Title

Apply or Die: On the Role and Assessment of Application Papers in Visualization

Journal

IEEE Computer Graphics and Applications, 38(3)

ISSN

0272-1716

Authors

Weber, Gunther H
Carpendale, Sheelagh
Ebert, David
et al.

Publication Date

2017

DOI

10.1109/mcg.2017.51

Peer reviewed

This is the author's version submitted to IEEE Computer Graphics and Applications before final editing and layouting. The definitive version of this paper will appear in IEEE Computer Graphics and Applications Volume 37, Number 3, May/June 2017.

Apply or Die: On the Role and Assessment of Application Papers in Visualization

Gunther H. Weber[1], Sheelagh Carpendale[2], David Ebert[3], Brian Fisher[4], Hans Hagen[5], Ben Shneiderman[6] and Anders Ynnerman[7]

[1] Lawrence Berkeley National Laboratory & University of California, Davis, USA [2] University of Calgary, Canada [3] Purdue University, USA
[4] Simon Fraser University & University of British Columbia, Canada [5] Technische Universität Kaiserlautern, Germany
[6] University of Maryland, College Park, USA [7] Linköping Universitet, Sweden

In his controversial 2004 paper "On the Death of Visualization,"[1] Bill Lorensen asked "can it survive without customers?" Concerns about the need for documented impact on applications has inspired outreach to application stakeholders and efforts to increase the presence and visibility of application-driven research in VIS conferences. Despite a general agreement that application-oriented papers are of value—application papers have won several honorable mentions, e.g., at the 2016 SciVis and VAST conferences—it remains an open question as to what criteria should be applied to judge whether an application paper merits acceptance. This is evidenced by the wide range of evaluations that this paper type receives in conference reviews and in the diversity of opinions voiced in the discussion between reviewers. These discussions frequently focus on how best to achieve the goals of relevance to application problems as well as the more familiar criteria of technical excellence and methodological rigor that are expected for IEEE venues (conferences and journals).

The panel "Application Papers: What are they and how should they be evaluated?" at IEEE VIS 2016 in Baltimore, Maryland brought together leading researchers in all three VIS main areas—InfoVis (Carpendale and Shneiderman), SciVis (Hagen and Ynnerman) and VAST (Ebert and Fisher). Our goal was to gain a better understanding of prevalent views in the VIS community and to start a discussion on how to evaluate application papers more consistently. This Visualization Viewpoint summarizes points that arose in this panel to encourage continued discussion and derives a first set of conclusions from them.

Current Trends Favoring Application Papers

Three major trends that favor an increased emphasis on application papers emerged from the discussion: 1) the need for bigger teams with an increased emphasis on integration and infrastructure in order to realize the ambitious visions outlined in proposals; 2) changing research policies; and 3) the increasing number of researchers involved in interdisciplinary research.

Realizing the "grand vision" of overall data understanding requires significant infrastructure-building and integration efforts. One of the main drivers of VIS research is to achieve the grand vision of enabling data understanding in science, engineering and society. Technical VIS papers play an important role in accomplishing this mission by advancing the state of the art in algorithms and methods. These ultimately serve as building blocks or "dots" for achieving this grander vision. Realizing the overall vision also requires significant infrastructure-building and integration work to "connect the dots" to build a complete large-scale system (Figure 1). From this perspective, application papers are success stories that demonstrate that we are achieving our goal and accomplishing this grander vision.

