



heuritech



SCIENCES  
SORBONNE  
UNIVERSITÉ

# INSIGHTS FROM THE FUTURE FOR CONTINUAL LEARNING

CVPR CLVISION WORKSHOP 2021

Arthur Douillard, *Sorbonne Université & Heuritech*

Eduardo Valle, *University of Campinas*

Charles Ollion, *CMAP École Polytechnique & Heuritech*

Thomas Robert, *Heuritech*

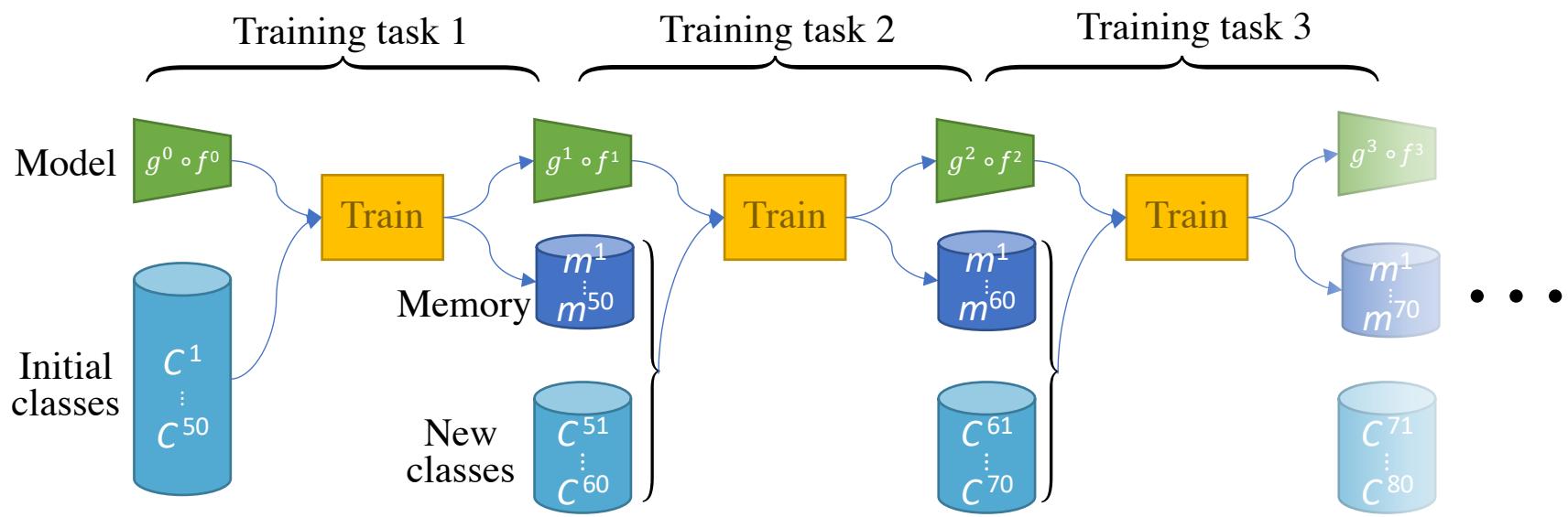
Matthieu Cord, *Sorbonne Université & Valeo.ai*



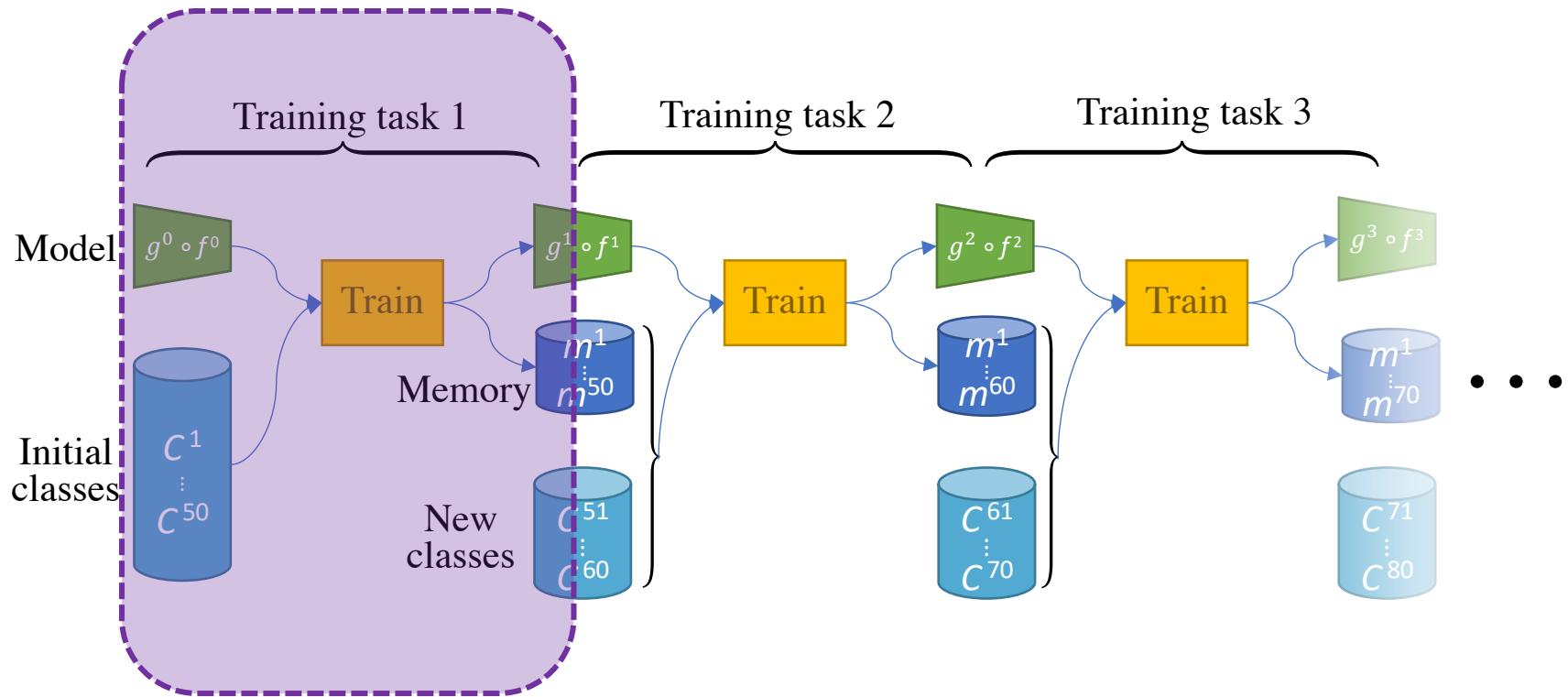
Machine Learning &  
Deep Learning for  
Information Access

