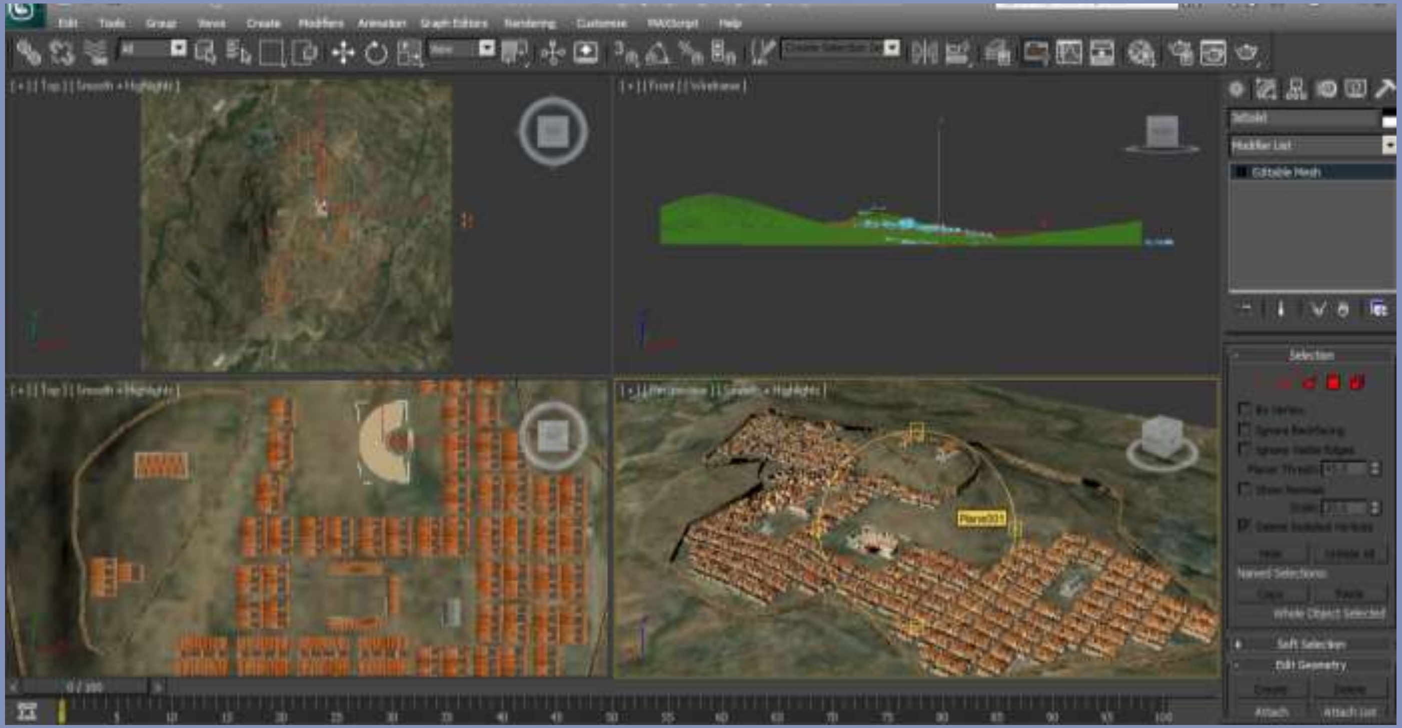
Koroneia's 3D visualisation project

Initial approach: manual Computer Graphic modeling
(3D Studio Max and Blender)

3D visualisation of Hellenistic Koroneia made with manual modelling techniques
(C. Piccoli)

Koroneia's 3D visualisation project

- The creation of manually modeled variations in the architectural shapes is very time consuming; the result still displays unrealistic regularities.
- Not efficient work pipeline: updating the 3D model according to fieldwork results is very time consuming



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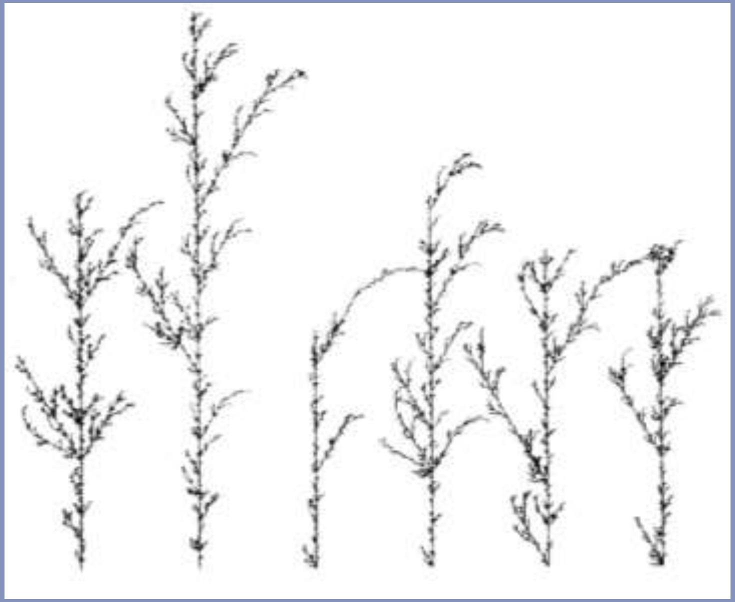
Procedural modeling

To create 3D models and textures from a set of **rules** following a given shape grammar

Traditionally used to model geometry that is recursive and too tedious to be modeled manually e.g. plants (a single tree pattern can be used to create an entire forest) and landscapes.



P. Prusinkiewicz and A. Lindenmayer 1990 (digital version: 2004), *The Algorithmic Beauty of Plants*, 29.

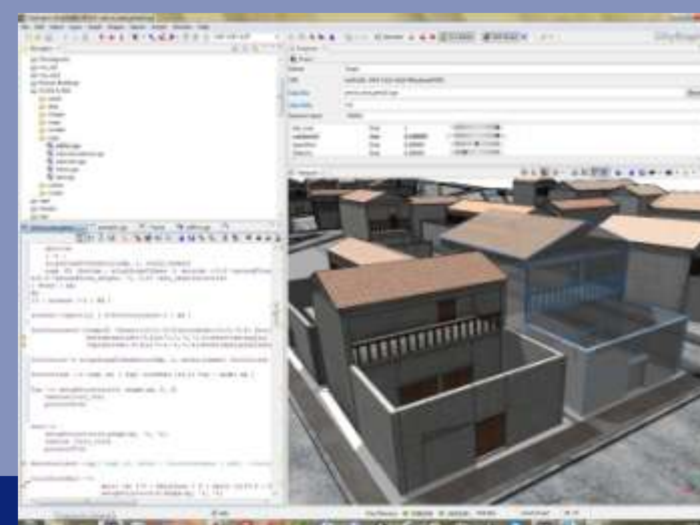
CityEngine

2001: Developed by Pascal Mueller during his PhD at ETH Computer Vision Lab, Zurich (2008: distributed by his company Procedural)

2011: Procedural bought by ESRI (strong link with ArcGIS; 3D GIS for urban environments)

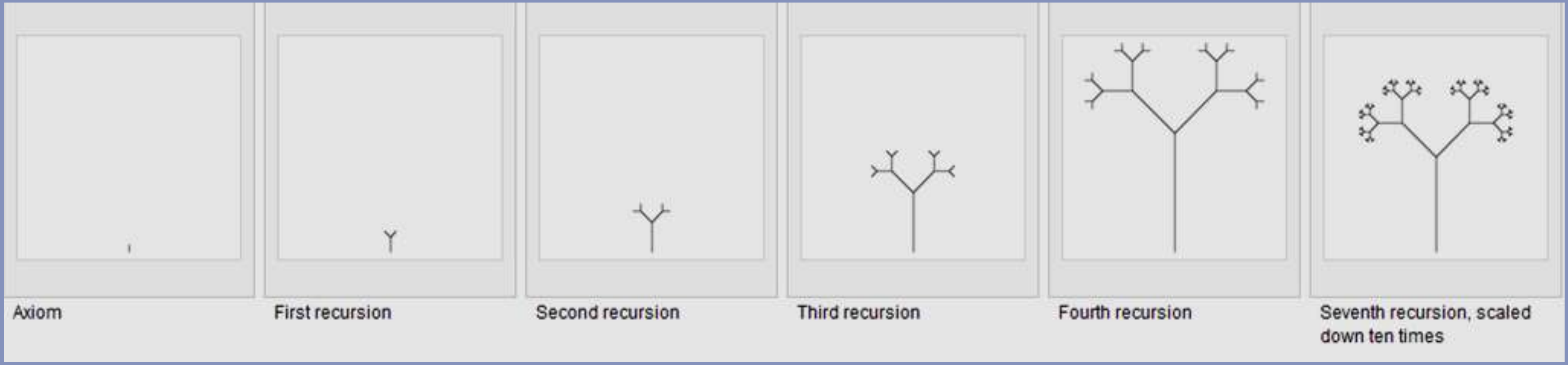
Import of real data (GIS data, Aerial images, 2D building footprints, 2D street network)

Export of the created 3D environment in ArcGIS to perform spatial analysis, visibility analysis, shadow and visual impact of buildings on the surrounding cityscape



CityEngine shape grammar

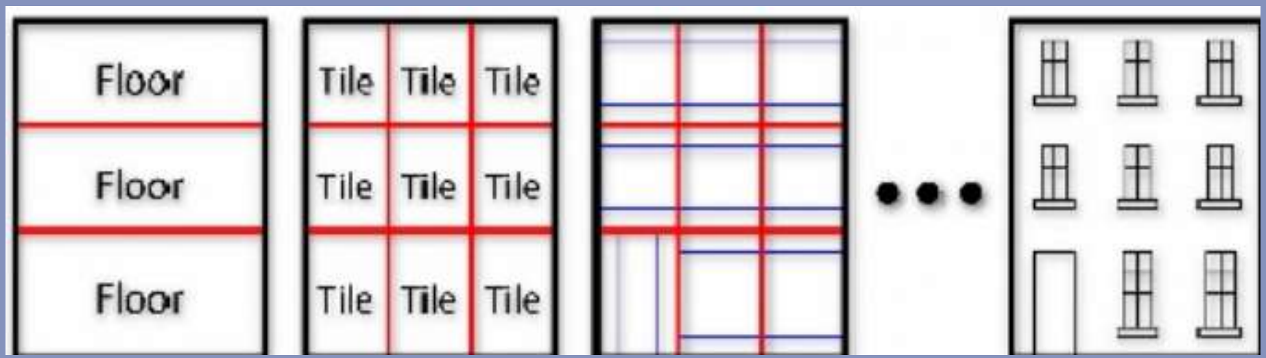
CityEngine's shape grammar is based on the so called "L-systems" developed in 1968 by the Hungarian biologist Lindenmayer to describe the growth of plants in a formalised language

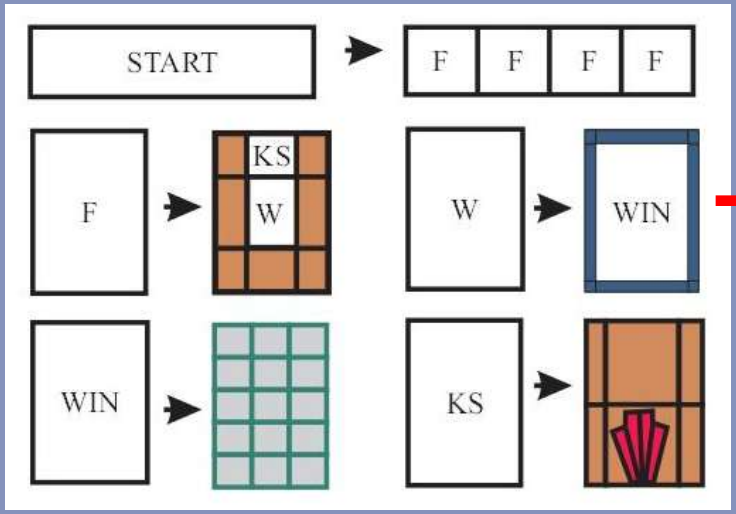


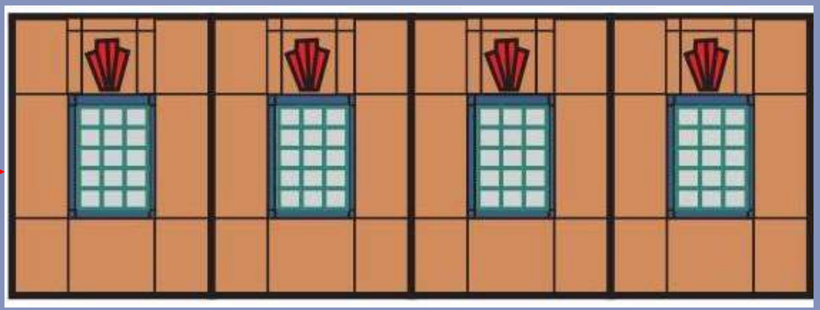
http://en.wikipedia.org/wiki/L-system

CityEngine shape grammar

The same principle is applied to architecture: the 3D geometry is created by iterative horizontal and vertical splits of an initial shape. The steps for shape creation are written in a so called “CGA rule”

