

Resonant Laboratory and Candela: Spreading Your Visualization Ideas to the Masses

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1 INTRODUCTION

Visualization practitioners are constantly developing new, innovative ways to visualize data. However, while many of these new techniques are general enough to be useful to a wide audience, many of them do not make it into production in professional systems.

There are many reasons that this happens. Academic researchers often don't have the funding or time to continue work on tools once a paper has been published. Many tools aren't engineered to handle real-world datasets—software that we see at conferences like IEEE VIS are often designed as demonstrations of research concepts, not as tools for real data analysts to use. Furthermore, connecting data to these tools is often non-trivial—to even try out a tool with their own data, users often have to follow complex setup procedures, including running shell scripts, moving files to special places, setting up servers or databases, or even programming.

In recent years, we have seen dramatic improvements with regard to archiving and reusing basic information visualization techniques through efforts such as `bl.ocks.org` and Treevis [14]. However, while these archival demonstrations of techniques are giving new users exposure to the rich world of data visualization, actually connecting a dataset to one of these visualizations still requires a degree of expertise beyond most users.

We have developed and informally tested two systems that can help solve these two inter-related problems. *Candela* is a framework and API for creating visualization components for the web that can wrap up new or existing visualizations as needed. Because Candela's API generalizes the inputs to a visualization, we have also developed a system called *Resonant Laboratory* that makes it possible for novice users to connect arbitrary datasets to Candela visualizations. Together, these systems enable novice users to explore and share their data with the growing library of state-of-the-art visualization techniques.

2 RELATED WORK

The scope of this work is limited to the problem of connecting a dataset to a visualization and sharing the result. While some overlap exists, its primary focus is not attempt to address the problems of data reshaping [16, 11], visualization creation [13, 6], or visualization customization [10, 7]. For example, Resonant Laboratory supports some data reshaping tasks, such as paging and filtering—but it only provides these features as far as they assist in the connection problem. Instead, the goal is for Resonant Laboratory to work alongside data reshaping tools, such as those cited above.

Our systems come closest to functionality present in tools like Tableau [15], Plotly [5], Raw [8], and Polestar / Voyager [17]. Compared to these systems, there are three significant advantages that Candela and Resonant Laboratory bring:

1. Candela can **incorporate new visualization techniques** very soon after code is available. For example, anyone can create a Candela wrapper for the published source code of UpSet [12] directly (see Figure 5), rather than wait for a professional team to re-implement the technique as part of a proprietary system.
2. Resonant Laboratory **adds database connectivity with filtering and sampling features** (see Figure 4). Cutting-edge visualization techniques that weren't designed to work at scale can now use these features right out of the box.
3. Candela and Resonant Laboratory are **open source projects**, released under a permissive Apache License.

Naturally, each of the tools mentioned above have slightly different objectives, that are in turn slightly different from those of Candela and Resonant Laboratory. Powerhouse programs like Tableau take a different approach to visualization design, emphasizing different sets of features for different target audiences, and the techniques for matching data attributes to visual encoding channels differ across each of these tools. Observing the differences between existing approaches to the matching problem is not without precedent [17], and future research can and should be conducted in this direction.

3 CANDELA

Candela [2] is a JavaScript framework library for creating, running, and sharing visualization components for the web using a standardized API that aims for simplicity and generality. It serves as the engine for driving visualizations in Resonant Laboratory.

Components are simple: the *VisComponent* class has a constructor for initializing a component with the DOM element where it will live, and a *render()* method to specify how it is drawn. Other commonly needed functionality, such as automatic resize behavior and event management, is provided via mixin classes; traditional OOP techniques such as subclassing can also extend functionality.

A component can declare its expected inputs by describing the types of input data fields that are meant for certain visual channels. For instance, as shown in Figure 1, a scatterplot might require two numeric data column inputs, one for each axis, and additional optional inputs, such as text labels. Resonant Laboratory uses such specifications to build its matching UI, enabling users to match different columns with visual channels on demand.

Candela ships with several predesigned, general-purpose components. Several are driven with Vega specifications [3] to create basic chart types such as scatterplots, bar charts, and line charts. Others wrap around existing, independently developed visualizations such as LineUp [9] and UpSet [12], using the input specification approach to allow them to be interactively driven from Resonant Laboratory. Doing so takes some manual work to identify how the foreign component is instantiated, how it receives input, and what kinds of events or signals it expects to respond to. Despite the fact that the process is currently not automatable, we have had success in “porting” several such components into Candela, include LineUp, UpSet, and OnSet. Candela's general and flexible API enables the creation of varied and unanticipated visualization components, whether general purpose offerings such as those that

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ship with the library (e.g. bar charts, scatter plots, etc.), or project-specific components that take advantage of the API and standard mixins for consistency and reusability. Examples might include a survivability plot for visualizing experimental drug therapy outcomes, using mixins to make such a chart automatically resize in the space provided to it, or to connect and deliver external UI events to the component to highlight one drug therapy course or another. Many such components can be automatically exposed via Resonant Laboratory, widening their appeal to general audiences who are unwilling or unable to do the programming to use such tools under ordinary circumstances.

