Data Visualization Tools

A Comparative Analysis

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Contents

1 Overview

Data visualization (data viz) is a discipline that aims at making information more meaningful by giving it a graphical format. It is a fast-growing and rising field due to the unprecedented growth of the global data supply in our increasingly digital age. A wide variety of tools exists to help create data visualizations, ranging from data visualization-specific JavaScript libraries like D3.js to software applications for creating graphics like Adobe Illustrator. The number of tools on the market continues to expand with the visualization field itself.

Good data visualizations are developed through a tool agnostic process, which eliminates any potential bias a specific tool might have on the final visual output. That said, tools are required at every stage of visualization development: capturing ideas, prototyping, and deploying the final product. Thus, tool selection becomes an important step in the overall visualization design process.

With such a large number of possibilities, knowing which tool to use often proves challenging. Each tool has its own strengths, weaknesses, and constraints. There are few resources available comparing all of the different tool options to support an informed selection of a given tool for a specific project or project phase.

This comparative analysis attempts to alleviate this problem by classifying and evaluating a wide range of the most well-known and effective data visualization tools on the market. Categories of visualization tools are defined based on tool groupings identified by domain experts. Criteria are established for evaluating a given tool's effectiveness along three key dimensions: usability, capability, and accessibility. Metrics for each criteria are created in order to score individual tools and enable cross-tool comparisons. The most prominent or interesting tools for each category are selected and scored.

The analysis should provide insight into picking the right tool for a given project or project phase. A summary of results for all tools, including a full comparative matrix and competitive positioning scatter plots, is presented as well as detailed information and resources corresponding to each individual tool.

2 Methods

2.1 Categorization

Several categorizations of data visualization tools have been suggested by domain experts. Fisher and Meyer propose a two category classification: **Visualization Creation Tools** and **Visualization Programming Environments**.[1] Visualization Creation Tools support easy data importing and automated visual representation specification. While these tools are typically easier to learn and use, the possible visualizations they support are often limited. Visualization Programming Environments rely on non-visual techniques (programming) to render sophisticated and flexible visualizations. These environments are often more difficult to learn, but enable a wide variety of visualization possibilities.

Bret Victor suggests a similar classification system, calling Fisher and Meyer's Visualization Creation Tools **Chart Generators** and their Visualization Programming Environments **Coding Tools**.[2] Victor, however, extends this classification system by introducing a third category: **Drawing Tools**. Drawing Tools allow users to engage in intuitive mark-marking, but lose any automated connection between the data and its visual representation.

Here, three main categories for data visualization tools are defined, building off of Fisher, Meyer, and Victor's classification systems: **Creation Tools**, **Coding Tools**, and **Drawing Tools**.

Creation Tools

Coding Tools

Drawing Tools

[1] Reflections on how designers design with data. Danyel Fisher, Miriah Meyer, et al

[2] Drawing Dynamic Visualizations. Bret Victor

The first category, Creation Tools, includes two sub-categories: **Chart Generators** and **Dashboard Generators**. Chart Generators are limited to creating single visualizations while Dashboard Generators can combine multiple visualizations into a single view and connect them with interactivity and controls.

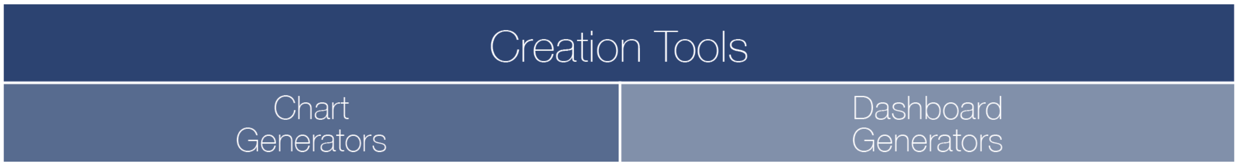
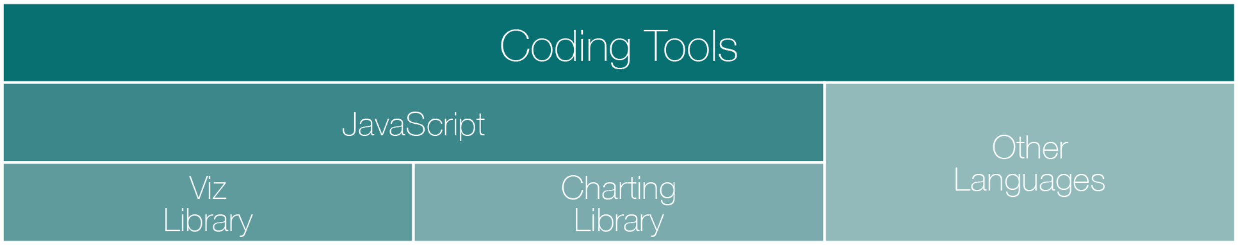

Creation Tools

Chart Generators

Dashboard Generators

The second category, Coding Tools, contains two sub-categories: **JavaScript** and **Other Languages**. This distinction reflects the disproportionate number of coding tools that use the JavaScript language. Indeed, the JavaScript sub-category is so extensive that it can be further broken down into **Visualization Libraries** and **Charting Libraries**. Visualization Libraries provide a variety of functions developed to make visualization easy, customizable, and modular. For example, one function might create an axis while another creates a mark. On the other hand, Charting Libraries offer an assortment of pre-made plug-and-play visualizations. For example, one function might generate an entire pie chart while another creates a bar chart. A number of non-JavaScript visualization tools are captured in the Other Languages category.


Coding Tools

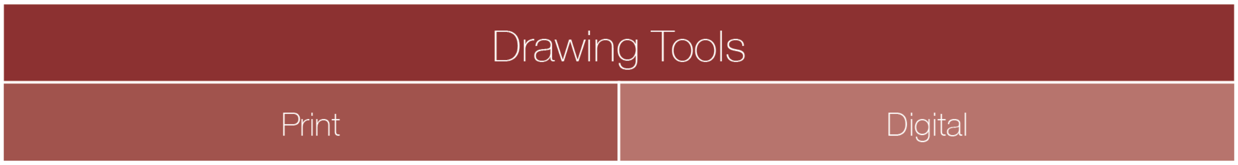
JavaScript

Viz Library

Charting Library

Other Languages

The third and final category, Drawing Tools, also includes two sub-categories: **Print** and **Digital**. Print refers to physical drawing, as with pen and paper. Digital includes software tools for creating prototypes and graphics.


Drawing Tools

Print

Digital

2.2 Criteria for Evaluation

In order to evaluate and compare each tool, 12 criteria that contribute to a tool's success were identified: installation, learning, support, cost, variety, data connection, data processing, interactivity, web compatibility, portability, security, and scalability. These dimensions aim to represent what is most important to a practitioner selecting a tool and are based on the literature as well as personal experience in the field.

The criteria were grouped into 3 main categories: usability, capability, and accessibility. Usability captures how easy the tool is to use. Capability refers to what the tool is able to produce. Finally, accessibility describes how the tool outputs can be made accessible to others. The table below shows each criterion and the questions used to investigate a tool's performance on that dimension.

	Criteria	Questions
Usability	Installation	How is the tool installed? How straightforward is the installation process? What are the system requirements?
	Learning	How hard is it to learn? What prior knowledge is required?
	Support	How many existing examples are there? What support systems are available?
	Cost	How expensive is the tool? Does it require a subscription or flat fee?
Capability	Variety	How many different visualization types are supported? Is the creation of novel visualization types supported? How many dimensions can the graphics have?
	Data connection	Are the visuals connected to the data? Does changing the data automatically update the visuals? What data sources are supported?
	Data processing	Does the tool support internal data processing? What parsing and analysis techniques does it offer?
	Interactivity	Are visualizations interactive or static? Are interactions customizable? What types of interactions are supported?
Accessibility	Web compatibility	Can visualizations be embedded on a website? Are visualizations constructed with web elements? Are visualizations responsive to screen size?
	Portability	What export file types are supported? Can visualizations be moved to different locations? Can visualizations be viewed using many programs?
	Security	How does the tool access data? Is data used by the tool secure? How much control over security does the user have?
	Scalability	Are there limits on the dataset size? How much information can be reasonably processed? How responsive is the system with a large dataset?

2.3 Metrics for Evaluation

Each tool was ranked on a scale of 1 to 5 for each criterion, where 1 is poor performance and 5 is excellent performance. Details about what a given score means for a particular criterion were determined by breaking the range of abilities for all tools into meaningful groups. This approach guarantees a scoring system that is coordinated across tools and that provides a concrete meaning beyond a general numeric rating. Additionally, the use of a number scale allows for averaging across criteria in order to compare an overall score for each tool. The table below shows what each numeric score means for each criterion.

	Criteria	Scores
Usability	Installation	5: Automatic installation for all OS 4: Automatic installation only available for certain OS 3: Requires registration, internet connection, and browser 2: Automatic installation plus set-up of libraries 1: Special file and library set-up
	Learning	5: No application to learn 4: Simple application 3: Complex application 2: Programming languages with plug-and-play examples 1: Unique programming language to learn
	Support	5: Resources and support provided by large company 4: Resources and support provided by small company 3: Open-source tool with strong user community 2: Online resources 1: Few resources and no active support
	Cost	5: Completely free 4: Free option with inexpensive flat monthly subscription 3: Free option with tiered monthly subscription 2: Less than $1000 per license 1: More than $1000 per license
Capability	Variety	5: Infinite variety 4: Virtually infinite variety 3: 20 or more visualization types 2: Between 10 and 20 visualization types 1: 10 or fewer visualization types
	Data connection	5: Extensive data source connection options 4: Text files; other data connections can be programmed 3: csv, xls(x); other data connections can be programmed 2: csv or xls(x) format only 1: No data connection
	Data processing	5: Extensive data processing options 4: Some processing options; more can be programmed 3: Some processing options 2: Limited, but programming language can be leveraged 1: Few built-in data processing options
	Interactivity	5: Customizable interactions in and between charts 4: Interactive in and between charts; some customizability 3: Interactive in charts 2: Interactivity can be simulated with prototyping tricks 1: Static

	Criteria	Scores
Accessibility	Web compatibility	5: Web elements with transparent source code 4: Web elements with sometimes inaccessible source code 3: Web elements; source code inaccessible 2: Can be web compatible with effort 1: Not web compatible
	Portability	5: Can export as vector graphic (svg, eps, or pdf) 4: Vector graphic export requires additional subscription 3: Can export as non-vector image (png, bmp, or jpg) 2: Can export as non-vector image with effort 1: No export available
	Security	5: Data on-site; secure sharing 4: Data on-site; sharing configurable 3: Data might leave site 2: Data uploaded to application; private sharing 1: Data uploaded to application; pay for private sharing
	Scalability	5: Direct connection to big data sources 4: No size constraints, but performance needs optimization 3: Large data size with inherent constraints 2: Data size limited to approximately 5,000 rows 1: No data connected

2.3 Tools Selection

A huge number of data visualization tools exist on the market. Further, the selection of tools is constantly changing; new tools are being developed and existing tools are falling out of fashion. For the purposes of this evaluation, the goal was to select the most important or unique tools currently in use across the range of tool categories. These are the tools that are most used and talked about in the data visualization community, but they certainly do not represent the complete list of possibilities. Though the tools selected here could become outdated rapidly, the evaluation approach used within this paper can be applied to new tools or existing tools whose abilities have changed.

For Creation Tools, four Chart Generators (ChartBlocks, GraphSketcher, Infogram, and Microsoft Excel) and three Dashboard Generators (Tableau, Power BI, and Quadrigram) were selected for evaluation.

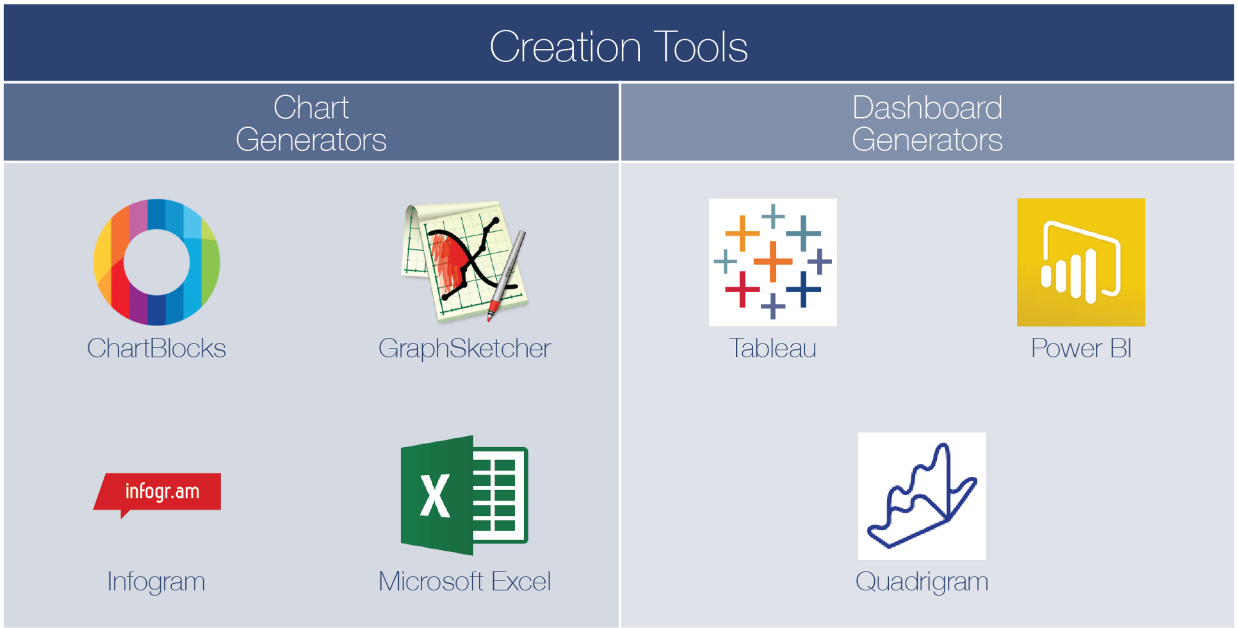

Creation Tools

Chart Generators

Dashboard Generators

ChartBlocks

GraphSketcher

Tableau

Power BI

Infogram

Microsoft Excel

Quadrigram

For Coding Tools, two Visualization Libraries (D3.js and p5.js), two Charting Libaries (Highcharts and Google Charts), and three Other Languages (Processing, R, and Plotly APIs) were selected for evaluation.

Coding Tools		
JavaScript		Other Languages
Viz Library	Charting Library	
D3.js	Highcharts	Processing
		R
p5.js	Google Charts	Plotly APIs

For Drawing Tools, one Print tool (pen & paper) and three Digital tools (Adobe Illustrator, Omnigraffle, and Axure RP) were selected for evaluation.

Drawing Tools			
Print	Digital		
Pen & Paper	Adobe Illustrator	Axure RP	Omnigraffle

3 Results Summary

The scores for each tool on each criterion were aggregated and a comparative matrix was created (section 3.2). Additionally, the average score for each group of criteria (usability, capability, and accessibility) was computed for each tool. Plotting these scores on scatter plots offers a graphical representation of the competitive postioning of the different tools and tool types (section 3.3). By comparing the scores for different criteria and criteria groups across all tools, a number of key takeaways emerge.

3.1 Lessons Learned

No single tool is best

No particular tool emerges superior than the others across all criteria. On average, Microsoft Excel, Tableau, Power BI, D3.js, p5.js, Processing, and R score higher than the other tools. Yet, each of these tools has its own unique weaknesses; Microsoft Excel, for example, has limited visualization variety, while Tableau is more expensive than most other tools, and Power BI visualizations are not very portable.

Each tool category has its own strengths

We see patterns associated with each category and sub-category. Creation Tools are generally strong in usability, but less reliable in capability and accessibility. Of the Creation Tools, Dashboard Generators offer stronger capabilities than Chart Generators. Coding Tools, while weak in installation, learning, and support, excel in capability and accessibility. Visualization Libraries in particular have the strongest capabilities of all tool types. Other Languages share strong capabilities, but tend to be less web compatible. Drawing Tools are easy to install and offer the best chart variety. Both Print and Digital Drawing Tools suffer in their data connection, data processing, interactivity, web compatibility, and scalability.

Tool selection involves trade-offs

Tools often meet certain criteria at the expense of others. For example, D3.js, p5.js, and R are all highly sophisticated tools with excellent capabilities. Yet, this sophistication comes at the expense of their ease of use. Due to these inherent tensions, selecting an appropriate tool involves weighing certain features against others and deciding what is needed and what can be let go.

Programming ability improves potential output

Many of the best tools assessed here require a high level of programming ability: D3.js, p5.js, Processing, and R. Some knowledge of coding can extend the functionality and potential of the other top tools: Microsoft Excel, Tableau, and Power BI. Thus, while knowing how to code is not a prerequisite for designing good data visualizations, it can certainly help to create high-quality visualizations by breaking down the barriers to use of the best tools and enabling the utilization of many advanced features across a variety of tools.

Tool selection depends on the project

Given the findings above, a tool should be selected based on the needs of a particular project and the skill set of the visualization creator. Certain tools might also prove more useful for particular phases of projects. For example, Drawing Tools are good for rapid ideation, Creation Tools for exploratory data analysis, and Coding Tools for customizable, interactive graphics. Furthermore, when a single tool is used exclusively before a visualization is fully developed, the tool itself can influence the form of the final visualization. It is important to remember that a good data visualization design is developed through a tool agnostic process.

Better tools are possible and necessary

The current space of data visualization tools leaves much room for improvement. Of particular importance is the development of tools that allow sophisticated capabilities while remaining easy to operate. While this is easier said than done, the limits of this product space are constantly being pushed, and the future will undoubtedly offer a myriad of solutions beyond what we have access to today.

3.2 Comparative Matrix

Symbol Key

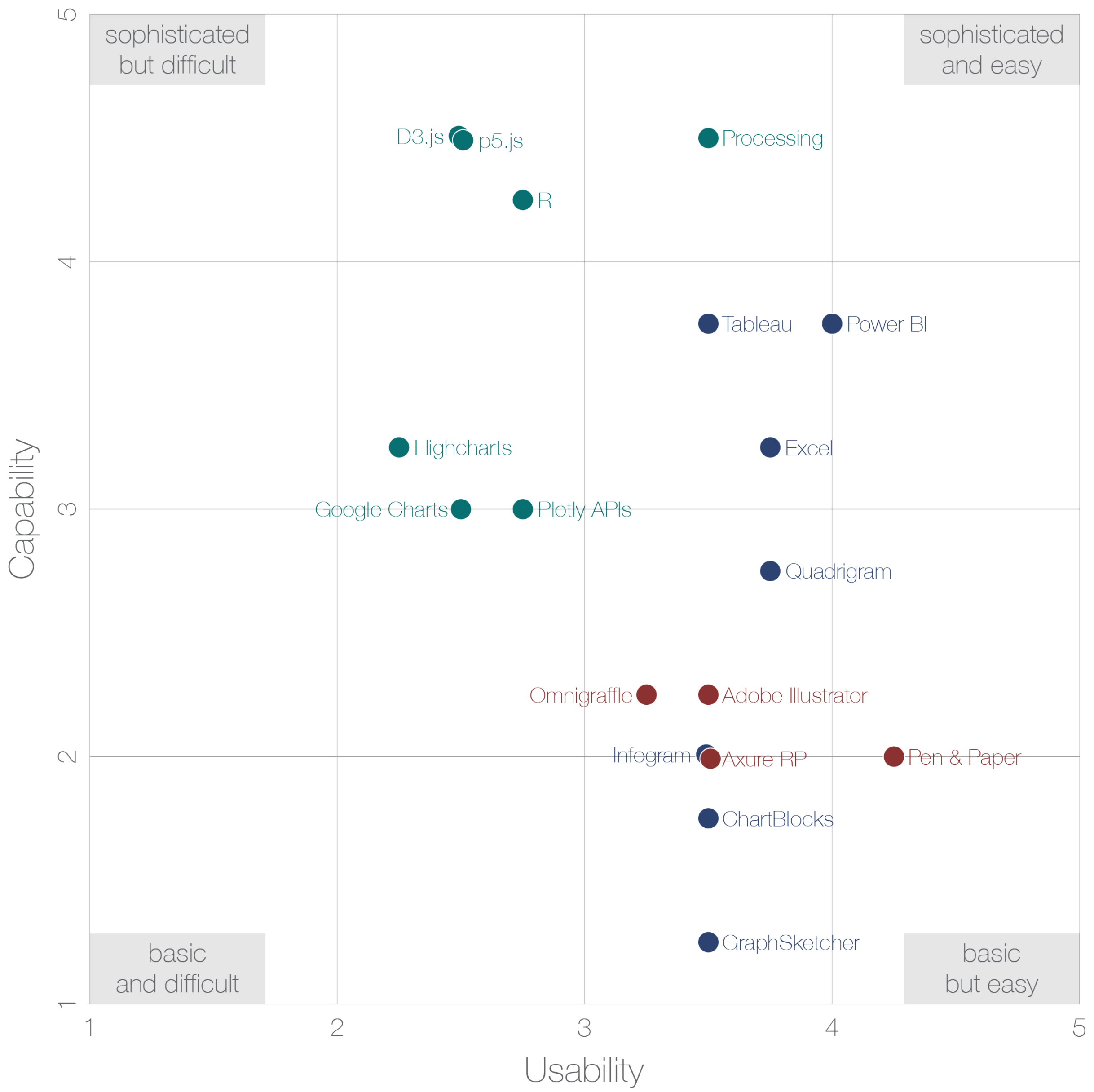
1	2	3	4	5
fair				best

			Usability				Capability				Accessibility			
			Installation	Learning	Support	Cost	Variety	Data Connection	Data Processing	Interactivity	Web Compatibility	Portability	Security	Scalability
Creation Tools	Chart Generators	ChartBlocks	3	4	4	3	1	2	1	3	3	4	1	2
		GraphSketcher	4	4	1	5	1	2	1	1	1	5	4	2
		Infogram	3	4	4	3	2	2	1	3	3	4	1	2
		Microsoft Excel	5	3	5	2	2	3	5	3	2	5	5	3
	Dashboard Generators	Tableau	5	3	5	1	3	5	3	4	3	3	5	5
		Power BI	4	3	5	4	3	5	3	4	3	1	5	5
		Quadrigram	3	4	4	4	2	2	3	4	5	5	2	2
Coding Tools	Viz Library	D3.js	1	1	3	5	5	4	4	5	5	2	4	4
		p5.js	1	1	3	5	5	4	4	5	5	4	4	4
	Charting Library	Highcharts	1	2	4	2	3	4	2	4	5	5	4	3
		Google Charts	1	2	2	5	3	3	2	4	4	2	3	3
	Other Languages	Processing	5	1	3	5	5	4	4	5	1	5	4	4
		R	2	1	3	5	4	4	5	4	2	5	4	3
		Plotly APIs	1	2	4	4	3	4	2	3	3	4	1	3
Drawing Tools	Print	Pen & Paper	5	5	2	5	5	1	1	1	1	2	4	1
	Digital	Adobe Illustrator	5	3	5	1	5	2	1	1	2	5	4	2
		Omnigraffle	4	3	4	2	5	1	1	2	1	5	4	1
		Axure RP	5	3	4	2	4	1	1	2	2	3	5	1

