

Visualizing cityscapes of Classical antiquity: from early modern reconstruction drawings to digital 3D models

Piccoli, C.

Citation

Piccoli, C. (2018, May 16). Visualizing cityscapes of Classical antiquity: from early modern reconstruction drawings to digital 3D models. Retrieved from https://hdl.handle.net/1887/62359

Version: Not Applicable (or Unknown)

License: License agreement concerning inclusion of doctoral thesis in the

Institutional Repository of the University of Leiden

Downloaded from: https://hdl.handle.net/1887/62359

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle http://hdl.handle.net/1887/62359 holds various files of this Leiden University dissertation

Author: Piccoli, Chiara

Title: Visualizing cityscapes of Classical antiquity: from early modern reconstruction

drawings to digital 3D models

Date: 2018-05-16

VISUALIZING CITYSCAPES OF CLASSICAL ANTIQUITY: FROM EARLY MODERN RECONSTRUCTION DRAWINGS TO DIGITAL 3D MODELS

With a case study from the ancient town of Koroneia, in Boeotia, Greece

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof.mr. C.J.J.M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op woensdag 16 mei 2018
klokke 16.15 uur

door

Chiara Barbara Maria Piccoli geboren te Trento in 1982

Promotor:

Prof. dr. John L. Bintliff

Co-promotor:

Dr. Karsten Lambers

Overige leden:

Prof. dr. Jan Kolen

Prof. dr. Ruurd B. Halbertsma

Prof. dr. Eleftheria Paliou (University of Cologne)

Prof. dr. Henk Scholten (Vrije Universiteit Amsterdam)

Prof. dr. Frank Vermeulen (Ghent University)

Contents

List of Figures	V
English Summary	xiii
Nederlandse Samenvatting	XV
Acknowledgements	xvii
1. Introduction	1
Chapter overview	3
2. Reconstructing past cityscapes before the digital age: A view on Greek and Roman	towns 6
2.1 Introduction	6
2.2 The 14th and 15th centuries	
2.3 The 16th century	13
2.4 The 17th century	24
2.5 The 18th century	29
2.6 The 19th and 20th centuries	34
2.7 Conclusions	47
3. Three-dimensional visualizations in archaeology: An additional tool in the archaeo toolbox	
3.1 Introduction	49
3.2 Creating computer-aided 3D models	
3.2.1 Manual 3D modelling	
3.2.2 Procedural modelling	55
3.3 Interactive environment: virtual and augmented reality	60
3.4 The scientific value of 3D reconstructions	67
3.4.1 Rules for 'intellectually transparent' 3D visualisations in archaeology	67
3.4.2 3D reconstructions as analytical tools	
Visibility analysis in a 3D GIS	77
Analysis of visibility and the use of space using computer graphics methods	78
Simulation of lighting conditions	
Analysis of construction techniques and structural behaviour	
Simulation of acoustics	
Simulation of human behaviour	
3.5 Discussion	
4. The ancient town of Koroneia: Geographical context, historical background and syn	
the preliminary results by the Boeotia survey	
4.1. Introduction	
4.7. Koroneja: Geographical context and historical background	88

4.3 Previous research at Koroneia	97
4.3.1 Attested cults during the Classical, Hellenistic and Roman times	101
The temple of Athena Itonia	103
4.4. Preliminary results of the 'Ancient Cities of Boeotia' project	105
4.4.1 Acropolis	112
Architecture	112
Pottery	115
Stone finds	115
Discussion	117
4.4.2 Northern slope	118
Architecture	118
Pottery	120
Stone finds	121
Geophysics	121
Water infrastructures	121
Discussion	121
4.4.3 Eastern slope	123
Architecture	
Pottery	127
Stone finds	129
Geophysics	130
Water infrastructures	131
Discussion	131
4.4.4 Southern slope	
Architecture	
Pottery	134
Stone finds	136
Geophysics	136
Discussion	137
4.3.5 Western slope	137
Architecture	137
Pottery	137
Stone finds	138
Discussion	
4.5. Conclusions	139
5. The Graeco-Roman town as a physical entity: Sources for a comparison	142
5.1. Introduction	142
5.2 A brief overview of Greek town planning	144
5.2.1 Archaic period (end of the 8th century – 480 BC)	146
5.2.2 Classical period (480 – 323 BC)	149

