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Information Visualisation Tools to Explore Fra Mauro's World Map (dated 1460 CE)

Keywords: Information Visualisation, Digital User Experience, Fra Mauro's Map of the World

Summary: Historical maps are a traditional source for historical research. Their significance as historical and cultural artefacts have increased in the digital space. However, the user experience does not take full advantage of what the digital space can offer. This research shares how the international initiative Engineering Historical Memory (EHM) designed and developed online tools to facilitate an engaging and practical user experience at different education levels. EHM used Fra Mauro's world map (dated 1460) to showcase information visualisation solutions to enhance the user interaction with the historical information embedded in historical cartography.

Introduction

There are many historical world maps online engaging users in museums and libraries. The digital format now represents the basis for obtaining evidence and discovering new understanding in historical map research. Online access and digitised maps allow users to deal with different world maps simultaneously. Expert users such as geographers and historians use historical maps as primary resources for their historical research. However, new visualising and analytical approaches in line with digital sharing are necessary to engage a larger audience. Yet, there is a dearth of research concerning enhancing user satisfaction and understanding of scholarly and casual users who access online resources to find better solutions to traditional questions and generate new insights (Danyun, 2021).

This paper used information visualisation to enhance users' understanding of data/information in the Fra Mauro Map dated 1460. In this way, it can save time, increase efficiency, update research methods, and expand research topics (Nanetti, 2022b). Initially, the paper introduces the map integration approach, data representation, and map image coordinates specific to the Fra Mauro Map. Subsequently, it illustrates the types of information visualisation approaches utilised in the Fra Mauro Map. Subsequently, it demonstrates various types of information visualisation approaches applied to the map, including radial tree, force-directed graph, satellite view, treemapping, and OpenStreetMap. These techniques are showcased through an online application accessible on the EHM (Engineering Historical Memory) website (Nanetti, 2021). Consequently, the paper examined the development process and data analysis and how to choose the right visualisations for different historical map projects. Lastly, the

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paper also highlights the research contributions on historical maps, addressing the visualisation of hierarchically structured data, discovering the promotion of new insights and reduction of cognitive load and demonstrating the design of visual narratives.

Applying Information Visualisation to the Web-Based EHM Application for Fra Mauro's Map

As a Venetian masterpiece in visualising geo-ethnographic knowledge, the Fra Mauro map was one of the most significant world maps of the fifteenth century. It measures about 2.23 by 2.23 meters (Cattaneo, 2011) and provided tantalising glimpses of new words and oceans with this manuscript map prepared circa 1450. Fra Mauro used the travellers, traders, and explorers' information to draw the map with more than 3,000 annotations, including cities, temples, funerary monuments, ships, cartouches, and earthly paradise in each corner (Brotton, 2014; Cattaneo, 2011; Edson, 2007; Kessler, 2017).

However, many questions will be raised by such a largely unanswered question: what does it show us? How can we understand? what knowledge is it based upon? How was it possible to coordinate and correlate such a mass of information? What relation does the old map have to contemporary knowledge? What stories and narratives? What's the insight? Although Fra Mauro tried to work within the conventional format of the *mappae mundi*, his words confirmed its certainties but left questions to be resolved by future explorers and cartographers.

Moreover, the information, especially the textural units and place names of the locations, are related to a collection of iconographic elements which are hard to identify and recognise. Therefore, the application of information visualisation enhances efficiency in identifying, searching, and retrieving text locations. By providing a visualizing database and augmented tools, users can more easily navigate and understand the information embedded within the map. In line with this objective, our research team has established online databases and platforms dedicated to the Fra Mauro Map for research purposes (Nanetti, 2022a). Additionally, the map has been accurately aligned with a modern coordinate system, specifically the Leaflet map, incorporating precise longitude and latitude information. This alignment enables users to correlate locations on the Fra Mauro Map with their corresponding positions in today's world, enhancing comprehension and contextualization.

Map Integration Approach

To facilitate analysis and visualisation, the information contained within the Fra Mauro Map has been digitised and integrated into a database. This enables the establishment of connections between parsed texts and historical evidence using a diverse range of sources (Nanetti, 2019). The Afro-Eurasia (1205-1433) project utilizes the Fra Mauro Map, along with the OpenStreetMap as a case study and Marco Polo's travel accounts, to provide historical evidence and explore the map's connectivity to contemporary maps like the Leaflet map. In the Fra Mauro Map project, both the Fra Mauro Map and a contemporary map (Leaflet map) are integrated into the system. The project provides a comprehensive result combining the detailed information from the Fra Mauro Map, along with data from sources such as Wikipedia and searchable resources like Europeana, JSTOR, Google Scholar, Gallica, Sage, Google Images, Getty Images, Blackwell, Routledge, and the European Library (see Figure 1).

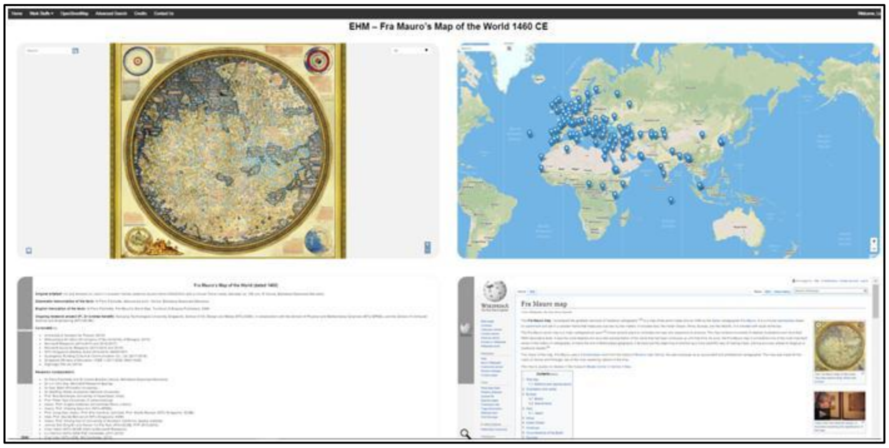


Figure 1: The Fra Mauro Map Online. Source: https://engineeringhistoricalmemory.com/FraMauro.php