3.3 Competitive Positioning

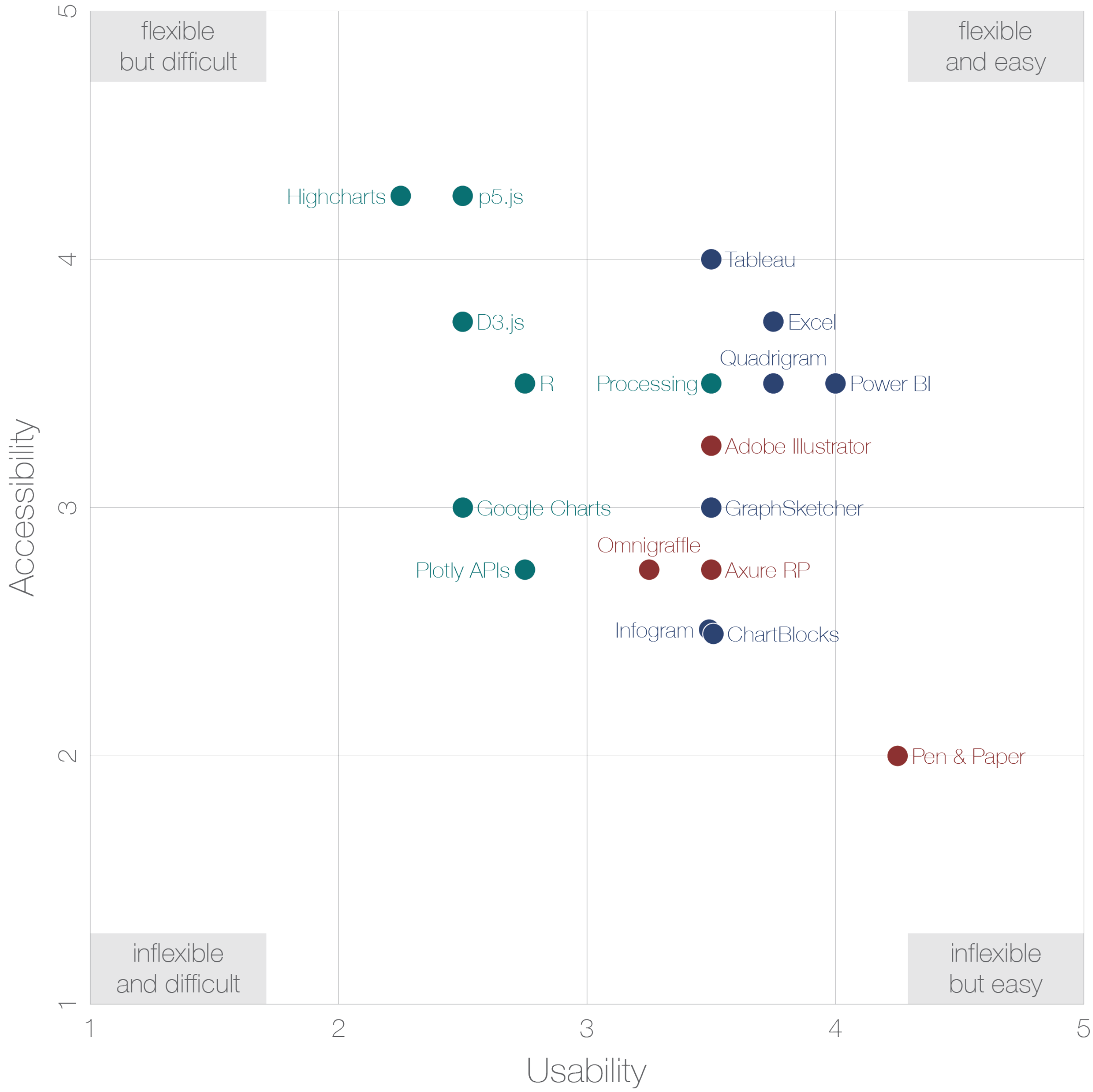
Usability vs. capability

Here the tool categories group together in space with coding tools tending to be sophisticated but difficult, drawing tools tending to be basic but easy, and creation tools tending to be easy and spanning from basic to sophisticated. Note that there are few tools in the upper right quadrant which represents the most highly desired positioning.



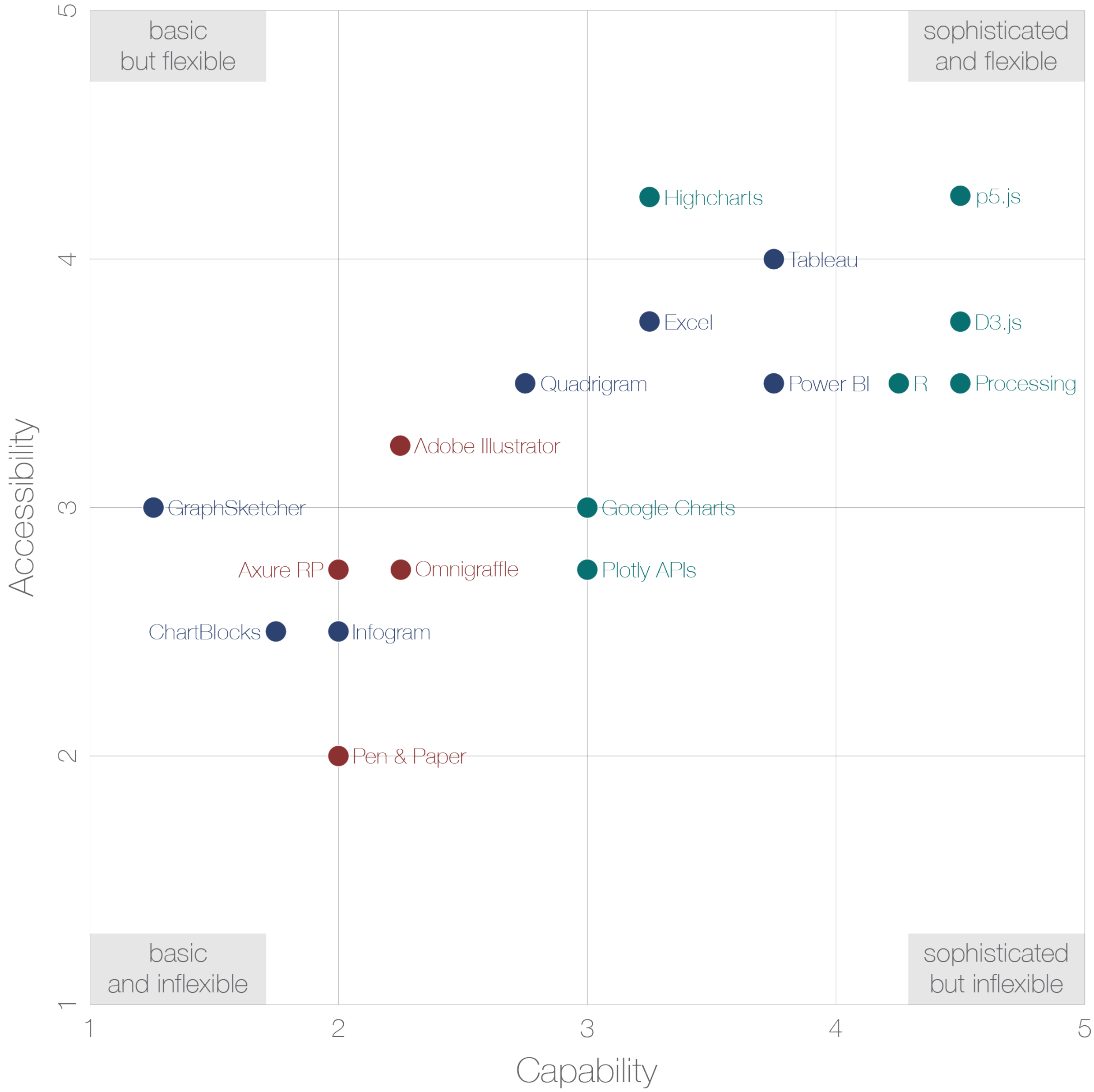
Usability vs. accessibility

In general, coding and creation tools score relatively well in accessibility, while drawing tools are less flexible. There is potential to increase the accessibility and usability of most tools, with few falling in the upper ranges of the “flexible and easy” quadrant.



Capability vs. accessibility

Here, a distinct linear relationship between capability and accessibility is visible. A wide spread is also noted, especially on the capability axis. Those tools that offer basic capabilities could especially stand to improve the accessibility of their outputs as easy-to-use tools are desirable for certain user groups.



4 Detailed Results

For each tool category, the definition of the category and any sub-categories it contains, the strengths and weaknesses of each sub-category, tools selected for this analysis, and a summary of scores for each tool are presented.

For each tool, a two-page scorecard was created which includes a paragraph description, key pros and cons, a summary of the scores for each criterion, links to resources for learning more, and a detailed table of scores and scoring rationale. These scorecards can be used to select a specific tool for a project or project phase as well as to compare tools. They are grouped by tool category and sub-category.

4.1 Creation Tools

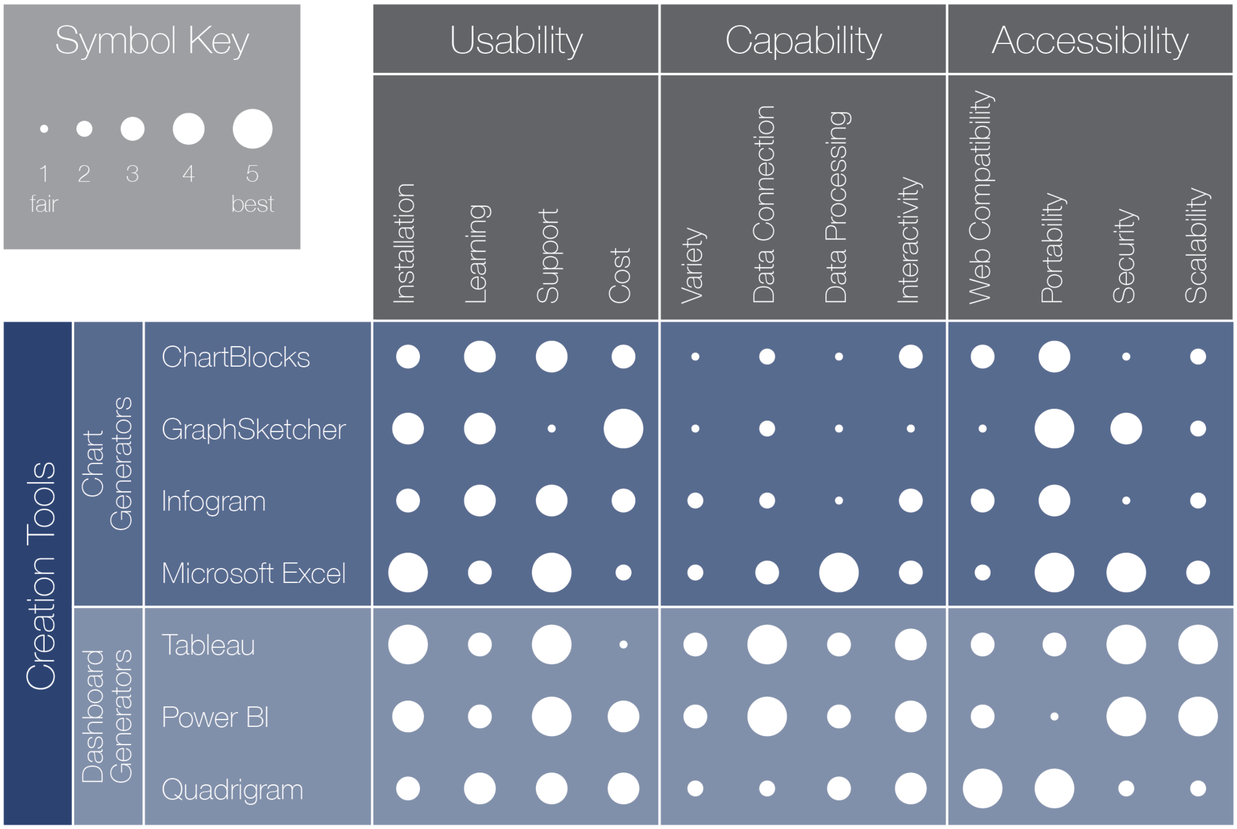
Creation Tools are software programs or web applications that offer programming-free interfaces for chart and dashboard creation. They typically support easy data importing, and they generate visual representations in an automated way based on imported data. These tools tend to be easy to learn and use. Almost all Creation Tools have good support, competitive cost, and high portability of generated visuals. However, they provide fewer chart types, weak data processing, and limited web compatibility.

Chart Generators

Chart Generators are designed for creating single charts or multiple charts that don't interact with each other. Compared to Dashboard Generators, they tend to be weaker in most capabilities.

Dashboard Generators

Dashboard Generators are capable of creating single charts, but have the extended ability to create groups of charts that interact with each other. These tools often include the ability to add controls, such as sliders or filters, that change the data views in the visualizations. Because they have most of the same strengths as Chart Generators with added benefits in variety, data connection and processing, and interactivity, they are the preferable Creation Tool in most cases.



			Usability				Capability				Accessibility			
			Installation	Learning	Support	Cost	Variety	Data Connection	Data Processing	Interactivity	Web Compatibility	Portability	Security	Scalability
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		Infogram	3	4	4	3	2	2	1	3	3	4	1	2
		Microsoft Excel	5	3	5	2	2	3	5	3	2	5	5	3
	Dashboard Generators	Tableau	5	3	5	1	3	5	3	4	3	3	5	5
		Power BI	4	3	5	4	3	5	3	4	3	1	5	5
		Quadrigram	3	4	4	4	2	2	3	4	5	5	2	2

ChartBlocks

Creation Tool

Chart Generator

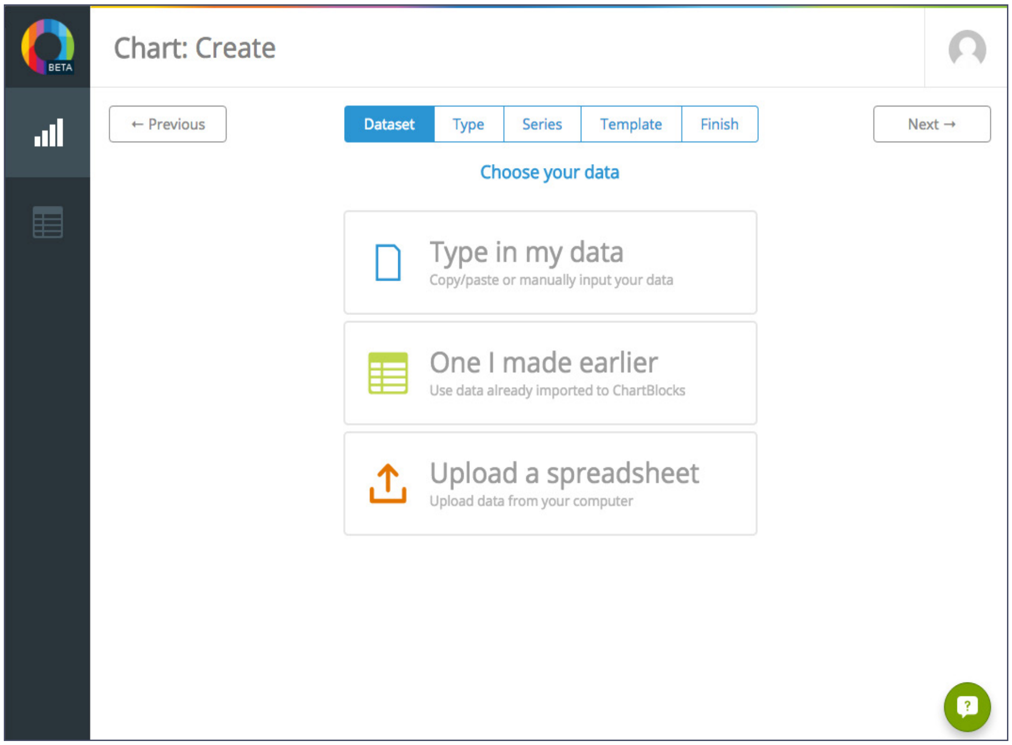


Chart: Create

← Previous | Dataset | Type | Series | Template | Finish | Next →

Choose your data

Type in my data
Copy/paste or manually input your data

One I made earlier
Use data already imported to ChartBlocks

Upload a spreadsheet
Upload data from your computer

ChartBlocks's step-by-step wizard interface showing dataset selection as the first step

Tool Description

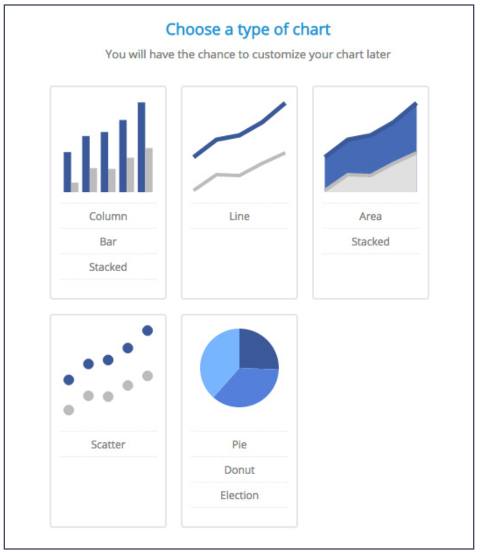
ChartBlocks is a useful web application for generating basic charts and graphs. Extensive use requires a monthly subscription to the tool. ChartBlocks provides a wizard interface that walks users through dataset import, chart type selection, data formatting, and chart generation. Each chart type comes with a variety of well-designed out-of-the-box templates that can be extensively customized. Generated charts can be published to the web or shared via social media with the click of a button.

Pros

- ✓ Extremely easy to use
- ✓ In-application chat promises fast support time for application issues
- ✓ Defaults look "more designed" than Microsoft Excel

Cons

- ✗ Limited number of chart types
- ✗ Data must be uploaded and hosted by the application itself
- ✗ Minimal in-application data processing options



Choose a type of chart

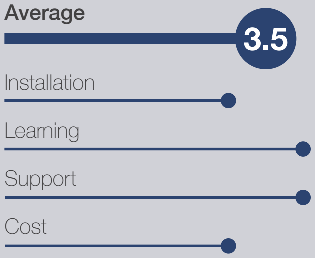
You will have the chance to customize your chart later

The five chart types offered by ChartBlocks

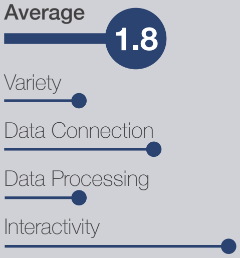
Score Summary

2.6 Fair

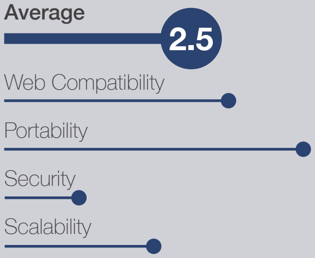
Usability



Capability



Accessibility



Scale

1: fair
3: average
5: best

Resources

Main website

Application website

Support page

Developer site

Chart gallery

ChartBlocks

Creation Tool

Chart Generator

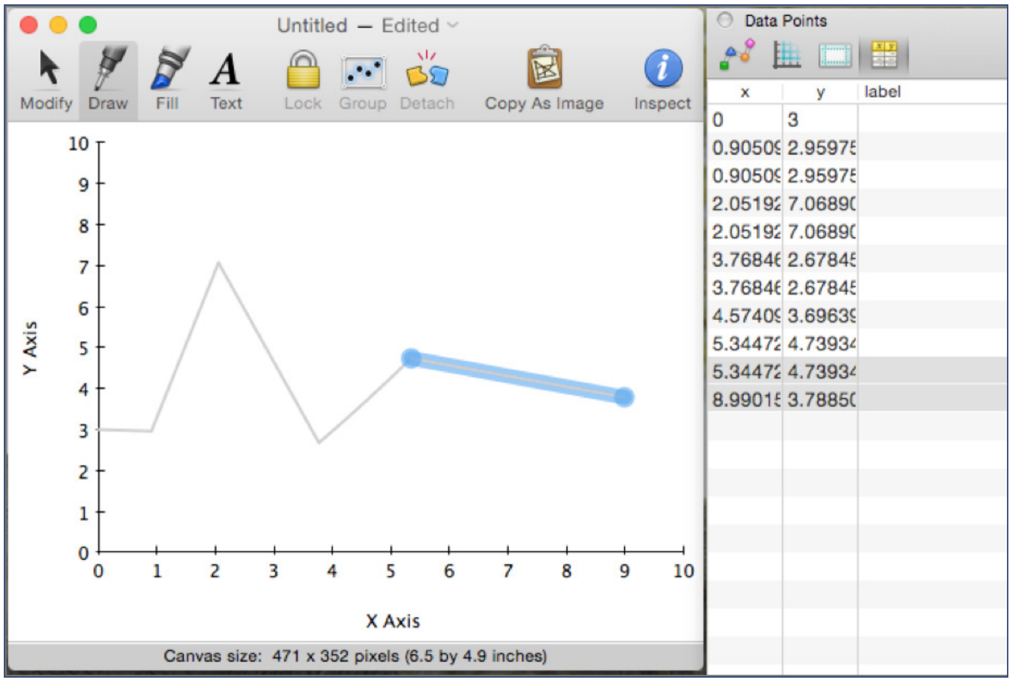
Evaluation Details

	Criteria	Notes	Score
Usability: 3.5	Installation	Browser-based tool is easily accessed after simple registration and log in using email, Facebook, Google, or Twitter. Requires an internet connection and browser.	3: Requires registration, internet connection, and browser
	Learning	Chart-building wizard steps through data import and chart creation process quickly and easily. No special prior knowledge is required.	4: Simple application
	Support	Many examples in the gallery of publicly available charts. Support systems include online FAQs, in-app chat (claims 1 hour response time on weekdays), and company email.	4: Resources and support provided by small company
	Cost	Monthly subscription with several plans: $0 Basic: up to 30 publicly available charts $8 Personal: up to 50 public or private charts, exportable as vectors $20 Professional: up to 75 charts; ChartBlocks branding removed $65 Elite: up to 200 charts; API access	3: Free option with tiered monthly subscription
Capability: 1.8	Variety	6 different 2D visualization types are supported: (stacked) bar, (stacked) column, line, (stacked) area, pie/donut/election, and scatter. Novel visualization types cannot be created.	1: 10 or fewer visualization types
	Data connection	The visuals are connected to the data, but data sources are currently limited to csv and Excel, with data feed (Twitter, OpenData) and database support "coming soon."	2: csv or xls(x) format only
	Data processing	Data can be transposed, grouped, and sorted. Subset of rows can be selected for display.	1: Few built-in data processing options
	Interactivity	Visualizations provide customizable tooltip on hover. Otherwise, no interactivity available.	3: Interactive in charts
Accessibility: 2.5	Web compatibility	Charts are web elements that are rendered as scalable vector graphics using D3.js. They respond to device and screen size and can be embedded on websites or shared directly to social media using ChartBlocks's internal sharing features.	3: Web elements; source code inaccessible
	Portability	Charts can be exported as png files with free subscription or pdf, svg, eps, and ps with pro subscription. They can be shared directly on Twitter, Facebook, or Pinterest.	4: Vector graphic export requires additional subscription
	Security	All data sources must be uploaded to the application and there is no control over how the system stores these. For Basic plans, all charts are publicly viewable. With paid plans, charts can be shared privately.	1: Data uploaded to application; pay for private sharing
	Scalability	Maximum file size of 50MB for csv and Excel data sources. System becomes slow with large datasets.	2: Data size limited to approximately 5,000 rows

GraphSketcher

Creation Tool

Chart Generator



x	y	label
0	3	
0.90509	2.95975	
0.90509	2.95975	
2.05192	7.06890	
2.05192	7.06890	
3.76846	2.67845	
3.76846	2.67845	
4.57409	3.69639	
5.34472	4.73934	
5.34472	4.73934	
8.99015	3.78850	

As the user draws on the canvas (left), data points are added to the dataset (right)

Tool Description

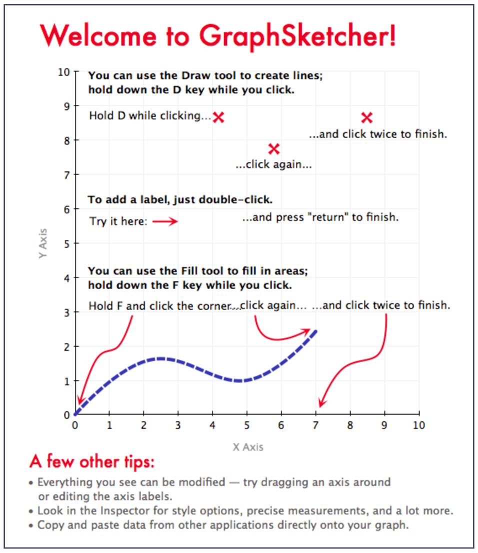
GraphSketcher is a simple OS X and iPad application for quickly sketching graphs and plotting data. Previously developed by the Omni Group as OmniGraphSketcher, the tool was open-sourced in 2014. It is now completely free to download and use, but is no longer under active development. GraphSketcher is unique in that it combines a Chart Generator with a Drawing Tool; users can upload data to generate visuals, but they can also freehand draw bars, points, and lines which are automatically converted into data points. In this way, users can sketch charts and the underlying data points are computed in real-time by the application.

