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Deep Mapping Uncertain Historical Sources

Visualizing Business Knowledge of Painters in Seventeenth-Century Amsterdam

▼ **SPECIAL ISSUE ARTICLE** in *Mapping Uncertain Knowledge*

▼ **ABSTRACT** This article navigates through the challenge of preserving and presenting uncertainties in digital maps, which are used to reconstruct practical knowledge in early modern artists' businesses. It introduces a novel methodology—deep mapping—as a multilayered spatial visualization within the Geographical Information Systems (GIS). This method adeptly facilitates the processing and visualization of complex art historical data, offering a nuanced approach that addresses the dual need of managing large-scale spatial analysis and maintaining the precision requisite in scholarly work. To operationalize the concept of deep mapping in knowledge production, this research has collected and integrated location-related descriptions of early modern addresses from various sources, translating them into georeferenced areas and visualizing them on historical maps with varying levels of uncertainties. Applying deep mapping to visualize painters' distribution patterns in seventeenth-century Amsterdam as an example, this article discusses two ways of presenting uncertainties in digital maps to facilitate historical observation. It shows that uncertainty is most effectively presented as fuzzy heat maps in the background to accentuate painters' choices of locations for their painting businesses. The deep maps demonstrate that painters in early seventeenth-century Amsterdam pragmatically

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practiced their business knowledge by making clustering decisions following market conditions.

▼ **KEYWORDS** digital humanities; uncertainty; practical knowledge; GIS; deep mapping; seventeenth-century Amsterdam

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For centuries, maps have carried and reflected our knowledge of the world. Our present ideas of maps and cartography are shaped by practices and conventions that were devised in early modern Europe. And yet, the knowledge and tools of early modern cartographers were preliminary, if not primitive. As other contributions in this special issue have illustrated, early modern mapmakers were constantly confronted with uncertainties in their knowledge of the world and subsequently established their visual languages to demarcate where the known ended and the unknown began.[1] Half a millennium later, advancements in spatial technologies have enabled maps to transcend their conventional roles of cartographic representation, turning them into observational tools for both our present world and the distant past. Concurrently, the humanities have experienced a "spatial turn" in the past decades, integrating mapping and spatial analysis into (art) historical scholarship. Consequently, a new generation of digital art historians has embraced mapping, adding it to their research toolkits.[2] While the early modern maps serve as reflective artifacts of their era, digital cartography facilitates the reconstruction of historical knowledge of everyday life by visualizing scattered or serialized information unobservable by other means.

Mapping—the visualization of geographic locations—is favored by art historians for its capacity to consolidate information from disparate sources, to generate and present knowledge of the past. In art history, this methodology is predominantly applied to trace the mobility of artists and the dissemination of art-related materials, skills, and ideas by mapping artists' travels.[3] Nevertheless, the existing use of mapping tools hardly goes beyond putting pins on the city where artists lived or connecting places through their inter-city and international travels. Art history has yet to profit from the full potential of spatial

1 See, for instance, the contribution by Van Duzer in this issue.

2 Notable projects are Gerson Digital and Mapping Artists at the RKD (led by Rieke van Leeuwen and Mayken Jonkman, respectively); the *GeoMAP* project (https://paris-art-market.huma-num.fr, accessed January 3, 2023), a georeferenced repository of the Parisian art dealers from 1815 to 1954; the *Mapping Art Markets in Europe, 1500–1800* project (https://pnd-artmarkets.huma-num.fr/presentation, accessed January 3, 2023); *Artists in Paris: Mapping the Eighteenth-Century Art World*, (www.artistsinparis.org, accessed January 3, 2023). See Williams, "Artists and the City"; and the mapping of London's art market in the nineteenth century (Fletcher and Helmreich, "Local/Global.") For a brief survey of mapping in art history, see Joyeux-Prunel, "Digital Humanities."

3 See, for example, the Gerson Digital project and the project "Mobility Creates Masters" in Denmark (https://www.smk.dk/en/article/mocma-mobility-creates-masters, accessed January 3, 2023).

analytical technologies such as Geographical Information Systems (GIS), systems that are designed to capture, store, manipulate, analyze, manage, and present mass spatial data. Scholars in other domains such as geography and archeology have shown that GIS have a remarkable capacity to process and present large quantities of spatial information more comprehensively and holistically than maps of a simpler form can do.[4] Yet, the ability of GIS to visualize space as a platform integrating the multiplicity of art historical data has not been fully utilized to reconstruct artists' practical knowledge of the painting business, partially because existing studies have yet to find a way to incorporate uncertainties that are ever-present in art historical research.

Admittedly, GIS and other spatial technologies have their limitations. They "favor precise data that can be managed and parsed within a highly structured tabular database."[5] This contradicts the nature of visual and documentary data on works of art and artists, which often seem to resist computational processing. The information concerning works of art and artists is often ambiguous and multilayered, obfuscating the process of knowledge generation using maps.[6] It means that art historical research using digital maps inevitably runs into the same issue that concerned early modern cartographers: how do we demonstrate and deal with uncertainties in maps to generate and visualize knowledge?[7]

This article hence seeks to explore answers to this question through a methodological discussion, using digital tools to reconstruct practical knowledge of the past while preserving and presenting uncertainties as they emerge from historical records. The rest of the article is organized as follows: It will first introduce a novel concept of "deep mapping" and explore its visual variables in communicating uncertainty on maps. Then it will use artists in seventeenth-century Amsterdam as an example to discuss the methods in the creation of deep maps. Lastly, it will showcase two approaches to visualizing uncertainties, discussing their impact on reconstructing painters' practical business knowledge using maps.

Deep Mapping Uncertainties in Knowledge Production

Addressing the challenges posed by often incomplete and imprecise historical data, art history and related humanities disciplines require a methodology that adeptly preserves and communicates uncertainty throughout visualization and analysis processes. Although (geographical) information scientists have

4 See MacEachren, "Visualization in Modern Cartography"; Zuk, "Visualizing Uncertainty."

5 Bodenhamer, "The Potential of Digital Humanities," 23.

6 For the discussion of the data processing and visualization for humanities disciplines, see Drucker, "Humanities Approaches to Graphical Display."

