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Layering London's History: Digital Mapping and Spatial Technologies in Historical Research*

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The opening decades of the twenty-first century have seen an explosion of spatial approaches to urban history, which have allowed historians to combine analyses to gain new cultural and experiential perspectives on historical cities. New tools and resources have introduced both ways to use historical maps as sources in new light, and new ways to create maps as part of historical research. London has often been at the heart of many of these developments. These approaches have unlocked new ways of understanding the historical city through historical map sources, as well as new ways of conceiving of other kinds of sources through a spatial lens.

KEYWORDS GIS; spatial history; spatial humanities; cartography; participatory history; crowdsourcing; London's Past Today

The growth of spatial history approaches over recent decades has opened new perspectives on urban history, and particularly on London history. Evolving tools and techniques, in tandem with shifting historiographical priorities, have allowed historians and scholars to delve into the complexities of urban spaces in ever more detail. Making premodern maps of the city more widely available, both through scanning and georeferencing, as well as through tracing or regression,

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has allowed historians to explore the ways in which the spaces of the city themselves shaped lives. Just as historical interest has shifted from top-down perspectives on urban politics, guilds, and institutions, to questions of participation, agency, and experience, spatial analysis has moved from conveying high-level summaries to exploring the intricacies of individual streets, buildings, and even rooms and yards. In addition to the research potential offered by urban spatial history, the embrace of map-based approaches has opened new opportunities to engage with the public in more accessible and intuitive ways, including through crowdsourcing and participatory history-making. This article explores the way in which both approaches to, and tools and infrastructure for, spatial urban history have emerged over the late twentieth and early twenty-first centuries.

The opening decades of the twenty-first century, particularly, have seen historians use spatial techniques to combine different forms of qualitative and quantitative analyses to gain new cultural and experiential perspectives on historical cities. New tools and resources have introduced both ways to use historical maps as sources and new ways to create maps as part of historical research—making new insights by viewing other kinds of sources through a spatial lens. London has often been at the heart of these developments. The emergence of spatial history has had profound impacts on the way that historians have been able to make sense of urban spaces and understand the contours and dynamics of social phenomena amongst the complexity of urban space. While the potential of the wealth of London-focused spatial history resources might not yet have been fully realised, there can be little question that maps and spatial approaches have shifted historical perceptions and perspectives in a broader sense.

The evolution of spatial approaches to urban history can be mapped onto the broader emergence of spatial history since the 1990s, and its growth out of quantitative social history and towards experiential, emotive, and subjective approaches within cultural history. Spatial approaches to urban history initially focused on traditional economic and social history questions such as the distribution of wealth, crime, or health. Crucially, though, the spatial paradigm and especially geographical information systems (GIS) allow the layering of different kinds of social analysis together, and in combination with historical maps themselves. While many of the highest profile projects, such as *Layers of London*, have focused on resource creation and publication of maps as historical sources, others such as *Locating London's Past* have demonstrated the value of using maps to better understand textual sources. Setting textual sources within their spatial context, especially voluminous individual texts such as the Old Bailey trials on *Locating London's Past*, not only allows straightforward analysis of spatial trends, but also a much deeper understanding of their contexts.

Spatial analytical approaches have also diversified from simply examining distribution to considering movement and the relationship between spaces and the senses. The growing infrastructure of spatial historical data is now allowing the development of a whole new field of cultural and experiential study, considering themes from the movement of street vendors to soundscapes of St Pauls or the Old Bailey itself. In these ways, digital spatially situated urban history is moving the questions from simply what and who was where in the

historical city to what they did and how. Despite this wealth of resources and infrastructure, however, its potential has in many respects yet to be fully realised, and rich opportunities exist for historians of London to enrich their work using extant digital maps, gazetteers, and spatial data sets.

The London Origins of Spatial History and Social Topography

There are several distinct branches of what we now consider spatial history or the spatial humanities, from social topography to spatial storytelling, which can be equated with the concepts of spatial analysis and spatial rhetoric. While now primarily seen through the lens of the digital humanities, these approaches can trace their origins to the long nineteenth century, and many of their most significant developments came from researchers trying to grapple with social questions in the context of the bewildering complexity of a city the scale of London.

Considering the spatial dimensions of social phenomena—from wealth and poverty to disease and crime—in terms of their geographies and spatiality has now long been a fundamental research technique. The earliest experiments with spatial analysis of data were focused on contemporary health questions but provided a model for other forms of social research, especially wealth, poverty, and crime, and eventually historical research, which also initially focused on wealth and poverty. While Laura Vaughan cites Valentine Seaman's 1797 'Inquiry into the Cause of the Prevalence of the Yellow Fever in New-York' as the true pioneer of the use of cartography to make sense of data, Dr John Snow's famous 1854 map of cholera cases in London's Broad Street is remembered by many as one of the key starting points for the conjunction of social research and cartography.[1] Snow's map depicted individual cases of cholera as lines above properties' street frontages on a line map: the close geographical correlation of the massed 'stacks' of lines constituted a dramatic and impactful visual rhetoric. This combination of spatial articulation of research and visual rhetoric was perhaps taken to its nineteenth-century apogee by Charles Booth's famous poverty maps (1886–1903), which depicted street frontages in shades of gold through to black, symbolising 'upper-middle and upper classes. Wealthy' through to 'Lowest class. Vicious, semi-criminal'.[2] Both maps are paradigmatic and pragmatic attempts to make sense of the spatial complexity of human phenomena, and both harness the potential of maps as visual rhetoric to show the spatial concentration of phenomena in ways that tables and charts simply could not. It was the complexity, and in the latter case especially the size of London's spaces, which encouraged this innovation and demonstrated its power.