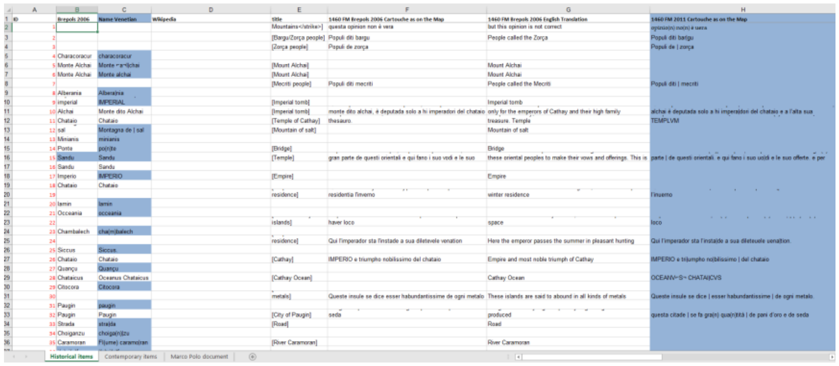
Data Representation

The Fra Mauro Map was divided into various sections representing different regions and areas, including China, China-India, Oceania-India, India, Africa, India-Persia-Arabia, Asia-Europe, Europe, Europe-Asia, and Asia. Each item on the map was assigned a sequence number for identification purposes, as illustrated in Figure 2a and Figure 2b. In total, there are 3086 items featured on the map, including place names, cartouches, and toponyms. These items encompass a wide range of categories such as bridges, capes, cartouches, cities, deserts, funeral monuments, gulfs, islands, lakes, mountains, people, regions, rivers, roads, seas, ships, temples, and others.

Figure 2a: Asian Part of the Fra Mauro Map, From Sequence No. 2499 to 2702. Figure 2b: Europe and Asia Part of the Fra Mauro Map, From Sequence No. 2913 to 3086.

To enhance data classification, the Excel data sheet was reconstructed into three parts: contemporary items, historical items, and the Marco Polo document (as shown in Figure 3). Moreover, each EHM post has a unique EHM post ID, which serves as a reference to map with both the historical and contemporary coordinates of the items. To effectively represent the information and items on the Fra Mauro

Map, it is necessary to collect item coordinates data and utilize it to construct a web-based interactive map system. This system will enable users to easily view each item and access relevant links associated with the Fra Mauro Map.



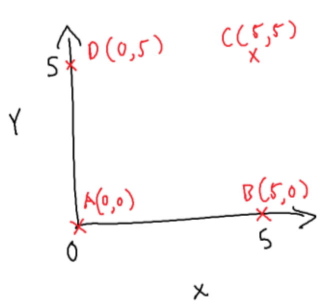
	A	B	C	D	E	F	G	H
1	ID	Brepols 2006	Name Venetian	Wikipedia	title	1460 FM Brepols 2006 Cartouche as on the Map	1460 FM Brepols 2006 English Translation	1460 FM 2011 Cartouche as on the Map
2	1				Mountains</strike>]	questa opinion non è vera	but this opinion is not correct	opinio(n) no(n) è uera
3	2				[Bargu/Zorça people]	Populi diti bargu	People called the Zorça	Populi diti bar|gu
4	3				[Zorça people]	Populi de zorça		Populi de | zorça
5	4	Characoracur	characoracur					
6	5	Monte Alchai	Monte ~a~l|chai		[Mount Alchai]		Mount Alchai	
7	6	Monte Alchai	Monte alchai		[Mount Alchai]		Mount Alchai	
8	7				[Mecriti people]	Populi diti mecriti	People called the Mecriti	Populi diti | mecriti
9	8	Alberania	Albera|nia					
10	9	imperial	IMPERIAL		[Imperial tomb]		Imperial tomb	
11	10	Alchai	Monte dito Alchai		[Imperial tomb]	monte dito alchai, è deputada solo a hi imperadori del chataio	only for the emperors of Cathay and their high family	alchai è deputada solo a hi impera|dori del chataio e a l'alta sua
12	11	Chataio	Chataio		[Temple of Cathay]	thesauro.	treasure. Temple	TEMPLVM
13	12	sal	Montagna de | sal		[Mountain of salt]		Mountain of salt	
14	13	Minianis	minianis					
15	14	Ponte	po(n)te		[Bridge]		Bridge	
16	15	Sandu	Sandu		[Temple]	gran parte de questi orientali e qui fano i suo vodi e le suo	these oriental peoples to make their vows and offerings. This is	parte | de questi orientali. e qui fano i suo uo|di e le suo offerte. e per
17	16	Sandu	Sandu					
18	17	Imperio	IMPERIO		[Empire]		Empire	
19	18	Chataio	Chataio					
20	19				residence]	residentia l'inverno	winter residence	l'inuerno
21	20	lamin	lamin					
22	21	Occeania	occeania					
23	22				islands]	haver loco	space	loco
24	23	Chambalech	cha(m)balech					
25	24				residence]	Qui l'imperador sta l'instade a sua diletevele venation	Here the emperor passes the summer in pleasant hunting	Qui l'imperador sta l'insta|de a sua dileteuele uena|tion.
26	25	Siccus	Siccus					
27	26	Chataio	Chataio		[Cathay]	IMPERIO e triumpho nobilissimo del chataio	Empire and most noble triumph of Cathay	IMPERIO e tri|umpho no|bilissimo | del chataio
28	27	Quançu	Quançu					
29	28	Chataicus	Oceanus Chataicus		[Cathay Ocean]		Cathay Ocean	OCEANV~S~ CHATAI|CVS
30	29	Citocora	Citocora					
31	30				metals]	Queste insule se dice esser habundantissime de ogni metalo	These islands are said to abound in all kinds of metals	Queste insule se dice | esser habundantissime | de ogni metalo.
32	31	Paugin	paugin					
33	32	Paugin	Paugin		[City of Paugin]	seda	produced	questa citade | se fa gra(n) qua(n)tità | de pani d'oro e de seda
34	33	Strada	stra|da		[Road]		Road	
35	34	Choiganzu	choiga(n)|zu					
36	35	Caramoran	Fi(ume) caramo|ran		[River Caramoran]		River Caramoran	

