BOHBVIS: A Comprehensive BOHB Experiment Result Visualization System

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1 Dataset Abstraction

1.1 Data Description

The *BOHB Sampled Configuration & Results* dataset, which I made, consists of the sampled configuration's data and its evaluation results while performing the hyperparameter optimization method, BOHB. BOHB optimizes randomly created hyperparameter configurations of the deep learning model using Bayesian Optimization and Hyperband method. The dataset's type is a table with 575 items, each comprising thirteen attributes. One attribute, **sample_id**, is a unique key attribute, and others are just values.

1.2 Data Abstraction Results

- Nominal Attributes

Name	Semantics	Values
sample_id	Key of Sample data	{bracket}-{round}-{trial}
sample_type	Where the configuration was sampled	random, samples, BO
config_optimizer	The type of optimizer in the sampled configuration	adam, sgd, rms
config_scheduler_p	Whether the learning rate scheduler is enabled or not	True, False
config_activation	The type of activation function in the sampled configuration	relu, lrelu, tanh

- Ordinal Attributes

Name	Semantics	Values	Direction
config_batch_size	The value of batch size in the sampled configuration	8, 16, 32	Sequential
config_hidden_size	The value of hidden size in the sampled configuration	16, 32, 64	Sequential

- Quantitative Attributes

Name	Type	Semantics	Range	Direction
budget	Ratio	Budget (e.g., epoch) used to evaluate the configuration	[1, 300]	Sequential
config_momentum	Ratio	The value of momentum in the sampled configuration	[0, 1]	Sequential
config_learning_rate	Ratio	The learning rate value in the sampled configuration	[1e-4, 1e-1]	Sequential
config_weight_decay	Ratio	The value of weight decay in the sampled configuration	[0, 1e-3]	Sequential
sample_loss	Ratio	Loss value for the sampled configuration	[0, inf)	Sequential
sample_acc	Ratio	Accuracy value for the sampled configuration	[0, 100]	Sequential

Figure 1: Ph.D. student Yuna Jeon

2 Task Abstraction

Through this visualization system, users should be able to visually analyze the experimental results of BOHB, gaining insights into the optimization of hyperparameters. Users can use these insights to set experiment settings in future BOHB experiments to achieve desired performance. The following are abstractions of tasks users can perform in this visualization system.

Task 1: Summarize the operational principles of BOHB

Given the complexity of the BOHB algorithm, it is essential to provide a visualization system that enables users to understand the operational principles of BOHB through active interaction.

Task 2: Present where the configuration with the best performance is.

BOHB creates the best configuration within a given budget through Bayesian Optimization and Hyperband. Hence, by presenting a visualization system, users can not only present the operational principles of BOHB but also explain the origin of the optimal configuration produced via BOHB.

Task 3: Compare the distribution of data for each bracket.

BOHB generates new configurations randomly in each bracket. If the distribution of the configurations generated in each bracket is similar, there is no need for multiple brackets. Therefore, to determine if each round is meaningful, it is necessary to visualize the data distribution per round. Through this, users will gain insights into appropriate budgets, ranges of hyperparameters, and their values.

Task 4: Discover the Correlation between Attribute Pairs

Hyperparameters are not always independent of each other; they often interact and influence each other. Therefore, discovering correlations between attributes through dedicated tasks can help users identify which attributes significantly impact the model's performance.

Figure 2: Machine Learning engineer Sangwoo Mun

3 Persona

3.1 Primary Persona: Ph.D. student Yuna Jeon

Yuna Jeon is a 31-year-old woman living in Seoul, South Korea. She is currently a fifth-year doctoral student in the field of Artificial Intelligence. Her primary goal is to graduate soon and secure a position in an international company. All that stands between Yuna and her graduation is the acceptance of one more research paper.

She is working on her final paper for graduation. The deep learning model used in her experiment had its hyperparameters optimized using BOHB, one of the hyperparameter optimization techniques. Her advisor has expressed interest in a detailed explanation of this optimization process. Although Yuna deeply understands BOHB, she believes data visualization is necessary to explain the process to her advisor. However, as her specialization is not in data visualization, she finds herself in a challenging situation, uncertain about how to proceed.

