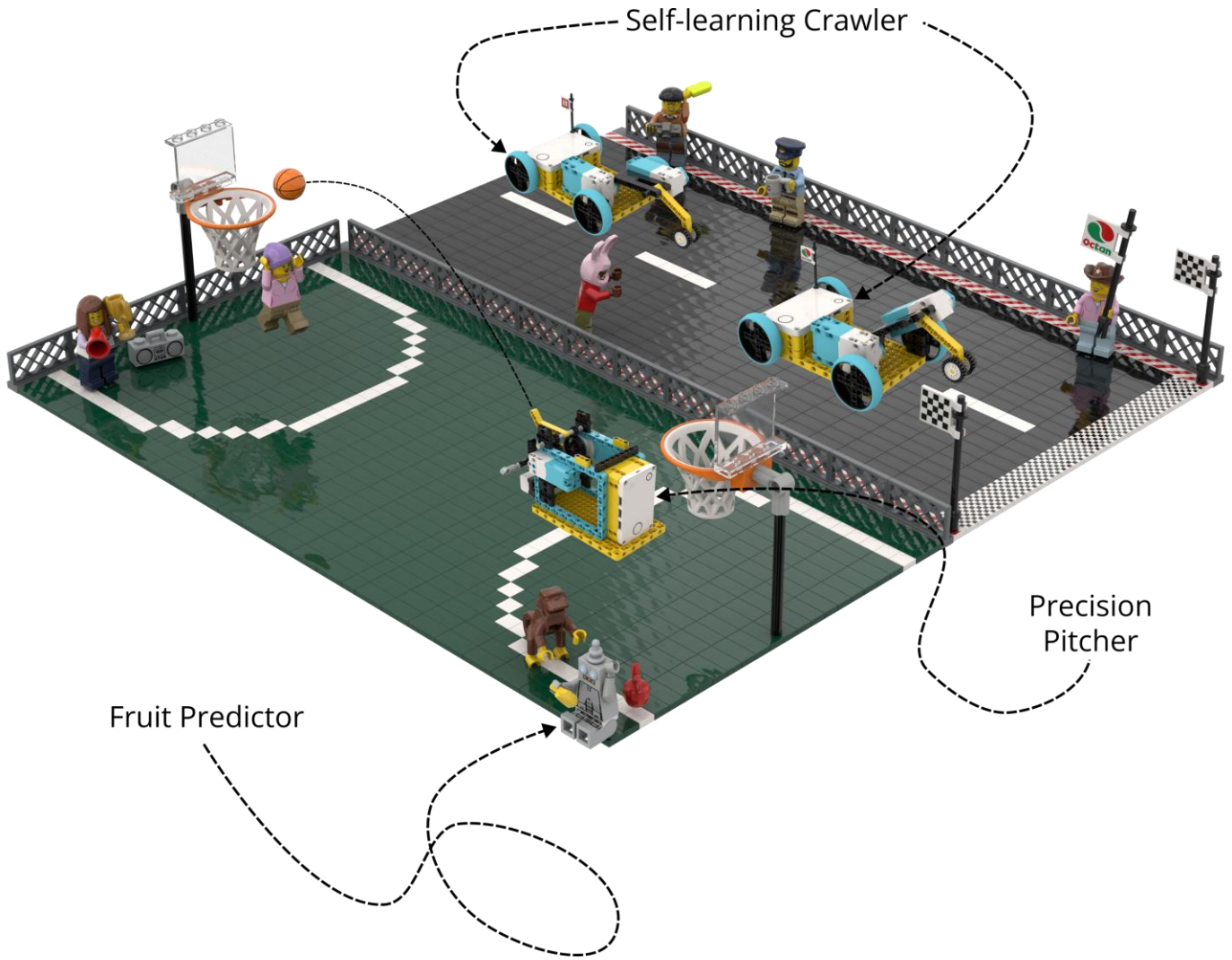
Machine Learning with LEGO® Bricks

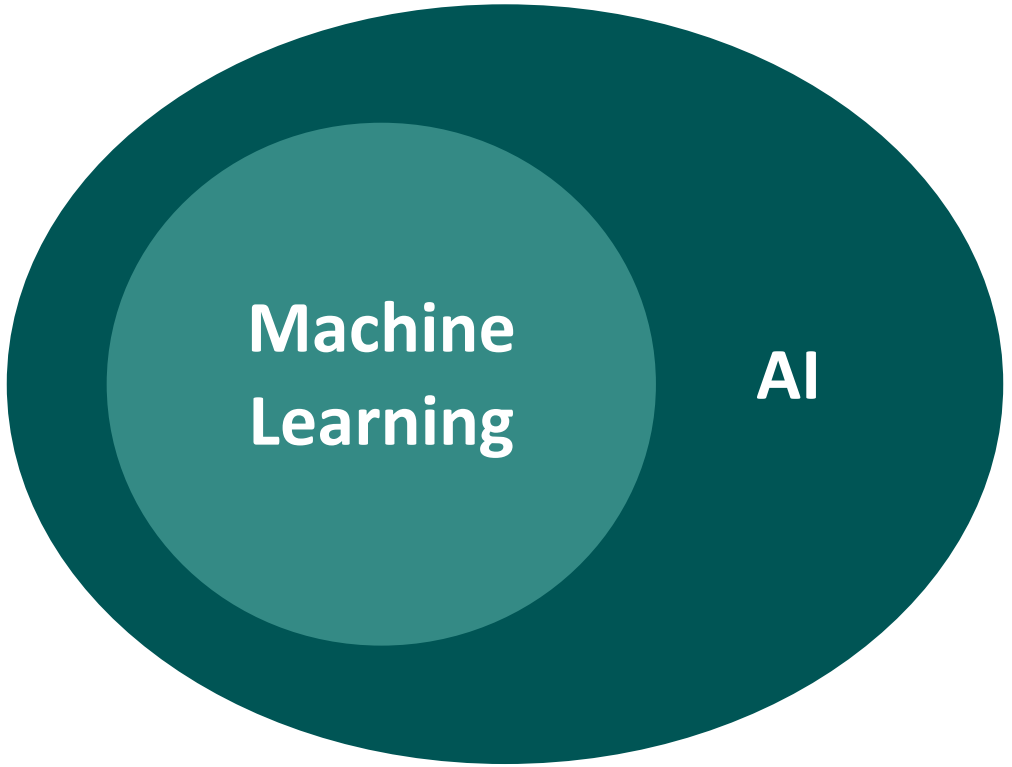
Viacheslav Sydora

Course overview



What is machine learning?

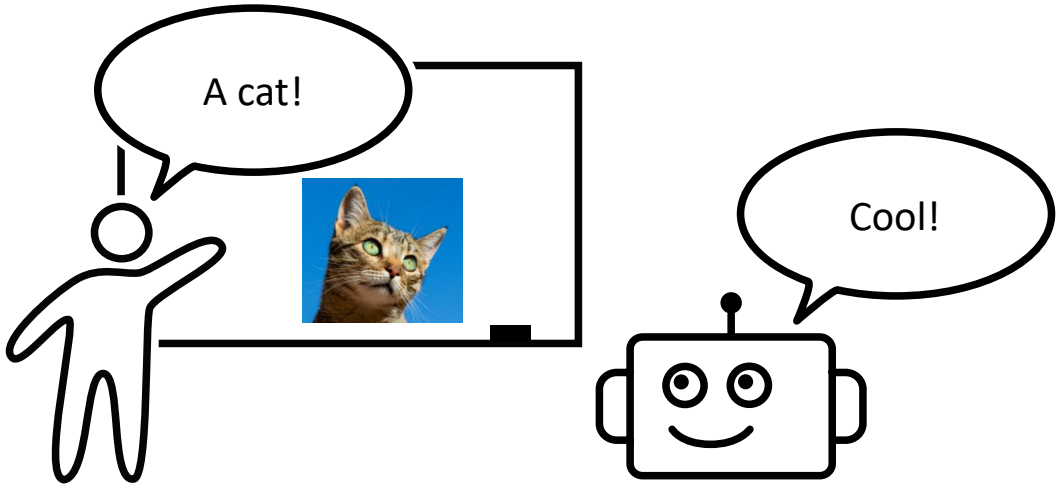
- Subfield of artificial intelligence



What is machine learning?

