

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

Chiara Piccoli

Access Archaeology





ARCHAEOPRESS PUBLISHING LTD
Summertown Pavilion
18-24 Middle Way
Summertown
Oxford OX2 7LG

www.archaeopress.com

ISBN 978 1 78491 889 7
ISBN 978 1 78491 890 3 (e-Pdf)

© Archaeopress and C Piccoli 2018

All rights reserved. No part of this book may be reproduced or transmitted, in any form or by any means, electronic, mechanical, photocopying or otherwise, without the prior written permission of the copyright owners.

Contents

List of Figures.....	v
Acknowledgements	xiii
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	7
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 archaeologist’s toolbox	49
3.1 Introduction	49
3.2 Creating computer-aided 3D models	53
3.2.1 Manual 3D modelling	53
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	74
Visibility analysis in a 3D GIS	77
Analysis of visibility and the use of space using computer graphics methods.....	78
Simulation of lighting conditions	80
Analysis of construction techniques and structural behaviour	82
Simulation of acoustics	83
Simulation of human behaviour.....	83
3.5 Discussion.....	84
4. The ancient town of Koroneia: Geographical context, historical background and synthesis of the preliminary results by the Boeotia survey.....	88
4.1. Introduction.....	88
4.2. Koroneia: 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.....	123
Pottery	127
Stone finds	129
Geophysics	130
Water infrastructures.....	131
Discussion.....	131
4.4.4 Southern slope	134
Architecture.....	134
Pottery	134
Stone finds	136
Geophysics	136
Discussion.....	137
4.3.5 Western slope	137
Architecture.....	137
Pottery	137
Stone finds	138
Discussion.....	139
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 Late Antiquity	157
5.3.1 Religious foci	158
Sanctuaries: Diachronic case studies	170
5.3.2 Agora	174
5.3.3 Theatres	184
5.3.4 Houses	190
Archaic period	192
Classical period.....	194
Hellenistic period.....	200
Roman period	204
Late antiquity	207
5.3.5 Training spaces.....	209
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 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.....	251
6.3.1 Visibility analysis in a 3D GIS	251
6.3.2 Estimating number of houses and population figures	253
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

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>]..... 9
- 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 Ashmolenensis, 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>]. 13
- 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>)..... 14
- 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>). 17
- 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>]. 21
- 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]. 22
- Figure 2.9 Reconstruction drawing of the siege of Plataea in Justus Lipsius' *Poliiorcticōn* (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>]..... 27
- 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. 32
- 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)..... 34
- Figure 2.13 Restored view of Athens by C. R. Cockerell in Williams 1829..... 36
- Figure 2.14 Reconstruction of one of the city gates of Pompeii (Gell 1852, pl. XIX). 38
- 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). 39
- 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). 40
- 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). 41

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).....	43
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).....	46
Figure 3.1 Example of reconstructive drawings of elements of the Mater Matuta’s temple (Satricum) by P. Lulof (after Ratto 2009).....	52
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.....	57
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.....	59
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).....	60
Figure 3.6 Two of Heilig’s inventions: (left) the ‘Sensorama Simulator’ and (right) the ‘Telesphere Mask’ (source: http://www.mortonheilig.com/InventorVR.html).....	61
Figure 3.7 Schematic diagram of the sources that are generally used for a 3D model of archaeological evidence (after Hermon 2008).....	68
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).....	71
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 triggered.	71
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/)	72
Figure 3.11 Archaeological site of Carnuntum, Austria. A perspex panel allows the viewer to see the Heidendor gate in its restored appearance (picture by Jan Madaras on panoramio).....	75
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).....	89
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.....	91

