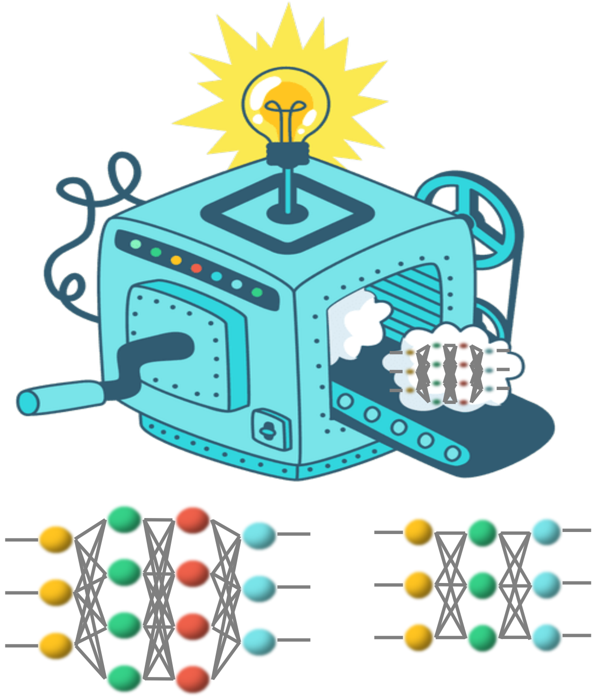
Reproducible and Efficient Benchmarks for Hyperparameter Optimization of Neural Machine Translation Systems

Xuan Zhang   Kevin Duh



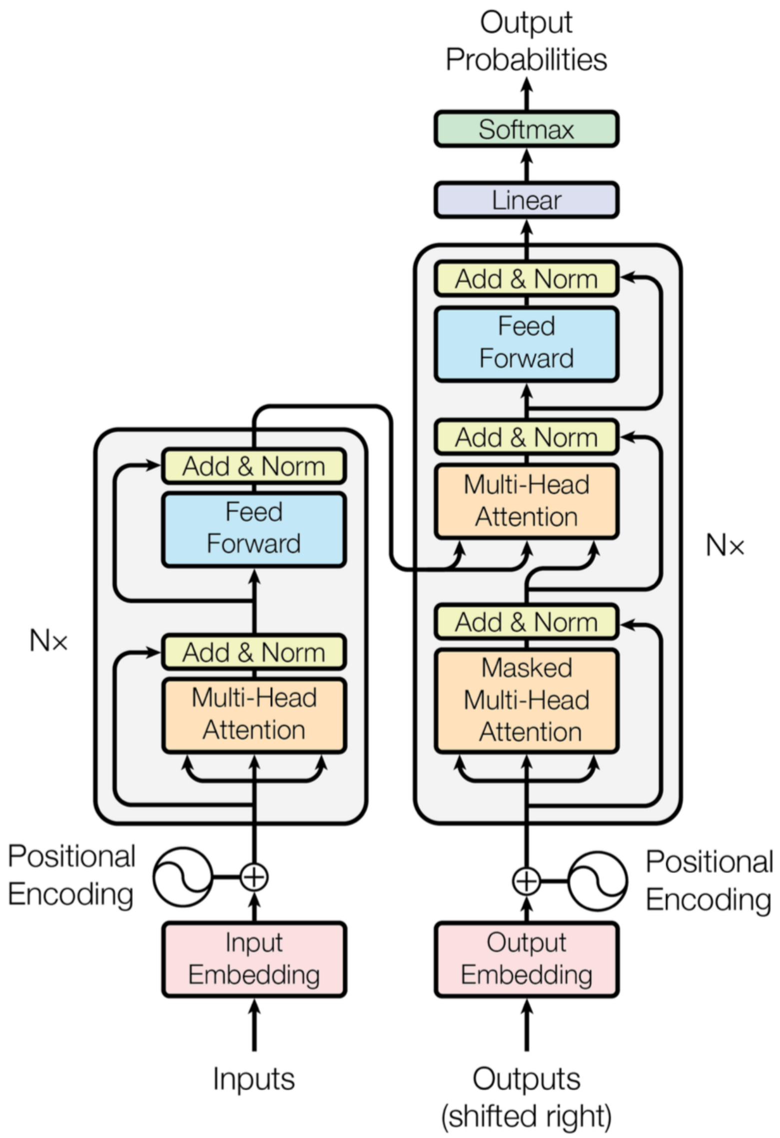
JOHNS HOPKINS
WHITING SCHOOL of ENGINEERING

EMNLP 2020

Machine Translation

Architecture Hyperparameters:
- #layer
- #units/layer
- #embed

Training Hyperparameters:
- optimizer type
- learning rate
- batch size



The Transformer model architecture.[1]

Objectives

Training Accuracy:
- BLEU
- perplexity

Computational Cost:
- inference speed
- model size

[1]Vaswani, Ashish, et al, "Attention is all you need." Advances in neural information processing systems. 2017.

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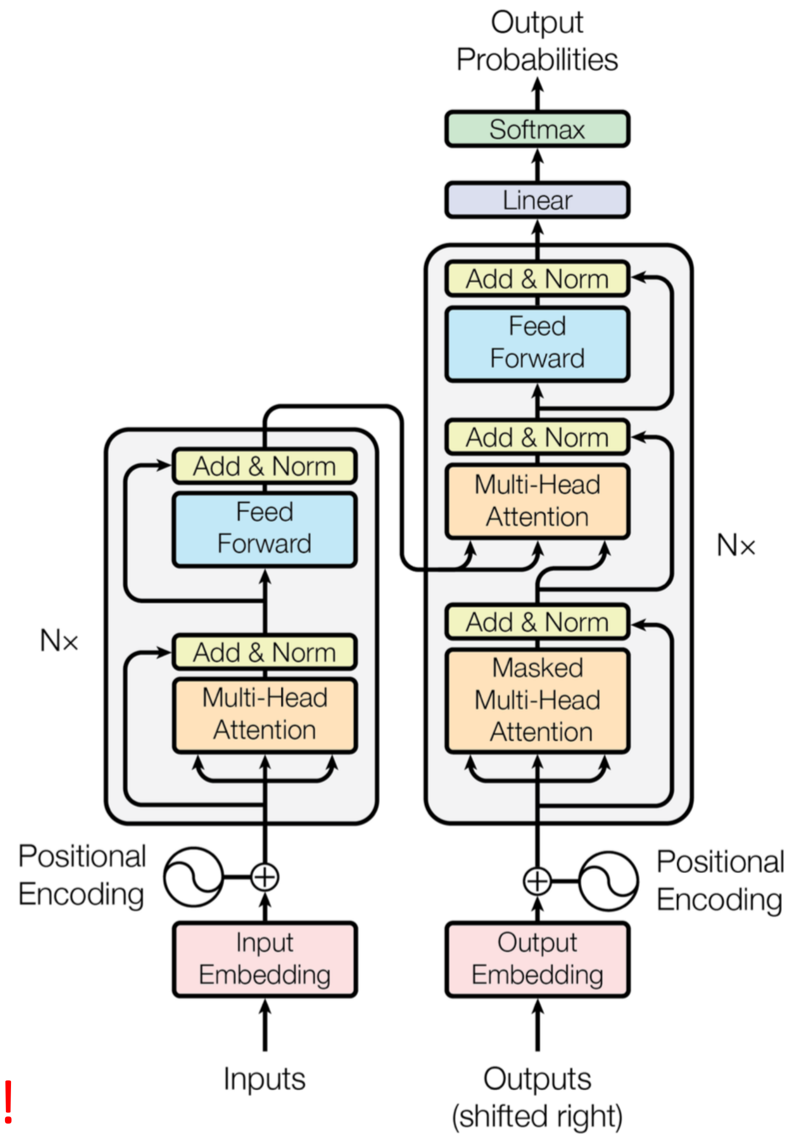
⚠ Exponential explosion of choices!