7 The contributions in this special issue, such as that by Danielle Gravon, illustrate early modern mapmakers' strategies dealing with uncertainties.

developed numerous tools to avoid the mishandling of information, the uncertainty in historical data is less about misinterpreting sources, but mainly about imperfect knowledge of things we do not or cannot know. This form of uncertainty is prevalent in the formal sciences such as mathematics, physics, and logic, and the most common approaches to preserve uncertain information in knowledge generation are using probability, likelihood estimates, and extrapolation from the known to the unknown.[8] In humanities, the concept of uncertainty is reflected in the longstanding debate in historical studies on whether there is sufficient evidence to know the "truth" of the past.[9] As the Australian historian Ann Curthoys puts it: "[Uncertainty is] part of historians' stock in trade, yet historians differ enormously in how uncertain they are."[10] Among the different types of uncertainty, two are particularly pertinent to humanities research: epistemic uncertainty, which is a consequence of incomplete or fallible knowledge, and ontic uncertainty, which is about the intrinsically indeterminate or variable properties of systems or knowledge.[11] (Art) historical research tries to eliminate the former and often ignores or acknowledges the latter without any treatment. Admittedly, the boundary between these two types of uncertainties is constantly shifting. New means of knowledge production may turn an ontic uncertainty into epistemic, which means that it is not possible to fully eliminate uncertainty. Therefore, the handling of it also shifts from elimination to exploring other options.[12] Recently, it has been argued that uncertainty itself can be a source of knowledge.[13] Kemp and Mostern in their study on spatial vagueness in the computational humanities asked scholars to "change their methods to suit technology, rather than making technology work for them."[14]

To acknowledge this "not knowing," and to make uncertainty a source of knowledge, scholars in various domains have tackled this challenge with distinctive approaches. Research in natural sciences has developed a wide range of standardized means to represent fuzzy knowledge, such as standard deviation, error bars, and confidence interval.[15] These abstract statistical measures, albeit useful, hardly help produce complex, multilayered (art) historical knowledge through visualization. Fortunately, in the past decades, the visualization research community has developed various techniques to deal with

8 For the discussion of the limitation of knowledge in mathematics and physics, see Couclelis, "The Certainty of Uncertainty." There are too many applications of probability, likelihood estimation, and extrapolation to be shown here. For notable applications of these ideas to the spatial analysis and data visualization, see, for instance, Bordoloi, Kao, and Shen, "Visualization Techniques"; Grigoryan and Rheingans, "Point-Based Probabilistic Surfaces."

9 Kouw, Van den Heuvel, and Scharnhorst, "Exploring Uncertainty in Knowledge Representation," 93.

10 Curthoys, "Historians and Disputes," 207.

11 Peterson, *Simulating Nature*, 52.

12 Brugnach et al., "Toward a Relational Concept," 13.

13 Kouw, Van den Heuvel, and Scharnhorst, "Exploring Uncertainty in Knowledge Representation."

14 Kemp and Mostern, "Spatial Vagueness," 1.

15 See Hullman, Resnick, and Adar. "Hypothetical Outcome Plots."

fuzzy knowledge, supporting research in domains as diverse as biology, geography, and, within humanities, archeology and media studies.[16]

Among these methods, visual cues such as size, color coding, opacity, density, and blurring (or fuzziness) stand out as a widely utilized technique across various disciplines originating from the graphic semiology in geovisualization, a concept established by French cartographer Jacques Bertin.[17] This approach was subsequently brought into the digital era by American geographer Alan MacEachren using GIS.[18] MacEachren and his colleagues examined a series of standard visual variables such as size, color saturation, transparency and fuzziness, for point symbol sets, representing different levels of uncertainty. Applying this visual vocabulary, uncertainties are made visible by, for example, smaller symbols, less saturated colors, higher transparency, or blurring edges as opposed to their counterparts with a higher level of certainty with bigger, saturated, opaque, or sharp-edged symbols. Although archeologists found color coding effective in communicating fuzzy knowledge in 3D environments, empirical studies have shown that the fuzziness with various degrees of the crispness of the edge, applying the metaphor of "focus" (certain) and "out-of-focus" (uncertain), is regarded as the most intuitive and effective way for the viewers to perceive uncertainty on the map.[19]

Building on techniques in geovisualization, historians introduced the conceptual framework of "deep mapping" to preserve and present uncertainties in the production of historical knowledge.[20] This concept emerged as an alternative to the traditional and isolated "thin map" or "flat map," on which a simple, static, single layer of information is presented. Although the "thin map" is effective in conveying a single message, it falls short in constructing a spatial narrative that matters to art historians and other humanists. Deep mapping, which results from the convergence of the multilayered GIS model, allows the cartographic representation "to be visual and experiential, immersing users in a virtual world in which uncertainty, ambiguity, and contingency are ever-present."[21] More importantly, it can work with the "imprecision and fluidity

16 For discussions of typologies of uncertainty, see MacEachren et al., "Visualizing Geospatial Information Uncertainty"; Potter, Rosen, and Johnson, "From Quantification to Visualization." For the uncertainties in none-geospatial data, see Spiegelhalter, Pearson, and Short, "Visualizing Uncertainty About the Future." For visualizing different certainty degrees, see Gershon, "Visualization of Fuzzy Data," 273, figure 3. For viewing uncertainty from a multidisciplinary perspective, see Skeels et al., "Revealing Uncertainty for Information Visualization." For a most recent survey, see Kamal et al., "Recent advances." For the application, see, for instance, Schäfer, "Digital 3D Modeling in Archaeology"; Zuk, "Visualizing Uncertainty"; Li and Piccoli, "Dealing with Multidimensional Uncertainty"; Noordegraaf, Opgenhaffen, and Bakker, "Cinema Parisien 3D."