4 RESONANT LABORATORY

Resonant Laboratory¹ is a web application with a Girder [1] backend that consequently has support for user account administration. As shown in Figure 2, it provides a secure location for users to store and manage their datasets in the cloud.

In Resonant Laboratory, users create *projects*, which we define as a dataset, a Candela component, and the matchings between them. As shown in Figures 1 and 3, Resonant Laboratory includes three collapsible views: a Dataset panel, a Matching panel, and a Visualization panel.

A major bottleneck in visualization is simply the amount of data that can be displayed at a time. This is especially true of web-based visualizations where data must pass over a network, and fit inside a browser's available memory. Resonant Laboratory's Dataset panel, outlined in Figure 4, includes basic tools for specifying how data is to be parsed and interpreted. It includes paging tools for controlling how many data items are loaded and passed to the visualization. Overview histograms provide tools for filtering every attribute in the dataset. These work together to help users understand the effect of any filters on the whole dataset, and provide context as to where the current page of data exists within the filtered set. By giving users the power to filter and page their data in this way, these tools make it possible to work with datasets that are an order of magnitude larger than what could traditionally fit in a browser.

Figures 1, 3, and 5 showcase its simple interface for establishing a many-to-many matching between the attributes of a dataset and the visual encodings available in a visualization. We conducted very informal user tests with eleven employees at Kitware Inc., an open source software company specializing in visualization, among other things. Participants ranged in expertise from programmers to communications specialists to graphic designers—all users were able to understand and use this interface with little to no difficulty, and in most cases users were able to perform the interactions without any instruction or demonstration. We are planning formal research in this direction, comparing Resonant Laboratory to other dataset-to-visual encoding matching interfaces.

The visualization panel embeds a Candela component. Figure 6 shows that, in addition to the ability to share projects via a URL, Resonant Laboratory exposes Candela's ability to export vector and bitmap images, as well as self-contained, interactive HTML files. This makes it possible to share visualizations in almost any conceivable way: a static image of the visualization can be customized and annotated in bitmap or vector drawing programs. Because the interactive HTML file can simply be opened in a browser, it can be shared via email, hosted via file sharing services, or embedded in an `iframe` in existing web pages—without any server configuration. A link to the original project in Resonant Laboratory and its associated dataset can be shared, enabling improved data provenance: recipients of the link can explore and change their own copies of the visualization for themselves. The possibilities for connecting visualization prototypes to bigger audiences than even before seem endless.

5 FUTURE WORK

Candela and Resonant Laboratory are projects that are focused on doing one thing, and doing it well. Candela makes it possible to reuse cutting-edge visualizations with arbitrary datasets, and Resonant Laboratory provides an intuitive and powerful, yet simple interface for novice users to connect datasets to a Candela component.

These technologies have additional features, such as parsing settings that can help with data cleaning, paging and filtering that address some data scalability problems, and export capabilities that help smooth the process of sharing or presenting a visualization. However, these features are not the focus—Resonant Laboratory does not solve scalability issues that cannot be addressed via filtering and paging, nor does Candela address the problems of designing or customizing visualizations. Instead, future work will likely involve separate applications dedicated to these separate tasks, such as another Girder plugin that reshapes or aggregates a dataset prior to exploration in Resonant Laboratory, or integration with existing tools that could be used to interactively design and customize Candela components. We also plan to explore ways to improve these two systems' main focus, including support for creating multiple linked views, embedding views in external pages, and support for graph visualizations.

