Speeding up visualisation of medieval urban landscapes: John Speed, GIS and 3D

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ABSTRACT

Most modern GIS packages include a 3D visualisation module, and it has become routine to project 2D datasets in this way as part of the data visualisation and interpretation process. However, 2D data sets tend to translate poorly to a 3D environment, appearing "flat" and lifeless. Techniques to enliven 2D data exist such as extrusion, but these can be mysterious to the user since they are not part of the basic GIS toolbox. The process of employing these tools satisfactorily can be frustrating, since there exists no "guide to good practice" for those wishing to move from 2D to 3D GIS representations. In this article I explore a range of techniques such as extrusion, 3D symbology and solid modelling, with reference to experiences gained producing 3D maps for the Mapping the Medieval Urban Landscape Project. In an attempt to find a consistent, coherent manner in which to implement these techniques I describe how I have found stylistic inspiration in 17th century cartography, and how this can offer a basic model for representing medieval urban forms in 3D.

INTRODUCTION

The Mapping the Medieval Urban Landscape project[1] is a two year project which seeks to further our understanding of the processes behind town design and layout in the middle ages. This project involves fresh field survey of a number of case study towns in the UK, and the analysis of archival maps together with archaeological and documentary evidence. The majority of the spatial analysis is done with GIS. One output of the project is a multimedia educational resource – an atlas of new towns of the 13th C in England and Wales, featuring reconstructions of the town plans c. 1300 AD. Along with these 2D reconstruction maps, we intend to produce a 3D version, more visually engaging and appealing to younger audiences. However initial experiments of producing these 3D maps, by importing the existing 2D GIS themes in the GIS 3D viewer software, produced unsatisfying results, retaining a distinctly 2D feel. It is the challenge of creating more convincing 3D visualisation of 2D GIS themes, without resorting to heavy use of specialist 3D modelling packages that I want to concentrate on in this paper. Part of the discussion will focus on how I have found inspiration in historical cartography, specifically the town plans of 17th century cartographer John Speed, who through cartoon-style iconography and a degree of artistic license produced both visually pleasing and practical maps. In this paper I will make specific reference to ESRI GIS products, although the principles outlined here will be applicable to most GIS packages.

THE MAPPING THE MEDIEVAL URBAN LANDSCAPE PROJECT

The Mapping the Medieval Urban Landscape Project focuses on the processes behind the design of new urban forms in the middle ages (Lilley *et al.*, 2005a). The middle ages saw increasing urbanisation across Europe, when existing centres expanded and new ones were founded in the countryside. Surprisingly however, we know little about how these towns were designed and laid out on the ground – there are few surviving documents which allude to the ideals of urban design during this period, and how new urban environments were physically engineered on the ground. The project seeks to address these issues through the analysis of a number of case study towns, the plans of which bear silent witness to the activities of those responsible for their design and implementation. The research in effect seeks to "reverse engineer" these plans in order to get closer to the design principles behind their physical form. The case study towns are 20 "new towns" of Edward I, dating to the late 13th and early 14th centuries AD. Sixteen of these towns are located in north and west Wales, with four spread along the south and east coasts of England (see Fig. 1).

Much of the research takes place within the formal analytical environment of the GIS. The GIS facilitates the collation of a diverse range of spatial information including cartographic sources (19th century Ordnance Survey mapping and older archival maps), archaeological plans, aerial photography, elevation data, and our own GPS/TPS surveys. The GIS assists in the implementation of analytical techniques such as "plan analysis" methods (see Slater, 1990; Whitehand and Larkham, 1992), and metrological analysis of urban features based on our survey data (Lilley *et al.*, 2005b). Through this combination of approaches we intend to be in a better position to answer some of the questions raised above.

1 **Funded by the Arts and Humanitites Research Council (AHRC), based in the School of Geography, Queen's University Belfast.**

THE MULTIMEDIA ATLAS

One of the outcomes of the project is a multimedia atlas of Edward I's new towns of England and Wales, intended as an educational resource aimed at schools, universities and heritage bodies. The atlas represents a visually engaging resource, accessible in school/university computer labs and libraries, and anywhere with an internet connection and suitable browser. It will shortly be accessible via the Archaeology Data Service website (http://www.ahds.ac.uk/archaeology/index.htm).
The atlas is intended to build upon work on medieval new towns and morphological study (Conzen, 1960, 1962; Beresford, 1967), and present the results of our own research, in a modern multimedia format. For each case study town it discusses the town's early history, its design and plan, and the town as it is today. Alongside this textual discussion a number of maps are presented, the most important of which is a reconstruction of the town plan c. 1300. These reconstructions are the result of integrating information from a range of archival map sources, archaeological interventions, and documentary sources. The maps were produced in GIS through a process of "heads-up" digitising from the archival sources and at this stage are presented in 2D planimetric form.
Along with the 2D representation of the reconstructions, we also intend to present a version in 3D, integrating an elevation model of the local area. Through this we hope to better communicate the character of the urban *landscape*, and how it interacts with the local topography. A colourful, 3D "birds-eye" view is also, we feel, potentially more appealing to younger audiences targeted for this resource. This is to be achieved using the ArcGIS 3D viewer, ArcScene, which can make immediate use of the datasets developed for the standard 2D representation since they are in native format. The basis of the 3D reconstructions are surface models of the local topography[2], which then have the 2D vector layers representing urban features "draped" on them. Initial experiments in this process were however, only considered partly successful. Figure 2, illustrates this using the town of Rhuddlan in Flintshire as an example. The Figure shows the 2D reconstruction, and initial attempts at producing a 3D version of the town plan, c. 1300.
The surface model provides topographic information lacking from the 2D version. In Figure 2 we can see how the town of Rhuddlan sits on the edge of high ground, above the river Clwyd overlooking the Vale of Clwyd. However the vector datasets look rather flat and lifeless, and require the viewer to be almost directly above in order to visually disentangle the vector lines. They also look at odds with the solid, rolling topography on which they lie. How can we improve the appearance of these 3D representations? How can we inject some life into the draped vector datasets? The answer to this is not straightforward. Whereas the 2D representations of the reconstructions can draw on centuries of cartographic convention, there does not appear to be a guide to "good practice" when working with urban GIS themes in 3D. It is this question, the challenge of producing convincing 3D urban landscapes from 2D vector data, which I wish to focus on in the rest of the paper, and how I personally have found inspiration in a rather unlikely source.