Locating London History

While the potential of social topography as a method of making sense of, and communicating, all kinds of social phenomena has been well known since these nineteenth-century innovations, historians have been relatively slow to apply these approaches to the study of the past. In one respect, fundamental technical

and infrastructural gaps have been a good reason for this slow adoption. Booth and Snow were able to construct their maps through the simple expediency of using pre-existing maps as their base; Booth's Poverty Map was literally layered upon then-contemporary Ordnance Survey maps. However, for the historian, the availability of suitable base maps for the period they are studying is often more difficult, but is still the fundamental prerequisite. Most obviously a base map avoids the extreme complication of drawing a map from scratch, but more fundamentally it addresses the challenge of being able to locate the phenomena you want to map in the first place. The pace of change in a city like London is such that you do not have look far into the past for a present-day map to cease to function as a reliable locator of streets and addresses.

The complexity of locating past events and details within urban space is such that the first historical applications of the technique within London focused not on Snow's scale of individual households, or Booth's scale of blocks, but at the level of much larger administrative units of parishes and wards. Rather than mapping individuals as data points, the approach of mapping social phenomena according to district averages, known as choropleth mapping, is just as well established. And in the context of London, especially London of the early modern period, not such a large compromise as might initially be expected: the core medieval City of London parishes were tiny—famously 100 in one square mile. When a parish might have contained only a few dozen households, the parish itself was not a bad form of 'spatial description'. London's early modern authorities themselves collected much vital data using the parish as unit of organisation, most famously in the Bills of Mortality, which recorded causes of death in each metropolitan parish every week from 1603 to 1840. Londoners also routinely identified themselves by their parish of residence in documents such as legal writs and wills. Barriers to mapping this kind of research have always been much lower when categories have been common to both the research material and digital map resources that can be used to map them.

Social historians were therefore quick to harness this meeting of readily available data with spatial units that were themselves well documented and relatively easily mapped cartographically. Studies in the 1960s and 1970s manually mapped key sources such as the Hearth Tax and the late seventeenth-century 'four shillings in the pound' taxation records, but it was work well suited to computing.[3] Administrative records, especially those based upon quantitative acts such as taxation, or easily quantified because of their intrinsically regularised use of regular boundaries, naturally lend themselves to this kind of work; so much so that as Adam Crymble argued, 'without taxes, we might never had had a need for computers in historical research'.[4]

Digital GIS-based mapping was first applied to making sense of the same complex pre-modern economic and demographic sources during the 1990s. Craig Spence's *London in the 1690s: A Social Atlas* was the culmination of a long and detailed Institute of Historical Research Centre for Metropolitan History (CMH) project on the Four Shillings in the Pound aid of 1693–1694. Setting the precedent used in almost all subsequent approaches, 1860s Ordnance Survey maps were used as the basis for redrawn vector (digital shape-based, rather than 'raster' image-based) maps of parishes as the key spatial units that were

(relatively) consistent between those nineteenth-century maps and the units of organisation of the original sources.[5] Statistical data on wealth and occupation was depicted through choropleth maps (shapes coloured according to a numerical scale), although reflecting the technical limitations of the era, these were published in an uneasy scale of black and white hatching patterns. Reflecting the difficulties of dealing with populations unevenly distributed between small and large, dense and less dense parishes, for which there are not convenient and accurate population figures that would allow the easy calculation of densities, Spence created artificial statistical districts either smaller or greater than the parishes that were the main unit of study. More detailed features, such as the locations of specific infrastructure (warehouses, wharves) assessed in the taxation had to be mapped more schematically in a format we would now call point clusters.[6] Illustrating the way in which underlying vector boundaries encourage further research, Justin Champion's 'London's Dreaded Visitation: The Social Geography of the Great Plague' applied these methods, crediting Spence for the creation of the base maps.[7] These adjacent projects represent the tradition of urban social and economic research embracing new technologies; the congruence of quantitative social topographies based on jurisdictional boundaries with the expectations of the 'new social history' of the 1970s and 1980s; and perhaps even a methodological bias towards the early modern city because of the more manageable scale of data (compared with later eras) balanced with the availability of maps and then digital boundaries.

