What is the Role of VIS in Combating COVID-19?

Min Chen* University of Oxford
David Ebert† University of Oklahoma
Lace Padilla‡ University of California Merced
Yixuan Zhang§ Georgia Institute of Technology
Alfie Abdul-Rahman¶ (Organizer) King's College London

ABSTRACT

Visualization and visual analytics (VIS) plays an important role in combating COVID-19. We can clearly observe this fact in the charts and graphs for public consumption in the media, and can also identify various visual analytics techniques that have been developed for domain experts in their analysis and modeling of COVID-19 data. In this panel, we ask four researchers – "What is the Role of VIS in Combating COVID-19?". Our panelists will cover a number of topics including developing VIS techniques and systems, conducting empirical studies, and deploying VIS for public health surveillance and intervention planning. The panelists will discuss a range of questions, reflecting on the recent and ongoing work by VIS colleagues and examining challenges in deploying a wide range of VIS techniques in emergency responses.

1 INTRODUCTION

The first COVID-19 case was reported to the World Health Organization (WHO) in December 2019 [15] and since then this global pandemic has impacted our lives in many ways that we have not imagined. Visualization plays an important role in helping us to understand the spread of COVID-19. The general public have been presented daily with the coverage of COVID-19 in the media through multiple visualizations and is probably now more aware of graphs and charts as well as some visual metaphors such as "flattening the curve". A number of visualization-rich web sites, e.g., John Hopkins – COVID-19 Dashboard [14], Our World in Data – Coronavirus Pandemic (COVID-19) [12], and CoronaVIS [6], have become well-known sources of information around the world.

Besides the general public, visualization and visual analytics (VIS) also plays an essential part in helping the government and policy makers. VIS can be used to help us decide what are the next steps that we should take in our fight against COVID-19. In the government briefings, for example, the explanation of the roadmap for lifting lockdown has typically featured visualizations. However, many colleagues in the VIS community may identify a good number of other aspects of VIS research that can be utilized to fight against COVID-19. Hence, one major question in the mind of many VIS colleagues is – **What is the Role of VIS in Combating COVID-19?**

In this panel, we ask four panelists to reflect on this question based on their observation and experience. Our objectives are:

- to reflect on the recent and ongoing work by VIS colleagues in supporting different efforts for combating COVID-19;
- to demonstrate the broad and important role of VIS in emergency responses;
- to examine challenges in deploying a wide range of VIS techniques in emergency responses; and
- to stimulate new research programs for addressing such challenges.

*e-mail: min.chen@oerc.ox.ac.uk
†e-mail: ebert@ou.edu
‡e-mail: lace.padilla@ucmerced.edu
§e-mail: yixuan@gatech.edu
¶e-mail: alfie.abdulrahman@kcl.ac.uk

2 WHY THIS PANEL AT IEEE VIS 2021?

While combating COVID-19 is no doubt an important application of VIS, one may wonder how VIS research in other areas of VIS may play a direct role in combating COVID-19. The four panelists will show that all six areas of VIS research indeed have a direct role to play. To prompt the panel discussion, we ask panelists to consider following questions:

- What are the major advances in VIS that have informed us how VIS can and should be deployed in the emergency response for combating COVID-19?
- Does the availability of different VIS techniques correspond well with the current level of deployment of VIS techniques in combating COVID-19? If not, what can we do to enhance the deployment of VIS techniques?
- In combating COVID-19, is existing **X** adequate or we need new **X**, where **X** may be VIS systems, visual representations, interaction techniques, data transformation algorithms, theories, methodologies, guidelines, taxonomies, understanding of perception and cognition, and so on.
- Is the perception of visualization primarily as an effective means for information dissemination by many domain experts an advantage or an hindrance in deploying VIS in the fight against COVID-19?
- Is there more that the VIS community can to do to increase the role of VIS in future emergency responses?

Above are just some of the questions for our panel to engage with the audience. It is important that we review the current role of VIS in combating COVID-19 and what lessons that can be learnt, in order for us to prepare the VIS discipline better for future emergency responses.

3 PANEL FORMAT AND LOGISTICS

The central topic for the panel is – **What is the role of VIS in combating COVID-19?** The panel is planned for a 90-minute session typically featured in the previous VIS conferences. This includes

- The introductory remarks will be made by Alfie Abdul-Rahman, who is the conveyor of the panel but not a panelist. Her introduction will last for 5 minutes. The panel format will also be described in the introduction.
- The four panelists will present their position statements in 40 minutes (10 minutes each).
- The panel conveyor will solicit audience feedback after the position statements have been delivered. This is followed by a discussion session of 35 minutes when the audience and panelists will participate in the discussion.
- All panelists will have the opportunity to offer a summary view at the end of the panel (2 minutes each).