5.2.3 Hellenistic period (323 – 31 BC)	150
5.2.4 Roman period (31 BC - ca. 330 AD)	153
5.2.5 Late Antiquity (330 – 650 AD)	154
5.3 The topography of Graeco-Roman towns: changes and continuities from the Archaic Period to	
Antiquity	
5.3.1 Religious foci	
Sanctuaries: Diachronic case studies	
5.3.2 Agora	
5.3.3 Theatres	184
5.3.4 Houses	
Archaic period	192
Classical period	194
Hellenistic period	
Roman period	204
Late antiquity	207
5.3.5 Training spaces	
5.3.6 Industrial spaces	212
5.3.7 Urban fortifications	216
5.3.8 Trees, groves and gardens	220
5.4 Discussion	223
6. Enhancing Koroneia's GIS survey data with the third dimension: A procedural modelling	ŗ
approach	225
6.1 Introduction	225
6.2 Workflow	227
6.2.1 A rule-based 3D GIS of architectural survey data	230
Interpretative visualization for intuitive insights into data clusters	230
6.2.2 Reconstruction of the ancient terrain morphology and urban layout	232
Map layers	233
Street network	236
6.2.3 Rule based modelling of Koroneia's 3D reconstruction	239
Domestic architecture	240
Agora	242
Theatre	245
Temple architecture	245
City walls	245
Slope dependency	249
Level of Detail	250
Sampling points on buildings' surfaces	
	251
6.3. Results	
6.3. Results	251

6.3.4 Exporting procedurally modelled Koroneia	259
Online publication	261
Interactive navigation and Virtual Reality	261
6.4. Discussion	264
6.4.1. Koroneia's 3D reconstruction: Intellectual transparency and reusability	265
6.4.2. Rule-based modelling: challenges and work-arounds	266
6.5. Conclusions and future work	270
7. Conclusions	274
Bibliography	280
Abbreviations	280
Bibliographical references	280
Curriculum Vitae	314

List of Figures

Figure 2.1 Page (13r) from the autograph copy of the Historia Imperialis by the antiquarian and historian from Verona, Giovanni de Matociis. This volume represents an early example of text that is accompanied with drawings, in this case of coins and of a schematic Roman circus (top right corner). The manuscript is kept at the Vatican Library (Ms. Chig. I. VII. 259). [source: https://www.ibiblio.org/expo/vatican.exhibit/exhibit/b-archeology/images/arch01.jpg]
Figure 2.2 Drawing of Rome in a 15th century copy of Fazio degli Uberti's Dittamondo (fol. 18r). [source: copy digitized by Bibliothèque National de France, http://gallica.bnf.fr/ark:/12148/btv1b8426808j/f41.image]9
Figure 2.3 'Forum' from Giovanni Marcanova's Collectio Antiquitatum (Estense Ms. Lat. 992, fol. 27R, 1465). [source: copy digitized by Princeton University library http://libweb5.princeton.edu/visual_materials/garrett/garrett_ms_158.final.pdf]10
Figure 2.4 Left: Reconstruction of the Mausoleum of Hadrian, copy from a drawing by Cyriac of Ancona. Codex Ashmolensis, Bodleian Library, fol. 63r [source: http://bodley30.bodley.ox.ac.uk:8180/luna/servlet]. Right: The imaginary map of Rome in the forgery by Annius of Viterbo: De Aureo Saeculo et de Origine Urbis Romae eiusque Descriptione (1498) [source: http://www.brynmawr.edu/library/exhibits/antiquity/use4c.htm]
Figure 2.5 Map of ancient Nola (engraved by Girolamo Micetto) in the De Nola by Ambrogio Leone (copy from the John Adams Library at Boston Public Library digitised by Internet archive and available at https://archive.org/details/denolaopusculumd00leon)
Figure 2.6 Reconstruction drawings of Rome in Fabio Calvo's Antiquae Urbis Romae cum Regionibus Simulachrum. Top: Romulus' square city, bottom: Rome in Pliny's time (from the digitised copy available at http://arachne.uni-koeln.de/books/FabioCalvo1532)
Figure 2.7 Reconstruction drawing of a Naumachia from Panvinio's De Ludis Circensibus (1600) [source: http://movio.beniculturali.it/bupd/lemusetrailibri/it/159/lapparato-iconografico]
Figure 2.8 The imaginative reconstruction drawing of the temple of Artemis in Ephesos by the Dutch painter Maarten van Heemskerck (1572) [source: https://commons.wikimedia.org/wiki/File:Temple_of_Artemis.jpg]
Figure 2.9 Reconstruction drawing of the siege of Plataea in Justus Lipsius' Poliorceticωn (1596), 66 [digitized by ECHO – Cultural Heritage Online]23
Figure 2.10 Hans Gross and a group of German tourists depicted next to the reconstruction of the Meta Sudans in Lauro's Antiquae Urbis Splendor, pl. 90. [source: http://www.harvardartmuseums.org/collections/object/176002]
Figure 2.11 Piranesi's drawing on the construction technique adopted for the funerary monument of Caecilia Metella, in Le Antichità Romane: Divisa in Quattro Tomi: Contenente gli Avanzi de' Monvmenti Sepolcrali di Roma e dell'Agro Romano, vol. III, pl. LIII.
Figure 2.12 Left: Restored view of Assos, in de Choiseul 1809, pl. 10; Right: Le Roy's reconstruction of the Temple of Athena in Les Ruines des Plus Beaux Monuments de la Grèce (plate XIII)
Figure 2.13 Restored view of Athens by C. R. Cockerell in Williams 1829
Figure 2.14 Reconstruction of one of the city gates of Pompeii (Gell 1852, pl. XIX)
Figure 2.15 Reconstruction of the 'Queen's Megaron' at Knossos for the Herakleion Museum made by Piet de Jong (after Papadopoulos 2007, Figure 1, p. 3)
Figure 2.16 Gatteschi's reconstruction and photograph of the area of the Via Sacra and the Temple of Jupiter Stator (Gatteschi 1924, 29-30)
Figure 2.17 Top, left: View of Athens, reconstruction drawing by P. Connolly (in Connolly and Dodge 1998). Top, right: The Roman town of Silchester by Alan Sorrel; Bottom: Preparatory stage for the reconstruction drawing of the temple area at Caerwent, Wales by Alan Sorrell with his annotations on the margin (after Catling 2013, 34 and 37)

