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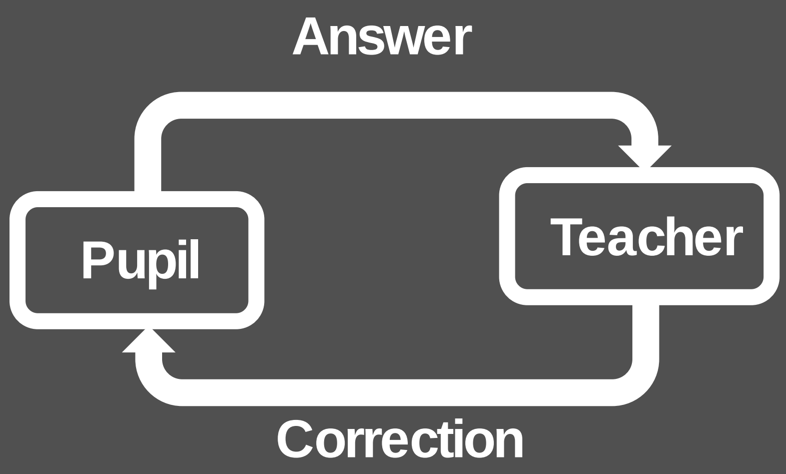
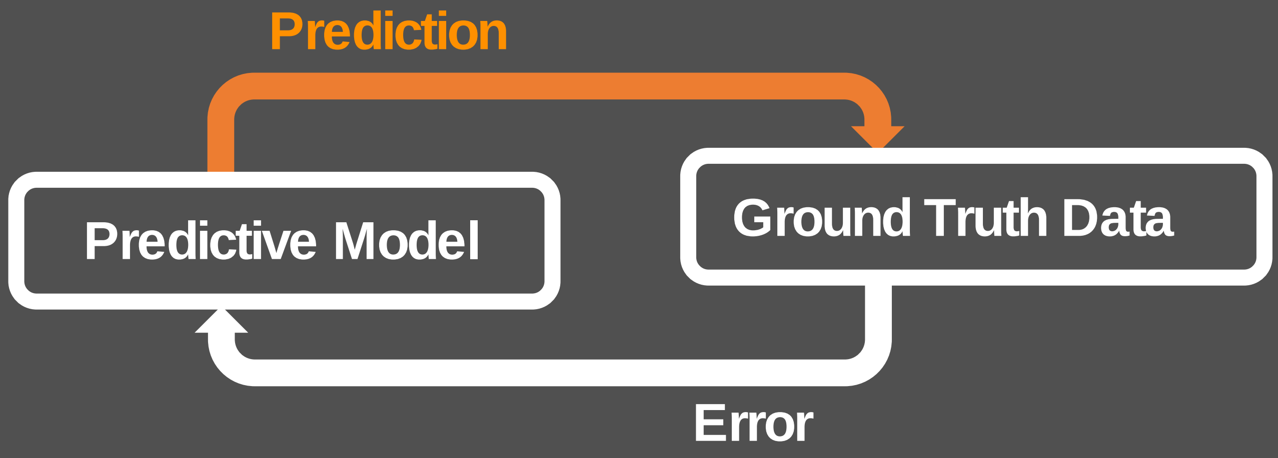
Reinforcement Learning

Introduction

Two Processes:

- Forward Propagation (Prediction)
- Backward Propagation (Weight Tuning)





Two Processes:

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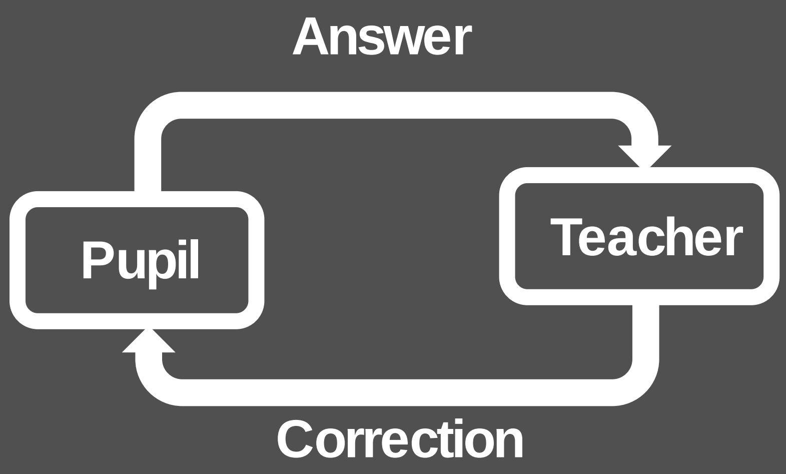
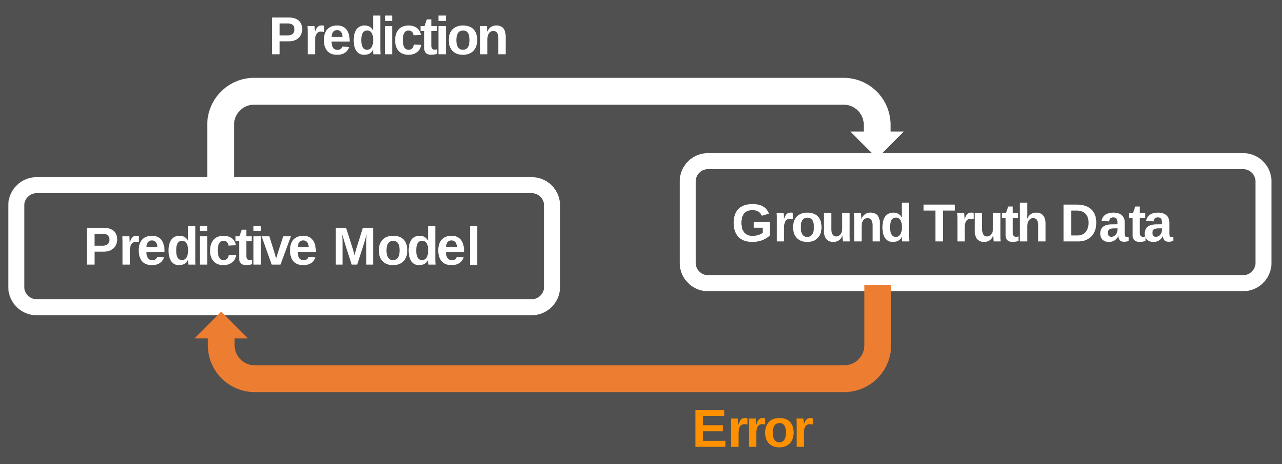
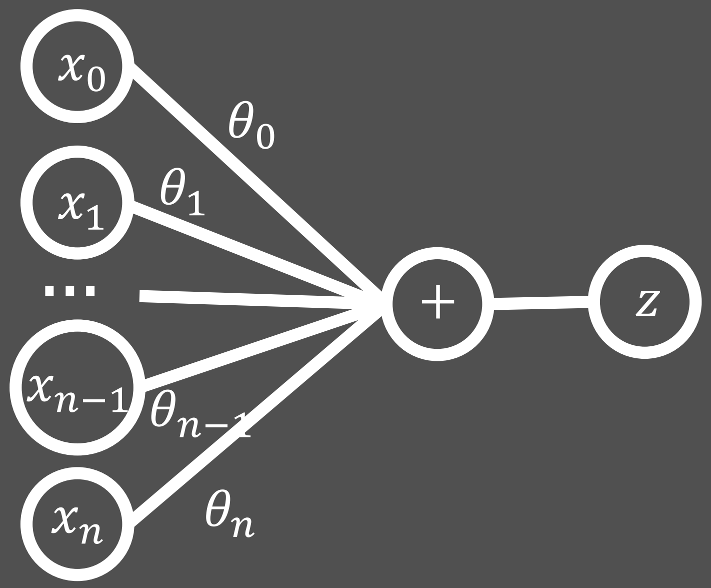
- Backward Propagation (Weight Tuning)





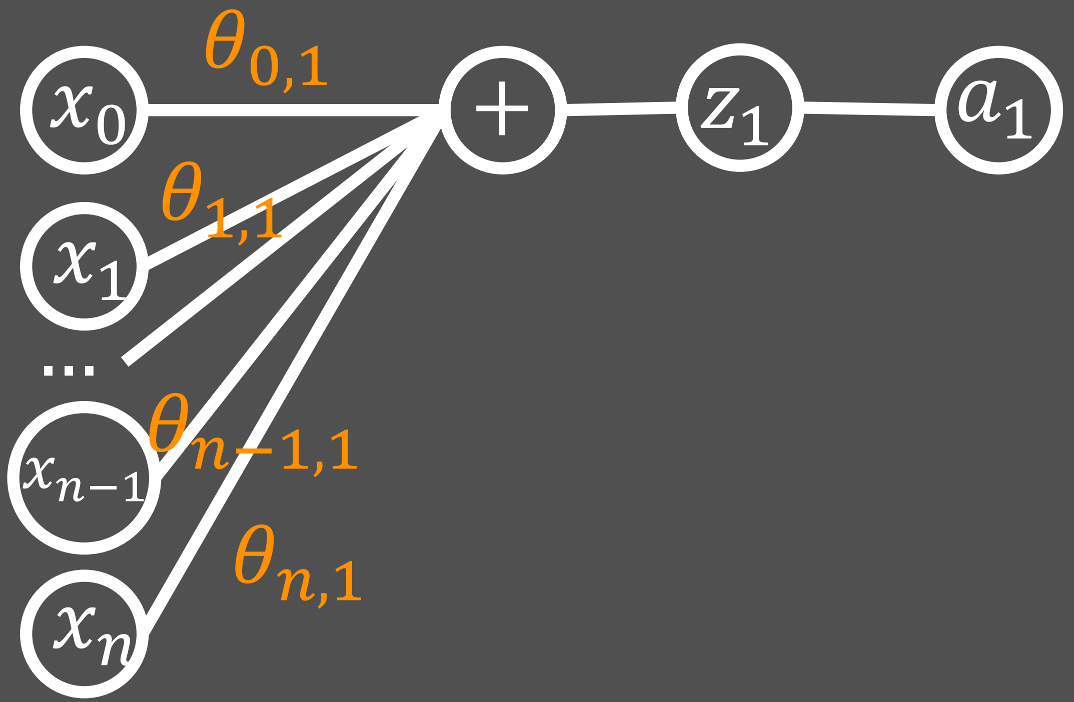
Forward Propagation

- Compute multiple weighted sums z_i
- Activate them to get $a_i(z_i)$
- Remember from Perceptron: $z = \theta x$

