Block IV - Continual AI

*1st **AI for People** Workshop*

09-08-2020

Vincenzo Lomonaco

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President of ContinualAI.org

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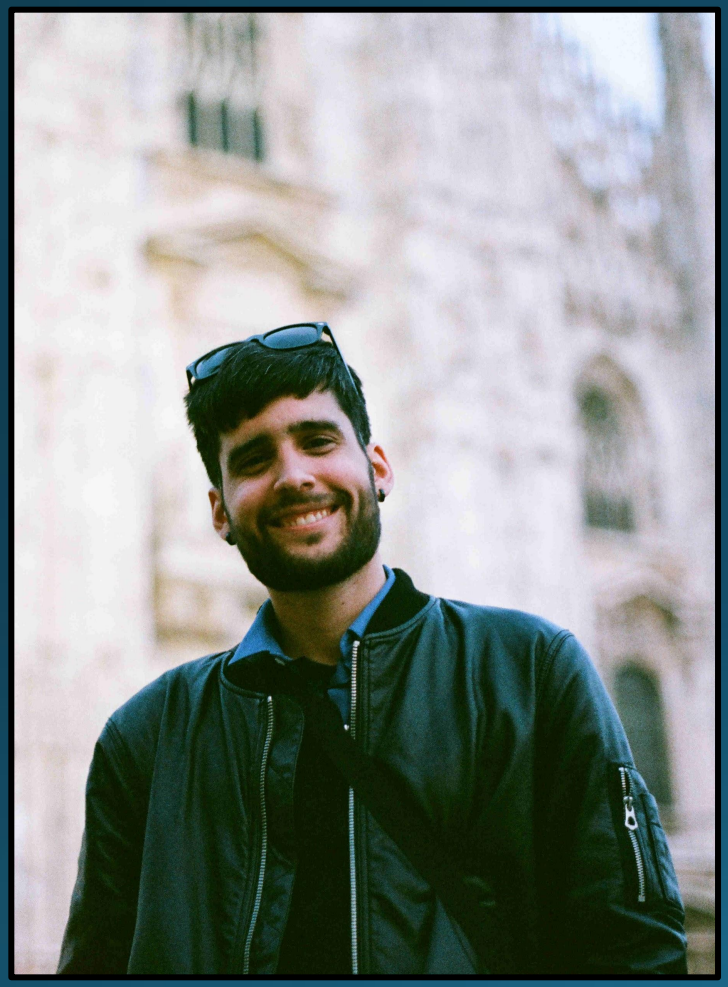
About me



- **AI** & **Continual Learning Post-Doc** @ University of Bologna
- **President** *and* **Co-Director of Research** *at ContinualAI.org*
- **Teaching Assistant** of the courses *Machine Learning* and *Computer Architectures @ UniBo*
- **Author** and **Technical reviewer** of the online course *Deep Learning with R* and book *R Deep Learning Essentials.*
- **Co-Founder** *and* **Board Member** *of AIforPeople.org*

What's ContinualAI?

- ***ContinualAI*** is a **non-profit research organization** and the largest research community on **Continual Learning** for AI.
- It counts more than **900+ members** in **19 different time-zones** and from top-notch research institutions.
- Learn more about *ContinualAI* at www.continualai.org

Workshop Outline

1. **Introduction** to Continual Learning (CL)
2. **[Hands-on]** A gentle introduction to CL in PyTorch
3. A new CL Benchmark: **CORe50**
4. A new CL strategy: **AR-1**
5. *Continual Unsupervised Learning*
6. *Continual Reinforcement Learning*
7. Examples of **CL applications**

State-of-the-art

- *Deep Learning* holds **state-of-the-art performances** in many tasks.
- Mainly **supervised** training with **huge** and **fixed** datasets.

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- Mainly **supervised** training with **huge** and **fixed** datasets.

The Curse of Dimensionality

$$3{,}9 \cdot 10^{372282}$$

# of possible 227x227 RGB images

The Curse of Dimensionality

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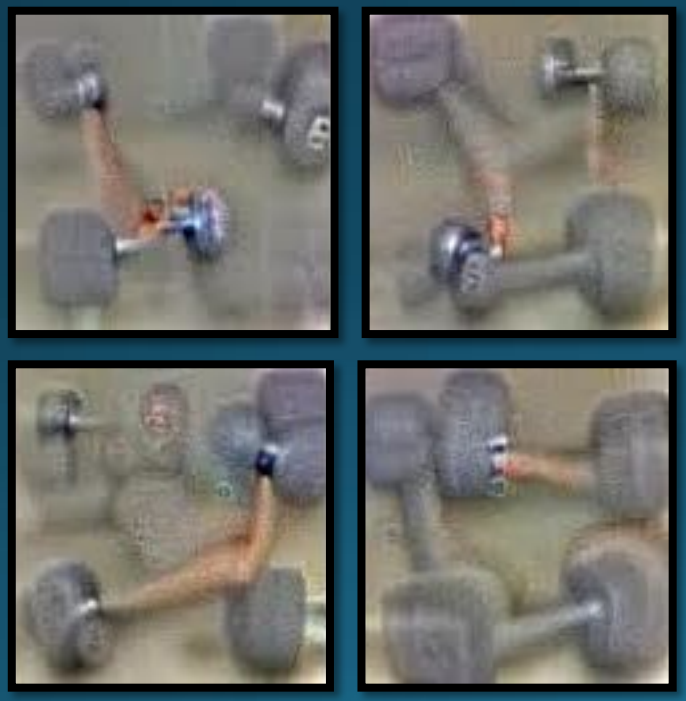
# of possible 227x227 RGB images



The Curse of Dimensionality

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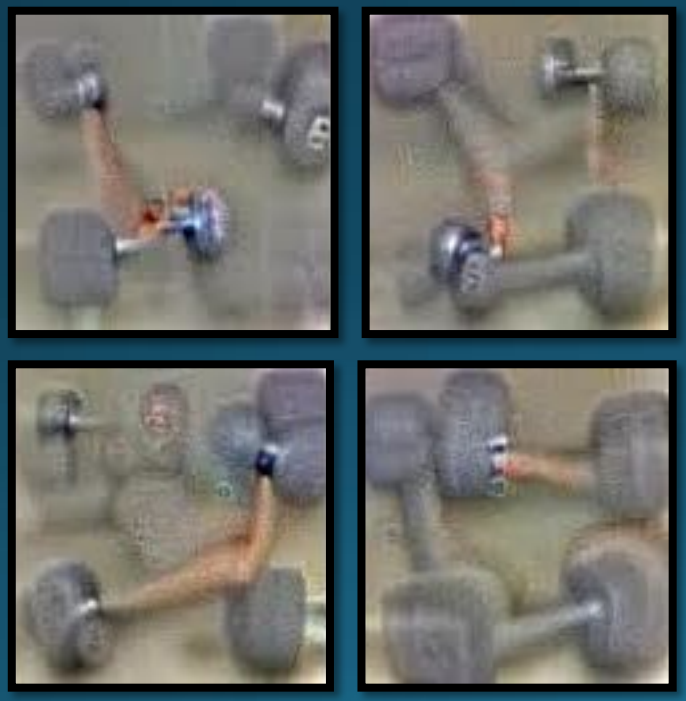
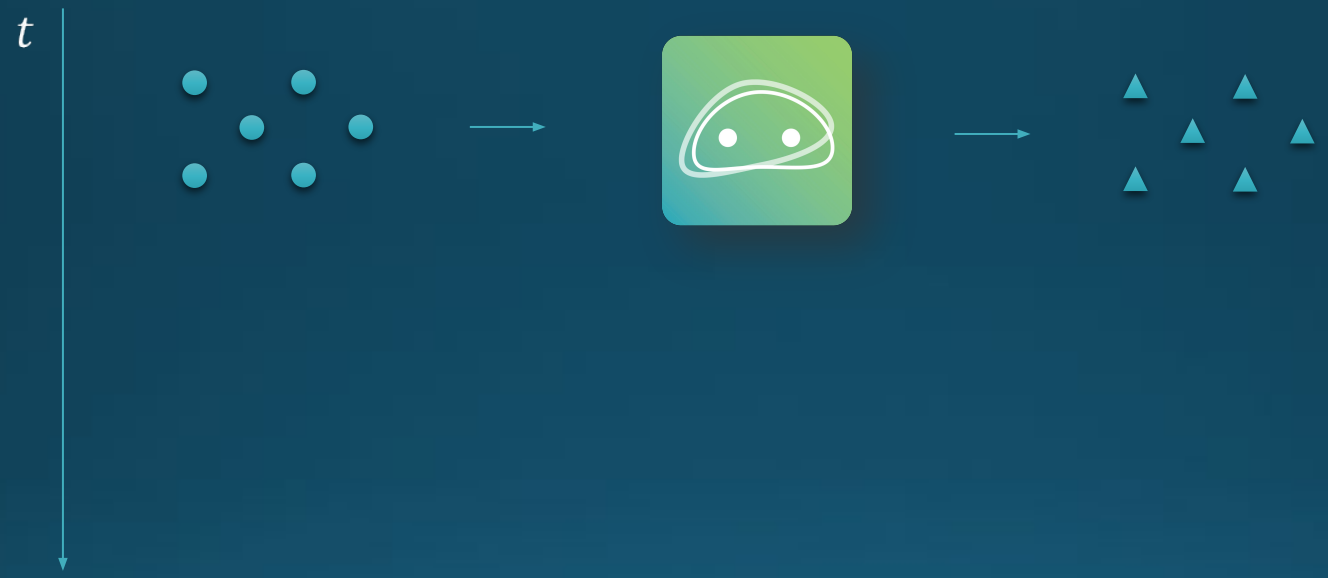


