Understanding Map Design in the Context of a Massive Open Online Course in Cartography

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Abstract. In this paper, we report on the analysis of more than one thousand maps created in *Maps and the Geospatial Revolution*, a Massive Open Online Course (MOOC) offered by the Pennsylvania State University (led by the second author). This course was developed in the context of recent advancements in spatial data collection, geographic information systems, and interactive mapping technologies. More maps are viewed, created, and used than ever before. However, the uninformed or misuse of spatial data and maps has implications for everything for which place matters. Mapping software, its popularity, and ease of use influences map aesthetics and design processes. We analyze how the interfaces and tools of spatial media authoring software are shaping the current cartographic state-of-the-art (and science). Our analysis offers a unique evaluation approach to large map collections, assesses the extent to which students integrate theoretical cartographic concepts with current mapping software, and can help guide future educators to design non-traditional cartographic learning environments and course content relevant to global cartographic aesthetics and demand.

Keywords: map design, massive open online course (MOOC), cartographic education, software studies, peer assessment

1. Introduction to the Geospatial Revolution

Advancements in spatial data collection, geographic information systems, and interactive mapping technologies via personal computers and mobile devices have revolutionized the ways in which we interact with, and make sense of, spatial information. More maps are viewed, created, and used than ever before. Google Maps, for example, is visited as many as 1 billion times a day (Chivers 2013). As of October 2014, about two million websites were embedding Google Maps, 38,856 embedding Bing Maps, and smaller mapping platforms such as MapBox, OpenStreetMap, and Esri ArcGIS were being deployed with increasing frequency (BuiltWith 2014). These statistics help illustrate this geospatial revolution, but do not capture the increasing number of static maps also created using both commercial and open-source mapping software as a result of advancing spatial awareness and user-friendly mapping technologies.

Traditional cartographic education cannot reach all of today's mapmakers and consumers; however, it is more important now than ever. A core objective in the ICA-organized International Map Year of 2015 is to educate society on the proper use of geographic information, and to ensure "that every global inhabitant has access to maps and to geographic information, and that maps and geographic information can be easily retrieved and used" (Fairbairn 2014, 19). The uninformed or misuse of spatial data and maps has implications for everything for which place matters.

In this paper, we explore how mapping software, its popularity, and ease of use is influencing map aesthetics and map design processes. To do so, we analyze over one thousand student-created map submissions from the 2014 offering of *Maps and the Geospatial Revolution*, a Massive Open Online Course (MOOC) offered by the Pennsylvania State University (led by the second author). Student map submissions are assessed and visualized based on the software used to create them, and on their visual characteristics to reveal current cartographic practices and trends.

2. Role of Education and Software in Map Design

Distance education approaches, including MOOCs, provide opportunities to engage large and diverse learner cohorts. The *Maps* MOOC has been offered twice, with a third offering scheduled for 2015. Over 75,000 students have enrolled in the course from 200 countries. In the *Maps* MOOC, students learn the fundamentals of geospatial technology and cartographic design; discuss topics like locational privacy and why "spatial is special"; and learn to make and share maps with each other. A major challenge in asynchronous, non-traditional cartographic learning environments is avoiding the trap of designing course materials and activities based on constantly changing mapping technologies (Robinson et al. 2014). The course adapts to this challenge by focusing the majority of content on cartographic theory and current events, leaving the smallest fraction to software-driven labs. In the final week of this MOOC, students are tasked with making original maps to tell stories. They are given *cartographic license* to map any topic using any data and tools. For most students in the course, this exercise represents the first time they have ever been given the charge to develop their own original map design.

The tools and software students choose to use for conveying their spatial stories affect the resulting map aesthetics and design. The persistent over- and misuse of the Web Mercator projection in online mapping environments, largely attributed to Google Maps, is an extreme example. Map designers have no choice but to use the suboptimal map projection, oftentimes completely inappropriate for the data and geographic area being mapped, and inconsiderate of map purpose and reader (Battersby et al. 2014). Other examples of how software might influence cartographic design processes include: default layout views (i.e., how and where are spatial data initially represented in the user interface), placement of options (e.g., are there tool panels, dropdown menus, or both), option availability (e.g., which thematic map types are supported), option documentation (e.g., is there an explanation on when to use choropleth maps as compared to proportional symbol maps), and ease of map customization (e.g., is spatial data representation modifiable using Boolean logic, interactive feature selection, etc.). These and other aspects of the interfaces and tools of spatial media authoring software contribute to the shaping of the current cartographic state-of-the-art (and science).

