Design Study Contributions Come in Different Guises: Seven Guiding Scenarios

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ABSTRACT

Design studies are projects in which visualization researchers seek to design visualization tools that help solving challenging real-world problems faced by domain experts. While design studies have become a vital component of visualization research, reflecting on actionable contributions from them often poses challenges. The goal of this paper is to better characterize different contributions that can result from design study projects. Towards this goal, a set of seven guiding scenarios for characterizing design study contributions is proposed. The scenarios are meant to help authors identify and depict design study contributions that are interesting and actionable for other visualization researchers. They are also meant to provide better guidance in evaluating design study contributions in the reviewing process.

CCS Concepts

•**Human-centered computing → Visualization design and evaluation methods;** *Empirical studies in visualization; Visualization theory, concepts and paradigms;*

Keywords

Design study, contribution, visualization, position paper

1. MOTIVATION

For a long time, the major forces behind visualization research were innovative and novel visual encoding techniques, such as treemaps [36], edge-bundling [11], or arc diagrams [39]. Today, hundreds, if not thousands, visual encoding techniques exist. A recent wave of surveys has provided summaries of them, together with interactive web interfaces for exploration [14, 17, 29] (just to name a few). While these surveys help make visualization techniques easier to access, the challenge of how to combine them into tools for real-world problems has become more and more pressing. If biologists [24], automotive engineers [30], or social scientists [10], for instance, face a complex network problem there is usually much more to it than simply representing the data as a standard node-link diagram, or a matrix view. The domain problem needs to be carefully analyzed and data abstractions, visual encodings, and interaction techniques effectively combined, in a way that helps domain experts to better work with and understand their data.

A common way of conducting and reporting such problem-driven endeavors are *design studies*. A design study can be defined as "a project in which visualization researchers analyze a specific real-world problem faced by domain experts, design a visualization system that supports solving this problem, validate the design, and reflect about lessons learned in order to refine visualization design guidelines" [34]. Many design study papers have been published over the last few years, and the most common contribution is a visualization tool that is built to help domain experts solve their problem. However, there is an intrinsic challenge with this contribution: while the tool usually provides a clear benefit for the domain experts, revealing a design study's value to the visualization community is often much harder.

To make design study research useful for other visualization researchers, its contribution needs to go beyond presenting a domain-specific tool only. Other researchers, for instance, might want to learn about how design decisions can transfer to their problems, get further insights into existing and potentially new guidelines, or simply better understand a visualization sub-area, such as network visualization, through an in-depth investigation of a real-world case study [34]. However, while this statement seems obvious, practically identifying, characterizing, and writing up such actionable design study contributions is, undoubtedly, a non-trivial endeavor in many cases.

In this paper, I want to shed some light on these aspects by discussing my perspective and experience with design study contributions, from conducting and writing up, and also from reading and reviewing design study projects. I will do this by characterizing *seven guiding scenarios for design study contributions*. In other contexts, the approach of scenarios has already turned out to be valuable, as it offers concrete guidance to researchers [15, 27]. After briefly characterizing each scenario, I will provide a few examples, and discuss practical challenges that might be faced. Table 1 gives an overview over all seven scenarios.

The intended audience of this work is twofold. The main intention is certainly to guide *authors* who might seek inspiration when conducting, reflecting about, and writing up design study contributions. Another important group, however, is *reviewers* who need to carefully judge and evaluate

BELIV '16, October 24 2016, Baltimore, MD, USA

ISBN 978-1-4503-4818-8/16/10...$15.00

DOI: http://dx.doi.org/10.1145/2993901.2993913

Table 1: Summary of the seven scenarios for design study contributions.

	Scenario	*Examples*	*Challenges*
1.	Propose a Novel Technique	SignalLens [13]	- Identify meaningful lower-level tasks - Write up as technique or design study paper?
2.	Reflect on Methods	LiveRAC [20], Methods papers [18, 32, 34, 35, 37]	- Reflection in design study or a separate methods paper? - Large body of related work outside of Visualization
3.	Illustrate Design Guidelines	HemoVis [3], CalendarViewer [38]	- Often hard to foresee at the beginning - Confirming/refining easier than rejecting/proposing
4.	Transfer to Other Problems	LineUp [7], Paraglide [2]	- Considerable amount of abstraction necessary - Transfer to understandable or important problems? - Potential threat of abstracting the problem too much
5.	Improve Understanding of a VIS Sub-area	RelEx [30]	- Considerable amount of abstraction necessary - May require to find a shared framework for comparison
6.	Address a Problem that your Readers Care About	VisRA [25], BallotMaps [40]	- Find a “good” problem
7.	Strong and Convincing Evaluation	Longitudinal studies [4, 33], Studies with different groups [8, 41], Studies with many participants [1], Controlled studies [3], etc.	- General challenges of evaluation

design studies to guarantee the quality of visualization publications. My hope is that with a clearer notion of design study contributions our ability to write good and constructive reviews for such papers will further improve. This position paper is meant as a starting point towards creating such a clearer notion.