The 1950s and 1960s also saw the emergence of a separate tradition of historical topographic and cartographic history in the form of map regression and cartographic reconstruction. Organised through the Europe-wide 'International Commission for the History of Towns', the Historic Towns Atlas projects set out to create topographically accurate maps of European Towns and cities depicting eras before the availability of widespread accurately surveyed cartographic maps.[8] Combining the spatial accuracy of the earliest standardised nineteenth-century maps with thorough topographic research, this approach essentially involves comparison with older topographical information and editing of the more modern map to, for example, edit out streets that were added or widened in the intervening years, and add back in lost detail based around the features that did remain consistent. In most cases this involves use of standardised Cadastral mapping of the Napoleonic era, but in Britain and Ireland relies upon the Ordnance Survey Town Plan 1:1,056 or 1:500 series, dating from between the 1840s and 1890s. London's *Historic Towns Atlas* was published in 1989. This volume, intended to be the first of a pair, reconstructed London's topography in Roman and Saxon eras, along with *c.*1270 and *c.*1520, all based upon topographical research by Mary Lobel and cartography by Colonel Henry Johns.[9] This atlas had a major impact on subsequent work on London's medieval and early modern history, allowing scholars with only a casual interest in geography to informally and easily locate and map locations of interest within the city. Decades of seminar and conference presentations on medieval and Tudor London have featured photocopies and scans of these maps with annotations in biro, highlighter, and latterly emoji. Such was the interest in these maps that the

Historic Towns Trust published a revised and updated version of the Tudor London map with cartography by Giles Darkes in 2018, and it has since been added to the *Layers of London* platform (see below) as a georeferenced overlay.[10]

While the fine cartography of the *Historic Towns Atlas* gives a visually impressive and readily comprehended means of navigating the premodern City of London, the style of their production (as a traditional cartographic project) has meant that even when presented digitally (such as via *Layers of London*) they are fundamentally just images ('rasters' in GIS terms) without interactivity or extensibility. Scholars wishing to layer on their own research have little option beyond the digital analogues of the biro and highlighter. Another prominent project, *The Map of Early Modern London* (MoEML), led by Janelle Jenstad at Canada's University of Victoria since 1999, forged its own distinctive path, presenting the Agas 'woodcut' map of Tudor London as an interactive image, but without spatial referencing.[11] While boundaries and features were traced to make them clickable and linkable, the choice to preserve the original cartography (which is far from accurate in Cartesian terms) means it lacks interoperability with any GIS system. Social and economic historians wishing to depict their research through social cartography would have to wait a while longer before the digital data to support their work would become available.

Digital resources that could be reused and employed dynamically within GIS to represent and contextualise any aspect of early modern London's history began to be created on a large scale from around 2011. At that time, UK and international funding bodies prioritised the digitisation of research resources and infrastructure: a short-lived era that Crymble characterises as the 'Age of Mass Digitization'.[12] It was at the height of this period that the e-Content Programme of the UK's Joint Information Systems Committee (JISC) funded the *Locating London* project. *Locating London*, a collaboration between the Universities of Hertfordshire and Sheffield, the Institute of Historical Research, and the Museum of London Archaeology, set out not only to join and georeference an image of John Rocque's 1746 map of the Cities of London and Westminster, but also to create vector layers (i.e. interactive digital points, lines, and shapes) that plotted the full detail of Rocque's map onto a standard modern GIS environment of Cartesian coordinates. The work involved in this was monumental. Rocque's map was originally engraved as twenty-four separate sheets, and while some printed copies were pasted together, they did not join up seamlessly. Only once the sheets were (digitally) stitched together could georeferencing begin, matching common points between this eighteenth-century map and the present day. This process yielded a map warped to conform to modern coordinates, incidentally exposing the patterns of high accuracy where Rocque was able to use many church towers in his surveying in the walled City of London, in contrast to the greater distortion in the suburbs where towers were sparse. This was followed by the tracing of individual elements from image into interactive digital shapes, or vectors, which allows for searching by names of streets or other features, as well as route planning, and much else. The warping created by the georeferencing meant that in practice the shapes of streets, buildings, and yards were mainly traced from the 1860s Ordnance Survey with reference to Rocque.[13] The work

involved in all of this processing is not to be underestimated, but it has great value in unlocking new possibilities for spatial analysis of early modern London. The vectors allow individual elements of Rocque's map, from ward or parish boundaries to roads and public spaces, to be combined or plotted independently; used to plot routes across the early modern city; and crucially to (semi-)automatically locate ('geocode') other pieces of historical data.

Locating London's Past launched in 2011 as a public-facing website giving access not only to a visually impressive georeferenced image of Rocque's original, but also a broad selection of already digitised historical data, from the tables of the Bills of Mortality to the Proceedings of the Old Bailey, geocoded onto it.[14] This combination of maps and data invites users to consider spatial patterns hidden in large data sets, such as the *Proceedings of the Old Bailey*, by considering geographical patterns in different kinds of crime. The vector elements of the project are not immediately visible, but function to locate the historical data. By 'slicing' each of the elements of the map data (parishes, wards, spaces, or roads) by each other, it was possible to create a bounding shape or central point for each combination, according neatly to 'vernacular' pre-modern descriptions of locations such as 'on Cheapside, in the parish of St Mary-le-Bow'. Locations in the central part of the City, at least, could therefore be mapped with considerable precision. Users can refine their search, working from text to location, generating new maps as they go, which highlights the potential of vector-based GIS maps of past cities. While the 2011 interface was not always intuitive and search sometimes problematic, the 2024 relaunch makes the relationship between searching the data and the way it is plotted onto the map more apparent, as well as tidying up the data to ensure the accuracy of search results.[15]

