Playing Atari games with an Interpretable Agent

Erwan Lecarpentier, Dennis G. Wilson, Sylvain Cussat-Blanc, Hervé Luga, Guillaume Jubelin, and, Lionel Cordesses

November 9, 2021

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1. [Context] Interpretability in Atari

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2. [Method] Cartesian Genetic Programming

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3. [Experiments] Results on Atari

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4. [Conclusion] Next steps

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[Context] Playing Atari games (from pixels input)

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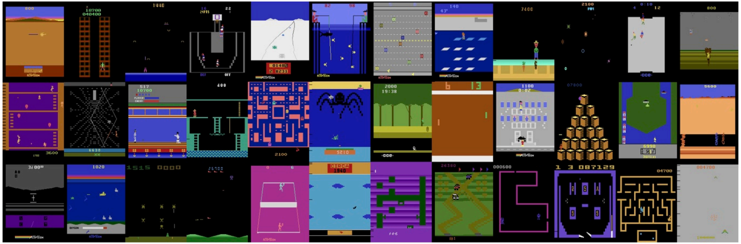

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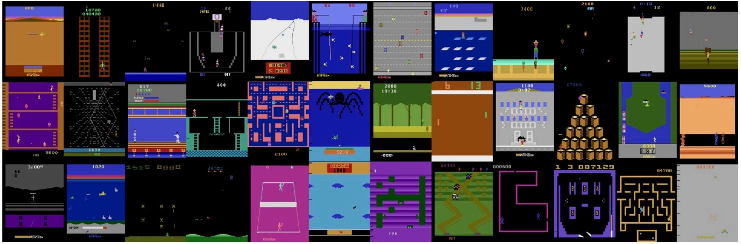

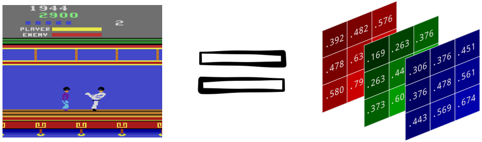

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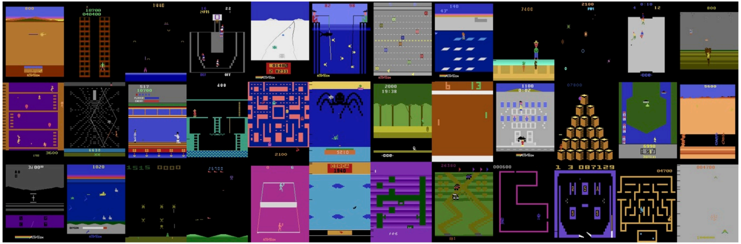

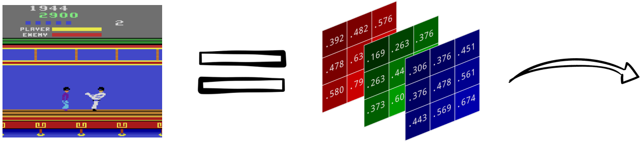

$a \in \mathcal{A}$

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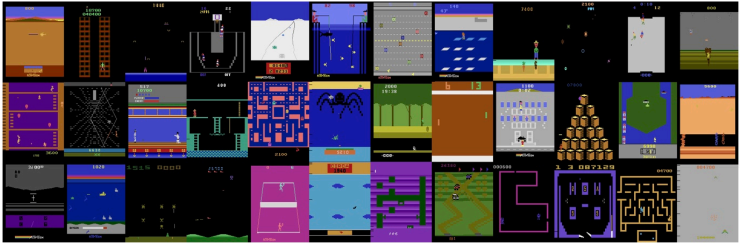
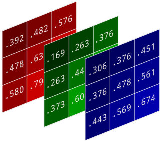
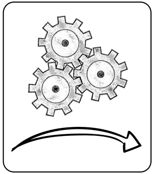


Agent

$=$





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[Context] Interpretability

Interpretability is the degree to which a human can understand the cause of a decision[1].

[1] Miller, Tim. "Explanation in artificial intelligence: Insights from the social sciences." Artificial intelligence 267 (2019): 1-38

[Context] Interpretability in Machine Learning

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Interpretability

"Techniques for Interpretable Machine Learning", Du, Liu, and Hu 2019

[Context] Interpretability in Machine Learning

Interpretability	**Inherent** *Self-explained model ...*	**Post-hoc** *Explain model with another model ...*

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[Context] Interpretability in Machine Learning

Interpretability	**Inherent** *Self-explained model ...*	**Post-hoc** *Explain model with another model ...*
Global *... for ALL decisions*		
Local *... for SOME decisions*		

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[Context] Interpretability in Machine Learning

Interpretability	**Inherent** *Self-explained model …*	**Post-hoc** *Explain model with another model …*
Global *… for ALL decisions*	Linear model	
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[Context] Interpretability in Machine Learning

Interpretability	**Inherent** *Self-explained model ...*	**Post-hoc** *Explain model with another model ...*
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Global *... for ALL decisions*	Linear model	Learn activating input images in CNN
Local *... for SOME decisions*	Attention mechanisms	

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Interpretability	**Inherent** *Self-explained model ...*	**Post-hoc** *Explain model with another model ...*
Global *... for ALL decisions*	Linear model	Learn activating input images in CNN
Local *... for SOME decisions*	Attention mechanisms	Local approximation with white-box model

"Techniques for Interpretable Machine Learning", Du, Liu, and Hu 2019

1. Interpretability in Atari

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Why did you take the action “kick”?

1. Interpretability in Atari

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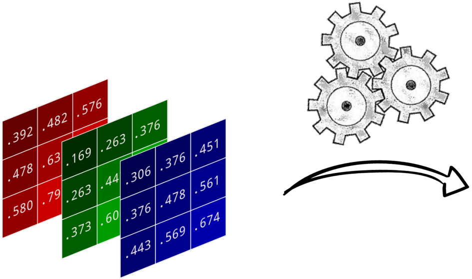
Because:



$$a = \text{kick}$$

1. Interpretability in Atari

Why did you take the action “kick”?

Because:

$\hat{M}\Big(a = \text{kick} \;\Big|$  $\Big) \geq \hat{M}\Big(a \neq \text{kick} \;\Big|$  $\Big)$

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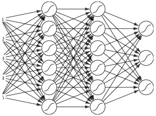

1. Interpretability in Atari

Why did you take the action “kick”?

