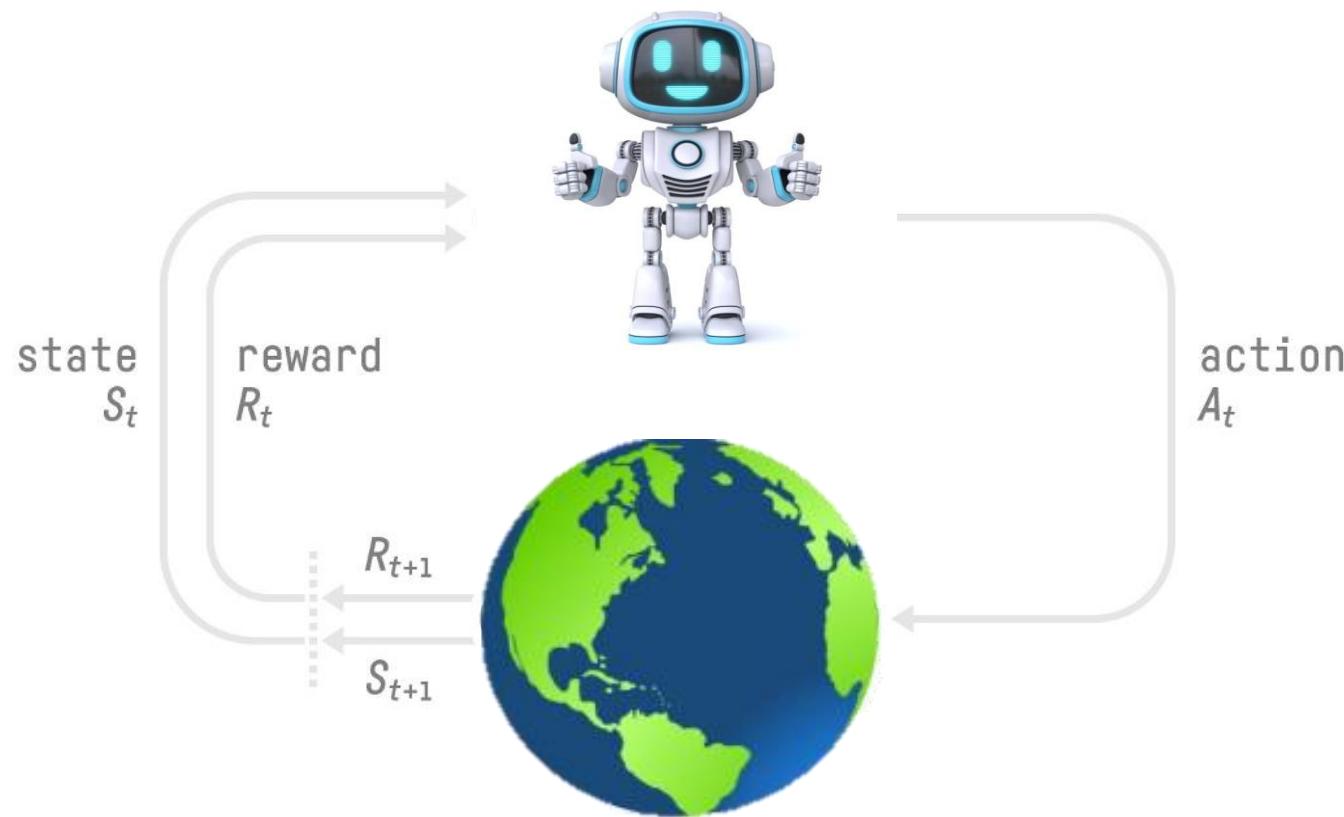

FOURIER NEURAL OPERATORS

As Encoder for Model-free Reinforcement Learning