Historical items | Contemporary items | Marco Polo document

Figure 3: The Fra Mauro Map Excel Worksheet Dataset.

Map Image Coordinates Highlight

To accurately identify and select each location or drawing on the Fra Mauro Map, small dots were used from a quadrilateral shape. Initially, the items were highlighted with red dots on the Fra Mauro Map, and their X and Y pixel coordinates were manually recorded using Adobe Photoshop. Due to the large number of items (3086) on the Fra Mauro Map, automatic tracing software was not feasible, necessitating a manual approach. Drawing from our experience with the Genoese World Map of 1457, we set a limit on the number of pixels used to encompass each item, ensuring that the system would not be overwhelmed. A quadrilateral boundary consisting of four points was plotted in an anti-clockwise direction to enclose each item on the map, as illustrated in Figures 4a and 4b. It's important to note that the highlighted pixels were not drawn directly on the Fra Mauro Map image itself; rather, the focus was solely on identifying the X and Y coordinates of each pixel. This approach resulted in the creation of an information matrix, storing the coordinates of each item's dots on a new layer in Adobe Photoshop. Storing the coordinates in this manner facilitated the identification of each item as a whole using the quadrilateral shape. This method proved to be efficient for extracting each item from the map. Following successful usability testing, the process was applied to all 3086 items, offering a rapid and standardized solution for collecting coordinates from historical maps. However, it is still challenging to highlight items in a way that avoids overlapping, as one item may encompass another.



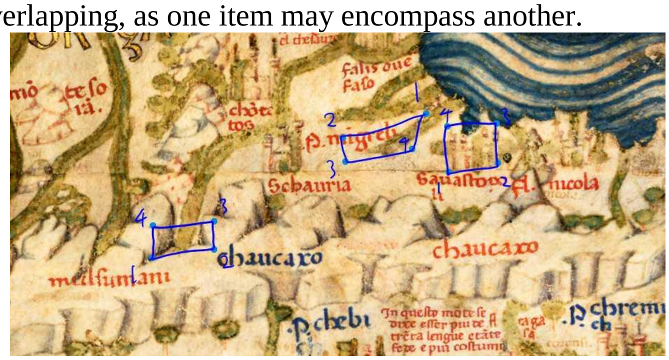


Figure 4a: Four Points Plotted Anti-clockwise to Collect the Coordinates. Figure 4b: A Quadrilateral (4 points) Boundary.

To efficiently import the gathered X and Y pixel coordinates into the database, we stored the data in an Excel worksheet. This approach offers flexibility in manipulating and accessing the data. In the Excel worksheet, we created a column for the item number and another column for the corresponding X and Y pixel coordinates. The coordinates were recorded in a specific sequence, following the template of Point A (0,0), Point B (5,0), Point D (0,5), and Point C (5,5), with each coordinate pair separated by a comma (see Figure 5). This structure enables easy organization and retrieval of the coordinates during the data import process.

ID	Coordinates
1	6754,3890,6739,3825,7065,3798,7073,3866
2	6648,4079,6651,3997,6912,4036,6914,4096
3	6190,4090,6189,4002,6372,4009,6376,4092
4	6648,4317,6652,4277,6893,4290,6892,4324
5	6843,4375,6844,4350,6983,4356,6983,4380
6	6446,4414,6490,4364,6604,4368,6606,4416
7	6207,4437,6212,4367,6410,4377,6409,4446
8	5197,4561,5198,4518,5258,4520,5258,4563
9	6457,4905,6463,4830,6710,4848,6711,4924
10	6447,5040,6451,4925,6774,4952,6770,5047

Figure 5: The Excel Worksheet for Pixel Conversion to Coordinates in the Fra Mauro Map.

Figure 6 illustrates the functionality of the developed system, wherein when a user hovers over or clicks on any item on the Fra Mauro Map, the corresponding location is displayed on both the historical map (Fra Mauro Map) on the left and the contemporary map on the right. The bottom left window provides detailed information about the selected item, while the bottom right window presents relevant Wikipedia pages related to the textual unit. This interactive setup enhances the user experience by providing immediate access to contextual information and facilitating comparisons between historical and contemporary maps.