How can we improve AI ***scalability*** *and* ***adaptability****?*

(Hence ***ubiquitousness*** *and* ***autonomy****)*

Continual Learning



X_1 $f_\theta: X_1 \rightarrow Y_1$ Y_1

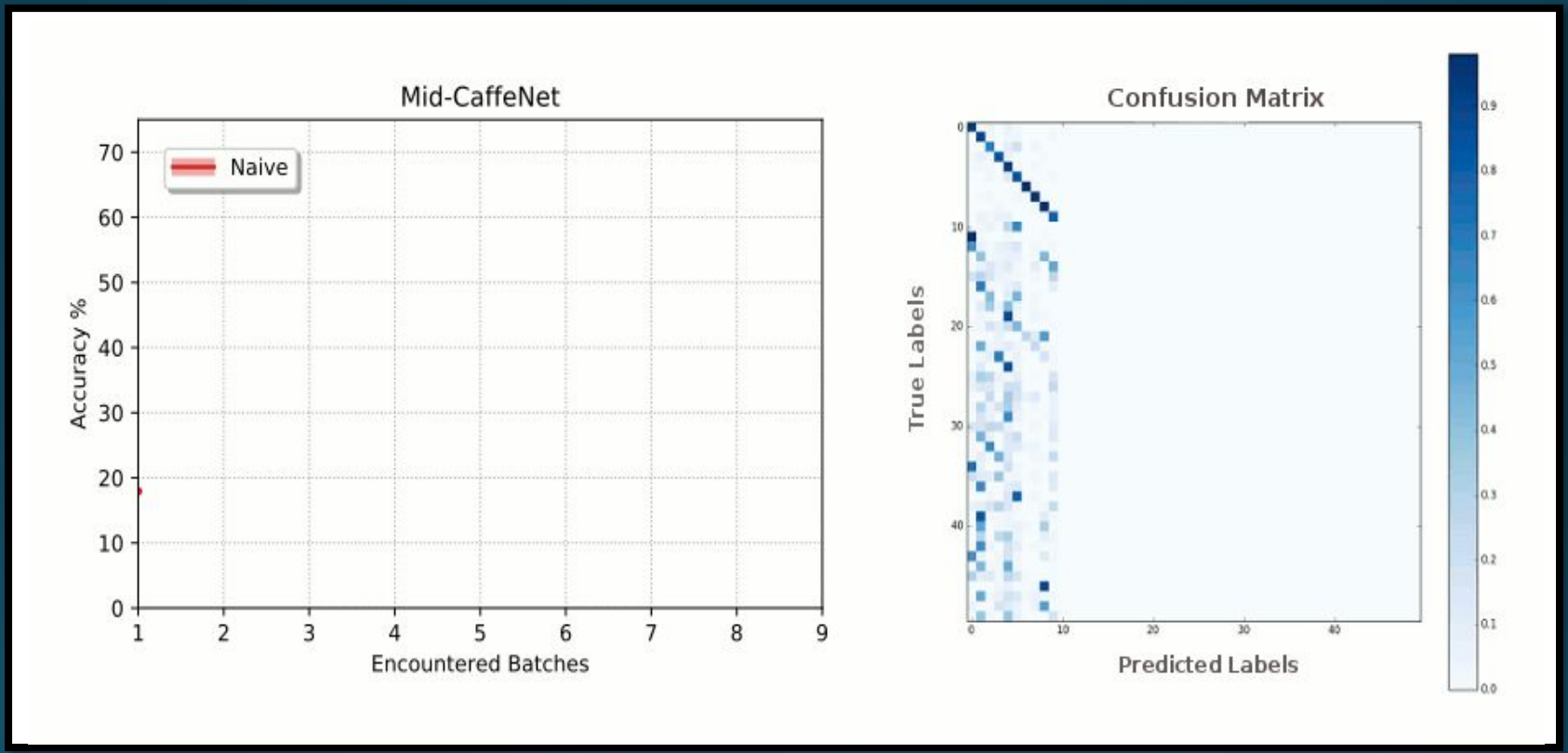
Continual Learning

X_2 $f_\theta: X_1 \cup X_2 \rightarrow Y_1 \cup Y_2$ Y_2

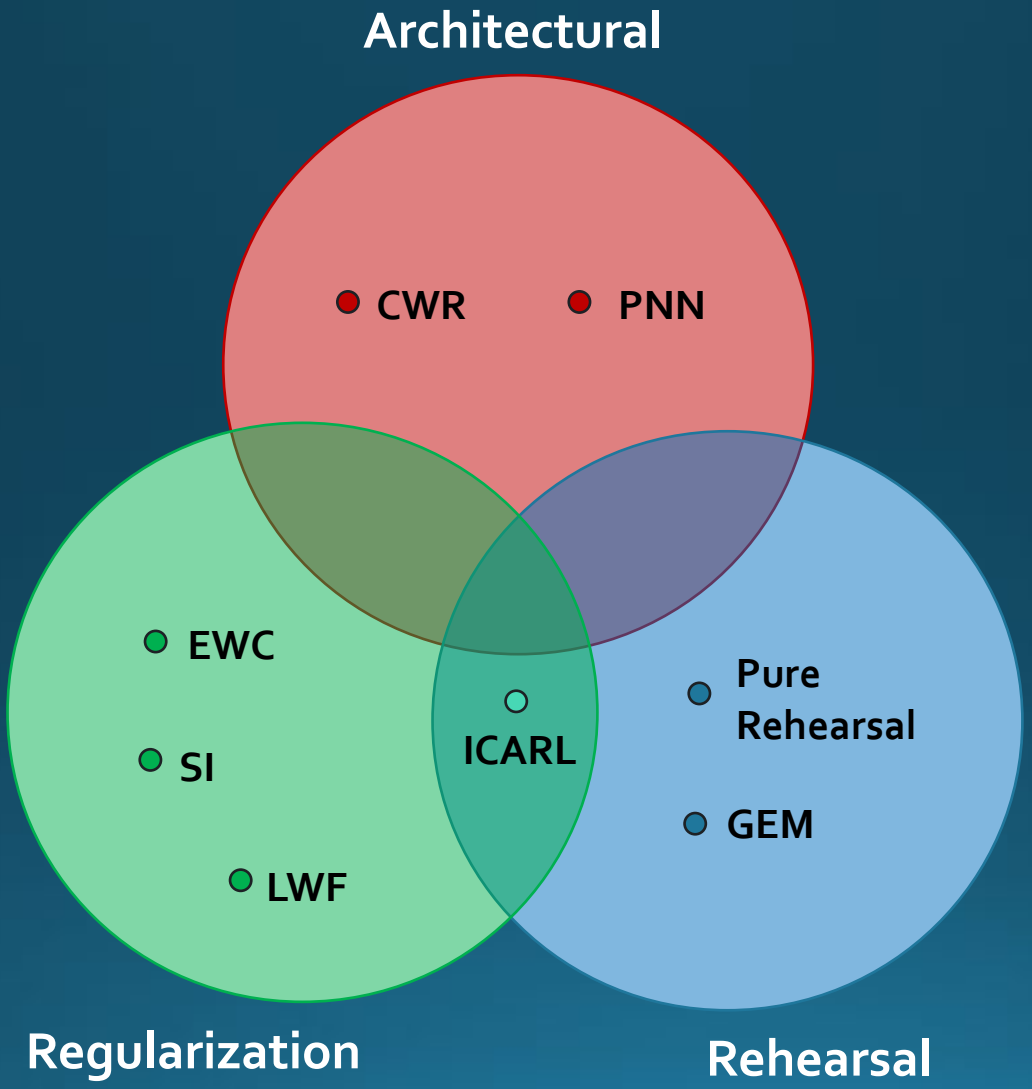
Continual Learning (CL)

- **Higher** and **realistic time-scale** where data (and tasks) become available **only during time**.
- **No access** to **previously encountered data**.
- **Constant** computational and memory resources.
- Incremental development of ever more complex **knowledge** and **skills**.

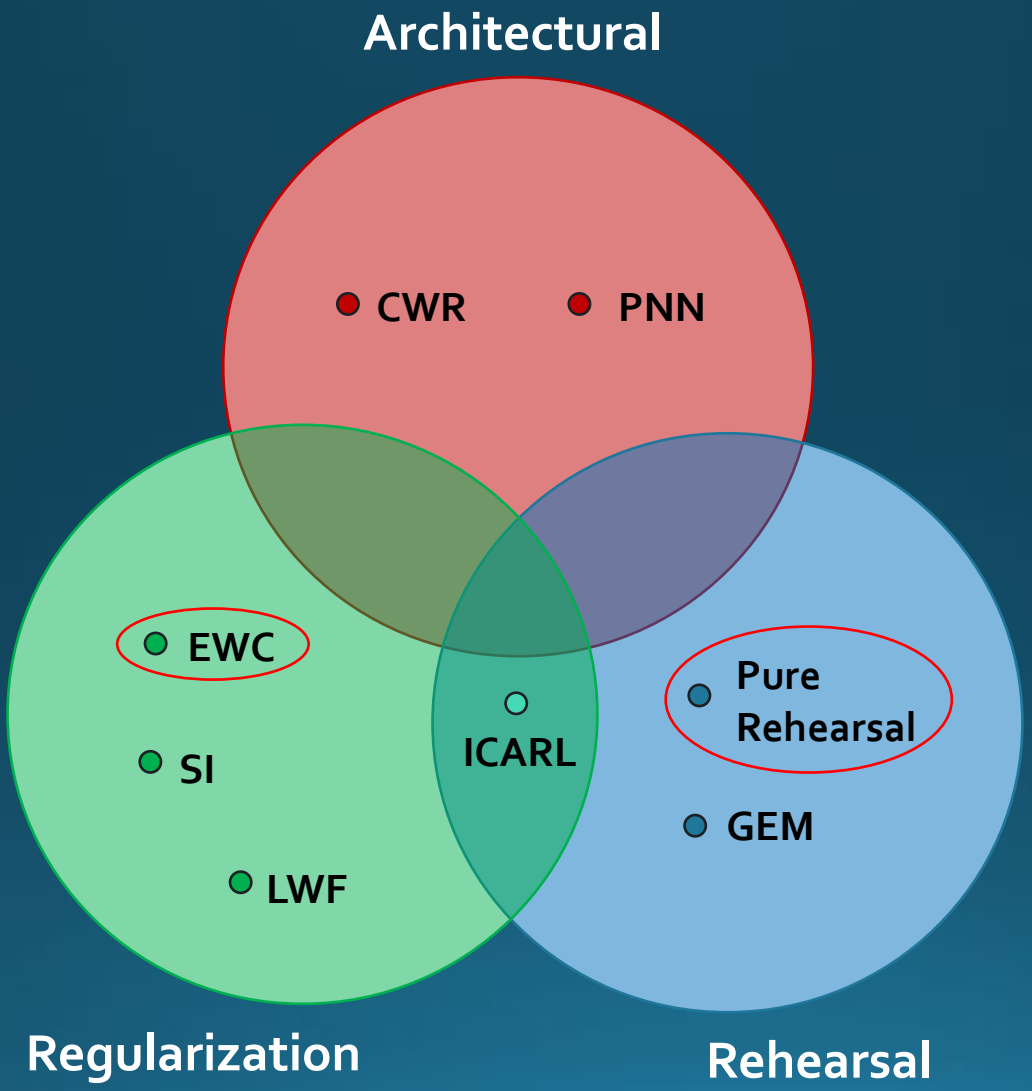
Why CL is a challenging (and fun) problem?



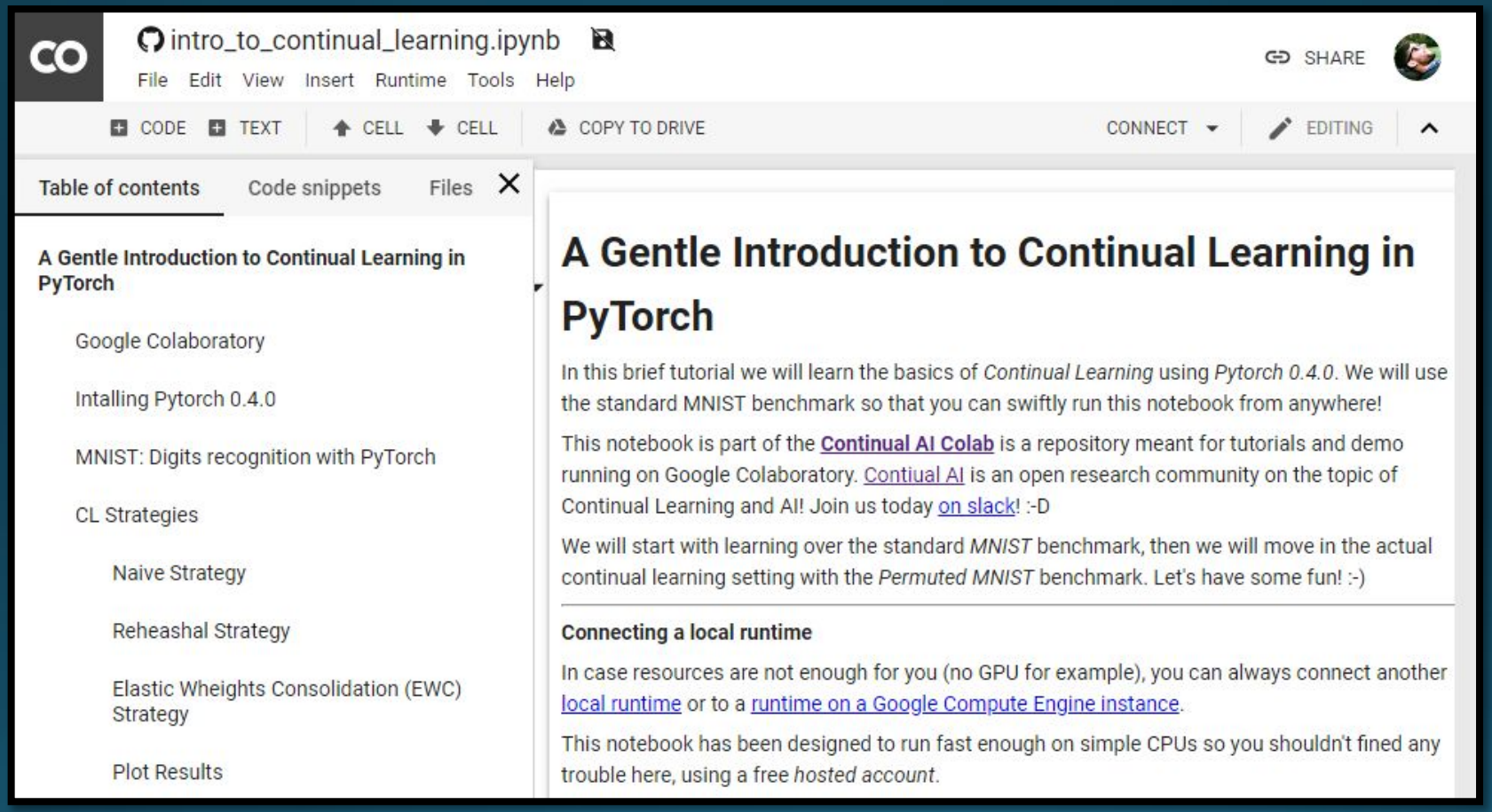
CL Strategies



CL Strategies

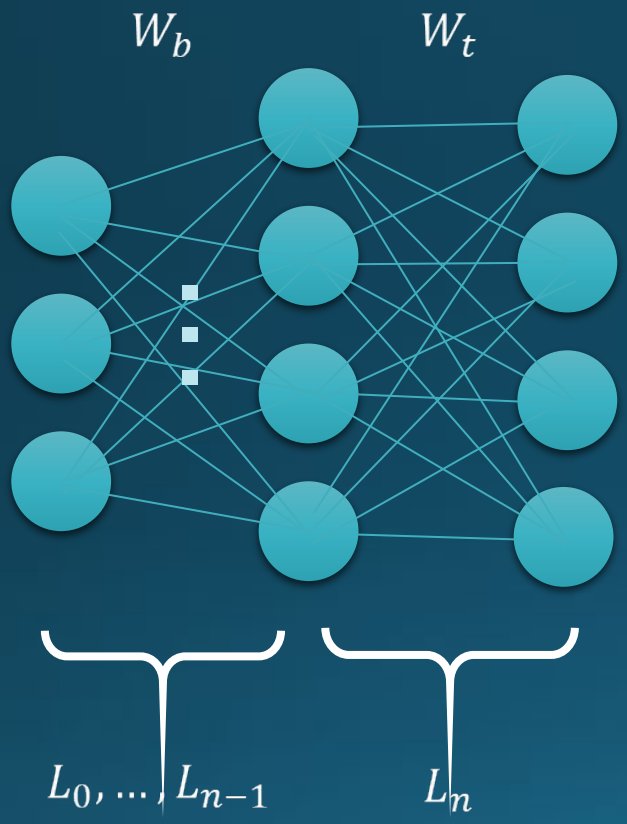


[Hands-on (40 minutes)] A Gentle Introduction to CL in PyTorch



https://github.com/aiforpeople-git/First-AI4People-Workshop

Elastic Weights Consolidation (EWC)



$$\tilde{L}_\mu = L_\mu + \lambda \sum_k \Omega_k^\mu \, (\bar{\theta}_k - \theta_k)^2$$

$$w_k^v = \int \left(\frac{\partial}{\partial \theta_k} \log f(x; \theta_k) \right)^2 f(x; \theta_k) \, dx$$