Figure 2.18 The 3D physical model of Pompeii at the National Archaeological Museum of Naples (source: https://it.wikipedia.org/wiki/File:Plastico_di_Pompei_1.JPG)43
Figure 2.19 Paul Bigot and his 3D model of Rome in 1911 (after Royo 2006, Figure 95, p. 165)
Figure 2.20 Scene from the movie QuoVadis (1951) in which Nero illustrates his plan for his new Rome in front of Gismondi's plaster model (from Wyke 1997, 141)
Figure 3.1 Example of reconstructive drawings of elements of the Mater Matuta's temple (Satricum) by P. Lulof (after Ratto 2009)
Figure 3.2 L-systems applied to plants and architecture. Left: picture from Prusinkiewicz et al., 2000, 397; Right: picture from CityEngine 2010.3 user manual
Figure 3.3 Example of a CGA rule for the creation of a building. Numerical values are stored as attributes at the beginning of the rule to control them more easily. In this case, buildings are assigned a random height between 6 and 8 meters (line 1). The 2D initial shape "Lot" is turned into a 3D building shell by extrusion (line 4). Next, a component split is used to separate the obtained 3D geometry in individual faces (line 5). A split rule along the y axis is used to divide horizontally the selected face corresponding to the building facade to create two floors (line 6). The first floor is then recursively split along the x axis to create a series of windows (line 7), which are substituted by an OBJ file containing a more detailed window frame (line 8) 57
Figure 3.4 Table from Koehl and Roussel 2015, 144 highlighting strengths and weaknesses of the CityEngine software
Figure 3.5 Process of creating a CGA rule from existing architecture using an inverse procedural modelling approach. Left: A 3D point cloud is evaluated to extract plane surfaces; Centre: detection of architectural elements and assessment of their size; Right: The reconstruction of the temple of Poseidon, Paestum, obtained with the above mentioned procedure (after Weissenberg 2014, figs. 7.1, 7.4 and 7.5)
Figure 3.6 Two of Heilig's inventions: (left) the 'Sensorama Simulator' and (right) the 'Telesphere Mask' (source: http://www.mortonheilig.com/InventorVR.html).
Figure 3.7 Schematic diagram of the sources that are generally used for a 3D model of archaeological evidence (after Hermon 2008)
Figure 3.8 Screenshots from the virtual environment elaborated by Kensek et al. Left: Hyperlinks point to additional information regarding the different confidence levels of the reconstruction and alternative hypotheses; Right: the interface that allows the user to choose different types of columns, capitals and shafts to be displayed (Kensek et al. 2004, 181 and 182)
Figure 3.9 Screenshots from the navigation through the virtual reality application of the Villa of Livia by CNR-ITABC, which used to be available at http://www.vhlab.itabc.cnr.it/flaminia/. The avatar that guides the user through the exploration of the Villa encounters icons that display extra content when triggered71
Figure 3.10 Left: Laser scanning session inside the Regolini-Galassi Tomb at the Sorbo necropolis, near Cerveteri (CNR-ITABC); Right: The installation of the virtual reconstruction at the archaeological museum in Leiden (RMO) (images from http://regolinigalassi.wordpress.com/)
Figure 3.11 Archaeological site of Carnuntum, Austria. A perspex panel allows the viewer to see the Heidentor gate in its restored appearance (picture by Jan Madaras on panoramio)
Figure 4.1 Koroneia's hill viewed from south-west (top: from Bintliff et al. 2009, 18; bottom: photo taken by D. Grosman during an exploratory flight in 2009).
Figure 4.2 The large plain once occupied by Lake Copais, north of Koroneia's hill (picture taken by the author on Koroneia's acropolis)90
Figure 4.3 Topographical map showing the location of ancient Koroneia in respect to Greece, its territory (bordered by a yellow dashed line), and surrounding sites (modified after Farinetti 2009, Appendix I.1, 1). Sites mentioned in the text: 4) Palaia Koroneia North – Spyropoulos' excavations; 5) Thymari; 6) Mamoura/ Alalkomenai; 7) Agoriani/Agia Paraskevi; 8) Alalkomenai; 21-22) Sanctuary of Herakles Charops; 22) Pontza – Agioi Taxiarchoi; 30) Butsurati

