Visualization Resources: A Survey

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Abstract

Visualization, a vibrant field for researchers, practitioners, and higher educational institutions, is growing and evolving very rapidly. Tremendous progress has been made since 1987, the year often cited as the beginning of data visualization as a distinct field. As such, the number of visualization resources and the demand for those resources is increasing at a rapid pace. After a decades-equivalent long search process, we present a survey of open visualization resources for all those with an interest in interactive data visualization and visual analytics. Because the number of resources is so large, we focus on collections of resources, of which there are already many ranging from literature collections to collections of practitioner resources. Based on this, we develop a classification of visualization resource collections with a focus on the resource type, e.g. literature-based, web-based, developer focused and special topics. The result is an overview and details-on-demand of many useful resources. The collection offers a valuable jump-start for those seeking out data visualization resources from all backgrounds spanning from beginners such as students to teachers, practitioners, developers and researchers wishing to create their own advanced or novel visual designs. This paper is a response to students and others who frequently ask for visualization resources available to them.

Introduction and Motivation

Data visualization has become an increasingly important solution for analyzing and exploring huge volumes of complex, multivariate data. As such, the number of data visualization resources has grown very rapidly over the past decades. However, for students, researchers, practitioners, developers or visualization scientists who work in the field, searching for data visualization resources can be challenging and time consuming due to the rapidly evolving landscape of visualization. A simple Google search will not always lead to the most valuable resources and will not lead to a curated source of visualization resources. This collection of visualization resources serves as an effective starting point when searching for both literature and tools related to visualization due to the many hours of searching and curating dedicated to this project and decades of collective teaching and research experience. By decades-equivalent long search process we mean a search process that required decades of person-years to conduct. The whole team of co-authors searched for resources for approximately two years. In addition to this, some of the co-authors have been discovering resources over the course of their career which spans decades.

Many students, teachers, practitioners, institutions and companies have been collecting data visualization resources, such as Souto [1] who provides a curated list of open-source data visualization developer resources such as programming libraries, software and websites. These collections focus on the tools and techniques of visualization. Survey papers and literature, such as Lam et al. [2] and Isenberg et al. [3] provide a collection of metadata on research papers at the annual conference series related to evaluating visualization.

By the term *resource* we mean content that provides benefits or utility to visualization students, practitioners, researchers, and developers. The inspiration behind this project comes from real-life experience. We are often asked what visualization resources are available from students, researchers, and practitioners. This is a response to this very common question.

This paper aims to provide an overview of collections of data visualization resources. It also provides a categorization of those resources. The contributions of this survey include:

- The first comprehensive survey of its kind on collections of resources for data visualization,
- An expanded categorization of visualization resource collections organized around readership with a focus on students, researchers practitioners, and developers.

We offer the collections in an interactive web-based browser. Our web-based collection of visualization resources is available at: https://sites.google.com/view/visres/.

Survey Scope

We focus on free, visualization-specific resources, e.g., open collections of visualization images or other collective meta-data. We catalog collections of visualization resources (as opposed to individual items), e.g. a survey of surveys and state-of-the-art reports rather than an individual survey, or a survey of books rather than an individual book. There are too many visualization research papers (estimated in the thousands) to list individually. However, there are resources that present and explore the large collection of visualization literature such as VisPubData [4], VisImageNavigator [5], and CiteVis [6]. Similarly, there are over 100 survey papers on the topic of visualization and visual analytics. Therefore, we focus on resources such as surveys of surveys [7 8 9]. We present collections of visualization resources spanning different types such as literature, software, and web pages. In

Table 1. An overview of the audiences and each part described in the Overview section. Note that audience categories are not mutually exclusive. The checkboxes indicate the target audience of each subject category.

Audience \ Subject	Refereed Literature	Websites	Software	Software-Developer	Color	geospatial	Blogs
Students	√	√	√		√	√	√
Researchers	√	√			√	√	√
Practitioners		√	√	√	√	√	
Developers		√	√	√	√	√	

summary, we include collections of visualization resources we believe provide great value to students, researchers, practitioners, and developers.

We focus on collections offered by non-profit institutions and organizations. This includes higher educational institutions, non-profit institutions such as Wikipedia, and collections of visualization resources gathered together for public use by volunteers.

Finally, in order to make the scope manageable, we ensure that the resources have a focus on visualization and visual analytics. See McNabb and Laramee[9] and Rees and Laramee[10] for detailed definitions of visualization and visual analytics.

The Search Process

The search process for visualization resources is challenging, time-consuming, and cannot be solved only by a series of Google searches. However, we do incorporate Google search for collections of visualization resources. Our search for visualization resources is influenced and guided by a number of projects, factors, and experiences spanning over a decade. Many of the visualization resources we describe were discovered through the following related projects and events:

- In the past we worked on extracting document-level details of visualizaiton publications. During this project, we summarize image collections from the entire history of the visualization conference[5] and metadata related to VisPubData[4].
- For two years we worked on a survey of surveys (SoS) for information visualization and visual analytics[9]. During this project, we came across many of the resources described here.
- For three years we carried out a survey of information visualization and visual analytics books[10]. This project helped us discover many resources.
- For over 10 years, we have been teaching a data visualization course in which the students are asked to search for visualization resources.
- For approximately 20 years, we have been reviewing several hundred visualization research papers for over 45 different related conferences and journals. During this time, the team has regularly attended visualization related events such as the IEEE VIS and Eurographics Eurovis conferences. Informed by these events, we regularly come across useful resources.

All of these projects and experiences have informed our search for visualization resources. This search process is difficult to systematize and it is the result of a team of visualization researchers and students with more than 20 collective years of experience. We pass on the benefits of this effort and its associated costs to the reader. We provide more details on how we search for resources in each sub-section of the paper based on resource type. We understand there is no way to guarantee we have found everything. That is why we offer a collection on the web. Readers can contribute to this web page: **https://sites.google.com/view/visres/**

The Benefits of Collections

Focusing on collections offers a number of benefits. First, a collection of collections serves as an effective approach to navigate the abundance of visualization resources. Second, resource collections are often developed and maintained by an individual or a team of curators. Third, by focusing on collections, we take advantage of the many hours of search and constructive labor already invested in collecting the resources. Fourth, by focusing on collections, we inherit the benefits that bring similar resources together and their respective categorization.

Categorization

There are many different ways to group and categorize visualization resources. One possibility is to classify them based on type. For example, collections of refereed research papers with accompanying online resources, visualization books with online resources, open-source collections of visualization software, non-profit websites with collections of visualization resources, etc. Another possibility is to categorize the resource collections based on visualization subfield. For example, visual analytics, information visualization, or scientific visualization. However, as we shall see, it would be difficult to categorize resources this way due to subject crossover. A third categorization could be based on target audience such as resource collections for students, researchers, practitioners, or visualization scientists. However, many resource collections are valuable to multiple types of users. Another possibility is to classify resource collections based on special subjects such as education, geospatial visualization, or data-centered resources. However, this might result in many different categories.

After considering several different categorization schemes, we have chosen a grouping based on resource type because we believe this is the most relevant with respect to the prospective readers' interest. In other words, resource type often aligns with the different categories of readership. For example, a researcher may be interested in finding starting points for relevant refereed literature. Thus, we group the collections of related refereed literature together. In another example, a student may specifically be interested in data visualization websites that offer a helpful collection of resources. Therefore, we have grouped the related

websites together. Attempting to categorize visualization resources by subject will result in large crossover between categories. Ultimately no categorization is perfect in this case, i.e. results in no crossover. Table 1 provides an overview of our classification.

Overview

This paper organized as following: Section 2 discusses the resources focused on collections of refereed literature. An overview of visualization-focused websites is illustrated in Section 3. Section 4 focuses on off-the-shelf software collections for data visualization practitioner, while Section 5 focuses on visualization software collections for programmers. The special topic of color in visualization is presented in section 6 (due to its popularity). Section 7 discusses visualization resources on another special topic: geospatial visualization. Section 8 presents collections of visualization related blogs. Section 9 provides the conclusion of this paper and a discussion of future work. See Table 1 for an overview.

Related Work

The website usabiliTEST[21] is an online tool for usability testing and information architecture on web usability issues. The website provides a page called, "Methods table" which provides a collection of resources on usability. It is a collection of resources for the Human-Computer Interaction (HCI) community. This is the closest related work we found on collections of resources. To our knowledge, this is the first comprehensive overview on this topic.

Liu et al.[22] provide a novel collection of visualization resources and a classification of the resources according to type. This short survey compiles and provides the descriptions, examples and information about the curators of each resource collection. It also serves as a novel starting point and concise overview on visualization resources for students, researchers, and practitioners with an interest in data visualization and visual analytics. This is an extension of their work. This paper extends previous work in the following ways: 1) It includes resources for developers, 2) It includes special focus topics such as color mapping, and 3) It is more comprehensive (approximately twice the size) covering new categories such as geospatial visualization and blog collections. Conceptually, what we present here can be seen as adding an additional row and five more columns to Table 1 as compared to Liu et al.[22] We have also added 4) a set of *reader recommendations* for each collection of resources for this extended version. The number of references has more than doubled.

Resources-Focused on Collections of Refereed Literature

This category focuses on peer-reviewed literature that offers collections of research papers. It offers a helpful starting point for readers interested in obtaining very helpful literature overviews. In this section, resources on surveys of surveys are presented. Next, research papers with online collections and resources are proposed. In the third subsection, we provide some surveys which gather online collections of images. The fourth sub-section focuses on SurVis[23] resources discussed in the literature. Lastly, surveys of visualization books are discussed.

Refereed Survey-based Resources (Surveys of Surveys)

Surveys present a valuable means to quickly find previous research on a particular topic. However, there are a growing number of topics and therefore a growing number of surveys. To address this, there have been recent developments on surveys of surveys[24 8 9 25]. These surveys of surveys are valuable resources offering a concise overview of the interactive data visualization and visual analytic fields.

The Search Process: In order to find these surveys, we searched for the phrase "visualization survey of surveys" and a number of variants on this phrase. After our initial findings we then did two further searches. The first one is a recursive search, i.e., we examined the references found in the initial survey of surveys. The second search is a forward looking search, i.e., we utilized Google's "cited by" feature for each survey of surveys. For the rest of this paper we refer to these searches as the recursive and forward-looking searches.
Inclusion Criteria: We include each survey of surveys we find on the topic of visualization or visual analytics.

This category was pioneered with the work of McNabb and Laramee who provide a comprehensive survey of 85 information visualization and visual analytics surveys[9]. This work is accompanied by a SurVis based web resource, listing a large collection of surveys and state-of-the-art reports.

Text visualisation has seen rapid gain in popularity in recent years, accompanied by a number of survey papers on the topic. Alharbi and Laramee provide an overview of these with a review of 14 text-based surveys[24]. Similarly, the surveys from the cross-disciplinary field of molecular dynamics have been analyzed by Alharbi et al.[8]

A premier journal for publishing surveys in data visualization and computer graphics, Computer Graphics Forum, has an extensive collection of surveys – every survey published in Computer Graphics Forum. The website by Chen[25] features, over 180 survey papers presented in chronological order dating back to 1985.