Pros

- Only tool that can convert freehand drawing into data points
- Charts can be exported as vector graphics for further refinement
- The application code itself can be downloaded and modified

Cons

- Very few existing examples and support resources
- Not under active development
- Limited number of chart types



Welcome to GraphSketcher!

You can use the Draw tool to create lines; hold down the D key while you click.

Hold D while clicking... ...click again... ...and click twice to finish.

To add a label, just double-click.

Try it here: → ...and press "return" to finish.

You can use the Fill tool to fill in areas; hold down the F key while you click.

Hold F and click the corner...click again... ...and click twice to finish.

A few other tips:

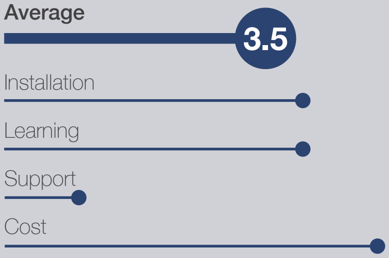
- Everything you see can be modified — try dragging an axis around or editing the axis labels.
- Look in the Inspector for style options, precise measurements, and a lot more.
- Copy and paste data from other applications directly onto your graph.

Quick start guide detailing the app's features

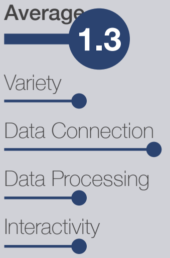
Score Summary

2.6 Fair

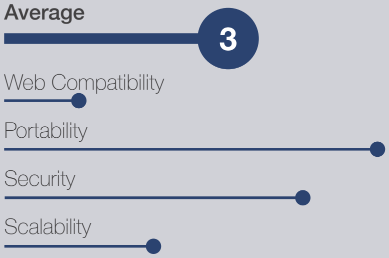
Usability



Capability



Accessibility



Scale

Resources

[GitHub project site]

[Releases page]

[Creator Robin Stewart's GraphSketcher paper submitted to 2009 CHI conference]

Evaluation Details

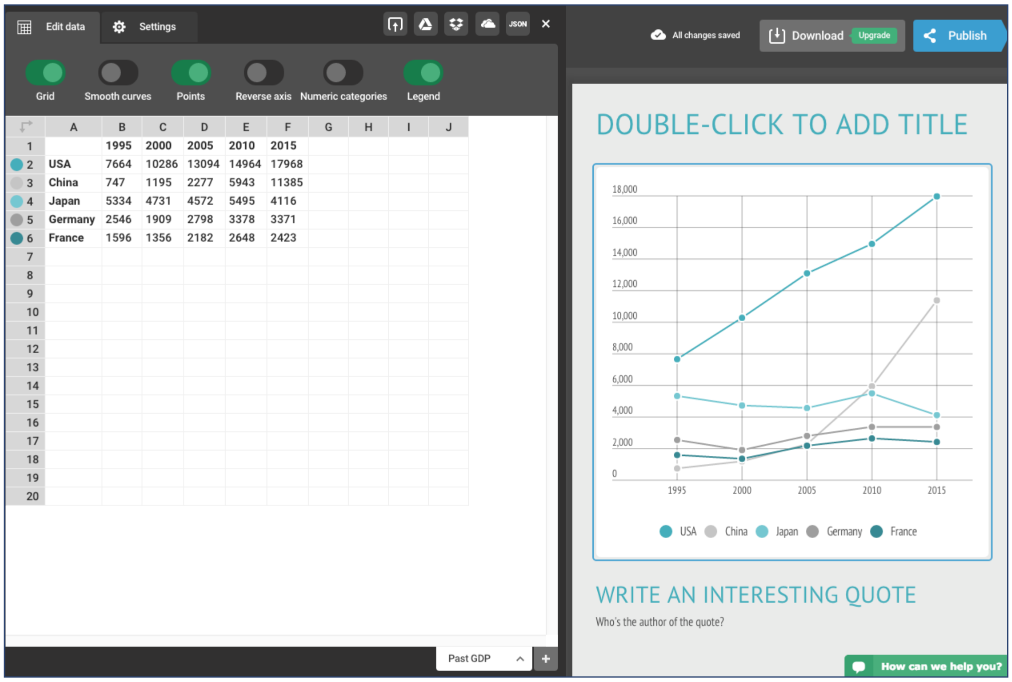
	Criteria	Notes	Score
Usability: 3.5	Installation	GraphSketcher can be installed by downloading the GraphSketcher zip file from the GitHub release site and dragging the application file into the Applications folder. Alternately, the application can be built from source by following the directions on its main GitHub site. The application is only available for OS X and iPad.	4: Automatic installation only available for certain OS
	Learning	The application is relatively intuitive to use and easy to learn. No special prior knowledge is required.	4: Simple application
	Support	The application has useful internal help and a getting started guide, but few other existing examples. As open source software, support and updates are not guaranteed. Indeed, the application hasn't been updated since September 2014.	1: Few resources and no active support
	Cost	The tool is completely free and requires no subscription.	5: Completely free
Capability: 1.3	Variety	5 different 2D chart types: scatter, line, (stacked) bar, (stacked) column, (stacked) area. The user can draw almost anything they want, but the generated data won't become a clean graph unless one of the above chart types is selected.	1: 10 or fewer visualization types
	Data connection	The visuals are connected to the data and changing the data updates the visuals. Furthermore, drawing can be used to generate data. Only well-formatted csv or Excel files are supported as data sources. The data must be copied and pasted into the application.	2: csv or xls(x) format only
	Data processing	Data processing is limited to grouping data points and rearranging dataset columns.	1: Few built-in data processing options
	Interactivity	Visualizations are completely static.	1: Static
Accessibility: 3	Web compatibility	Visualizations are not web elements. They can only be embedded on a website as a static image.	1: Not web compatible
	Portability	Charts can be exported as pdf, png, jpg, or eps.	5: Can export as vector graphic (svg, eps, or pdf)
	Security	Data is accessed locally, granting data security control to the user. Generated visualizations can be shared however the user wants.	4: Data on-site; sharing configurable
	Scalability	The dataset is limited to about 5,000 rows of data, but the application remains responsive at this maximum dataset size.	2: Data size limited to approximately 5,000 rows

infogr.am

Infogram

Creation Tool

Chart Generator



	A	B	C	D	E	F	G	H	I	J
1		1995	2000	2005	2010	2015				
2	USA	7664	10286	13094	14964	17968				
3	China	747	1195	2277	5943	11385				
4	Japan	5334	4731	4572	5495	4116				
5	Germany	2546	1909	2798	3378	3371				
6	France	1596	1356	2182	2648	2423				
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Data editing window (left) with infographic being developed (right)

Tool Description

Infogram is an online infographic and chart creation application available for a monthly subscription with tiered rates. It supports a better variety of chart types than many other browser-based chart generators. Individual charts can be used on their own or organized into well-designed infographics and reports that can include charts, maps, text, images, videos, and more. Charts, infographics, and reports are responsive by default and can be easily shared to social media or embedded using Infogram's publishing feature.

Pros

- ✓ Well-designed infographic templates
- ✓ Easy to combine charts, maps, text, images, and more into a single layout
- ✓ Wider variety of chart types than other browser-based chart generators

Cons

- ☒ Data sources must be uploaded to the application
- ☒ Limited data processing operations within the application
- ☒ Paid account is necessary to create private charts and export visuals as vector graphics

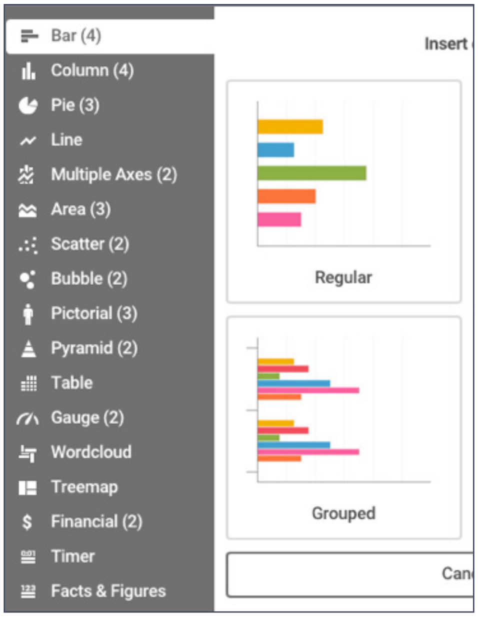
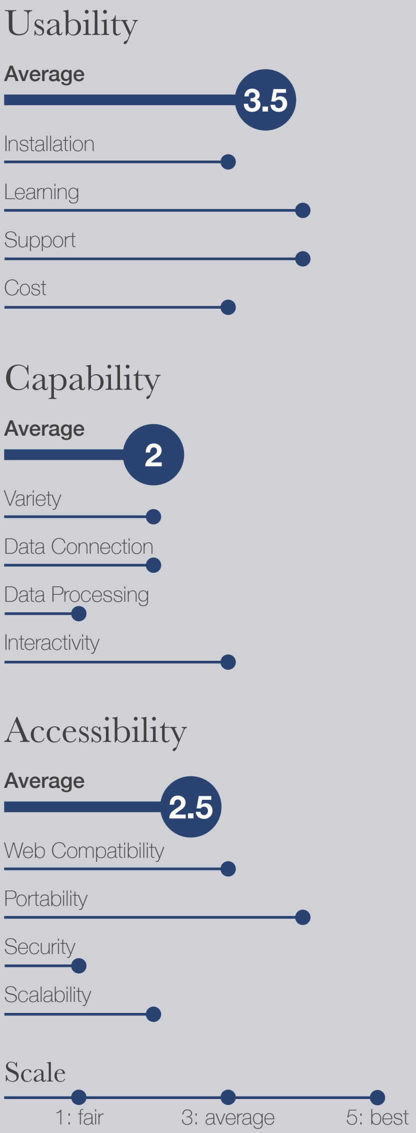


Chart options window

Score Summary

2.7 Fair



Resources

- Main website
- Application website
- Support page
- Knowledge base
- Pricing information

infogr.am

Infogram

Creation Tool

Chart Generator

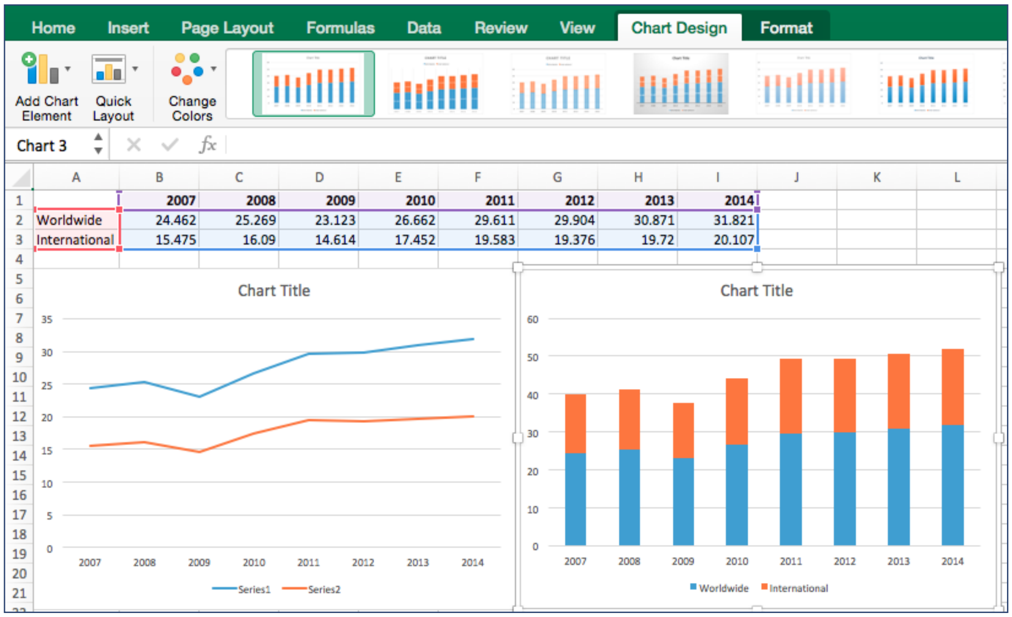
Evaluation Details

	Criteria	Notes	Score
Usability: 3.5	Installation	Infogram is a browser-based application that can be accessed after simple registration and log in using email, Facebook, Google, LinkedIn or Twitter. It requires an internet connection and browser.	3: Requires registration, internet connection, and browser
	Learning	The application is easy to learn with little prior knowledge required.	4: Simple application
	Support	Infogram offers many existing examples, tutorials, and FAQs. The Infogram team is easy to contact with questions and in-app chat support is sometimes available. Training and a dedicated account manager are provided with an enterprise-level account.	4: Resources and support provided by small company
	Cost	A tiered monthly subscription is offered: $0 Free: up to 10 public infographics $19 Pro: up to 100 infographics; private charts; exportable as vector $67 Business: 1,000 graphics; custom themes; analytics tracking $350 Enterprise: 10,000 graphics; special training; account manager	3: Free option with tiered monthly subscription
Capability: 2	Variety	Over 18 different 2D chart types: (stacked) bar, (stacked) column, pie, line, multiple axes, (stacked) area, scatter, bubble, pictorial, hierarchy, table, gauge, wordcloud, treemap, financial, timer, maps, and facts. Novel visualization types cannot be created.	2: Between 10 and 20 visualization types
	Data connection	The visuals are driven by uploaded data such that changing the data changes the visuals. Supported data sources are xls(x), csv, Google Drive file, Dropbox file, OneDrive file, JSON feed, or Google Analytics. A data search into global sources is also available.	2: csv or xls(x) format only
	Data processing	The only data processing supported is column/row transpose.	1: Few built-in data processing options
	Interactivity	Visualizations provide non-customizable hover, toggle, and tooltip interactivity. Multiple charts cannot be linked with interactivity.	3: Interactive in charts
Accessibility: 2.5	Web compatibility	Visualizations are responsive and interactive web elements. They can be embedded, shared on social media, or published via link (private or password protected links require subscription). However, the source code cannot be downloaded and modified so sharing is limited to Infogram's in-app options.	3: Web elements; source code inaccessible
	Portability	With subscription, visualizations can be downloaded as png or pdf. Otherwise, no download is available.	4: Vector graphic export requires additional subscription
	Security	Data must be uploaded directly to Infogram. Any of the paid subscription plans offer SSL encryption and private sharing. Otherwise, all charts created are publicly viewable by default.	1: Data uploaded to application; pay for private sharing
	Scalability	Dataset is limited to about 5,000 rows of data. The system becomes minimally responsive at this max dataset size.	2: Data size limited to approximately 5,000 rows

Microsoft Excel

Creation Tool

Chart Generator



	A	B	C	D	E	F	G	H	I
1		2007	2008	2009	2010	2011	2012	2013	2014
2	Worldwide	24.462	25.269	23.123	26.662	29.611	29.904	30.871	31.821
3	International	15.475	16.09	14.614	17.452	19.583	19.376	19.72	20.107

Excel interface showing chart design toolbar and several default charts

Tool Description

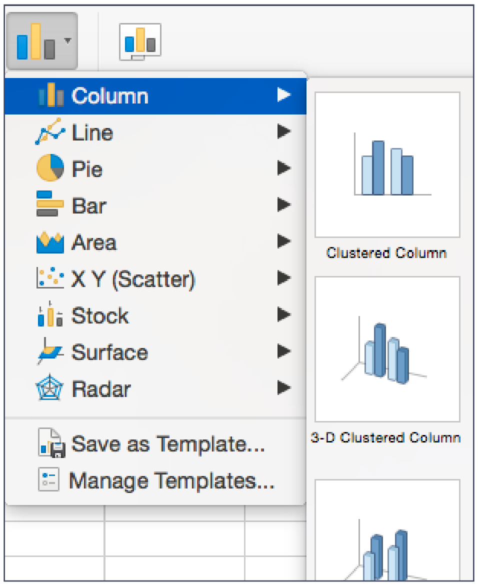
Microsoft Excel is a well-known spreadsheet application available through Office 365, Office Suite, or on its own. It provides data analysis, processing, and visualization tools all within the same program making it a convenient one-stop shop for all things data. While its default visualization options are fairly limited, it is a convenient choice for straightforward data graphics. With more extensive programming and configuration, it can be used to create more advanced visualizations including interactive dashboards with multiple linked charts. It is categorized as a Chart Generator for the purposes of this analysis because it is typically used for creating one-off charts. Here we evaluate Excel's latest release (2016) for Mac; please note that some capabilities may vary by version and operating system.

