Venice through the canals of time:

Mapping the physical evolution of the city

An Interactive Qualifying Project
Worcester Polytechnic Institute

Submitted to:
Professor Frederick Hart, Project Advisor
Professor Fabio Carrera, Project Co-Advisor

Submitted by:
Justin Chines
Eric Eoff
Alexander Reynolds
Amanda Weis

WPI

ve13-cart@wpi.edu
https://sites.google.com/site/ve13cart/

Table of Contents

Table of Figures

Authorship

All four members of the team contributed equally to the writing and editing of the report. Each member of the team was responsible for the writing of one of the main chapters (2-5) while the introduction and other chapters were written together as a group.

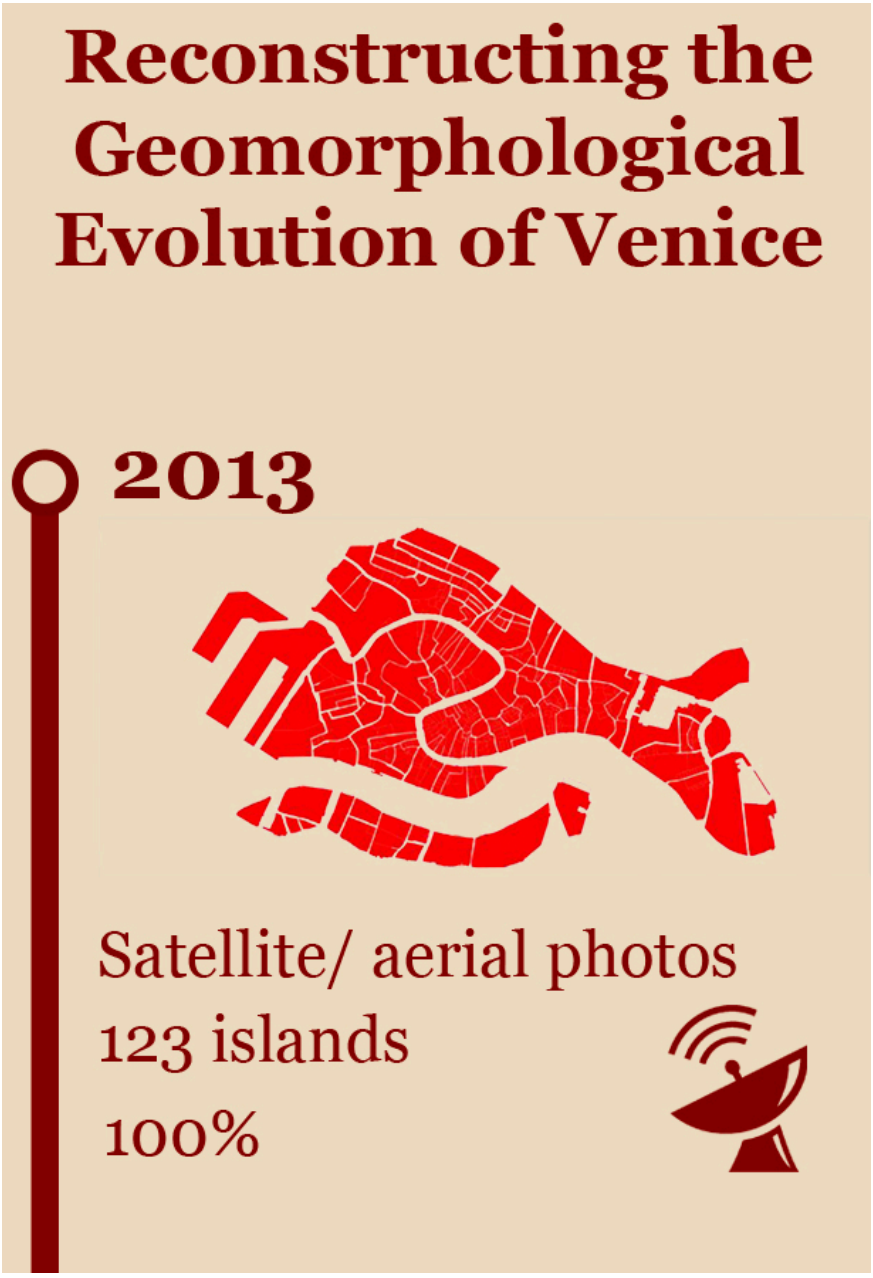
Acknowledgements

The 2013 Cartography Team would like to thank the following individuals for all of their help. First we would like to thank our advisors, Professors Fabio Carrera and Fred Hart for their valuable input and guidance. We would like to thank the Venice 25th Anniversary team for the technical help involving the console and for taking interest in our project's outcomes. We would also like to thank Marco Bortoletto for his input on archeological sites. We would like to thank Kyle Miller for all of his help gathering information and Ben Lichtner for his collaboration with City Knowledge and Venipedia.

Abstract

Venice is a city that has undergone many changes since it was first settled. Today, Venice is made up of 123 islands, but that has not always been the case. Over time, the islands of Venice have evolved; some canals have been filled in to combine islands, while other islands have been expanded or added. This project sought not only to reconstruct the evolution of the city, but also to create an easily navigable web-based source (for public use) to display the information. The reconstruction of the city involved gathering and analyzing maps, manuscripts, and archaeological records in order to rebuild the morphology of the islands. The reconstruction was then utilized in the creation of three web-based applications: the De'Barbari Explorer, the Evolution of a City, and Hidden Venice, all of which are available online.

Executive Summary



1821

Historic Maps
152 islands
81%

1500

De’Babari Map
153 islands
62%

1100

Ancient Manuscripts
128 islands
33%

600

Archaeological Records
94 islands
25%

1 Introduction

Maps have been an integral part of human societies for thousands of years. They have been used to assist in moving goods from Europe to India and helping students get to WPI from their homes. Cartography, the study of maps, dates back as far as 2300 BC. In ancient Babylon, clay tablets provide the earliest known maps. As cartography developed, maps became more detailed and intricate, carved in wood or drawn by hand. As the Renaissance dawned upon Europe and printing became a widespread capability, maps became widely available to the public for the first time. Today, with the aid of satellite imagery, maps are used to determine locations of landmarks and destinations and to understand how they have changed over time. Many major cities, such as Boston and Venice, have been defined by man-made efforts. Both cities have had projects undertaken to increase the availability of land. Unfortunately, the data depicting the evolution of such cities is often lost to the public's eye.

Venice has undergone several fascinating physical changes throughout its history. As the city's population grew, so too did the city's area. This led to attempts to increase the habitable land area available to the citizens over hundreds of years. Historic maps detailing Venice before such efforts were taken do exist, such as the de'Barbari map; however, these maps are difficult to compare to present-day data. This makes evaluating the physical changes that transpired across the years hard to visualize and understand for visitors to the city.

There are a variety of maps spanning hundreds of years in Venice that reside in multiple locations and are of varying quality. Past WPI projects have collected dozens of maps of Venice spanning from the 1500s to present day. Several other groups have utilized these records of Italian history. One project, Visualizing Venice, has created 3D models of the city that show how Venice would have appeared in the past. Aside from maps and images, ancient manuscripts are another useful resource for recreating historical landscapes. The manuscripts can be analyzed for mentions of locations throughout the island. Whenever a place appears in a manuscript, it is known that the location existed at least as far back as the manuscript. Archaeological data is another important contribution to recreating the evolution of the islands. Much archeological data about the islands of Venice exists detailing various factors because under Italian law, an archaeologist is required to be present at any groundbreaking project.

Despite being surrounded by history, tourists in Venice see only the modern-day city. Previous projects have invested much time and effort into collecting historic maps and information about the

city; however, due to time constraints and technological restrictions, there is not an easy way to access and compare the data. Existing archaeological data can also lead to inferences about the ages of different sections of the islands, but this data is not linked to maps. By associating archaeological age data and manuscript information to historic maps, it may be easier to see the changes in Venice's geomorphology throughout time. While the data exists for this project, it is not easily accessible by most people.

This project will contribute to the understanding of Venice's physical development. Using historical maps and images as well as archaeological data, we will reconstruct the morphology of the city and make the information available to the public in several creative manners. Using software and mobile applications, we will make interesting information about Venice's past available to the general public.

2 Venetian Cartography

Maps are a very important tool in the understanding of the geomorphology of Venice. Over the years, maps of all kinds have been made of Venice. They come in a variety of mediums and viewpoints and help provide an idea of what the city looked like at a given time. Analyzing maps allowed us to study Venice from today all the way back to the 15th century.

2.1 Contemporary Maps of Venice

Today, there are a number of sophisticated tools for acquiring maps of Venice. Most notably, in recent years satellite imagery has allowed for extremely detailed and accurate maps of the entire world to be created. Interfaces such as Google Maps and Open Street Map allow users to view satellite photos of the city, but they also allow display other maps as well. For instance, Google Maps provides options to view streets, terrain, and other interesting information about the land such as weather, traffic, and photos. Google Earth has even recently added the option to view historical images of many places. These historical images are aerial photographs taken as far back as the beginning of the twentieth century.

