CREATING STORY MAPS FOR LEARNING PURPOSES: THE BLACK DEATH ATLAS

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Abstract
In the current technological context new forms of mapmaking emerge. An increasingly common one produces story maps, maps that are shown with synchronized explanatory text, to visualize events in a spatial context. Story maps could be defined as the explicit display of such spatial and temporal landmarks on the grounds that a story is constructed. In this paper we present a story map oriented to pedagogical purposes. We have compiled an atlas displaying the expansion of the Black Death in Europe between 1346 and 1347, when the largest epidemic outbreak in the History of Europe ravaged the continent. To depict this event, we have used CartoDB, Odyssey and some other Web interactive tools to create eight interactive story maps gathered in an online atlas. The work was made in the frame of an end-of-degree Project (Geomatics Engineering, in Universidad Politécnica de Madrid). By now, it can be found in:
http://clarar92.wix.com/atlasdelapestenegra

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INTRODUCTION

The interactive maps and atlases are a valuable pedagogical resource for history and geography classes and their effectiveness has been studied since the nineties (Linn 1997). Back in year 1992, only at the ICA National and Regional Atlases Commission meeting eight different electronic atlases were demonstrated (Rystedt 1995). Ever since, interactive maps and atlases have flourished to explore territories, time lines and other aspects about a study topic (Neumann 2008) built through the available technology at the time. Currently, Web related tools are influencing the educational resources that make use of interactive maps and Web mapping features, and story mapping possibilities are starting to be explored. Amongst other peculiarities, story mapping technologies allow integrating maps, in a fluent and natural way, within a temporalized narrative estructure to be displayed in the Web browser. Thus, story maps offer new possibilities to communicate events in which the spatial component plays a key role –historic, social, environmental, etc. and might bring a new type of educational resources, in which cartographers and map designers have an important contribution to make.

In this work, we elaborate an educational resource on the Black Death of 1348 using both story mapping and Web mapping tools. Specifically Odyssey library and CartoDB technology have been used to produce a series of eight interactive maps, gathered in a Web atlas format. Each map is explored in stages or frames, being each frame displayed with a short explanation visible on screen, at a time. This way the corresponding story to one specific map is divided in sequences, which unfold either sequentially or controlled by user's interaction. The design of the atlas presented in this work was done in the context of an end-of-degree project in Universidad Politécnica de Madrid.

BACKGROUND

During 1347 y 1348 in Western Europe the Black Death, an epidemic of high mortality, began to spread rapidly. This misfortune left the population in distress, as it involved the death of 25% to 50% of the European population. The dramatic demographic decline affected many aspects of the 14th Century society (social, political, cultural and so on) and played an important role in the transition process from feudalism to capitalism. The Black Death is in fact regarded as a turning point marking the transitional period between the Middle and the Modern Ages. (Benedictow 2011)

Multiple books and publications can be found on the Black Death of 1348. Entering the term "Black Death" in Google, it yields 29 million results, some taking up the subject in a wide perspective, others providing specific approaches –like the economic, the medical or regional, e.g. (Sloan 1981, Raoult, Aboudharam et al. 2000, Hatcher 1977). Searching in Google Scholar, almost 3.5 millions results appear. However, regarding cartographic documentation on the subject a different situation is found. The available mapping corpus in the matter is not abundant and it appears scattered, as expected, normally diluted in books of History. For example Ole J. Benedictow's book, a reputed text on the Black Death (first published in 2004, although we have managed the Spanish Edition of 2011), only contains 10 maps throughout its 522 pages, all of them small and simple, with just one map in colour. Of course, these maps are drawn under the expected accuracy of data rooted in remote times and compiled by the means of secondary sources of information, as there were not censuses at the time –neither population censuses nor any other kind. Historians must deal with sparse, rather mixed, non-homogeneous and non-consistent data. In all events, data on the subject are available and many times they can be linked to the territory; our proposal involves using Web mapping tools for visualizing these data in a spatial manner and using story mapping tools in order to design an interactive study tool on the subject of the Black Death.

