

Towards Automated Deep Learning: Efficient Joint Neural Architecture and Hyperparameter Search

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In a Nutshell

- Optimizing hyperparameters and neural network architectures **separately** may be suboptimal due to interactions between them
 - We optimize a **joint** 17-dimensional architecture and hyperparameter space and achieve competitive results for just 3 hours of training
- Performance after short and long training budgets only **correlates weakly**
 - But correlation with intermediate budgets is much higher
 - We use BOHB (Bayesian Optimization Hyperband) [Falkner et al. 2018] to **incrementally increase budgets** during optimization

Related Work

Many recent works on neural architecture search, but all of them use **two-step optimization** (first architecture, then hyperparameters). E.g.:

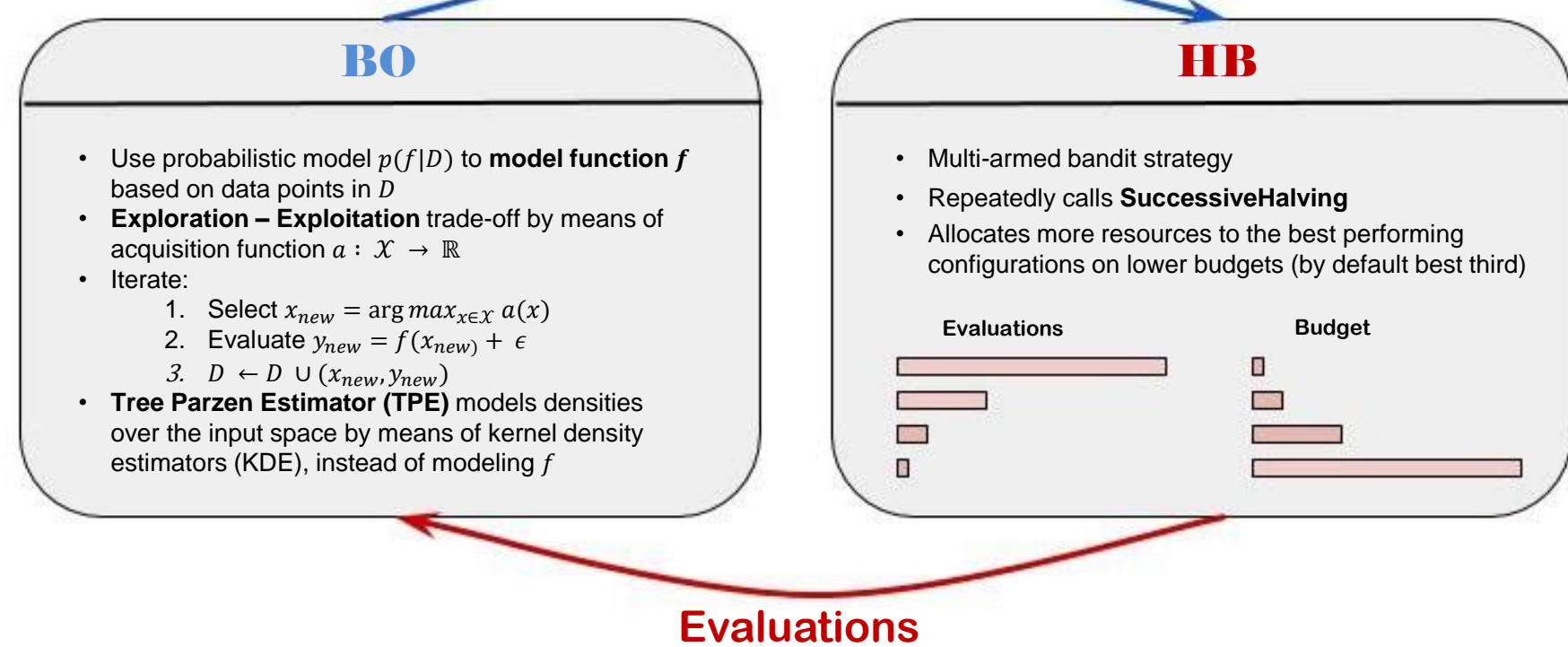
- Reinforcement Learning** [Zoph et al. 2018]: Train a controller RNN with PPO to sample string encoding of the architecture
- Neuro-evolution** [Liu et al. 2018a]: mutate population of models and add to the population the best offsprings (w.r.t. validation error)
- Sequential model-based optimization** [Liu et al. 2017]: learn surrogate model and sample more efficient architectures
- Gradient-based** [Liu et al. 2018b]: parameterize network architecture by creating mixed operations and optimize using gradient descent