2. BACKGROUND AND TERMINOLOGY

It is helpful to clarify some vocabulary and background information before discussing the actual scenarios.

Paper Types.

The visualization community usually follows the concept of distinguishing five types of research papers: technique papers, evaluation papers, system papers, model papers, and design study/application papers [22]. Here, my focus is on *design study projects*. While design study projects often lead to *design study/application papers*, they also can lead to other types of papers [34]. The former is the process, the latter a result.

Design Study Contributions.

In our previous work on design study methodology [34], we depicted three types of design study contributions:

- *problem characterization and abstraction* (usually divided into data and task abstraction)
- *a validated visualization design/tool* (traditionally the most common type of contribution), and
- *reflection on lessons learned* (to confirm, refine, reject, or propose guidelines)

A design study paper is not expected to provide a strong contribution along all three dimensions simultaneously, but the sum of contributions is considered. A crosscutting goal of all contribution types is *transferability*, that is, the idea to “share sufficient knowledge about a solution that it may potentially be transferred to other contexts” [9].

Scenarios.

The scenarios are meant as concrete instances of design study contributions, and each scenario is closely connected to at least one of them. The idea of scenarios has been used in other areas of visualization before, most well-known to guide choices of empirical evaluation [15]. As in this work, the scenarios presented below are neither meant to be orthogonal nor completely separate from each other. Instead, the idea is to provide concrete guidance through showcase examples that illustrate how design studies led to valuable and actionable contributions. The notion of “actionabilty” has been characterized and discussed before by Gleicher [6].

3. 7 SCENARIOS FOR DESIGN STUDY CONTRIBUTIONS

In the following section, I will discuss the seven scenarios for characterizing design study contributions, together with illustrative examples and potential challenges that might occur. The scenarios are presented in a prescriptive way, to underline their guiding nature, however, this should by no means entail that they are set-in-stone and final answers.

3.1 Propose a Novel Technique

Scenario.

While it should not be a mandatory expectation [34], one typical visualization contribution of a design study is certainly a novel technique. In the most cases, the technical novelty does not stem from a single design component, but more likely from an interesting, and hitherto unseen combination of existing building blocks. Straight-foreward technique-driven approaches, such as edge bundling [11], have the goal to *generalize* to many design situations. Technique contributions from design study projects are usually more tuned towards the specific underlying domain problem, but might still *transfer* to many other situations [9].

Figure 1: SignalLens [13]. A novel focus+context approach enriched with statistical measures to better navigate large time series data on small oscilloscope displays. *Courtesy of Kincaid [13], © IEEE 2010.*

With transferability, a presented approach might naturally also become helpful for other visualization researchers.

Example.

A good example for this scenario is the SignalLens design study by Kincaid [13]. The resulting technique is shown in Figure 1. Based on a collaboration with domain scientists, the motivation behind this study was the problem of showing large electronic time series data on small screens of oscilloscopes. The novel SignalLens approach nicely illustrated how focus+context navigation [5], combined with the additional representation of statistical aggregations (at the bottom) helped to tackle this challenge.

The technical contribution of SignalLens, hence, is to combine known approaches into a solution that supports a typical task. The addressed problem is low-level and generalizable enough, that it is easy to imagine how the approach might be transferred to other application domains as well. In other areas that deal with large scale time-oriented data and similar abstract tasks, some fine-tuning might be necessary. The larger design choices are likely to be still valuable though.

Challenges.

An important challenge in this scenario is the feasibility to decompose high-level tasks into meaningful lower-level tasks. Having meaningful low-level tasks with clear goals allows one to apply more generic visualization techniques as exemplified in SignalLens. Often, however, a design study problem is ill-defined to a degree that it cannot be easily and completely decomposed into independent low-level building blocks right away. In such cases, visualization designers need to build flexible tools that allow for more explorative approaches. The resulting tools often use multiple different views and interactions, tailored towards the specific domain problem. Transferring these tools to other problems is usually much harder. Examples of this type will be discussed later, for instance, in the RelEx design study in scenario 5 (see Figure 5).