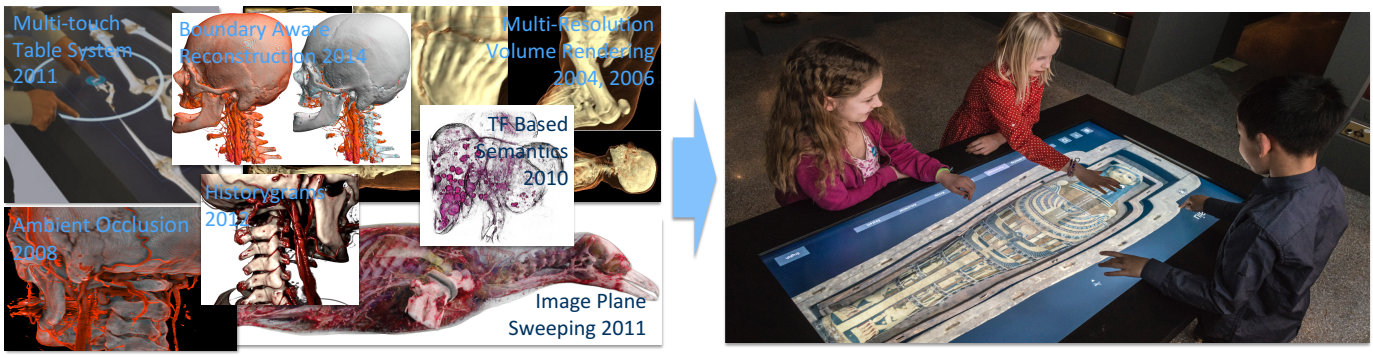

Figure 1: The visualization table developed at the Norrköping Visualization Center C, Linköping University, Sweden, is based on a progression of visualization papers over the past decade[2-9] (left hand side), integrated into an application that has impact both in the medical domain and is used in science communication. The image on the right hand side shows visitors to the Mediterranean Museum in Stockholm interacting with a combined surface and volumetric visualization of the mummy Neswaiu. A fuller account of this project has recently been published as a contributed article in the Communications of the ACM.[10] Papers of this kind provide valuable success stories to the visualization community showing how to combine and tailor the contributions of many technical VIS papers into a widely used system.

Integrating visualization techniques into a system—including work with application professionals, the combination and refinement of individual methods and detail work to create usable systems—requires large teams with dedicated researchers working at the interface between visualization and application. These researchers bridge the gap between fundamental visualization technology research and the grander vision of data understanding. Application papers document these efforts, providing valuable knowledge to peers on how to build these large scale systems. Furthermore, researchers at the interface between visualization and application science—who invest an immense effort in infrastructure-building and integration—need a clear career path, and in the traditional evaluation model this requires publications. Application-oriented papers are important for these researchers to earn recognition and to prosper in their careers. The success of these researchers in turn supports the field, demonstrating that innovation in newly developed methods can be used and will have an impact on real-world applications.

Current research policies favor application impact and societal relevance. Many sources of funding for visualization—e.g., from the National Science Foundation (NSF)—focus on basic research. However, many visualization research groups also rely on funding sources with an application-driven mission. Government agencies—such as the U.S. Department of Energy (DOE) and the National Institutes for Health (NIH)—as well as private foundations—like the Stiftung für Innovation and the Keck Foundation—have requirements that visualization can help to accomplish, but do not propose the development of new visualization techniques as the ultimate goal. Funding from these sources is increasingly dependent on a track record of refereed publications that demonstrate a group's accomplishments and the utility of visualization in accomplishing mission goals.

To remain competitive, groups funded by these institutions must publish papers that focus on the combination, adaptation and refinement of existing techniques to address a particular problem. More importantly, application papers also provide the "success stories" necessary to show the potential of visualization across a wide range of application domains and obtain funding in the first place. If we "shun" application papers from VIS venues, we rob ourselves and future generations of young visualization researchers of important funding opportunities. This trend is likely to be exacerbated as even funding agencies focusing on basic research are starting to encourage or even require collaborations with application scientists and professionals, e.g., applications are one method to show "Broader Impact" for NSF proposals.

The Emergence of Interdisciplinary Researchers. Computation is playing an increasingly important role in many sciences and the data deluge from simulations and experiments requires increasingly sophisticated computational analysis methods. As a result, a new generation of interdisciplinary students and researchers is emerging: as researchers in many disciplines become better versed in computational methods and computer science programs create new interdisciplinary degrees in computational science and engineering—such as computational chemistry, computational neuroscience, etc. Many schools are also creating new interdisciplinary programs in data science. This trend has grown to the point that some students even pursue doctoral degrees in two disciplines. These researchers are looking for appropriate venues for publishing their research results—which can be extremely interesting and valuable to our community—and we now have the choice between welcoming their contributions or pushing them to other places. The future growth of the visualization community—whether it will grow, stagnate or even shrink may depend on this decision.