17 Bertin, *Sémiologie Graphique*.

18 MacEachren, "Visualization in Modern Cartography"; MacEachren et al., "Visual Semiotics & Uncertainty Visualization," 2497.

19 Ibid.; MacEachren et al., "Visualizing Geospatial Information Uncertainty."

20 The term deep mapping was coined in Bodenhamer, Corrigan, and Harris, *The Spatial Humanities*, and further developed in Bodenhamer, Corrigan, and Harris, *Deep Maps and Spatial Narratives*.

21 Bodenhamer, "The Potential of Digital Humanities," 28.

as the nature of humanities questions and evidence demands," embodying a multiplicity of layered sources and narratives with the capacity to deal with uncertain, incomplete historical data.[22]

Therefore, the deep mapping approach offers a possible solution for generating art historical knowledge while accounting for the imprecise, fluid nature of its historical sources. The operationalization of the deep mapping concept draws on visual cues used across disciplines to preserve and present fuzzy knowledge with all its complexity. Applying deep mapping to the study of art and the art market can visualize art historical data in a sufficiently nuanced way to resolve the concerns of working with data that, by definition, are incomplete and not always precise, and thus balance the advantages of analysis at scale against the precision required in art historical scholarship. The application of deep mapping methodology to art history can open new research avenues for reconstructing painters' practical, everyday knowledge in their business through visual representations of spatial phenomena with uncertainties. As I have argued elsewhere, the collective choice of location revealed by mapping reflects painters' understanding of the art market, serving as a critical component in their business "playbooks."[23] Different from art historical research trying to reconstruct knowledge in artists' painting practice, the spatial distribution of painters' workshops reveals their business knowledge and how they changed their locations in response to the altered market conditions.[24]

Bridging this observational insight with practical application, this article will showcase how to use deep maps to study painters' choices when faced with imperfect knowledge in an uncertain market, adhering to one of the key approaches in the history of knowledge for the 2020s.[25] Notably, while most debates on deep mapping lack a practical dimension, this article tries to operationalize the concept with concrete examples in art history. To do so, it will delve into the experiences of seventeenth-century painters in Amsterdam as an example to not only showcase this methodology but also to explore their decision-making processes concerning residential or workshop locations, thereby gaining insights into their practical considerations within the painting business.[26]

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22 Ibid. The paradigm project CAVE, at West Virginia University, combines GIS with immersive technologies to recreate a sense of nineteenth-century Morgantown from maps and photographs through a projection-based virtual reality system. However, it seems to steer away from the art historian's main object of study, the works of art, and therefore will be excluded from this study.

23 Li, "Painters' playbooks."

24 For an excellent example in reconstructing artistic knowledge, see the ARTECHNE project (https://artechne.wp.hum.uu.nl, accessed January 3, 2023).

25 Östling and Heidenblad, "Fulfilling the Promise," 3; Burke, "Response," 7. For the full analysis of the painters' decision-making process in the seventeenth century, see Li, "Painters' Playbooks."

26 See Bodenhamer, Corrigan, and Harris, *The Spatial Humanities*; Bodenhamer, Corrigan, and Harris, *Deep Maps and Spatial Narratives*.

Methodologies to Preserve and Present Uncertainties in Historical Sources

The methodological challenge of creating deep maps to reconstruct early modern artists' business knowledge lies in integrating a large body of uncertain data from diverse sources in different formats and navigating through data to harvest meaningful results. To tackle this challenge, this section will first delineate the data sources and methodologies, followed by illustrating their application through case studies in the subsequent section. Concerning data sources, this research relied mainly on the *ECARTICO* database for information on artists' lives to study their choices of locations and business practices.[27] This database, built on a wealth of archival sources and literature, provides a comprehensive collection of structured biographical data concerning painters, engravers, printers, booksellers, gold-/silversmiths, and others involved in the "cultural industries" of the Low Countries in the sixteenth and seventeenth centuries.[28] Since it was first published online in 2011, *ECARTICO* has been expanding: as of October 12, 2023, it contains biographical data on 62,618 persons, including 9,586 painters, in its collection and is now being made available as linked open data through the large research infrastructure project *Golden Agents*.[29]

Delving into its rich spatial data, *ECARTICO* contains over 9,000 descriptions of addresses of painters and other creative individuals in Amsterdam between 1550 and 1750.[30] However, existing research has yet to fully explore the wealth of spatial information in *ECARTICO*, partially due to the often incomplete or imprecise location references found in many pre-cadastral, early modern sources. To handle the fuzzy locations, this research took advantage of the vast collection of structured big historical data from the *Golden Agents* project and systematically linked the archival materials with locational information in the Amsterdam City Archives. These materials include the marriage and burial registrations (*ondertrouw-/begraafsregisters*), tax registrations (*kohieren* and *verpondingsregisters*), court registrations of real estate transactions (*transportakten*), notarial deeds, and historical maps, all aimed at enhancing the accuracy of historical geo-locations.[31] In turn, the linked archival

27 *ECARTICO* (http://www.vondel.humanities.uva.nl/ecartico, accessed April 6, 2023, data retrieved via API on January 18, 2022).

28 *ECARTICO* has its roots in the research project *Economic and artistic competition in the Amsterdam art market c. 1630–1690: history painting in Amsterdam in Rembrandt's time*, headed by Eric Jan Sluijter and Marten Jan Bok. The database is currently hosted by the Huygens Institute and managed by Harm Nijboer, Judith Brouwer, and Marten Jan Bok.

29 For details about *Golden Agents – Creative Industries and the Making of the Dutch Golden Age* project and its linked open data, see https://www.goldenagents.org, accessed January 3, 2023). Also see Rasterhoff, *Cultural Industries*.

30 The locational data from *ECARTICO* was last accessed on January 18, 2022.

31 The Amsterdam City Archives have made over 6 million scans available online (https://archief.amsterdam/indexen/index.nl.html, accessed January 3, 2023).

materials in the *Golden Agents* have further enriched the *ECARTICO* database. Presenting painters' locational data in *ECARTICO* on deep maps, this research enabled the analysis of artists' physical and social milieu in which works of art were made. This approach provides an unprecedented opportunity to investigate painters' practical considerations and decision-making processes, while preserving and presenting uncertainties in the sources.[32] Subsequent subsections will elaborate on the three methods developed in this study to create deep maps and support spatial analysis.