A practical challenge is how to write up a technique contribution that stems from a design study, specifically with the existing distinction between design study and technique papers. Design studies leading to a technique contribution are intrinsically tricky to fit into these existing categories, and the final choice likely depends on the tradeoff between how interesting the problem analysis is, and how novel and generalizable the proposed technique is. While there is likely no single one-fits-all answer to this question, it is important to bear these tradeoffs in mind, both when writing up but also when evaluating/reviewing such papers.

3.2 Reflect on Methods

Scenario.

Another contribution scenario that has become common in the last few years is reflecting on the methodological approaches of conducting design studies. This approach has usually a clear value to other visualization researchers, as many also work on design study projects and appreciate methodological guidance.

Examples.

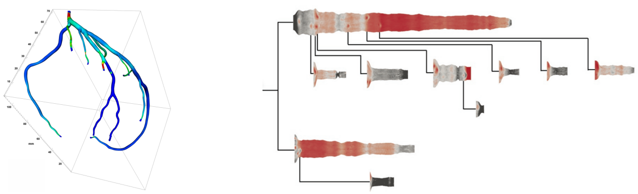
One of the early examples of this type of contribution is McLachlan et al.'s LiveRAC design study paper [20], in which the authors shared their experience of using a staged development process. A form that has become common more recently is to reflect not just on a single design study, but on multiple instances thereof. The design study methodology we proposed in 2012 [34] is an example of a methodological reflection that was based on multiple design studies, in this case 21. Other examples in the category include multi-dimensional in-depth longterm case studies (MILCs), an evaluation approach that is well suited for design study projects [35], Simon's work on the role of a Liaison in design study projects [37], or a reflection on how to evaluate visualization in large company settings [32].

A further interesting example in this category is Lloyd and Dykes' work on human-centered design in GeoVis, in which the authors introduce and provide guidance on methods such as chauffeured prototyping, data sketches, and autoethnography [18]. This example is interesting since the project focused on methodological approaches from the beginning. In contrast, in the other examples above the methodological reflection was more of a retrospective process after the actual design study project(s).

Challenges.

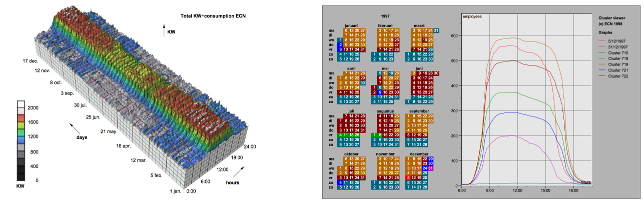
There are many challenges with respect to methodological reflections: should the reflection go into the same paper as the actual design study (domain problem and tool)? Or should it be a separate paper? How many design studies should the reflection be based on? A higher number seems to be more convincing as methodological approaches seemingly have proved their mettle repeatedly. Thus, one would assume that the probability of the methodological reflection being useful for other people's design studies is also higher. However, that does not mean that a lesson learned from a single design study cannot be similarly interesting and valuable.

Another important challenge is the consideration of related methodological work. A lot of methodological literature exists. In visualization, specifically the BELIV workshop has provided a large number of such interesting methods papers. However, related methodological aspects will likely also be found outside the visualization community, as many of the research approaches are not unique to visualization. In terms of design study methods and methodologies, there is a particularly close connection to the human-computer interaction (HCI) community, which provides many closely related approaches, such as user-centered, contextual, participatory, or ethnographically-informed design processes [16]. While there can be certainly much learned from these related areas, there are often also specific visualization



(a) (b)

Figure 2: HemoVis project [3]. (a) Current practices of doctors visualizing artery data. (b) New solution, HemoVis, which better supports the doctors' tasks. *Courtesy of Borkin et al. [3].*



(a) (b)

Figure 3: CalendarViewer project [38]. (a) The 3D approach obscures patterns such as weekend vs. weekday. (b) Proposed new solution based on clustering and a 2D representation, which perceptually better supports identifying such patterns. *Courtesy of van Wijk and van Selow [38], © IEEE 1999.*

characteristics and challenges that are not directly covered by generic HCI methodologies (e.g., due to the ill-defined and data-centric nature of the problems we face). Understanding and clearly characterizing these differences, however, is definitely non-trivial.

3.3 Illustrate Design Guidelines

Scenario.

In the previous scenario, reflection was employed to improve methodological guidelines. Another type of guidelines are design guidelines, which most commonly provide guidance on visual encoding and interaction design decisions [21]. In design studies, we often work with real users facing important scientific, technical, or societal problems. "Confirming, refining, rejecting, or proposing guidelines" [34] in design studies, hence, can provide illustrative and convincing evidence from the real world in terms of what works and what not.