Because:

$$\sigma (0.403 \times 0.635 + 0.472 \times 0.687 + 0.281 \times 0.53 + 0.866 \times 0.931 + 0.182 \times 0.427 + 0.834 \times 0.913 + \sigma (0.986 \times 0.993 + 0.169 \times 0.412) + 0.755 \times 0.869 + 0.352 \times 0.593 + 0.366 \times 0.605) + \sigma (0.662 \times 0.813 + 0.639 \times 0.8 + 0.281 \times 0.53 + 0.516 \times 0.718 + 0.187 \times 0.432) + \sigma (0.867 \times 0.931 + 0.917 \times 0.958 + 0.793 \times 0.89 + 0.393 \times 0.627 + 0.281 \times 0.531 + 0.5 \times 0.707 + 0.772 \times 0.879) + \sigma (0.854 \times 0.924 + 0.411 \times 0.641 + 0.052 \times 0.228 + \sigma (0.712 \times 0.844 + 0.959 \times 0.979) + 0.197 \times 0.444 + 0.456 \times 0.675 + 0.785 \times 0.886) + \sigma (0.72 \times 0.849 + 0.998 \times 0.999 + 0.216 \times 0.465 + 0.034 \times 0.184 + 0.003 \times 0.058 + 0.55 \times 0.741 + 0.949 \times 0.974 + 0.815 \times 0.903) + \sigma (0.768 \times 0.876 + 0.494 \times 0.703 + 0.838 \times 0.915) + \sigma (0.153 \times 0.391 + 0.103 \times 0.322 + 0.344 \times 0.587 + 0.136 \times 0.369 + 0.115 \times 0.339 + 0.295 \times 0.543 + 0.656 \times 0.81 + 0.04 \times 0.2) + \sigma (0.403 \times 0.635 + 0.472 \times 0.687 + 0.281 \times 0.53 + 0.866 \times 0.931 + 0.182 \times 0.427 + 0.834 \times 0.913 + \sigma (0.986 \times 0.993 + 0.169 \times 0.412) + 0.755 \times 0.869 + 0.352 \times 0.593 + 0.366 \times 0.605) + \sigma (0.662 \times 0.813 + 0.639 \times 0.8 + 0.281 \times 0.53 + 0.516 \times 0.718 + 0.187 \times 0.432) + \sigma (0.867 \times 0.931 + 0.917 \times 0.958 + 0.793 \times 0.89 + 0.393 \times 0.627 + 0.281 \times 0.531 + 0.5 \times 0.707 + 0.772 \times 0.879) + \sigma (0.854 \times 0.924 + 0.411 \times 0.641 + 0.052 \times 0.228 + \sigma (0.712 \times 0.844 + 0.959 \times 0.979) + 0.197 \times 0.444 + 0.456 \times 0.675 + 0.785 \times 0.886) + \sigma (0.72 \times 0.849 + 0.998 \times 0.999 + 0.216 \times 0.465 + 0.034 \times 0.184 + 0.003 \times 0.058 + 0.55 \times 0.741 + 0.949 \times 0.974 + 0.815 \times 0.903) + \sigma (0.768 \times 0.876 + 0.494 \times 0.703 + 0.838 \times 0.915) + \sigma (0.153 \times 0.391 + 0.103 \times 0.322 +$$

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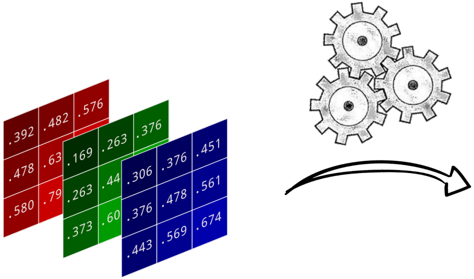

$$a \in \mathcal{A}$$

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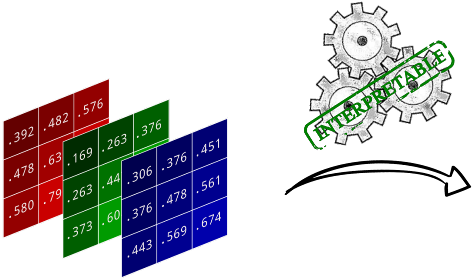

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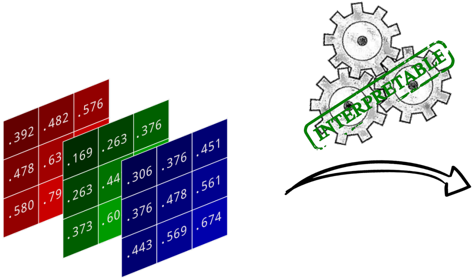

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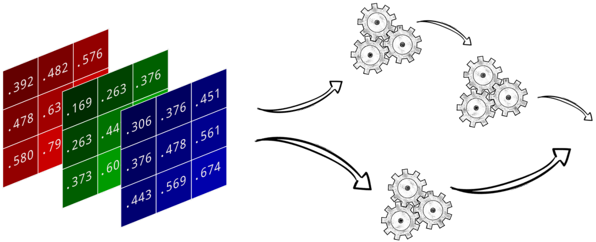

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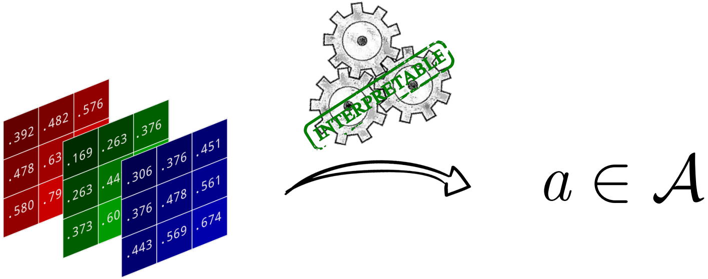

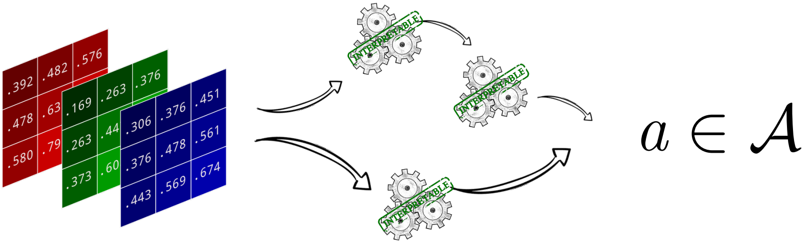

Content

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2. [Method] Cartesian Genetic Programming
3. [Experiments] Results on Atari
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[Method] Approach: Interpretable Encoder – Controller