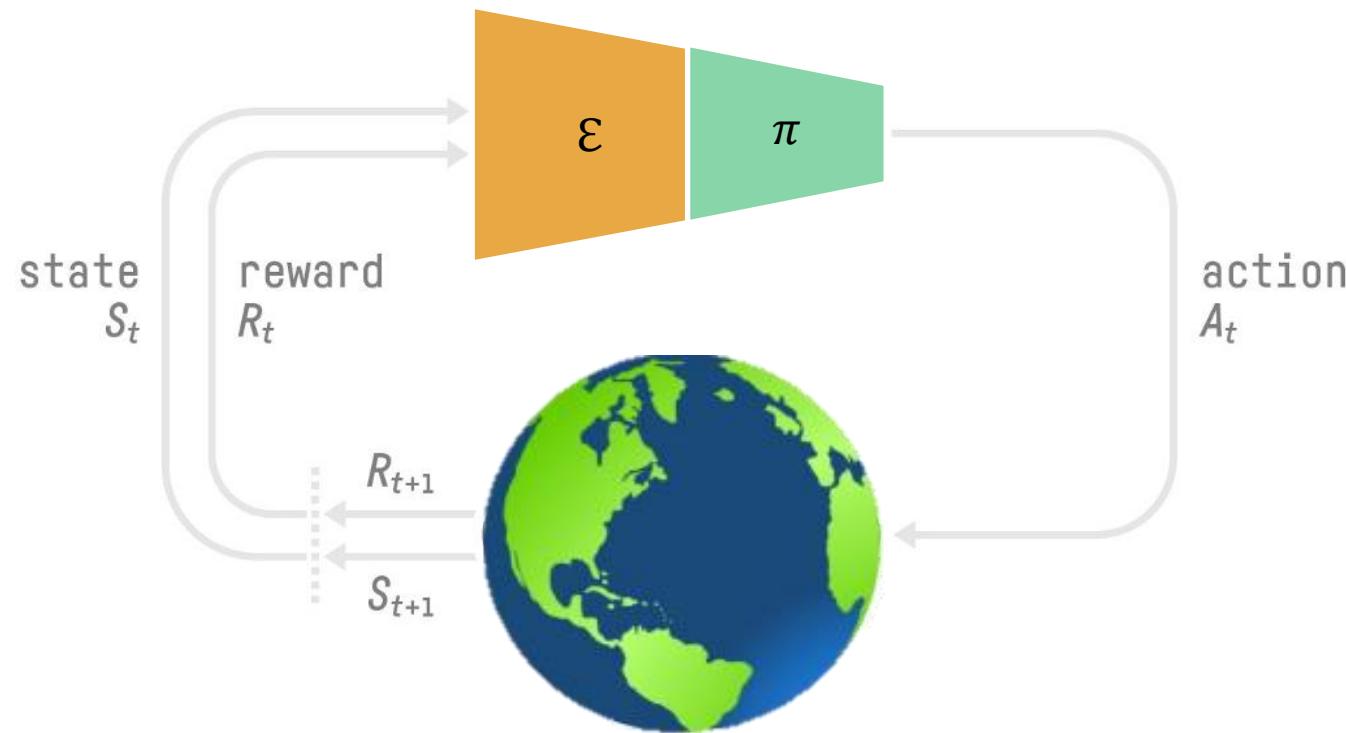
By **Parag Dutta**, Mohd Ayyoob, Shalabh Bhatnagar and Ambedkar Dukkipati