The vectorised map data based on Rocque's 1746 map itself also enabled further map regression. Map regression depends on comparison between an accurate map and a target map that might be less accurate but depict a different era. The first step in this direction was the Institute of Historical Research and Museum of London Archaeology project *Mapping London*, which georeferenced Morgan's 1682 map of London, and then regressed the vector shapes from Rocque's map. The *Layers of London* project went on to repeat this methodology and has expanded the range of vector map layers to span the range from 1658 (Faithorne and Newcourt) to 1828 (Greenwood).[16] The pace of growth of London in the early modern period was so fast that the changes between these maps were dramatic, and part of the beauty of the vectorised map elements is the fact that comparison can be immediate and simple, or can be enhanced with methodologies such as Space Syntax analysis of possible paths between every part of a space. Space Syntax depth analysis of Morgan and Rocque's maps in Figures 1 and 2 shows the shift in the most easily reached—or 'central'—locations as the west end of the city grew.[17]

Researchers have also been able to use these vector maps as the basis for further regression of London's earlier and even medieval past within GIS. Limiting analysis back to administrative units of ward and parish, where changes through time are much less complex and better documented than is the case for streets or buildings, has allowed the mapping of locations in the medieval city using the

FIGURE 1 Vectorised road networks from Morgan (1682) shown with results of Space Syntax analysis (400 m radius).

FIGURE 2 Vectorised road networks from Rocque (1746) shown with results of Space Syntax analysis (400 m radius). 'Warmer' colours represent more connected or 'central' locations.

same GIS framework as later periods. Adapting the vector boundaries of London's parishes from 1682 to their pre-Reformation layout has been relatively easy, and has underpinned both my own work on questions such as the distribution of occupations in the late medieval city, and social networks and emotional attachments across the late medieval city in the work of Charlotte Berry.[18] The technologies of GIS have made the production of maps for publication much

more feasible for lone scholars and small teams without professional cartographic support.

The creation of GIS vector layers of eighteenth-century London and Middlesex catalysed the development of early modern research projects focused on employing the ability to dynamically map locations and concentration across London, although this potential remains to be fully exploited.[19] *Locating London's Past*'s formal geocoding process based on vector layers has also been employed to enhance other early modern data sets, such as the Furniture History Society's *British and Irish Furniture Makers Online*, which is fully geocoded and available via *Layers of London* (discussed below).[20] Maps based on the vectors from the Rocque data set have appeared in a wide range of other research publications, such as Charlie Taverner's work on early modern hawkers and street food.[21] Other historians have exploited these geodata resources in a less formal way, including Alexi Baker's innovative 'vernacular GIS' approach to mapping eighteenth-century scientific instrument makers' shop locations.[22] While the number of projects directly using this GIS infrastructure might be fewer than envisaged, making maps of the early modern city widely and freely available has inspired historians to think in terms of location and space more broadly in their work.

Other Approaches to Mapping London's Past

While the technical barriers to making a fully featured GIS-based project using historical maps, like *Locating London's Past*, have remained high, other historians took advantage of the growth of more generic web mapping services during the 2010s. The growth of the popularity of platforms such as Google Maps has made the concepts and functionality of digital mapping paradigms so ubiquitous as to be essentially invisible to the general public: being able to search, zoom, and pan a map have become simply second nature to most. This has opened the possibility of applying digital mapping to the dissemination of historical spatial data in a simple and accessible way, albeit initially only with modern basemaps.

Bombsight was another project funded by the JISC 2011–2013 eContent Programme, which followed a simpler interface concept than *Locating London's Past*.[23] Working on the twentieth century meant that the modern street plan is much more applicable, and also obviously allows users to make connections with their experience of place more immediately. *Bombsight* assembled spatial sources in a variety of forms; the 'first night of the Blitz' census was transcribed with addresses that had to be geocoded (using modern tools), while most of their other sources were archival maps that were scanned, georeferenced, and vectorised into point data. This project provoked great interest, receiving almost 185,000 unique visitors on one day when it was featured on BBC Online in 2012.[24] The project undoubtedly raised awareness of the potential of World War Two bomb censuses as sources, and can perhaps be credited with inspiring similar projects in many other regions, including the *Surrey World War Two*

Bomb Incident Map project.[25] This is notably run by volunteers through the Surrey Heritage Centre, and makes use of the National Library of Scotland's comprehensive and high-quality georeferenced Ordnance Survey maps as its base map, showing the improving accessibility of these resources and tools since the 2010s.

Crowdsourcing and Deep Mapping

The period after 2010 saw a flourishing of very different approaches to the production of historical spatial information, reflecting the convergence of social and cultural historians' desire for histories from below and participatory history with the 'participatory web' known at the time as 'Web 2.0'.[26] In the realm of spatial history, this took the form of both crowdsourcing and what might be regarded as examples of Bodenhammer's 'deep mapping' of diverse media and stories.[27] While influential, the concept of deep mapping is amorphous, and can perhaps be better regarded as a desiderata rather than a definition, or as a process rather than a product: an aim to map qualitative experience and, or, to represent a narrative.[28] Again, London was at the vanguard at putting these ideas into action.

