

NOVA: A Practical Method for Creating Notebook-Ready Visual Analytics

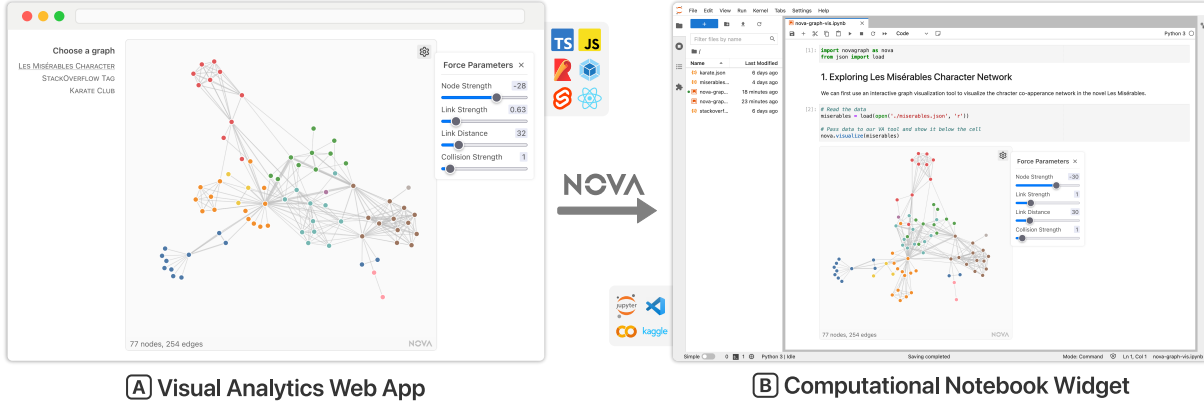
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Guidelines (not a package or tool)

Fig. 1: NOVA allows visualization researchers and practitioners to quickly adapt existing web-based visual analytics tools to support computational notebooks. **(A) Web apps** are a popular medium for developing interactive visualization systems that users can access in their web browsers. **NOVA converts web apps** developed with diverse web technologies, such as programming languages and frameworks, **to (B) notebook widgets** that end-users can easily install and use in different notebook environments.

ABSTRACT

How can we develop visual analytics (VA) tools that can be easily adopted? Visualization researchers have developed a large number of web-based VA tools to help data scientists in a wide range of tasks. However, adopting these standalone systems can be challenging, as they require data scientists to create new workflows to streamline the VA processes. Recent surveys suggest computational notebooks have been dominating data scientists’ analytical workflows, as these notebooks seamlessly combine text, code, and visualization, allowing users to rapidly iterate code experiments. To help visualization researchers develop VA tools that can be easily integrated into existing data science workflows, we present NOVA, a simple and flexible method to adapt web-based VA systems for notebooks. We provide detailed examples of using this method with diverse web development technologies and different types of computational notebooks. Deployed application examples highlight that NOVA is easy to adopt, and data scientists appreciate in-notebook VA. NOVA is available at <https://github.com/poloclub/nova>.

Index Terms: Human-centered computing—Visualization

1 INTRODUCTION

Over recent years, our VIS community has developed a large number of visual analytics (VA) tools that can help data scientists in a wide range of tasks, such as exploring and comparing data [2], conducting analytical experiments [10], and interpreting ML models [3]. Many VA tools are standalone web applications (Fig. 1A) that users access through their web browsers. However, it can be challenging for data scientists to adopt these systems, as they require data scientists to tailor data structure to fit different systems, switch between multiple

programming environments, and develop new workflows to streamline VA processes. Recent researchers suggest that, instead of standalone VA systems, we should design and develop more reusable and composable toolkits and libraries that fit into existing workflows [9].

On the other hand, computational notebooks such as Jupyter Notebook [5] have become the most popular programming environment among data scientists [4]. These notebooks present a fluid programming environment that consists of any number of cells—small editors for markdown text and code. Users can execute a code cell, and its output, such as texts, tables, and visualizations, are displayed below the cell. Users can freely edit, execute and organize these cells—creating a literate programming environment for data science [6]. Visualizations play a critical role in the success of notebooks: data scientists appreciate that they can rapidly visualize dataset and machine learning models while exploring the dataset and building ML models [8]. Therefore, to develop VA tools that can be easily integrated into existing data science workflows, visualization researchers and practitioners can enhance their tools with computational notebook compatibility (Fig. 1B). To lower the barrier to developing notebook-ready VA tools, we **contribute**:

- **NOVA, a simple and flexible method** to adapt existing web-based VA tools into computational notebook widgets. End-users can easily install these widgets and use them directly in notebooks. NOVA works with all popular web development technologies, such as Svelte, React, and Vanilla JS. The result notebook widgets support all types of popular computational notebooks, such as Jupyter Notebook/Lab, Google Colab, and VSCode Notebook.
- **Detailed examples of applying NOVA** to convert a “toy” VA tool to a notebook widget that users can easily install and use in notebooks. We present three examples with detailed documentation, where each example corresponds to a popular VA web development stack. We also show how one can create a web page that demonstrates a VA tool in both web app and notebook widget forms simultaneously. To continuously improve NOVA and provide up-to-date examples, we maintain a list of VA tools that apply NOVA. This list and all examples can be accessed through a GitHub repository: <https://github.com/poloclub/nova>.