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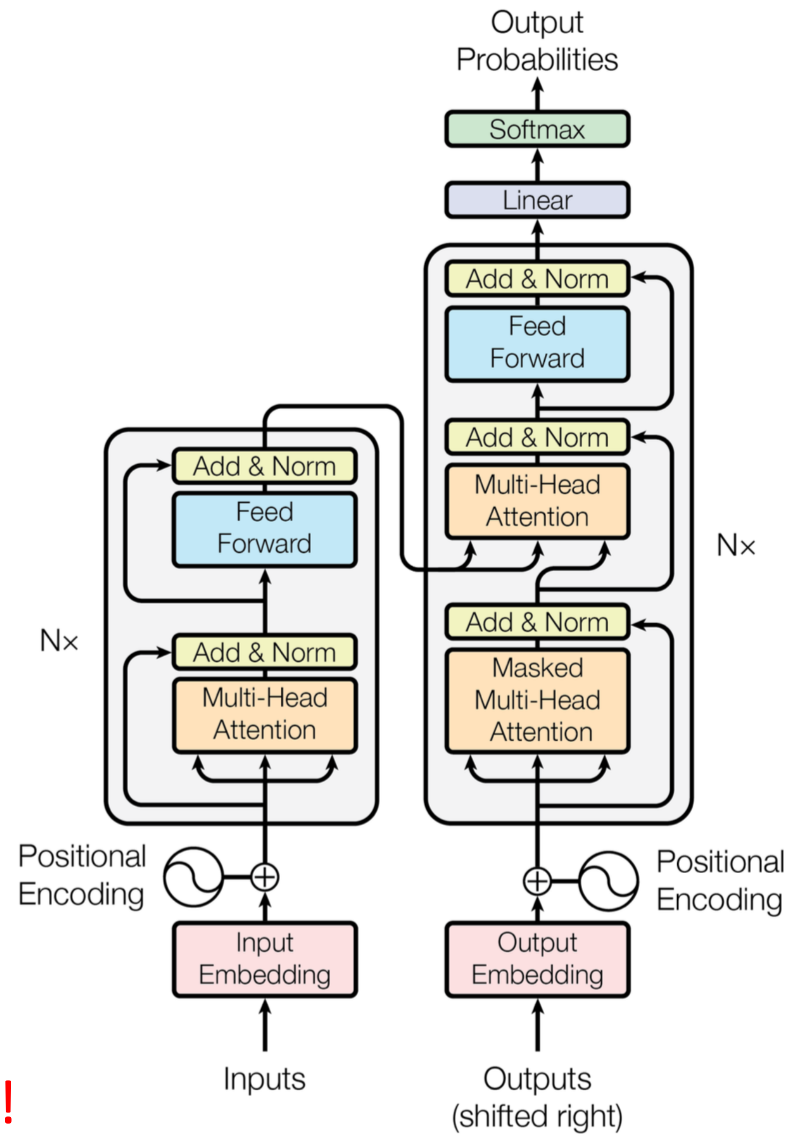

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⚠ Difficult to optimize multiple objectives!

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Machine Translation

⚠️ Require significant computational resources to train!

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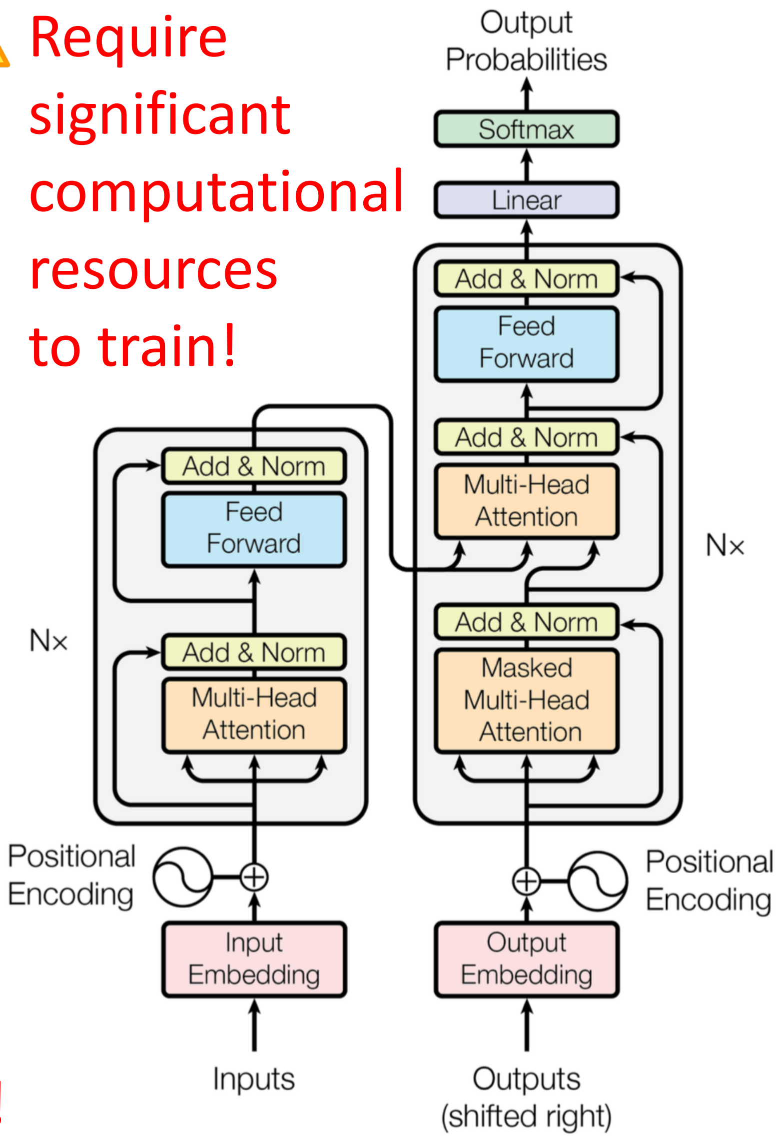

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Hyperparameter Optimization (HPO)

Definition

HPO allows to **automatically** find good hyperparameter settings.

Let

- $\boldsymbol{\lambda}$ be the hyperparameters of a ML algorithm with domain $\boldsymbol{\Lambda}$,
- $\mathbf{L}(\boldsymbol{\lambda}, \boldsymbol{D_{train}}, \boldsymbol{D_{valid}})$ denote the loss of the ML algorithm, using hyperparameters $\boldsymbol{\lambda}$ trained on $\boldsymbol{D_{train}}$ and evaluated on $\boldsymbol{D_{valid}}$.