Pros

- ✓ Part of the Microsoft Office Suite which is available through most employers or schools
- ✓ Robust integrated data analysis and manipulation capabilities
- ✓ Highly customizable with a wide variety of plug-ins and macros

Cons

- ✗ Limited number of visualization types
- ✗ Takes time and effort to produce elegant visualizations
- ✗ Difficult to publish graphics to the web

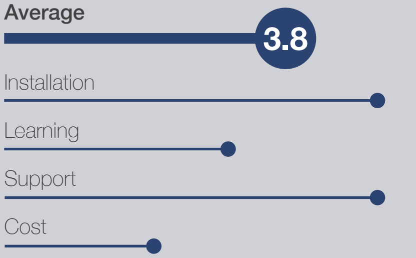


Excel chart type options dropdown

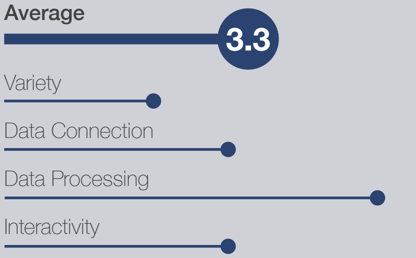
Score Summary

3.6 Best

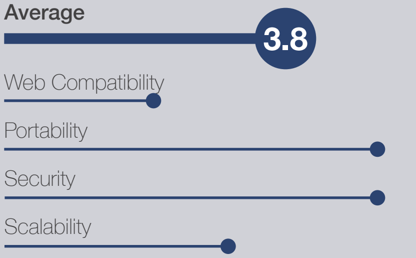
Usability



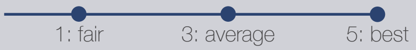
Capability



Accessibility



Scale



Resources

[Main website]

[Online support site]

[Microsoft Office application store with many data visualization Excel apps available]

Microsoft Excel

Creation Tool

Chart Generator

Evaluation Details

	Criteria	Notes	Score
Usability: 3.8	Installation	Excel is pre-installed on many work and school computers. If it is not pre-installed, the desktop and web applications can be accessed and installed from Office 365 or the Microsoft website.	5: Automatic installation for all OS
	Learning	Many people are already familiar with Excel. Using the tool to its full potential takes commitment and data analysis or programming skills. Creating good visuals requires some extra finesse and know-how.	3: Complex application
	Support	There are many existing templates and extensive online documentation and trainings. Since Excel is so ubiquitous, it is easy to find help through simple online searches.	5: Resources and support provided by large company
	Cost	Office Suite, including Excel, costs $120. Office 365 monthly subscription costs $70 per year or $7 per month.	2: Less than $1000 per license
Capability: 3.3	Variety	11 main chart types: column, bar, line, pie, area, scatter, stock, surface, doughnut, bubble, and radar. Many charts can be made 3D. More variety can be created using combination charts or with add-on apps. Novel visualizations could be created through development of a new app, but this would involve extensive programming.	2: Between 10 and 20 visualization types
	Data connection	Visuals are connected to the data so changing the data automatically updates the visuals. Data can be housed internally (xls or csv format) or pulled from an external source with a more complex set-up (text file, web sites, data feeds, and databases).	3: csv, xls(x); other data connections can be programmed
	Data processing	Excel is fundamentally spreadsheet software designed for data analysis. Consequently, it supports substantial data processing, including data formatting, Pivot Tables, grouping, summarizing, transposing, complex analyses, and more.	5: Extensive data processing options
	Interactivity	Visualizations are static by default, but some within-chart interactions (such as mouse-over, selection, and filter) can be jerry-rigged with more advanced set-up and VBA programming.	3: Interactive in charts
Accessibility: 3.8	Web compatibility	Excel worksheets are not web elements by default. However, they can be saved as webpages and then embedded on other sites. They are not responsive and maintaining interactivity when saving as a webpage is an involved process.	2: Can be web compatible with effort
	Portability	Worksheets can be saved as pdfs and charts can be saved as images (png, jpg, pdf, gif, bmp). Either can be inserted easily into other Microsoft documents.	5: Can export as vector graphic (svg, eps, or pdf)
	Security	Worksheets can be secure. Data is local or hosted on Office 365.	5: Data on-site; secure sharing
	Scalability	Excel has a row limit of 1 million and a column limit of about 16,000. Pulling in data from external sources and advanced processing, such as Pivot Tables, can take considerable memory and time.	3: Large data size with inherent constraints

Tableau

Creation Tool

Dashboard Generator

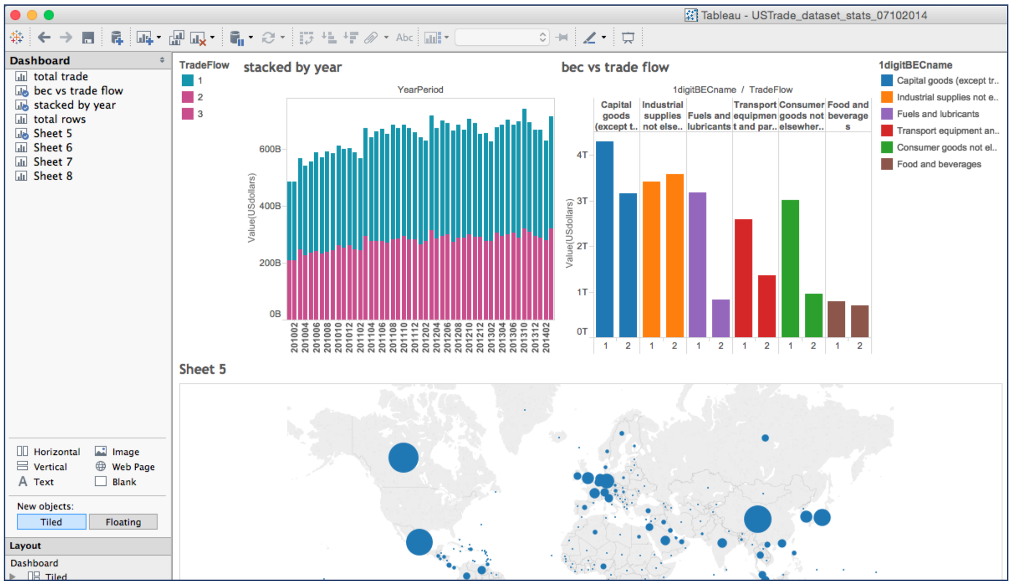


Tableau dashboard creation interface showing multiple interactive charts laid out on a single page

Tool Description

Tableau Software offers five main products: Tableau Desktop, Tableau Server, Tableau Online, and Tableau Public. Tableau Desktop mainly supports creation of visualizations while Tableau Online and Tableau Server support online sharing and collaboration. Tableau Public is a free, unlicensed version of Tableau Desktop. Here we evaluate Tableau Desktop (referred to as Tableau going forward). Tableau offers a simple drag-and-drop interface and is capable of connecting to a wide array of data sources, including big data environments. It is an excellent tool for data exploration as well as for producing interactive dashboards.

Pros

- ✓ Automatic connection to a huge variety of data sources, including big data environments
- ✓ Drag-and-drop interface enables fast data exploration
- ✓ Can generate "stories," sequenced views of charts and dashboards that tell a specific narrative

Cons

- ✗ Individual licenses are expensive
- ✗ Interactive dashboards and stories are difficult to share without an additional subscription to Tableau Server
- ✗ Unable to generate vector graphics from individual charts or dashboards

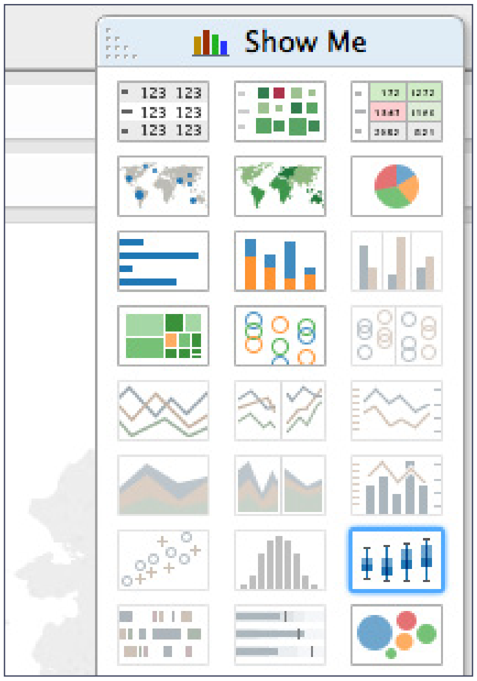


Chart options; invalid types are grayed out

Score Summary

3.8 Best

Usability

Average 3.5

Installation

Learning

Support

Cost

Capability

Average 3.8

Variety

Data Connection

Data Processing

Interactivity

Accessibility

Average 4

Web Compatibility

Portability

Security

Scalability

Scale

1: fair 3: average 5: best

Resources

[Main website]

[Support page]

[Product demos]

[Visual gallery]

[Training and tutorials]

Tableau

Creation Tool

Dashboard Generator

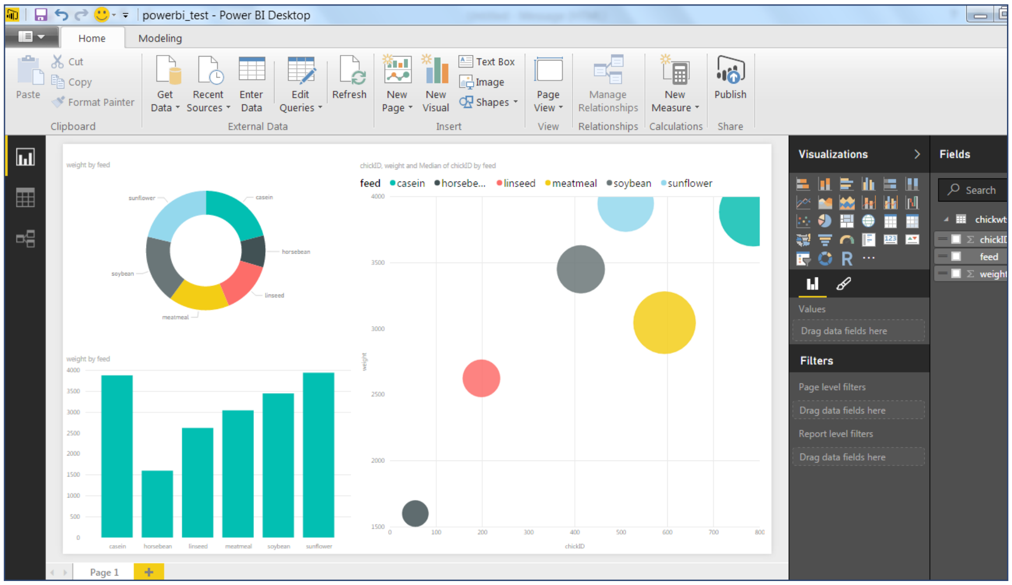
Evaluation Details

	Criteria	Notes	Score
Usability: 3.5	Installation	Tableau Desktop can be downloaded from the Tableau website and installed automatically. Compatible with Windows and Mac.	5: Automatic installation for all OS
	Learning	The drag-and-drop interface makes Tableau relatively intuitive and quick to learn. No prior knowledge is required, though familiarity with spreadsheet software or databases is helpful. Mastering Tableau, like any complex application, takes time and effort.	3: Complex application
	Support	There is a wide variety of online support documentation, including examples, tutorials, a knowledge base, quick start guides, and more. Online, in-person, and on-site trainings are also possible, often at an additional cost. Support consultations available through Tableau staff. Tableau user groups exist in many big cities around the world.	5: Resources and support provided by large company
	Cost	Tableau Desktop professional costs $1999 per user. Tableau Server starts at $10,000 for 10 users. Tableau Online costs $500 per user per year.	1: More than $600 per license
Capability: 3.8	Variety	Tableau offers 24 main 2D visualization types. Some novelty can be added to these by varying parameters and the types of marks used, but no completely new visualization types can be created.	3: 20 or more visualization types
	Data connection	The visuals are connected to the data. Data sources can be connected "live" such that data changes will be updated in the visuals in real time. A wide variety of data sources can be used including databases, big data frameworks, excel files, and text files.	5: Extensive data source connection options
	Data processing	Some data processing is supported such as grouping, trend lines, averaging, and new field computation. Advanced analyses are intensive and require tool expertise.	3: Some processing options
	Interactivity	Many standard interactions are built-in: brushing, filtering, details on click, etc. These built-in interactions are somewhat customizable, but like visualization varieties, these are limited to whatever is built into the tool. For example, there is no way to create a new interaction type.	4: Interactive in and between charts; some customizability
Accessibility: 4	Web compatibility	Tableau Server & Tableau Online offer web-based access to Tableau visualizations. Visualizations can be embedded into non-Tableau sites using the JavaScript API. This involves some web-coding savvy.	3: Web elements; source code inaccessible
	Portability	Visualizations can be exported as images (png, bmp, jpg), but are low quality. They are best viewed through Tableau software. Worksheet and dashboard files are readable by Tableau only.	3: Can export as non-vector image (png, bmp, or jpg)
	Security	The tool pulls data from its source. Users have control over what data is shown to whom based on Tableau Server login accounts.	5: Data on-site; secure sharing
	Scalability	Tableau integrates with several big data platforms (Cloudera Hadoop, Amazon Redshift) making it highly scalable, at least in theory.	5: Direct connection to big data sources

Power BI

Creation Tool

Dashboard Generator



Report generation interface of the Power BI desktop application

Tool Description

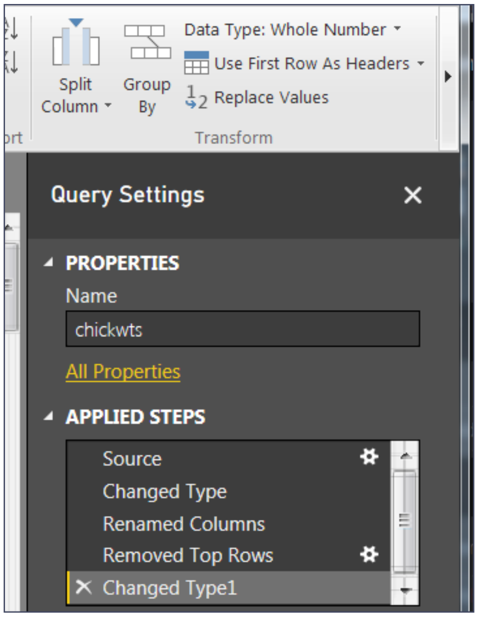
Power BI is Microsoft's new "cloud-based business analytics service." Similar to Tableau, it offers drag-and-drop chart, report, and dashboard creation. With the Power Q&A feature, users can query their data with natural language and receive visual answers. The application is available for free or the pro edition can be purchased for a small monthly fee. It has three components: a desktop application, a web application, and a mobile application. The desktop application is used for data import, shaping, processing, and report creation, harnessing the strength of Microsoft PowerView and PowerPivot to streamline complex data tasks. The web and mobile apps are primarily used for sharing and viewing content.

Pros

- Connects to a wide variety of data sources, including big data environments and HTML tables
- Excellent in-application data processing features
- Aggressive development schedule with user input on proposed features

Cons

- Visualizations mostly restricted to the Office 365 web application
- Limited chart variety
- Source code for D3.js-driven charts cannot be accessed



Query Settings

PROPERTIES

Name

chickwts

APPLIED STEPS

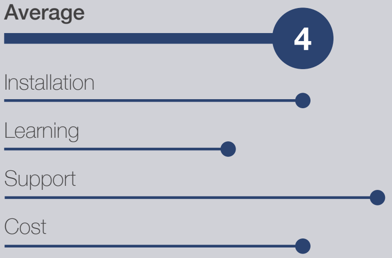
- Source
- Changed Type
- Renamed Columns
- Removed Top Rows
- Changed Type1

Query editor showing data transform steps

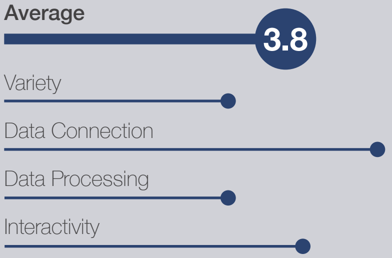
Score Summary

3.8 Best

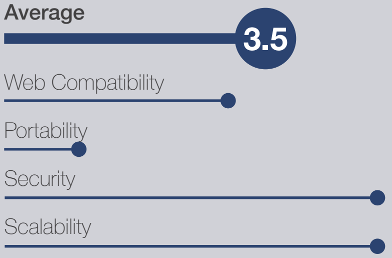
Usability



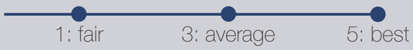
Capability



Accessibility



Scale



Resources

- Main website
- Documentation page
- Support page
- Visuals gallery
- Pricing plan details

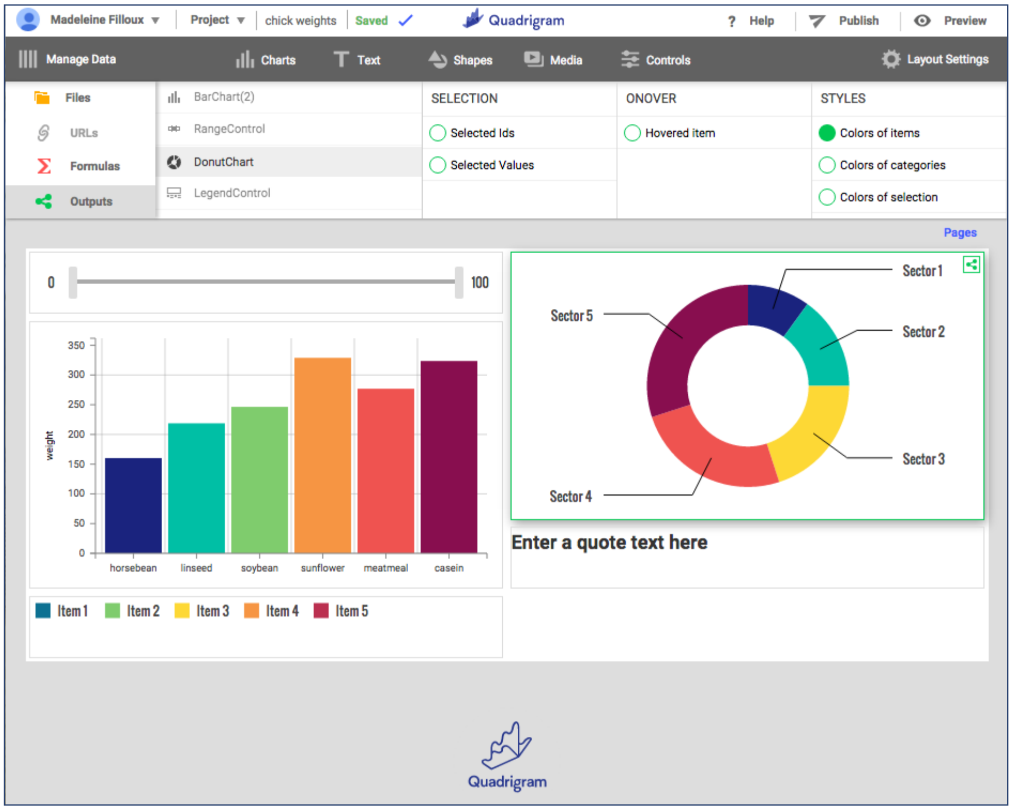
Evaluation Details

	Criteria	Notes	Score
Usability: 4	Installation	Power BI Desktop can be downloaded and installed automatically from the Power BI home page. It can only be run on a PC.	4: Automatic installation only available for certain OS
	Learning	Not as intuitive as Tableau and takes some time to learn how to use it well. Spreadsheet and database knowledge useful, but not required. Becoming an expert would take some time and commitment.	3: Complex application
	Support	Good online documentation, tutorials, and support site. Microsoft develops a new release each month. Email support for free accounts. Faster phone and email support with pro account. Active user community creating examples and custom charts.	5: Resources and support provided by large company
	Cost	Monthly subscription with two pricing plans: $0 Free: 1 GB/user, daily data refresh, 10K rows/hr of streaming data $9.99 Pro: 10 GB/user, live and on-prem data, collaboration features	4: Free option with inexpensive flat monthly subscription
Capability: 3.8	Variety	24 built-in 2D visualization types. Customizable visualizations are possible using the developer tools, by importing custom visuals created by others, or by using an R script.	3: 20 or more visualization types
	Data connection	Visuals are connected to the data. Supports a huge variety of data sources, including spreadsheets, on-premise data sources, big data environments such as HDFS, and streaming data. It can even scrape data from HTML tables given a web address.	5: Extensive data source connection options
	Data processing	Robust query editor allows repeatable data shaping and combining. Includes grouping, splitting, reformatting, transforming, and more.	3: Some processing options
	Interactivity	Visualizations are interactive enabling mouse-overs and filters. More complex interactions could potentially be created with custom visuals. Otherwise, interactions are not very customizable. For example, tooltip info is pre-determined.	4: Interactive in and between charts; some customizability
Accessibility: 3.5	Web compatibility	Visualizations can be published publicly to websites outside of Office 365. They are constructed with web elements and are responsive to screen size.	3: Web elements; source code inaccessible
	Portability	Currently visualizations can only be privately shared within an organization through Power BI itself. Requires others to have a Power BI account. Visualizations can only be saved as Power BI .pbix files.	1: No export available
	Security	Secure data model built on Microsoft Azure. Users can choose who sees what dashboards and what permissions they have for each.	5: Data on-site; secure sharing
	Scalability	There are limits on certain data source sizes (such as Excel files). However, the ability to connect to big data sources like HDFS indicates the tool can handle big datasets when formatted correctly.	5: Direct connection to big data sources

Quadrigram

Creation Tool

Dashboard Generator



Application interface showing dashboard design (bottom) and chart controls (top)

Tool Description

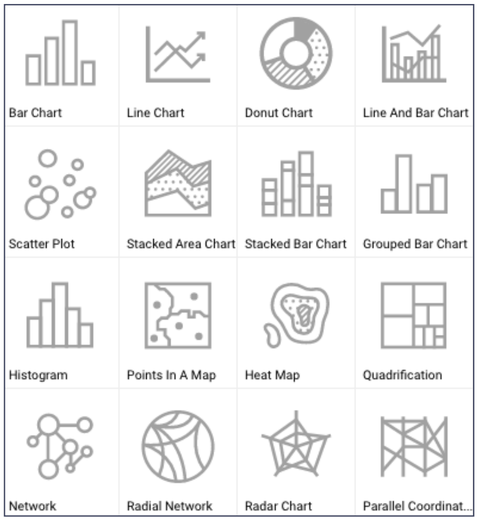
Quadrigram is a freemium drag-and-drop web-based application for creating and publishing interactive data driven websites. It integrates with a Google account and saves data directly to Google Drive. Charts, text, shapes, media, and controls can be assembled into unique layouts and shared easily on the web by hosting the site at quadrigram.com, embedding it on another site, or by using the project's downloadable source code.

Pros

- ✓ Individual visualizations can be exported as vector graphics
- ✓ Entire project's source code can be downloaded and modified at will
- ✓ Easily combine controls, text, and media with charts in a single layout

Cons

- ☒ All data is saved to Google Drive
- ☒ Only xls(x) or csv files supported
- ☒ Limited data processing options

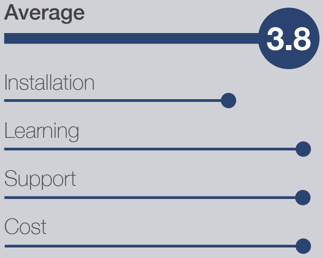


16 of Quadrigram's 19 chart type options

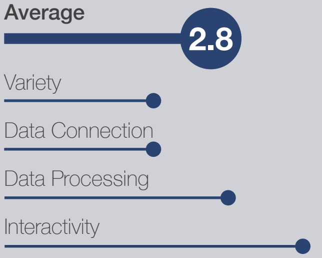
Score Summary

3.3 Good

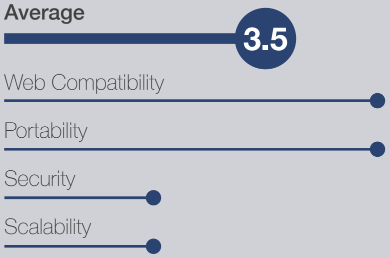
Usability



Capability



Accessibility



Scale

1: fair
3: average
5: best

Resources

Main website

Pricing plans

Help page

Application site

Project gallery

Quadrigram

Creation Tool

Dashboard Generator

Evaluation Details

	Criteria	Notes	Score
Usability: 3.8	Installation	The tool is accessed through the browser and requires a Google account to log in.	3: Requires registration, internet connection, and browser
	Learning	The tool is fairly easy to learn with an intuitive drag and drop interface that updates visualizations as you change parameters. No special prior knowledge is required.	4: Simple application
	Support	Online resources include a project gallery, a quick start guide, a help page, tutorials, and a community forum. In addition, there is a useful in-app help guide and the ability to email the company.	4: Resources and support provided by small company
	Cost	Tiered monthly subscription: $0 Free: 12 public publications $22 Pro (available soon): 120 publications; private sharing; training Tailored Corporate: custom themes; dedicated account manager	4: Free option with inexpensive flat monthly subscription
Capability: 2.8	Variety	19 different 2D visualization types are supported. Custom visualizations are not supported. Shapes and text can also be combined manually to create new visual approaches.	2: Between 10 and 20 visualization types
	Data connection	The visuals are connected to the data. When a file is edited, it needs to be reloaded in the application. Only spreadsheet data (xlsx or csv) made available in a Google Drive folder is supported.	2: csv or xls(x) format only
	Data processing	Formulas allow operating on data including: set value, filter, transpose, join, get names, sort, summarize, and aggregate. Each must be applied as its own formula which becomes cumbersome if extensive analysis and processing is needed.	3: Some processing options
	Interactivity	Visualizations are interactive with tooltips and a variety of controls (dropdowns, buttons, etc.). Some customization of interactions is possible including linking two visualizers (charts).	4: Interactive in and between charts; some customizability
Accessibility: 3.5	Web compatibility	Visualizations can be published to the web via Quadrigram hosting, embedded on a website with an embed code, or downloaded as source code (HTML, CSS, JavaScript). Visualizations are responsive to screen size.	5: Web elements with transparent source code
	Portability	Each chart can be saved as svg or png. The project can be published to the web, embedded, or downloaded as source.	5: Can export as vector graphic (svg, eps, or pdf)
	Security	Data and visualization files are automatically saved to Google Drive. Data security hinges on trust of Google's security. Sites hosted by Quadrigram can be password protected. Source code can be protected using whatever methods one chooses.	2: Data uploaded to application; private sharing
	Scalability	Dataset sizes are limited by Google Drive. Spreadsheets can contain up to 2 million cells. A total of 15GB of free space is offered for all of Google Drive.	2: Data size limited to approximately 5,000 rows

4.2 Coding Tools

Coding tools are programming languages or libraries for developing visualizations. They require varying degrees of computer science knowledge and generally take longer to learn than Creation or Drawing Tools. They provide a strong data-visuals connection and typically greater flexibility in visualization and interaction types. Custom visualizations are more easily developed with Coding Tools than with Creation Tools. Most coding tools are in JavaScript due to the demand for web-based interactive graphics.

