ASK 2024 논문집
Annual Symposium of KIPS 2024
www.kips.or.kr

신진학자 워크숍

Task-Adaptive Meta-Learning: for Computer Vision

백성용 교수
(한양대학교)

Task-Adaptive Meta-Learning: for Computer Vision

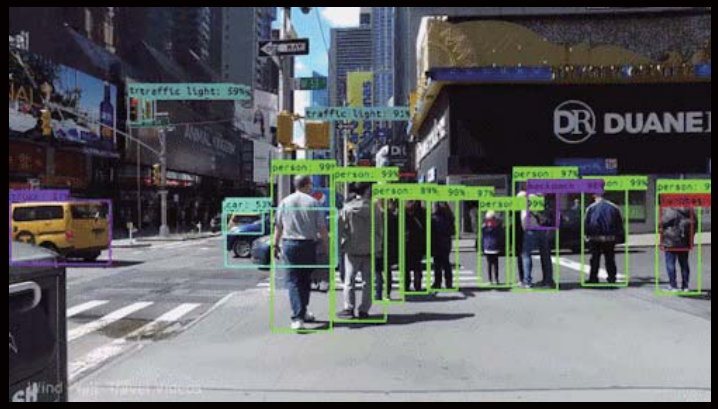
Sungyong Baik

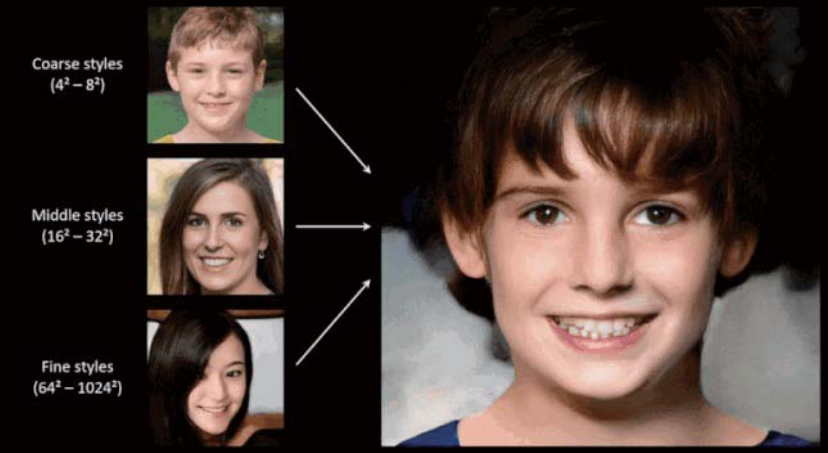
May 24th, 2024

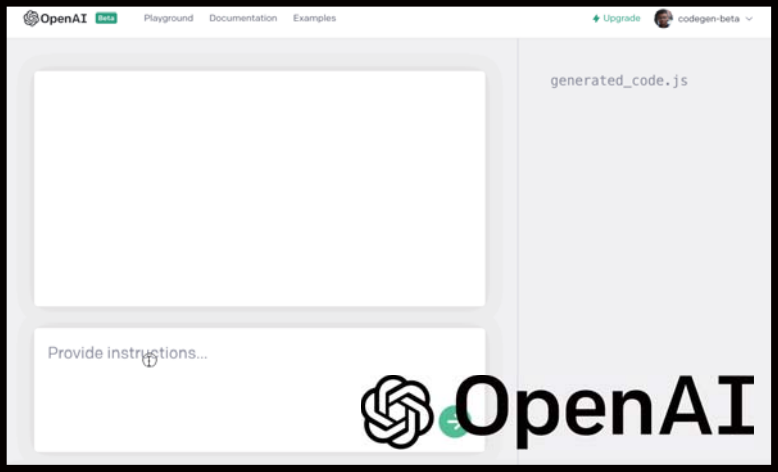
Hanyang University
Department of Data Science
https://dsybaik-hy.github.io

Motivation for Few-Shot Learning

- **Deep Learning: A lot of breakthroughs**







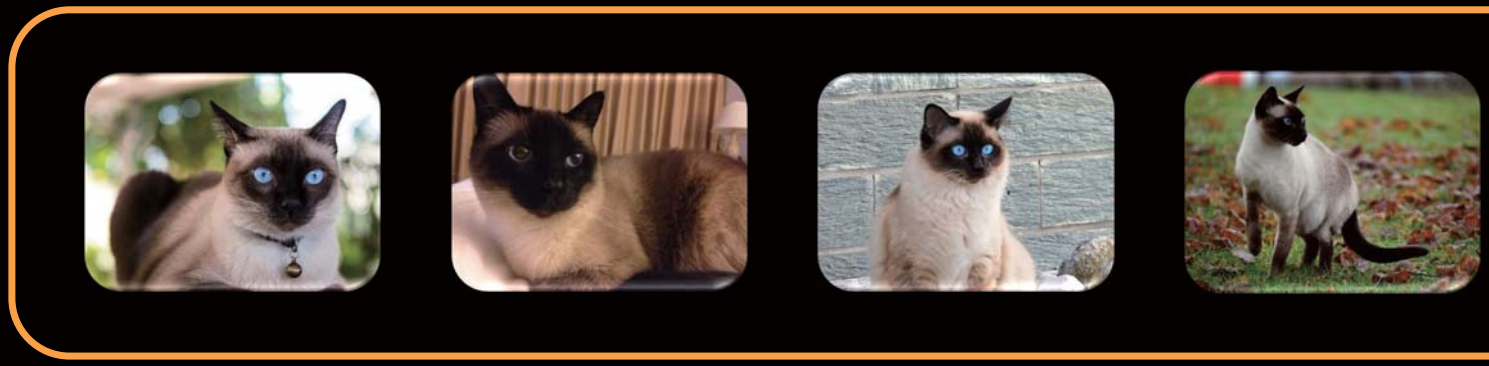
>>

Need a lot of data!!

Motivation for Few-Shot Learning

- Humans can **quickly learn new concepts with few examples**

Siamese Cat



Motivation for Few-Shot Learning

- Humans can **quickly learn new concepts with few examples**

Siamese Cat

Siamese Cat?

Motivation for Few-Shot Learning

- Humans can **quickly learn new concepts with few examples**

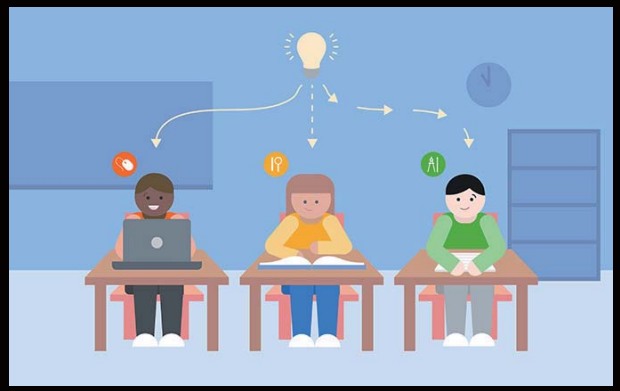
Siamese Cat

Siamese Cat?