THE TOWN PLANS OF JOHN SPEED, 17TH CENTURY CARTOGRAPHER

Many of the towns in north Wales where we conducted our fieldwork have castles attached, some of them spectacular, such as Caernarfon and Harlech, and are rightfully UNESCO World Heritage sites. Located outside these castles are public information boards erected by the Welsh heritage service Cadw. These information boards often feature a map of the castle and town drawn by the 17th century cartographer John Speed. These maps are visually pleasing, and to me, despite using basic techniques, they manage to not only communicated the basic street plan, but also something the architectural character and geographical situation of the town. Figure 3 shows two of Speed's town plans, those of Flint and Harlech in north Wales. It occurred to me that modern mapmakers, using sophisticated GIS-based tools can learn a lot from cartographic techniques developed nearly four hundred years ago. For his town plans Speed devised a remarkable graphical style, employing a set of visual devices and a mixed plan/elevation perspective. I would suggest that by adopting some of Speed's techniques, we can produce more immediate and user-friendly 3D reconstructions of our urban landscapes. Before I go into more detail about Speed's style I wish to present a short biography of the man.
Not a great deal is known about the life of John Speed. A number of published works discuss his life and mapmaking techniques (Nicolson and Hawkyard, 1988; Skelton, 1952, 1970). He was born in about 1552, in Cheshire, England, the son of a tailor. His first career followed the family business, and in his spare time he adopted the hobby of map drawing. He then came under the patronage of Lord Brooke, who recognised his mapmaking skills, and found him a job in government, working for Customs, and negotiated a subsidy from Queen Elizabeth which enabled him to more seriously pursue his sideline mapmaking career.
Speed produced maps at a variety of scales, from the national, regional and county level, down to the scale of individual towns. Speed often drew on the works of others, especially when constructing maps at the smaller scale. He is known to have, for example, drawn heavily on the groundbreaking maps of Saxton, in terms of both content and style. The distortions in the shape of coastlines and islands would suggest that he copied these errors and never visited many of the places he mapped. The label "Performed by I Speed" on some of his maps would suggest that these are largely modified

2 **NEXTMap Digital Terrain Model (DTM) radar-derived data, supplied by Bluesky International Limited (http://www.bluesky-world.com/). This data carries a quoted accuracy of +/- 1 m.**

copies of existing maps. Rather than seeing Speed as a plagiarist it would perhaps be more correct to see him as a compiler of the researches and surveys of others.

Speed's maps provide us with a pleasing image of the landscapes of Elizabethan and Jacobean Britain, a landscape complete with large tracts of surviving woodland and areas of open field systems. He produced his maps at a time when there was increasing need to coherently map the diverse landscapes and peoples of Britain and Ireland. The crown was increasing its control over the land, and military and naval tacticians needed more than the sketches they were used to working with. There was also a growing sense of national pride, a Tudor England that was aware of its past and a promising future. Speed was a member of the Society of Antiquaries, and his maps show an appreciation for its heritage, depicting notable archaeological and historical monuments, and awareness of cultural diversity, depicting in the margins people from across Britain and Ireland in an array of traditional and vocational costume.

Speed considered himself primarily a historian, and he published regularly, his works drawing on the historical works, complete with errors, of other scholars. He produced his maps to accompany his histories, the latter of which he considered his greatest contribution. It is interesting how later generations have reversed this priority, with his maps still popular today, and his histories largely consigned to the archives. His maps were published in a single bound volume entitled *The Theatre of the Empire of Great Britain* in 1612, which contained 67 maps of Britain and Ireland at the national, regional or county scale, and also some 73 maps of individual towns. It is these town maps which Skelton (1952) considers to be his greatest contribution. In Speed's time there were relatively few maps drawn at the town scale, and those that did exist Speed did not hesitate to use and modify to his own style. However the majority of the town maps in the bound volume he mapped for the first time. It is these maps, and the stylistic methods contained within which I wish to examine in more detail in the following section. Speed died in 1629, aged around 77, the father of 18 children. He left an important cartographic legacy, his maps remaining the basis of British cartography for a century and a half (Nicolson and Hawkyard, 1988).

SPEED'S STYLE

Nicolson (1988) has suggested that the perspectives taken in Speed's town maps are best described as "map/views", since they are a combination of ground plan with elevated perspective, the buildings and some topographic features being drawn in elevation. The street pattern is in plan view, and this is emphasised by widening the streets disproportionately. General housing are depicted as rows of little "cartoon-style" huts, complete with doors, windows and chimneys. For the more elaborate buildings, including castles, the ground plan becomes less important and the depictions turn into mini-elevation drawings. There are no people or vehicles in the streets, although people are depicted working in the fields, or in boats in the sea. Occasionally some urban furniture is included, for example crosses, wind/water mills, maypoles, stocks and gallows. The maps were intended to charm, and portray urban scenes of peace and industry.