ACKNOWLEDGEMENTS

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REFERENCES

- [1] <http://girder.readthedocs.io>.
- [2] <https://github.com/kitware/candela>.
- [3] <https://github.com/vega/vega/wiki>.
- [4] <https://jsfiddle.net>.
- [5] <https://plot.ly/>.
- [6] A. Bigelow, S. Drucker, D. Fisher, and M. Meyer. Iterating between tools to create and edit visualizations. *Visualization and Computer Graphics, IEEE Transactions on*, 2016. To appear.
- [7] S. Carter, G. Aisch, and M. Bostock. Svg crowbar, 2015.
- [8] G. Caviglia, M. Mauri, M. Azzi, and G. Uboldi. Raw: The missing link between spreadsheets and vector graphics, 2013.
- [9] S. Gratzl, A. Lex, N. Gehlenborg, H. Pfister, and M. Streit. Lineup: Visual analysis of multi-attribute rankings (best paper award). *IEEE Transactions on Visualization and Computer Graphics (InfoVis '13)*, 19(12):2277–2286, 2013.
- [10] J. Harper and M. Agrawala. Deconstructing and restyling d3 visualizations. In *Proceedings of the 27th Annual ACM Symposium on User Interface Software and Technology*, UIST '14, pages 253–262, New York, NY, USA, 2014. ACM.
- [11] S. Kandel, A. Paepcke, J. Hellerstein, and J. Heer. Wrangler: Interactive visual specification of data transformation scripts. In *ACM Human Factors in Computing Systems (CHI)*, 2011.
- [12] A. Lex, N. Gehlenborg, H. Strobel, R. Vuilleumot, and H. Pfister. Upset: Visualization of intersecting sets. *IEEE Transactions on Visualization and Computer Graphics*, 20(12):1983–1992, Dec 2014.
- [13] A. Satyanarayan and J. Heer. Lyra: An interactive visualization design environment. *Comput. Graph. Forum*, 33(3):351–360, June 2014.
- [14] H. J. Schulz. Trevis.net: A tree visualization reference. *IEEE Computer Graphics and Applications*, 31(6):11–15, Nov 2011.
- [15] C. Stolte, D. Tang, and P. Hanrahan. Polaris: a system for query, analysis, and visualization of multidimensional relational databases. *IEEE Transactions on Visualization and Computer Graphics*, 8(1):52–65, Jan 2002.
- [16] R. Verborgh and M. De Wilde. *Using OpenRefine*. Packt Publishing Ltd, 2013.
- [17] K. Wongsuphasawat, D. Moritz, A. Anand, J. Mackinlay, B. Howe, and J. Heer. Voyager: Exploratory analysis via faceted browsing of visualization recommendations. *Visualization and Computer Graphics, IEEE Transactions on*, 22(1):649–658, Jan 2016.

