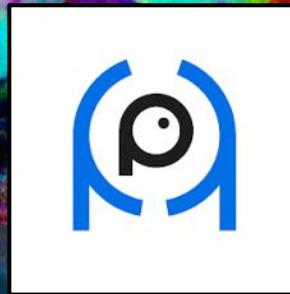


Block IV - Continual AI

1st AI for People Workshop

09-08-2020



Vincenzo Lomonaco

*Postdoc @ University of Bologna
President of ContinualAI.org*

vincenzo.lomonaco@unibo.it

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 AlforPeople.org**

What's ContinualAI?



Continual**AI**

- *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.



State-of-the-art

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State-of-the-art

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



The Curse of Dimensionality

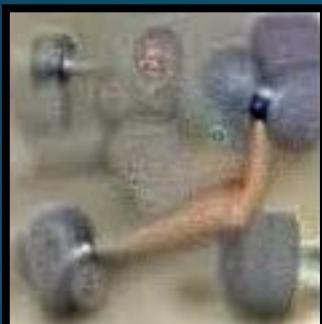
$3,9 \cdot 10^{372282}$

of possible 227x227 RGB images

The Curse of Dimensionality

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

of possible 227x227 RGB images



The Curse of Dimensionality

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

of possible 227x227 RGB images

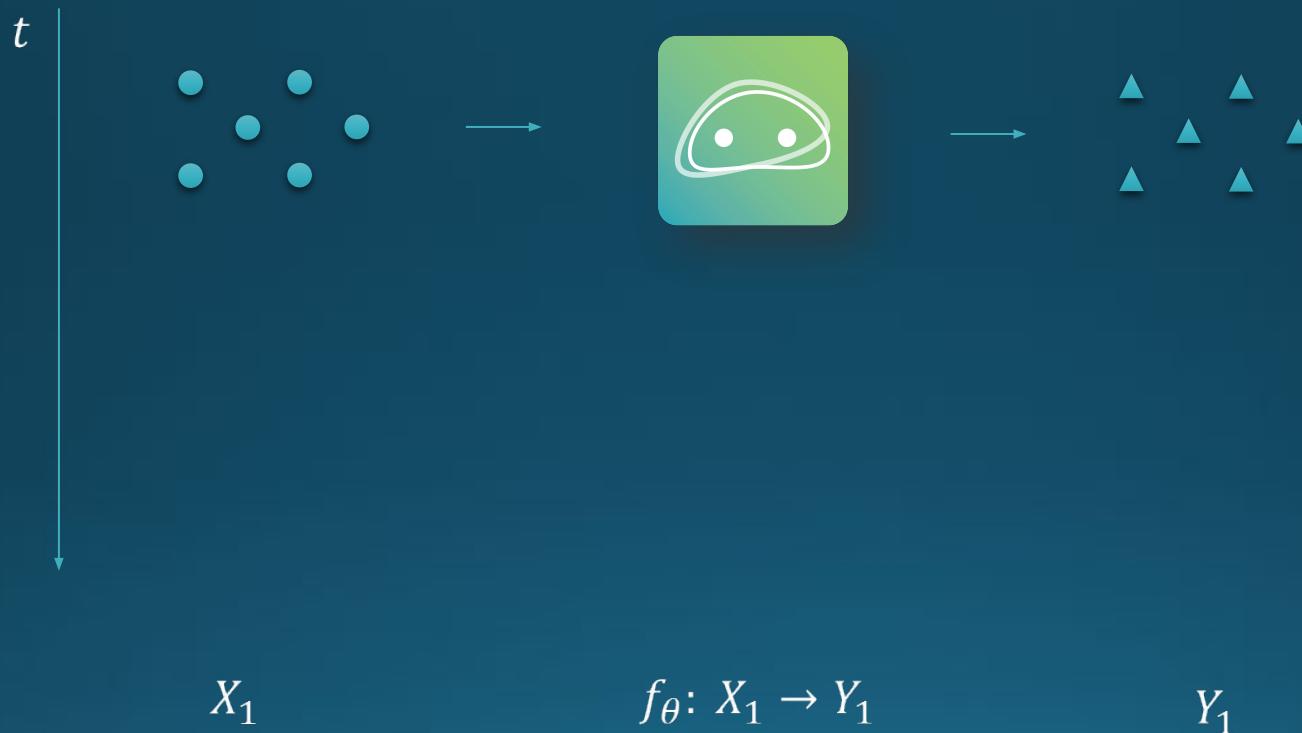


a group of people standing on
top of a beach

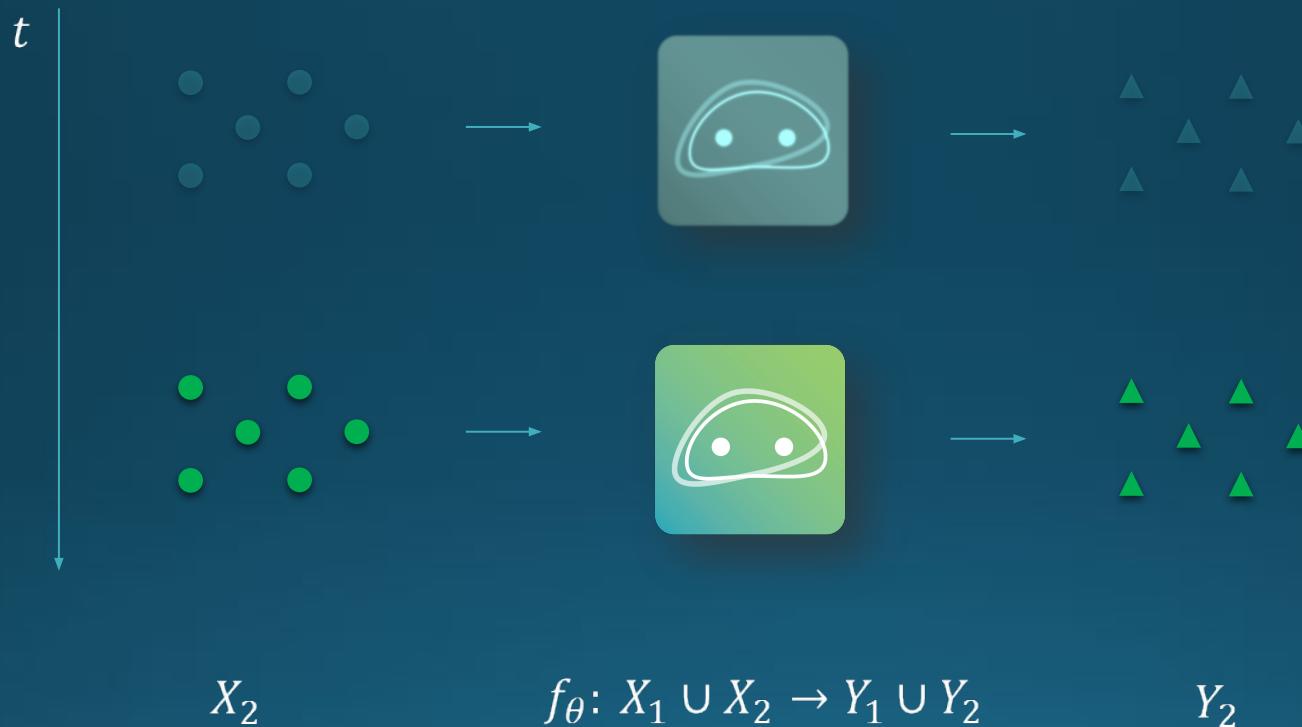
*How can we improve AI
scalability and adaptability?*