The *Layers of London* project was both a continuation of the Institute of Historical Research's Centre for Metropolitan History's programme of spatially situated urban history projects and a step change in approach and scale to all that had gone before it. Unlike previous projects that had addressed specific research questions, or on the creation of resources to support other researchers, which were typically funded by research councils, *Layers* was funded by the National Lottery Heritage Fund, and therefore had quite different aims. Rather than research leading towards impact and engagement, this was a project where engagement and community history led the way; crowdsourcing and volunteer activity was not a means to a (research) end, but was in many ways the aim itself. The name *Layers of London* playfully captures the fact that it uses map layers to capture and convey the 'layers' of parallel experiences of such a complex city as London.

Layers of London contains 359 georeferenced historical map overlays (as of mid-2024). The georeferenced maps range in scale from the Ordnance Survey 1798–1809 survey drawings and 1890s Ordnance Survey 5 inches to the mile maps covering the vast majority of the present-day Greater London, to a profusion of often intricate estate plans, surveys, and maps of local interest that were digitised and georeferenced in partnership with many of London's borough archives.[29] All can be compared and contrasted using transparency tools, and many, including all of the vectors, can be made available to researchers for use in their own projects.[30]

Layers of London had co-production and crowdsourcing as a key aim. This took two forms: crowdsourced map processing tasks, and co-production through community archiving. The enthusiasm of the wider public for map-based crowdsourcing tasks was already clear: the British Library's 2013 *Georeferencer*

project completed the spatial referencing of thousands maps much quicker than expected, and quickly expanded to around 50,000 maps.[31] Similarly, the *GB1900* project transcribed 2.6 million map annotations from the Ordnance Survey County Series maps in just over a year with 1,000 volunteers.[32] The success of these projects highlighted the 'sweet spot' of employing maps as a means of engaging the public in crowdsourcing history: they both offer an accessible means of engagement (many find maps more familiar than historical texts), and they often offer a relatable 'hook' through the connection to the local. This form of direct map-based georeferencing was employed in two aspects of *Layers of London*: georeferencing the RAF aerial collection (1945–1947) and the vectorisation of Charles Booth's Poverty Map (1889). The RAF collection, held by Historic England, comprises thousands of oblique photographs captured by aircraft over London immediately post-war, capturing immense detail of the city at a time of flux. Using a similar tool to that used by the British Library, a similarly enthusiastic response (perhaps aided by the first of the COVID-19 lockdowns) saw all the images georeferenced by volunteers between January and June 2020.[33] The vectorisation of Charles Booth's famous Poverty Map was somewhat more complex, involving the creation of a new tool to help members of the public trace the blocks of colour from the map into digitised shapes that unlock great potential for spatial analysis (Figure 3). While just four years later

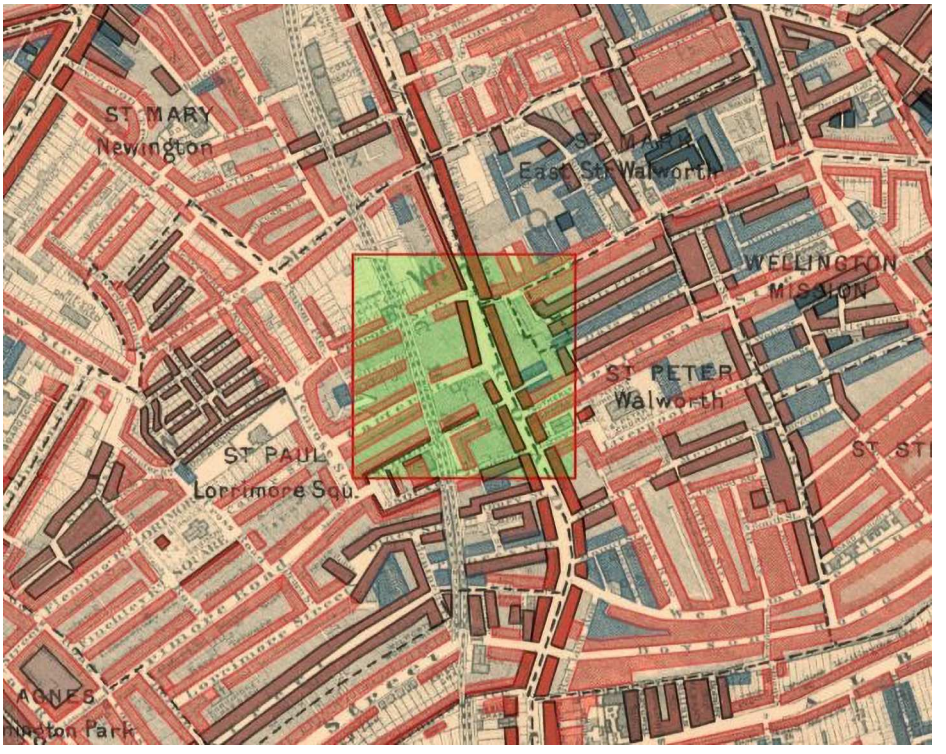

FIGURE 3 Screenshot of in-progress vectorisation on the *Layers of London* map tracer tool. The bolder shapes adjoining the main road have already been traced.

each of these crowdsourcing projects might now be candidates for artificial intelligence (AI)-based workflows, it is worth remembering the potential impact and engagement generated through offering these opportunities for the public to engage in enriching the history of their city through structured crowdsourcing tasks. Working on these maps raised the awareness and familiarity of London's spatial history within this community, even if it is acknowledged that, beyond organised engagement activities such as the classroom georeferencing sessions run by *Layers of London*, those who engage in these crowdsourced map-processing tasks are a self-selecting group, many of whom are already highly engaged in history or mapping.

