

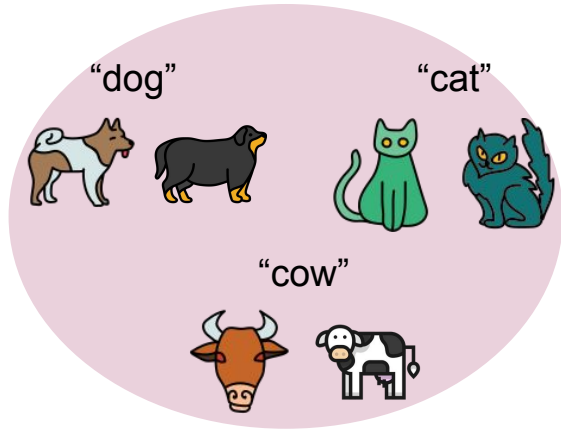
# Towards Label-Efficient Incremental Learning

Mert Kilickaya, Joost van de Weijer, Yuki Asano

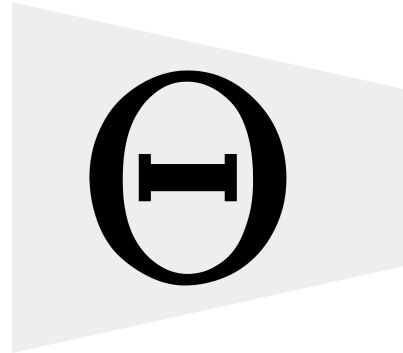
Eindhoven University of Technology  
Autonomous University of Barcelona  
University of Amsterdam