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

Continual Learning



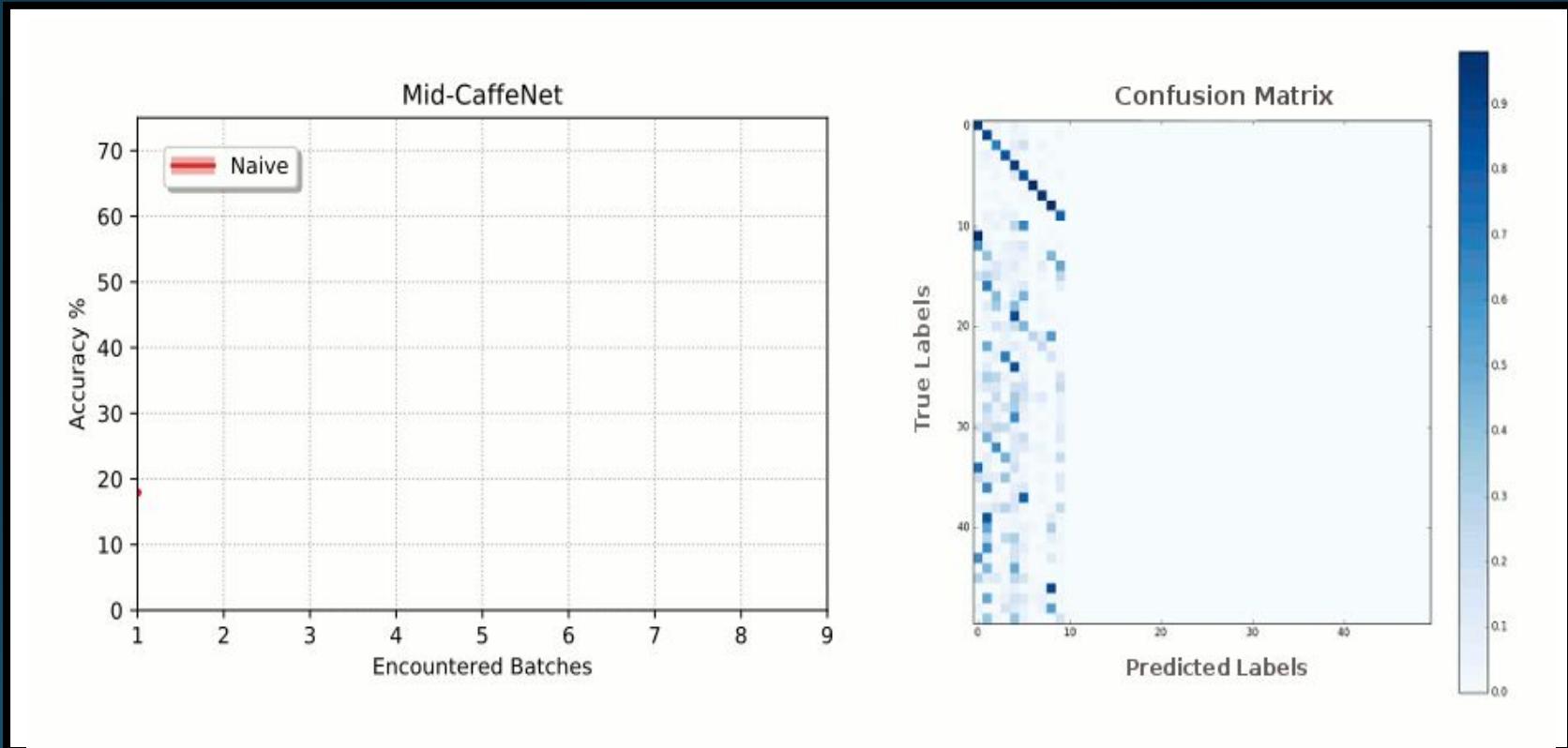
Continual Learning



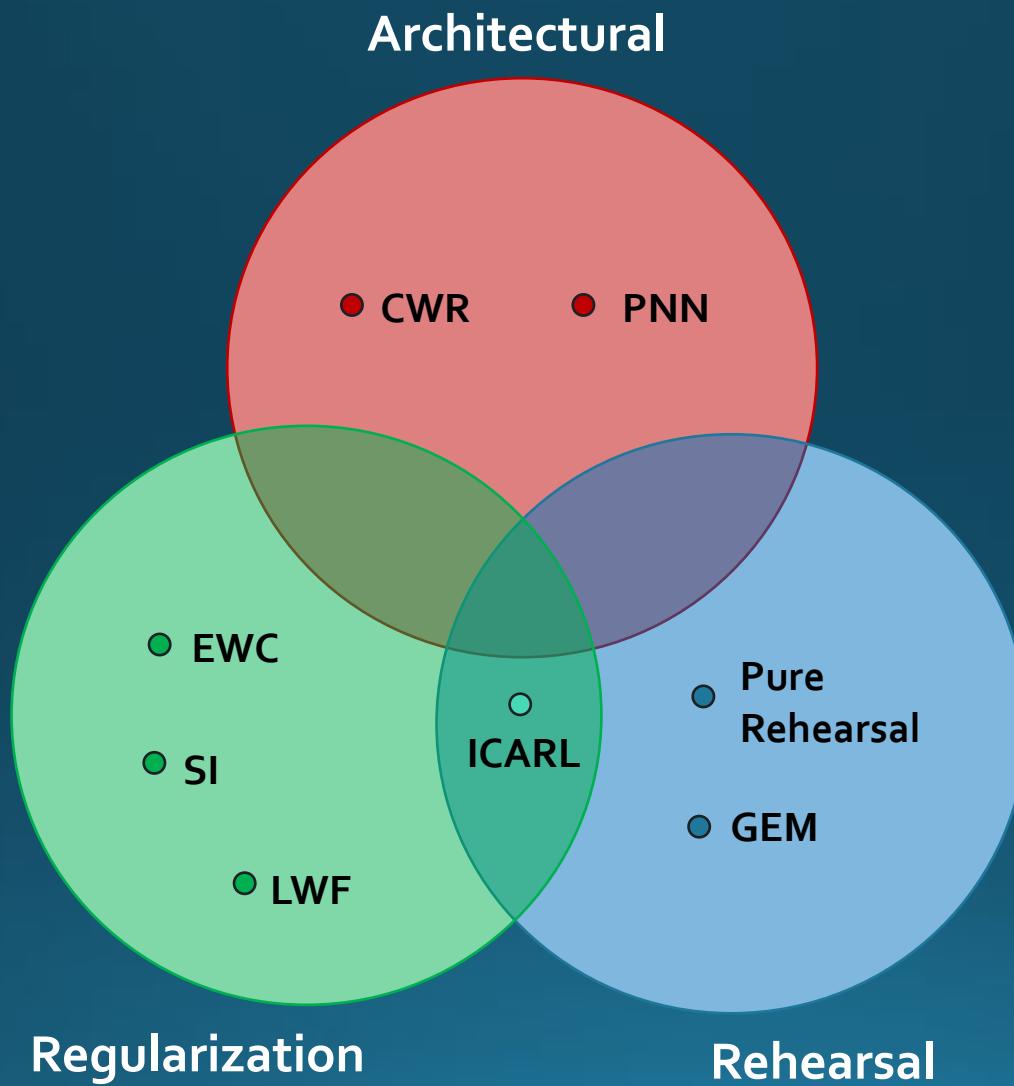
Continual Learning (CL)

- 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**.

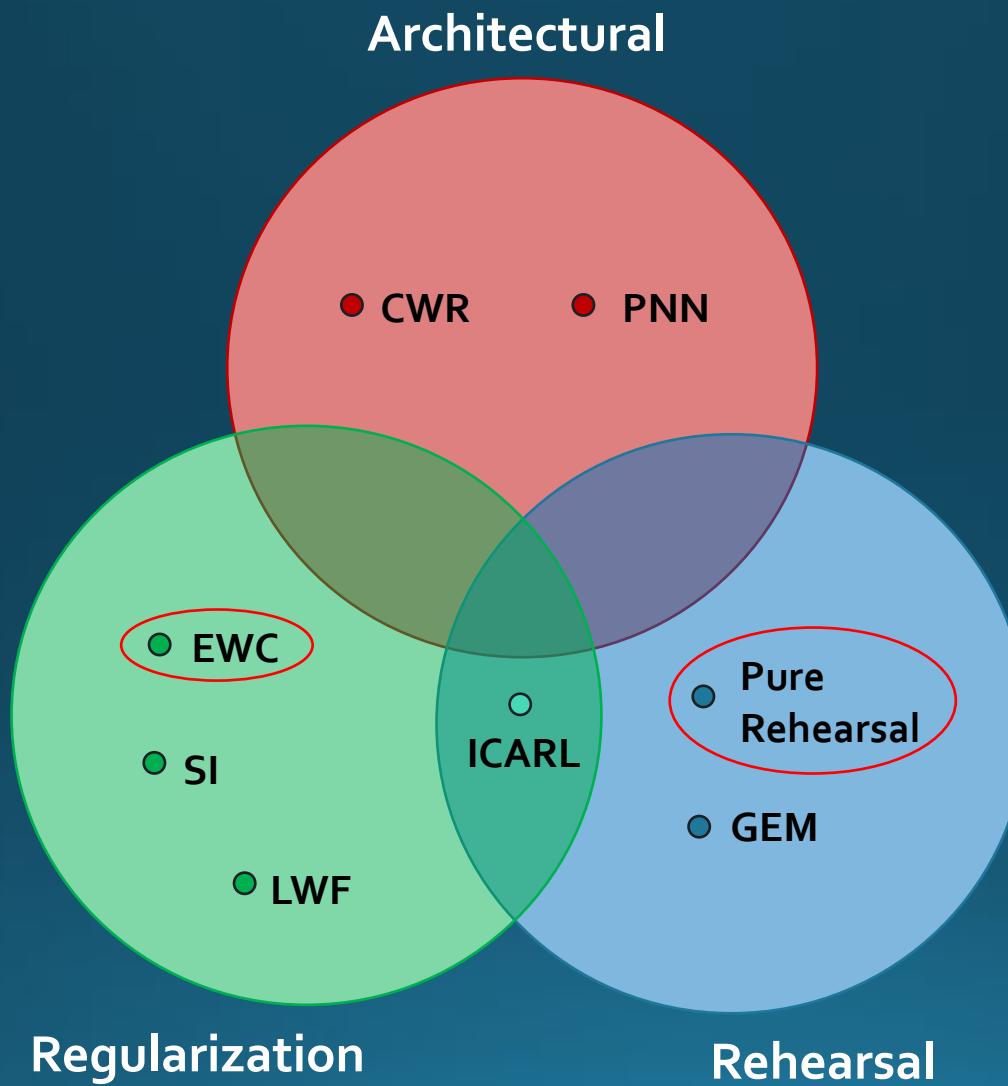
Why CL is a challenging (and fun) problem?



CL Strategies



CL Strategies



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

The screenshot shows a Google Colaboratory notebook interface. The title bar reads "intro_to_continual_learning.ipynb". The menu bar includes File, Edit, View, Insert, Runtime, Tools, Help, SHARE, CONNECT, EDITING, and a user profile icon. The left sidebar contains a "Table of contents" with the following sections: A Gentle Introduction to Continual Learning in PyTorch, Google Colaboratory, Installing Pytorch 0.4.0, MNIST: Digits recognition with PyTorch, CL Strategies, Naive Strategy, Reheashal Strategy, Elastic Wheights Consolidation (EWC) Strategy, and Plot Results. The main content area displays the following text:

A Gentle Introduction to Continual Learning in PyTorch

In this brief tutorial we will learn the basics of *Continual Learning* using Pytorch 0.4.0. We will use the standard MNIST benchmark so that you can swiftly run this notebook from anywhere!

This notebook is part of the [Continual AI Colab](#) is a repository meant for tutorials and demo running on Google Colaboratory. [Continual AI](#) is an open research community on the topic of Continual Learning and AI! Join us today [on slack!](#) :-D

We will start with learning over the standard *MNIST* benchmark, then we will move in the actual continual learning setting with the *Permuted MNIST* benchmark. Let's have some fun! :-)

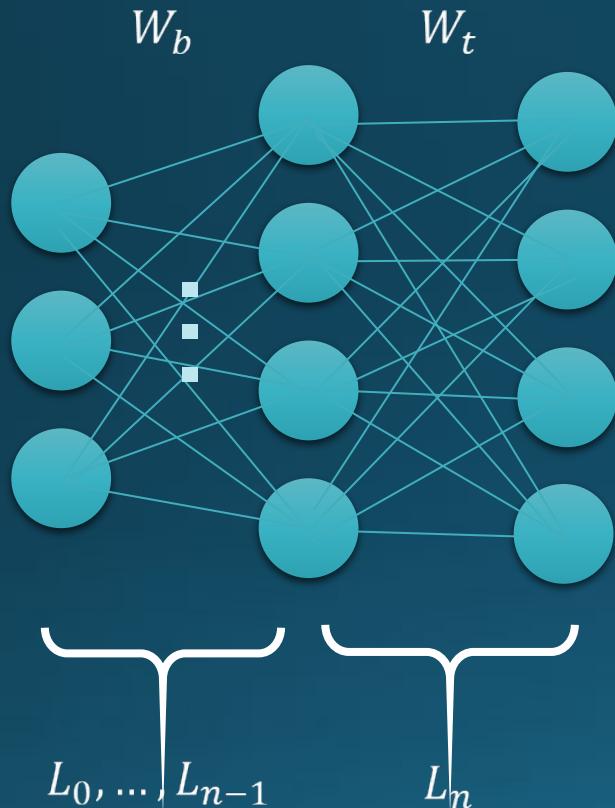
Connecting a local runtime

In case resources are not enough for you (no GPU for example), you can always connect another [local runtime](#) or to a [runtime on a Google Compute Engine instance](#).

This notebook has been designed to run fast enough on simple CPUs so you shouldn't fined any trouble here, using a free [hosted account](#).

<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

| <i>Dataset</i> | <i>Strategy</i> |
|-------------------|-----------------|
| 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.



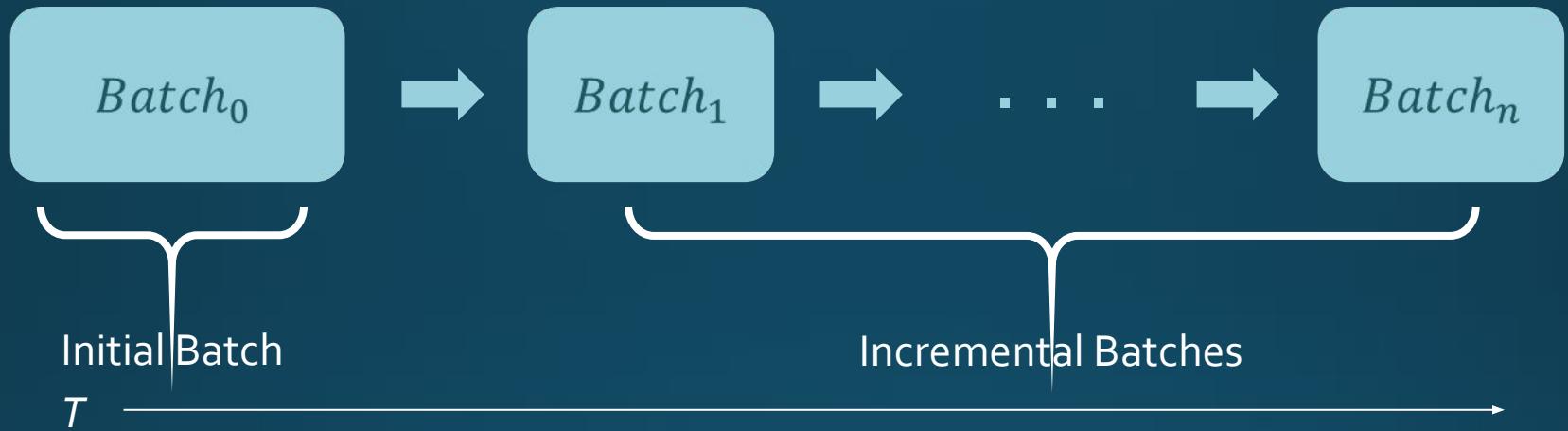
CORe50: a Video Benchmark for CL and Object Recognition/Detection