WEB MAPPING TOOLS

It has taken about two decades to reach the current available variety of technologies for publishing Web maps. Twenty years ago, the first Internet maps were deployed on the screen static, almost as paper maps, using image formats like tiff and gif, and later jpg and pdf. In a second stage, Web maps allowed the user to make requests to the map through the Web browser. Theses requests would be solved in the Web server by accessing a Geographic Information System (GIS), which would generate the map on the fly before displaying it on the screen. These maps are still static, and their dynamism depends on the data bases associated to the remote information system. The introduction of expanded interactivity added via scripting to the Web client, characterises the third stage of the evolution of Web mapping. Some requests are solved in the Web client, with no need of a Web server (Peng, Tsou 2003). The current stage of Web mapping involves the use of GIS services in which the different components on the client side can directly communicate with the GIS hosted in a remote server without using any http server. For creating maps with this technology, many tools are available.

For a general public the most popular Web mapping tool well may be Google Maps, but there exist many more and users begin to be acquainted with names like CartoDB, MangoMap or Arcgis Online, for example. In 2015, Roth et al. compared 35 different available Web mapping tools focusing on four different aspects; base map, representation techniques, interaction possibilities and mobility (Roth, Donohue et al. 2015). Additionally, these Web mapping tools are now being supplemented with new utilities. Our interest is centered on those technologies that allow the coupling of Web maps with articulated discourses for describing specific subjects linked to the spatial dimension. They are known as story mapping tools, named after storytelling, with which we can describe occurrences and stories using Web maps.

STORY MAPPING

Story mapping combines interactive maps with other contents –text, photographs, video, audio and so on, organizing and presenting all these resources threaded around a speech describing an occurrence, for ultimately narrate and broadcast a story. Stories are useful for many reasons, including their pedagogical capability. As valuable lessons, stories may recall memories, touch the emotions and eventually they may lead to action. Many stories are strongly linked to the spatial component and frequently, the places defining the context in which the action happens play a major role in the story. Different media (like scientific reports, journalism or education) make use of maps and cartography in order to anchor to the spatial dimension the agents and events involved in the explanation of a fact, an occurrence or a story.

Back in the Middle Ages, even the major works of medieval cartography could be considered good medieval story mapping samples: The one in the Hereford Cathedral, the largest medieval map known to exist, and the one in the Ebstorf Cathedral. The symbolism of these magnificent disc-shaped medieval mappaemundi is a blend of the historical and the geographical, condensing the telling of the Holy Scriptures (Harley, Woodward 1987). It seems that

pedagogical and indoctrination purposes were already making use of graphic narrative with a gaze to the geographic space. In those motionless images, making chronologies explicit was still a problem though.

Today, the means to support a clear narrative discourse with cartographic documents can be found in story mapping tools. They can be accessed online and used to deploy, in a desired sequence and at appropriate times, the visualisation of diverse contents related to a specific story –basically maps, texts, images, data and sounds. Additionally, they offer interactivity and let the users take action in the narrative flow as they provide controls to make stop-and-go and forward-backwards movements. They also let the user intervene in the visualisation of the maps modifying frames and zoom levels, and activating and deactivating information categories or layers. Although story maps can also incorporate analytic functions, they have not been conceived with that purpose more related to the geographic information systems (GIS). They just make use of GIS functions to get the results to offer to users with no specific technological skills (Esri España, Year unknown). While undoubtedly they can be useful for specialist audiences, story maps seem to be designed usually for a general public.

So far, story maps usually target a varied public taking a journalistic approach in an issue. The digital journalism gives many examples: "How DC residents get to work", by The Washington DC Economic Partnership WDCEP; "The Uprooted" on Syrian refugees' crisis, and "Zika Virus: 1947 to 2016", about the expansion of this outbreak, both by Esri Story Map Team. While there are fewer such examples, story maps can also target more specific audiences. "Health Map", an initiative from Boston Children's Hospital, visualises emerging infectious diseases, and it is addressed "to local health departments, governments, and international travellers" (http://www.healthmap.org/). "Where On Mars?" (European Space Astronomy Centre, 2015) utilizes Web mapping and story mapping to disseminate specific aspects of ExoMars 2018 project. They make a presentation of the criteria followed to select the candidate landing sites for their rover. Story maps are also being used to describe historical topics as well as to disseminate environmental knowledge –see The Amazonian Travels of Richard Evans Schultes, "On the Brink: The Sixth Great Extinction" (The Amazon Conservation Team 2016). Ultimately, there are many map-based storytelling references to use in this work, and just visiting the Esri and Odyssey story mapping galleries, offers a broad range of valuable examples.