- Subfield of artificial intelligence
- **Learning** patterns **from examples**

Machine Learning



Not Machine Learning

What is machine learning?

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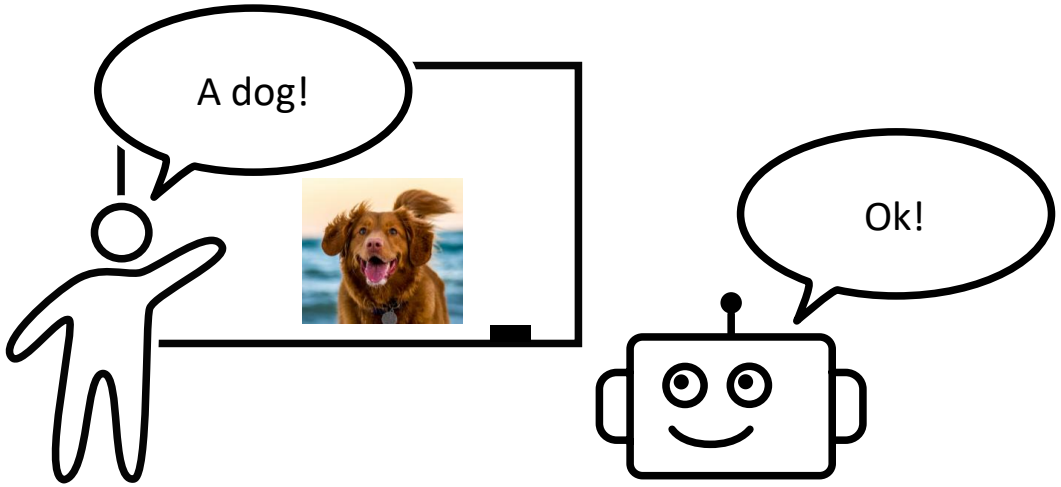
Machine Learning



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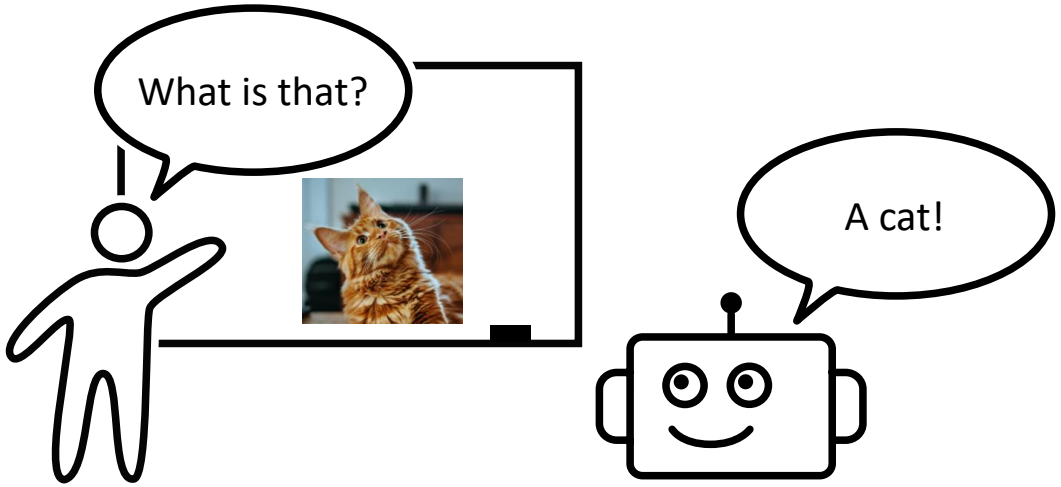
Machine Learning



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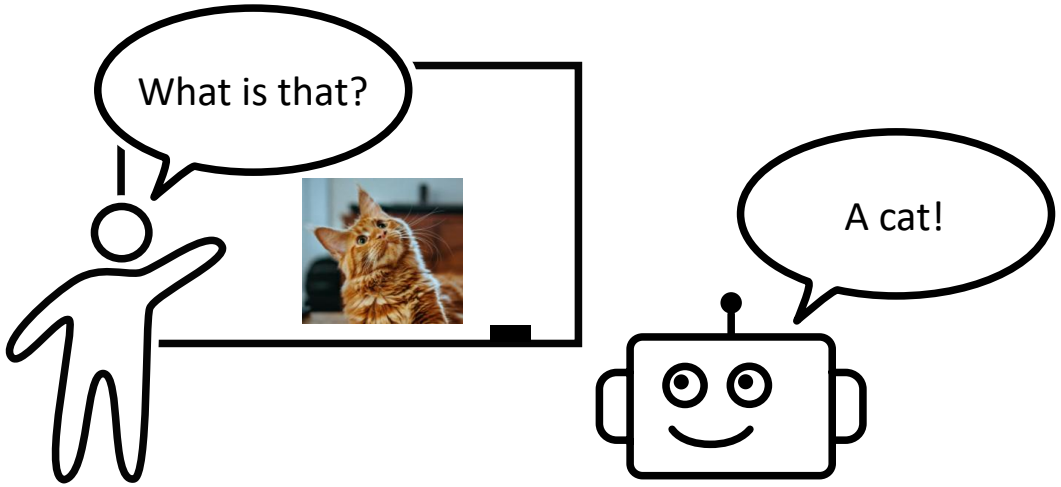
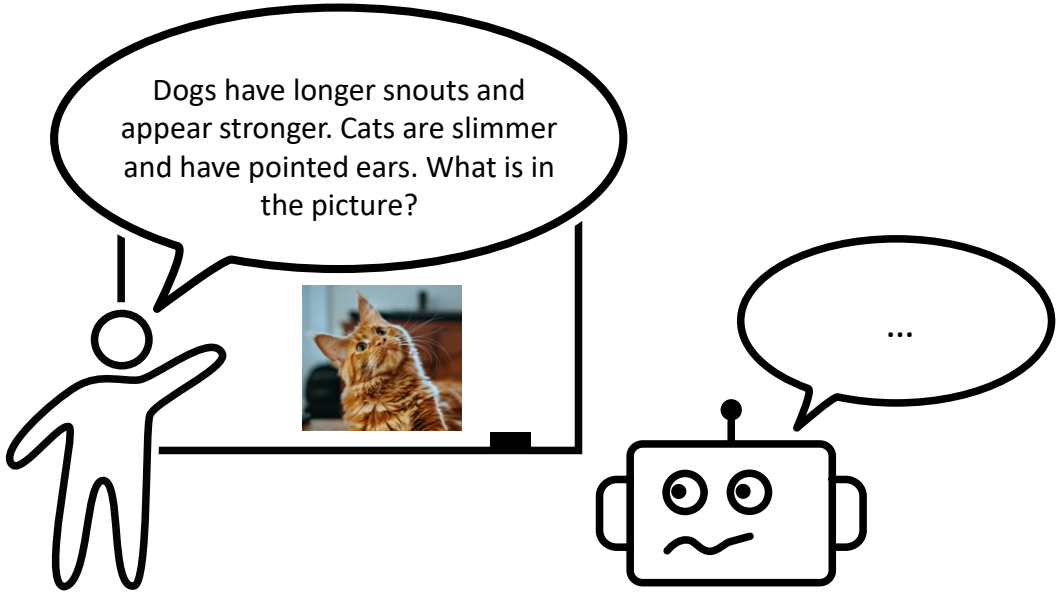
Machine Learning