As with the vectorisation of the eighteenth-century London maps, vectorising the shapes and colours from Booth, or the Bomb Damage maps, makes the data on each building or street individually available for analysis and comparison, including by reference to other spatially referenced data. For example, economist Thiemo Fetzer created vectorised coding from *Layers of London*'s georeferenced Bomb Damage maps, which he combined with modern postcode-based planning and Energy Performance Certificate data to examine correlations between wartime damage, planning control, and energy efficiency.[34] Generating this historical vector geodata therefore brings it into conversation with a whole world of other forms of data, even if not all applications might be recognisably historical.

Layers of London's aims with regard to co-production were more ambitious than just the crowdsourcing of map-processing tasks. The core of *Layers of London* is its ever-growing and totally open collection of 'Records'. Each spatially situated record can contain text, multiple images, links, and embedded YouTube videos or SoundCloud audio clips: it is a deep map in practice. Records can be grouped into thematic 'Collections' and also into 'Trails' (which generate a literal walking trail and invite the linear exploration of a curated narrative of records). Users can collaborate as teams, building collections together, and reuse each other's records in other contexts. All of this is, perhaps somewhat radically, open. Anyone can register an account and contribute new records and collections, and image uploads are governed by Creative Commons CC-BY licenses. Contrary to some fears, this has rarely resulted in problems with spam or abuse. Records considered inappropriate can be reported or corrections suggested, but in practice this function rarely raises any issues more impactful than suggesting corrections to dates or precise locations.

As of mid-2024 there are just over 15,000 records and 660 collections records on *Layers of London*. The most visited collections include the encyclopaedic 'London Pubs' and the vast collection of digitised articles from *The London Archaeologist*, as well as a diverse collection curated by Friends of Hackney Archives; a collection from the Courtauld Institute's Conway Library of architectural photography; and 'Inventive Vents', which highlights the invisible workings of the city. This neatly encapsulates the conjunction of diverse aspects of professional heritage work with other forms of civic action and enthusiastic general and local interest that drives *Layers of London*'s continued popularity. *Layers* continues to grow, and currently attracts around 35,000 visitors per month, illustrating the sustained depth of interest that an actual deep map can attract.[35] The public contributions

might at first be regarded as random or unrepresentative, but as a live experiment in unconstrained community archiving, they can more fruitfully be seen as a reflection of the city's diverse and eclectic practices of memory-making.

Community groups that worked directly with the project have reflected positively on the way in which finding out about *Layers of London* prompted them to digitise their community archives, and with the help of workshops, to put that into practice. Greenwich's Ashburnham Triangle Association, for example, described the way in which *Layers* 'has provided a focal point and vehicle for galvanising the group—bringing people together with a shared purpose', as well as providing the means for those who self-identify as having 'relatively limited technical skills' to record their places in digital form.[36] This form of historical co-production not only builds a historical record and a spatial data set, but also serves an important contemporary social function within communities.

*Layers of Lond*on's use of co-production is a reflection of the convergence of academic interest in the cultural experience of space and the desire to capture history from below, along with evolving funding priorities. In one sense it is possible to look at the evolution of projects addressing the spatial history of London as a case study in the evolution from the quantitatively grounded academic approaches popular during the 1980s and 1990s into the growing influence of cultural history and place-writing, capturing and celebrating the multitude of subjective perceptions of places via user contributions during the 2010s.[37] This aspect of *Layers of London* was embraced by the Mayor of London's Commission for Diversity in the Public Realm *Unseen London* programme, which aimed to amplify community histories to wider audiences, and has the potential to be a significant primary source for future histories of place.[38] In another sense, it can be seen as a reflection of the evolution of technology and availability of tools and data. The early GIS maps of the social topography of early modern London created during the mid-1990s reflected the possibilities and limits of both the computational technology of the time and the constraints of small teams of post-doctoral researchers working in highly structured workflows. Growing computational power and richer GIS algorithms and tools enabled not only the tracing of administrative boundaries into digital maps, but also the mass digitisation of both maps and texts. Crowdsourcing unlocked another step change in resourcing as a handful of pairs of eyes could be replaced by thousands, impacting both the scale and ambition of what has been possible to recover of the city's spatial past.

Cultural history and spatial data infrastructure have also combined to catalyse a much wider range of approaches. Partially enabled by the generation of digital spatial resources, historical attention is increasingly turning to embodied and experiential interpretations of the city: senses, sights, sounds, and emotions. Considering the experience of the city through bodies and senses inevitably depends on their spatial situation. This involves looking through an even closer lens; whereas the spatial social history of the 1990s tended to map the ward or parish, and then attention and capacity turned to the level of the street and its buildings, thinking about historical spaces through embodiment narrows the focus still further, literally to the human scale of yards, doors, windows, and