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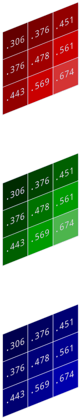
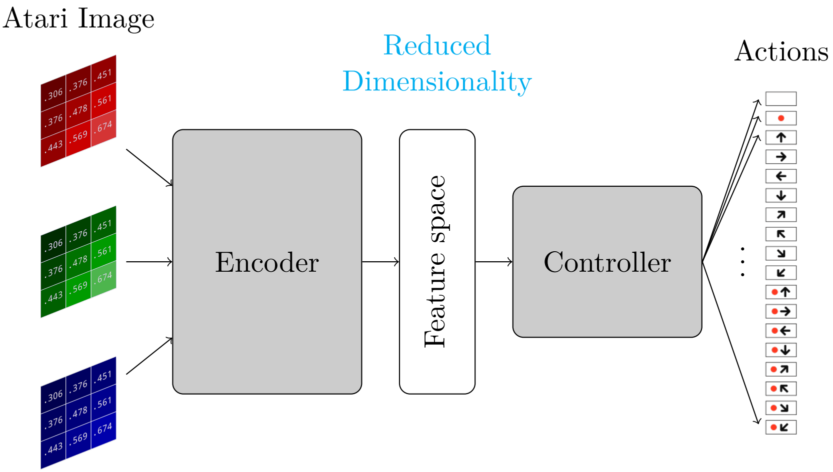
Atari Image



Actions

[Method] Approach: Interpretable Encoder – Controller



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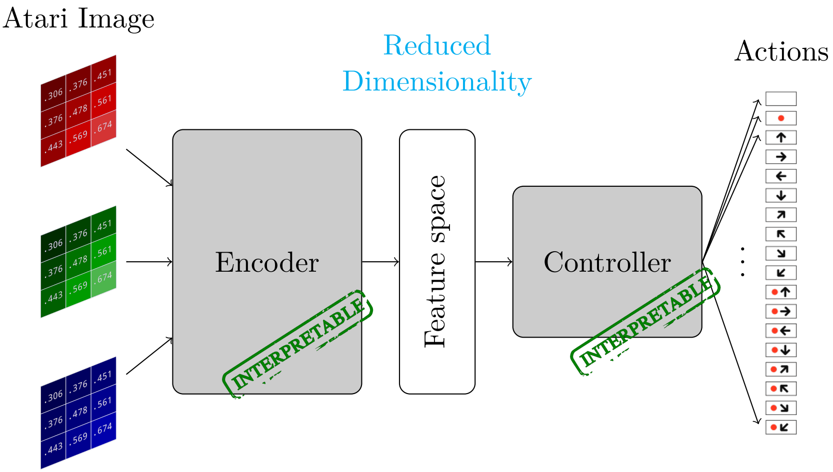

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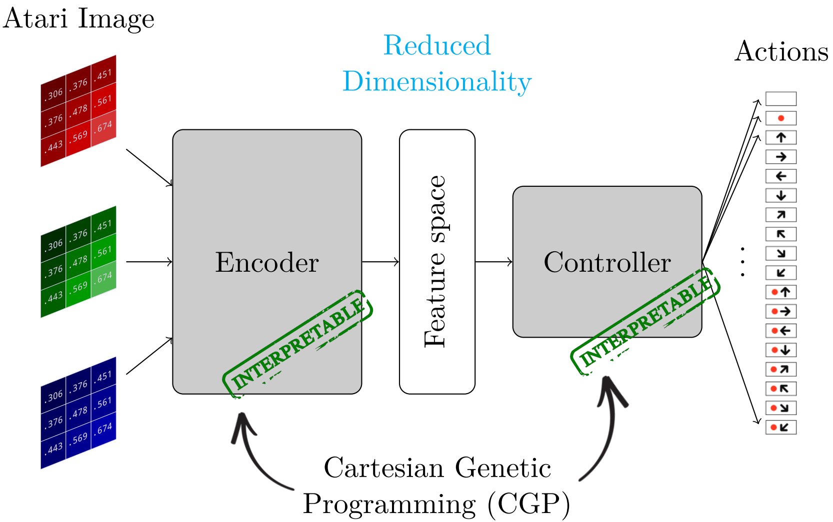

[Method] Cartesian Genetic Programming (CGP)

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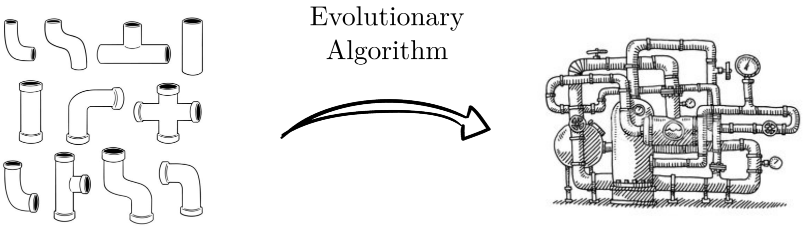

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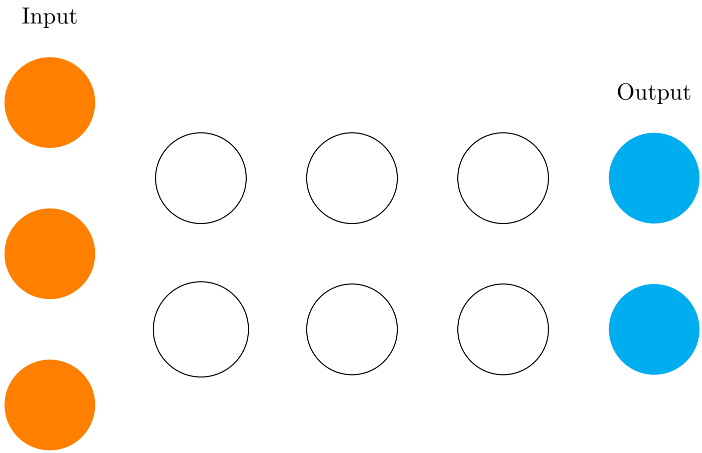

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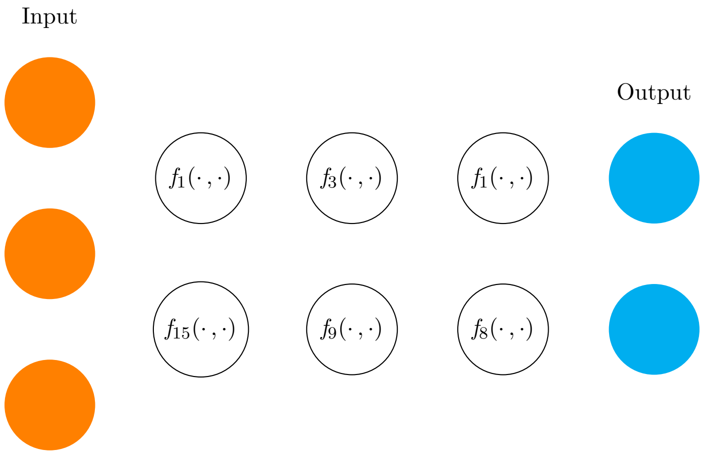