# Prescient Continual Learning

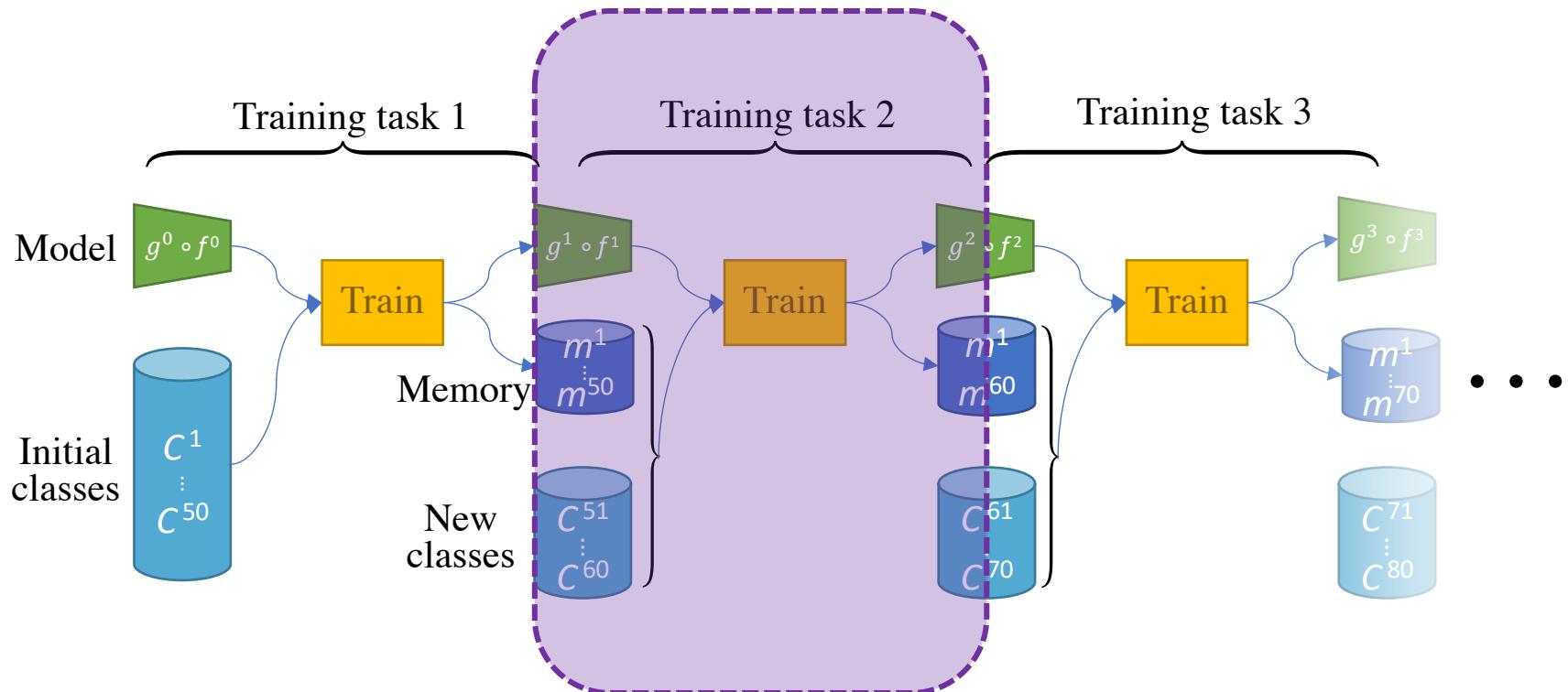
# Selflessness



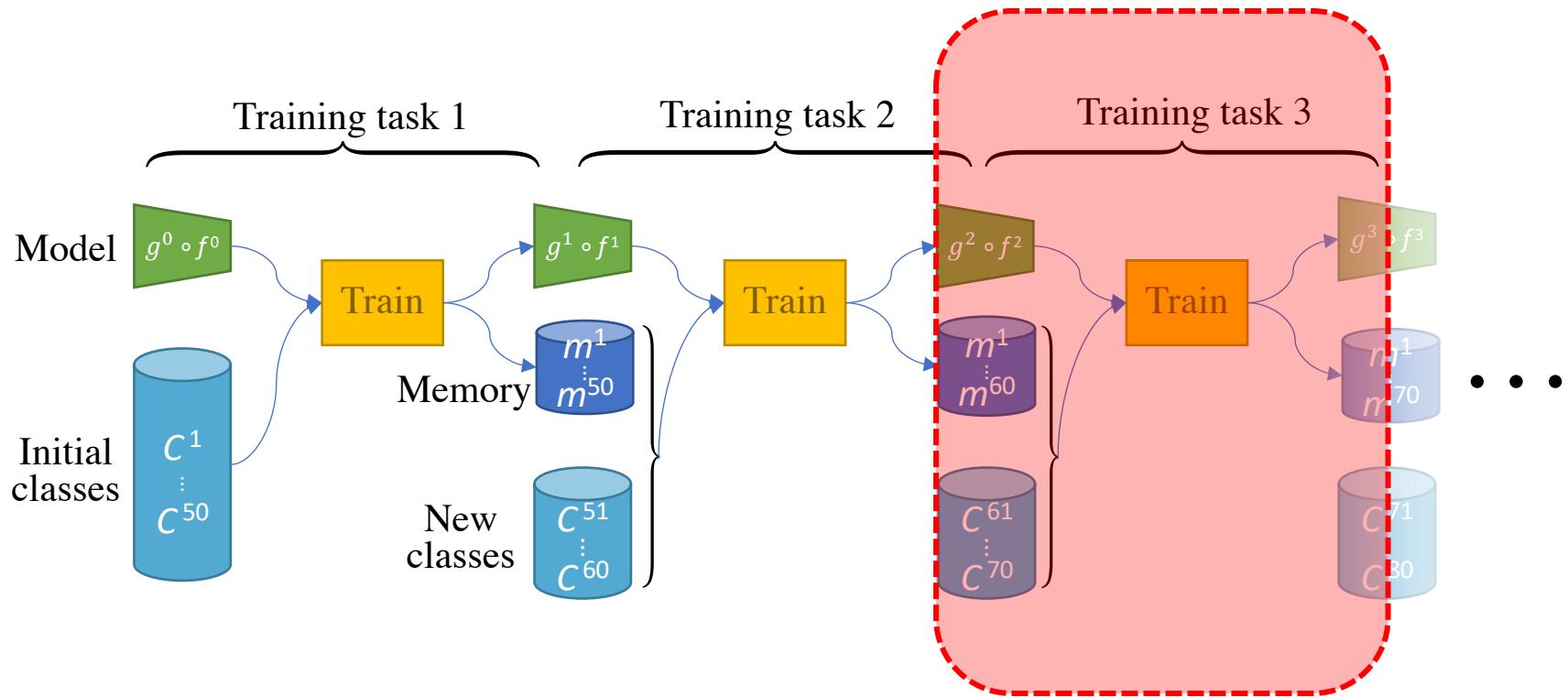
# Selflessness



# Selflessness



# Selflessness



Hard to adapt to new classes without forgetting

# Selfless Network

## Selfless Network:

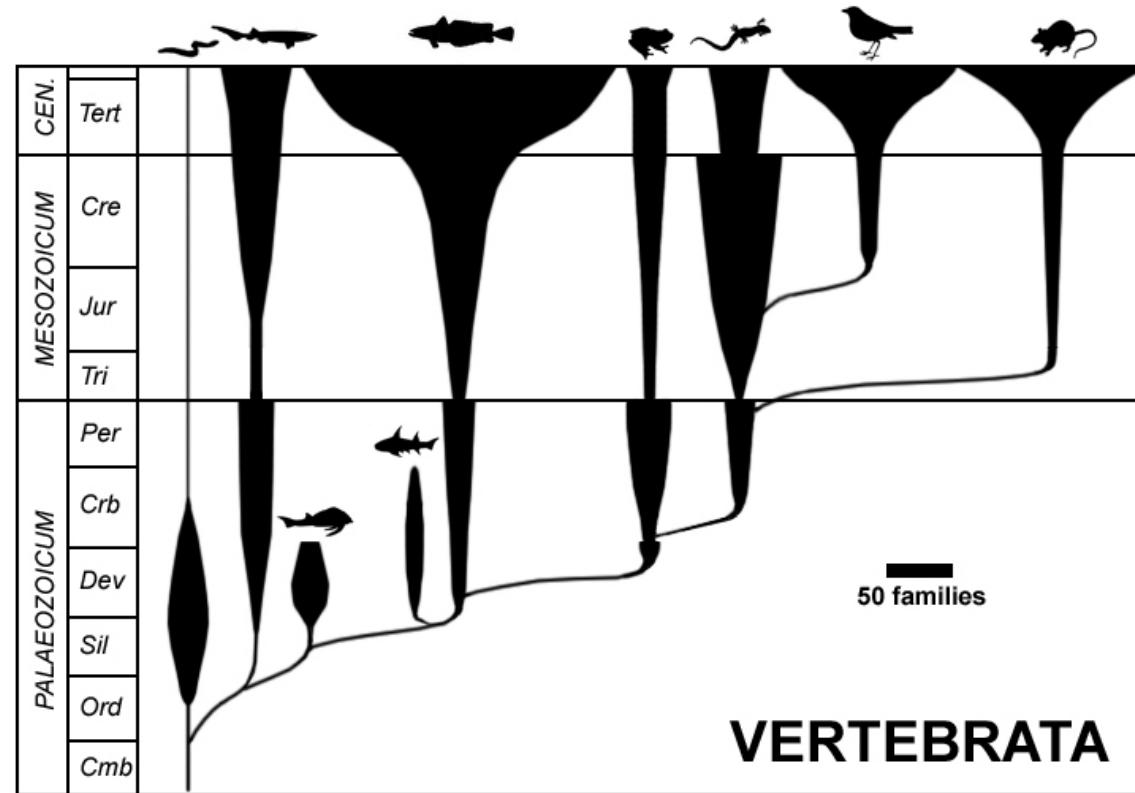
*A network leaving enough capacity to learn new classes.*

# Insights from the Future

What if we could have a prior on the future?

# Future's priors

**Phylogenetic-like tree** of the different classes to be learned  
e.g. *ImageNet, iNaturalist...*