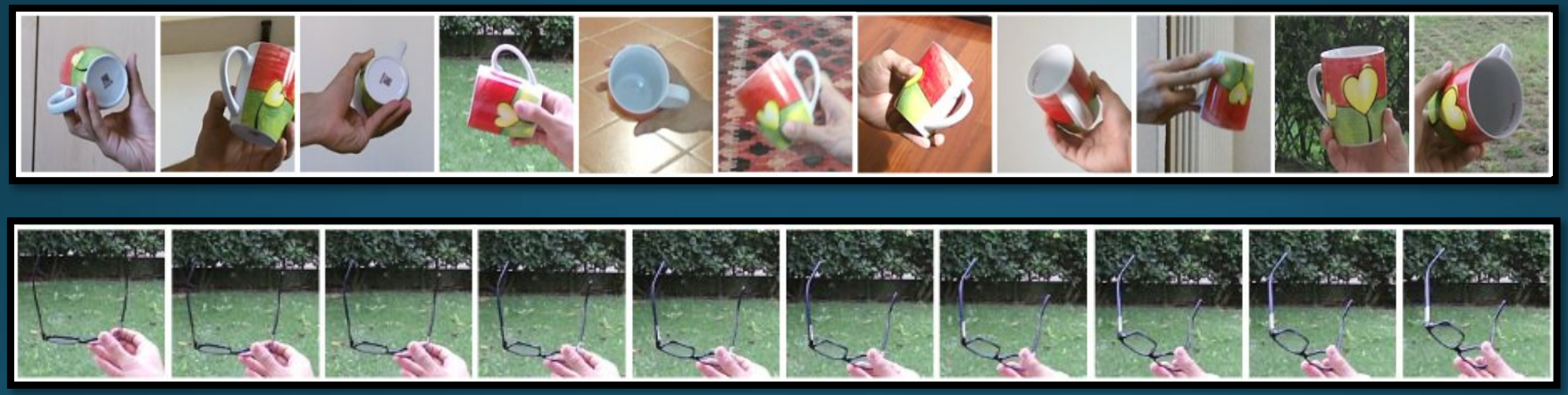
Fisher Information

Common CL benchmarks

Dataset	*Strategy*
Permuted MNIST	EWC, GEM, SI
Rotated MNIST	GEM
MNIST Split	SI
CIFAR10/100 Split	GEM, iCARL, SI
ILSVRC2012	iCARL
Atari Games	EWC

CORe50: a Video Benchmark for CL and Object Recognition/Detection

Continual Learning needs the **presence of multiple (temporal coherent and unconstrained) views** of the same objects taken in different sessions.



Lomonaco V. and Maltoni D. ***CORe50: a New Dataset and Benchmark for Continuous Object Recognition***. CoRL2017.

CORe50: a Video Benchmark for CL and Object Recognition/Detection

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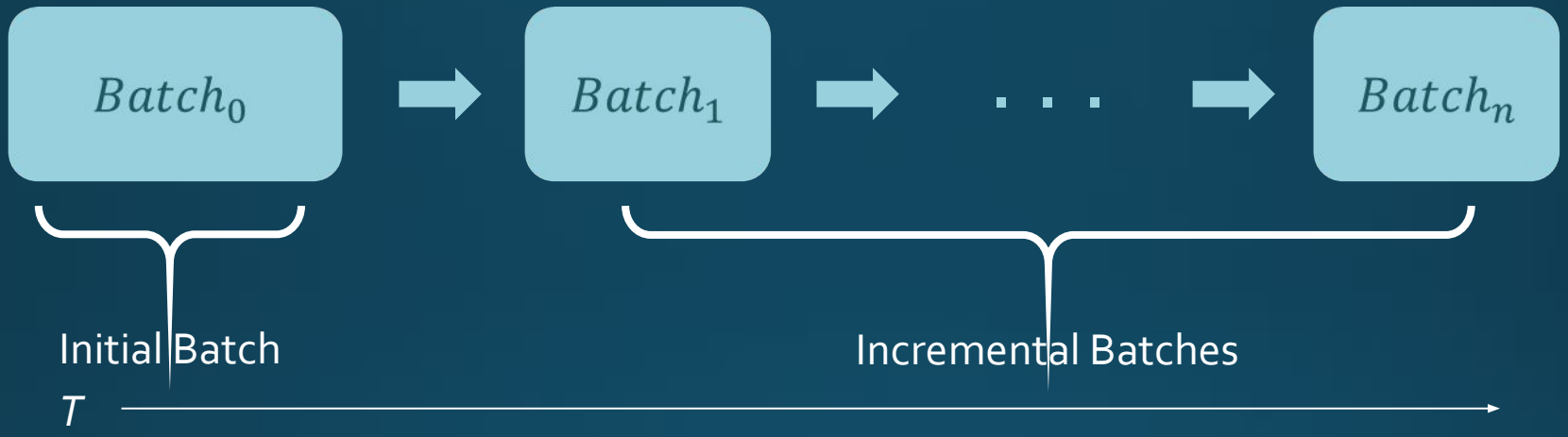
CORe50: a Video Benchmark for CL and Object Recognition/Detection

# Images	164,866
Format	RGB-D
Image size	350x350 128x128
# Categories	10
# Obj. x Cat.	5
# Sessions	11
# img. x Sess.	~300
# Outdoor Sess.	3
Acquisition Sett.	Hand held

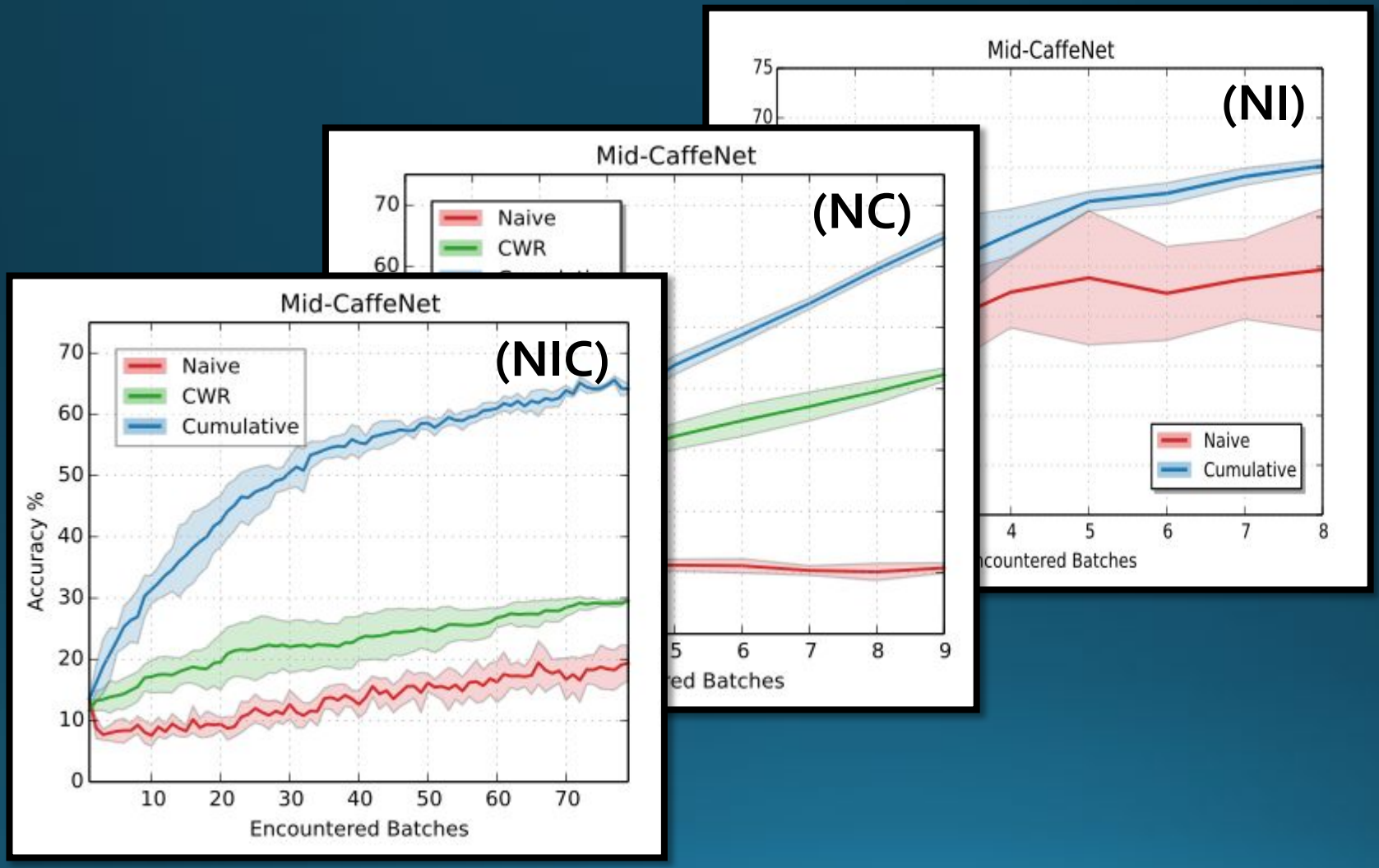
Lomonaco V. and Maltoni D. ***CORe50: a New Dataset and Benchmark for Continuous Object Recognition***. CoRL2017.

Single Incremental Task

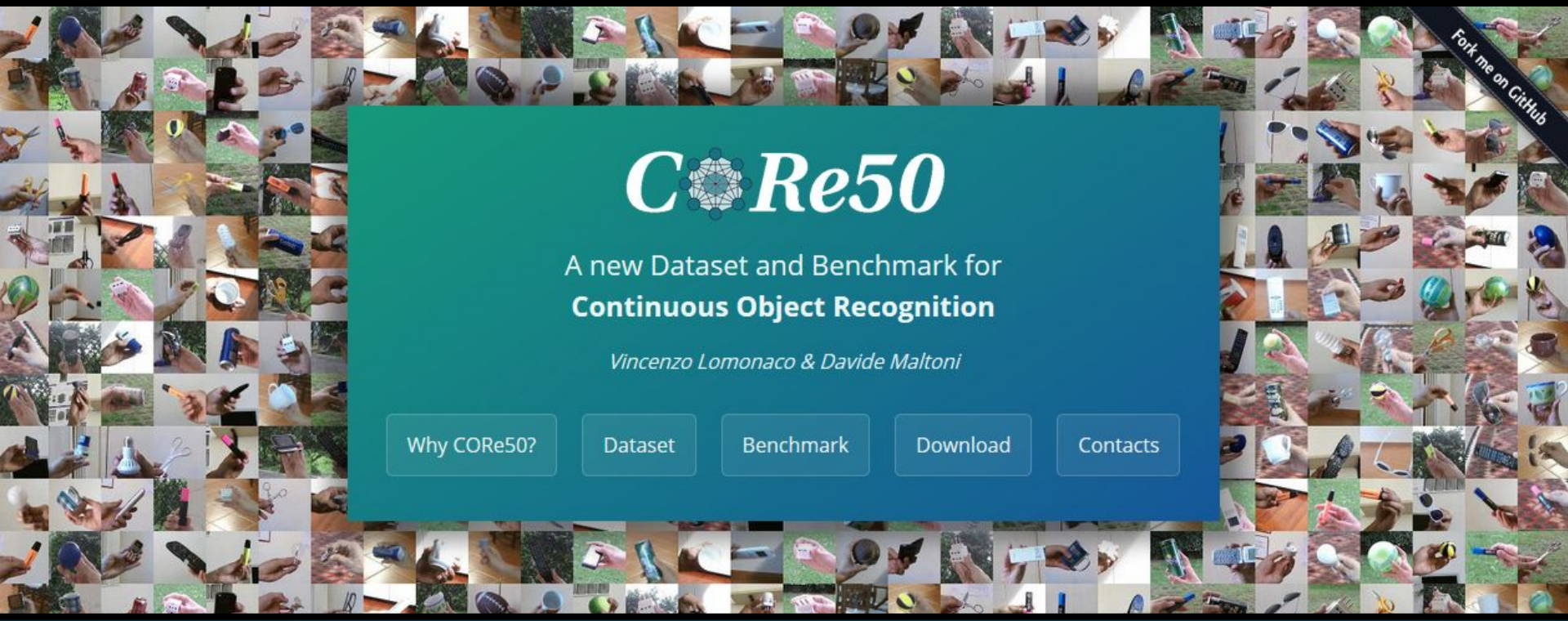


1. **New Instances (NI)**
2. **New Classes (NC)**
3. **New Instances and Classes (NIC)**