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

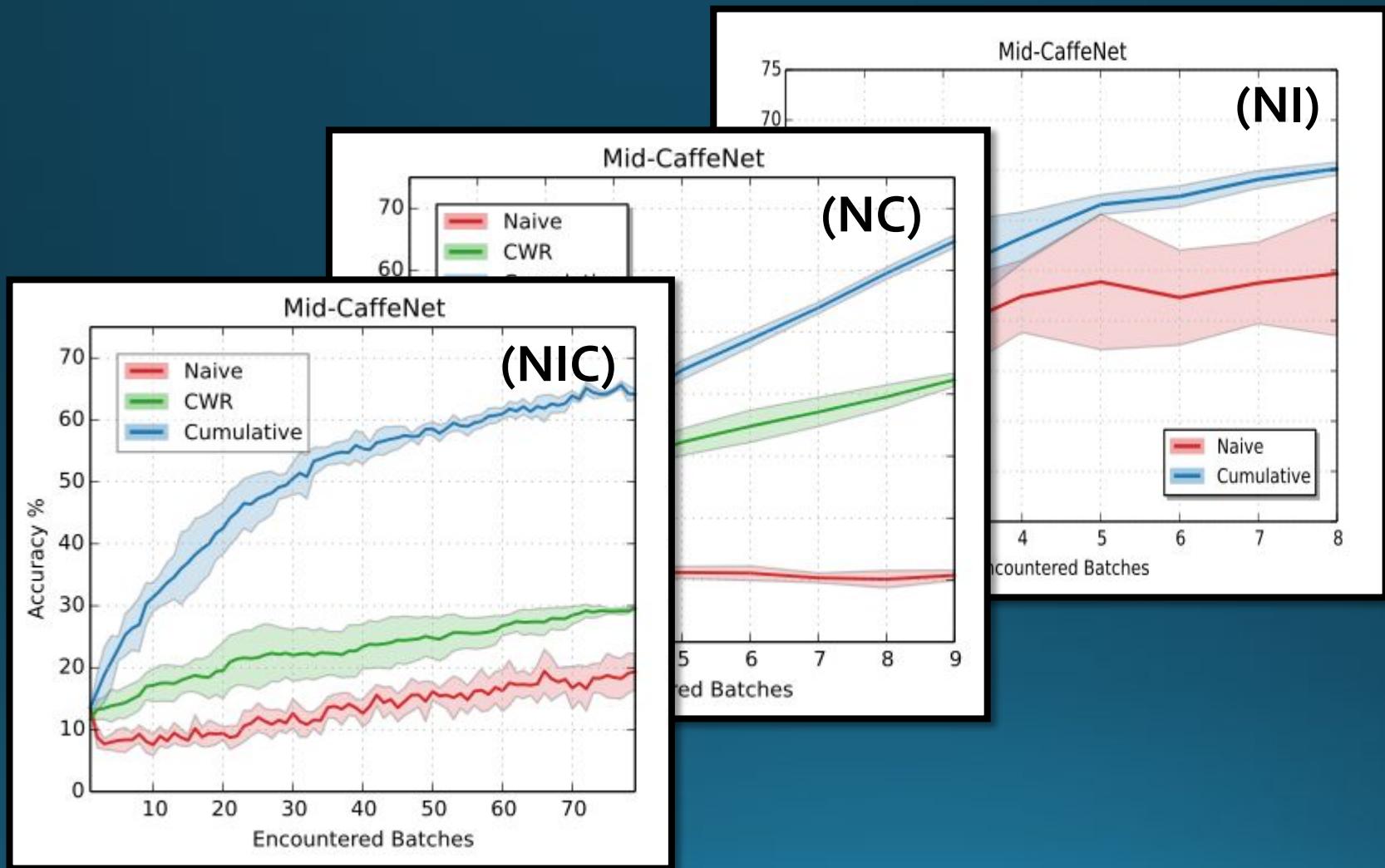
| | | |
|---|--------------------------|--------------------|
|  | # Images | 164,866 |
| | Format | RGB-D |
| | Image size | 350x350 128x128 |
| | # Categories | 10 |
| | # Obj. x Cat. | 5 |
| | # Sessions | 11 |
| | # img. x Sess. | ~300 |
| | # Outdoor Sess. | 3 |
| | Acquisition Sett. | Hand held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

Single Incremental Task

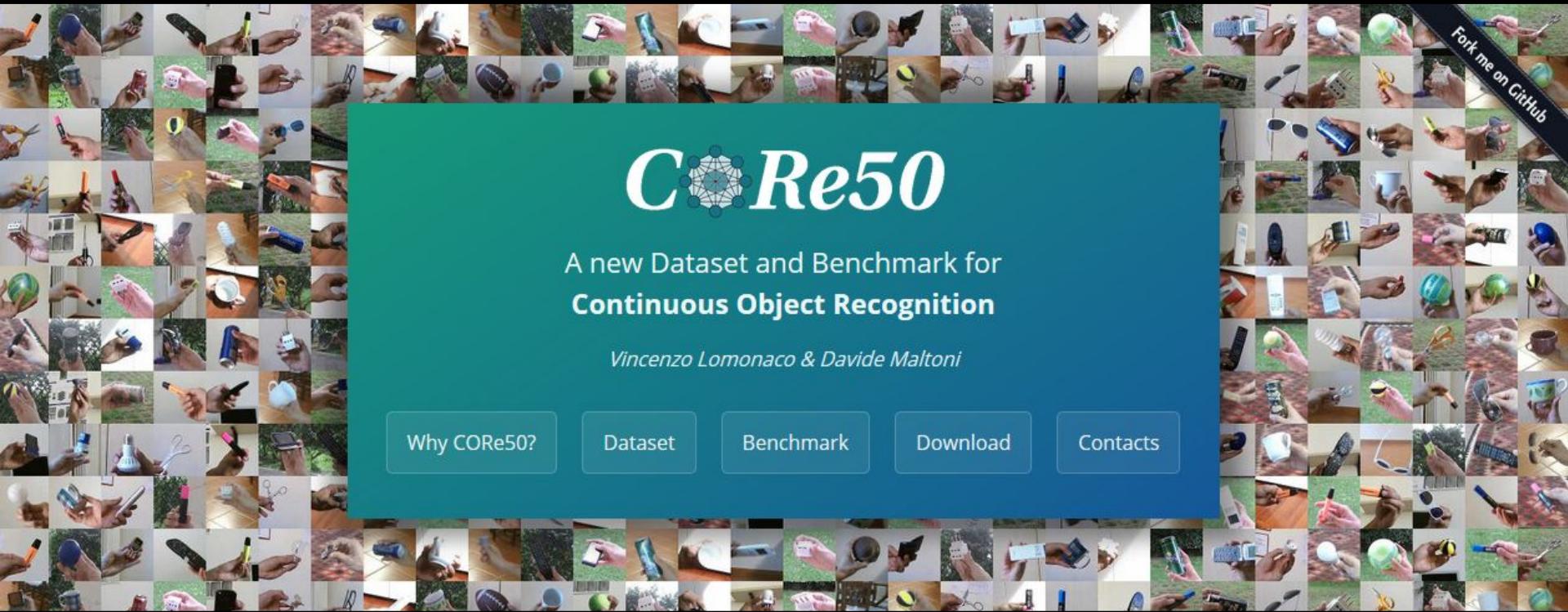


1. **New Instances (NI)**
2. **New Classes (NC)**
3. **New Instances and Classes (NIC)**

CORe50 Benchmark



CORe50 Website



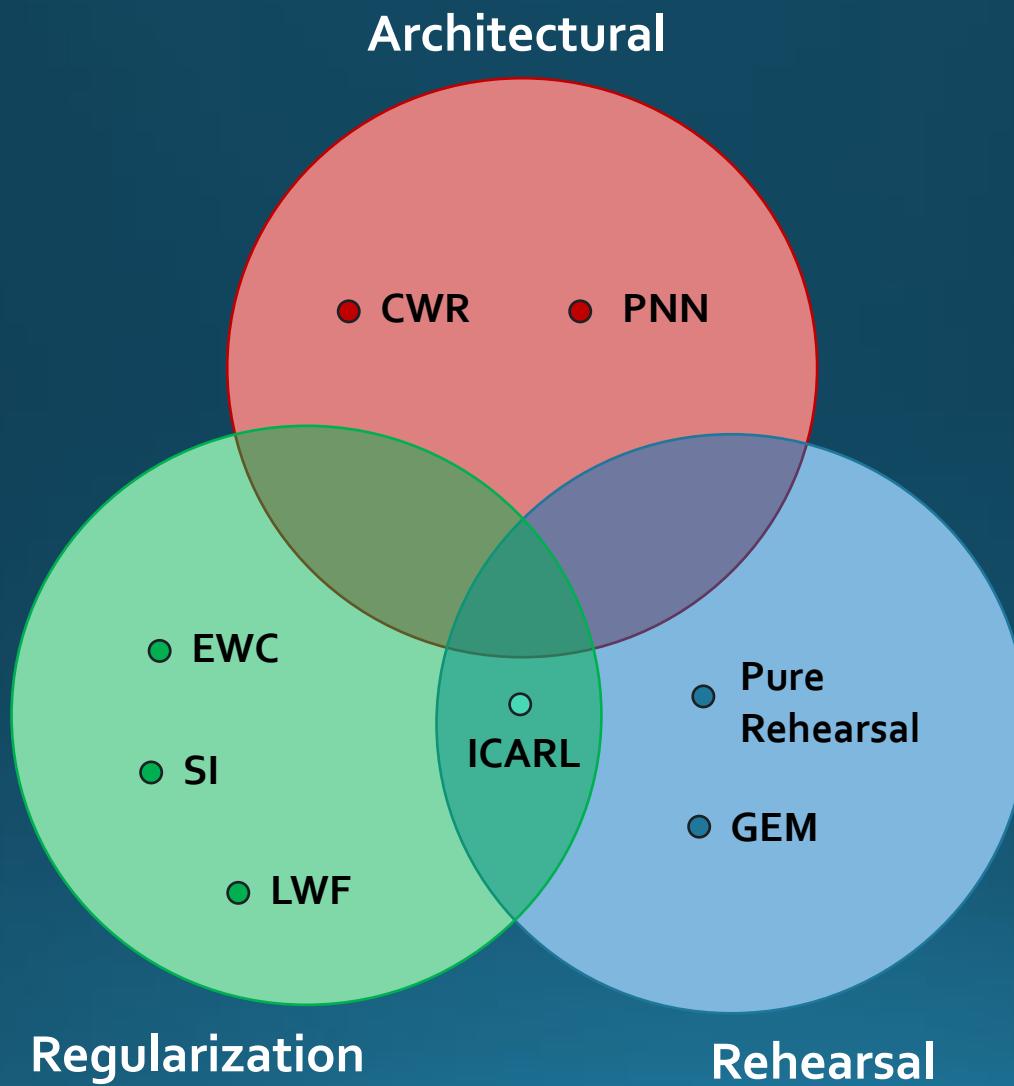
Dataset, Benchmark, code and additional information freely available at:
vlomonaco.github.io/core50