4 Position Statements

Min Chen

Position statement:
As soon as the epidemic phenomenon of COVID-19 was reported, data visualization became an indispensable tool for information dissemination. We are all grateful to many global and national data platforms that have provided the public with daily update though easy-to-understand statistical graphics. We can find numerous examples on the web and governmental press conferences. We commend the visualization practitioners behind such information dissemination effort. While disseminative visualization has been prevalent, there have been sparse reports on using visualization and visual analytics (VIS) to support domain experts in observing, analyzing, and modelling complex data. Among colleagues in the VIS community, we must all believe that there should be much more use of VIS in combating COVID-19, and many are perhaps frustrated by a lack of opportunities to contribute our expertise. In May 2020, the open-minded epidemiologists and modelling scientists in the Scottish COVID-19 Response Consortium (SCRC) offered VIS colleagues in the UK the opportunity to volunteer our expertise. The work by the group of volunteers (RAMP VIS [11]) was reported in an arXiv report [3]. Our experience has confirmed that VIS can and should play a more significant role in supporting domain experts in combating COVID-19. Meanwhile, our reflection has suggested that we in the field of VIS need to overcome a number of obstacles in order for VIS to be better utilized in future emergency responses.

In emergency responses, it is necessary is to conduct requirements analysis and design VIS systems in a **speedily** manner. However, a few common obstacles may hinder a speedy process. (a) Experts in many disciplines may not have witnessed previous instances of having VIS specialists to support their workflows other than for dissemination. (b) Many expert users often see visualisation as "for informing others" rather than "for helping myself". (c) In VIS, we place a strong emphasis on gathering requirements from users through face-to-face engagement, and many papers reported such processes taking 3-12 months. (d) During COVID-19 pandemic, epidemiologists and modelling scientists were extremely busy. (e) Face-to-face engagement or field observation was largely impossible. (f) We were not aware of any suitable VIS infrastructure that could be adapted gradually according to emerging requirements.

Nevertheless, "complaining does not work as a strategy" [10], and "every challenge [we] face today makes [us] stronger tomorrow" [2]. During June–December 2020, the 20+ RAMP VIS volunteers took a number of approaches to address these obstacles [3]. We also identified several issues that the VIS community can work together to address. (i) We need to improve the broad awareness that VIS is not only for information dissemination. (ii) We need to improve the "readiness" of deploying VIS by building exemplar VIS infrastructures that can be adapted for specific emergency responses. (iii) We need to improve our theoretical understanding and develop design methodologies that can be applied to requirements analysis and system designs in a speedily manner.

The RAMP VIS activities show that it is feasible to address these challenges in an emergency response by having the courage to take initiatives in requirements analysis and suggest VIS requirements in discussions with domain experts [3], to design and build a deployable VIS infrastructure speedily, innovatively, and in an agile manner [3, 7], and to apply known theoretical understanding to practice when rapid decision processes are necessary [4, 5].

Biography: Min Chen developed his academic career in Wales between 1984 and 2011. He is currently Professor of Scientific Visualization at Oxford University and a fellow of Pembroke College. His research interests include many aspects of data science in general, and visualization and visual analytics in particular. He has co-authored over 200 publications, including his recent contributions in areas such as theory of visualization, visual analytics for machine learning, and perception and cognition in visualization. He has worked on a broad spectrum of interdisciplinary research topics, ranging from the sciences to sports, and from digital humanities to cybersecurity. His services to the research community include papers co-chair of IEEE Visualization 2007 and 2008, Eurographics 2011, IEEE VAST 2014 and 2015; co-chair of Volume Graphics 1999 and 2006, EuroVis 2014; associate editor-in-chief of IEEE Transactions on Visualization and Computer Graphics; editor-in-chief of Computer Graphics Forum; and co-director of Wales Research Institute of Visual Computing. Since May 2020, he has been coordinating the RAMP VIS activities [11]. He is a fellow of British Computer Society, European Computer Graphics Association, and Learned Society of Wales.