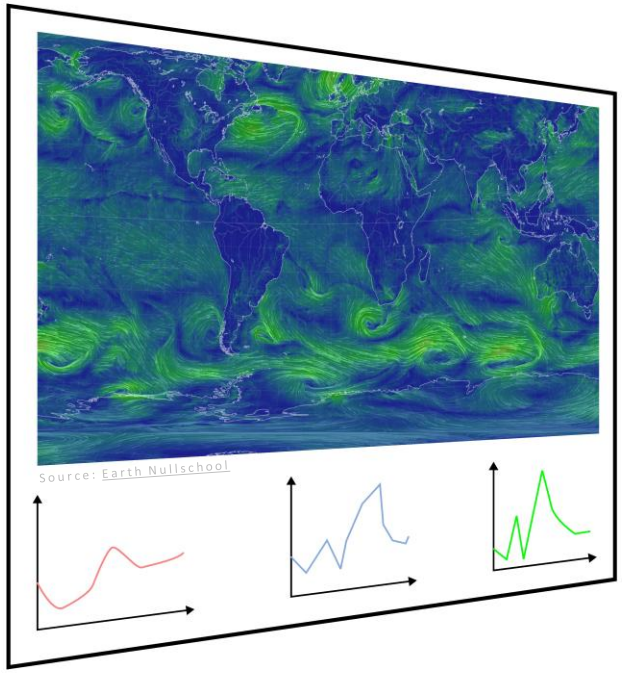


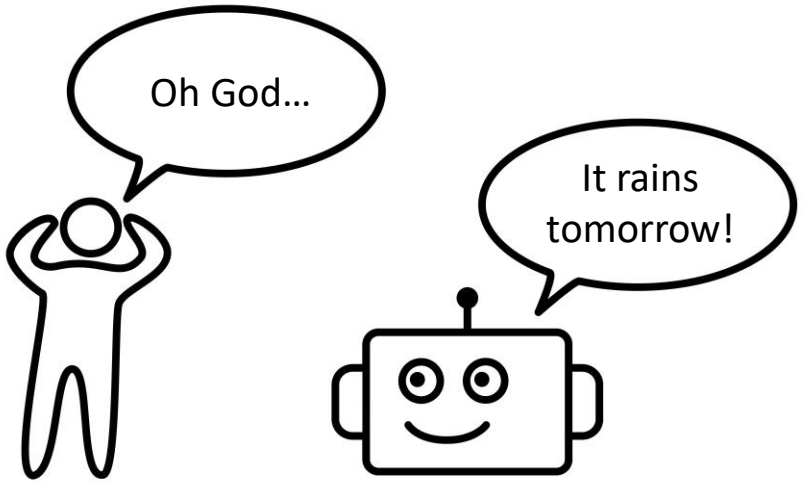
Not Machine Learning



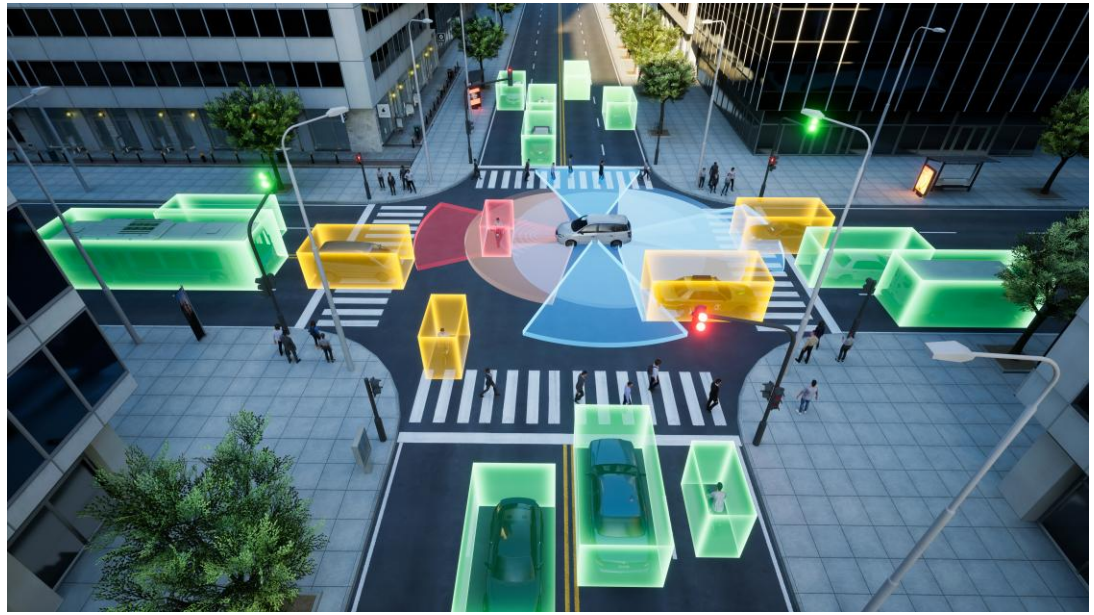
Why machine learning?

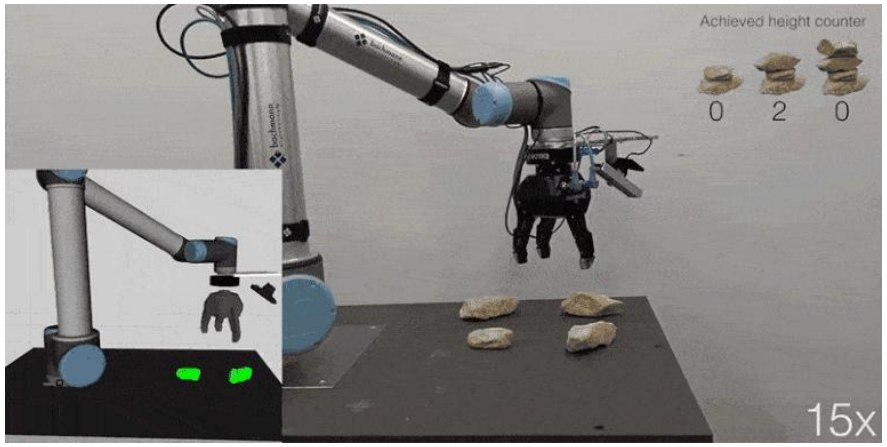
- works automatically
- can surpass humans



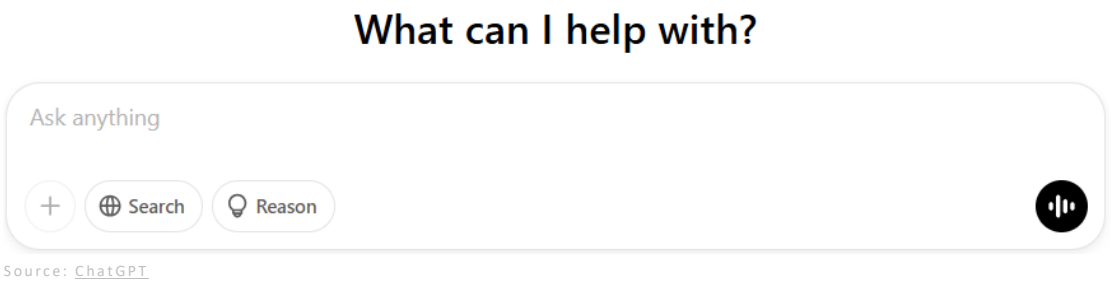


What else can machine learning do?