2.2 Maps of Venice from the 16th to 19th centuries

However, prior to 1900, printed maps were the only visual medium available to show the geography of Venice. Technology played a large role in cartography of the 19th century, introducing such techniques as lithography and chromolithography. Maps of Venice during this time period were not only extremely detailed, but also quite artistic as well. Most of the maps of Venice created after 1800 utilized an orthographic viewpoint. The orthographic viewpoint is exactly perpendicular to the ground, so it provides an extremely useful and accurate map for navigating the geography of the city and observing the layout of the canals without the obstruction of bell towers

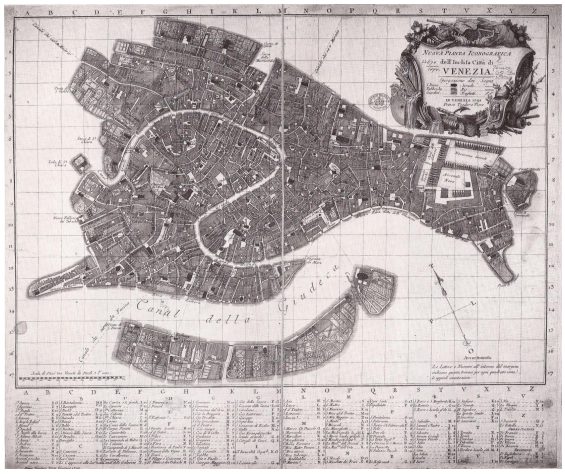


Figure 1: Teodoro Viero's 1792 "New Iconography Plan of the Illustrious City of Venice"

and other tall buildings.

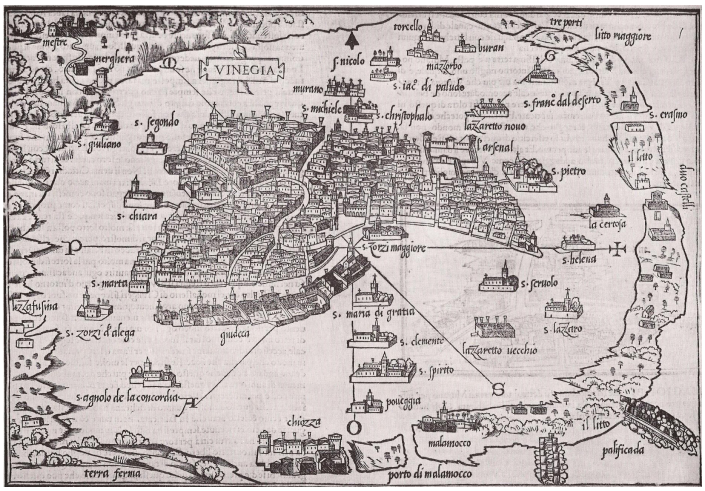


Figure 2: A Bird's Eye View of Venice by an anonymous mapmaker (1528)

Prior to 1800, maps were mainly created as prints of wood engravings or copper engravings and were less detailed than their later counterparts. Unfortunately, orthographic maps were very difficult to produce because there was no technology available to allow for the vantage point necessary. During this time period, bird's eye view maps were by far the most popular. These maps were drawn from the highest point that the artist could reach (usually a bell tower in Venice) and they provide a unique perspective of the city. Though not entirely geographically accurate, they did provide a good general layout of the city.

2.3 Early maps of Venice

The earliest maps of Venice date to the 14th and 15th centuries. Of the maps that do exist from this time period, most used a panoramic perspective of the city. Panoramic perspectives show the city from the side and highlight major recognizable features of the area. Though not usually geographically accurate, panoramic maps provide an idea of portions of the city and major recognizable landmarks.[1] They focused much more on iconography and artistry than geographical accuracy.

Figure 3: A portion of a portolan map

Another example of a type of early map of Venice is a portolan chart. As their name suggests, portolan charts were navigational charts used by sailors to navigate ports in relatively small bodies of water. Because Venice is a city surrounded by water and was historically an important port city, several charts

[1] Harley, J. B., and David Woodward. *The history of cartography*. Chicago: University of Chicago Press, 1987-2003.

exist which include Venice. Again, these maps are not geographically accurate; however, the portolan charts provide useful insight about both relations to other cities and important landmarks of a city. Figure 5 shows an example of an early portolan map with Venice at its center.

2.4 An online catalogue of Venetian maps

In order to establish a complete record of all maps of Venice, we first began by compiling our available resources from past projects. We gained most of our data from the 1991 Cartography project by studying their database of 295 maps that they collected. By using this database, we were able to find a majority of the maps of Venice that were created from the 15th century until the 18th century and trace them back to the two books that they were collected from: The Printed Panoramic Views of Venice by Juergen Schulz and Venezia Piante e Vedute, printed by the Correr museum. With these two print sources and the digital database, we could easily compile and organize high quality digital scans and files of these maps for use on our website and in our mobile application.

Since these resources did not provide us with a complete record of all maps created depicting Venice, we used online resources and the Forma Urbis past project to find important maps of the island that were made before the 15th century and after the 18th century. These maps were then added to the database that was created in 1991 so that future groups will have a more complete set of historical maps to work with. Each map was cataloged with important meta-data about the map including the author, date of creation, view, level of completeness, printing method, and general description.

Once all of the images of the maps and corresponding information were compiled in a single location, this data was added Venipedia for use by future project groups. Each map that we have in our database has its own Venipedia page.

Figure 4: Sample Venipedia page for the de'Barbari map

Bringing the maps and their information to Venipedia allows for researchers and students to access the maps anywhere in the world. This is a vast improvement over the last project's database, because it is more modern and easily accessible for individuals outside of the WPI community.

2.5 Recommendations

Due to time and logistical constraints, we were unable to scan every map available to us. Future projects should certainly consider adding to the database of maps. In particular, there are many maps that we gathered information about but which were never scanned. In the future, these maps should be scanned and the images should be added to Venipedia, as outlined in Appendix A.

3 The de'Barbari Bird's Eye View of Venice

The de'Barbari map is one of the most important historical maps of Venice we know of. It was created by Jacopo de'Barbari in the year 1500 by carving the image into 6 large wooden blocks. The map was designed to be used to print additional copies, so de'Barbari actually carved his map in reverse. The end product was a huge (2820 by 1350 mm) map of the city. What is especially remarkable about the map is that despite its age, it is extremely detailed.

To accomplish this feat, de'Barbari used the views from multiple bell towers throughout Venice. These gave him a vantage point from which he could see more accurately what Venice looked like from above. He had no way of knowing exactly what it looked like from directly above, so for his map, a bird's-eye view was used. Additionally, because multiple different towers were used, the layout of the city is highly distorted.

Despite its imperfections, it is still a great resource for historians and people interested in the history of Venice. Each church that existed at the time is labeled with its name engraved on the map. This makes it especially easy to see what churches existed at the time. Many churches have been destroyed since de'Barbari's time, and his map provides a good record of their existence.

Because the map is so detailed, we are able to see other details as well. On each church we can see its convent (if it existed) clearly separated from the church. Each building, even those without major historical significance, has been carved into the map as it was seen at the time. Even the small bridges have been recorded with extreme detail.

Figure 5: Full print of the de'Barbari map of Venice

The map has become a favorite of historians and Venetians for viewing pieces of old Venice. For buildings without well-done paintings, the de'Barbari map provides a good view of what they and their surrounding areas looked like. It is especially useful for churches that are now demolished. While we can't see what they look like exactly today, detailed representations of their locations and shapes exist in the map. When reading books and webpages about Venetian history and churches, it is not uncommon to see pieces of the map shown.

3.1 Navigating the map online

The problem with the map is that despite its detail and labels, it is often difficult to extract useful information from. The map is so large and distorted that finding buildings that are not in obvious places, such as those far from the Grand Canal and those at the edges of the islands, are often difficult to find. The labels, while extremely useful, are sometimes extremely difficult to read and are impossible to see while looking at the map from afar. From a distance, one would not even know that the labels and all the intricate details exist.

For these reasons, we have created a tool that will help people view and explore the de'Barbari map. Our tool is meant to be accessible by people all over the world, so we chose a platform that will reach many people: the web. Hosting the map on the web allows people to experience the map and get information from it without having to download the whole thing. No software needs to be installed except for a web browser. The result of our efforts was The de'Barbari Explorer.