Despite having knowledge on the fundamental principles of cartographic representation, cartographers – beginners and experts alike – typically choose their mapping software and tools based on ease of use, familiarity, and popularity. Software studies is an emerging, interdisciplinary field of research that integrates methods and theory from the digital humanities with computational perspectives on software to understand the role of technology in guiding, in this case, ever evolving cartographic practices (Manovich 2013). Below we present a case study exploration of these evolving cartographic trends by analyzing 1,243 original maps created by students of the second *Maps* MOOC, representing a sample of cartographers from all across the globe.

3. Map Design Analysis

In this section we first describe the attributes and format of students' final map submissions. We highlight some of the challenges in evaluating map design in the context of such a large and diverse learner cohort. Coding considerations and approaches to extracting visual characteristics from map images are detailed, and the section concludes with visualizations that capture "visual signatures" of both *global* (entire class) and *local* (individual student) map design decisions.

3.1. Assignment Structure

The *Maps* MOOC culminates with a final project assignment where students are asked to create an original map design that tells a story about spatial data. Students are given free rein to choose a topic of interest and to decide which tools they utilize to create and share their map. The vast majority of students taking the *Maps* MOOC are novices for whom this class represents the first time they have engaged with the mapping sciences. In the first four weeks of the this MOOC, students gain experience in manipulating and sharing maps using ArcGIS Online's free public account features, so this platform is by default the one they are most familiar with by the time they reach the final mapping activity. The final project instructions encourage students to try ArcGIS Online, Esri's StoryMaps tools, CartoDB, and QGIS as potential platforms in which they can create their original map.

Completed maps for this final project phase are submitted to a peer assessment tool provided by the Coursera platform. Peer assessments are used in courses of all sizes to support peer grading activities. They are commonly used in MOOCs when assignment grading must necessarily occur on an individualized basis, but there is no possible way for the instructor to conduct this kind of grading across thousands of submissions. In the *Maps* MOOC, students were assigned five map submissions at random to review using a standardized rubric to evaluate the quality, completeness, clarity, and map design dimensions for each submission. We report the results of this peer grading activity in Luo et al. (2014).

3.2. Data Collection and Description

Upon final map submission to the Coursera peer assessment tool, students were prompted to provide screen shots of their maps, brief descriptions of where/ what they mapped, and URL links to live maps (if interactive). Final submission map data are delivered in .html format. *Figure 1* illustrates a raw and complete submission. Along with the attributes requested from the students, submission and user identification numbers are also provided for each map record. To develop a corpus of maps to analyze, we extracted students' map images as .png files, and created a database to relate student identification numbers to their respective images. In many cases, however, submissions were incomplete. For example, many students neglected to upload screenshots of their maps, often providing only a link to their maps with no descriptive content. In these occurrences, we visited the links and manually extracted screenshots of the maps.

As indicated above, the peer assessment framework generates data from student evaluations of each submission, but this evaluation approach provides no collective insights on map design choices, overall aesthetics, or creation methods. Obtaining these insights for such a large swath of map images is challenging, because our ability to extract meaningful features from inconsistent and unstructured data is limited. Another challenge is deciding which features are worth manually coding, and which computational methods are relevant to apply to analyze the map images.