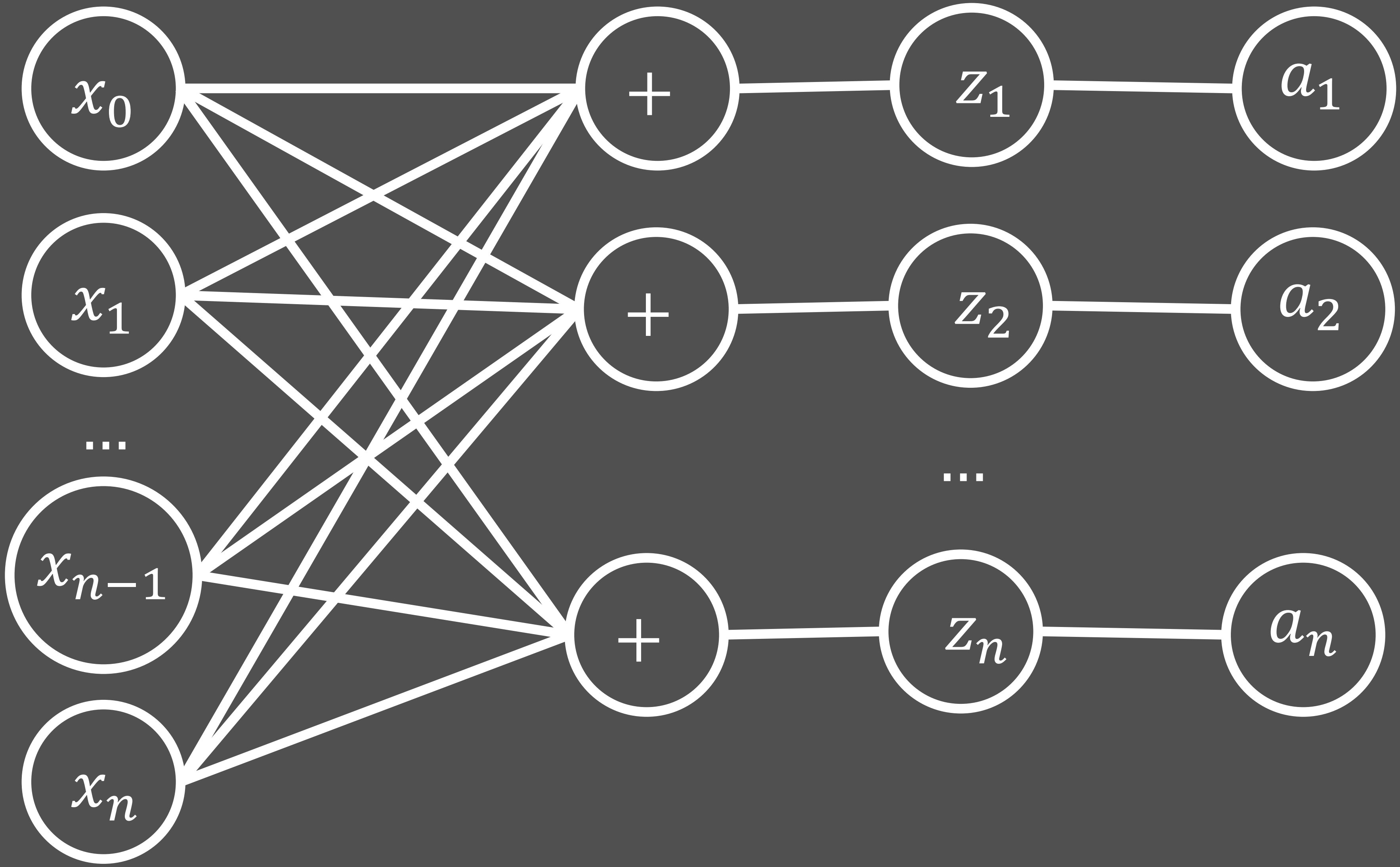


$$z_{to} = \theta_{from,to} x_{from}$$

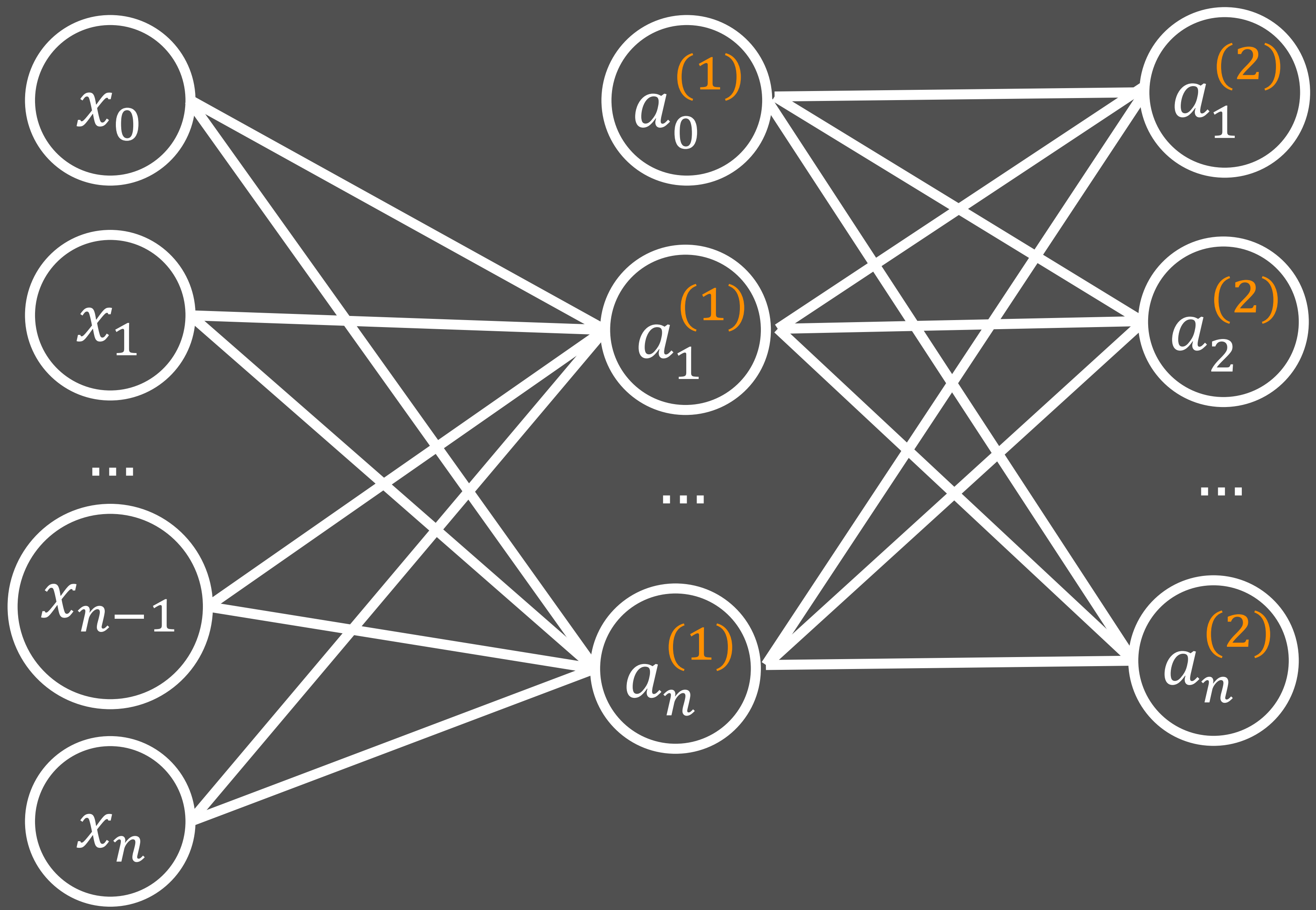
e.g. $z_1 = \theta_{0,1} x_0$



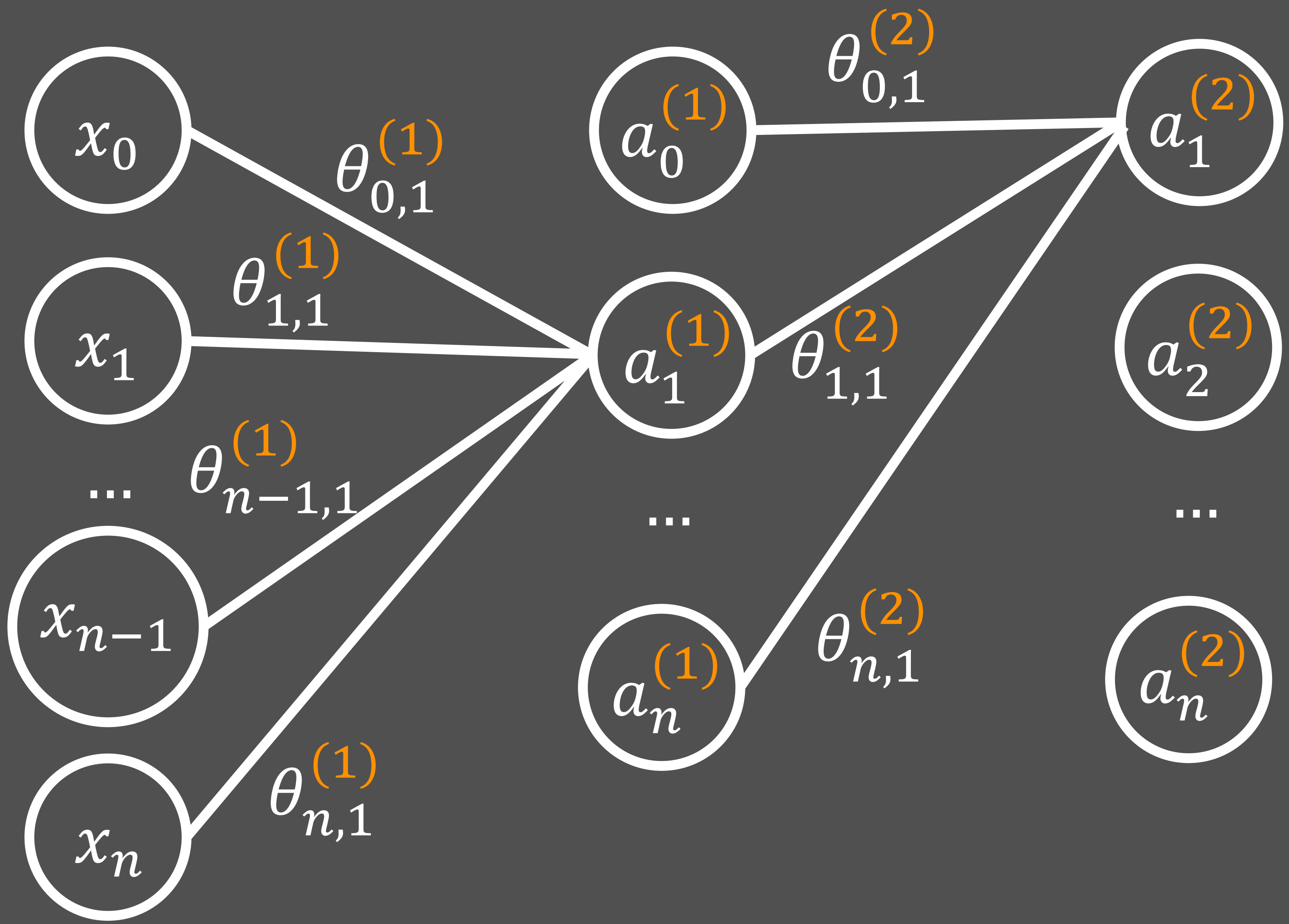
Forward Propagation



Forward Propagation

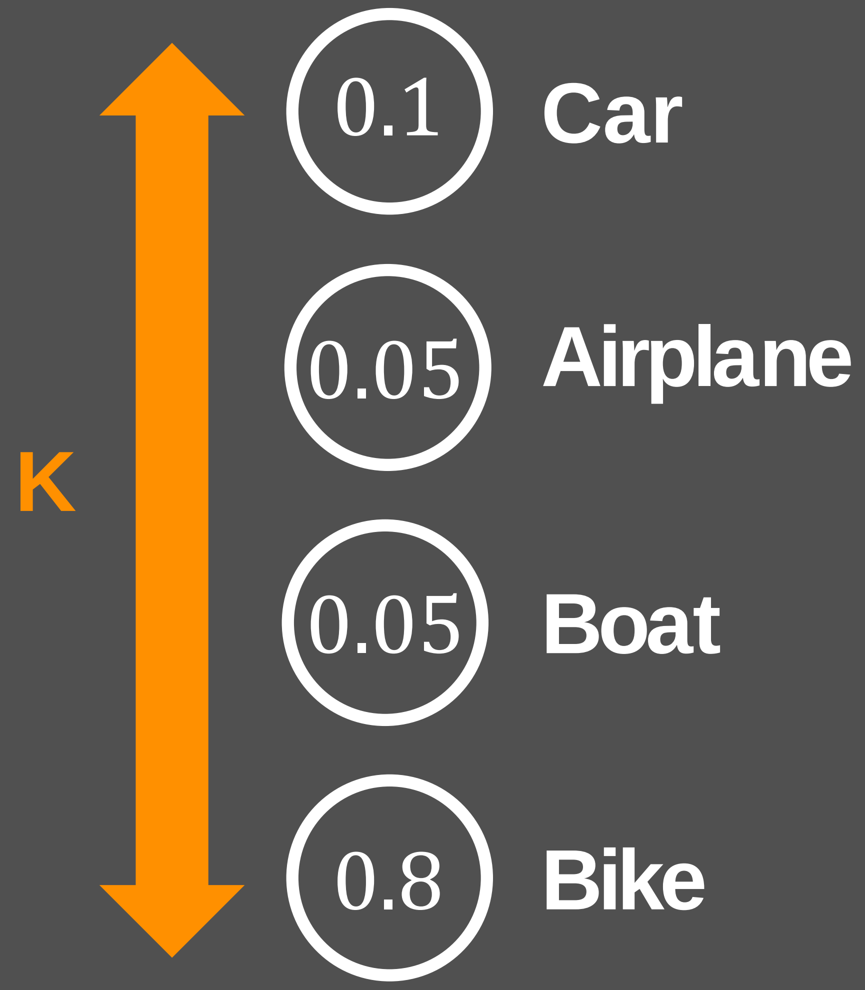


Forward Propagation



Forward Propagation

- Object Recognition
- Assume 4 classes
- L-Layer (L is the last layer)
- Softmax: $a = \frac{e^{z_j}}{\sum_{k=1}^{K} e^{z_k}}$
- Use Softmax for the last Layer