Traditionally, design guidelines are often derived from controlled experiments. According to McGrath's three competing criteria of research methods [19], deriving design guidelines from controlled experiments is certainly good in terms of *precision* and probably also in terms of *generalizability*. However, controlled experiments are usually less strong in terms of ecological validity, that is, how well the tested situation reflects *reality*. Design studies provide an excellent opportunity to add this dimension in the process of defining and validating good visualization design guidelines.

Examples.

In this category, a good example is Borkin et al.'s design study on artery visualizations for heart disease diagnosis [3]. Working with doctors, Borkin et al. found that their current practices of cardiovascular imaging mostly relied on 3D representations, with data encoded using rainbow color maps (see Figure 2(a)). Before their study, both aspects were criticized extensively in the visualization research community. For many tasks, 3D and rainbow color maps are inappropriate choices with respect to human perceptual capabilities [22]. Hence, Borkin et al. hypothesized that a projected 2D representation with a proper color map would better support the doctors' daily tasks (see Figure 2(b)). In an experiment with doctors, they then compared the two approaches and found out that their new approach led to significantly fewer diagnostic mistakes. This result impressively showed the impact of such design choices in a real-world environment, and hence confirmed existing guidelines in this specific application domain.

While this example was mostly about confirming guidelines, similar examples can be imagined for refining, rejecting, or proposing guidelines. Consider, for instance, the venerable design study from van Wijk and van Selow on visualizing calendar data [38]. Back in 1999 when this work was published, the perceptual inappropriateness of 3D for abstract data was definitely less well-known than today. Van Wijk and van Selow illustrated how clustering, together with a 2D interface (see Figure 3(b)), can be superior to a visually more impressive 3D representation of the same data (see Figure 3(a)). This design illustration definitely helped in refining, if not proposing, the guideline of 2D vs. 3D for abstract data.

Challenges.

Often, it can be hard to foresee whether there will be something interesting to say about guidelines at the beginning of a design study project. This is particularly true if the project is mainly driven by a domain problem that does not already come with clearly sub-optimal visualization practices. However, researchers might still arrive at interesting insights into guidelines, for visual encodings, interaction, or data aggregation, even if they were not obvious from the very beginning of the project.

In the process of reflecting on design guidelines, confirming and refining well-known guidelines such as "Boo 3D for abstract data", "Boo rainbow colormaps", or "Boo piecharts" seems to be the easier case. One natural reason is that various application domains have not yet adopted state-of-the-art visualization practices. This fact leaves room to show how existing design guidelines can help to improve their work practices, as shown in the artery visualization design study above. Another reason is that confirming and refining goes with the general expectations of the visualization community. Nevertheless, confirming and refining guidelines can be a very valuable contribution for other researchers and designers.

However, care is needed to avoid blindly confirming mainstream guidelines without carefully scrutinizing potential other explanations. In some application domains, for instance, there are extreme expectations from domain users to use certain approaches that would be considered sub-optimal in the visualization community (such as abstract 3D plots).

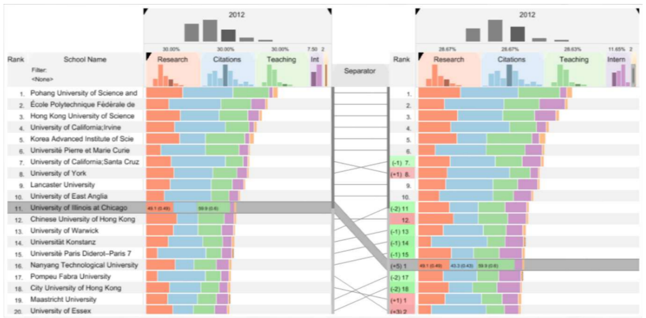


Figure 4: The LineUp interface [7] allows users to explore different parameter weights in tasks such as ranking universities. *Courtesy of Gratzl et al. [7].*

In some cases, researchers would not even get a chance to work and test their tools with real domain experts unless they also integrate such common practices [26]. The general expectation is that such effects simply stem from habituality, and can be changed to the better with slow and iterative design processes. However, another explanation, which we usually do not consider, is that we haven't carved out and characterized the underlying problem enough yet, and that there might be something more to be learned from the habits and long-standing practices of end users. In any case, a "real reject" of existing guidelines or "proposing an entirely new" guideline is certainly much harder, but should definitely not be dismissed for this reason. The impact might be very high.