# Batch Learning

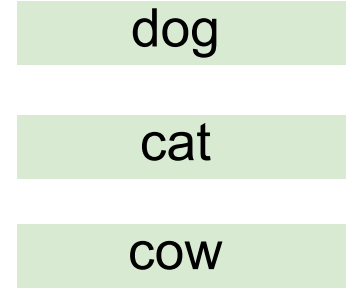
Dataset



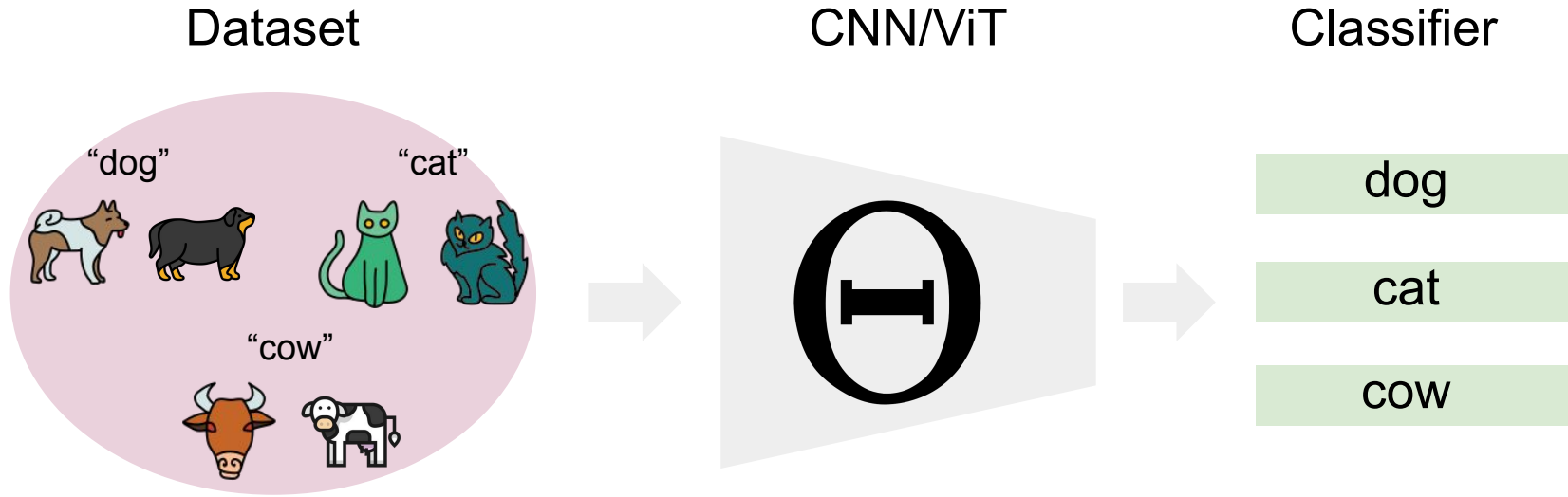
CNN/viT



Classifier



# Batch Learning



**Static:** Can't adapt & expand

# The models have to constantly adapt



500 hours of videos uploaded per minute



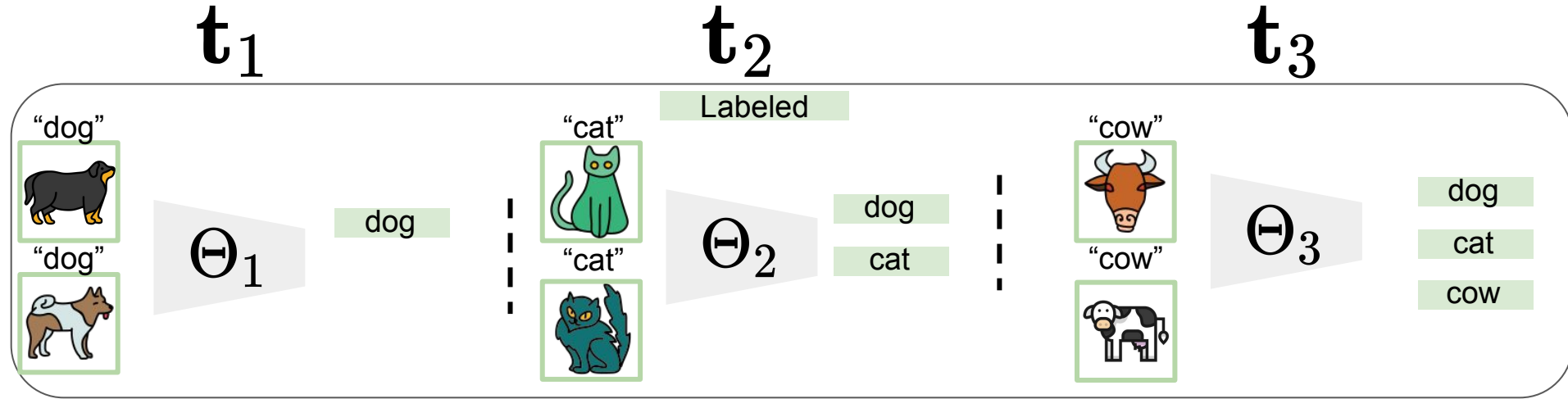
200k images uploaded per minute



400k images uploaded per minute

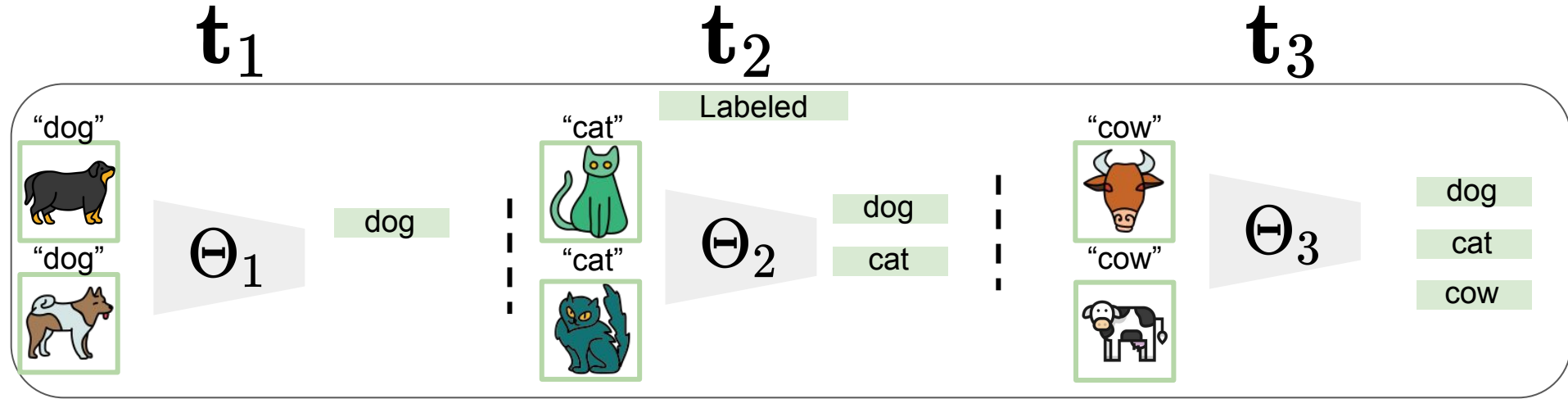
\*Figures from 2021

# Incremental Learning



**Dynamic:** Can adapt & expand

# Incremental Learning

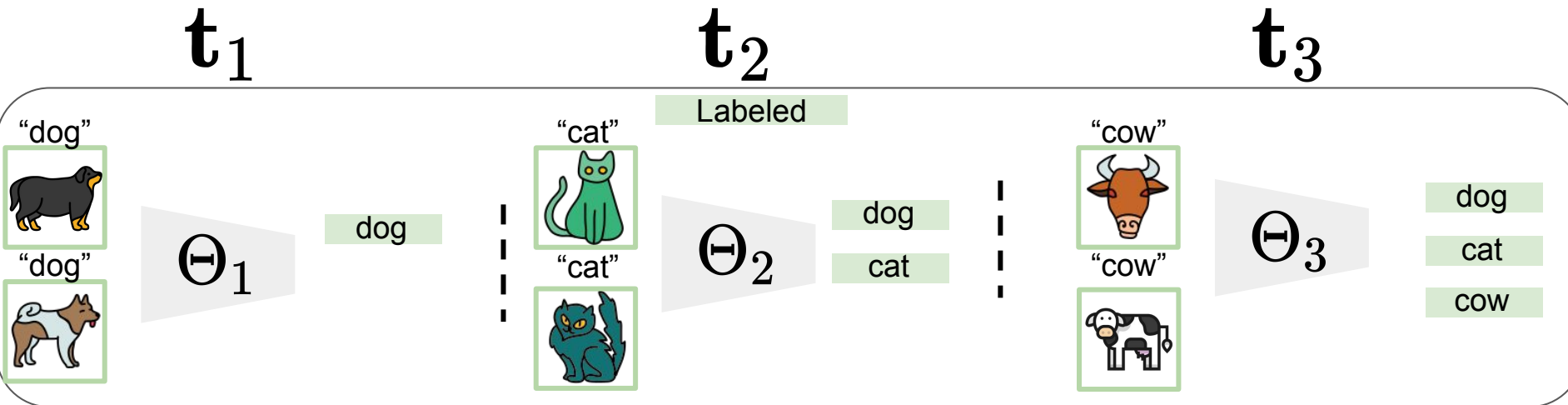