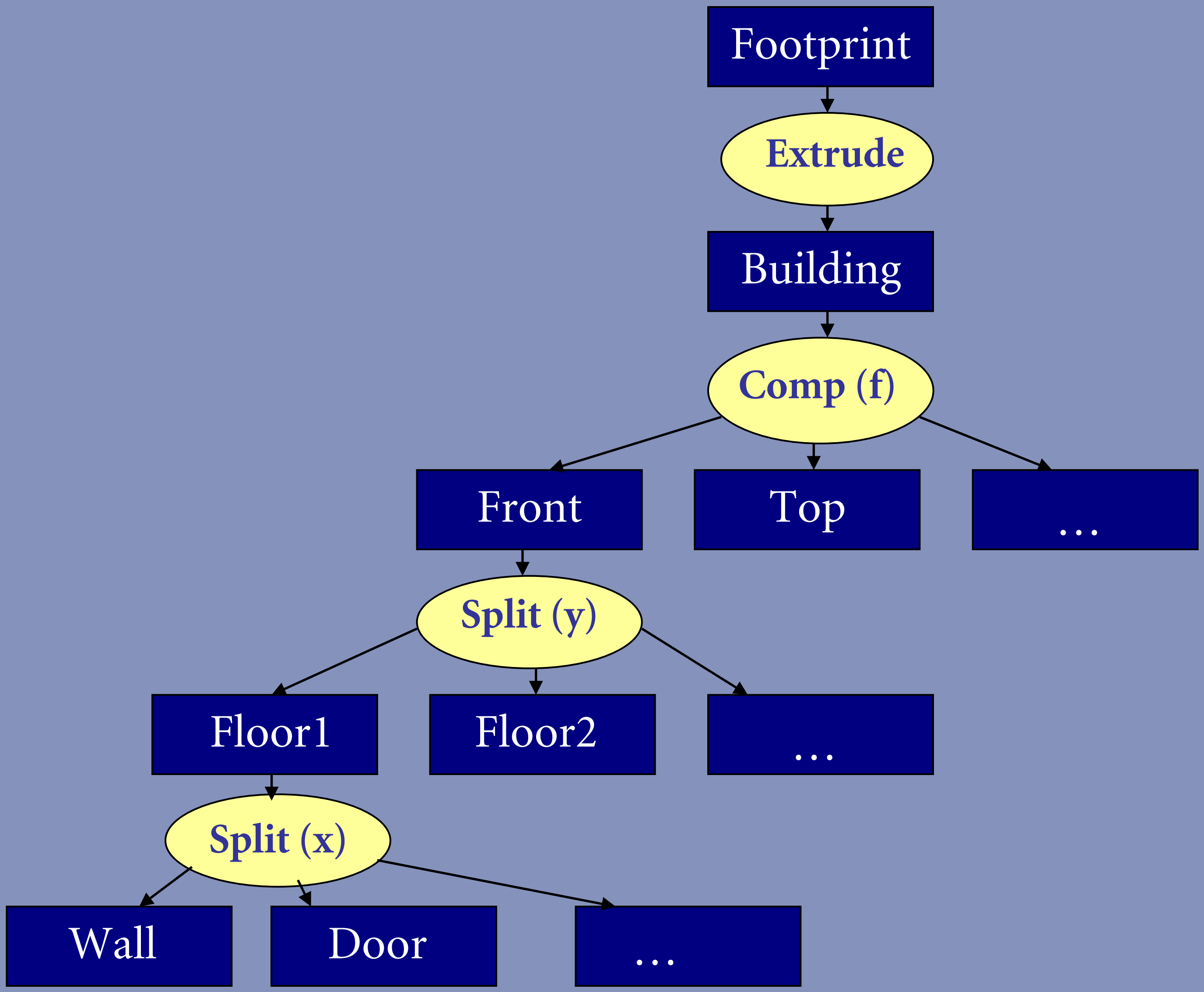






Wonka *et al.* 2003. Instant Architecture. In A. P. Rockwood (ed.), *Proceedings of ACM SIGGRAPH 2003 / ACM Transactions on Graphics* 22(3), 672

CGA rule – basic operators

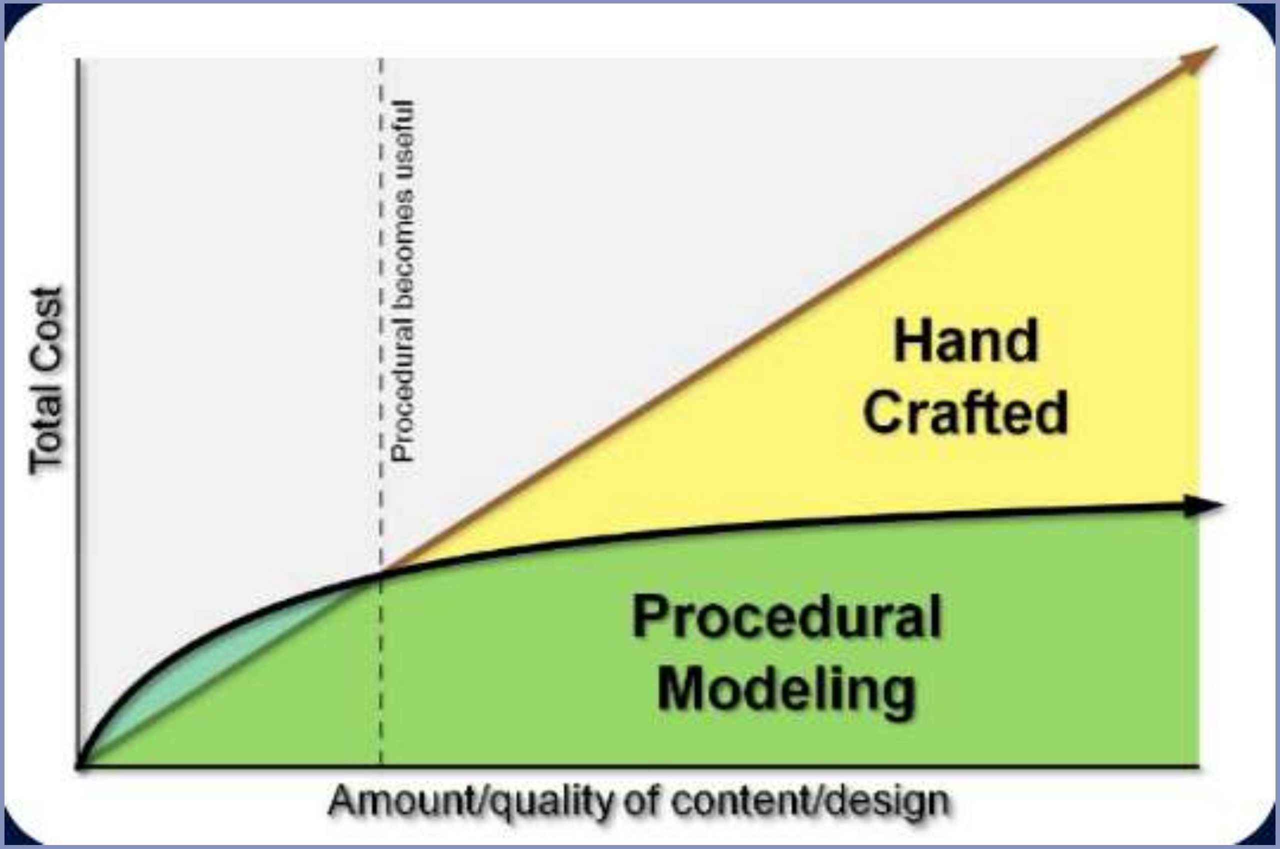


Procedural modeling approach

Advantages:
- speeding up of the modeling process
- (controlled) randomness
- easy to update
- flexible
- re-usable
- easy creation of multiple 3D models
- the process of creation is recorded on the rule file (= increased intellectual transparency)

Procedural modeling approach

Disadvantages:
less user friendly than manual 3D modeling techniques



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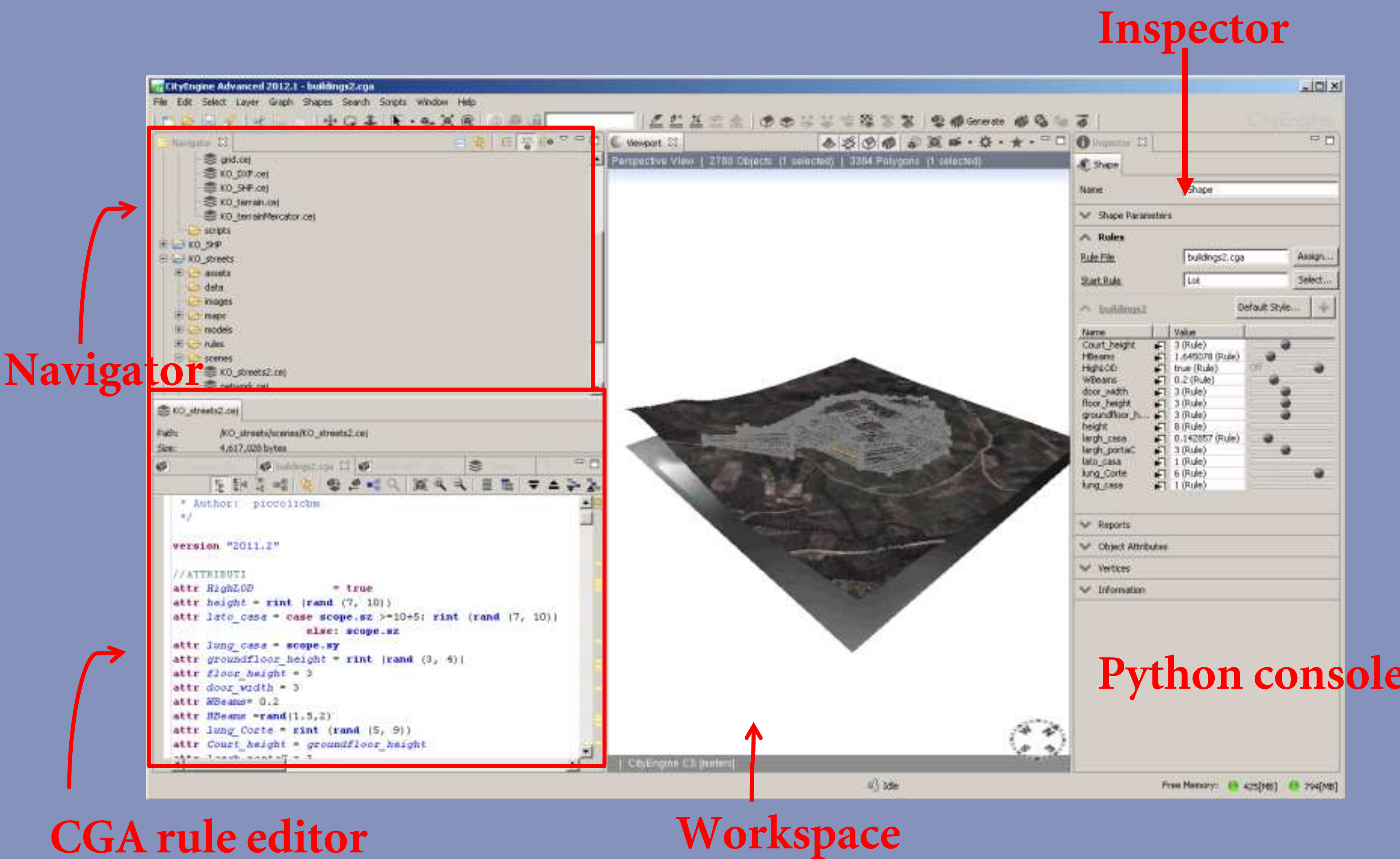
CityEngine interface



Elements for the modeling process in CityEngine

1) Terrain (heightmap/texture map) and control map layers (images)

2) Street network (automatically/manually created in CityEngine, or imported from DXF, SHP files)

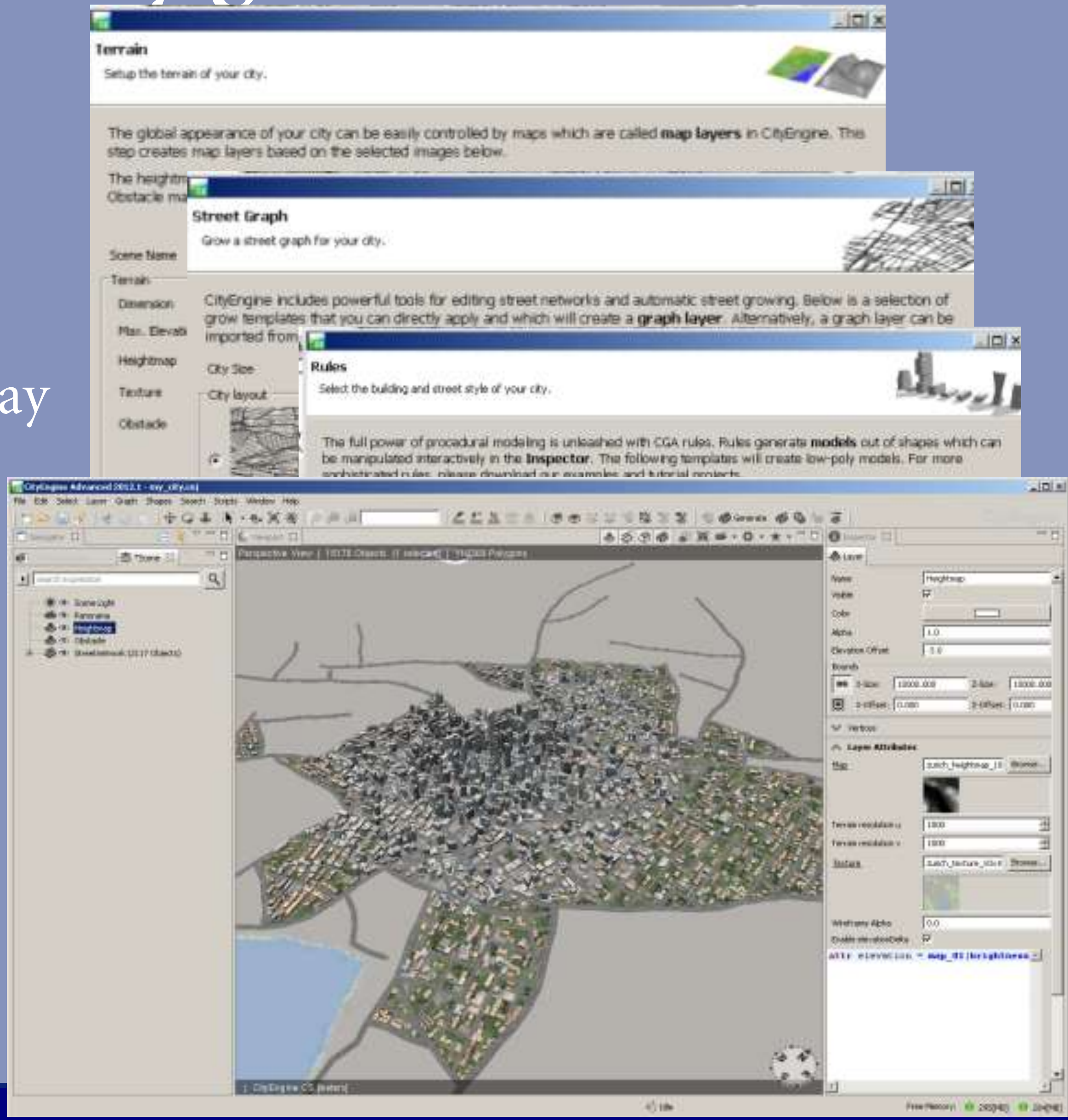
3) Building footprints (automatically/manually created in CityEngine, or imported from DXF, SHP files)

4) CGA rule file

CityEngine 3D city generation

CityEngine allows for various degree of user's control on the city generation:

From a semi automatic way (with target: game and movie industry)…

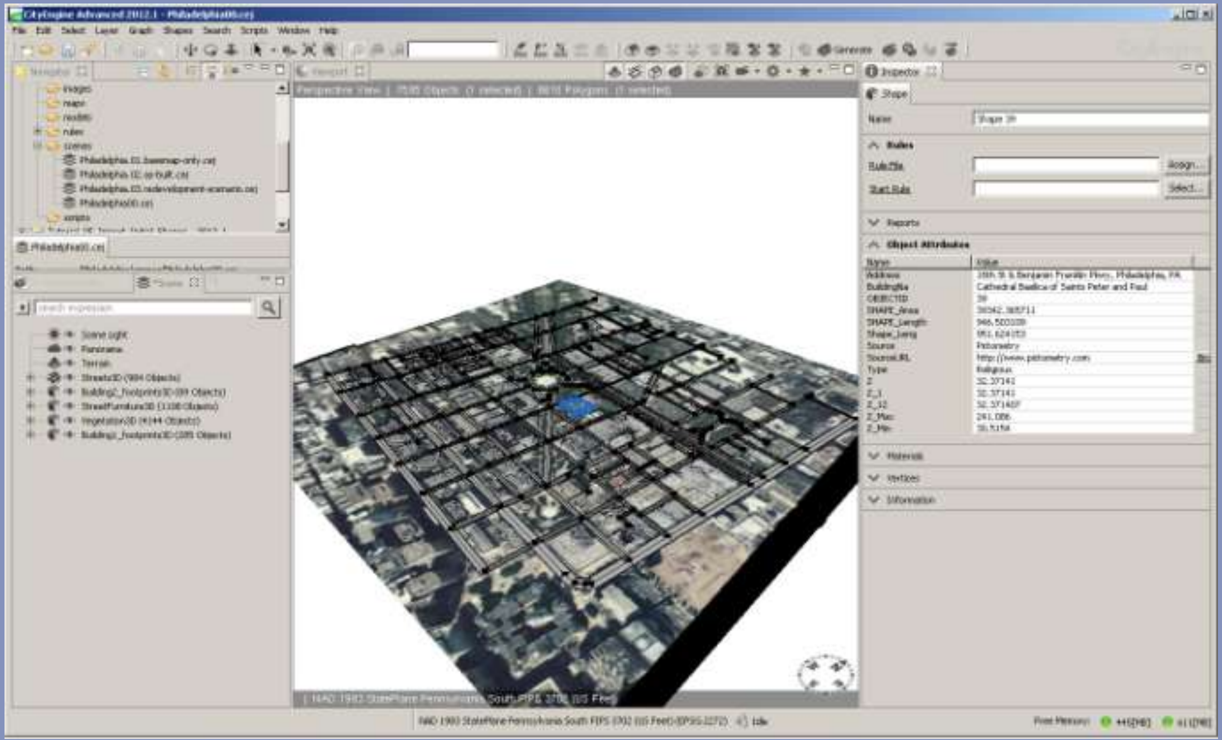


CityEngine 3D city generation

…to a 3D cityscape generation based on real data, e.g. by importing GIS data and writing *ad hoc* CGA rule files that describe the required architecture typology

(Target: urban planners

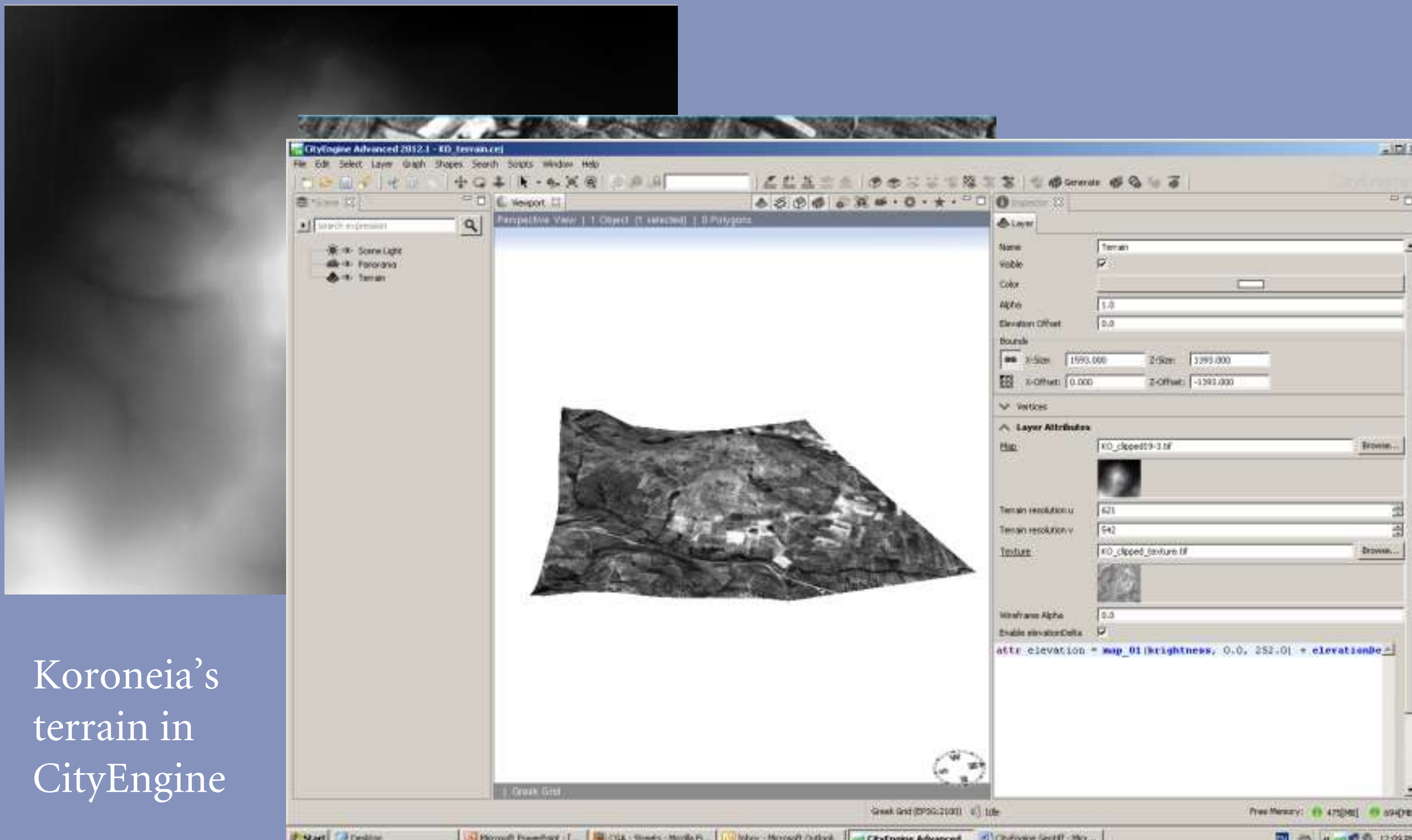
…archaeologists)



CityEngine template: Philadelphia

Map layers

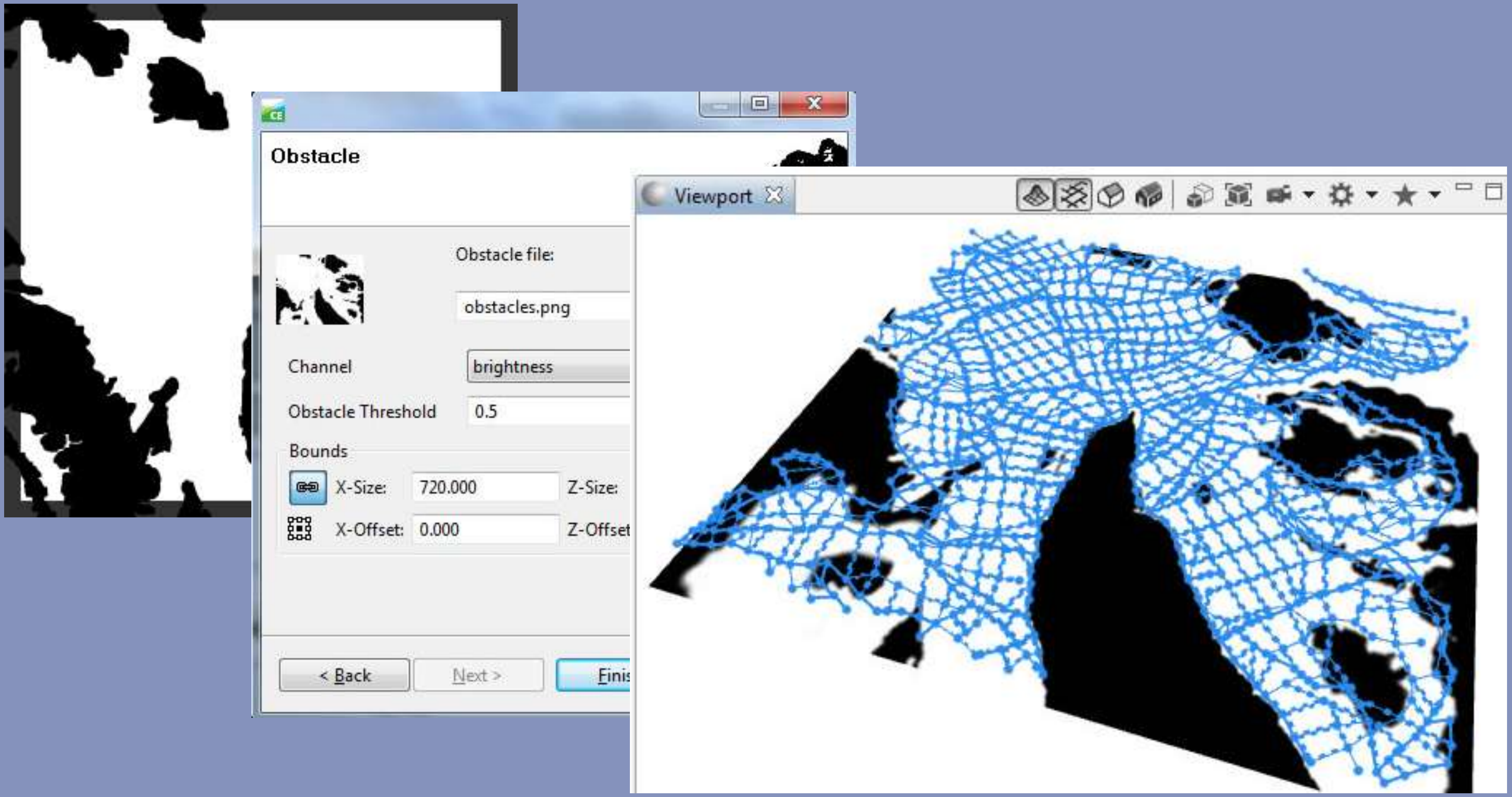
Terrain creation



Koroneia's terrain in CityEngine

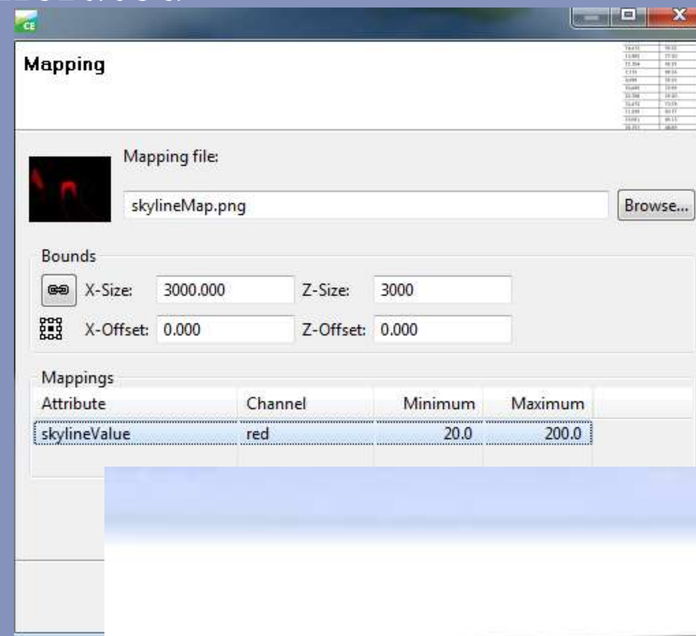
Map layers

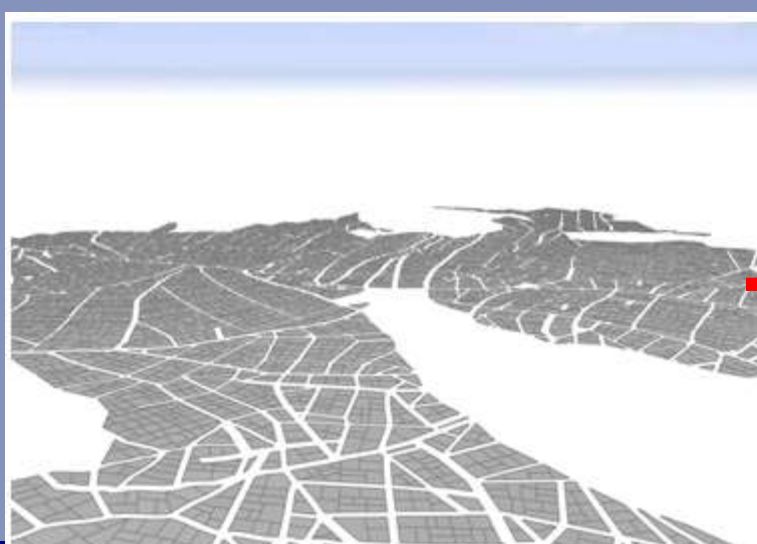
Obstacle maps can be used to avoid geometry generation in specific areas

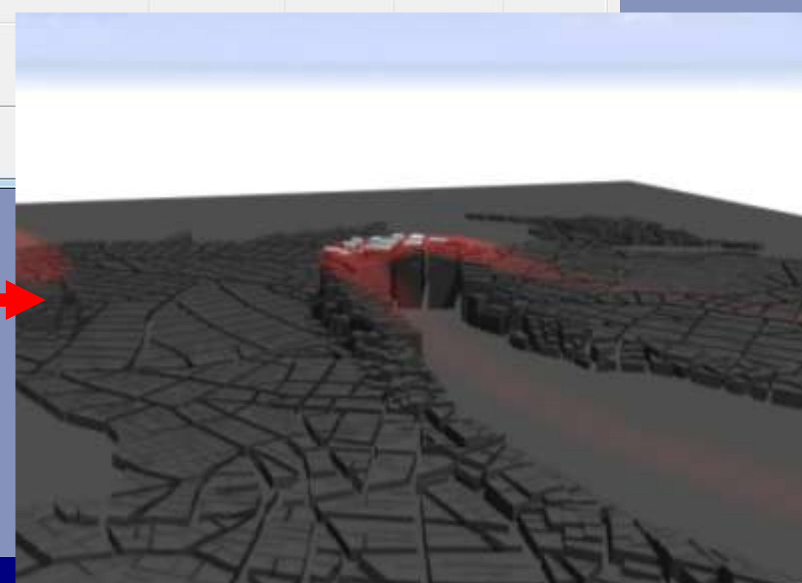


Map layers

Color maps help to control how and where geometry (e.g. buildings and vegetation)is generated