1) Geotranslating Descriptions of Location

Initiating the creation of deep maps involves translating location-related descriptions from archival sources into concrete, georeferenced locations, while accounting for the inherent uncertainty and ambiguity within the historical materials. This study anchored its approach in the immutable, objective geolocations of places and houses, aligning the ever-changing historical events and individuals to observe the spatial distribution and their changes over time. Using the physical, geo-coded locations—vectorized in the first cadastral map of Amsterdam by the HisGIS project—as a foundation, this study introduced a geotranslation process to link historical maps, archival materials, and databases such as *ECARTICO* [**Fig. 1**].[33] By integrating various historical sources into multilayered maps, this research revitalized urban spaces through deep mapping, enabling the study of artists' choices and their artworks *in situ*.

Figure 2 illustrates the structure of the multilayered deep maps of Amsterdam, serving as a scalable platform for research [**Fig. 2**]. When zooming out at the city level, the deep maps reveal the spatial patterns of painters' workshops within the urban context. When zooming in to the individual painters and houses, they present a wealth of information regarding the life and work of a chosen painter or the content of the selected house with greater precision, supported by a plenitude of sources. Deep maps demonstrate how painters, by choosing or staying in a specific location, embedded themselves into the spatial and social milieu of their surroundings, thereby reflecting their understanding of the market within the limit of practical constraints.[34] In this way, the deep mapping approach can reconstruct painters' collective knowledge of

32 For examples of existing studies on the influence of economic factors on the development of style, see Montias, "The Influence of Economic Factors on Style"; Montias, "Cost and Value"; Sluijter, "Over Brabantse vodden."

33 For the HisGIS project, see https://hisgis.nl (accessed January 3, 2023). Several historical maps are georeferenced and published online from the Amsterdam time machine project (https://amsterdamtimemachine.nl, last accessed January 3, 2023).

34 Admittedly, not every painter could choose their locations freely due to convenience and financial means. However, it can be argued that artists made choices within their means suitable for their career. See more reasoning in Li, "Painters' Playbooks."

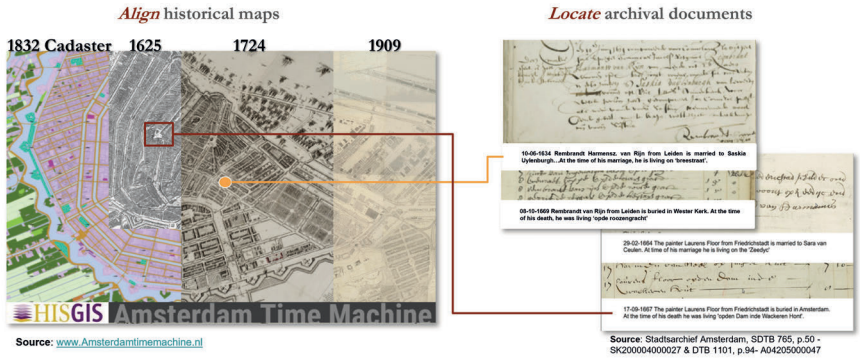

Figure 1. Using historical maps to align and locate historical documents. Illustration by the author.

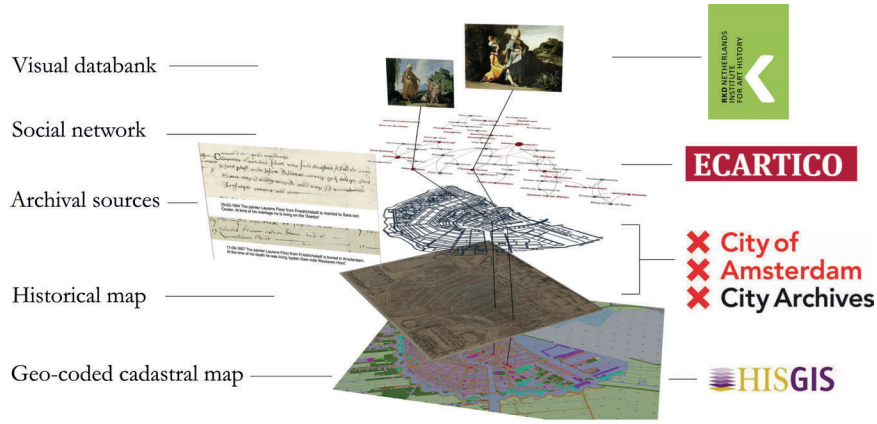

Figure 2. Multilayered deep map of historical sources on the vector cadastral map. Illustration by the author.

the market and the painting business by mapping their houses and workshops. Utilizing deep mapping to visualize intangible business knowledge may open new research avenues in studying practical, everyday knowledge in history.

2) Reducing Uncertainties through Cross-referencing

Cross-referencing various sources enhances the precision of spatial information in archival records. As mentioned earlier, the references to locations in pre-cadastral sources are often imprecise and uncertain. In many instances, the only information available regarding the location of an artist's residence or workshop is a street name mentioned in his (less often her) marriage or burial registration. However, many streets in Amsterdam have changed their names, were merged with other roads, or have vanished altogether from the present-day map. These changes make tracing streets in historical maps

Figure 3. Balthasar Florisz van Berckenrode, Map of Amsterdam, 1625, engraving, 140×160 cm, Amsterdam: Rijksmuseum, inv. RP-P-1892-A-17491D. Artwork in public domain.

pivotal to augmenting the accuracy of the geotranslation process. To this end, the 257 streets listed in the famous map of 1625 [**Fig. 3**] by Balthasar Florisz Berckenrode (1591–1645) emerged as the main source for locating the historical street in the first half of the seventeenth century. Berckenrode's map, which provides striking details about Amsterdam in the first decades of the seventeenth century, serves not only as an excellent reference for modern digital mapping but also as a means of minimizing uncertainties in locating historical streets in the data. Unlike the many early modern cartographers discussed in Van Duzer's article in this issue, Berckenrode was able to observe his home city closely enough to alleviate or even eliminate uncertainties in his map, and the blank space within the city walls indicates unpopulated neighborhoods rather than missing information or the unknown, as discussed by Hellström in this issue.[35] As the city kept expanding after Berckenrode's death, Johannes de Ram

35 See Petter Hellström's contribution for the use of blank space. See also Chet Van Duzer's discussion of different uncertainty presentation used by several early modern cartographers.