Figure 4.4 The Frankish tower on the small eminence north-east of Koroneia's hill (picture taken by the author from the lower northern slope of the hill looking south-east)
Figure 4.5 Map of Koroneia's hill as published in Maier 1959, 129100
Figure 4.6 Sketch of Koroneia's hill and surrounding by Lauffer (1986, Figure 86, p. 77). Note the drawing of the theatre, the Frankish tower, a spring at the eastern foot of the hill and a temple on a lower terrace from the acropolis 100
Figure 4.7 Stele found at Koroneia depicting a ritual connected to the worship of Sabazios (Bonanno 2008) 102
Figure 4.8 Top left: Remains of one of the excavated building (A in Spyropoulos' report) as photographed by the author in August 2013. Note the visual connection with Koroneia's hill (the Frankish tower is visible in the background); Bottom left: The original position of the reused tripod bases blocks as recorded by P. Amandry (1978, Figure 2), viewed from west; Top right: View of building B (now covered by overgrown vegetation) from building A (Spyropoulos 1973, Figure 225, b)
Figure 4.9 General overview of Koroneia's hill, showing the survey units and the location of some classes of finds that will be discussed in this section, such as architectural remains (both in situ and erratic), funerary and honorific elements, miniature vases, kantharoi and column drums. Pappadakis' excavations at the supposed Itonion are marked with A
Figure 4.10 Overview of water infrastructures on the hill: 1) modern fountain constructed by reusing parapet blocks; 2) water channel built with the same technique as the Frankish tower situated in its proximity; 3) sewer with EW orientation (probably flanking a street); 4) underground spring covered by a large fig tree; 5) seasonal stream; 6) cistern (perhaps corresponding to the well excavated by Pappadakis in which the headless statue of Hadrian was found); 7) GPR results possibly indicating a stretch of the Hadrianic aqueduct
Figure 4.11 Geology of the hill (as mapped in the field by K. Wilkinson).
Figure 4.12 Overview of the in situ wall lines recorded during the survey and extended to better show their orientation (map made by B. Noordervliet)
Figure 4.13 Location of the areas in which the hill has been divided for the discussion of survey finds111
Figure 4.14 Examples of some of the fragments of vaulted ceilings recorded on the acropolis (pictures by I. Uytterhoeven)
Figure 4.15 Overview of architectural finds on the acropolis
Figure 4.16 Map showing the location of millstone types (made by B. Noordervliet, in Brasser 2013, 46)116
Figure 4.17 Modern quarry located on the north-western side of the hill (see Figure 4.9 for its position)118
Figure 4.18 Overview of the finds on the northern slope
Figure 4.19 Architectural survey at Koroneia: Inge Uytterhoeven recording some large blocks between grids 709-710 and 704-707 (photo: author)
$Figure\ 4.20\ Results\ and\ interpretation\ of\ the\ magnetic\ survey\ conducted\ by\ Eastern\ Atlas\ on\ the\ lower\ northern\ slope\ 122$
Figure 4.21 Overview of the finds on the eastern slope where the theatre (grid 377) and the agora (grids 98-128) were located
Figure 4.22 The depression on the slope of the hill once occupied by Koroneia's theatre (picture taken by the author inside the supposed cavea looking north-west).
Figure 4.23 The Hellenistic – Roman Ionic capital reused as a press weight probably in Late Antiquity (photos by I. Uytterhoeven)
Figure 4.24 Eastern slope, southern part
Figure 4.25 The Roman tomb with arcosolium illegally excavated on the eastern side of the hill. Broken slabs were found in its proximity (picture by the author)
Figure 4.26 Sample of finds from the Archaic-Classical cemetery, the figurines highlighted (Bintliff et al. 2010, 39) 129