¹A public deployment is available at <http://resonantlab.kitware.com>

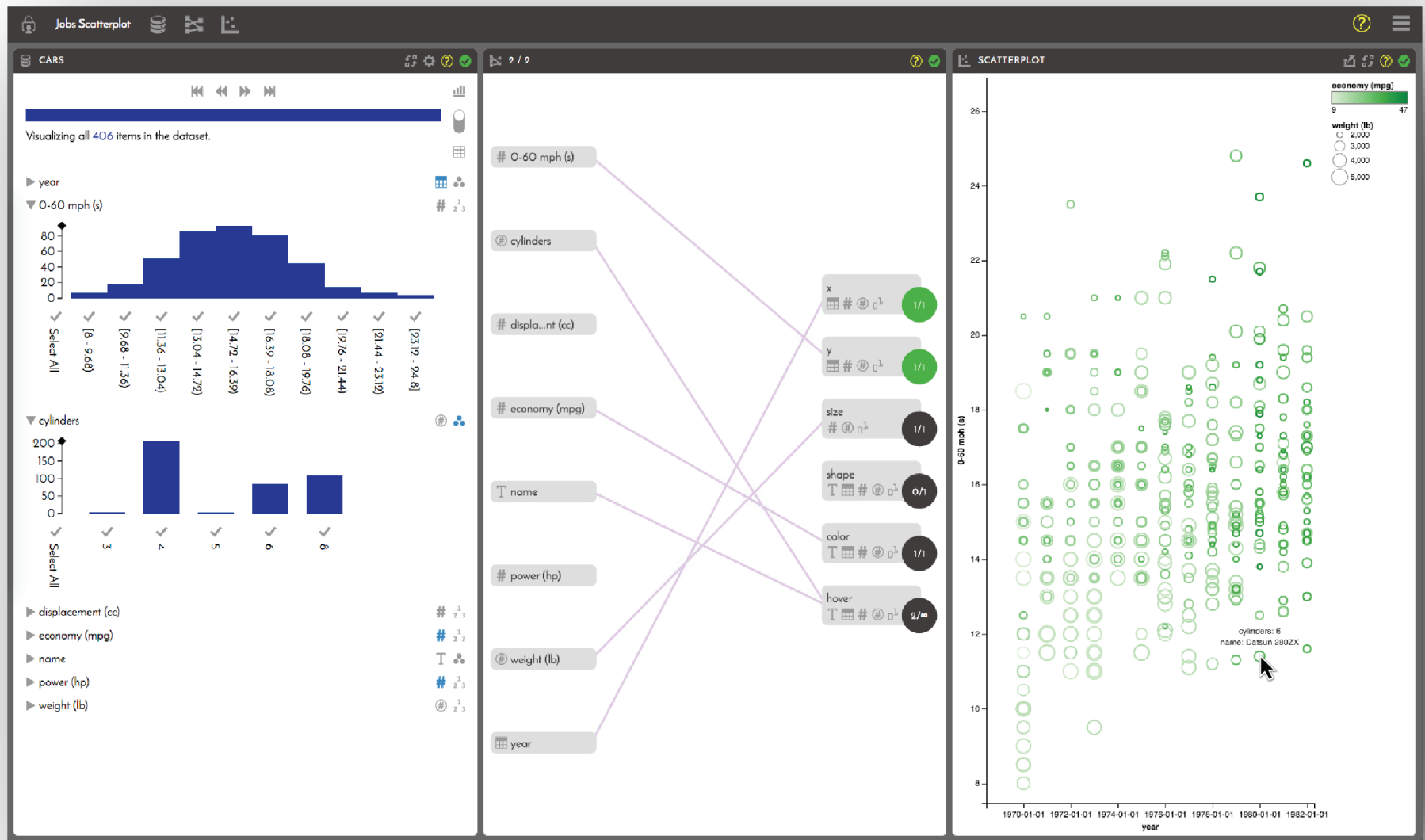


Figure 1: The Resonant Laboratory interface includes three panels. A dataset panel (left) helps users incorporate their own data into the visualization. A matching panel (center) helps users associate data attributes with visual encodings. A visualization panel (right) shows the resulting Candela component.

In this example, the user has configured the x-axis of the visualization to show the "year" attribute of the data. The y-axis shows "0-60 mph (s)", "weight (lb)" is encoded by the size of the marks, "economy (mpg)" is encoded by a color map, and the "cylinders" and "name" attributes are displayed when the mouse hovers over a point in the scatterplot.

