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THEIA: An offline tool for tradespace visualization

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Abstract

Within the Army Corps of Engineers (USACE), there is a need to evaluate tradespaces. Tradespace datasets are the result of large parameter sweeps run over numerous design options and can consist of thousands or even millions of design configurations and the corresponding performance metrics. Because of the immense size of these datasets, the ability to effectively visualize the data is essential for proper evaluation. At the USACE Engineer Research & Development Center (ERDC), an easy-to-use plotting tool known as the Tradespace Holistic Exploration & Insight Application (THEIA) has been developed for visualizing this complex tradespace data related to the acquisitions process. THEIA was developed using Python libraries including Panel, Param, Holoviews, Bokeh, and Plotly. When combined, these libraries offer a wide range of widgets and plots that allow the user to visualize their data in multiple ways. Additionally, users can easily save plots, export findings, and utilize multiple data files at once. THEIA is also capable of importing tabular data while presenting options to customize visualizations and help the end-user make informed decisions.

Keywords python, panel, holoviews, holoviz, param, plotly, bokeh, tradespace

1. Background/Motivation

Within the United States Army Corps of Engineers (USACE) the evaluation of tradespaces has become an important capability. Tradespaces, in essence, are extensive datasets generated from broad parameter sweeps across a multitude of design options. These datasets can encompass thousands, if not millions of design configurations, each accompanied by its respective performance metrics. This process results in an immense amount of data, which, while rich in information, presents a challenge in terms of analysis and interpretation. Because of the colossal size of these datasets, the ability to visualize them effectively is not just beneficial, but essential for comprehensive evaluation. This visualization is particularly crucial when it come to the acquisitions process, where understanding the implications of each design choice can have far-reaching consequences. To address this need, the USACE Engineer Research & Development Center (ERDC) has developed a user-friendly plotting tool, named the Tradespace Holistic Exploration & Insight Application (THEIA).

2. Tradespaces - A simple example

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Type	Year	Price	MPG	Range (miles)
SUV	2014	$44,998	16	350
Truck	2015	$45,998	12	325
Crossovers	2016	$30,998	24	390
Sedans	2019	$21,998	28	400
Sports Car	2020	$48,998	22	320

Figure 1: This is a simple example of a tradespace in the context of car shopping. When shopping for a new vehicle, buyers often compile a list of pros and cons based on certain vehicle types. The dataset the buyer creates is, in essence, a tradespace. For example, a buyer may want to maximize potential range, while minimizing vehicle cost. By analyzing this tradespace, the buyer would be able to see that opting for a sedan provides both the best price and the best potential range.

3. Methods

THEIA's primary function is to provide a means of visualizing intricate tradespace data, thereby facilitating a more thorough understanding of the various design configurations and their corresponding performance metrics. It's a robust tool built upon several Python libraries, including Panel, Param, HoloViews, Bokeh and Plotly. The integration of these libraries equips THEIA with a diverse array of widgets and plots, enabling users to visualize their data in various ways simultaneously. Panel, Param, and HoloViews are all a part of the HoloViz suite of Python packages, which allows for excellent synchronization between them.

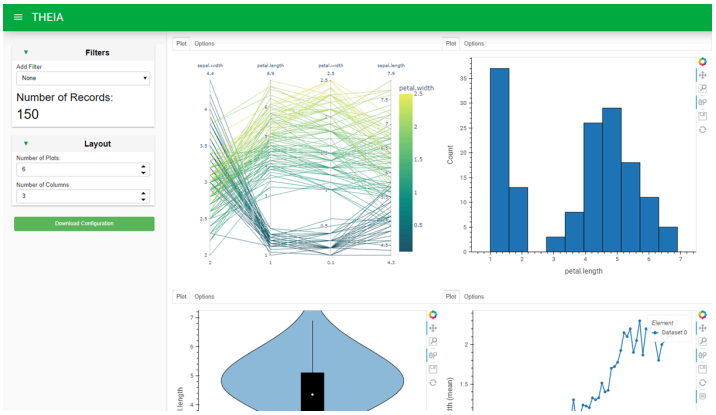

Figure 2: View of the Graphical User Interface (GUI) leveraged by users for interracting with plots.