Skelton (1952) suggests that Speed conducted his surveys by first talking to informants within the town, he then moved to an elevated viewpoint outside the town from which he drew a perspective. He then went back to the town and paced out key distances between points, which explains the accuracy of his drawings. Conventional symbols were employed in the engravings, such as clusters of little trees for woods and parks. Open sea water is given a rippled effect at the larger scale, a watered-silk pattern at the smaller scale, the latter being a Flemish stylistic introduction. Representing relief caused some problems. Speed employed the standard medieval device of using shaded "mole-hills", which were varied in scale according to the topography – contour lines were not introduced until 1730 by Dutch chart maker Cruquius. Although we often see Speed's maps today in colour, in their original form they were uncoloured. The colouring was added at the later, post-engraving stage. These later colour washes adopted standard rules, such as brown for terrain, green for woods, brick-red for general housing, and so on.

INTEGRATING SPEED INTO GIS-BASED RECONSTRUCTIONS

We have seen that the style adopted by Speed is particularly suitable for the visualisation of medieval urban landscapes. So how can we go about introducing his style into our own GIS-derived maps, with a view to producing more immediate, digestible reconstructions. The most straightforward way to do this would be to work in 2D and rectify the maps of Speed to modern, spatially accurate plans of the towns. Experimentation with this process however, results in large RMS errors at the control points, with parts of the map requiring heavy distortion to conform. This suggests that the accuracy of Speed's maps is spatially variable. A way around this is to cut-up Speeds maps into smaller blocks, the most suitable division being the discrete housing blocks common in many of these medieval urban designs. Doing this results in much smaller RMS errors in the rectification process, commonly around the +/- 10 m area, suggesting that locally Speeds plans are relatively accurate. Figure 5 shows Speed's plan of Beaumaris, Anglesey.

Figure 6 (left), shows the results of cutting up the individual street blocks, and rectifying these to the OS first edition map of 1889. While this exercise is interesting and brings the map to life somewhat, it is uncertain how to proceed from here. The Speed elements look out of place against the other data sets, even when overlaid on the basic elevation model (see Fig. 6, right). They are also raster blocks and therefore not particularly editable. One could digitise the houses and other

details from the Speed elements, but this would be a very time consuming task. The best recourse to produce Speed-like reconstructions within the GIS software is to break down the individual elements that comprise a Speed map, and "paint" with these as "building blocks" in the GIS software's 3D viewer.

3D RECONSTRUCTION OF URBAN LANDSCAPES: LESSONS FROM SPEED

If we analyse the style of Speed's town plans we can identify a number of core elements that we can seek to reproduce in GIS. These are 1) the modelling of terrain, 2) the modelling of buildings, and 3) the modelling of geographic elements such as forests and marshes. The modelling of terrain is fairly straightforward as long as we have access to an elevation model, and the visualisation of this can be enhanced in ArcScene through exaggeration of the vertical axis, and hill-shading. The modelling of buildings is not as straightforward, but thanks to some enhancements in the latest version of ArcScene (v9), this is more easily achieved than previously. The two main ways buildings can be modelled in ArcScene is through 1) the extrusion of vector features, and 2) the use of 3D symbols. I now wish to describe these two methods in more detail.

EXTRUDING IN ARCSCENE

Perhaps the most straightforward way to model buildings in ArcScene is through the use of the extrusion feature. This feature is not new to ESRI GIS and has been present as far back as ArcView 3.1. Extrusion can be performed on vector datasets such as polyline or polygon themes. Extrusion "pulls up" these features into the z-axis giving a 3D appearance. This can have a dramatic effect on 2D datasets, transforming them into solid, upstanding monuments. In ArcScene 9, extrusion can be a constant value, the value in a specific field in the attribute table, or can be provided by a mathematical expression. This tool is most effective when working with the digitised polygon footprints of buildings. Figure 7 shows the effect of extruding the town walls of Caernarfon in northwest Wales.

3D SYMBOLISATION IN ARCSCENE

ArcGIS Desktop 9 saw the introduction of 3D symbolisation. Point data can now be represented using these symbols, in both ArcMap and ArcScene. The symbols range from a selection of primitives, such as cones, spheres and blocks, to more sophisticated symbols representing buildings, street furniture and plants. Figure 8 shows a selection of these primitives.

Particularly advantageous about this new functionality is that users can create their own 3D symbols in external modelling programs (such as 3D Studio or AutoCAD), and then import these into ArcGIS to be used as 3D symbology. 3D symbology is ideal for populating our medieval town reconstructions with housing and grander buildings, to give an impression of an inhabited, vibrant town, à la Speed. Unfortunately however, amongst the varied building types supplied with ArcGIS as standard, there are no buildings that would pass for a simple medieval house as routinely depicted in Speed's maps. In this case we must recourse to creating our own buildings in external modelling software and import them back into ArcScene. At this point I would like to introduce a software package which I find particularly suitable for this task, but which may not be known to the majority of GIS users, SketchUp.

SKETCHUP

SketchUp, by @ Last Software, is a 3D modelling program with a number of features which make it an ideal companion to ESRI ArcScene. The advantage that SketchUp has over the majority of 3D modelling packages is its sheer user-friendliness. It is essentially a mini-CAD program, that makes no claims to being a full package like AutoCAD. There is a limited toolset on screen, which makes it quick to learn, and therefore great for the occasional user. The hidden strength of SketchUp is its powerful sense of inference. Whenever the user is drawing on screen, the program is always trying to guess what the user is attempting to do next, such as snapping the mouse pointer perpendicular to the line just drawn. This makes drawing basic shapes, such as the footprint of a building fast and accurate. Such footprints can then be extruded up, and textures applied to make realistic looking buildings. These can then be saved in 3D Studio format, which can be imported as 3D symbology into ArcGIS. SketchUp also includes some functionality to make it directly interact with ArcGIS. A SketchUp toolbar can the added to ArcMap or ArcScene, so that when a vector feature is selected, SketchUp is launched with the feature ready for further modelling. Figure 9 shows experimental use of SketchUp to produce a Speed-like house. I would now like to move onto the case study where these techniques are combined to produce a 3D reconstruction of the town of Caernarfon in northwest Wales.