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).	96
Figure 4.5 Map of Koroneia’s hill as published in Maier 1959, 129.....	100
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).	105
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.....	107
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.....	108
Figure 4.11 Geology of the hill (as mapped in the field by K. Wilkinson).	108
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).	110
Figure 4.13 Location of the areas in which the hill has been divided for the discussion of survey finds.....	111
Figure 4.14 Examples of some of the fragments of vaulted ceilings recorded on the acropolis (pictures by I. Uytterhoeven).	113
Figure 4.15 Overview of architectural finds on the acropolis.	114
Figure 4.16 Map showing the location of millstone types (made by B. Noordervliet, in Brassler 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.....	119
Figure 4.19 Architectural survey at Koroneia: Inge Uytterhoeven recording some large blocks between grids 709-710 and 704-707 (photo: author).	120
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.....	124
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).	125
Figure 4.23 The Hellenistic – Roman Ionic capital reused as a press weight probably in Late Antiquity (photos by I. Uytterhoeven).	125
Figure 4.24 Eastern slope, southern part.	127
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).....	128
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 4.29.....	131
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.....	133
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.....	135
Figure 4.31 Western slope with surveyed towers (A and B).	138
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 roofiles bearing the city mark Koppa (Ϟ).	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).	148
Figure 5.3 Megara Hyblaea: general plan of the site (after Tréziny 2005, Figure 2, p. 58).	148
Figure 5.4 Knidos: general plan of the site (after Love 1973, 414).	150
Figure 5.5 Kastro Kallithea: site map on contour lines (Haagsma et al. 2014, 198).	152
Figure 5.6 Petres of Florina: general plan and detail of the excavated areas (modified after Adam Veleni 2000).	152
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).	156
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).	157
Figure 5.10 Map of Delos' excavated areas (modified after Moretti et al. 2015, pl. 7).....	161
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).	163
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).	168
Figure 5.15 The sanctuary of Demeter and Kore from 500 BC to the Roman period (modified after Bookidis and Strout 1997).....	171
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).	173

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).	183
Table 1 Audience orientation in a sample of 123 preserved theatres 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 (Fraise and Moretti 2007, Figure 425).	187
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); Right, bottom: reconstruction drawing of a house’s courtyard and pastas (in Hoepfner 2009, 176).	195
Figure 5.23 Left: Plan of the excavated houses around the agora in Lato; right: Detailed plan of House Δ (Westgate 2007, 429-30).	196
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).	197
Figure 5.25 Plan and reconstruction of House II at Eretria (Ducrey 2004, 161 and 163).	197
Figure 5.26 Plan of an insula of ‘normal houses’ in Delos (Trümper 2003, plate 1).	202
Figure 5.27 Delos: Plan of the excavated quarters near the theatre with the distribution of houses, shops and workshops (Trümper 2003, plate 4).	202
Figure 5.28 Delos: Architectural development of Houses IC and ID (Zarmakoupi 2014, 562).	203
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).	207
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).	209
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).	210
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).	210
Figure 5.36 Pottery factory in Messenia in the 1940s (Stillwell 1948, pl. 4b).	212

Figure 5.37 Plan and reconstruction drawing of the Archaic workshop of Mandra di Gipari, Crete (Rizza et al. 1992, 17 and 155).....	215
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).....	218
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).....	220
Figure 5.40 Left: Plan of the Hephasteion; 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).....	222
Figure 6.1 The workflow for the creation of Koroneia’s 3D visualization.....	226
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 and WidthFIN) to modulate size and appearance of the architectural finds based on their characteristics as recorded in the field.....	228
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.	229
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.	231
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.	232
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).	233
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 map.....	234
Figure 6.8 Rule file that guides the mapping of different land uses according to the input image represented in Figure 6.7.....	234
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 sparsely or more densely built up.....	235
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.	236

Figure 6.11 Screenshot from CityEngine showing the overlap between the terrain heightmap and the layer with streets and blocks.	237
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.	238
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).	238
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.	239
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.	239
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 applied.	240
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.	241
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).	242
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.	242
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 swapped in real time by switching the attribute ‘amphiprostyle’ on or off.	243
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).	246
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.	247

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.....	248
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.....	248
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.....	249
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.....	250
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.....	252
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.....	256
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.....	256
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.....	260
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.	262
Figure 6.37 A screenshot of the VR experience with a smartphone and a cardboard VR viewer.....	262
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.	264
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 shape.....	266
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.....	267
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.....	268
Figure 6.42 Lines of rule that allow a consistent indexing of the L-shaped building's facades.....	268
Figure 6.43 Results of the test analysis on global (top) and local (bottom) integration values of Koroneia's reconstructed street network.....	271

Acknowledgements

This work results from the research that I conducted for my PhD at the Faculty of Archaeology, Leiden University. The successful completion of this book would not have been possible without the support, encouragement and feedback of many people that I would like to thank from the bottom of my heart.