AR-1

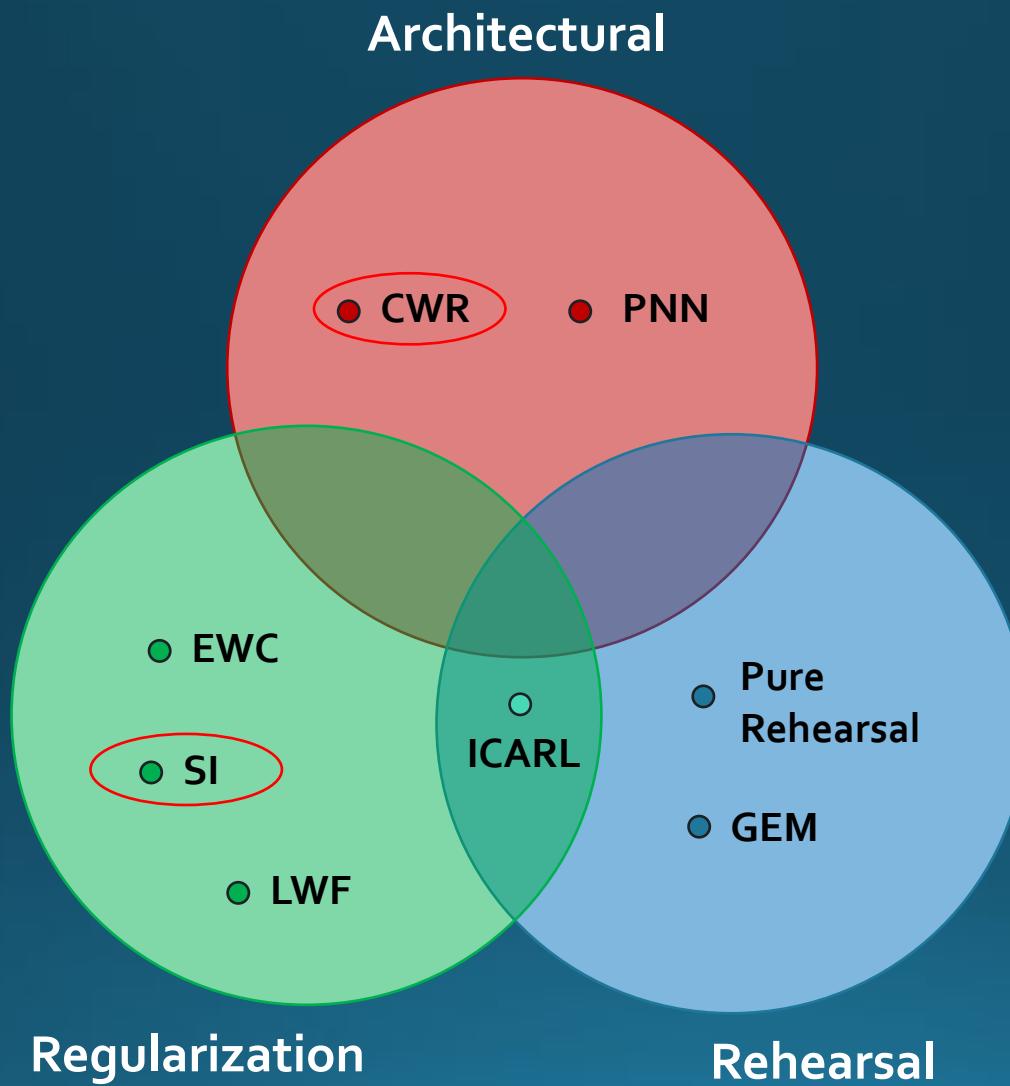
A large rocket engine test stand is shown from a low angle, looking up at the massive engine bell. A powerful, bright orange-yellow flame is erupting from the nozzle, illuminating the surrounding metal structures. The test stand is a complex network of steel beams, ladders, and walkways. A dark rectangular overlay contains the text.