BLACK DEATH IN MAPS

The expansion of the Black Death in Europe has been mapped more than once and many textbooks and History books contain cartographic illustrations of this event. Searching the words "black death map" in quotation marks, Google delivers 3680 general results displaying a good bunch of maps under the "images" category, these images normally linking to static maps. All these maps pursue a common goal, to describe the expansion of the epidemic (although only two images amongst the results of the quoted search "black death expansion" are maps). With regard to the search of interactive maps, the results are dramatically reduced. Typing quoted "Black Death Interactive Map" leads to only 141 links, less than ten, under the tag "images", showing maps. Typing "Interactive plague map" 275 results appear, and the very same ten map images set. Typing "Black Death"+Interactive+Map resolves 101,000 links but only fifty or so of the resulting images are maps. (Last search in April 2016.)

Focusing on the few existing examples of interactive maps on the Black Death, most of them are in Flash format. That is the case of "Black Death in Europe" an interactive presentation, published in a Web for online educational resources by McGraw-Hill and displayed under the banner of the National Geographic (Glencoe Online Learning Center and National Geographic, year unknown). This is a simple but effective map, with the only aim of describing the expansion. It shows the growing affected areas using multiple layers, organised by the plague affectation dates that the user can show and hide. An audio makes a presentation of the issue, although the speech is not connected to the map displayed. In the same repository of educational resources, another online map about the expansion can be accessed (Glencoe Online Learning Center 2016), featuring the anti-semitic riots of the 14th Century. Another worth mentioning example, also in Flash format, is found in the EDSITEment webpage –a compilation of educational websites "selected on the basis of educational excellence in the humanities and high-quality website design" (EDSITEment, year unknown). This map illustrates the Plague's expansion, and also describes visually its relation with the main commercial routes of the time. Although basic in its design, this map involves the users asking questions to make them connect the map's elements with the written text or story. The aforementioned resources are valuable references for the intended work as they design maps, presented with their corresponding text, on the same subject we are interested in, and using interactivity. However, being useful, they have limitations not only in the scope of the topic but also in the conception of both map design and the features of interaction. In addition, they consist in closed systems, with no dynamism, making it difficult the upgrading or the implementation of new modules. In this sense, we find more useful resources like "A Frightful Number! - Mapping Daniel Defoe's A Journal of the Plague Year" (Digital Research Centre, Hofstra University, year unkonwn). This map tracks the spread of the 1665 London plague, annotating the epidemic's progress, by month and by parish. It was created with *Itinerary*, a Web based mapping tool for humanities teaching and research by Hofstra's Digital Research Center. Even though, this map does not focus on the dates we are interested in. The same happens with another example found in Historic UK Magazine, also about the city of London in the same dates (1665-

1666), "The Reputed Plague Pits of London" (Historic UK, year unknown) which utilizes Google Maps for localizing the plague pits.

Apart from Web maps on the issue, downloadable tablet applications also exist. At least we found one, released by Time Maps Company (TimeMaps 2013), which uses story mapping techniques. (The application is available on itunes for 2.99$, April 2016.) It allows the user to move forward-backwards in a timeline, and to get the details of specific spots on the map. Its pedagogical aim is clear, as a questionnaire appears at the end of the explanation of the maps. However, as regards our interests, an important issue is found; its geographic visualization is very limited, for the whole visualization is based in one only map, always shown under a single frame and fixed zoom level.

DEFINING THE BLACK DEATH ATLAS

Motivation

As mentioned, the expansion of the Black Death in Europe has been the subject of many cartographic representations. However, there is no cartographic representation in the consulted texts about the important consequences of the disease in late medieval society and economy. For example, during the worst years of the Black Death (1346-1353) between a quarter and half of the European population died due to this disease (Benedictow 2011). This makes us wonder how evolved the population growth before, during and after these years. In addition, the disease, due to its high mortality rate, resulted in a reduction of the cultivated area in Europe and the dramatic drop in agricultural production. This fall became 40% in the north of Italy. Economically, the plague also affected to food prices and wages, and it impacted socially in the persecution of Jews during the period of the epidemic, as they were made responsible for spreading the disease poisoning wells. These issues, which relate to each other in the textbooks, are not found visually described in maps, less still gathered together. This absence seems logical, since it is not possible to obtain data about these topics with uniform precision to make complete maps.