CASE STUDY: SPEEDING UP CAERNARFON

To end this article I would now like to introduce a case study, where I endeavour to produce a 3D reconstruction of the

town of Caernarfon, using 2D vector themes, a surface model, and some of the modelling techniques described above, in order to produce a visualisation of the medieval urban landscape.

Caernafon in Gwynedd, NW Wales, is a new town of Edward I, constructed in 1283. It is a relatively small town in comparison with Edward I's other new towns, especially if one considers the height of the town wall and the spectacular nature of the castle. The site was formerly a Welsh port and borough court, which itself replaced an Anglo-Norman motte and bailey. The site is located on a sandy knoll at a bend in the Afon Seiont river, as it heads out to the Menai Strait.

Figure 10 (left) shows an aerial photograph of the town, much of which is in shadow due to the high, enclosing nature of the town and castle walls. Figure 10 (right) shows our 2D reconstruction of the town c. 1300, featuring our conjectured burgage plot (house plot) layout. The 3D reconstruction will use these 2D themes, along with a surface model as its core data. Additionally buildings will be modelled using 3D symbology and extrusion, and some trees will be added, again via 3D symbology.

Figure 11 shows the 3D reconstruction. The elevation model was exaggerated in the vertical dimension of x1.5 to bring out subtleties in what is a relatively flat area. The model was given a suitable colour scheme and hill-shade effects applied. The themes from the 2D reconstruction were added, and then draped over the surface model. The first monuments to be modelled were the castle and town walls. This was achieved with the extrusion tool. The correct heights for the respective walls and towers was gained from the Royal Commission for Historic Monuments in Wales (RCHMW) architectural surveys, and also from our own GPS/TPS field surveys. The next buildings to be added were a number of houses, to be positioned on the reconstructed burgage plots, in order to give the impression of the new town at the start of its life as burgesses were just beginning to take up the plots available for rent. A standard house model was created in SketchUp (see Figure 9 above), modelled on the hut-like houses often shown in Speed maps. This model was then imported into ArcGIS. In order to define where these houses should be place, a new point theme was created and house locations were digitised on screen using the reconstructed burgage plot pattern as a guide. The house model was then selected as the symbology for this point file. Some of these symbols were rotated to give a more natural, organic feel to the town. Finally, in order to provide at least some sense of the local geographic situation, a number of trees were added. The positions for these were, fittingly, copied from the Speed map of Caernarfon (1610). A new point theme was created and the tree locations were digitised on screen using a rectified scan of the Speed map as a guide. Two of the ESRI standard tree models were used to symbolise these trees. Figure 11 (bottom) shows a "walk" down one of the streets in the reconstruction where some of these trees can be seen in the distance, in front of the castle.

CONCLUSIONS

When discussing the form of medieval urban landscapes, traditional 2D maps of these landscapes can only present part of the picture. A 3D representation informs much further on the way the urban landscape interacts with the location topographic context. However a straight transfer of 2D GIS datasets into a 3D environment is not always successful, and there is no standard procedure for improving the visualisation of these datasets in a 3D environment. However, models do exist in historical cartography, for representing urban form along with geographical elements in a concise, engaging manner. The maps of John Speed with their hybrid perspective and "cartoon" style representation of buildings and topography communicate urban form in a descriptive, practical and pleasing manner. I have argued in this paper that to be mindful of the techniques of earlier cartographers can help us as GIS mapmakers to produce more successful maps. Many of the techniques used by Speed can be emulated in GIS through the use of extrusion and 3D symbology. Such modelling in 3D may also make our maps more appealing to younger audiences who are regularly exposed to such perspectives in their contact with computer games or the internet.

This paper has concentrated on the 3D visualisation of medieval urban landscapes in the 3D module of the ArcGIS Desktop suite. Obviously, similar ends could be achieved through the use of dedicated modelling packages such as 3D Studio. However I chosen to keep the discussion within the GIS environment since this will often be the most fastidious solution to GIS users who may not be familiar with (or have access to) specialist 3D modelling software. The other advantages are the immediate access to existing GIS themes, perhaps created for traditional 2D mapping, and of course, the spatial integrity between elements is maintained, and they retain the quotable accuracy levels defined at their creation.

The relatively basic 3D visualisation provided by ArcScene, with its limited support for raster modelling and texture mapping, is not considered a problem. I would argue that perfectly rendered, photo-realistic reconstructions should not be our aim, since such endeavours only lead to the need for ever more sophisticated software and hardware. As Gillings and Goodrick argue (1996), when performing 3D reconstructions in archaeology, it is the use of space, the *spatial syntax* which we are trying to communicate, to further our understanding of how people used and experienced the urban landscape in the past. Such ends can be achieved with basic 3D modelling software. There is no better analogy to this than the 17th C engravings of John Speed, who, using basic cartographic techniques, produced charming and practical maps that are still commonly reproduced four hundred years later.