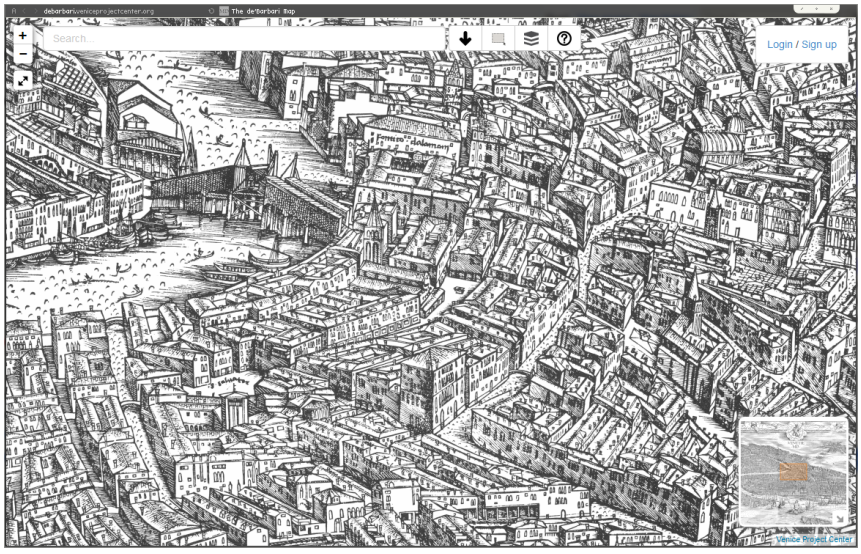


Figure 6: Screenshot of the de'Barbari explorer interface

3.2 The de'Barbari Explorer

The de'Barbari Explorer is a web site for viewing the Venice Project Center's extremely high quality scan of the de'Barbari map image. The project center has printouts of the famous map, which were scanned and joined by a previous student project. The digital image created by this team was very well done, but is unfortunately too large for most computer systems to use easily, even today. However, thanks to the Internet and the rise of web technologies, we are finally able to present the map in an easy-to-use format.

When users arrive at the site, they are presented with a zoomed-out view of the map. Zoom control are at the top left of the page. Much like popular map services of today, such as Google Maps, users can zoom in and out, and pan. Users can zoom in quite far, which gives them a chance to truly appreciate how detailed the map really is. For when it is useful, users can hit the full-zoom-out button under the zoom controls to zoom out and see the whole map. A mini-map exists in the bottom right corner, which shows where you are in the map. It is especially useful for users to see where they are when they are zoomed far into the map.

One of the most striking features of the web interface when you reach the page is the search box at the top left. Users can search for different landmarks such as churches, convents, and bridges. Simply start typing in the search box and auto complete suggestions will begin to appear. Select one of those options and the map will automatically zoom to that location.

Because using pieces of the de'Barbari map is so popular, we have created tools for downloading pieces of the map. The down arrow tool in the toolbar next to the search box downloads the entire view that's currently being shown. Users simply have to pan and zoom the map to the view they want, and click the down arrow button to download a copy of the image image. If users want only a piece of the current view they can use the selective download tool next to the main download tool. After selection this tool, users draw a rectangle on the map with their mouse to select the area they want, and the image will be downloaded.

One of the most exciting features of this map are the layers options. By click on the layers menu in the toolbar, the user can choose different layers to enable. After choosing a layer, all items in the chosen category will be highlighted in the map. For example, after enabling the demolished churches layer, all churches that exist in the map but not in the Venice of today will be highlighted and outlined in red. Any combination of layers can be enabled using the layers menu. Users can click on

the highlighted items, and popups will appear with additional information. Every popup shows the name of the item clicked, and some provide links to additional information resources, such as Venipedia. When layers are enabled, the search box is modified so that only items in the selected layers are searchable. This should make it easier for people to find what they are looking for.

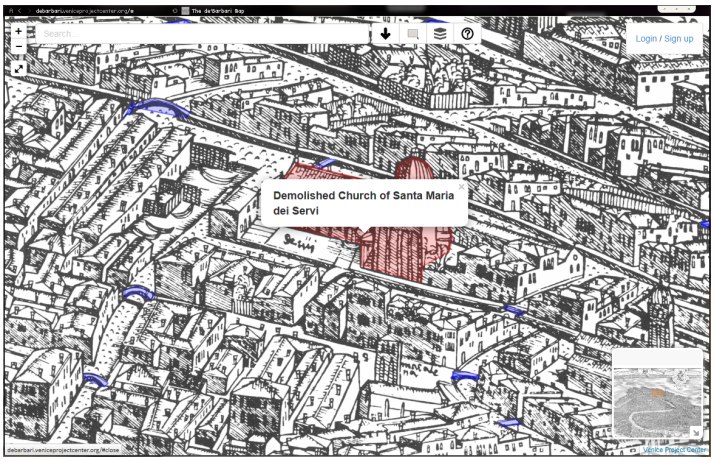


Figure 7: Activating layers and selecting objects in the de'Barbari Explorer

We hope that the de'Barbari Explorer will be a useful tool for historians, Venetians, and future Venice Project Center students. This system put in place will allow for people in the future to continually add new information to it. The tool will continue to evolve, and new advancements will be created. We're excited to see what others are able to find and share.

3.3 Demolished churches and rii tera in the de'Barbari map

In order to enhance the value and scope of information provided by our mobile application tools, we created many informational pages on the Venepedia website. In the de'Barabri explorer one of the viewable layers is the demolished churches layer, which highlights all churches that no longer stand in Venice. When the layer is selected, you can click on any given demolished church and a link will appear to its respective Venipedia page. The demolished churches pages are also linked to our Hidden Venice app, when a church is selected from the google map, an infobox appears with a link to the individual church Venipedia page.

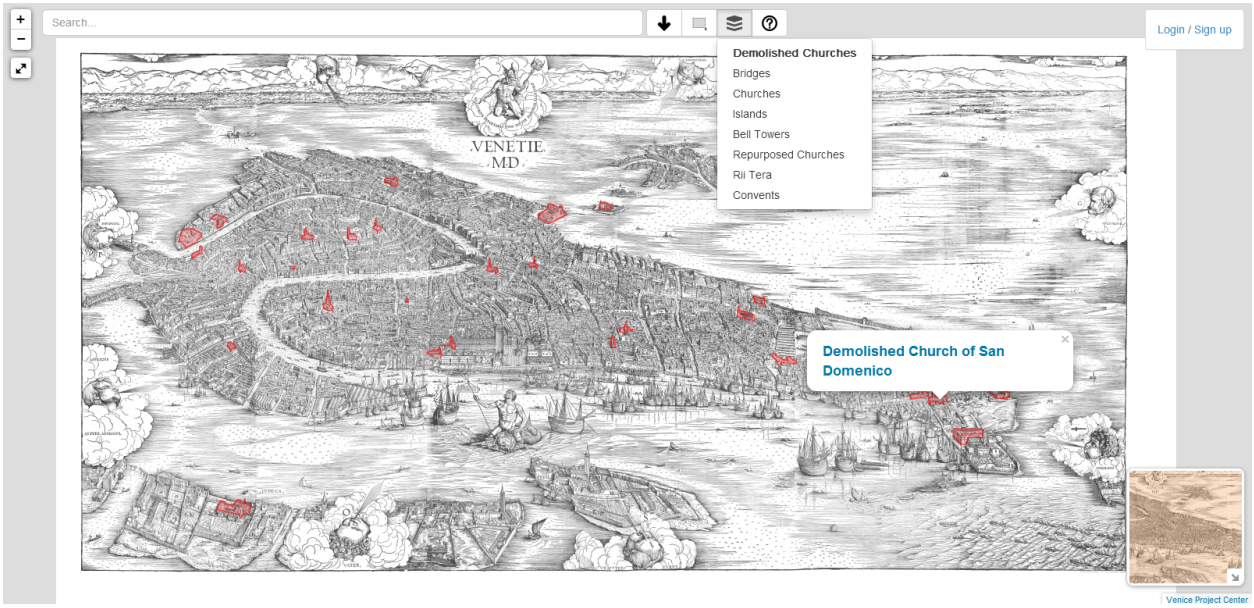


Figure 8: Demolished churches layer in the de'Barbari Explorer

Like the demolished churches, the filled in canals or Rii Tera pages are also linked to the de'Barabari map in a separate layer. When the Rii Tera layer is selected, most of the 50 known filled in canals appear highlighted in blue on the map. These individual canals can also be selected and are linked to individual Wikipedia pages as that include relevant information about them.