The data sources

On the Black Death there exist much specialized literature, and gathering data and information is not a particularly difficult task. Information found in books and essays should be contrasted and evaluated accordingly. This task is beyond the scope of work though, since we are not doing research in the topic, but proposing new ways for its representation. It was therefore decided to choose a limited number of reliable and rigorous historical sources, and to indicate in each interactive map, the data source used for its elaboration.

Specifically, we used the following sources. Four textbooks on medieval history, one of them the mentioned book by Ole. J. Benedictow (Benedictow 2011). This document is a reliable source on the spread and mortality of the disease. Maps relating to population, economy and society drew on data obtained from essays on medieval history from (Benedictow 2011) and (García de Cortázar y Ruiz de Aguirre, J. A., Sesma Muñoz 1998), and the work of demographer Boris Urlanis (Urlanis 1941). We also used data from Paolo Malanima, researcher of historical economy who offers economic data from Italy and England (Malanima 2016); and data on food prices in Bruges published by historian Adriaan Verhulst (Verhulst, year unkown). Finally, we also employed information bulletins on current outbreaks of plague provided by WHO (World Health Organization 2016), and data from the Jewish Encyclopedia (Cyrus Adler, Gotthard Deutsch, Louis Ginzberg et al. 2011) was used for mapping the anti-semitic riots occurred during the plague. When the sources provided data in tabular form, they were directly used for map elaboration. This was the case of the maps related to population, agriculture, economy, mortality and society. In other cases, the tables had to be constructed with data extracted from documents and textbooks (the maps of the spreading of the disease and the map of commerce).

Story mapping to deal with the incompleteness of the data

Despite the abundant literature, the nature of the subject and its remoteness in time make the available data scarce and highly fragmented. Lots of empty spaces remain, as the data may be associated to geographically dispersed areas. Frequently, only data referred to specific locations can be found. Sometimes, the map to obtain will have more gaps or empty spaces than areas with information. In the Atlas, this happens in two maps, the anti-semitic riots and the prices maps. For the depiction of food prices, for example, we found data associated to just two locations, being spatially distant one from each other –Bruges and Tuscany. Nevertheless, the use of maps for visualizing this data, visually relating them to their locations and accepting the existing data-gaps, will be useful to bring spatial order in the mind of the person interested in the topic. In this sense, we think story mapping tools can be of great help when it comes to deal with the graphic presentation of fragmented and not complete datasets.

Story maps define a sequential scan of the map, guiding the user in this itinerary. The narration unfolds sequentially, synchronizing the explanation with specific states of the map –a proper frame and proper zoom level, with selected layers of information visible. Being chronology important, the time is also present by the use of a timeline slider. The timeline is also linked to the different frames of the map and may be used as an interactive control. For example, the anti-semitic riots map, starts framing the French Riviera and the Ligurian Sea. The first step forward, pans the map to the west, framing the Iberian Peninsula; the next interaction moves the map up to the North, framing France; the last one, stops in Germany. Each step has a small fragment of text narrating the related events.

This ability of changing the center of attention in line with all its corresponding components in just one click (text, layers, timeline and map acting synchronously) can be used to overcome the aforementioned difficulties with data. Data from different sources, with different accuracies, related to different dates, and even data of different nature, can be gathered under one only story mapping. This is possible because each representation is explained in the accompanying text, creating an appropriate context for the presentation of each data set. The frames and states of the map-and-text defined for the story map, along with the users' personal clicks and movements to explore the Web map, work together to help mentally organizing the events and data related to the described events.

Like any other atlas, the Atlas of the Black Death brings together various resources (text, graphics, images...) including maps. The techniques used for representation are diverse, mainly presence locators, coropleths and proportional symbols. The choice of one or the other depends on the subject to represent.

In conclusion, story mapping is useful for mapping historical phenomena in which there are no homogeneous data, complete or with the same precision. It allows us to make useful spatial visualizations and to help organize the user's mind by guiding him to concrete scales and frames, accompanying with explanations each of these events.

The content of the maps

Eight maps, presenting the causes and consequences of the Black Death's spreading across Europe, compose the Black Death atlas. In this section we present the content and the information sources used for each map.

Black Death spreading across Europe (M1): This map highlights among others as it represents the main focus of research, the expansion of the Black Death in Europe. The presentation is based in the animated emergence of point locators in the corresponding cities to reflect the direction and chronology of the spread of the disease. It also presents the registered number of deaths. These data come from the book of Benedictow (Benedictow 2011), and were recovered by the author by searching in death records.