Benefits and Contributions of Application Papers

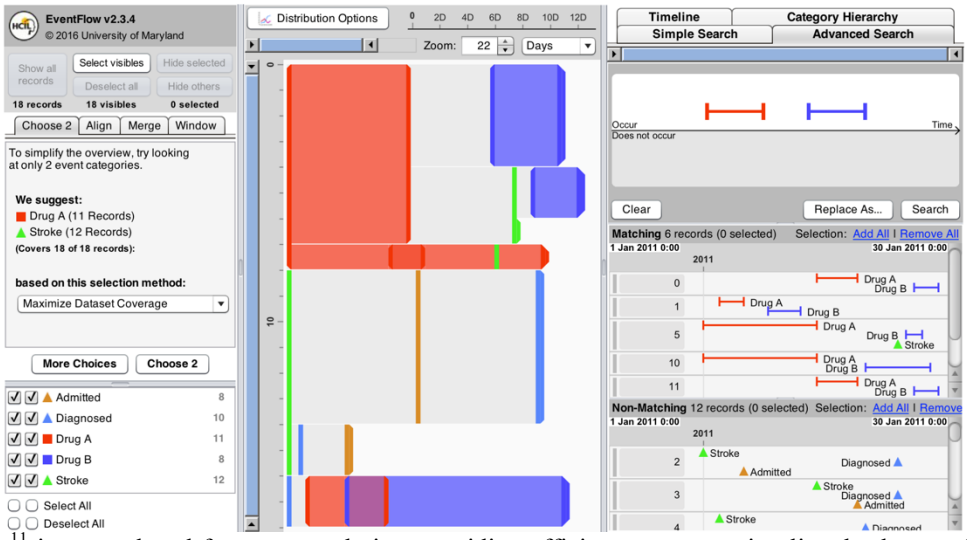

Figure 2: EventFlow[11] is a novel tool for event analytics, providing efficient means to visualize databases of records containing time-stamped categorical event sequences. This figure illustrates EventFlow with a healthcare example, showing a small database of 18 patient records with three point events (Admitted, Diagnosed, Stroke) and two interval events (Drug A, Drug B). The most common pattern in the central overview is that 7 patients receive Drug A, after which 4 shift to Drug B, while 3 of them have a stroke. For 8 patients the first event in their record is a stroke. On the right a search for patients who received Drug A followed by Drug B, find 6 matches. EventFlow exemplifies the integration of basic and applied research: Using a theory-driven development approach, collaborating with healthcare professionals with real problems, made it possible to develop appropriate control panels and innovative visual designs that present data in ways that support problem solving.

While the increasing importance of application papers is in part motivated by necessity—developing research infrastructure, funding and adjusting to new trends in research and education—they have an immensely beneficial influence on visualization. Most importantly, application-driven work also guides basic visualization research, ensuring it solves relevant problems, and accelerates the rate of scientific discovery due to the challenging complexity of real-world problems. Furthermore, it encourages evaluating new visualization research based on real data. In addition, application papers build a tacit knowledge about problem domains and communicate successes and failures to peers and funding agencies.

Applications improve the quality of basic research. Traditional models of research posit a linear model that separates basic research from applications. This assumes that knowledge flows from basic "curiosity-driven" research into applied research. To a certain degree, there is disdain in academic circles for applied research. This belief was promoted in Vannevar Bush's 1945 manifesto on "Science: The Endless Frontier."[12] However, numerous critics have pointed out the flaws in this conceptualization, pointing out the substantial successes from integrated application oriented work.[13,14] For example, applied research labs—such as the Bell Labs and U.S. National Laboratories—contribute to both basic and applied research. These applied projects have produced Nobel Prize winning research. Similarly, the Fraunhofer Gesellschaft in Germany as well as the automobile and aerospace industries successfully produce basic research that is driven by applications.

It is possible to measure the positive impact of close collaboration between academic and applied researchers. At a recent ACM conference for Knowledge Discovery and Data Mining (KDD)—the top ranked conference in data mining—out of 1036 submissions those papers written in collaboration between academic and industry researchers received a statistically significantly higher rating than pure academic or pure industry papers.

There are many ways in which applications promote basic research that accelerates the development of new visualization techniques. First, applications provide challenging problems for visualization, which often generate new research questions that then trigger new directions in basic research (mathematics, computer science, visualization), such as during the development of EventFlow (Figure 2). Real-world problems have strict requirements on solution quality and ensure that a developed theory or technique is able to handle meaningful data, providing an alternative form of empirical test of a basic research hypothesis. The result is a positive feedback loop where applied and basic research cross-fertilize each other.

Application professionals also provide real data sets for the development and evaluation of visualization methods, and application-oriented papers make this data and the

insights to be gleaned from it available to the larger VIS community. For example, the data sets used by the IEEE SciVis contest and VAST Challenge are now often used as examples when describing and evaluation new algorithms in technical papers with a positive impact on evaluation sections of VIS papers. Finally, discussions with application professionals can be inspiring and illuminating as they provide a fresh perspective. Seeing how our new techniques are used to gain new knowledge is also an extremely rewarding experience.