David Ebert

Position statement:
COVID-19 has rapidly disseminated statistics and data-driven information to people across the world and led to statistics and visualization being an important part of people's lives over the past 18 months. These representations and interactive visualizations have shown the value and pitfalls of visualization for the masses. The role of visualization and visual analytics for decision-making, policy, and interdiction efforts is even more critical since it enables health officials and politicians to increase their situational awareness, explore the impact of decisions and potential decisions, and reduce the spread or consequences of COVID-19. Unfortunately, most of the tools available to public health officials and local, county, state, and federal decision-makers lack effective models, and don't provide information and analysis for effective consequence evaluation and decision-making. The use of machine-learning applied to available data also has often led to mispredictions and misinformation since the appropriate factors and appropriate scale of the data are not incorporated or applied. Interactive visual analytic and exploration environments play a key role in exposing errors in models, incorrect assumptions, and issues with predictive models when the evolving situation is not represented by historical data (e.g, the out of data distribution problem in machine learning). However, while there have been failures, there are also examples of successes and new partnerships being formed between public health officials and visualization researchers to design visualization and visual analytic environments that operate at the correct spatial and temporal scale and that are designed around the decision points and intervention metrics to enable effective analysis and planning. We have had initial success working with public health officials in pandemic preparedness and interdiction planning for the previous threat of a global influenza pandemic and built upon these experiences working with health officials during COVID-19 to provide tools that incorporate their decision metrics, operate at a local/county scale for effective analysis, and incorporate multiple models and carefully instrumented machine-learning models for effective analysis and intervention planning. Based on this work, it is clear that there are key characteristics/issues for effective use and deployment of visual analytics for public health surveillance, intervention planning, and response:

- **Local Information:** Given the demographic variation of communities and states, effective analysis, modeling, and planning needs to be performed at the community or county level, which goes against most actions that have occurred at the state and national level. Accurate county demographic, movement, policy, and incidence information is key. Effective local information and creation of similar/surrogate communities enables more effective models and intervention evaluation.
- **Interactivity:** Interactive querying and analysis are key for decision-makers to increase situational awareness and perform what-if analysis. Models must be tuned to provide interactivity and must also be continually-updated based on available

information.

- **Transparency:** Transparency of the models and machine learning is key for understandability, trust, and use. Opaque machine learning models lead to mistrust and adoption failure. Interactive exploration and effective visualization increases both transparency and trust and leads to more effective solutions and their adoption. Transparency to see which data is influencing which portion of models or predictions is key since data quality, errors, and omissions are common.
- **User Guidance:** Enabling user-input, correction, and guidance of analysis and models increases their accuracy, effectiveness, and use.

Based on experience over the past 18 months, it is clear that interactive visualization and visual analytics tools will become a key component of public health surveillance and pandemic response systems over the next five years.

Biography: David Ebert is an Associate Vice President for Research and Partnerships, the Gallogly Professor of Electrical and Computer Engineering, and Director of the Data Institute for Societal Challenges at the University of Oklahoma. He is an IEEE Fellow, an adjunct Professor of Electrical and Computer Engineering at Purdue University and Director of the Visual Analytics for Command Control and Interoperability Center (VACCINE), the Visualization Science team of the Department of Homeland Security's Visual Analytics and Data Analytics Emeritus Center of Excellence. Previously, he was the Silicon Valley Professor of Electrical and Computer Engineering at Purdue University, Director of the Purdue Integrated Data Science Initiative, and Director of the Center for Education and Research in Information Assurance and Security (CERIAS). Dr. Ebert received his Ph.D. in Computer and Information Science from The Ohio State University and performs research in visual analytics, novel visualization techniques, interactive machine learning and explainable AI, human-computer teaming, advanced predictive analytics, and procedural abstraction of complex, massive data. He is the recipient of the 2017 IEEE Computer Society vgTC Technical Achievement Award for seminal contributions in and helping define the field of visual analytics, and was elected to the IEEE vgTC Visualization Academy in 2019.

Ebert has been very active in the visualization, visual analytics, and computer science communities, through teaching courses, co-chairing conference program committees, and successfully managing a large program of external funding to develop more effective methods for creating efficient visual decision-making and information communication environments. He has been developing public health syndromic surveillance and pandemic visual analytic tools for more than 15 years.

Lace Padilla

Position statement:
Accurately understanding risk during a pandemic is vital for ensuring that the public takes appropriate actions to mitigate the spread of a virus and reduce personal risk. The fast-acting and deadly nature of SARS-COV-2 (also known as COVID-19 and the coronavirus) has prompted scientists and media outlets to produce visualizations of known cases of COVID-19 as well as population-level predictions of an exponential increase in cases. While accurate communication is vital to ensure that the public is adequately informed, it is unclear how people understand the widely distributed depictions of pandemic data.