As a hot topic in comprehending patterns and predicting trends of data, machine learning models have developed quickly in many different areas. Accordingly, information visualization of machine learning models provides an effective solution in interpreting the workings of these models. Chatzimparmpas et al.[26] contribute a survey of surveys on the exploration and interpretability of machine learning models. This work contributes 18 papers related to the visualization of machine learning (2014 - 2018).

Recommendations: As a starting point, we recommend the Survey of Surveys by McNabb and Laramee[9] because it features an overview of the field of information visualization and visual analytics in a well-structured and organized layout. For more specialized topics such as text visualization we recommend the reader consult Alharbi and Laramee[8], likewise Chatzimparmpas[26] for machine learning. Additionally, for a large collection that also includes computer graphics literature, we recommend the resource provided by Chen[25].

Table 2. Research Papers with online metadata collections: A summary of the online collections described in Section Research Papers with Online Metadata Collections and Resources. These papers feature a refereed collection of research papers with online resources.

Research Paper Topic	Url
Lam et al. [2] **Information visualization and Evaluation**	https://docs.google.com/document/d/1uSius4qLHHAERhUtuMrfJ5nMyE-X9cot3ewUdZfR01Q/edit?authkey=CIjs31Q
Stakso et al. [6] **Citation visualization**	https://www.cc.gatech.edu/gvu/ii/citevis/
Isenberg et al. [11] **Paper contribution types**	https://vis-contribution-types.github.io/
Isenberg et al. [12] **keywords**	http://keyvis.org/
Isenberg et al. [4] **dataset of IEEE VIS publications**	https://sites.google.com/site/vispubdata/home
Matejka and Fitzmaurice [13] **Statistical datasets generation**	https://www.autodesk.com/research/publications/same-stats-different-graphs
Diehl et al. [14] **Community-based discussion and educational platform**	https://visguides.org/
Borkin et al. [15] **Massive Visualization Dataset**	http://massvis.mit.edu/
Ren et al. [16] **Bespoke Chart Layouts**	https://charticulator.com/
Borgo et al. [17] **Information visualization evaluation using crowdsourcing**	https://crowdsourcing4vis.github.io/
Connor et al. [18] **Color palettes for information visualization**	http://vrl.cs.brown.edu/color
Wang et al. [19] **"Cheat sheets" for visualization techniques**	https://visualizationcheatsheets.github.io/
Fuchs et al. [20] **A Visual Education Platform for Teaching Clustering Algorithms**	https://educlust.dbvis.de/

Research Papers with Online Metadata Collections and Resources

There are a number of previous related papers that examine collective metadata from published visualization papers and publish the metadata itself as a contribution for further research and analysis.

The Search Process: In order to find refereed literature offering a collection of resources, we started with research papers that we read firsthand offering metadata collections. We came across these research papers through regular reading and reviewing of research literature, consistently attending visualization conferences and related events, and personal communication with other researchers in the field. Moreover, these findings are based on a collective experience of many years. In other words, the search is based on a team effort by all the co-authors of this manuscript. After our initial findings based on reading and experience, we then performed two further searches for each research paper in this category: the recursive search and the forward looking search described previously. **Inclusion Criteria:** We include each visualization paper that offers a valuable collection of metadata that facilitates both search and comparison of visualization literature on a collective level.

Lam et al. analyze information visualization papers and classify their evaluation types into seven categories. They published the full list of information visualization papers along with their classifications online [2]. This paper was later extended to cover scientific visualization papers [3]. Stakso et al. published an online tool called Citevis that shows which visualization papers are cited by others using interaction [6]. Isenberg et al. examine and classify the types of contribution made by each visualization paper and publish the full classification online [11]. Isenberg et al. also examine and classify the keywords used in each visualization research paper and compare them to keywords used by a typical visualization research paper submission system [12]. They accompany their analysis with an online keyword browser.

Matejka and Fitzmaurice implement a method to create a dataset by slightly modifying a given one [38] while at the same time preserving the mean, standard deviation, etc, of both of them. In other words, the statistical properties of the two datasets are are the same. They demonstrate that statistics are not always adequate to understand data models and how visualization can be of help in these cases. Their work was based on the theory of Anscombe's Quartet presented by Anscombe [39] and the Datasaurus Dozen created by Cairo [40]. Based on these methods, a web page is also provided to demonstrate the variation of datasets [13].

Diehl et al. created an educational platform called VisGuides [14] that promotes the discussion of visualization guidelines and well established concepts. It targets different kinds of audiences such as students, practitioners, and scientists, and teachers. It collects the advice and recommendations on visualization design from experts in the field.

Borkin et al. created an online database which aims to provide deeper insight into the elements of a visualization that affect its memorability, recognition, recall, and comprehension [15]. The database consists of over 5,000 static images of which over 2,000 contain visualization type information, and hundreds of these visualizations have extensive annotations, memorability scores, eye-movement metadata, and labels. In addition to providing insight on visual encoding techniques and designs utilized by the different publication venues, this database is also a resource for cognitive and perceptual experiments. Resources like these contribute to applications such as image extraction from document analysis [5 41].

Ren et al. present an interactive authoring tool that enables the creation of bespoke and reusable chart layouts [42]. The website is free and open source from Microsoft Research and available at the Charticulator URL [16]. The gallery in the website consists of 26 visualization charts with videos.

Borgo et al. created a free resource page called Crowdsourcing4Vis, for a Eurovis 2018 State of the Art Report (STAR) on the use of crowdsourcing in information visualization for evaluation [17]. The website contains a spreadsheet of 82 papers, specifing the crowd-sourcing metadata ralated to each paper, on crowdsourcing for evaluation in the information visualization community.

Wang et al. introduce "cheat sheets" [19] summary sketches of visual designs for data visualization techniques. Wang et al. implemented an iterative design process of data science and visualization and generated six types of cheat sheets: anatomy, construction, visual patterns, pitfalls, false-friends and well known relatives. They evaluate the results with a qualitative user study and demonstrate the readability and utility of the cheat sheets.

Fuchs et al. contribute an online visualization platform called EduClust [20] for teaching clustering algorithms. The web application features visual representations, interactions and animations to help users understand clustering input, parameters and algorithms. Also, the website can be used as a teaching tool to demonstrate the effect of different clustering

Table 3. Image Browser References: A summary of the image collection browsers described in Section Survey Papers with Accompanying Image Collection Browsers. These papers feature a collection of refereed, visualization-related images. See Figure 1 for images of the image collection web pages.

Image Browser Name	Subject	URL
Treevis.net [27]	Tree visualization	https://treevis.net/
TimeViz Browser [28]	Time-oriented visualization	https://vcg.informatik.uni-rostock.de/~ct/timeviz/timeviz.html
Multiviz.net [29]	Multivariate and multifaceted scientific visualization	https://multivis.net/
Text Visualization Browser [30]	Refereed text visualization	https://textvis.lnu.se/
BioVis Explorer [31]	Biological visualization	https://biovis.lnu.se/
SentimentVis Browser [32]	Sentiment visualization	https://sentimentvis.lnu.se/
TrustMLVis Browser [33]	Machine learning visualization	https://trustmlvis.lnu.se/
Finance Vis Browser [34]	Finance visualization	http://financevis.net/
Predictive Visual Analytics Browser [35]	Predictive visual analytics	http://104.196.253.120/pva_browser/
MVN Visualization Techniques [36]	Multivariate network visualization	https://vdl.sci.utah.edu/mvnv/
UncertaintyViz Browser [37]	Uncertainty visualization	https://amitjenaiitbm.github.io/uncertaintyVizBrowser/
VisImageNavigator [5]	IEEE VIS conferences visualization	https://visimagenavigator.github.io/

parameters on various datasets while animating through each algorithm step.

Recommendations: The papers in this section cover a range of varied topics. For a subject-specific topic, we refer the reader to Table 2 which indicates the theme of each. Lam et al. [2] is recommended for those readers interested in the topic of evaluation. We recommend Stasko et al [6] for those interested in exploring the space of paper citations across the different tracks of the annual IEEE Visualization (IEEE VIS) conference. In order to explore the different categories of contributions in the visualization literature, we recommend Isenberg et al. (2018) [11] We recommend Isenberg et al. (2014) [43] for readers interested in exploring how keywords are used in the visualization literature.

The work of Isenberg et al. (2016) [4] is a collection of metadata for every IEEE VIS conference paper. This is a resource we cite and use regularly. We recommend it to readers who are interested in a complete collection of visualization reference material for every visualization conference paper published since 1990. The work of Matejka and Fitzmaurice [13] is often cited and provides a very valuable illustration necessitating the need for visualization. As valuable as statistics are, statistics can remain the same for very different images. This resource illustrates this.

Diehl et al [14] is a very valuable resource for both teachers and students of visualization and visual analytics. We recommend VisGuides for discussions of visualization guidelines and best practices in Visualization and all readers involved in teaching or studying those topics. We also recommend the study sheets offered by Wang et al [44] for students and teachers, as well as the helpful teaching material on clustering algorithms by Fuchs et al [20].

The image collection provided by Borkin et al [15] is recommend for those interested in studying the use of visualization "in the wild" i.e. including reports, infographics, news media, and scientific journals. It contains over 5000 sample images. Ren et al [42] is a recommended resource for practitioners interested in creating advanced charts. They can be customized by the user in ways beyond the typical off-the-shelf software.

The literature metadata collection provided by Borgo et al. [17] is recommended for those readers interested in the use of crowdsourcing to conduct user studies.

Survey Papers with Accompanying Image Collection Browsers

A number of visualization survey papers have been published that assemble an online collection of images related to the theme the survey covers. The list of websites with accompanying image collection browsers is provided in Table 3.

The Search Process: We came across these survey papers during a multiyear search process for visualization survey papers and state-of-the-art reports. This search process was undertaken while we were writing the Survey of Surveys (SoS) in Information Visualization [9]. During our search for survey papers in information visualization and visual analytics, which is described in detail by McNabb and Laramee [9], we made special note of all the surveys with accompanying image collection browsers. After our initial findings based on publishing the SoS, we then performed two further searches for each research paper in this category: the recursive search and the forward looking search described previously.

Inclusion Criteria: We include visualization survey papers and state-of-the-art reports that offer a collection of refereed visualization images that facilitate both search and comparison of special sub-topics in visualization and visual analytics. Table 3 and Figure 1 provide an overview of image collection browsers.

One example of such a survey paper with an image collection browser is from Schulz [27] which features a collection of over 300 images that exemplify tree visualization. Another excellent example of this is presented by Aigner et al. [28 45] which hosts an online collection of over 100 images on the theme of time-oriented visualization. Kehrer and Hauser present an online collection of visualization images on the topic of multivariate and multifaceted scientific data [29]. The collection features over 160 images related to this topic from refereed sources.