CORe50 Benchmark



CORe50 Website



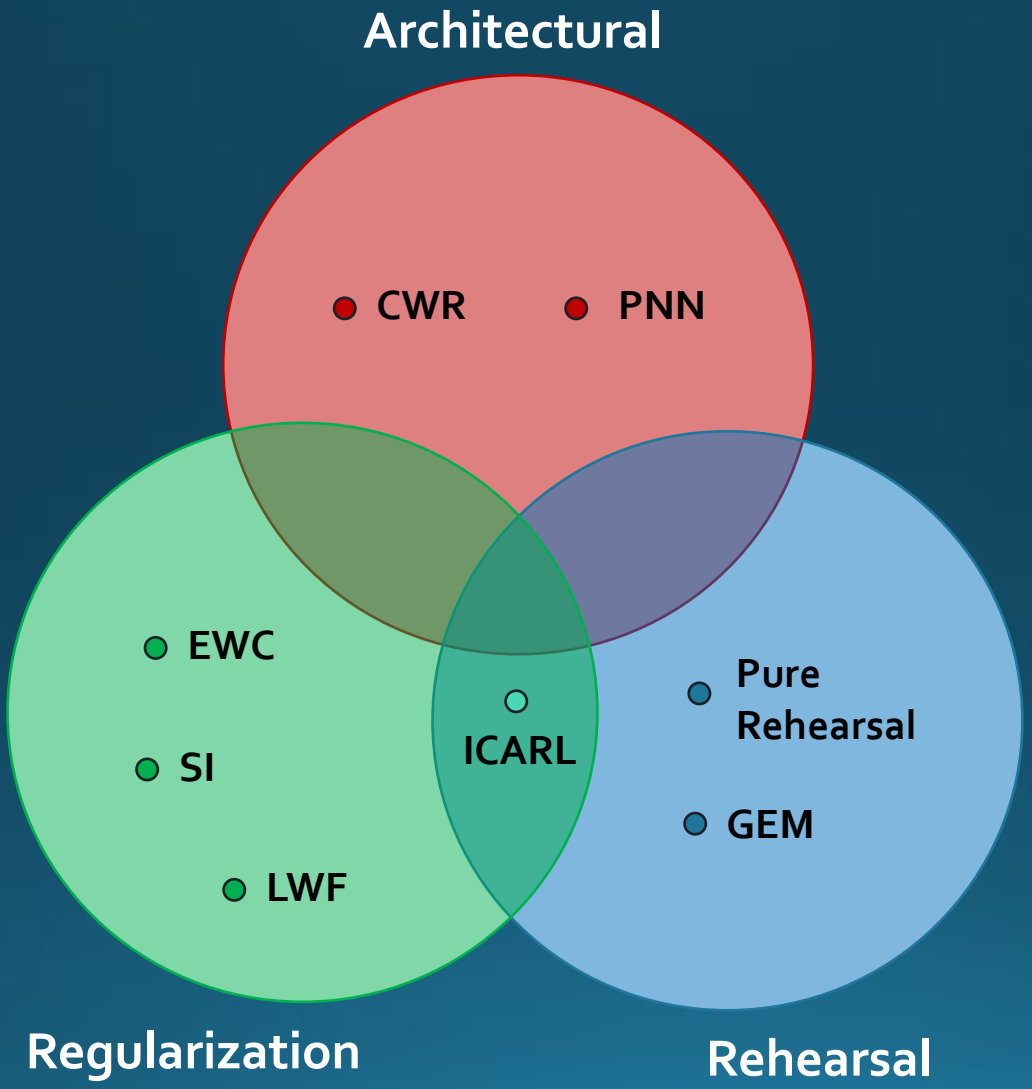
Dataset, **Benchmark**, **code** and additional information freely available at:

vlomonaco.github.io/core50

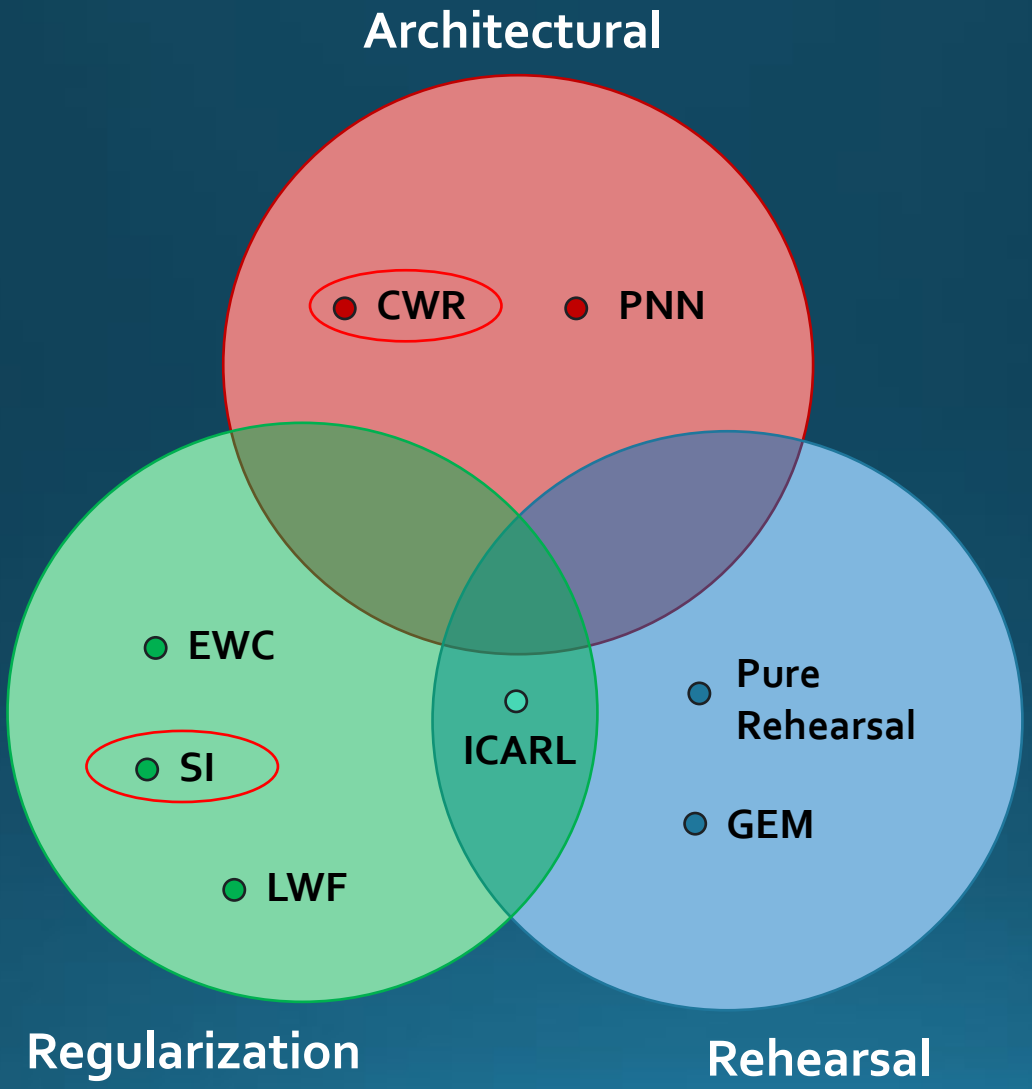
AR-1

Lomonaco V. and Maltoni D. ***Continuous Learning in Single-Incremental-Task Scenarios***. Pre-print arxiv:1806.08568v2.

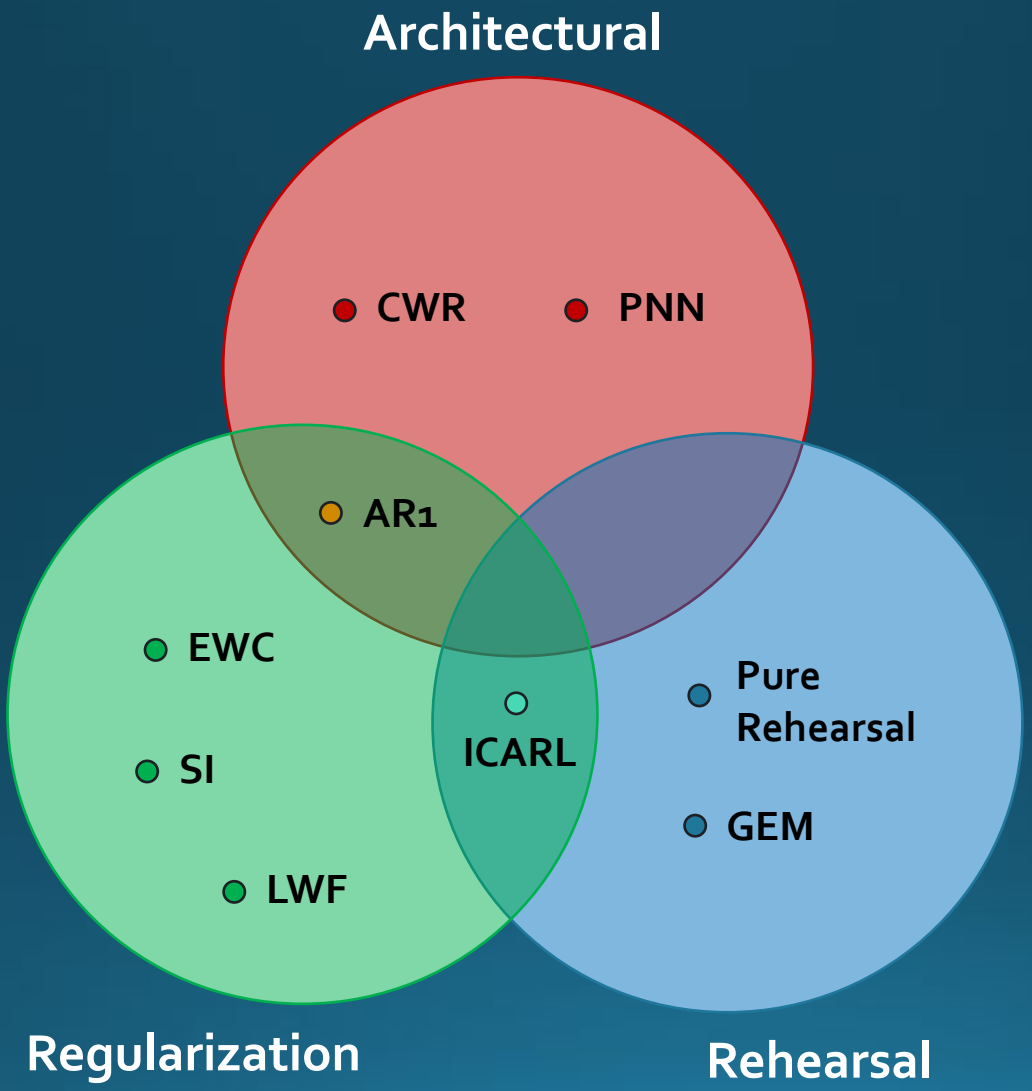
CL Strategies



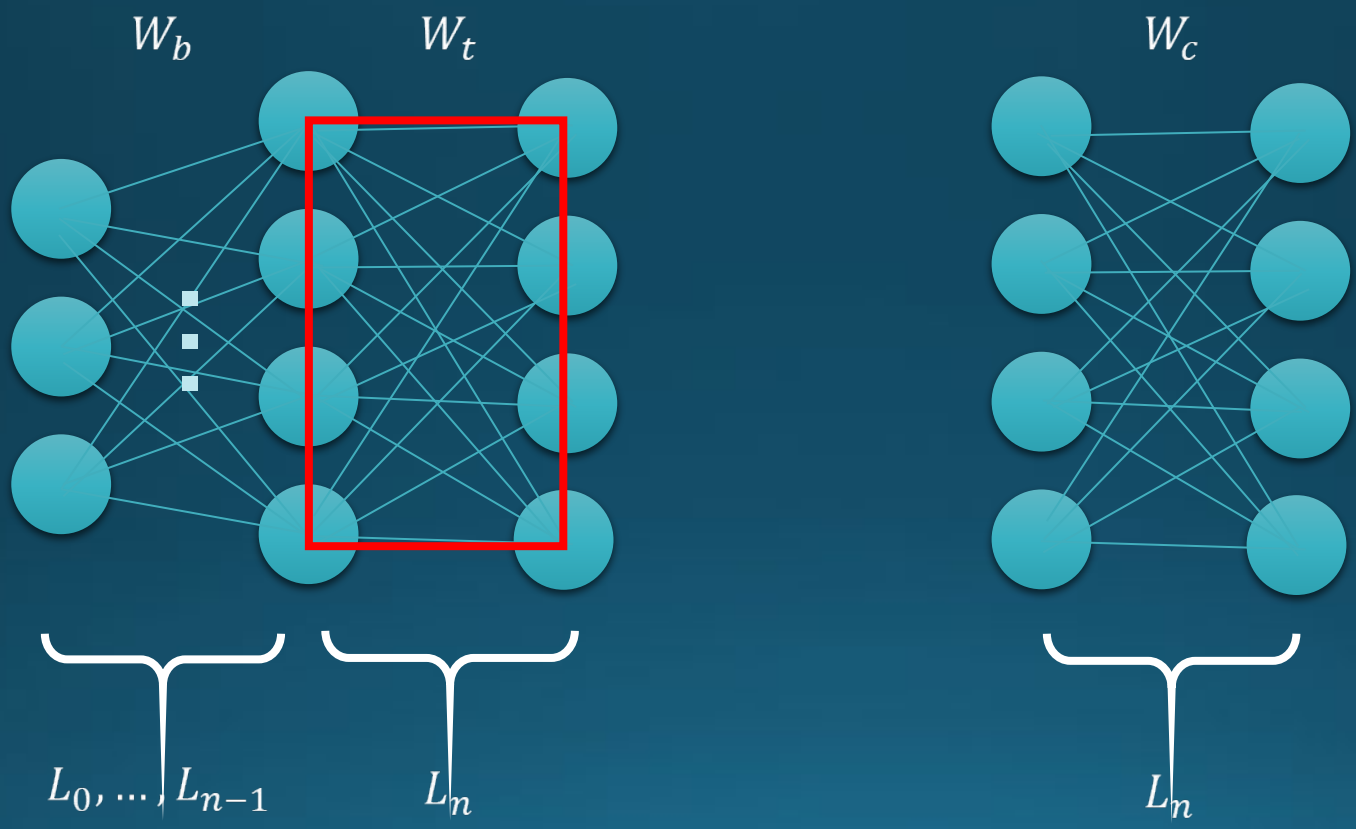
CL Strategies



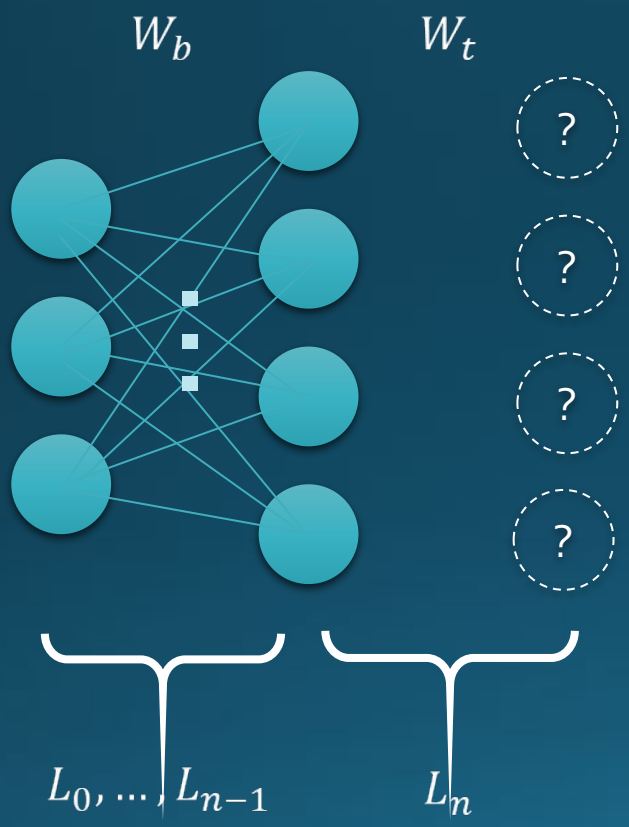
CL Strategies



AR-1: Architectural Part



Copy Weights with Re-init (CWR)