First of all, I would like to thank my supervisor John Bintliff for his guidance and support during these years. I could have not imagined what path my life would have taken after we first met by chance at the Tijdschrift voor Mediterrane Archaeologie Jubileumdag in Groningen when I had just moved to the Netherlands in 2008. His breath of knowledge has always been a source of inspiration and I am grateful that he has trusted me in developing this research in the direction I wanted, while giving me at the same time the necessary feedback. I must thank him also for his genuine interest in my professional development, and for offering me numerous opportunities to teach and give workshops on my research topics. Secondly, I would like to thank my co-supervisor Karsten Lambers for his thorough feedback on my research, which has greatly improved the content of my dissertation. I would like also to thank him for giving me the chance to continue with research and teaching within the Digital Archaeology Research Group, an opportunity which I took with much enthusiasm and commitment. Next, I would like to thank Hans Kamermans, who has been always a constant reference point over the years in Leiden and helped me to develop a critical view on 3D modelling in archaeology. I owe a big thanks also to Hanna Stöger, with whom I have shared the office at the faculty for many years. She has been a constant and trusted support, help and a source of inspiration and advice. Thank you to the PhD committee for taking the time to read the manuscript and send their feedback. I would like to express my gratitude especially to Eleftheria Paliou for her useful comments on chapters 3 and 6.

I consider myself lucky to have conducted my research at the Faculty of Archaeology in Leiden. This faculty offers a vibrant research environment which allowed me to broaden my knowledge about the wide spectrum of archaeologies that are carried out by faculty members covering a broad spatial and temporal range. The large PhD and postdoc community provides always occasions to listen to and discuss about interesting topics. I would like to single out Anita Casarotto, Gianluca Cantoro, Marike van Aerde and Mark Locicero. The time I spent at the faculty would not have been the same without their presence and the chats, coffees and meals that we shared. The support of the Graduate School has been crucial for the completion of this PhD; for this I would like to thank especially the director Miguel John Versluys and the coordinator Roswitha Manning.

My research would not have been possible without the work of the many dedicated members of the Boeotia survey team. First of all, I would like to thank Janneke van Zwienen and Bart Noordervliet for having shared their knowledge on Koroneia with me, for their technical support during fieldwork, and their genuine interest in my research. Next, I would like to thank Inge Uytterhoeven with whom I spent many pleasant hours in the field recording, and learning a lot from her about, the architectural remains at Koroneia and Hyettos. My experience of the Boeotia survey would not have been the same without the company of Athanasios Vionis, whom I also would like to thank for entrusting me with the recording and 3D modelling of the Byzantine churches in Boeotia, which allowed me to expand my knowledge of this phase of Greek history. Chrystalla Loizou has been a great companion during numerous fieldwork seasons, not least during our adventurous recording of the Haliartos tower. I thank Emeri Farinetti, for her support and precious advice in many occasions during my PhD, and Keith Wilkinson, Cornelius Meyer and Dana Pilz for their approachability in discussing the Koroneia's dataset. The work Yannick Boswinkel has done on the architectural finds at Koroneia has been an important data source for this research, so I would like to thank him for his availability in discussing numerous topics about Koroneia's

architectural remains. Many thanks also to Fabienne Marchant for providing us with her synopsis on inscriptions related to Koroneia and to the pottery specialists Kalliope Sarri, Mark van Der Enden, Philip Bes and Vladimir Stissi, who have always been available when I had some questions.