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FIGURES

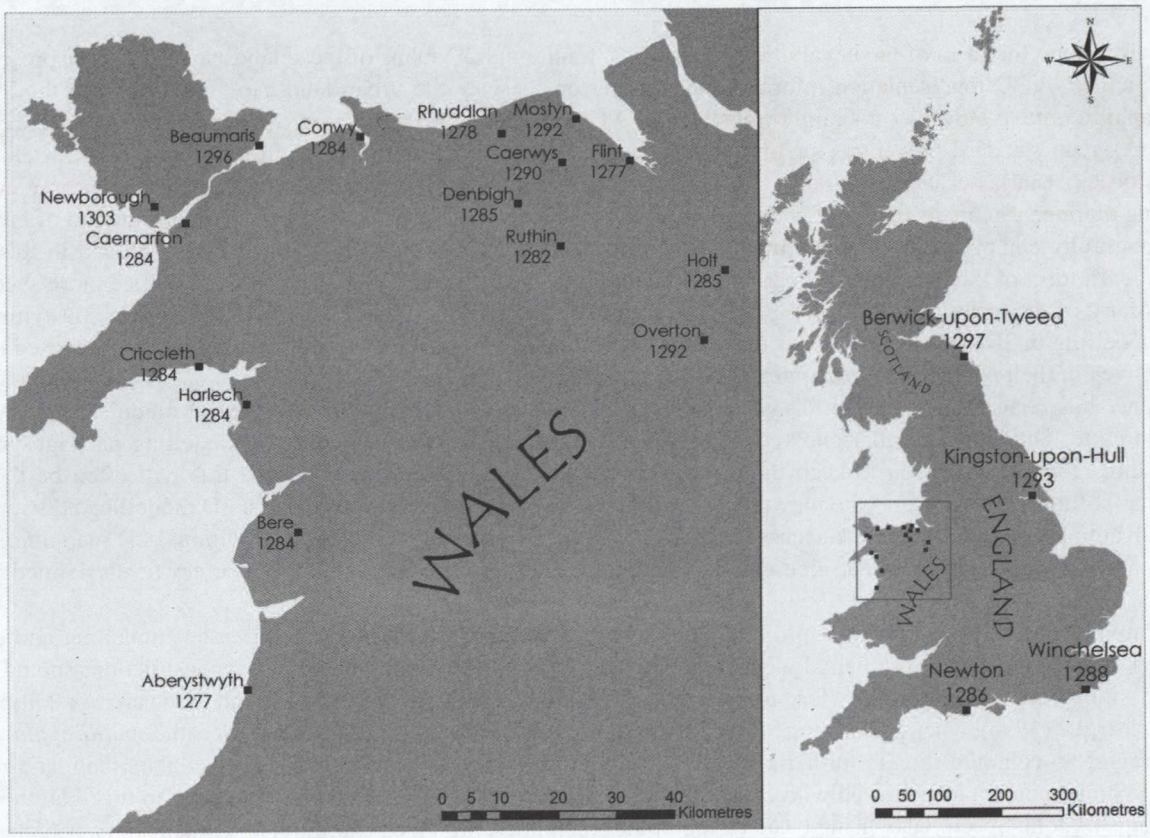

Fig. 1 – The study towns, with the date of their charter.

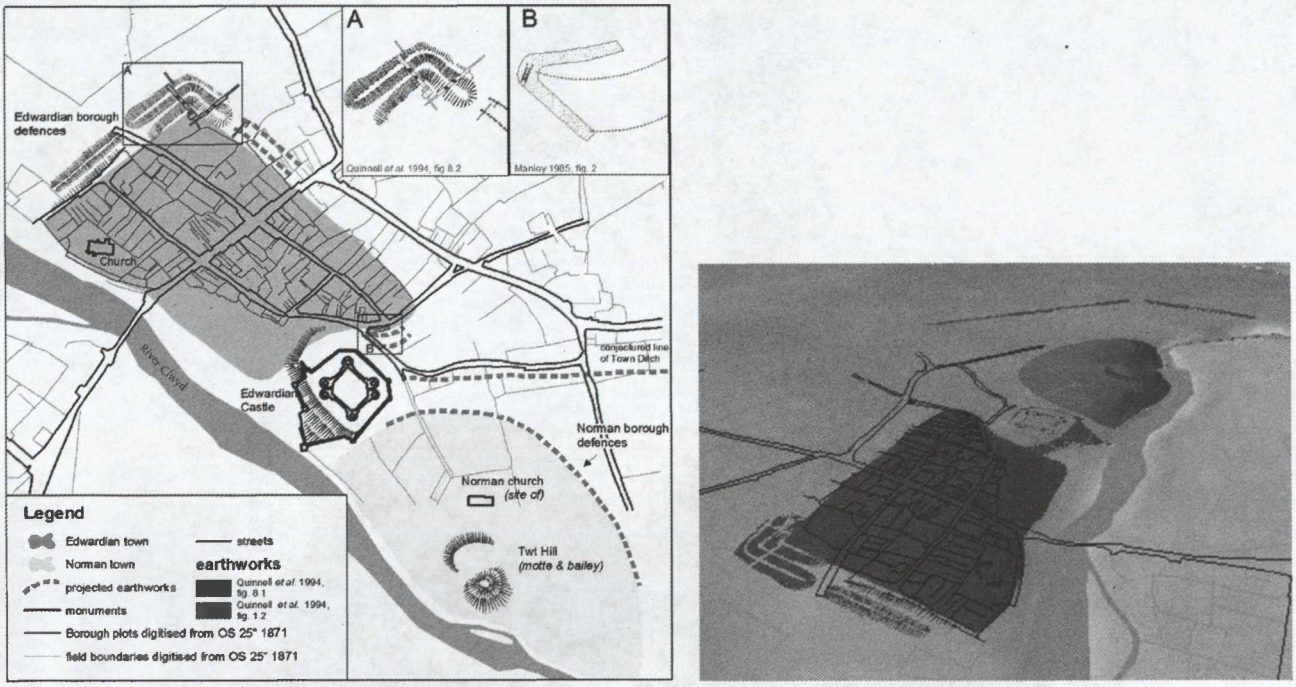

Fig. 2 – The town of Rhuddlan, Flintshire, showing 2D reconstruction (left) and initial 3D version (right).