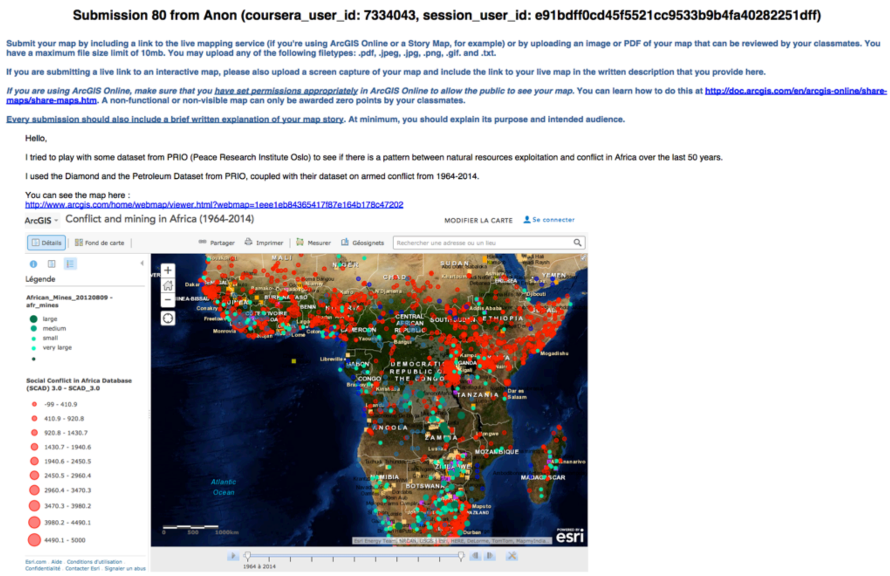

Figure 1. Example of a complete final map submission record.

3.3. Map Coding

To begin addressing the challenges discussed above, we first coded the software or tool used by the students to create their maps, and added the attribute to the map image database. This attribute reveals the scope of mediums being used to generate cartographic products across the globe; assesses the extent to which students are applying the tools taught in the MOOC to make maps; and can help guide future course offerings in selecting the most relevant tools to introduce students to. *Table 1* shows the seven key categories for classifying map types, and the distribution of maps submitted in each category.

Of the 1,243 maps in our corpus, 78% were interactive. Almost 91% of the interactive maps were created using some form of an ArcGIS Online mapping template, while the remaining 9% of interactive maps were created using CartoDB, Google Maps, Google Earth, and various others. We chose to merge the non-ArcGIS Online maps into a single “Interactive (other)” category, because of the large variety in interactive mapping tools that students applied.

Map Type	Count	Percent
ArcGIS Online (standard)	556	44.7
ArcGIS Online (story map)	269	21.64
ArcGIS Online (slider)	31	2.49
ArcGIS Online (lens)	13	1.05
ArcGIS Online (change matters)	10	0.80
Interactive (other)	91	7.32
Static	273	21.96

Table 1. Map type classification, count, and percent.

Five flavors of ArcGIS Online were used, namely the *standard* (556 maps), *story* (269 maps), *slider* (31 maps), *lens* (13 maps), and *change matters* (10 maps) map templates. The *standard* template provides basic functionality, such as add/ remove data; data creation; pan and zoom; symbol selection; and table views. Other templates provide additional options to suit more specific user needs. *Story* map templates, for example, allow users to easily and aesthetically communicate place-based stories through photo-story-map integration. *Slider* and *change matters* templates focus on telling stories about places over time, and the *lens* template allows users to explore spatial stories at two scales consecutively. *Figure 2* shows map examples for each of the five ArcGIS Online templates.

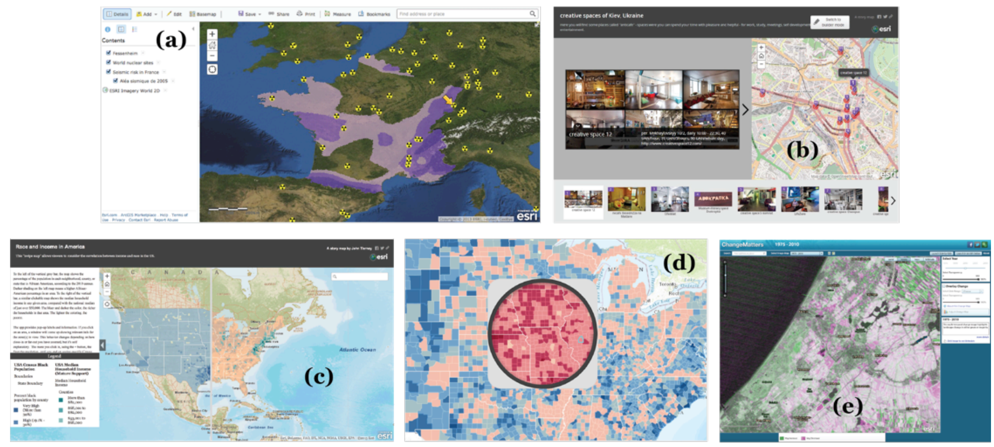

Figure 2. ArcGIS Online map templates: **(a)** *standard*, **(b)** *story*, **(c)** *slider*, **(d)** *lens*, and **(e)** *change matters*.