The types of contributions that an application paper can make to improving basic research include the following:

C-1 Put previous research contributions in an application context, and describe a combination of methods to accomplish a visualization/analysis objective;
C-2 Present valuable application specific contributions, such as tailoring of existing methods;
C-3 Provide a foundation for future visualization research and pose research challenges; and
C-4 Provide new means (data sets, evaluation criteria) for the evaluation of visualization methods.

Building deep knowledge about an application domain and its tools. A good application paper will go beyond proposing methods for visualizing data from a given application domain to demonstrating support for the work processes, including cognitive work, that experts currently use. The best application papers go beyond current work practices to propose new technological capabilities for domain experts that will enable them to improve on their current practices. For these projects, it is necessary for visualization designers to conduct a deep analysis of tacit as well as explicit knowledge in the domain. Contributions from these papers include:

C-5 Conveying the "language" of the application domain and assessment methods for particular situations, thus facilitating deep collaborations with application professionals.
C-6 Enabling the VIS community to learn how researchers in other communities approach problems as individual analysts and in collaboration with others.
C-7 Documenting successes and failures of visualization approaches for a given application domain and deriving lessons learned from the visualization experts perspective; and
C-8 Discussing both design methodologies and individual design decisions that have proven to successfully address the users' need.

Papers that make contributions at the level of cognitive and collaborative work practices will have a stronger impact on how the VIS community can best approach visualization for a given application domain.

Application papers provide success stories. In addition to providing success stories for funding agencies, application papers also communicate the successful application of VIS to many different fields. These success stories are useful for VIS researchers to see what methods work and what methods need improvement as well as see how their techniques and algorithms are applied to real-world data. The latter is helpful, for example, in steering future work on VIS techniques. Finally, success stories help in attracting new collaboration partners and create new ideas for VIS techniques.

Contributions in this area include:

C-9 Creating awareness in application domains of the importance of visualization;
C-10 Documenting a success story for dissemination, both inside and outside of the visualization community;
C-11 Describing innovation processes and commercial impact; and
C-12 Contributing to a wide-spread understanding of visualization science.

Application papers do not fit a set "template." An application paper can thus serve many different purposes and it is therefore not possible to describe one "template" for how to document these different contributions. Quite the contrary, several panel participants argued that "one size doesn't fit all" and that there should be no fixed rules to write such a paper. Shoehorning an application paper into rigid guidelines could prevent the paper "singing the way it should." There was consensus however, that a paper should make contributions to our own VIS community and not just to the application domain, i.e., that an application paper should go beyond an "instruction manual." While the paper should be targeted at an audience whose core competencies consist of designing new visualization and analysis methods and evaluating them, there are many ways in which an application paper can contribute to the state of the art of VIS research.

Assessment in the Review Process

The variance of application papers and the "one size doesn't fit" all makes application papers difficult to review and assess. This does not mean that they should not be evaluated, but rather that reviewers should consider the whole spectrum of possible contributions, some of which are mentioned in the previous section. It would, however, be an interesting exercise to look at each of these contributions and see how they would best be described and put forward in guidelines for authors.

Weighing technical and other contributions. Application papers contribute in many different areas, and reviewers should not expect an application paper to present a new