We hope our work inspires and informs future research and development of accessible VA tools that fit into data scientists’ workflows.

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2 NOVA METHOD

NOVA supports any web-based VA tools that **do not require a dedicated backend server**, and it results in a Python package that launches a VA interface with end-user specified data in a notebook cell. In this section, we outline the three steps of applying NOVA. Each step's implementation details vary depending on the VA tool's development stack; readers can refer to three detailed examples on GitHub.

S1. Convert the VA tool into a single HTML file. We first combine a VA tool's mark-ups, style sheets, scripts, and assets into a single HTML file. This allows us to embed the VA tool as a configurable iframe widget in notebooks. This step is simple: with module bundlers, such as Rollup and Webpack, one can bundle their VA tool into an HTML file with one command.

S2. Design Python wrapper API. To enable end-users to feed data and configurations into the VA widget, we can create a Python function API that (1) displays the widget in a notebook cell, and (2) collects and sends user input to the widget through standard Web Events. Thus, the VA widget can listen to these events and behave accordingly. This one-directional messaging approach is generalizable to all types of web-based notebooks.

S3. Publish the VA widget in a software repository. The last step is to package the VA widget as a Python library and publish it in the software repository Python Package Index (PyPI). This enables end-users to install the widget with one command and access it in notebooks. Our examples use Python, as it is the most popular programming language among data scientists [4]. However, one can easily adapt NOVA to other languages, such as R and Julia, and publish their widgets in corresponding software repositories, such as CRAN and Julia Registries.

Many VA tools provide companion demo pages that users can easily access and try out the tool [e.g. 3, 12]. Leveraging recent advancements in Python's in-browser programming environment, NOVA provides instruction on creating a web page that demonstrates a VA tool in both web app form and notebook widget form simultaneously.

3 APPLICATION EXAMPLE

NOVA has already been used in real-life VA applications. A recent example is GAM CHANGER [12]—a VA tool that enables data scientists and domain experts to edit model weights of Generalized Additive Models (GAMs). GAM CHANGER is originally developed as a stand-alone web app using Svelte, JavaScript, and WebAssembly; we then apply NOVA to create a notebook widget. We first bundle this tool with all assets including images and WebAssembly binaries into an HTML file with Rollup bundler (S1). Then, we design a simple Python function API that allows end-users to feed GAM CHANGER with their data and model weights and control the widget's size (S2). Finally, we publish the notebook widget on PyPI (S3) and open source it under the InterpretML ecosystem [7]. Feedback from data scientists and physicians highlights that GAM CHANGER's notebook widget fits into their ML development workflows, and they appreciate using this tool directly in notebooks.

Interestingly, VA notebook widgets not only enhance data scientists' analytical workflow, but a notebook environment also improves the user experience of VA tools themselves. In GAM CHANGER, users can only inspect and edit the model's behavior on one feature at a time; users sometimes would like to compare the model's prediction patterns across multiple features simultaneously. To do that with the web app, users would need to follow a cumbersome process to open the app in multiple browser windows and then resize and arrange these windows. In contrast, with GAM CHANGER's notebook widget, users can simply launch this tool in multiple cells in the same notebook. Moreover, with sticky notebook cells [11], users can even arrange notebook cells in non-linear ways and mix-and-match multiple VA tools to create a full-fledged dashboard.

StickyLand mention

4 DISCUSSION & FUTURE WORK

To support diverse VA development technologies and different types of computational notebooks, NOVA has made two compromises. First, NOVA only supports web-based VA tools that do not require a dedicated backend server or tools whose backend code can be replaced with front-end scripts. It is possible to host a web server inside a Jupyter Notebook and launch a VA widget with a backend [14], however, this functionality is not supported by all computational notebooks. Also, **NOVA only supports a one-way communication** from the notebook to the VA tool. With ipywidgets,¹ it is possible to create a VA widget that supports two-way communication [1]. However, for security reasons, **other notebooks besides Jupyter Notebook and Lab do not support ipywidgets or similar two-way communication protocols**. Many existing VA tools do not require a backend server nor two-way communications [e.g. 3, 12, 13].

We will maintain a public list of open-source VA tools that apply NOVA to create notebook widgets. This list will provide more up-to-date examples for future VIS researchers and practitioners. It also helps us monitor VA development trends and continuously improve this workflow. For future work, we will reflect on our experience with NOVA and engage with diverse stakeholders to distill design guidelines and best practices for in-notebook VA tools.

Conclusion. We present NOVA, a simple and flexible method to convert existing web-based VA tools to notebook widgets that can be easily accessed in computational notebooks. Three detailed examples with a toy VA tool demonstrate how one can apply NOVA on VA tools developed with different web technologies. We hope our work will lower the barrier to creating interactive visualization systems that work in computational notebooks and inspire future researchers to create VA tools that fit into data scientists' workflows.

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¹<https://github.com/jupyter-widgets/ipywidgets>