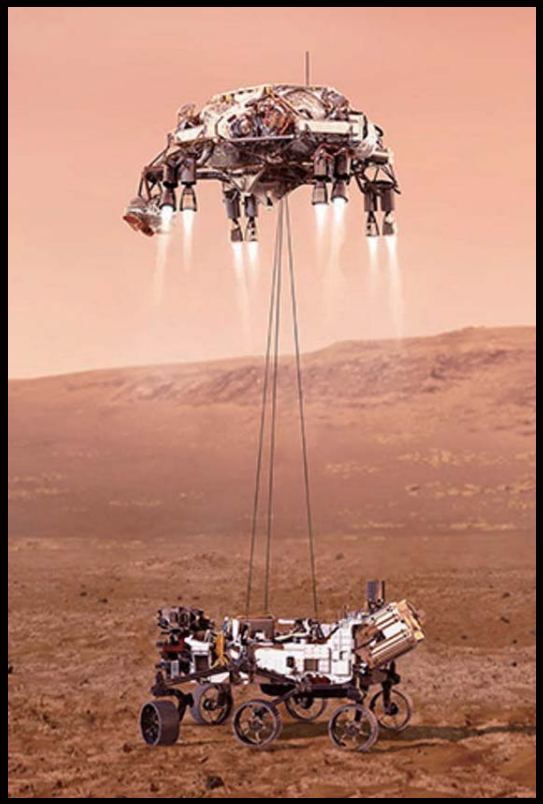
Motivation for Few-Shot Learning

Personal Robot

Medical Imaging



Personalized Education



Robot Navigation

Recommendation System

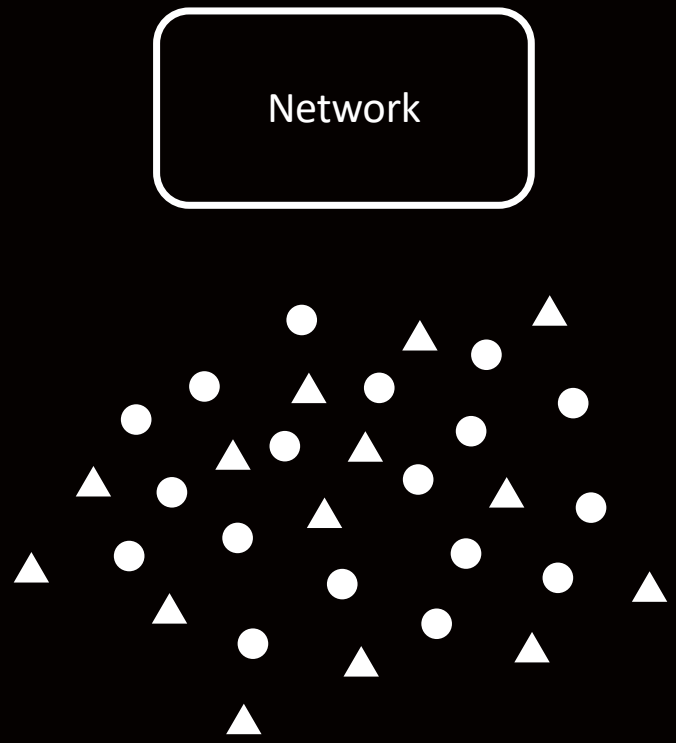
>>

Motivation for Few-Shot Learning

Robot Navigation

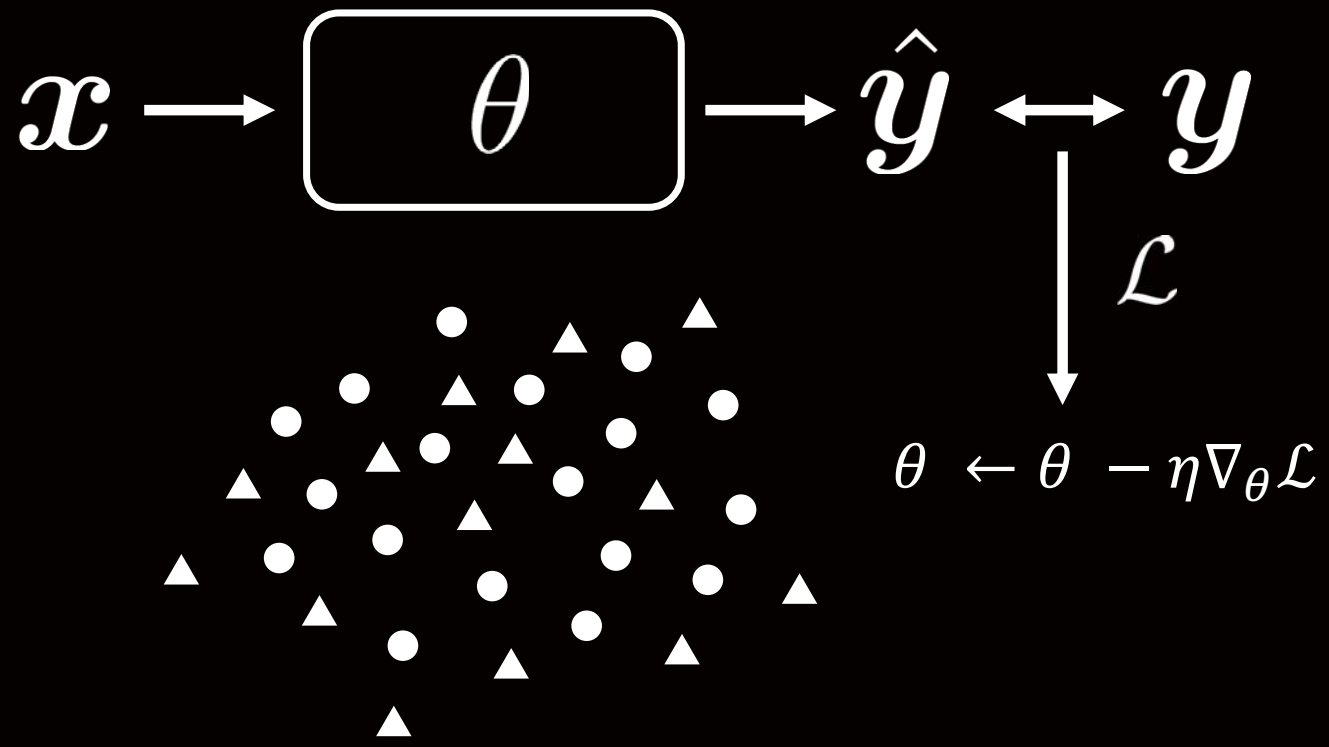
Motivation for Few-Shot Learning

- Standard Supervised Learning:
  - One network for each task
  - A large amount of data for each task



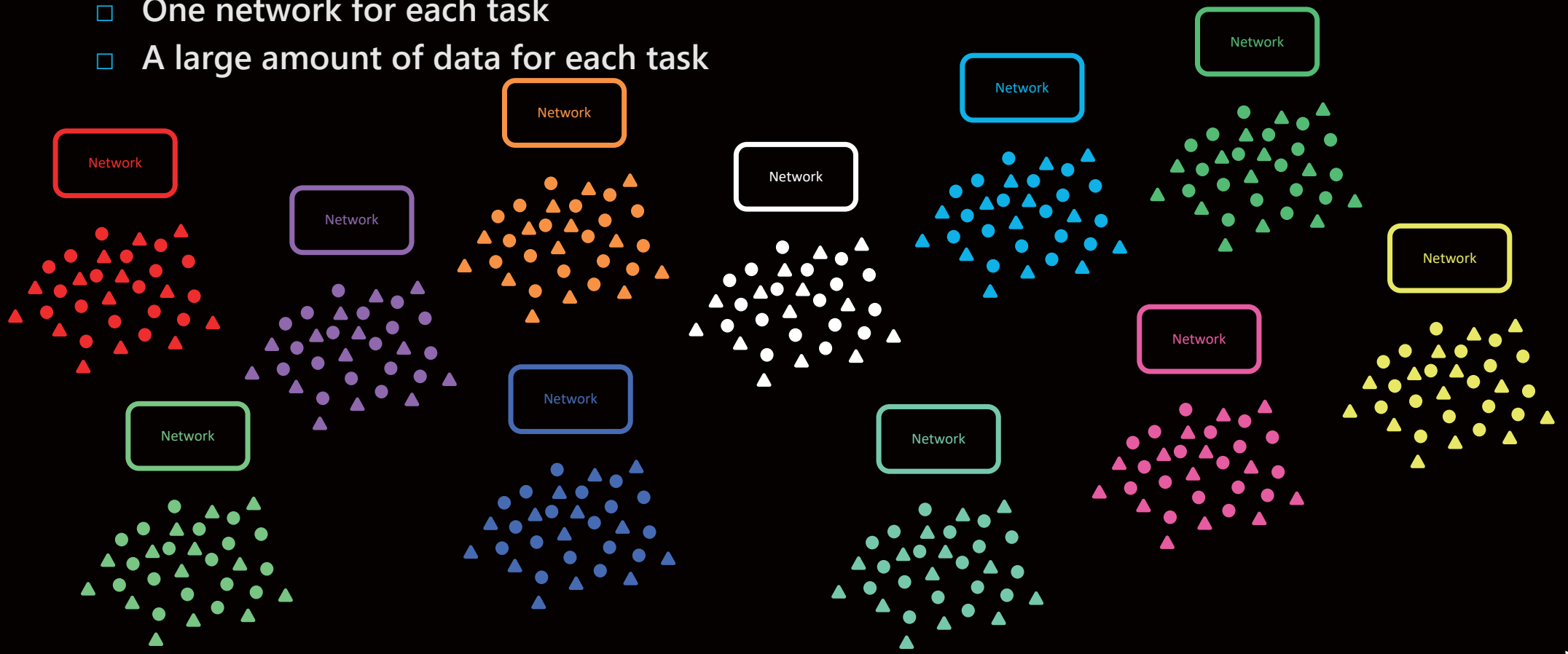
Motivation for Few-Shot Learning

- Standard Supervised Learning:
  - One network for each task
  - A large amount of data for each task