THE REINFORCEMENT LEARNING FRAMEWORK



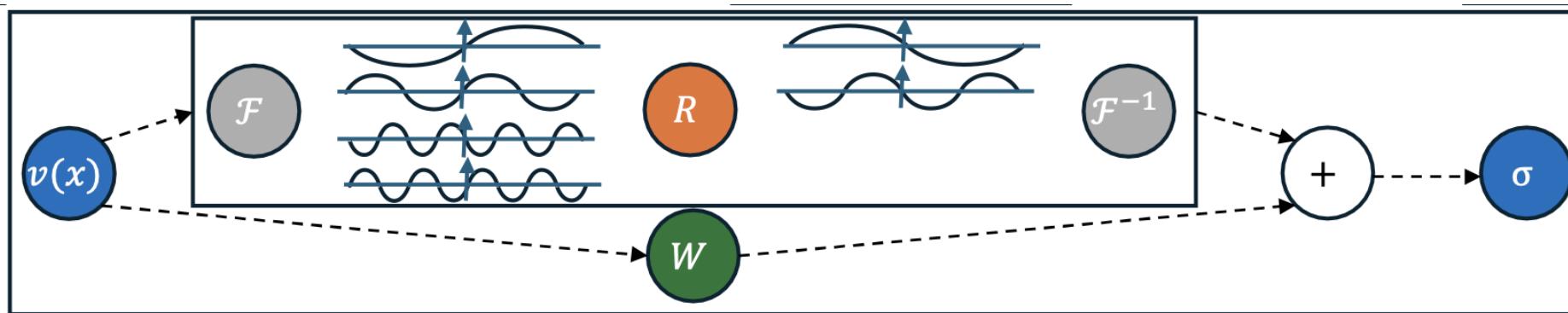
THE REINFORCEMENT LEARNING FRAMEWORK



CHALLENGES WITH EXISTING ENCODER ARCHITECTURES

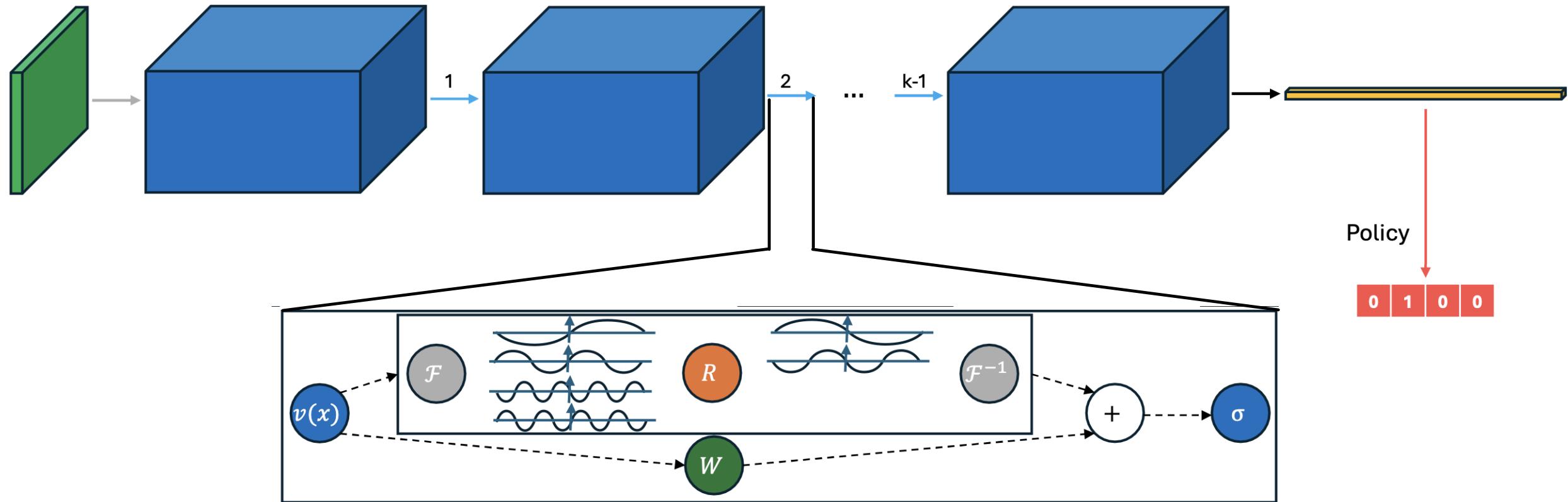
- Requirement of Hyper-parameter tuning with each modification
- Not much performance gain with after modification
- Highly sensitive to Training Domain

FOURIER NEURAL OPERATORS



Reference: Fourier Neural Operator for Parametric Partial Differential Equations,
ICLR 2021 - <https://openreview.net/forum?id=c8P9NQVtmnO>

OUR PROPOSED ENCODER



WHY FNO?