3.4 Transfer to Other Problems

Scenario.

Another way to convincingly present design study contributions to a visualization audience is to abstract and transfer the solution to other problems. This approach has several benefits. A simpler and easier problem could be used to illustrate the proposed tool, although the actual motivating domain might have been a different one. Furthermore, it seemingly underlines the importance of the abstract problem as it could be transferred to a different domain. Similarly, the developed tool will be judged as potentially useful beyond the specific domain problem and the small group of users it is developed with.

Examples.

A good example for this scenario is the LineUp tool by Gratzl et al. [7] (see Figure 4). LineUp allows users to interactively explore different weights in ranking tasks. While the paper is likely to be judged as a classical technique paper, the approach behind it was at least initially problem-driven, i.e., more like a design study project. The underlying domain was molecular biology, and interviews with molecular biologists were conducted to gather design requirements. The problem, however, turned out to be more generalizable. This characteristic allowed the authors to describe their tool in terms of much simpler and generic problems, ranking food nutrition and ranking universities, instead of the much harder problem of analyzing molecular data.

Another example in this category is the tool Paraglide by Bergner et al. [2]. Paraglide allows to interactively explore simulation models by partitioning their parameter spaces.

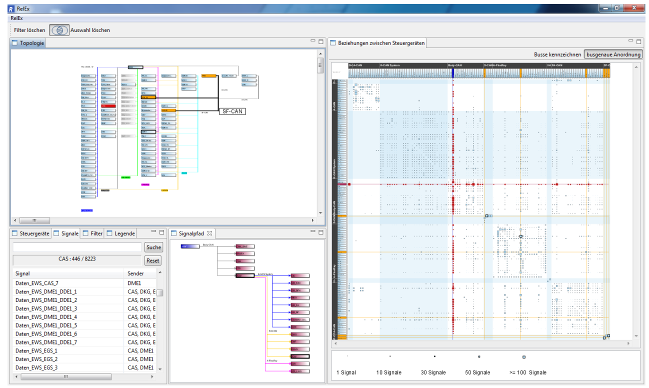


Figure 5: RelEx [30]. Different types of node-link and matrix views support automotive engineers in better understanding the design of in-car communication networks. © *IEEE 2012.*

It was developed and successively refined with user groups from three different application domains: mathematical modeling of flocking behavior, configuring image segmentation algorithms, and simulating fuel cells. All faced the same abstract problem of parameter space analysis.

Challenges.

The challenge in this scenario is to identify a more general problem underlying the domain-specific problem. While this identification challenge naturally will vary from problem to problem, and from domain to domain, it likely will require a thoughtful and thorough problem abstraction, and a thorough understanding of the field of visualization. Understanding the underlying situation in a more abstract way will allow to draw potential connections to other problems relevant to visualization.

Another interesting challenge is to decide which problems to transfer it to. Should it be easy to understand, and increase the readability of the paper (as in the example of LineUp)? Or should it be other important problems from other application domains (as in the example of Paraglide)? This tradeoff needs to be judged on a case-to-case basis.

Finally, it is also interesting to think about the level of abstraction. Abstracting a problem to a large extent would make the proposed solution certainly easier to transfer to other visualization problem instances. At the same time, however, a more general solution might not be as useful for the actual domain experts as a tailored solution. This tradeoff can play an important role in how to conduct and report on design study projects.

3.5 Improve Understanding of a VIS Sub-area

Scenario.

In the previous scenario, problem abstraction was used to illustrate the transferability of a visualization tool. Problem abstraction, however, can also be used to more broadly understand a specific sub-field of visualization, in terms of typical tasks and data characteristics. These characteristics can be valuable for other visualization researchers as they can inform design decisions when building generic visualization tools and techniques, but also decisions when designing user tests.

Example.

One example in this category is the RelEx design study [30] (see Figure 5 for a screenshot). The RelEx design study puts a strong focus on data and task abstraction, with the goal to provide a better understanding of how visualization can help in the general area of network analysis. Before the RelEx study, the prevalent problems addressed in design studies on visual network analysis stemmed from social network analysis. The RelEx paper points out that this might give a biased view on the potential breadth of real-world problems in visual network analysis. Abstractly, social network analysis focuses strongly on tasks of finding clusters and central nodes. The problem faced in RelEx was different in that automotive engineers needed to better support for specifying in-car communication networks. Abstractly, their tasks could be characterized as mapping different types of networks onto each other, actively changing them, and manually optimizing traffic flow given various constraints. Abstraction permitted the comparison of both problem instances to each other, leading to a richer and more complete understanding of the general area of visual network analysis.