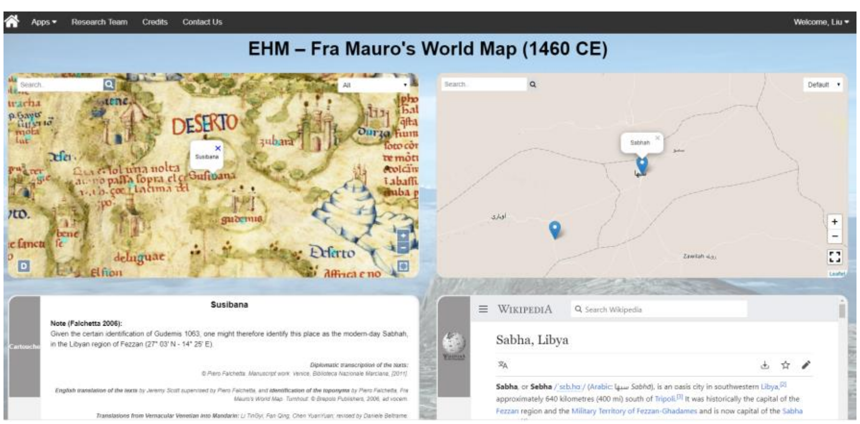


Figure 6: An Example of a Selected Item (location) on the Fra Mauro Map. Source: https://engineeringhistoricalmemory.com/FraMauro.php

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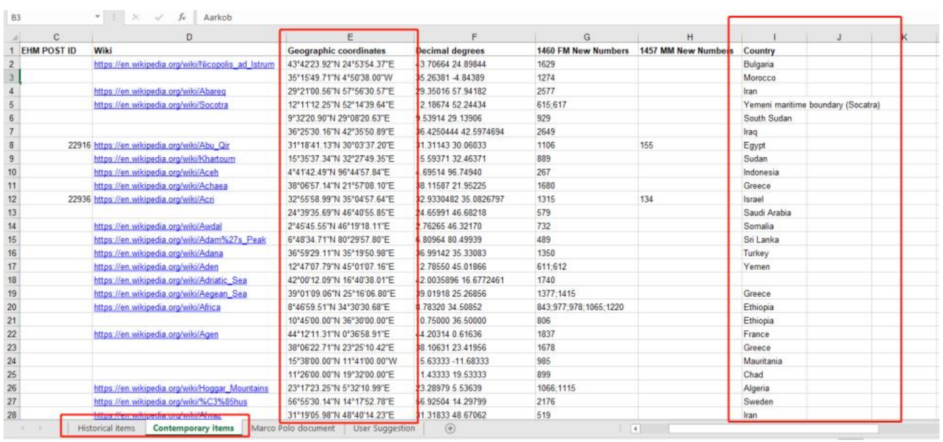
Data Analysis

When analyzing the data for the visualisations, the primary goal is to highlight the significant functionality and display variables that present characteristics across different dimensions. The visualisations (1, 2, 3, and 4) were developed using data extracted from the Fra Mauro Map datasheet, which consists of three tables: contemporary items, historical items, and the Marco Polo document. The relevant columns used for visualisation development included place name today, 1460 FM (1460 Fra Mauro), new numbers, country, categories, and historical item ID (see Figure 7).

To prepare the selected data for display in E-charts, we processed the data into a usable format, namely, the JSON (JavaScript Object Notation) format. This involved merging the two main tables in the Excel sheet (contemporary and historical items) and converting them into JSON format. Since the 'ID' field in the historical items table corresponds to the '1460 FM New Numbers' field in the contemporary items table, we integrated the related data into the current items table. This integration was achieved by traversing each data piece in '1460 FM New Numbers' and extracting all the corresponding data from 'historical items' under the 'ID' field. This approach effectively unified the data into a suitable format for visualisation.

During the integration process, it's essential to handle scenarios where multiple 'ID' values exist in the '1460 FM New Numbers' field of the contemporary items table. In such cases, each number should be separated independently into a single data record. Additionally, there might be data duplication in the datasets, requiring filtering to eliminate such redundancies. By following these steps, the data is properly processed and ready for visualisation, enabling effective presentation and analysis of the information from the Fra Mauro Map.