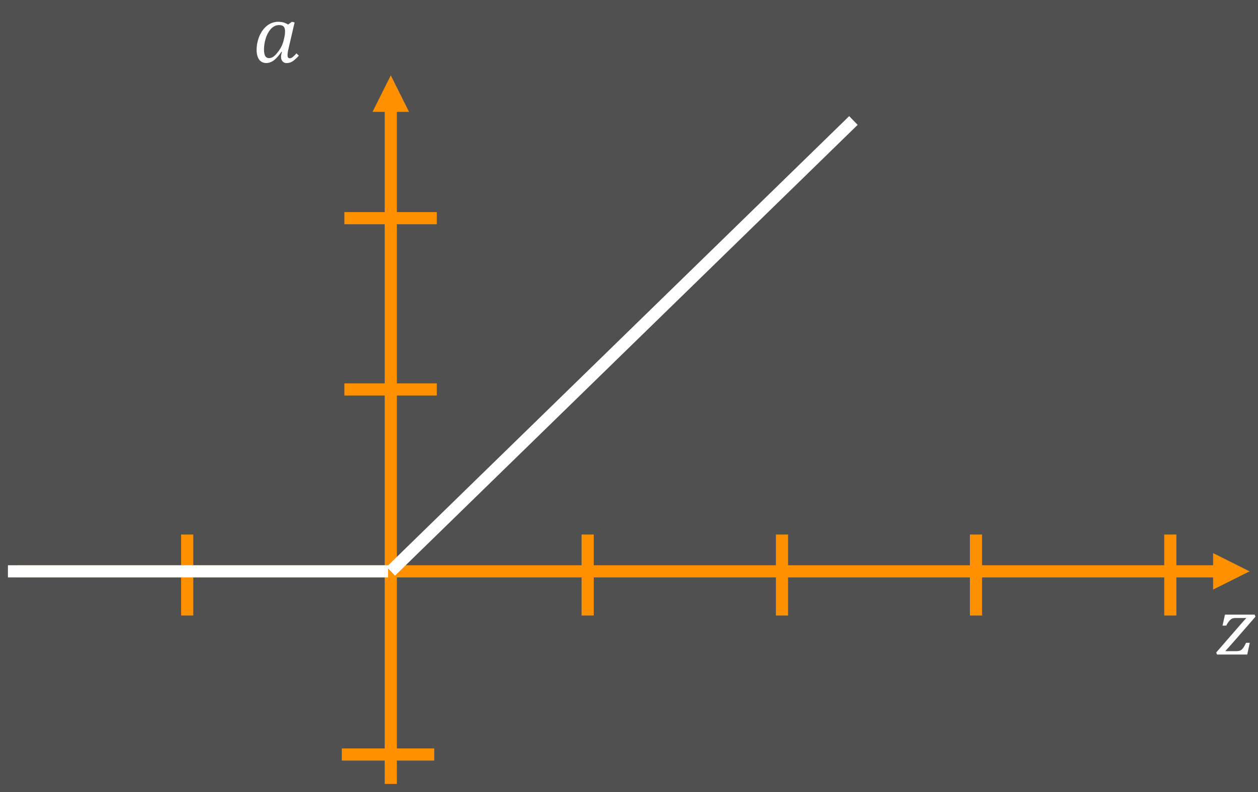
Forward Propagation

Hidden Layer Activation Functions $a(z)$:

- **Linear Neuron:** $a(z) = z$
- **Binary Threshold Unit:** $a(z) = \begin{cases} 0, z < 0 \\ 1, z \geq 0 \end{cases}$
- **Rectified Linear (ReLu):** $\boldsymbol{a(z) = \begin{cases} 0, z < 0 \\ z, z \geq 0 \end{cases}}$
- **Sigmoid:** $a(z) = \frac{1}{1+e^{-z}}$
- **Tanh:** $a(z) = \tanh(z)$

Forward Propagation

Rectified Linear (ReLu): $a(z) = \begin{cases} 0, z < 0 \\ z, z \geq 0 \end{cases}$

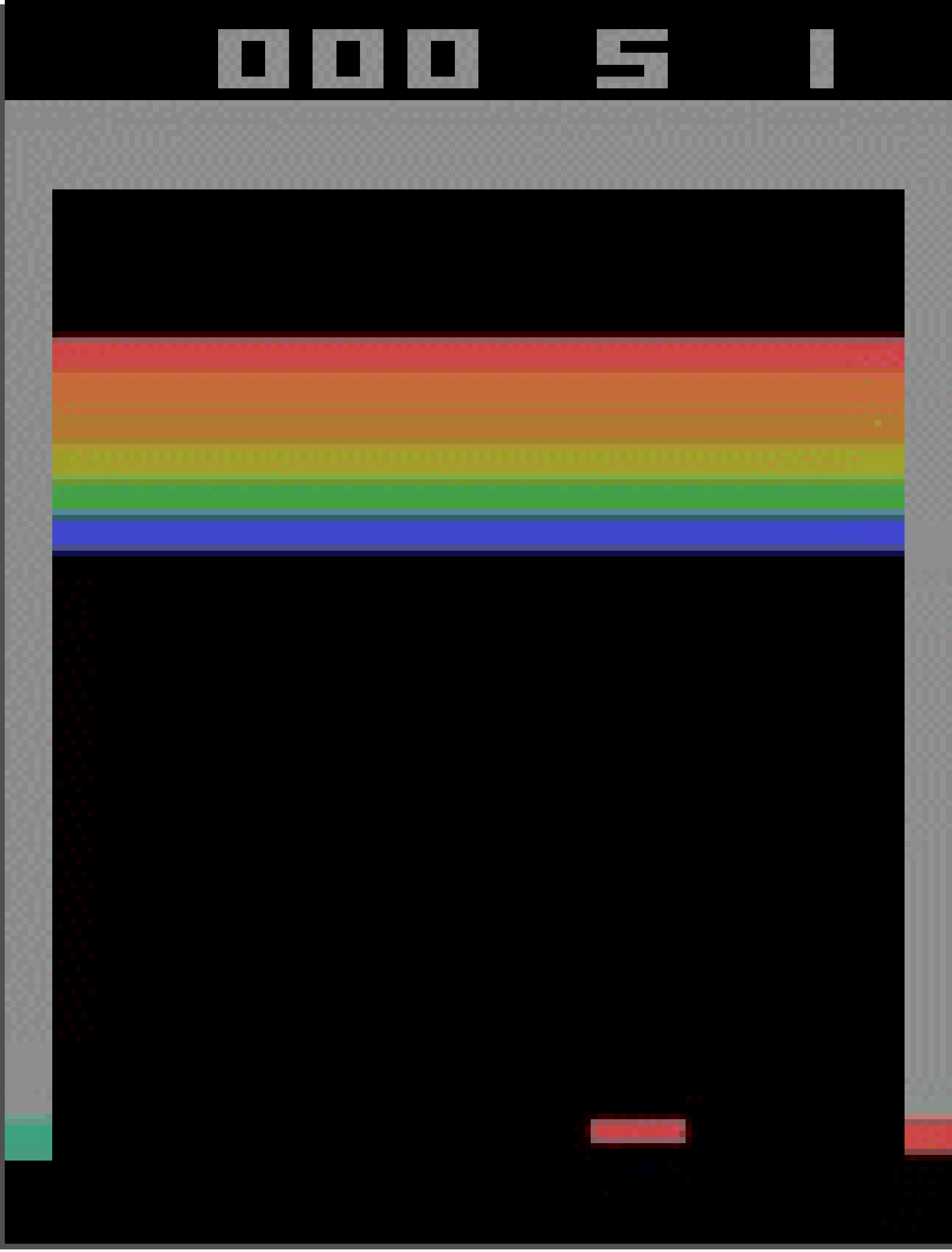


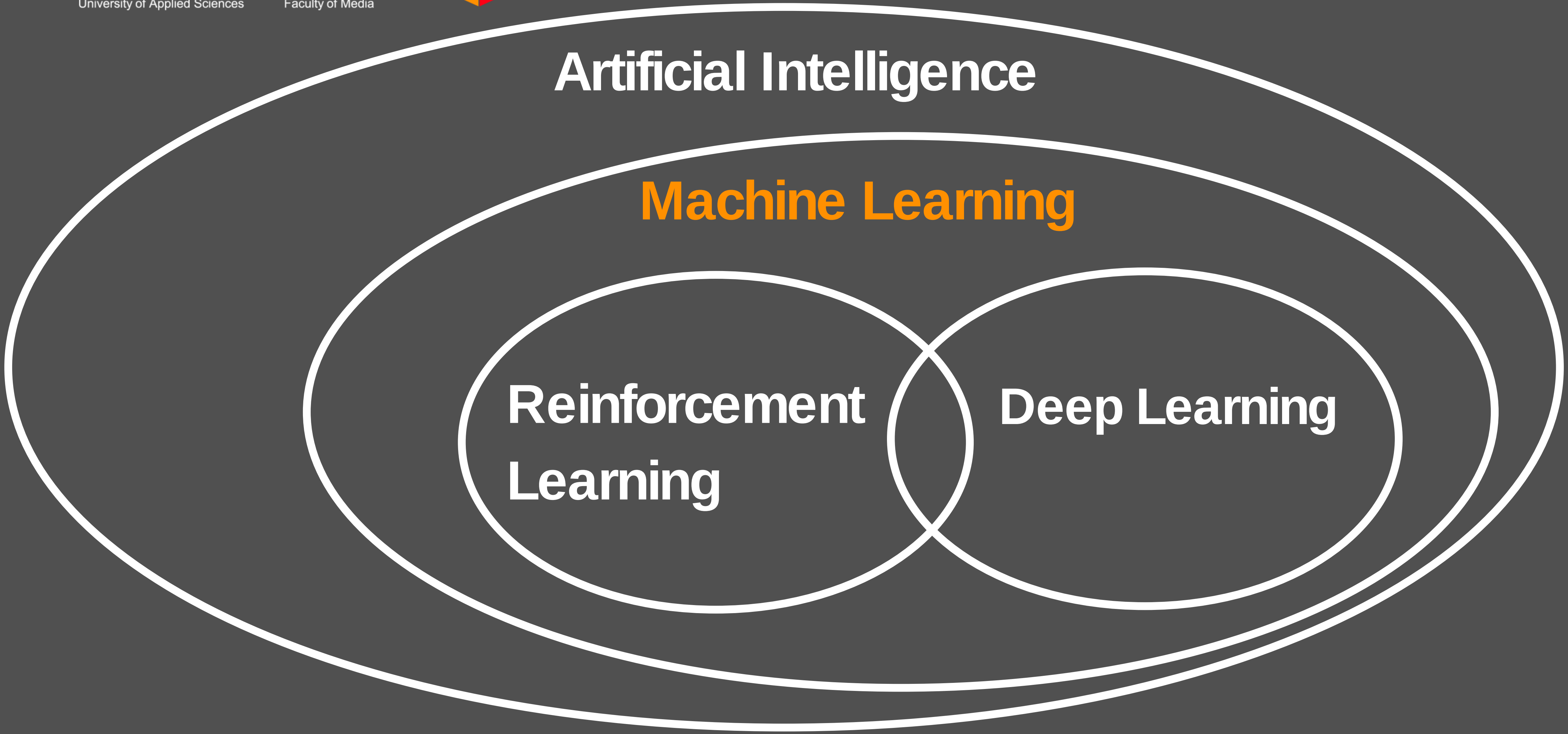
Exercise:

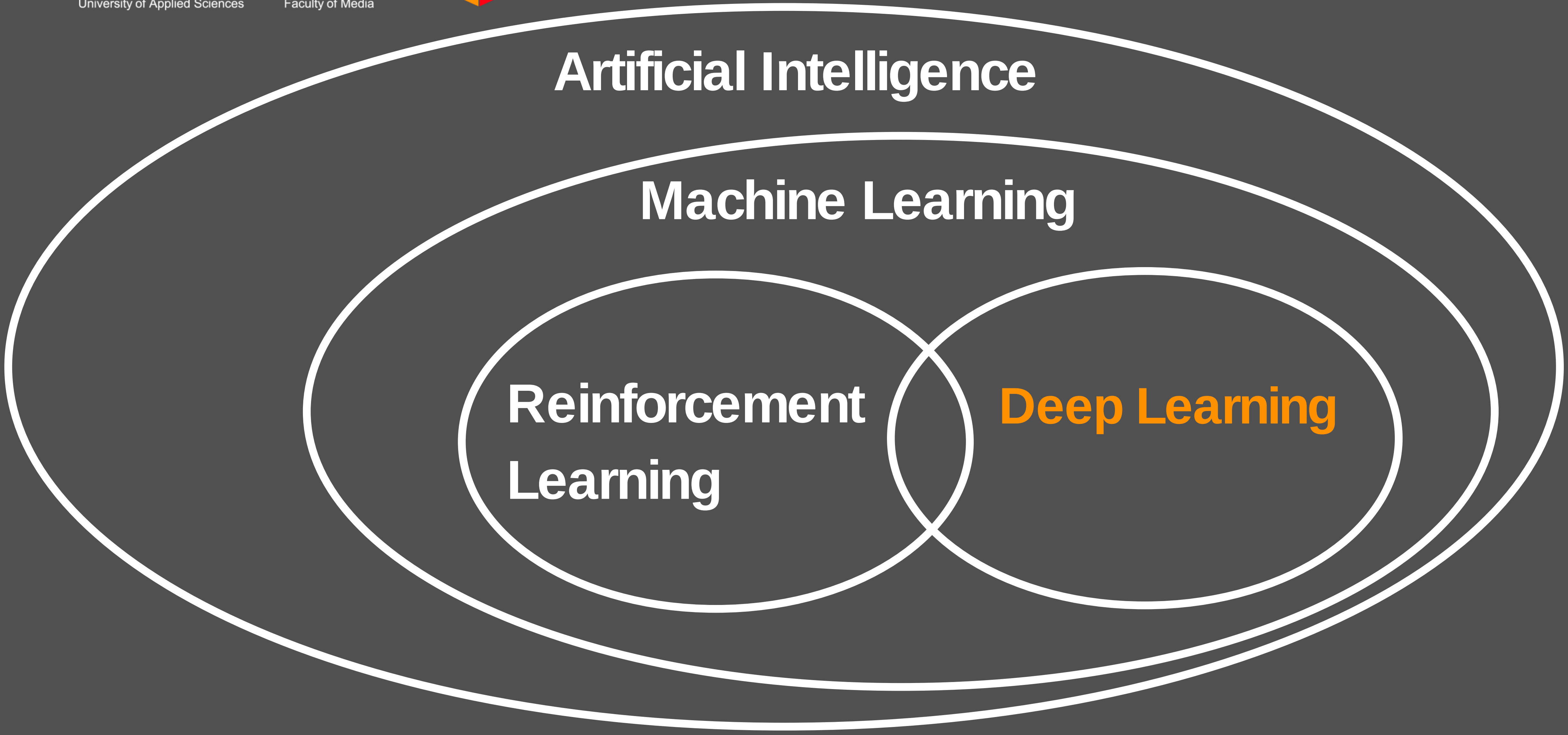
- Construct a MLP (input: 3, hidden: 4, output: 3)
- All activation functions are ReLu-Function
- The output activation is a softmax-function
- Initialize the weights randomly
  - No zero values allowed!
- The input vector is $\mathrm{x} = (1, -2, 1)^T$
- Compute one forward-propagation step!

What we will do?

- Applied AI
- Reinforcement Learning
- Train Agent to play Atari-Games




Artificial Intelligence
Machine Learning
Reinforcement Learning
Deep Learning


Artificial Intelligence
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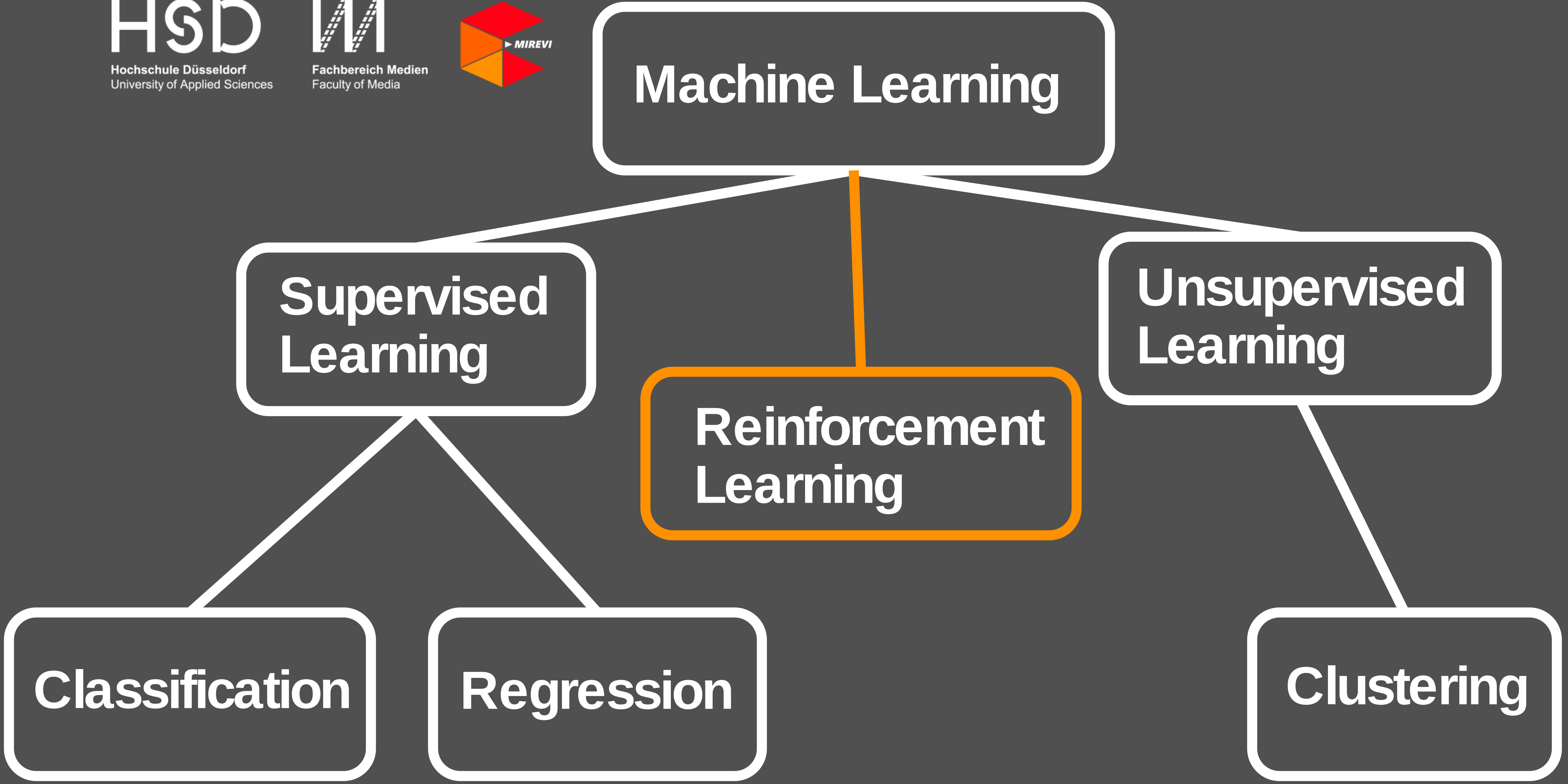
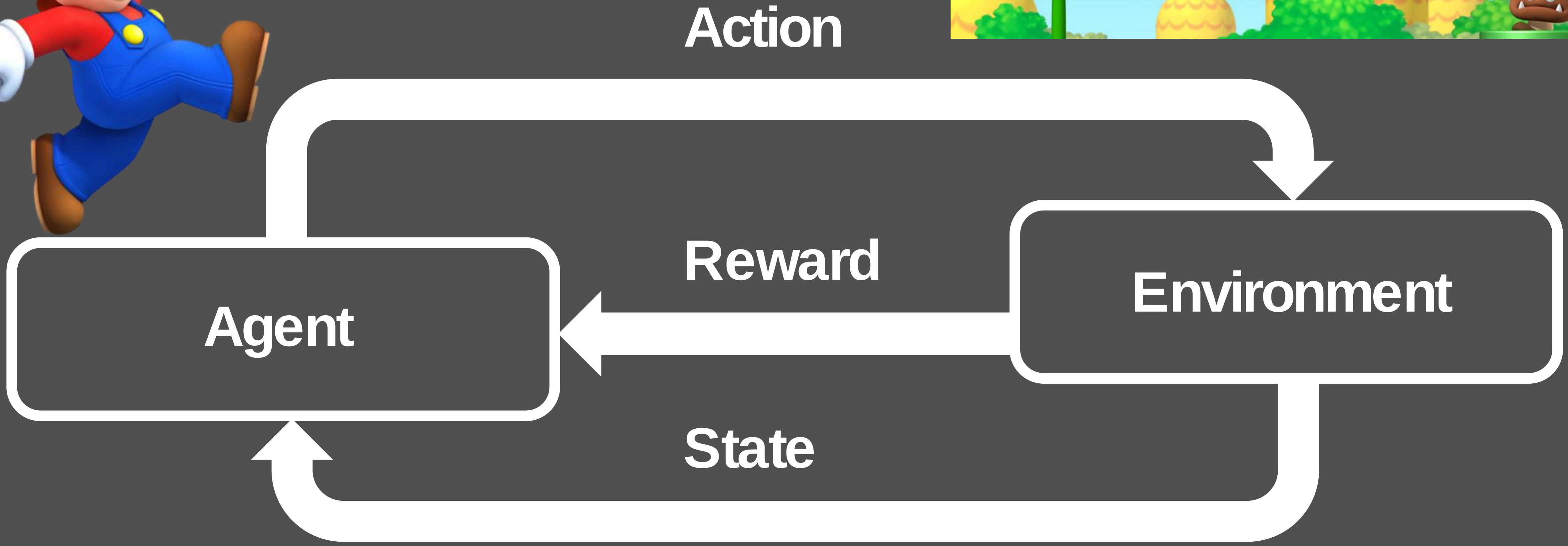
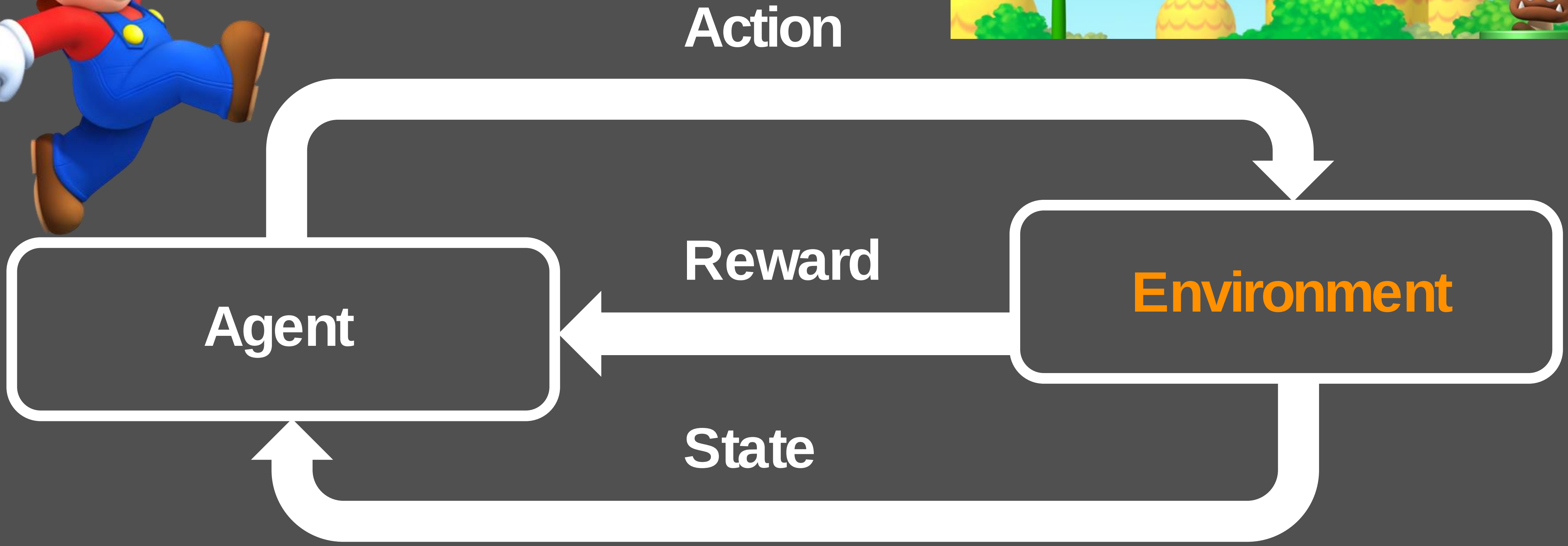