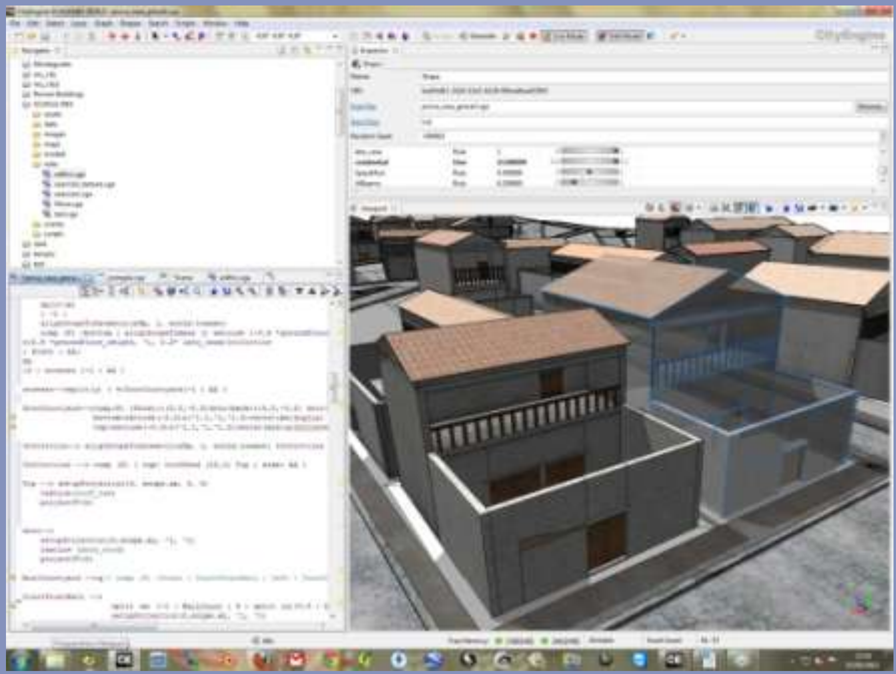


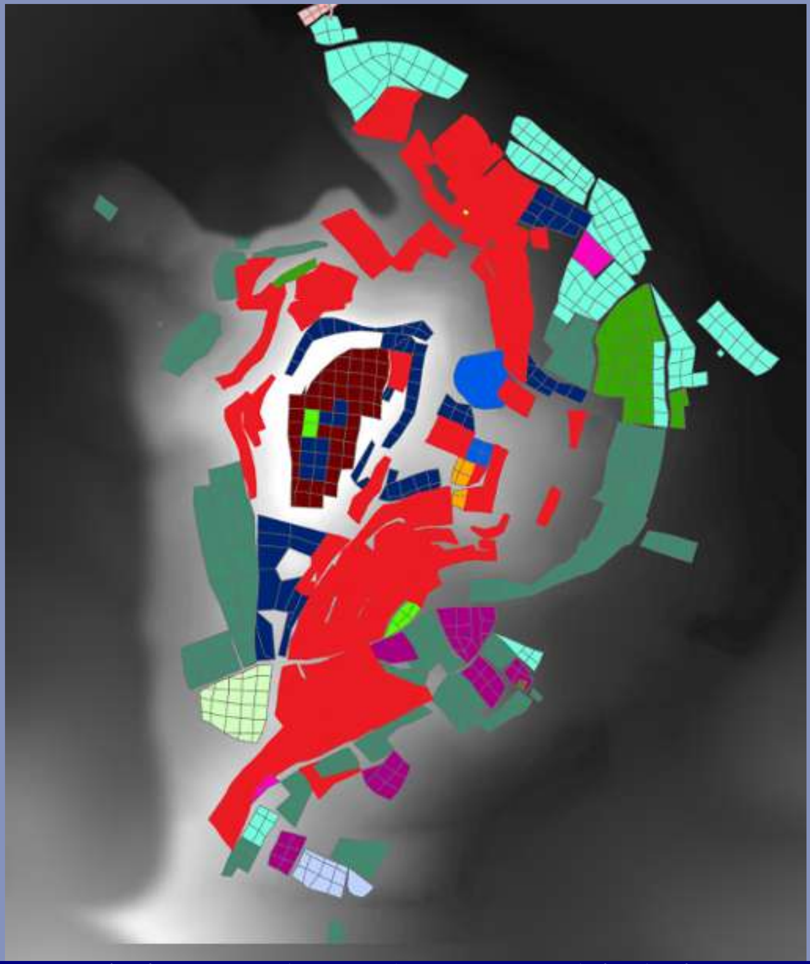


Map layers

In the case of Koroneia I used color maps to assign different building typologies to the corresponding functional areas, as they have been interpreted based on the current archaeological data (e.g. red = domestic areas)

Advantage: it is possible to quickly modify the city layout by updating the color map and assigning the same CGA rule.



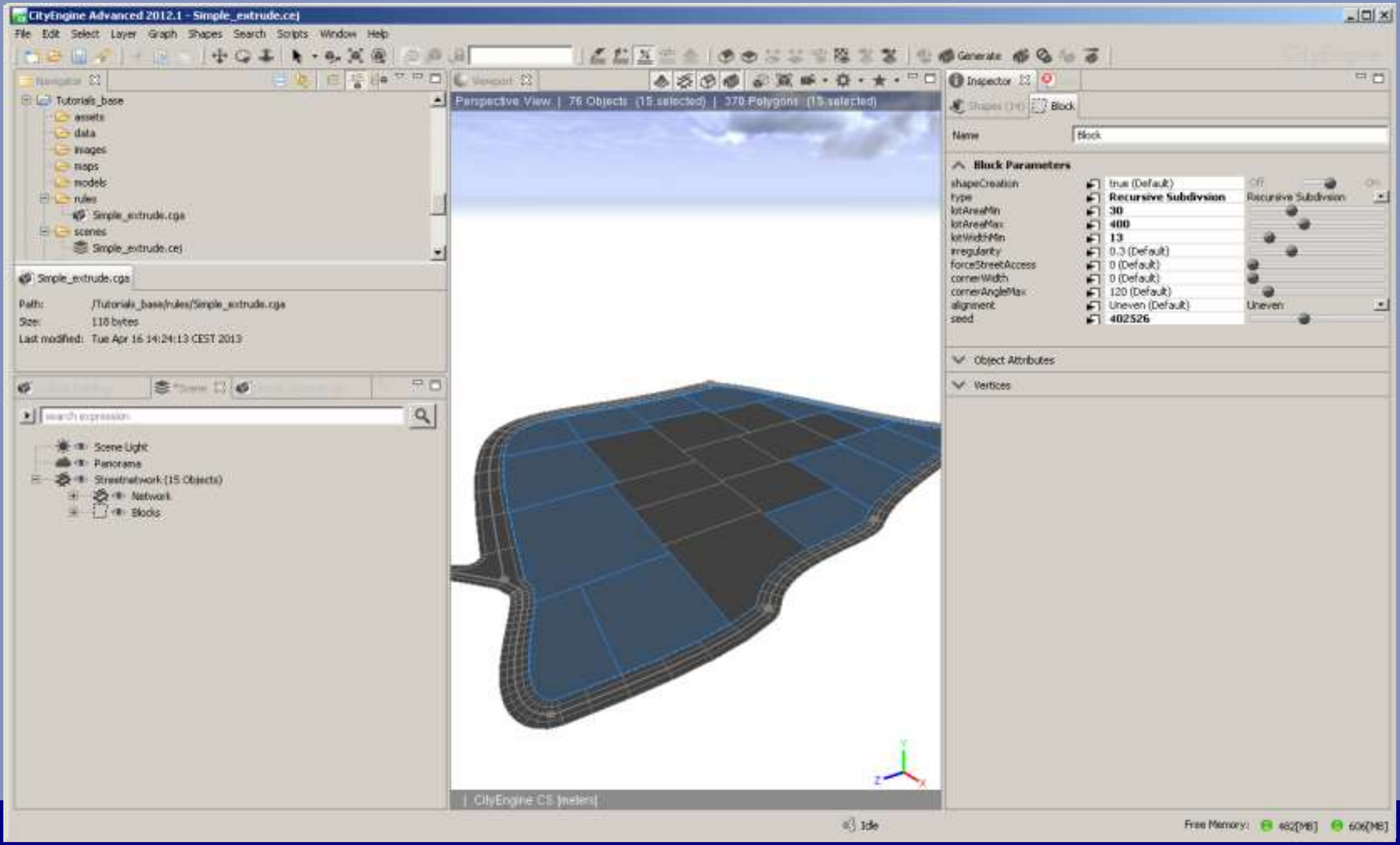


Left: screenshot from Koroneia's buildings in CityEngine; right: Koroneia's functional areas (picture modified after J. Van Zwienen)

CityEngine modeling process

Street network creation → block shapes creation

Default block parameters can be easily changed in the Inspector



CityEngine modeling process

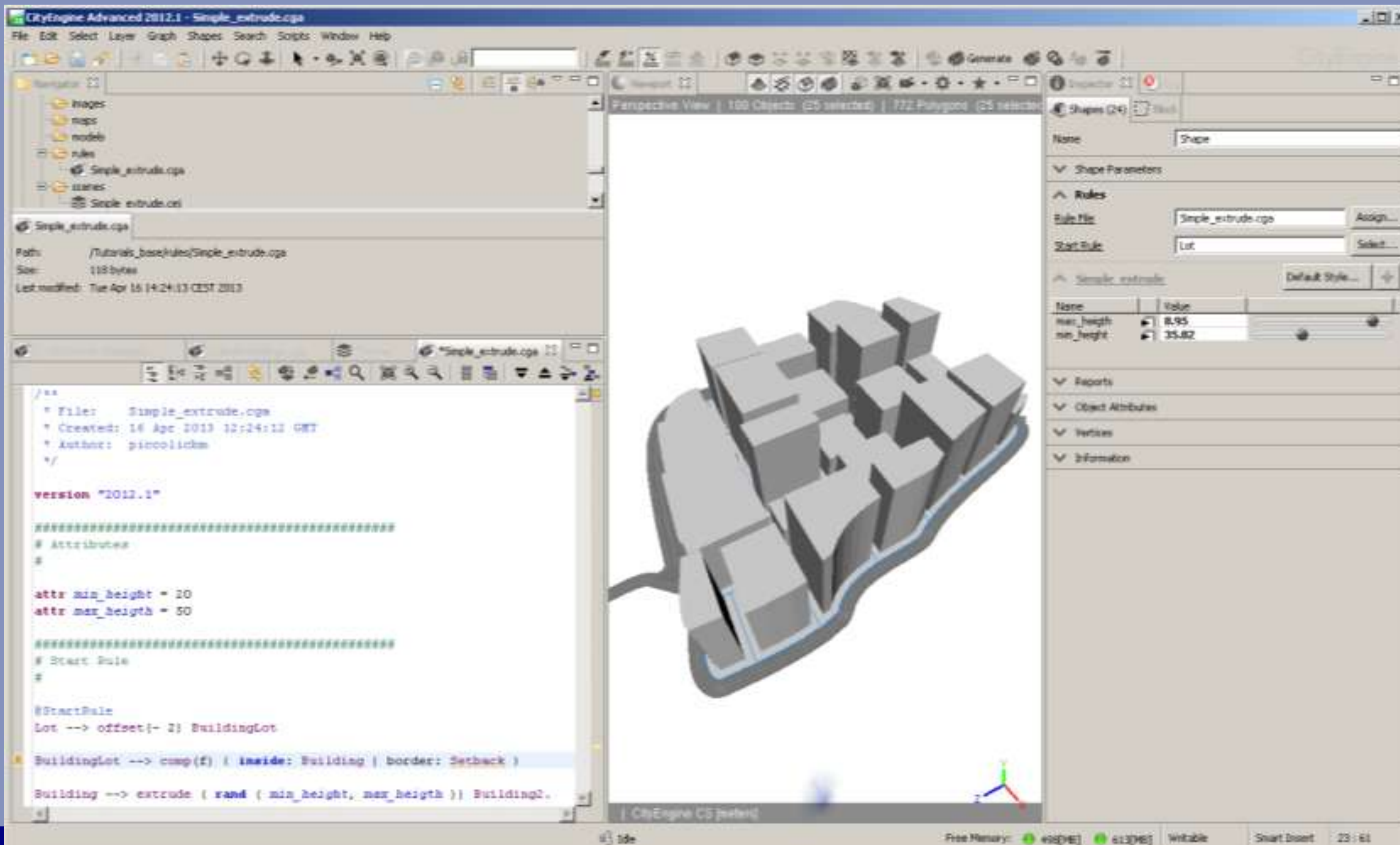
Example of CGA rule with stochastic parameters

*Simple_extrude.cga   *Scene

```
/**
 * File:    Simple_extrude.cga
 * Created: 16 Apr 2013 12:24:12 GMT
 * Author:  piccolicbm
 */

version "2012.1"

##############################################
# Attributes
#

attr min_height = 20
attr max_heigth = 50

##############################################
# Start Rule
#

@StartRule
Lot --> offset(- 2) BuildingLot

BuildingLot --> comp(f) { inside: Building | border: Setback. }

Building --> extrude ( rand ( min_height, max_heigth )) Building2.
```

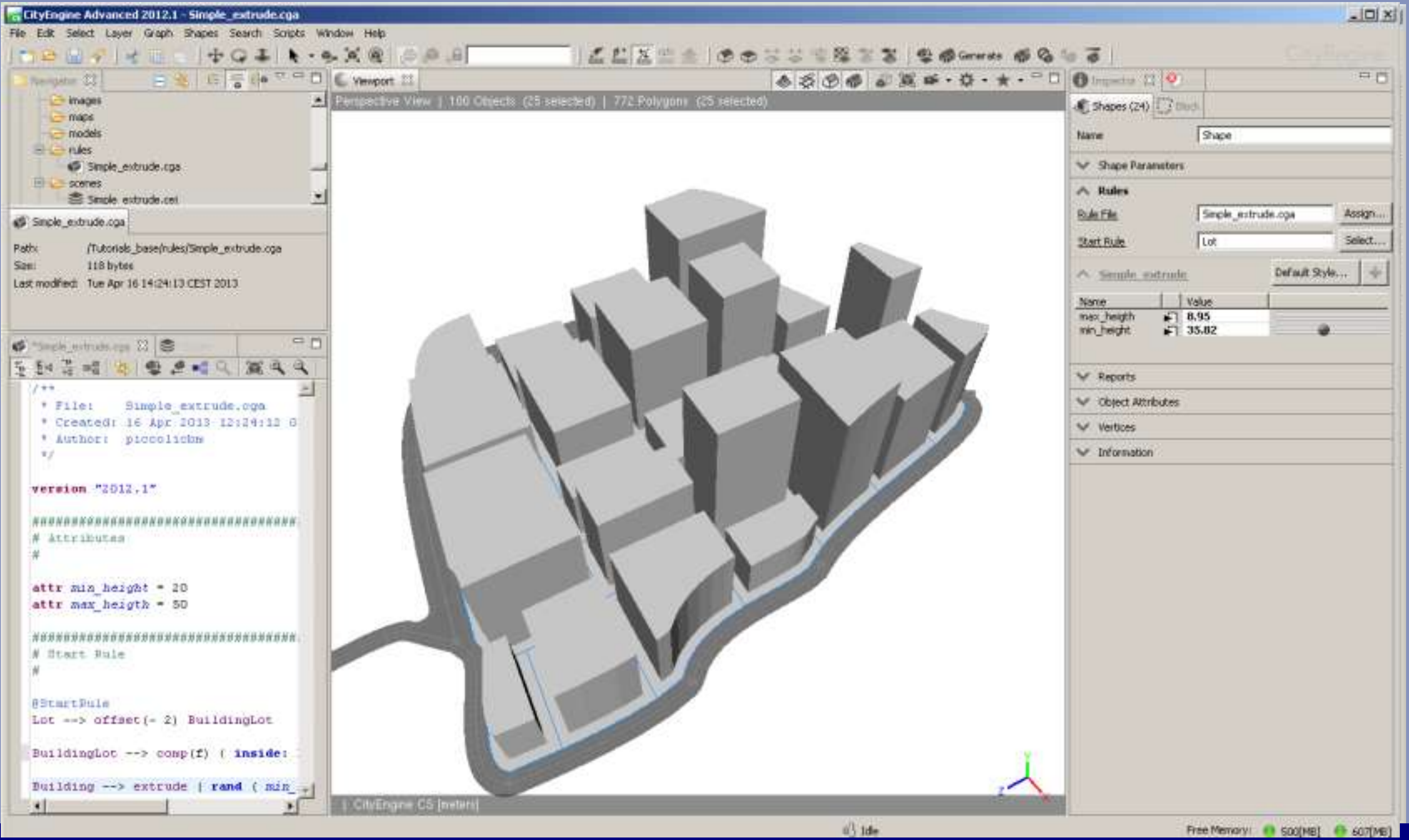
CityEngine modeling process

The CGA rule is assigned to the blocks and the geometry is generated according to the height range that was set in the rule file