Visualization Library

Visualization libraries are JavaScript libraries that provide a variety of methods developed to make visualization easy, customizable, and modular. They can be used to assemble a seemingly limitless number of visualization types as they enable essentially automated digital drawing.

Charting Library

Charting libraries are the JavaScript equivalent of chart generators. They offer pre-made plug-and-play visualizations with some amount of built-in customization. Deploying these graphics still requires web development knowledge, but the visualizations themselves are assembled with pre-built blocks of code.

Other Languages

There are several programming languages apart from JavaScript that support visualization. These languages tend to be harder (or impossible) to implement on the web and thus have fallen out of style to some extent with the recent push towards interactive web-based graphics. Nevertheless, they remain important tools in the toolbox and can be highly effective for creating static visualizations.

Symbol Key

1	2	3	4	5
fair				best

			Usability				Capability				Accessibility			
			Installation	Learning	Support	Cost	Variety	Data Connection	Data Processing	Interactivity	Web Compatibility	Portability	Security	Scalability
Coding Tools	Viz Library	D3.js	1	1	3	5	5	4	4	5	5	2	4	4
		p5.js	1	1	3	5	5	4	4	5	5	4	4	4
	Charting Library	Highcharts	1	2	4	2	3	4	2	4	5	5	4	3
		Google Charts	1	2	2	5	3	3	2	4	4	2	3	3
	Other Languages	Processing	5	1	3	5	5	4	4	5	1	5	4	4
		R	2	1	3	5	4	4	5	4	2	5	4	3
		Plotly APIs	1	2	4	4	3	4	2	3	3	4	1	3

D3.js

Coding Tool

JavaScript Visualization Library

The D3.js homepage showing a gallery of example visualizations

Tool Description

D3.js is an open-source JavaScript library developed by Mike Bostock, former graphics editor at the New York Times. D3 derives its name from its ability to bind data to elements of the Document Object Model (DOM), thus creating “data-driven documents.” This method of creating visualizations means that D3 integrates seamlessly with web standards for HTML, SVG, and CSS. D3 has an extensive user community, responsible for generating thousands of examples and providing a variety of resources and support. Its ability to create completely customized interactive web-based visualizations has made it a gold standard for visualization tools.

Pros

- Complete control over visual representation and interactions
- Excellent data processing methods
- The de facto standard for web-based interactive visualizations

Cons

- Requires programming ability and knowledge of web development
- Takes time to master
- Developer must make more decisions for themselves

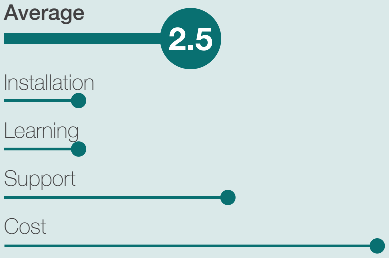
Box Plots
Bubble Chart
Bullet Charts
Calendar View
Non-contiguous Cartogram
Chord Diagram
Dendrogram
Force-Directed Graph
Circle Packing
Population Pyramid
2000
Stacked Bars
Streamgraph
Sunburst
Node-Link Tree
Treemap
Voronoi Diagram
Hierarchical Edge Bundling
Voronoi Diagram
Symbol Map
Parallel Coordinates

A subset of examples from the D3 gallery

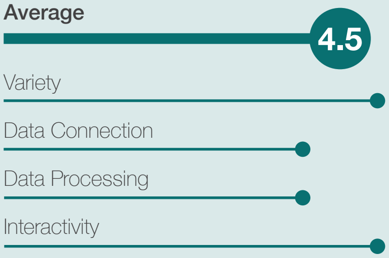
Score Summary

3.6 Best

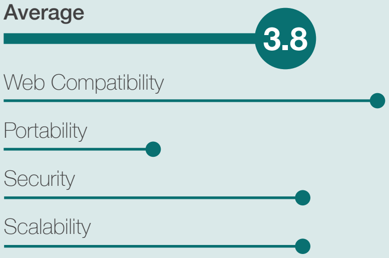
Usability



Capability



Accessibility



Scale

Resources

[Main website]

[Documentation]

[Source]

[D3 gallery]

[D3 CDN]

D3.js

Coding Tool

JavaScript Visualization Library

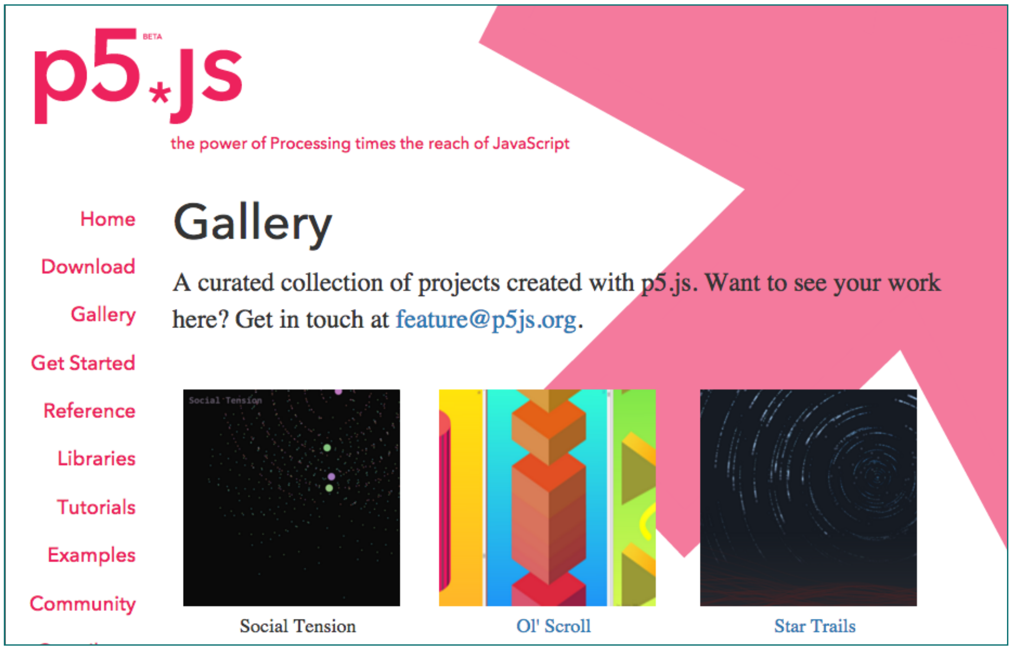
Evaluation Details

	Criteria	Notes	Score
Usability: 2.5	Installation	The D3 library can be downloaded from GitHub or linked to directly from an HTML file using a CDN. This process takes some familiarity with web programming, but is not difficult once learned. D3 supports modern browsers, including Chrome, Firefox, and Safari.	1: Special file and library set-up
	Learning	D3 is its own language and requires time and effort to become fluent. It hinges on a strong understanding of web development fundamentals including HTML, CSS, and JavaScript. Existing charts can be repurposed with minimal programming.	1: Unique programming language to learn
	Support	There are thousands of examples online, both from Bostock and from the greater D3 community. The language is well-documented in its API reference. Online tutorials and books on D3 abound. Specific questions are often answered on StackOverflow or Google Groups.	3: Open-source tool with strong user community
	Cost	The library is free and open-source under the BSD license.	5: Completely free
Capability: 4.5	Variety	D3 supports virtually infinite visualization types since it allows unencumbered manipulation of the DOM. Examples exist for all standard chart types and many unique options. 3D visualizations require the use of additional JavaScript libraries such as three.js.	5: Infinite variety
	Data connection	Data-visuals connection is strong. D3 itself is good at reading csv, json, xml, and other flat files. More advanced coding can be used to integrate D3 with databases or other data sources.	4: Text files; other data connections can be programmed
	Data processing	D3 ships with a number of methods for working with arrays, such as transpose, merge, and even rollup. Virtually any analysis should be possible using either D3's methods or generic JavaScript.	4: Some processing options; more can be programmed
	Interactivity	Visualizations are interactive and interactions are fully customizable. These include tooltips, animations, filters, zoom, etc.	5: Customizable interactions in and between charts
Accessibility: 3.8	Web compatibility	Visualizations are constructed with DOM elements. They are not responsive be default, but can be configured to be responsive. Visualizations must be hosted or served locally in order to share.	5: Web elements with transparent source code
	Portability	A variety of methods can be used to save D3 graphics as png, svg, or other formats, but there is no easy, automated process to do so.	2: Can export as non-vector image with effort
	Security	Data can be hosted locally or on a server using whatever security standards are required.	4: Data on-site; sharing configurable
	Scalability	While large dataset sizes, high amounts of data processing, or lots of data rendering can slow system response, methods to streamline the program are possible. D3 sites need to be optimized to meet necessary performance. D3 itself is a relatively light-weight library.	4: No size constraints, but performance needs optimization

p5.js

Coding Tool

JavaScript Visualization Library



the power of Processing times the reach of JavaScript

Gallery

A curated collection of projects created with p5.js. Want to see your work here? Get in touch at feature@p5js.org.

Social Tension | Ol' Scroll | Star Trails

p5.js gallery showing example projects

Tool Description

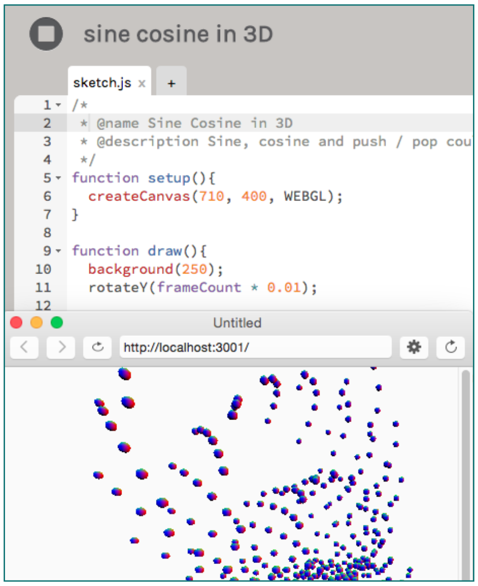
p5.js is a JavaScript library based on the Processing programming language. It seeks to provide accessible interactive web coding for visual and interactive media. Like D3.js, p5.js is extremely flexible and interactive. However, p5.js is not designed specifically for data-driven graphics; it lacks many of the data visualization-specific functions of D3. The result is that similar graphics can be produced using both tools, but are likely programmed more easily and quickly in D3. p5.js exceeds D3's abilities in certain areas: 3D rendering, image manipulation, audio functionality, and more. This expanded toolset makes p5.js a preferred tool for multimedia and creative coding ventures.

Pros

- ✓ Extensive tools for multimedia interaction including 3D, video, audio, and webcam
- ✓ Designed to make coding accessible for beginners
- ✓ Free and open-source

Cons

- ✗ Lacks D3's visualization-specific functions such as axes and layouts
- ✗ Requires learning and set-up hinging on web development knowledge
- ✗ Repeated actions are scripted as loops which becomes tedious

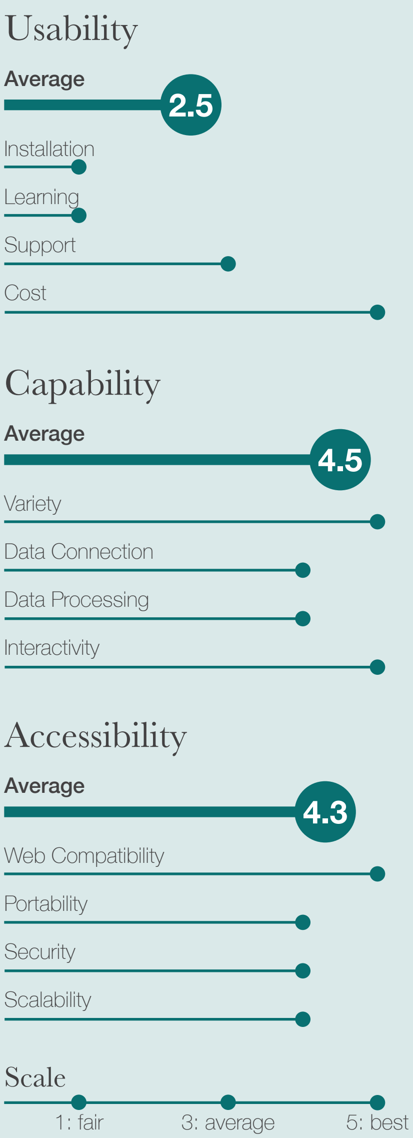


```
/*
 * @name Sine Cosine in 3D
 * @description Sine, cosine and push / pop cou
 */
function setup(){
  createCanvas(710, 400, WEBGL);
}

function draw(){
  background(250);
  rotateY(frameCount * 0.01);

```

3D sine cosine example in p5.js IDE

Score Summary

3.8 Best



Resources

- Main website
- Download site
- Examples page
- Tutorials page
- Exhibition gallery

p5.js

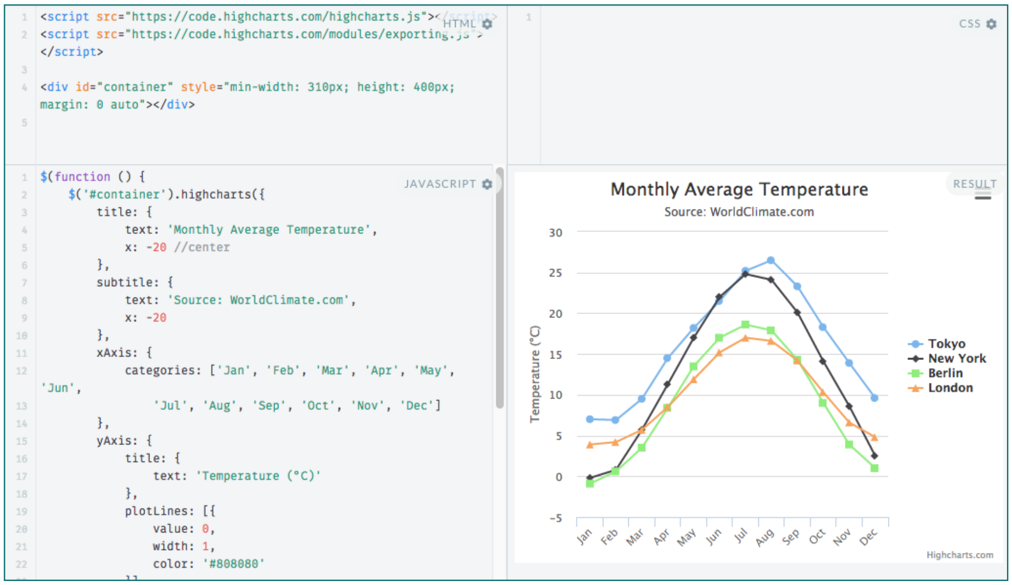
Evaluation Details

	Criteria	Notes	Score
Usability: 2.5	Installation	The p5.js libraries can be downloaded or linked to directly from an HTML file using a CDN. This process takes familiarity with web programming. p5 supports modern browsers, including Chrome, Firefox, and Safari. An official p5 IDE is in development.	1: Special file and library set-up
	Learning	p5.js is its own language and takes time to learn. The language is designed to teach programming, making it more accessible to new programmers. A background in web development goes a long way.	1: Unique programming language to learn
	Support	Since it was designed for teaching programming, p5.js has tons of examples and support systems. The p5.js website directs to a language reference, gallery, examples page, and tutorials site. p5.js profits from the strong user community of the Processing language.	3: Open-source tool with strong user community
	Cost	The tool is completely free.	5: Completely free
Capability: 4.5	Variety	In p5.js, there are no predefined visualization types to draw from. Instead, 2D and 3D visualizations are created by looping through drawing actions. This creates a lot of flexibility and novelty, but can be time-consuming to create canned charts and graphs.	5: Infinite variety
	Data connection	Visuals can be connected to the data through programming statements and need to be updated if the data is changed. p5.js is best at loading text data (csv, txt, xml, json, etc). More advanced coding can be used to load other data sources (like a database). Loading data locally requires setting up a local server.	4: Text files; other data connections can be programmed
	Data processing	p5.js supports a wide variety of data processing techniques: matrix methods, basic calculations, string and array functions, and more. Other analyses can be performed using generic JavaScript.	4: Some processing options; more can be programmed
	Interactivity	Visualizations can be interactive, incorporating customizable mouse and keyboard events and more.	5: Customizable interactions in and between charts
Accessibility: 4.3	Web compatibility	p5.js visualizations are web elements and can be embedded on websites. p5.js extends Processing to the web. Visuals are not responsive by default, but can be configured to be responsive. Visualizations must be hosted or served locally in order to share.	5: Web elements with transparent source code
	Portability	Visuals can be exported as images (jpg and png). They can then be moved or viewed with different programs at will. Libraries for vector export (pdf) exist as add-on libraries.	4: Vector graphic requires additional subscription
	Security	Data can be hosted locally or on a server using whatever security standards required. Sites can be shared however a user wants.	4: Data on-site; sharing configurable
	Scalability	p5.js can accommodate large dataset sizes, likely limited to local memory. However, no exact size limits could be found.	4: No size constraints, but performance needs optimization

Highcharts

Coding Tool

JavaScript Charting Library



```html
<script src="https://code.highcharts.com/highcharts.js"></script>
<script src="https://code.highcharts.com/modules/exporting.js">
</script>

<div id="container" style="min-width: 310px; height: 400px;
margin: 0 auto"></div>
```

```javascript
$(function () {
    $('#container').highcharts({
        title: {
            text: 'Monthly Average Temperature',
            x: -20 //center
        },
        subtitle: {
            text: 'Source: WorldClimate.com',
            x: -20
        },
        xAxis: {
            categories: ['Jan', 'Feb', 'Mar', 'Apr', 'May',
'Jun',
                'Jul', 'Aug', 'Sep', 'Oct', 'Nov', 'Dec']
        },
        yAxis: {
            title: {
                text: 'Temperature (°C)'
            },
            plotLines: [{
                value: 0,
                width: 1,
                color: '#808080'
```

Line chart demo showing editable code block (left) and interactive chart (right)

Tool Description

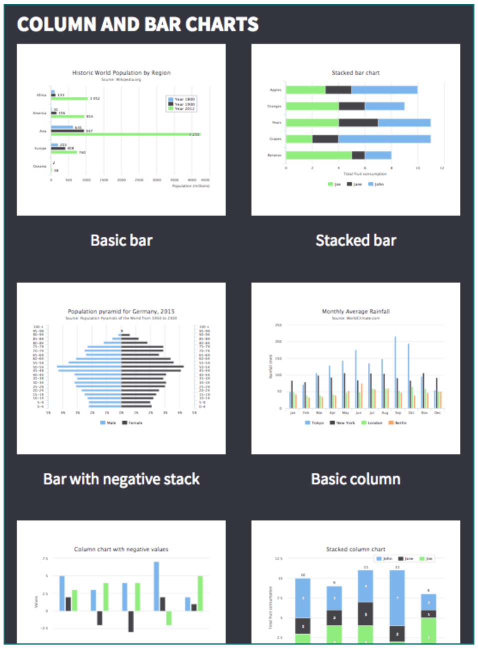
Highcharts (or Highcharts JS) is one of several offerings from the Norwegian company Highsoft AS. Highcharts is a JavaScript charting library that offers pre-made customizable code blocks for a wide variety of common chart types. The library has four pre-made style options and each chart's parameters can be adjusted. The charts are interactive by default and include an easy export dropdown. Highsoft AS also produces Highstock JS (for financial visualizations), Highmaps JS (for geographic visualization), Highslide JS (for image and media galleries), and Highcharts Cloud (a web application for producing charts without needing to code). These products combined provide a way of integrating web-based visualizations into sites with minimal coding.