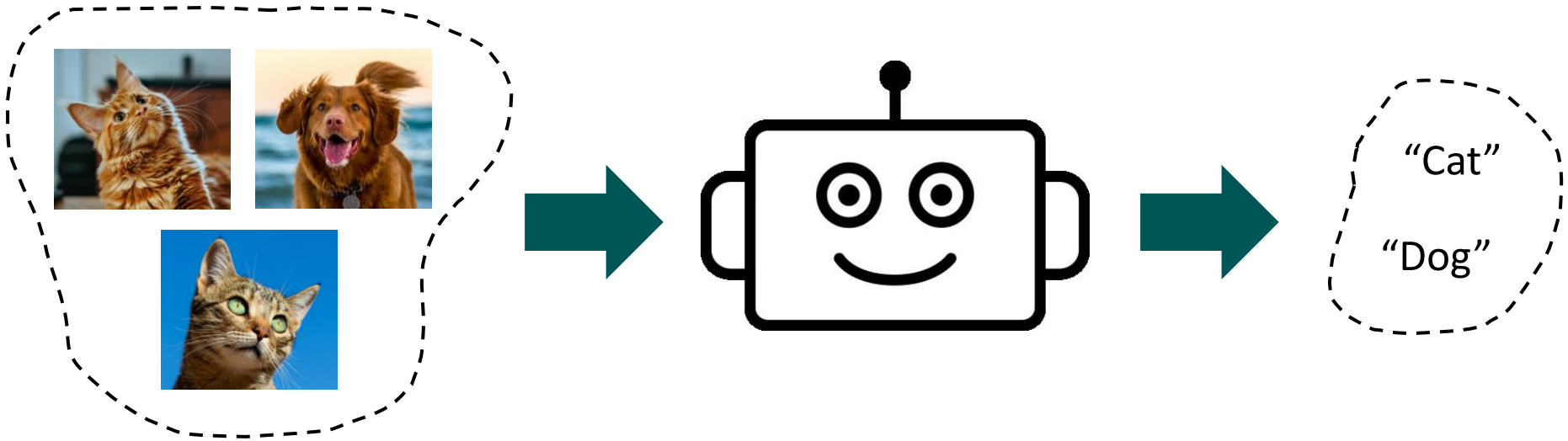
Source: freeCodeCamp



Source: ChatGPT

Data, Features & Labels

- **Learning** patterns **from examples**



Inputs

(Features)

Predictor

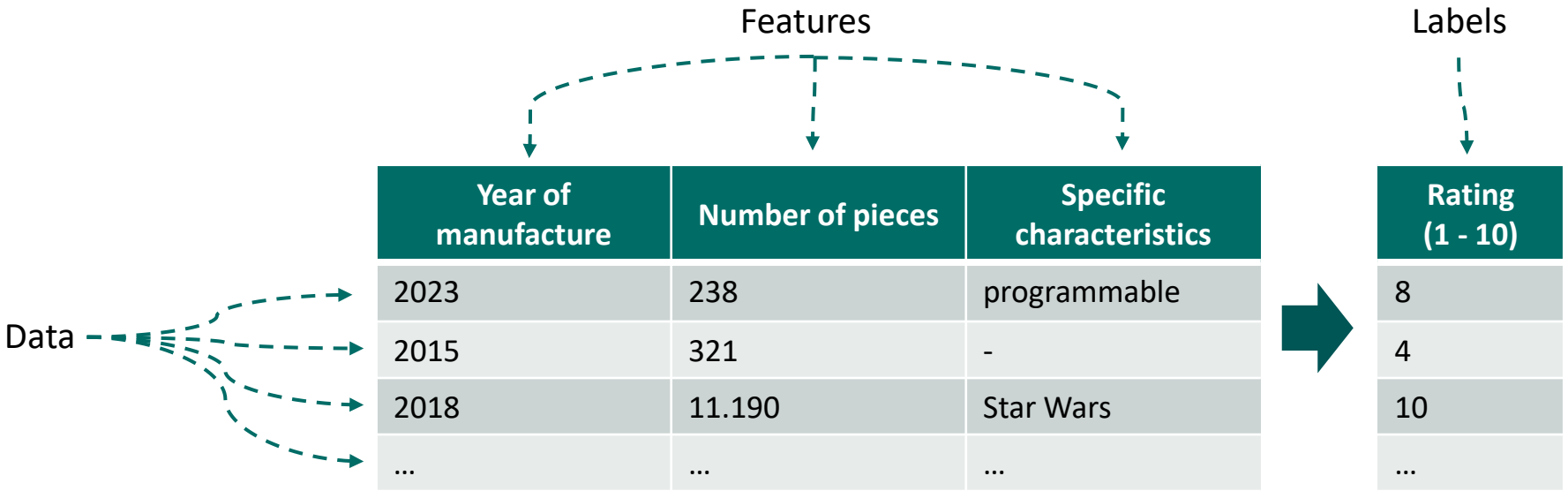
(Modell)

Outputs

(Labels)

Data, Features & Labels

- **Data** – observations, measurements, …
- **Features** – what predictions are made from (input)
- **Labels** – what to predict (output)

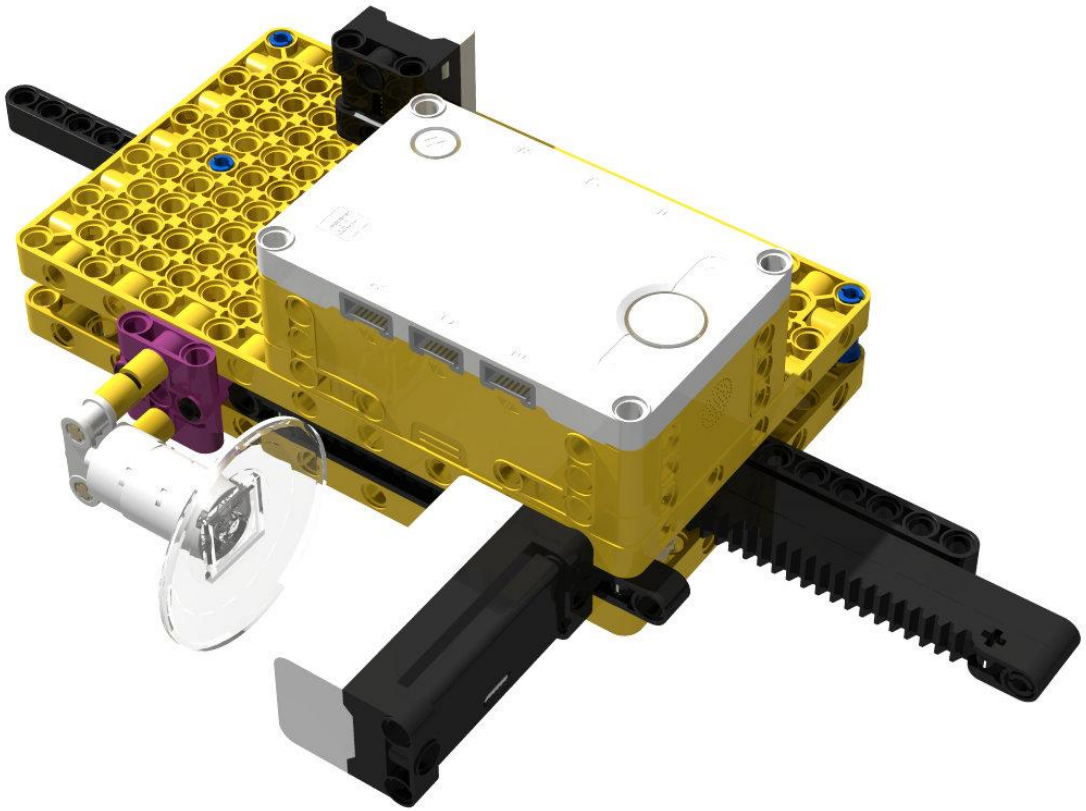


Fruit Predictor – Concept

- **Features:** ?
- **Label:** ?

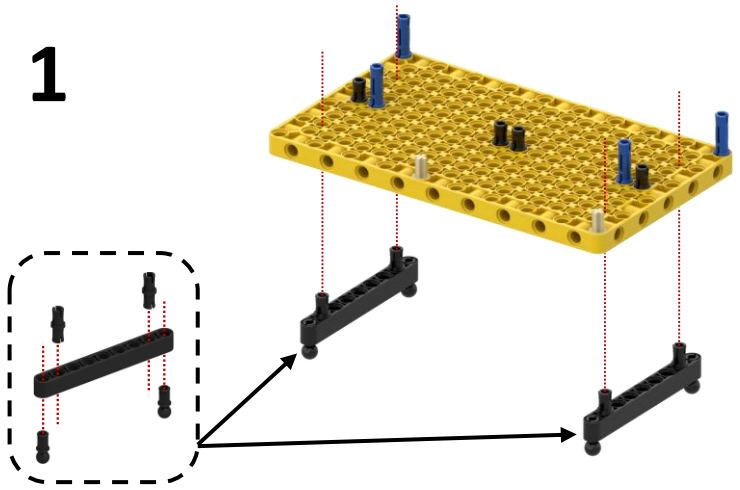
Fruit Predictor – Concept

- **Features:** length and color of the fruit
- **Label:** fruit name (apple/banana)

