AutoML: Neural Architecture Search (NAS)

Speedup Techniques

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Overview of NAS Speedup Methods

- Multi-fidelity optimization
- Learning curve prediction
- Meta-learning across datasets
- Network morphisms & weight inheritance
- Weight sharing & the one-shot model

NAS Speedup Technique 1: Multi-fidelity optimization

- Analogous to multi-fidelity optimization in HPO
  - Many evaluations for cheaper fidelities (less epochs, smaller datasets, down-sampled images, shallower networks, etc)
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- Compatible with any blackbox optimization method
  - Using random search: ASHA [Li & Talwalkar, 2019]
  - Using Bayesian optimization: BOHB [Zela et al, 2018]
  - Using differential evolution: DEHB [Awad et al, under review]
  - Using regularized evolution: progressive dynamic hurdles [So et al, 2019]

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  - Using regularized evolution: progressive dynamic hurdles [So et al, 2019]
- Often used for joint optimization of architecture & hyperparameters
  - Auto-Pytorch [Mendoza et al, 2019] [Zimmer et al, under review]
  - "Auto-RL" [Runge et al, 2019]

NAS Speedup Technique 2: Learning Curve Prediction

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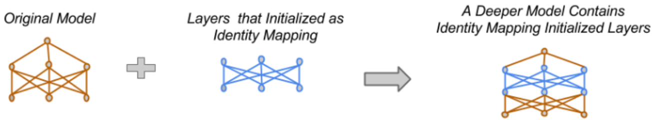
- Compatible with any blackbox optimization method
  - Using random search and Bayesian optimization: [Domhan et al, 2015]
  - Using reinforcement learning: [Baker et al, 2018]

NAS Speedup Technique 3: Meta-Learning

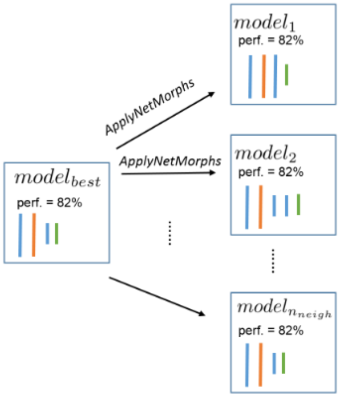
- Lots of work on meta-learning for HPO
- Only little work on meta-learning for NAS
  - Find a set of good architectures to initialize BOHB in Auto-Pytorch [Zimmer et al, under review]
  - Learn RL agent's policy network on previous datasets [Wong et al, 2018]
  - Learn neural architecture that can be quickly adapted [Lian et al, 2019; Elsken et al, 2019]

NAS Speedup Technique 4: Network Morphisms

- Network Morphisms [Chen et al. '16; Wei et al. '16; Cai et al. '17]
  - Change the network structure, but not the modelled function
  - I.e., for every input the network yields the same output as before applying the network morphisms operations
  - Examples: "Net2DeeperNet", "Net2WiderNet", etc.



Network Morphisms Allow Efficient Moves in Architecture Space



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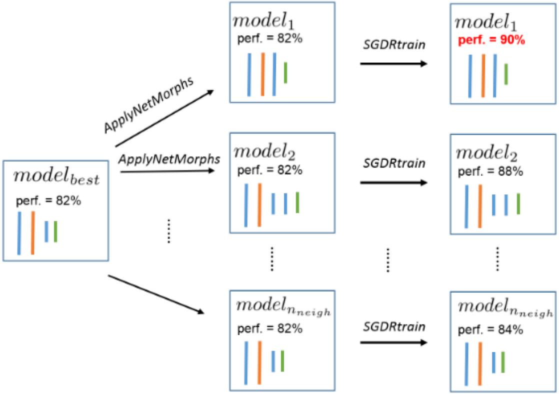