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	C	D	E	F	G	H	I
1	EHM POST ID	Wiki	Geographic coordinates	Decimal degrees	1460 FM New Numbers	1457 MM New Numbers	Country
2		https://en.wikipedia.org/wiki/Nicopolis_ad_Istrum	43°42'23.92"N 24°53'54.37"E	43.70664 24.89844	1629		Bulgaria
3			35°15'49.71"N 4°50'38.00"W	35.26381 -4.84389	1274		Morocco
4		https://en.wikipedia.org/wiki/Abareq	29°21'00.56"N 57°56'30.57"E	29.35016 57.94182	2577		Iran
5		https://en.wikipedia.org/wiki/Socotra	12°11'12.25"N 52°14'39.64"E	12.18674 52.24434	615;617		Yemeni maritime boundary (Socatra)
6			9°32'20.90"N 29°08'20.63"E	9.53914 29.13906	929		South Sudan
7			36°25'30.16"N 42°35'50.89"E	36.4250444 42.5974694	2649		Iraq
8	22916	https://en.wikipedia.org/wiki/Abu_Qir	31°18'41.13"N 30°03'37.20"E	31.31143 30.06033	1106	155	Egypt
9		https://en.wikipedia.org/wiki/Khartoum	15°35'37.34"N 32°27'49.35"E	15.59371 32.46371	889		Sudan
10		https://en.wikipedia.org/wiki/Aceh	4°41'42.49"N 96°44'57.84"E	4.69514 96.74940	267		Indonesia
11		https://en.wikipedia.org/wiki/Achaea	38°06'57.14"N 21°57'08.10"E	38.11587 21.95225	1680		Greece
12	22936	https://en.wikipedia.org/wiki/Acri	32°55'58.99"N 35°04'57.64"E	32.9330482 35.0826797	1315	134	Israel
13			24°39'35.69"N 46°40'55.85"E	24.65991 46.68218	579		Saudi Arabia
14		https://en.wikipedia.org/wiki/Awdal	2°45'45.55"N 46°19'18.11"E	2.76265 46.32170	732		Somalia
15		https://en.wikipedia.org/wiki/Adam%27s_Peak	6°48'34.71"N 80°29'57.80"E	6.80964 80.49939	489		Sri Lanka
16		https://en.wikipedia.org/wiki/Adana	36°59'29.11"N 35°19'50.98"E	36.99142 35.33083	1350		Turkey
17		https://en.wikipedia.org/wiki/Aden	12°47'07.79"N 45°01'07.16"E	12.78550 45.01866	611;612		Yemen
18		https://en.wikipedia.org/wiki/Adriatic_Sea	42°00'12.09"N 16°40'38.01"E	42.0035896 16.6772461	1740		
19		https://en.wikipedia.org/wiki/Aegean_Sea	39°01'09.06"N 25°16'06.80"E	39.01918 25.26856	1377;1415		Greece
20		https://en.wikipedia.org/wiki/Africa	8°46'59.51"N 34°30'30.68"E	8.78320 34.50852	843;977;978;1065;1220		Ethiopia
21			10°45'00.00"N 36°30'00.00"E	10.75000 36.50000	806		Ethiopia
22		https://en.wikipedia.org/wiki/Agen	44°12'11.31"N 0°36'58.91"E	44.20314 0.61636	1837		France
23			38°06'22.71"N 23°25'10.42"E	38.10631 23.41956	1678		Greece
24			15°38'00.00"N 11°41'00.00"W	15.63333 -11.68333	985		Mauritania
25			11°26'00.00"N 19°32'00.00"E	11.43333 19.53333	899		Chad
26		https://en.wikipedia.org/wiki/Hoggar_Mountains	23°17'23.25"N 5°32'10.99"E	23.28979 5.53639	1066;1115		Algeria
27		https://en.wikipedia.org/wiki/%C3%85hus	56°55'30.14"N 14°17'52.78"E	56.92504 14.29799	2176		Sweden
28		https://en.wikipedia.org/wiki/Ahvaz	31°19'05.98"N 48°40'14.23"E	31.31833 48.67062	519		Iran

Historical items | Contemporary items | Marco Polo document | User Suggestion

Figure 7: The Selected Dataset.

Enhancing User Experience: Selected Information Visualisation Tools for Fra Mauro's Map

Based on the data analysis result, five different visualisations, such as a radial tree, treemapping, OpenStreetMap, force-directed graph, and satellite view, were selected to help users interact with the visual representations of different dimensions. For ease of understanding the data of the Fra Mauro Map, scholarly primary and secondary sources are represented not only in the Fra Mauro Map but also in a contemporary map, OpenStreetMap, Wikipedia, and other linked search engines. This is more useful to users with clear objectives (such as scholars) than to users with less clear goals. However, the idea is that both can gain information and insights immediately from the visualisation application, which is available in the web-based Afro-Eurasia (1205-1433) platform (Danyun, Yisi, Siew Ann, Khoi, & Nanetti, 2021).

Radial Tree

In the Fra Mauro Map, the radial tree visualisation technique (Yee, Fisher, Dhamija, & Hearst, 2001) was utilized in Visualisation 1. This visualisation represents a hierarchical structure, starting from the root at the center and branching out to countries (rendered on circular levels) and cities (represented by the number of cities) on subsequent circular levels. This design allows users to interact with the data and gain insights into the amount of data present in each layer.
When users hover over the red circle, the number of cities associated with that location is displayed. Additionally, the cities themselves are displayed on both the Fra Mauro Map and the Genoese World Map of 1457, enabling users to locate and understand the ancient cities in real-time. Figure 8 illustrates that the diagram on the right is automatically generated based on the selected filters shown on the left side of the interface under the 'Categories' section. The purpose of this visualidation is to provide an easily understandable representation of an ancient map, such as the Fra Mauro Map.

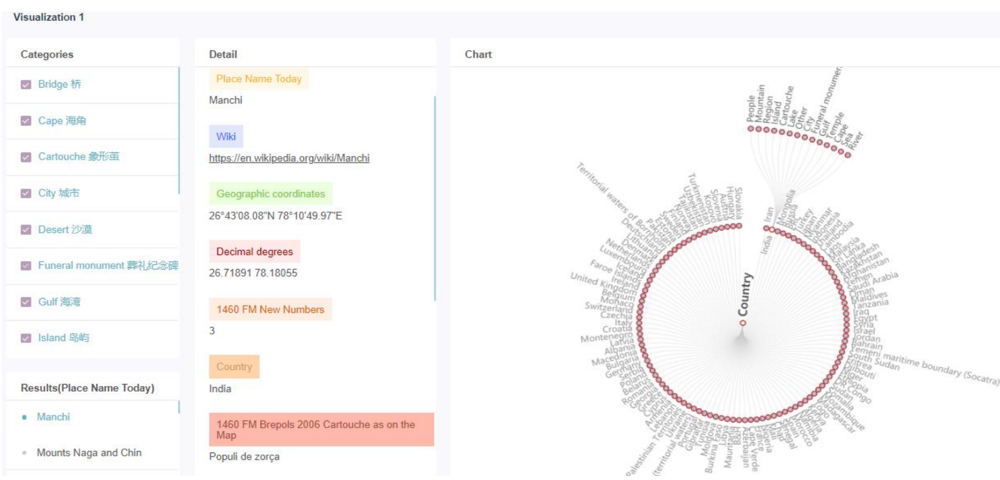

Figure 8: Radial Tree of the Fra Mauro Map.