# Future's priors

World knowledge from **word embeddings** trained on encyclopedias  
*e.g. word2vec from Wikipedia*

Not logged in Talk Contributions Create account Log in

Article Talk Read View source View history Search Wikipedia

 WIKIPEDIA The Free Encyclopedia

**Cat**

From Wikipedia, the free encyclopedia

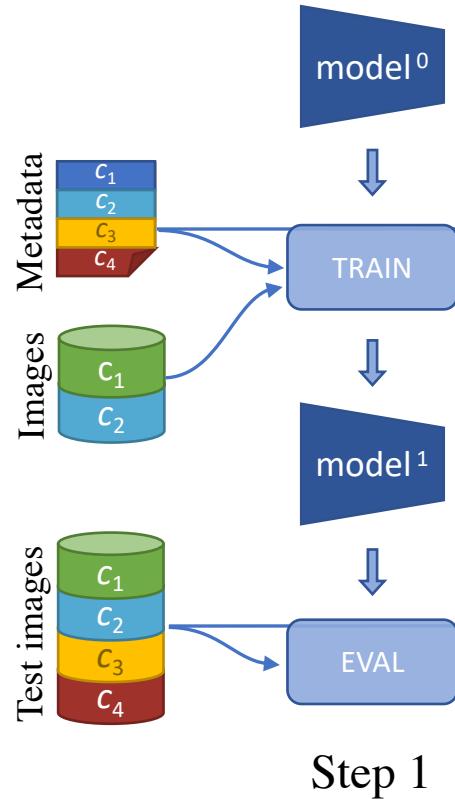
*This article is about the species that is commonly kept as a pet. For the cat family, see [Felidae](#). For other uses, see [Cat \(disambiguation\)](#) and [Cats \(disambiguation\)](#).*