Figure 4.27 Detail of the interpretation of the magnetometry survey's results (by Eastern Atlas) on the eastern slope of the hill. The raster image of the results in this area is shown in Figure 4.29131
Figure 4.28 Overview of the areas on the eastern and southern slopes that have been covered by geophysical survey. The features interpreted as roads (in light pink) and the remains of foundations and walls (in brown) show a regular lay out on the plateau and on part of the southern slope, while at the foot of the latter the orientation shifts, probably to adapt to the terrain. Two large anomalies at the foot of the southern slope (A and B) have been interpreted as the city wall circuit. C identifies the supposed path of the Hadrianic aqueduct resulting from the GPR survey by L. Verdonck
Figure 4.29 Results of the magnetometry survey on the hill's plateau and southern slope (by Eastern Atlas) 134 $$
Figure 4.30 Overview of the finds on the southern slope
Figure 4.31 Western slope with surveyed towers (A and B)
Figure 4.32 Reconstruction hypothesis of the path followed by the acropolis and lower city wall circuits based on the hill's contour lines, geophysical results and related finds such as funerary elements and stamped rooftiles bearing the city mark Koppa (Q)139
Figure 5.1 Lato: general plan of the site (Kalpaxis in Greco 1999, 120 after Hadjimichali 1971, 168)147
Figure 5.2 Plan of Halieis abandoned around 300 BC (Ault 2005, Figure 1)
Figure 5.3 Megara Hyblaea: general plan of the site (after Tréziny 2005, Figure 2, p. 58)
Figure 5.4 Knidos: general plan of the site (after Love 1973, 414)
Figure 5.5 Kastro Kallithea: site map on contour lines (Haagsma et al. 2014, 198)
Figure 5.6 Petres of Florina: general plan and detail of the excavated areas (modified after Adam Veleni 2000)
Figure 5.7 Ephesos's grid in Hellenistic (left) and Roman (right) times (Groh 2006, 55 and 73)154
Figure 5.8 Corinth: The extent of the Late Antique settlement revised according to recent investigations (Slane and Sanders 2005, 245)
Figure 5.9 The results of geophysical prospections at Tanagra show that what was initially thought as the Classical fortification, marks instead the perimeter of the Late Roman town, while the Hellenistic town occupied a larger area, here hypothetically mapped with the red line by J. Bintliff on map 1621-101 contained in the report by Eastern Atlas (Meyer et al. 2017)
Figure 5.10 Map of Delos' excavated areas (modified after Moretti et al. 2015, pl. 7)
Figure 5.11 Top: Map of the sanctuary of Zeus at Nemea showing the facilities around the sanctuary such as the Xenon, highlighted in red (modified after Miller 1990, 34); bottom: Reconstruction drawing of the Xenon at Nemea (Kraynak 1992, 121).
Figure 5.12 The sanctuary of Zeus at Dodona around 400 BC (top) and in the 3rd century BC (bottom) [source: http://ancient-greece.org/archaeology/dodona.html]165
Figure 5.13 Plans of a Greek, an Etruscan and a Roman temple. 1) Podium or base; 2) engaged column; 3) freestanding column 4) entrance steps; 5) porch and 6) cella (from Cunningham et al. 2014, 132)167
Figure 5.14 Reconstruction drawing of the nymphaeum of Herodes Atticus and Regilla at the sanctuary of Zeus in Olympia (after Longfellow 2009, 230)
Figure 5.15 The sanctuary of Demeter and Kore from 500 BC to the Roman period (modified after Bookidis and Strout 1997)
Figure 5.16 Top: Plan of the sanctuary of Artemis Orthia in Sparta at the end of the excavations in 1910 where the excavated temples, the altars and the Roman theatre are visible (Dawkins 1929, pl. 1); bottom: Reconstruction drawing of the Roman theatre (from Pausanias Project at http://www.pausanias-footsteps. nl/english/sparta-eng.html).