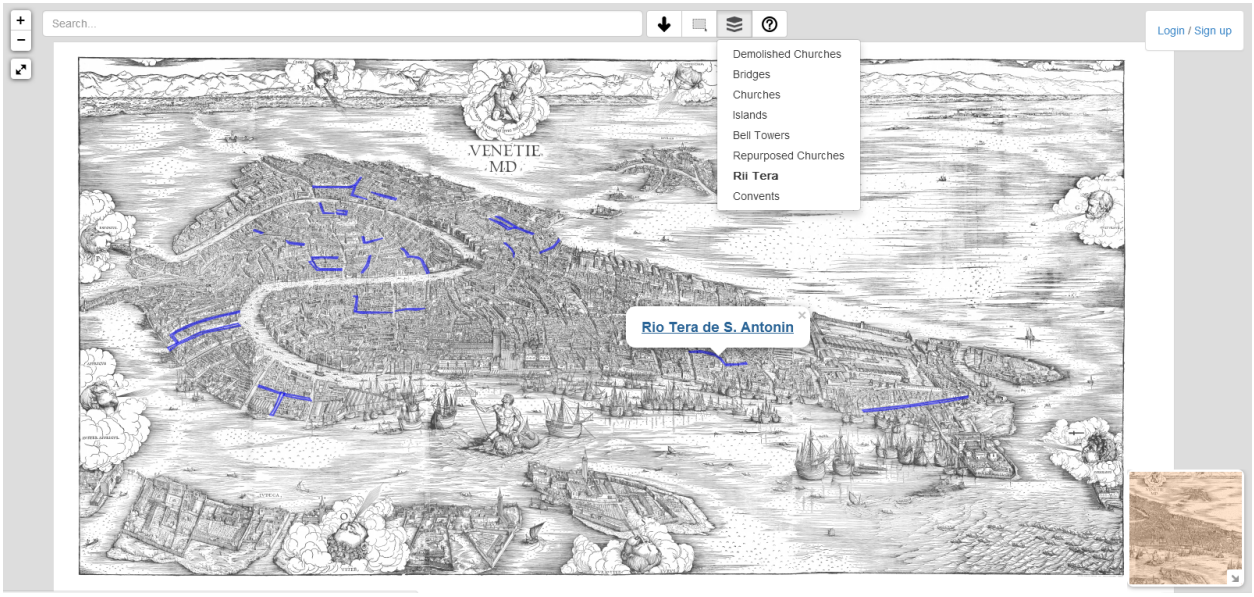


Figure 9: Rii Tera layer in the de'Barbari Explorer

Each individual demolished church page includes information such as the date it was founded, date it was demolished, its location, why it was demolished, government it was demolished by, and information about its history. All information was translated from either Venezia Scomparza or Edifici di Venezia. The page displays a google map layer of all of the demolished churches that will allow you to navigate to other pages easily. Another feature of the pages is the navbox, which is an index of all known demolished churches separated by Sestiere that includes links to all of the pages that we created. The picture displayed in the infobox of the page is either the current view of the church, a painting of the church, or a zoomed in view of the building from the de'Barbari map. Every demolished church page also includes a redirect of the Italian translation of the page title. For example, if a native Venetian were to search Chiesa Demolita di San Domenico, they would be redirected to the English version of the page instead of having to translate their search terms.

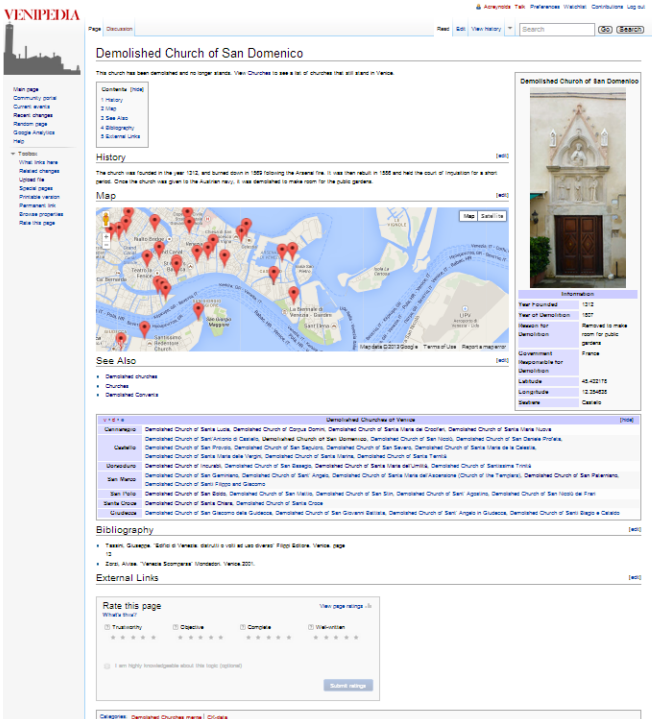


Figure 10: Demolished church sample Venipedia page

Each of the 50 Rii Tera pages include useful information such as the date that they were filled in, what government they were filled in by, the length of the filled in canal, where it is on a map, and what the street is actually labeled in Venice today. The street label is very useful because many of the filled in canals are not labeled as rii tera on their street signs, so a common pedestrian would not be able to tell that they used to be canals. Similarly to the demolished church pages, on each individual page there is a navbox at the bottom that is linked to every other rii tera page. The table is organized by the government responsible for filling the canal. Along with the individual pages, we edited the plural pages for Rii Tera and Rio Tera by adding more useful information and statistics relevant to the topic. To further develop the pages we would like to add pictures of either the street signs or a street view of the canal to each individual page so that users can more easily determine what the streets look like today.

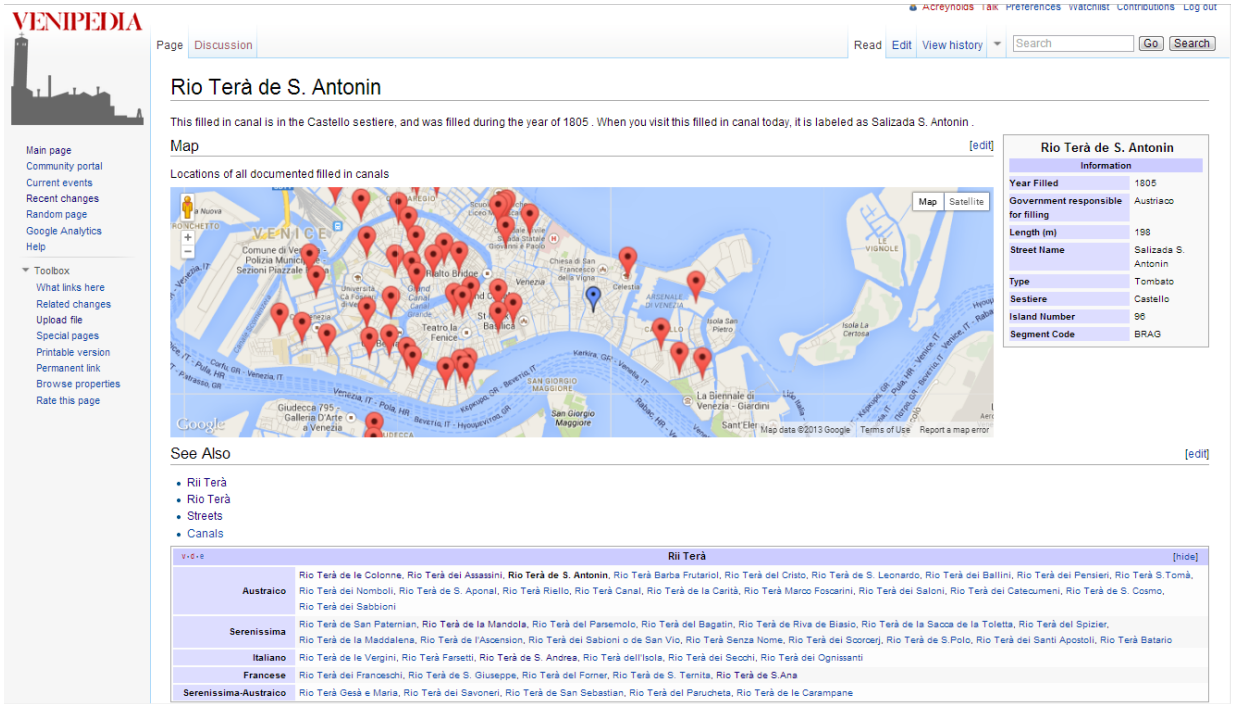


Figure 11: Rio Tera sample Venipedia page

3.4 Recommendations

Not every feature we considered was able to make it into the map. One feature we wondered about was whether a modern day coordinates system could be applied to the map, such as longitude and latitude. This would provide enormous benefits. Modern day streets and addresses would become accessible, and geolocation technology could place users right on the map itself. Unfortunately, the map is so distorted that such a project would be nearly impossible. Even if the shape of the islands was altered to match modern projections, the streets and canals within the islands would be incorrect. A project to properly match every canal and street up to modern data would be an immense undertaking, and is unfortunately probably not possible to complete in the time frame given to IQPs.

Another major feature the map is missing is the ability to edit polygons and their associated data. Ideally, there should be a system in place where users can fix data that is incorrect or inaccurate, and even delete data points altogether. At the moment, the only way to edit information is by manipulating the Firebase, which is most easily done from Firebase forge. One way to

efficiently view the data is to export the features as JSON, and edit them in a text editor of your choice. Be careful: importing the edited JSON will destroy and replace all existing data in that location. Make backups.