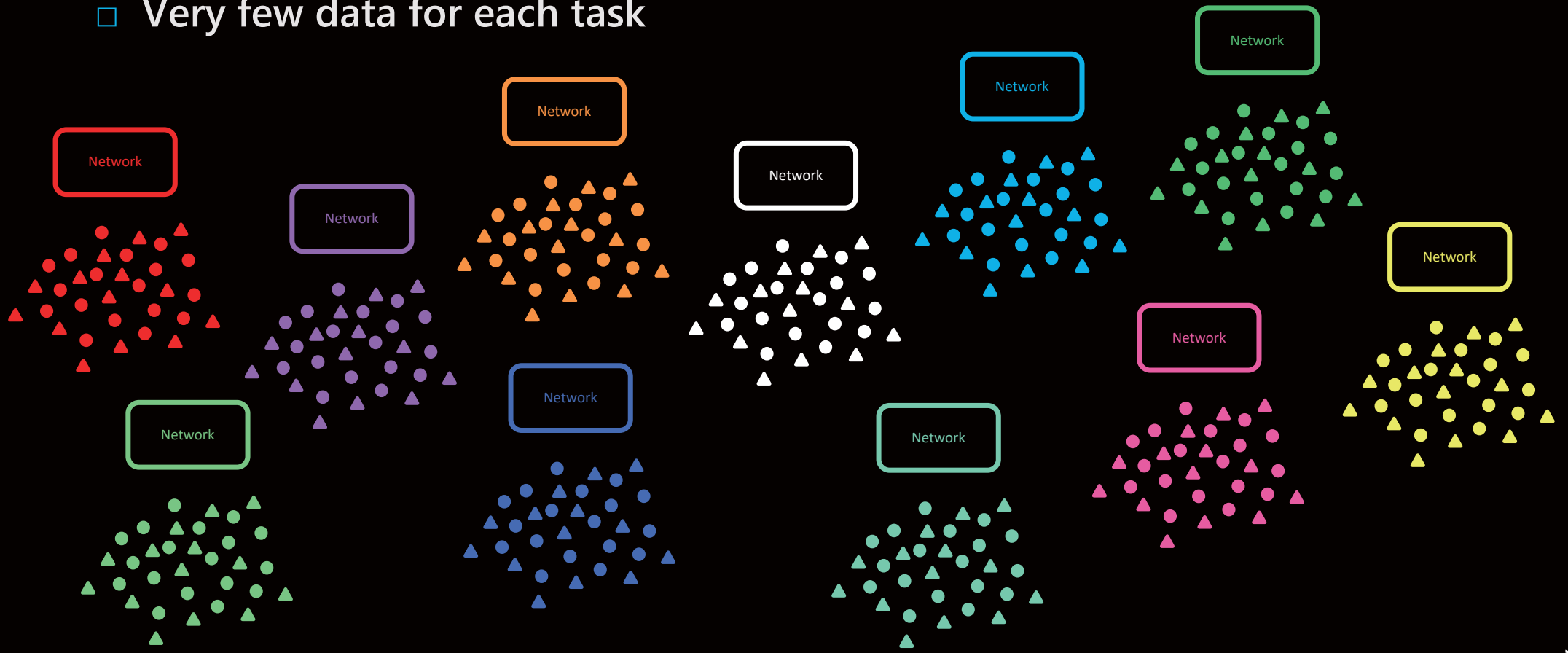
Motivation for Few-Shot Learning

- Standard Supervised Learning:
  - One network for each task
  - A large amount of data for each task