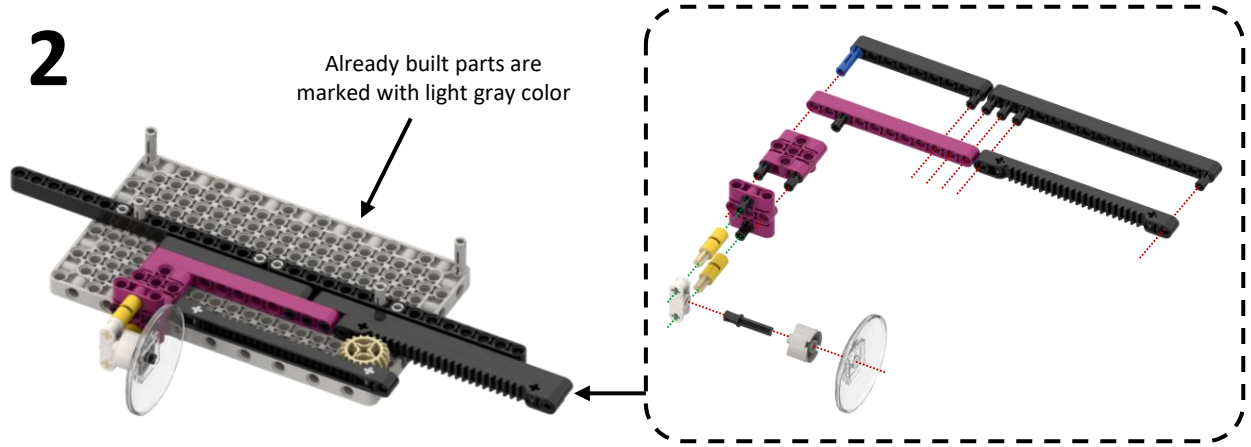


Fruit Predictor – Assembly

1



2



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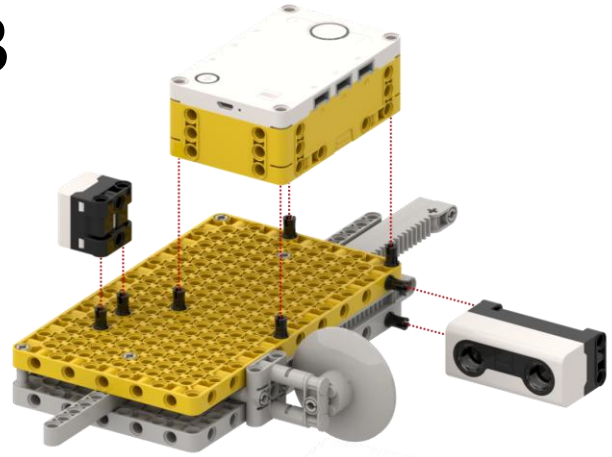
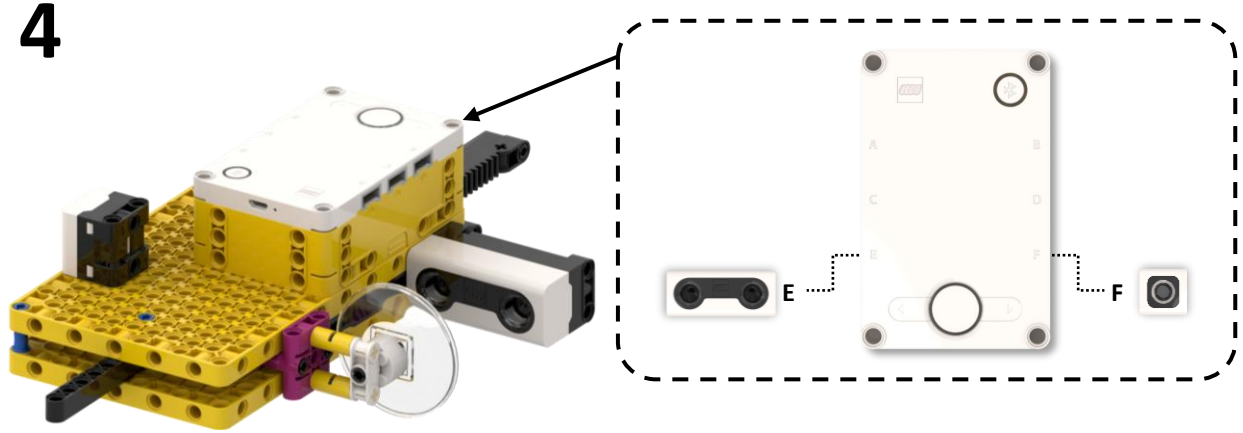
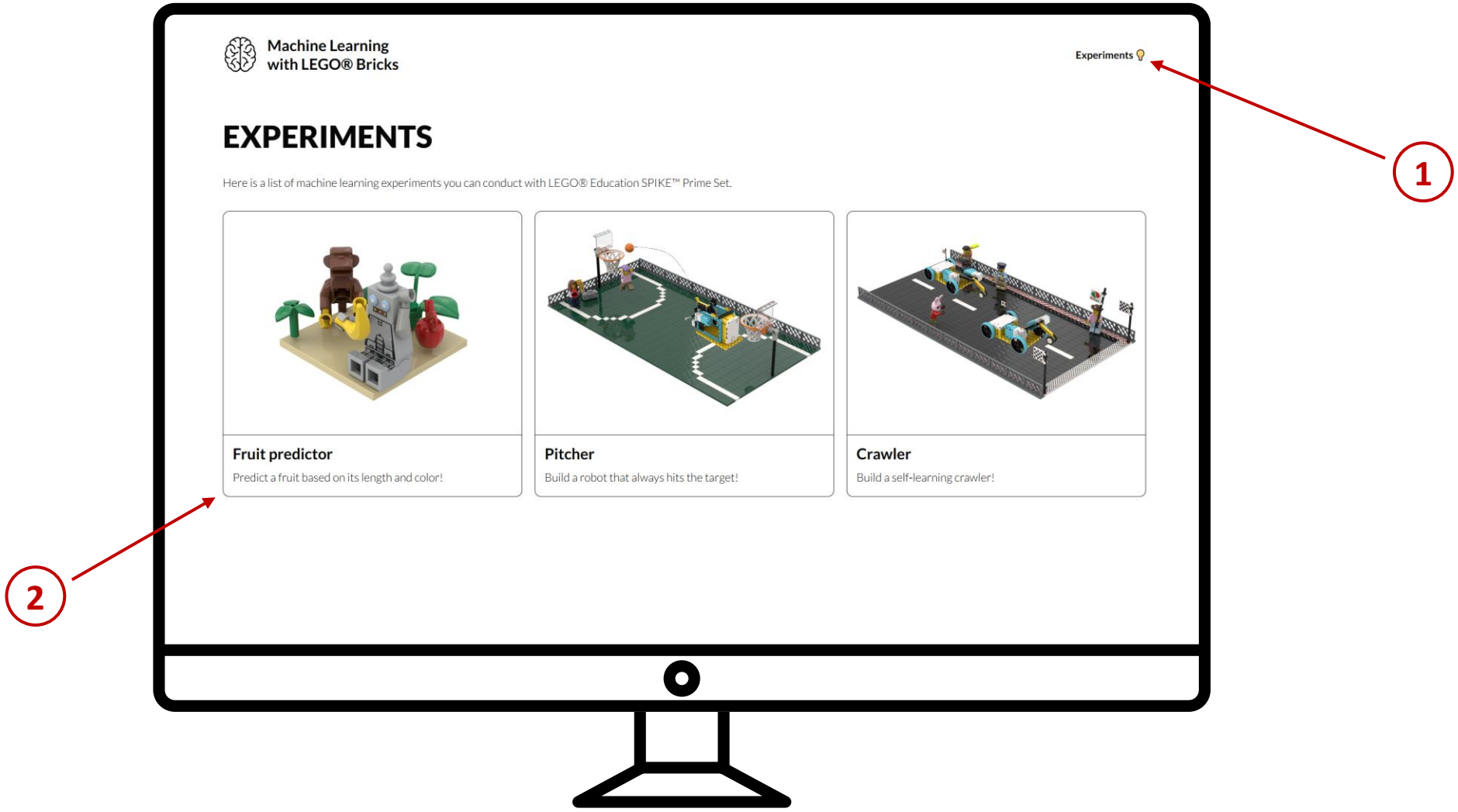