Original Bayesian optimization NAS papers already used **joint optimization**:

- Bayesian optimization** [Bergstra et al. 2013, Domhan et al. 2015, Mendoza et al. 2016]: achieved state-of-the-art on several datasets using tree-based models

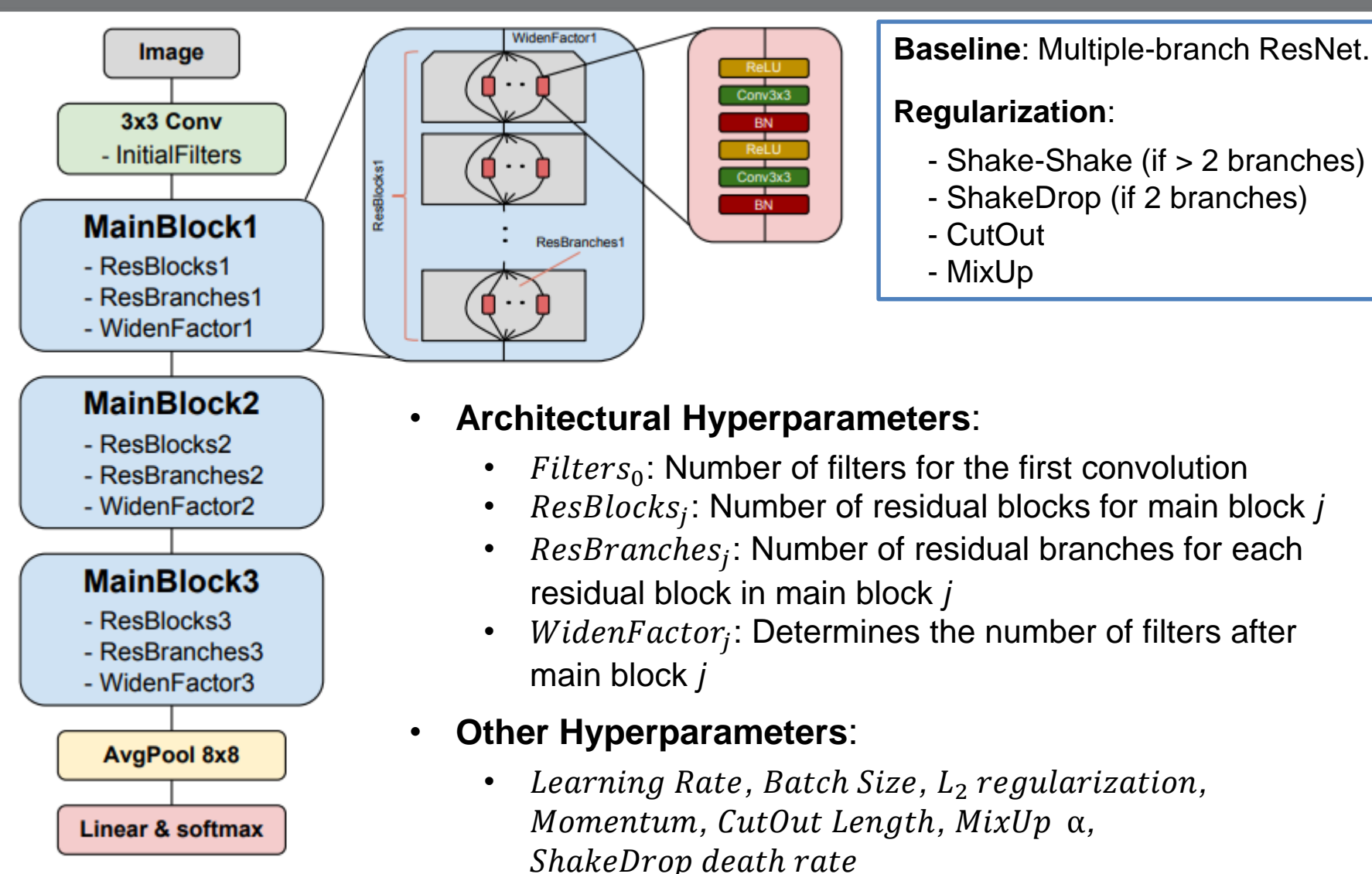
BOHB

Configurations



- BOHB samples from a **learned probabilistic model** instead of randomly