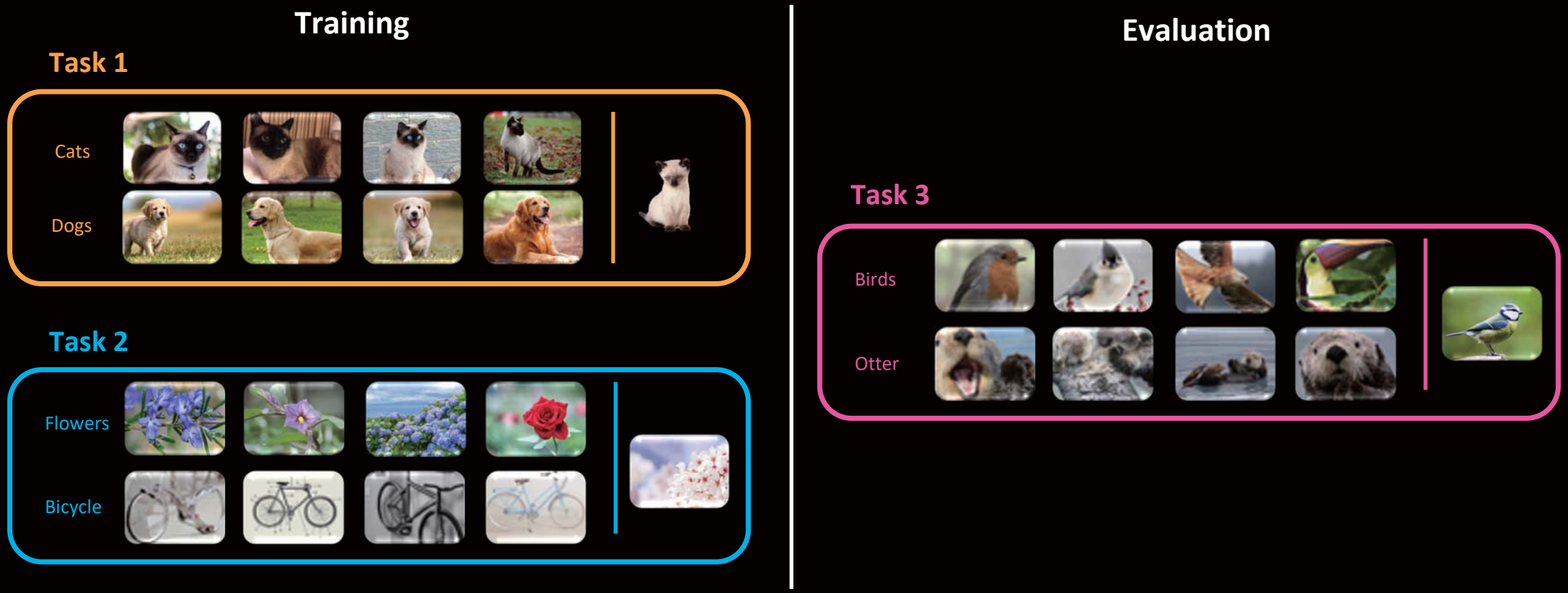
Motivation for Few-Shot Learning

- Few-Shot Learning:
  - Very few data for each task



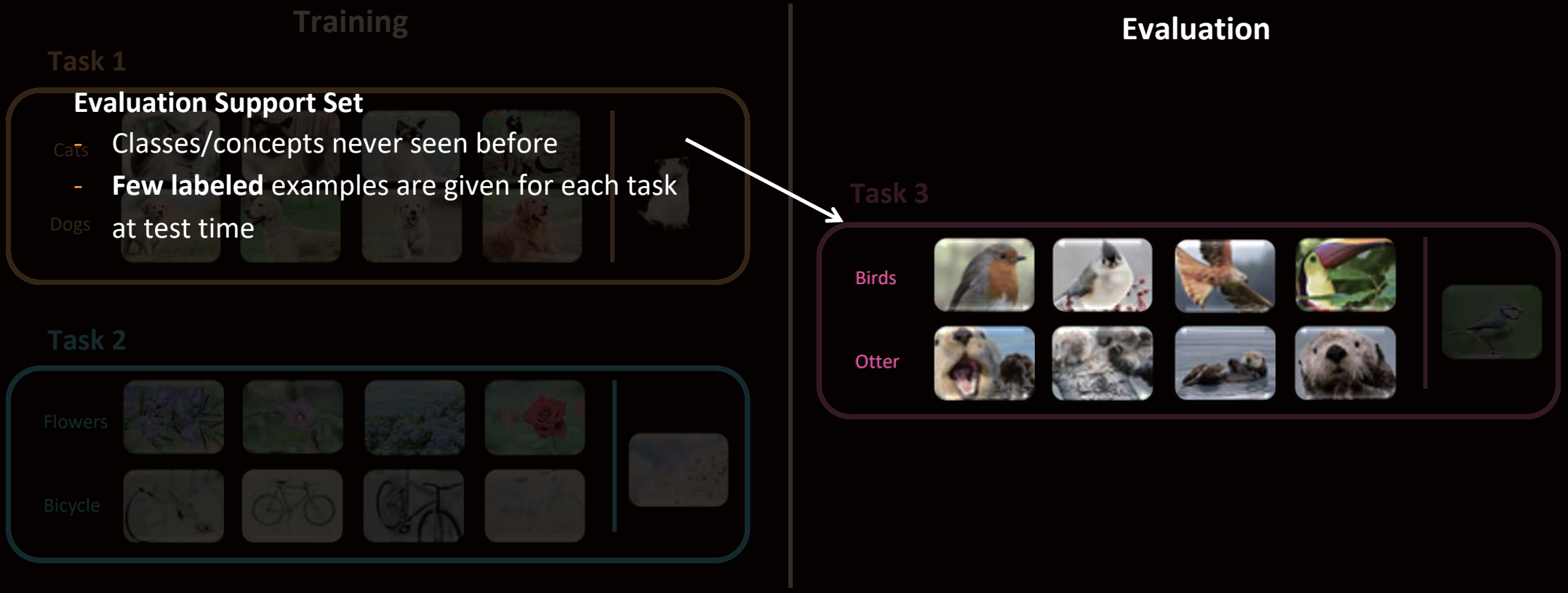
Motivation for Few-Shot Learning

- Few-shot learning (episodic) scenario



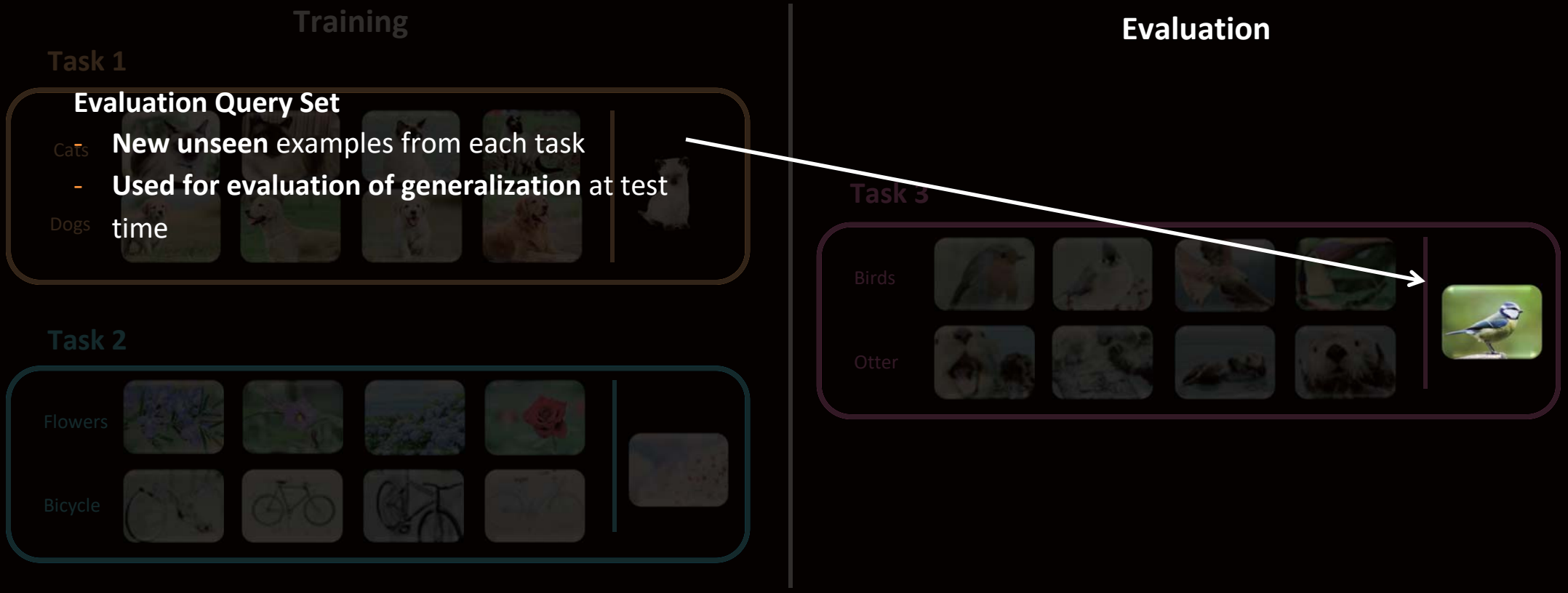
Motivation for Few-Shot Learning

- Few-shot learning (episodic) scenario



Motivation for Few-Shot Learning

- Few-shot learning (episodic) scenario



Motivation for Few-Shot Learning

- Few-shot learning (episodic) scenario

Training

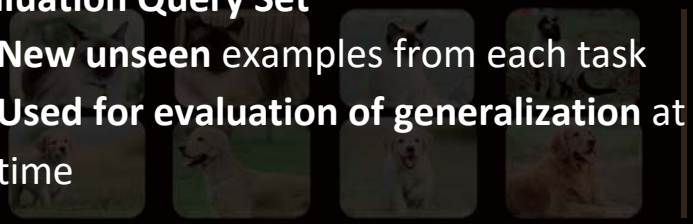
Task 1

Evaluation Query Set

- **New unseen** examples from each task
- **Used for evaluation of generalization** at test time

Cats

Dogs



Task 2

Flowers

Bicycle

Evaluation

Want accurate prediction on unseen example from new task

Task 3

Birds

Otter

>>

Motivation for Few-Shot Learning

- Few-shot learning (episodic) scenario

We aim to learn a meta-model that will find the network with few given examples for new task

Want a network to have accurate prediction on unseen example from new task

Training

Task 1

Evaluation Support Set

- Classes/concepts never seen before
- **Few labeled** examples are given for each task at test time

Cats

Dogs

Task 2

Flowers

Bicycle

Evaluation

θ

ϕ^*

ϕ^*

Task 3

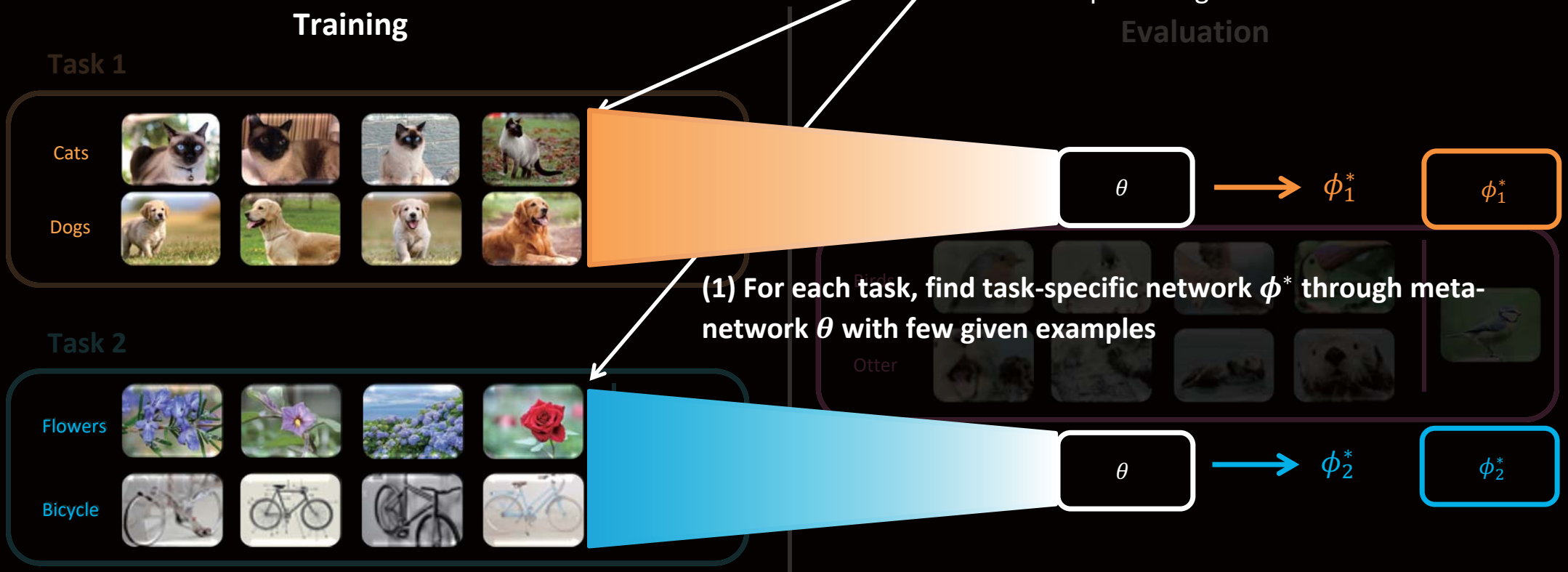
Birds

Otter

>>

Motivation for Few-Shot Learning

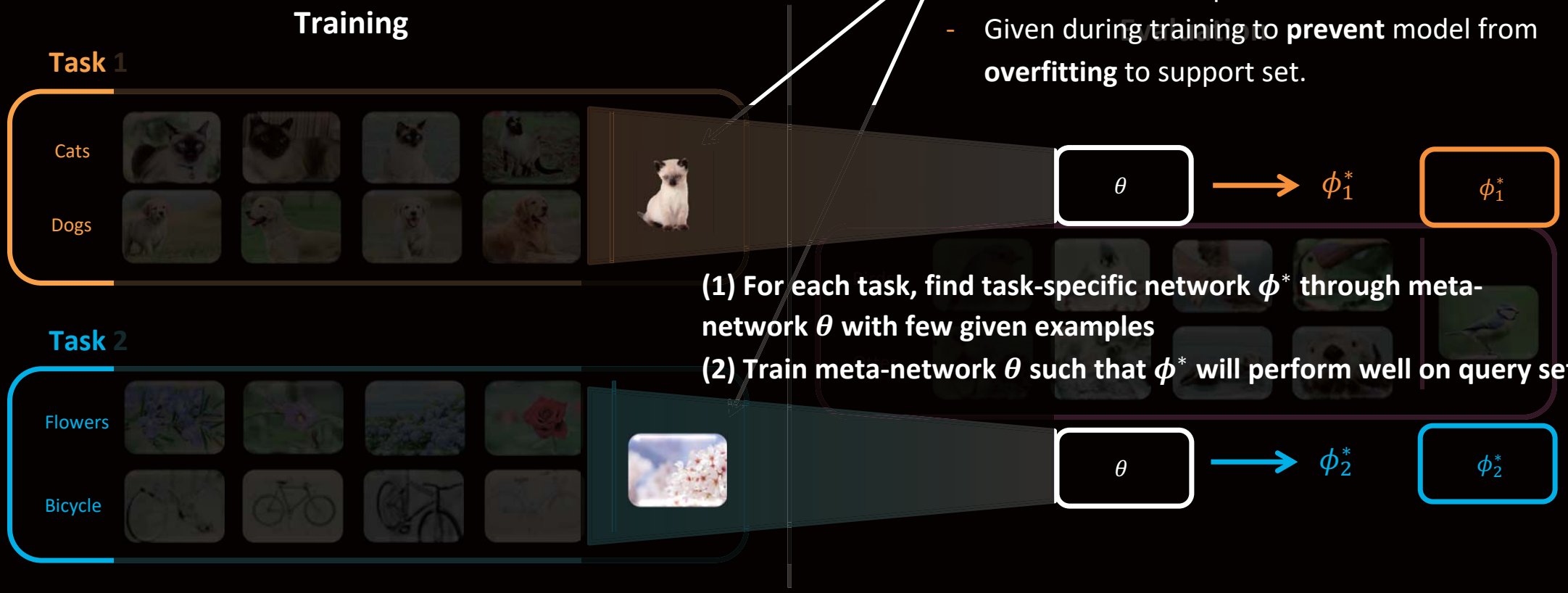
- Few-shot learning (episodic) scenario



>>

Motivation for Few-Shot Learning

- Few-shot learning (episodic) scenario



Training Query Set

- New unseen examples from the same task
- Given during training to **prevent** model from **overfitting** to support set.