Machine Learning
Supervised Learning
Reinforcement Learning
Unsupervised Learning
Classification
Regression
Clustering

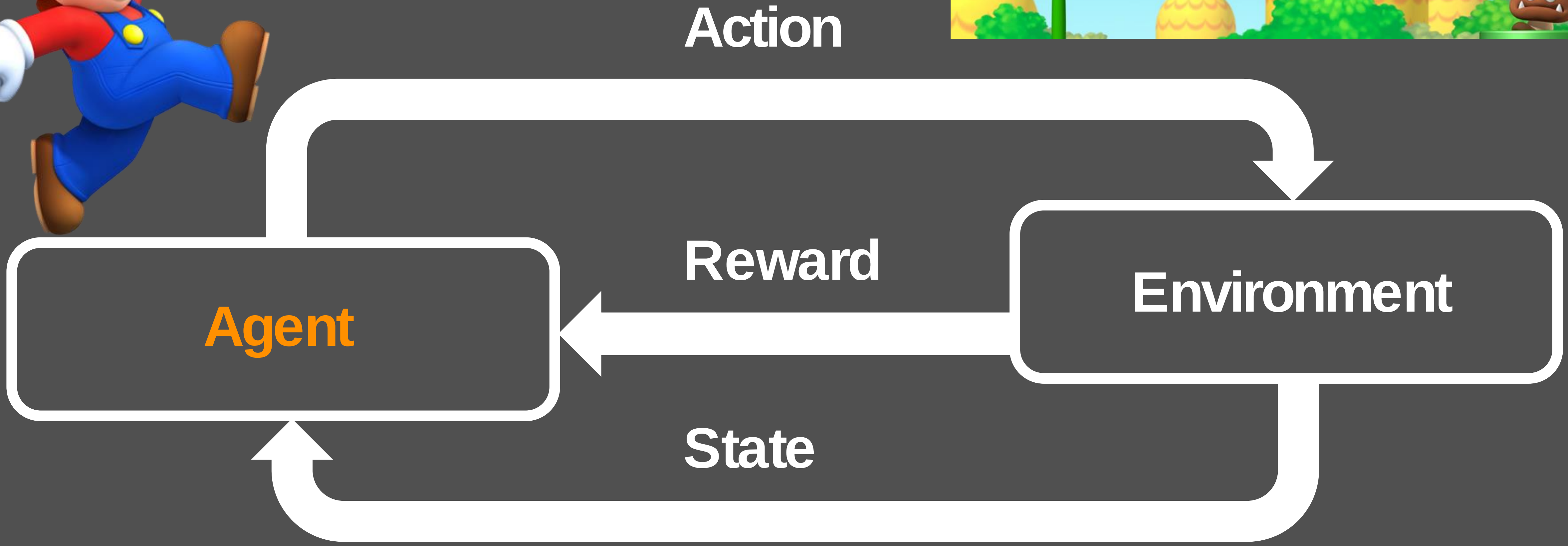
Reinforcement Learning



Reinforcement Learning



Reinforcement Learning



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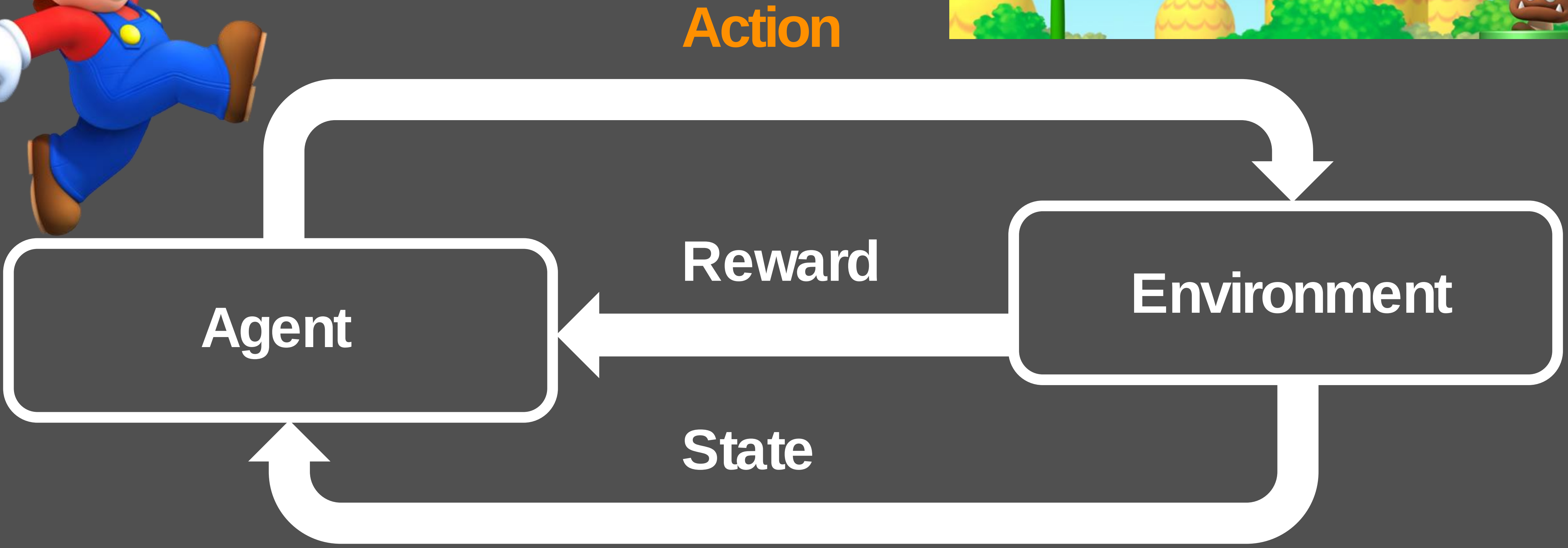
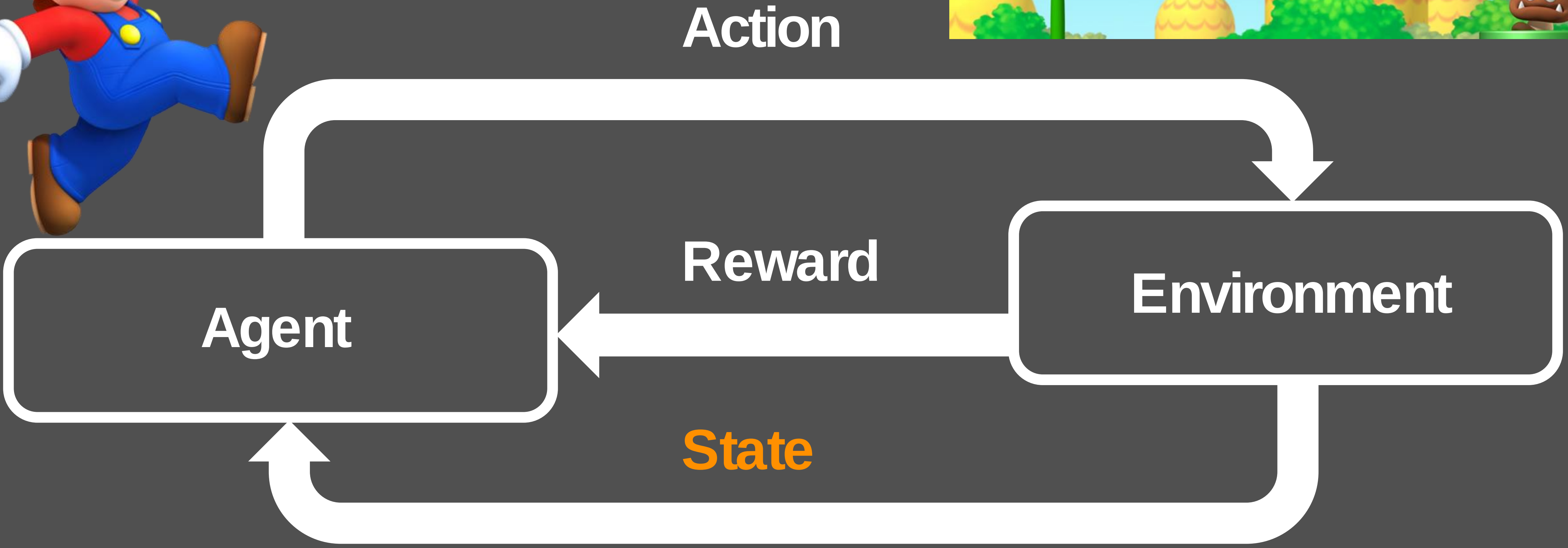
Reinforcement Learning



Reinforcement Learning



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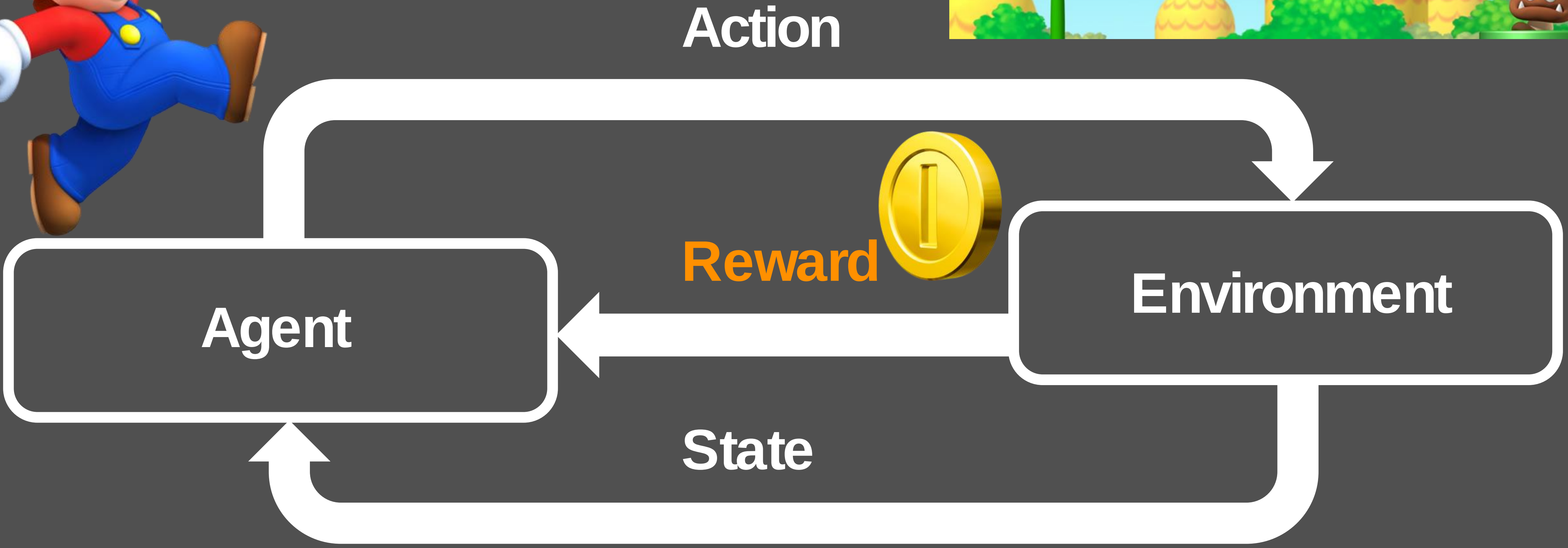
Reinforcement Learning