Function pool: $\{f_i : \mathcal{X}^2 \to \mathcal{X}\}_i$

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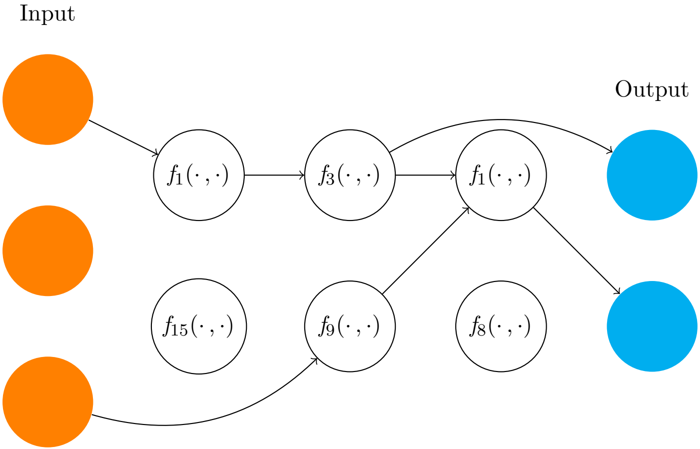

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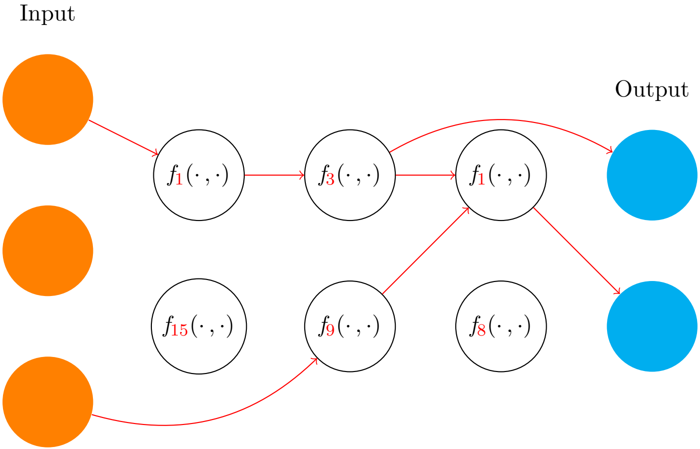

Function pool: $\{f_i : \mathcal{X}^2 \to \mathcal{X}\}_i$

Genotype: $[1, 1, 2, 13, 1, \ldots, 3] \in \mathbb{N}^{3\times\text{number of nodes} + \text{number of outputs}}$

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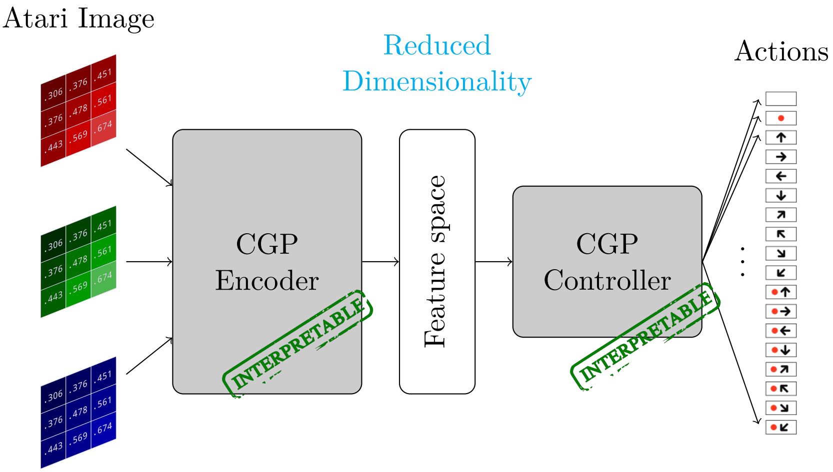

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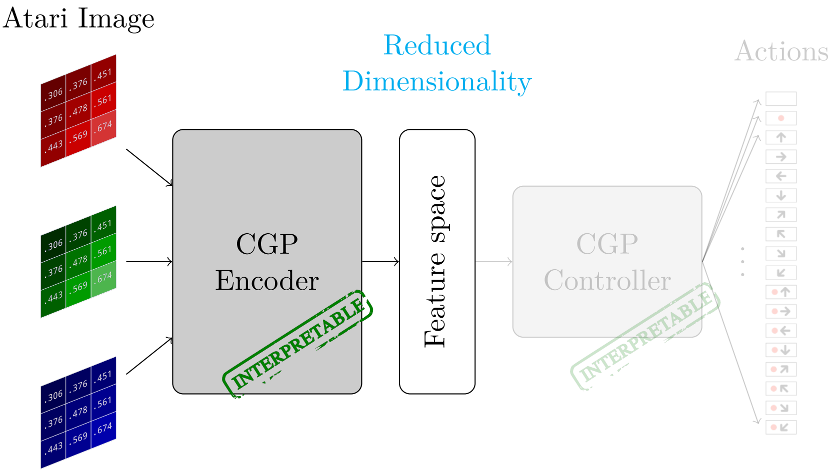

[Method] Encoder's Functions

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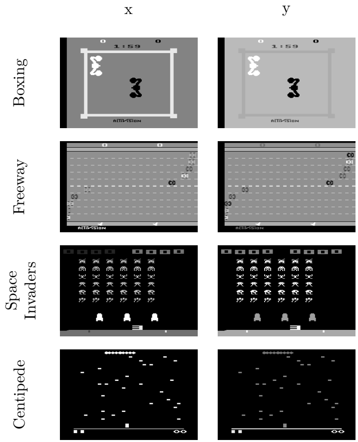

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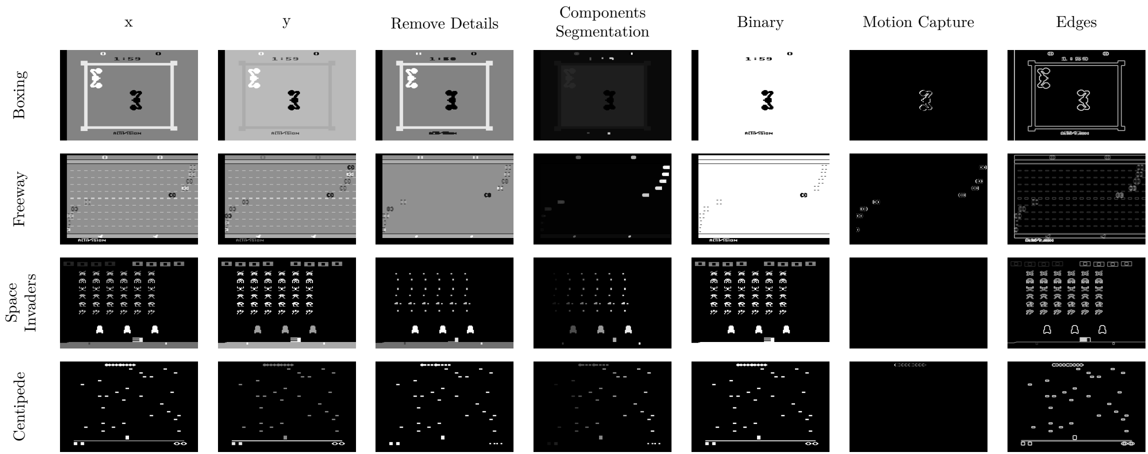