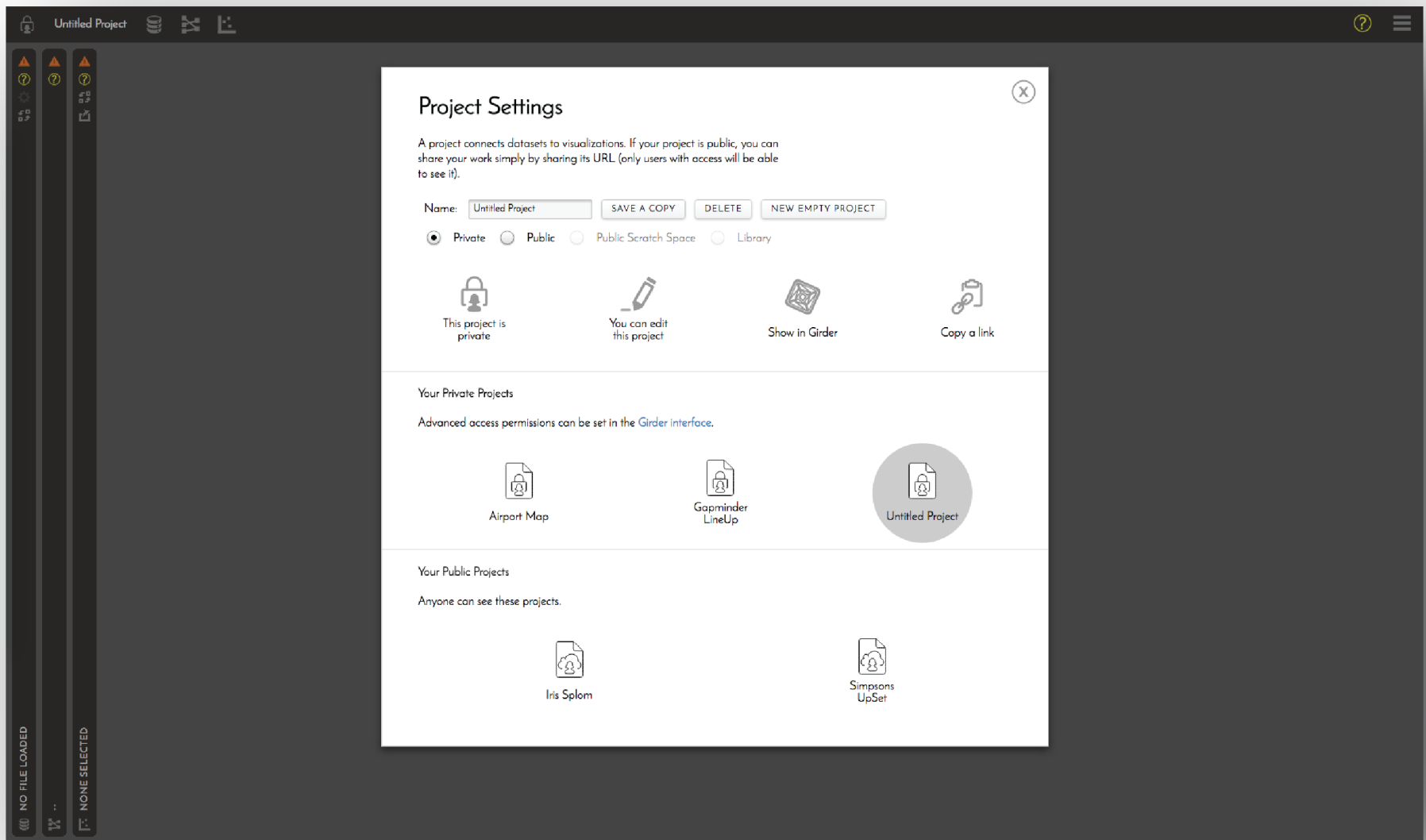


Figure 2: Users can control the visibility of datasets and projects. Even more advanced controls, such as file organization or granting user-specific access permissions, can be accessed in the Girder interface. When users interact with a project that they do not own, a copy is automatically created. When users are logged out or do not have an account, a public scratch space is used, similar in spirit to online services such as JSFiddle [4].