I would not have been able to carry out this work without the financial support of the CEEDS project, for which I worked as a researcher for 4 years. Working together with computer scientists, engineers and psychologists has been an enriching experience from many points of view, not least as it challenged my perspective on how we communicate archaeology outside our circle of peers. The scholarships offered by the Dutch Institute at Athens have greatly facilitated my research. I would like to thank the former director Christiane Tytgat and the secretary Emmy Mestropian-Makri for their hospitality and help. The scholarship that I obtained in 2012 at the Virtual Heritage lab of the Italian Institute for Technologies applied to Cultural Heritage (CNR-ITABC) in Rome has been a crucial experience for the development of this work. I learned a lot from every person working in the lab while I was there: Sofia Pescarin, Eva Pietroni, Augusto Palombini, Ivana Cerato, Emanuel Demetrescu, Francesco Vallecoccia, Cécile Thevenin, Andrea Adami, Sara Zanni, Guido Lucci Baldassari, Bruno Fanini and Bartolomeo Trabassi. In particular, I would like to single out Daniele Ferdani and thank him for his feedback on procedural modelling in an early stage of this research. During my stay I have been lucky to find Paola Spataro as my flat mate, I cannot thank her enough for having warmly welcomed me in her Rome.

In the Netherlands, the meetings with the group of Henk Scholten about CityEngine have been particularly helpful, especially in a time when I felt ‘like an island’ in working with CityEngine. I wish to thank in particular Maurice De Kleijn for the fruitful discussions about 3D in archaeology. The year I spent studying for the Master in Book and Digital Media Studies in Leiden has been enriching and rewarding in so many ways. Not only I got to deepen myself in the history of the beautiful city of Leiden, discovering gems that were previously unknown to me, but I also met wonderful people with whom I shared unforgettable moments. The content of chapter 2 is inspired by the research I carried out during this time, for which I am most indebted to my former thesis supervisor Paul Hoftijzer who introduced me to the world of book history, printing and publishing in the early modern period.

I most certainly would not have finished the writing of my thesis without the help of my parents. Being so distant is difficult, more than ever now that you have become grandparents, but your support and trust in my choices throughout the years have been always reassuring and encouraging for me. I am also lucky to have the best friends one could possibly ask for, who I can always turn to for advice, a laugh and a hug: Giulia Raffaelli, Fabrizia Faes, Cinzia Staltari, Valentina Bellavia, Raffaella Militello, Teresa Sicà and Eleonora Bernardoni, thank you for being part of my life. Finally, I would like to thank my life companion, Jan, for being always at my side. I could not think of a better partner to share this adventure called life with. You are my best friend and my greatest support, as well as a wonderful father. You understand my struggles and my aspirations better than anyone else. We’ve come so far and we continue to grow together.

This work is dedicated to our daughters, Aurora and Alice, who encourage me to become a better version of myself every day. I wish them to always keep their eagerness to learn new things, and to never doubt what they are capable of.

1. Introduction

It was 1519 when Raphael, together with the humanist Baldassarre Castiglione, wrote his famous letter to Pope Leo X in which he explained his method of architectural representation. He was about to endeavour on an ambitious plan, which Leo X had commissioned him to carry out, to draw the first visual reconstruction of Imperial Rome. This project, which was interrupted by Raphael's death in 1520, aimed to preserve and restore the city which had been ruined by the passing of time, the incursion of barbarian tribes, spoliations and neglect under the Popes. As we learn from the letter, Raphael was convinced that he could in all truthfulness ('per vero argomento') and unerringly ('infallibilmente') reconstruct the buildings in ruins by accurately and systematically documenting the still standing examples, using them as comparison to infer the missing elements, and studying the principles of ancient Roman architecture in the works of Latin authors.

Along with the development of a scientific method of archaeological inquiry, Raphael's self-assurance in the possibility of reconstructing accurately ruined buildings has been progressively substituted for by the awareness of the limitations in our ability to understand the past, and of the necessity to rely on conjectures when trying to reconstruct it. In recent years, the introduction of digital techniques has brought about a revolution in the speed and accuracy with which archaeological evidence can be recorded, and has offered new tools to visualize and analyse complex archaeological datasets. In particular, the use of 3D models in archaeology has increased dramatically in the last few years.¹ Two major topics can be identified, one related to the application of 3D recording techniques to obtain digital replicas of extant remains (which represents the majority of the papers), the other regarding the use of 3D modelling techniques in order to create virtual reconstructions of lost artefacts (which makes up only about 20% of the sample of papers in a survey by Münster).² These two branches are conceptually and practically very different, even though they are often subsumed under the common label of 3D modelling.