Lastly, the system for signing up and using different user accounts needs to be created. At the moment, only the Venice Project Center account exists, but having additional accounts has huge potential. People could add their own landmarks that the map is missing. The data created by other users could be kept private, or they could request for their data to be included with the main data set. This should encourage additional contributions to the map.

4 Manuscripts

Historical documents hold a mass of information that spanning the years they were taken. These documents include anything from a marriage licenses to robbery reports. A government overseeing Venice can be dated back to the early 800's. Historical documents and manuscripts far proceed the first maps produced depicting Venice. Thus through the use of maps we are able to understand and reproduce the shape of the city before the first maps were ever created. A large portion of the documents recorded over the years are available within the Venetian archives.

The Venetian archives hold a vast amount of information dating back hundreds of years. The documents held in the archives are a combination of many different types of historic records spanning from robbery reports to important manuscripts. The archives hold these documents secure by limiting the accessibility of the original documents to historians. On occasion a digital version is available for close study after requesting the document through the archives.

4.1 Evolution of Venice 1100-1300

Through our research we created a series of GIS layers displaying Venice from the years 1300-1100 based on historical documents from the era. The maps contain information about the source documents along with the specific year each location can be traced back through the use of historical documents.

The majority of the documents we focused on were from before the year 1500 when the information from maps becomes scarce and too inaccurate to rely on. The documents from this era are mostly in Latin, thus we started by looking for key words and phrases to focus in on the documents we wished to look at in more detail. We started our research by visiting the Venetian archives. From there we looked into other projects done in Venice that incorporated historical documents shelved at the archives.

Through our research we found that Wladimiro Dorigo had compiled a lot of historical documents in his book, Venice Romanesque. This book provides a lot of interesting information about Venice from the 1100's to the 1300's. Wladimiro Dorigo created two main maps of Venice that displayed land, one from the 1300's and another from the 1100's, breaking Venice up in each map into the parish's that existed during that era. Wladimiro Dorigo also made detailed maps of Venice from these eras, displaying buildings and other structures that existed from the two time periods. These focused maps however only showed data on one specific section of the city at a time

usually only including one to two parish's per map. These maps provided information that would be nearly impossible to find without such a detailed source.

Now that we had all of this information in one source we focused on putting everything into GIS and linking all of the source documents to the GIS information in such a way it would be accessible to the public.

4.2 Maps of Venice based on manuscripts

We started digitizing this data by creating a GIS layers of Venice from the 1100's and 1300's centuries, the comparison of these maps can be seen in figure 12.

Figure 12: Comparison of venice from 1100 and 1300

Venice was divided up into Parish's in the 1300's Dorigo mapped the parish. Figure 13 depicts Venice in the year 1300. This is a one of a kind map because it is based on the documents available associated with that era. This map does not only display the land from the era it also displays the parish that the land was associated with.

Figure 13: Dorigo map of Venice with individual parishes

As you go back further in time to the 1100's the shape of the city changes. Figure 14 is the estimation of what the city looked like in the 1100's.

Figure 14: Venice in 1100

Focusing in on one section of Venice in this era, the team mapped two parishes in more detail. The produced maps display each building, street, church and field that existed in the 1100's. These

maps are linked to the source document in such a way that by clicking on any of the locations brings up the reference document available in its original form and translated into English. Some sections of the map are also lined to PDF scans of the reference document as references as well.

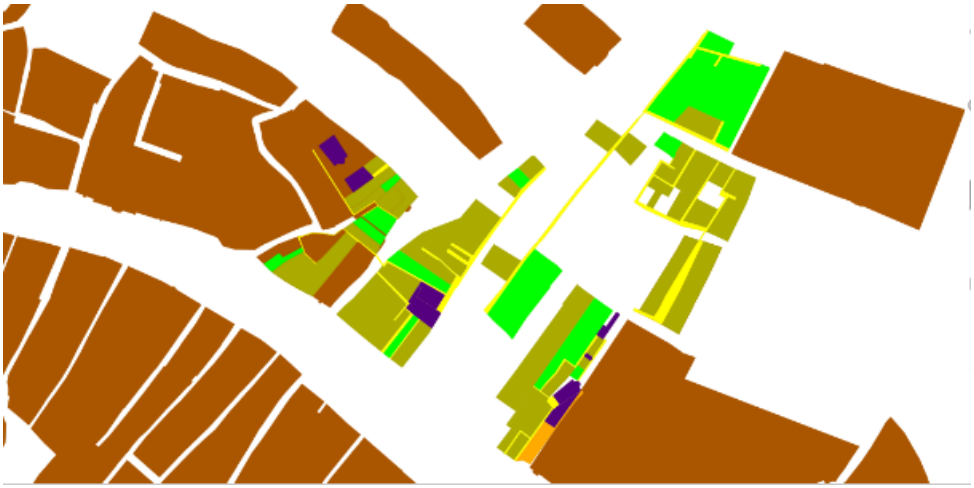
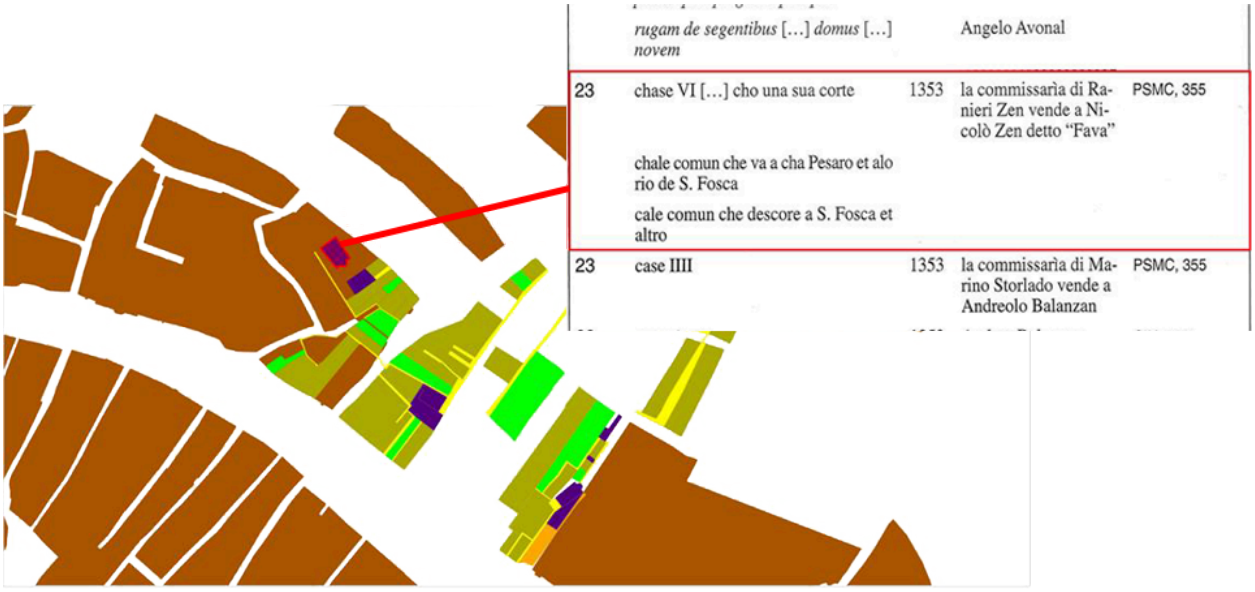


Figure 15: Zoomed view of individual parish in Dorigo's map



	rugam de segentibus […] *domus* […] *novem*		Angelo Avonal	
23	chase VI […] cho una sua corte chale comun che va a cha Pesaro et alo rio de S. Fosca cale comun che descore a S. Fosca et altro	1353	la commissarìa di Ranieri Zen vende a Nicolò Zen detto "Fava"	PSMC, 355
23	case IIII	1353	la commissarìa di Marino Storlado vende a Andreolo Balanzan	PSMC, 355

Figure 16: Corresponding historical document for a selected church

This map has an interactive side that can be used to search historical documents representing the sections of the map. Each location in the map is linked to a reference document describing the owner of the property, year of the document, description of what the location was in that year, along

with the reference number for the source document in the Venetian Archives, proving the existence of that specific building at that time. The map's most interesting feature is the detail that is shows.

4.3 Recommendations

Future projects should scan in images from the book and use the raster field plugin that was developed lately to use as a reference to create the maps. The team created an excel document to use to link with the map, this document can be expanded upon to incorporate all of Venice.

During our time in Venice we were able to create a detailed map of Venice from the 1100's focused on 20. S. Feliece parish along with portions of the 21. S. Fosca parish from Venice Romanesque. Future teams should continue using the text to map the rest of Venice from the 1100's. Once a detailed map from this era has been created archeologists can use it to date different islands. A detailed map of Venice that identifies what existed in the 1100's could be used to help identify and categorize future construction sites based on the possibility that they would unearth important artifacts.