**Dynamic:** Can adapt & expand




**Forgetful:** Past classes

# Incremental Learning is *Not* Scalable



 **Dynamic:** Can adapt & expand

 **Forgetful:** Past classes

 **Unscalable:** Many-Labels

# Towards Label-Efficient Incremental Learning

**1** **Semi-Supervision** Within/Auxiliary/Test data

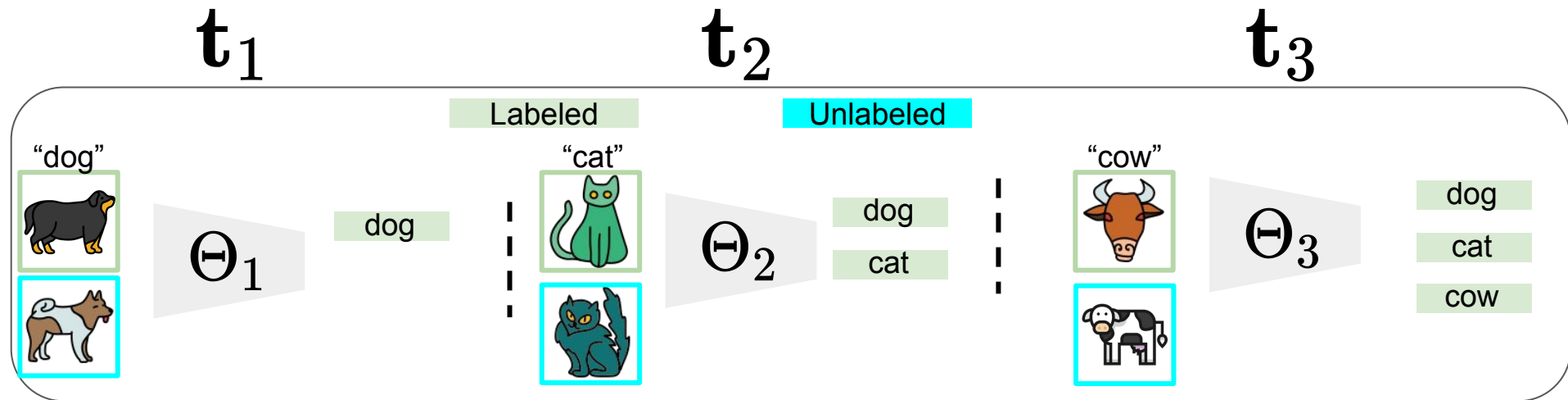
**2** **Few-shot-Supervision** Graph/Clustering/Architectural methods

**3** **Self-Supervision** Pre/Auxiliary/Main training



1

# Semi-Supervision for Incremental Learning



Perform self-training via pseudo-supervision on unlabeled task data by leveraging labeled data.

# 1 Semi-Supervision for Incremental Learning

Labeled