Combining Architectural and Regularization
approaches

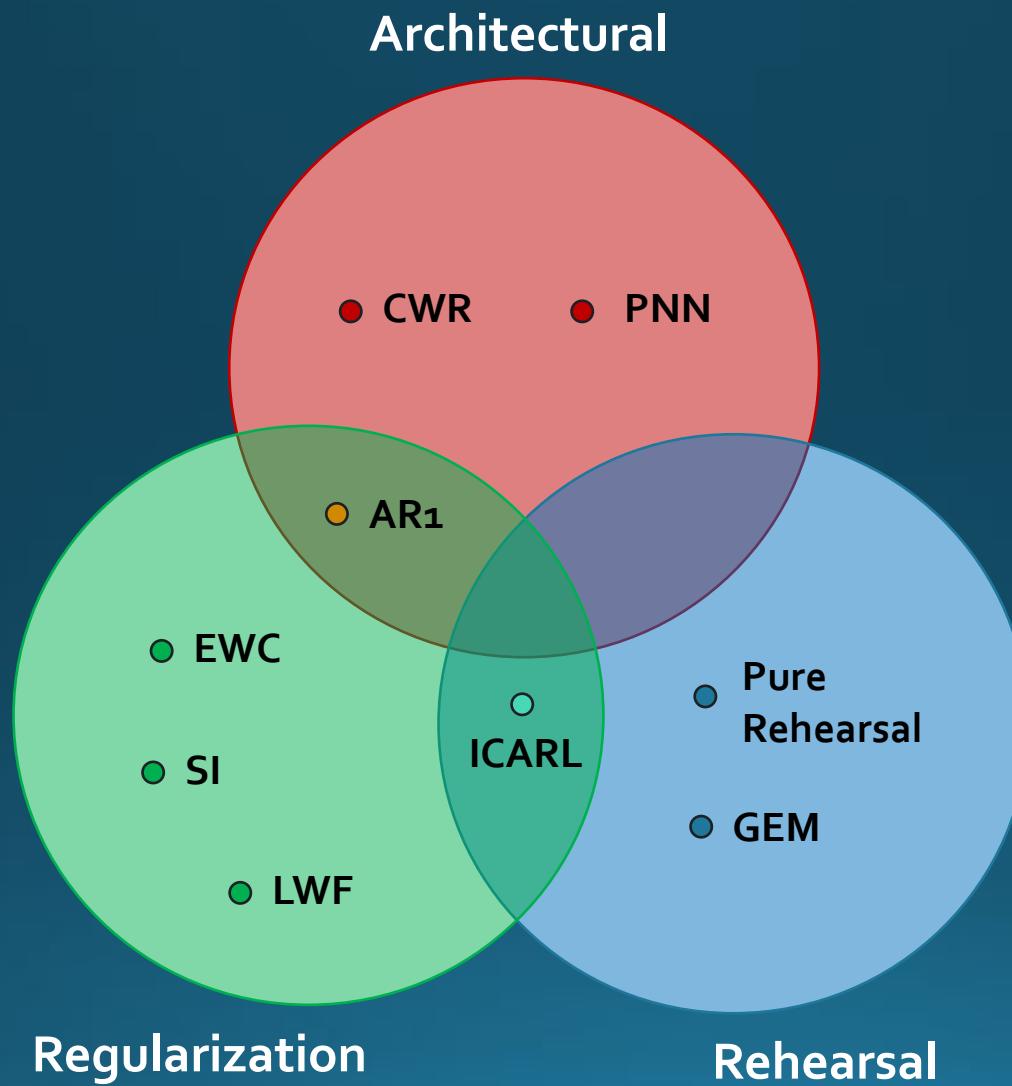
CL Strategies



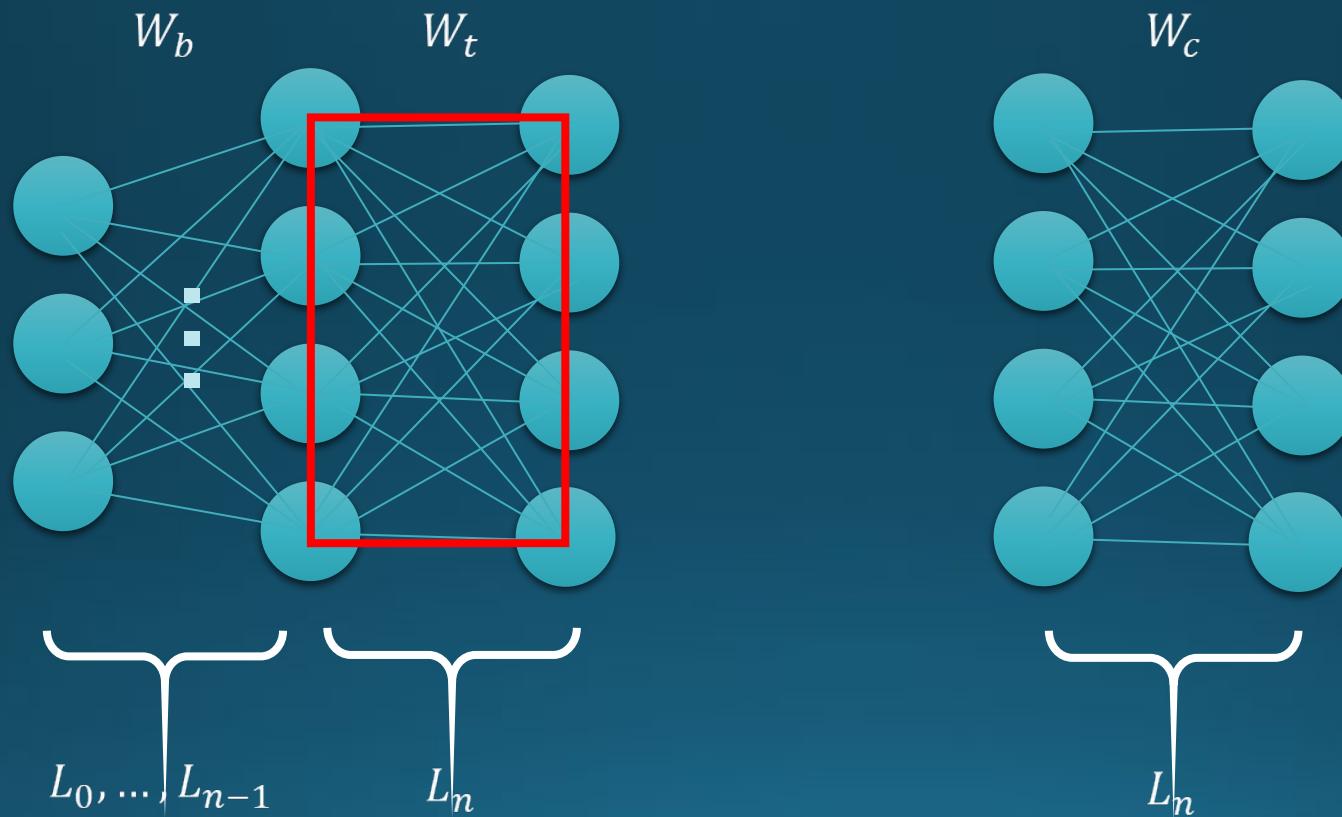
CL Strategies



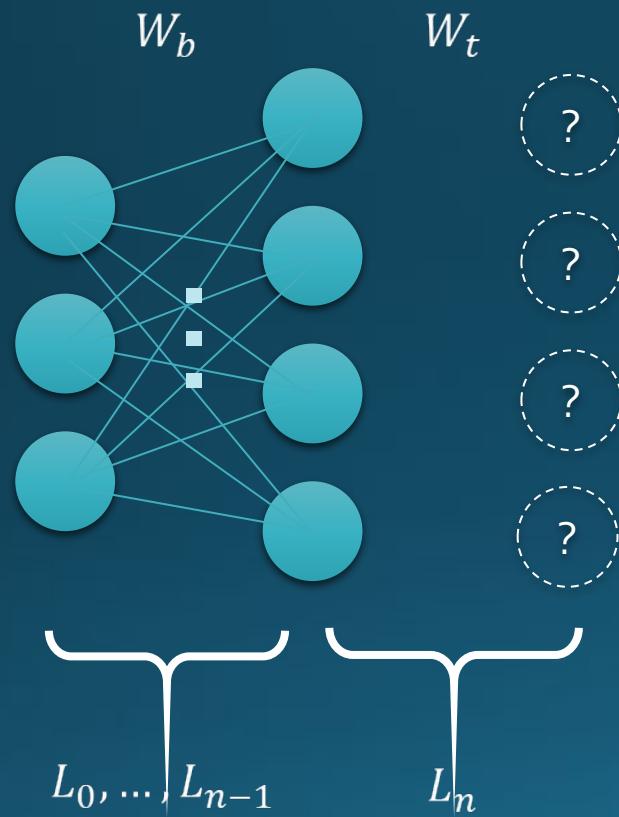
CL Strategies



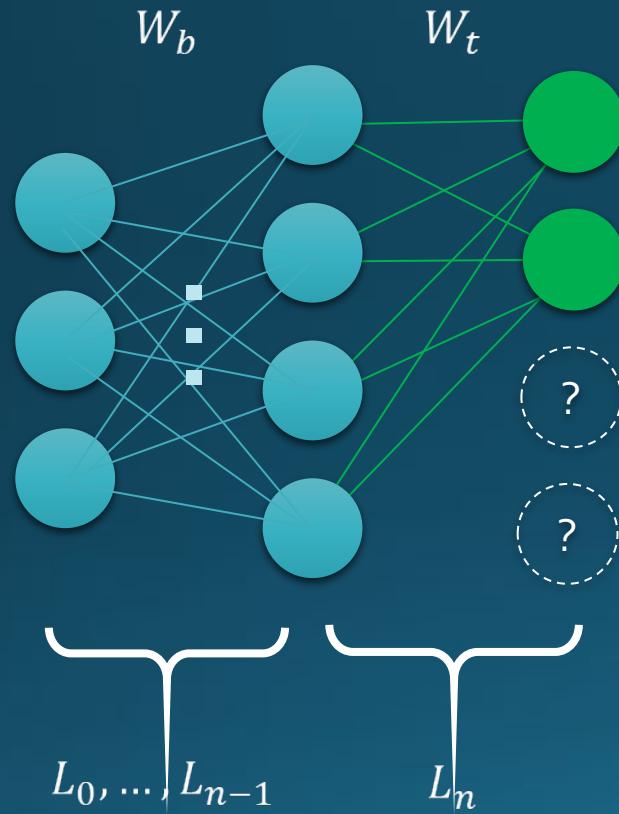
AR-1: Architectural Part



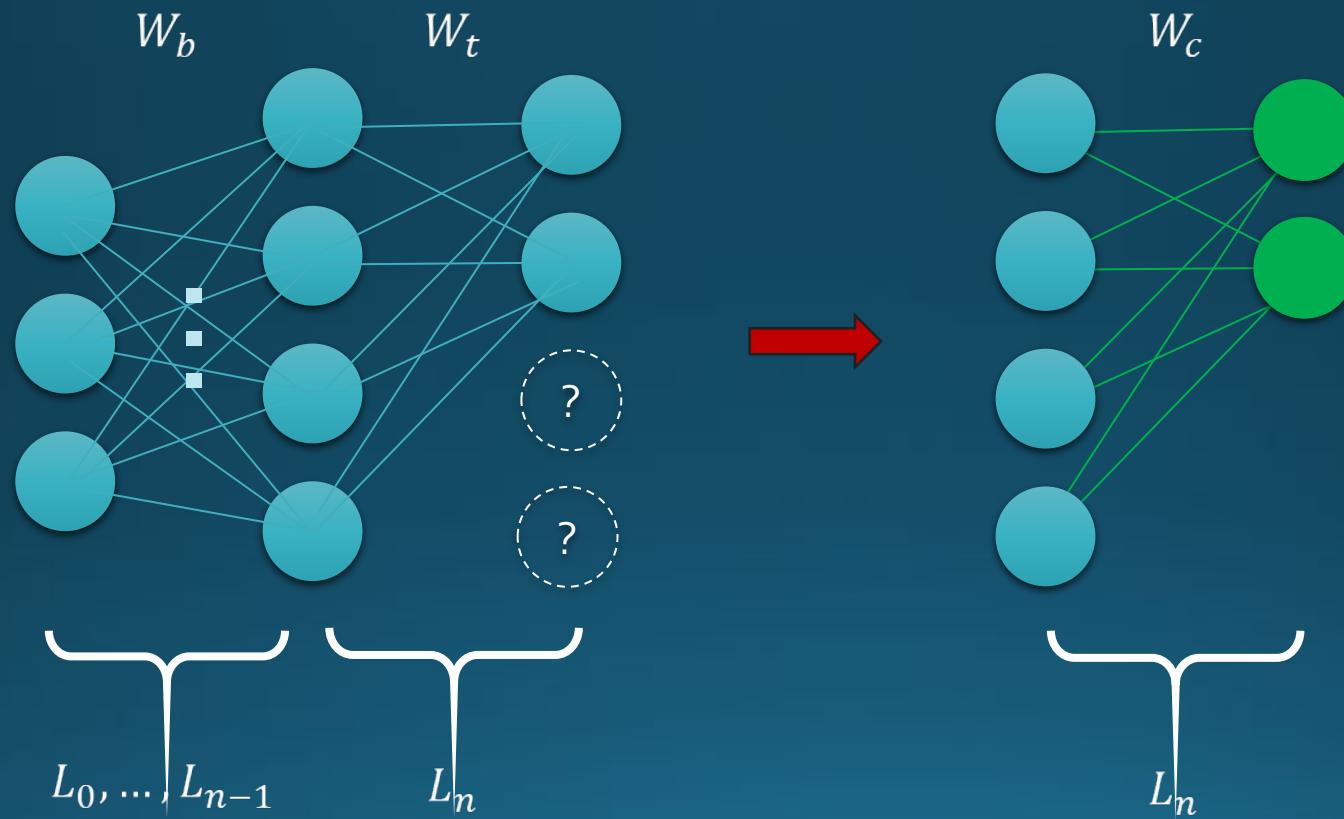
Copy Weights with Re-init (CWR)



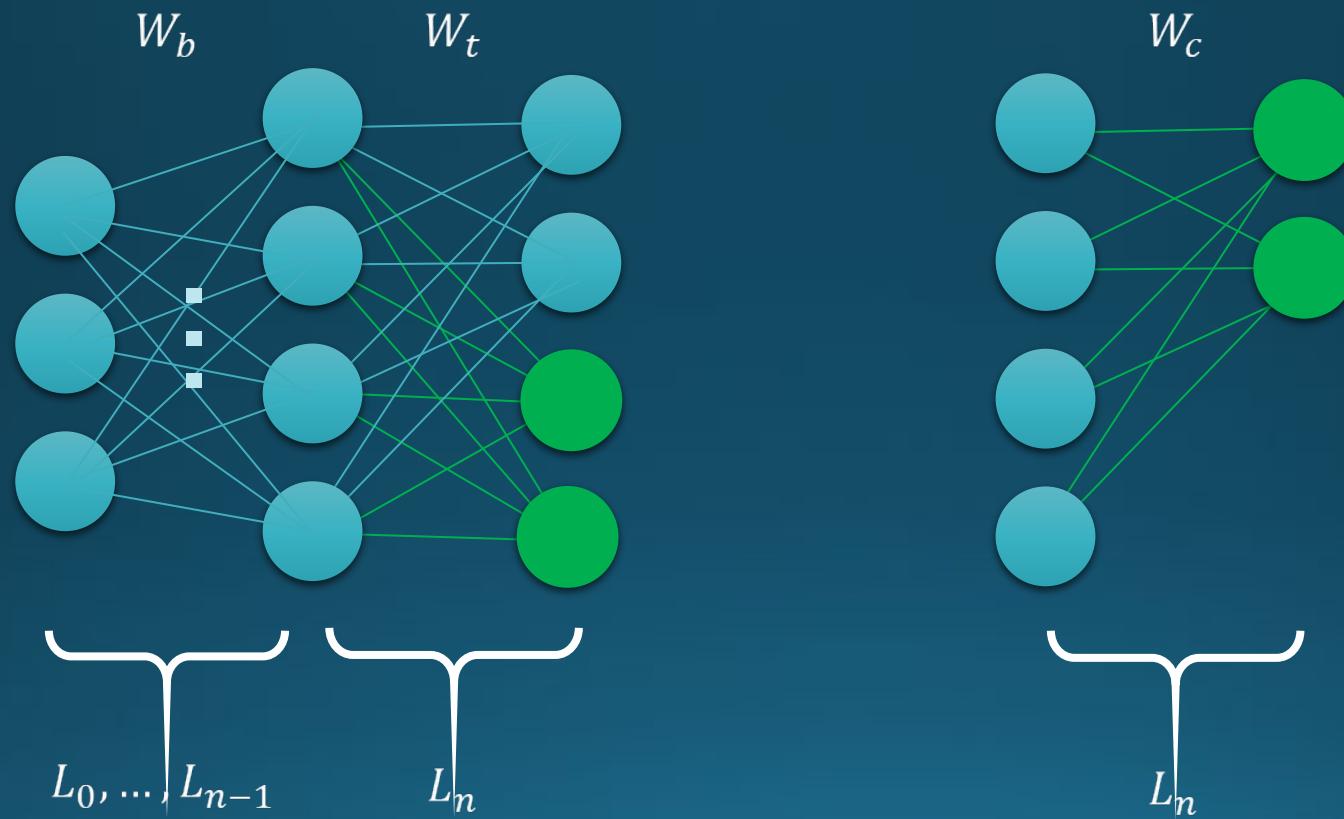
Copy Weights with Re-init (CWR)



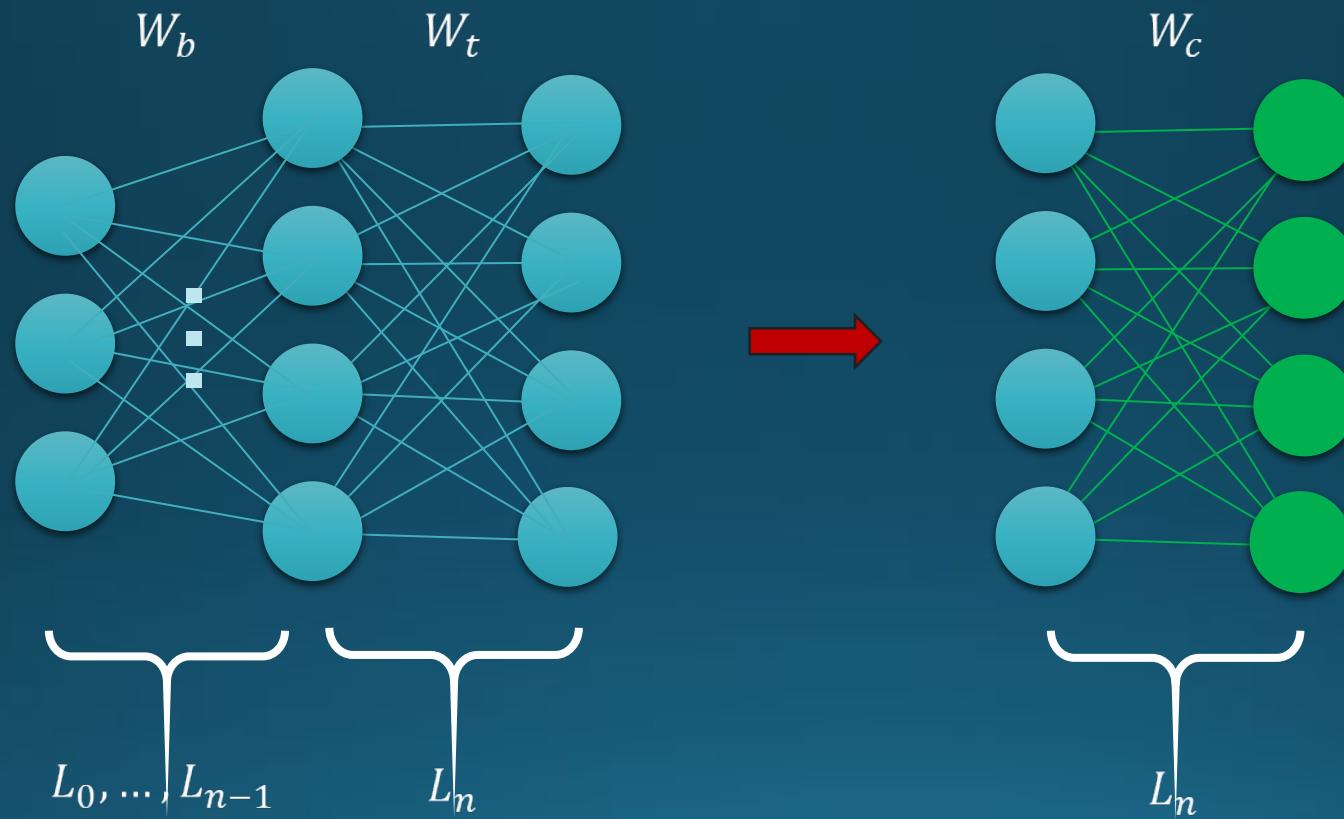
Copy Weights with Re-init (CWR)