The ever-growing use of computer-based visualizations and the ubiquitous presence of digital 3D reconstructions have created a new set of challenges for archaeologists working in this field and has made more apparent the conflictual relationship that many archaeologists have with visual representations. While the written word allows an in-depth discussion of the available data and the exploration of the possible alternative interpretations, the visual language calls in fact for more simplified and immediate ways of representation, thus making it challenging to account for the fragmentary nature of the archaeological data and the existence of equally plausible alternative hypotheses in a (on paper or digital) reconstruction drawing. For these reasons, images are traditionally not equated to authoritative interpretations and, as Smiles and Moser put it, 'as a result archaeologists have tended to overlook images or, at best, to consider their existence as an adventitious phenomenon, divorced from the work of 'real' archaeology.'³

This unsolved tension between scholarly production and popular culture in archaeology has been reinvigorated by the introduction of 3D modelling techniques, especially in regard to the use of digital archaeological reconstructions. The problematic aspects related to the validation of virtual archaeology have been evidenced by scholars soon after its inception,⁴ and the term 'reconstruction' itself has

¹ According to a recent survey conducted by Olson *et al.*, among the works that were published in the *Journal of Archaeological Science* those concerning 3D models have increased by 300% in the last decade (Olson *et al.* 2014, 162).

² Münster 2013, 198.

³ Smiles and Moser 2005, 6; cf. also Favro 2006, 325-6, who cites the 'scholarly discomfort with visual representations of ideas'.

⁴ E.g. Miller and Richards 1995; Gillings 2000; Forte 2000; Ryan 2001.

been under debate for its implying a certain degree of certainty in the way archaeologists are able to interpret the past through the surviving artefacts. Some scholars have indeed suggested to avoid to use this term completely, and to opt instead for the use of other definitions such as ‘re-presentation’,⁵ ‘simulation’,⁶ ‘visualization’,⁷ or ‘construction’⁸, which reflects the postmodern view that these models are our construction of the past, mediated by our present culture – contrary to the term reconstruction, which conveys a ‘false sense of knowledge’.⁹

The implementation of methods for intellectual transparency in relation to the original data and interpretations to ensure a philologically correct 3D reconstruction have indeed received much attention by scholars working in this field and the debate that has sparked for best practices resulted in the publication of documents such as the London Charter and the Seville principles.¹⁰ Despite this progress made in setting standards for computer-based visualizations in archaeology, a recent survey analysing papers presented at major conferences in 2012 has shown that still only a very small percentage of published papers on 3D models in archaeology (1% of 686 papers) included methods to integrate information on the modelling choices and to validate their results.¹¹ Moreover, since usually the 3D reconstruction is still seen as an accessory phase for the communication of the results to the public, research has been rarely directed to developing a methodology to embed the creation of the 3D model within the cycle of knowledge generation. Advances in computer graphics and 3D GIS, greater accessibility of computer power and 3D modelling software have resulted in an increased knowledge of dedicated programmes by archaeologists allowing them nowadays to experiment more broadly than what was possible before with the use of 3D modelling as a research tool to formulate new hypotheses and analyse complex datasets. Yet in the last decades, there have been only a few examples of 3D visualizations that are exploited for research purposes before (or instead of) being used for public outreach,¹² this latter field comprising still the vast majority of the applications of 3D reconstructions.

The impression one gets is indeed that 3D reconstructions still mainly follow the path that was set since their first popularization in archaeology, when few archaeologists were practically involved in their creation. Especially in early projects related with 3D reconstructions, the quest for realism and for spectacular renderings or interactive experiences could not be fulfilled by archaeologists themselves, who were lacking the computer skills and infrastructure necessary to obtain such results. For this reason, the creation of virtual past environments was often passed over to computer graphics designers or to people that were not directly involved in the data collection and interpretation. Being the focus on delivering the end product, the process of creating the reconstruction and its use as an integral part of research was therefore most of the time overlooked. Except for a few cases (some of which I will discuss in chapter 3), these 3D models are still mostly used as digital counterparts of traditional 2D drawings and as presentation aids for knowledge that is already acquired, namely when the process of data gathering, comparison and interpretation is completed. In doing so, these tools are excluded from the process of hypothesis generation.

This research aims to contribute to current debate on the implementation and use of 3D digital reconstructions in archaeology by developing an intellectually transparent, replicable 3D visualization

⁵ Kolb 1997.