5 Archaeology

As an important historic site, Venice has been subject to several archaeological investigations. Archaeology can provide clues to understand Venice's rich and complex history. In Venice, these finds can suggest how old different sections of the city are. By dating artifacts found in various parts of the city, we can try to begin to understand where people settled first, and when.

Venice poses an interesting challenge for archaeologists. Typically, archaeological research is completed at digs looking in the ground. However, in Venice many of the locations interesting to researchers are underwater. Artifacts can be recovered from underwater excavations, but they are typically very fragile. Artifacts must be kept in water and treated with special chemicals to ensure they remain intact[2].

Figure 17: Flooding in the Streets

When most people think of archaeology, they likely think of extracting artifacts from the earth at dig sites, though today that is not always what is done. For example, it is possible to search for artifacts using special seismic equipment. Rather than dig and tunnel through the ground, in Venice it is possible to detect artifacts by using seismic sonar equipment. The technology sends pulses through solid structures to try and find objects of interest[3]. This technique is especially useful for underwater studies.

Researchers have also looked at the history of water level changes. By collecting data on church floors, archaeologists have researched what water levels were likely at in the past. Churches were built with high floors to prevent any flood damage, so it can be inferred that church floors were built slightly above the average flooding levels. This data can be used to determine where the coasts of Venice used to be.

---

[2] Hamilton, Donny Leon. *Basic methods of conserving underwater archaeological material culture.* Washington, D.C.: U.S. Dept. of Defense, Legacy Resource Management Program, 1996.

[3] Wynn, Jeffrey C.. "A Review Of Geophysical Methods Used In Archaeology." *Geoarchaeology* 1, no. 3 (1986): 245-257.

5.1 Organizations that Collect and Store Data

Within Italy, data and regulations pertaining to cultural history, archives, and tourism are handled by the Ministero dei Beni e delle Attività Culturali e del Turismo. This organization is split into several Soprintendenze. These "superintendents" act for the ministry in different parts of the country. In Venice, the superintendent focused on archaeological data is the Soprintendenza per i beni archeologici del Veneto.[4]

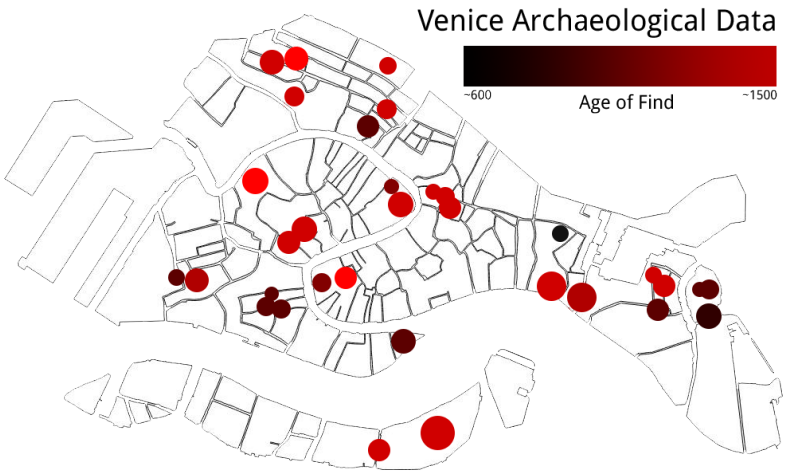


Figure 18: Archaeological Sites in Venice

This organization, as well as others, maintains several archaeological records. There is a law in Venice that states that every "dig" must have an archaeologist present. These required studies show reflect the importance that Venetian authorities give to archaeology.

Naturally, this project is not the first to attempt to discover the history of the Venetian islands. Even recent projects from WPI students have addressed this issue. In 2004 a team of WPI students attempted to form a history of island settlement by primarily using information on churches[5].

There are several archaeological sites present in Venice. The aforementioned 2004 team created a record of what was then recent archaeological digs, and found that there have been hundreds of sites researched since the 1990's. These sites exist within Venice itself, and also on its surrounding islands.

5.2 Dating Islands Through Archaeological Data

By looking at the available archaeological data, we can attempt to date sections of the island. The oldest immovable object found at an archaeological site makes a good indicator of its age. Such an immovable object will likely be a structure of some kind. It's important to look at immovable

---

[4] McGowan, Nicola; Niella, Reinaldo; Schrappe, Pierre; Smith, Jennifer. *Lagoon Archaeology.* WPI IQP Report 1991

[5] Baker, Christopher; Brache, Jose; Dakin, Samantha; Saracel, Cem. *Evolution of a Forma Urbis. WPI IQP Report 2004*

structures rather than more common artifacts, such as coins and jewelry, because the movable objects simply may have been dropped in an area at some other point in time.

Using these dates and other information, we can construct a picture of how the islands evolved. Rii Tera data tell us how islands were split up, and flooding information can tell us what water levels were like throughout history.

Using the data that we found from the Insula online database, we were able to prove the existence of multiple islands at given dates in history. Although there was not enough data to provide information about every island in Venice, we were able to begin filling in the map with ages of different islands around the city, as you can see in the map below.

Since the Dorigo map and record of historical documents provided us with records for every island that existed in 1100, we only needed to focus on archaeological data that was dated before that time in order to further date the islands. Once we removed all digs dating after 1100 we then isolated all of the finds that included permanent structures such as buildings or other landmarks. After doing this we were able to produce the map below, which shows islands that were proved to exist before 1100 according to the insula data.

Figure 19: Archaeological finds dating before 1100

For some of the archaeological records, they provided us with useful information about buildings that are still visible today, and can also be seen on the DeBarbari map. For example, the church of Santa Fosca still remains today in the northern Cannaregio area, can be seen highlighted in the churches layer of the DeBarabari explorer, and can be found in the Dorigo map. This means

that the church existed until at least the year 1100, and we used our archaeological data to prove that the church was on the island in the year 873. While this tells us the age of the church, it also tells us that the island it was built on existed in 873 as well.

To make all of the data on the insula website and in our databases more easily accessible and easy to understand we created an application that combines the GIS map that we have created with the data available online, so that people can see where each data point comes from. Within this app, the user is presented with the map of archaeological finds shown above highlighting areas for which we have data. To find out more about each individual data point you can click on an individual island in the map, and important archaeological information will appear. The infobox shows when the archaeological dig took place, who conducted the dig, what was found, and the age of the find. This information is much more useful than just simple data points on a map, and allows researchers to find out more about each individual dig.

Figure 20: Example of infobox for a selected archaeological record

5.3 Splitting the City Using Known Rii Terà

Using previously collected data, we have access to a database of the known filled in canals on the island and where they are located. These filled in canals have been highlighted on maps in QGIS layers and can be used as a reference to split islands that have conflicting historical records. Since

we know that the island was once divided, we can sift through our maps, historical documents, and archaeological reports to determine when exactly the canal was filled in.

While we were able to clearly identify most of the known filled in canals in the maps that we have available, it was much more difficult to confirm the existence of potential filled in canals that we had identified. As shown below in the DeBarbari explorer, most of the known filled in canals could be seen clearly in the DeBarbari map and I was able to create a layer highlighting them.

5.4 Identifying Potential Rii Terà

Currently, there are 50 known rii tera on the island of Venice that have been successfully documented. However, this number is believed to be much lower than the actual number of filled in canals on the island. As a part of our research process, we determined streets in Venice that are likely rii tera that have yet to be confirmed by any other group.

To do this, we examined the existing filled in canal data which gave us the locations of every filled in canal on an editable map in GIS format. We then combined this map with layers of flooding data available in GIS which showed us areas of the island that flood at different water levels. With the flooding data, we were able to determine that at 110-120cm above regular water level most of the known rii tera will flood. Then using the flooding data for that water height, we looked at other streets and areas of the island that were not known rii tera, using our chosen water height as a guide for predicting new rii tera. Although combining the data in this way is very useful, it will not definitively confirm that a street is a filled in canal. To provide further evidence for these predictions, we can use the archaeological data and historical documents to reinforce our claims.

5.5 Splitting the Islands with Potential Rii Terà

Once we had determined likely rii tera from our flooding data, we then applied these predictions to a base map of the island again. If any of the islands are split by our predicted rii tera, we worked to confirm our hypothesis by consulting our historical maps and archaeological data.

For the streets that showed evidence of being filled in from the flooding data available we were unable to find any archaeological data that could reinforce our hypotheses. Our limited access to archaeological data and the limited number of digs that have been recorded restricted our ability to study the unconfirmed rii tera more closely. However, as we created digital versions of our

historical maps using GIS, they provided us with further evidence that some of the canals had been filled in but again evidence from hand drawn maps is not substantial enough to prove our claims.

5.6 Recommendations

For future groups and projects there are various aspects of our work that could be continued and developed further. On Venipedia, we would like to add pictures to all of our Rii Tera pages that show either a street view of the filled in canal or a picture of its street sign. To further improve our archaeology application in the future, we would like to add more data points from a larger variety of sources. The ultimate goal for this project would be to completely fill the GIS map of Venice with archaeological data about every dig that has been conducted in the city. This would then provide archaeologists with a database to record data for future digs, creating a single resource for archaeological information. Eventually, we hope that data could be collected and stored about every individual island in Venice, so that we could effectively date all parts of the city.