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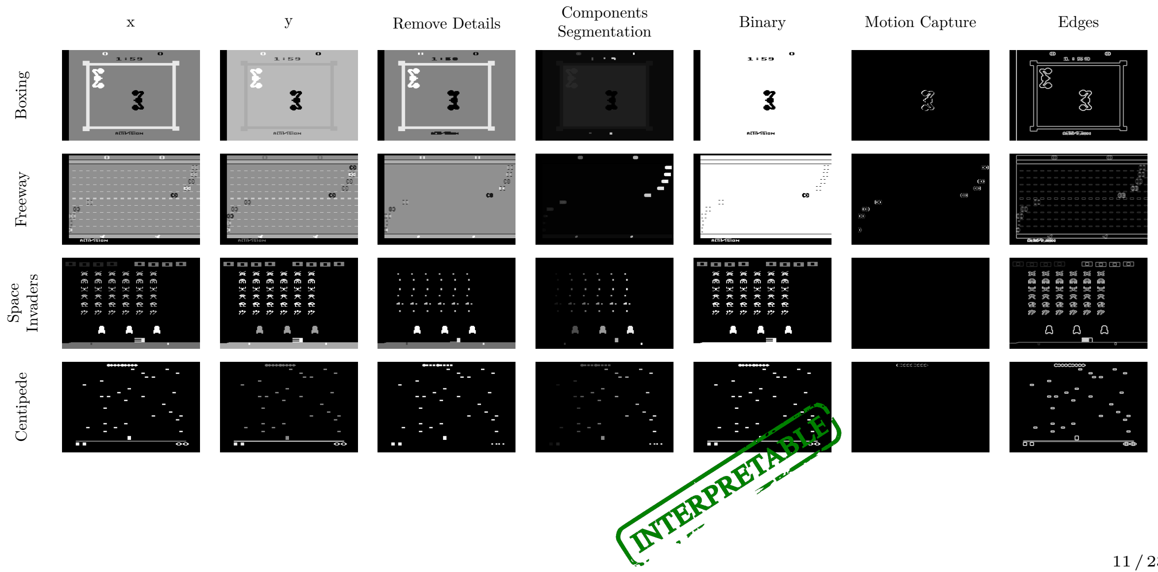

[Method] Encoder

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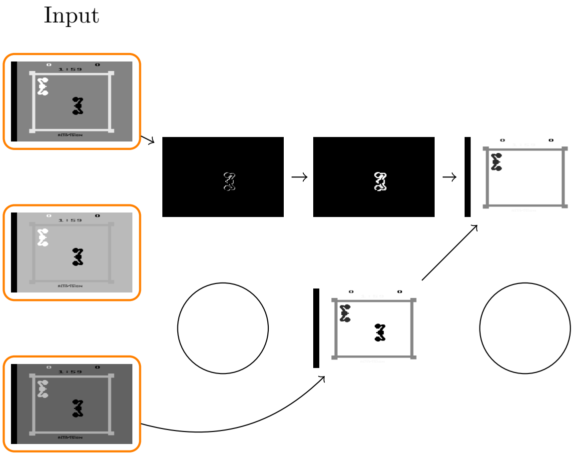
Input

[Method] Encoder



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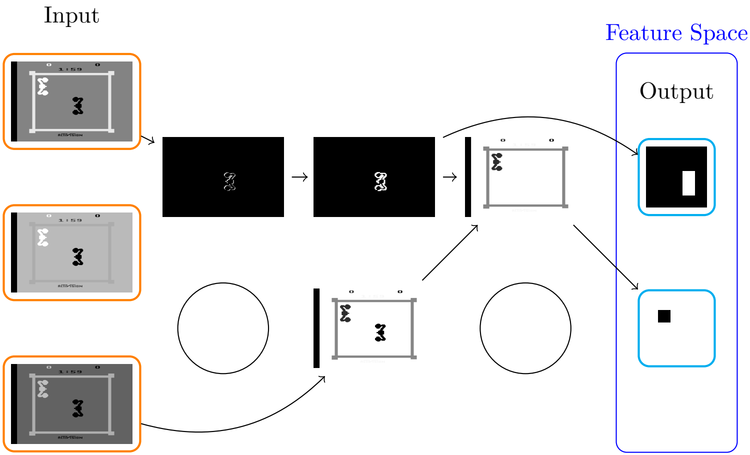

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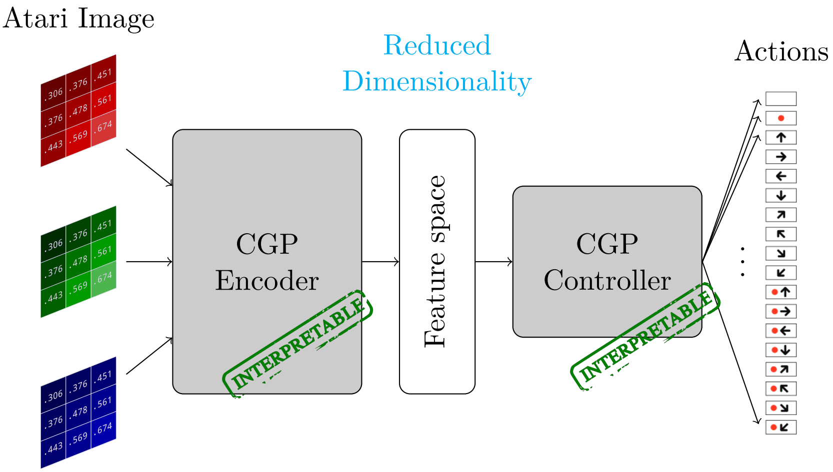

