An Evaluation of COVID-19 Dashboards from Cartographic and Epidemiological Perspectives

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Introduction

At the end of 2019, the Coronavirus (COVID-19) outbreak occurred in Wuhan, China, and spread worldwide. On March 11, 2020, COVID-19 was declared a global pandemic by the World Health Organization (WHO). In reaction, many groups developed COVID-19 dashboards with map components, animation, and/or interactivity. However, these dashboards' cartographic characteristics vary widely, opening questions regarding the best way to visualize spatial epidemiological data during a pandemic. This research investigates the technical and cartographic choices behind 39 COVID-19 dashboards. This research aims to support better information visualization on dashboards to serve the general population meaningfully in the future. Our observations motivated the development of an open COVID-19 visualization (COViz) project (eiu.edu/gisci/coviz) to encapsulate best practices in web-based cartography during an epidemic.

Research Questions

Epidemiological maps are important in disease control and prevention because they help identify vulnerable communities and facilitate collaboration between experts (Menghistu et al. 2018). Many factors determine the quality of an epidemiological dashboard. Underlying technologies, including out-of-the-box GIS components and customized code, lay the foundations for efficient construction of dashboards that load quickly and incorporate multiple capabilities. Simultaneously, adherence to cartographic principles is important to promote readability, avoid misleading interpretations, and generate maps that are attractive in appearance. Cartography encompasses activities ranging from raw data compilation to map conception and construction, and finally to interpretation and interaction by map consumers (Morrison, 1978). This paper examines three cartographic questions and one technological question regarding COVID-19 dashboards:

1. Are data variables properly selected, well defined, and easy to decipher?

2. Are visual variables appropriately symbolized?

3. Is map animation and/or interactivity used effectively?

4. Is the dashboard fast and responsive?

Methods

Researchers from Eastern Illinois University reviewed 39 dashboards (Appendix 1) created by governments, non-government organizations, volunteers, educational entities, and private enterprises from China, Hong Kong, Japan, South Korea, and the United States. The researchers used a combination of quantitative and qualitative, subjective, and objective survey items. For example, page load speed was measured using Google PageSpeed Insights, with results corroborated by a subjective evaluation based on user experience. Survey items were organized into four groups based on the research questions above.

1) *Data Variable Definition and Selection*

Poorly described data variables make map patterns difficult to interpret or even misleading. Each dashboard was evaluated subjectively on ease of interpreting the definition of epidemiological variables on a scale of Difficult (1) to Easy (5).

During a pandemic, personal decisions should be guided by current risk levels, not past events. To assess relevance to current risk, each dashboard was marked as showing recent cases, cumulative cases, or both.

Furthermore, dashboards that show only raw case counts might bias map readers to perceive less danger in sparsely populated regions. To assess this bias, dashboards were marked as showing raw case counts, case rates, or both.

2) Cartographic Symbolization

According to cartography canon, data for choropleth maps of disease should be standardized to show rates per population, whereas raw amounts are naturally communicated by symbol size (Slocum et al. 2009). Therefore, each dashboard using choropleth and/or symbol maps were marked as using raw counts or standardized rates (Figure 1). Boxes on the main diagonal (green) in Figure 1 indicate adherence to standard cartographic principles, whereas the boxes in the lower left and upper right (pink) indicate a violation of these principles.

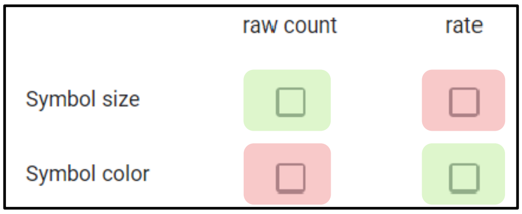

Figure 1: Checkbox for an association of cartographic variables with raw counts vs. rates.

Dashboards were also evaluated subjectively as to whether visual variables were hard to discern or disambiguate, inconsistent, or otherwise designed in a way that might cause confusion for map readers. To evaluate each dashboard's visual variables, researchers focused on criteria such as positioning, inconsistent use of color, and color selection.

3) Animation and Interactivity

The course of a pandemic will change over time, and animation seems a natural way to express data patterns through time to help people understand trends. We recorded if each dashboard provided map animation and if charts or graphs were synced when animation was playing.

Web technology enables linking and brushing to connect different views of the same data and achieve a better understanding of complex datasets (Dang et al., 2001). Map consumers can misread maps when visual elements such as legends, charts, and graphs are not synced promptly with the map. Hence, dashboards were marked if linking and brushing connected map components with other elements.

4) Speed and Underlying Technologies

Speed and responsiveness are parts that can greatly affect user experiences. A website should have less than 5 seconds of page interactive time to provide a good user experience. Google PageSpeed Insights (Google, LLC) was used to measure “Time To Interactive” (TTI - how long it takes a page to become fully interactive). Because quantitative metrics might not capture all aspects of the interactive experience, subjective interactive time was evaluated through user experience on a scale of Slow (1) to Fast (5).