3.2 Secondary Persona: ML Engineer Sangwoo Mun

Sangwoo Mun is a 27-year-old male residing in Pangyo, South Korea. He recently joined KAOKAO, a company specializing in machine learning solutions related to stock market prediction, as a junior Machine Learning Engineer. His immediate goal is to gain recognition for his technical prowess and to ascend to a senior engineer position as quickly as possible.

In a new project he is tasked with, he is responsible for optimizing the hyperparameters of a deep learning model. Among various methods, he decided to employ BOHB, an optimization technique. However, due to his limited understanding of BOHB, he needs help to analyze the results and determine how to improve them. Consequently, he is actively searching for resources and tools that could help him address this problem.

3.3 Difference between two personas.

Yuna Jeon, a doctoral student, and Sangwoo Moon, a novice machine learning engineer, exhibit unique needs in their respective situations. Yuna, well-versed in using BOHB for hyperparameter optimization, is challenged by visualizing and effectively expressing its results under a tight research paper deadline. Her primary goal is to complete her research for timely graduation swiftly. In contrast, Sangwoo, new to BOHB, aspires to enhance his technical competency to accelerate his career. He seeks resources or tools to help him comprehend and utilize this optimization technique.

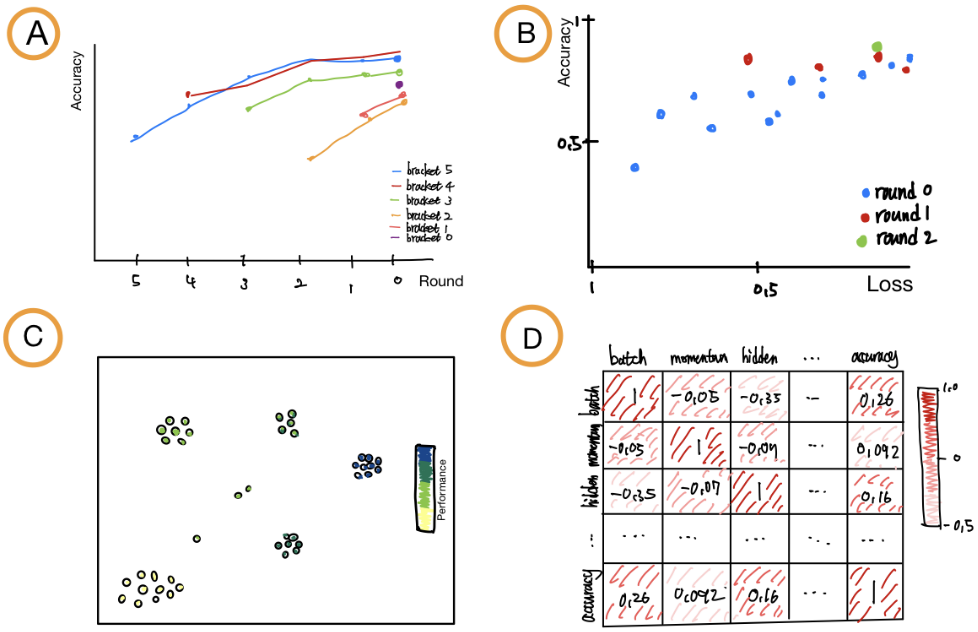


Figure 3: Sketch of the Visualization Idioms.

4 Visualization Idioms

4.1 Line Chart

In Figure 3-A, the line chart summarizes the average and maximum accuracy for each round per bracket. The x-axis represents the rounds, the y-axis indicates accuracy and different colors denote various brackets. The user selects the choice between the average and best accuracy through buttons at the top of the line chart. As this visualization represents the average accuracy of each bracket, it ensures adequate scalability. It supports Task 1 and Task 2, enabling users to understand the overall operational principle of BOHB through interaction and verify the high-performance configuration.