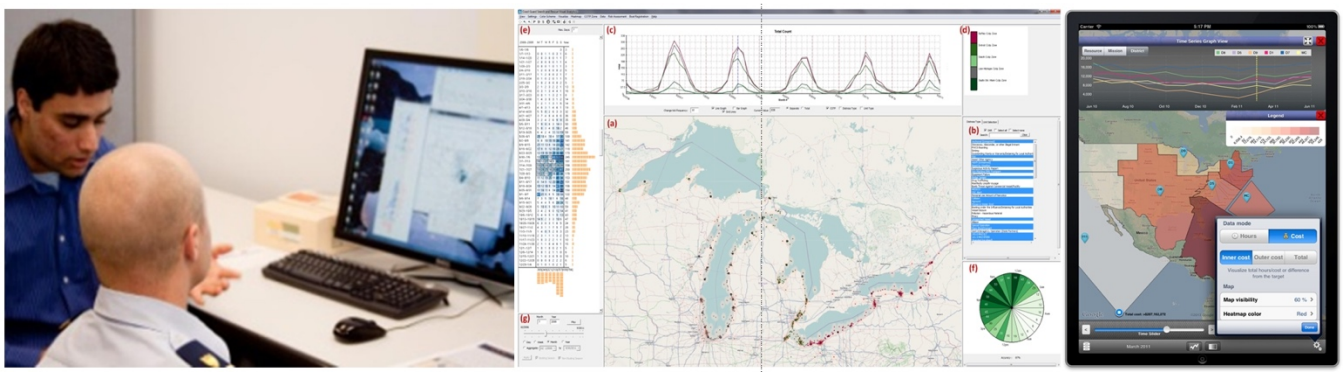

Figure 3: The Coast Guard Search and Rescue (cgSARVA) tool[15] (left and center panels) provides visual analytics capabilities to decision makers and analysts within the U.S. Coast Guard, where the user group of potential users may be dozens to a hundred people. The interactive Operations Performance and Assessment Report (iOPAR) tool (right panel) is intended for use by coast guard Vice Admirals in charge of the Atlantic or Pacific area operations—a user community of size two. Commonly formal user studies are conducted to answer questions, such as if the new technique helps people be faster or more accurate. Using a study to find such an answer is only one of the commonly recognized laudable goals for empirical research, and impractical with busy, small, and expert user communities.

technique or algorithm—or focus too much on any single area. Instead, they should ask the overarching question: Does this paper have an impact? What is this impact? Does it contribute new knowledge to the VIS community? Does this paper have common ground with the VIS community and core capabilities that can inform other areas? While this recommendation is already mentioned to some degree in the VIS review guidelines, some reviewers still reject papers just because they do not introduce a new method. The VIS community should continue to embrace diversity of applications and aim for an inclusive review process. Review forms for conferences already contain questions that guide a reviewer in evaluating strengths and weaknesses of a paper—such as about novelty, reproducibility by graduate students and appropriate evaluation. Perhaps the VIS community can agree on a set of questions—based on the list of possible contributions of application papers listed in the previous section—that can guide reviewers similarly, ensuring that reviewers consider a wide spectrum of contributions. This questionnaire could also be a separate list to which reviewers are pointed, although a separate document may be more easily overlooked and not as effective as questions included on the review form. Associated events, such as "Visualization in Practice" can serve as a forum to facilitate this process.

Evaluation of developed methods. The panel also discussed another contentious aspect of the review process. Currently, the VIS community has an extremely strong focus on formal, often laboratory-based, user studies for the evaluation of new visualization techniques. However, the variability of application papers also implies that a user study is not always a possible and/or an appropriate means for evaluation. One important "dimension of variability" that influences the utility of user studies is the size of the user community, which may range from "a few specialists" to "every citizen." For larger user communities, user studies are an important and appropriate evaluation metric, but application papers describing a system for a few specialists are also valuable. One example from VAST—brought up during the panel—is a tool for analysts and commanders of coast guard operations, see Figure 3. Analysts consider the tool useful for making important decisions, yet the small sample size as well as time constraints by the experts make it difficult to impossible, and not always appropriate[16] to perform typical user studies. McGrath[17] discusses how *precision* (finding an answer to a question as above), *generalizability* (finding an answer that will apply beyond the participants studied), and *realism* (finding out how some factors relate to the real world) are all equally valued goals. However, no study method has yet been devised that provides all three. When choosing the best empirical method for application papers it is most common that realism will be the main goal. This will lead to empirical approaches such as:

- Observational field studies and more controlled field experiments—these include both long and short term studies,[17]
- Diary studies—including autobiographical,[18] single participant[19] and small group case studies,
- Technological probes,[20,21]
- Focus groups,
- Expert reviews,[22] and
- Various forms of participatory design practices.

Appropriate evaluation of application oriented papers will need to continue to be an evolving practice that can involve considering previously successful methods that have been used in visualization[23] making use of McGrath's discussion of eight empirical approaches and tradeoffs between them,[17] and adapted methods from other empirical sciences.[24]

Another factor limiting the effectiveness of user studies is that often it is not possible to reduce analysis to simple

tasks or that tasks are not known *a priori*.[25,26] For example, in some cases developing visualization tools is an iterative process—application professionals learn what types of visual analysis are possible while working with VIS researchers—that refines the problem statement during development.

The take-away message from this is that reviewers should not expect a user study with 20 to 40 participants for each paper. In evaluating the contribution of the paper, reviewers should be more inclusive. The overarching questions for an evaluation should be: Has the method produced relevant results? Are experts using the method, i.e., is there expert buy-in? For many of these questions, reviewers should have some level of expertise in the application area, or should consult those who do. The VIS community should consider actively soliciting additional reviews from application domain experts who can determine more authoritatively whether the developed methods are useful in the domain. A reviewer pool could consist of VIS experts evaluating soundness of the VIS methods and domain experts evaluating the impact and insight gained in the domain science.