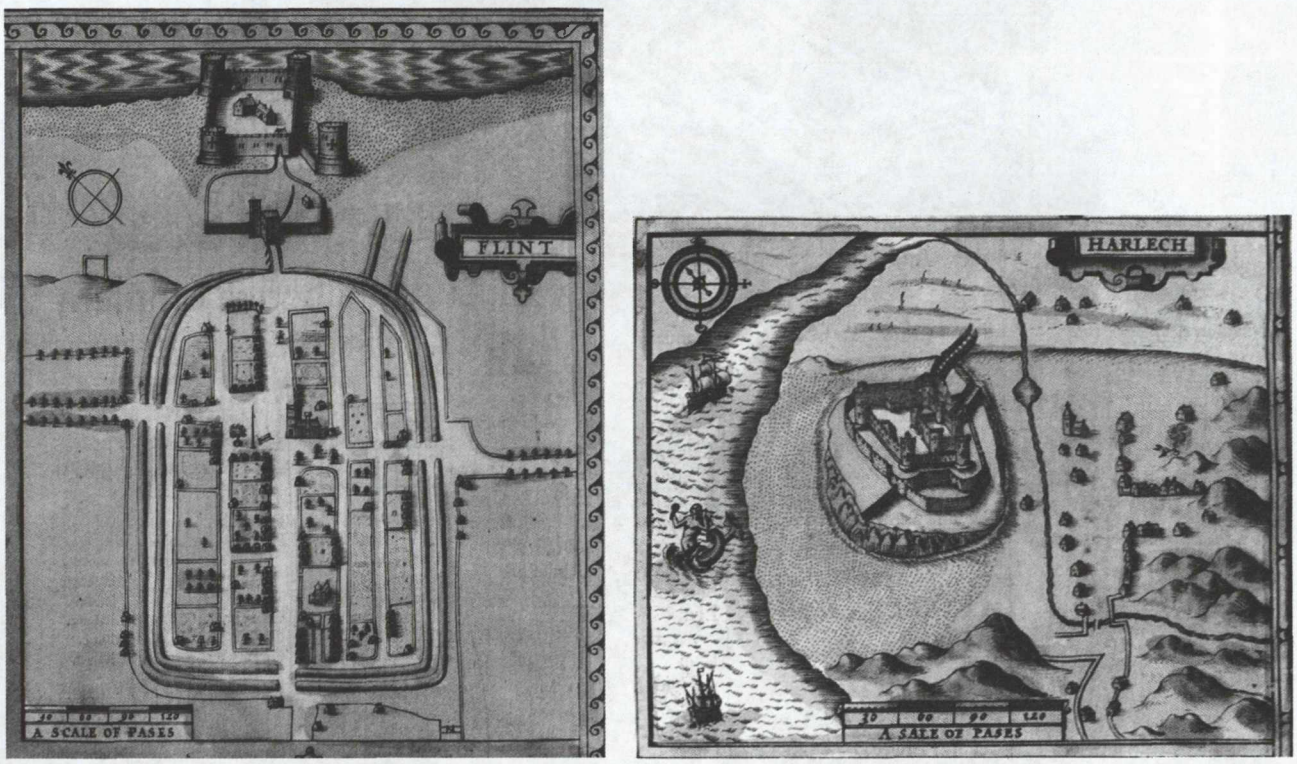

Fig. 3 – Speed's town plans of Flint (left) and Harlech (right), both 1610.

John Speed (c. 1552-1629).

Fig. 4 – John Speed.

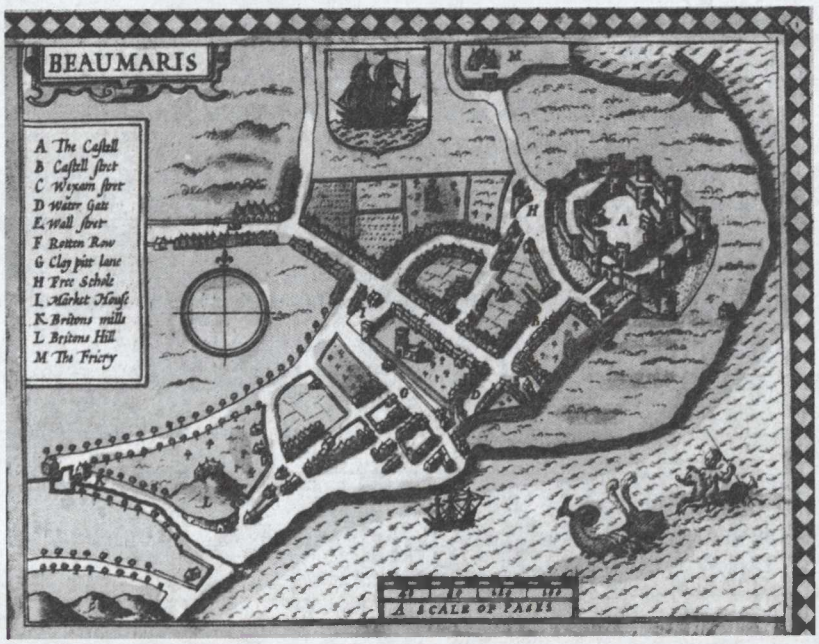

Fig. 5 – Speed's plan of Beaumaris, Anglesey (1610).