(1648–1693) supplied a new set of streets in his map of 1692, which included 406 streets covering areas developed after the mid-century.[36]

With the georeferenced streets in place, if a painter's home is only known by the street name, an area (or polygon) was then created for that street, covering all the houses on both sides to include all possible places where this painter could have lived. Likewise, if a more detailed description was available that mentions intersections of two or more streets or landmarks (e.g., churches, markets), only the street section or the area near the landmark was included in the polygon. For example, painter Zacharias Webber (1644–1696) lived on "*Singel op [de] hoek [van] Huiszittensteeg*" (Singel on the corner of Huiszittensteeg).[37] This description was geotranslated using the geometries of both the street and the canal to define a small polygon (marked in red in **Fig. 4**) covering only a handful of houses near the intersection.

Occasionally, the names of the house, its gable stone (*gevelstenen*), or its street signboard (*uithangbord*) were mentioned.[38] According to the registrations of real estate transactions (*transportakten*), however, the same gable stone could appear on many different streets in the city, and the owner of a house could take the *uithangbord* with them when moving to a new place. As a result, the location of a house often needs to be viewed in conjunction with the streets and other landmarks mentioned in the description, which can be done by linking locational descriptions to additional archive materials to improve the accuracy of the geotranslation. For instance, painter Jacob Lyon de Fuijter's wife indicated in a testimony that her family lived "*op de Keysersgraft in 't Wapen van Oostvrieslandt naest de Seepsiedery van de drie Spiegels*" (on the Keizersgracht in the *Coat of Arms of East Friesland*, next to a soap factory called *Three Mirrors*).[39] Without any context, the description, "*'t Wapen van Oostvrieslandt*," cannot narrow down the search within hundreds of houses along the Keizersgracht [**Fig. 5**]; and the houses in the *transportakten* with the same name were all located in a different part of the city. Nonetheless, the painter's neighboring house, *de Seepsiedery van de drie Spiegels*, is mentioned in the *transportakten* with more details: it was located "*op de Keyersgraft aende westzyde tussschen de run- en de bere-straet*" (on the west side of Keizersgracht between Runstraat and Berenstraat).[40] With the geometries of Runstraat and Berenstraat from the historical road network extracted from historical maps,

36 See Johannes de Ram, *Map of Amsterdam in four sections commissioned by burgomaster Bors van Waveren*, ca. 1692, Amsterdam: Amsterdam City Archives, inv. KOKA00098000001. Another important digital source that includes line geometry of Amsterdam streets is AdamLink (https://adamlink.nl, last accessed January 3, 2023).

37 Zacharias Webber is known to have lived in this location from 1654 to 1678, according to *ECARTICO*. The geotranslation process described here is semi-automatic with manual corrections. The automated program was made possible by Leon van Wissen in the *Golden Agents* project.

38 The historical gable stone in Amsterdam has been collected and digitized at https://www.gevelstenenvanamsterdam.nl (accessed January 3, 2023).

39 Bredius, *Künstler-Inventare*, 7: 136, note 2.

40 Amsterdam City Archives, Archive nr. 5062, inv. 61, fol. 32.

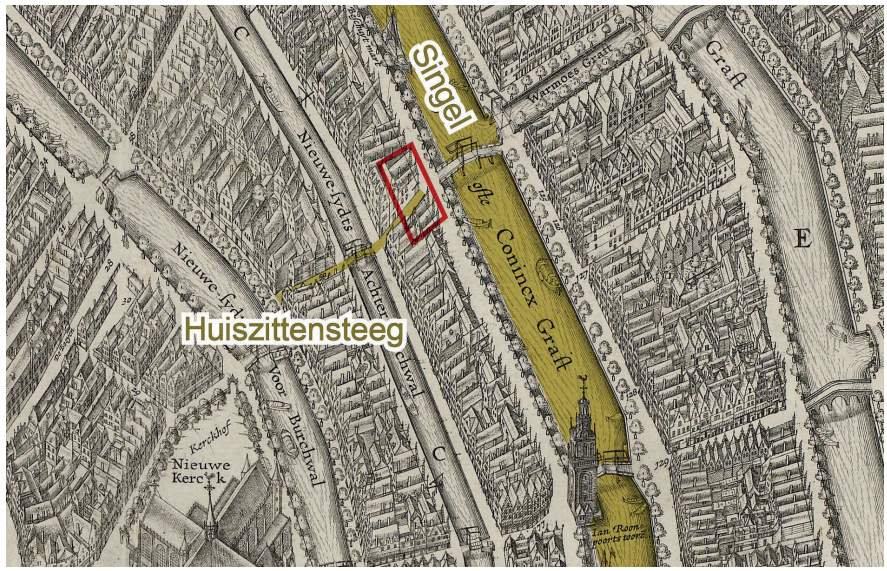

Figure 4. The polygon (marked in red) capturing the possible location of the house of Zacharias Webber (Illustration by the author).