Treemapping

In Figure 9, Visualisation 2 features a treemapping technique (Shneiderman, 1992), organized into a hierarchy of countries, categories, specifics, and details. The purpose of this treemapping is to visually represent the number of cities in each country, allowing users to comprehend the relative proportions of cities and countries within the Fra Mauro Map.
By interacting with each country, users can view the group of cities associated with that particular country, which are displayed on the Fra Mauro Map. The treemapping consists of boxes that represent countries, with the size of each box indicating the percentage of countries in the world. Users have the

flexibility to select categories on the left or countries/cities on the right, which results in different visualisations based on their selections.

The size of the treemapping is dynamically generated according to the number of cities, providing users with an intuitive understanding of the quantity and density of countries and cities within the Fra Mauro Map.

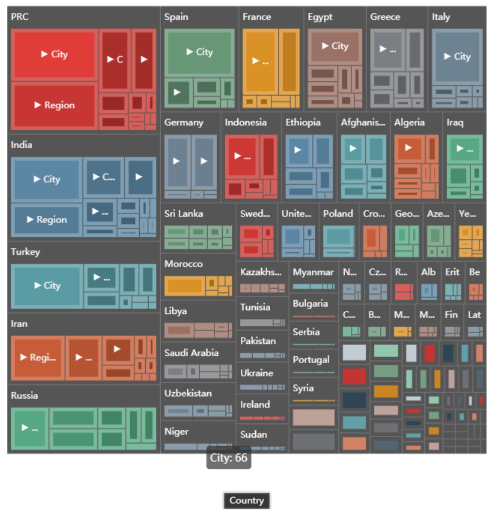

Figure 9: Treemapping of the Fra Mauro Map.

OpenStreetMap

To facilitate hierarchical and density research of the Fra Mauro Map, Visualisation 3 incorporates the use of OpenStreetMap. This visualisation employs a grid-based clustering technology called MarkerClusterer, which divides the map into squares to showcase the density of locations on five continents (refer to Figure 10). The purpose is to group markers into each square on the grid zoom level, aiding in the analysis of location density within the Fra Mauro Map.

An interactive OpenStreetMap is utilized to display a large number of places based on their density in the Fra Mauro Map. Clusters on the map represent groups of locations, with the number displayed on each cluster indicating how many places it contains. When a user zooms into any cluster, the number decreases, allowing them to view individual spots on the map. Conversely, zooming out consolidates the places into groups again.

In Visualisation 3, the density of locations is represented by different colors. Clusters containing 2-9 locations are displayed in blue, 10-99 in orange, 100-999 in red, and clusters with more than 1000 locations are indicated in pink. Users have the ability to zoom in or out on the map, and the visualisation dynamically recalculates and displays the varying densities of places based on the currently displayed map area.

Moreover, users can also view the map in different display modes, including map and satellite. Furthermore, as we used Google Map, users may also take advantage of some of the functionalities of Google Map, such as Street View. Finally, users can explore more details from the detail window to get information about the ID, place name today, geographic coordinates, decimal degrees, country, and place names in Venetian from the book Fra Mauro's World Map (Falchetta, 2006) and Fra Mauro's Mappa Mundi and The Fifteenth-Century Venice (Cattaneo, 2011).

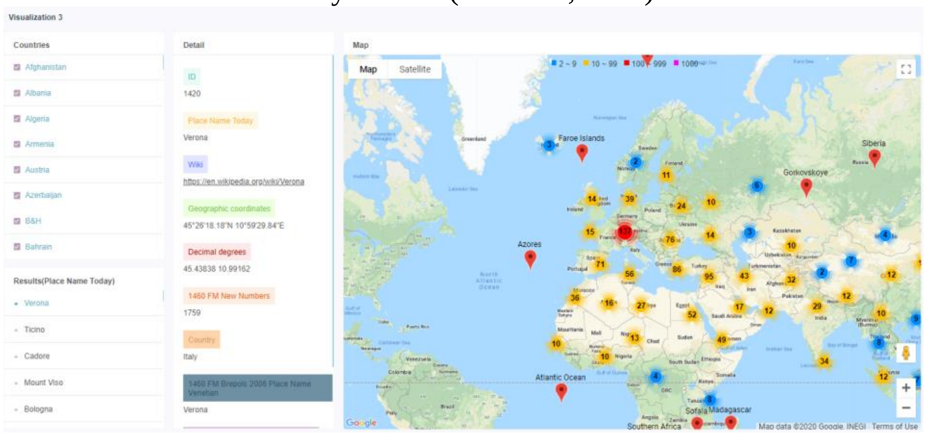

Figure 10: OpenStreetMap of the Fra Mauro Map.

The Force-Directed Graph

Visualisation 4 adopts a node-link representation, specifically the force-directed graph, which is a widely used method in various domains such as network visualisation, knowledge representation, and mesh visualisation. The force-directed graph is designed in an organic and aesthetically pleasing manner, taking advantage of inherent symmetric and cluster structures. This arrangement ensures a well-balanced distribution of nodes and links, addressing the challenges of comprehending large-scale information. It also allows for the extraction of hierarchical information structures (Robertson, Mackinlay, & Card, 1991).

In Figure 11, nodes (points) represent different cities, while edges (curve lines) indicate the relationships between these cities across the world. The size of each node corresponds to the number of cities connected to it (larger nodes indicating more connections). The nodes are further categorized based on three continents derived from the Fra Mauro Map. The cities are placed on the graph according to their geographic coordinates. Clicking on a country's node provides more detailed information about the cities within that country. Different colours are used to represent various areas, such as Asia, Europe, Africa, and sub-items, offering users a more interactive, effective, and instantaneous way to gain profound knowledge and understanding of the information presented in the Fra Mauro Map. This enhances user satisfaction by facilitating an immersive exploration of the data.