Prior research on uncertainty communication demonstrates that conventional visualizations of uncertainty can be confusing, even for experts [1, 8]. Further, in other domains, such as weather forecasting, researchers find that standard visualizations of path uncertainty cause substantial confusion about personal risk [9]. In the fields of data visualization and health communication, little work has examined how people understand visualizations of pandemic data and how to best communicate the uncertainty in predictions of virus impact.

My collaborators and I believe that lacking an understanding of risk and epidemiological uncertainty contributes to inappropriate responses to COVID-19, including disproportionate actions (e.g., stockpiling supplies, drinking sanitizer) as well as lack of proportionate action (e.g., going on vacations, hosting get-togethers).

We received an NSF RAPID grant to study the impacts of COVID-19 data visualization with uncertainty on risk judgments. We conducted two experiments (N = 2,549) during the height of the COVID-19 epidemic in the United States to examine if real time COVID-19 visualizations influenced participants' beliefs about the risk of the pandemic to themselves and others. This work also examined the impact of two elements of COVID-19 data visualizations, data properties (cumulative- vs. incident-death metrics) and uncertainty visualization techniques (historical data only, and forecasts with no uncertainty, vs. nine uncertainty visualization techniques).

The results revealed that viewing COVID-19 visualizations with rising trends resulted in participants believing themselves and others at greater risk than before viewing the COVID-19 visualizations. Further, uncertainty visualization techniques that showed six or more models evoked the largest increases in risk estimates compared to all the visualizations tested. This work provided the first evidence that visualizations of pandemic data impact risk perceptions. How these influential instruments should be used and calibrated is a judgment call to be made by risk communicators.

Biography: Dr. Lace Padilla is an assistant professor in the Cognitive and Information Sciences department at the University of California Merced. She received a Ph.D. in Cognitive and Neural Sciences and an MFA in Design from the University of Utah. Padilla and collaborators were awarded an NSF RAPID grant in 2020 to study uncertainty in COVID-19 data visualizations and an NSF EAGER grant in 2021 to study uncertainty communication for wildfire risk mitigation. In 2018, she was awarded a Visionary Grant for research on Improving Trust in Uncertain Science funded by NASA. In her spare time, she is a strong advocate for minoritized groups in STEM. She received an NSF postdoctoral award in 2018 for broadening participation in STEM at Northwestern, is a member of the Diversity committee at IEEE VIS, and is on the board of SPARKS Society.

Yixuan Zhang

Position statement: Myriad COVID-19 visualizations designed to communicate, understand, analyze, and predict a constantly changing situation appear on the Internet daily, created by our biomedical community, health care organizations, governments, news media, and the visualization community at large. During COVID, we have seen how the fast-evolving nature of a crisis can result in constant changes in visualization techniques and messages [16]. From the visualization production side, visualization creators have updated, adapted, and transformed visualizations regularly to suit various needs, different data, and to answer ever-changing public questions. From the consumer side, people are increasingly engaged with visualization design in times of crisis in different ways.

Some research questions that may help us critically examine the role of visualization during COVID-19, such as:

- **Who**: What's behind the knowledge production of COVID visualizations? What resources are marshaled to assist in bringing infrastructure into existence, and maintaining it over time?
- **(Uses) What Data**: What and how do we select data sources? Visualizations are not merely about the visual representation of data, yet visualizations start with the methodology of data collection and data sharing practices.
- **(To Communicate) What Message**: What are the messages

of these visualizations? Whose perspectives are prioritized? Who is silenced?
- **In What Form**: To what extent have existing visualization methods and techniques been applied in situ for the COVID visualizations? What are the challenges and constraints of applying empirical findings into the COVID context?
- **Under What Circumstances**: Essentially, a crisis is characterized by its intense and broad impact, high risk, urgency, fast-evolving nature, and high level of uncertainty. How do these circumstances influence visualization design?
- **With What Effect**: Since visualizations have changed throughout the crisis, what methodological approaches should we consider when designing and evaluating visualizations in situ?