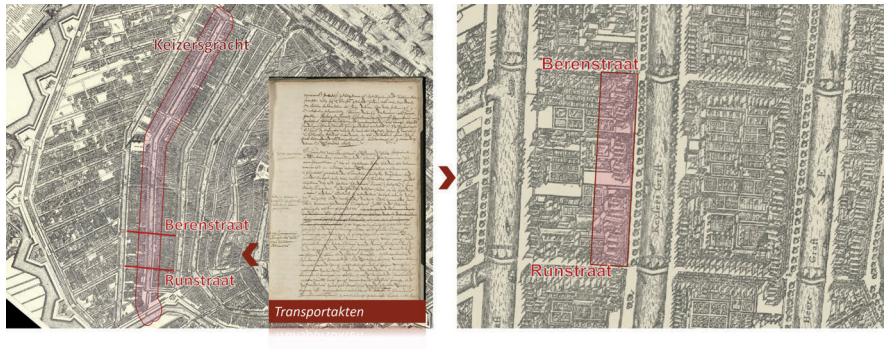

Figure 5. Locating painter Jacob Lyon de Fuijter's home from various sources (Left: Polygons of the Keizersgracht parsed by two streets; Right: the resulting polygon from this cross reference) (Illustration created by: Leon van Wissen, CREATE Lab UvA).

the geometry for Keizersgracht was then cut into the small area between these two streets to generate a new area on its west bank [**Fig. 5**]. While we still could not know which exact houses belonged to the painter or the soap factory, this multi-source cross-referencing significantly reduced the uncertainty of the possible location of a painter's house, providing adequate details for the analysis of spatial clustering or fragmentation among other painters at the city level.[41]

3) Presenting Uncertainties

While cross-referencing can enhance the precision of the geotranslation process, it cannot eliminate all uncertainty inherent in the sources. For painters such as Rembrandt, scholars have found the exact houses in which they lived; for those such as Zacharias Webber or Jacob Lyon de Fuijter, a small area becomes our best guess; but for many others, street names are the only references. Consequently, the polygons created for each painter during the geotranslation process varied greatly in the areas they covered. To account for this heterogeneity and to visualize uncertainties in geolocations, I applied a probabilistic approach and randomly assigned a hundred points to each polygon. Employing the most efficient visual cues—fuzziness and transparency—to convey uncertainty, I turned the points within polygons into a heat map. For a street-level ambiguous location (such as Keizersgracht, Fig. 5), the whole area (or polygon) is more transparently colored with blurred edges, whereas a precise house is almost opaque with sharper edges. Figure 6 gives an example of one painter who is only known to have lived on Keizersgracht and another who lived on the Dam Square near the old city hall [**Fig. 6**].[42] The level of uncertainty, perceptible through degrees of transparency and fuzziness, is intuitive even to uninstructed eyes. In this way, this mapping approach ensures a clear representation of the spatial patterns of artists' workshops or homes, while preserving the uncertainty rooted in the sources.

41 For the discussion of painters' clusters at city level, see Rasterhoff, *Cultural Industries*.

42 The second location came from Rembrandt's former employer and dealer, Hendrick Uylenburgh (ca. 1587–1661), who rented this house from 1647 to 1653. See Amsterdam City Archives, Archive nr. 5044, inv. 272, fol. 6.

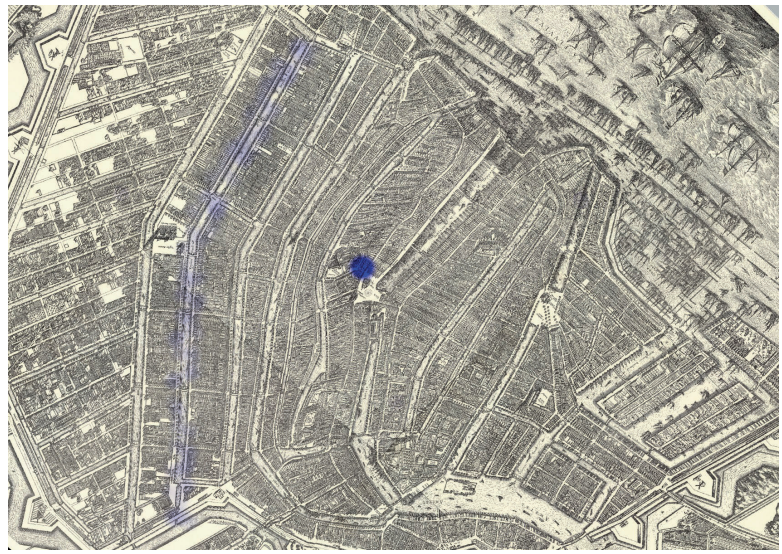

Figure 6. Examples of locations with low and high levels of uncertainty (left and right). Illustration by the author.

Two Approaches to Incorporating Uncertainties in Art Historical Observations

Equipped with painters' locational and biographical data and deep mapping methodologies, I was able to plot painters' locations in early seventeenth-century Amsterdam with varying degrees of certainty. It is worth noting that visualizing uncertainties is not the end goal of this research, rather it serves as a means to facilitate art historical observations to understand painters' business knowledge. To this end, this section will discuss two ways of presenting uncertainties—either highlighting or implying them—and evaluate both methods for reconstructing practical knowledge of artists' lives.

The spatial distribution of painters in Amsterdam between 1585 and 1610 will be used as an example.[43] This time period was chosen because the city of Amsterdam witnessed the first rapid expansion of its artist community during this time, offering an excellent test ground to demonstrate changes in painters' location choices. From 1585 to 1610, the number of painters active in Amsterdam surged from around twenty to over seventy, a growth that outpaced the city's rapid population increase from 30,000 to over 80,000 people during the same period.[44] To explain this extraordinary growth in the number

43 The case studies in this section are developed for my dissertation. For in-depth art historical analysis, see Li, "Painters' Playbooks," 79–111.

44 For the painters' population, see the *ECARTICO* database. For the population estimation, see Nusteling, "Population," 74.

of painters, art historians have stressed the importance of immigrant artists, who contributed to the development of art in the early seventeenth century.[45] It remains unclear, however, where immigrant painters chose to operate their painting businesses within the city and how they organized themselves alongside the local artists' community. Now, with the help of deep maps, it is possible to gain a comprehensive view of the collective choices of locations made by painters of different origins between 1585 and 1610. This section will use two kinds of deep maps to understand how painters—both those native to Amsterdam and those originating in the southern Netherlands or elsewhere—made collective location choices in response to the rapid expansion of the art market.