Kucher and Kerren collect a large, online collection of refereed text visualization images [30]. Their collection holds over 470 images. Kerren et al. present an advanced image browser related to biological visualization techniques [31]. This image browser has a special interactive feature that shows citations in the form of a graph with over 140 images. Kucher et al. present another survey paper on the state-of-the-art in sentiment visualization [32]. This is also an advanced image browser that features a valuable collection of metadata shown when clicking on an image. It holds over 160 peer reviewed visualization images. Chatzimparmpas et al. collect

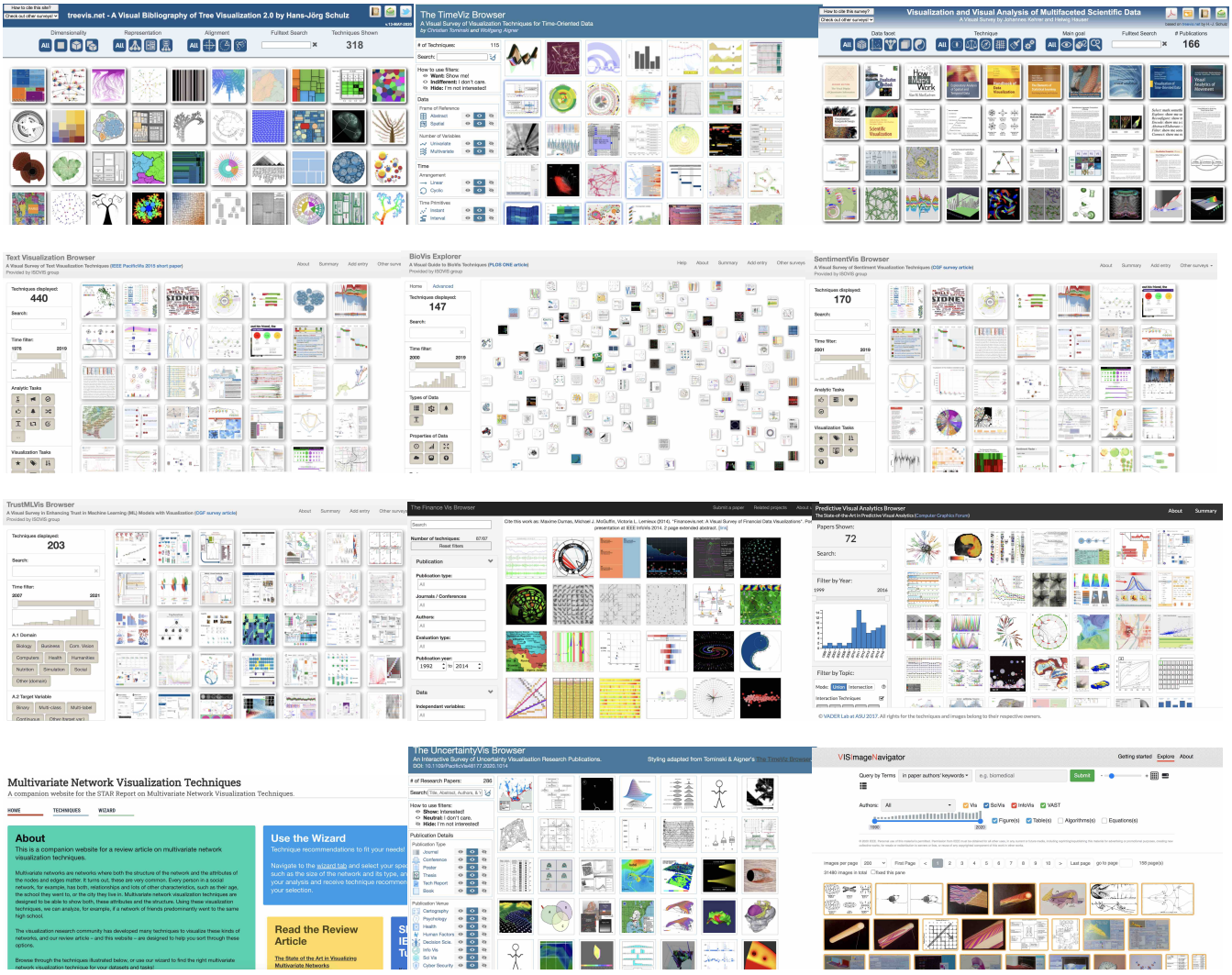

Figure 1. Thumbnails of Image Collection Browser web pages. They are presented in the same chronological order as Table 3.

200 refereed images on the topic of building trustworthy machine learning methods using visualization[33]. The image browser also offers a detailed set of metadata for each image.

Dumas et al. developed an online collection of visualization images focussing on finance[34]. The image browser supports a number of filtering options and stores over 85 peer-reviewed images.

Lu et al. collect an archive of online images related to the topic of predictive visual analytics[35]. A number of interactive filtering methods are available for over 70 images. Nobre et al. showcase both a collection of images and guidance on visual designs related to multivariate network visualization techniques[36]. Jena et al. present an impressive visualization image browser with advanced filtering options for over 280 images[37] all of which are dedicated to the topic of uncertainty visualization.

Chen et al.[5] have the most complete collection of image data (figures, tables, equations, and algorithms) of all three conference tracks of IEEE VIS (Visual Analytics, Information Visualization, and Scientific Visualization) in its 31 years of history with approximately 30k images in total. This dataset is also cross-linked to vispubdata[12] so the user can find images by keyword search. Their open source models[41] can make the subsequent data collection easier with less human intervention.

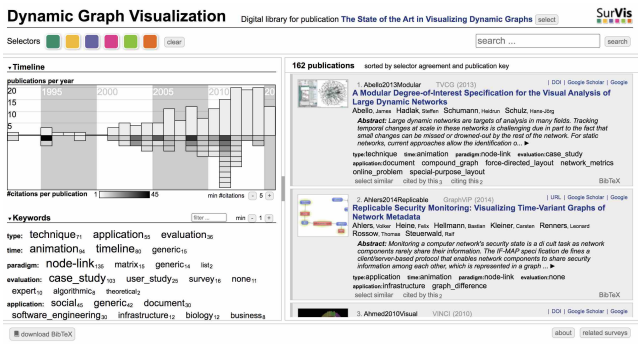

Figure 2. A sample images of a SurVis web page. The full list is presented in Table 4

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Recommendations: All of the image collection browsers we present here present a valuable collection of related images. We recommend the reader to consult Table 3 and Figure 1 for collections of images related to the focus topic the reader is interested in by consulting the "Subject" column in Table 3. The TimeVis image browswer features a number

Table 4. SurVis References: A summary of the SurVis web pages described in Section Survey Papers with an Accompanying SurVis Web Page. These papers feature a related SurVis web page. See Figure 2 for an example image of a SurVis web page.

Visualization Topic	SurVis URL
Beck et al. **Dynamic Graph Visualization**[46]	http://dynamicgraphs.fbeck.com/
Isaacs et al. **Performance Visualization**[47]	http://hdc.cs.arizona.edu/people/kisaacs/STAR/
Vehlow et al. **Group Structures in Graphs**[48]	http://groups-in-graphs.corinna-vehlow.com/
Nusrat and Kobourov, **Cartograms**[49]	http://cartogram.cs.arizona.edu/survis-cartogram/
Liu et al. **Visualizing High-Dimensional Data: Advances in the Past Decade**[50]	http://www.sci.utah.edu/~shusenl/highDimSurvey/website/
Beck and Weiskopf, **Sparklines Literature**[51]	http://sparklines-literature.fbeck.com/
Windhager et al. **Collectionvis.org**[52]	http://collectionvis.org/

of user options for filtering[45]. The same is true for the Multi-Vis image browswer[29]. For the most comprehensive collection of images, we recommend the collection by Chen et al.[5]. This collection includes all of the visualization images published at the annual IEEE VIS conference.

Survey Papers with an Accompanying SurVis Web Page

SurVis[23] is a flexible visual analytics tool used to structure and present a list of references in surveys. The list of websites with SurVis Web Page are summarized in Table 4 and Figure 2.

The SurVis interface is divided into two main views. An overview of the literature collection and a detailed list of references accompanied by an image. In the overview, the collection is presented using a timeline that provides an annual chronology of the publication collection. A bar chart is integrated into the timeline to summarize the number of publications in each year. The rest of the overview leverages selectable word-sized sparkline visualizations embedded in word clouds to show the publications metadata and clusters. The selector mechanism enables linkage between the two views.

The Search Process: We discovered several survey papers with accompanying SurVis web pages during a multi-year search process for visualization survey papers and state-of-the-art reports. The initial search process was carried out while we were writing the Survey of Surveys (SoS) in Information Visualization and Visual Analytics[9]. During our search for survey papers in information visualization and visual analytics we made special note of all the surveys with accompanying SurVis web pages. After our initial findings based on publishing the SoS, we then performed a forward looking search based on the original SurVis publication[23]. We used Google's "cited by" feature to find all research papers citing the SurVis paper. **Inclusion Criteria:** We include refereed visualization and visual analytics survey papers and state-of-the-art reports that offer an accompanying SurVis web page.

Several surveys incorporate SurVis to structure and visually analyze a literature collection. Beck et al.[46] use SurVis to systematically derive a hierarchical taxonomy of dynamic visualizations. Isaacs et al.[47] and Vehlow et al.[48] use SurVis to exhibit their literature collection. The former presents visualization approaches that inform users on optimizing software performance. The latter presents approaches that explicitly depict group structures in graphs. Nusrat and Kobourov[49] use SurVis in their bibliographic analysis. Nusrat and Kobourov applied some modifications to SurVis to incorporate different cartogram types and applications. Liu et al.[50] survey the approaches that visualize high-dimensional data. Beck and Weiskopf[51] present the state-of-the-art of embedding word-sized graphics within scientific texts. Windhager et al.[52] also use SurVis to present their literature collection which focuses on visual interface design for cultural heritage collection data.

Recommendations: Each SurVis web page adheres to the same template[23]. Thus, they all resemble one another. We recommend the reader refer to Table 4 for the specific topic of interest as indicated in the first column. The image in Figure 2 is also hyperlinked for convenience.

Surveys of Visualization Books

Books are traditionally overlooked when compiling state-of-the-art reports, however, they can contain a vast trove of information. A survey by Rees and Laramee addresses this by reporting on information visualization books[10]. In total, 41 books are reviewed totalling over 23,000 pages with a combined value of approximately $3,600 USD. Books are classified according to the audience with recommendations provided for readers, along with an indication of how many pages are dedicated to each topic.

The Search Process: A number of web resources also list information visualization books. In order to find collections of information visualization books, we used search terms such as "List of Information Visualization Books", "Collections of Information Visualization Books", and "Information Visualization Book Recommendations". We also browsed the collection of websites described in Section Visualization-Focused Websites. **Inclusion Criteria:** We include the lists we found that were recent, less than two years old, and that listed at least 10 relevant books.

The team at Information is Beautiful has compiled a list of 73 books on information visualization and infographics with a short description[53]. An extended list of 155 books also includes books covering programming tools[54]. Another list of 18 books has been compiled by Durcevic on the datapine blog along with a brief description of each book[55]. As part of their data visualization field guide, Tableau has compiled a list of 12 books including a few paragraphs of description[56]. Yet another list has been compiled by King from Solutions Review which includes 30 books and a single paragraph description of each[57]. The book recommendation website Goodreads lists books in the information visualization genre with a total of 54 books[58].