- Our Encoder exploits the underlying PDEs that govern the transition dynamics
- The conventional CNN encoder can be replaced with FNOs for all major classes of model-free RL algorithms, i.e.:
 1. Policy gradient
 2. Actor-Critic
 3. Q-Learning
- No need for any additional hyper-parameter search after replacing CNN with FNO
- FNOs enable zero-shot domain adaptation from low-resolution training images to high-resolution inference images without any additional fine-tuning.



EXPERIMENTS



ATARI GAMES (ONLINE Q-LEARNING)

Game	Rainbow	Efficient Rainbow	CURL	Rainbow FNO (Ours)
Breakout	1.74	0.69	11.1	42.7
Freeway	0.0	94.26	90.20	101.01
Pong	0.28	3.97	11.90	36.83
Qbert	-0.30	7.44	6.61	18.44
Seaquest	0.15	0.68	0.75	0.75

Average rewards obtained across 3 runs on **Atari100K** benchmark.

Our Encoder outperforms the CNN encoder in Efficient Rainbow in **20/26** games

We achieve median **26.1% HNS** compared to 16.1% HNS in CURL

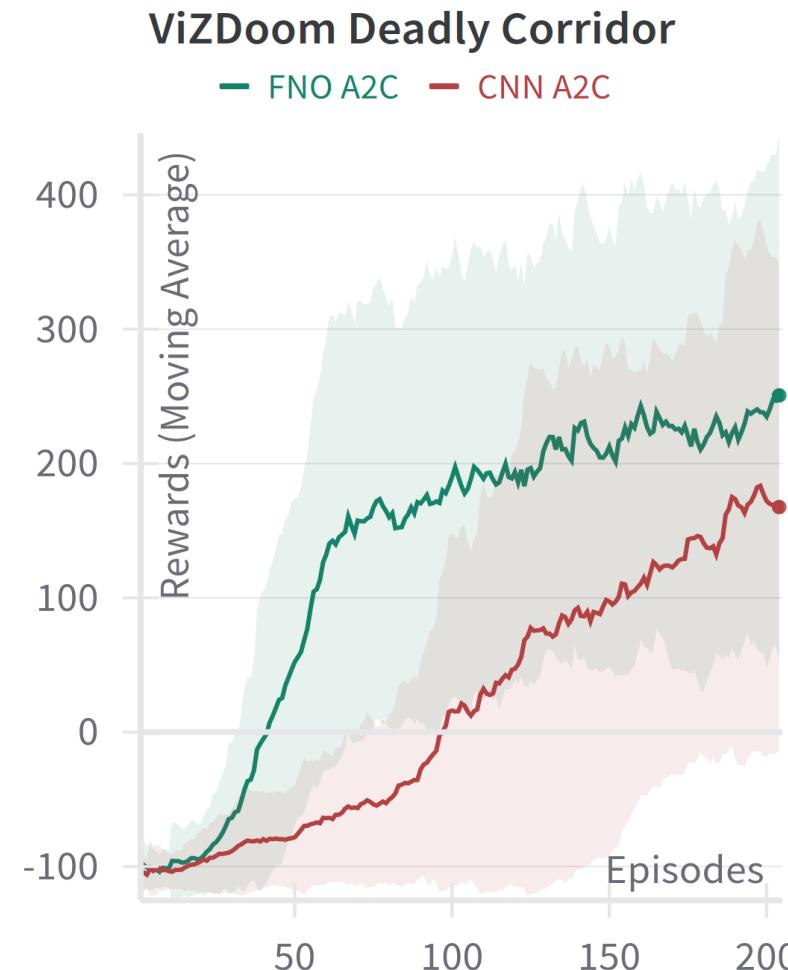
ATARI GAMES (OFFLINE)

Game	BC	QR-DQN	CQL	DT	R-BVE	Ours
Breakout	138.9	17.1	211.1	267.5	110.5	555.1
Pong	85.2	18.0	111.9	106.1	92.6	112.8
Qbert	17.3	0.0	104.2	15.4	72.7	110.7
Seaquest	2.1	0.4	1.7	2.5	2.3	3.1

Average rewards obtained across 3 runs on **OfflineAtari 1%** benchmark.