Figure 5.17 Plan of the agora of Kastro Kallithea and 3D reconstructions of the excavated buildings: Building 1 (stoa), Building 4 and Building 5 (Temple) (Haagsma et al. 2014, figs. 2 and 9; 3D modelling by R. C. Lee)179
Figure 5.18 Top, left: The agora of Kos during the 4th century BC; Top, centre: The modifications of the 2nd century BC; Top, right: The substantial changes during the 2nd century AD including the creation of a monumental access to the square (Rocco and Livadiotti 2011, 387; 397; 407); Bottom: Reconstruction drawing of the monumental access to the square by arch. G. Campanile, G. Carella, E. Cappilli, D. D'Oria, M. Fumarola, S. Valentini, based on the study of G. Rocco and M. Livadiotti (Rocco and Livadiotti 2011, 404) 182
Figure 5.19 The agora of Thasos (Grandjean and Salviat 2000, Figure 21).
$Table\ 1\ Audience\ orientation\ in\ a\ sample\ of\ 123\ preserved\ the atres\ across\ the\ Greek\ world\ (after\ Ashby\ 1999,\ 104)\ 185$
Figure 5.20 Reconstruction (a) and cross section (b) of the theatre of Delos at the beginning of the second half of the third century BC (Moretti 2014b, 122); c) Detail of the last phase of the skene in an aquarelle by Th. Fournet (Fraisse and Moretti 2007, Figure 425).
Figure 5.21 Left: Examples of Archaic house plans (a-b) Emporios, Chios; c) Thorikos, Attica; d) Eretria, Euboea; e) Aigina; f) Limenas, Thasos; g) Dreros, Crete; h) Koukounaries, Paros; i) Onythe, Crete; j) Vroulia, Rhodes; k) Kopanaki, Messenia, from Lang 2005, 16. Right: Phases of the Archaic house in Lemnos (Caruso 2011, 190) 193
Figure 5.22 Olynthos. Left: Plan of the town (Cahill 2002, 26); Right, top: reconstruction drawing of a domestic insula (Carroll-Spillecke 1989, Figure 3, p. 18); Rigth, bottom: reconstruction drawing of a house's courtyard and pastas (in Hoepfner 2009, 176).
Figure 5.23 Left: Plan of the excavated houses around the agora in Lato; right: Detailed plan of House Δ (Westgate 2007, 429-30)
Figure 5.24 Plan (left) and reconstruction (right) of House 7 at Halieis. The entrance is characterized by a roofed vestibule (prothyron) (Ault 2005, Figure 7 and 9)
Figure 5.25 Plan and reconstruction of House II at Eretria (Ducrey 2004, 161 and 163)
Figure 5.26 Plan of an insula of 'normal houses' in Delos (Trümper 2003, plate 1)
Figure 5.27 Delos: Plan of the excavated quarters near the theatre with the distribution of houses, shops and workshops (Trümper 2003, plate 4)
Figure 5.28 Delos: Architectural development of Houses IC and ID (Zarmakoupi 2014, 562)
Figure 5.29 Left: Reconstruction drawing of three houses at Petres with hagiati-like roofed open area (Adam-Veleni 2000, 57); Right: Characteristic hagiati in a house at Livadeia, Boeotia (Sigalos 2004, Figure 97, p. 282) 203
Figure 5.30 Examples of masonry techniques for stone socles in Late Classical and Hellenistic domestic architecture: (Right) Eretria (Ducrey 2004, 160) and (left) Knidos (Love 1970, Figure 11)204
Figure 5.31 Plan of the Roman house at Kos with the three representational spaces in color (Albertocchi 2010, 41)206
Figure 5.32 Reconstructed court and peristyle of the Roman house at Kos after recent restoration (Sideris 2015, 80-1).
Figure 5.33 Left: Plan of the excavated house at Hephaisteia, Lemnos (Papi et al. 2008, Figure 44, p. 982); rooms 10, 12 and 13 correspond to the Late Antique house-shop; Right: Reconstruction hypothesis of the house-shop (Piccoli 2008, 244)
Figure 5.34 Plan of the south side of the Athenian agora in ca. 400 BC with the area occupied by the race track (Camp 2003, 24).
Figure 5.35 Plan and reconstruction model of the palaistra-gymnasion complex at Delphi (ca. 330 BC) (plan: Scott 2013, Map 19.1; picture from http://davidgilmanromano.org/courses/ancient-athletics/lecture-images/24).
Figure 5.36 Pottery factory in Messenia in the 1940s (Stillwell 1948, pl. 4b)