Recommendations: The most comprehensive collection of books we found is by Rees and Laramee[10]. We recommend this resource for those readers who are interested in a comprehensive overview of information visualization and visual analytic books including detailed comparisons and recommendations. We recommend the collection on Information is Beautiful[53] for an easy-to-browse collection

Table 5. Survey References: A summary of the surveys of books described in Section Surveys of Visualization Books. These resources feature refereed collections of information visualization and visual analytics books. See Section Surveys of Visualization Books for a description of how they are selected.

Authors	Subject and URLs
Rees and Laramee[10]	a survey of information visualization books
	http://visbooks.swansea.ac.uk/
Team of Information is Beautiful[53]	information visualization and infographics books
	https://informationisbeautiful.net/visualizations/dataviz-books/
Information is Beautiful[54]	extended list of[53]
	http://bit.ly/dataviz-books
Durcevic[55]	datapine blog
	https://www.datapine.com/blog/best-data-visualization-books/
Tableau[56]	12 great books about data visualisation
	https://www.tableau.com/en-gb/learn/articles/books-about-data-visualization
King[57]	30 Best Visualization Books
	https://solutionsreview.com/business-intelligence/best-data-visualization-books-on-amazon-you-should-read/
GoodReads[58]	Information Visualization Books
	https://www.goodreads.com/shelf/show/information-visualization

of book recommendations that also includes the design of charts and infographics.

Visualization-Focused Websites

As part of our search for visualization resources, we examined websites that focus on visualization and visual analytics.

The Search Process: Our search process actually began while we compiled the list of Information Visualization books[10]. During this multi-year search process, we made note of authors with high quality, accompanying web pages that featured a substantial collection of visualization resources (and not simply a web page for marketing their own work). We also searched for "Data Visualization websites" and "Visual Analytics websites". We did not include all websites that we found related to these topics. Each website featured in this section went through a quality and appropriateness checklist in order to be included.

Inclusion Criteria: One of the criteria we used is that each website features a substantial and well organized collection of visualization resources that offers value to the reader audience and is not simply for commercial purposes. Another criteria we included was that the website content is up to date, updated within the last year. We checked for quality website organization with clear content categories as well as offering a substantive amount of valuable visualization resources. These resources can include:

1. Guidance on choosing a visual design
2. Blog(s)
3. Visualization training and educational resources
4. Events such as conferences, workshops etc
5. Visualization related publications
6. Visualization book collections and recommendations
7. Visualization tools and software
8. Data sources
9. Case studies and examples
10. Links to related web pages

The above list also serves as a quality checklist for inclusion. The list of websites we found that meet our quality criteria are summarized in Tables 6 and Table 7. We do not include web pages of individual authors simply listing their own publications. We do not include solely for-profit news articles. An overview of the websites is provided by Figure 3, and Tables 6 and Table 7.

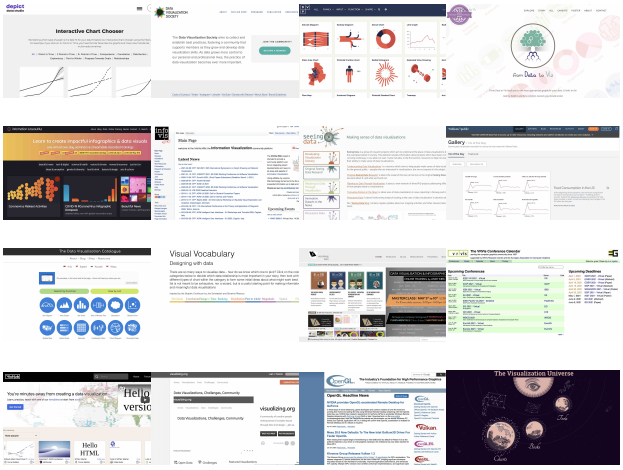

Figure 3. Thumbnail images of Visualization-Focused Websites presented in the same order as Table 6.

Depict Data Studio[59] hosts a website for presenting visualizations, reports, slideshows and dashboards to non-technical audiences. The website was created in 2014. Content includes online courses, group training, live events information, and related blogs. The website also hosts an online tool called an interactive chart chooser providing guidance on the most suitable visualization types for a given set of data. The visual designs are categorized into 10 types: 1 point in time, 2 points in time, 3+ points in time, comparisons, correlation, distribution, exploratory, part-to-whole, and progress towards goals and relationships. Under each label, suitable visual layouts are provided with a brief introduction and several illustrations.

The data visualization society.com (**DVS**) website[60] is a platform for community building targeted at professionals and practitioners incorporating visual data analysis into their professional practice. Founded recently in 2019, and based primarily in North America, DVS is focused on building a community for sharing best practices, skills, and experiences. DVS content consists of video-based panels and tutorials, a survey of data visualization practitioners, a buddy program pairing more experienced practitioners with those less experienced, an online publication featuring visualization case studies, a collection of data sources, a schedule of meetups and events (including conferences and workshops), and a collection of awards related to data visualization. There are also data visualization challenges for those looking to practice their technical skills, a spreadsheet

Table 6. Website References: A summary of the Visualization-Focused web pages described in Section Visualization-Focused Websites. These websites feature a quality collection of visualization-related resources. See Figure 3 for images of the websites. See Section Visualization-Focused Websites for a description of how these websites are filtered.

Web Page Name	URL
Depict Data Studio [59]	https://depictdatastudio.com/charts/
DVS [60]	https://www.datavisualizationsociety.com/
DVP [61]	https://datavizproject.com/
From Data to Viz [62]	https://www.data-to-viz.com/
InformationIsBeautiful.net [63]	https://informationisbeautiful.net/
The InfoVis Wiki page [64]	https://infovis-wiki.net/wiki/Main_Page
Seeing Data [65]	http://seeingdata.org/
Tableau Public [66]	https://public.tableau.com/en-us/gallery/?tab=viz-of-the-day&type=viz-of-the-day
Data Visualisation Catalogue [67]	https://datavizcatalogue.com/
Visual Vocabulary [68]	https://ft-interactive.github.io/visual-vocabulary/
Visualisingdata.com [69]	https://www.visualisingdata.com/
VRVis Conference Calendar [70]	https://confcal.vrvis.at/conferences/
VizHub [71]	https://vizhub.com/
Visualizing.org [72]	https://www.visualizing.org/
OpenGL [73]	https://www.opengl.org/
The Visualization Universe [74]	http://visualizationuniverse.com/

of visualization related books, a list of visualization related courses ranging from a single day to a multi-year degree program, and a list of podcasts, blogs, and related websites.

The Data Viz Project (**DVP**)[61] is website created by a data visualization agency[75] in Copenhagen. The DVP is an online tool enabling users to find the most appropreate visual layouts for their data and learn how to create images. The website provides different perspectives to inspire users who struggle to creating their visual interface. Users can view visual designs according to the kind, input data, the functions to deliver the methods, as well as the shape of the visualization.

From Data to Viz[62] is an online chart selector for data visualization, created by Yan Holtz. The website provides a tool to explore and display data according to types of data and the variety of visual designs. It offers a well organized taxonomy of charts and graphs.

InformationIsBeautiful.net[63] is a website for data visualization techniques founded by David McCandless. The examples provided by the website are regularly updated and revised. The website provides a collection of visual designs on different topics: new, tech and digital, science and health, nature and climate, money and economy, ideas and perception, gender and diversity, food and drink, data visualization design, as well as arts and culture. Furthermore, there are also blogs, online training and recommendations on creating visual images from scratch.

The InfoVis Wiki page[64] is an online community platform related to information visualization. The InfoVis project was created (and maintained) by the InfoVis Wiki team in 2003. The aim of the project is to provide up-to-date developments and information on the field of information visualization. The page adopts Wiki technology and is editable by anyone. The platform contributes news, a glossary, visualization design patterns, visualization events, web resources, publications, research and educational information to users. In addition, information about researchers, companies, jobs, techniques and software is provided. Although this project does not generally include Wikipedia pages (due to quantity), we make an exception for the InfoVis Wiki page due to its substantial collection of resources.

Seeing Data[65] is a website hosting a collection of data visualization projects. The online resource was founded by the Seeing Data project team University of Sheffield. The aim of this project is to help users understand how to explore data in the form of images. The website provides guidance in developing visualization literacy, relating to data through visualization, and innovative news on data visualization and blogs.

Tableau Public[66] is an online platform for sharing and exploring data visualizations. It is a free product owned by Tableau Software, LLC. The website hosts a collection of visualization resources created by Tableau Public tools and a list of authors working on visualization. The website also contributes free visualization tools for users.

The **Data Visualisation Catalogue**[67] is a project developed by Severino Ribecca. The project aims to create a library that provides a variety of information visualization resources. The website hosts a collection of data sources, dataviz blogs, code-based chart generation tools, chart generation WebApps, and examples showcasing visual samples and infographics, libraries, publications, podcasts, conferences, etc.

Visual Vocabulary[68] is an online platform created by Andy Kriebel. The webpage is also featured by Tableau Public[76]. It serves as a starting point for making informative and meaningful data visualisations. Visual Vocabulary provides different strategies to explore data: deviation, correlation, ranking, distribution, change over time, part-to whole, magnitude, spatial and flow.

Visualisingdata.com[69] is a website featuring a collection of tools and resources related to data visualization. The website was founded by Andy Kirk in 2010 based in Leeds. Apart from podcasts, blogs, training courses and books, the website also hosts a collection of visualization resources. The visualizations in the collection contains data handling, applications, programming, web-based tools, qualitative, mapping, specialist and color mapping.

The **VRVis Conference Calendar**[70] is a website for searching data visualization and related conferences. The website was founded on the basis of Helwig's Conference Calendar and created by Helwig Hauser at the Vienna University of Technology in 1997. The website hosts a

Table 7. Website References: A summary of the web pages and relevant resources described in Section Visualization-Focused Websites.

	Design Guidance	Blog(s)	Training	Events	Related Publications	Book Collections	Tools and Software	Data Sources	Case Studies	Related Web Pages
Depict Data Studio[59]	√	√	√	√		√				
DVS[60]	√	√	√	√	√	√		√	√	√
DVP[61]	√						√			
From Data to Viz[62]	√						√	√		
Information Is Beautiful.net[63]	√	√	√				√		√	
The InfoVis Wiki page[64]			√	√	√					√
Seeing Data[65]	√	√	√	√						
Tableau Public[66]	√	√					√	√	√	√
Data Vizualisation Catalogue[67]	√	√	√	√	√		√	√	√	√
Visual Vocabulary[68]	√		√							
Visualisingdata.com[69]	√	√	√				√		√	√
VRVis Conference Calendar[70]				√						
VizHub[71]	√		√				√		√	
Visualizing.org[72]	√	√		√			√	√	√	
OpenGL[73]	√		√	√			√	√		√
The Visualization Universe[74]	√					√	√			

collection of more than 1,000 data visualization related events since 1972.