Commerce in the Late Middle Age and its impact on the spread of the epidemic (M2): This map presents the main European trade routes during the 14th Century, from the book of Cortázar and Sesma Muñoz (García de Cortázar y Ruiz de Aguirre, J. A., Sesma Muñoz 1998), plus the cities and main commercial areas of the era. Major navigable rivers, used for transportation of goods, were also included. This map intends that the reader establishes any causal link between the flow of people through trade routes linking Asia and Europe and the expansion of the Black Death. Additional information on the most important materials for trading in each city is provided.

Evolution of the population during the Late Middle Age: the rebirth of cities (M3): This map describes the evolution of the population density in Europe, by country and region, every fifty years from 1250 to 1450. It shows the slow growth of the European population from 1250 to 1350, which experienced a sharp decline caused by the Black Death and other causes (explained on maps), and its subsequent slow recovery until 1450. This variation was calculated from population data by countries and regions from 1000 to 1500, present in (Urlanis 1941).

Mortality during the epidemic period (M4): This map shows the rate of mortality organized by three orders of territorial distribution, in the English, French and Italian regions. Within each region, data is visualized by counties, provinces, districts and communes, depending on the country. Other factors that influence the spread of disease, and the death rate, are also described: climate and population density. The information displayed is extracted from (Benedictow 2011).

Crops: Wheat yields in England between 1347 and 1351 (M5): This map shows the yields of wheat in the 1347-1351 period in some English counties with available data, which come from the database "Three centuries of English crops yields 1211-1491" (Campbell 2007). Being wheat the main food that sustained Late Medieval European population, it is possible to assess the impact of the epidemic in the abandonment and later recovery of wheat harvests produced during the years in which the epidemic ravaged the British Isles.

Economy: Prices, wages and currency values (M6): This map shows the evolution of food prices (wheat, butter, rye, barley, oats and cheese) in Bruges before, during and after the epidemic; rural and urban average wages of population in Italian Tuscany during the plague; changes in the value of the Florentine lira during the epidemic; and the evolution of

value of the English penny, to show how they were affected by the epidemic. For this map data from Paolo Malanima have been used (Malanima 2016), and the food prices table from AdriaanVerhulst's website (Verhulst, year unkown).

Social consequences: The persecution of the Jews (M7): One consequence of the epidemic, due to religious fanaticism of the time, was the persecution of the Jewish people. This map focuses on Spain and Germany, showing, on one hand, the regions who had Jewish communities, with additional information such the number of Jews families that populated a city. On the other hand, it is presented a record of the persecution of Jews during the period from 1347 to 1351 with information about the massacres recorded and the number of victims. The data have been extracted from (Cyrus Adler, Gotthard Deutsch, Louis Ginzberg et al. 2011) and (Vives 1972).

The Black Death today (M8): The latter map records the current outbreaks caused by the Black Death disease. Since the epidemics of the 17th Century in Seville, London, Vienna and Italy, until the outbreak of the last decades, produced mainly in Africa. The data provided are the places of transmission, the date of the outbreak, the estimated number of infections and deaths. The source consulted in this case has been the site of the World Health Organization (World Health Organization 2016).

Figure 1. Commerce (top) and mortality (bottom) in the Late Middle Age

MAP IMPLEMENTATION

The implemented atlas contains one base map and eight interactive maps. In this section we explain the tools used for the preparation of these maps, applying filters, customizing styles, providing different modes of interaction with the map and displaying historical information and data associated with the phenomena represented.

Implementation requirements and employed tools

Story mapping allows displaying various resources and enables some interactivity and user intervention in the narrative flow. This intervention is materialized by the actuation on the timeline, activation and deactivation of categories of

information and finally, navigation by specific map areas, obtaining additional information from the phenomena represented. To meet these requirements we need to analyze and incorporate certain tools.

In relation with the provision of geographic information and representation of geometries we must have a geospatial database available on the Web. We chose *CartoDB* tool for this purpose (https://cartodb.com). CartoDB is a geospatial database (PostGIS) in the cloud with features for Web display. CartoDB editor enables the addition and load of geospatial data in the browser (in formats such as CSV, ESRI shapefiles, etc.), and has a console to perform database queries to PostGIS, allowing to modify the stored data and display data changes on the map in real time. Through this editor it is possible to create views of real-time maps, customizing styles, legends and symbols through CartoCSS, a CSS-based language for style definition.