Foregrounding Uncertainties

The first kind of deep maps make uncertainties explicit, showcasing the spatial-temporal evolution of painters' residences in Amsterdam, differentiated by their origins during the late sixteenth and early seventeenth centuries. Figure 7 prominently displays the uncertainties of painters' locations as fuzzy areas [**Fig. 7**], indicating the street-level locations of their residences as mentioned in historical sources. This series of maps reveals a notable influx of painters migrating to Amsterdam from the late sixteenth century to the first decade of the seventeenth century. These deep maps that foreground uncertainty illustrate Amsterdam's transformation from an artistic backwater with few painters to a burgeoning cultural hub as the artistic landscape evolved over time. They also indicate that immigrants from the southern Netherlands displayed notably different locational preferences compared to their local Amsterdam colleagues, whether driven by their likings or practical constraints.

While these fuzzy heat maps are useful for observing city-wide patterns, they become cumbersome when undertaking close observations of individual painters' biographical details and artistic profiles. The emphasis these maps place on presenting uncertainty can obscure investigations into painters' practical knowledge. In fact, these fuzzy visualizations, when used alone, appear detached from all the information bearing direct art historical relevance. The maps that highlight uncertainty, regrettably, are insufficient to provide convincing insights into the development of Amsterdam's art scene in the early seventeenth century. Consequently, this research explored an alternative way, showing uncertainties in the background while highlighting the individual artists and their living environment.

45 De Vries, "Art History," 265; Montias, *Delft*, 73; Montias, "Cost and Value," 459; Bok, "Vraag en aanbod," 97–98; Briels, *Vlaamse schilders*. For the discussion of the lack of traceable records of their work, see Van der Linden, "Coping with Crisis"; Sluijter, "Over Brabantse Vodden."

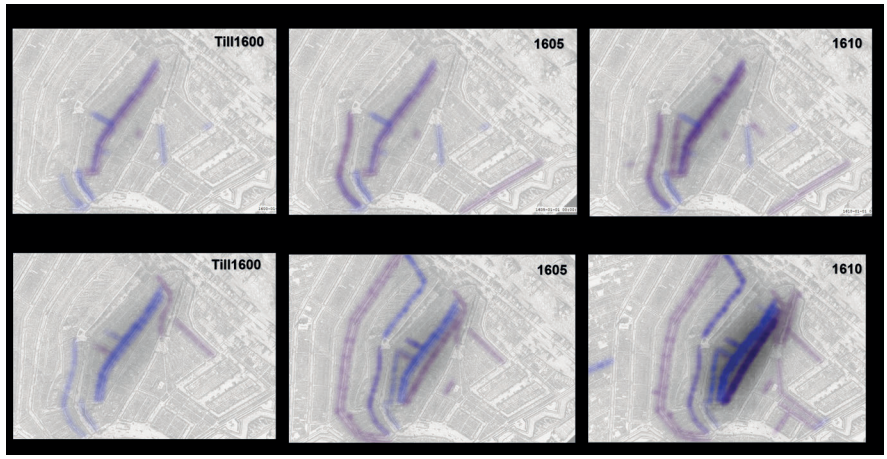

Figure 7. The spatial-temporal distribution of southern immigrants (top) and local artists. Within each community, the artistic painters (kunstschilders) are marked in red, and possible artistic painters (schilders) in blue.

Moving Uncertainties to the Background

Acknowledging the limitation of fuzziness in mapping, the second method moved the layer that highlighted uncertainties to the background, simultaneously bringing forth the possible locations of painters' homes as solid points on the map. Rather than suggesting a precise location of an artist's residence, each point was generated within the possible areas following the probabilistic approach and was placed on top of the fuzzy areas to facilitate observations, as shown in Figure 8 [**Fig. 8**].[46] It uses the heat map in the background to suggest the areas where the point layer comes from, while also employing the point size as an additional indication of uncertainty: the larger the point is, the more precise and certain we are about the location of the artist's home. In an interactive environment, this point layer can be further enhanced by highlighting the fuzzy area when hovering a mouse over it, thereby mitigating any false sense of certainty regarding artists' residential locations.[47] Compared to the fuzzy heat maps in Figure 7, the second approach enables close observations of an individual painter's choices of location without losing the city-wide context of the art scene in Amsterdam. This visualization also allows more room to display multiple layers of information on the same map, as promised by the deep mapping method. This method maximizes the storytelling potential of the deep maps without losing the indication of uncertainty.

46 For examples in other fields, see Schulz et. al, "Probabilistic Graph Layout"; Grigoryan and Rheingans, "Point-Based Probabilistic Surfaces."

47 For the prototype, see the Virtual Interior project's 2D virtual research environment: https://2d-demo.virtualinteriorsproject.nl/ developed by Hugo Huurdeman.

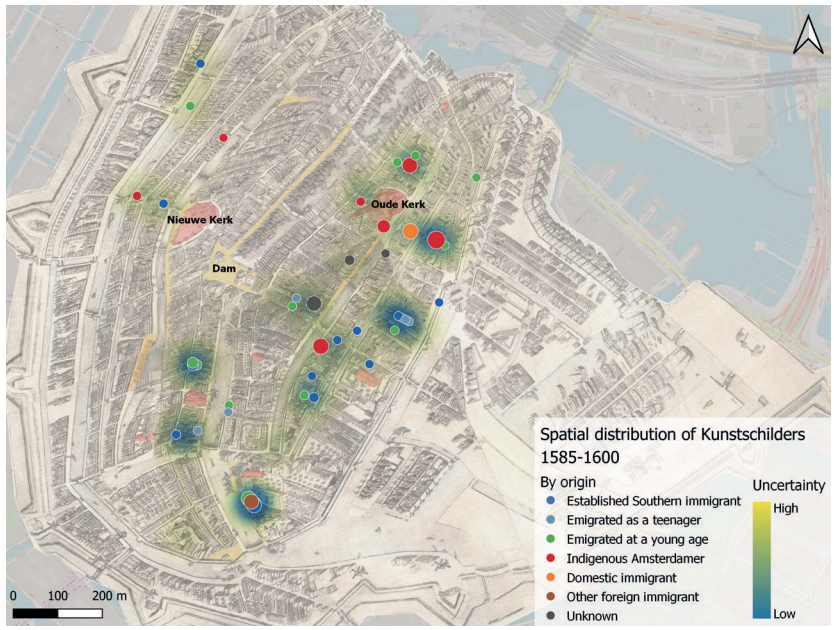

Figure 8. Deep maps of kunstschilders (artistic painters) in Amsterdam 1585–1600, colored by origin. Both the size of the nodes and the blurred area signify the level of uncertainty regarding the location. The larger the node is (and the smaller the blur is), the more certain we are about the exact location.