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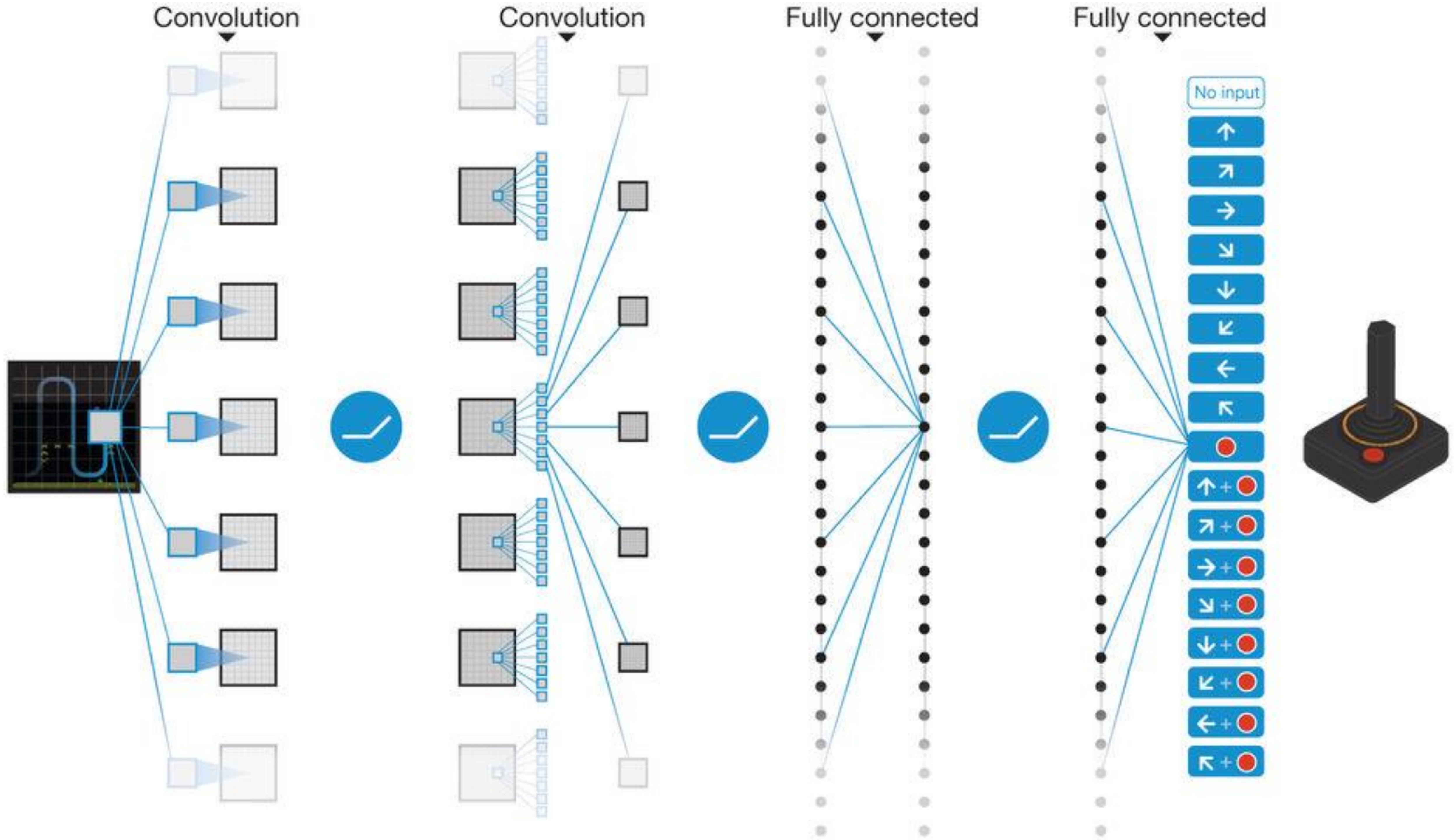
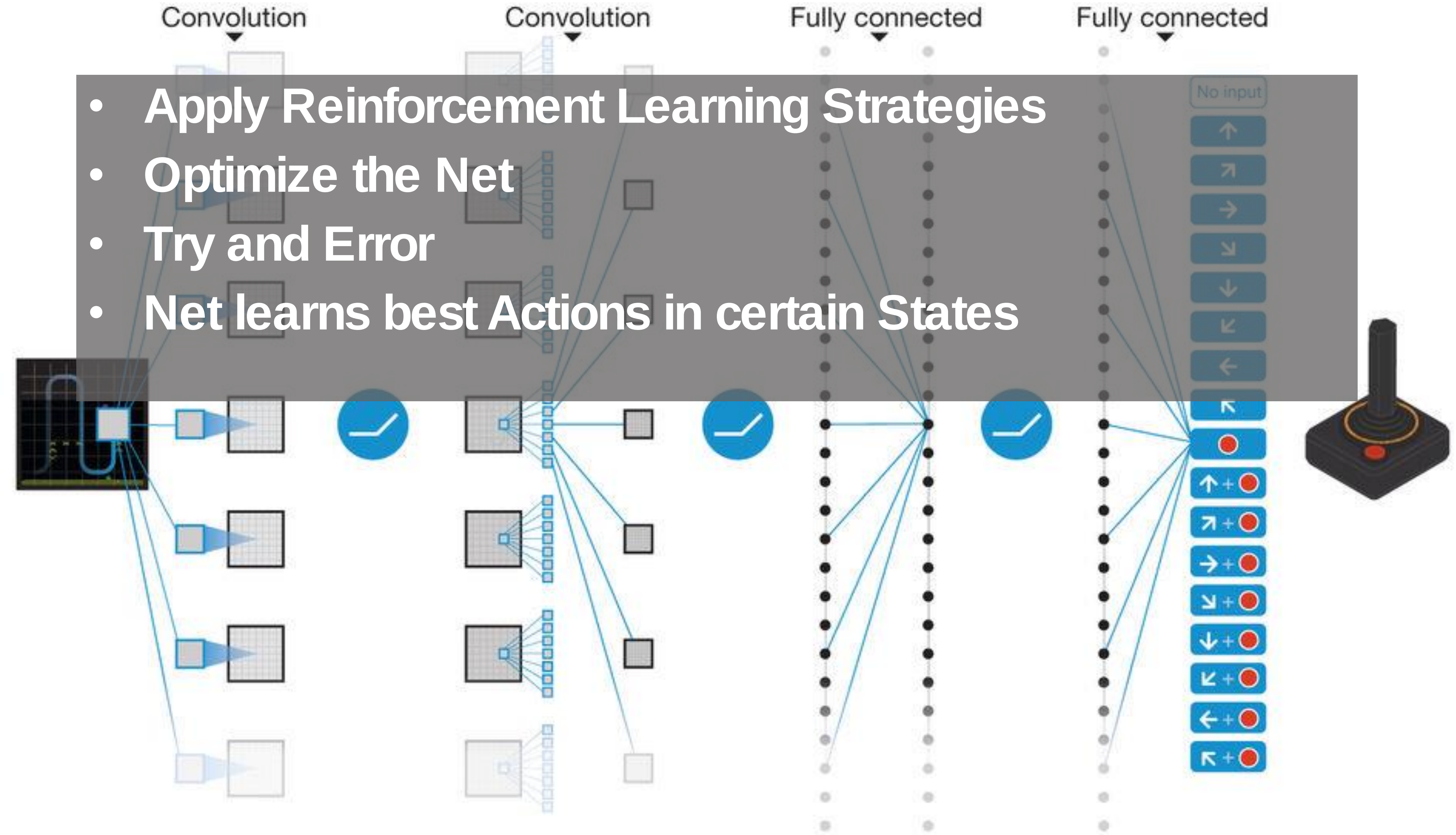
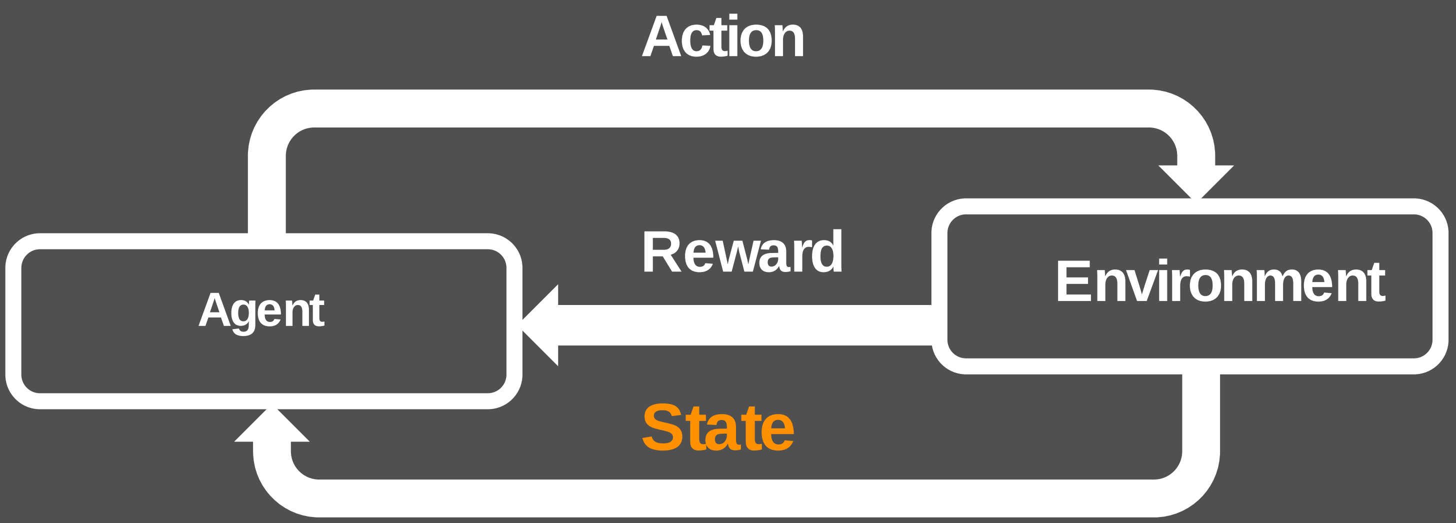
Rewards = Goals

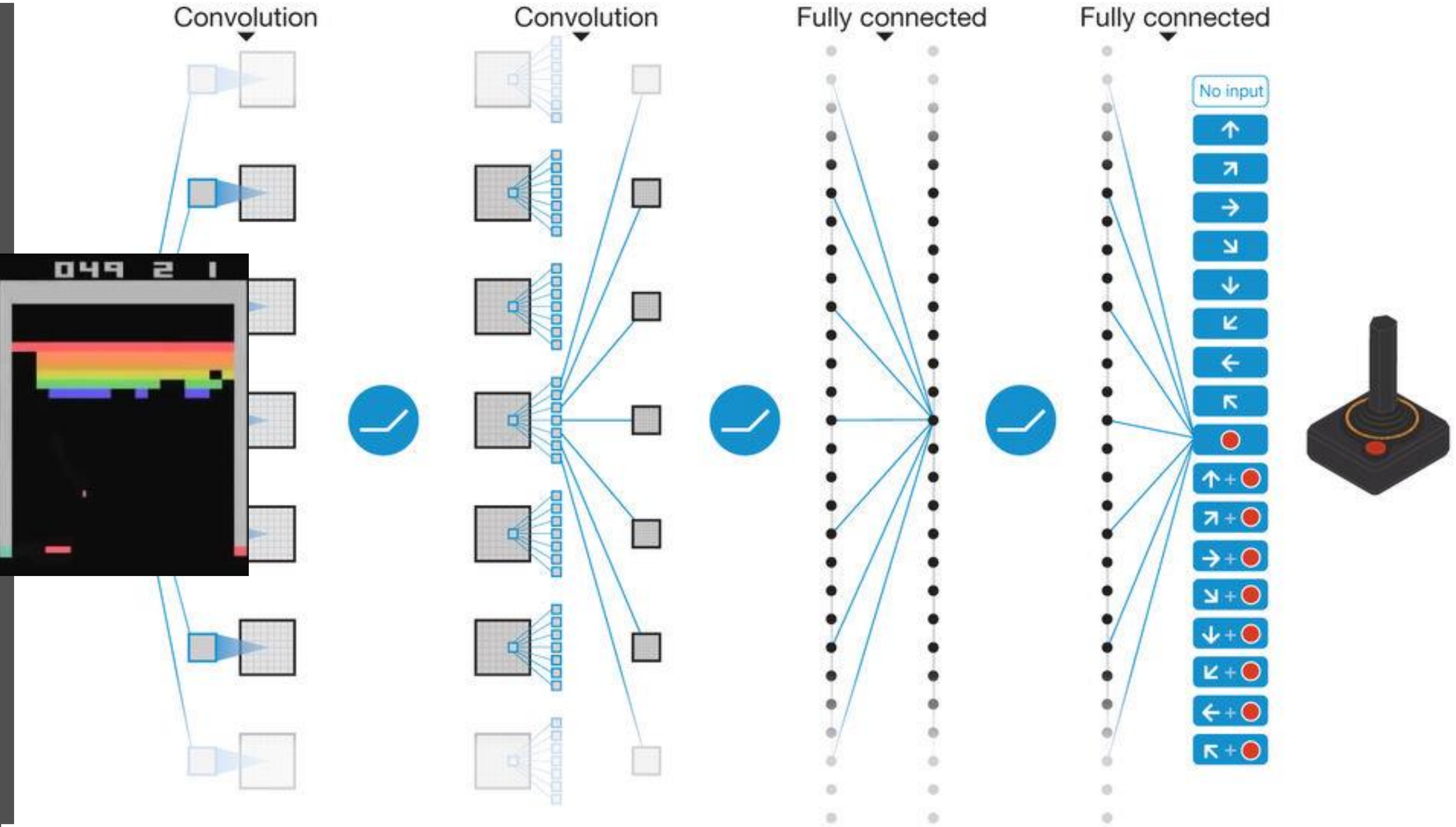

Convolution
Convolution
Fully connected
Fully connected
No input

- Apply Reinforcement Learning Strategies
- Optimize the Net
- Try and Error
- Net learns best Actions in certain States