Challenges.

Similar to the previous scenario, the first challenge is that a considerable amount of abstraction work is necessary. In addition, however, it is also likely that authors not only will need to think about the problem abstraction of their own work but also of the existing related work, as the goal is to create a common framework for comparison. For some subareas of visualization, theoretical frameworks for data and task characteristics already exist, as for instance for 'visual parameter space analysis' [31]. Such theoretical frameworks ease the comparison of design studies across different application domains as they introduce the necessary layer of abstraction. However, the process of building up a solid theoretical foundation of visualization has just started. So, authors still face the challenge to first create a common abstract framework for cross-domain comparison. In the case of the RelEx example, for instance, the phase of reflection/abstraction took just as long as designing the actual visualization tool.

3.6 Address a Problem that your Readers Care About

Scenario.

When selecting problems, design study projects might also (on purpose or accidentally) follow the idea of "eating your own dog food". That is, the proposed solution addresses a problem that is also faced by visualization researchers themselves (the readers). These problems range from issues relevant to the general public, to the target audience of scientists and designers, or the most specific group of visualization researchers.

If a reader can easily associate her/himself with a certain problem, there are several characteristics that might ease the communication and transferability of a design study. Because readers can connect the design study to their previous experience, it is likely that they (a) care more about the issue at hand, (b) better appreciate the insights gained through the approach, (c) see how the visualization tool could help for their own work, and (d) have an easier time to follow the reasoning behind the work. These aspects are much harder

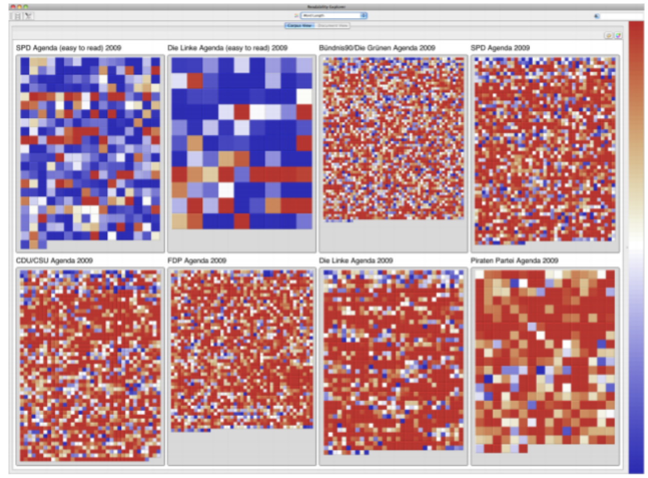


Figure 6: VisRA [25]. Visual analysis of 8 different documents. Blue pixels indicate good readability scores, red means low readability of the respective sections in these documents. *Courtesy of Oelke et al. [25], © IEEE 2010.*

if the problem stems from a highly complex domain that is distant to the readers own experience (although abstraction can be of great help, as discussed in scenarios 4 and 5). If a reader can associate with a problem, they likely will be able to transfer the discussion at hand to other problems, without the need for extensive abstraction. Note, that this does not mean that one of these problem types (easy or hard to relate to own background) should be treated as more important than the other.

Examples.

In 2010, Oelke et al. published an application, VisRA, that helps writers to visually analyze the readability of their manuscripts [25]. The user can select different readability metrics, such as word length or vocabulary difficulty, which are used on the text and then mapped to a pixel-based overview (see Figure 6). With this overview, the user can identify sections of the manuscript with low readability that would benefit from further revision (red areas). As writing papers, grants, and other manuscripts is a typical task in research, it is likely that many visualization researchers could easily associate with this problem.

Another example in this category is the BallotMaps design study by Wood et al. [40]. Here, the authors tried to identify name and ordering biases in ballot papers in a London election. Using a spatial treemap layout (see Figure 7), the design study visually revealed insights that could not be seen in previous statistics-only analyses. The visual approach showed significant biases stemming from the position of a political candidate on the ballot paper, as well as geographic and ethnicity influences on voting behavior. As most people can associate with political elections, the value of this work is immediately clear to the reader of the paper.

Challenges.