Pros

- ✓ Compatible with most browsers: SVG used for modern browsers and VML used for legacy browsers
- ✓ Each chart has a dropdown enabling easy export to a vector or raster graphics file
- ✓ Wide variety of plug-and-play chart types that are easily customizable

Cons

- ☒ Same knowledge of web dev needed as for p5.js or D3.js, but less flexibility with chart and interaction types
- ☒ Few data manipulation functions
- ☒ Developer plans are costly

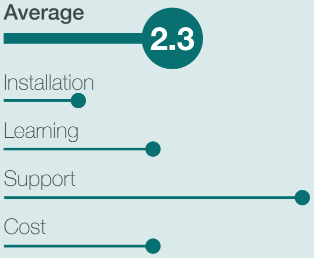


Subset of column and bar chart options

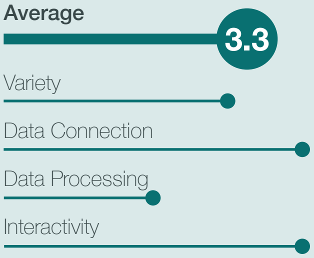
Score Summary

3.3 Good

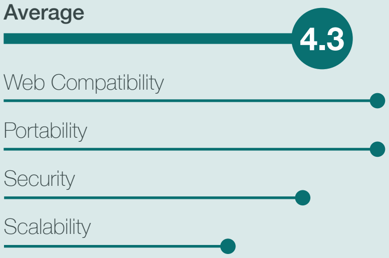
Usability



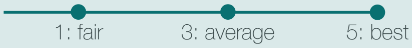
Capability



Accessibility



Scale



Resources

Main website

Support page

Highcharts demos

Documentation

Highcharts cloud

Highcharts

Coding Tool

JavaScript Charting Library

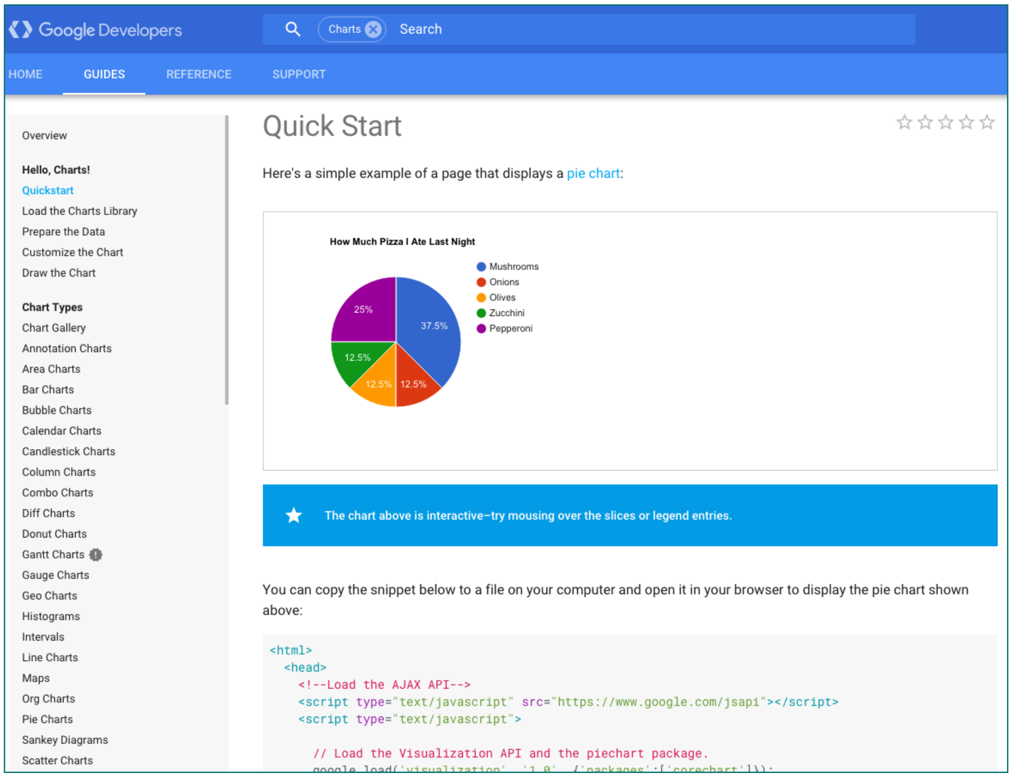
Evaluation Details

	Criteria	Notes	Score
Usability: 2.3	Installation	The library can be downloaded or linked to directly using a CDN. Takes some familiarity with web programming. Compatible with all modern browsers and even compatible with legacy IE browsers by using VML instead of SVG. Highcharts cloud can be used directly from the browser after logging in with email or other account.	1: Special file and library set-up
	Learning	Knowledge of web development is necessary (HTML, CSS, JavaScript, and even PHP in some cases). Highcharts cloud provides a chart generator-like interface for using Highcharts without coding.	2: Programming languages with plug-and-play examples
	Support	Many existing examples that are also editable in jsfiddle. Support systems include a forum, Stack Overflow, and helpdesk email. Licenses with maintenance and support include guaranteed 36 hour response time and provide chat via Skype during business hours.	4: Resources and support provided by small company
	Cost	Free for non-commercial use. Tiered pricing for commercial use: $150 Single Website $390 Single Developer $590 Single Developer + Maintenance & Support	2: Less than $1000 per license
Capability: 3.3	Variety	Over 20 different visualization types. Novel visualization types could be cumbersomely developed using the “general drawing” method, but this is not recommended. Some 3D graphics are possible.	3: 20 or more visualization types
	Data connection	The visuals are connected to the data. Webpage can be reloaded when data file is changed or live data can be used. Data connection involves some programming, but can be used to get data from csv, html table, google spreadsheet, xml, json, or a database.	4: Text files; other data connections can be programmed
	Data processing	Not much in the way of data processing, though it could be done with pure JavaScript first before passing the data to Highcharts.	2: Limited, but programming language can be leveraged
	Interactivity	Visualizations are interactive, including tooltips, filter, zoom, drilldown, and brushing. Interactions can be somewhat customized but novel interactions are hard to create.	4: Interactive in and between charts; some customizability
Accessibility: 4.3	Web compatibility	Visualizations are responsive web elements and can be embedded on websites or created as standalone sites. All source code can be downloaded and modified as needed.	5: Web elements with transparent source code
	Portability	Charts have an optional dropdown that allows for easy export as png, jpg, pdf, or svg.	5: Can export as vector graphic (svg, eps, or pdf)
	Security	Data can be hosted locally or on a server using whatever security standards required. Sites can be shared however the user wants.	4: Data on-site; sharing configurable
	Scalability	Limitations on dataset size are not spelled out, but some documentation exists on how to load millions of points.	3: Large data size with inherent constraints

Google Charts

Coding Tool

JavaScript Charting Library



Overview

Hello, Charts!

Quickstart

Load the Charts Library

Prepare the Data

Customize the Chart

Draw the Chart

Chart Types

Chart Gallery

Annotation Charts

Area Charts

Bar Charts

Bubble Charts

Calendar Charts

Candlestick Charts

Column Charts

Combo Charts

Diff Charts

Donut Charts

Gantt Charts

Gauge Charts

Geo Charts

Histograms

Intervals

Line Charts

Maps

Org Charts

Pie Charts

Sankey Diagrams

Scatter Charts

Quick Start

Here's a simple example of a page that displays a pie chart:

★ The chart above is interactive–try mousing over the slices or legend entries.

You can copy the snippet below to a file on your computer and open it in your browser to display the pie chart shown above:

```
<html>
  <head>
    <!--Load the AJAX API-->
    <script type="text/javascript" src="https://www.google.com/jsapi"></script>
    <script type="text/javascript">

      // Load the Visualization API and the piechart package.
      google.load('visualization', '1.0', {'packages':['corechart']});
```

Google Developers site showing Google Charts Quick Start Guide and documentation

Tool Description

Google Charts is a completely free API (application programming interface) that allows for easy web-based chart creation. It is the library that Google itself uses for charts appearing on its own websites. The API offers a large range of plug-and-play chart types that can be customized and assembled into interactive dashboards. Google Charts is compatible with legacy browsers, adopting VML for old IE versions. Use of Google Charts requires knowledge of web-based programming, including HTML and JavaScript. Google Charts have a less sophisticated design by default than other chart libraries such as Highcharts.

Pros

- ✓ Completely free to use
- ✓ Wide variety of plug-and-play chart types with many configuration options
- ✓ Excellent documentation on Google Developers site

Cons

- ✗ The API source code is a black box and cannot be downloaded
- ✗ Web development skills necessary
- ✗ Few data processing functions

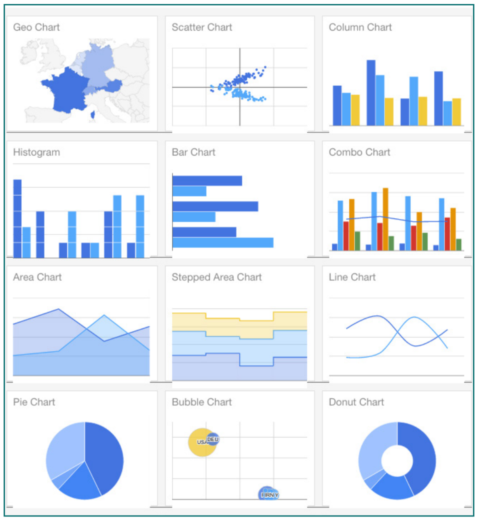
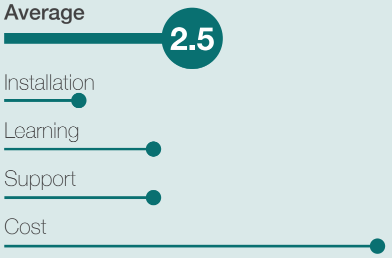


Chart gallery showing variety of chart types

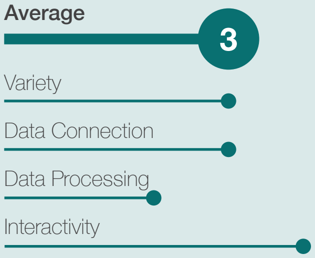
Score Summary

2.8 Fair

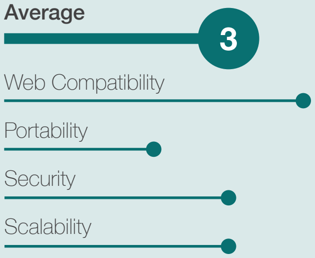
Usability



Capability



Accessibility



Scale

1: fair
3: average
5: best

Resources

Main website

API reference

Support site

Chart gallery

Forum

Google Charts

Coding Tool

JavaScript Charting Library

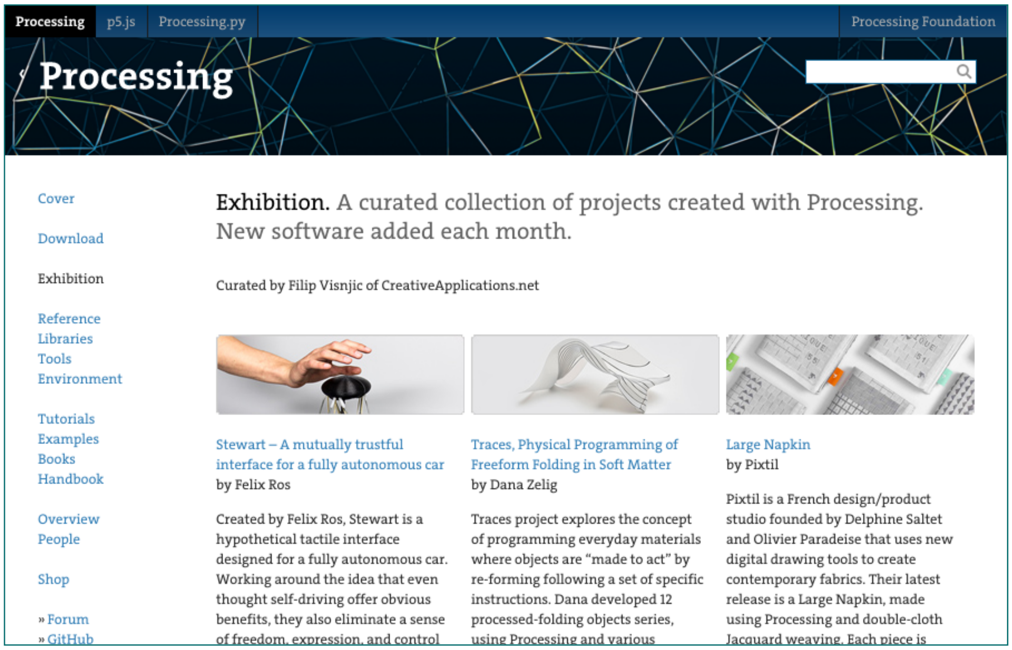
Evaluation Details

	Criteria	Notes	Score
Usability: 2.5	Installation	No real installation required. Instead, specific APIs and packages need to be called in each HTML file. Google Charts are compatible with all web browsers (adopting VML for old IE versions).	1: Special file and library set-up
	Learning	At minimum, familiarity with HTML and JavaScript is necessary to know where to add customized content.	2: Programming languages with plug-and-play examples
	Support	Many existing examples are available through the chart gallery. The site has good documentation on each chart type, how to use the charts, and how to customize them. There is an active user forum.	2: Online resources
	Cost	Google Charts API is completely free. However, caution should be used since the API can be updated or deprecated without notice.	5: Completely free
Capability: 3	Variety	28 preconfigured 2D chart types. New chart types can be developed and existing chart types can be modified, though these could prove to be complicated processes.	3: 20 or more visualization types
	Data connection	Visuals are connected to the data. The browser needs to be refreshed if data is changed. Data is easily accessed through Google Spreadsheets or Google Fusion Tables. Other options include csv and SQL but these are more complicated to configure.	3: csv, xls(x); other data connections can be programmed
	Data processing	Data grouping and joining are supported. Otherwise, data processing needs to be implemented in pure JavaScript.	2: Limited, but programming language can be leveraged
	Interactivity	Interactions include tooltips, crosshairs, animation, and controls (filter, select, etc.). Controls can be used to link charts in interactive dashboards. Some customization of interactions is possible, such as tooltip customization.	4: Interactive in and between charts; some customizability
Accessibility: 3	Web compatibility	Visualizations are web elements and can be embedded on websites. Charts are not inherently responsive, but can be altered to be. Some of the API source code is hidden from users. Thus, the charts cannot be accessed offline.	4: Web elements with sometimes inaccessible source code
	Portability	Charts can be converted to png using a function or screenshot.	2: Can export as non-vector image with effort
	Security	Google charts has documentation on its specific data policy and whether data is sent from the page.	3: Data might leave site
	Scalability	There are no built-in limits to dataset size, but the performance will decrease as data size increases.	3: Large data size with inherent constraints

Processing

Coding Tool

Other Programming Language



Cover
Download
Exhibition
Reference
Libraries
Tools
Environment
Tutorials
Examples
Books
Handbook
Overview
People
Shop
» Forum
» GitHub

Exhibition. A curated collection of projects created with Processing. New software added each month.

Curated by Filip Visnjic of CreativeApplications.net

Stewart – A mutually trustful interface for a fully autonomous car
by Felix Ros

Created by Felix Ros, Stewart is a hypothetical tactile interface designed for a fully autonomous car. Working around the idea that even thought self-driving offer obvious benefits, they also eliminate a sense of freedom, expression, and control

Traces, Physical Programming of Freeform Folding in Soft Matter
by Dana Zelig

Traces project explores the concept of programming everyday materials where objects are "made to act" by re-forming following a set of specific instructions. Dana developed 12 processed-folding objects series, using Processing and various

Large Napkin
by Pixtil

Pixtil is a French design/product studio founded by Delphine Saltet and Olivier Paradeise that uses new digital drawing tools to create contemporary fabrics. Their latest release is a Large Napkin, made using Processing and double-cloth Jacquard weaving. Each piece is

Processing website showing project exhibition

Tool Description

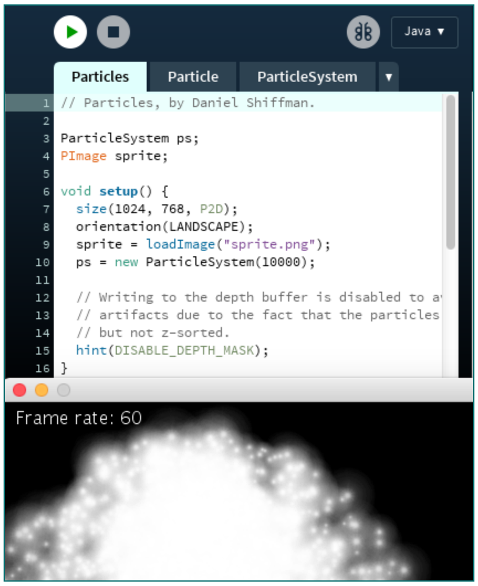
Processing is a free and open-source programming language and environment designed for creating visual and interactive media developed by Casey Reas and Ben Fry while they were graduate students at the MIT Media Lab. Processing is the non-web-based precursor to p5.js. Similar to p5, Processing seeks to provide an accessible language for interactive coding, making it a preferred tool for artists, creative coders, and multimedia designers. Processing allows users to draw on the computer screen in an automated fashion, enabling flexible and interactive graphics. Like p5, it lacks the data visualization-specific functions of D3.

Pros

- ✓ Extensive and unique tools for multimedia interaction including video, audio, and webcam
- ✓ Designed to make coding accessible for beginning programmers
- ✓ Free and open-source

Cons

- ✗ Lacks D3's visualization-specific functions such as axes and layouts
- ✗ Not designed for web-based graphics or visualizations
- ✗ Repeated actions are scripted as loops which becomes tedious



```
// Particles, by Daniel Shiffman.

ParticleSystem ps;
PImage sprite;

void setup() {
  size(1024, 768, P2D);
  orientation(LANDSCAPE);
  sprite = loadImage("sprite.png");
  ps = new ParticleSystem(10000);

  // Writing to the depth buffer is disabled to a
  // artifacts due to the fact that the particles
  // but not z-sorted.
  hint(DISABLE_DEPTH_MASK);
}
```

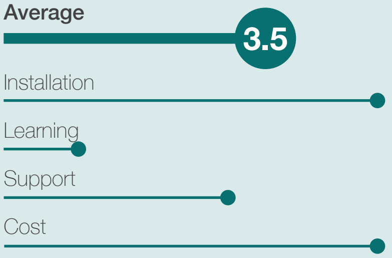
```
Frame rate: 60
```

IDE (top) with example demo (bottom)

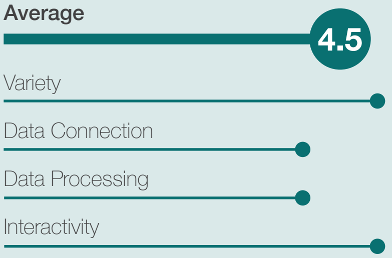
Score Summary

3.8 Best

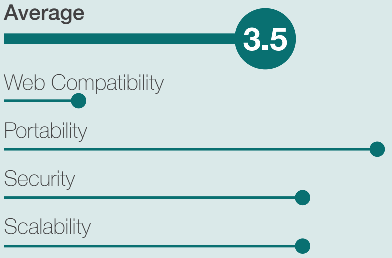
Usability



Capability



Accessibility



Scale

1: fair
3: average
5: best

Resources

Main website

Download site

Examples page

Video tutorials

Exhibition gallery

Processing

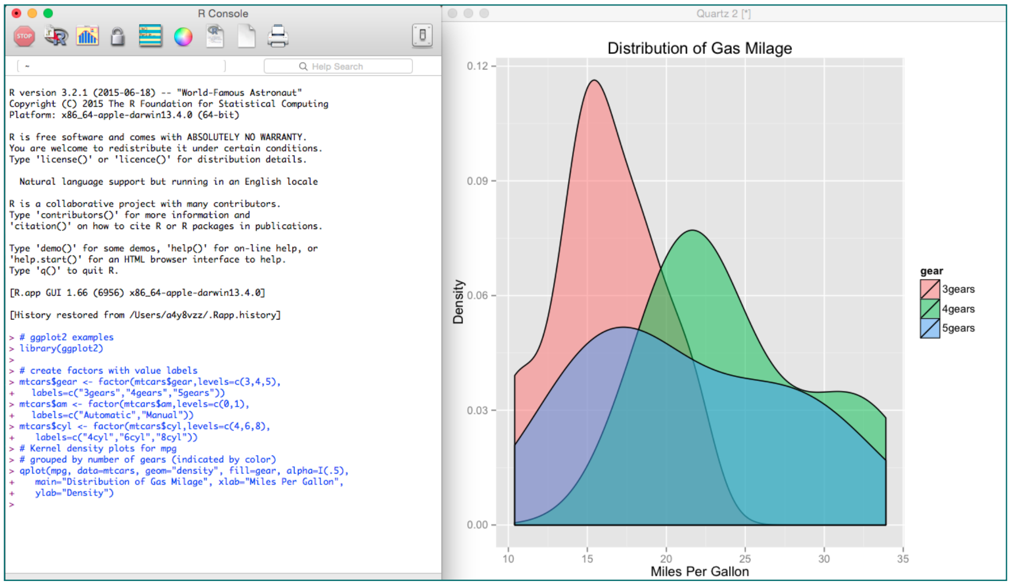
Coding Tool

Other Programming Language

Evaluation Details

	Criteria	Notes	Score
Usability: 3.5	Installation	Processing can be downloaded and installed automatically for Windows, Linux, and Mac OS X. It will run on any computer that can run the Java Runtime Environment (JRE).	5: Automatic installation for all OS
	Learning	Processing is its own language and thus takes time to learn. However, it is designed to teach programming fundamentals, making it more accessible to new programmers. A background in Java is very helpful since the syntax is similar. Alternatively, processing.py can be used to write Processing in python.	1: Unique programming language to learn
	Support	Since it was designed for teaching programming, Processing has tons of examples and support systems. The Processing website directs to a language reference, exhibition gallery, and examples page. Many books have been written on the language and it has a forum, wiki site, and strong user community.	3: Open-source tool with strong user community
	Cost	The tool is completely free.	5: Completely free
Capability: 4.5	Variety	In Processing, there are no predefined visualization types to draw from. Instead, visualizations are created by looping through drawing actions. This creates a lot of flexibility and potential novelty, but can make it time-consuming to create canned charts and graphs. Visuals can have up to three dimensions.	5: Infinite variety
	Data connection	Visuals can be connected to the data through programming statements. Processing is best at loading text data (for example, csv, txt, and xml). More advanced coding can be used to load other data sources, like databases.	4: Text files; other data connections can be programmed
	Data processing	Processing supports a wide variety of data processing techniques: matrix methods, calculations, string and array functions, and more.	4: Some processing options; more can be programmed
	Interactivity	Visualizations can be interactive, incorporating customizable mouse and keyboard events and more.	5: Customizable interactions in and between charts
Accessibility: 3.5	Web compatibility	Processing visualizations are not web elements and cannot be embedded (as interactive images) on websites. p5.js extends Processing to the web.	1: Not web compatible
	Portability	Visuals can be exported as tif, tga, jpg, png, and pdf. They can then be moved or viewed with different programs at will.	5: Can export as vector graphic (svg, eps, or pdf)
	Security	Data can be stored with whatever necessary security procedures. Programs and visuals are shared however the user wants.	4: Data on-site; sharing configurable
	Scalability	Processing can accommodate large datasets, likely limited to local memory. However, no details on exact size limits could be found.	4: No size constraints, but performance needs optimization

R



```
R version 3.2.1 (2015-06-18) -- "World-Famous Astronaut"
Copyright (C) 2015 The R Foundation for Statistical Computing
Platform: x86_64-apple-darwin13.4.0 (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

[R.app GUI 1.66 (6956) x86_64-apple-darwin13.4.0]

[History restored from /Users/a4y8vzz/.Rapp.history]

> # ggplot2 examples
> library(ggplot2)
>
> # create factors with value labels
> mtcars$gear <- factor(mtcars$gear,levels=c(3,4,5),
+   labels=c("3gears","4gears","5gears"))
> mtcars$am <- factor(mtcars$am,levels=c(0,1),
+   labels=c("Automatic","Manual"))
> mtcars$cyl <- factor(mtcars$cyl,levels=c(4,6,8),
+    labels=c("4cyl","6cyl","8cyl"))
> # Kernel density plots for mpg
> # grouped by number of gears (indicated by color)
> qplot(mpg, data=mtcars, geom="density", fill=gear, alpha=I(.5),
+    main="Distribution of Gas Milage", xlab="Miles Per Gallon",
+    ylab="Density")
>
```

R console (left) showing example graphical output using the ggplot2 library (right)

Tool Description

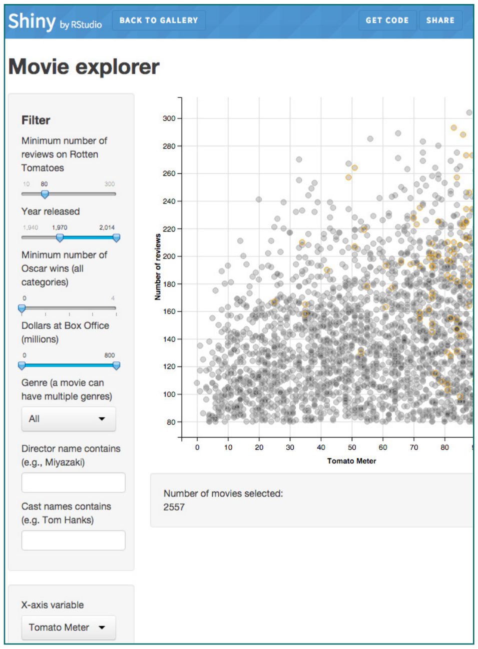
R is a free and open-source software language and environment designed for statistical computing and graphics. R is easily extended via packages (libraries of functions) making it a highly robust tool for nearly any type of data processing, calculation, or graphical information display. It is a mainstay for scientists, statisticians, and analysts and excels at producing publication-ready plots. Out-of-the-box R offers a command line interface. However, several graphical IDEs (integrated development environments), such as RStudio, are also available and can make programming in R much more efficient. While R typically generates static images, various packages can be used to create interactive graphics. Notably, the Shiny package creates interactive web-based visualizations using R.