The **VizHub**[71] is a website created by the Datavis Tech Inc providing courses and open source code examples for data visualization. VisHub also serves as an online tool to create and develop visualizations using web technologies such as HTML, CSS, JavaScript and JSX(React). In addition, the website can be used as an educational platform to produce an online course in data visualization.

Visualizing.org[72] is an online community created by GE and the Seed Media Group. The website focuses on visualizing important events for designers, organizations, teachers and schools, as well as audiences who are trying to exploring data visualization and infographics.

OpenGL[73] is a graphics standard for developing portable, interactive 2D and 3D graphics applicatons. It was created by the Khronos Group Inc in 1992. In the website, books, tutorials, online coding examples, and coding seminars, are provided.

The Visualization Universe[74] is a collaboration project between Google News Lab[77] and Adioma[78]. The project is an analytical, up-to-date visualization resource that aims to present the state of the data visualization based on the current user's search and interest activities. The website features three primary content categories: tools, books, and charts.

Recommendations: Depict Data Studio[59], DVP[61], From Data to Viz[62], Data Visualisation Catalogue[67], and Visual Vocabulary[68] are all very good for students and practitioners seeking guidance on visual design. Each offers guidance on choosing an appropriate visual representation for a given dataset or data characteristics. They also offer training and educational opportunities.

VisualisingData.com[69] and InformationIsBeautiful[63] are recommended for those interested in training opportunities in visual analytics and visualization.

InformationIsBeautiful[63], Seeing Data[65], Tableau Public[66], the VizHub[71], and Visualizing.org[72], are excellent resources for those interested in seeing how visualization is applied to real-world data. They include a large collection of high-quality case studies and examples in visual data representation.

The InfoVis Wiki Page[64] is a good resource for those interested in applying for a job as a visualization scientist. It is one of the few resources that collects job advertisements in visualization and visual analytics as well as the industries and business hiring in these areas.

DVS[60] and VRVis[70] are recommended for practitioners who are interested in participating in activities such as meetings and visualization events and developing their professional network.

Free, Off-the-Shelf Software Collections for Data Visualization Practitioners

This section describes free off-the-shelf software for data visualization in practice. Since the start of visualization as a field, hundreds of software tools related to visualization have been developed. Due to the large volume, we do not list individual programs but rather collections of applications. Luckily, a few dedicated practitioners have worked very hard at curating an organized collection of off-the-shelf software collections.

The Search Process: When we started our search for collections of data visualization tools, we were already familiar with two well known collections that we commonly refer to in our data visualization class. In our data visualization assignments, one of the requirements is to use a minimum of three different off-the-shelf visualization tools on a given dataset. Over the course of several years both students and staff searched for visualization tools and the two high-quality collections we found are from Andy Kirk[69] and Keshif LLC[79]. Using this experience as a starting point, we conducted further searches by examining the visualization websites described in Section Visualization-Focused Websites and through Google searches. We searched for "Collections of Visualization Tools", "Collections of Visual Analytic Software", and variants of those terms. **Inclusion Criteria:** We include collections of free, off-the-shelf visualization and visual analytic tools that have been updated within the last two years and that contain at least 20 applications. Commercial collections are not included.

One of these collections is created by Andy Kirk[69] (www.visualisingdata.com/resources/) who has organized links to over 190 applications related to visualization. Each application is represented by an image. The programs are organized into the following groups: data handling, desktop application, web-based, qualitative, geospatial mapping, specialized applications and color tools. There is also a specialized category for visualization APIs for programmers (not strictly off-the-shelf).

Keshif LLC has put together an impressive collection of over 400 visualization tools[79] (gallery.keshif.me/VisTools).

The tools can be filtered based on a number of attributes. For example, free (240+), proprietary (70+), and both free and commercial versions (30+). Tools can also be filtered based on features including charting, web-based, color, etc. or the type of data they can analyze such as temporal, multivariate network, geospatial, and text. The filtering and selection options are numerous and detailed.

Interactive things, a group dedicated to visualization, has also published a collection of 56 off-the-shelf tools that they use in their work[80]. Rather than maintaining a comprehensive list, they present a collection of over 50 tools that they use and recommend to others. The tools are organized into the following categories: maps, charts, data, and color (datavisualization.ch/tools/selected-tools/).

A team of University of Edinburgh has created an website called VisBrowser[81] which provides visualization tools and related resources. The online platform contains over 45 visualization tools. All resources are organized under 6 categorization of resources, namely, availability, programming skills, platform, features, type of data, and visualization.

Recommendations: The collections of tools we use most frequently are those of Andy Kirk[69] and Keshif LLC[79]. These are the most comprehensive collections of visualization and visual analytics tools with advanced filtering options (to our knowledge). We recommend them as a starting point for those searching collections of free, off-the-shelf visualization software tools.

Free, Visualization Software Collections for Programmers

We make a distinction between software solutions which are complete and form the basis of an entire application versus library solutions which are imported into existing software applications. We focus on complete, open software solutions and collections of open libraries, e.g., collections of chart libraries. The descriptions of the software collections convey their size and their organization.

The Search Process: In order to find open source library collections for developers, we started by looking at the related links provided by the visualization websites in Section Visualization-Focused Websites. Afterwards, we conducted some Google searches on the terms "Collections of Visualization Developer Libraries", "Visualization Tools for Developers", and "Visualization APIs for Programmers". We also performed searches using variants of these phrases and on Github.

Inclusion Criteria: We include collections of free, open source, visualization and visual analytic tools for developers. We include collections that have been updated within the last two years and that contain at least 20 resources. Collections which are primarily commercial are not included. We also focus on well-organized collections.

Open Source Library Collections for Developers

There are now a myriad of open source visualization libraries for developers. There are so many that it is impractical to list each individual one here. Thus, we present a selection of curated collections of free developer libraries to assist in visualization and visual analytics. Luckily, we can exploit the work others have already carried out in collecting and archiving these resource links. An overview of these resources is provided in Table 8.

The first collection is called the **Awesome Dataviz Collection**[1] and is inspired by the Awesome Python Project[110]. It features an extensive list of developer resources including more than 35 JavaScript charting libraries, including graph libraries, geospatial and map libraries, the React API, as well as others. There are also developer libraries for Android, Excel, C++, Golang, and IOS. The collection also includes over 15 Python visualization libraries, 8 R tools, Ruby, Markup-based tools, as well as others. The Awesome Dataviz Collection also features lists of related books, podcasts, twitter accounts, and websites.

The next collection is dedicated to **Awesome-D3**[82]. It features a very impressive collection of over 65 chart libraries, 20 third party libraries, over 20 libraries dedicated to maps and geospatial visualization, over 35 utility, enhancement, and extension libraries, e.g., multivariate datasets, label placement, enhanced tooltips, etc. It also includes more than 15 special purpose APIs for visual designs like word clouds, cartoon style rendering, and flowcharts, etc. It also contains resources for server side development and code editors.

D3 tutorials[83] is a developer collection providing D3 charts and libraries. It features a collection of tutorials including 55 introductions and core concepts, over 15 articles about specific techniques, e.g., maps and geospatial visualization, real-time and live-updating charts, and motion capture data visualization. There are also 9 articles on the version 4 of D3, 8 blogs, and over 15 books on visualization with D3. Furthermore, it includes 2 courses, over 20 talks and video resources, over 10 meetups, and a selection of research papers.

Another collection is called the **Awesome Charting Collection**[84] which is inspired by the Awesome Lists project[111]. It features a curated list of chart and data visualization resources for developers, including 7 commercial libraries, over 20 free, and open source libraries. There is also a collection of over 10 framework-specific libraries for specific APIs, e.g., Angular, Ember, jQuery, and React. The Awesome Charting Collection also features a list of 7 resources for chart visualizations.

AntVis[85] hosts a collection of open source visualization libraries for JavaScript. It includes 3 types of data visualization resources: G2, G6 and L7. G2 is an interactive data-driven visualization library for statistical charts. It features a data visualization collection of 9 line charts, 7 area charts, over 15 column charts, 11 bar charts, 14 pie charts, 7 point charts. There are also 3 radar charts, 4 funnel charts, 9 heatmaps, 5 box charts, 3 k charts, 4 gauges, 6 maps, 10 facets, over 10 graphs, and over 10 other visualizations such as kagi charts, word clouds, and punch cards. The G6 is another AntVis collection for graph visualization including over 15 tree graphs, over 35 layout graphs, 8 animated visualizations. It also features components and items such as nodes, tooltips, context menus for graphs. L7 is a collection of resources on geospatial visualization. It features over 20 point layers, 15 line layers, 7 polygon layers, over 10 heatmap layers, and 5 raster maps. It also provides 6 react demos of COVID-19 maps.

Table 8. Open Source Libraries: Software development library collections for visualization developers described in Section Open Source Library Collections for Developers. These resources feature a quality collection of free open source libraries.

Name of Library	Url
Awesome Dataviz Collection [1]	https://github.com/fasouto/awesome-dataviz
Awesome-D3 [82]	https://github.com/wbkd/awesome-d3
D3 tutorials [83]	https://github.com/d3/d3/wiki/Tutorials
Awesome Charting Collection [84]	https://github.com/zingchart/awesome-charting#readme
AntVis [85]	https://github.com/antvis
VTK [86]	https://vtk.org/
VisIT [87]	https://wci.llnl.gov/simulation/computer-codes/visit
Observable [88]	https://observablehq.com/

Table 9. Collections of Color Resources: A summary of the collections of color resources described in Section Collections of Color Resources and Section Noteworthy and Popular Color Resources. These resources feature a quality collection of color resources references.

Web Page Name	URL
Visualisingdata.com [69]	https://www.visualisingdata.com/
RapidTables [89]	https://www.rapidtables.com/web/color/index.html
SciVisColor.org [90]	https://sciviscolor.org/tools/
ColorBrewer.org [91]	https://colorbrewer2.org/
Colorgorical [18]	http://vrl.cs.brown.edu/color
Color Oracle [92]	http://colororacle.org/index.html
ColorHex.com [93]	https://www.colorhexa.com/
Adobe Color Wheel [94]	https://color.adobe.com/create
Chroma.js Color Palette Helper [95]	https://vis4.net/palettes
ColorPicker [96]	http://tristen.ca/hcl-picker
Data Color Picker [97]	https://learnui.design/tools/data-color-picker.html
hclwizard.org [98]	https://hclwizard.org/
I Want Hue [99]	https://medialab.github.io/iwanthue/
Paletton [100]	http://paletton.com/
Viz Palette [101]	https://projects.susielu.com/viz-palette
Spectrum [102]	https://github.com/richardroberts1992/Spectrum
D3 color mapping library [103]	https://github.com/d3/d3-scale
CCC-Tool [104]	http://www.ccctool.com/html_v_0_9_0_3/CCC_Tool/cccTool.html
Color Map Advice [105]	https://www.kennethmoreland.com/color-advice/
Color Calculator [106]	https://www.sessions.edu/color-calculator/
Color Gradients Explorer [107]	http://geotests.net/couleurs/gradients_en.html
Color Palette Generator [108]	https://www.degraeve.com/color-palette/
Color Wheel [109]	https://www.canva.com/colors/color-wheel/

Recommendations: We recommend the Awesome Datavis Collection [1] for developers that are interested in a comprehensive overview of developer resources. It features other related visualization and visual analytics resources including books, podcasts, and even Twitter accounts. Awesome D3 [82] is clearly for D3 and web developers. The collection of D3 resources is quite long and comprehensive. D3 Tutorials [83] is recommended for both students and developers as it features a long, comprehensive list of educational resources related to D3. Blogs, books, and entire courses are provided. We recommend the Awesome Charting Collection [84] for developers interested in Javascript library collections and more framework-specific APIs. AntVis [85] is likely the most comprehensive collection of JavaScript libraries for visualization and is a valuable resource collection for web-developers.