furnishings. The *Virtual Paul's Cross* and *Virtual St Pauls' Cathedral* projects, run by John Wall at North Carolina State University from 2014, have been extremely influential in setting out the possibilities of examining historical events through the framework of a spatially situated simulation. The projects not only mapped St Paul's and its churchyard in 3D in great detail, but also modelled its acoustic qualities—involving detailed consideration of materials as well as design—alongside the texts of sermons and setting of music.[39] This elevates the established archaeological 3D reconstruction into a way to experience the influence of specific spaces on a specific historical moment. This approach has been further developed in, for example, Tim Hitchcock and Ben Jackson's explorations of the physicality of the Old Bailey courtroom and the sensory experiences of defendants and the other actors of the trial process.[40] Other projects have begun to explore and infer other sensory experiences through the detailed study and virtual reconstruction of micro-geographies, often aiming to add new context to 'traditional' sources such as John Stow's *Survey of London*, or seventeenth-century pageant texts. These have included studies of street selling in early modern London, animal experiences of the city, and of course playhouses and drama.[41] This explicitly interdisciplinary approach undoubtedly adds a new dimension to understandings of past spaces, although these ways of inferring the experiential can only ever offer an expression of how people *might* have experienced spaces. Drawing these approaches together with explorations of contemporary art and literature, as a recent special issue of this journal on early modern pageants set out to do, offers the potential to further enrich our understanding of the *experience* of spaces.[42]

New Directions in London's Spatial History: Using Artificial Intelligence?

Each stage in the development of spatial study of London's history has been the product of the conjunction of the development of tools and expanding infrastructure of spatial data with the shifting methodological and theoretical aims of historians. From the simple boundaries that individuals could draw to the more complex geographies that could be digitised by larger professional teams during the era of mass digitisation, and then the era of crowdsourcing, the growth of spatial data infrastructure has depended on ever more people joining the effort to create it. The development of machine learning and 'artificial intelligence' in the 2020s promises to upend this traditional relationship and allow the creation of new digital spatial infrastructure in a much less labour, and cost, intensive way—which has the potential to unlock ever more detailed, and wide-ranging, historical explorations.

The most notable artificial intelligence tools of 2023 and 24 have been Large Language Models (LLMs), built from, and best able to work with, texts. LLMs will surely impact on spatial history through the annotation and analysis of large data sets and texts, allowing them to be geocoded, promising a reprise to the age of mass digitisation. However, a rather different branch of machine learning—

computer vision, image classification, and segmentation—promises to make the biggest impact on urban spatial history. One aspect of computer vision, Handwriting Recognition, will also contribute to the creation of dramatically larger data sets. For instance, the *Material Culture of Wills* project led by Jane Whittle is developing Handwriting Recognition Models in order to analyse 25,000 early modern Prerogative Court of Canterbury (PCC) wills.[43] While their immediate aim is to annotate and analyse material objects described in the wills, these documents are also a trove of spatial information; indeed, the high proportion of London wills in the PCC should be possible to map the distribution of the ownership of material objects across the city and its hinterland.

Machine learning has also begun engaging directly with maps, drawing on the principles of computer vision developed in other fields of research. Most prominent in recent years has been Katharine McDonough and the Turing Institute's *Machines Reading Maps* project. Building upon initial work that extracts text contained within maps into searchable vector point annotations (which would allow the crowdsourced work of *GB1900* to be replicated automatically), this ambitious project has primarily focused on applying image classification techniques to characterize 100 m^2 grid squares based on the presence of features such as woodland or rail infrastructure. This technique is initially suited to a distant analysis, comparing simple proximity—as opposed to connectivity or qualities—of different features within large maps, and preliminary publications have offered somewhat predictable conclusions about the impact of rail infrastructure on industrialisation.[44] In this sense, MapReader's current capabilities are in a way suited to the quantitatively based questions of earlier approaches to social and economic history than to the qualitative questions of the uses and experiences of urban spaces that currently dominate historical discourse. Just as technologies such as 3D modelling have been applied to diverse qualitative as well as quantitative approaches, future historians will likely develop ways of exploit machine learning technologies to ask qualitative questions at large scale. Nonetheless, this application of computer vision fundamentally makes the visual content of historic maps, as opposed to simply their text or manual translation derived from them, available for digital analysis directly.

Urban spatial history is perhaps most distinctively concerned with the intricacies of topographical form (both socially and materially) so the ability of computer vision to aid in vectorisation of individual features from historic maps likely offers the most potential. The New York Public Library's *Building Inspector* project, which ran between 2013 and 2019, developed a machine learning-powered map vectorizer tool described as 'like OCR for maps'.[45] Regular shapes are identified and rendered into vector shape boundaries on the map, just as the volunteers contributing to the *Layers of London* vectorisation of Booth's Poverty Map did. The *Building Inspector* element of the project was the public interface required for the crowd-sourced checking and tidying of its output. This early tool was hard-coded to work with the colour-coded style of the Perris insurance atlases of New York, which are strongly reminiscent of the Goad insurance maps of British cities from the late nineteenth century. These

approaches are continuing to develop, with cadastral maps of European cities being a particular focus.[46] Adapting the tool to the predominantly monochrome style of most other pre-digital British urban maps would be possible, if challenging.