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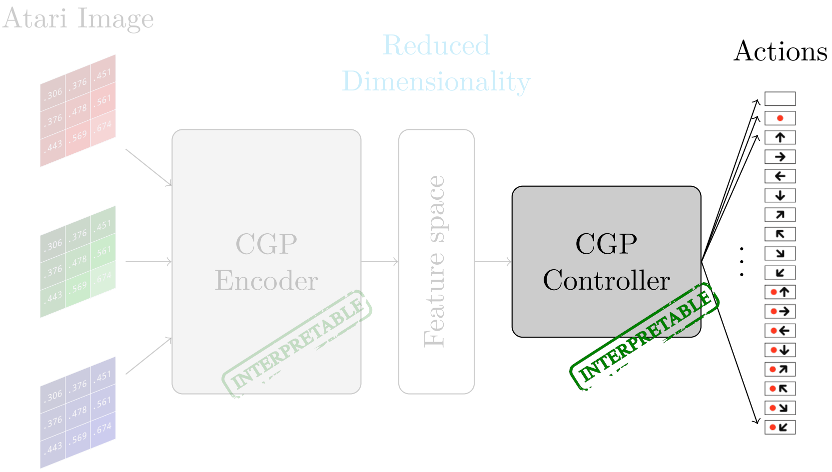

[Method] Controller

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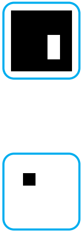
Encoder's
Output



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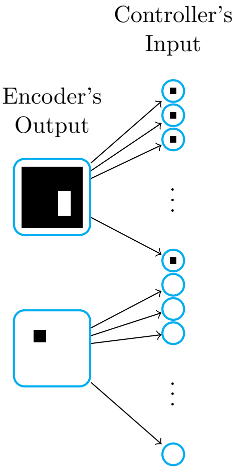

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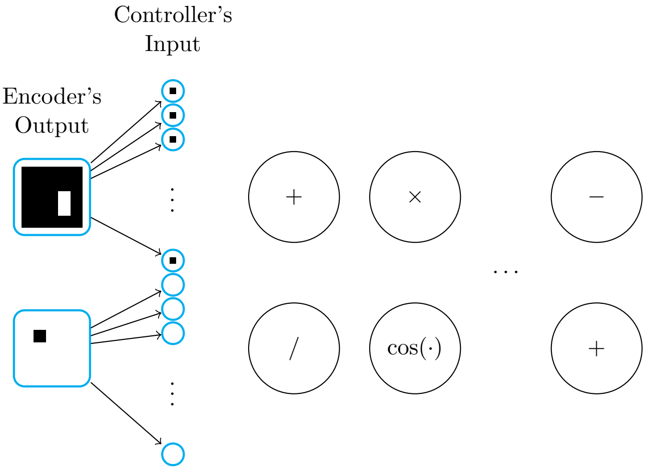

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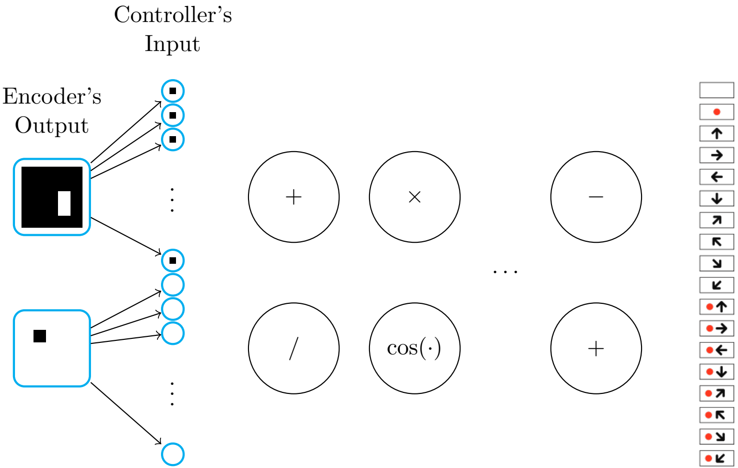

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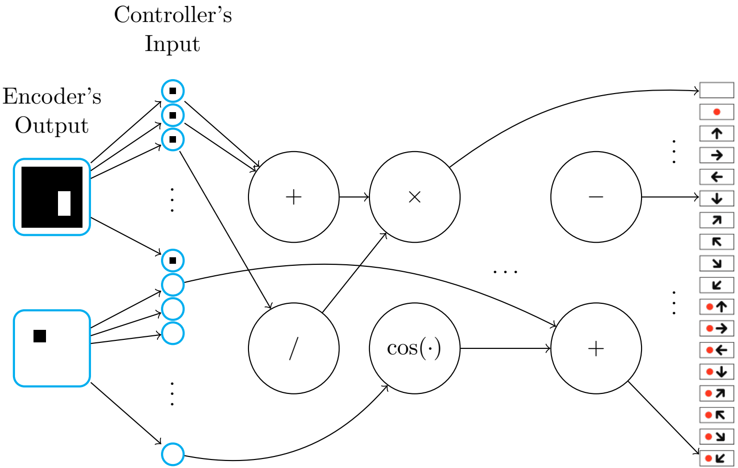

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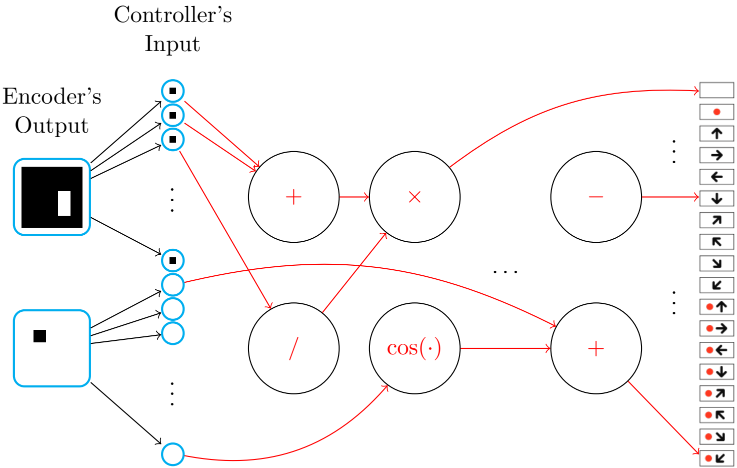