Unlabeled

Within-data

Auxiliary-data

Test-data

train



“dog”

train



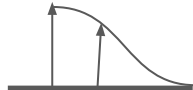
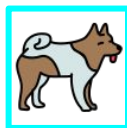
“dog”

train

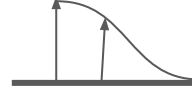


“dog”

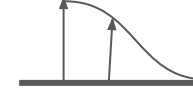
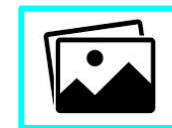
self-train



self-train



self-train

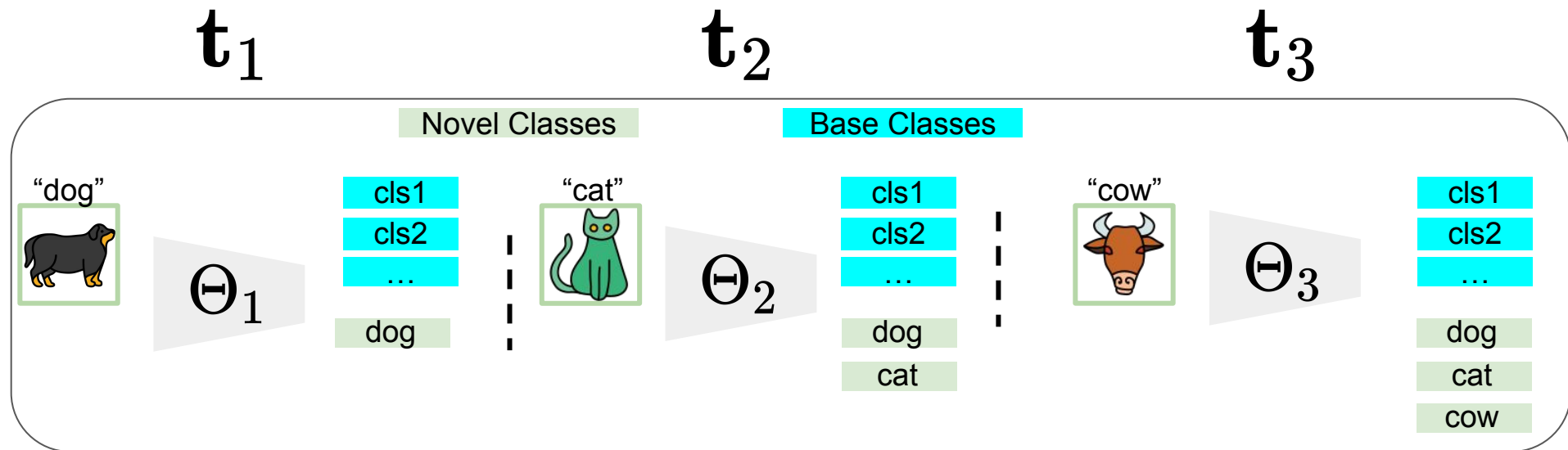


[CNLL](#), ACM'17

[DMC](#), WACV'20

[CoTTA](#), CVPR'22

## Few-shot-Supervision for Incremental Learning



Learn to expand a pre-trained (base) category with novel classes with few examples (i.e. 1-shot)