The **cat** (*Felis catus*) is a [domestic species](#) of small [carnivorous mammal](#).<sup>[1][2]</sup> It is the only domesticated species in the family [Felidae](#) and is often referred to as the **domestic cat** to distinguish it from the wild members of the family.<sup>[4]</sup> A cat can either be a **house cat**, a **farm cat** or a **feral cat**; the latter ranges freely and avoids human contact.<sup>[5]</sup> Domestic cats are valued by humans for companionship and their ability to hunt [rodents](#). About 60 [cat breeds](#) are recognized by various [cat registries](#).<sup>[6]</sup>

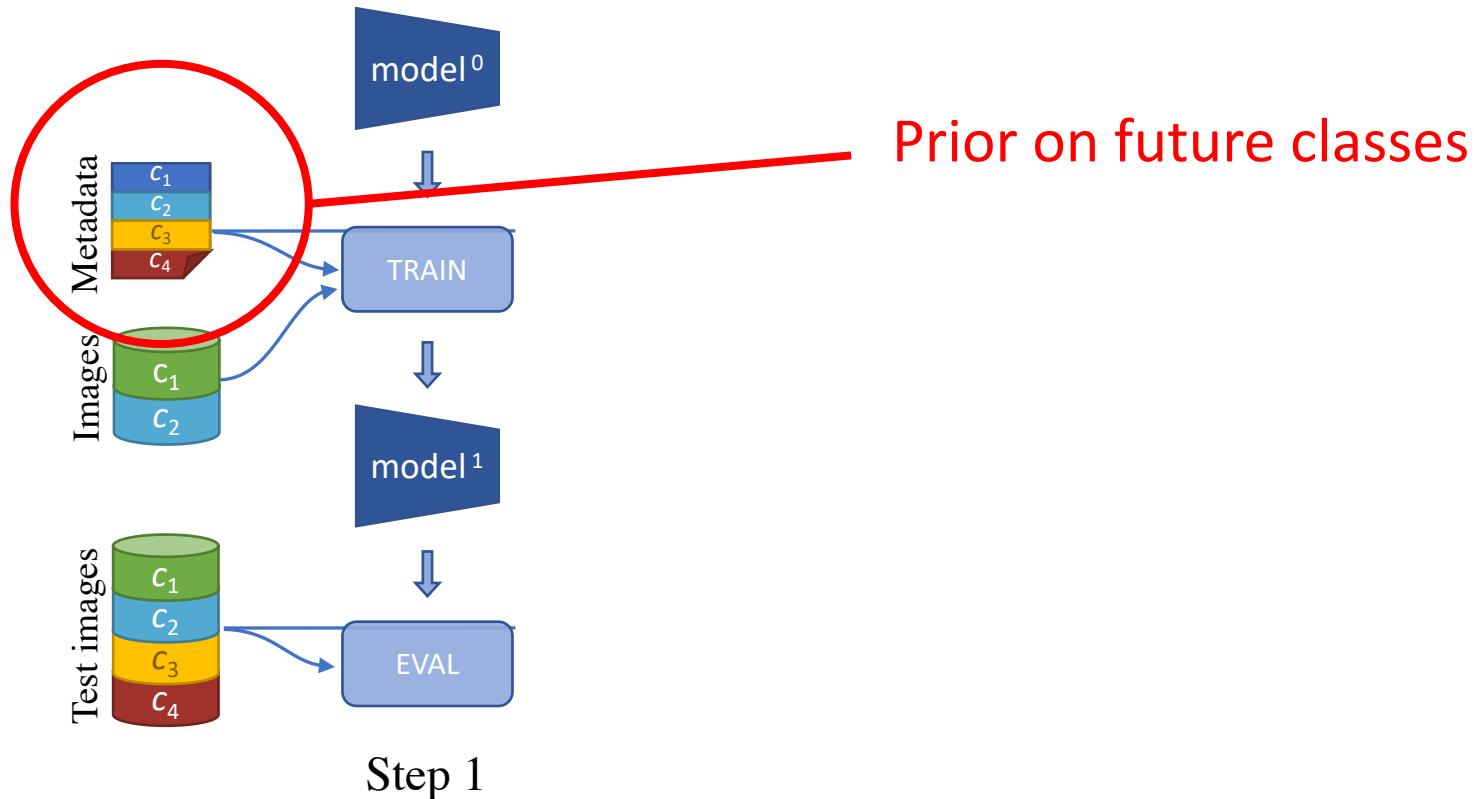