4



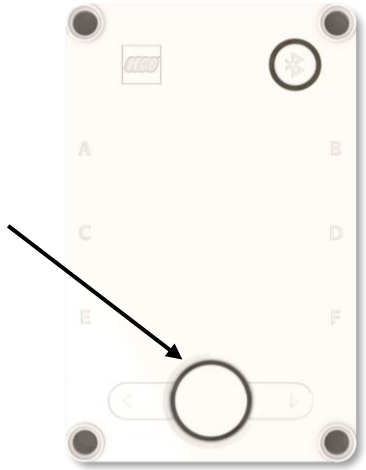
Open the experiment page



Connect hub and start the program

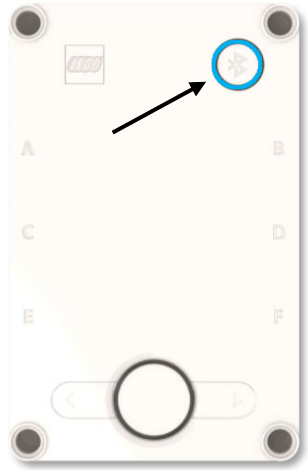
1

Switch on the hub by pressing the large button for about 3 seconds.



2

Click on the Bluetooth button and wait until the hub starts beeping.



3

Click on ''Connect hub'', find your hub in the window, select it and click on '''Pair'''.

4

Click on 'Start program' and wait until a notification appears on the website.

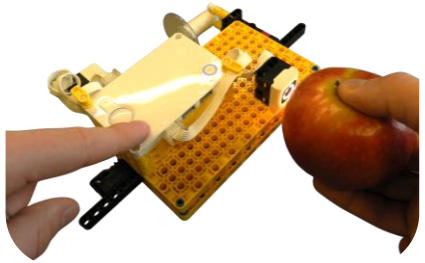
Fruit Predictor – Data collection

1

Select the fruit for which data will be collected.

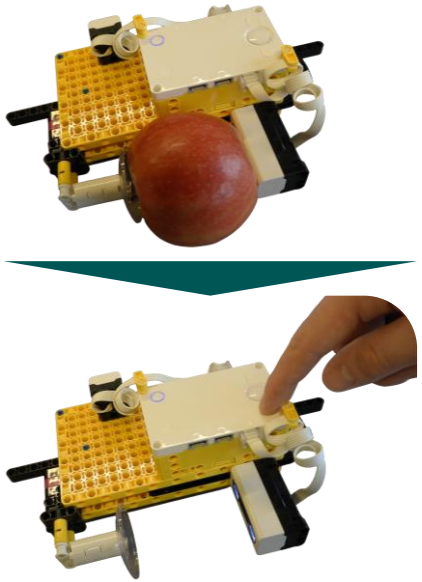
2

Scan the color. Hold the fruit near the color sensor and press the right button on the hub.



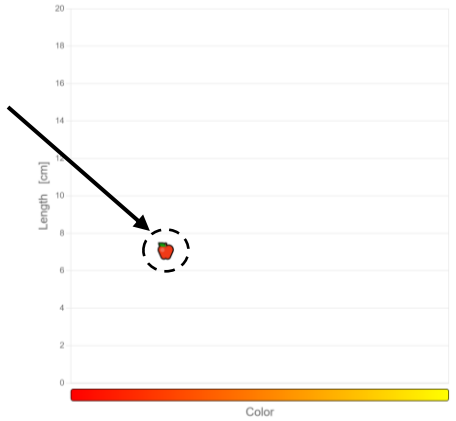
3

Place the fruit in the caliper, close the gripper, remove the fruit, and press the left button on the hub to measure the length.

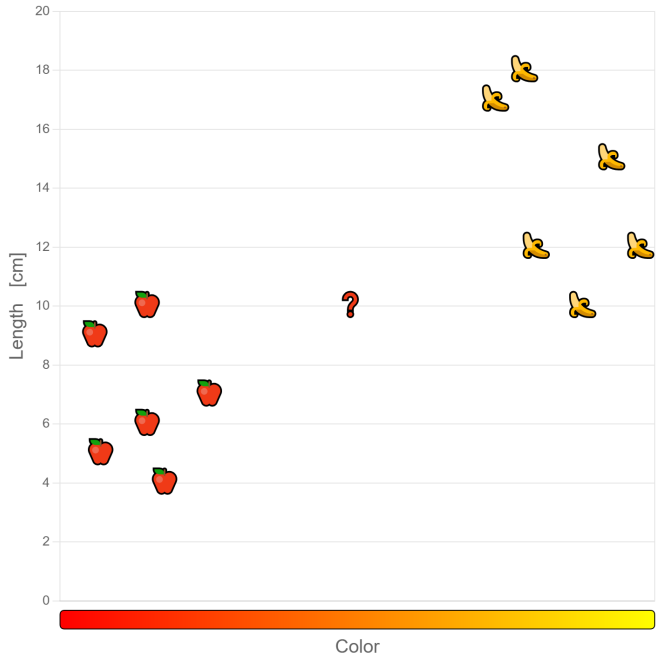


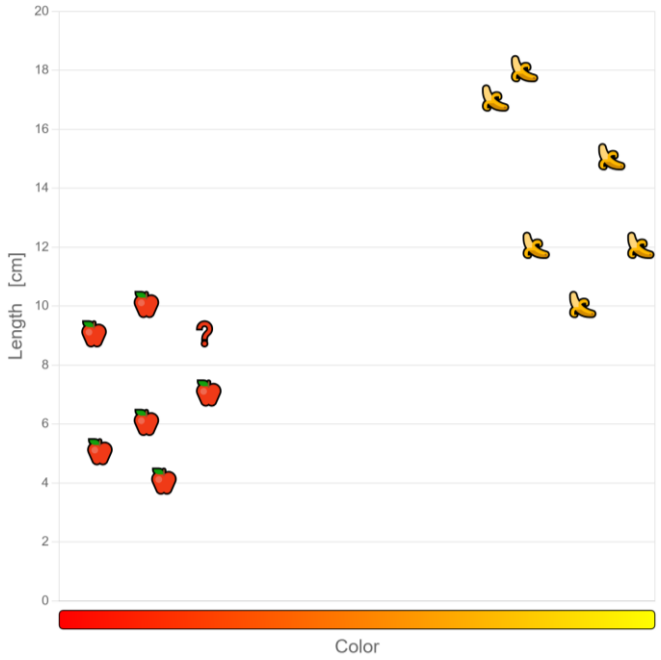
4

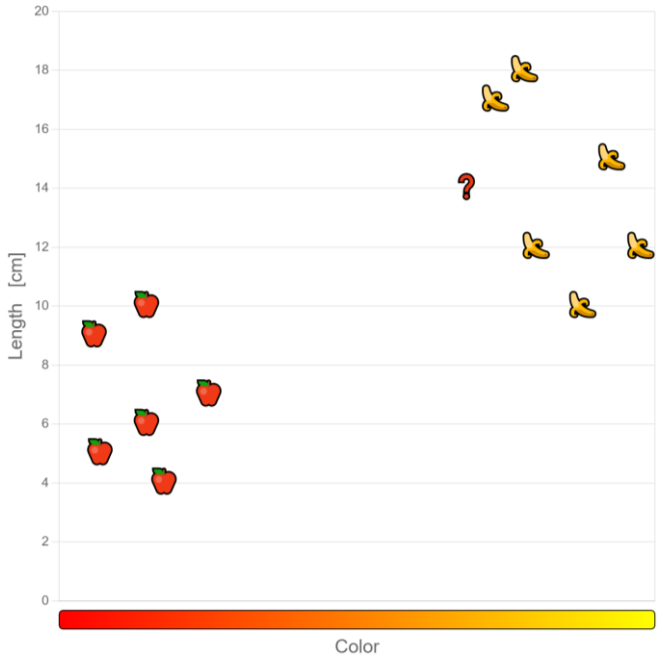
The data point will now be displayed on the website! Repeat the steps for other apples and bananas!