The HPO problem is to find a configuration $\boldsymbol{\lambda}^*$ that minimizes this loss:

$$\boldsymbol{\lambda}^* \in argmin_{\boldsymbol{\lambda} \in \boldsymbol{\Lambda}} \mathbf{L}(\boldsymbol{\lambda}, \boldsymbol{D_{train}}, \boldsymbol{D_{valid}})$$

Hyperparameter Optimization (HPO)

Algorithms

Model-Free Optimization Methods:

- Grid Search
- Random Search
- Population-based methods
  e.g. genetic algorithms, evolutionary algorithms --- CMA-ES

Sequential Model-Based Optimization Methods (SMBO):

- Bayesian Optimization
- Tree Parzen Estimator

Hyperparameter Optimization (HPO)

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This talk

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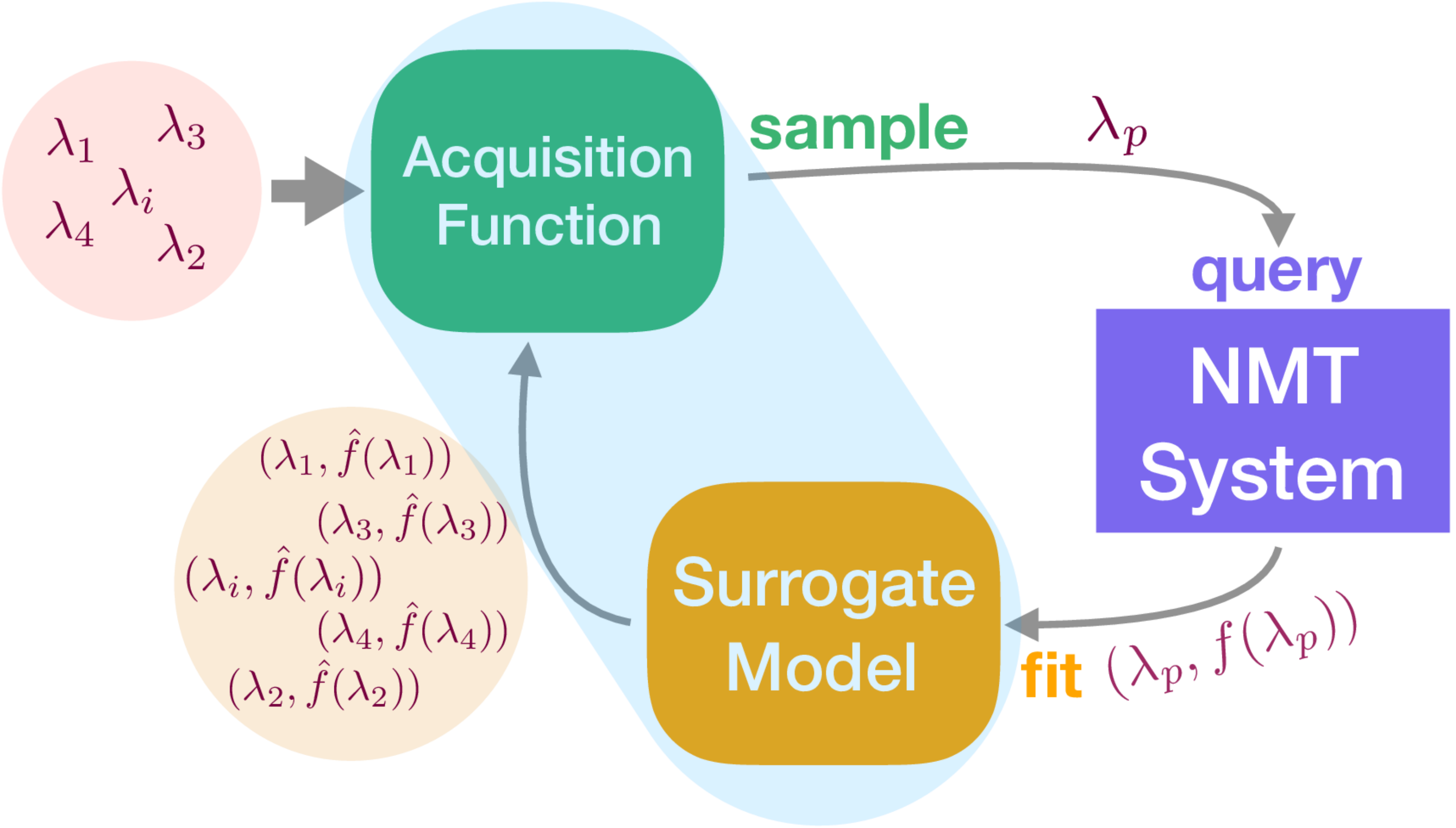
Hyperparameter Optimization (HPO)

SMBO Framework

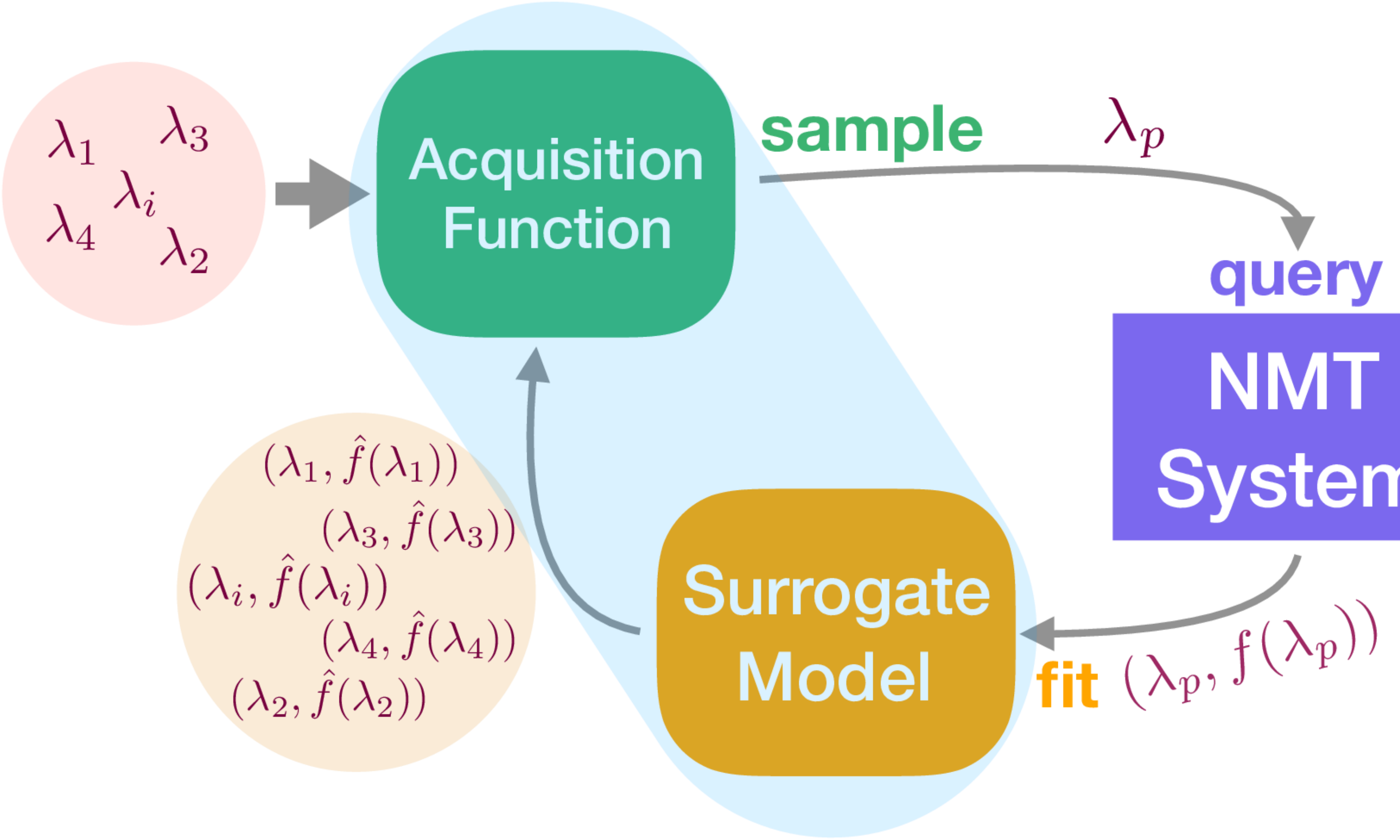


λ: hyperparameter configuration

$f(\lambda)$: model performance (e.g. BLEU)