To support the thematic phenomena a base map is designed by *MapBox Studio* tool (https://www.mapbox.com/mapbox-studio/). MapBox Studio is a MapBox *add-on* to create maps from scratch or customize existing maps using CartoCSS. In this case the base map is configured to make it consistent with the topics to represent, with administrative elements, roads, hydrography and terrain shading.

Regarding the provision of narrative flow in the story map, *Odyssey.js* was used (https://cartodb.github.io/odyssey.js/). Odyssey is an open-source tool that can be integrated in any Web page, and enables combining maps, narratives, and other multimedia into an interactive story. This tool facilitates creating new stories, enhancing the narrative and multimedia by using Actions (e.g. map movements, video and sound control, or the display or new contents). Templates are used to control the overall look and feel of the story in predefined layouts.

Related to the provision of interactivity on the map, the navigation controls have been implemented using the *Leaflet* library (http://leafletjs.com/). This small size and high performance library is used for Javascript development of interactive maps. Leaflet allows the introduction of navigation controls to the map, such as zoom buttons, attribution, layer switcher and scale. Maps created with Leaflet can be displayed properly on mobile devices.

Other animations considered for the development of interactive maps have been implemented using the *Torque* library (https://github.com/CartoDB/torque/) which is used in CartoDB for the representation of multidimensional data with geospatial coordinates based on the Tile Map Service Specification from OSGeo foundation (http://wiki.osgeo.org/wiki/Tile_Map_Service_Specification/). Torque is used to render big, time series or categorical data in the client. This is useful for providing dynamic maps representing human movement, social network activity, biodiversity data, and other large-scale datasets.

Finally, a Web page in HTML5, Javascript and CSS is implemented for the publication of the atlas. This Web resource links maps and provides an overview of the atlas: an introduction to the theme of the atlas, a presentation of maps, a collection of images, information of authorship and bibliography. The website was created based on a template provided by *WIX.com*. Website content was published in *neocities.org*, a free Web hosting service.

Implementation strategies

Selected tools allow the development of mechanisms for interaction with users through three different levels: the animation plane, the symbology plane and the data plane.

Animation plane: It collects the techniques to give dynamism to the map, promoting interactivity and user intervention in the narrative flow. Using the Torque library, three animation models can be selected:

- Slides: Displays the visualization chapters like slides in a presentation. Once a slide is changed, the map is moved to the location of the following event.

- Scroll: The visualization is transitioned to a new window when the reader moves through the narrative.

- Torque: Story elements are linked to moments using an animated map template based on CartoDB's torque functionality.

In most cases, the slide template was chosen, giving more prominence to the map and displaying the text as a supplement. In other cases, the Torque animation was used, which offers some interesting options for maps showing evolution or directions. For maps representing very close points, such as the Black Death spreading across Europe, we have defined the option to accumulate the points, so that the visualization of overlapped points is highlighted, and the spreading of the disease across the continent is easily observed. We have also defined the option to represent buffers around points. This technique makes the map visualization more attractive, but buffer intensity must be moderate to avoid distracting the user with the effect.

The Torque technique has the disadvantage that it does not allow the deployment of information windows. Torque-based maps have been complemented with an auxiliary Slide-based map for infowindow and tooltip representation.

Symbology plane: Integrates any technique for visual representation of geographic information, considering the representation of geometries, application of styles (colors, line weights, opacity, size of symbols, etc.) and interpolation.

Concerning the choice of color for the presentation of geometries, representative colors were chosen depending on the information. For example, black for the disease, blue for Jewish communities and red to describe tragic events. The thickness of these lines depends on the importance of information, setting a thickness of two points for overlays and one point for information from the base map.

Point opacity was set at 0.3 of 1.0, so that points can overlap (establishing an appropriate size for them) and provide a greater sense of intensity in areas where more points are accumulated.

Display of labels was activated, showing the name of places, usually cities and regions. A zoom limit was established for the visualization of these labels so that these names do not overlap at low zoom levels.