Pros

- ✓ Robust data analysis and processing functions and tools
- ✓ Easily extended with a huge variety of libraries and packages
- ✓ Completely free and open-source with large user community

Cons

- ☒ Visualizations are not interactive or web-based by default
- ☒ Unique programming language takes time and effort to master
- ☒ Takes time to get the R environment set up with the correct packages and an optional IDE



Movie explorer

Filter

Minimum number of reviews on Rotten Tomatoes: 10 80 300

Year released: 1,940 1,970 2,014

Minimum number of Oscar wins (all categories): 0 4

Dollars at Box Office (millions): 0 800

Genre (a movie can have multiple genres): All

Director name contains (e.g., Miyazaki)

Cast names contains (e.g. Tom Hanks)

X-axis variable: Tomato Meter

Number of movies selected:
2557

Example interactive visualization using Shiny

Score Summary

3.5 Best

Usability

Average 2.8

Installation

Learning

Support

Cost

Capability

Average 4.3

Variety

Data Connection

Data Processing

Interactivity

Accessibility

Average 3.5

Web Compatibility

Portability

Security

Scalability

Scale

1: fair 3: average 5: best

Resources

[Main website]

[Comprehensive R Archive Network]

[RStudio IDE website]

[Shiny package site]

[ggplot2 site]

R

Coding Tool

Other Programming Language

Evaluation Details

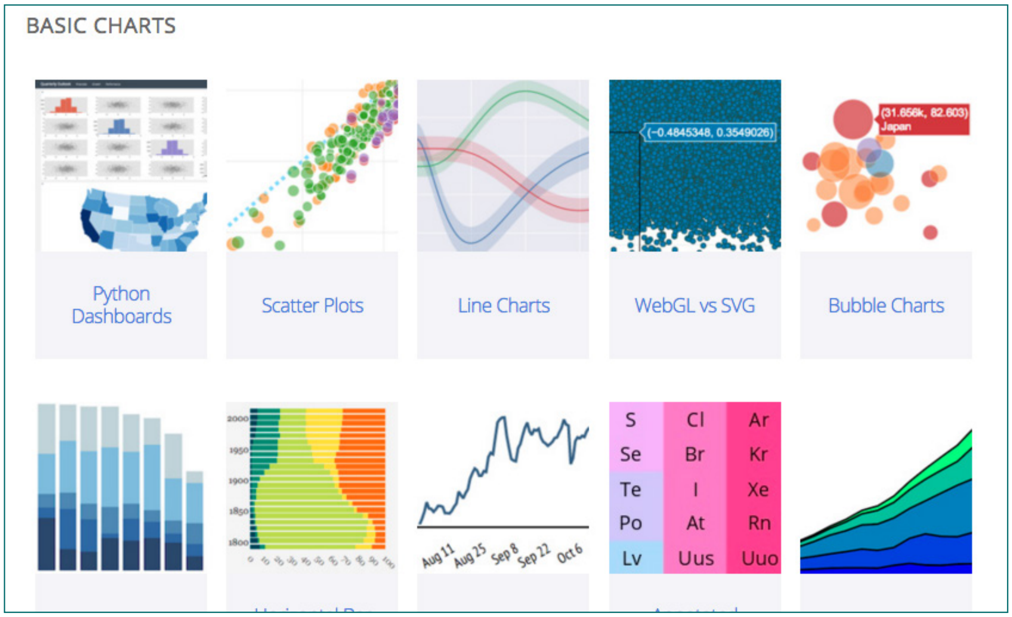
	Criteria	Notes	Score
Usability: 2.8	Installation	R can be installed easily using precompiled binary distributions, or the source code can be downloaded separately. Distributions exist for Linux, Mac OS X, and Windows. Installing all the necessary packages for visualization can take some effort. The RStudio IDE can be useful for programming, debugging, and generating plots.	2: Automatic installation plus set-up of libraries
	Learning	R is its own programming language and takes time to learn and master. Coding experience goes a long way in helping to learn R quickly as does knowledge of data structures and statistics.	1: Unique programming language to learn
	Support	There are tons of R examples on the web and each R package typically has a detailed reference guide with examples. Many support systems exist including a variety of books and references, standard support sites such as Stack Overflow, and R's built-in help system.	3: Open-source tool with strong user community
	Cost	R is completely free and requires no subscription or fee to download.	5: Completely free
Capability: 4.3	Variety	R and its many visualization-specific packages support a huge variety of different 2D and 3D visualizations. Hadley Wickham's ggplot2 library is a good place to start for a wide variety of visuals. Novel visualizations can be created provided coding expertise.	4: Virtually infinite variety
	Data connection	Visuals are connected to the data, but need to be updated if data is changed. R is good at importing text (csv, json, xls). More advanced coding can be used to connect to other data sources.	4: Text files; other data connections can be programmed
	Data processing	R's data processing tools are arguably its greatest asset. Data can be easily parsed and analyzed using basic tools and advanced packages. Examples include image analysis and machine learning.	5: Extensive data processing options
	Interactivity	Visualizations are typically static, but certain packages can be used to create interactive visualizations. Notably, the Shiny package can be used to create interactive web applications. Interactions depend on the package used and have some customizability.	4: Interactive in and between charts; some customizability
Accessibility: 3.5	Web compatibility	Visualizations are typically not web elements. Packages like Shiny or Plotly enable interactive web-based visualizations.	2: Can be web compatible with effort
	Portability	Visuals can be exported as raster or vector graphics (png, bmp, pdf, tiff, jpeg, and svg).	5: Can export as vector graphic (svg, eps, or pdf)
	Security	Data can be stored anywhere with whatever necessary security procedures. The user has high control over security as R runs locally.	4: Data on-site; sharing configurable
	Scalability	Some limits on dataset size exist, (e.g. vector length is limited to 2^31-1). Techniques can be used to extend R to big data scenarios. However, visualization packages may become unresponsive given large dataset sizes.	3: Large data size with inherent constraints

plotly

Plotly APIs

Coding Tool

Other Programming Language



Gallery of chart options for Plotly's Python API

Tool Description

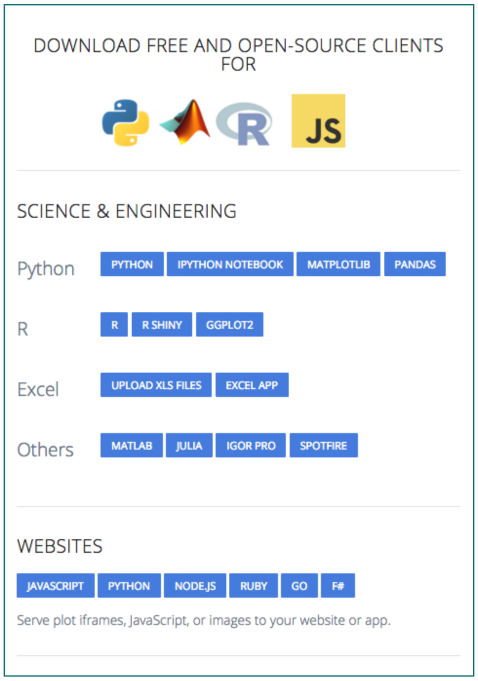
Plotly is an online chart, report, and dashboard maker with an emphasis on scientific visualization built on top of D3.js using its own open-source JavaScript graphing library called plotly.js. It offers API clients for Python, MATLAB, R, and more making it easy to use these traditional analytic environments to create interactive web-based graphics without needing to learn web development. Here, we evaluate the Plotly APIs (rather than plotly.js or the Plotly web app). Plotly provides well-designed defaults with a wide variety of built-in interactions including zoom, pan, select, tooltip with axis marker, autoscale, and more.

Pros

- ✓ Well-designed default visuals with built-in interactivity
- ✓ Visuals are easy to export as high-res vector graphics
- ✓ Provides a way to create web-based graphics for programs that would otherwise default to static images

Cons

- ☒ A plotly account is required to publish API charts online
- ☒ Paid account is required to create more than one private chart
- ☒ Getting the API connected takes some configuration and is different for each program



DOWNLOAD FREE AND OPEN-SOURCE CLIENTS FOR

JS

SCIENCE & ENGINEERING

Python	PYTHON · IPYTHON NOTEBOOK · MATPLOTLIB · PANDAS
R	R · R SHINY · GGPLOT2
Excel	UPLOAD XLS FILES · EXCEL APP
Others	MATLAB · JULIA · IGOR PRO · SPOTFIRE

WEBSITES

JAVASCRIPT · PYTHON · NODE.JS · RUBY · GO · F#

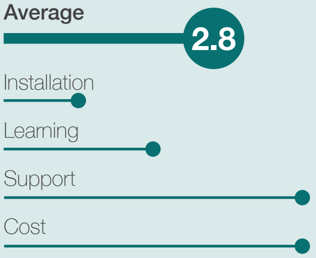
Serve plot iframes, JavaScript, or images to your website or app.

List of available Plotly API clients

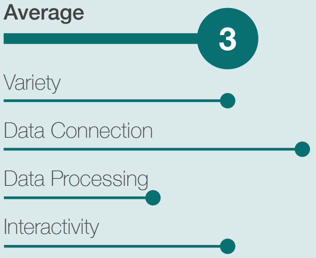
Score Summary

2.8 Fair

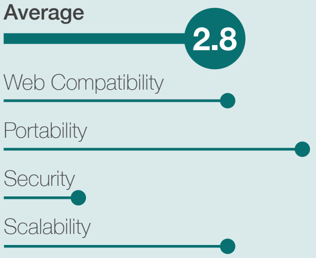
Usability



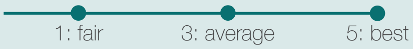
Capability



Accessibility



Scale



Resources

[Main website](#)

[Python API site](#)

[MATLAB API site](#)

[R API site](#)

[Support site](#)

Plotly APIs

Coding Tool

Other Programming Language

Evaluation Details

	Criteria	Notes	Score
Usability: 2.8	Installation	Python and R APIs are installed as packages; hosting on Plotly's site requires an API key and special set-up. MATLAB API requires download, API key, and setup script. The APIs work most easily with an internet connection, but can be configured to work offline. Python, R, and MATLAB must be installed in advance.	1: Special file and library set-up
	Learning	Plotly has its own charting syntax that requires programming knowledge to master. However, basic examples can be copied and repurposed easily. Knowledge of Python, R, or MATLAB is required for each respective API.	2: Programming languages with plug-and-play examples
	Support	Each API's landing page has a large number of examples showing different configurations of chart attributes. Plotly offers a forum and knowledge base. Pro plan offers email support.	4: Resources and support provided by small company
	Cost	Tiered monthly subscription fees per user: $0 Community: 1 private chart, API rate limits (50/day or 30/hour) $19 Professional: unlimited private charts, unlimited API calls, support	4: Free option with inexpensive flat monthly subscription
Capability: 3	Variety	More than 20 chart types, including a number of 3D plots, are supported and highly customizable. Novel visualizations could be possible with extensive coding, but are not easily supported.	3: 20 or more visualization types
	Data connection	Data is loaded using Python, MATLAB, or R, and the visuals are connected to the data.	4: Text files; other data connections can be programmed
	Data processing	The API itself doesn't support data processing, but Python, R, and MATLAB can be leveraged to perform the necessary processing before the data is piped to Plotly to graph.	2: Limited, but programming language can be leveraged
	Interactivity	All Plotly charts are interactive by default with click, hover, and zoom events, but custom interactions can also be added (buttons, dropdowns, and sliders).	3: Interactive in charts
Accessibility: 2.8	Web compatibility	Visualizations are web elements and can be embedded on websites. Visualizations created using the API must first be hosted by Plotly (private hosting requires subscription). Visualizations are responsive by default.	3: Web elements; source code inaccessible
	Portability	Visualizations can be exported as static images (png, pdf, eps, or svg). The code created with the API is not sufficient to host the interactive graphic oneself.	4: Vector graphic export requires additional subscription
	Security	Data is bundled with the hosted visualization. Visuals can be public, private, or secret.	1: Data uploaded to application; pay for private sharing
	Scalability	Plotly uses stack.gl to provide high performance 2D and 3D rendering, of up to millions of x-y points.	3: Large data size with inherent constraints

4.3 Drawing Tools

Drawing Tools offer free-form visual expression, allowing designers to create visualizations unencumbered by standard visualization types or default stylings. They require manual encoding, meaning there is no automatic data-visuals connection and shapes must be sized by hand according to the data they represent.

Print

Print Drawing Tools are an often underestimated way of creating visualizations. They are easy to use and learn and allow for rapid ideation. They don't require any software set-up making them highly accessible, even to non-technical users.

Digital

Digital Drawing Tools are typically prototyping or graphic design software. Like Print Drawing Tools, this group falls short on data connection and processing as well as interactivity. However, these tools are often good to understand when interfacing with other designers so that visualizations can be incorporated into prototypes or graphic designs. In practice, Digital Drawing Tools are often leveraged during the final step of static visualization design to polish a visualization created using another tool.

Symbol Key

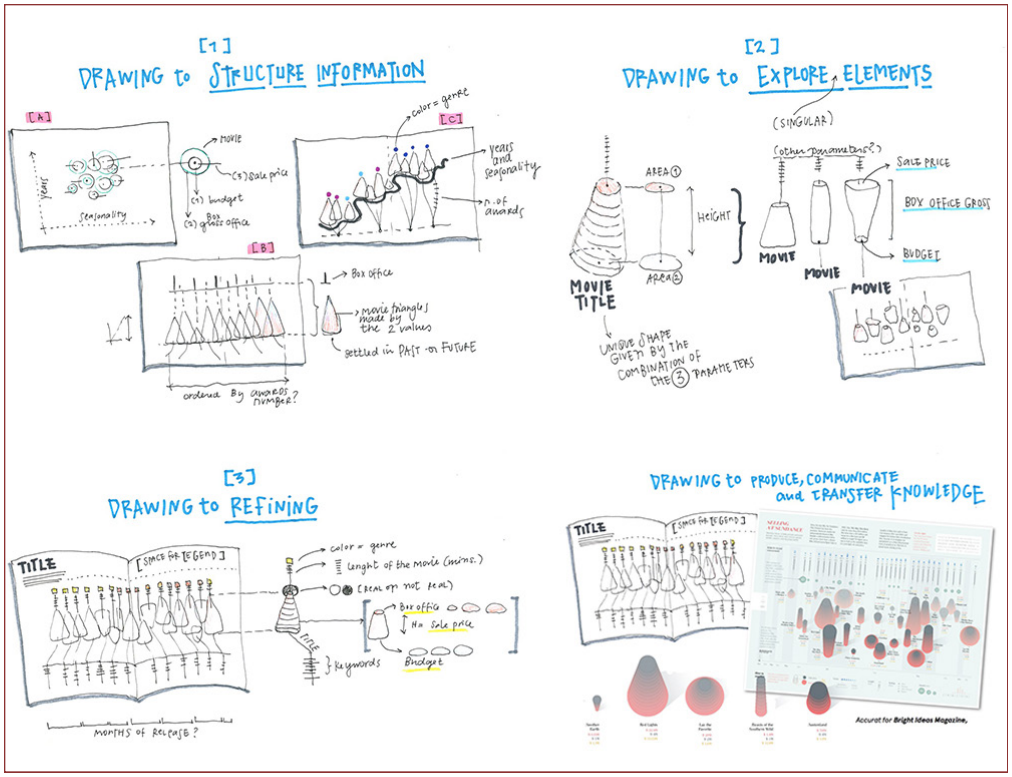
•	●	●	●	●
1 fair	2	3	4	5 best

			Usability				Capability				Accessibility			
			Installation	Learning	Support	Cost	Variety	Data Connection	Data Processing	Interactivity	Web Compatibility	Portability	Security	Scalability
Drawing Tools	Print	Pen & Paper	5	5	2	5	5	1	1	1	1	2	4	1
	Digital	Adobe Illustrator	5	3	5	1	5	2	1	1	2	5	4	2
		Omnigraffle	4	3	4	2	5	1	1	2	1	5	4	1
		Axure RP	5	3	4	2	4	1	1	2	2	3	5	1

Pen & Paper

Drawing Tool

Print


[1]
DRAWING to STRUCTURE INFORMATION
[A]
[B]
[C]
[2]
DRAWING to EXPLORE ELEMENTS
MOVIE TITLE
MOVIE
SALE PRICE
BOX OFFICE GROSS
BUDGET
[3]
DRAWING to REFINING
TITLE
DRAWING to PRODUCE, COMMUNICATE and TRANSFER KNOWLEDGE
TITLE

Motivations for drawing with data from Giorgia Lupi's 2014 presentation "The Shape of My Thoughts"

Tool Description

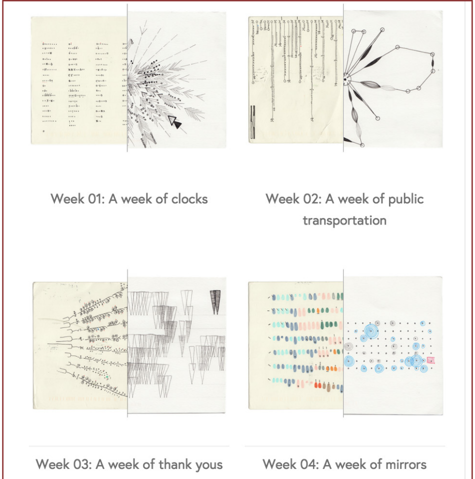
Pen (or any drawing instrument) and paper are often underestimated tools for data visualization. They can be used to imagine an infinite variety of visual forms, and the looseness of freehand drawing helps to keep the space of visualization possibilities open. In this way, this type of tool is particularly well-suited to the ideation and prototyping phases of visualization design. Furthermore, pen and paper are inexpensive to purchase and relatively easy to use, though lots of practice can certainly improve data sketching skills. Using digital modification (scanning followed by digital editing), drawn visuals can easily by adjusted, combined, or modified.

Pros

- ✓ Infinite variety of visuals possible
- ✓ No installation or learning of a new software is required
- ✓ Very inexpensive

Cons

- ☒ No data-visuals connection
- ☒ No interactivity
- ☒ Any data processing required must be performed manually



Week 01: A week of clocks

Week 02: A week of public transportation

Week 03: A week of thank yous

Week 04: A week of mirrors

Dear Data: a hand-drawn data postcard project

Score Summary

2.8 Fair

Usability

Average 4.3

Installation

Learning

Support

Cost

Capability

Average 2

Variety

Data Connection

Data Processing

Interactivity

Accessibility

Average 2

Web Compatibility

Portability

Security

Scalability

Scale

1: fair 3: average 5: best

Resources

Drawspace: online drawing lessons

Printable graph paper

Adobe Illustrator Image Trace guide

Utrecht art store

Quick, Useful UI Sketches

Pen & Paper

Drawing Tool

Print

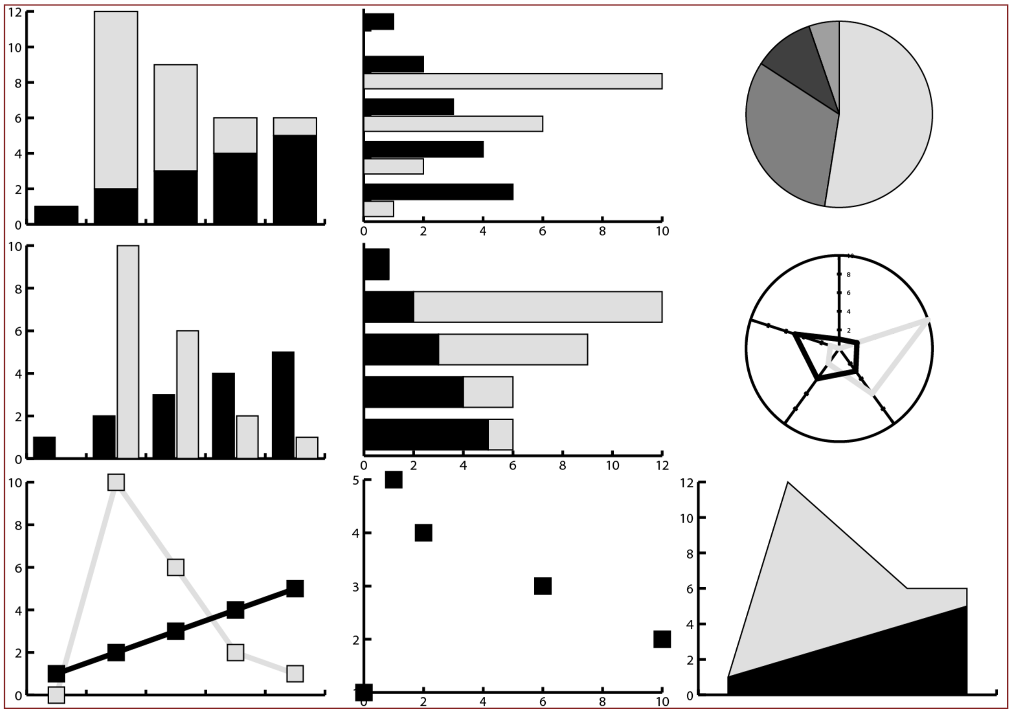
Evaluation Details

	Criteria	Notes	Score
Usability: 4.3	Installation	No installation necessary. Just grab a piece of paper and a writing instrument and get started!	5: Automatic installation for all OS
	Learning	Most people have at least some experience drawing, and it is easy to learn to create basic drawings. To become very good at sketching takes practice and time.	5: No application to learn
	Support	There are some examples and online resources from data visualization and user experience professionals. Other support systems include university courses or art workshops.	2: Online resources
	Cost	Most people own pens and paper already so we assume they can be used for free. Special pens, pencils, and paper can be purchased as necessary, but remain relatively inexpensive.	5: Completely free
Capability: 2	Variety	Any visualization can be created with this tool including completely novel visualization types. Drawing 3D visuals is possible, but takes more artistic skill and practice.	5: Infinite variety
	Data connection	There is no connection between the visuals and the data. The data can be encoded manually, using graph paper or measurements, or simply approximated.	1: No data connection
	Data processing	No internal data processing. Users must do any data crunching manually or in another tool.	1: Few built-in data processing options
	Interactivity	Visualizations are static. Repeated views showing different states can be used to mock up interactivity.	1: Static
Accessibility: 2	Web compatibility	Visualizations are not web elements. They can only be embedded on websites as images if they are scanned into the computer.	1: Not web compatible
	Portability	Visualizations can be scanned as raster graphics. Techniques can be used to convert raster graphics into imperfect vector graphics (for example, image trace in Adobe Illustrator).	2: Can export as non-vector image with effort
	Security	All the data is on the paper, so the user is in complete control of the security of the information.	4: Data on-site; sharing configurable
	Scalability	Drawn data visualizations have very limited scale as it takes a long time to create each manually encoded data point.	1: No data connected

Adobe Illustrator

Drawing Tool

Digital



Examples of default style for each graph type

Tool Description

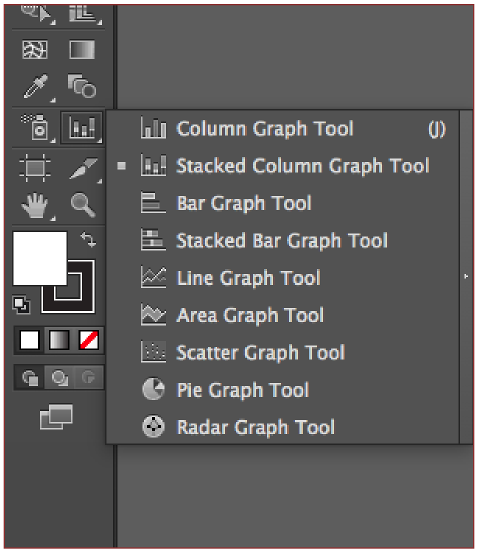
Adobe Illustrator is part of the Adobe Creative Suite and is specifically designed for working with vector graphics. It can be purchased and downloaded using an Adobe Creative Cloud membership as a standalone application or as part of the full suite of available apps. The tool is used most often by graphic designers creating infographics or data graphics with low data density. It offers the ability to create precise vector images, but most visuals require manual data encoding. A few chart types can be clumsily connected with spreadsheet data, including line charts and bar charts. Illustrator is also an excellent tool for refining visuals created in other applications.