Hyperparameter Optimization (HPO)

SMBO Framework



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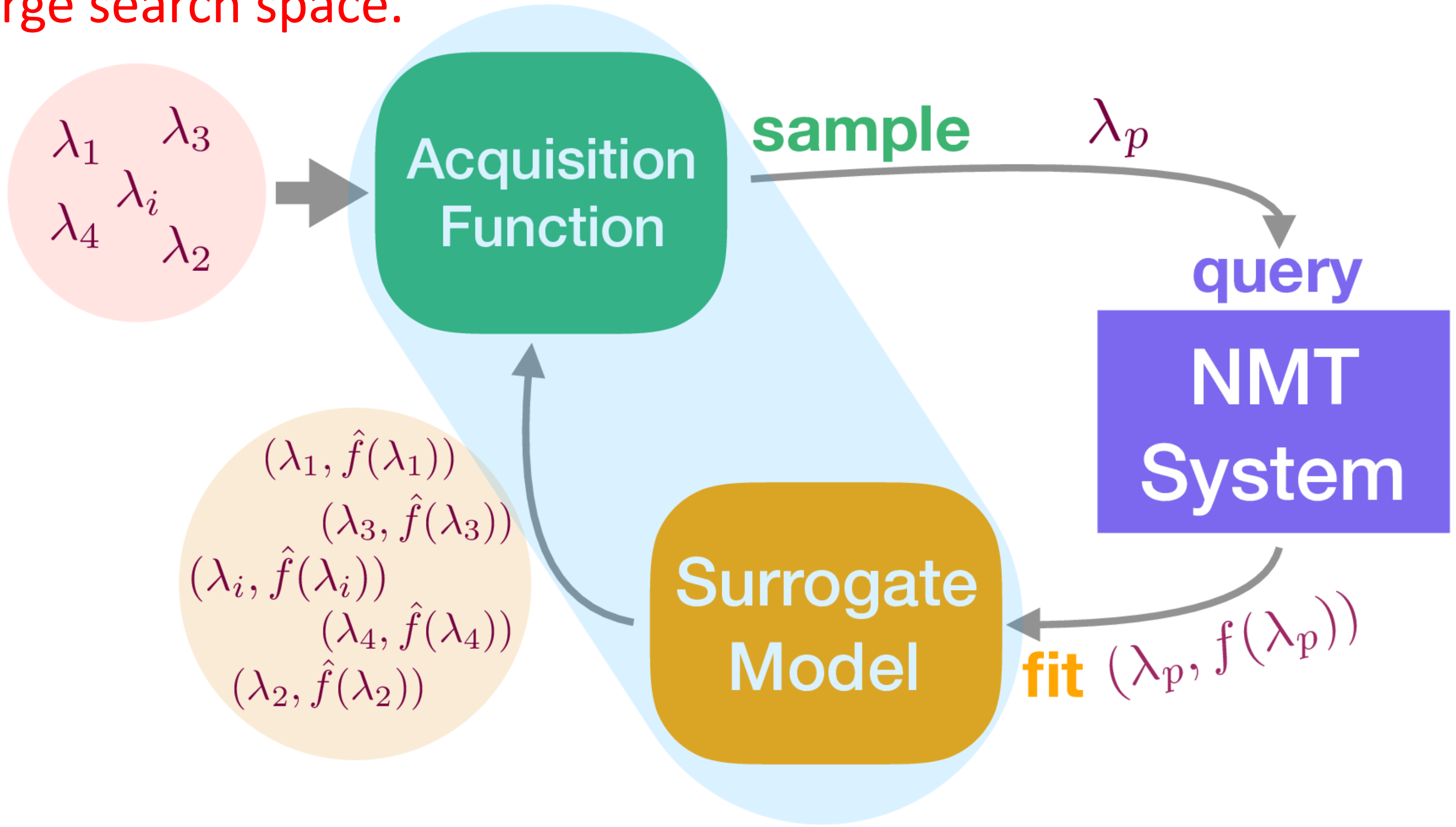
⚠ Each model takes days to weeks to train.

Hyperparameter Optimization (HPO)

SMBO Framework

⚠ Large search space.



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Hyperparameter Optimization

Challenges

- HPO algorithms are expensive. It is not feasible to run too many experiments and compare different HPO algorithms on NMT tasks in practice.

- Li and Talwalkar (2019)[1]: *"Of the 12 papers published since 2018 at NeurIPS, ICML, and ICLR that introduce novel Neural Architecture Search methods, none are exactly reproducible."*

[1]Li, Liam and Talwarkar, Ameet, "Random search and reproducibility for neural architecture search." ICML workshop on automated machine learning. 2019.

Goal

Enable **reproducible** Hyperparameter Optimization (HPO) research on Neural Machine Translation (NMT) tasks.

Contributions

– 01 –

DATASET

We release a benchmark dataset for comparing HPO methods on NMT models.

– 02 –

BENCHMARKS

We benchmark the performance of several HPO methods on both single-objective and multiobjective optimization on our dataset.

– 03 –

ALGORITHM

We propose a novel graph-based HPO method.

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Dataset

Table-Lookup Framework

Procedure:

1. Train a large number of NMT systems with diverse **hyperparameter configurations** and record their **performance**.
2. Constrain HPO methods to sample from this finite set of models.

Dataset

Table-Lookup Framework

Procedure:

1. Train a large number of NMT systems with diverse **hyperparameter configurations** and record their **performance**.
2. Constrain HPO methods to sample from this finite set of models.

Benefits:

1. Allows HPO developers to simply lookup the performance of NMT systems without training them.
2. Reproducible and efficient HPO experiments.

Limitations:

Table needs to be large enough to cover the hyperparameter space.