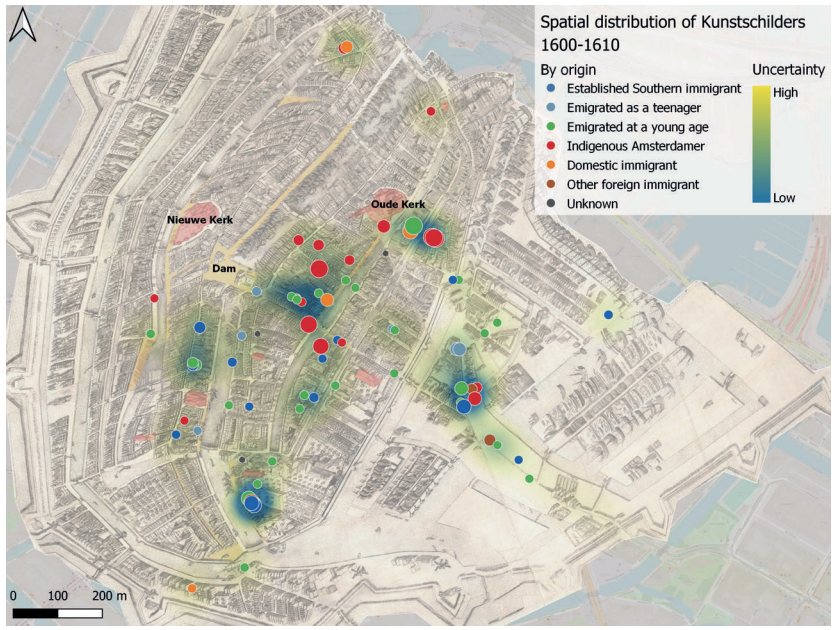

Figure 9. Deep maps of kunstschilders (artistic painters) in Amsterdam 1600–1610. For source and other details, see Figure 8.

The second method also provides additional art historical findings. Figure 9 shows that the decade following 1600 marked a time of transition, both artistically and spatially. On the one hand, many established masters who had dominated the art market before 1600 continued to influence artistic development in the new century. Meanwhile, a wave of young artists, originating from local and immigrant parents, rose to prominence. These young painters breathed new life into the art scene and strategically shifted the artistic landscape in Amsterdam eastward to the newly developed Sint Antoniesbreestraat, opting to cluster among themselves and reap the benefit of a spatial cluster [**Fig. 9**].[48] In this way, the deep maps reveal the painters' collective choices, thereby disclosing their practical knowledge about the painting businesses.[49] In contrast to the deep maps in Figure 7, the combination of point and heat map layers in Figures 8 and 9 provides a more flexible platform to observe painters' location choices during the early phase of the development of the art market. When uncertainties in digital maps are relegated to the background, they can effectively account for the imprecise and fluid nature of early modern sources, facilitating a better understanding of painters' practical knowledge of their business.

Concluding Discussions

This article has introduced the methodology of deep mapping uncertainties in digital art history research and showcased different ways of preserving and presenting uncertainty in our knowledge of the past. While it does not present a one-size-fits-all solution to visualizing fuzzy historical knowledge, it may nonetheless open new paths for future research. In this study, the deep mapping approach demonstrated its advantage in visualizing imprecise historical knowledge over traditional means. It employed visual cues that are widely used across disciplines, facilitating observations of business knowledge in history through mapping. In particular, it offered a scalable platform to visualize scattered, uncertain historical evidence and reveal phenomena that were otherwise impossible to observe using traditional methods. The deep mapping methodologies have demonstrated the value of mapping in reconstructing practical, everyday knowledge by visualizing actors' collective behaviors.

The deep mapping approach, however, still has its limitations. First, although deep maps adeptly preserve and present the known uncertainties, they still cannot address the issue of the unknown ones, such as missing or unrepresentative data. Second, the multilayered information in deep maps can hardly appear simultaneously in a static map due to readability issues. For instance, overlaying the painters' locations with other socio-economic attributes, such as the spatial distribution of wealth, can make the map

48 See Rasterhoff, *Cultural Industries*, 21–24, 169–192.
49 Ibid.; Li, "Painters' Playbooks."

overly complex and visually overwhelming, making it difficult to discern any meaningful patterns. Although this study has experimented with various ways to present uncertainties alongside other layers of spatial information, these uncertainty illustrations, when standing alone, can hardly convey any additional information beyond uncertainties, thus defeating the purpose of assisting observations. After weighing the pros and cons of various means of visualizing spatial uncertainties on static maps, I opted to use fuzzy heat maps in the background in tandem with painters' biographical and artistic data in the foreground. But there remains a need for more innovative visualization strategies. Going beyond static maps, this limitation can be partially mitigated by an interactive platform, wherein layers can be toggled on and off according to specific needs. In essence, the limitations of deep mapping fundamentally pertain to the static visualizations of complex, fuzzy information. Digital scholarship still awaits more interactive platforms to realize the full potential of deep mapping in preserving and presenting uncertainty. Much like the early modern mapmakers who devised visual tools to tackle the unknown, future scholars and cartographers, empowered by deep mapping methodologies, can navigate through uncertain historical sources with advanced visual tools and interactive platforms to reconstruct the practical knowledge of the past with all its complexities.

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