## 2 Few-shot-Supervision for Incremental Learning

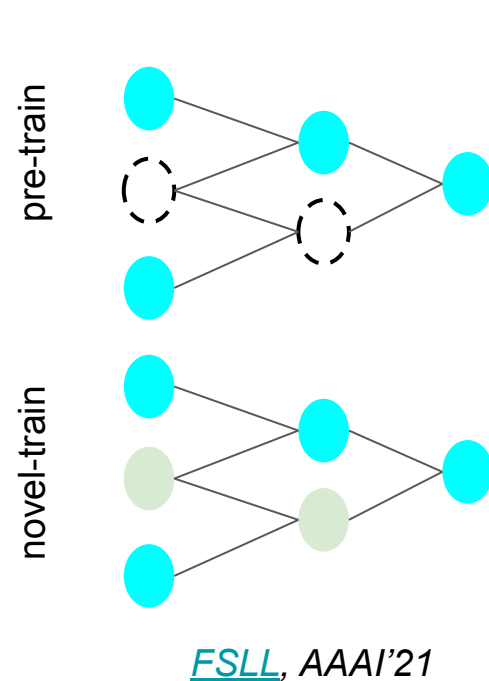
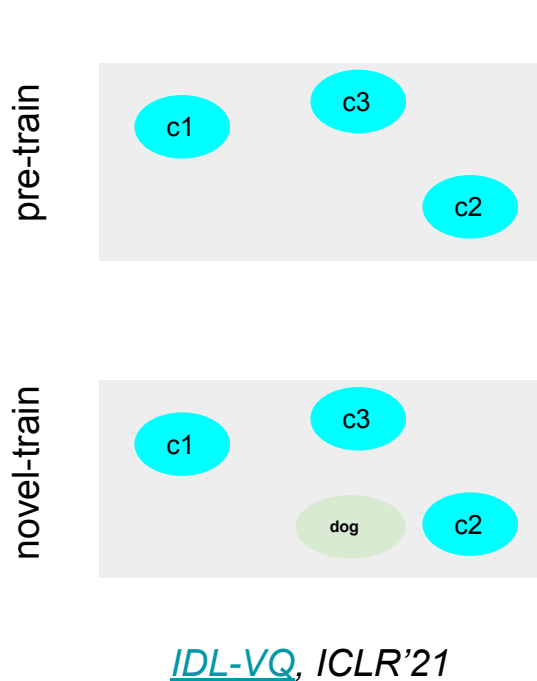
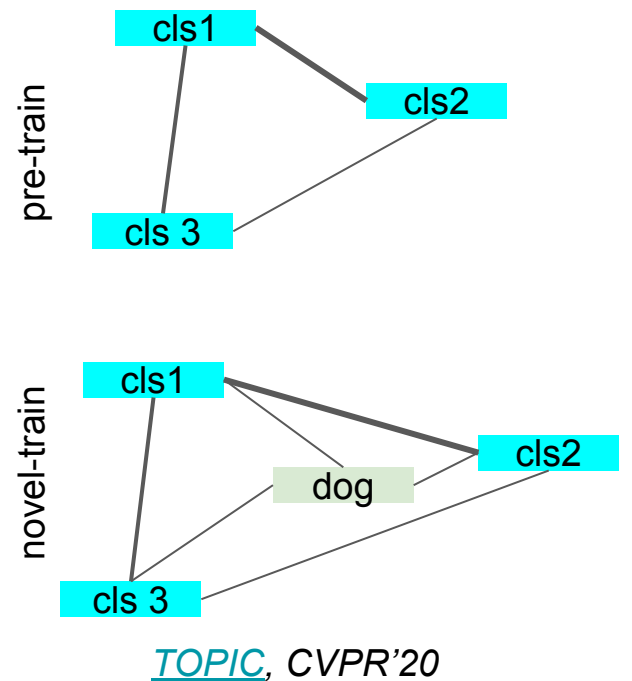
Novel Classes