Dataset

Specification

- **6 MT Corpora:**
  - large resource (WMT2019 Robustness): ja-en, en-ja (4M lines)
  - mid resource (TED Talks): zh-en, ru-en (170k lines)
  - low resource (IARPA MATERIAL): sw-en, so-en (24k lines)
- **Search Space:** 2245 Transformers (1547 GPU days)

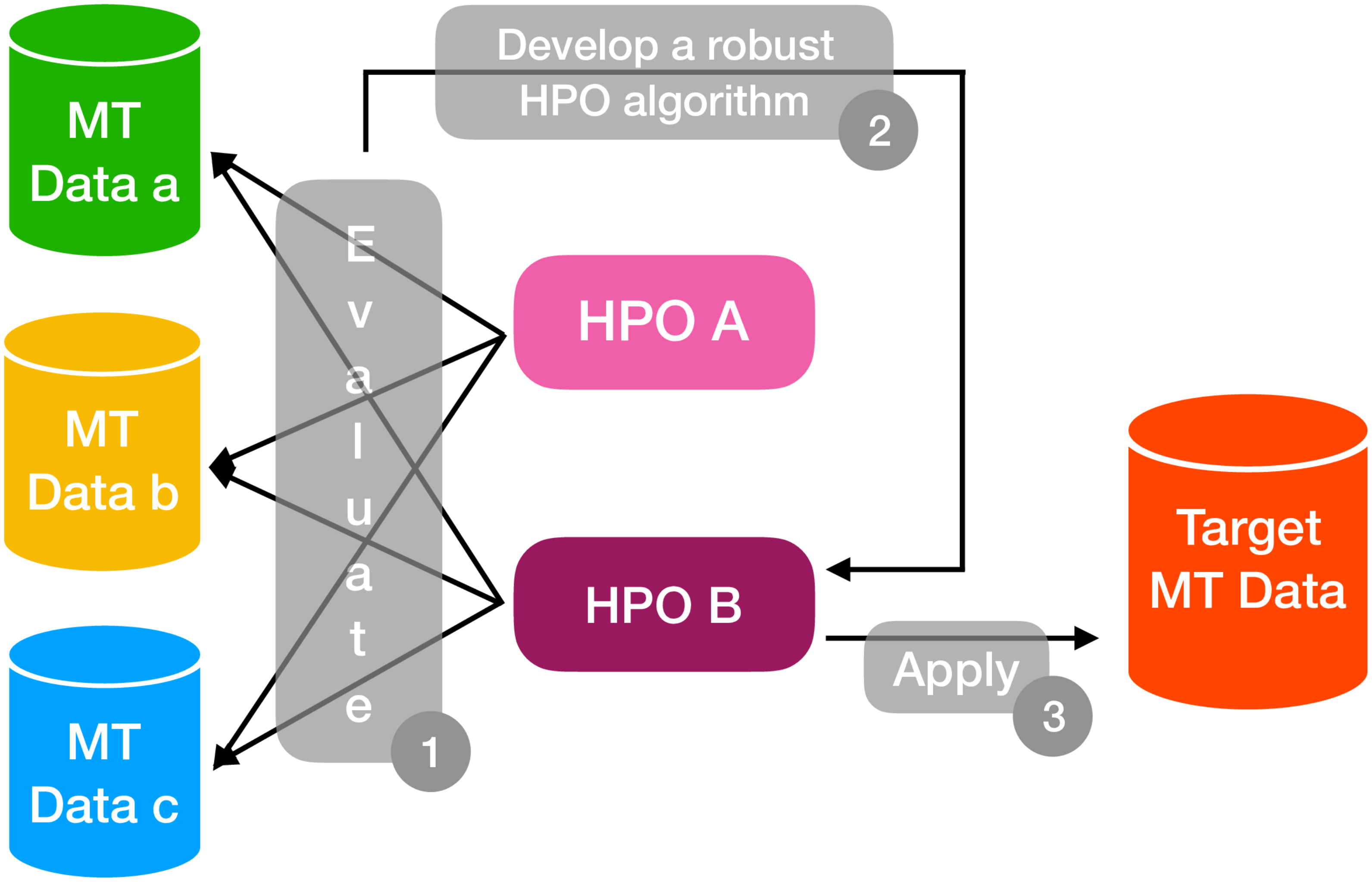
dataset	bpe (1k)	#layers	#embed	#hidden	#att_heads	init_lr (10^{-4})
zh, ru, ja, en	10, 30, 50	2, 4	256, 512, 1024	1024, 2048	8, 16	3, 6, 10
sw	1, 2, 4, 8, 16, 32	1, 2, 4, 6	256, 512, 1024	1024, 2048	8, 16	3, 6, 10
so	1, 2, 4, 8, 16, 32	1, 2, 4	256, 512, 1024	1024, 2048	8, 16	3, 6, 10

- **Objectives:** BLEU, perplexity;
  decoding time, #updates, GPU memory, #model parameters