273 maps in the "Static" category, accounting for 22% of the total map submissions, were created using software such as ArcGIS Desktop, QGIS, Adobe Creative Suite, or by hand in the case of one mental map submission.

Other attributes considered for manual coding included: the place of interest (e.g., Pennsylvania or Rio de Janeiro) and coarse map scale (e.g., global, regional, local). Such codes, however, are highly subjective and not always meaningful. For example, a student may choose to map data particular to Pennsylvania, but may upload a map image depicting the entire United States or the New England region. In these cases, it is unclear whether the place being mapped should be coded "Pennsylvania", "United States", or "New England". And, is the associated scale "local" or "regional"? The bounds that designate a region, and what constitutes a place at various spatial scales are unclear at best, and indefinable in many instances. These dimensions suggest challenges for future research to address.

3.4. Visual Features

Next, we computationally extracted visual features from map images, using ImageJ, a free and open source image processing tool (Rasband 2014). Features extracted from each map image included: hue median (HM), hue standard deviation (HSD), saturation median (SM), saturation standard deviation (SSD), brightness median (BM), and brightness standard deviation (BSD). These attributes were then appended to the map image database using unique image identification numbers (*Table 2*).

Map Type	HM	HSD	SM	SSD	BM	BSD
ArcGIS Online (standard)	60.88	56.15	38.69	41.11	213.56	39.47
ArcGIS Online (story map)	66.06	60.37	44.05	59.01	176.96	70.03
ArcGIS Online (slider)	58.61	68.06	28.29	55.43	204.58	66.44
ArcGIS Online (lens)	39.38	62.44	23.08	47.92	205.54	62.03
ArcGIS Online (change matters)	120.9	72.89	55.8	55.75	163.8	50.61
Interactive (other)	73.00	53.86	42.99	49.03	201.2	41.41
Static	30.59	50.44	26.34	53.17	233.07	45.74

Table 2. Mean values by map type for median hue, standard deviation hue, median saturation, standard deviation saturation, median brightness and standard deviation brightness.

In the context of map design, these features are useful because they summarize the complexity of maps' visual aesthetics into a small number of statistics for each map. When aggregated by map type, these attributes illuminate subtle differences in the visual composition (and the visual variation within that composition) of maps designed in each category. For example, ArcGIS Online *story* and *change matters* maps tend to be more saturated, whereas maps in the static category are brightest. These differences result, in part, from the (in)flexibility of the mapping software to allow users to create or remove empty space in the map canvas, or to alter default layout views and templates.