If it could be determined, each dashboard’s underlying technology was also recorded to see whether there was any relationship between the choice of technology and user experience.

Results

1) Data Variable Definition and Selection

Of the 39 dashboards examined, 11 (28%) included at least one map for which the meaning of a data variable was not well defined or difficult to interpret. Maps on 3 (8%) dashboards did not have a legend or label to show which data variables are indicated (Figure 2).

Figure 2: Map with no label or data variable indication. From ncov2019.live.

Out of 39 dashboards, there were 8 (21%) dashboards that used recent, case rate per population data (Table 1). Also, 13 dashboards provided a second theme on deaths, and among these, 1 (8%) dashboard used a recent, death rate.

30 (77%) dashboards displayed a map with raw, cumulative case counts, which may bias map readers as described above.

	Case Rate per Population	Raw Case Count
Recent	8 (21%)	8 (21%)
Cumulative	14 (36%)	30 (77%)

Table 1: Number of dashboards showing
Raw case counts vs. Case rates & Cumulative vs. Recent cases.

2) Cartographic Symbolization

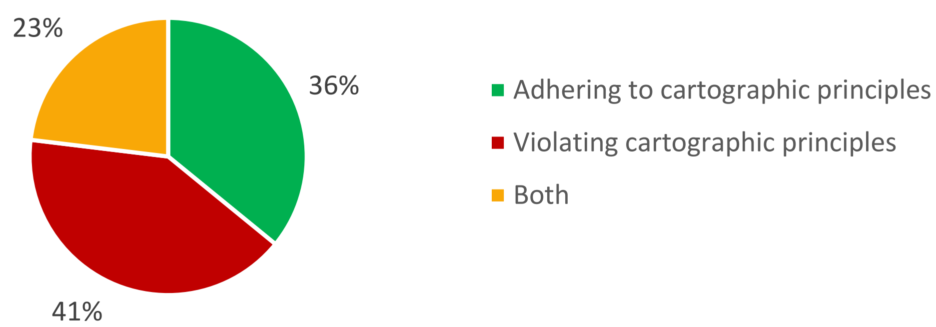

Figure 3: Percentage of dashboards adhering to or violating cartographic principles of using choropleth maps to visualize rates and/or symbol size to show raw counts.

14 (36%) dashboards followed basic cartographic principles of using choropleth maps to visualize rates and/or symbol size to show raw counts. 16 (41%) dashboards did not follow basic cartographic principles and used choropleth maps to visualize raw counts (Figure 4-A) or symbol size to show rates (Figure 4-B). In addition, 9 (23%) dashboards had two or more map themes and followed basic cartographic principles in one map theme but did not follow the principles in other themes.

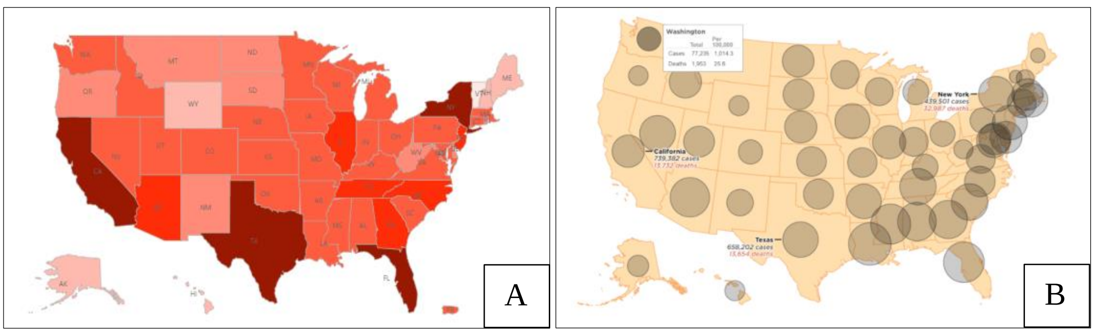

Figure 4: (A) - Using choropleth maps to visualize raw counts. (B) - Using symbol size to show rates. From 1point3acres.com & npr.org.