⁶ Forte 1997, 12-3.

⁷ Pletinckx 2007, 4.

⁸ Clark 2010, 66.

⁹ Clark 2010, 66.

¹⁰ <http://www.londoncharter.org/>; <http://smarterheritage.com/seville-principles/seville-principles> (last accessed Sept. 2016).

¹¹ Cerato and Pescarin 2013, 290.

¹² A selection of these projects using 3D reconstructions as research tools is discussed in chapter 3 (§ 3.4.2). It must be noted that in other branches of 3D modelling in archaeology such as DEM based regional research, analytical or research uses are much more common (e.g. for visibility studies or optimal path analysis).

that uses advanced methods for the quantitative analysis of the built environment. The approach that I follow in this work is inspired by the use and definition of models in science, namely as dynamic representations of complex systems and phenomena, which are employed as tools for reasoning and continuously evaluated, adapted and updated.¹³

The starting point of this study has been the archaeological survey of the multi-period site of Koroneia, which is located on a hill on the spurs of Mount Helikon in Boeotia, Central Greece. This site has been investigated since 2006 by an international and multidisciplinary team (under the directorship of John Bintliff), which I joined in 2009. The survey research methodology includes a combination of methods such as pottery collection, recording of architectural remains, geophysical prospections and geomorphological analysis, with the aim of shedding light on Koroneia's urban development. The application of such non-destructive methods allows the study of large areas and the collection of a vast quantity of data in a reasonable amount of time. Such investigations add key elements to the comprehension of regional historical development, creating also new narratives for local communities as testimony of their own neighbouring heritage.¹⁴ The sites that are investigated exclusively with such methods continue however to be invisible, which poses challenges for their protection, preservation and valorisation. The use of 3D reconstructions, therefore, is helpful in visualizing the archaeologists' interpretations of the site, both as a way to look at the data from another point of view and as a way to present it to a larger public.¹⁵ The creation of 3D visualizations of past cityscapes, however, presents challenges in itself and therefore the methodology should be chosen carefully to be able both to handle the complex dataset and to enable further engagement with the data and the re-elaboration of the 3D reconstruction.

Koroneia shares the common destiny of 'invisible' town with many other ancient Graeco-Roman settlements, and therefore offers a case study to test methodologies that can be applied also to other contexts. Specifically, the methodology we propose uses in an innovative way tools that are targeted to geo-design and modern urban planning to create a 3D visualization of Koroneia in a GIS environment. With a strong focus on the automation and iteration of the reconstruction process, our visualization allows an intuitive insight into hidden relationships and associations among data and can be used not only as a visualization aid, but also as a platform for generating hypothesis and performing analysis of the townscape.

Chapter overview

The structure of this book is as follows. In **chapter 2**, I will discuss a selection of archaeological reconstructions (both drawings and 3D plaster models) of Roman and Greek cities from the 15th to the 20th century, focussing especially on the motivations, the aims and the methods that guided such endeavours. The attempt to 'reconstruct' ancient urban sites, in fact, is not a novelty of the digital age and, although little research has been done so far in this direction, much can be learned on the role, potential and pitfalls of 3D visualizations in archaeology by taking an historical perspective on reconstructions of archaeological evidence before the introduction of digital techniques. This chapter will shed light on how much the process of reconstruction resulted in a 'construction' of a past that was in fact the re-elaboration of present needs, thoughts and beliefs. The progressive development of a method based on first-hand experience and critical assessment of previous sources led to an increased awareness for the problematic aspects related to 'reconstructing' the past, which can offer food for thoughts to the present day 3D modeller.

¹³ See the concept of Model-Based reasoning as explored in Magnani *et al.* 2002 and Magnani and Nersessian 2002.

¹⁴ Bintliff 2013b.

¹⁵ Examples of townscapes surveyed with an integrated approach and visualized in 3D are discussed in Corsi and Vermeulen 2012 and Vermeulen forthcoming.