**Domestic cat**



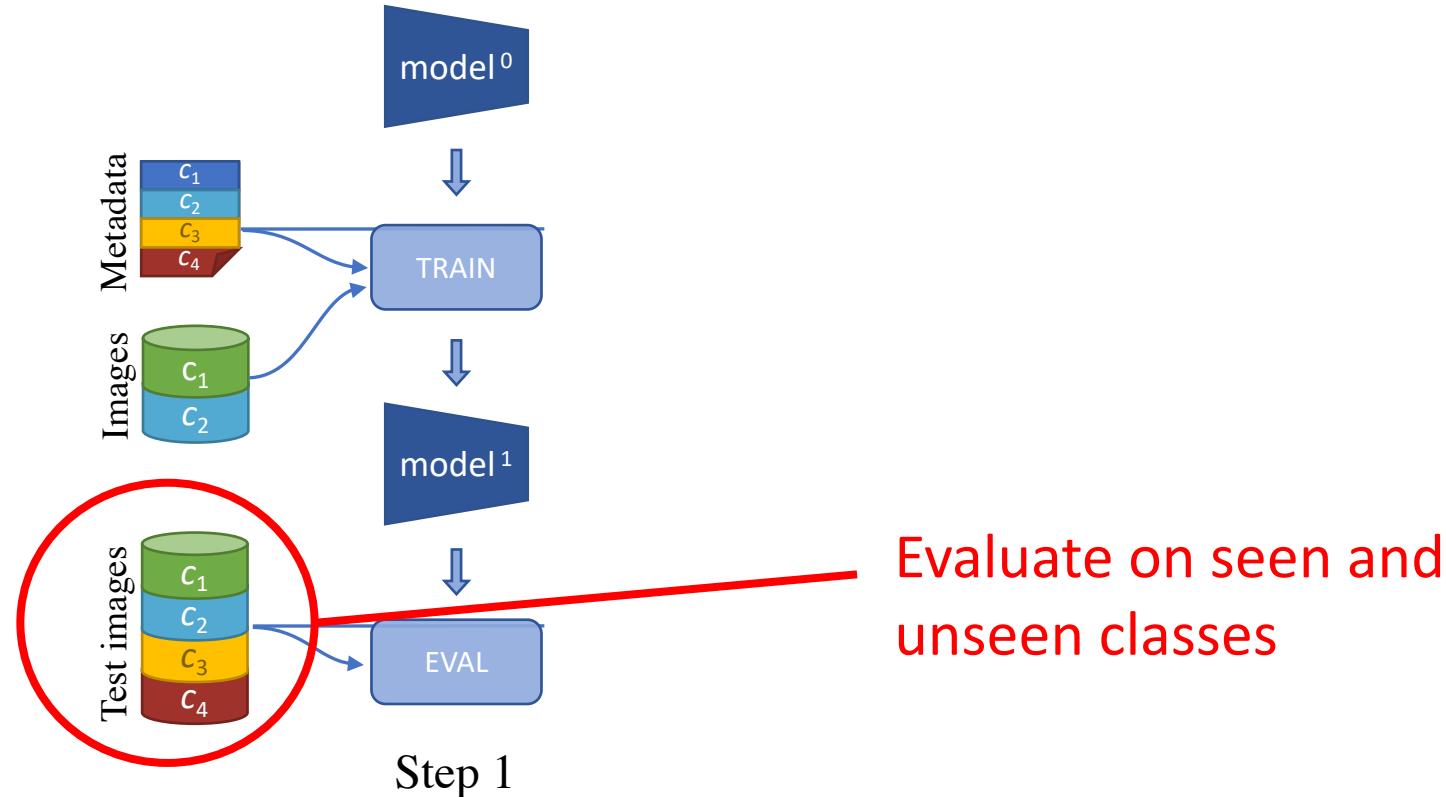
# Prescient Continual Learning



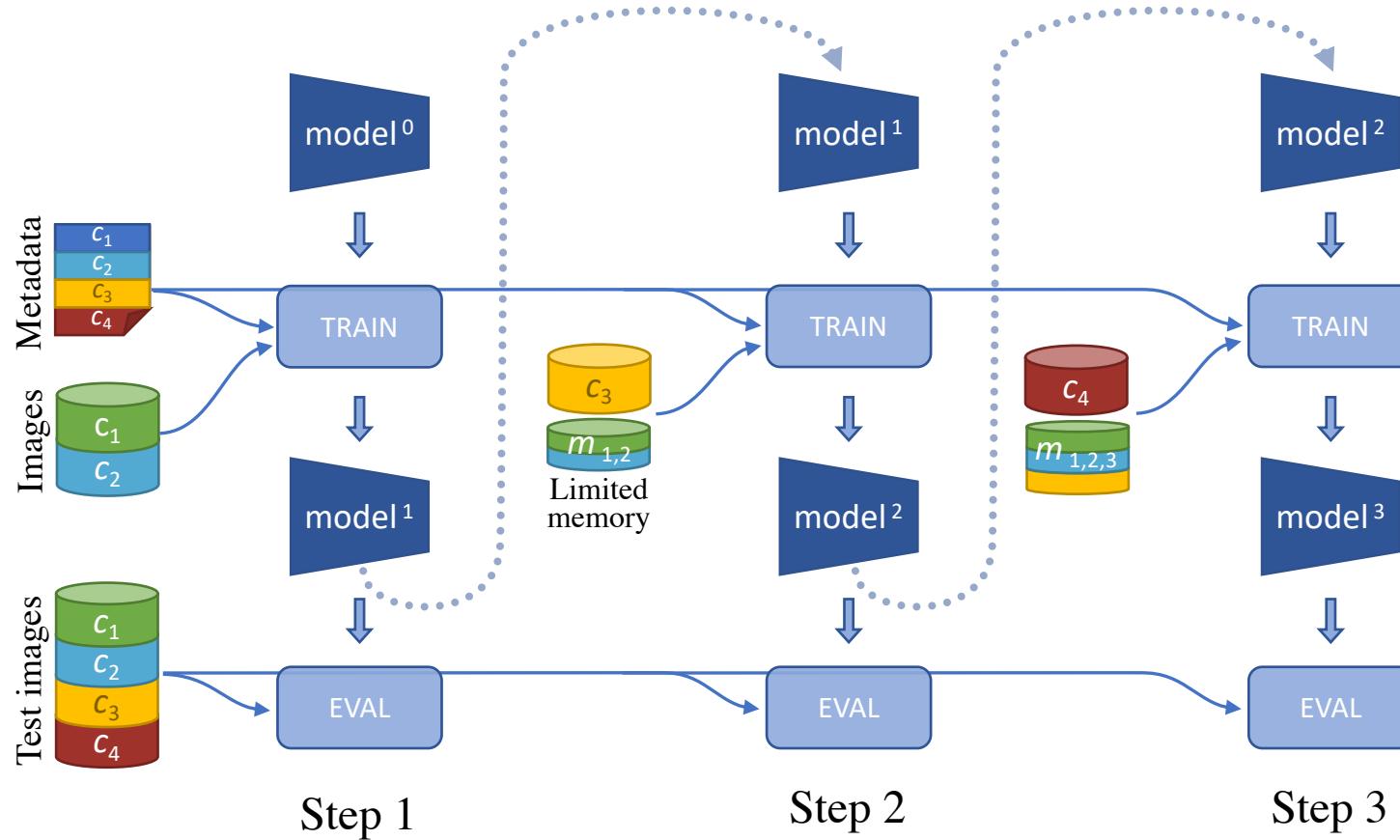
# Prescient Continual Learning



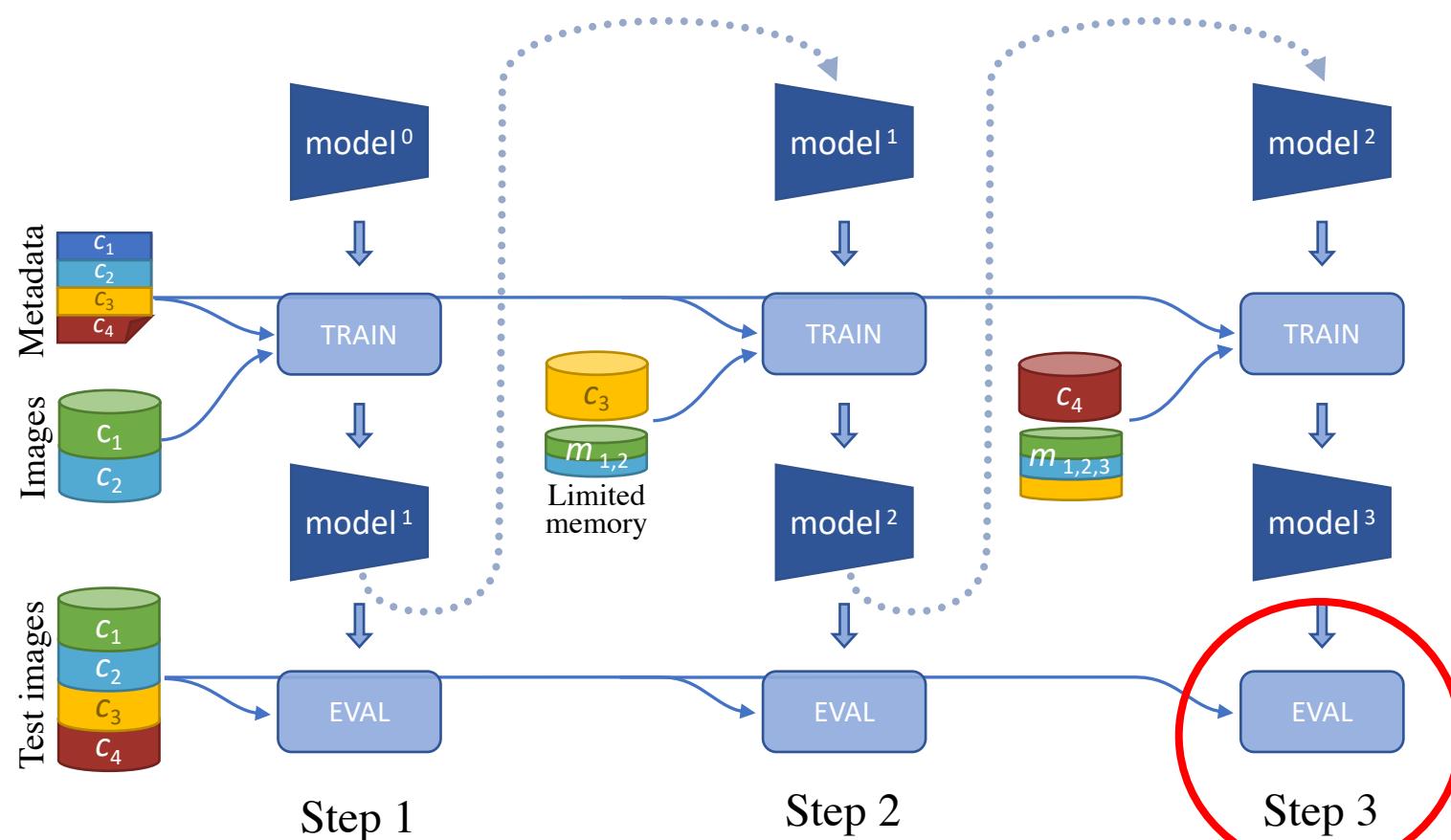
# Prescient Continual Learning



# Prescient Continual Learning



# Prescient Continual Learning



Only seen classes at the end

# Ghost Strategy

# General Strategy

1. Train on task  $T_1$
2. For all task  $T_{i>1}$ :
  1. Train features generator
  2. Generate fake unseen classes
  3. Train with real and fake features
  4. Eval on all classes

# General Strategy

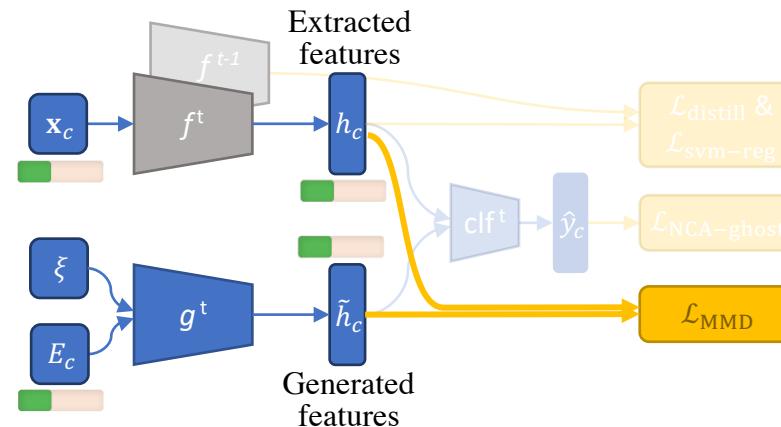
- 1. Train on task  $T_1$**
2. For all task  $T_{i>1}$ :
  1. Train features generator
  2. Generate fake unseen classes
  3. Train with real and fake features
  4. Eval on all classes

# General Strategy

1. Train on task  $T_1$
2. For all task  $T_{i>1}$ :
  1. **Train features generator**
  2. Generate fake unseen classes
  3. Train with real and fake features
  4. Eval on all classes

# Feature Generation

Legend:  Trained  Frozen Indicate if  $c$  belong to  $\left\{ \begin{array}{l} \text{“Seen” classes } (C^{1:t}) \\ \text{“Unseen” classes } (C^{t+1:T}) \\ \text{Both} \end{array} \right.$