Scientists frequently resort to reductionism in their work, and many science courses teach us to solve problems by breaking them into smaller parts and analyze them. Yet, it seems like the whole is often more than the sum of the parts when it comes to real-world situations. We also know that we are now in the third wave of HCI [13] with an emphasis on the interaction design in situ and in the wild. Part of this trend has come about through a growing interest in how people react, change, and integrate these novel technologies into their everyday lives. But we also know that in visualization research, most work still focuses on lab studies, rather than embracing the context and in situ. I argue that we need more work that examines the epistemic accomplishments and possibilities regarding visualizations that have been produced during COVID and reflects on the broader implications of research in visualization, visualization through visualization, and research for visualization that go beyond the COVID-19 crisis.

Biography: Yixuan Zhang is a Ph.D. candidate in Human-Centered Computing at Georgia Institute of Technology. Her research interest lies at the intersection of visualization, health, and crisis informatics. She is broadly interested in studying how people perceive and use information and communication technologies (ICTs), with a focus on equity in technology design and vulnerable populations. To guide her empirical and design work, she employs both qualitative and quantitative methods in her research, such as interviews, participatory design, surveys, and experimental evaluation. Her research broadly contributes to the fields of Human-Computer Interaction (HCI), Computer Supported Cooperative Work (CSCW), Information Visualization (VIS), and Health Informatics.

REFERENCES

[1] S. Belia, F. Fidler, J. Williams, and G. Cumming. Researchers misunderstand confidence intervals and standard error bars. *Psychological methods*, 10(4):389, 2005.

[2] R. T. Bennett. *The Light in the Heart*. Roy Bennett, 2020.

[3] M. Chen, A. Abdul-Rahman, D. Archambault, J. Dykes, A. Slingsby, P. D. Ritsos, T. Torsney-Weir, C. Turkay, B. Bach, A. Brett, H. Fang, R. Jianu, S. Khan, R. S. Laramee, P. H. Nguyen, R. Reeve, J. C. Roberts, F. Vidal, Q. Wang, J. Wood, and K. Xu. RAMPVIS: Towards a new methodology for developing visualisation capabilities for large-scale emergency responses. arxiv:2012.04757, 2020.

[4] M. Chen and D. S. Ebert. An ontological framework for supporting the design and evaluation of visual analytics systems. *Computer Graphics Forum*, 38(3):131–144, 2019.

[5] M. Chen and A. Golan. What may visualization processes optimize? *IEEE Transactions on Visualization and Computer Graphics*, 22(12):2619–2632, 2016.

[6] Data Analysis and Visualization Group - University of Konstanz. CoronaVIS. `https://coronavis.dbvis.de/`, 2021.

[7] S. Khan, P. H. Nguyen, A. Abdul-Rahman, B. Bach, M. Chen, E. Freeman, and C. Turkay. Propagating visual designs to numerous plots and dashboards. *IEEE Transactions on Visualization and Computer Graphics*, 28(1), 2022.

[8] L. M. Padilla, S. H. Creem-Regehr, M. Hegarty, and J. K. Stefanucci. Decision making with visualizations: a cognitive framework across disciplines. *Cognitive research: principles and implications*, 3(1):1–25, 2018.

[9] L. M. Padilla, I. T. Ruginski, and S. H. Creem-Regehr. Effects of ensemble and summary displays on interpretations of geospatial uncertainty data. *Cognitive research: principles and implications*, 2(1):1–16, 2017.

[10] R. Pausch. *The Last Lecture*. Two Roads, 2008.

[11] RAMP VIS. Visualization and visual analytics in support of rapid assistance in modelling the pandemic (ramp). `https://sites.google.com/view/rampvis`, 2020.

[12] H. Ritchie, E. Ortiz-Ospina, D. Beltekian, E. Mathieu, J. Hasell, B. Macdonald, C. Giattino, C. Appel, L. Rodés-Guirao, and M. Roser. Coronavirus pandemic (covid-19). *Our World in Data*, 2020. https://ourworldindata.org/coronavirus.

[13] Y. Rogers. Hci theory: classical, modern, and contemporary. *Synthesis lectures on human-centered informatics*, 5(2):1–129, 2012. doi: 10.2200/S00418ED1V01Y201205HCI014

[14] The Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU). Covid-19 dashboard. `https://coronavirus.jhu.edu/map.html`, 2021.

[15] World Health Organization (WHO). Listing of WHO's response to COVID-19. `https://www.who.int/news/item/29-06-2020-covidtimeline`. Accessed: 15 June 2021.

[16] Y. Zhang, Y. Sun, L. Padilla, S. Barua, E. Bertini, and A. G. Parker. Mapping the landscape of covid-19 crisis visualizations. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, CHI '21. Association for Computing Machinery, New York, NY, USA, 2021. doi: 10.1145/3411764.3445381