Open Source Software Solutions for Developers

There are a handful of complete, whole package solutions that are supported by textbooks, companies, mailing lists, technical support, mature, older, classic, and feature large datasets. We use the term "software" to indicate a complete solution and not just a library that is imported into an existing program.

The **VTK** (Visualization toolkit) is one of the very first books (circa 1993) dedicated to developing visualization software. The authors, Schroeder, Martin and Lorensen are all early pioneers in the data visualization field. The VTK is a comprehensive, free, open source software application for scientific visualization. Their textbook [86] describes techniques that focus on scalar, vector, and tensor field data. Other important topics include color mapping, isosurface construction, flow visualization, meshing, texture mapping for visualization, and volume rendering techniques. The book comes with the full software libraries, sample datasets, sample applications and source code. The website to accompany the book and software [86] offers technical support including a free developer forum. It is a comprehensive resource for developers. Kitware, the parent company of VTK, also offers a number of related open source software

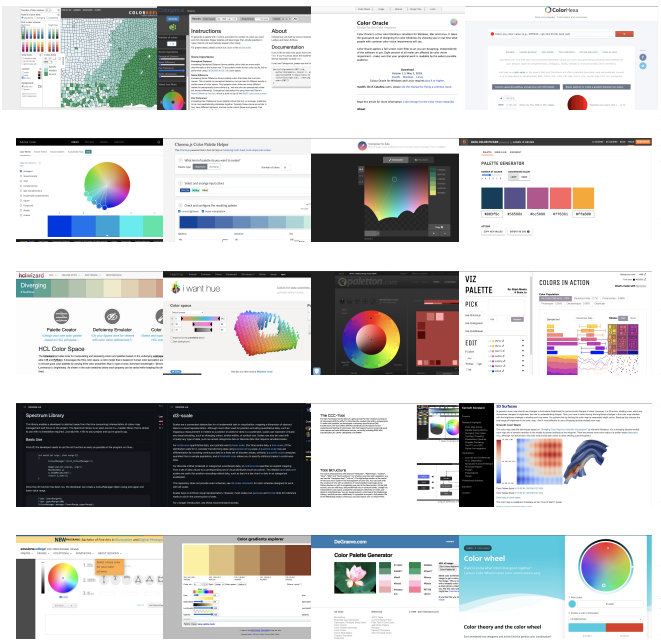

Figure 4. Thumbnail images of web pages of the color resources presented in the same order as Table 9

.

libraries including the ITK[112] and Paraview[113]. Paraview is focused on very large scientific datasets that exceed the size of main memory.

VisIT[87] is another free, open source developer solution for scientific visualization. It supports a range of scalar, vector, and tensor field visualization techniques on both structured and unstructured grids. VisIT is focused on very large datasets (terabyte scale) and offers parallel computing functionality and support. It uses a distributed computing architecture to support very large simulation datasets.

Observable[88] is a Jupyter-Notebook-style web service for data visualization with real-time collaboration in javascript. The service is well known in the community.

Recommendations: The VTK[86] is recommended for developers interested in scientific visualization and visualization of very large datasets. It is a valuable resources for teachers, students, and developers due to its maturity and extensive documentation. It also provides technical support. The same is true for VisIT[87], however, VisIT is especially designed for extra large (giga and tera-scale) datasets requiring out-of-core and in-situ processing. We recommend Observable[88] for developers and practitioners that are interested in collaborating on a team project or would like to share and communicate their visual designs with others including the public. The web-based platform is designed for showcasing visual designs in a shareable setting.

Special Topic: Color

Although we have focused on collections of visualization resources thus far, we make an exception for the subject of color mapping. Color mapping is a core topic in the fields of data visualization and visual analytics thus the demand for color mapping solutions and resources is high. Furthermore, color mapping is still not considered to be a completely solved problem. We dedicated a special section to the topic of color mapping due to its ubiquitous importance.

The Search Process: Our search process for color mapping resources started with the research literature. We have been using the well known tools of color-brewer[91] and colorgorical[18] for several years. The SoS[9] contains a color mapping survey paper by Zhou and Hansen[114] and we are already familiar with the color mapping chapters of dozens of visualization books[10]. In addition, we read the book dedicated to color mapping by Maria-Rhyne[115]. Starting with these literature resources, we performed the recursive and forward looking searches. Some of the visualization websites feature pages dedicated to color (See Section Visualization-Focused Websites). We also added some Google searches using phrases such as "Color mapping tools", "Color mapping library", "Color mapping software".

Inclusion criteria: We include color mapping resources that are well organized, of high quality and useful to students, researchers, developers, and practitioners. An overview of color mapping tools is provided in Table 9.

Collections of Color Resources

Visualisingdata.com[69] presents an organized collection of over 25 different color resources and applications for students, practitioners, and developers. The color tools offer a myriad of color-related functionality including testing color variations, color schemes, foreground and background color combinations, color scales, calculating color values, associating colors with cultures, exploring color spaces and color gradients, offering recommendations for the color blind, a color blog, as well as other tools. It is a subpage of visualisingdata.com from Section Visualization-Focused Websites.

RapidTables[89] presents a very useful collection of color-based tables applicable to web-based and visualization color mapping. It features a large selection of over 20 different color tables. Each entry in each color table displays the numeric RGB value in both decimal and hexadecimal scales.

SciVisColor.org[90] features a set of 13 different visualization applications, some of which are dedicated specifically to color including: CCC-Tool[104], Colorbrewer[91], Colorgorical[18], and Kenneth Mooreland's color mapping web page[116].

Recommendations: We recommend Visualisingdata's[69] (click on the "Colour" tab) collection of color resources for practitioners looking for off-the-shelf color tools. RapidTables[89] is an excellent resource for students, practioners, and developers to explore color space in general. It enables the user to observe a variety of color spaces and an essentially unlimited color values in those spaces. We recommend SciVisColor.org[90] for users interested in exploring color scales and color mapping for scientific visualization.

Noteworthy and Popular Color Resources

ColorBrewer.org[91] is an online tool designed to help people select good color schemes for maps and other graphics. This online tool allows users to display data by designing color schemes. Users are able to create up to 12 color categories for their data visualization. In addition, it provides three types of color schemes: sequential, diverging and qualitative,

with multi- or single-hue. After selecting a scheme, the tool offers guidance for use with the color blind, color printing, photocopies or laptop display. For the context of a map, appearance of roads, cities and borders are provided if the user would like to highlight certain locations. For the background of the maps, solid color and terrain are offered.

Colorgorical developed by Gramazio et al.[18] enables users to create customized color palettes for information visualization. It adopts empirically derived color preference data to inform categorical palette generation. It generates a palette by balancing color discriminability and user preference.

Color Oracle[92] is an open source tool for color blindness simulation. It offers guidance for the design for color blindness by displaying in real time what people with common color vision impairments see. The tool provides functions to convert visualization work into a palette that simulates views of colorblind people.

ColorHex.com[93] is a free color tool providing exploratory options for color and generating matching color palettes. By entering a color code or selecting a color from the palette, users obtain meta-data of the color, such as the combination of the color with other color spaces, hue angle, shades and tones, hex code, RGB values and other color value of similar color, etc. The online tool also provides features such as gradient generator, color blender, color subtraction, 216 safe colors, and colors by name.

Adobe Color Wheel[94] is an official Adobe tool to help users create a color palette. It enables the user to upload an image to generate a color scheme. The online color wheel features a color harmony rule which ensures all colors selected by users are in harmonic balance. Four color schemes are available, namely, RGB, CMYK, HSB, and LAB.

Chroma.js Color Palette Helper[95] is a color tool developed on the basis of Chroma.js[117] is a JavaScript library for color conversations and color scales. The color tool allows users to manage multi-hued and multi-stop color scales. By inputting two colors, the users can obtain a palette of the color range. In addition, palette types such as sequential and diverging, number of colors displayed in the range, figures of lightness, saturation, and hue are featured in the color schemes.

The **Color Palette Generator**[108] is part of a website called DeGraeve.com which is an online platform providing open source, high quality, web-based tools. The Color Palette Generator enables users to import an image and derive a color palette that matches the image.

ColorPicker[96] is a color tool to design color gradients from a color map. It enables users to select a color range from a color chooser and to see the effects when applying the color schemes to a geospatial visualization. In the ColorPicker tool, users are allowed to select color ranges based on three options: hue-lightness, chroma-lightness, and hue-chroma. Also, users can customize the numbers of color in the color range.

Color Wheel[109] from Canva.com is an online RGB color combination generator. For each given color scheme a designer intends to create, it suggests four types of color combinations.

Data Color Picker[97] is another useful tool to generate colors by defining the first and the last color. It features three color schemes: palette generator, single hue scale generator, and divergent hue scale generator. In each palette, information on visualization context is provided, using a description on how to use the palette.

The **hclwizard.org**[98] is a useful color tool to manipulate and assess colors. The palettes of the tool are developed based on colorspace which is another library available in R and Python. It supports creating color maps for the color blind.

I Want Hue[99] is a color tool to generate and refine palettes of optimally distanced colors. The online color tool provides 22 color spaces with HCL parameters selector and 15 for color displaying. Also, the color points in the palette can be clustered according to methods such as k-means or force vector. It also enables users to access color codes in the format of plain text, Json, CSS, as well as JavaScript. Another interesting feature provided by this tool is it provides a differentiation report and color vision deficiency.

Paletton[100] is a color tool similar to Adobe Color CC. It contains a color wheel for choosing color combinations and a palette for the color schemes accordingly. The tool is helpful for beginners learning how to design a proper color scheme for their images.

Viz Palette[101] is a tool for choosing colors for data visualizations. This work enables users to evaluate their color schemes and improve them. It features a palette with 6 data visualization types and 5 categories of users: no color deficiency, Deuteronomy, protanomaly, protanopia, deuteranopia and greyscale. Furthermore, it generates a color report of the schemes.