6 Online and Mobile Applications

In addition to the aforementioned de'Barbari Explorer tool that we created, we wanted to find a way to bring together all of the information that we gathered and analyzed about the geomorphology of Venice. To do this, we chose to make two applications that showcase how much Venice has changed since it was settled.

6.1 Evolution Slider

The Evolution Slider is a visualization tool for understanding the changes that Venice's land has undergone over time. It is available at http://evolution.veniceprojectcenter.org. When a user visits the website, they are asked to choose between the GIS evolution and the full evolution of the city. Each provides a different way to view Venice's evolution.

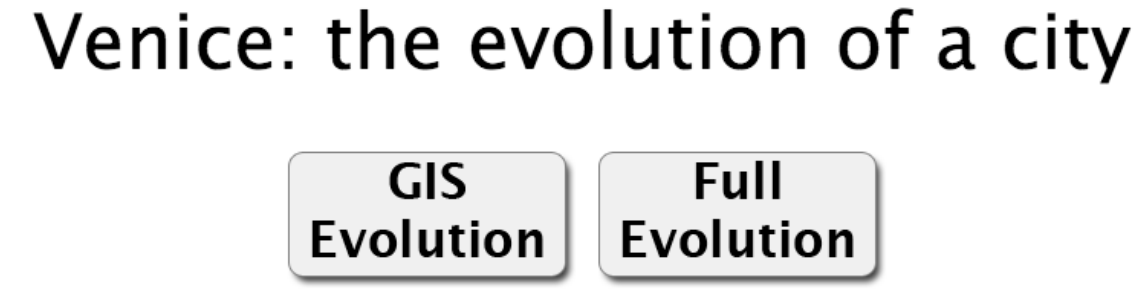


Figure 21: Homepage of the Evolution Slider

The GIS evolution of the city contains only maps created by our team in GIS. This allows for the user to see a very simple and elegant view of how the islands evolved, becoming what we know as Venice today. The images span from 1100 all the way to 2013 and using the slider, a user can watch Venice expand.

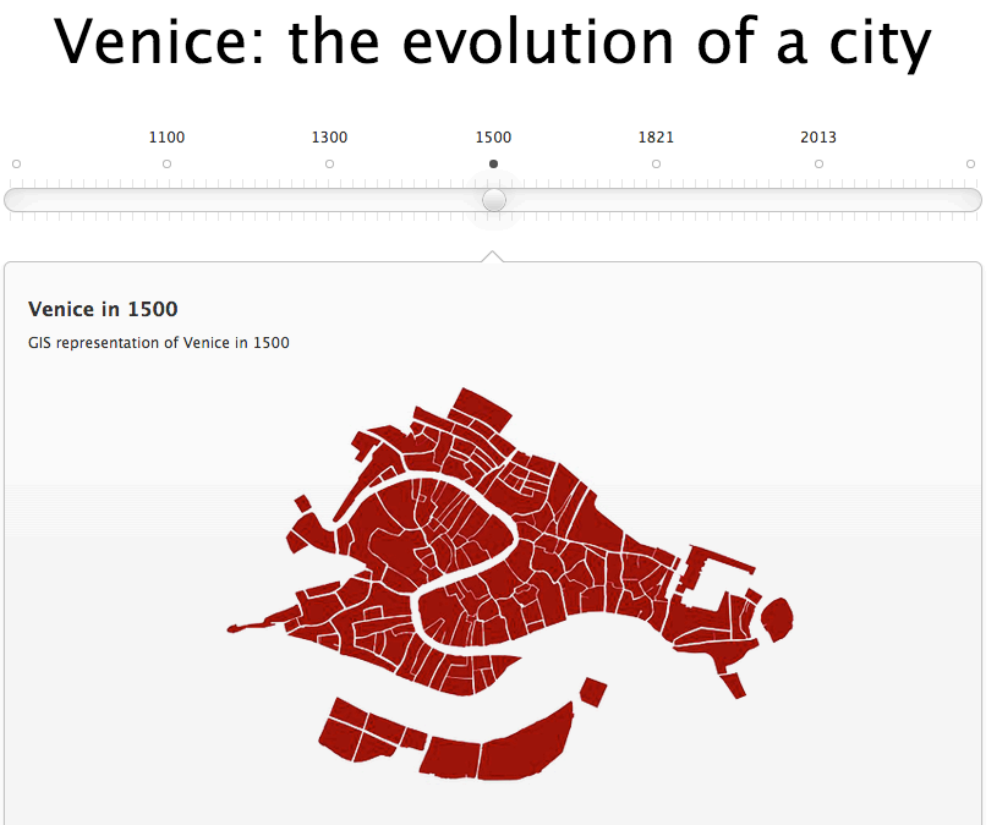


Figure 22: GIS evolution slider interface

Choosing the full evolution webpage will allow the user to see even more images of the city. Not only does this page include the GIS maps created by our team, but it also provides a selection of maps from our large database. Hence, the user can see how portrayals of the city changed as the land developed.

Figure 23: Full database evolution slider

The application is web-based but it also works well on mobile devices and tablets because the slider is touch-enabled, allowing users to scroll through on their touch-screen device.

6.2 Hidden Venice Application

Another application that we developed is the Hidden Venice application, designed for use especially on mobile phones and available at http://hidden.veniceprojectcenter.org. This application allows users to view churches that no longer exist in Venice. The application opens with a Google map of the city filled with markers. Choosing a marker will bring up an infobox with the name of a demolished church as well as an image.

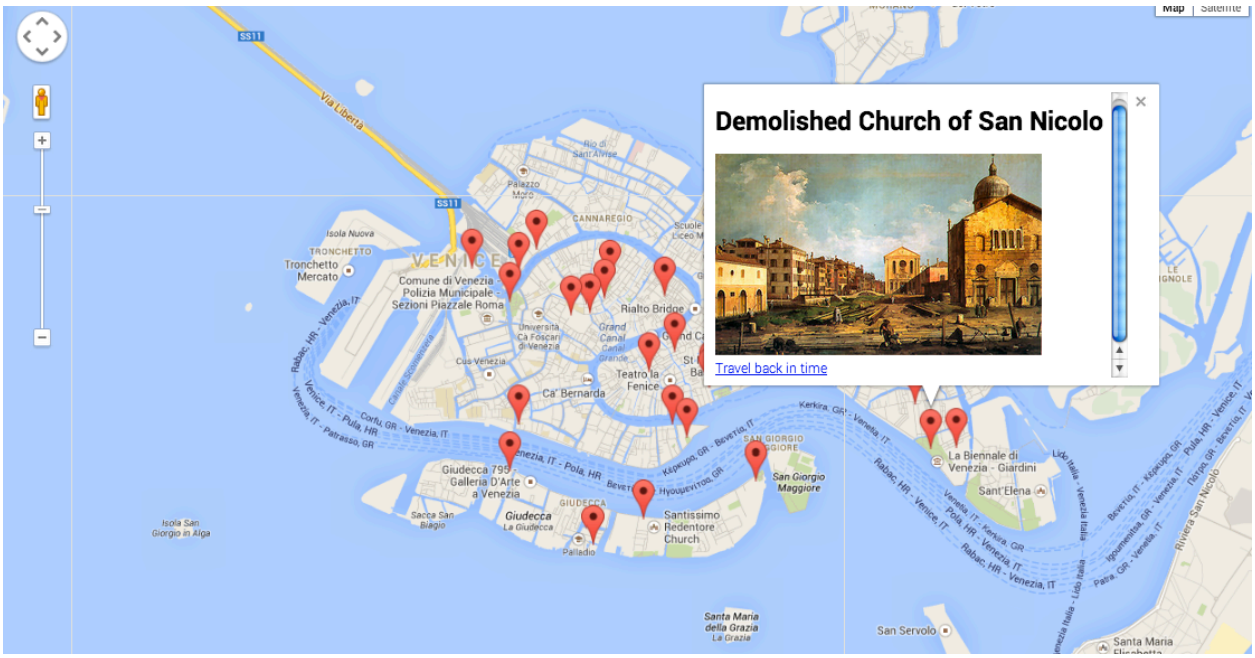


Figure 24: Hidden Venice application

Figure 25: Using the Hidden Venice app

When viewed on a mobile phone, users can select "Take me back in time" and allow the application to access their camera. Then, the application will overlay the image of the demolished church with the scene visible through the mobile device's camera. Essentially, this allows the user to view the past through the convenient screen of their mobile phone.

6.3 Recommendations

While both of these applications are very exciting ways to visualize the evolution of the city of Venice, there is still a large amount of work that could be done on them.