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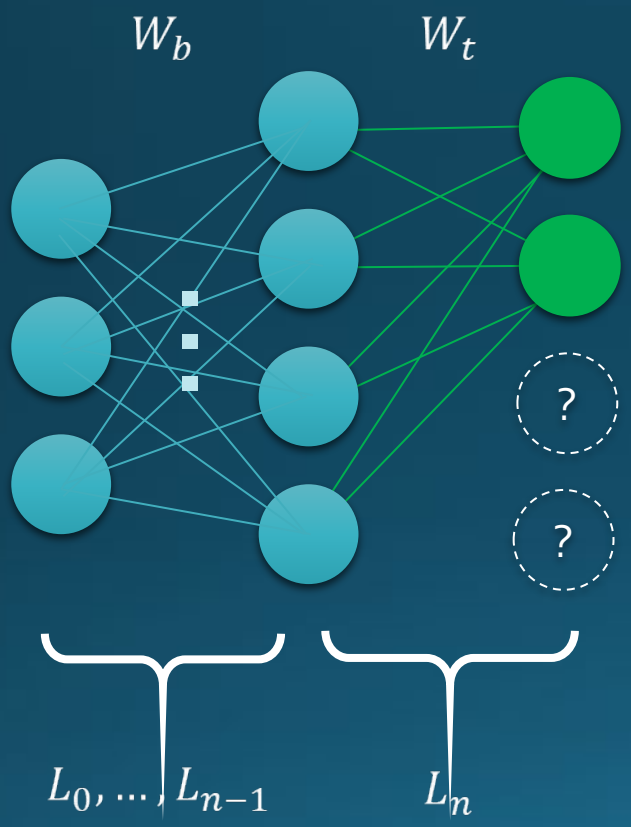

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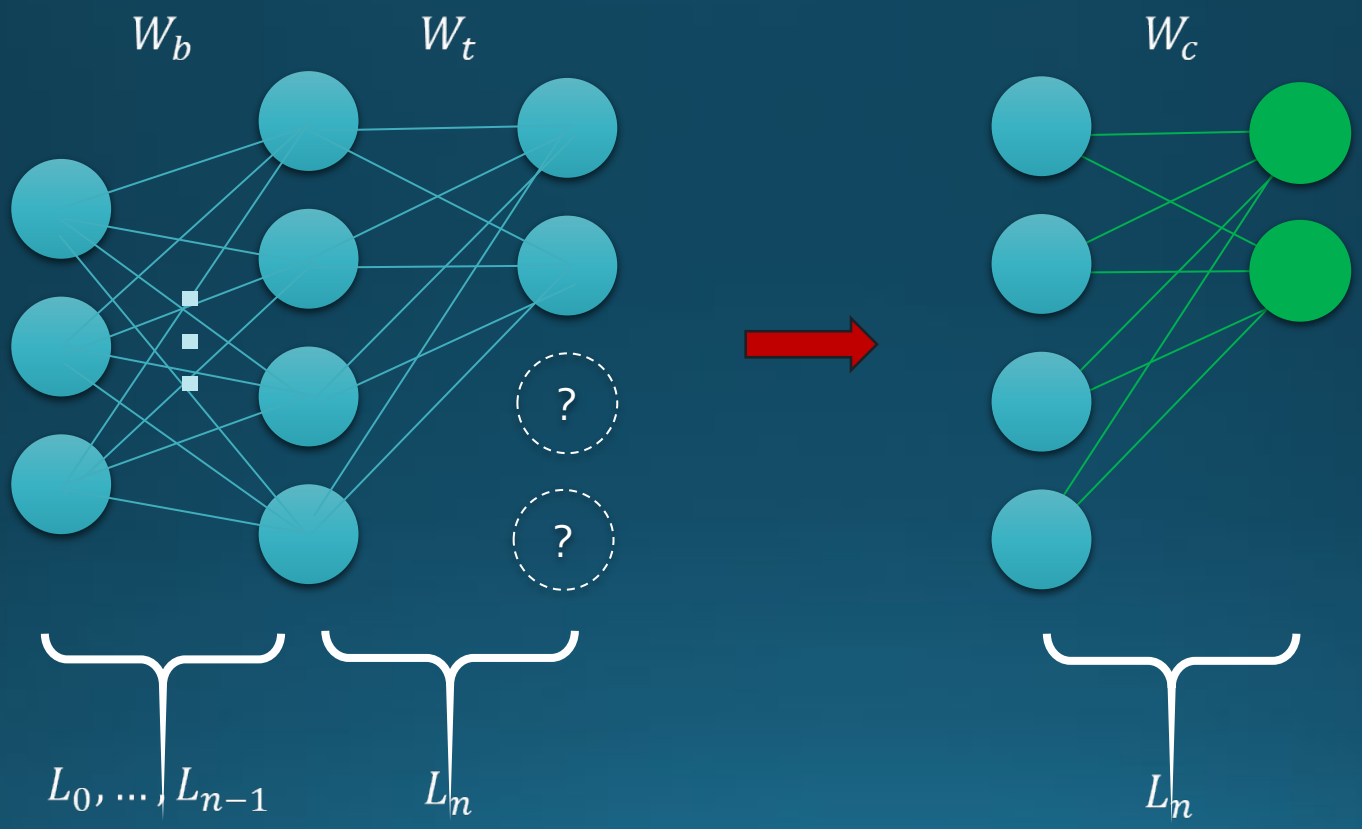

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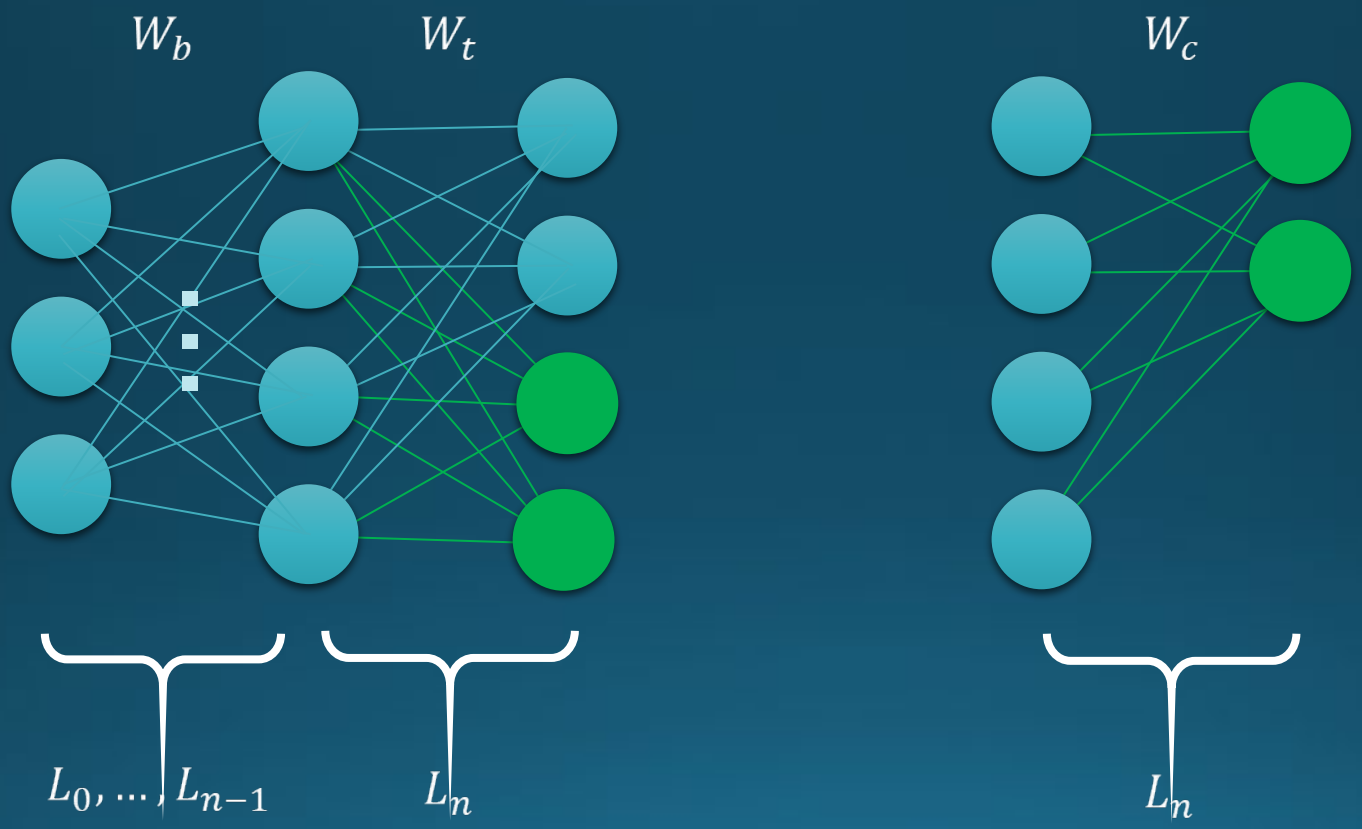