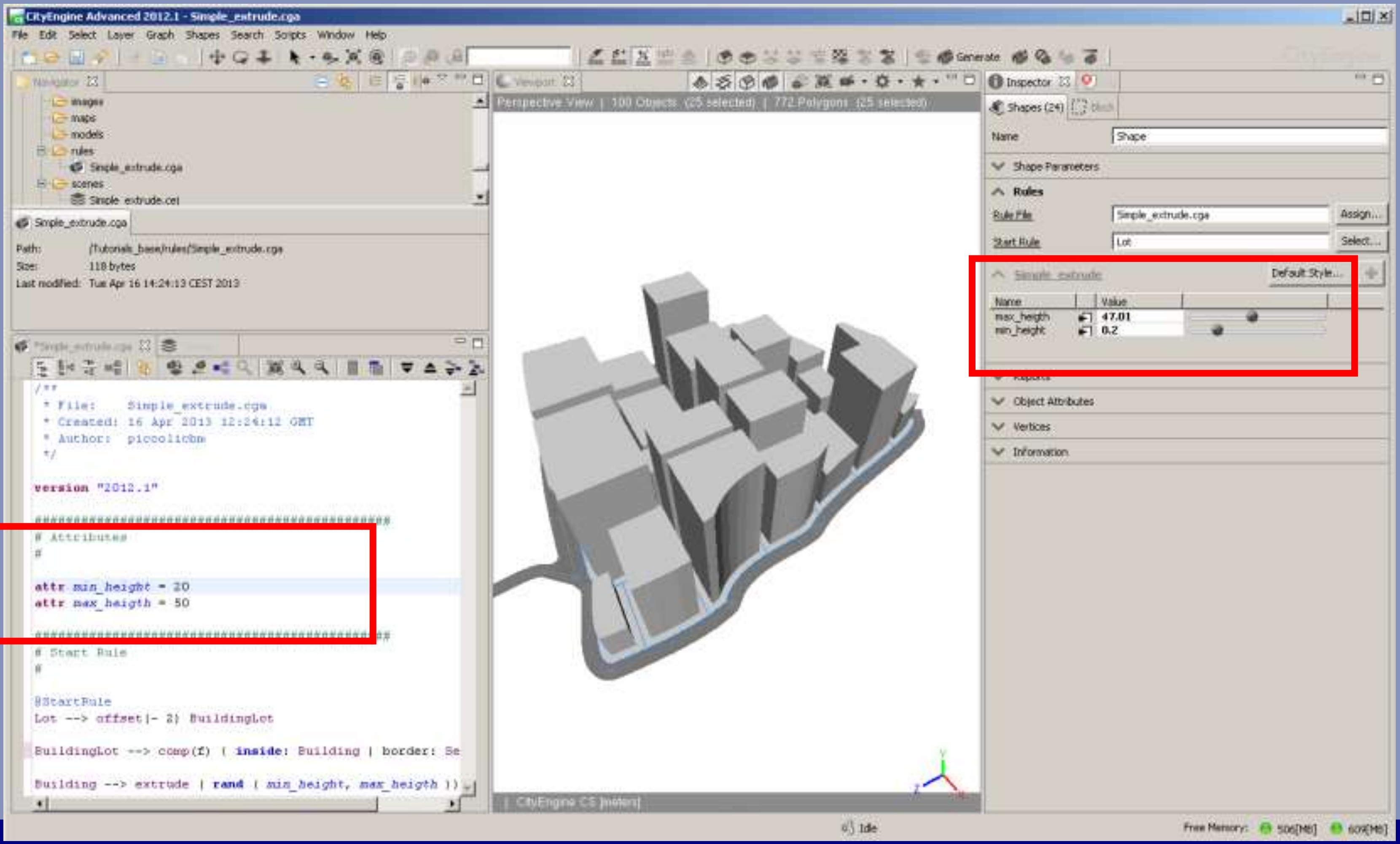
CityEngine modeling process

Every time that the 'Update seeds and generate models' button is hit, the geometry is stochastically updated within the parameters set in the rule file



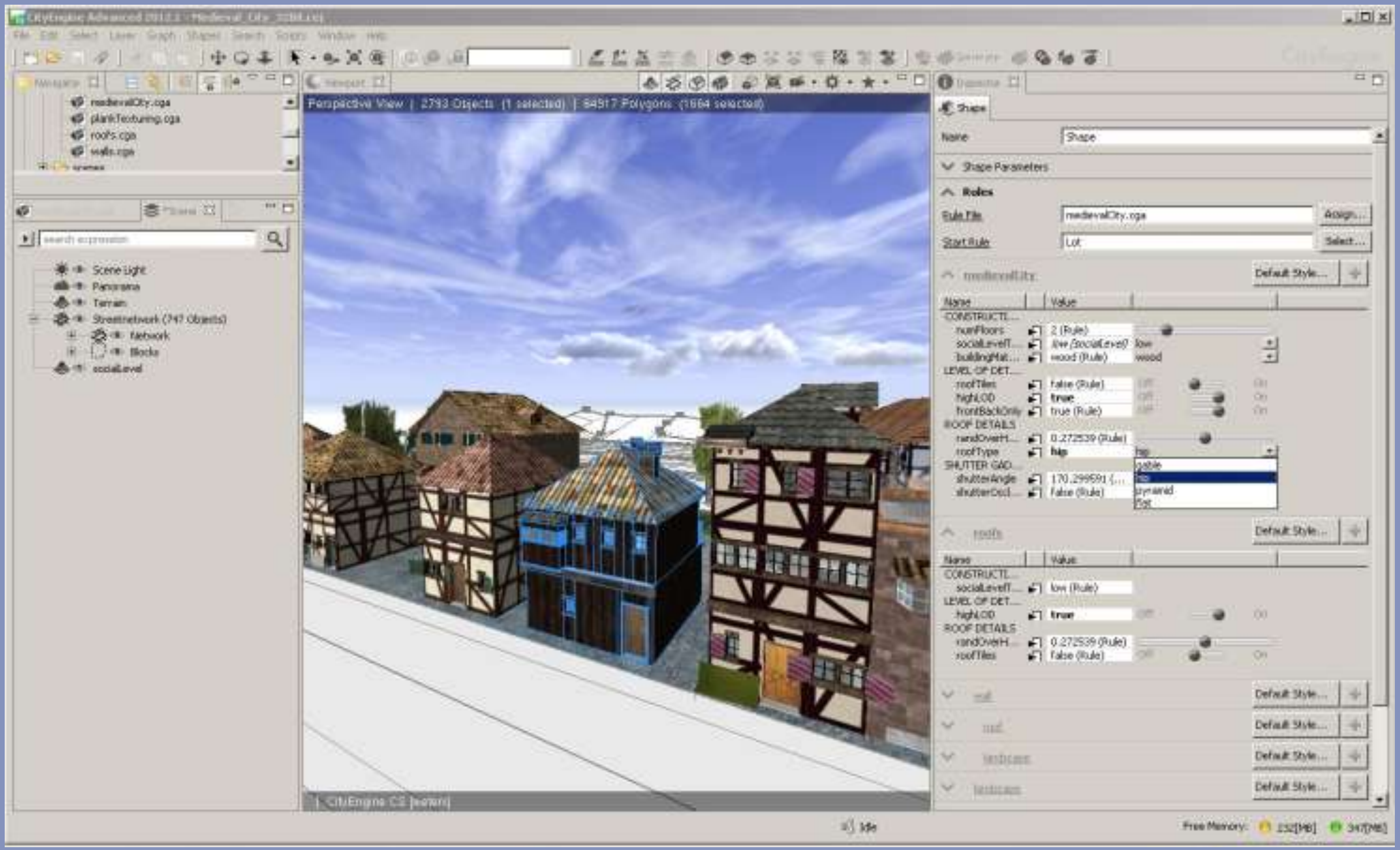
CityEngine modeling process

The height range can be changed both in the rule file editor and in the inspector, where all the attributes that are stated in the rule files are automatically displayed



CityEngine modeling process

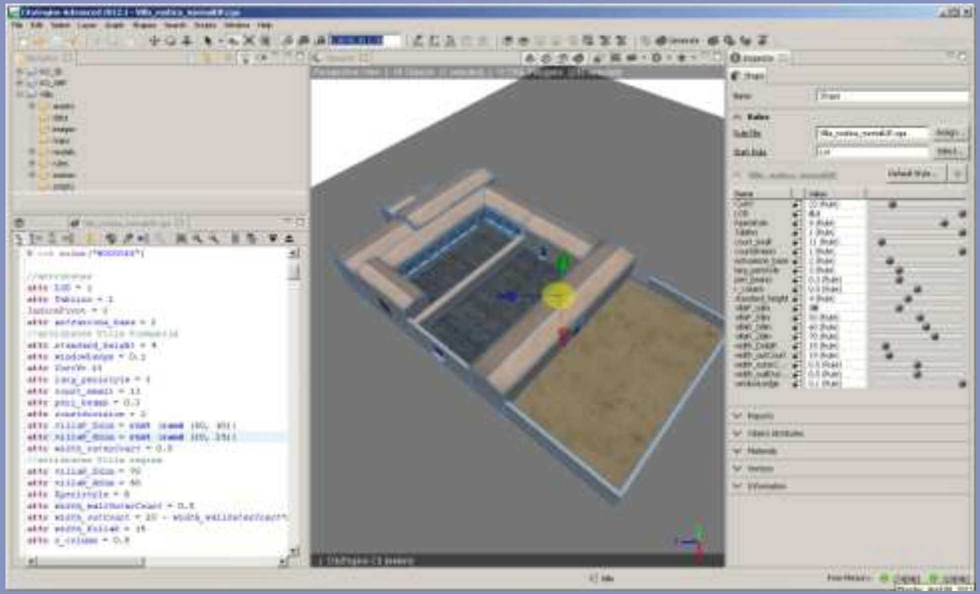
From the inspector it possible to modify the parameters of one single 3D model by changing its attributes, e.g. roof shapes…



CityEngine template: Medieval city

CityEngine modeling process

…or Level of Detail (according to the parameters set in the CGA file)



Screenshot from one of the Villa Rustica's for the Montegrotto project

LOD = 0

(quads only)

LOD = 1

(doors and windows)

LOD = 2

(thick walls)

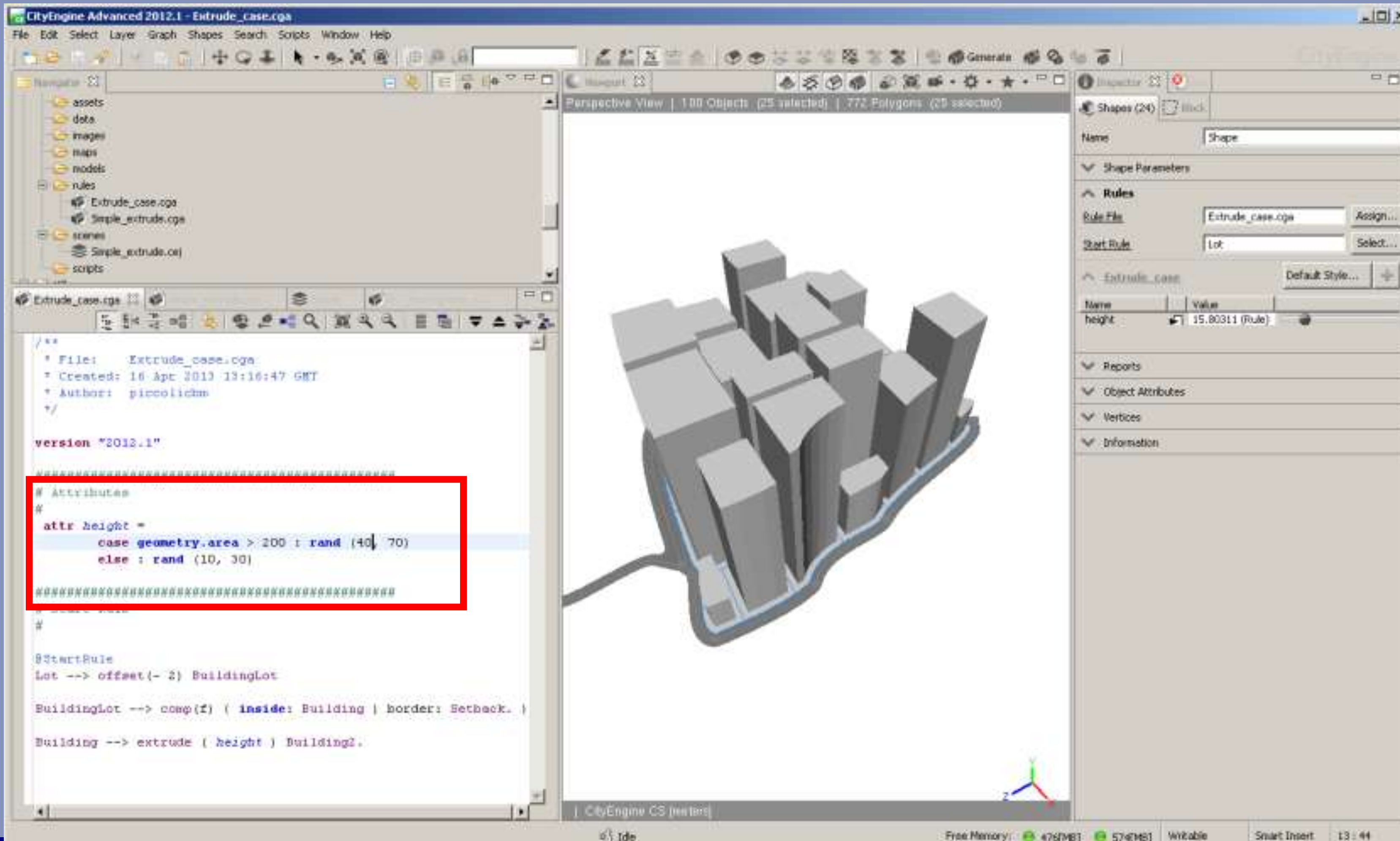
LOD = 3

(individual roof tiles)