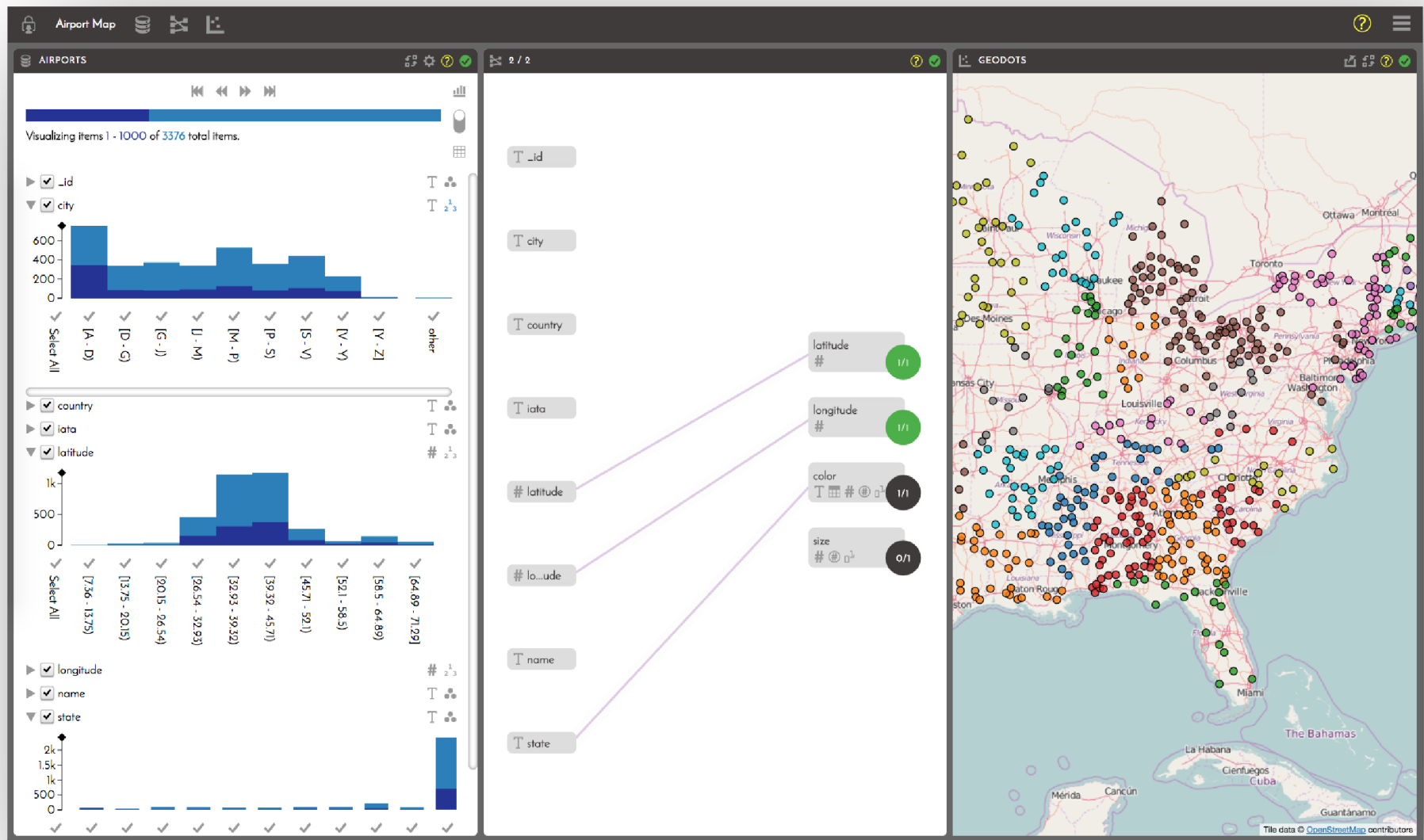


Figure 3: In this example, the “latitude” and “longitude” fields of the airport dataset have been associated with visual channels of the same names in the GeoJS component. The “state” field is also driving a categorical color map to differentiate airports by the state they are located in.

This example demonstrates how a larger dataset can be explored via paging; the dataset panel on the left indicates that only the first 1000 records are shown in the visualization. Paging can provide two benefits: it makes it possible to explore datasets that are larger than can fit in memory, and it also makes it possible to reduce clutter in the visualization by only showing a subset at a time. This example shows the latter use case (the browser could easily load all 3376 data points at once).

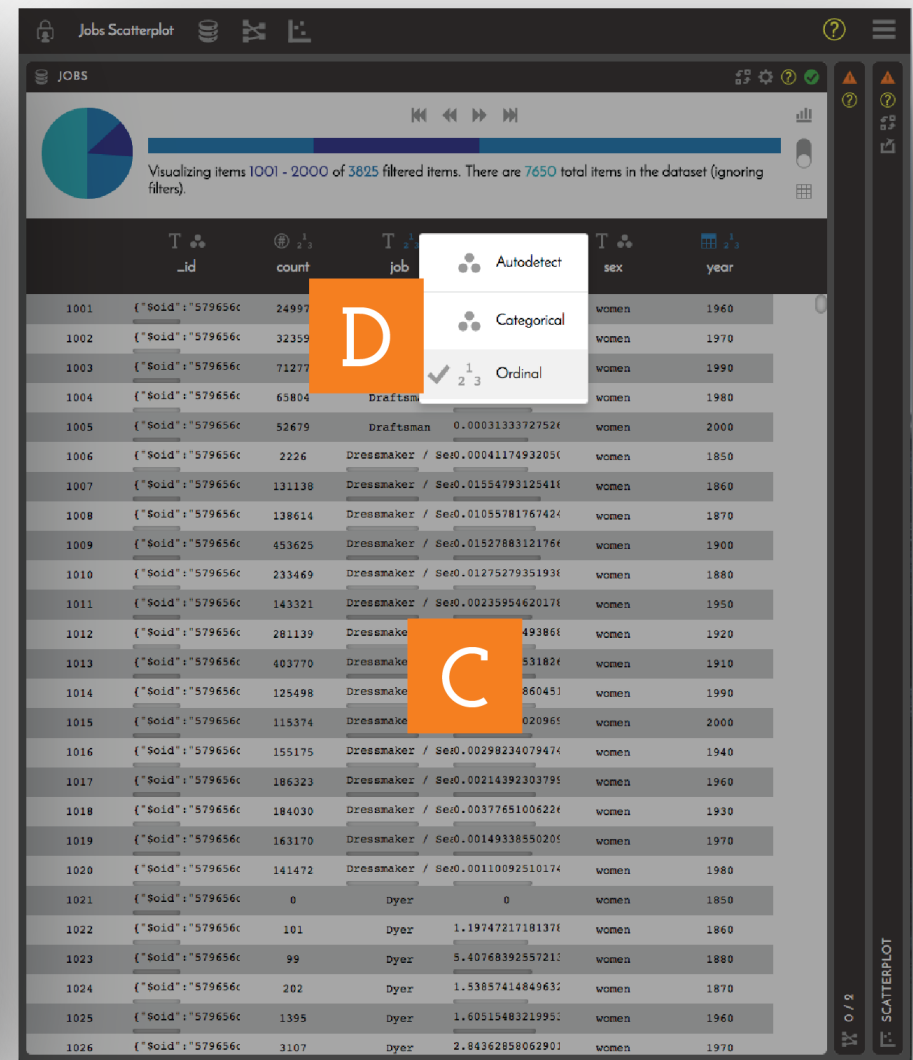


Figure 4: In addition to paging, it is also possible to filter a dataset. In this example, the dataset has been filtered to show only the jobs that women held (E).