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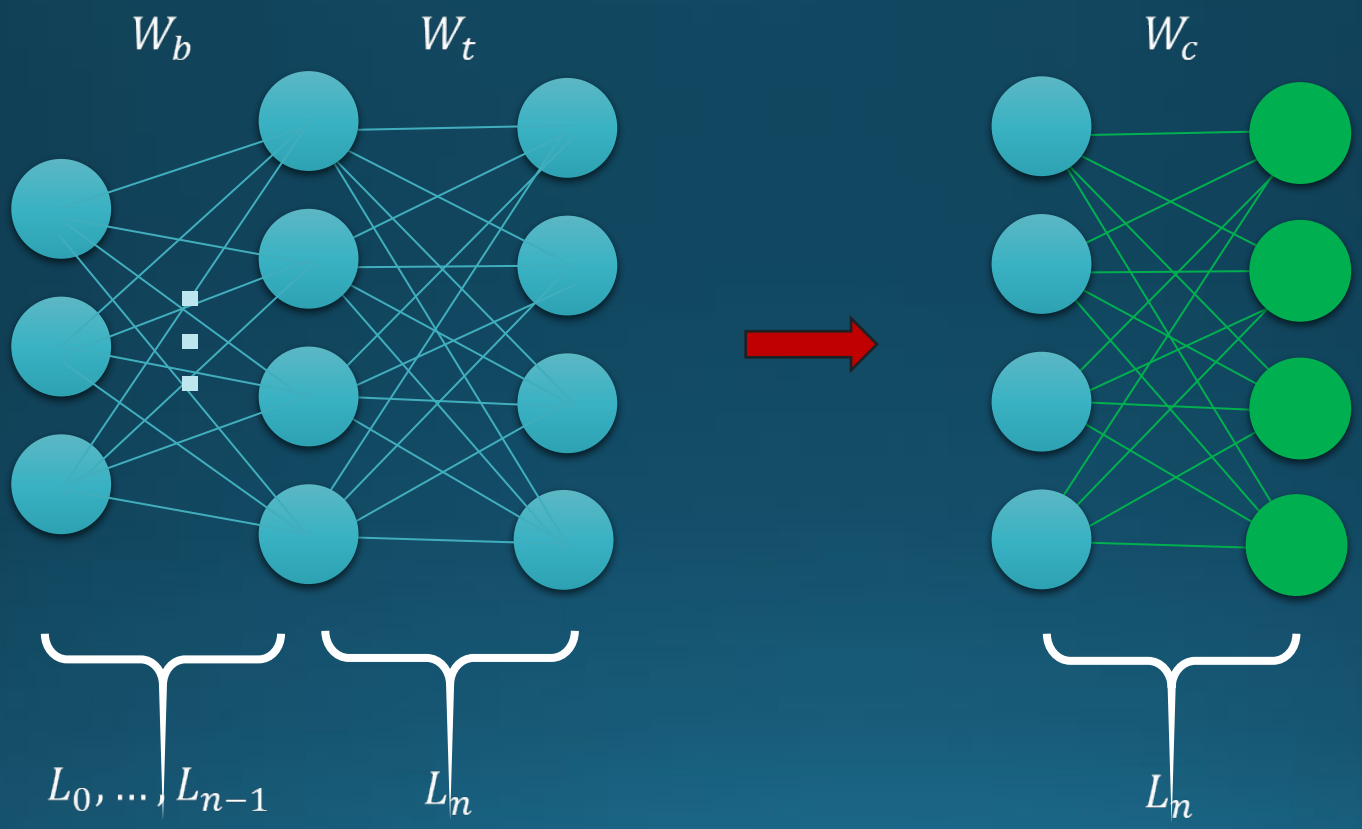
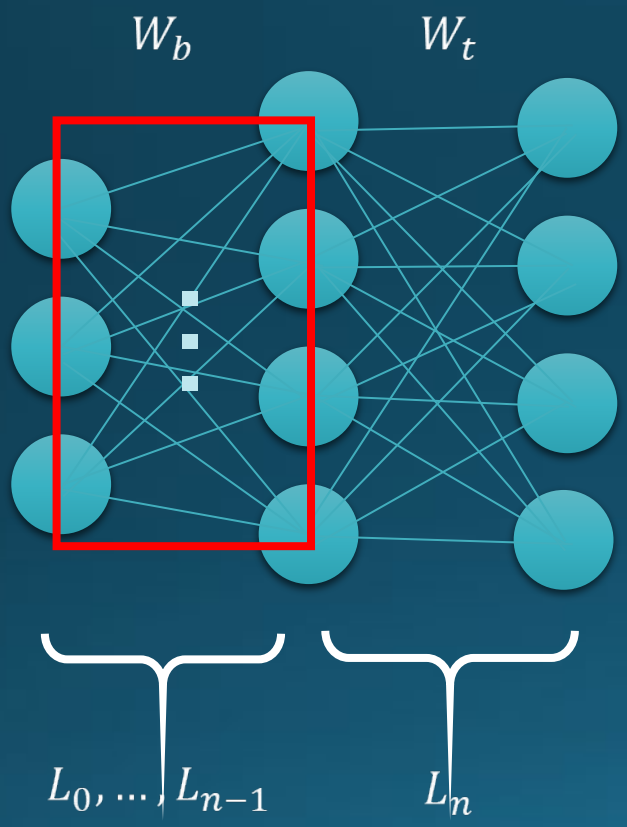


Lomonaco V. and Maltoni D. ***CORe50: a New Dataset and Benchmark for Continuous Object Recognition***. CoRL2017.

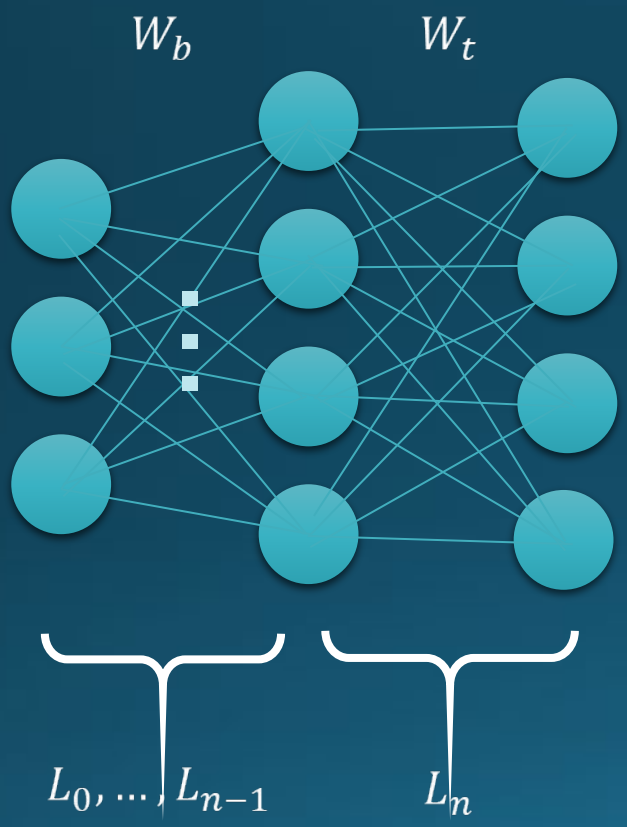
AR-1: Regularization Part



$$\tilde{L}_\mu = L_\mu + \lambda \sum_k \Omega_k^\mu \, (\bar{\theta}_k - \theta_k)^2$$

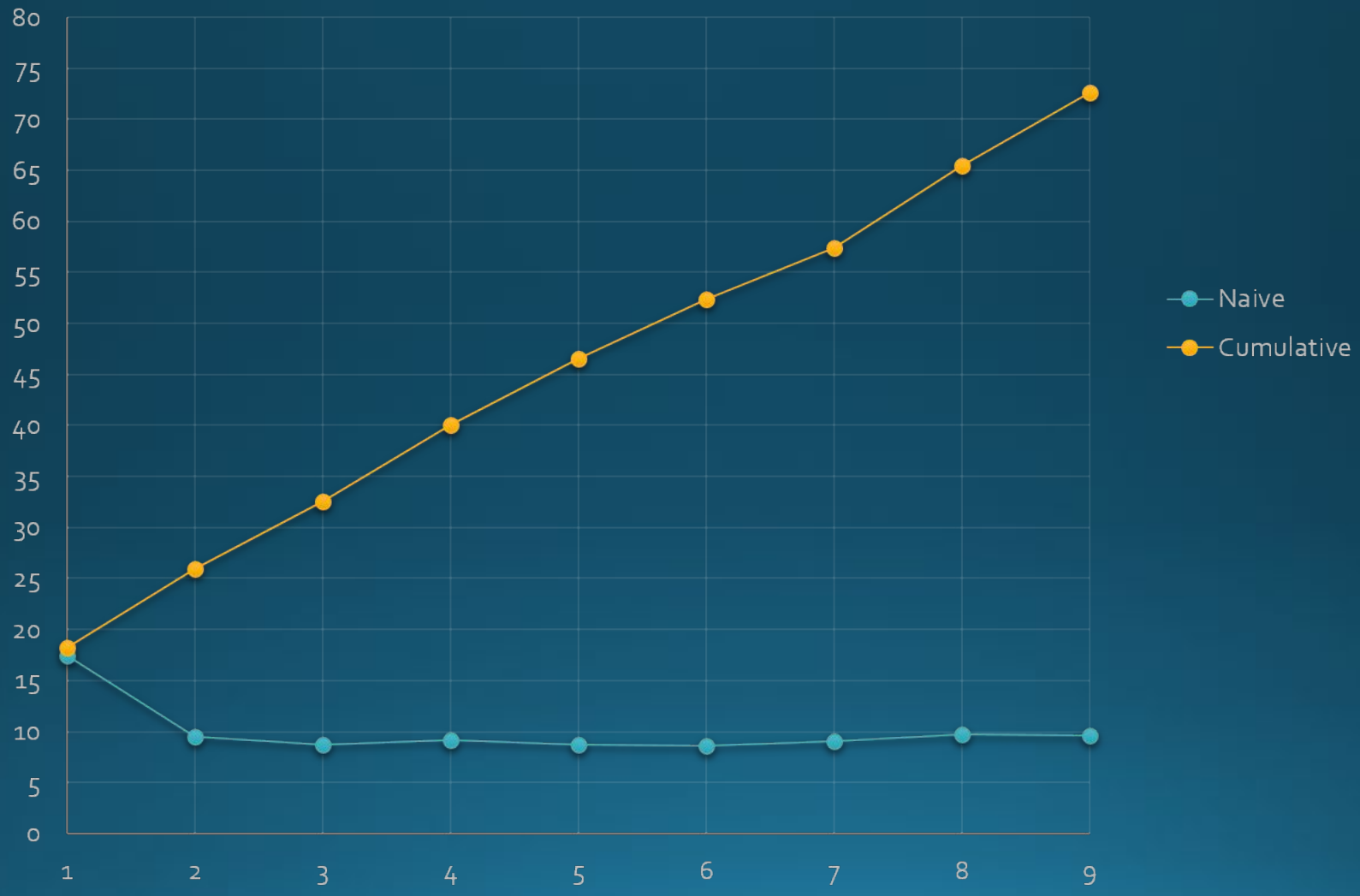
$$w_k^v = \int_{t^{\mu-1}}^{t^\mu} \frac{\partial L}{\partial \theta_k} \cdot \frac{\partial \theta_k}{\partial t}$$

AR-1: Additional features



- **Computational efficient** (independent from the number of training batches)
- Just one Ω_k (*running sum* + *max clip*)
- CWR with ***zero-init***
- CWR with ***mean-shift***

AR-1 results on CORe50



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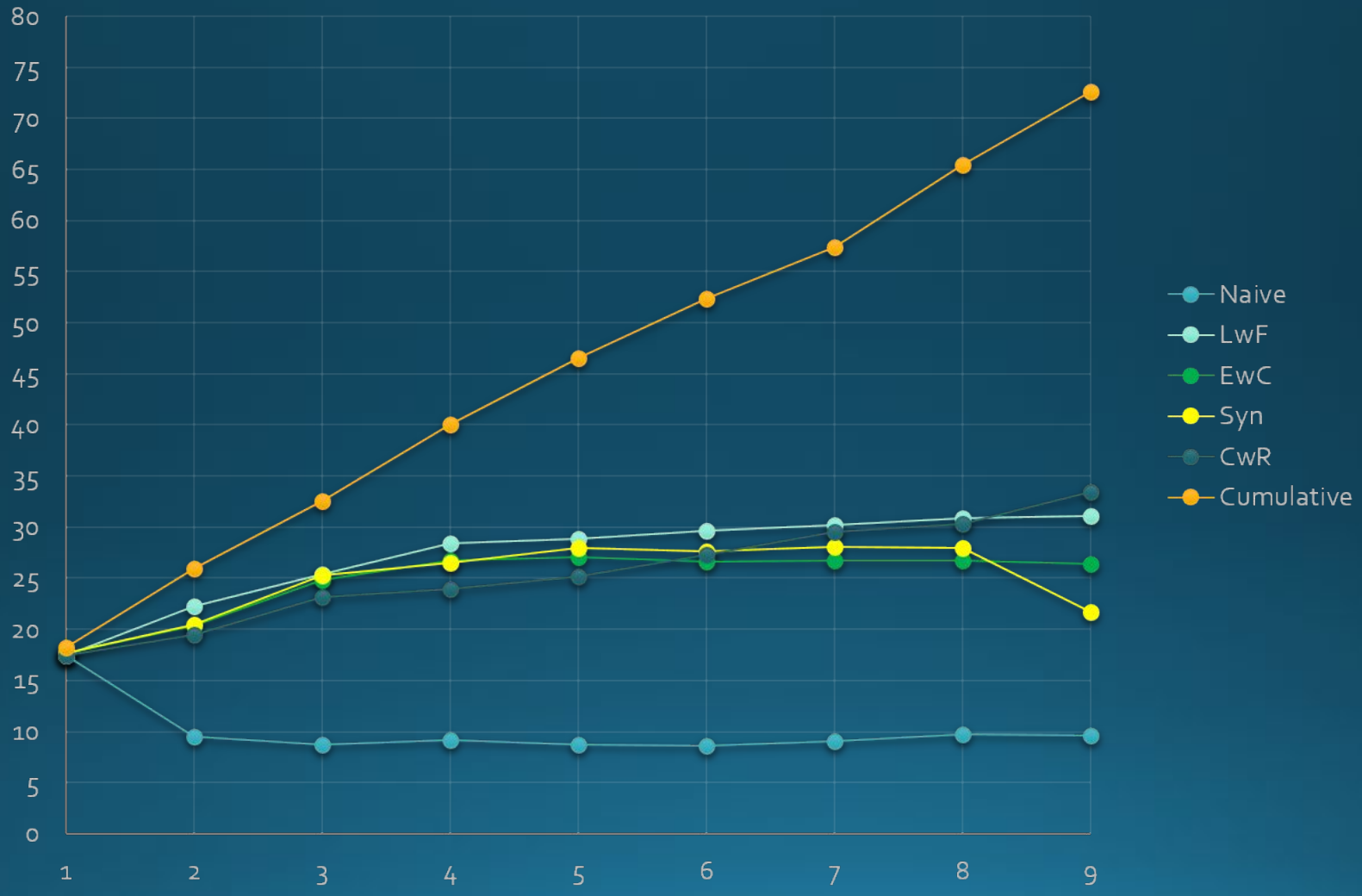
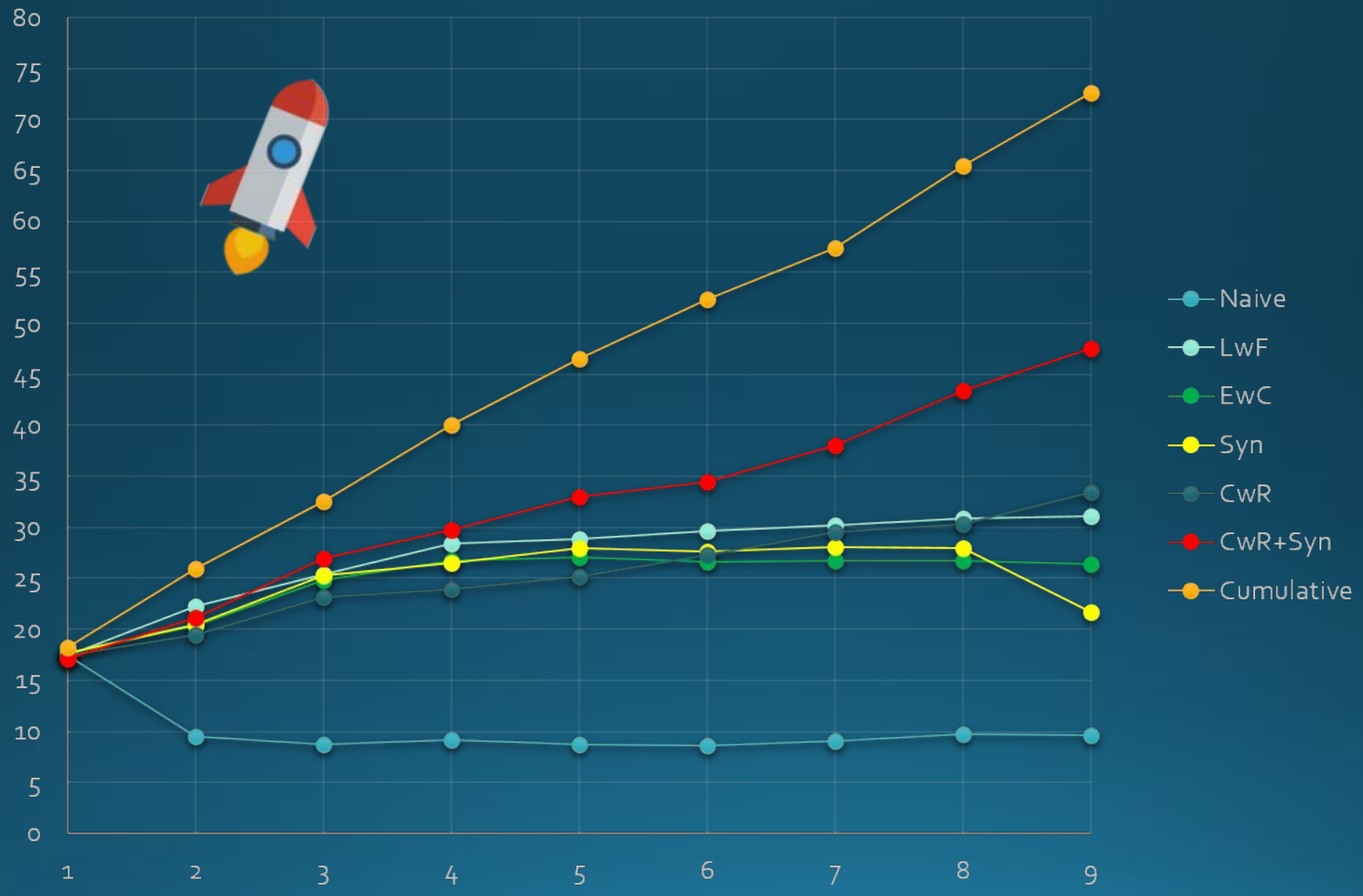