(1) For each task, find task-specific network ϕ^* through meta-network θ with few given examples

(2) Train meta-network θ such that ϕ^* will perform well on query set

>>

Previous Solution for Few-Shot Learning?

- Supervised learning from scratch :
  - Given **few data** may be ***not enough***
  - High chance of overfitting
- Supervised learning from pre-trained network:

  -> need *careful* ***hyperparameter tuning***
  - When to stop finetuning?
  - What about learning rate?
  - Can we guarantee generalization?
  - Hinder prompt applications

>>

Why Meta-Learning for Few-Shot Learning?

- Meta-Learning for general tasks:

  Learn an optimization algorithm for each task

  - e.g. hyperparameters

  For each task,

  - Need long training time
  - Assume a lot of data

Why Meta-Learning for Few-Shot Learning?

- Meta-Learning for general tasks:

  Learn an optimization algorithm for each task

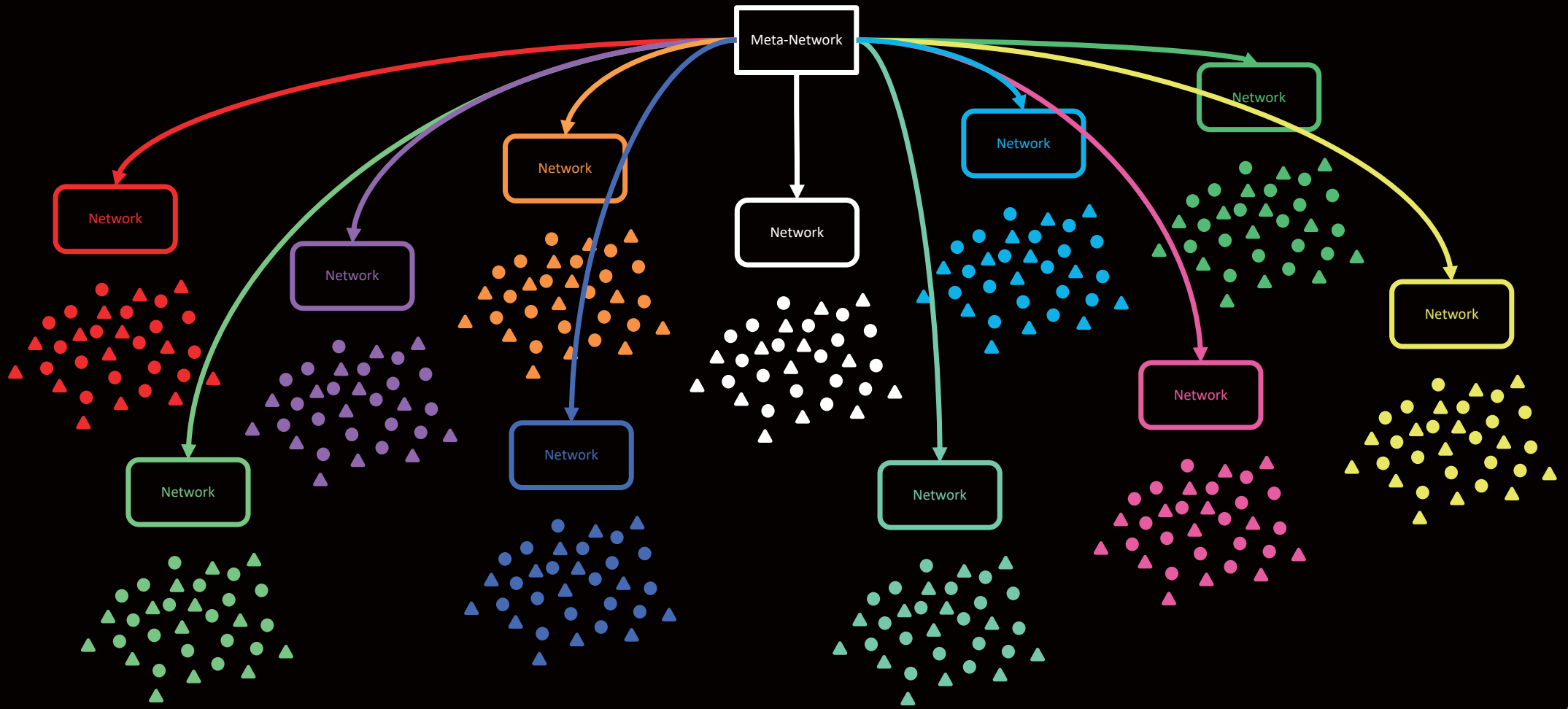
  - Need a lot of data & time for each task

- Meta-Learning for Few-Shot Learning

  Finding ***a good adaptation process*** that *works for all tasks*

  - Utilizes the knowledge shared among different tasks
  - Use the prior knowledge to facilitate adaptation to each task

Meta-Learning for Few-Shot Learning



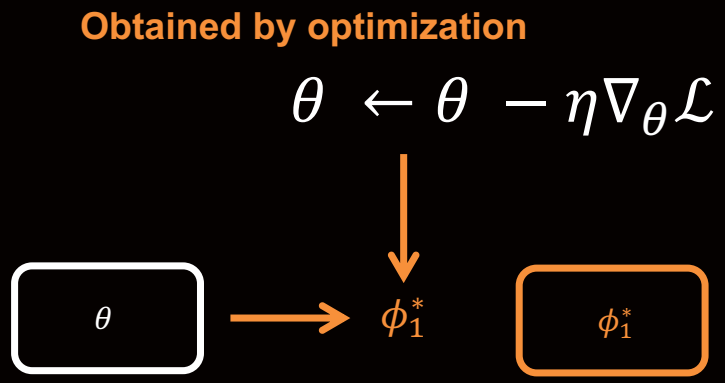
>>

Meta-Learning for Few-Shot Learning

- **Meta-Learning**
  - Learn to share the ***prior*** knowledge across tasks
  - Learn to use the prior knowledge to **quickly adapt to each task**
- **Metric-based**
- **Model-based (Blackbox approach)**
- **Optimization-based**

Meta-Learning for Few-Shot Learning

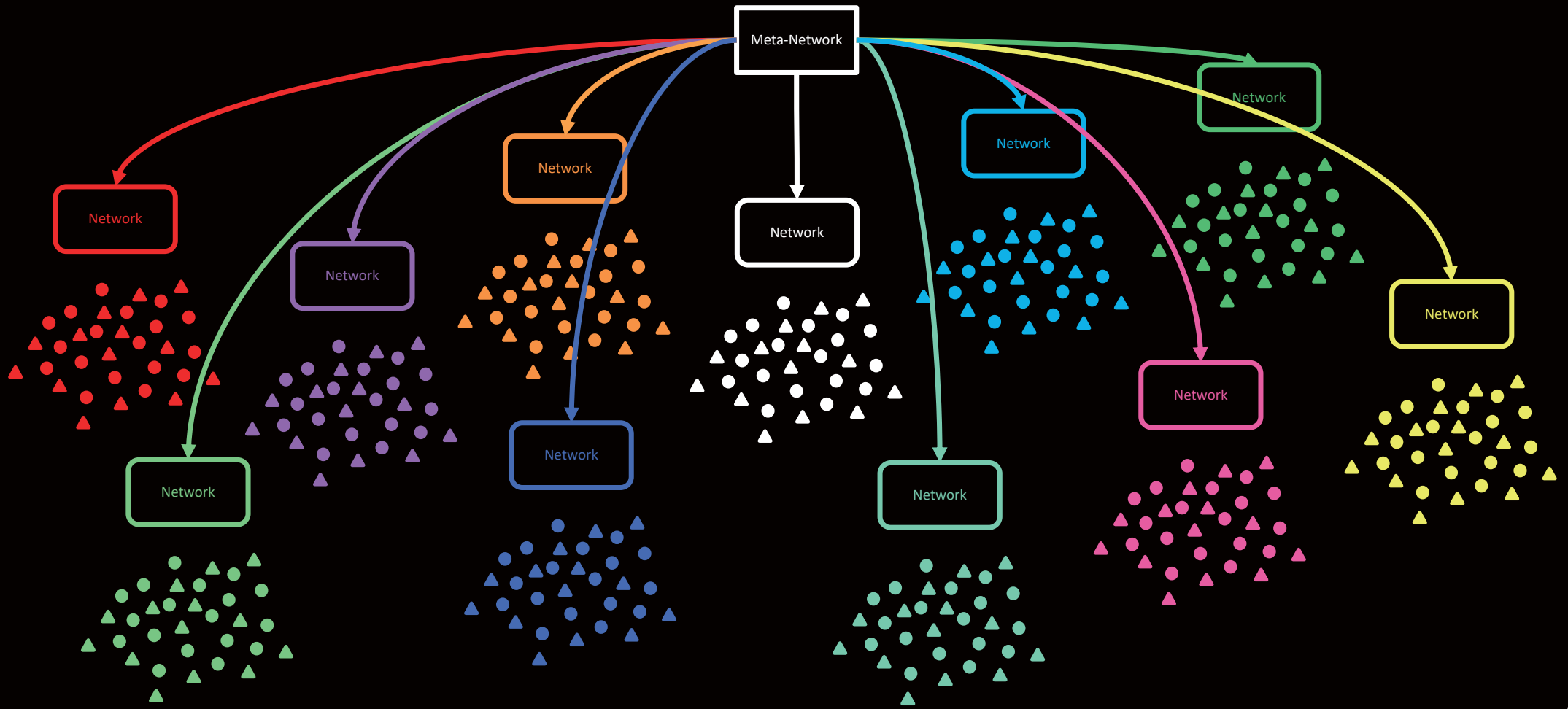
- **Meta-Learning**
  - Learn to share the ***prior*** knowledge across tasks
  - Learn to use the prior knowledge to **quickly adapt to each task**
- **Metric-based**
- **Model-based (Blackbox approach)**
- **Optimization-based**
  - **Adjust optimization** itself for fast adaptation
  - **Flexible, generalizable** across domains
  - **Relatively low performance**