Conclusions

In writing this article the authors came to the realization that contrasting applied and basic research imposes unnecessary limitations on our field. Rather than discussing tradeoffs and compromises between basic and applied work, we should see them as mutually reinforcing streams of research. Basic research may take place independently for some time, but in the end effective visualization techniques will inevitably be incorporated into the development of applications. Applied research may continue in some isolation until a fundamental research question, new assessment method, or groundbreaking implementation inspires visualization researchers to explore the implications for basic research. We conclude that by exposing the VIS community to real-world problem settings, application papers will improve the quality of fundamental VIS research as well as building a bridge to real-world applications and potential funding sources. Application papers also tell our success stories, demonstrating that we accomplish our goal of enabling data understanding in science, engineering and society. VIS research needs these success stories for securing continued funding, to attract inter- and interdisciplinary researchers and to reward researchers that build the infrastructure to ensure the use of newly developed VIS techniques.

The diversity of contributions and the wide spectrum of target audiences make the evaluation of application papers particularly difficult. There is no single "mold" or "template" for application papers. As a consequence, both authors and reviewers should be flexible and open-minded when it comes to application papers. Authors should ask themselves, what benefit a fellow VIS researcher could get from reading their paper. How does the paper contribute to the knowledge of the VIS community at large? Many VIS papers today already have a contribution list at the end of the introduction. Authors can help reviewers by clearly articulating the contributions that are relevant to the VIS community in this list.

Reviewers should have an open mind on how a paper can benefit a VIS audience. Instead of following a check-list and expecting the paper to make contributions in familiar and narrowly defined areas—such as new techniques—or to evaluate new methods using familiar methods such as formal user studies, they should ask themselves higher-level questions such as "Does this paper present something that is new and useful to the VIS community?" and "Does the paper present plausible evidence that the new system is useful in the application domain?" The challenge for this approach is that these higher-level questions can lead to increased subjectivity in the review process. The VIS community should work to develop common ground among reviewers and objective criteria for evaluating application papers. For the main conference, associated events, such as "Visualization in Practice" can help to develop these criteria based on their domain knowledge and smaller, more integrated program committees and reviewer pools. Similarly, the IEEE SciVis Contest and VAST Challenge could also help to guide the development of usable and constant assessment criteria. For example, the SciVis contest already considers both scientific relevance and overall visualization approach for the choice of winning entries. It also involves application scientists and professionals during assessment—an idea that may be beneficial to the main conference as well.

The panel also agreed that the focus on acceptance rate as the measure of quality is counter-productive and harms our community. While this focus affects all papers—including technique papers—it seems to influence application paper reviews the most. Computing has lower acceptance rate and lower impact factor than many other fields, in part because a strict focus on acceptance rate reduces the exposure of innovative early-stage work, resulting in slower progress for the field as a whole.

The visualization community can also learn from the experience of other, more application-focused computing conferences. For example the Conference on Knowledge Discovery and Data Mining (KDD) has increased industry participation very successfully with its conference track of Industry & Government Invited Talks with its own Co-Chairs and Advisory committee.

In summary, the authors would like to call for a number of actions in the visualization community to increase the presence, traction and appreciation of science applications:

- Invite application leaders to VIS conference program and review committees.
- Engage application communities with more outreach to their leaders, events, and publications.
- Include application keynotes, panels, presentations, and exhibits.
- Feature application successes with media releases and awards for best cross-sector collaborations.
- Encourage governing bodies for journals and conferences to adapt reviewing criteria to appreciate the list of application contributions provided above.
- Discuss and expand our initial list of ways in which application papers can make contributions to VIS.
- Develop criteria for how application papers should be presented to make contributions clear and assessable.

Overall, application papers provide an important way to invigorate and cross-pollinate our field. They will help to increase the visibility of visualization with visual analytics success stories. They will generate research challenges that support novel and potentially groundbreaking research to advance our field in meaningful directions. We feel that a healthy dose of application contributions is key to building a lively, relevant, and vibrant visualization research community for decades to come. Consequently, we call upon the community to develop more inclusive guidelines for application papers that will invigorate the field with increased diversity of uses of visualization and visual analytics.