In addition, 3 (8%) were judged in other ways to cause map consumers distraction or confusion. Examples are:

1) Hard to discern individual symbols due to the overlap (Figure 5-A).
2) Using inconsistent color (Figure 5-B).
3) Selecting a not proper color scheme for the COVID-19 dashboard. (Figure 5-C)

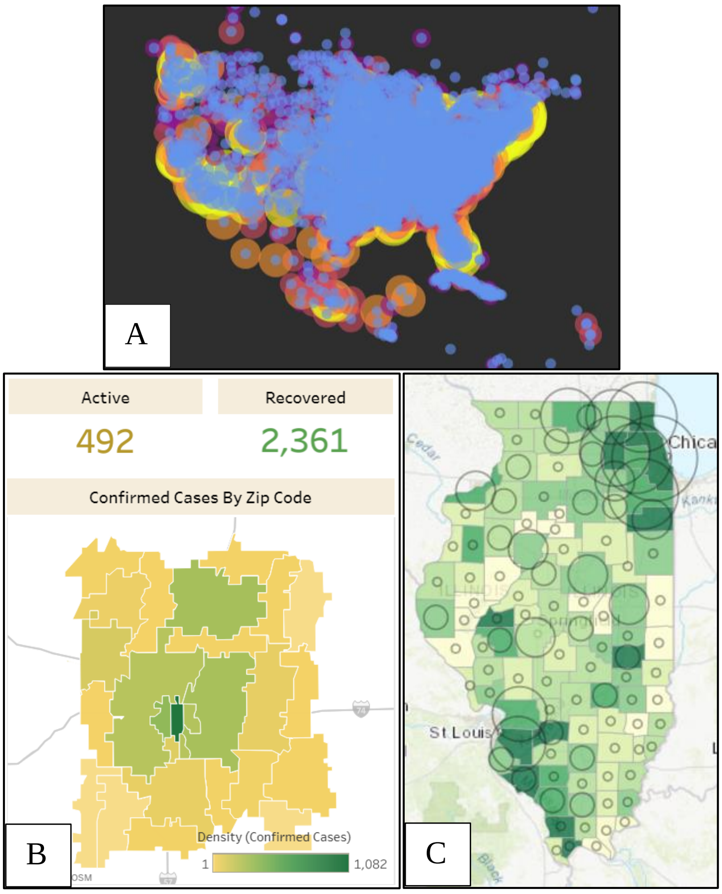

Figure 5: (A) – Blue dots that represent new cases are covering other symbols.
(B) – Using the same green color on the text and map to show different variables.
(C) – Using a green-ivory color scheme that is a popular choice for an agricultural map.
From healthmap.org, c-uphd.org & univofillinois.maps.arcgis.com.

3) Animation and Interactivity

There were 5 (13%) dashboards using animation, and 1 (3%) dashboard provided interactive visual elements synced with animation.

There were 18 (46%) dashboards using linking and brushing. Of these, 16 dashboards implemented 2-way linking and brushing. Whether users click the map or other elements, both interacted with each other. However, 2 out of 18 dashboards worked only one-way. For example, a chart or graph will not interact if users click the map, but the map interacts when users click a chart or graph.

4) Speed and Underlying Technologies

According to Google PageSpeed Insights (Google, LLC), 18 (46%), dashboards took less than 5 seconds, and 21 (54%) took more than 5 seconds to be fully interactive. The validity of the TTI metric was supported by subjective evaluation: 17 (44%) dashboards were recorded as "slow" by user experience, and among them, 14 dashboards were included in the Google PageSpeed Insights' result that took more than 5 seconds.

The researchers were able to collect information about underlying technologies from 24 dashboards. 23 (96%) dashboards used out-of-the-box components, and 1 (4%) dashboard was created from customized code.

TTI appeared to be heavily dependent on the amount of data provided. However, underlying technology also played a role. TTI was more than 7 seconds for 8 (73%) of 11 ESRI products and more than 5 seconds for 5 (83%) of 6 Mapbox products. This suggests that commercial software providers should ensure that their solutions optimize speed.

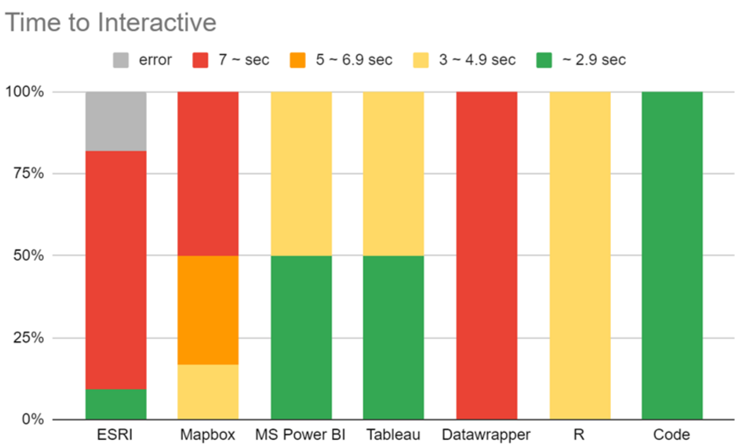

Figure 6: Seconds to become fully interactive sorted by underlying technologies.