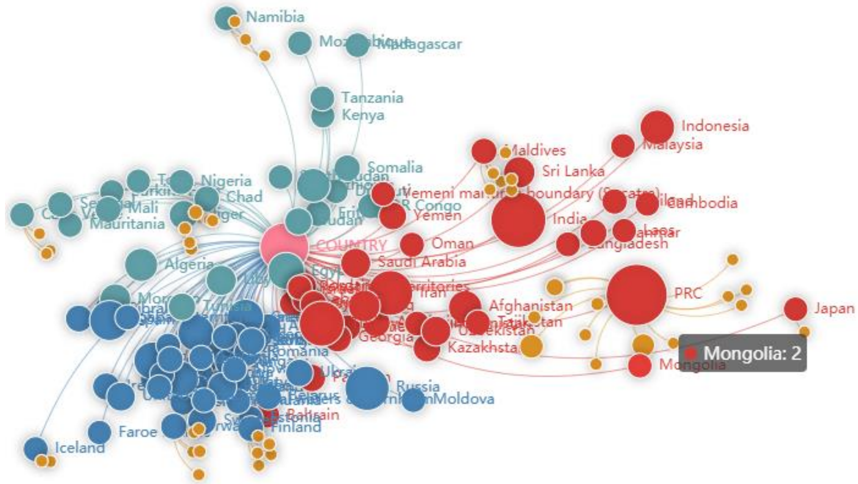

Figure 11: Force-Directed Graph of the Fra Mauro Map.

Historical and Contemporary Comparison in Satellite View

Visualisation 5 presents a satellite view representation that juxtaposes three maps on a single page. The maps included are the Fra Mauro Map, the Genoese World Map of 1457 (both ancient maps), and a contemporary Google Map. The purpose of this comparison is to provide users with a clearer view of the hotspots and locations by simultaneously displaying them side by side. The design objective of this comparison is to offer an overview of locations depicted in the ancient maps while highlighting the significance of these places in a contemporary context.

The data utilized in Visualisation 5 consist of two datasets extracted from the Fra Mauro Map and the Genoese World Map of 1457, as well as an integrated dataset (merge.json) compiled using Excel. To process the Excel data and obtain the merge.json dataset, an online conversion tool was employed. The information points from the three maps have been processed and integrated, allowing users to click on any of the three maps to view the geographic information of the other two maps.

The juxtaposition of the three maps enables users to interact with them by selecting and pointing to any location on the map. As a result, the same location and coordinates will be instantly displayed on the other two maps (refer to Figure 12). By exploring these locations, users can gain insights that demonstrate new approaches for studying toponyms (place names) and provide a means to reflect on the central metaphors present in the maps.

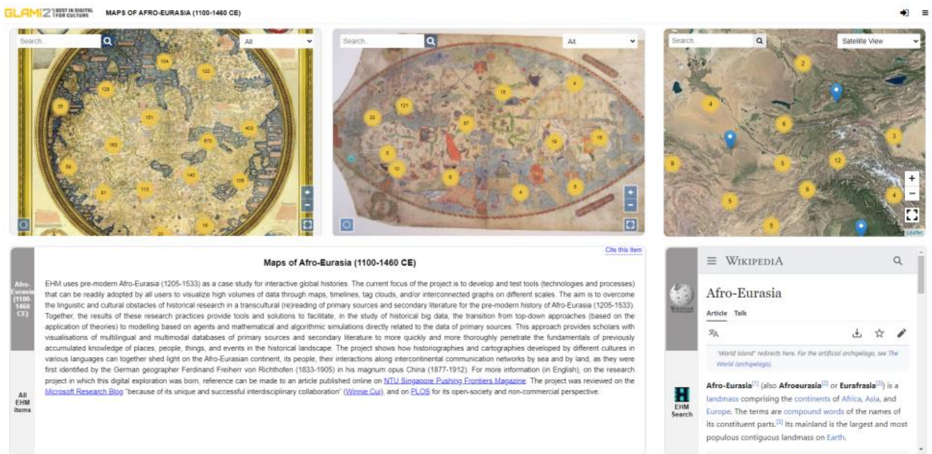

Figure 12: Historical and Contemporary Maps Comparison in Satellite View.

To summarize, in all the visualisations, users have the ability to click on specific locations to access a wealth of information including the ancient name, modern name, categories, geographic coordinates, Marco Polo documents, and other relevant data associated with that particular place. This interactive feature enables users to gain deeper insights and enhances their understanding of the content, allowing for an amplified cognition experience.

Contributions to the Research on Historical Maps

Visualisation of Hierarchically Structured Data

As Banissi, Marchese, and Forsell (2014) information visualisation has proven to be a valuable and effective approach for representing hierarchical data. These visualisation methods have demonstrated their ability to simplify the complexity of information derived from primary historical sources. They also enhance the capability of users to comprehend and interact with different levels of expertise and knowledge. By employing information visualisation techniques, the presentation of hierarchical data becomes more accessible and manageable, allowing users to navigate and explore complex information in a more intuitive and engaging manner. This contributes to a better understanding of the data, facilitates interaction, and accommodates users with varying levels of expertise in comprehending historical information.