Chapter 3 continues the discussion taking in consideration the use of 3D modelling in the digital age. The various methodologies available to obtain 3D models in archaeology will be presented, and their use, including applications such as Virtual and Augmented Reality, will be discussed from an historical point of view. Attention will be given to the progress made so far towards the creation of more intellectually transparent 3D visualizations, a key element to assess their reliability and their scientific value. I will moreover investigate in more detail what has been done so far to use 3D visualizations as research tools in archaeology and discuss some of the projects that have successfully proven that the potential of 3D goes beyond accurate documentation and public outreach.

After these two introductory chapters, **chapter 4** focusses on the site of Koroneia itself, by presenting its geographical and historical context and discussing both previous research and the currently available preliminary results of the survey on the hill. The combination of old data coming from 19th century travellers' accounts and 20th century excavation reports with the new insights of the survey, will allow us to formulate new hypotheses on the function of some of the surveyed architectural elements and on the urban organization of the hill, which will be further explored and elaborated on in chapter 6.

To offer comparisons to interpret the survey data from Koroneia, in **chapter 5** I shall consider the topographical development of Graeco-Roman towns over the centuries by relying on published material from Boeotia and elsewhere in Greece. In this chapter I will discuss general trends in urban planning in Greece from the Archaic to the Late Roman period, and select specific case studies showing changes or continuities in the architecture and use of public and private spaces (e.g. *agorai*, sanctuaries, theatres and houses). The study of the ancient city has a long tradition, starting from the pioneering work of the French historian Numa Denis Foustel de Coulanges (*La Cité Ancienne*, 1864). The body of literature dealing with aspects of the ancient Greek city (religious, economic, political) and with the development of individual buildings within the city (e.g. *stoas*) has grown immensely over the years. These approaches, however, have often interpreted the ancient city under the light of a dominant socio-economic framework, and presented it as a disjointed ensemble of discrete entities instead of a unified, layered, and ever-changing system. Similarly to the modern city, for which models describing urban growth have been developed since the 20th century (such as the concentric zone model by the Chicago school, or the sector model devised by the economist Homer Hoyt at the end of the 1930s),¹⁶ models have been proposed to explain the origin and development of ancient urban sites. The study of cities has been approached from very different angles and the analytical instruments of various disciplines, such as geography, history, social science, anthropology and economy, have been deployed to investigate urban environments. These models, although complementing each other in partially explaining some aspects of urban developments, focus however on only one element of ancient urban life, such as economic aspects which predominate in the Weber-Finley 'consumer' city and in the 'service' city model proposed by Engels.¹⁷ By simplifying the dynamics of urban life and overemphasizing some aspects over the others, these models evidence the complexity of the city as an entity whose development is difficult to grasp, analyse and predict. The aim of chapter 5 is therefore specifically to reconnect the various phases of the life of Greek urban sites that are often dissected in smaller units, either physical or chronological, due to constraints in the extent of excavation or the deliberate choice of focussing on the best attested phase of occupation, thus offering the background information needed to integrate Koroneia's data and suggest a 3D reconstruction of this site in one of its historical phases.

Finally, in **chapter 6**, the methodology that I have adopted to create a 3D GIS of Koroneia is presented. The workflow is mainly based on the exploitation of procedural modelling techniques and GIS with the

¹⁶ For a discussion on the most influential models that have been developed to explain the growth of cities, see Marcus and Sabloff 2008, 3-12.

¹⁷ Engels 1990.

additional assistance of manual modelling software packages. The chapter will focus on the practical implementation of a 3D visualization both of Koroneia's surveyed architectural elements, and of alternative reconstructions of the 4th century BC urban layout. The aim of this work is to provide an intuitive insight into types and concentrations of the recorded architectural pieces, and to create different models that explore a range of possible solutions for building on slope and their impact on urban population size. Our methodology is centred on the exploitation of a rule-based modelling approach, which enables the automation of the 3D modelling process in order to allow for an easy update of the survey data, the iterative display of different reconstruction hypotheses in a time efficient manner, and the creation of a 3D GIS in order to exploit this platform for a quantitative analysis of the built environment. This book concludes with **chapter 7**, in which I summarize the main points that I have explored in this research, discuss the results of the proposed approach, and provide a future outlook for the use of scientific 3D visualizations in archaeology. The rules that I have created for this project are distributed via github for research and educational purposes.¹⁸

¹⁸ <https://github.com/cpiccoli/rules>.