Discussion and Conclusion

The research found that 28% of COVID-19 dashboards used inappropriate or poorly defined epidemiological variables. Also, 64% violated standard cartographic principles for the use of colors and sizes, and 8% had additional problems in the use of visual variables that could cause distraction or confusion. Regardless of the difficulty of calculating and updating accurate numbers daily, any dashboard should use good cartographic elements to deliver the facts.

In addition, several dashboards visualize rates with symbol sizes. Cartographic texts are somewhat ambiguous about whether this should be considered a cartographic mistake (Slocum et al. 2011), so perhaps some research is warranted to provide clear guidance to map-makers about visualizing rates with symbol sizes.

Overall, this research finds common problems in COVID-19 dashboards that could easily be avoided. To the degree that policymakers and the general public use such dashboards, these problems could lead to misunderstanding of the current situation, poor decision making, and inefficient policy responses. The purpose of developing COViz is to explore principles of appropriate variable selection, cartographic symbolization, and animation during a pandemic, with the hope that these principles will be adopted in other dashboards.

References

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Appendix

SITE_NAME	**URL**
ncov2019.live	https://ncov2019.live/
The New York Times	https://www.nytimes.com/interactive/2020/us/coronavirus-us-cases.html
Johns Hopkins University	https://coronavirus.jhu.edu/us-map
Florida COVID Action	https://experience.arcgis.com/experience/d2726d6c01c4486181fec2d4373b01fa
1point3arces	https://coronavirus.1point3acres.com/
University of Illinois at Chicago	https://univofillinois.maps.arcgis.com/apps/opsdashboard/index.html#/488249e280bf4821ae9d5c70b80a6163
Baidu – China	https://voice.baidu.com/act/newpneumonia/newpneumonia
KSIC - S.Korea	https://dev.ksic.net:8099/eng.html
Covid19japan - Japan	https://covid19japan.com/
Healthmap.org	https://www.healthmap.org/covid-19/
TIME	https://time.com/5800901/coronavirus-map/
National Public Radio	https://www.npr.org/sections/health-shots/2020/03/16/816707182/map-tracking-the-spread-of-the-coronavirus-in-the-u-s
world mapper	https://worldmapper.org/map-animation-covid19/

University of Colorado Denver	https://clas.ucdenver.edu/working-remotely/2020/04/22/animated-map-covid-19-united-states-march-2-april-18-2020
WHO	https://covid19.who.int/
Illinois	https://www.dph.illinois.gov/covid19
Indiana	https://www.coronavirus.in.gov/2393.htm
New York State	https://covid19tracker.health.ny.gov/views/NYS-COVID19-Tracker/NYSDOHCOVID-19Tracker-Map
Florida	https://experience.arcgis.com/experience/96dd742462124fa0b38ddedb9b25e429
Georgia	https://dph.georgia.gov/covid-19-daily-status-report
Texas	https://txdshs.maps.arcgis.com/apps/opsdashboard/index.html#/ed483ecd702b4298ab01e8b9cafc8b83
North Carolina	https://covid19.ncdhhs.gov/dashboard
California	https://calcat.covid19.ca.gov/cacovidmodels/
Wisconsin	https://www.dhs.wisconsin.gov/covid-19/cases-map.htm
Washington	https://www.doh.wa.gov/Emergencies/NovelCoronavirusOutbreak2020COVID19/DataDashboard
Pennsylvania	https://www.health.pa.gov/topics/disease/coronavirus/Pages/Data-Animations.aspx
Ohio	https://coronavirus.ohio.gov/wps/portal/gov/covid-19/public-health-advisory-system/
Puerto Rico	https://experience.arcgis.com/experience/852c30ea3baa48278175c13c211728e0/
Arizona	https://www.azdhs.gov/preparedness/epidemiology-disease-control/infectious-disease-epidemiology/covid-19/dashboards/
Michigan	https://www.michigan.gov/coronavirus/0,9753,7-406-98163_98173---,00.html
New York City, NY	https://www1.nyc.gov/site/doh/covid/covid-19-data.page
Washington, D.C.	https://coronavirus.dc.gov/page/coronavirus-data
Los Angeles County, CA	http://dashboard.publichealth.lacounty.gov/covid19_surveillance_dashboard/
Mecklenburg County, NC	https://www.mecknc.gov/news/Pages/Mecklenburg-County-COVID-19-Data-for-August-9.aspx
Champaign-Urbana	https://www.c-uphd.org/champaign-urbana-illinois-coronavirus-information.html
Baltimore City	https://coronavirus.baltimorecity.gov/
City of Minneapolis	http://www2.minneapolismn.gov/coronavirus/dashboard
South Korea	http://ncov.mohw.go.kr/bdBoardList_Real.do?brdId=1&brdGubun=13&ncvContSeq=&contSeq=&board_id=&gubun=
Hong Kong	https://chp-dashboard.geodata.gov.hk/covid-19/en.html