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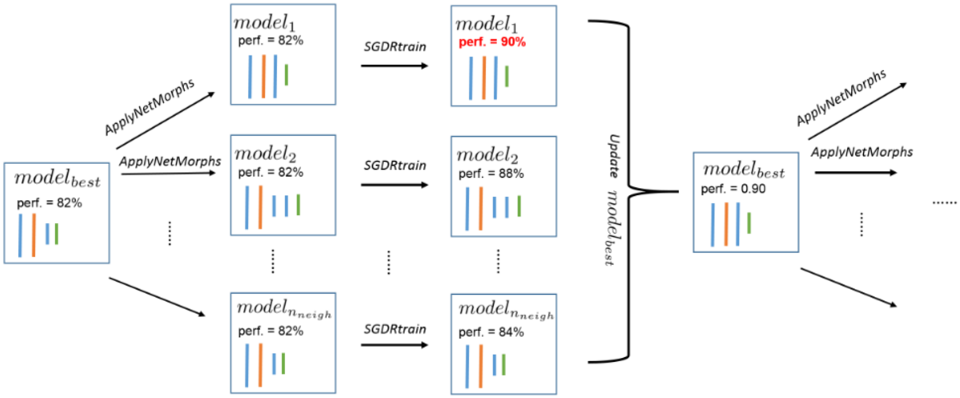

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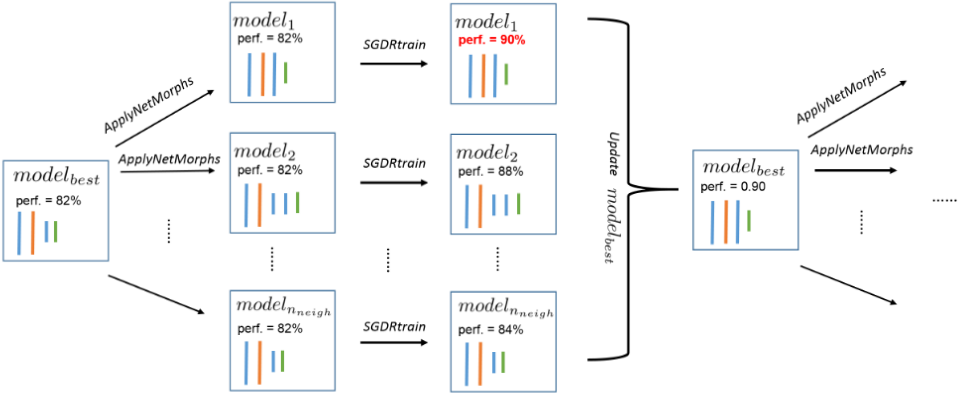
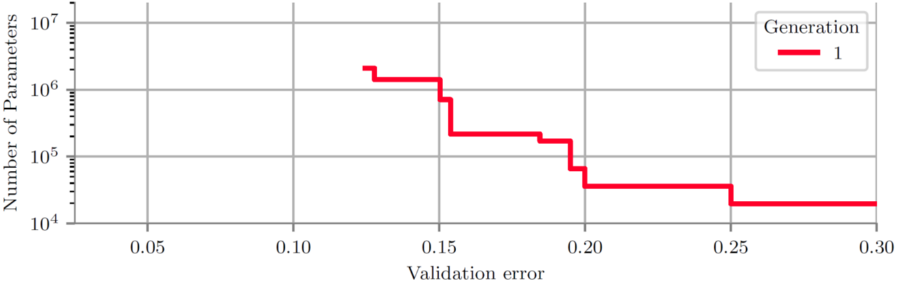


Weight inheritance avoids expensive retraining from scratch

[Real et al, 2017, Cai et al, 2018, Elsken et al, 2017, Cortes et al, 2017, Cai et al, 2018, Elsken et al. '19]

Network Morphisms for Multi-objective NAS [Elsken et al. '19]

- To trade off error vs. resource consumption (e.g, #parameters):
  - Maintain a Pareto front of the two objectives
  - Evolve a population of Pareto-optimal architectures over time



