Advanced topics in Deep Reinforcement Learning
Week 9 slides
Evo-MAML: Meta-Learning with Evolving Gradient 2023

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Evo-MAML: Meta-Learning with Evolving Gradient 2023

- **Challenges of Classical MAML** (Model-Agnostic Meta-Learning)
  - Expensive due to second-order derivative calculations
  - High memory and computational costs, limiting practicality
- **Evo-MAML** (Evolving MAML)
  - Improved computational efficiency and generalization in meta-learning
  - Incorporates evolving gradients within the inner loop to address the central challenges.

$$\theta_\sigma^i = w_1\theta_1^i + w_2\theta_2^i + \cdots + w_P\theta_P^i \quad (8)$$

$$g_{evo} := \nabla f_i(\theta_\sigma^i, Q_{\mathcal{T}_i}) \quad (9)$$

Fig.1: Formulas, as used in Fig.2.

Algorithm 1: Evolving Model-Agnostic Meta-Learning (Evo-MAML)

Input: Distribution over tasks $\mathcal{T}$, noise σ, temperature τ, number of perturbation models P, inner step size α, outer step size β_k

Randomly initialize θ
while *not done* **do**
  Sample batch of tasks $\mathcal{T}_i \sim \mathcal{T}$
  for *all* $\mathcal{T}_i$ **do**
    Sample B datapoints $(x^{(i)}, y^{(i)})$ from $\mathcal{T}_i$
    Update $\theta_{k+1}^i = \theta_k - \alpha\nabla f_i(\theta_k)$
    Sample P noise factors $\epsilon_p \sim \sigma\text{sign}(\mathcal{N}(0, I))$ and create $\theta_p^i = \theta_{k+1}^i + \epsilon_p$
    Evolutionary update using Equation (8)
    Compute the meta-gradient g_{evo} with Equation (9)
  end
  $\theta_{k+1} = \theta_k - \beta_k \frac{1}{B} \sum_{i \in \mathcal{B}_k} g_{evo}$
end

Fig.2: Pseudocode of Evo-MAML demonstrating the integration of evolutionary updates and the use of first-order gradients to efficiently estimate the meta-gradient.

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- **Comparison**
  - The meta-learning curves corresponding to different first-order approximation methods combined with MAML
  - Consistently outperforms other methods
  - Evo-MAML exhibits higher generality and competitive performance

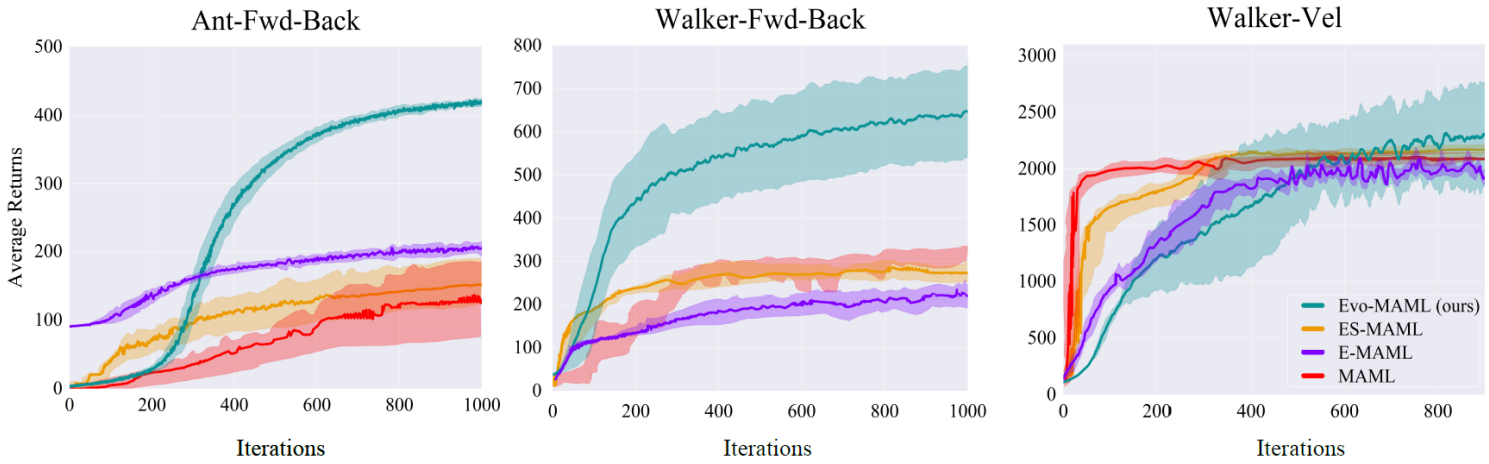

Fig.3: Performance comparison in some reference tasks between MAML, E-MAML and ES-MAML (evolutionary methods to circumvent second order gradients) and Evo-MAML (the in the paper proposed algorithm)