Acknowledgments

Gunther H. Weber was supported by the Director, Office of Science, Office of Advanced Scientific Computing Research, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231 through the project "Towards Exascale: High Performance Visualization and Analytics Program," program manager Lucy Nowell. Sheelagh Carpendale and the InnoVis Research Team would like to thank Canada's Natural Science and Engineering Research Council, Alberta Innovates Technology Futures and SMART Technology for research support and the University of Calgary for encouraging cross-disciplinary collaborations. David Ebert would like to thank the U.S. Department of Homeland Security Center of Excellence program for funding this work and supporting this application driven research (Award Number 2009-ST-061-CI0003). Brian Fisher would like to thank the Boeing Company for their collaboration, research funding, and contributions to the Vancouver Institute for Visual Analytics (VIVA). VIVA is a joint research institute of Simon Fraser University, the University of British Columbia, and the British Columbia Institute of Technology that promotes the value of visual analytics, provides training about visual analytics tools, techniques and theory, and connects university research with industry needs. Ben Shneiderman and the University of Maryland EventFlow team would like to thank Oracle and Adobe for their research sponsorship, which also brought them in touch with knowledgeable practitioners who challenged them to deal with significant real problems. Anders Ynnerman would like to thank the Knut and Alice Wallenberg Foundation, The Swedish eScience Research Center and the Swedish Research Council for generous support of the projects described in this paper. Examples and images have been provided by collaborators at Linköping University.

The authors would like to thank panel audience that contributed to the discussion and whose views have shaped the opinion presented in this Viewpoint. Special thanks are due to Meghan Haley for ensuring the panel video was accessible in time for writing this Viewpoint and to Bernd Hentschel for valuable discussions and comments on the paper narrative. Finally, we thank the anonymous reviewers for their comments that helped to improve this Viewpoint article.

References

1. B. Lorensen, "On the death of visualization," in *Position Papers NIH/NSF Proc. Fall 2004 Workshop Vis. Research Challenges*, https://erie.nlm.nih.gov/evc/meetings/vrc2004/position_papers/lorensen.pdf, 2004.
2. E. Sundén, A. Ynnerman, and T. Ropinski, "Image plane sweep volume illumination," *IEEE Trans. Vis. & Comp. Graph*, vol. 17, no. 12, pp. 2125–2134, 2011.
3. S. Lindholm, D. Jönsson, C. Hansen, and A. Ynnerman. Boundary aware reconstruction of scalar fields. *IEEE Trans. Vis. & Comp. Graph*, vol. 20, no. 12, pp. 2447–2455, 2014.
4. S. Lindholm, P. Ljung, C. Lundstrom, A. Persson, and A. Ynnerman, "Spatial conditioning of transfer functions using local material distributions," *IEEE Trans. Vis. & Comp. Graph*, Vol 16, no. 6, pp.1301-1310, 2010.
5. F. Hernell, P. Ljung, and A. Ynnerman, "Local ambient occlusion in direct volume rendering," *IEEE Trans. Vis. & Comp. Graph*, vol. 16, no. 4, pp. 548-559, 2010.
6. D. Jönsson, J. Kronander, T. Ropinski, and A. Ynnerman, "Historygrams: Enabling interactive global illumination in direct volume rendering using photon mapping," *IEEE Trans. Vis. & Comp. Graph*, vol. 18, no. 12, pp. 2364–2371, 2012.
7. C. Lundström, T. Rydell, C. Forsell, A. Persson, and A. Ynnerman, "Multi-touch table system for medical visualization: Application to orthopedic surgery planning," *IEEE Trans. Vis. & Comp. Graph*, vol. 17, no. 12, pp. 1775–1784, 2011.
8. P. Ljung, C. Winskog, A. Persson, C. Lundström, and A. Ynnerman, "Full body virtual autopsies using a state-of-the-art volume rendering pipeline," *IEEE Trans. Vis. & Comp. Graph*, vol. 12, no. 5, pp. 869–876, 2006.