Base Classes

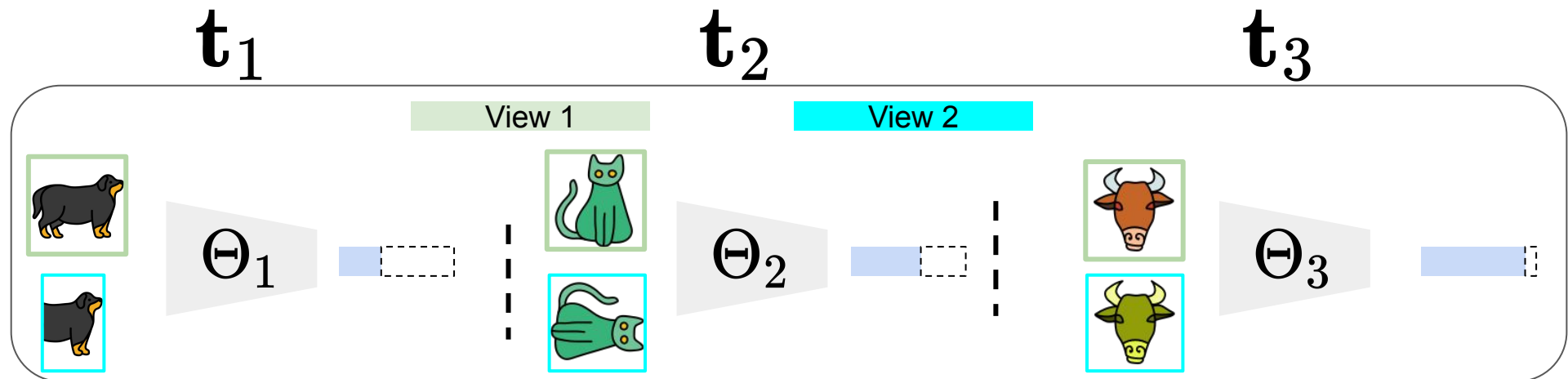
Graph-based

Clustering-based

Architectural-based



## Self-Supervision for Incremental Learning



Pre-train a backbone via contrastively matching different image views (i.e. crop, rotation, color jitter)

## Self-Supervision for Incremental Learning

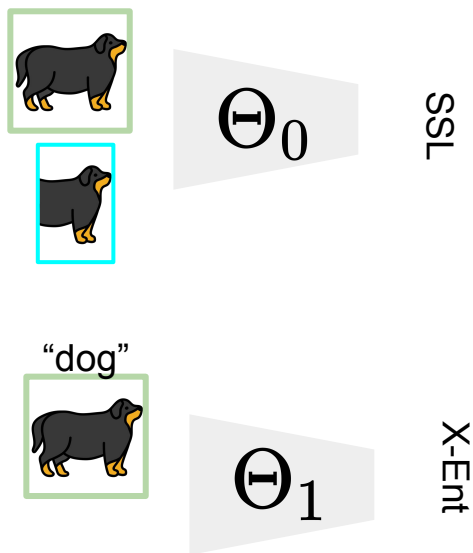
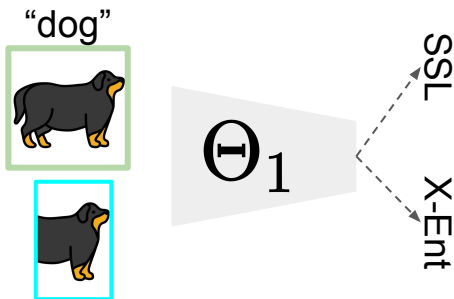
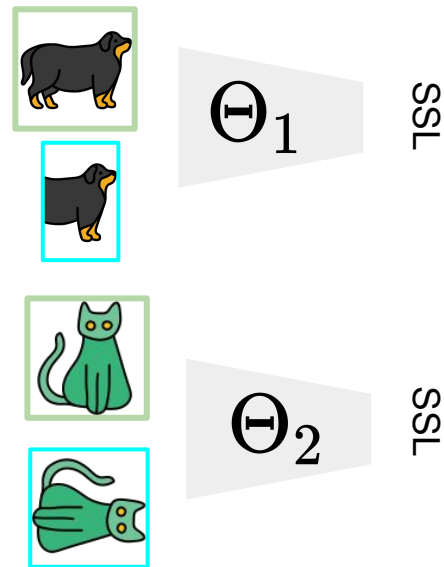
View 1