Dataset

Application

HPO Algorithm Selection

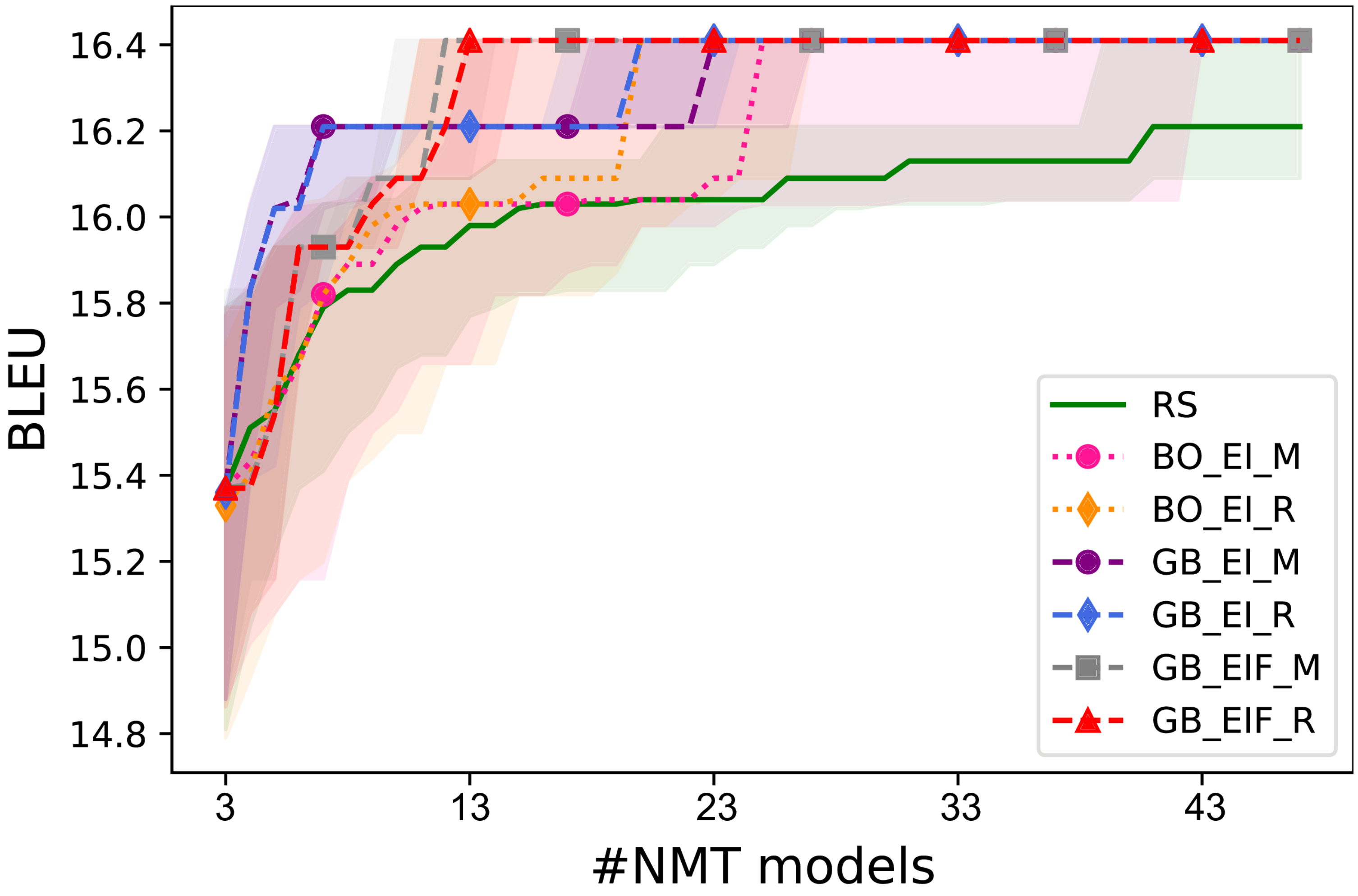


Dataset

Application

HPO Algorithm Selection

Single-objective Optimization



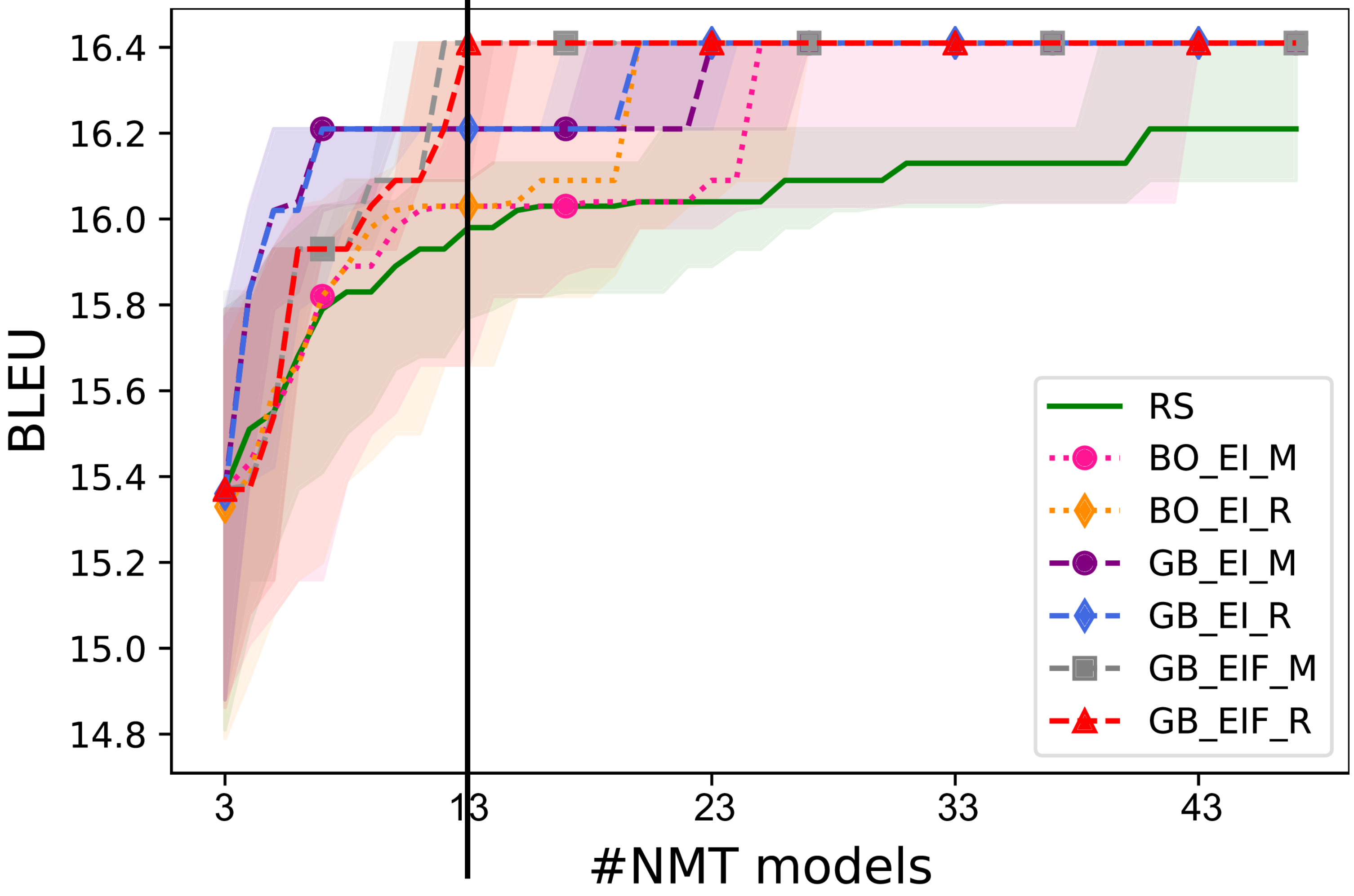
Dataset

Application

HPO Algorithm Selection

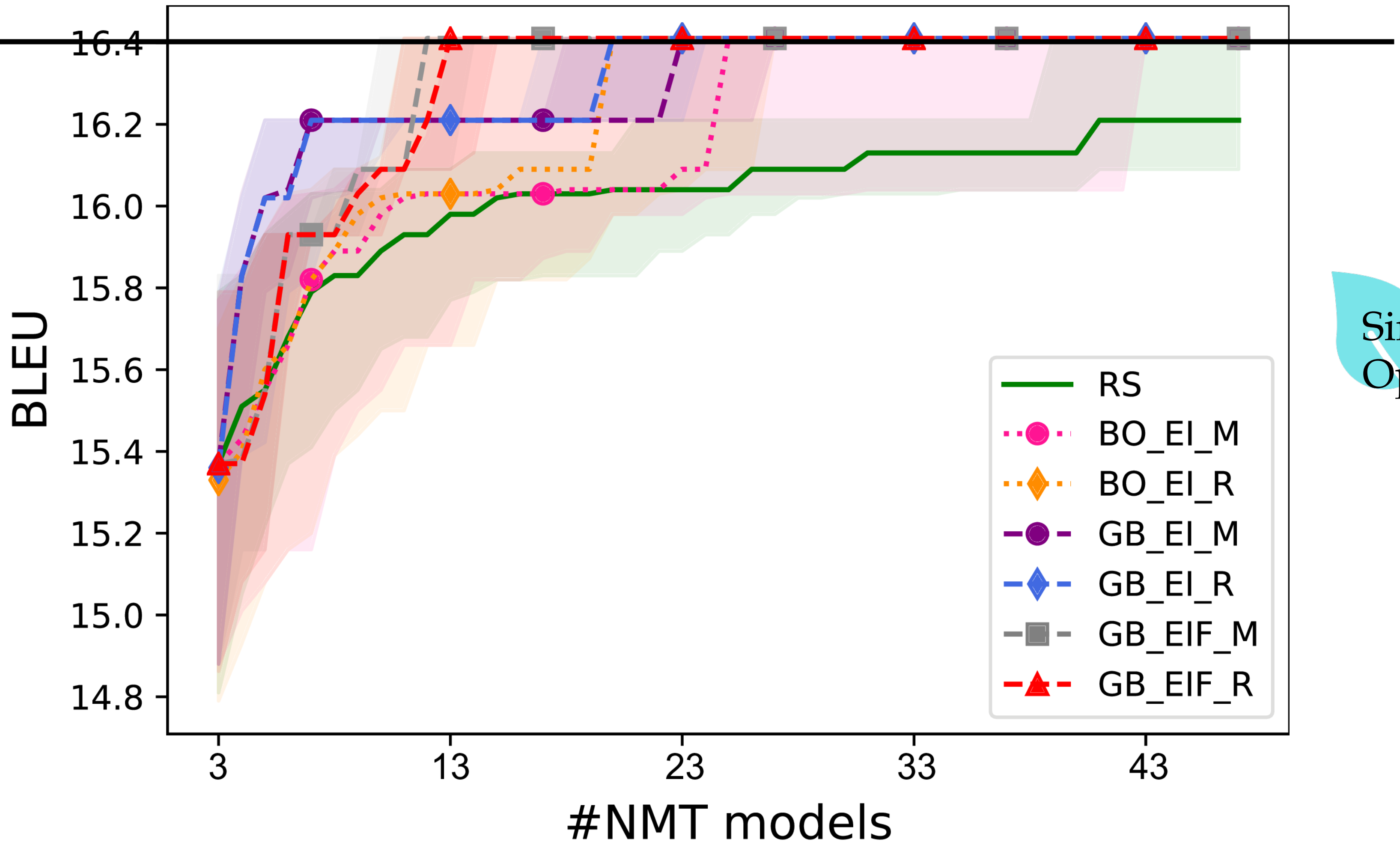
Single-objective Optimization

fix the budget



Dataset

fix the target BLEU

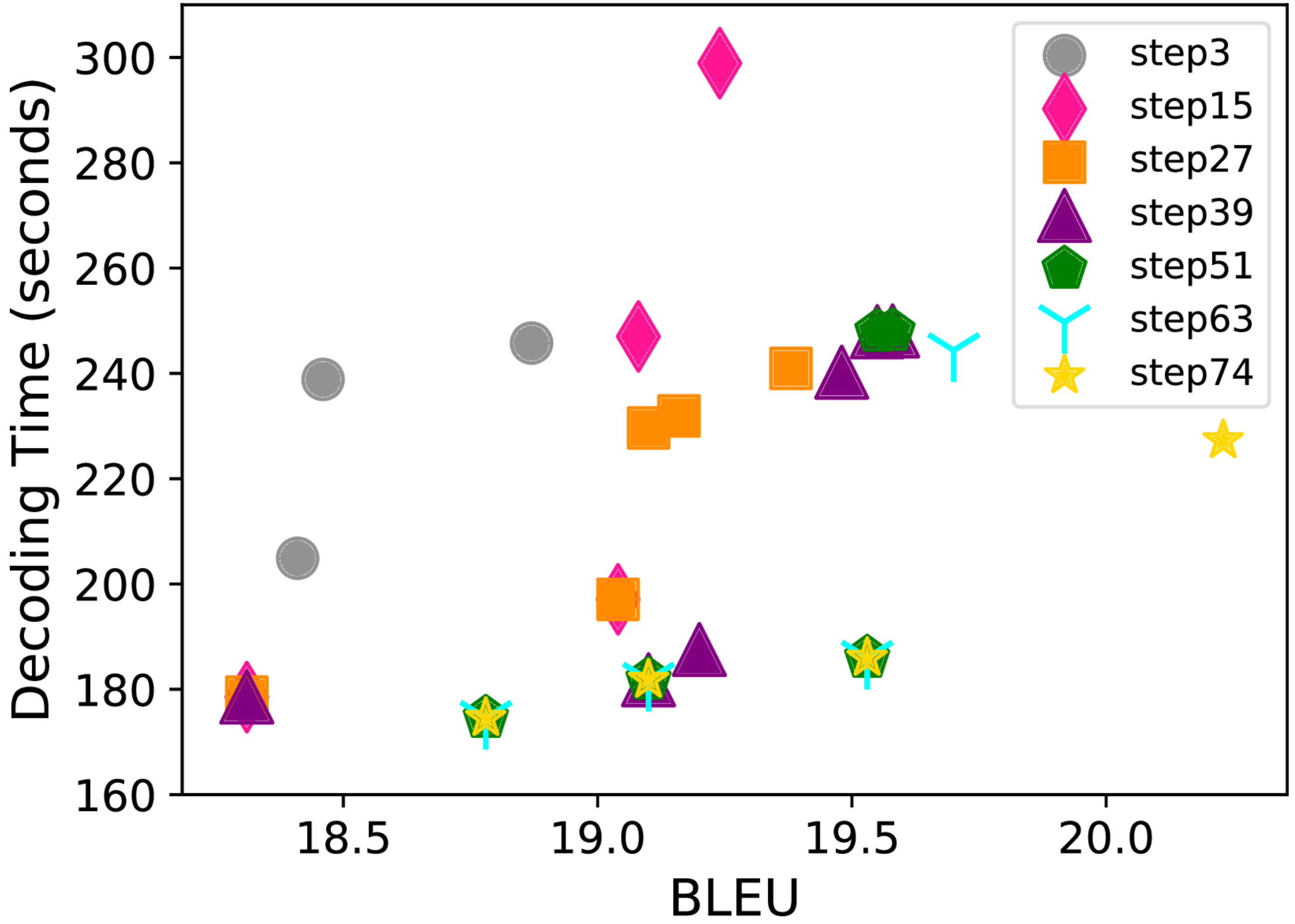


Application

HPO Algorithm Selection

Single-objective Optimization

Dataset