Meta-Learning for Few-Shot Learning

- **Meta-Learning**
  - Learn to share the ***prior*** knowledge across tasks
  - Learn to use the prior knowledge to **quickly adapt to each task**
- **Metric-based**
- **Model-based (Blackbox approach)**
- **Optimization-based**
  - **Adjust optimization** itself for fast adaptation
  - **Flexible, generalizable** across domains
  - **Relatively low performance**

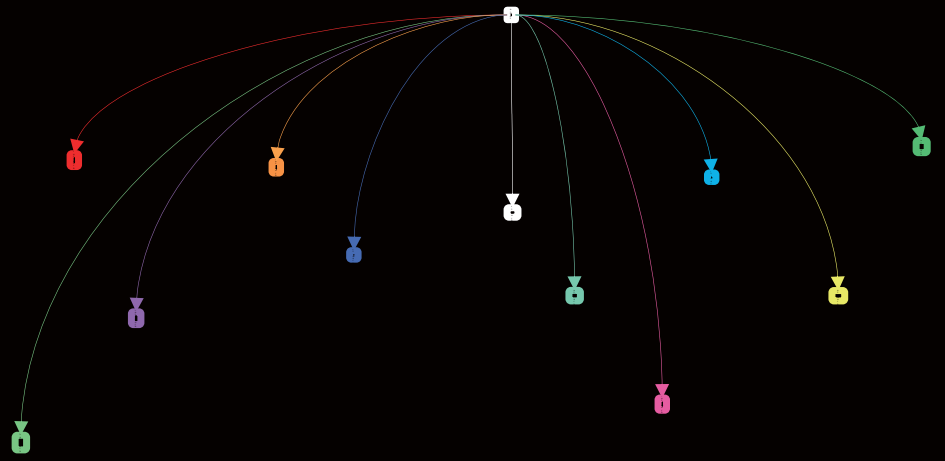
Meta-Learning for Few-Shot Learning



>>

Meta-Learning for Few-Shot Learning

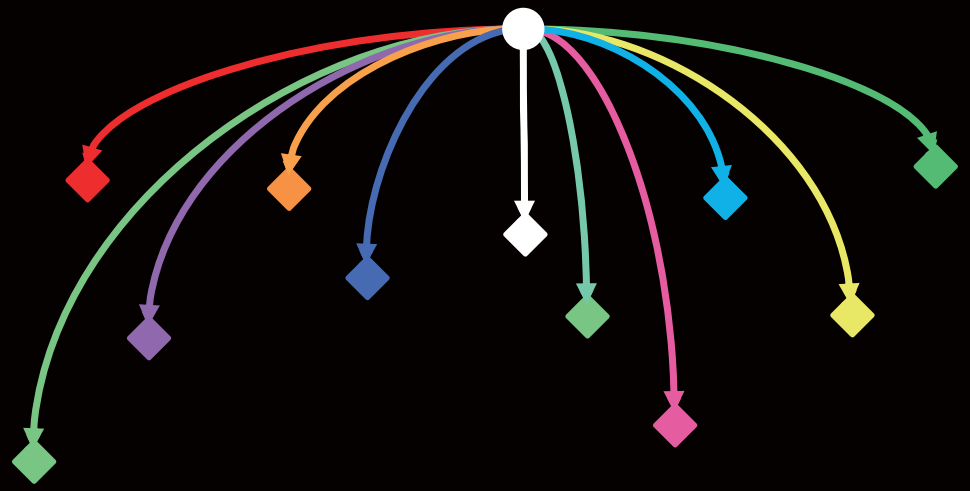
- One of widely used approaches:
- ***Model-Agnostic Meta-Learning (MAML)***
  - Meta-model: initialization



Meta-Learning for Few-Shot Learning

- One of widely used approaches:
- ***Model-Agnostic Meta-Learning (MAML)***
  - Meta-model: initialization
- Optimization process:

$$\theta_i' = \theta - \alpha \nabla_\theta \mathcal{L}(\theta, \mathcal{D}_i)$$



>>

Meta-Learning for Few-Shot Learning

- Adaptation process is ***fixed*** and ***shared*** for all tasks

- Tasks are diverse

  -> each task may prefer different adaptation process

Why *Task-Adaptive* Meta-Learning for Few-Shot Learning?

- Adaptation process is ***fixed*** and ***shared*** for all tasks

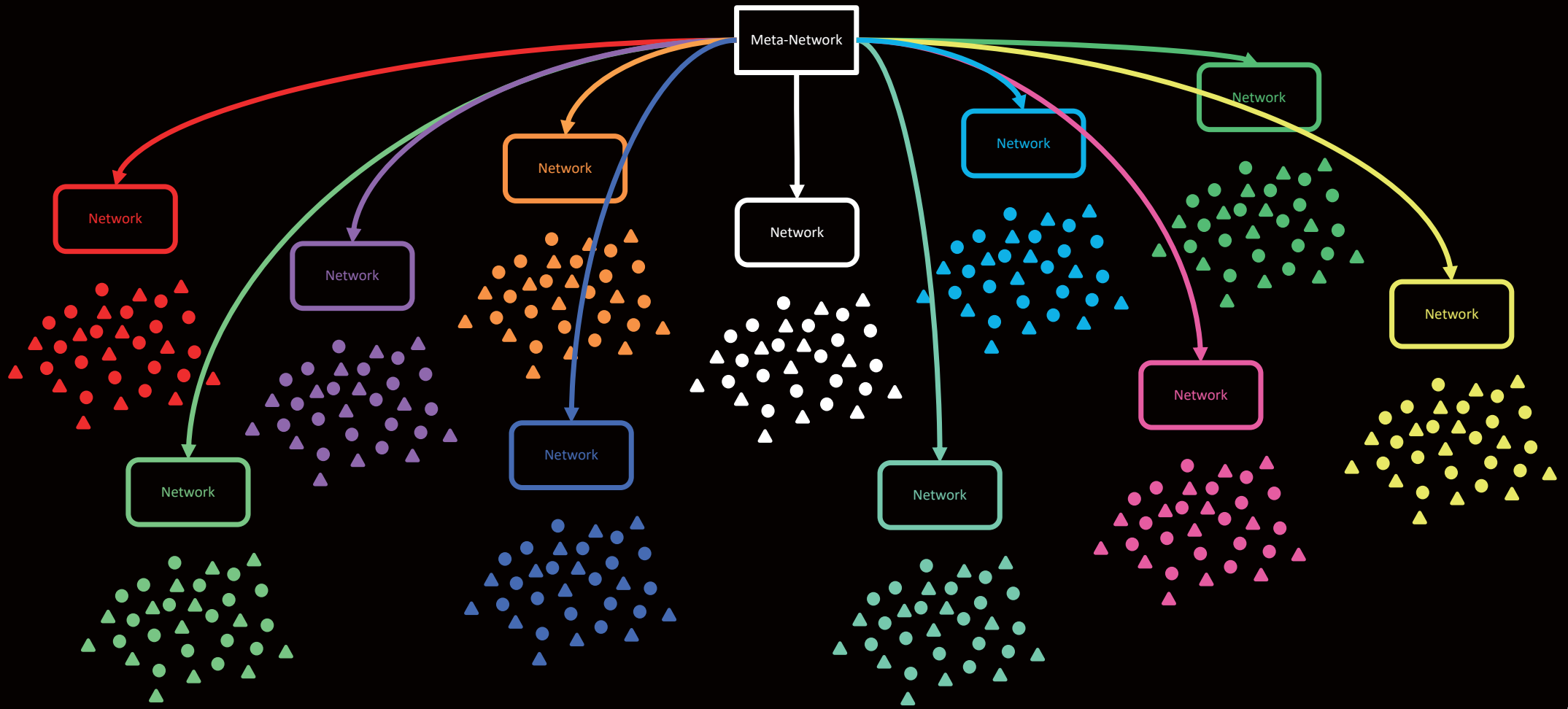
- Tasks are diverse

  -> each task may prefer different adaptation process

- Main question:

  Can we utilize prior knowledge to ***adapt an adaptation process*** to each given task?