The main challenge in this scenario is finding a good problem. In the ideal case, the problem should be interesting, important, and non-trivial from a visualization point of view,

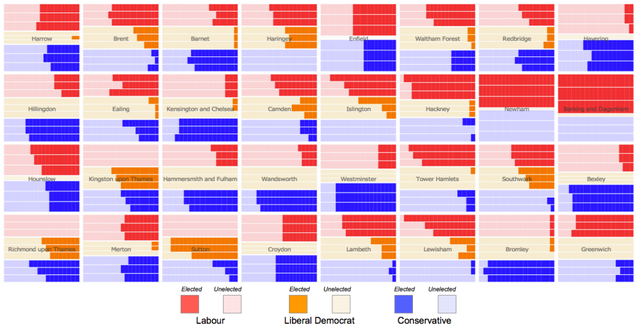


Figure 7: BallotMaps [40]. Spatially ordered treemaps are used to reveal different biases in voting behavior in London. *Courtesy of Wood et al. [40].*

and at the same time it should resonate well with readers. Fulfilling all these criteria is challenging, not at least as the notion of a "good problem" also varies from person to person. What is considered easy to understand and important for one person, might be the opposite for another, specifically in an inter-disciplinary research community such as visualization.

3.7 Strong and Convincing Evaluation

Scenario.
The last scenario is cross-cutting all the above scenarios. In my experience, a strong and convincing evaluation really helps to build up trust in the presented design choices and results, and increases the probability that I rely on them in the future. Evaluation is at the heart of the BELIV workshop, and the past has shown that good evaluation can come in many forms. This is also true for design studies.

Examples.
Convincing studies can result from different types of evaluation. For instance, case studies with a few users over a long period of time can reveal compelling and deep insights into work processes, stumbling blocks, or the value of visualization. Examples are the Cardiogram design study that was based on a three-year field investigation within a large automotive company [33] or the Overview design study that was based on an intense three-year remote collaboration with different journalists [4]. Breadth, that is, conducting case studies with multiple different user groups, can be similarly convincing. Wood et al., for instance, presented an impressive multi-channel design study [41]. For this study, bike sharing data is visualized and evaluated in seven different "channels", ranging from tools for transport operators and policy makers, to a visualization installation at a museum. Similarly, Guerra-Gómez et al. presented 12 case studies of their tool TreeVersity2 [8].

Such qualitative case studies are common for design studies. Nevertheless, there are also other evaluation approaches that can convincingly reveal the value of contributions that stem from design study projects. The above mentioned example of artery visualization by Borkin et al. [3] (Figure 2) successfully employed a controlled experiment to confirm existing guidelines in a real-world setting. In a design study on visualizing music listening histories [1], Baur et al. made their visualization tool available online. An impressive number of 5,000 people downloaded and used the tool, and 243 participated in an additional survey study.

Challenges.
In the BELIV community, it is well known that conducting good evaluations is hard. Many evaluation challenges for visualization exist, and many of them are also applicable for the more specific case of design study research. The good news is that many good papers now exist that provide guidance on evaluation choices [12, 15, 23, 28, 32, 35] (just to name a few). BELIV has played an imperative role in this process, by starting and continuing methodological discussions on visualization evaluation.

4. DISCUSSION

In the following, I discuss possible implications that we can draw from this work. The discussion is organized into two parts. The first part addresses implications for judging the value of design studies, for instance, as a reviewer. The second part comes more from an author perspective and discusses potential implications towards improving the characterization of design-study contributions.

Judging Design Study Contributions.
With the scenarios depicted above, I assume a rather broad understanding of design studies, basically including what others might consider as applications, or more generally as problem-driven work. In this paper, I took a broad stance of seeing design studies as a methodological approach that can lead to all sorts of different contribution types, not only those that might be typically associated with design study and application papers. Borkin's study, for instance, could be considered as an evaluation paper [3] (Figure 2), or Gratzl et al.'s LineUp tool as a technique paper [7] (Figure 4). However, all examples started more or less from a problem-driven point of view, working with domain experts on driving problems, and continued to do so to different extents.

This notion of design studies is mainly characterized by working on driving real-world domain problems. As characteristics of real-world problems vary significantly, we should also *not expect a one-size-fits-all model for design studies.* Some problems faced in design studies, for instance, might necessitate a close and intensive involvement of domain experts along the entire process, such as the design studies from the automotive domain discussed above [30, 33]. Here, domain experts had multiple years of training and tacit expertise, which needed to be carefully taken into account for the design of new tools. At the other end of the spectrum, there are design studies, in which visualization researchers themselves can conduct most of the necessary analysis without the need to closely involve end users at each stage. The BallotMap design study is an example for this approach [40].