1992, 17 and 155)21	.5
Figure 5.38 Examples of (top, left) courtyard gate; (top, right) overlapping gate and (bottom) postern gate with overlooking tower at Kastro Kallithea (created by R.C. Lee, source: http://people.tamu.edu/~ryanlee/kallithea.html)	.8
Figure 5.39 Typical Late Antique gates in the Roman East: a) the North Gate of Blaundos; b) a smaller gate at Selge; c) the North Gate of Zenobia and d) the East Gate of Resafa (drawings by I. Jacobs, in Jacobs 2009, 199) 22	20
Figure 5.40 Left: Plan of the Hephaisteion; on the left, the rows of cutting in the bedrock to host trees and flower pots; Right: Flower pots from Olynthos (Burr Thompson 1937, 399; 406; 409)22	22
Figure 6.1 The workflow for the creation of Koroneia's 3D visualization	6
Figure 6.2 Left: Part of the procedural rule written in CityEngine which evaluates the information contained in the specified columns in the architectural pieces' shapefile (e.g. LengthFIN, HeightFIN sand WidthFIN) to modulate size and appearance of the architectural finds based on their characteristics as recorded in the field	28
Figure 6.3 An example of some data layers of Koroneia's 3D GIS: the DEM with overlaid grid of the areas that were accessible during the survey, the terraces mapped during the geomorphological survey, the provisional results of the ongoing geophysical prospections, and the architectural finds. The latter are scaled according to their dimensions (here multiplied by a factor of 10 for visualization purposes) as recorded in the field, and categorized per stone type with a procedural rule that was written in CityEngine and imported in ArcGIS. In this way, clusters of stones, the relationship between the dimension of the blocks and the stone type, and special finds (of which 3D models are automatically imported as OBJ files) become immediately apparent 22	29
Figure 6.4 Top: Examples of historical aerial imagery that was used together with the terraces mapped by age (overlaid on the DGPS points representing the current terrain morphology) as guides to create a reconstruction hypothesis of the terrain in antiquity. Green lines represent ancient terraces, red lines modern terraces, yellow lines terraces of uncertain age. Points were added to (represented in blue) or subtracted from those originally recorded on the hill during the microtopographic survey. As a result, a new DEM was created by interpolating the points in ArcGIS using a Kriging interpolation method (see prediction error map). This DEM was then stylized as a grey scale image and exported in TIFF format to be used as a terrain heightmap in CityEngine.	31
Figure 6.5 A TIFF image of the geophysical results and the in situ walls (in red) is imported as map layer in CityEngine, thus allowing the retention of the visual and spatial relationship between the original data and the reconstructed street network	32
Figure 6.6 The two obstacle maps that limit the generation of the 3D environment only within the white area. Left: the obstacle map covers the largest town extent with the northern stretch at the foot of the slope according to the surveyed architectural remains; right: obstacle map covering the town extent when the geophysical features are considered (for the discussion of the available archaeological evidence, see chapter 4)23	33
Figure 6.7 Left: TIFF image loaded as attribute layer in CityEngine to guide the creation of different land uses; Right: Window menu that allows the creation of an attribute (i.e. 'Zoning') associated with the land use map23	14
Figure 6.8 Rule file that guides the mapping of different land uses according to the input image represented in Figure 6.7	34
Figure 6.9 Screenshot from the CityEngine viewport showing the results of the application of the attribute map (visualized as the black and grey image underneath the reconstructed town). This map assigns the rule for the creation of buildings to the light grey area and the rule for the generation of vegetation to the darker grey area. In this way, it is possible to quickly create two reconstruction hypotheses that show the northern area of the town as either sparely or more densely built up	35
Figure 6.10 Left: Screenshot from ArcMap's workspace displaying the geophysical results and the in situ wall stretches which have informed the reconstruction of the street network (in blue, the lines that were stored in a shapefile and imported as input data into CityEngine); Right: The reconstructed urban grid adapted to the terrain in one of the proposed hypotheses.	36

streets and blocks
Figure 6.12 Example of the parameters that I have set as attributes in the rule for domestic architecture. Note the addition of explanatory comments preceded in this case by a double slash (//) to exclude them from the parsed code
Figure 6.13 Lines from the rule of domestic architecture which categorize the houses according to their size. Note the insertion of comments, which explain the modelling choices that are recorded in the rule files. In this case the multi-line explanation is excluded by the processed script by adding /* and */ at its beginning and end (cf. other scripting languages such as C)
Figure 6.14 Examples of the procedurally modelled house shapes: Type 2 (top, left); Type 3 (top, right); Type 4, in this instance with closed ground floor (bottom, left), and type 5 (bottom, right). Scan the QR code to view a 3D model of one of the houses on SketchFab.
Figure 6.15 Example of how an attribute (in this case 'porch') is used to guide the random, yet controlled generation of 3D geometry. In this case, 70% of the instances will be created with a porch, while the rest will be assigned a closed ground floor.
Figure 6.16 Top: Examples of the images that I have created for texturing and bump mapping (texture/ bump image for doors; texture for the outer walls). Bottom: Example of rendering (in e-on VUE Infinite 2015 PLE) of the procedurally modelled town with textures applied240
Figure 6.17 The procedurally modelled agora area which is occupied by a long stoa on the eastern side and scattered trees and altars on the open space
Figure 6.18 The 3D model of the theatre (in OBJ format) that I have created in Blender and imported into the CityEngine using an ad hoc rule. To create some vegetation around the theatre, I have used a scatter operation which randomly places on the surface a set number of 3D models of trees according to a Gaussian distribution. Left: The original 3D model of the theatre as modelled in Blender; right: screenshot from the CityEngine viewport showing the result of the application of the CGA rule file (with vegetation displayed with a high LoD)
Figure 6.19 Lines added in the rule file for temple architecture to be able to visualize two possible reconstruction hypotheses of the supposed Itonion
Figure 6.20 Left: Screenshot from the CE inspector with highlighted the Boolean attribute 'amphiprostyle' defining whether columns are only at the front or also at the back of the temple. Right: Visualization of the two reconstruction hypotheses that can be swopped in real time by switching the attribute 'amphiprostyle' on or off
Figure 6.21 The shapefile containing the remains of the temple as recorded in the field (grey lines) is imported into CityEngine and the procedurally generated 3D reconstruction of the temple (here in wireframe mode) is created on top of it, thus making clear the spatial relation between the original data and the reconstruction. 243
Figure 6.22 Textures of the city wall circuit of the lower town and screenshot from the CityEngine workspace displaying a rule based modelled stretch of the walls. The rule allows the creation of towers at crossing points with streets by inserting 'Crossing' in the inspector's field 'Start Rule'244
Figure 6.23 Beginning of the annotated rule file for the modelling of Koroneia's houses, showing the lines that allow setting the pivot of the initial shape to a defined location (see section 6.2.3 for a more detailed explanation of this work-around). In this case I chose the north-east corner of the shape's scope as target pivot to be able to orient the courtyards towards south and east. The rule includes moreover the function to calculate the slope, which informs the generation of the 3D environment and has been used to calculate the number of houses in relation to different slope input values (see below, § 6.3.2)
Figure 6.24 Beginning lines of the CGA rule file that is applied to streets. The file starts with commented out references to the dimensions of streets in other 4th century BC sites that have been excavated or surveyed in Boeotia and elsewhere. The proper rule starts at @StartRule and includes the formula to calculate the slope degrees and the conditional rule (case else) that guides the creation of a street or different types of steps within the set range of slope degrees. For reference, I have included as a comment the indications from modern construction guidelines.