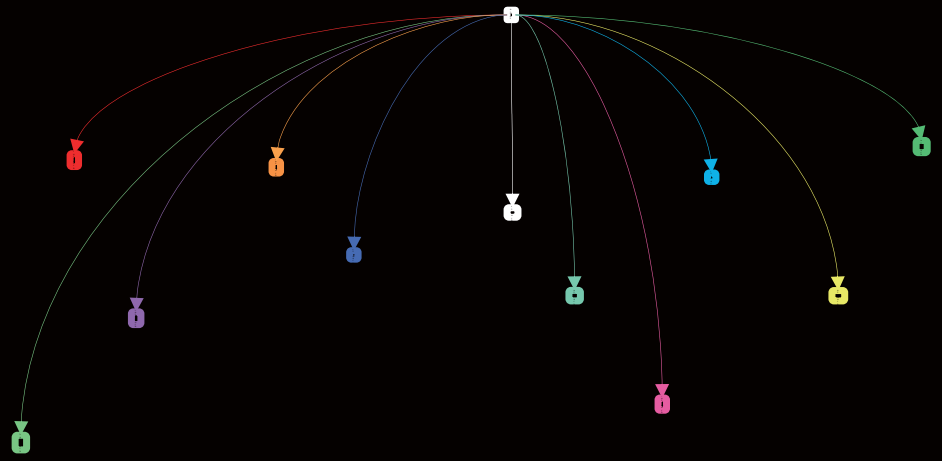
Meta-Learning for Few-Shot Learning



>>

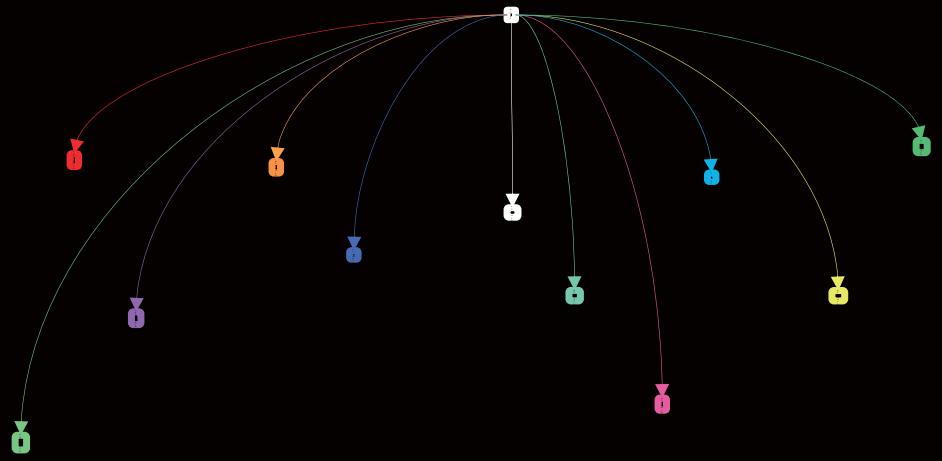
Task-Adaptive Meta-Learning for Few-Shot Learning

- Main question:
- ***adapt an adaptation process*** to each given task?



Task-Adaptive Meta-Learning for Few-Shot Learning

- Main question:
- ***adapt optimization*** to each given task?

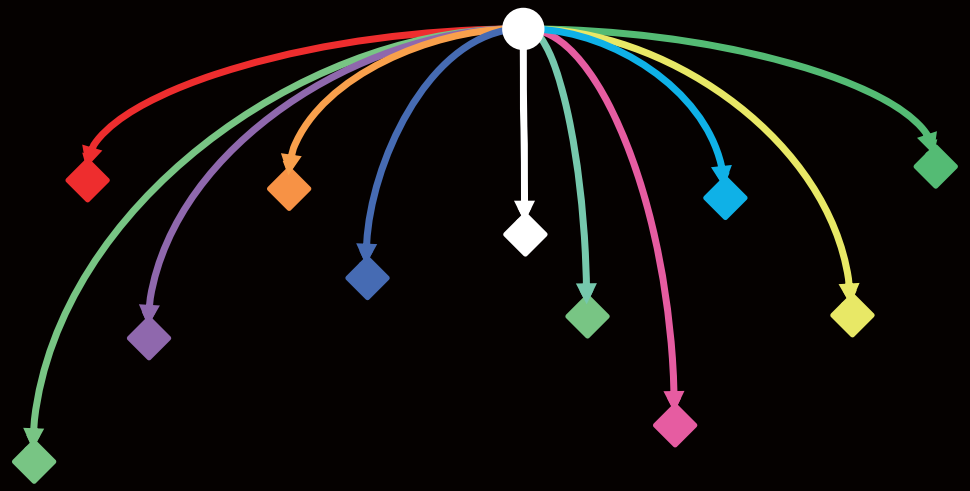


Task-Adaptive Meta-Learning for Few-Shot Learning

- Main question:
- ***adapt optimization*** to each given task?
- Optimization process:

$$\theta_i' = \theta - \alpha \nabla_\theta \mathcal{L}(\theta, \mathcal{D}_i)$$

- Initialization
- Loss function
- Update rule



Task-Adaptive Meta-Learning for Few-Shot Learning

$$\theta_i' = \theta - \alpha \nabla_\theta \mathcal{L}(\theta, \mathcal{D}_i)$$

Task-Adaptive Meta-Learning for Few-Shot Learning

$$\theta_i' = \theta_i - \alpha_i \nabla_\theta \mathcal{L}_i(\theta, \mathcal{D}_i)$$

Task-Adaptive | **Initialization**

Task-Adaptive | **Update Rule**

Task-Adaptive | **Loss Function**

Integration & | **Applications**

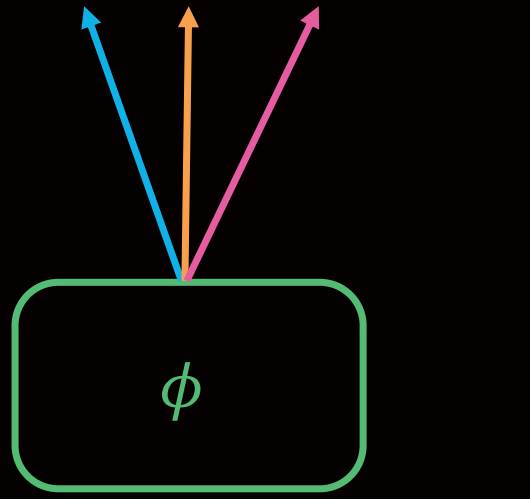
>>

Integration & Applications

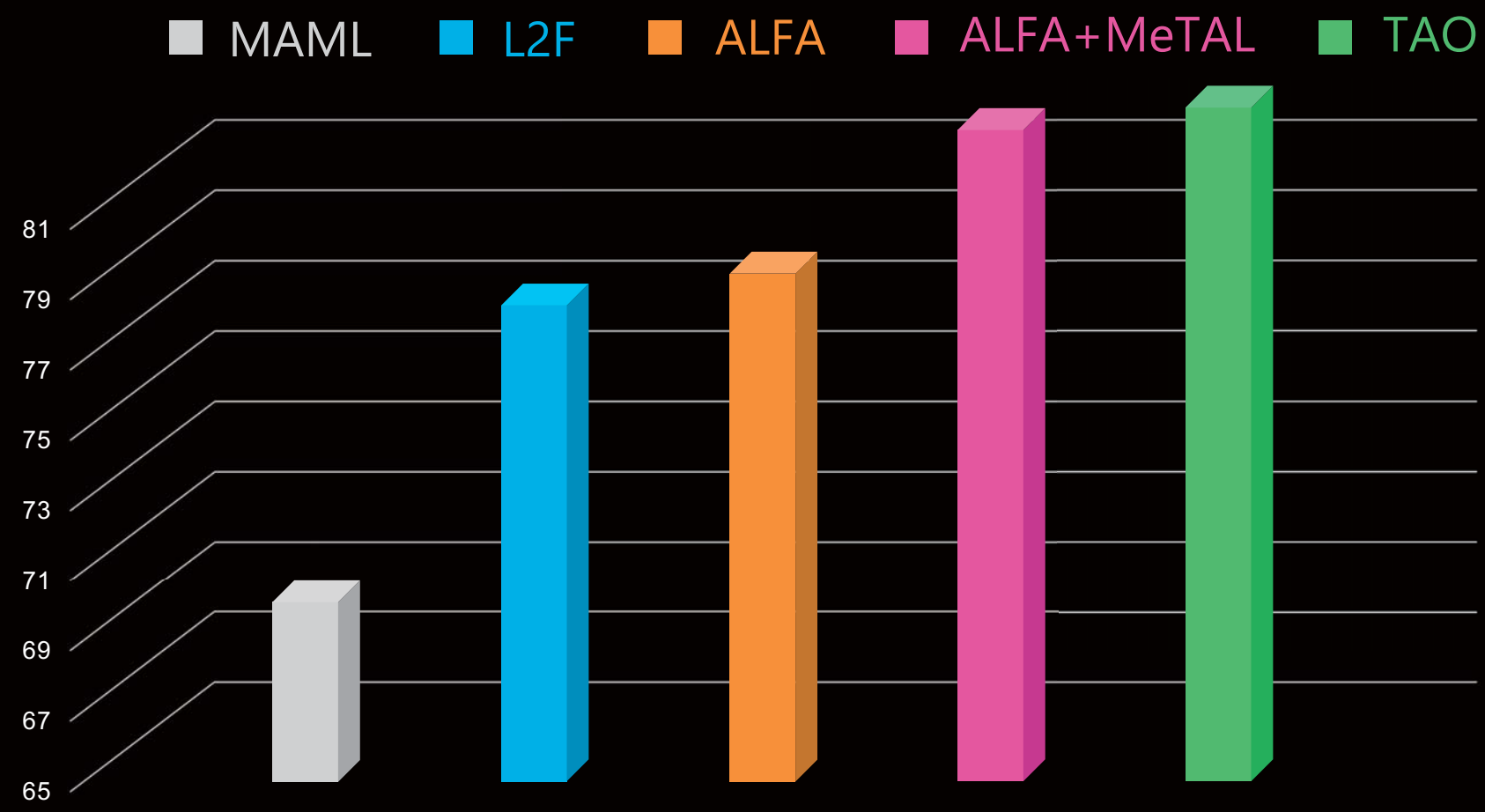
Integration

- **Task-Adaptive Optimization (TAO)**
  - Combine all three proposed modules into one

$$\theta_i' = \theta_i - \alpha_i \nabla_\theta \mathcal{L}_i(\theta, \mathcal{D}_i)$$