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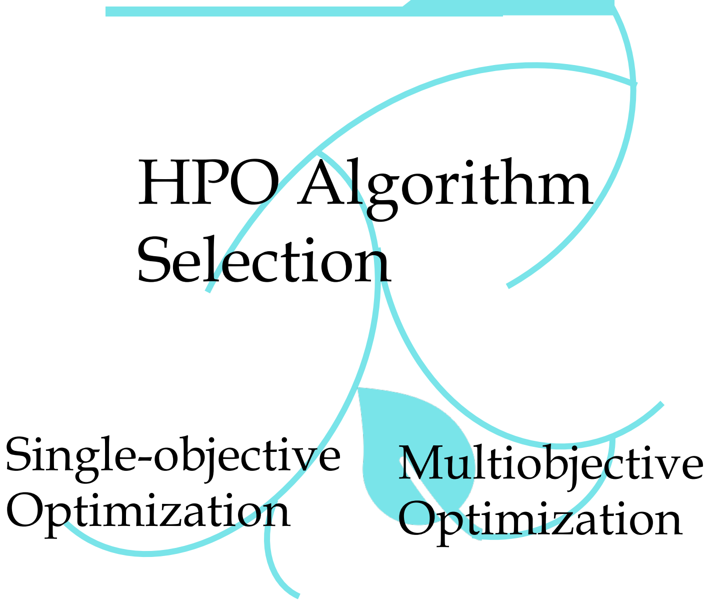
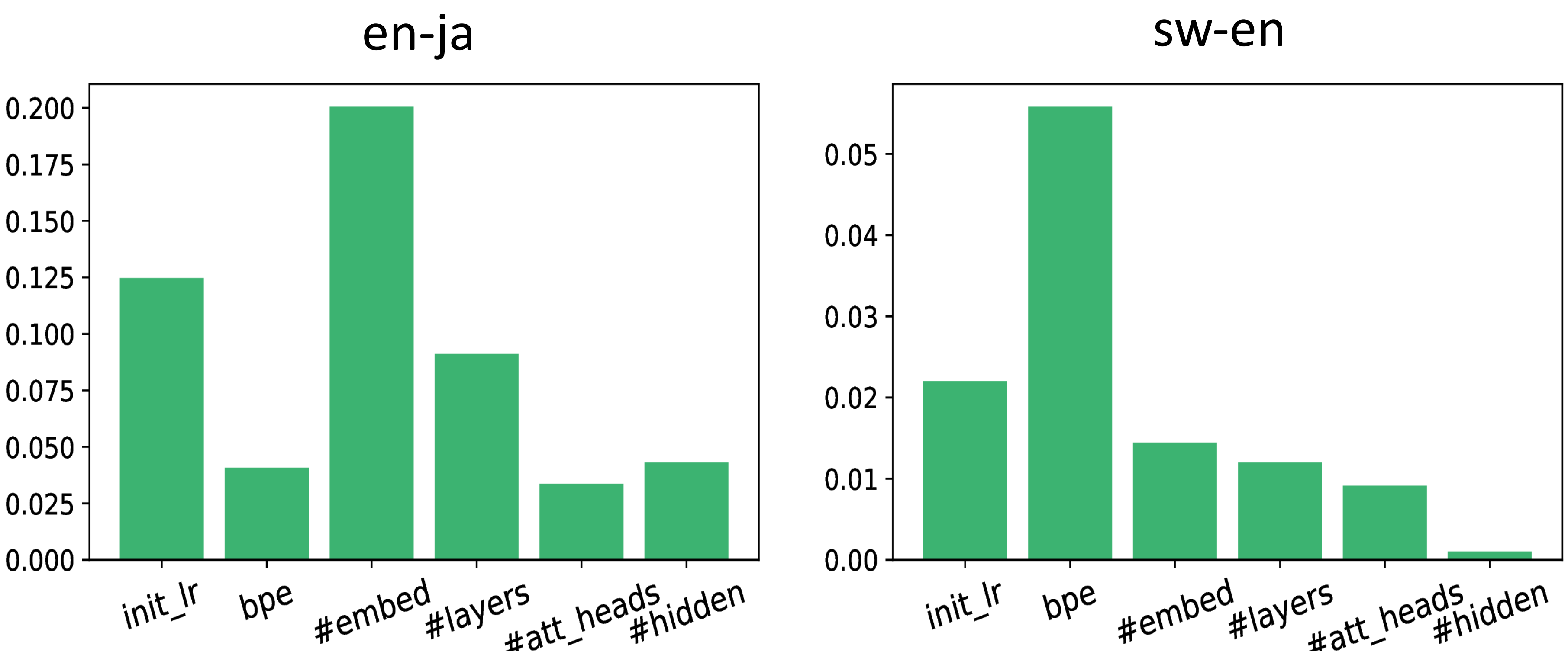


Dataset



Hyperparameter Importance

Application

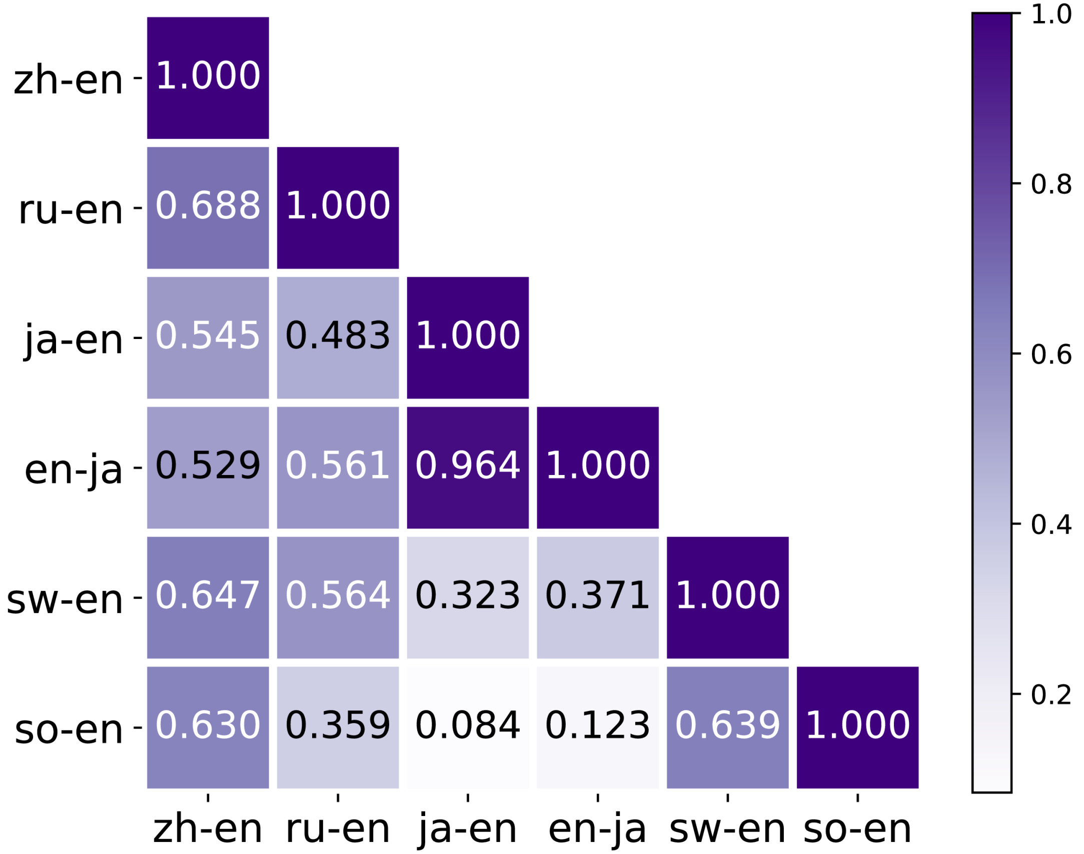
HPO Algorithm Selection

Single-objective Optimization

Multiobjective Optimization

Hyperparameter Analyses

Dataset



Model Ranking Correlation

Application

HPO Algorithm Selection

Single-objective Optimization

Multiobjective Optimization

Hyperparameter Analyses

Summary

We provide a tabular dataset for comparing HPO methods on NMT models.

- **Our benchmarks are reproducible.**
  Dataset and code are publicly available.
- **Our benchmarks are efficient.**
  One can perform multiple random trials of the same algorithm to test robustness.

Feel free to utilize our dataset to develop your new HPO methods.

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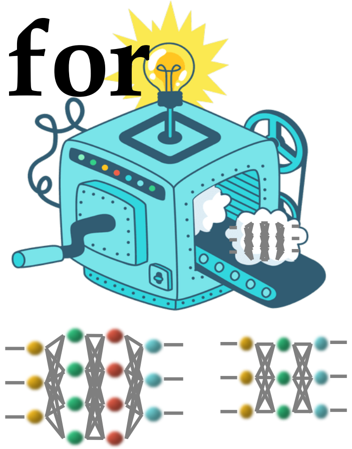

PAPER

https://www.mitpressjournals.org/doi/pdf/10.1162/tacl_a_00322

DATASET

https://github.com/Este1le/hpo_nmt

CODE

https://github.com/Este1le/gbopt