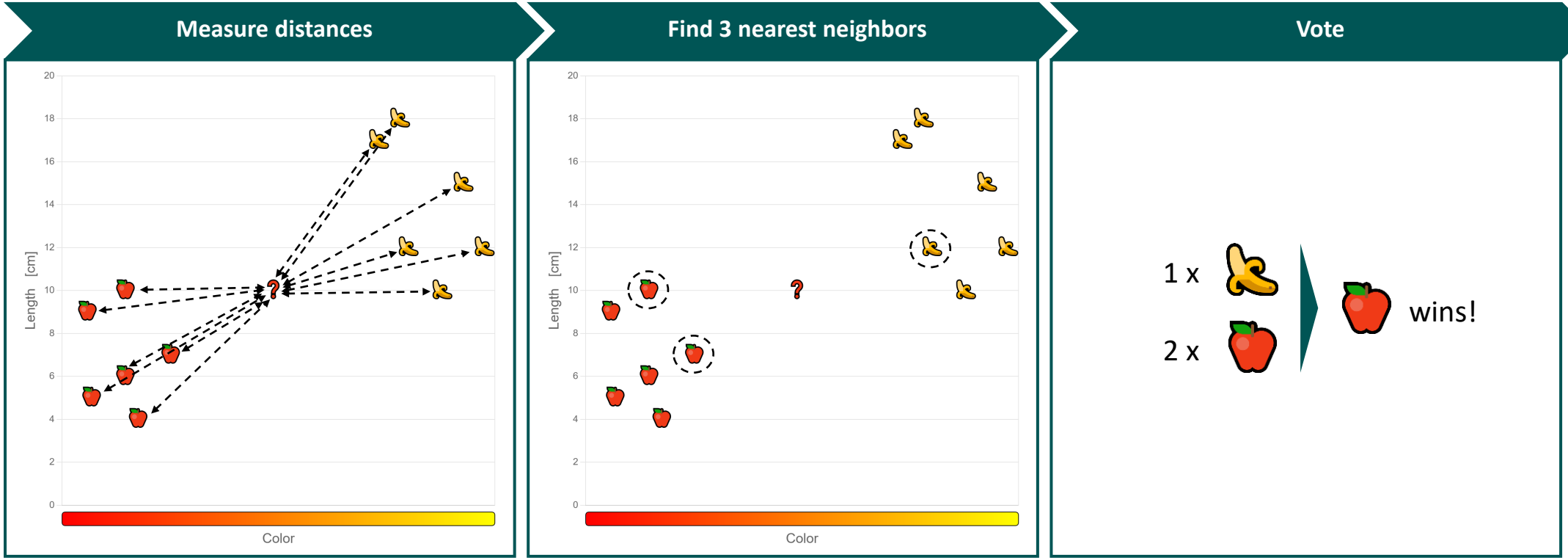
How can we predict a new fruit?







K-Nearest Neighbors – Algorithm



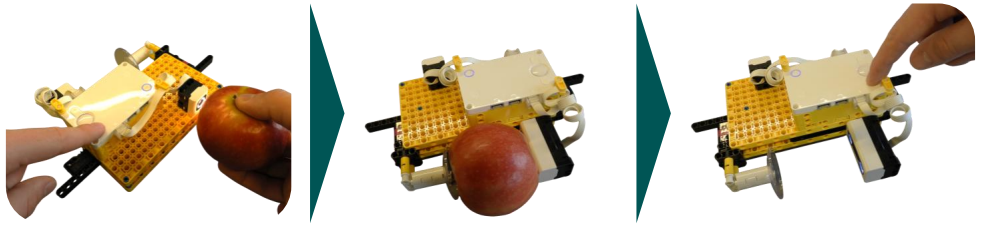
Fruit Predictor – Prediction

1

Switch the device to prediction mode.

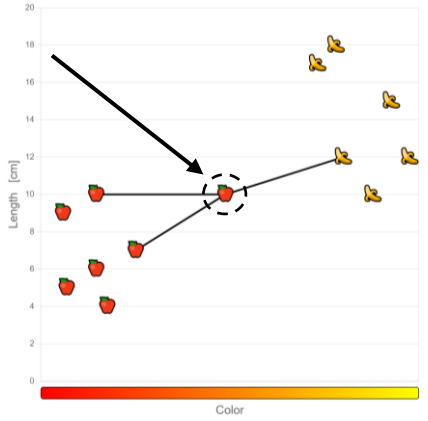
2

Scan the color and measure the length of the fruit as you did during data collection.



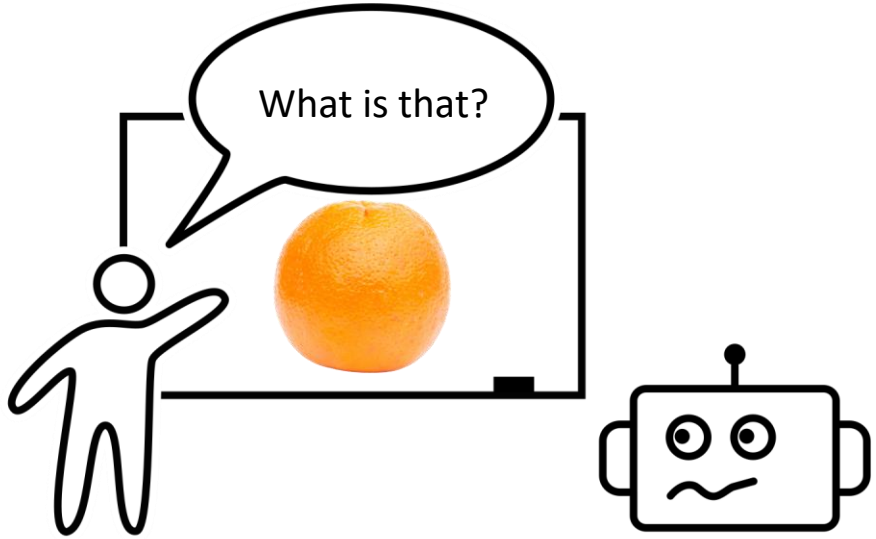
3

The prediction and the nearest neighbors will now be displayed on the website!



Phases of model development

What if there is a previously unseen example?