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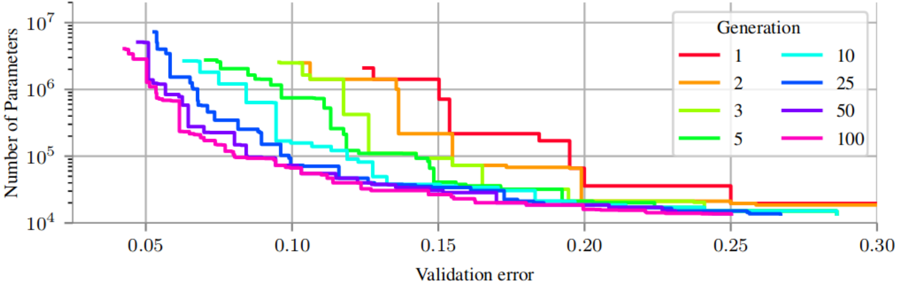
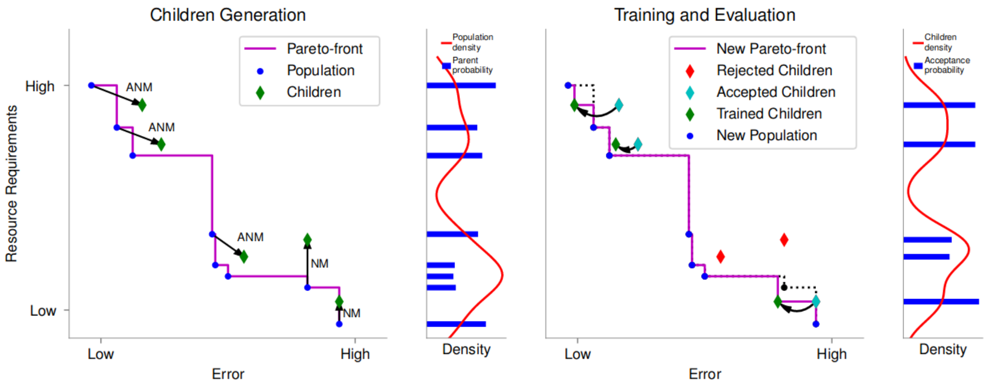


Network Morphisms for Multi-objective NAS [Elsken et al. '19]

- LEMONADE: Lamarckian Evolution for Multi-Objective Neural Architecture Design
- Weight inheritance through approximate morphisms (ANMs)
  - Dropping layers, dropping units within a layer, etc (function not preserved perfectly)



NAS Speedup Technique 5: Weight Sharing and One-shot Models [Pham et al, 2018; Bender et al, 2018]

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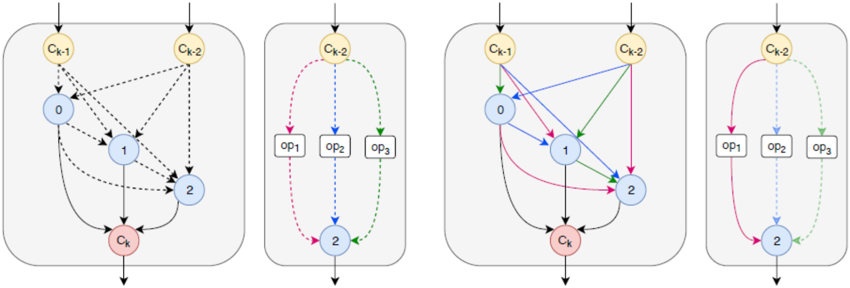
- All possible architectures are subgraphs of a large supergraph: the one-shot model
- Weights are shared between different architectures with common edges in the supergraph
- Search costs are reduced drastically since one only has to train a single model (the one-shot model).

NAS Speedup Technique 5: Weight Sharing and One-shot Models [Pham et al, 2018; Bender et al, 2018]

- The one-shot model can be seen as a directed acyclic multigraph
  - ⇒ Nodes - latent representations.
  - ⇒ Edges (dashed) - operations.



(a) One-shot search **(b)** Final evaluation

- Architecture optimization problem: Find optimal path from the input to the output

Questions to Answer for Yourself / Discuss with Friends

- Repetition:
  List five methods to speed up NAS over blackbox approaches
- Repetition:
  Which speedup techniques directly carry over from HPO to NAS?
- Discussion:
  Why do network morphisms and the one-shot model only apply to NAS, and not to HPO?