Figure 6.25 Screenshot from the CityEngine workspace where only the street network is selected, to show the dynamic rendering of streets and steps according to the slope degree by applying the rule file written for this project
Figure 6.26 A city block generated by the procedural rule for domestic architecture; in a) one of the possible different configurations of space that are encoded in the rule file are represented (HighLOD = true); b) displays the low Level of Detail scene, which generates geometries as coloured volumes (HighLOD = false); c) shows the panels and points that can be exported and used to perform visibility analysis in ArcGIS, as shown in Figure 6.29.
Figure 6.27 The procedure of sampling points and panels on the building's walls and roofs is triggered by switching between the options of the attribute Panels-Generate in the inspector
Figure 6.28 Screenshot from ArcScene workspace showing the overlay between the architectural data displayed using the procedural rule described above and the procedurally modelled reconstruction hypothesis (in low LoD) imported as gdb
Figure 6.29 The application of the possibility to sample points on the buildings' facades. Top: the results of the Line of Sight analysis that was run in ArcScene on a portion of the procedurally modelled environment in CityEngine to map which parts of the temple are visible from the observer points that were located on the agora, on the theatre and in other parts of the lower town. Bottom: A close-up of the temple which shows the sight lines coded according to the target points' visibility from the observers
Figure 6.30 Hypothesis 1: The threshold for the terrain suitable for buildings is up to 9°. This scenario returns a total amount of 321 houses (automatically calculated by including the report operation in the rule) 255
Figure 6.31 Hypothesis 2: The threshold for the terrain suitable for buildings is up to 12°. This scenario returns a total amount of 615 houses.
Figure 6.32 Hypothesis 3: The threshold for the terrain suitable for buildings is up to 13°. In this case, the total amount of houses is 765
Figure 6.33 Hypothesis 4: The threshold for the terrain suitable for buildings is up to 14°, which allows 965 houses 257
Figure 6.34 Hypothesis 5: The threshold for the terrain suitable for buildings is up to 24°, which allows 1883 houses 257
Figure 6.35 Koroneia's 3D visualization exported in the *.3ws format and viewed in the CityEngine Web Viewer: a) Alternative scenarios can be compared using the swipe view; b) buildings can be tagged so that they are easily searchable, and as shown in c) the lighting conditions can be changed to see their impact on the 3D scene
Figure 6.36 Screenshot from Unity3D showing the 3D reconstruction of Koroneia both from a bird-eye view and as it would appear as a first person navigation.
Figure 6.37 A screenshot of the VR experience with a smartphone and a cardboard VR viewer262
Figure 6.38 The main layers that compose Koroneia's 3D GIS environment. Bottom: terrain layer; middle: survey data (for the moment limited to architecture and geophysical prospections) and survey grids; top: one of Koroneia's procedurally modelled reconstruction hypotheses based on the current state of the data
Figure 6.39 A screenshot from CityEngine showing the reference system of the initial lot, which consists of an oriented bounding box ('scope') governing all the operations that are performed on the shape266
Figure 6.40 Lines of the CGA rule for domestic architecture which allows a more robust control on the reference system of the initial lot
Figure 6.41 The problematic treatment of building facades in default L-shapes: using CityEngine's standard syntax faces 1 and 3 cannot be distinguished and neither can 2 and 4, which makes it challenging to assign a different texture to facades facing the courtyard with respect to those that face the street. The adopted solution is given below
Figure 6.42 Lines of rule that allow a consistent indexing of the L-shaped building's facades
Figure 6.43 Results of the test analysis on global (top) and local (bottom) integration values of Koroneia's reconstructed street network.