When filters are present, the paging interface (A) expands to indicate how much data has been filtered (shown in the pie chart), in addition to showing which page of the filtered subset is currently loaded in the browser (shown in both the pie chart and in the horizontal bar). Histograms (B) of each data attribute are shown, also indicating the filtered subset, and the page within that subset. A table (C), showing the raw page of data that has been loaded in the browser. Additional controls available in both views (D) that allow the user to override both data type specifications, as well as how data is to be interpreted for binning. Filter controls (E) allow users to change filters by toggling bins, or dragging to select or deselect bins.

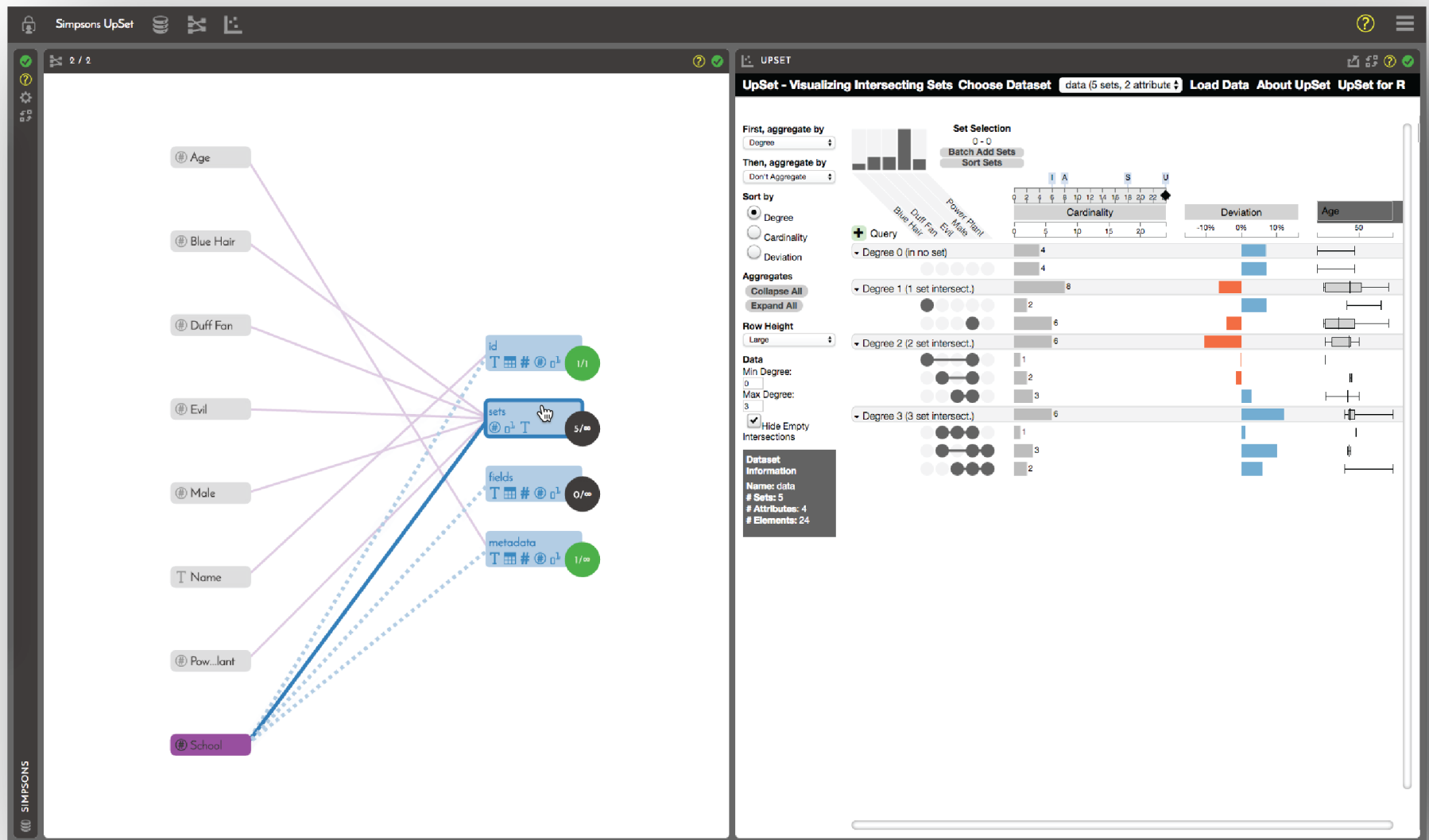


Figure 5: This example shows UpSet, developed independently at Harvard for set relationship visualization, adapted into a Candela component, and then driven interactively via Resonant Laboratory.