- It uses a multivariate KDE to better model interactions between parameters

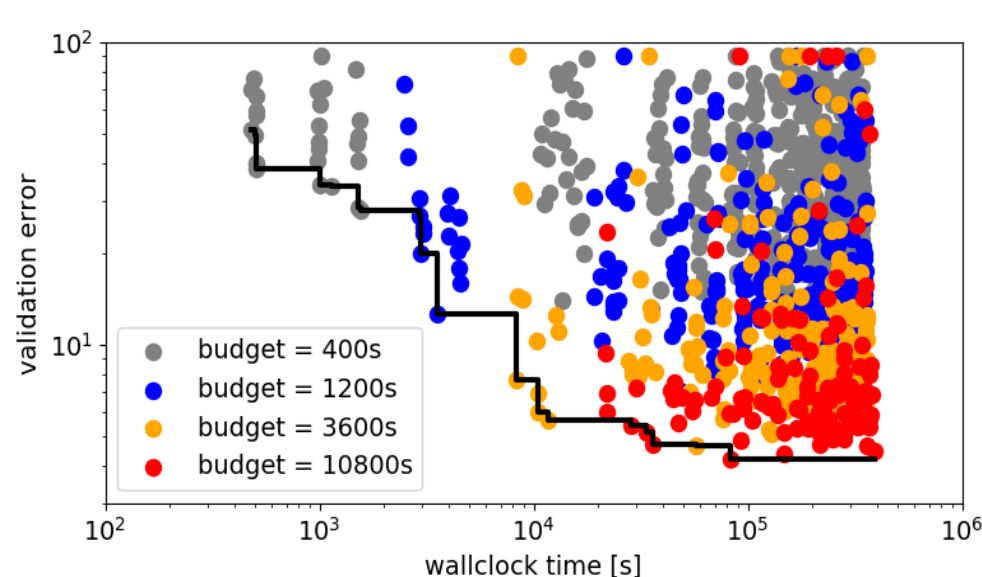
Search Space



Experiments

Results

- Limited budgets** (training time): 400s, 1200s, 1h and 3h



Model	Param (M)	Test Error
ResNet-18	11.2	3.34 \pm 0.11
Shake-Shake 26 2x32d	2.9	3.91 \pm 0.09
Shake-Shake 26 2x64d	11.7	3.38 \pm 0.07
Shake-Shake 26 2x96d	26.2	4.42 \pm 0.06
Ours	27.6	3.18 \pm 0.16