4.2 Scatterplots

When a user clicks on a specific bracket line in Figure 3-A, the data related to that bracket is filtered, and Figures 3-B and 3-C are subsequently rendered. As only a subset of the total data is visualized, the scalability of both scatterplots is appropriately maintained.

Figure 3-B visualizes the loss and accuracy for the selected bracket via a scatterplot. The x-axis represents the loss value, the y-axis signifies accuracy, and different colors denote various rounds. As the tooltip enables users to verify the configuration information for each data point, Task 1 is fulfilled.

Figure 3-C portrays the data distribution for the corresponding bracket through a scatterplot. Dimension reduction techniques map the attributes of the data to two-dimensional values(x and y), and colors represent the performance of each data point. This idiom lets users observe each bracket's data distribution, satisfying Task 3.

4.3 Heatmap

The heatmap in Figure 3-D represents the correlation values among various attributes. By fulfilling Task 4, this idiom allows users to discern the extent of correlation among the attributes.

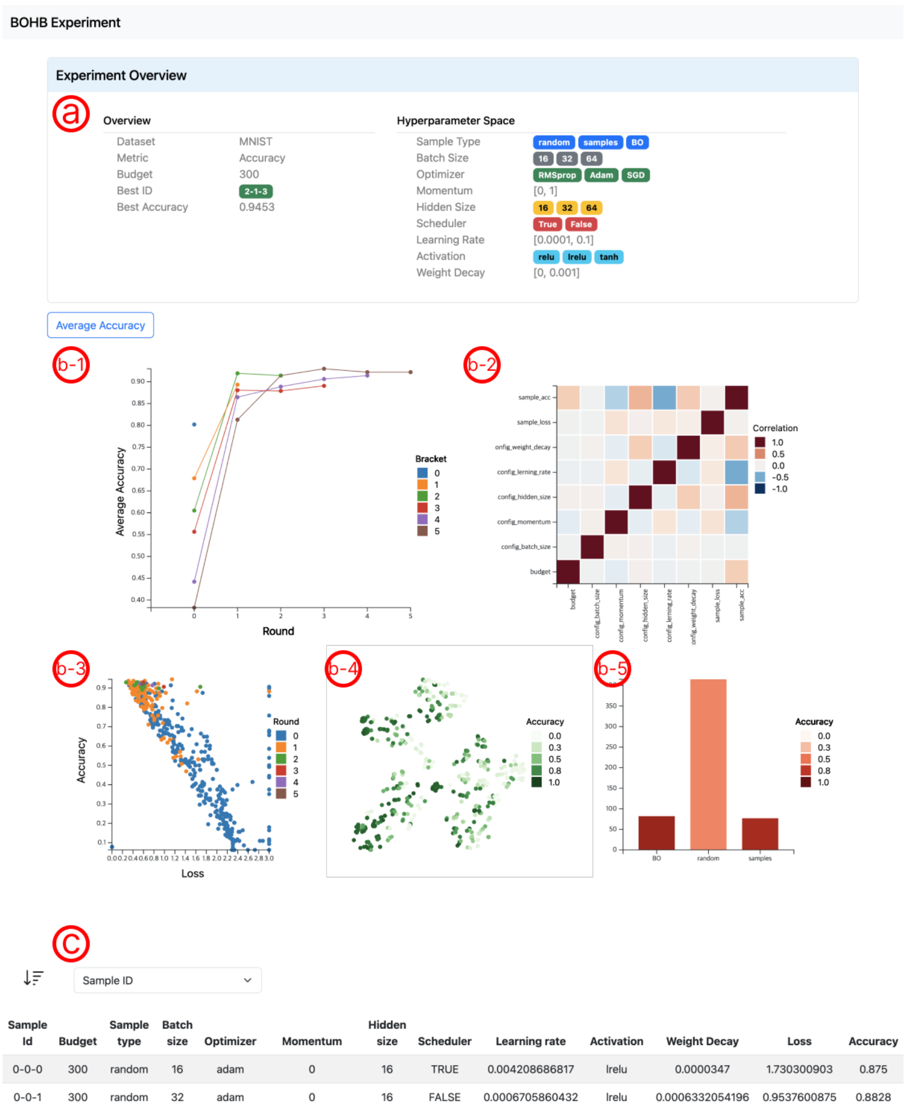


Figure 4: The Interface of BOHBVIS. Users can view the general information of the BOHB experiment in the overview panel (a) and explore and analyze the results of the BOHB experiment using the visualization panel (b). Users can see the detailed information on the selected data in the data panel (c).