Different types of design studies can lead to interesting visualization contributions. This view has, in my opinion, important implications for our reviewing practices of design studies. Rather than expecting a one-size-fits-all methodological approach and a clear delimitation from other paper types, we should *be open-minded to new approaches and different contributions.* After all, we should not forget about the flexibility that is needed to succeed in many research endeavors, specifically if they stem from driving real-world problems. In my humble opinion, evaluative statements such as "but there is no real user" or "there is no technique contribution" should be carefully weighted with respect to other potential contributions that might have stemmed from the very specific circumstances of a design study project at hand.

Characterizing Design Study Contributions.

At the same time, we can and should not simply assume that—given this line of reasoning—every design study automatically leads to an interesting contribution and hence merits a high-tier publication. Conducting design studies is often a non-trivial endeavor with many pitfalls [34], and so is the process of clearly characterizing their contributions. The scenarios in this paper are meant as a starting point to provide better guidance and support of this characterization process.

One way to more generally characterize the 'value' of a design study contribution is through *Gleicher's notion of 'actionability' and 'persuasiveness'* [6]. While Gleicher originally proposed these terms for evaluation in general, they are also helpful for discussing design study contributions. Good actionability of a contribution means that the audience, that is, the readers of the paper, can act upon it. Consider, for instance, scenario 2 (reflect on methods), which has the inherent goal of sharing some hands-on, methodological advice or lesson learned that readers can act upon. Good persuasiveness, on the other hand, makes the contribution very convincing to the audience. Consider, for instance, scenario 3 (illustrate design guidelines), or scenario 7 by its very definition (strong and convincing evaluation).

In projects such as design studies, we often evangelize user-centered design approaches. By closely involving end users in all development phases, we seek to tailor our tools to their tasks, needs and challenges. The papers stemming from these projects, however, often target a different audience, that is, visualization researchers[1]. In the process of reflecting on and writing up design study contributions we consequently should *recognize a visualization-centered approach*, with the idea of making the contributions actionable and/or persuasive to other visualization researchers. This duality of target audiences is likely much stronger in design study and applied projects, than it is in more technique-driven endeavors.

While there is likely no one-and-only silver bullet recipe for arriving at good design study contributions, there is undeniably a recurring theme in the above scenarios: abstraction. I think that *abstraction is often key* when characterizing design study contributions. In the SignalLens design study [13] (Figure 1), for instance, abstraction fostered the process of turning a problem-driven motivation into a technique contribution (scenario 1). In the LineUp example [7] (Figure 4), abstraction helped to transfer the proposed solution to other problems (scenario 4). More generally, abstraction allows us as a community to expand our knowledge of the research area of visualization beyond the borders stemming from specific application areas. Contributing to such a richer understanding can, for instance, include illustrating design guidelines (scenario 3), or extending our knowledge of task and data abstractions (scenario 5).

[1]The underlying assumption here is that visualization papers are mostly read by other visualization researchers.

5. LIMITATIONS

The seven scenarios presented above are only meant as a starting point to trigger awareness and discussion in our community; awareness and discussion about the need and value of more clearly specifying the visualization contributions that we, as a community, expect from design studies. The scenarios are by no means intended to be set in stone, neither are they meant to be complete, or orthogonal to each other. It is rather a loose and unsorted collection of ideas and thoughts, without any magic bullet answers and guarantees for getting a paper accepted.

Also, the selection of examples is certainly biased towards my own past work, and the work of acquainted peers. This selection is simply based on the fact that I know these papers well, and have used them to organize my ideas about the much larger space of design study research. That said, there are likely many other good examples that I could have used. And for some scenarios, there might even exist counter examples.

In short, this is a position paper, not a full-fledged research paper, and future discussion is highly encouraged.

6. CONCLUSIONS

In this paper, I discussed potential design study contributions with an eye towards how to make them more valuable for the visualization community. The discussion was organized around seven guiding scenarios for design study contributions. Table 1, at the beginning of the paper, lists all seven scenarios, together with the examples and challenges that were discussed. The scenarios are meant as a starting point to trigger more discussion on the value that the visualization community can draw from design studies, and how we can better support authors in conducting and writing them up, and reviewers in evaluating them. While the scenarios were created under the dedicated lens of design study research, it certainly is possible that some insights might also generalize to the larger area of visualization research.

7. ACKNOWLEDGMENTS

This paper is based on a talk that I gave at a retreat of the Data Analysis and Visualization Group, University of Konstanz. I thank all group members for their helpful feedback, and specifically Daniel Keim for the opportunity to give this talk. I also thank Tamara Munzer, Miriah Meyer, and Heidi Lam who inspired much of my initial thinking about the above scenarios, and Thomas Torsney-Weir for proofreading and feedback. Last but not least, this work was partly funded by FFG project 845898 (VALID).

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