J. Maim *et al.* 'Populating Ancient Pompeii with Crowds of Virtual Romans' VAST 2007, 26-30.

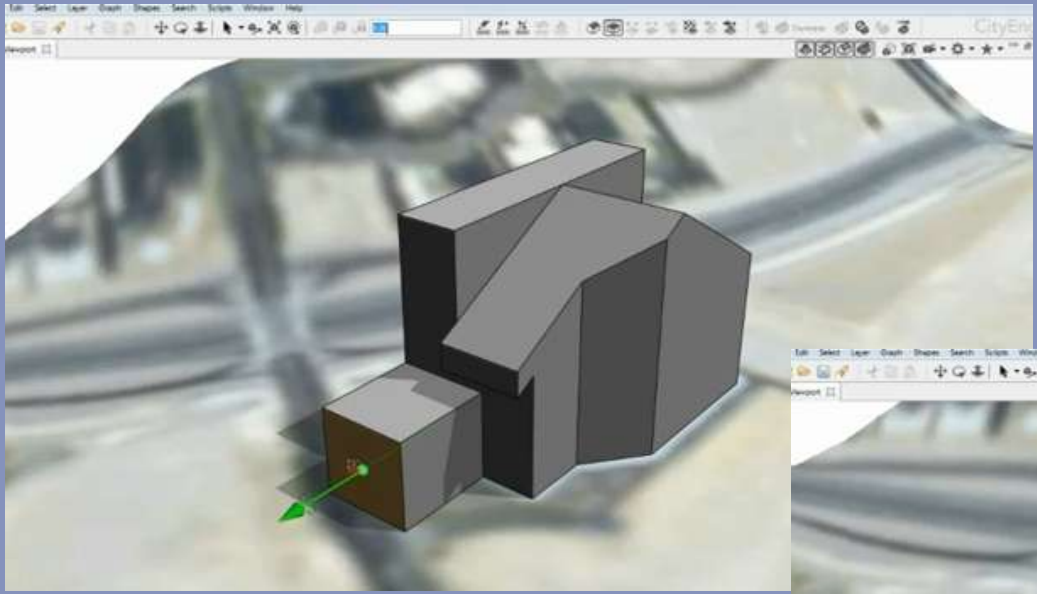
CityEngine modeling process

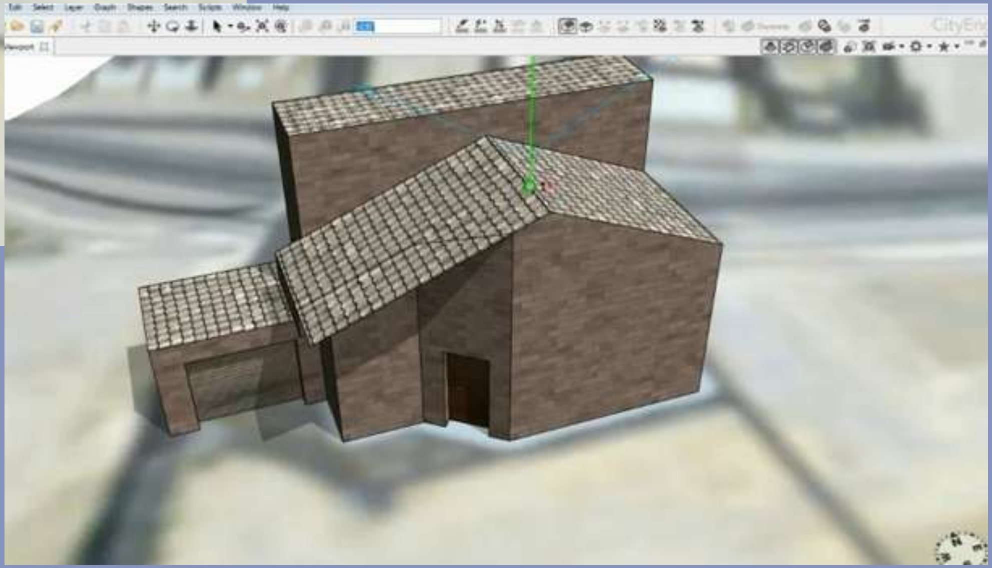
The shape grammar gives a high degree of freedom in specifying the rule for the geometry creation, e.g.



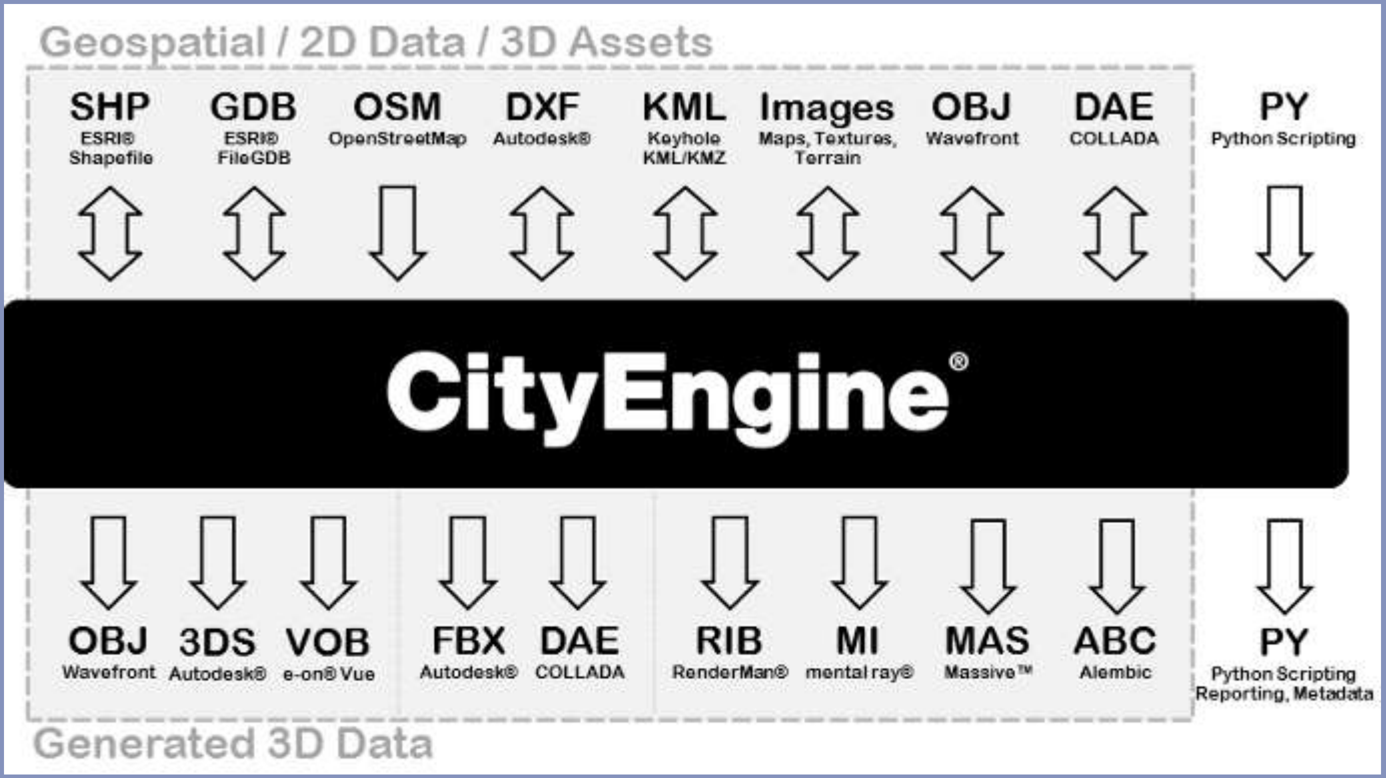
CityEngine modeling process

From version 2012 a Polygonal modeling tool (similar to 'Sketch Up') was introduced





Import/export



Import/export

CityEngine doesn’t handle well curved shapes.
In these cases and for complicated shapes or land mark buildings, it is more convenient to create the objects in a Computer Graphics software and import them into the scene in OBJ or DAE formats

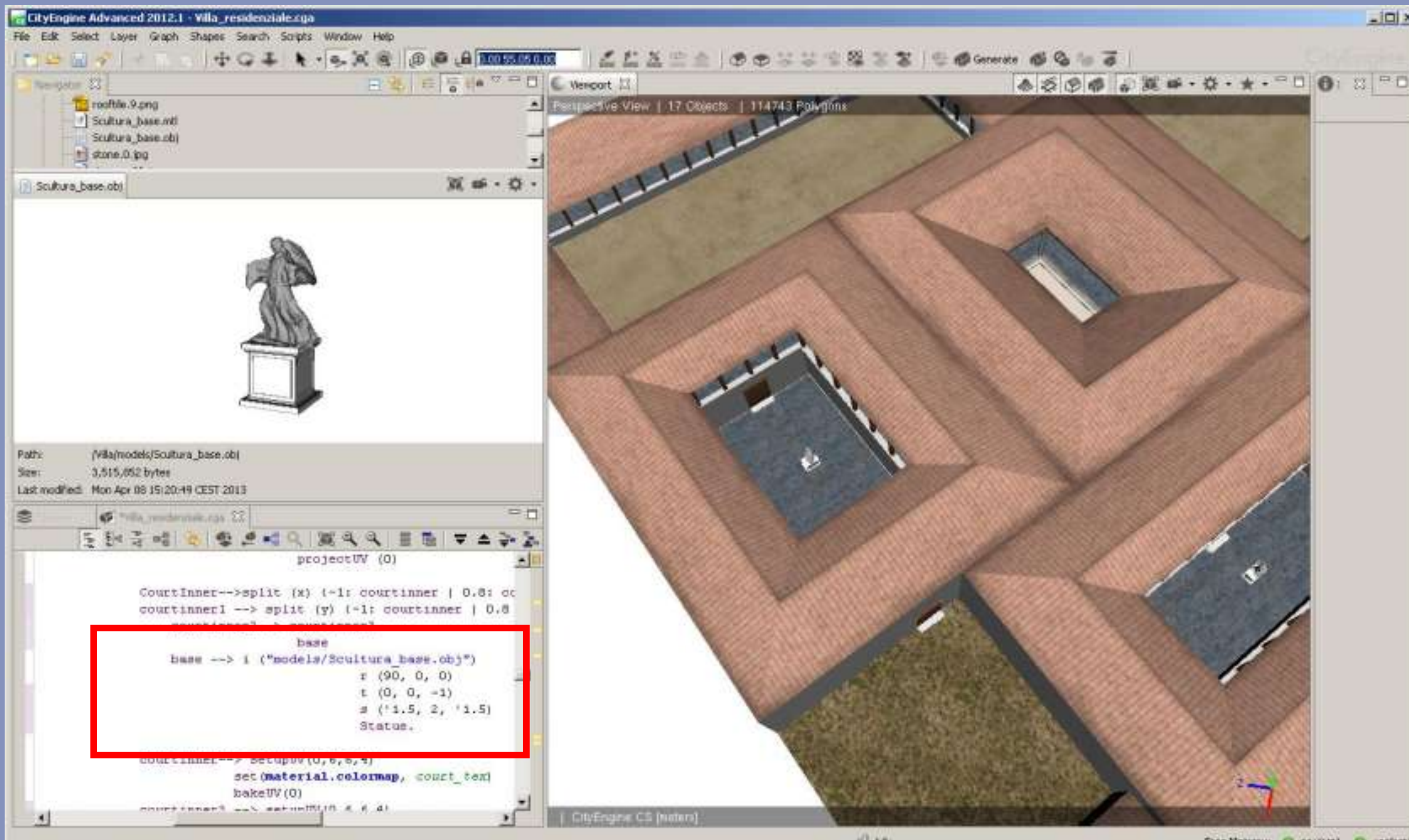
Images from CityEngine user manual

Import OBJ

3D model of a statue created in Autodesk 123D Catch and exported as OBJ file

Rendered 3D model in Blender

Import OBJ



Inserting the OBJ of the statue in CityEngine scene (Villa Rustica at Montegrotto)

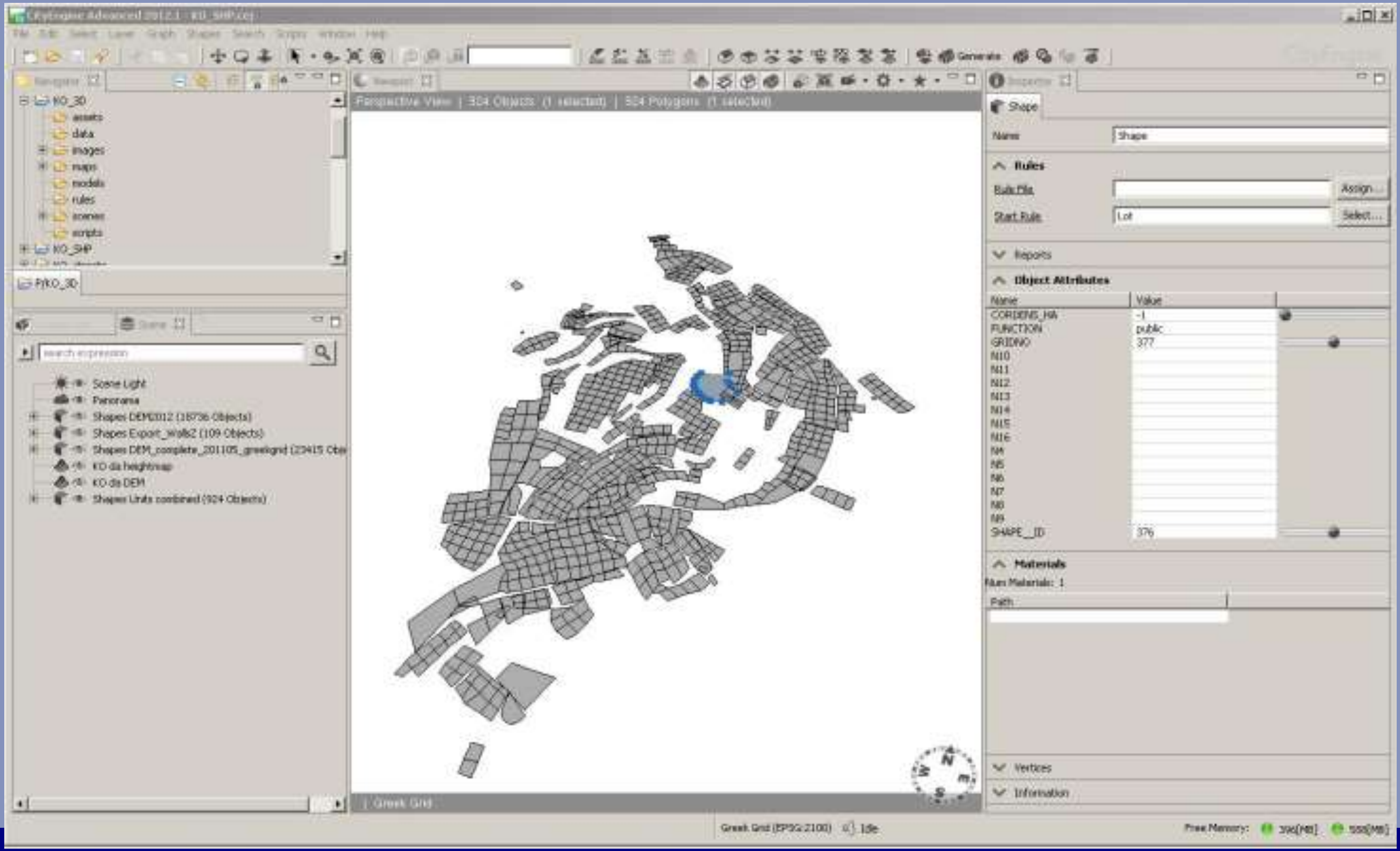
Export OBJ

CityEngine has no rendering capabilities. In order to render a scene properly, the 3D models have to be exported into a Computer Graphics software (e.g. Blender)