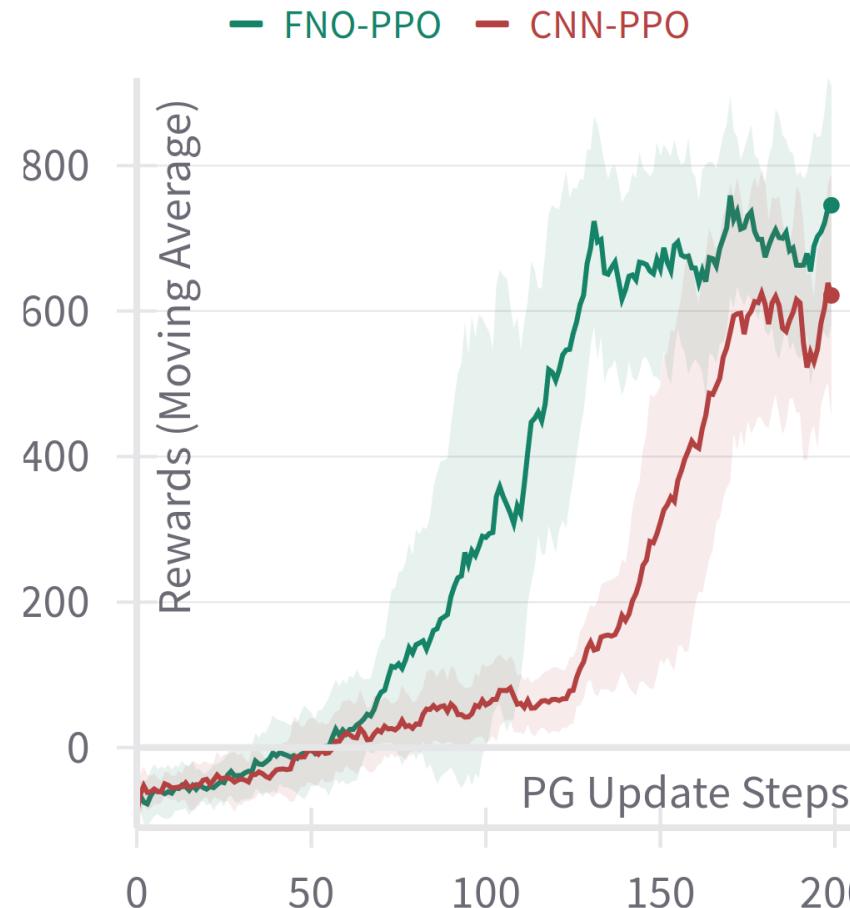
We achieve 2.9x HNS compared to SOTA transformer based models.