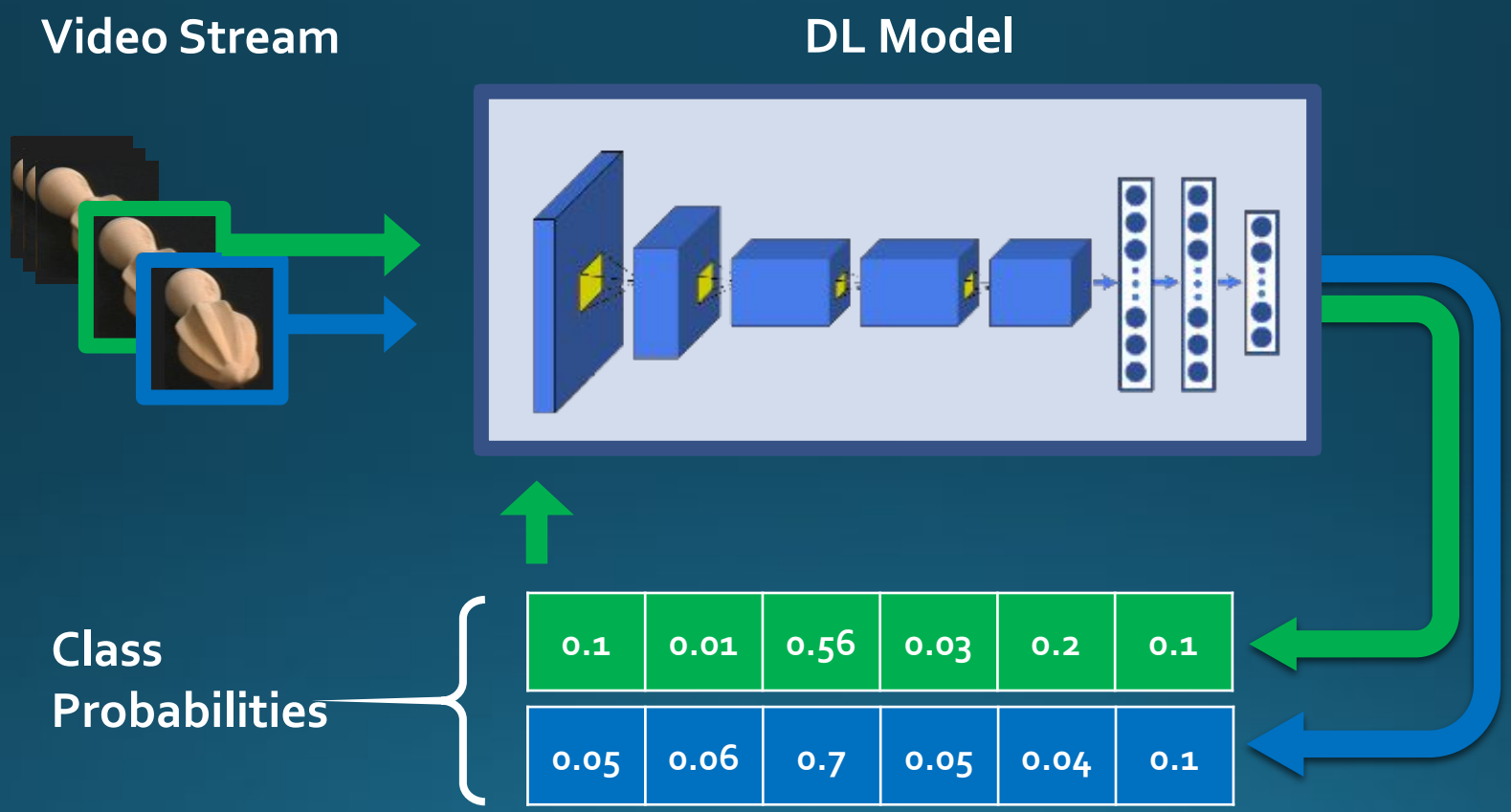
AR-1 results on CORe50



Unsupervised Continual Learning

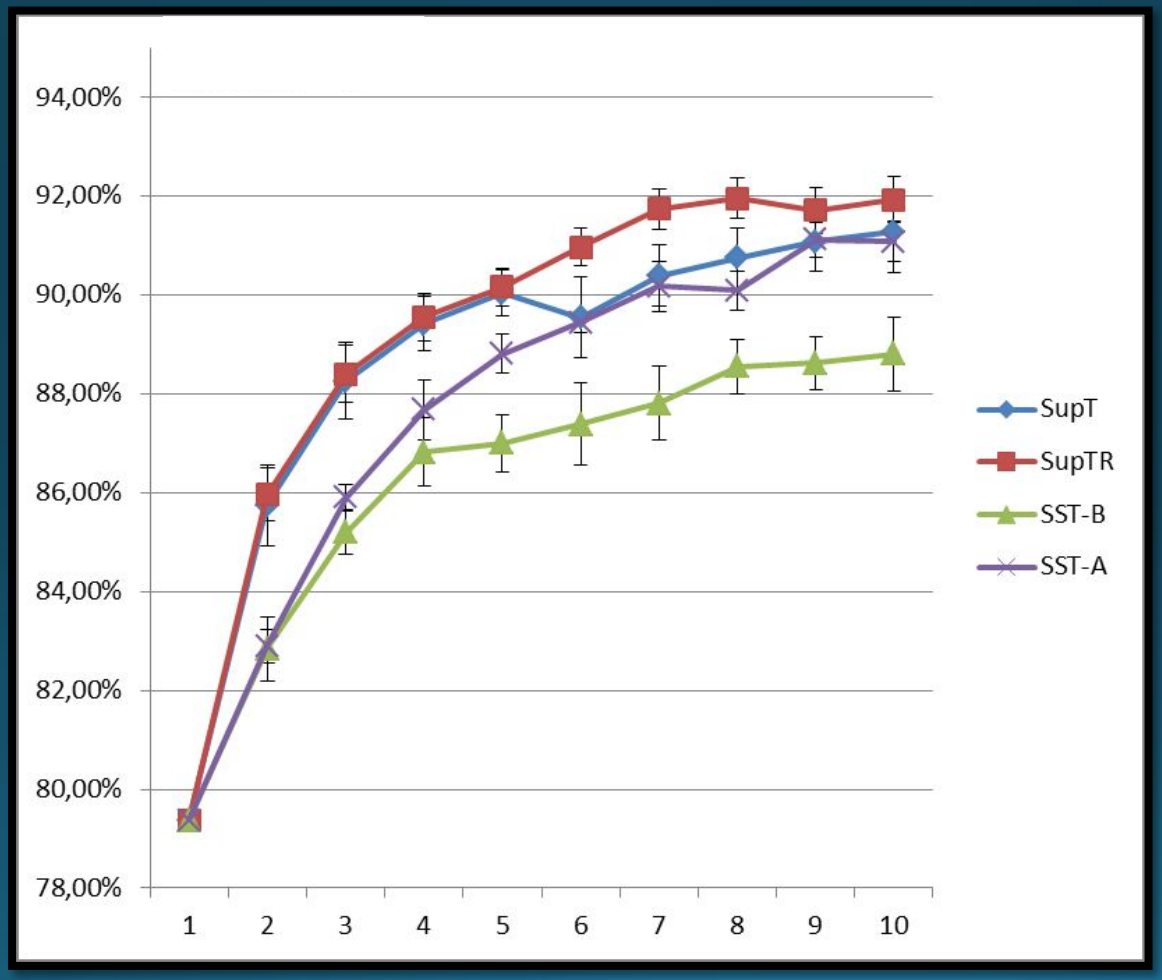
- **"Continual Labeling"** is one of **greatest barrier** after Catastrophic Forgetting for CL
- *Unsupervised Learning* is where CL can really shine
- **Difficult** to find **complex tasks** where Unsupervised Learning **alone can suffice**
- What about **Semi-Supervised Tuning**?

Semi-Supervised Tuning from Temporal Coherence



Lomonaco V. and Maltoni D. ***Semi-Supervised Tuning from Temporal Coherence***. ICPR 2016.

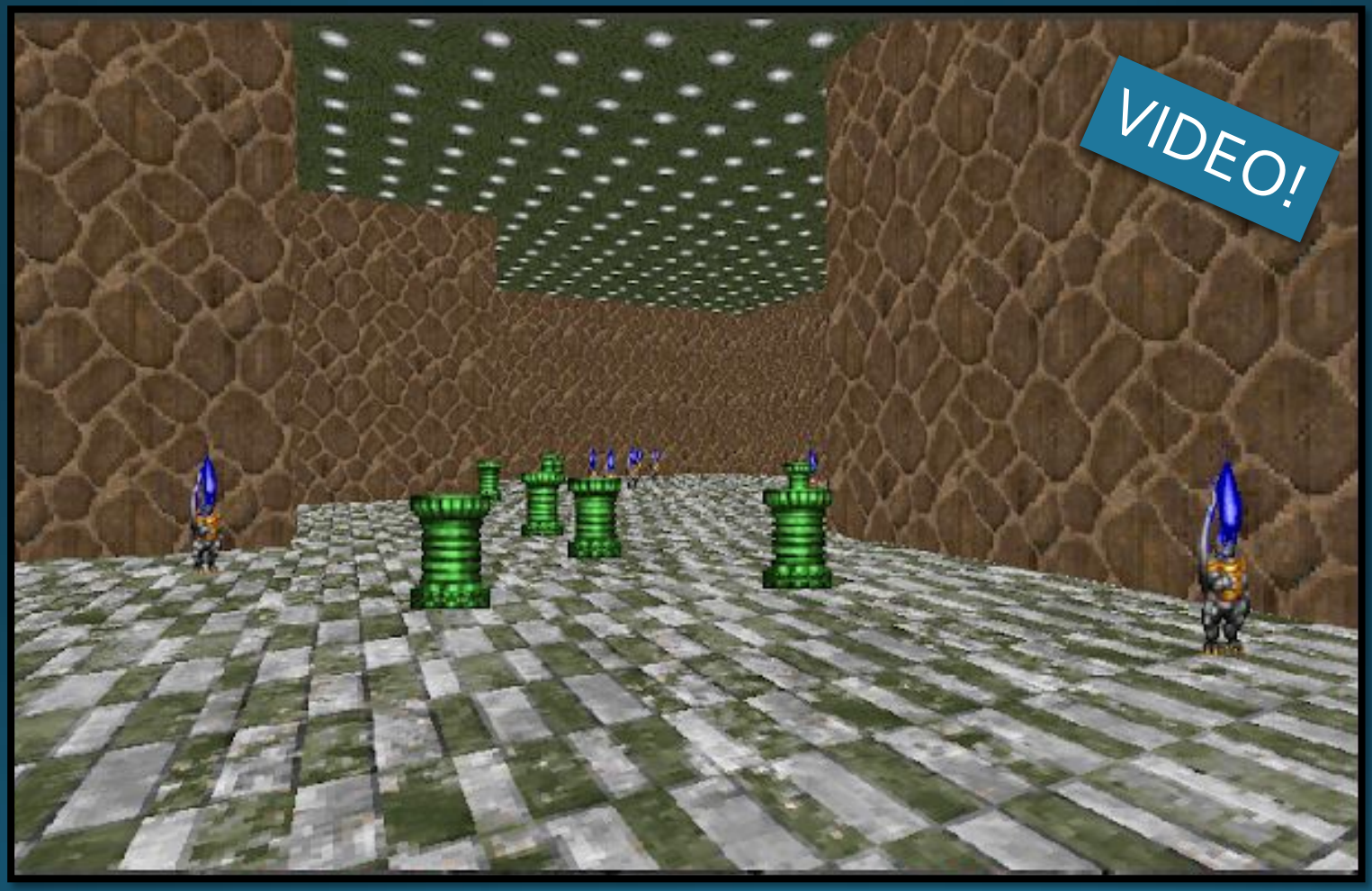
Semi-Supervised Tuning from Temporal Coherence



Continual Reinforcement Learning

- Very interesting for **futuristic Robotics applications**
- **Too many trials needed** for end-to-end learning
- Yet, many possibilities for **soft adaptation**!