CityEngine template: Pompeii

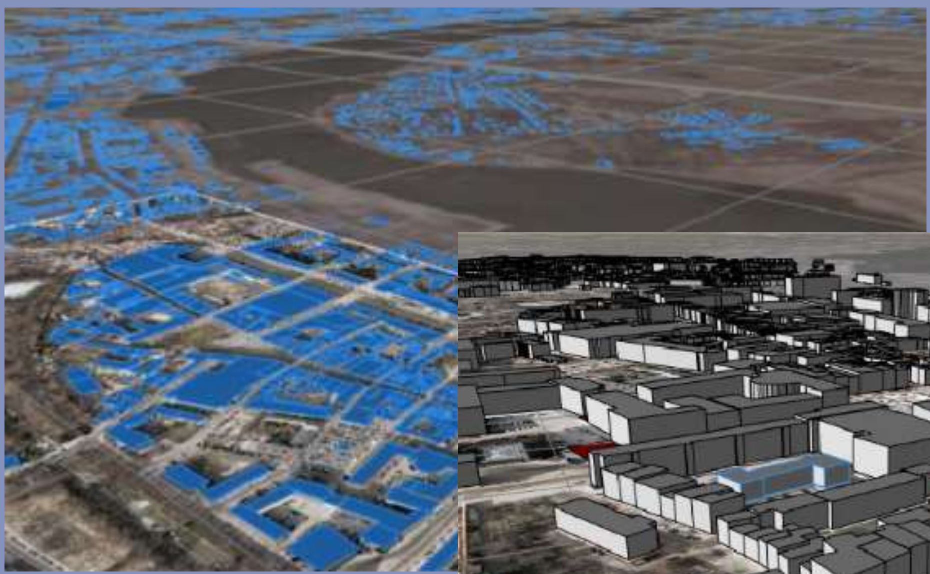
Import SHP

CityEngine imports SHP directly – the coordinates system is automatically recognised and the attributes that are stored in the GIS file are displayed in the inspector
(e.g. SHP file with Koroneia's grid units)

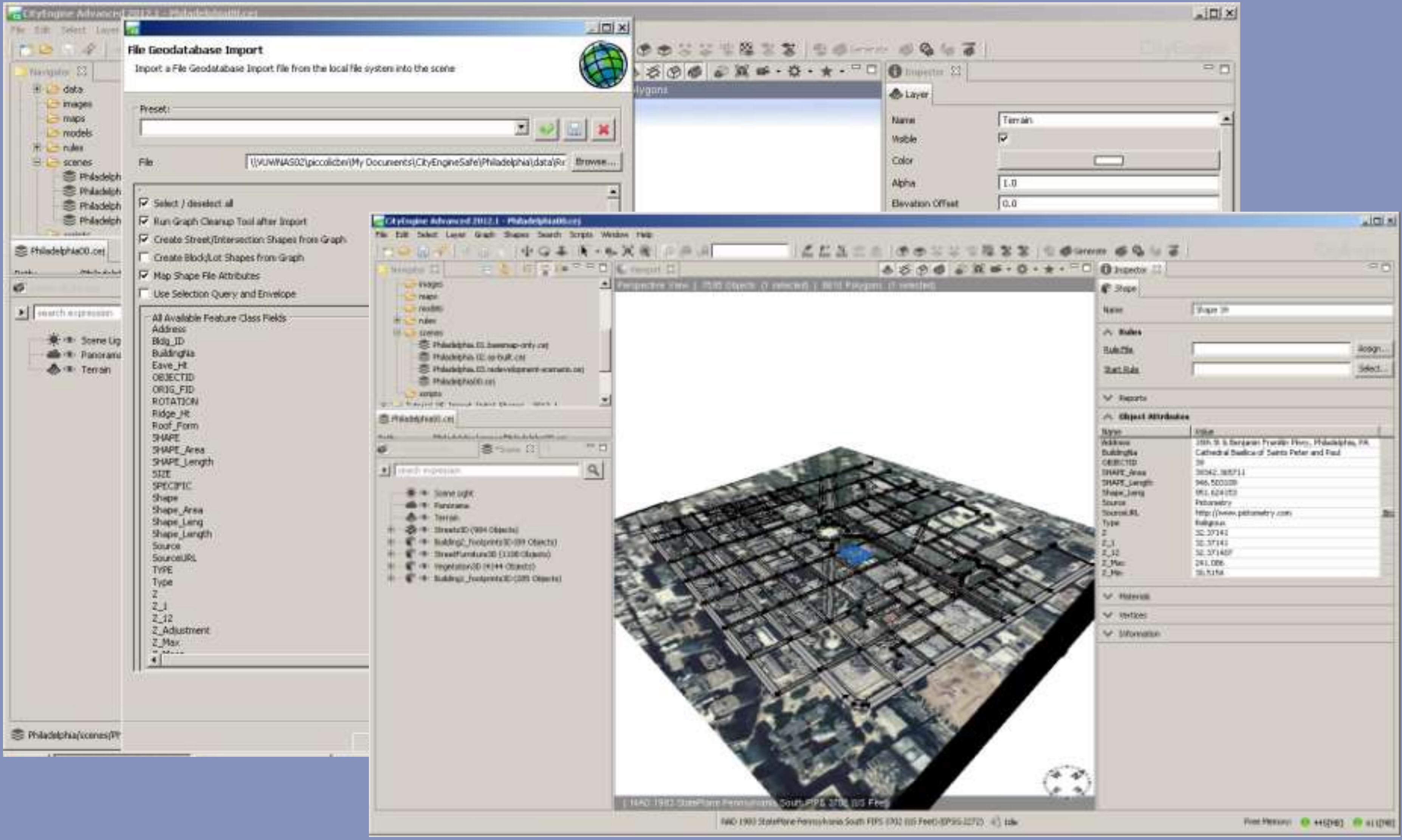


Import SHP

It is possible to quickly create 3D buildings by assigning a CGA rule that extrude the building footprints according to the height attributes that are contained in the SHP file



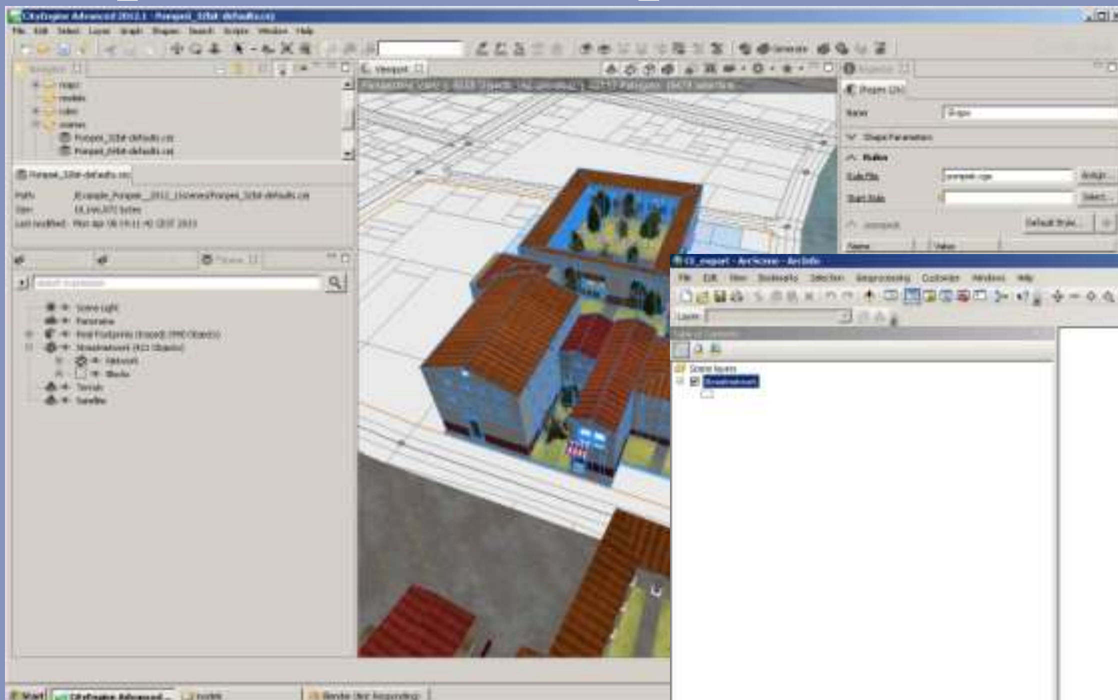
Import GDB

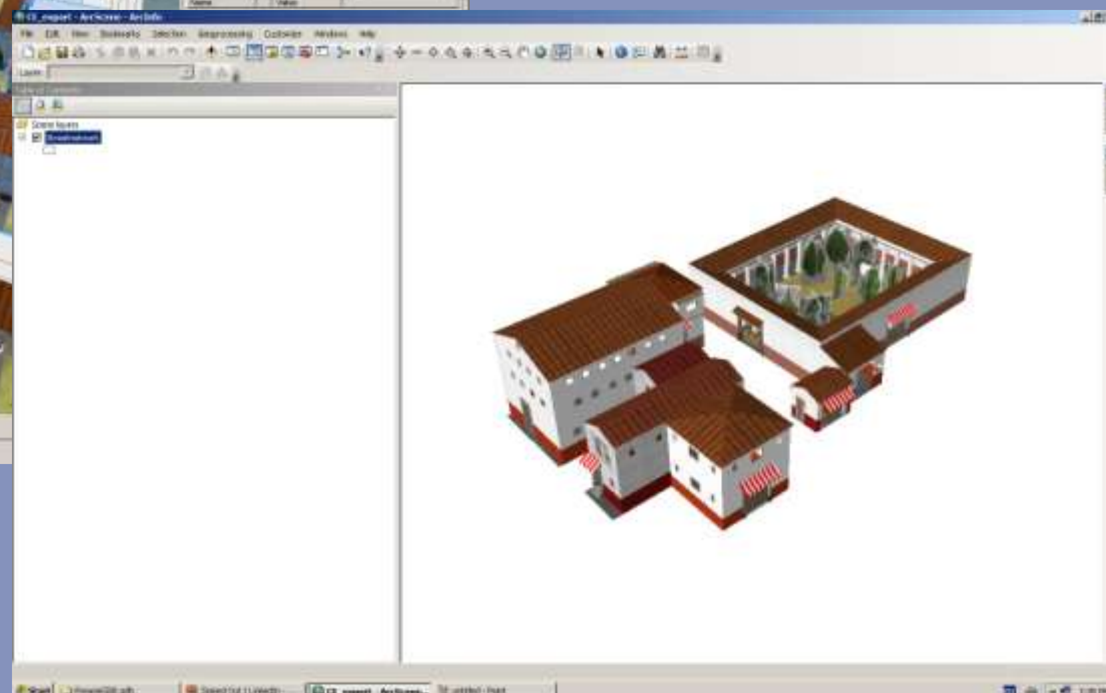


CityEngine template: Philadelphia

Export GDB

From CityEngine to ArcGIS: 3D geometry exported as multipatch

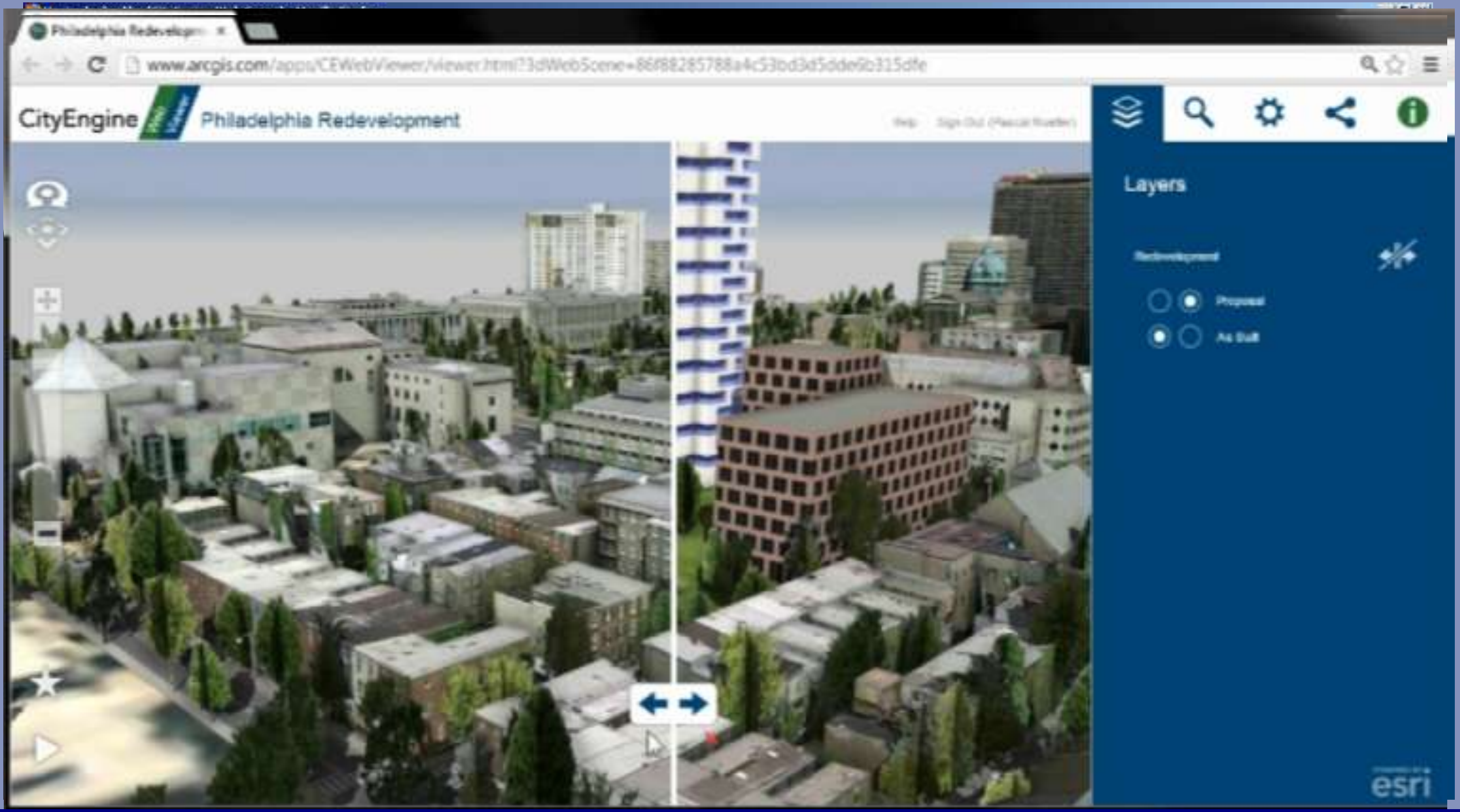




3D models exported from CityEngine into ArcScene

CityEngine webviewer

-Online publication with CityEngine Web Viewer (baseb on WebGL technology, no plugin is required for most browsers)
Slider before and after



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CityEngine in archaeological projects

-Rome Reborn
(Virginia University and Politecnico di Milano)

- "Apa, an Etruscan from Bologna"
(CINECA, ITABC-CNR, University of Bologna)

- Portus project
(Universities of Southampton and Cambridge)

Aquae Patavinae - Montegrotto
(University of Padova and ITABC-CNR)

Rome reborn

7,000 buildings were created with CityEngine to fill the surrounding urban environment of Rome.