VIZDOOM – DEADLY CORRIDOR – ONLINE ACTOR CRITIC

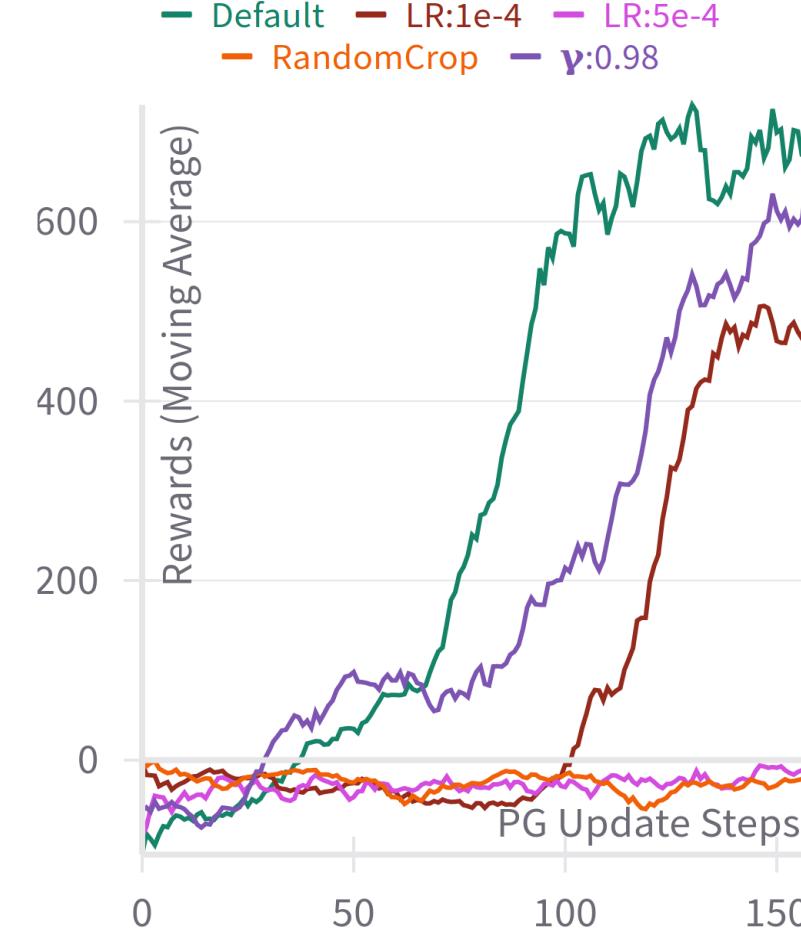


CARLA AUTONOMOUS DRIVING - ONLINE POLICY GRADIENTS

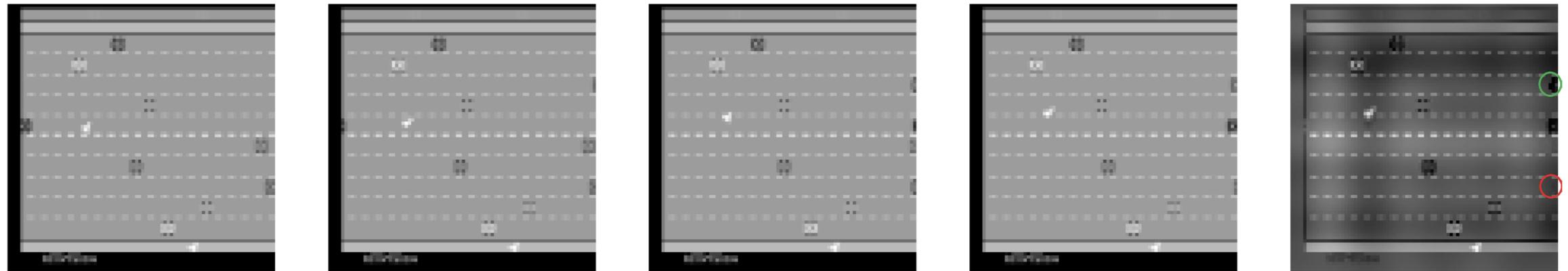
Carla Lane (Image Observations)



Carla Lane - Ablation Experiments



ATARI - ABLATION



- The left 4 images correspond to the 4 sequential images given as input to the model.
- The right image is a weighted combination of the final feature maps, which turns out to be the model's prediction of how the next frame might look like.

SUMMARY

- We propose a Fourier Neural Operator (FNO) encoder for model-free visual RL.
- We demonstrate that FNOs are superior to CNNs and transformers
- We additionally try to understand the representations learned.
- FNO encoders are invariant to the image input resolution and thus performs zero-shot domain adaptation.
- Code is available at: <https://github.com/paragduttaiisc/FNO-RL>

Thank You!