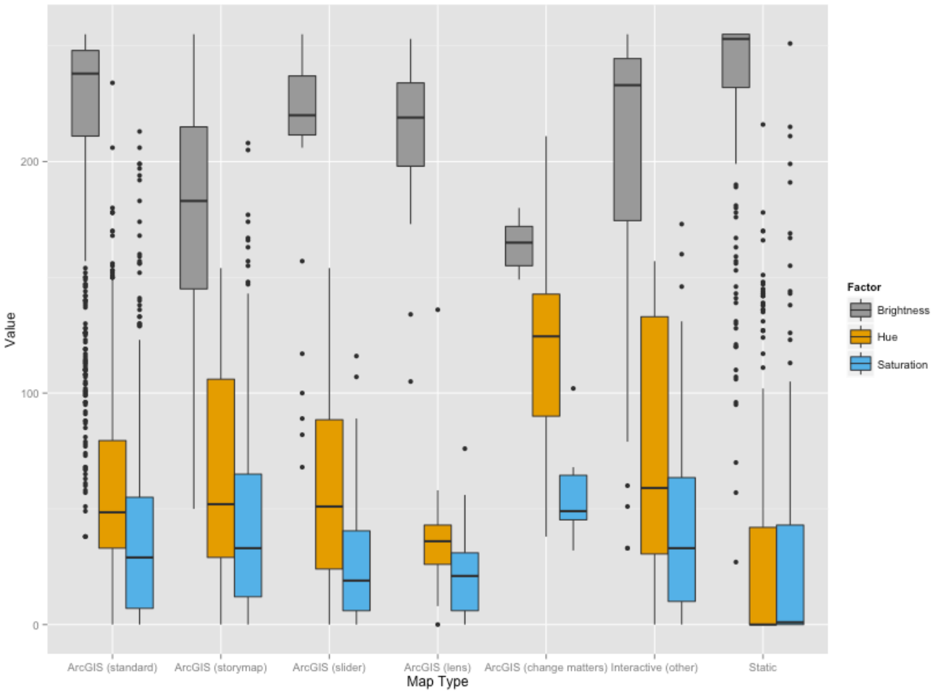

Figure 3. Boxplots of brightness, hue, and saturation distributions by map type.

The boxplots in *Figure 3* depict the distributions of median values for brightness, hue, and saturation for maps in each of the seven map type categories. The hue and saturation distributions for ArcGIS Online *standard*, *story*, *slider*, and *lens* templates are quite similar. Story maps, however, tend to be slightly less bright, and the variability in the brightness for standard map templates is quite high if we consider the outliers. Nonetheless, the visual aesthetics built into these four ArcGIS Online templates have a pronounced effect on final map designs. Interactive maps other than

ArcGIS Online templates tend to have more variation in hue. Distributions for brightness, hue, and saturation for static maps are highly skewed, dominated by high values for brightness and low values for hue and saturation. In this case, students' decisions and ability to add more white space to their maps may explain some of the skew in these distributions.

Figure 4. Map image montage organized by map type, then sorted darkest to brightest, left to right. Insets at the bottom to show detail.

3.5. Visual Signatures

Last, we present two map image visualizations, both that depict all 1,243 maps concurrently. We use the map codes and visual features described above to plot map images in two-dimensional spaces, thus depicting unique "visual signatures" for each map type, as well as for the entire map collection. We borrow the concept of "visual signatures" from Hochman and Manovich (2013). These authors extracted visual features from 2.3 million photographs of 13 global cities, and depicted the entire image collection using radial and montage image plots to visualize the unique global structure and individual makeup of photos for each city.

Figure 4 depicts the map image montage, which visualizes the entire collection of students' maps, organized by the seven map type categories, then sorted from darkest to brightest, left to right. This montage conveys the distributions of maps by software type and highlights map types that tend to be brighter or darker overall. At full resolution, one can zoom and pan on the image to explore map designs at the group or individual level. Thus, the visualization allows us to assess map design at the collection, map type, or individual student level.