5 Implementation

Figure 4 shows the overall interface of BOHBVIS. This system was implemented based on course materials[1] of the Information Visualization class using D3.js. One can check out the source code[2] and see a live demo[3].

6 Case Study

Yuna used BOHBVIS to provide her advisor with a detailed explanation of the BOHB optimization process and to support her choice of configurations.

[1] `https://github.com/e-/d3-examples`
[2] `https://github.com/sth49/infovis_final`
[3] `https://sth49.github.io/infovis_final/`

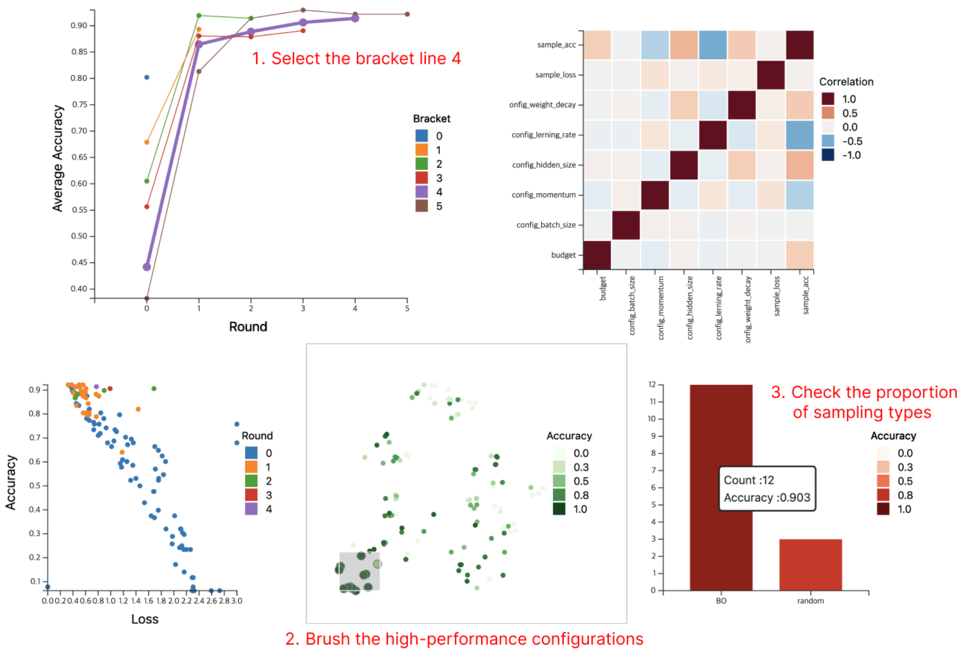


Figure 5: Interaction example of understanding the principle of BOHB.