CRL in 3D non-stationary environment



Lomonaco V., Desai K., Maltoni D. and Culurciello, E. ***Continual Reinforcement Learning in 3D non-stationary environments***. To be published.

Environment Illumination

100%

62%

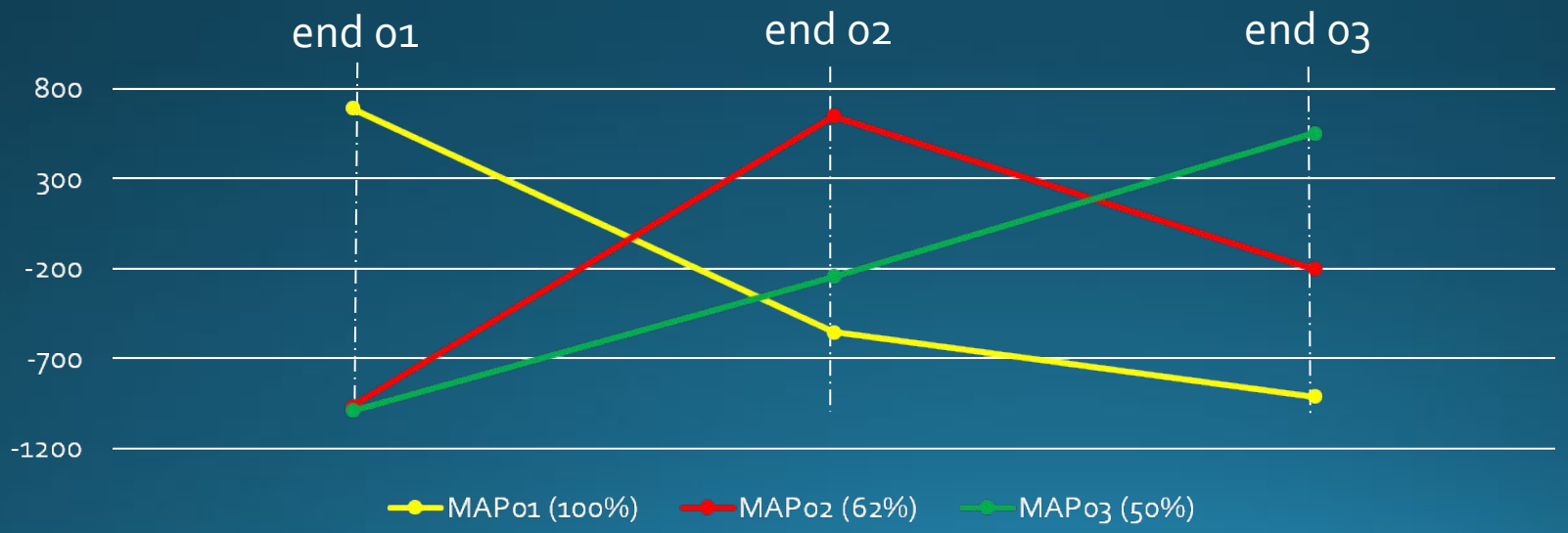
50%

Environment Illumination

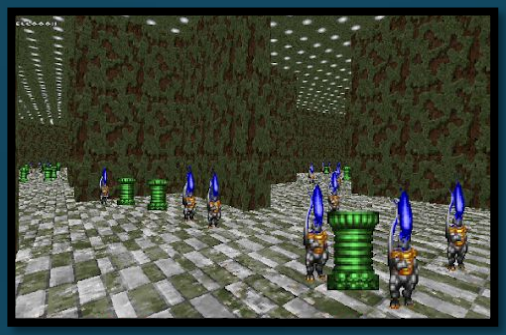
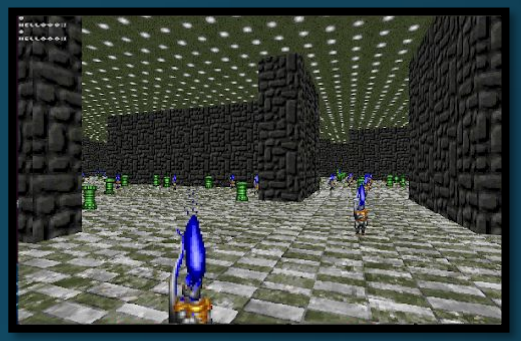
100%

62%

50%

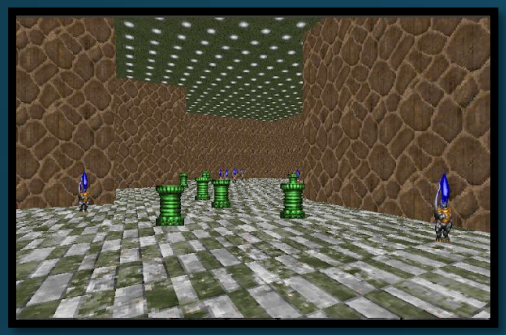


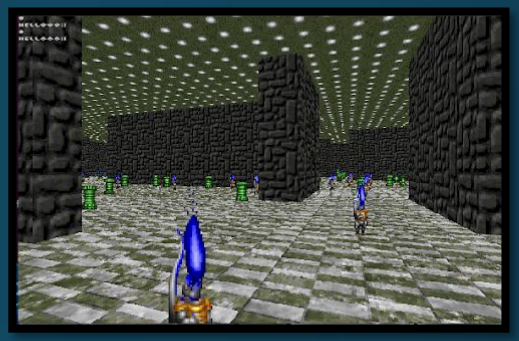
Other Considered Variations

Walls Textures

Other Considered Variations





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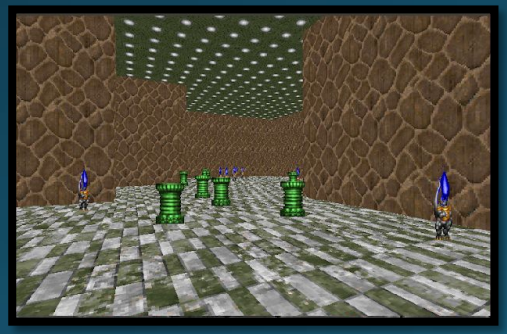


Objects Shape & Color

Continual Reinforcement Learning

Objectives:

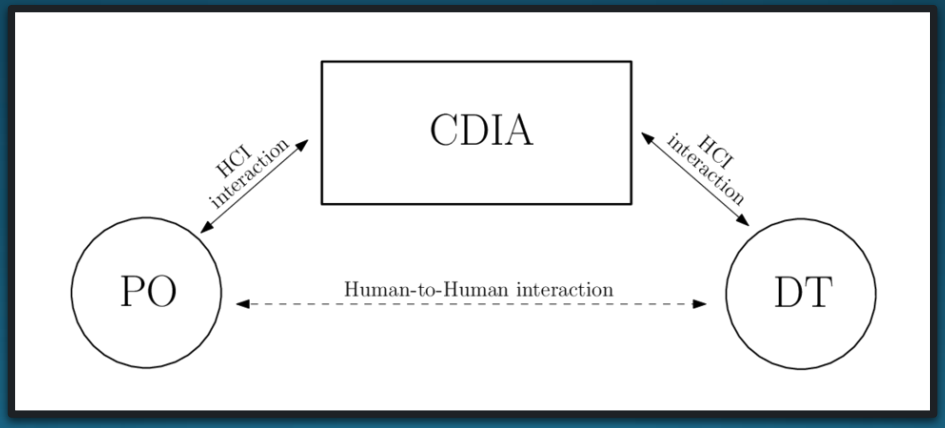
- **Avoid Forgetting**
- **Improve Generalization**
- **Speeding-up Adaptation**

… without "***end-of-task***" supervised signal!

Examples of CL Applications

Software Engineering

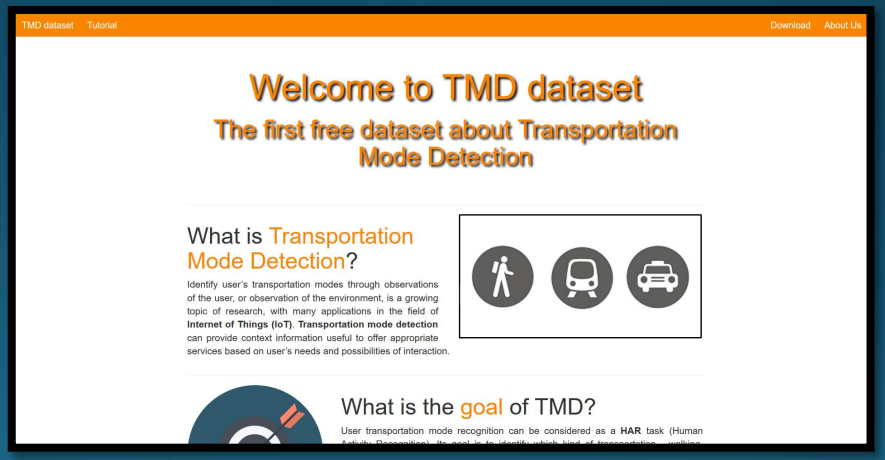
A Machine Learning Approach for Continuous Development. *Russo Daniel, Lomonaco Vincenzo and Ciancarini Paolo. Proceedings of 5th International Conference in Software Engineering for Defense Applications, 2018.*



Examples of CL Applications

IoT Devices

Custom Dual Transportation Mode Detection by Smartphone Devices Exploiting Sensor Diversity. *Carpineti Claudia, Lomonaco Vincenzo, Bedogni Luca, Di Felice Marco and Bononi Luciano. IEEE International Conference on Pervasive Computing and Communications Workshops, 2018.*

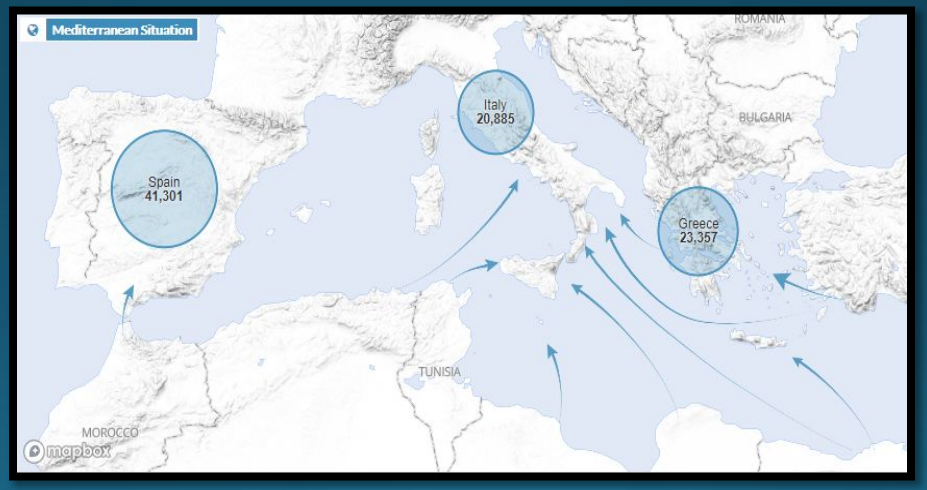


http://cs.unibo.it/projects/us-tm2017

Examples of CL Applications

Drones

Intelligent Drone Swarm for Search and Rescue Operations at Sea. *Vincenzo Lomonaco, Angelo Trotta, Marta Ziosi, Juan de Dios Yáñez Ávila, Natalia Díaz-Rodríguez. Yet To be published.*



Examples of CL Applications

Smart Cameras

Comparing Incremental Learning Strategies for Convolutional Neural Networks. *Lomonaco V. and Maltoni D. IAPR Workshop on Artificial Neural Networks in Pattern Recognition. Springer International Publishing, 2016.*

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Even buying us a coffee
would mean a lot for us! :-)

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Questions?

*1st **AI for People** Workshop*

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