As for the symbolism, different symbols to represent specific locations were used when those places contain additional information, such as in the case of Jewish communities, in which date of establishment and estimated population were available. Choropleths and proportional symbols were used to classify different zones according to some criteria. For choropleth maps, color ramps in brown and red tones were used for positive variations and blue tones for negative ones. Color Brewer tool (http://colorbrewer2.org/) was used for selecting colors. For the utilization of proportional symbols a minimum radius was assigned to minimum data values, and an interpolation was generated towards the maximum data value. Colors were chosen trying to not to interfere with the rest of the layers.

Finally, for the design of the base map, as discussed in the previous section, the MapBox Studio tool was used using CartoCSS. Administrative units, roads, hydrography and terrain shading were considered. The color of the sea *(#water fill-color)* and ground were changed to gray shades, and administrative divisions were reduced to only counties or higher (*#admin_country admin-level=2*), sufficient for the purpose of the atlas. The road network (*#road_major*) remained, although with low contrast, as many current roads were placed over old roads of the time of the spreading. Representation of the relief, by shades (*#hillshade*) also remained. They were defined specific ranges of zoom for displaying the different elements of the terrain (*#place_label zoom_min, zoom_max*), including place names. In this regard we must highlight the fact that place names are separated from the base map, so that they can be displayed above vector data (this feature is not supported by many analyzed story maps).

Data plane: Integrates the presentation of data inside and outside the map, the use of place names and functions for querying additional information about a geographical phenomenon through infowindows. Geometry of countries was retrieved from Eurostat website. These data were transformed by processes of dissolution and fusion with ESRI® ArcGIS tool.

Place names (sources of infection, commercial and most populated cities, Jewish communities or where Jews were persecuted) were geocoded through the Batchgeocoding tool, which offered better performance than the geocoding tool provided by CartoDB. Commercial routes were digitalized with data from the book of Cortázar and Sesma Muñoz (García de Cortázar y Ruiz de Aguirre, J. A., Sesma Muñoz 1998), using ArcGIS for map creation at scale 1:4000000.

We present Table 1, mentioning the implementation decisions on each map, divided by the three explained implementation planes. Fig. 1 contains two screenshots from two representative maps.

Table 1. Implementation decision for each story map

Map ID	Animation	Symbology	Data
M1	- Torque-based to see direction of spreading, cumulative data for disease spreading. - Zoom and pan controls.	- Points used to avoid unknown zonal representation. - Point transparency to reflect density by color intensity. Use of buffers in points.	- Presence of legend. - Supplementary map for tooltip deployment on mouse over.
M2	- Slide-based - Zoom and pan controls - Use of photos in animation	- Lines and points - Dull colors for elements from base map (rivers). - Vivid colors and thick lines for commercial routes.	- Multi-thematic legend. - Infowindows for representing data in routes - Tooltips for city names.

M3	- Slide-based - Zoom and pan controls. - Dynamic change of symbology	- Polygons - Proportional symbols and coropleths	- Relative values of density between slides. - Supplementary map for tooltip deployment and legend.
M4	- Slide-based - Zoom and pan controls	- Zonal representation with coropleths	- Supplementary map for tooltip deployment and legend.
M5	- Slide-based - Zoom and pan controls - Layer selector and search functionality	- Polygons - Zonal representation with coropleths	- Average calculation in crop yield performance. - Supplementary map for tooltip deployment on mouse over.
M6	- Slide-based - Zoom and pan controls	- Combination of points and polygons	- Use of interactive charts for food and currency value evolution.
M7	- Slide-based - Zoom and pan controls	- Different symbolization for the two datasets (blue and red tones)	- Legends - Tooltip deployment on mouse over.
M8	- Slide-based - Zoom and pan controls - Use of photos in animation	- Points used to avoid unknown zonal representation. - Proportional symbols	- Legends - Infowindow deployment on mouse click

CONCLUSIONS

History maps are a good pedagogical resource for teaching. In this work we present a study tool based on story mapping for a better comprehension of the Black Death disease. The aim of this work is the proposal of an atlas displaying the spatial expansion of the Black Death in Europe during the first half of the 14th Century, along with other resources to better understand the causes and consequences of this plague in Europe. By using emerging Web technologies such as CartoDB and Odyssey we can create an exploration sequence through time and space, complementing map navigation with historic information and other interactive tools such as tooltips, charts and other pictures.

Particularly, we have created an atlas created by eight interactive maps, considering the animation, symbology and data planes, providing on each map the features and controls needed for proper exploration. Finally, we present a table mentioning the implementation decisions on each map and some screenshots of the most representative ones.

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