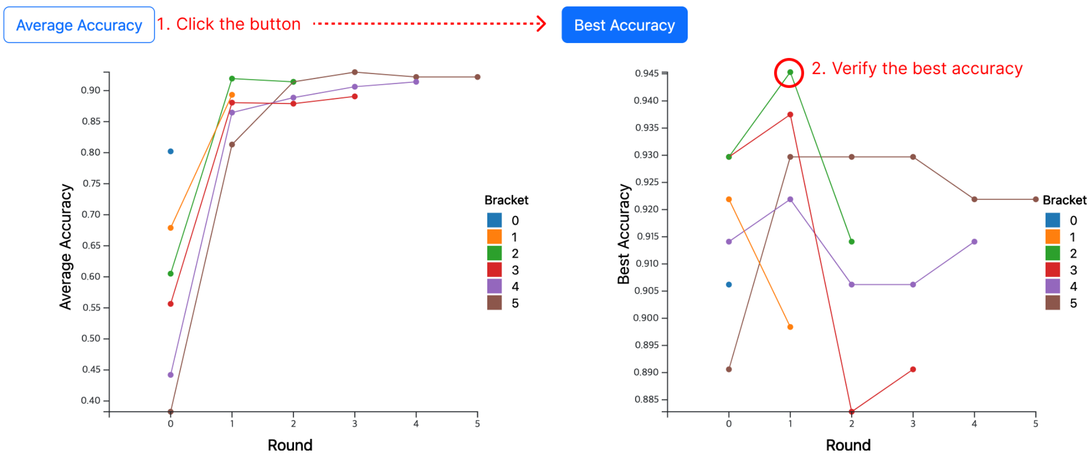
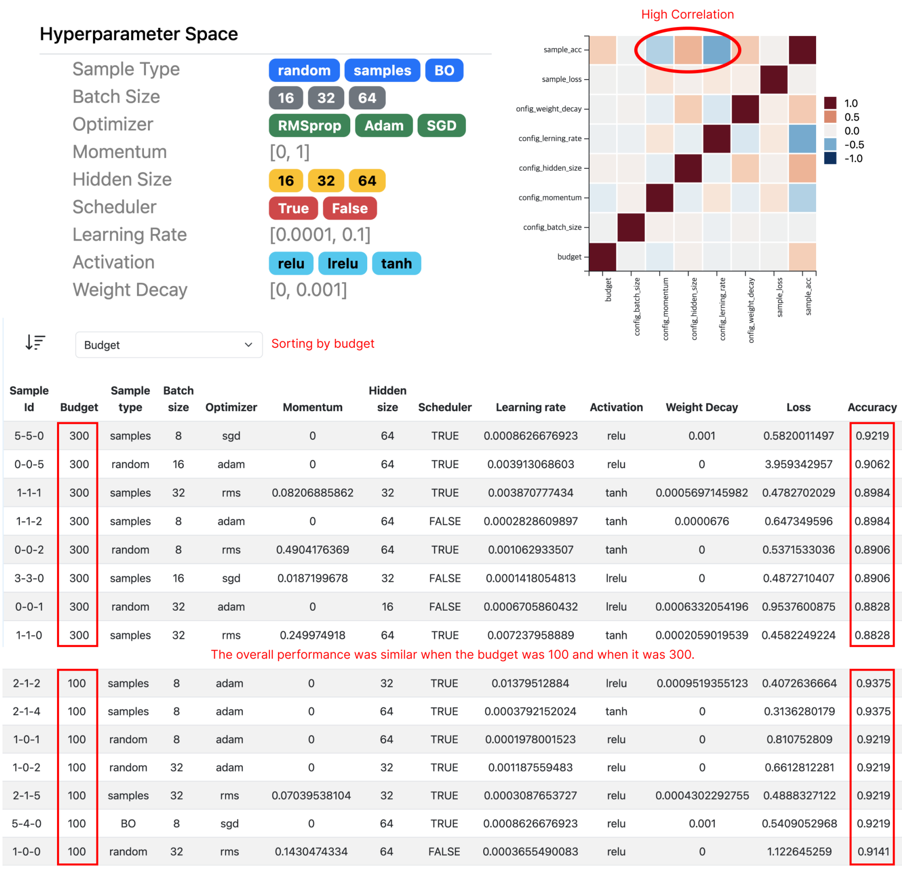


Figure 6: Interaction example of finding the best hyperparameter configuration.