9. P. Ljung, C. Lundström, A. Ynnerman, and K. Museth, "Transfer function based adaptive decompresion for volume rendering of large medical data sets," in *Proceedings of IEEE/ACM Symposium on Volume Visualization 2004, Austin, USA*, pp. 25–32, 2004.
10. A. Ynnerman, T. Rydell, D. Antoine, D. Hughes, A. Persson, and P. Ljung, "Interactive visualization of 3D scanned mummies at public venues," *Commun. ACM*, vol. 59, pp. 72–81, Dec. 2016.
11. M. Monroe, R. Lan, H. Lee, C. Plaisant, and B. Shneiderman, "Temporal event sequence simplification," *IEEE Trans. Vis. & Comp. Graph*, vol. 19, no. 2, pp. 2227–2236, 2013.
12. V. Bush, "Science: The endless frontier," *Trans. Kansas Academy of Science*, vol. 48, no. 3, pp. 231–264, 1945.
13. B. Shneiderman, *The New ABCs of Research: Achieving Breakthrough Collaborations*. Oxford University Press, 2016.
14. V. Narayanamurti and T. Odumosu, *Cycles of Invention and Discovery: Rethinking the Endless Frontier*. Harvard University Press, 2016.
15. A. Malik, R. Maciejewski, Y. Jang, S. Oliveros, Y. Yang, B. Maule, M. White, and D. S. Ebert, "A visual analytics process for maritime response, resource allocation and risk assessment," *Information Visualization*, vol. 13, no. 2, pp. 93–110, 2014.
16. S. Greenberg and B. Buxton, "Usability evaluation considered harmful (some of the time)," in *Proc. ACM SIGCHI Conf. on Human Factors in Computing Systems*, pp. 111–120, 2008.
17. J. E. McGrath, "Methodology matters: Doing research in the behavioral and social sciences," in *Readings in Human-Computer Interaction: Toward the Year 2000*, pp. 152–169, Morgan-Kaufman, 2nd ed., 1995.
18. C. Neustaedter and P. Sengers, "Autobiographical design in HCI research: Designing and learning through use-it-yourself," in *Proceedings of the Designing Interactive Systems Conference*, pp. 514–523, ACM, June 2012.
19. U. Hinrichs, S. Forlini, and B. Moynihan, "Speculative practices: Utilizing InfoVis to explore untapped literary collections," *IEEE Trans. Vis. & Comp. Graph*, vol. 22, no. 1, pp. 429–438, 2016.
20. A. Thudt, D. Baur, S. Huron, and S. Carpendale, "Visual mementos: Reflecting memories with personal data," *IEEE Trans. Vis. & Comp. Graph*, vol. 22, no. 1, pp. 369–378, 2016.
21. B. Gaver, T. Dunne, and E. Pacenti, "Design: Cultural probes," *Interactions*, vol. 6, no. 1, pp. 21–29, 1999.
22. M. Tory and T. Möller, "Evaluating visualizations: do expert reviews work?," *IEEE Comp Graph. & Appl.*, vol. 25, no. 5, pp. 8–11, 2005.
23. H. Lam, E. Bertini, P. Isenberg, C. Plaisant, and S. Carpendale, "Empirical studies in information visualization: Seven scenarios," *IEEE Trans. Vis. & Comp. Graph*, vol. 18, no. 9, pp. 1520–1536, 2012.
24. T. Hogan, U. Hinrichs, and E. Hornecker, "The elicitation interview technique: Capturing people's experiences of data representations," *IEEE Trans. Vis. & Comp. Graph*, vol. 22, no. 12, pp. 25790–2593, 2016.
25. C. North, "Toward measuring visualization insight," *IEEE Comp Graph. & Appl.*, vol. 26, no. 3, pp. 6–9, 2006.
26. R. Chang, C. Ziemkiewicz, T. M. Green, and W. Ribarsky, "Defining insight for visual analytics," *IEEE Comp Graph. & Appl.*, vol. 29, no. 2, pp. 14–17, 2006.

Gunther H. Weber *is a Staff Scientist/Engineer in the Computational Research Division at the Lawrence Berkeley National Laboratory and an Adjunct Associate Professor in the Department of Computer Science at the University of California at Davis. Contact him at GHWeber@lbl.gov.*
Sheelagh Carpendale *is a Professor in the Department of Computer Science at the University of Calgary. Contact her at sheelagh@ucalgary.ca*
David Ebert *is the Silicon Valley Professor of Electrical and Computer Engineering at Purdue University. Contact him at ebertd@purdue.edu.*
Brian Fisher *is a Professor at Simon Fraser University. Contact him at brianfisher@ieee.org.*
Hans Hagen *is a Professor at the University of Kaiserslautern. Contact him at hagen@informatik.uni-kl.de.*
Ben Shneiderman *is a Distinguished University Professor of Computer Science at the University of Maryland and a Member of the U.S. National Academy of Engineering. Contact him at ben@cs.umd.edu.*
Anders Ynnerman *is Professor of Scientific Visualization at Linköping University and director of the Norrköping Visualization Center C, in Sweden. Contact him at Anders.Ynnerman@liu.se.*

Contact department editor Thereas-Marie Rhyne at theresamarierhyne@gmail.com.