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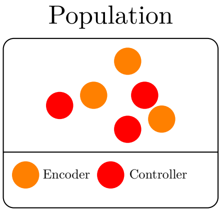
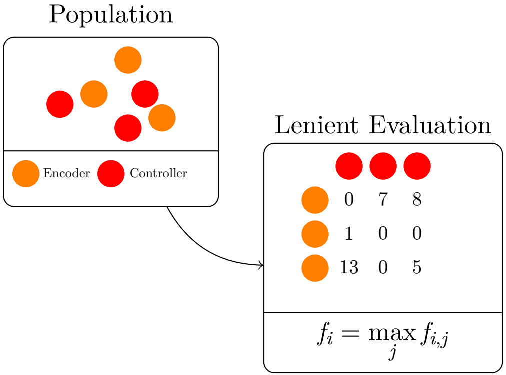
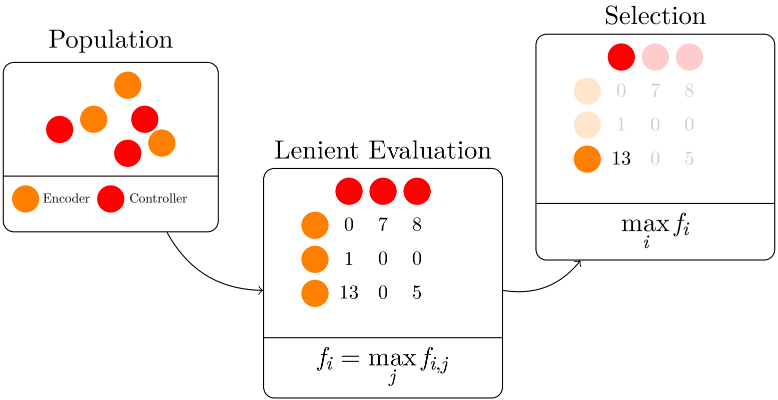


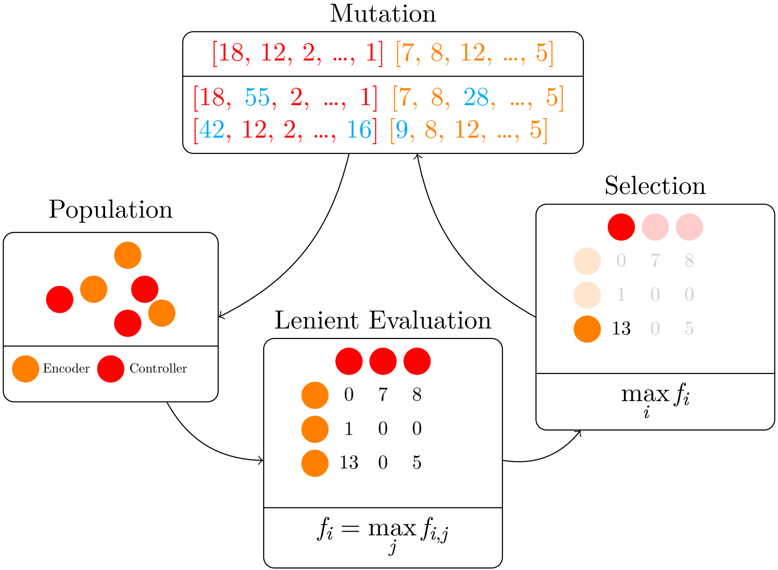
[Method] Optimizer: $1 + \lambda$ co-evolution



[Method] Optimizer: $1 + \lambda$ co-evolution



[Method] Optimizer: $1 + \lambda$ co-evolution



Content

1. [Context] Interpretability in Atari
2. [Method] Cartesian Genetic Programming
3. [Experiments] Results on Atari
4. [Conclusion] Next steps

[Experiments] Settings

[Experiments] Settings

- **Encoder input:** 1 gray-level down-scaled image

[Experiments] Settings

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[Experiments] Settings

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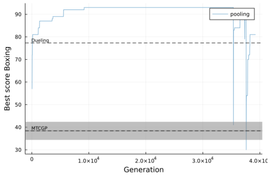
[Experiments] Settings

- **Encoder input:** 1 gray-level down-scaled image
- **Stochasticity:** `repeat_action_probability = 0.25`
- **Fitness evaluation:** score obtained after 1 roll-out
- **Seed:** same seed for all evaluations

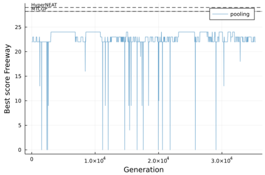
[Experiments] Results: performance

[Experiments] Results: performance

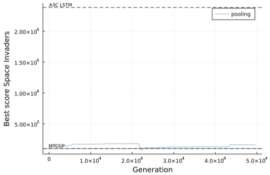
Boxing



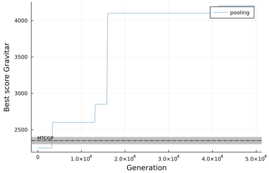
Freeway



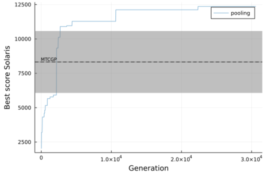
Space Invaders



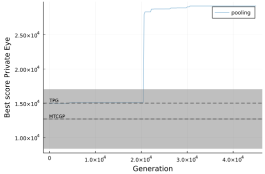
Gravitar



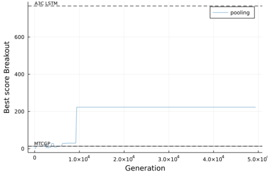
Solaris



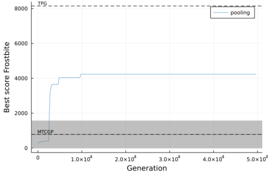
Private Eye



Breakout



Frostbite



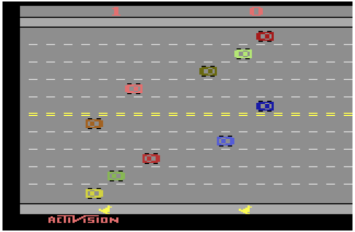
https://github.com/erwanlecarpentier/ICGP-results

[Experiments] Results: interpretability

[Experiments] Results: interpretability

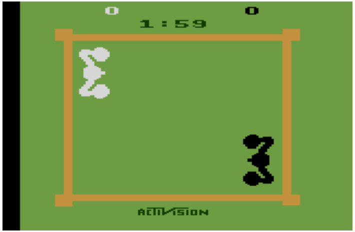
Videos:

`Freeway`



`Space Invaders`

`Boxing`



[Experiments] Stochastic setting

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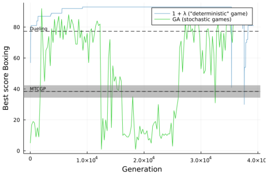
Same setting with a different seed for each generation