The evolution webpages could be expanded by adding more maps and images. In particular, some of our research took us back as far as 600AD; however, we did not have time or enough resources to create a GIS map that went beyond the year 1100. Future projects should consider creating such a map so as to allow users to see even further back into time.

The Hidden Venice application has several features that would be interesting if they were added. Firstly, the images of the demolished churches could be linked to the Venipedia pages for each entry, which would allow users to easily access more information. Another feature that we considered adding but did not have time to implement was the addition of location-specific information. For instance, we considered the addition of a pointer on the map that indicated the location of the user so that users could more easily find points of interest nearby to them. Unfortunately, the GPS technology in Venice is not especially accurate, so this would prove to be rather difficult. In addition, future teams should consider creating a guide for the user to line himself or herself up with the location. As the churches are demolished, it can be difficult to line up the image on the phone with the one on the camera. Accessing the gyroscope and compass in the phone and directing the user which way to orient him or herself would be a great addition to the application.

Finally, future teams may want to consider adding other aspects to the Hidden Venice application beyond demolished churches. Some examples that we considered were rii tera and archaeological sites.

Bibliography

Baker, Christopher; Brache, Jose; Dakin, Samantha; Saracel, Cem. *Evolution of a Forma Urbis. WPI IQP Report 2004*

Dorigo, Wladimiro. , 2003. Venice Romanesque: the formation of the medieval town until the age Gothic . Venice: Venetian Institute of Sciences, Letters and Arts

Hamilton, Donny Leon. *Basic methods of conserving underwater archaeological material culture.* Washington, D.C.: U.S. Dept. of Defense, Legacy Resource Management Program, 1996.

Harley, J. B., and David Woodward. *The history of cartography*. Chicago: University of Chicago Press, 1987-2003.

McGowan, Nicola; Niella, Reinaldo; Schrappe, Pierre; Smith, Jennifer. *Lagoon Archaeology.* WPI IQP Report 1991

Schulz, Juergen. *Jacopo dé Barbari's view of Venice: map making, city views, and moralized geography before the year 1500*. New York: College Art Association of America, 1978.

Tassini, Giuseppe. "Edifici di Venezia: distrutti o volti ad uso diverso" Filippi Editore. Venice.

Wynn, Jeffrey C.. "A Review Of Geophysical Methods Used In Archaeology." *Geoarchaeology* 1, no. 3 (1986): 245-257.

Zorzi, Alvise. "Venezia Scomparsa" Mondadori. Venice. 2001.

Appendices

Appendix A: Scanning additional maps

Unfortunately, the Venice Project Center's collection of map images is quite lacking. Non-free and unsourced images exist throughout the web, but are unsuitable for Venipedia. However, the project center does have books containing reproductions of many of the maps in our data set.

We were not able to scan these images during this project, but they can be added later. The naming convention "Author Year" for the file names of our images. These scans can then be added to the collection of existing scans in possession, which is contained in the data set produced with this project.

These scans will then have to be reuploaded and remerged to the City Knowledge console. The existing data can be found on the project center console account, under "groups shared with me" and "jfchines@wpi.edu". Edit the data in the "Historical Map Data" group to contain the filename on the "image" field of the new scans. Edit the "bibliography" field with the image source if it not already there. For many, the bibliography already contains sources that the map images can be scanned from. The "Historical Maps Media" group needs to then be destroyed and reuploaded. Next merge the "Data" and "Media" groups using the "image" and "filename" fields respectively. This will create a new set of merged data. Then copy over the wiki template from the original merged group to the new one. At this point, then old data group can be destroyed and the new one can be used to regenerate the wiki pages. It is very important to migrate the wiki template. If it is lost, a copy of it as it exists at the end of this project has been included with the project data.

Appendix B: Coloring the de'Barbari map

Highlighting landmarks on the map is not a trivial task, so a system has been put in place for people to contribute. A user account system exists for people to create accounts and contribute data. By logging into the special VPC account using the venice.wpi@gmail.com credentials, users can make additions to the map that will appear for all users of the site. The VPC account contains the data everyone sees.

Once logged in, a new item appears in the toolbar: a pencil. This is a tool for highlighting new features on the map. Users place points around the item to be highlighted, forming a polygon around it. Once all desired points are placed, clicking the original point again brings up a window for entering information about the new landmark. Users can are required to add a name, type (such as

"Demolished Church" or "Convent") to the item. Optionally, a link to additional information, such as a Venipedia page, can be added. If the user does not want to save the highlight he or she created, the discard button will discard the information. Otherwise, the save button will save the information in a database and the search and layers will be updated accordingly.

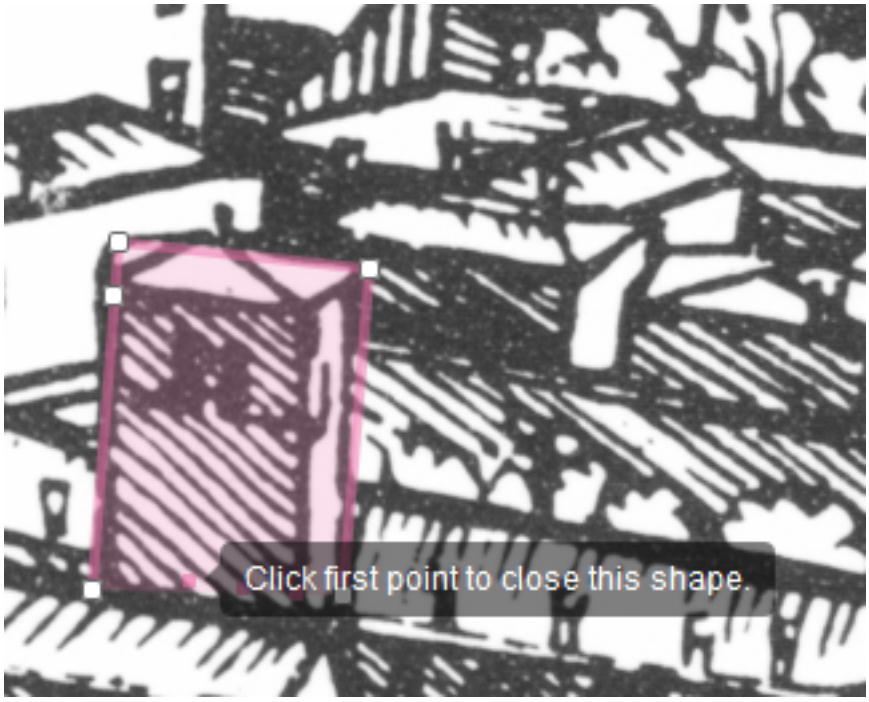


Figure 26: Adding new features to the map is made easy by an interactive tool

It may be useful to add additional layers in the future, so an option for this exists once logged in. In the layers menu, the bottom option will become "New Layer". Clicking this will open a window in which a new layer can be created. It needs a name, an identification string, and a color. Once the layer is created, there will be no data in it, but it will appear in the layers menu. Users can then start adding highlighted features to the new layer.

Appendix C: Major technical notes about the de'Barbari Explorer

This appendix will focus on major technical details of how the site was implemented. This will hopefully provide useful base information for future teams if they want to edit the de'Barbari map.

To serve the map image itself, the map was split into thousands of tiles taken at different view levels. This was accomplished using the program gdal2tiles.py. The original map files can be

found in the VPC data section of the VPC Google Drive account. These files are very large (over 2GB in size), and are very difficult to work with.

The site itself is mainly powered by Leaflet. The tiles are loaded from the images as the users pan and zoom. The layers are stored as vector polygons that outline each of the items on the map. All data, including the names of all the features, their types, and their highlighting information, is stored in a Firebase on the VPC account.

The data is stored in GeoJSON objects. The polygons are stored as points in the geometry field. Note that the points in the GeoJSON object are in opposite order that leaflet uses. All other details are stored in the properties field of the object.

To accomplish the image downloading, a special trick is used. All of the images exist as tiles, so they need to be pieced together in order to do this. This is accomplished by rendering the image elements to a canvas element and extracting the data URI from the canvas. This is often quite slow, so it may be better to move the image joining to a server one day. This will also allow downloading of extremely large high quality sections, rather than is just what is seen on the screen.

Appendix D: Venice Romanesque manuscripts

The Venice Romanesque book uses a complicated numbering system linking reference documents to the focused maps. This numbering system can be broken down by examining the aerial number given to sections of the map along with the classification. In order to properly link the data to the map that was produced the team translated multiple reference documents. These documents were then examined and using the descriptions from the documents they were assigned to their respective locations on the map.

When the reference document was unclear concerning the dissertation between separate private buildings the ownership was looked at along with the description of the building. This description was then examined with the reference documents from the 1300 to identify each building. In the odd case that the 1300's reference documents did not have the required information, the de' Barbari map was referenced. This was done as a final option, examining the architecture of buildings in question and comparing them to possible descriptions in order to identify the buildings.