Historians' uses of GIS occupy just a small niche within the geodata ecosystem, and we often either have to 'work against the grain' to apply tools to our data or face a long wait for tools that suit our materials, such as archival maps, to emerge. Only in 2024 has an easy-to-use tool been launched to bring this machine-learning approach to a wider range of maps. Bunting Labs' 'AI Vectorizer' plugin for QGIS uses computer vision to allow users to 'trace' features from georeferenced images of maps by following the map line closest to the path of your mouse. Much as ChatGPT has simplified and democratised the use of LLMs, this kind of application promises to make computer vision technology available to map scholars without the time or ability to customise code or train their own models, multiplying the amount of vectorisation that can be completed by individuals. The vectorisation of the maps of seventeenth- to early nineteenth-century London carried out by *Layers of London* was time-consuming, highly skilled, and expensive. These new tools offer the promise of being able to create even more detailed results with less effort, potentially allowing the vectorisation of historic maps of much larger areas or multiple cities much more quickly and with less expense. But it is important to remember that AI applications are not magic bullets but tools, multiplying the effort of those who use them.

Conclusion

Charting the development of spatial histories of London has not only highlighted the interrelationship between shifting historiographical trends and lines of questioning on one side and the availability and capabilities of the tools and digital infrastructure with which to ask them, but also revealed much unrealised potential. The period since the early 1990s has seen an explosion in the volume, extent, and detail of digital spatial infrastructure available for the study of London in past centuries. From the early GIS adaptation of sketch maps of administrative boundaries, suited to building choropleth maps of statistical summaries, to detailed 3D reconstructions of early modern architectural spaces, this has depended on not only advancing computational power but more significantly ever-increasing investments of time (professional and then crowd-sourced) to build that historical digital infrastructure.

The increasingly intricate and detailed digital spatial information has, whether by coincidence or consequence, suited the trend for historians to seek to examine the past of the city in ever finer-grained terms. Historical interest has largely shifted from the abstract qualification of characteristics to the intricacies of urban life and experience. Whether those experiences are co-produced memories and family histories from the public or interpreted from historical sources, considering them in spatial terms requires a depiction and understanding of urban space at the human scale. Whether the possibilities of mass distant reading through machine

learning shift historians' focus back to the scale of more abstract comparisons remains to be seen. Either way, spatial techniques and tools are just that: tools in service of historians' questions.

London is now possessed of an impressive corpus of digital historical spatial resources that can help historians address questions at a range of scales and qualitative and quantitative approaches, and tools and training to use them are widely available. The comprehensive geographical temporal range of digitised maps available for London certainly far surpasses the availability for any other British city, and most globally. Georeferenced historical maps are now quite ubiquitous, not least from aggregated collections such as *OldMapsOnline*, although a broad chronological sequence for a single city tends to only be found where a dedicated project has sought them out.[47] Vectorised historical urban maps are most commonly available in the form of nineteenth-century cadastres, most impressively in the form of the almost complete digital historical cadastre of the Netherlands, and exciting work to incorporate cadastres into a '4D map' as part of the *Lausanne Time Machine* project.[48] Having such a rich combination of both types, as London now possesses, is a great advantage. Spatial history proves its worth, however, when historians apply powerful and innovative questions to this data.

The degree to which historians have made use of this infrastructure does not seem to have yet realised its potential. Somewhat paradoxically, while historians have expressed frustration with the all-pervasiveness of text digitisation in terms of the ways that projects such as Google Books have influenced and shaped historical studies, potentially without full understanding of their limitations, it can seem that not enough historians are aware of all the map digitisation work that has been carried out, or the potential it offers.[49] Already extant digitised maps and geocoded data sets, as well as digitised sources that could easily be geocoded using the gazetteer resources created through the vectorisation of early modern maps by *Layers of London*, offer great potential for historians to explore a host of sources and themes spatially. Coroners' records, hospital records, guild and tax records, and directories could all fruitfully support much new spatial research; combining and intersecting these sources, which is so easy in a GIS system, multiplies the potential. While digital spatial tools have become easier for end users, initial setup of any project reusing historical map materials remains somewhat complex. More broadly, digital skills are often still regarded by many historians as a separate domain, and reusing data does not often take an integral part of project planning for historians in the way it does in the social sciences. While the number of direct uses of the spatial data created by *Locating London's Past* or *Layers of London* are so far relatively limited, it is easier to see a broader influence of mapping and spatial analysis in historical practice. It is relatively rare to see a conventional research publication explicitly acknowledge the importance of digital spatial resources, such as Colin Rose's recent article on homicide in early modern Bologna, which avowedly depends on the *Origine di Bologna* project's open-access vector data.[50] More broadly, though, these platforms make historical maps, and the ability to navigate them or compare change through time, seamlessly available to historians and all heritage

practitioners. Their use might not be directly cited, but even informal use of these historical map resources has become embedded and anecdotally appears to have 'shifted the dial' towards spatial thinking being a standard part of historical practice, even if only manifested through the near-ubiquity of annotated screenshots of historical maps in seminar presentations. Perhaps most visibly, the developers of the next instalment of cult computer game *Civilisation VII* have publicly reflected on the influence of *Layers of London* in helping them to develop the mechanics by which cities in the game evolve over time.[51] Understanding and communicating this complexity of change and flow in urban spaces is undoubtedly the greatest value of applying digital spatial techniques to urban history.

Disclosure Statement

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