## Generative Moment Matching Network

generating **fake features** from metadata

to mimick real features of **seen classes**

# General Strategy

1. Train on task  $T_1$
2. For all task  $T_{i>1}$ :
  1. Train features generator
  2. **Generate fake unseen classes**
  3. Train with real and fake features
  4. Eval on all classes

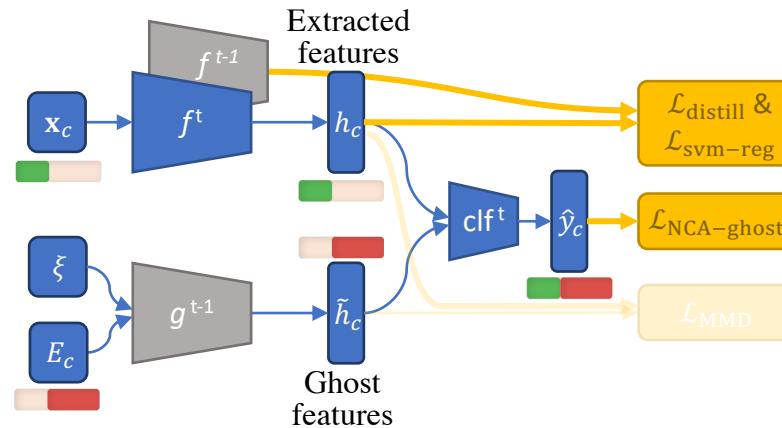
# General Strategy

1. Train on task  $T_1$
2. For all task  $T_{i>1}$ :
  1. Train features generator
  2. Generate fake unseen classes
  - 3. Train with real and fake features**
  4. Eval on all classes