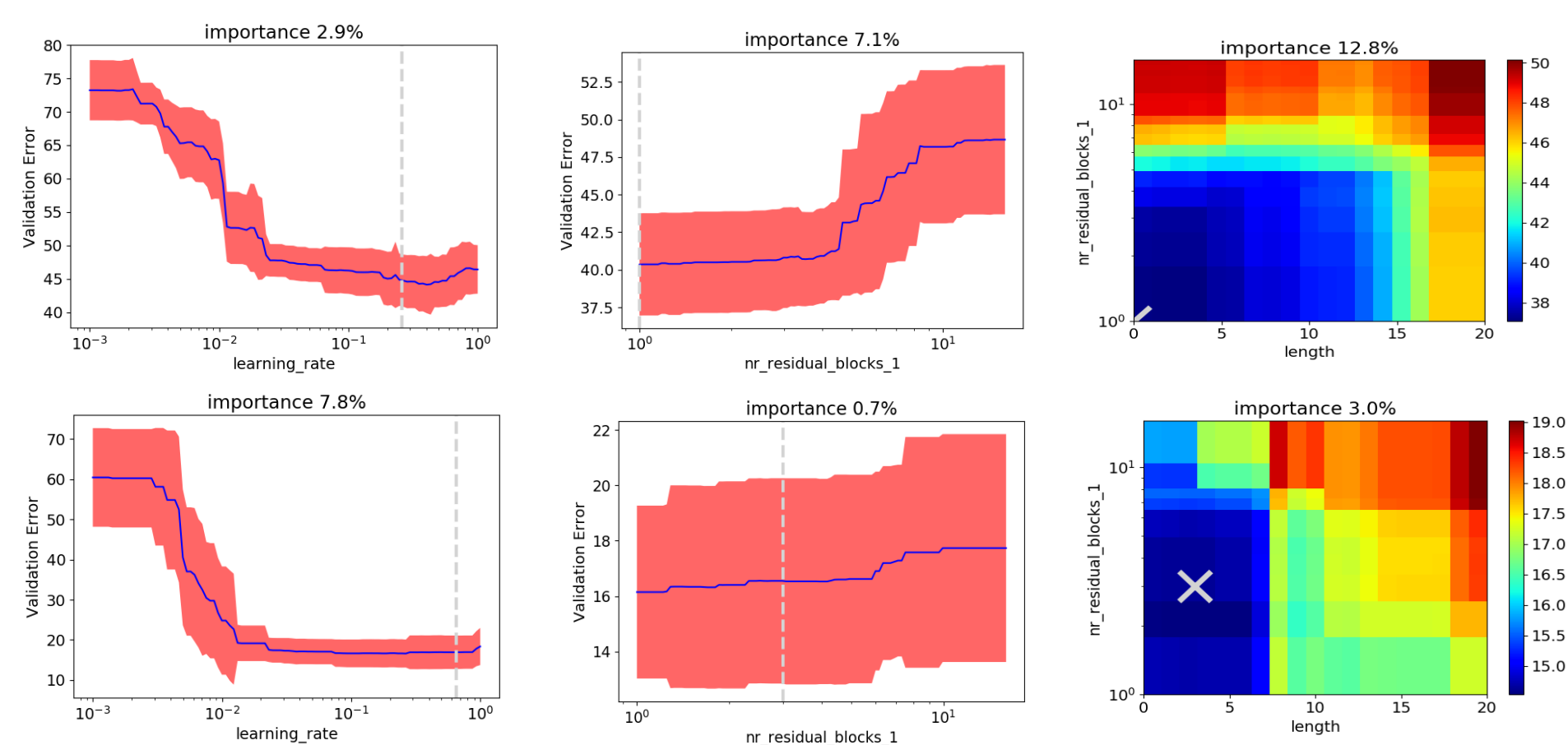
- 256 evaluations** on the full budget of 3h (32 GPU days)
- Exploration-exploitation trade-off**:
 - explored sufficiently
 - covered good regions of the space
- Better results than manually constructed architectures that are part of the search space when trained for 3h
- Optimizing jointly** architecture and hyperparameters beneficial

Analysis

- Spearman rank correlation** between budgets performances
 - Conclusion**: short runs ranking \neq long runs ranking

	1200s	1h	3h	
	0.87	0.31	0.05	400s
		0.88	0.64	1200s
			0.86	1h

- fANOVA** – quantifies global importance of all parameters
 - Conclusion**: strong interaction between architectural choices, hyperparameters and the training time



Top row: 400s budget Bottom row: 1h budget Gray dashed line/cross: best performance