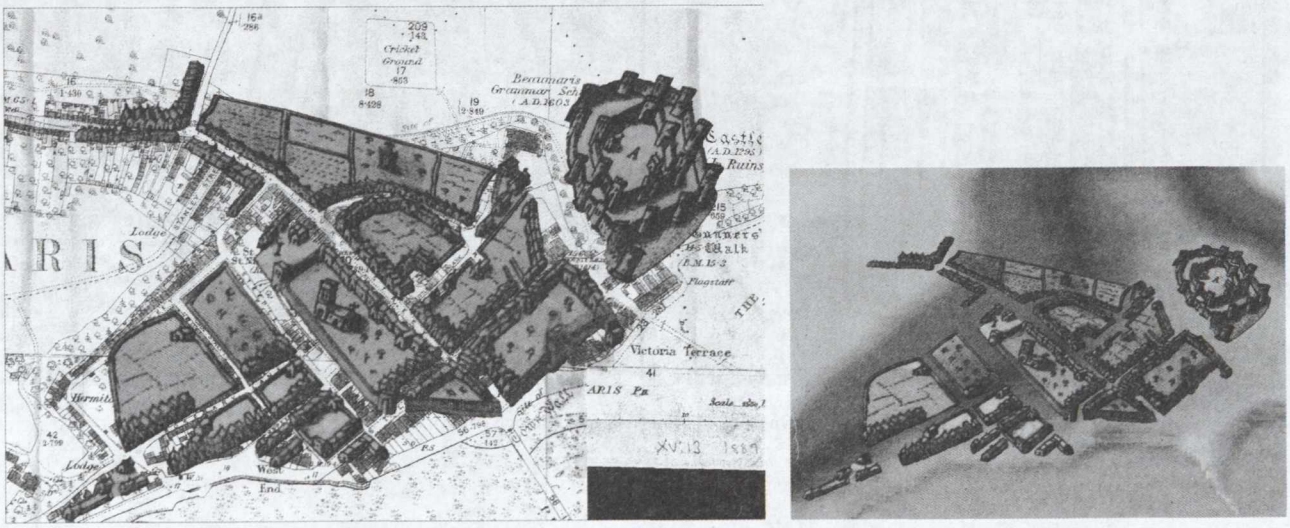

Fig. 6 – Left: the results of cutting up the street blocks and rectifying them to the OS 1889 plan. Right: Placing these rectified blocks on the surface model.

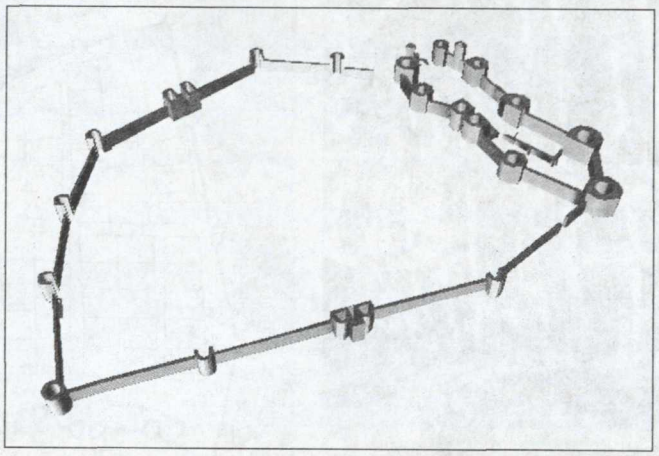

Fig. 7 – Extruding the polygon footprints of the castle and town walls of Caernarfon, northwest Wales.

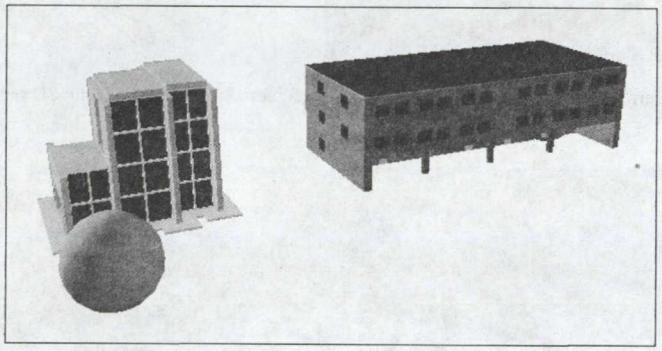

Fig. 8 – Some ArcGIS 9 3D symbols.

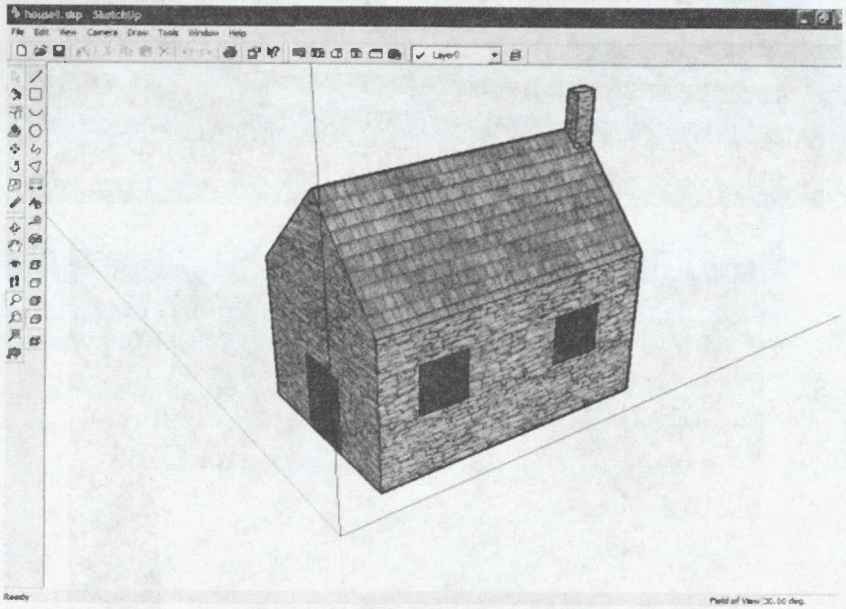

Fig. 9 – Producing a medieval town house in SketchUp.