Few-Shot Classification

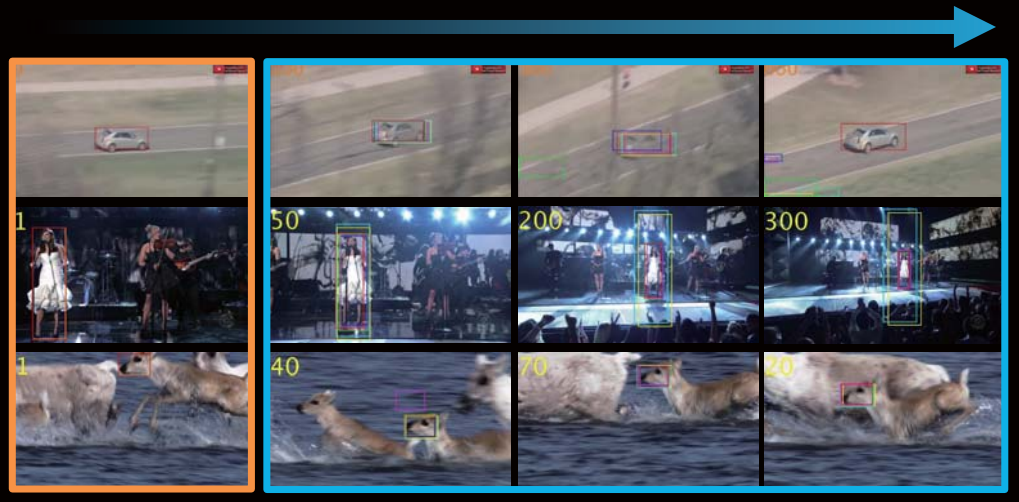


Computer Vision Applications

- **During inference, new test image may provide new information that was not present during training**
- **Idea: Use meta-learning to adapt the network to new test image**
- **Challenge: Need to obtain (few) supervision signals meta-learning can use**

Computer Vision Applications

- **Visual Tracking**
  - **Goal:** Estimate target object state in consecutive video frames
  - **Input:** Initial target state, RGB frame image
  - **Output:** Target bounding boxes in every frame



Practical Applications

- **Visual Tracking**

Practical Applications

- **Video Frame Interpolation**
  - **Goal:** Given low frame-rate input video

Practical Applications

- **Video Frame Interpolation**
  - **Goal:** Given low frame-rate input video, synthesize intermediate frames

>>

Practical Applications

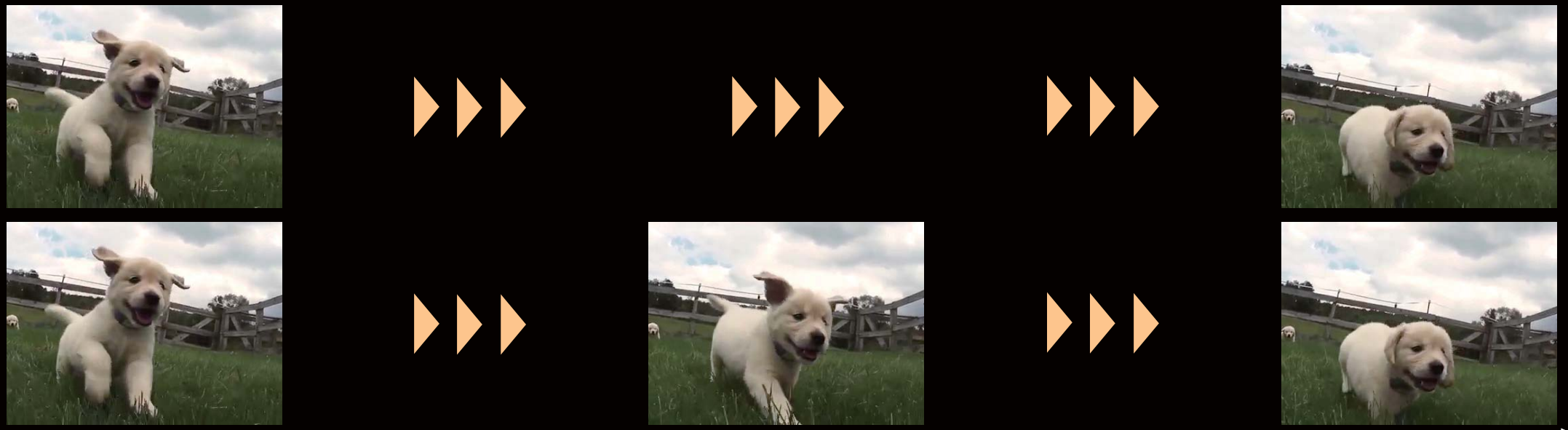
- **Video Frame Interpolation**
  - **Goal:** Given low frame-rate input video, synthesize intermediate frames
  - Idea: Create few-shot examples by lowering input frames
    - (e.g., 30fps → 15fps)

Practical Applications

- **Video Frame Interpolation**
  - **Goal:** Given low frame-rate input video, synthesize intermediate frames
  - Idea: Create few-shot examples by lowering input frames
    - (e.g., 30fps → 15fps)

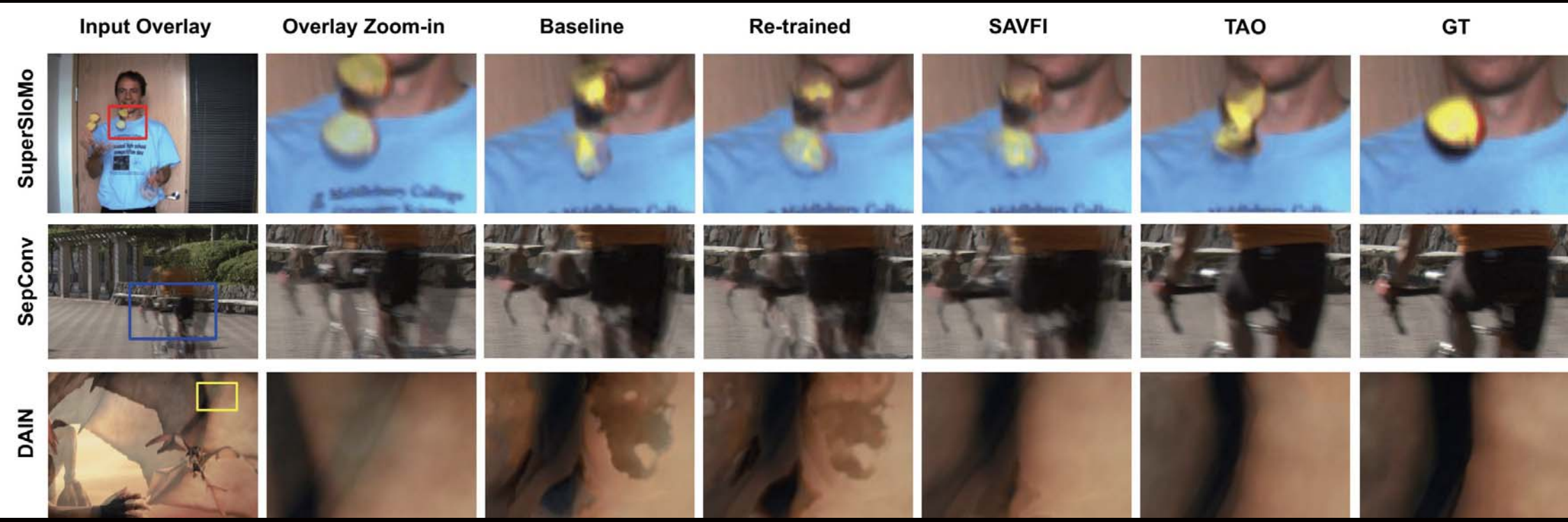
Practical Applications

- **Video Frame Interpolation**
  - **Goal:** Given low frame-rate input video, synthesize intermediate frames
  - Idea: Create few-shot examples by lowering input frames
    - (e.g., 30fps → 15fps)



Practical Applications

- **Video Frame Interpolation**
  - **SAVFI [15]**



[15] Choi et al., “Scene-Adaptive VIdeo Frame Interpolation via Meta-Learning”, CVPR 2020

Practical Applications

- **Video Frame Interpolation**

Thank you

https://dsybaik-hy.github.io

>>