Action
Reward
Agent
Environment
State

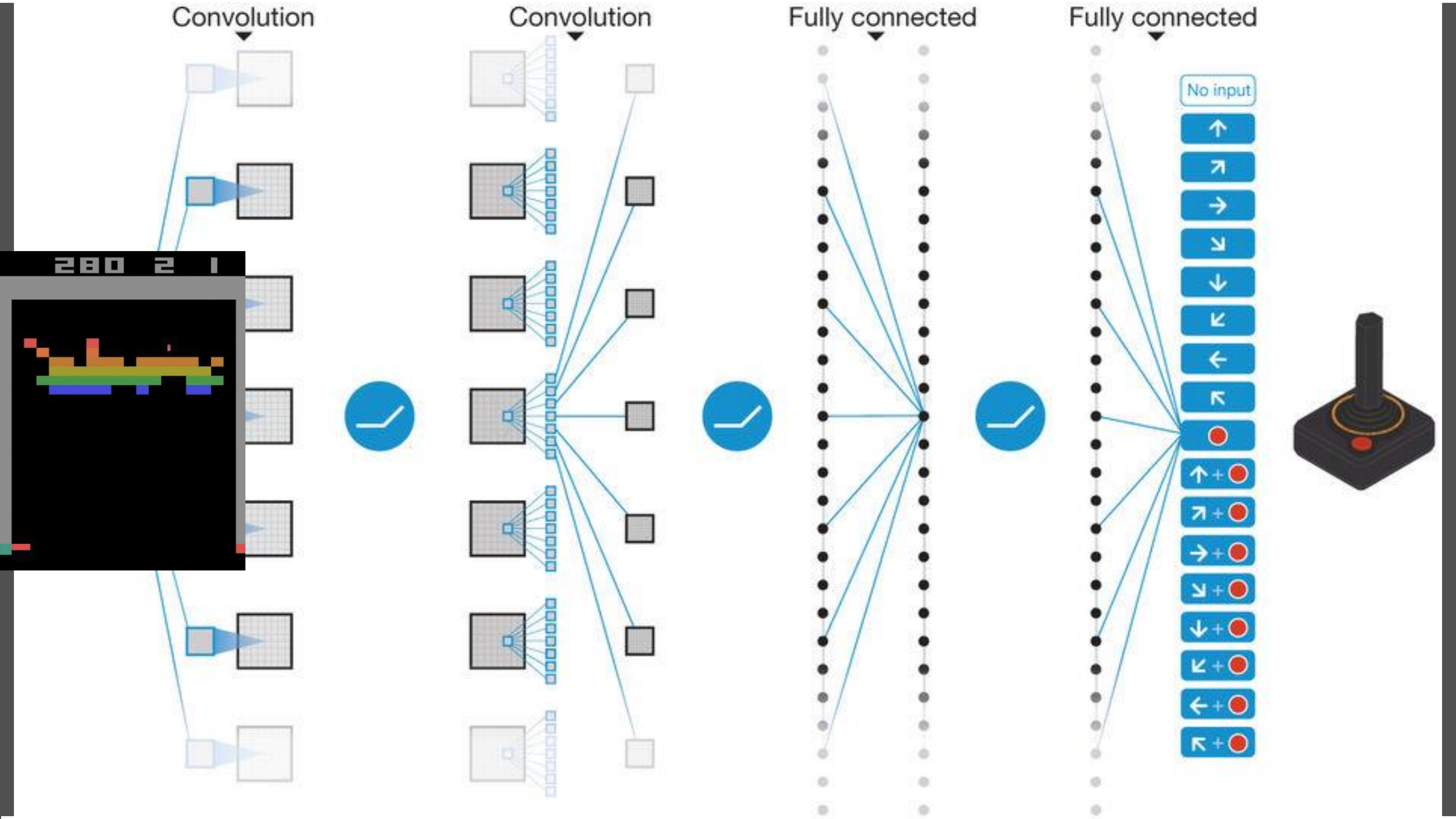

049 2 1


Convolution
Convolution
Fully connected
Fully connected
049 2 1
No input

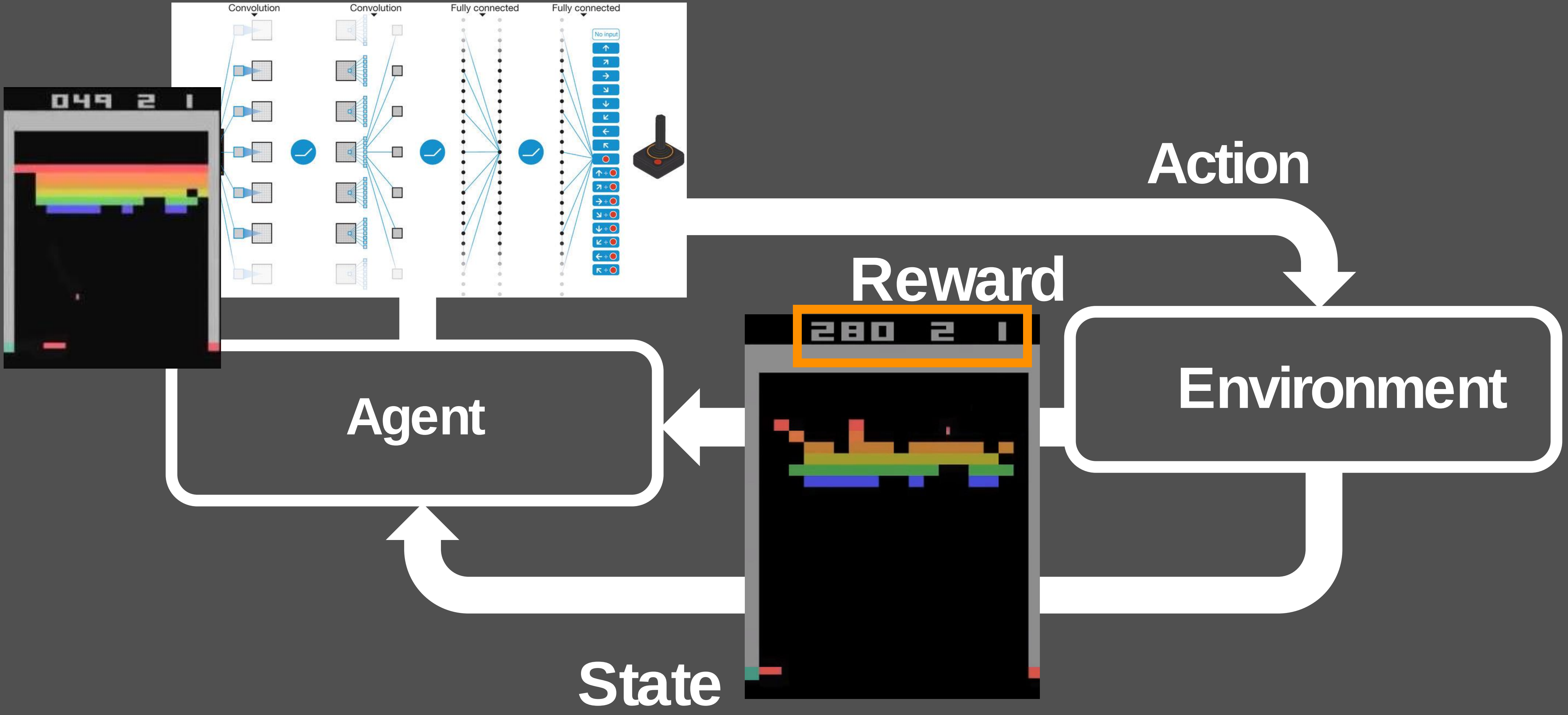

049 2 1


280 2 1

Reward



Convolution
Convolution
Fully connected
Fully connected
No input
280 2 1


Convolution
Convolution
Fully connected
Fully connected
No input
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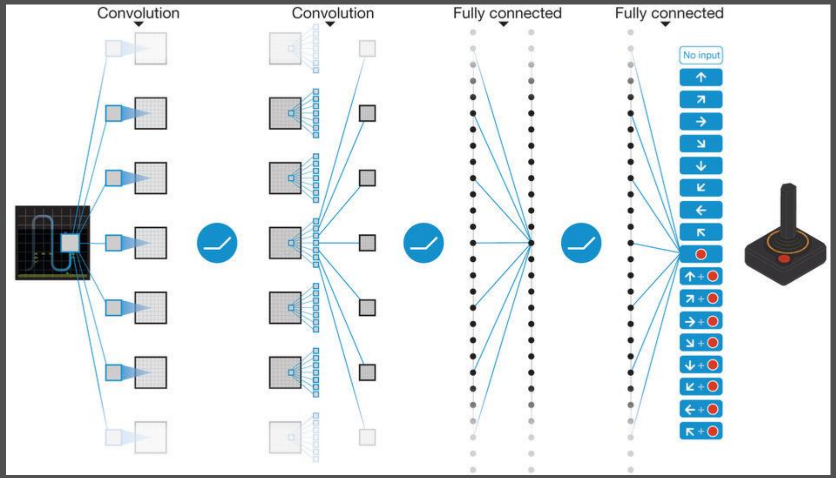
Deep Q(uality) Network



Actions

$$Q = \begin{array}{cc} \begin{array}{ccc} 0 & 1 & 2 \end{array} & \\ \begin{pmatrix} -1 & 1 & 0 \\ -1 & 0 & -1 \\ 10 & 0 & -1 \end{pmatrix} & \begin{array}{c} 0 \\ 1 \\ 2 \end{array} \end{array}$$

States

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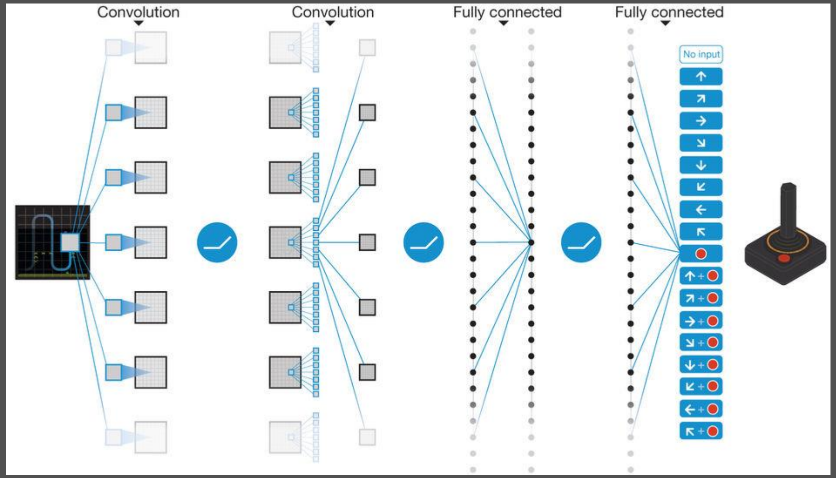