Recommendations: ColorBrewer.org[91] is a good starting point for students and practitioners who are interested in exploring and designing categorical color maps. It features a large variety of options and enables the users to preview the color scales on a map. The Chroma.js Color Palette Helper[95] features options that are similar to ColorBrewer. It offers guidance on deriving quality categorical color scales including divergent color maps. Viz Paletter[101] is an extension of Chroma.js and even makes recommendations for color edges and arcs. Another tool similar to the previous ones is Data Color Picker[97]. It generates categorical color maps with visually equidistant hues. ColorPicker[97] also recommends high quality categorical color maps based on interactive user selection of two hues in color space. We recommend this tool for any user interested in color map exploration.

We recommend Colorgorical[18] to students, researchers, and practitioners who are interested in advanced exploration and design of color scales and color mapping. The user-options featured are more advanced and support the design of custom-made color maps. Users may even design color scales with optimizations for aesthetics. Color Oracle[92] is especially targeted at users with color blindness or color impairment. It facilitates the design of color spaces for that special category of users. We recommend ColorHexa[93] for those users interested in exploring different color scales and possible designing their own customized color map. The

website offers guidance on choosing and converting colors as well as colors that are compatible with each other.

The Adobe Color Wheel[94] is an advanced color developer tool for more experienced users. Among other features, it enables the user to derive a color map based on an image provided by the user. Color Palette Generator[108] has this same functionality. They can automatically generate color themes and gradients as well as color map recommendations. Paletton[100] is comparable to the Adobe Color Wheel and is recommended for advanced users.

Hclwizard.org[98] is another advanced color generation tool that enables the user to vary three color properties: Hue (= type of color, dominant wavelength) - Chroma (= colorfulness) - Luminance (= brightness). I Want Hue[99] is an advanced feature-rich, open source tool that also offers several color-related resources including tutorials and color theory content. We recommend this tool for users that would like to explore color maps in depth.

We do not recommend Color Wheel[109] as it is not very user-friendly and feature rich compared with the other color palette generation tools.

Color Libraries for Developers

This section presents color libraries for developers. Table 9 features an overview of the color developer resources.

Spectrum[102] is an open source color map management library supporting a wide variety of features for the majority of use cases. The tool implements various color maps bundled into the library and accommodates the addition of new maps through a simple coding interface. The developer can switch freely between a selection of color maps without modifying their own code by simply updating a static index value associated with the color manager.

D3 color mapping library[103] is a JavaScript color library derived from ColorBrewer mentioned in Section Noteworthy and Popular Color Resources. It hosts 27 sequential, 9 diverging and 10 of categorical color schemes designed to work with D3-Scale's d3.scleOrdinal and d3.sclaeSequential[118].

CCC-Tool[104] is a color tool enabling the user to organize stored colormap specifications, and add new colormaps, and import/export the color schemes.

The **Color Map Advice**[105] provides guidance on using colors in scientific visualization. It contains a collection of color maps that can be applied in scientific visualization. Each case is demonstrated using a 2D heat map and 3D surface. In addition, Jupyter Python notebooks are provided to illustrate how each resource is generated.

Color Calculator[106] is an interactive color wheel that helps designers to develop their color schemes for their projects. This developer tool enables users to 1) identify harmonious color combinations 2) choose the optimal colors 3) adjust both color values and saturation.

Color Gradients Explorer[107] is a handy online platform that enables developers to pick color gradients and export the color palettes into comma-separated value (CSV) files. During the process of adjusting the color schemes, 5 visualizations are provided as examples.

Recommendations: Spectrum[102] is a simple-to-use C++ color map library. We recommend it to developers that would like a very quick and convenient solution to color maps in C++. D3 color mapping library[15] is recommended for D3 developers and provides well-documented support for data-to-color encoding.

The CCC-Tool[104] is an open source desktop tool for advanced users who would like to explore color spaces and color maps in depth. It also offers support for continuous, customizable color maps. However, this tool is still in development and may be less mature than others. We recommend Color Map Advice[105] for developers of scientific visualization applications as the library focuses on continuous color maps. Several related research papers on this topic are also offered. Color Gradients Explorer[107] is recommended for advanced users who would like to vary multiple properties of color gradients including hue, saturation, luminosity, and opacity.

We do not recommend the use of Color Calculator[106] as it is of limited functionality and not very user-friendly compared to other color tools.

Special Topic: GeoSpatial Visualization Resources

Geospatial visualization is an important subtopic in visualization. It emphasizes the expression of physical, spatial, demographic, and political organizations of data. Geospatial visualizations resources are widely used in industries such as navigation, weather forecasting, as well as aviation. Hence, we classify geospatial visualization as a special topic in visualization.

The Search Process: Our search process started with well known geospatial visualization research papers with additional online resources such as the Worldmapper[119]. Starting with the known research papers, we then performed the recursive and forward-looking literature searches described earlier. We also searched for geospatial resources while compiling the SoS[9] which features a number of geospatial visualization survey papers. The survey of information visualization books[10] also contains a special section on geospatial visualization books which we incorporated into our search. We accompanied this literature-centric search with complementary Google (and Github) searches using phrases such as "Online Geospatial Visualization Resources", "Geographic Visualization" and variations thereof.

Inclusion Criteria: There are too many geospatial visualization resources to list individually. This is why we focus on collections of geospatial visualization resources. Those collections, in turn, feature the most popular visualization tools used in practice. In addition to the collections, we include two special categories, refereed research papers with supplementary geospatial visualization resources and popular geospatial visualization resources for developers. We include refereed research papers with accompanying online geospatial visualization resources. Table 10 and Table 11 provide overviews of geospatial resources.

Geospatial Visualization Research Papers with Online Resources

Geospatial images are often projected onto a map or a geographical representation. These representations may not

Table 10. Geospatial Research Paper References: A summary of the geospatial research papers with online resources described in Section Geospatial Visualization Research Papers with Online Resources. These references feature supplementary online geospatial resources.

Authors	Subject	Url
Dorling et al. [119]	Distorted World Maps	https://worldmapper.org/
Rosling and Zhang [120]	Health Metrics	https://www.gapminder.org/
Bock et al. [121]	Global Wind Patterns	https://www.openspaceproject.com/
Wiemann et al. [122]	Climate Visualization	https://climatecharts.net/
Jänicke et al. [123]	Geospatial-temporal Visualization	http://www.informatik.uni-leipzig.de/geotemco/index.html
Šavrič et al. [124]	Map Projection	https://projectionwizard.org/

Table 11. Website References: A summary of the geospatial web pages described in Section Online Geospatial Visualization Resource Collections.

Web Page Name	URL
BGS [125]	https://www.bgs.ac.uk/information-hub/data-centres/
CDC [126]	https://www.cdc.gov/dhdsp/maps/gisx/resources/gis-resources.html
GIS [127]	https://unimelb.libguides.com/GIS
University of Waterloo Geospatial Center [128]	https://uwaterloo.ca/library/geospatial/collections
List of GIS data sources [129]	https://www.wikiwand.com/en/List_of_GIS_data_sources#/

be geometrically correct and may contain distortion to represent the data. An example of distorted world maps is provided by Dorling et al. in an online resource called the WorldMapper [119]. Each country on the map has its size mapped to a user chosen variable, distorting the area of the representation.

Not all geospatial data is represented in a geographical representation. Rosling and Zhang present various health metrics of different countries, enabling a comparison over time [120]. These comparisons along with others are available as an online resource.

Geospatial visualization is not limited to representations of data on Earth. The OpenSpace project provides software that enables exploration of the entire known universe [121].

The representation of weather is an example of geospatial data, predominantly represented with maps. ClimateCharts.net by Wiemann et al. enables users to visualize the temperature and precipitation on every place on Earth [122]. A variety of different data sources can be selected over a range of time spans. Another metrological-based web resource displays the global wind patterns in near real time, enableing the user to easily explore the data in a visually appealing manner [123].

Projecting the globe onto a flat medium such as a screen will always cause a distortion. To address this challenge, Šavrič et al. present Projection Wizard, a web application that helps cartographers select an appropriate projection for their map [124].

Recommendations: We recommend the Worldmapper project to all users that are interested in continuous cartograms [119]. The paper and accompanying web page feature a large collection of world maps distorted using a continuous value-by-area algorithm. The Gapminder project [120] is very helpful to teachers and researchers interested in the current state of global development and emerging economies. OpenSpace is recommended for astronomers [121] and any reader interested in exploring outer space. Climate Charts is recommended for researchers interested in studying global weather patterns [122]. The Geospatial-temporal visualization project [123] is especially for researchers interested in studying the temporal evolution of global weather patterns. The Projection Wizard [124] is recommended for those readers that are interested in increasing their understanding of global map projections.

Online Geospatial Visualization Resource Collections

The British Geological Survey (BGS) is a public organization dating back to 1835. They provide geological data and services to both public and private sectors [125]. Their website hosts over 400 databases covering environmental monitoring, digital databases, physical collections (borehole core, rocks, minerals and fossils), records and archives. They offer a range of data and maps spanning from open source and free to licensed data. Their open geoscience offerings include maps, geospatial data, scans, photos, and mobile phone applications. The BGS website offers detailed descriptions of its research publications and services.

The Centers for Disease Control and Prevention (CDC) was founded in 1946, after World War II, in an effort to control malaria outbreaks. In addition to hosting a large collection of datasets, they publish a special webpage dedicated to geospatial visualization [126], they call GIS Exchange (GISX). GISX offers a collection of resources including map making resources, online public health maps, geospatial data resource, GIS software and tools, GIS blogs and forums, and databases for public health research.

The Library of University of Melbourne, established in 1853, hosts rich collections of resources beyond books. They contribute an online collection of geospatial visualization resources [127] administered by David Jones. The resources include map materials of Victoria, portals of Australia and States data collection, spatial resources of Australian specialists and institutions, international sources of GIS, and specialized data collections, map libraries, blogs, societies, as well as a list of GIS spatial applications.

The University of Waterloo Geospatial Center is an inviting hub which provides GIS services and information resources to both the university community and the public. The Geospatial Centre hosts a large collection of data and cartographic resources: Canadian geospatial data resources, U.S. and world geospatial data resources, maps and atlases, and online mapping resources [128].

Table 12. Geospatial visualization resources references: A list of collections for geospatial visualization resources described in the Section Geospatial Visualization Resources for Developers.

Name	Url
BigQuery Geo Viz [130]	https://bigquerygeoviz.appspot.com/
GeoCMS [131]	https://portail.indigeo.fr/geocms/maps/
GeoJS [132]	https://opengeoscience.github.io/geojs/
ITowns [133]	http://www.itowns-project.org/
Kepler.gl [134]	https://kepler.gl/
OpenGlobus [135]	http://www.openglobus.org/
OpenLayers [136]	https://openlayers.org/
Polymaps [137]	http://polymaps.org/

Wikipedia is another website which contributes a list of GIS data sources. The list of datasets [129] is collected for building GIS systems, spatial data bases and other work related to geospatial analysis and visualization. Their web page of GIS data sources includes data from around the world.