View 2

Pre-training

Auxiliary-training

Main-training

[SSL-OCL](#), BMVC'21[PASS](#), CVPR'21[CaSSLe](#), CVPR'22

# Summary: Overall

Method	Subgroups	Supervision	Reference
<b>Incremental Learning (IL)</b>		Label-only	LwF [Li and Hoiem, 2017]
<b>Semi-Supervised IL</b>	<i>Within-Data</i>	Pseudo & Label	CNLL [Baucum <i>et al.</i> , 2017]
	<i>Auxiliary-Data</i>	Pseudo & Label	DMC [Zhang <i>et al.</i> , 2020]
	<i>Test-Data</i>	Pseudo-only	CoTTA [Wang <i>et al.</i> , 2022]
<b>Few-shot-Supervised IL</b>	<i>Graph-Based</i>	Label-only (Few)	TOPIC [Tao <i>et al.</i> , 2020]
	<i>Clustering-Based</i>	Label-only (Few)	IDL-VQ [Chen and Lee, 2020]
	<i>Architectural-Based</i>	Label-only (Few)	FSSL [Mazumder <i>et al.</i> , 2021]
<b>Self-Supervised IL</b>	<i>Pre-Training</i>	Label-only	SSL-OCL [Gallardo <i>et al.</i> , 2021]
	<i>Auxiliary-Training</i>	Self & Label	PASS [Zhu <i>et al.</i> , 2021]
	<i>Main-Training</i>	Self-only	CaSSLe [Fini <i>et al.</i> , 2022]

# Summary: Algorithms

## Semi-Supervision

Algorithm	Data	Pre-training	Replayed Entity
CNNL	Within	✗	Pseudo-labels
DistillMatch	Within	✗	Pseudo-labels
ORDisCo	Within	✗	Pseudo-labels & Data
MetaCon	Within	✗	Pseudo-labels & Data
PGL	Within	✗	Pseudo-gradients
DMC	Auxiliary	✓	Pseudo-labels
CIL-QUD	Auxiliary	✓	Pseudo-labels
CoTTA	Test	✓	Pseudo-labels
NOTE	Test	✓	Data

## Self-Supervision

Algorithm	Setting	Self-Supervision
SSL-OCL	Pre-training	MOCO/SwAV
PASS	Auxiliary-training	SLA
Buffer-SSL	Main-training	SimSiam
LUMP	Main-training	SimSiam/Barlow-Twins
CaSSLe	Main-training	SimCLR/Barlow-Twins/etc.
PFR	Main-training	Barlow-Twins

## Few-shot-Supervision

Algorithm	Method	Regularization	Replay	Semantic
TOPIC	Graph	Anchor Loss	✗	✗
CEC	Graph	✗	✗	✗
IDL-VQ	Clustering	Center Loss	✓	✗
SA-KD	Clustering	✗	✓	✓
SUB-REG	Clustering	$\ell_1$ Loss	✓	✓
FACT	Clustering	Augmentation	✗	✗
FSLL	Architectural	$\ell_1$ Loss	✗	✗
C-FSCIL	Architectural	Orthogonal Loss	✓	✗



# Limitations



**Semi-Supervision:**

Pseudo-supervision

Still many labeled examples

**Few-shot-Supervision:**

Only few-shots per-class

Requires large-scale pre-training

**Self-Supervision:**

No labels at train-time

Labels needed for evaluation

# Future Directions

## **Incremental Dense Learning:**

Continual object detection/segmentation, etc.

## **Incremental Active Learning:**

Learning to select label-worthy exemplars.

## **Incremental Object Discovery:**

Learn to recognize and discover novel objects.

~Thank you! Any questions?~