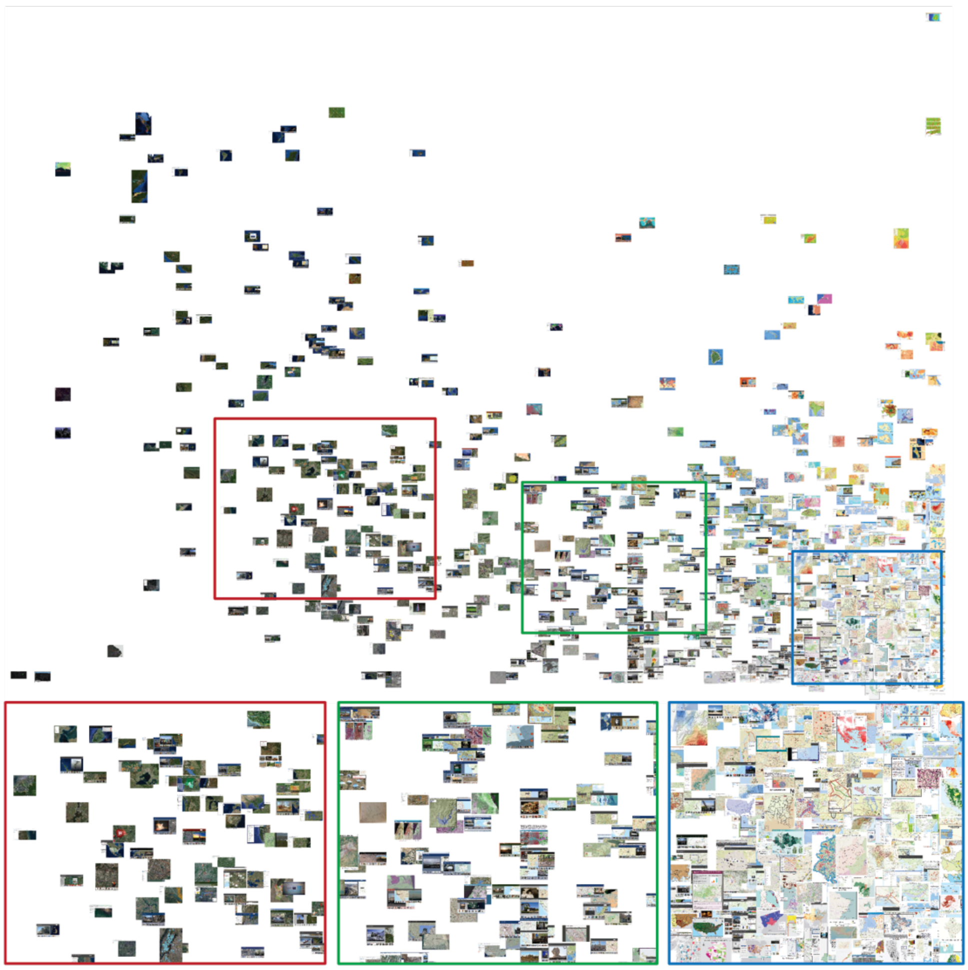

Figure 5. Map image scatterplot: maps plotted by median brightness values on the horizontal axis and median saturation values on the vertical axis. Insets at the bottom to show detail.

Another approach to visualizing map design is to plot map images in a scatterplot using the values associated with their visual features. *Figure 5* plots map images by median brightness values on the horizontal axis and median saturation values on the vertical axis. Immediately apparent is the dense packing of map images in the bottom right corner of the plot, denoting a strong tendency for students to design bright, unsaturated maps. This trend seems to align with both cartographic theory and with the default map layouts in spatial media authoring software designed with cartographic theory in mind; in that, these maps take into consideration visual hierarchy. In these map images, the visual characteristics of the base map data which, in most cases, dominate the visual features extracted from the map images are subtle and bright. The darker, more saturated colors are used sparingly in these maps to bring primary data to top of the visual hierarchy.

At the inverse end of the plot, map images are dark, saturated, and typically representative of map designs that use satellite imagery as base map data. Maps located more centrally in the plot tend to be vector/ raster mash-ups, ArcGIS Online *story* maps that integrate photographs into the map design, or large-scale maps composed primarily of landmass. Outliers in the scatterplot may represent novel map designs, or represent map designs that could benefit from constructive critique. Thus, the scatterplot captures students' individual design decisions on visual hierarchy, selection of spatial data type, and map scale, as well as software's influence on guiding those decisions.

4. Conclusion

In a case study exploration of constantly evolving cartographic trends, we analyzed 1,243 student map submissions from the second *Maps* MOOC course offering. These maps were coded based on the software used to create them, and visual attributes such as median hue, brightness, and saturation were computationally extracted from the map image collection. We plotted the maps in two-dimensional spaces, arranging them based on the tools used to design them and their various visual characteristics. The resulting visualizations provide snapshots of global structures of the mediums used to generate cartographic products, and can help us understand students' individual design choices from an assignment corpus that is too large for any single instructor to manually evaluate. Our analysis offers a unique evaluation approach to large map collections, assesses the extent to which students integrate theoretical concepts with current mapping software, and can help guide future course offerings in designing content relevant to global cartographic aesthetics and demand. Directions for future research include assessing the role of components, options, and functionality of particular software and tools in influencing current map design trends, as well as exploring the relationships among places mapped, map scale, and mapping software. We also see the need for new tools that can couple together peer ratings, including numerical scores and qualitative feedback, with visual signature capabilities to provide actionable information for cartographic educators to understand collections of original map designs in large classes.

Acknowledgements

This work was supported by the National Science Foundation under IGERT Award #DGE-1144860, Big Data Social Science and Pennsylvania State University.

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