6.1 Understanding the Principle of BOHB (Task 1, Task 3)

Yuna started by checking the information about the budget and the hyperparameter space of the BOHB experiment through the overview panel (Figure 4a). In this experiment, a budget of 300 was allocated for the MINST dataset, and optimization was conducted for nine hyperparameters. Afterward, she checked the average accuracy and distribution for each bracket and each round through the line chart and Accuracy-Loss scatterplot in the visualization panel (Figure 4b-1, 2). She could see that the average performance improved as the rounds within each bracket increased. She clicked on the line in the line chart and verified that the configuration distribution was evenly spread across each bracket (Figure 4b-4). Using this scatterplot, she brushed over the high-performing configurations and checked the proportion of the sampling types used to create these configurations. The proportion of BO (Bayesian Optimization) was generally high, and she confirmed through this that Bayesian Optimization produced meaningful results. See the Figure 5.



Sample Id	Budget	Sample type	Batch size	Optimizer	Momentum	Hidden size	Scheduler	Learning rate	Activation	Weight Decay	Loss	Accuracy
5-5-0	300	samples	8	sgd	0	64	TRUE	0.0008626676923	relu	0.001	0.5820011497	0.9219
0-0-5	300	random	16	adam	0	64	TRUE	0.003913068603	relu	0	3.959342957	0.9062
1-1-1	300	samples	32	rms	0.08206885862	32	TRUE	0.003870777434	tanh	0.0005697145982	0.4782702029	0.8984
1-1-2	300	samples	8	adam	0	64	FALSE	0.0002828609897	tanh	0.0000676	0.647349596	0.8984
0-0-2	300	random	8	rms	0.4904176369	64	TRUE	0.001062933507	tanh	0	0.5371533036	0.8906
3-3-0	300	samples	16	sgd	0.0187199678	32	FALSE	0.0001418054813	lrelu	0	0.4872710407	0.8906
0-0-1	300	random	32	adam	0	16	FALSE	0.0006705860432	lrelu	0.0006332054196	0.9537600875	0.8828
1-1-0	300	samples	32	rms	0.249974918	64	TRUE	0.007237958889	tanh	0.0002059019539	0.4582249224	0.8828
2-1-2	100	samples	8	adam	0	32	TRUE	0.01379512884	lrelu	0.0009519355123	0.4072636664	0.9375
2-1-4	100	samples	8	adam	0	64	TRUE	0.0003792152024	tanh	0	0.3136280179	0.9375
1-0-1	100	random	8	adam	0	64	TRUE	0.0001978001523	relu	0	0.810752809	0.9219
1-0-2	100	random	32	adam	0	32	TRUE	0.001187559483	relu	0	0.6612812281	0.9219
2-1-5	100	samples	32	rms	0.07039538104	32	TRUE	0.0003087653727	relu	0.0004302292755	0.4888327122	0.9219
5-4-0	100	BO	8	sgd	0	64	TRUE	0.0008626676923	relu	0.001	0.5409052968	0.9219
1-0-0	100	random	32	rms	0.1430474334	64	FALSE	0.0003655490083	relu	0	1.122645259	0.9141

Figure 7: Interaction example of finding the best hyperparameter configuration.

6.2 Finding the Best Hyperparameter Configuration (Task 2)

Yuna was curious about which hyperparameter configuration delivered the best performance. She clicked the button on the line chart to switch from displaying Average Accuracy to Best Accuracy (Figure 4b-1). The line chart now showed the highest accuracy per round for each bracket. This view allowed her to identify where the best configuration originated quickly. After verifying the top performance, Yuna decided to conduct additional BOHB experiments as the performance still did not meet her expectations. See the Figure 6.

6.3 Gaining Information for the Next Experiment (Task 4)

Yuna planned to set the range of the hyperparameters for a new BOHB experiment. She examined the heatmap that depicts the correlation between hyperparameters and accuracy, identifying the hyperparameters with a high correlation to accuracy (Figure 4b-2). Using the data panel, she explored the specific values of the hyperparameters that had performed well and determined the range of hyperparameters for the additional BOHB experiment (Figure 4C). Furthermore, Yuna looked at the performance based on the budget and discovered little difference between 300 and 100. As a result, she decided to set the budget to a value lower than 300 for the additional experiment. See the Figure 7.

Through this visualization system, Yuna was able to visually explain the process of the hyperparameter optimization technique, BOHB. Along with the choice of the best configuration, she also gained information for the additional experiment.