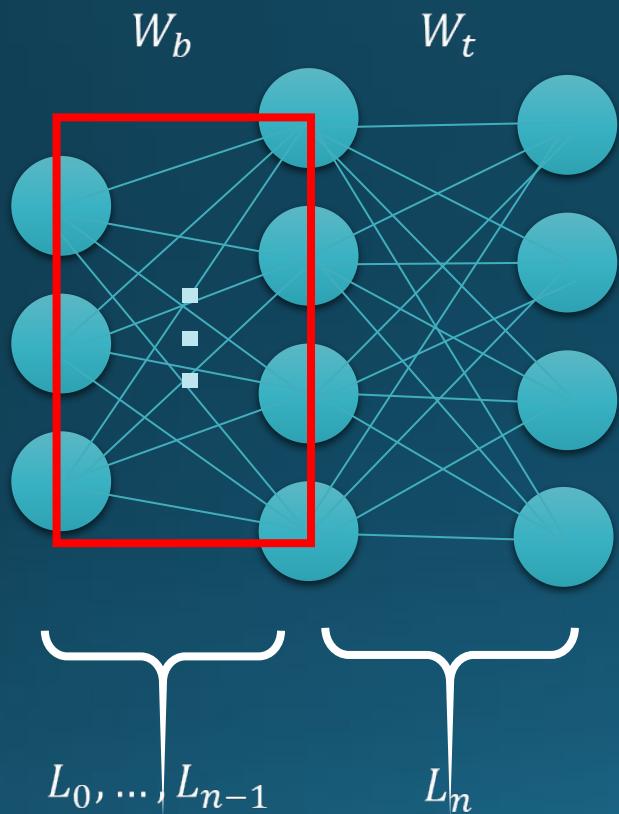
Copy Weights with Re-init (CWR)



Copy Weights with Re-init (CWR)



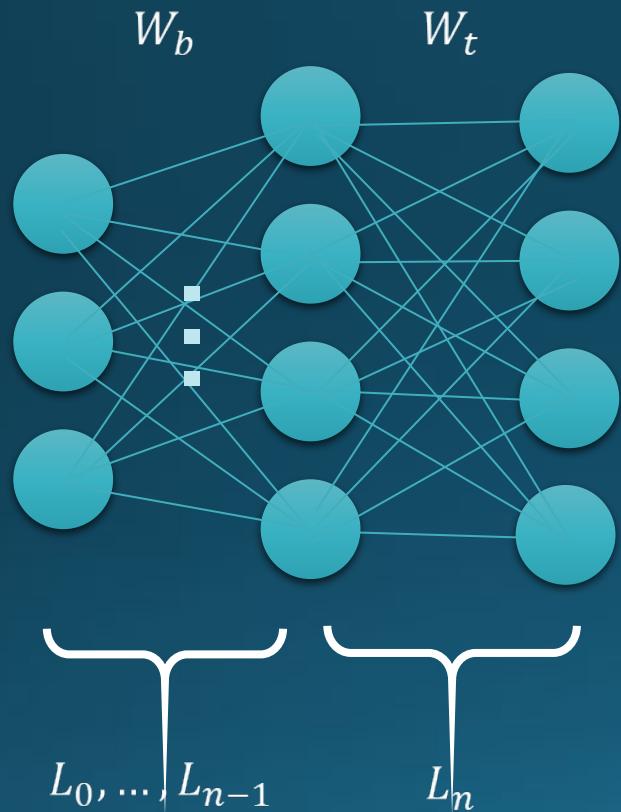
AR-1: Regularization Part



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

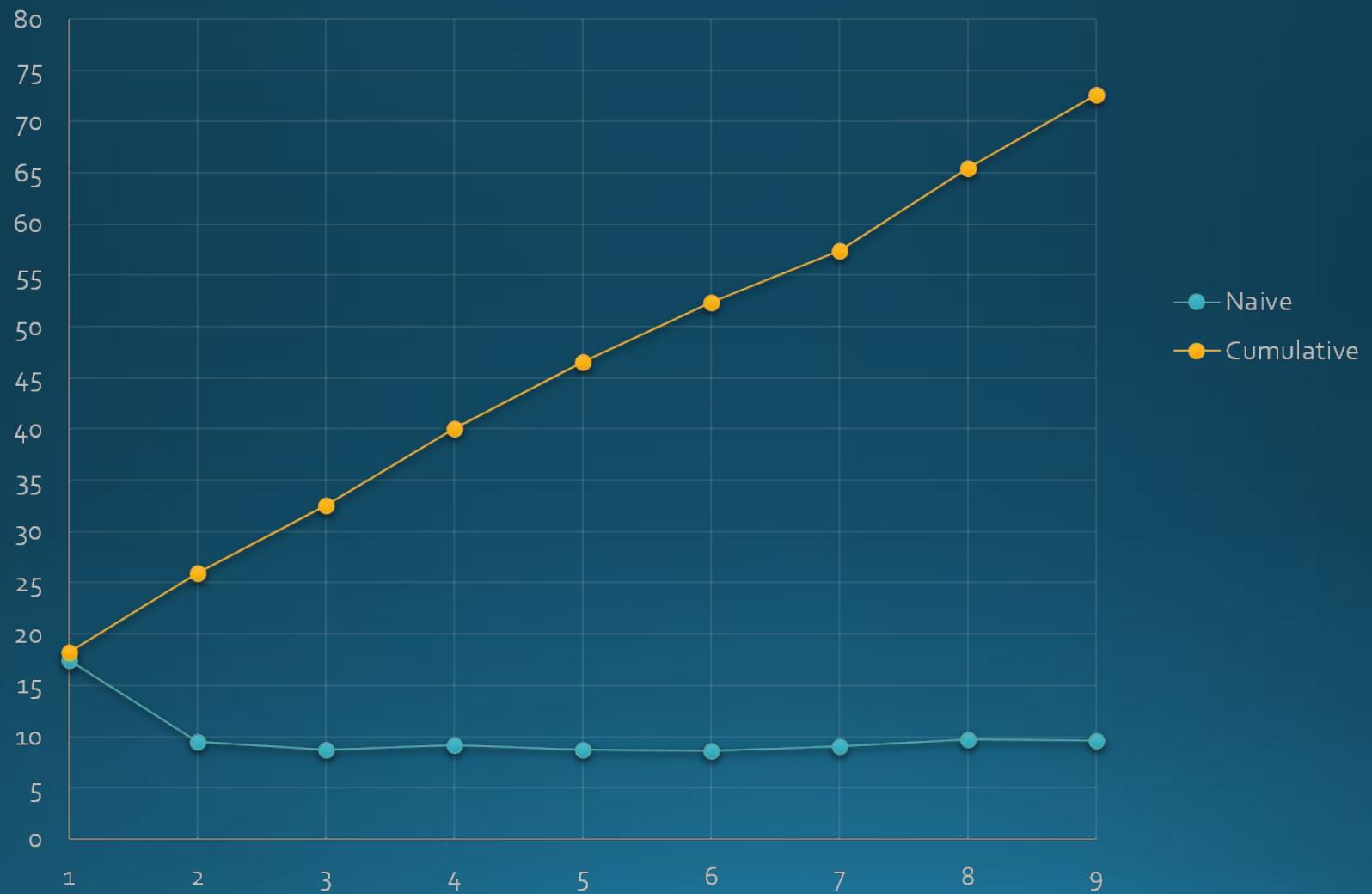
$$w_k^\nu = \int_{t^{\mu-1}}^{t^\mu} \frac{\partial L}{\partial \theta_k} \cdot \frac{\partial \theta_k}{\partial t}$$

AR-1: Additional features

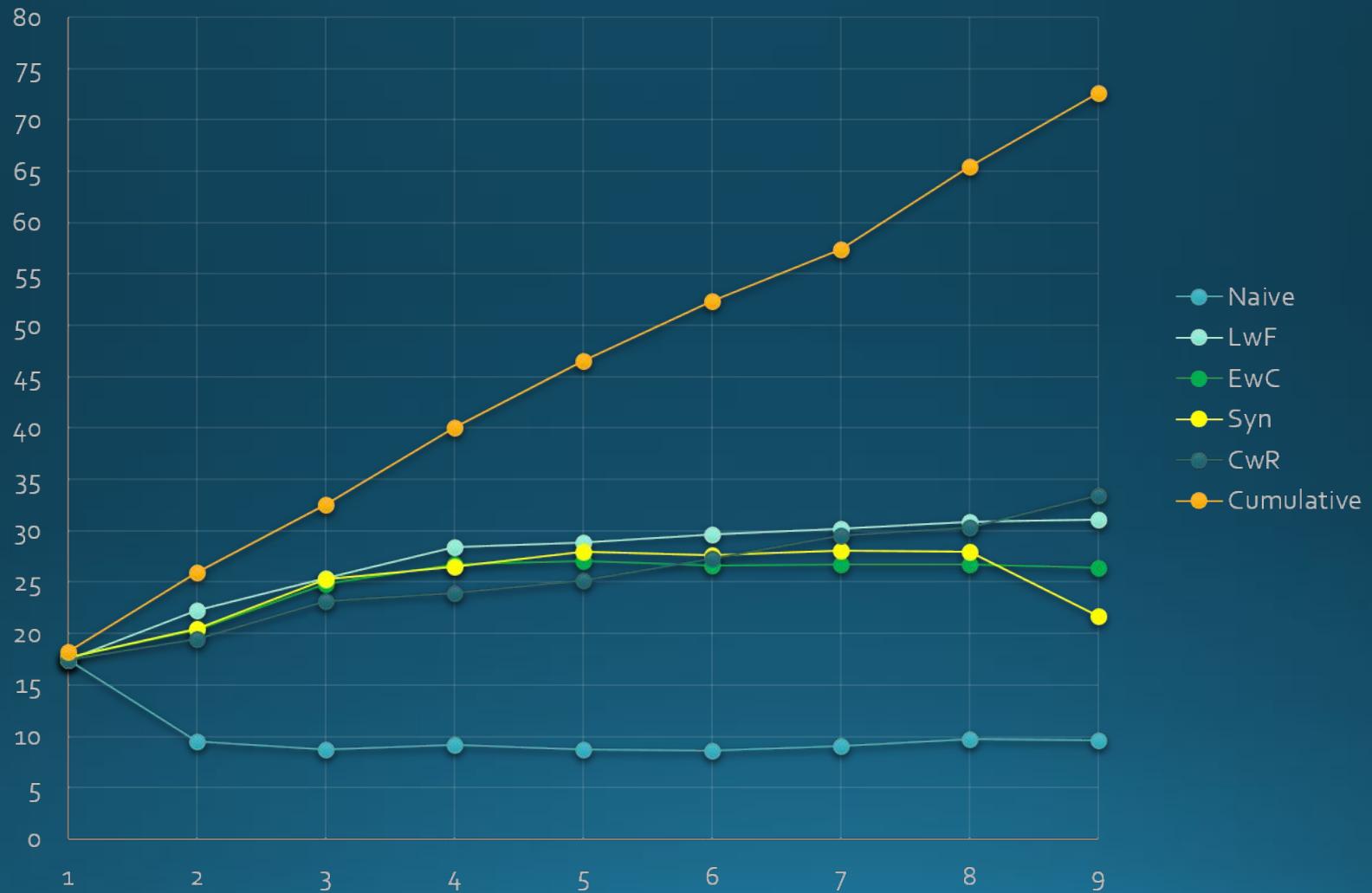


- **Computational efficient** (independent from the number of training batches)
- Just one Ω_k (*running sum + max clip*)
- CWR with ***zero-init***
- CWR with ***mean-shift***