Recommendations: We recommend the British Geological Survey (BGS) [125] to readers that require services or resources connected to UK businesses, government, academics, and the general public. Much of the content is dedicated to decreasing carbon emissions and sustainability. The CDC collection [126] offers a wide range of resources for practitioners interested in generating their own maps as well as health-related data. Their resource collection includes map generation tools and software as well as health-related data repositories. The GIS project [127] is recommended for geospatial researchers interested in studying Australia and the surrounding areas. The Waterloo Geospatial Center [128] is for those interested in geospatial studies related affiliated with Canada. The Wikiwand project [129] hosts and outstanding and comprehensive collection of geospatial data resources that are not tied to any particular region. This is the most comprehensive collection of geospatial data that we have seen.

Geospatial Visualization Resources for Developers

BigQuery Geo Viz [130] is a developer tool designed for the Google maps API. It lets users run and debug API calls interactively using Google maps.

GeoCMS [131] is an open source API that supports web-based visualization of geospatial data. It is a mixture of software technologies including Ruby on Rails, AngularJS and LeafletJS, HTML, JavaScript, CSS and coffeescript.

GeoJS is a JavaScript library to support visualization of geospatial data in a web browser [132]. It enables the developer to combine images from multiple resources including WebGL, canvas, and SVG into a single dynamic map. It also provides support for additional information visualization techniques such as heatmaps, pixelmaps, vectors, contour plots, graphs, and geometric primitives. The library is developed by Kitware and Epidemico.

ITowns [133] is an advanced library for geospatial visualization that uses JavaScript, WebGL, and Three.js. It supports several data types including 3D tiles, DEM, OGC standards, Point Clouds, Geojson, Gpx, KML, and 3D formats such as Collada, GLTF, and OBJ. Their demonstration video showcases many impressive and advanced geospatial visualization applications.

Kepler.gl [134] is a web-based application for geospatial data analysis and visualization. It was developed based on Map Mapbox GL [138] and deck.gl [139], both of which are online geospatial tools. Kepler.gl also serves as a React component. The tool supports several map visualization techniques such as Arc, Line, Hexagon, Heatmap, and GeoJson.

OpenGlobus [135] is an open source JavaScript library for interactive 3D maps and planets with map tiles, imagery and vector data, markers and 3d objects. It was built using WebGL technology. It provides techniques to create tile layers, WMS, vector layers, canvas tiles, and GeoJson. In addition, developers can use the tool to build 3D visualizations.

OpenLayers [136] is a high-performance JavaScript library to build dynamic maps and geospatial visualizations. It is open source and released under the 2-clause BSD License. It allows users to pull tiled layers from online sources such as OSM, Bing, MapBox, and Stamen. And it supports various data types including GeoJson, KML, GML, Mapbox vector tiles, etc.

Polymaps [137] is a free JavaScript library for dynamic and interactive maps using Scalable Vector Graphics (SVG). The tool is developed on the basis of SimpleGeo (EXIF.org, exchangeable image file format) and Stamen. It serves as a tool to extract cartography from OpenStreetMap, CloudMade, Bing, and other online map resources.

Recommendations: We recommend BigQuery GeoViz [130] for web developers interested in incorporating Google maps into their application. GeoCMS [131] is recommended for web developers interested in integrating multiple sources of data into their geospatial visualization application. We recommend GeoJS [132] for advanced developers that would like to combine multiple layers including vector graphics, a visualization layer, and interaction together in one application. ITowns [133] is recommended for developers looking to extend their application to three spatial dimensions. Kepler.gl [134] is recommended for developers working with large geospatial datasets because it uses WebGL technology for performance. OpenGlobus [135] also uses the WebGL API in order to support 3D geospatial visualization and is recommended for developers interested in a 3D application. We recommend the OpenLayers [136] library for developers new to geospatial visualization. It features a large collection of sample code in order to support the development process. Polymaps [137] is

Table 13. A list of collections for blogs described in Section Visualization Focused Blogs: Collections of Blogs. These resources feature a quality collection of free source blogs.

Name of Blog	Url
Data Visualisation Catalogue Blog [67]	https://datavizcatalogue.com/blog/
Data Visualization Society [60]	https://www.datavisualizationsociety.com/
VizWiz [140]	https://www.vizwiz.com/p/data-viz-blogs.html
Medium [141]	https://medium.com/search?q=Data%20Visualization%20Blogs
The 10 best data visualization blogs to follow [142]	https://www.tableau.com/learn/articles/best-data-visualization-blogs
Top 60 Data Visualization Blogs, Websites & Influencers in 2021 [143]	https://blog.feedspot.com/data_visualization_blogs/
Top 11 splendid data visualization blogs to follow in 2020 [144]	https://www.webdatarocks.com/blog/top-11-splendid/
Michael Sandberg's Blog [145]	https://datavizblog.com/my-favorite-data-visualization-blogs-beta/
PolociViz [146]	https://policyviz.com/blog/

recommended for developers interested in making tiled and image-based maps based on OpenStreetMap.

Visualization Focused Blogs: Collections of Blogs

Blogs are a collection of articles written by authors who like to share information on a variety topics. In this section, we present collections of blogs on data visualization. As part of our search for visualization resources, we include collections of blogs that focus on visualization and visual analytics. There are too many blogs to describe individually.

The Search Process: Our search process began while we compiled the list of websites in Section Visualization-Focused Websites. During this search process, we made note of websites that feature a collection of blogs. We also searched for "Data Visualization Blogs" and "Visual Analytics Blogs". Each collection of blogs in this section went through a quality and appropriateness checklist in order to be included.

Inclusion Criteria: One of the criteria we used is each blog collection must feature a substantial and well organized group of visualization and visual analytic blogs that offer educational value to the reader audience and are not simply for commercial purposes. Another criteria we included was that the blog collection is up-to-date, updated within the last year. We also checked for quality blog collection organization with an ordering that is clear to the reader.

Data Visualisation Catalogue is a visualization project developed by Severino Ribecca. The project hosts a collection of visualisation resources including a list of blogs. The webpage [67] contains over 70 blogs related to data visualization. The blogs are divided into 7 categories including website news, data visualization, chart types, chart combinations, learning and resources, technology, and miscellaneous posts.

Data Visualization Society [60] also hosts a collection of resources including blogs. The blog collection is stored in a Google sheet that contains information on 14 blogs. The DVS is also featured in the visualization web cites section.

VizWiz is a website managed by Andy Kriebel. The website features a collection of data visualizaton resources. The website contains a forum called Data Viz Blogs [140]. The list includes over 163 blogs sorted in alphabetical order.

Medium is an open resources platform where people can share ideas in their articles. The website features multiple topics such as arts and entertainment, culture, equality, health, industry, etc. Each topic hosts a collection of blogs which features blogs related to each topic. Among all the collections, a collection of data visualization blogs [141] is provided. The list consists of 20 blogs. The blogs are grouped into topics on data visualization, data science, data analysis, machine learning, Tableau, design, visualization, Python, data and analytics.

Tableau hosts an article called: The ten best data visualization blogs to follow [142]. The article introduces 10 valuable websites and platforms which contains collections of blogs on data visualization. Each resource in the article contains the author, website link, and a description of the resource.

"Top 60 Data Visualization Blogs, Websites & Influencers in 2021" is a Feedspot article of collections on the topic [143]. The article hosts 60 sources of data visualization blogs. Each resource contains a description, author, link, and email contact of the collection. The resources are ranked according to the relevancy, individual brands, blog post frequency, number of followers in social media, domain authority, age of the blogs, as well as other parameters.

Another article on the topic is "Top 11 splendid data visualization blogs to follow in 2012" written by Rovnik [144]. The resource contains 11 data visualization blogs. Apart from the link to the website, each resource is followed by a description of features of the blog list.

Michael Sandberg's blog [145] features a comprehensive list of data analytics and data visualization blogs. The list is sorted in alphabetical order. The list is updated regularly and features 180 blogs to date. The list provides the blog's authors and the links to the blog webpage and RSS feed if it exists.

PolociViz [146] is a website focused on free resources on research, analysis and ideas by Jonathan Schwabish. The website hosts a collection of blogs on data visualization techniques such as processing, analyzing, sharing, and presenting data. The list contains 23 pages of blogs and all blogs are ordered chronologically.

Recommendations: The Data Visualization Catalogue [67] is recommended for readers interested in a news style collection of blogs by a varied collection of authors. PolociViz [137] is also recommended for casual readers interested in a new-style layout of articles on visualization. The VizWiz [68] collection of blogs is quite large and offers a great starting point for readers looking for blog resources also arranged alphabetically. We recommend Medium [141] for casual readers interested in a wide variety of visualization related blogs due to its news magazine style layout. The Tableau collection [142] is recommended for readers interested in a focused collection of the most mature visualization blogs for visualization practitioners. The Feedspot collection of blogs [143] is ranked by volume of traffic and number of social media followers and thus is recommended for readers

interested in the most popular blogs. The blog collection by Rovnik[144] is rather small and is not recommended for readers interested in a comprehensive collection but perhaps for beginners needing a more nageable starting point. The Data Visualization Catalogue[145] by Sandberg is recommended for readers interested in a comprehensive collection of visualization blogs sorted alphabetically by author name. The Data Visualization Society[60] collection of blogs is smaller than the Data Visualization Catalogue's.

Discussion

Collecting visualization resources is a challenging process. A simple Google search will not yield all of the visualization resources we describe here.

Unsolved Problems

Here we provide some unsolved problems to inspire future work.

- **Timeliness:** One limitation is the landscape of visualization resources is constantly evolving. While individual resources will rapidly appear, hopefully, collections of resources will have a longer shelf-life.
- **Literature Explosion:** Also, there are a number of survey papers published every year, thus, keeping up with the literature is very challenging, even with the survey papers. However, this challenge is not limited to the field of visualization. We hope that this collection of resources helps with this challenge.
- **Resources for Developers:** A major challenge still remains on the topic of visualization resources for developers. We are often asked for recommendations on developer libraries to support visualization. It is difficult to make recommendations without actually testing out the developer resources. We believe that a separate survey could go into more depth into this topic, i.e., dedicated to developer resources only. This would be a valuable contribution to the field. However, this would be a labor intensive task and perhaps very lengthy.
- **Color Resources:** Another contribution would be to put together an evolving collection of color resources. We believe this survey features the first such collection of color resources for visualization. However, a collection that is updated annually would be helpful.
- **Geospatial Resources:** We also struggled on the collection of geospatial resources. There is a gap between the visualization and the geospatial visualization communities. Geographic Information Science requires its own set of special expertise and the landscape of geospatial resources is quite different from the information visualization community. We believe that closer cooperation between these two fields would be beneficial. We also believe that a collection of geospatial resources could be its own survey and could go into greater detail.

Conclusion

In this paper, we present an extended collection of visualization resources. We classify the resources according using a reader-centric typology, i.e., taking into consideration the target reader audience. We compile and provide the descriptions, examples and information about the curators of each resource collection. This paper serves as a valuable resource, a novel starting point, and comprehensive overview on visualization resources for students, researchers, practitioners, and developers with an interest in data visualization and visual analytics and potential future work directions which can be explored. There are many other types of resources such as online videos. Therefore, we would like to expand our survey with more categories. We also think collections of resources that focus on more special topics in data visualization will make the survey even more comprehensive.

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