In my practicums, I proposed five types of information visualisation techniques, each serving a specific purpose and showcasing different aspects of historical maps. Whenever a new insight was discovered, the provenance of that insight was tracked and shared in a collaborative and interactive environment. In the radial tree visualisation, different sets of written or depicted elements in the historical maps such as geographical names, cities, people's names, regions, ships, rivers, temples, and mountains were categorised and visualised in a radial hierarchical representation of countries-cities-categories-details. The approach of the rectangular treemapping utilised the different divided proportions to visualise the extensive hierarchical data in a divided display with visual interpretability. Using this technique in identifying the categorised analysis tasks, structures of the country, cites, and numbers of each unit are generated hierarchically; this shows the value of each unit and its attributes and elements. Boundary gaps, colour saturation, and edge thickness changes are utilised to help when converting views from different levels. Put in a different way, the OpenStreetMap allows users to explore the density of locations through multi-hierarchical layers of the historical maps. The last satellite view visualisation compares historical and current locations of place names on different maps to facilitate an instantly structured data retrieval.

Promotion of New Insights and Reduction of Cognitive Load

The digitised maps provided opportunities for exploration and examination. However, it is difficult for users to analyse and gain insights from the past of such ancient historical maps. To address these gaps, five interactive visualisations were proposed to extract historical world maps from historical data and to show various insights into their relationships, which resulted in high-level user satisfaction. In addition, the usefulness of information visualisation also reduces the end user's entire cognitive load of an unguided discovery of ancient historical maps responding to the user's cognition (Dove & Jones, 2012). There are two types of experiential insight that a product of this nature can offer up (Dove & Jones, 2012). From the information visualisation community's point of view, insights can be gained through interactive information visualisation. As Plaisant, Fekete, and Grinstein (2007) defined, insight can be seen as essential data findings. Saraiya, North, and Duca (2005) also emphasised insight regarding the participants' observation of data as a discovery component. On the contrary, North (2006) categorised the main characteristics of insights more broadly. They are qualitative, complex, relevant, profound, and unexpected. Yi, Kang, Stasko, and Jacko (2008) emphasised this recognition. They further indicated insight is the starting point of theoretical creation, which can be the by-product of ongoing exploration. However, from the cognitive psychology point of view, insight can be experienced. Scholars have also acknowledged that insight can be stated to a solution involving new ways of understanding and new structures (Bowden, Jung-Beeman, Fleck, & Kounios, 2005; Csikszentmihalyi & Sawyer, 2014; Kounios & Beeman, 2009; Sandkühler & Bhattacharya, 2008; Schooler, Fallshore, & Fiore, 1995).

For instance, in the radial tree scenario, the radial tree stimulates a deep understanding of historical figures. Rectangular treemapping successfully enhances information visibility and shows the focus of attention by distinguishing diverse sub-hierarchical structural layouts. These positive results demonstrate identification tasks' effectiveness, usefulness, and playfulness. The force-directed graph used in the selected historical maps, as the narrative visualisation experimental techniques, can help to generate new insights and share insights for both authors and end-users through discovery. This ongoing exploratory addressed the view that insights can be gained from the visual representation. It enables users to understand relations in different regions in the past more clearly by exploring points and clusters in the relationships between locations. The topological wraparound was provided by the force-directed graph, which enables users to see the correlations of each other in an edges and nodes representation.

The Design of Visual Narratives

Earlier studies have also considered how visualisation rhetoric can be built from critical theory, decision theory, journalism, and semiotics, which provide a narrative framework to promote insight sharing to influence users' understanding of original data (Hullman & Diakopoulos, 2011). The insight data sharing was discovered through the exploration and the storytelling. As Fischer, Giaccardi, Eden, Sugimoto, and Ye (2005) suggested, a successful narrative visualisation design can represent the author's experience in the end-user experience.

For instance, in the force-directed graph visualisation, the relations among each element can be 'read' in the historical maps. The convergence of the edges and points represents the network from the centre to other countries, in which interactive visualisation techniques are incorporated into storytelling. Users can read the story and structure of past society from the connections in the network of historical items to understand the underlying reason between such elements.

In summary, the practicums of information visualisation facilitate the exploration, analysis, and extraction of datasets related to historical figures. They provide a narrative structure and tools that aid in searching for new knowledge and supporting the sharing of insights. In future work, it is essential to explore the relationships between existing knowledge and unknown information regarding specific people or events. By delving deeper into these connections, a more comprehensive understanding of historical contexts can be achieved.

Conclusion and Outlook

As the use of digital maps and digital history involving quantitative data continues to grow, there is a pressing need for complex tools, methods, and innovative ways of presenting data. Information visualisation emerges as a valuable solution to address these challenges. By transforming raw data into interactive visual representations, information visualisation empowers users to explore, comprehend, and analyze the underlying information effectively. It goes beyond mere graphical representations and enhances the user's cognition, leading to deeper insights and understanding.

However, it has been observed that the underlying data analysis in visualisation, particularly the conversion of raw data into graphs, can be intricate for users due to a lack of sufficient usability studies in information visualisation. Therefore, it is crucial to base decisions on empirical evidence to assess the effectiveness of information visualisation processes and ensure their meaningfulness to users. It would be worthwhile to explore different types of insights, each with its unique characteristics, to better understand their impact on the visualisation process.

Moreover, information visualisation is increasingly crucial in various services and for empowering citizens in their interactions with data. To achieve universal usability, future information visualisation technologies must address three key aspects: user diversity (including language, age, and disability considerations), the variety of technologies utilized (such as varying network speeds and screen sizes), and user knowledge (including application domain expertise, prior knowledge, and familiarity with interface syntax).

By addressing these aspects, information visualisation can play an even more vital role in facilitating data exploration, knowledge discovery, and informed decision-making for a broader range of users, ultimately leading to more accessible and meaningful interactions with data and historical information.

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