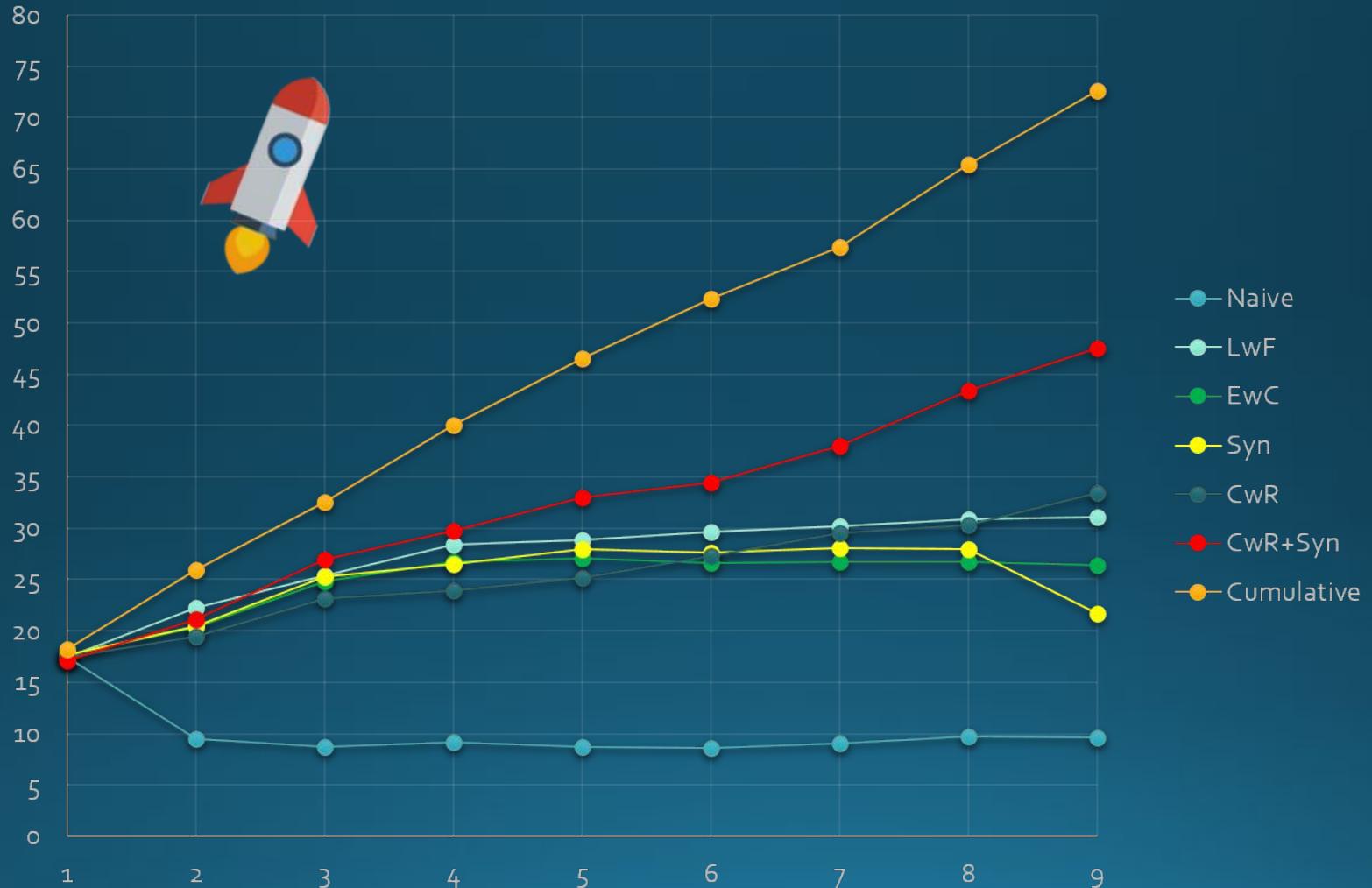
AR-1 results on CORe50



AR-1 results on CORe50



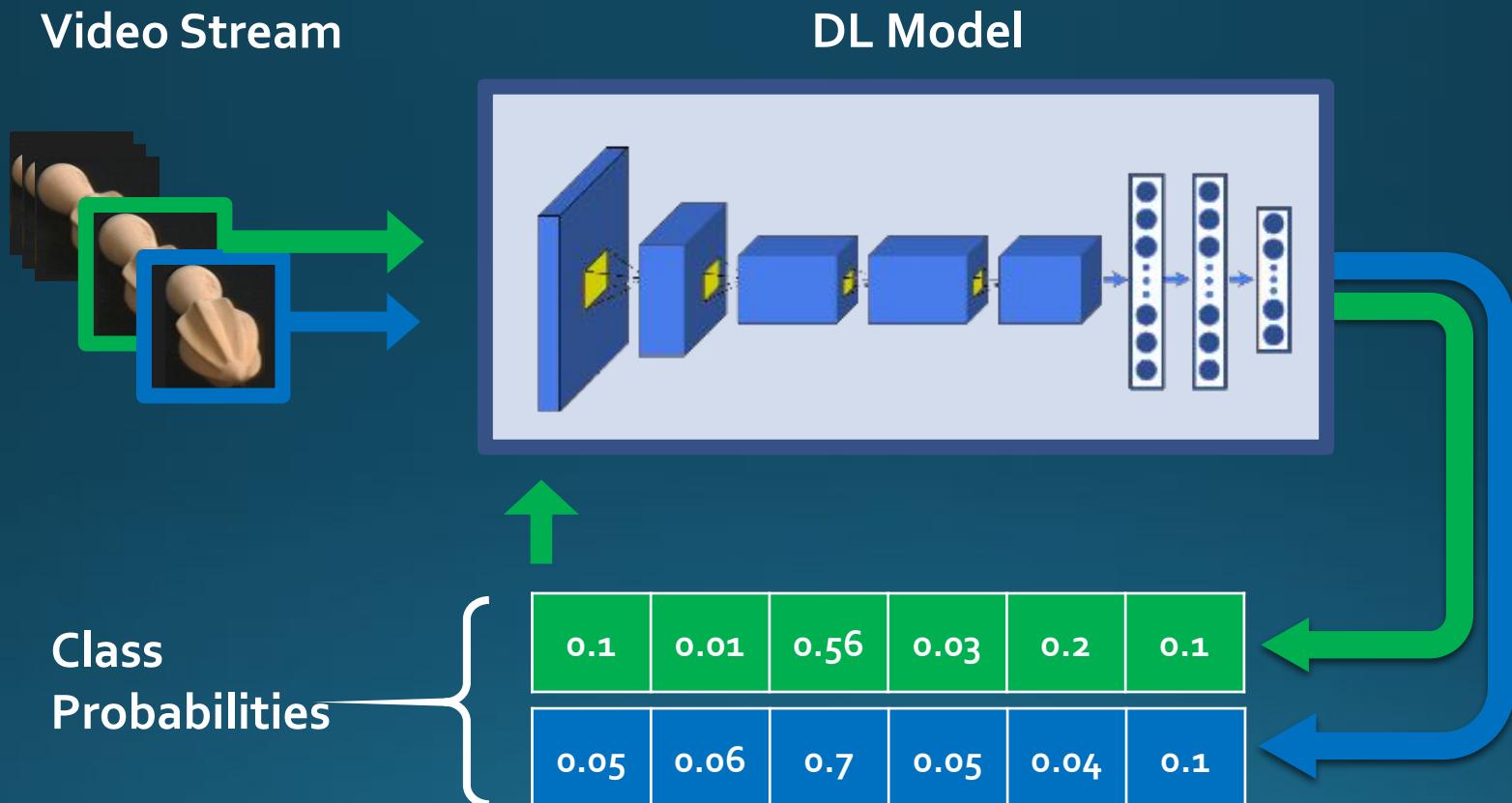
AR-1 results on CORe50



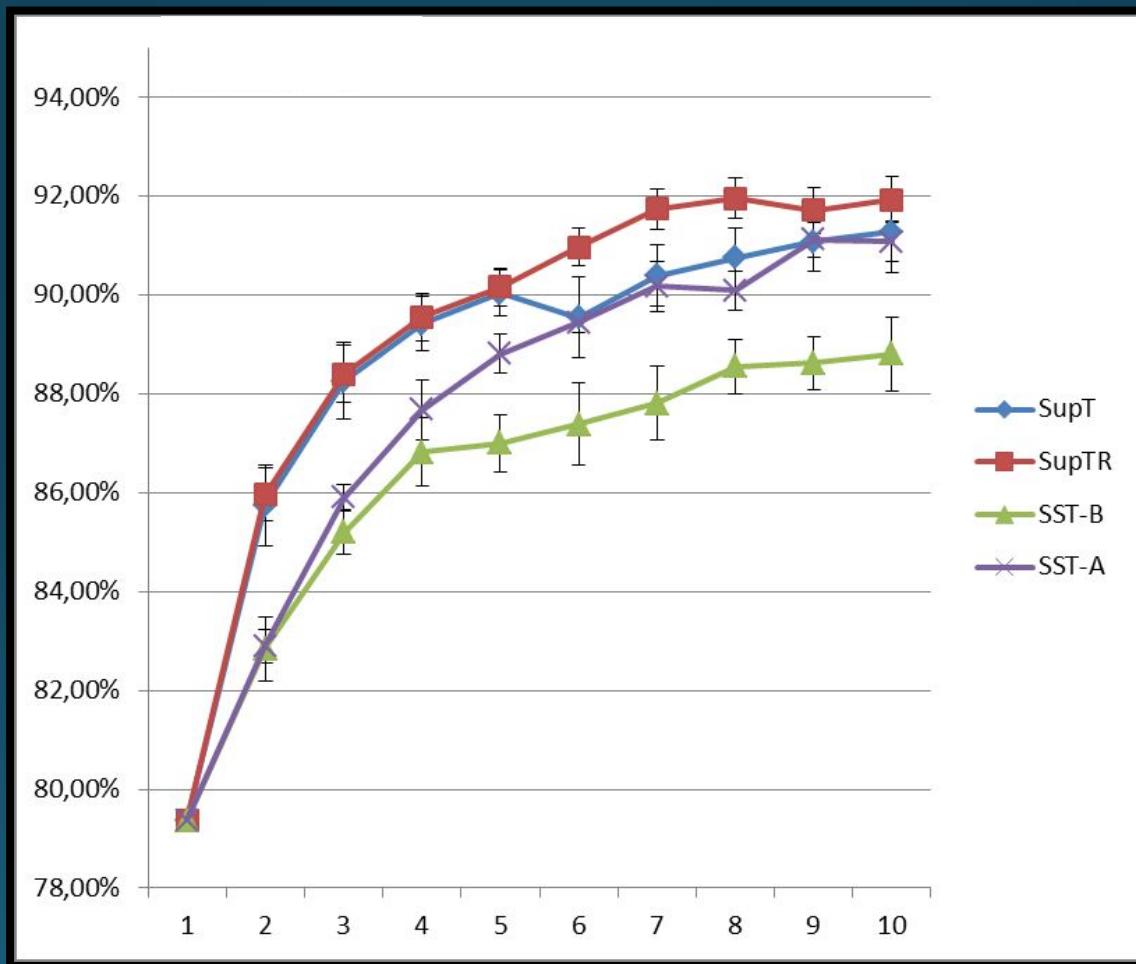
Unsupervised Continual Learning

- “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



Semi-Supervised Tuning from Temporal Coherence



Continual Reinforcement Learning

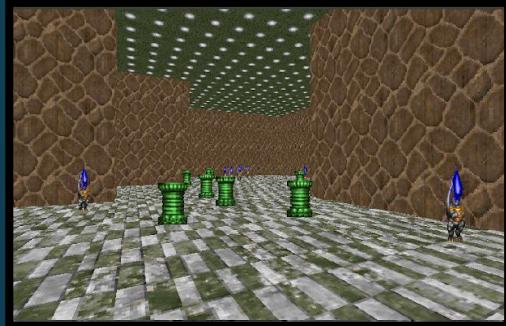
- Very interesting for **futuristic Robotics applications**
- **Too many trials needed** for end-to-end learning
- Yet, many possibilities for **soft adaptation!**

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



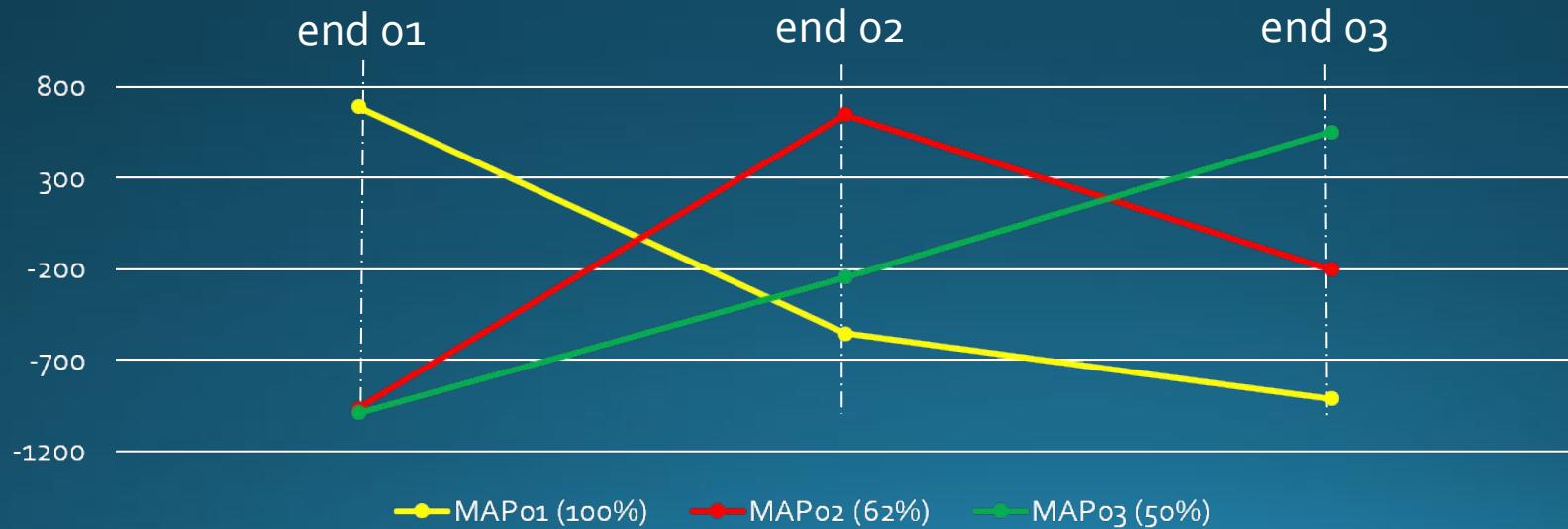
100%



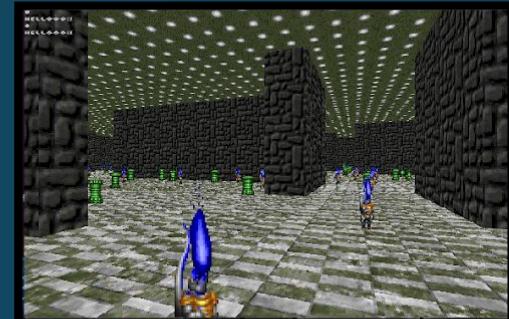
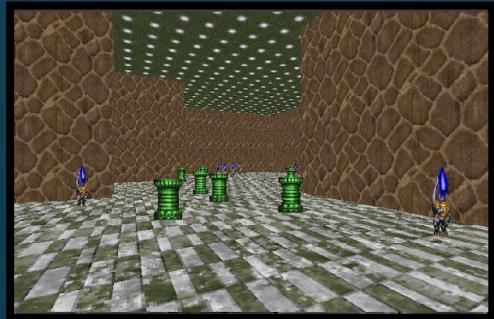
62%



50%

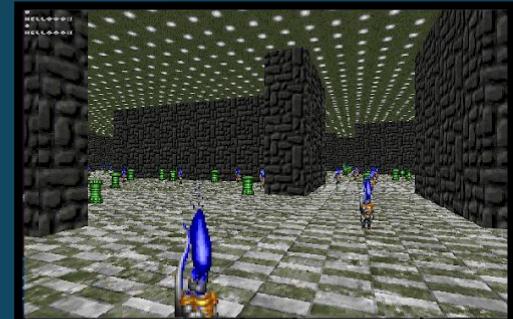
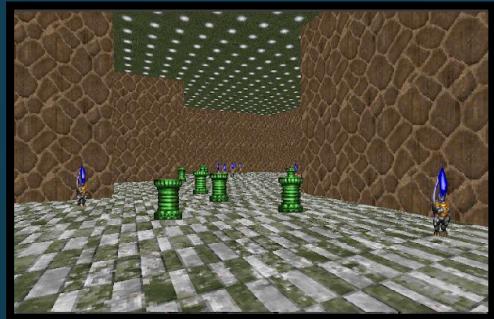


Other Considered Variations

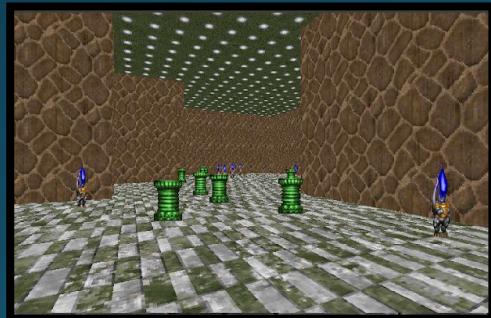


Walls Textures

Other Considered Variations



Walls Textures



Objects Shape & Color

Continual Reinforcement Learning

Objectives:

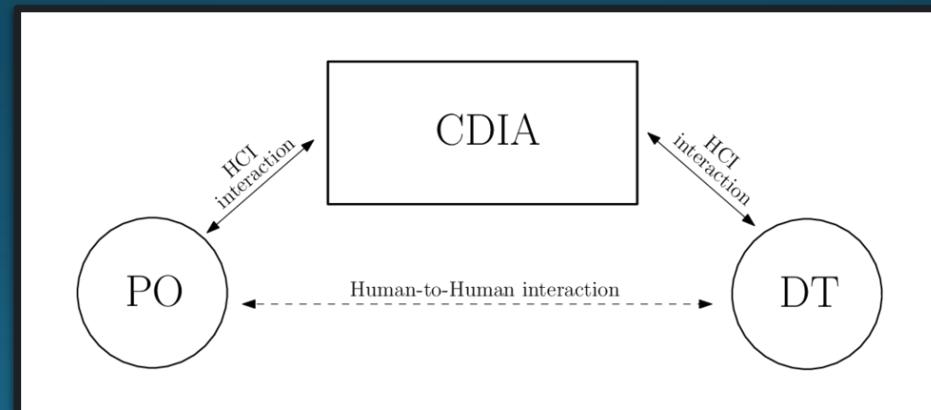
- **Avoid Forgetting**
- **Improve Generalization**
- **Speeding-up Adaptation**

... 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.*



TMD dataset - Tutorial Download About Us

Welcome to TMD dataset