Pros

- Infinite variety of visuals possible
- Good for refining any vector visuals exported from other tools
- The only drawing tool providing a data-visuals connection for certain chart types

Cons

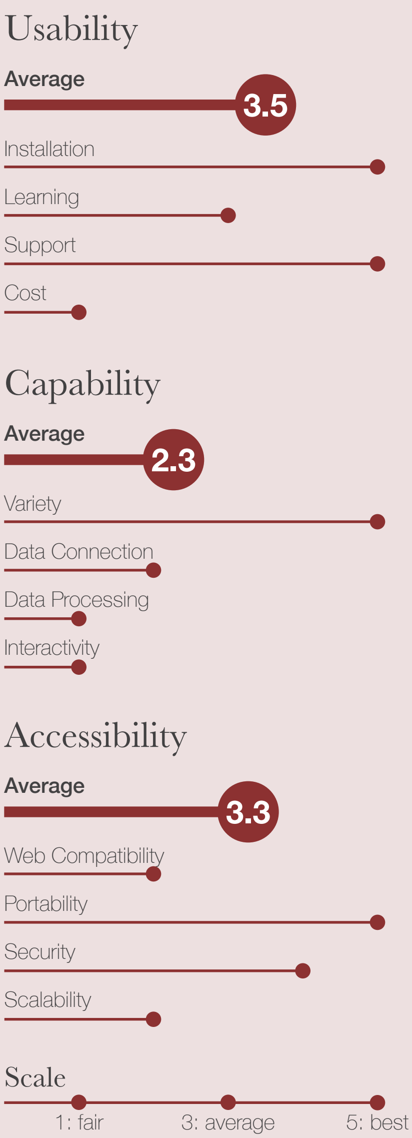
- Minimal data-visuals connection
- No interactivity
- Data processing must be performed manually or in a separate tool



Pop-out showing Illustrator graph tool options

Score Summary

3 Good



Resources

Main website

Guide to graphs in Illustrator

Support page

Pricing plans

Behance gallery of Illustrator projects

Adobe Illustrator

Drawing Tool

Digital

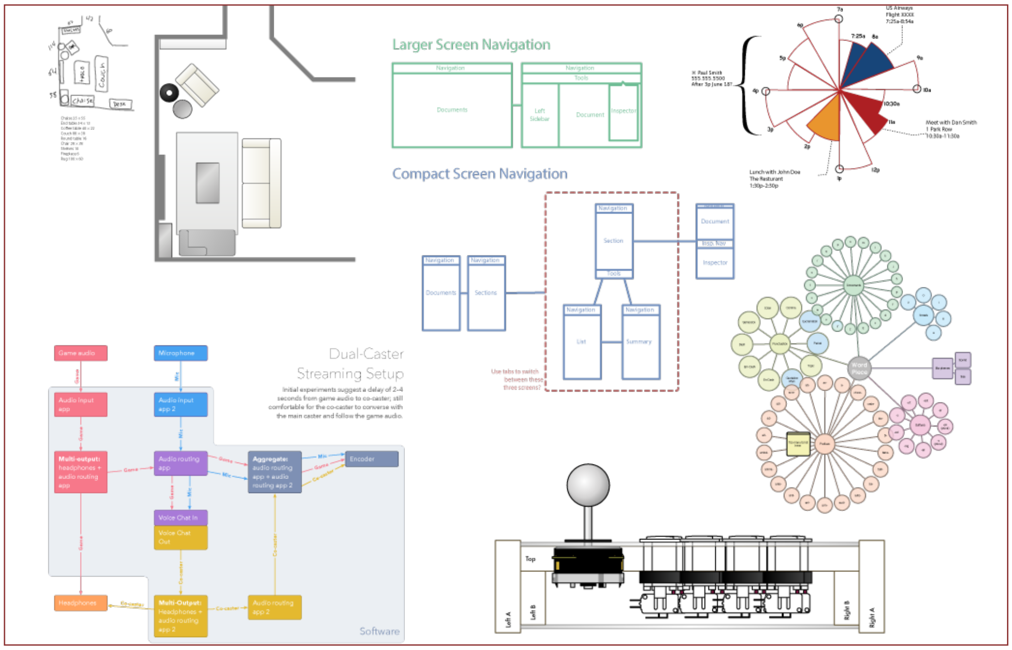
Evaluation Details

	Criteria	Notes	Score
Usability: 3.5	Installation	The tool can be downloaded and installed automatically from the Adobe website with a Creative Cloud (CC) subscription as a standalone app or as part of the full suite of Adobe apps. It is available for any operating system.	5: Automatic installation for all OS
	Learning	Illustrator is a complex application that takes some time and effort to master. No special prior knowledge is required though familiarity with other Creative Suite applications would make Illustrator easier to learn.	3: Complex application
	Support	Lots of online resources including a wide array of tutorials, in-depth user manual, FAQs, community forum, and direct customer care. Many existing examples can be found online. Other support options include courses at colleges or design studios.	5: Resources and support provided by large company
	Cost	Tiered monthly subscription cost (note that boxed hardcopy versions of the software have been discontinued): $19.99 Single App: access to one desktop app $49.99 All Apps: access to 20+ desktop and mobile apps $79.98 All Apps + Adobe Stock: 20+ apps and 10 free stock images	1: More than $1000 per license
Capability: 2.3	Variety	9 different 2D visualization types can be made automatically: column, stacked column, bar, stacked bar, line, area, scatter, pie, and radar. However, any other visual form can be created by combining vector shapes and lines.	5: Infinite variety
	Data connection	The visuals are connected to the data for the nine visualization types described above. For these charts, data can be imported as csv or xlsx files or pasted into the data editor window directly. Any other visualization requires manual encoding.	2: csv or xls(x) format only
	Data processing	For the nine built-in visualization types, the only data processing operation available is data transpose.	1: Few built-in data processing options
	Interactivity	Visualizations are static. Interactivity can be simulated using multiple static visuals showing different interaction states.	1: Static
Accessibility: 3.3	Web compatibility	It is possible to use Illustrator to generate CSS and export scalable SVG files that can be embedded on websites.	2: Can be web compatible with effort
	Portability	Visualizations can be exported in the following file formats: png, bmp, css, jpg, psd, tif, and svg.	5: Can export as vector graphic (svg, eps, or pdf)
	Security	The data is saved locally as part of the Illustrator file. Sharing is configurable by the user.	4: Data on-site; sharing configurable
	Scalability	The application becomes slow to respond with large datasets (greater than approximately 5,000 rows).	2: Data size limited to approximately 5,000 rows

Omnigraffle

Drawing Tool

Digital



Example of the range of graphics that Omnigraffle can be used to create

Tool Description

Omnigraffle is a software application for Mac and iOS, designed by the Omni Group for creating precise graphics, such as diagrams, wireframes, flowcharts, and more. The Mac application can be purchased for $99.99 for the standard version or $199.99 for the pro version. Stencils (groups of shapes) and templates (page layouts) can be purchased or constructed to speed up design creation. While there are no built-in data visualizations, shapes can easily be combined to prototype visualizations. Tables with integrated visuals, for example sparklines, are especially easy to create in Omnigraffle as groups of shapes can be copied and pasted into table cells. Omnigraffle allows for limited interactivity such as hyperlinking to different pages in a document.

Pros

- Ability to create and style a variety of shapes into custom visualizations
- Files can be exported as vector or raster graphics in a variety of formats
- Stencils can be created to increase prototyping speed

Cons

- No data-visual connection or integrated data processing
- Visuals are not web elements
- Creating visualizations representing real data is a tedious, manual process

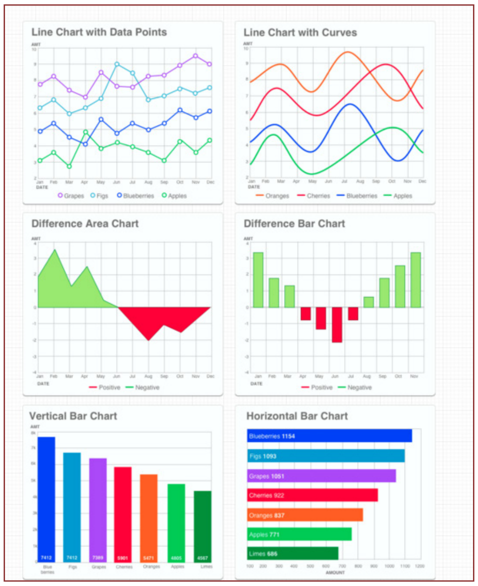


Chart stencils created in Omnigraffle

Score Summary

2.8 Fair

Usability

Average 3.3

Installation

Learning

Support

Cost

Capability

Average 2.3

Variety

Data Connection

Data Processing

Interactivity

Accessibility

Average 2.8

Web Compatibility

Portability

Security

Scalability

Scale

1: fair 3: average 5: best

Resources

Main website

Support page

Pricing information

Gallery

Chart stencils for purchase

Omnigraffle

Drawing Tool

Digital

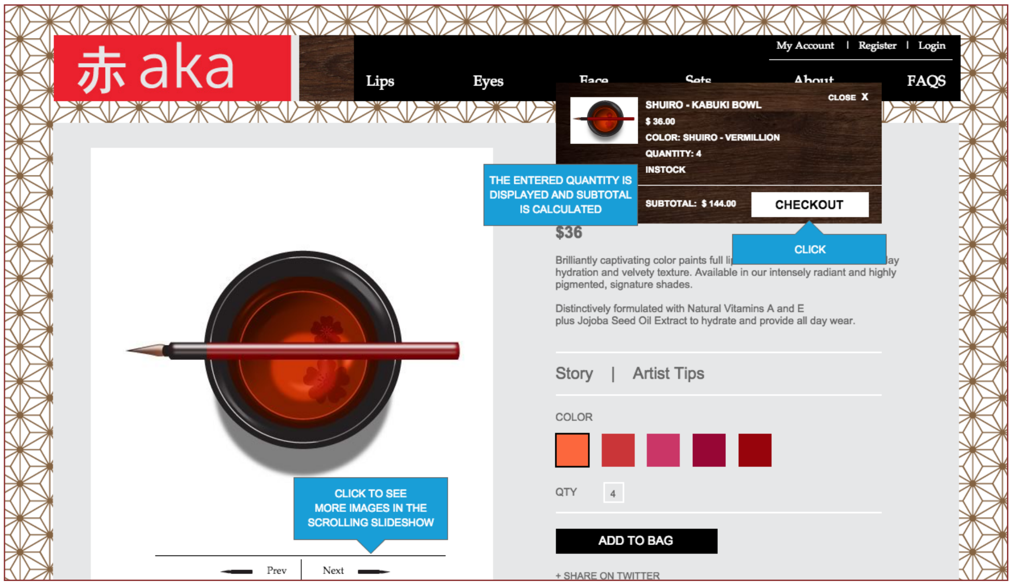
Evaluation Details

	Criteria	Notes	Score
Usability: 3.3	Installation	The tool can be downloaded directly from the main website or the Mac App Store and installs automatically. It requires Mac OS X 10.10 or higher for desktop version or iOS 9 for iPad and iPhone version.	4: Automatic installation only available for certain OS
	Learning	No prior knowledge is required, and the tool is relatively easy to learn. Complete mastery takes time and effort.	3: Complex application
	Support	Some existing examples in the site's gallery. Support systems include an online forum, downloadable manual, release notes, and a direct email and phone to the Omni Group support system. The system is being actively developed with releases multiple times per year.	4: Resources and support provided by small company
	Cost	Tiered flat fee for purchasing the desktop application: $99.99 Standard $199.99 Pro: shared layers, notes & custom data, and more	2: Less than $1000 per license
Capability: 2.3	Variety	Unlimited shapes can be combined to create any type of 2D visualization, including novel visuals. However, no visualization types are automatic (unless chart stencils are purchased). Instead, they must be constructed manually with shapes, lines, and text.	5: Infinite variety
	Data connection	There is no connection between the data and the visuals. Data must be encoded manually using shape size and position.	1: No data connection
	Data processing	No internal data processing is supported.	1: Few built-in data processing options
	Interactivity	Some interactivity is possible: opening a URL or file, jumping to another page, showing or hiding layers, and running an AppleScript file. This can be used to mock up some minimal within or between chart interaction, but gets clunky when trying to demonstrate complex or extensive interactions.	2: Interactivity can be simulated with prototyping tricks
Accessibility: 2.8	Web compatibility	Visualizations are not constructed with web elements and can only be placed on websites as images.	1: Not web compatible
	Portability	Visualizations can be exported in a variety of file types, both vector and non-vector, including png, bmp, gif, jpeg, svg, tiff, eps, Photoshop, and Visio.	5: Can export as vector graphic (svg, eps, or pdf)
	Security	Data is manually encoded into the image so data sharing is completely up to the user.	4: Data on-site; sharing configurable
	Scalability	Hard to scale given that each data value must be manually encoded.	1: No data connected

Axure RP

Drawing Tool

Digital



SHUIRO - KABUKI BOWL
$ 36.00
COLOR: SHUIRO - VERMILLION
QUANTITY: 4
INSTOCK

SUBTOTAL: $ 144.00

THE ENTERED QUANTITY IS DISPLAYED AND SUBTOTAL IS CALCULATED

$36

Brilliantly captivating color paints full li[…]ay hydration and velvety texture. Available in our intensely radiant and highly pigmented, signature shades.

Distinctively formulated with Natural Vitamins A and E plus Jojoba Seed Oil Extract to hydrate and provide all day wear.

Axure prototype showing high fidelity and global data variable ability (check out quantity).

Tool Description

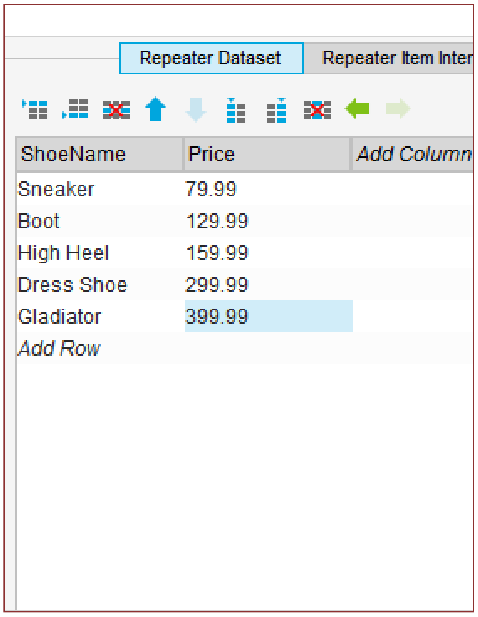
Axure RP (referred to as Axure for short) is a software prototyping tool first released by Axure Software Solutions Inc. in 2003. Axure version 8 can be purchased for $495 per user for a pro license or $895 per user for a team license. The tool excels at creating high-fidelity, fully interactive prototypes. Like Omnigraffle, widgets, text boxes, shapes and a line drawing tool can be used to construct visualizations. Additionally, Axure offers some unique features over other prototyping tools: visualizations created using web elements can be plugged into an Axure wireframe using an iFrame and "repeater" elements can be used with small datasets to create interactive tables of data. In some ways these features allow Axure to offer the best of both worlds: a robust prototyping tool and interactive data-driven visualizations.

Pros

- ✓ Prototypes can be hosted, password protected, and shared as links
- ✓ Team projects can be used to collaborate on shared prototypes
- ✓ "Repeaters" can be used to create interactive data tables

Cons

- ✗ No integrated data processing
- ✗ Many visualization types must be constructed with images or web elements through an inline frame
- ✗ No connection between data and visuals (except for "repeater" tables)

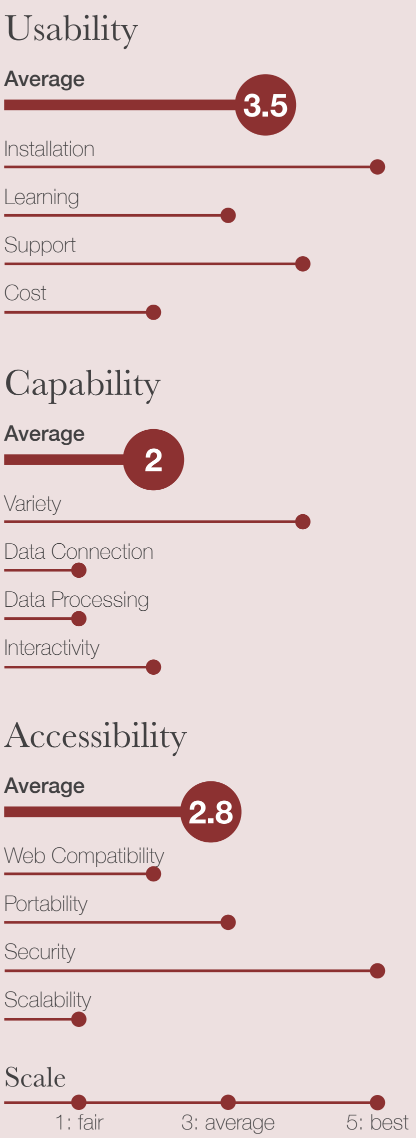


ShoeName	Price	Add Column
Sneaker	79.99	
Boot	129.99	
High Heel	159.99	
Dress Shoe	299.99	
Gladiator	399.99	
Add Row		

Repeater editor showing manual data import

Score Summary

2.8 Fair



Resources

[Main website]

[Pricing page]

[Training page]

[Community and support forum]

[Features and example prototypes]

Axure RP

Drawing Tool

Digital

Evaluation Details

	Criteria	Notes	Score
Usability: 3.5	Installation	Axure can be downloaded and installed for either PC or Mac directly from the tool's website. Installation is automatic and there are no special system requirements.	5: Automatic installation for all OS
	Learning	Axure is a complex application that takes time and effort to master. For creating interactivity, knowledge of programming logic is helpful.	3: Complex application
	Support	There are many support resources for Axure including online tutorials, training documents, online community and forum, and direct support email. Many existing examples can be found on Axure's website or on the forum. The application is actively developed with a new release expected sometime in 2016.	4: Resources and support provided by small company
	Cost	The tool is sold on a per license (or per month) basis: $495 ($29) Pro $895 ($49) Team: generate documentation, team collaboration	2: Less than $1000 per license
Capability: 2	Variety	Many 2D or 3D visualizations can be created by cobbling together shapes, lines, text boxes, images, hotspots, dynamic panels, and inline frames.	4: Virtually infinite variety
	Data connection	Visualizations themselves have no connection to data. Small datasets can be used with "repeater" elements to create dynamic tables. Data entry for repeaters is manual.	1: No data connection
	Data processing	Repeaters can be sorted and filtered, but no data associated with visualizations can be processed within Axure.	1: Few built-in data processing options
	Interactivity	Prototyping tricks like hotspots and dynamic panels can be used to simulate a full range of interactivity both in and between charts, including tooltips, filter, select, zoom, brushing, and more.	2: Interactivity can be simulated with prototyping tricks
Accessibility: 2.8	Web compatibility	Axure prototypes can be exported as HTML, CSS, and JS files that can be shared on AxShare (Axure's own hosting site) or uploaded to one's own server. These files are not written in release-ready code.	2: Can be web compatible with effort
	Portability	Files can be exported as both vector and non-vector images: png, bmp, gif, and jpg. Word, Excel, and HTML documentation can be automatically generated with a Pro license.	3: Can export as non-vector image (png, bmp, or jpg)
	Security	Prototypes can be hosted on AxShare using password protection or HTML, CSS, and JS files can be generated and hosted on-site and secured as needed.	5: Data on-site; secure sharing
	Scalability	No data can be attached to visuals. For repeaters, prototype slows as dataset gets larger so they are best for relatively small datasets.	1: No data connected

5 Conclusion

18 data visualization tools were selected, classified into tool categories and sub-categories, evaluated on 12 criteria according to devised metrics, and compared. For each tool, a scorecard was produced with scoring details and reference information. Additionally, a summary of all results was presented.

This methodology attempts to aid in the tool selection process as well as quantify the current product space of data visualization tools. The analysis shows that there is no single best tool, and that tool selection involves trade-offs and should hinge on the needs of a specific project or project phase.

As the data visualization tool market continues to grow, the methodology presented here can be used to evaluate new tools as well as to drive exploration of desirable yet underrepresented areas in the current product space.