Deep Q(uality) Network

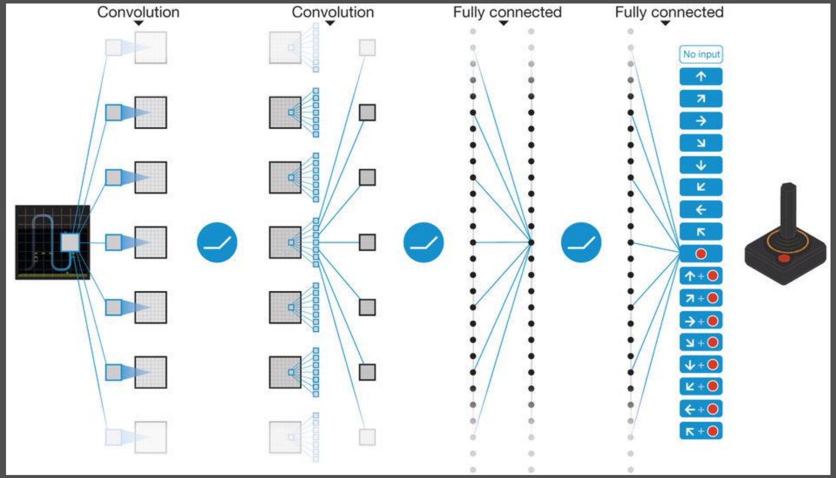
Value of take action 0 in state 0

Actions

$$Q = \begin{array}{c} \\ \\ \\ \end{array}\begin{array}{c} \begin{array}{ccc} 0 & 1 & 2 \end{array} \\ \begin{pmatrix} -1 & 1 & 0 \\ -1 & 0 & -1 \\ 10 & 0 & -1 \end{pmatrix} \end{array} \begin{array}{c} \\ 0 \\ 1 \\ 2 \end{array}$$

States

Deep Q(uality) Network

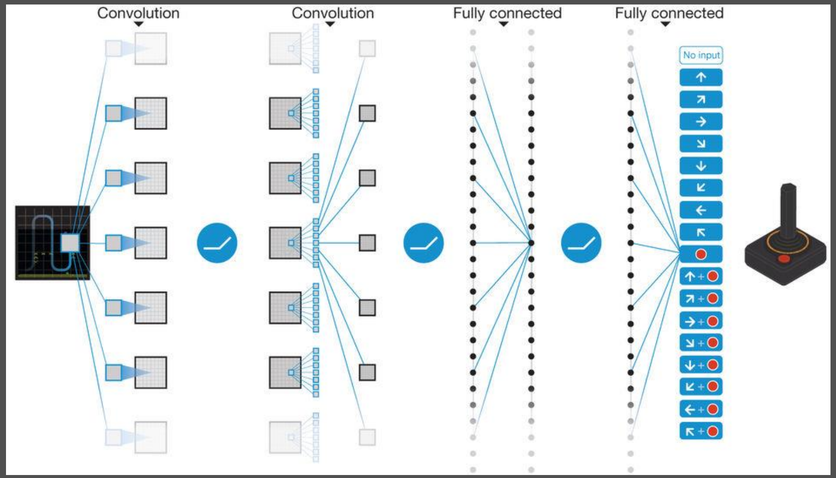


How good is it to take action 0 in state 0?

Actions

$$\begin{array}{cc} & \begin{array}{ccc} 0 & 1 & 2 \end{array} \\ Q = & \begin{pmatrix} -1 & 1 & 0 \\ -1 & 0 & -1 \\ 10 & 0 & -1 \end{pmatrix} \begin{array}{c} 0 \\ 1 \\ 2 \end{array} \end{array}$$

States



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Deep Q(uality) Network

Q Table will be optimised by Neural Net

Actions

States

$$
Q = \begin{array}{cc}
\begin{array}{ccc} 0 & 1 & 2 \end{array} & \\
\begin{pmatrix} -1 & 1 & 0 \\ -1 & 0 & -1 \\ 10 & 0 & -1 \end{pmatrix} & \begin{array}{c} 0 \\ 1 \\ 2 \end{array}
\end{array}
$$

Q-Learning Algorithm:

- Estimate row in the Q table for the current state (Prediction)
- Apply action and get next state + reward
- Estimate row in the Q table for next state
- Apply Bellman Equation (Target):
  - $Q(s,a) := r + \gamma * max_{a'} Q(s',a') = Q(s,a) * max_{a'} Q(s',a')$
- Minimize Loss between Target and Prediction:
  - $L = \frac{1}{2}(r + \gamma * max_{a'} Q(s',a') - Q(s,a))^2$

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$$Q(s,a) := r + \gamma * max_{a'} Q(s', a')$$

Maximum future reward for this state and action is the immediate reward plus maximum future reward for the next state

- **Minimize Loss between Target and Prediction:**
  - $L = \frac{1}{2}(r + \gamma * max_{a'} Q(s', a') - Q(s, a))^2$
- $r + \gamma * max_{a'} Q(s', a') \in R^n$
- $Q(s, a) \in R^n$
- **Q-Learning is very similar to regression**
  - **Try to predict continous variables**

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Implementation Tricks:

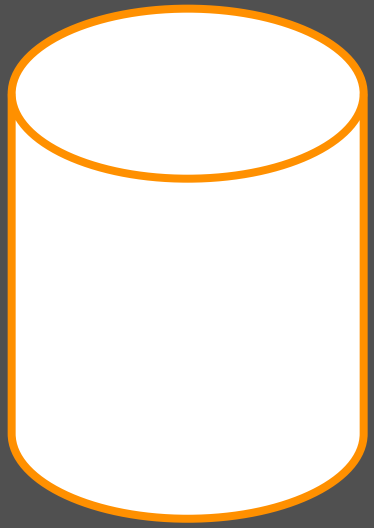
- Use ε–Greedy Policy
- Experience Replay
  - Minibatch training samples from past experience
  - Avoid to get stuck in a local minimum
- Discount Future Reward with γ
  - $Q(s,a) := r + \gamma * max_{a'} Q(s', a')$

- **4 Images form a training sample for the neural net**

Will the ball go up or down?

Your Task:

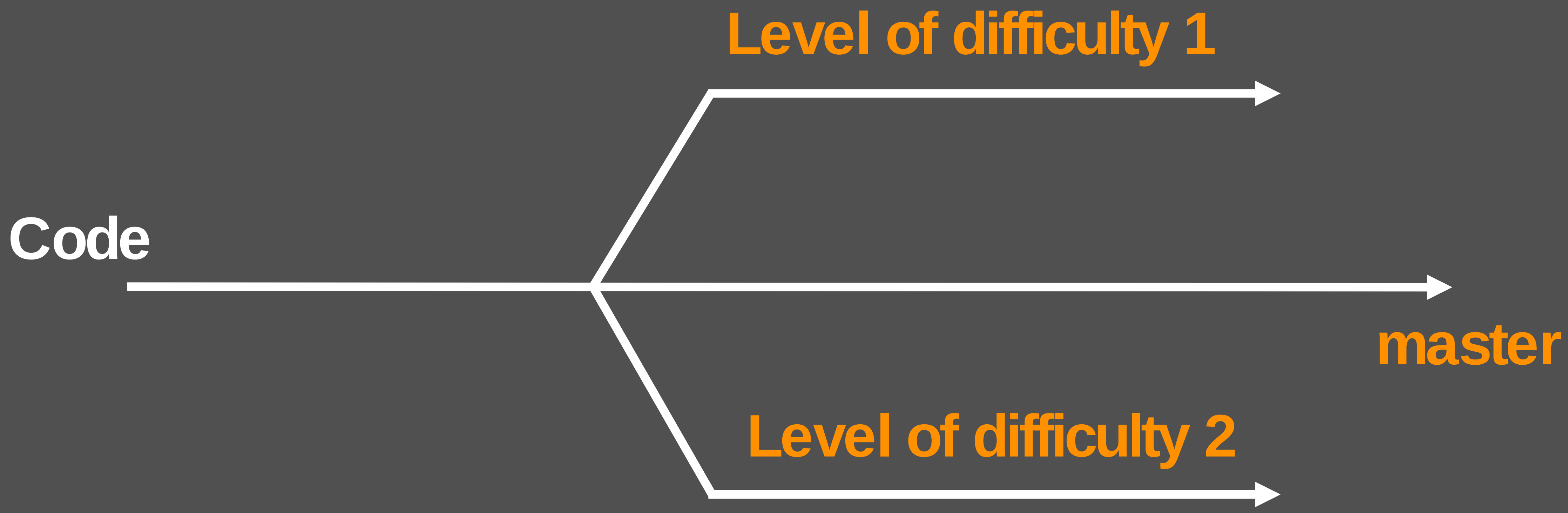
- We give you code with gaps
- You have to **fill in the gaps** with appropriate code
- The **gaps** are marked with a **comment with TODO**
- Gaps can be in all scripts
- Each script has an order of the TODOs, e.g. TODO 1, TODO 2, …



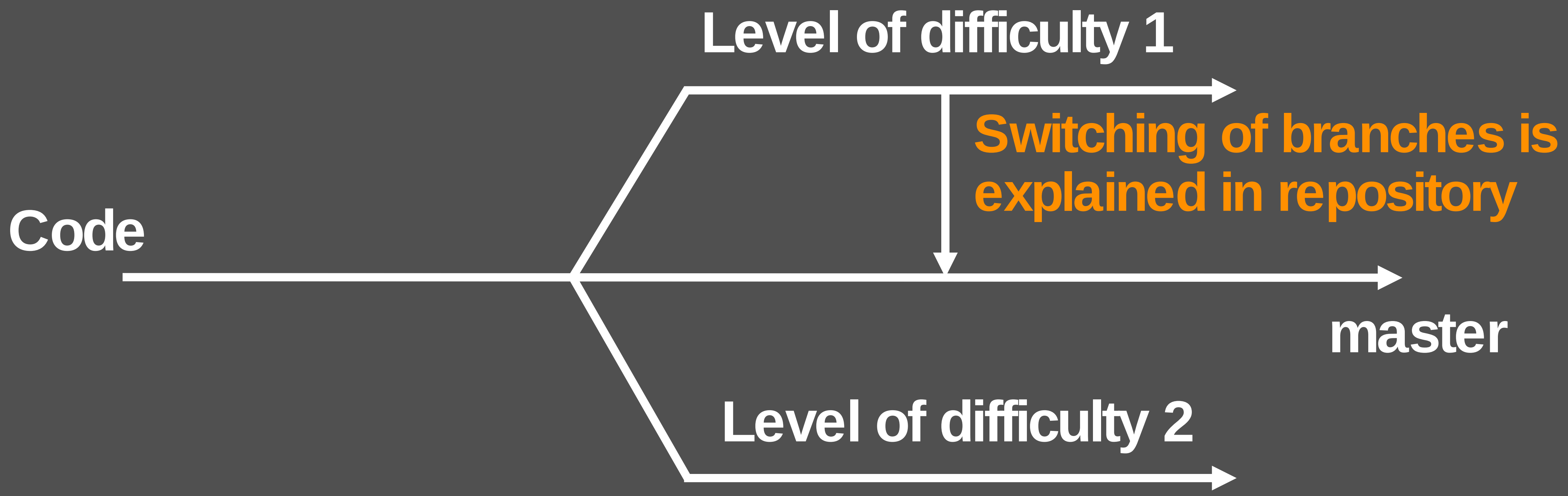
https://github.com/mati3230/MetaMarathon

- Code-Repository
- How to setup the working environment
- Tipps and recommendations
- 3 branches for different levels of difficulties
  - easy, medium, hard
- Solution will be pushed (uploaded) at the end in the master branch ;)

Branching:



Branching:


Level of difficulty 1
Switching of branches is explained in repository
Code
master
Level of difficulty 2

3 Files:

- main.py: should be executed
- estimator.py: neural net
- state_processor.py: image preprocessing

main.py: should be executed

- Mother-Script
- Management processes (training, playing)
- Execution of steps in the environment
- Optimization of Q-values

estimator.py: neural net

- Convolutional Neural Net (CNN)
- Prediction of Actions
- Training of Network

state_processor.py: image preprocessing

- Grayscale
- Cropping of relevant area
- Scaling to 84x84

First Steps:

- Go to the repository: https://github.com/mati3230/MetaMarathon
- Setup the environment (use manual)
- Clone Repository
- Choose a level of difficulty and switch branch
- Search TODOs and get familiar with code

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