The first free dataset about Transportation Mode Detection

What is Transportation Mode Detection?

Identify user's transportation modes through observations of the user, or observation of the environment. It is a growing topic of interest with many applications in the field of Internet of Things (IoT). Transportation mode detection can provide context information useful to offer appropriate services based on user's needs and possibilities of interaction.

What is the goal of TMD?

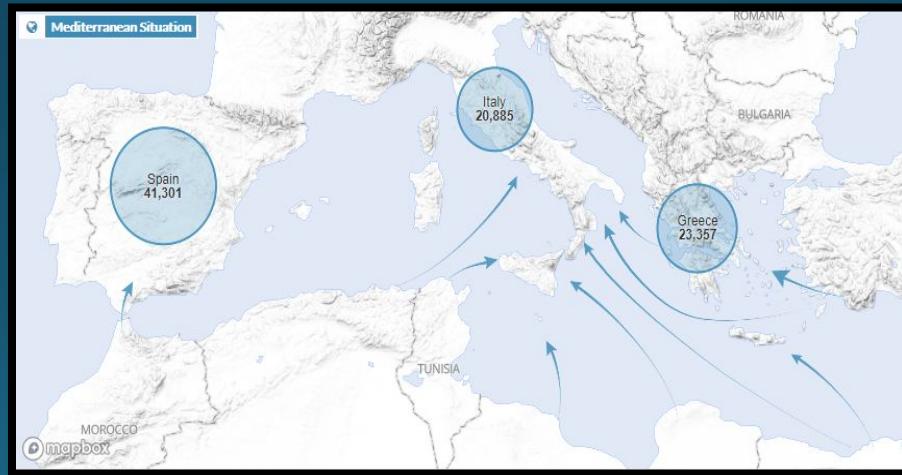
User transportation mode recognition can be considered as a HAR task (Human Activity Recognition). It is used to identify which kind of transportation is being used.

<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

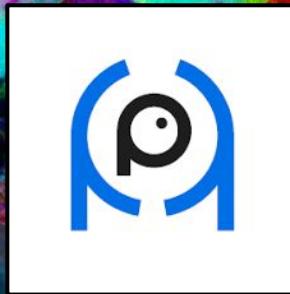
Comparing Incremental Learning Strategies for Convolutional Neural Networks. *Lomonaco V. and Maltoni D. IAPR Workshop on Artificial Neural Networks in Pattern Recognition. Springer International Publishing, 2016.*





Support AI for People

with a small Donation!



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

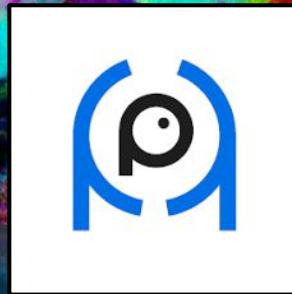
<https://www.aiforpeople.org/supporters>



Questions?

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President of ContinualAI.org*

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