Temples were created with CGA rules following the proportions described by Renaissance architect Palladio.

Rome reborn is available as layer in Google Earth

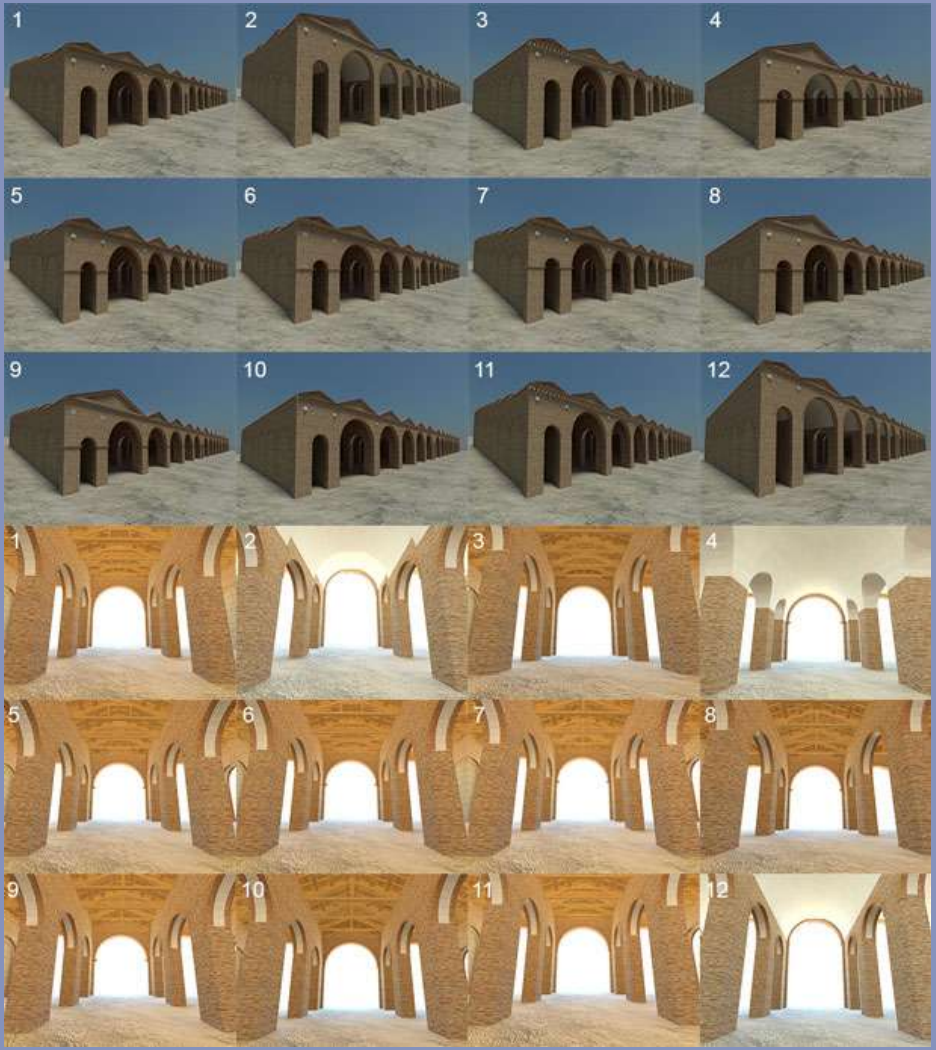
Apa, an Etruscan from Bologna

Short movie created for the new City Museum of Bologna. The Etruscan, Roman, Medieval and contemporary phases of Bologna were philologically reconstructed using CityEngine (D. Ferdani, ITABC)

Portus project

CityEngine was used for the reconstruction and interpretation of *Building 5* at Portus (Fiumicino, near Rome)

Multiple reconstructions of the building have been created



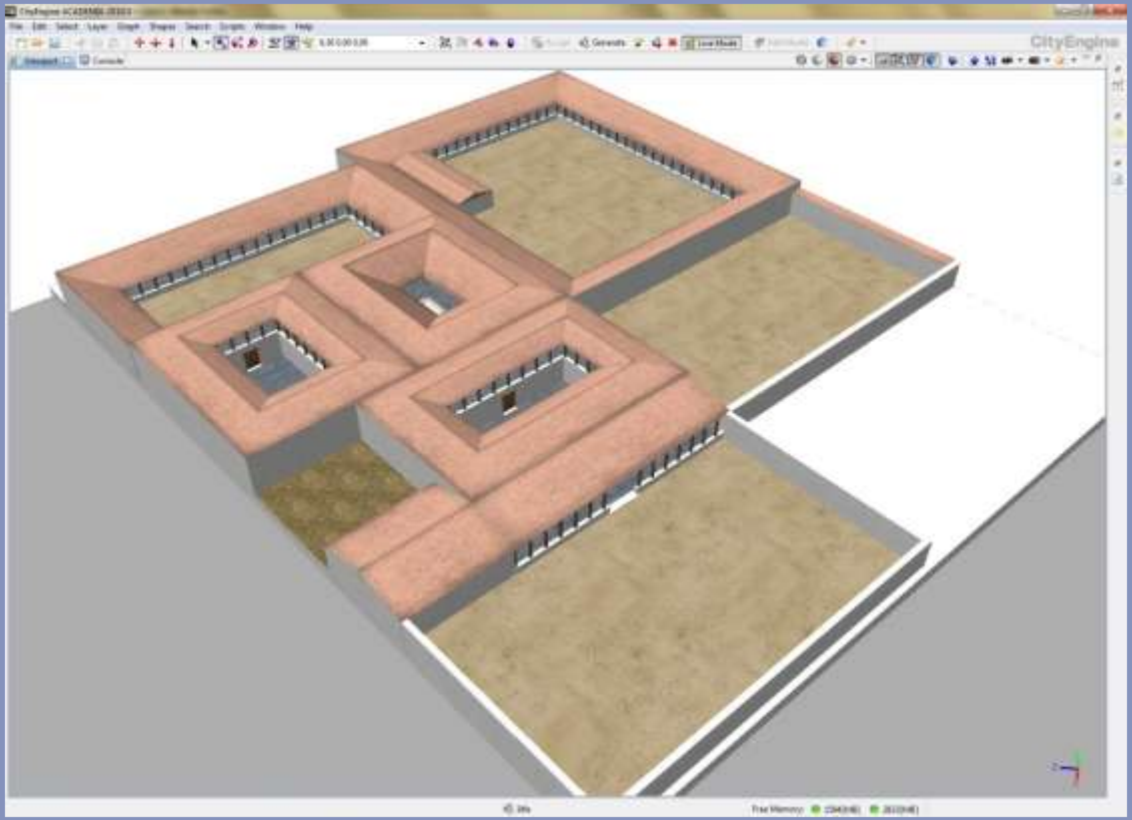
Montegrotto

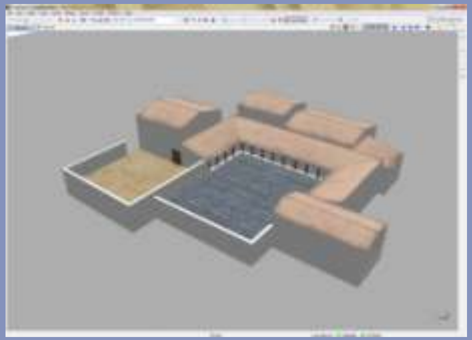
Virtual visit at http://www.aquaepatavinae.lettere.unipd.it/portale/
Buildings footprint from cadastral map - rectified pictures of buildings' facades as textures.

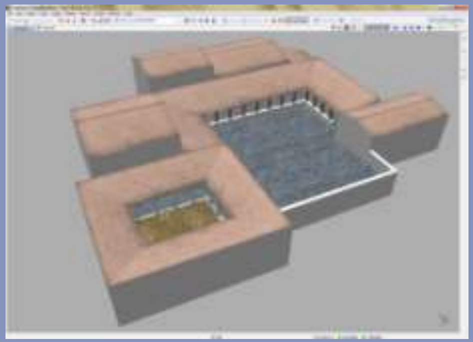
S. Pescarin, B. Fanini, D. Ferdani, G. Lucci Baldassari, 'Archeologia virtuale a Montegrotto Terme' in M. Bassani, M. Bressan, F. Ghedini, Aquae Patavinae. Montegrotto Terme e il termalismo in Italia, Padova University Press 2012, 309-326

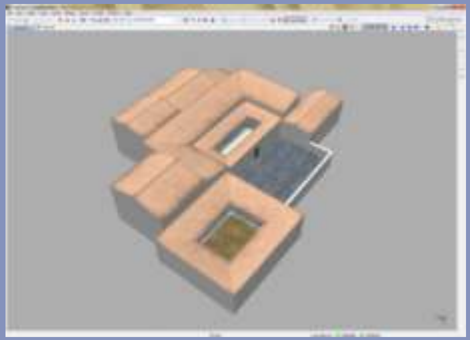
Roman Montegrotto

Instances of "Villa Rustica" created in CityEngine for the Aquae Patavinae project from the same set of CGA rules (C. Piccoli)









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Transparent 3D models in archaeology

"Noticeable gaps are represented by the fact that the models are not 'transparent' in respect to the initial information (what were the initial data?) and by the use of peremptory single reconstruction without offering alternatives"
(M. Forte, 2000 About Virtual Archaeology: Disorders, Cognitive Interactions and Virtuality. In J. A. Barceló, M. Forte, D. H. Sanders (eds.), *Virtual Reality in Archaeology*, 247-259)

Greek plasterer at work on the model of the acropolis of Athens

London Charter (2009), joined effort by several academic and cultural institutions to set guidelines and principles for computer-based visualisations in cultural heritage.
http://www.londoncharter.org/

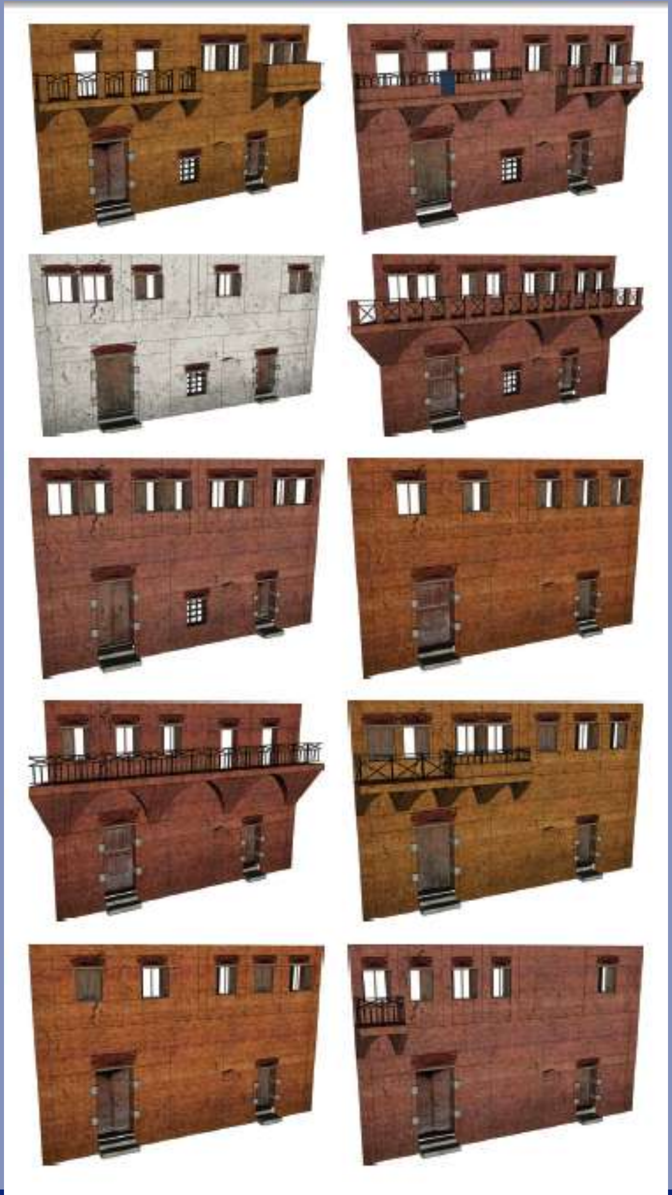
A rendering of the 3D model of Koroneia from the acropolis (C. Piccoli)

Multiple 3D reconstructions

With procedural modeling it is easier to create multiple models to convey the uncertainty of the reconstructed archaeological evidence

Variations in shapes can be easily included in the rule file to clarify what is uncertain and what is more precisely documented in the archaeological record

Example from Haegler *et al.* 'Procedural Modeling for Cultural Heritage' , EURASIP 2009: archaeological evidence of doors thresholds; no evidence for the window in between and the standing wall.



Improved intellectual transparency

-The modeling process is 'recorded' step by step in the rule file
-Annotations and metadata can be included in the rule to explain reconstruction choices and to give extra information
e.g. CGA rule for the Villa Rustica at Montegrotto (C. Piccoli)

```
const columnStep_tex = fileRandom ("*/StoneBlock.*.c.jpg")
const impluvium_tex = "pietra.jpg"
const lintel_tex = "general/stonework/stone.c.03.jpg"
const packed_earth = "packed-earth-floor.jpg"
const plaster = "plaster.jpg"


//For comparisons with the building architecture cfr villa Pisanella and villa Regina at Boscoreale, Naples.
//Rule starts

Lot --> case convert(y, scope, world, pos, 0,1,0) - convert(y, scope, world, pos, 0,0,0) < 0 :
          reverseNormals
          LotNormalUp
     else:
          LotNormalUp

LotNormalUp --> alignScopeToGeometry(yUp, auto)
                      villaRustica

villaRustica -->50% : villaPisanella
                      else : villaRegina

// Villa Pisanella
villaPisanella --> t (4, 0, 4)
                      InizioVillaP
InizioVillaP --> split(x) { ~1 : NIL
                                      |villaP_Xdim: villaPXdim
                                      |~1: NIL}
```

Discussion

Strong points:
- Efficient modeling of 3D large environments / easy to update
- Very useful to ‘fill in’ areas
- Easy creation of multiple reconstructions
- Flexible shape grammar that allows the creation of archaeological reconstructions
- Strong connection with GIS data

Weak points:
- Exported files can be very large (OBJ, DAE)
- No grammar-based generation of curved shapes

Thank you for your attention!

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