The matching panel (left) presents a very simple interface for establishing a many-to-many relationship between data attributes and the visual encodings specified by the Candela component. Connections can be established or removed with two clicks—in this case, the user has clicked the “School” data attribute, and is about to click the “sets” parameter of the visualization. Icons and colors indicate data type compatibility, and circular badges indicate which requirements have been satisfied.

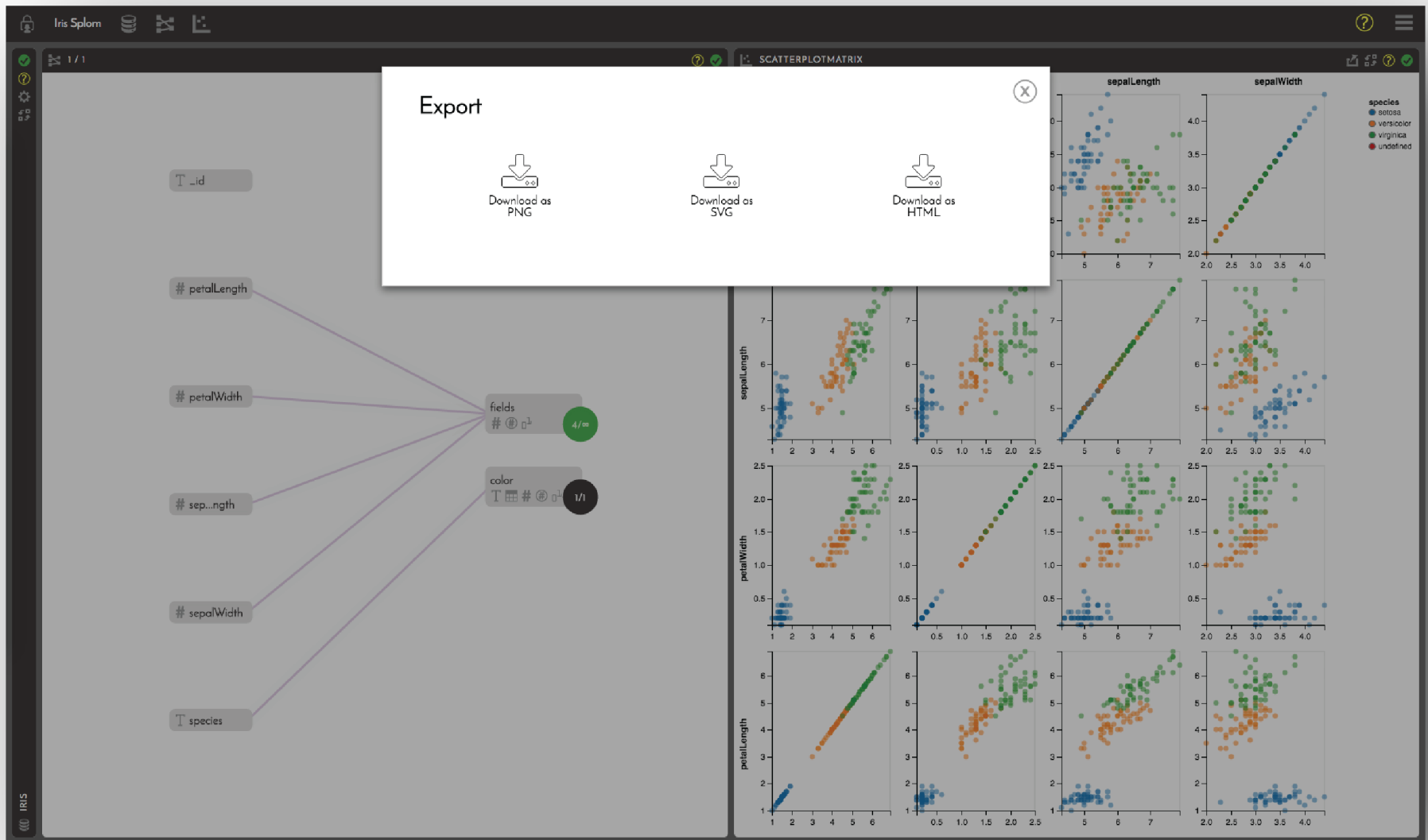


Figure 6: In addition to sharing Resonant Laboratory projects, the UI includes options for exporting the visualization. The visualization can be exported to bitmap or vector image formats. It is also possible to export a standalone, interactive HTML version of the visualization.