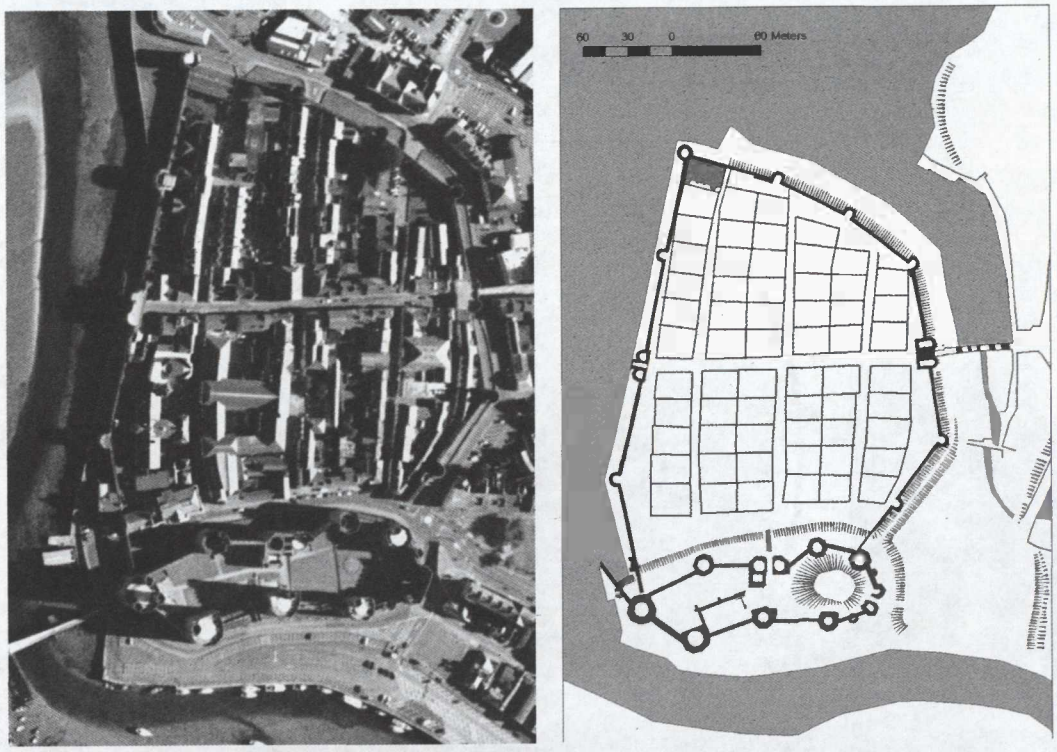

Fig. 10 – Caernarfon, Gwynedd, northwest Wales. Left: aerial photograph, Right: 2D reconstruction.

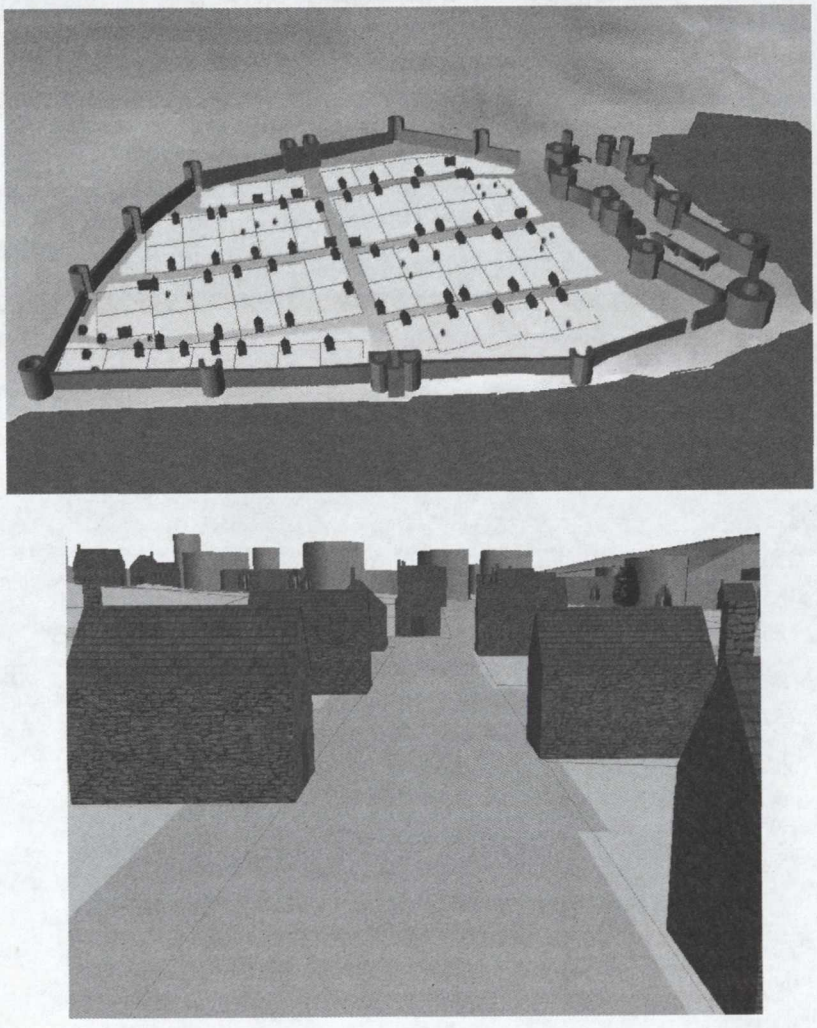

Fig. 11 – The 3D reconstruction of Caernarfon. Top: the town. Bottom: a virtual walk down one of the streets towards the castle.