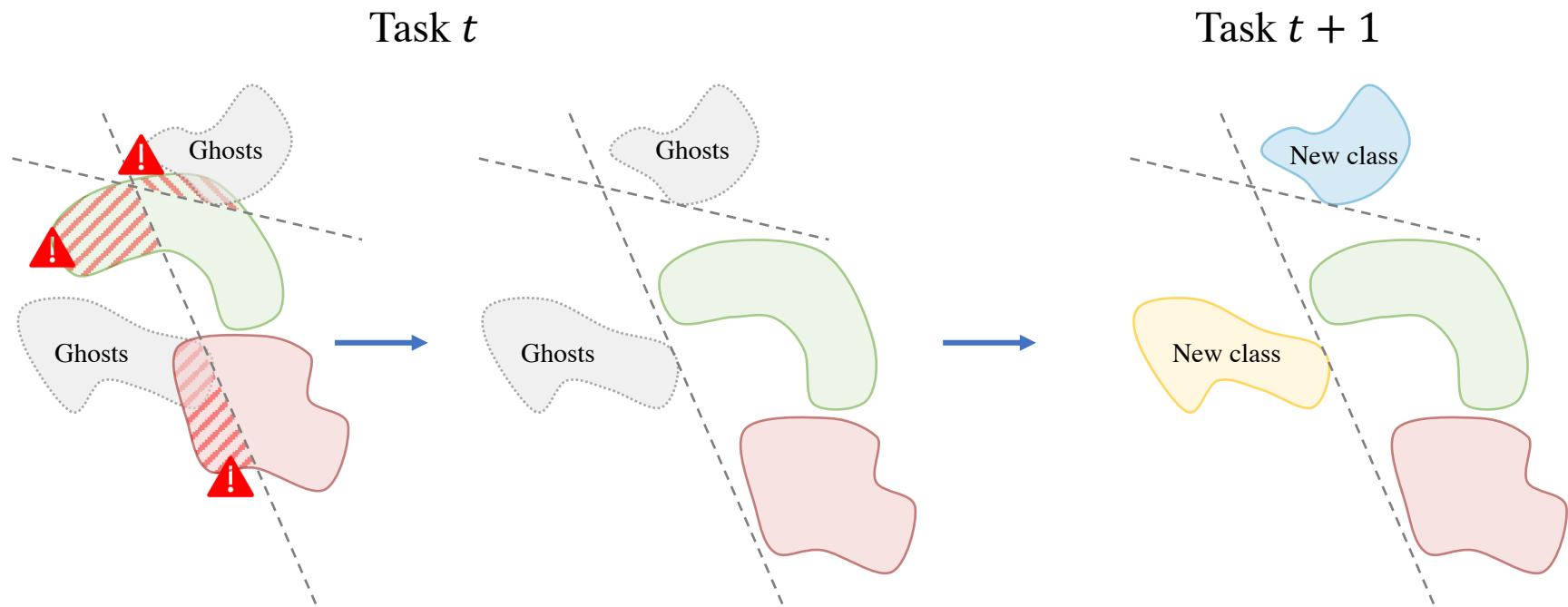
# Train on real and *Ghost* features

Legend:  Trained  Frozen Indicate if  $c$  belong to 

-  "Seen" classes ( $C^{1:t}$ )
-  "Unseen" classes ( $C^{t+1:T}$ )
-  Both



# Exclusion zones

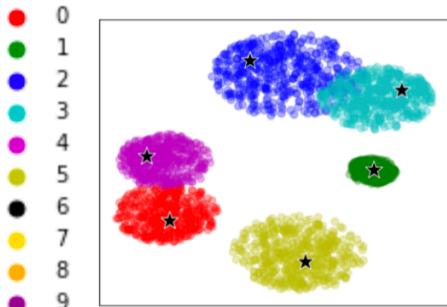


# Results

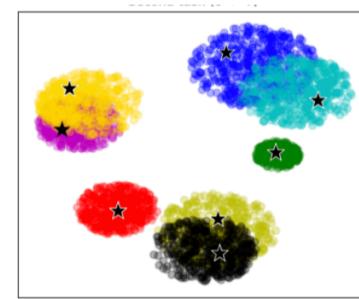
# Qualitative Results

## Split-MNIST with a 2-dimensions features

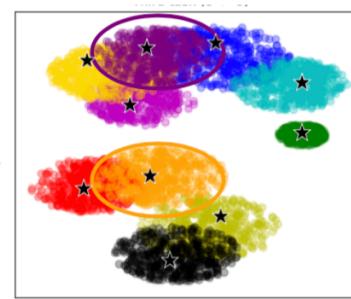
Task  $T_1$



Task  $T_2$

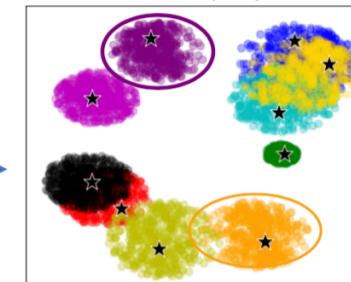
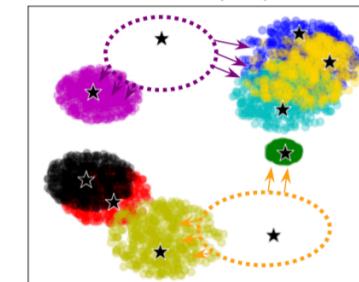
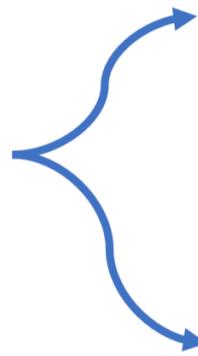


Task  $T_3$



Baseline

Ghost



Interference with  
new classes is  
minimized with  
**Ghost**

# Quantitative Results

## Average incremental accuracy

	AwA2 25 classes + 5 × 5 classes	
	PODNet	UCIR
Base Continual Learner	62.92 ± 0.12	62.66 ± 0.17
+ $\mathcal{L}^{\text{nca-ghost}}$	68.31 ± 0.36	64.96 ± 0.12
+ $\mathcal{L}^{\text{nca-ghost}} + \mathcal{L}^{\text{svm-reg}}$	<b>68.46 ± 0.47</b>	<b>65.37 ± 0.35</b>
	aP&Y 16 classes + 8 × 2 classes	
	PODNet	UCIR
Base Continual Learner	58.64 ± 0.66	45.96 ± 0.22
+ $\mathcal{L}^{\text{nca-ghost}}$	62.08 ± 0.25	59.67 ± 0.84
+ $\mathcal{L}^{\text{nca-ghost}} + \mathcal{L}^{\text{svm-reg}}$	<b>62.73 ± 0.60</b>	<b>60.12 ± 0.74</b>

# Quantitative Results

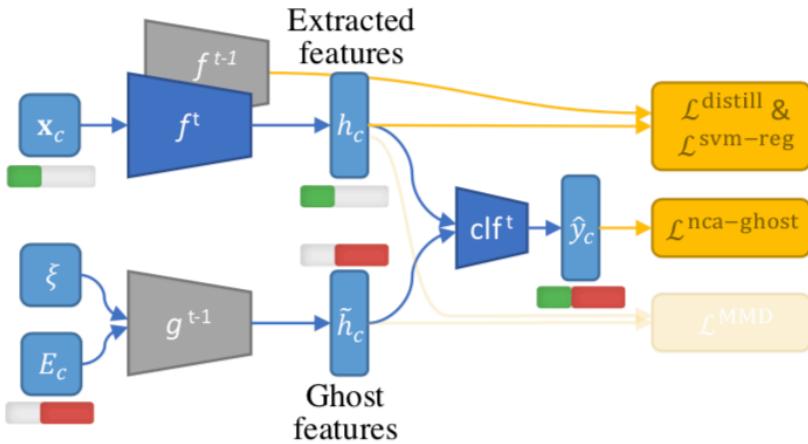
## Final accuracy

	AwA2	
	25 classes + 5 × 5 classes	
	PODNet	UCIR
Base Continual Learner	77.63 ± 0.06	76.36 ± 0.28
+ $\mathcal{L}^{\text{nca-ghost}}$	78.70 ± 0.46	<b>77.32 ± 0.40</b>
+ $\mathcal{L}^{\text{nca-ghost}} + \mathcal{L}^{\text{svm-reg}}$	<b>79.08 ± 0.53</b>	77.27 ± 0.35
	aP&Y	
	16 classes + 8 × 2 classes	
	PODNet	UCIR
Base Continual Learner	57.80 ± 0.97	45.40 ± 0.17
+ $\mathcal{L}^{\text{nca-ghost}}$	62.47 ± 0.40	54.13 ± 0.90
+ $\mathcal{L}^{\text{nca-ghost}} + \mathcal{L}^{\text{svm-reg}}$	<b>63.30 ± 0.98</b>	<b>56.07 ± 1.29</b>

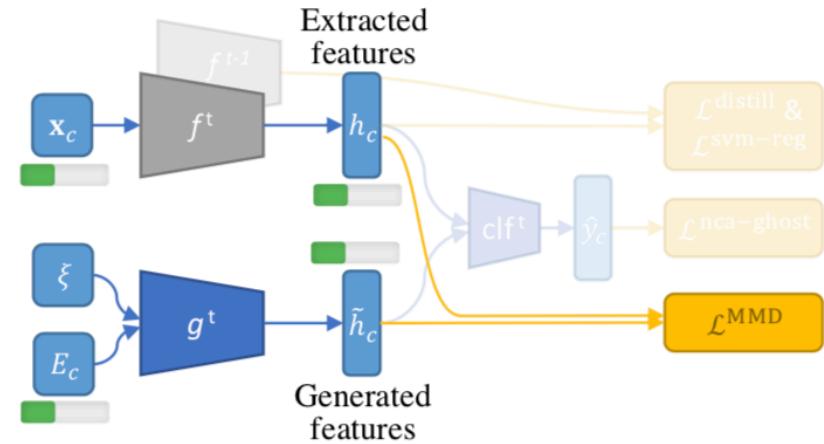
# Thank you for listening

Legend:

-  Trained
-  Frozen
- Indicate if  $c$  belong to  $\left\{ \begin{array}{l} \text{“Seen” classes } (C^{1:t}) \\ \text{“Unseen” classes } (C^{t+1:T}) \\ \text{Both} \end{array} \right.$



(a) Training of the classifier



(b) Training of the generator

**Arthur Douillard, Sorbonne Université & Heuritech**

**Eduardo Valle, University of Campinas**

**Charles Ollion, CMAP École Polytechnique & Heuritech**

**Thomas Robert, Heuritech**

**Matthieu Cord, Sorbonne Université & Valeo.ai**