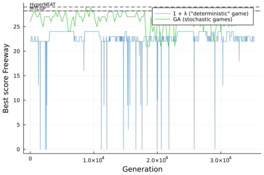
[Experiments] Stochastic setting

Same setting with a different seed for each generation

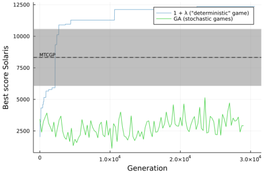
Boxing



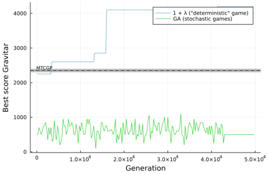
Freeway



Solaris



Gravitar

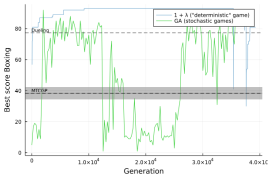


https://github.com/erwanlecarpentier/ICGP-results

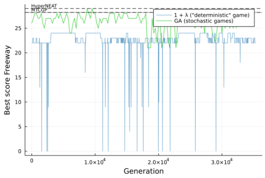
[Experiments] Stochastic setting

Same setting with a different seed for each generation

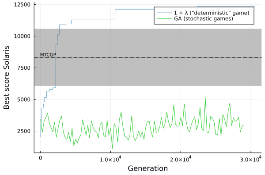
Boxing



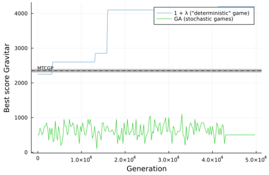
Freeway



Solaris



Gravitar



- Boxing: collapse
- Freeway Solaris Gravitar: no learning progress

https://github.com/erwanlecarpentier/ICGP-results

Content

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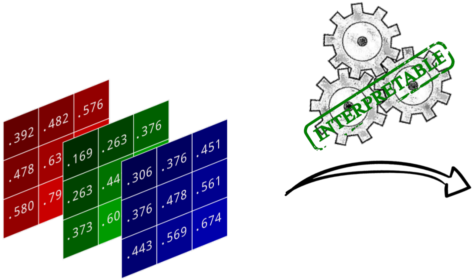
[Conclusion]

[Conclusion]

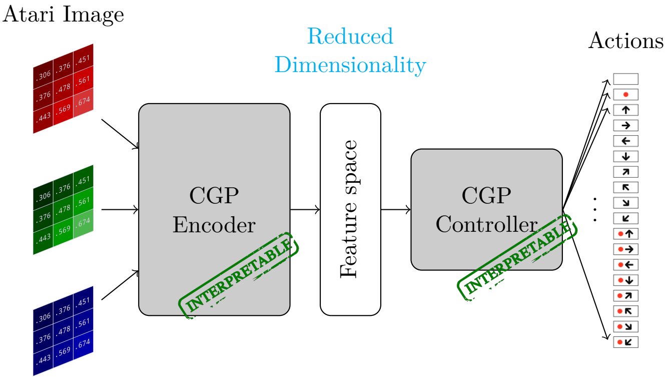
- Goal: interpretable agent in pixel-based Atari games



$a \in \mathcal{A}$

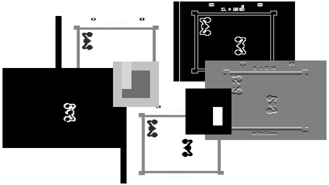
[Conclusion]

- Goal: interpretable agent in pixel-based Atari games
- Method: CGP co-evolution in an encoder-controller scheme



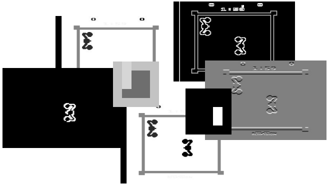
[Conclusion]

- Goal: interpretable agent in pixel-based Atari games
- Method: CGP co-evolution in an encoder-controller scheme
- Encoder: interpretable image processing functions



[Conclusion]

- Goal: interpretable agent in pixel-based Atari games
- Method: CGP co-evolution in an encoder-controller scheme
- Encoder: interpretable image processing functions
- Controller: interpretable scalar functions



cos

$\times \quad - \quad \div$

$+$

[Conclusion]

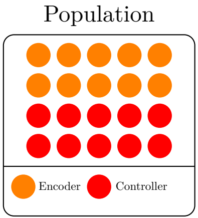
- Goal: interpretable agent in pixel-based Atari games
- Method: CGP co-evolution in an encoder-controller scheme
- Encoder: interpretable image processing functions
- Controller: interpretable scalar functions
- Experiments:

	Performance	Interpretability
Atari deterministic	OK	OK
Atari stochastic	NOT YET	OK

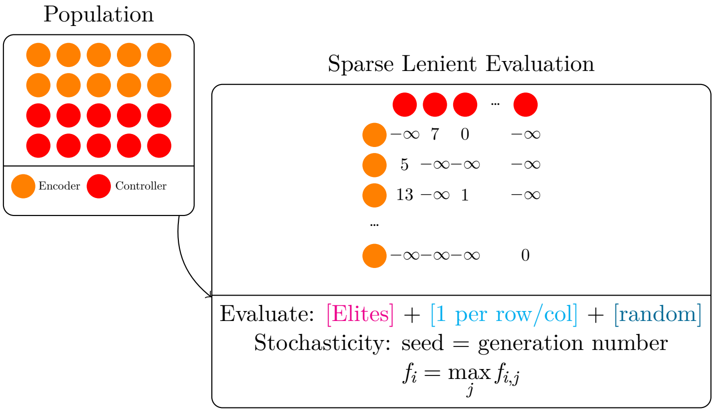
Images: pixabay.com and Wilson, Dennis G., et al. ”Evolving simple programs for playing Atari games.” GECCO 2018

GA co-evolution

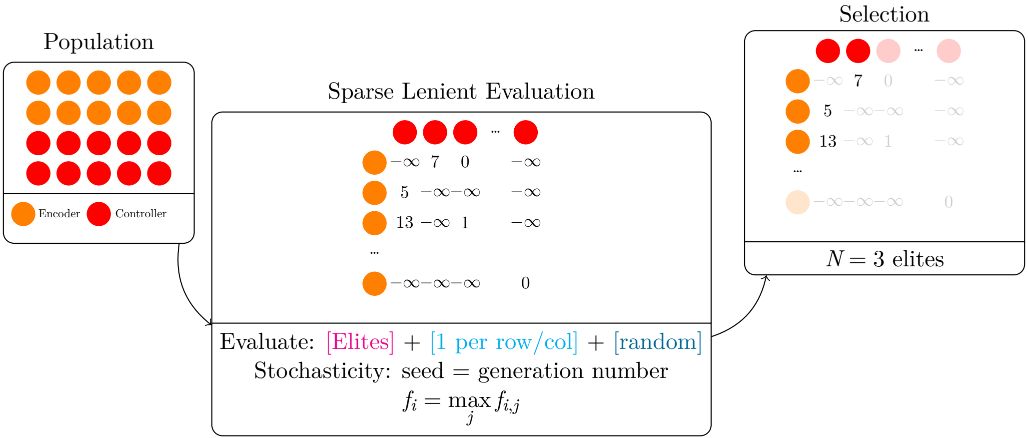
GA co-evolution



GA co-evolution



GA co-evolution



GA co-evolution