3.a. THEIA - Panel

Panel Philipp Rudiger (2024a) is a library for easily building tools, dashboards, and complex applications, all within Python. It's role in THEIA is to define the layout of the application, as seen above.

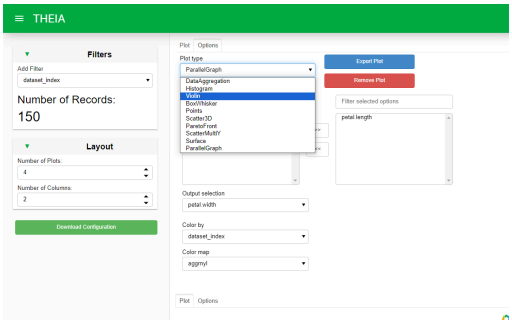

Figure 3: View of THEIA's plot type options.

3.b. THEIA - Param

Param Philipp Rudiger (2024b) is a library built for handling user-modifiable parameters, arguments, and attributes that control your code. These capabilities are used in THEIA to monitor for user inputs and changes. This library is responsible for handling user inputs such as the plot type and color map options shown above.

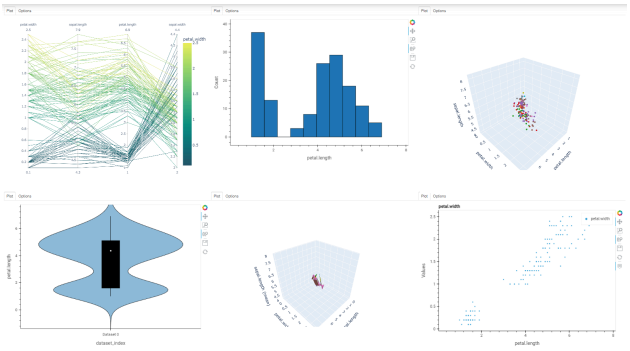

Figure 4: View of various plots generated by THEIA and rendered in the browser.

3.c. THEIA - HoloViews/Bokeh

HoloViews Philipp Rudiger (2024c) is a library built for data analysis and visualization with small amounts of code. This library is the backend that provides many of the plots in THEIA. Bokeh Team (2018) is a library for creating visualizations in modern web browsers. Both the Panel and HoloViews libraries leverage Bokeh. Panel utilizes Bokeh for rendering the layout, while HoloViews uses Bokeh to render some of the plots.

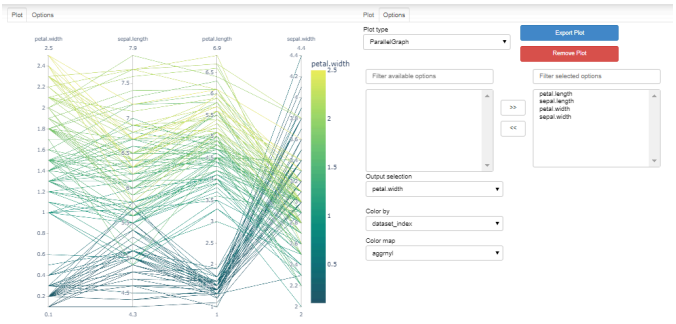

Figure 5: Detailed view of customization options for parallel plots generated by THEIA.

3.d. THEIA - Plotly Parallel Plot

Plotly Inc. (2015) is a high-level API for creating figures. Plotly is utilized by HoloViews for rendering supplementary plots, such as the parallel plot seen above.

4. Results

Together, these scientific Python libraries allowed the Rapid Application Development team at ERDC to develop a robust visualization tool capable of running in the browser without being reliant on an internet connection. THEIA allows users to tailor the types of plots displayed, as well as adjust color themes. This is an important feature when working with tradespace data because it allows the user to choose the theme which best distinguishes the complex data. THEIA allows users to easily save plots for future reference, export findings for further analysis, and utilize multiple data files simultaneously. Another key feature THEIA provides is the ability to import tabular data. Ultimately, through the utilization of these scientific Python libraries, the USACE ERDC was able to develop a robust solution to the tradespace visualization problem.

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