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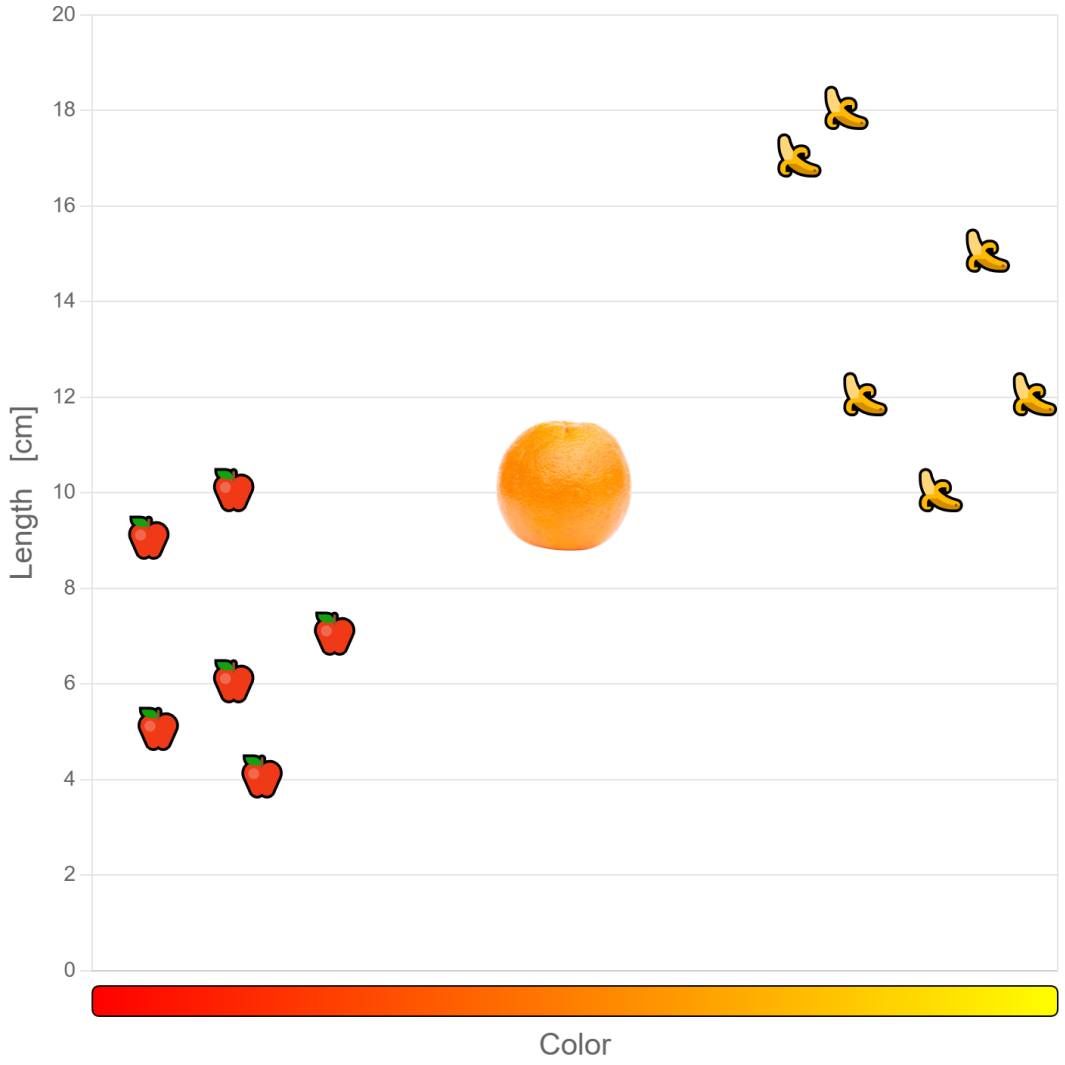

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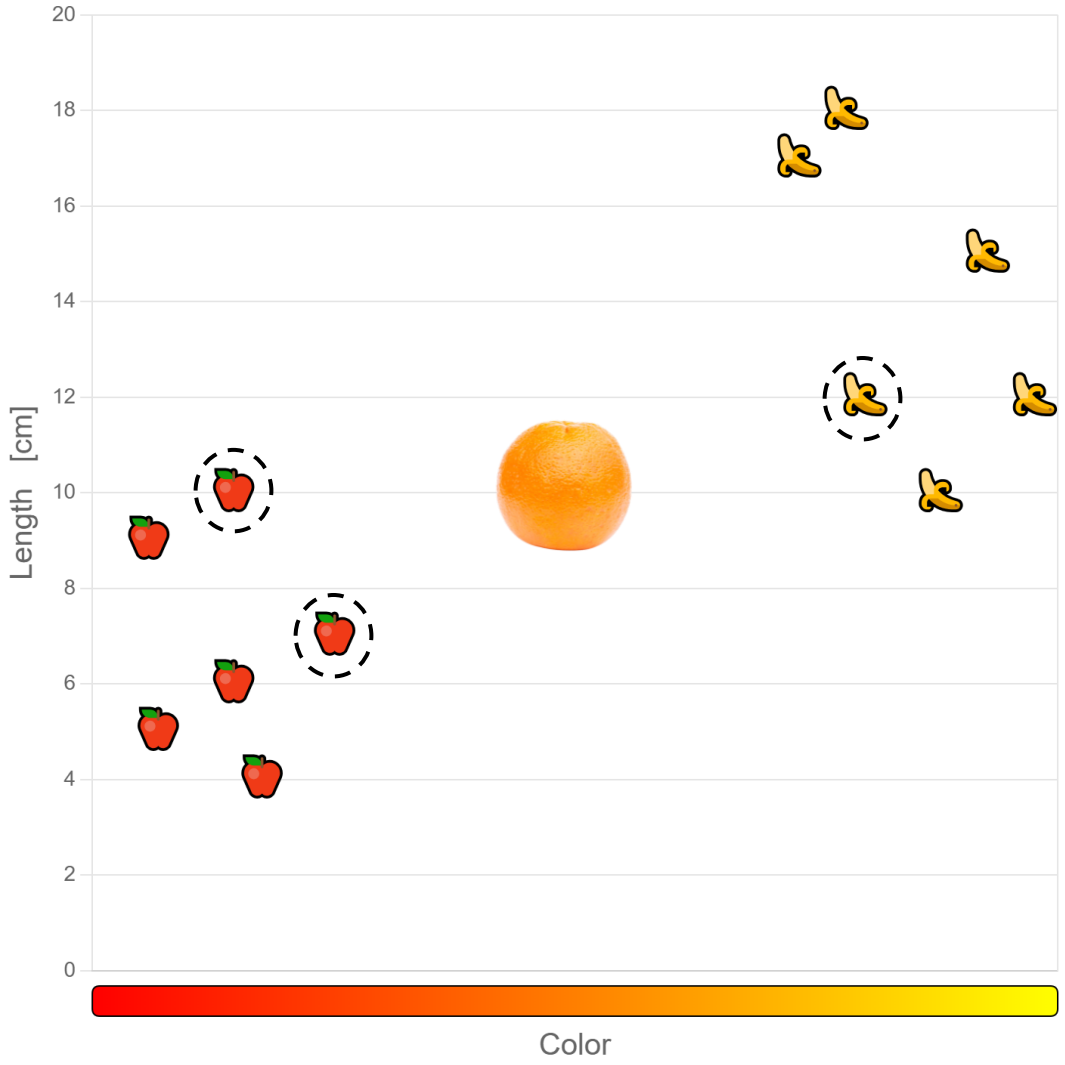

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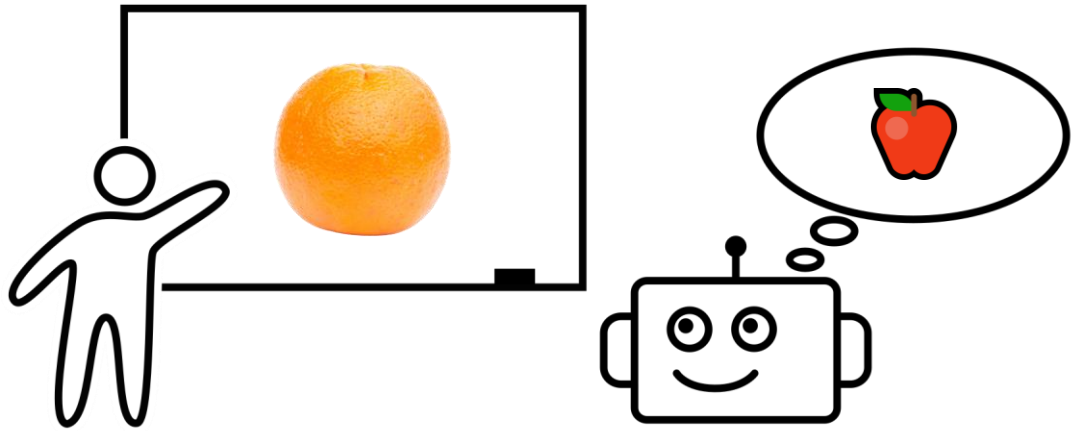


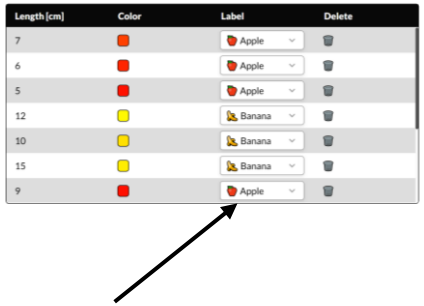
Influence of corrupted data

1

Switch the device to prediction mode and display the decision boundary.

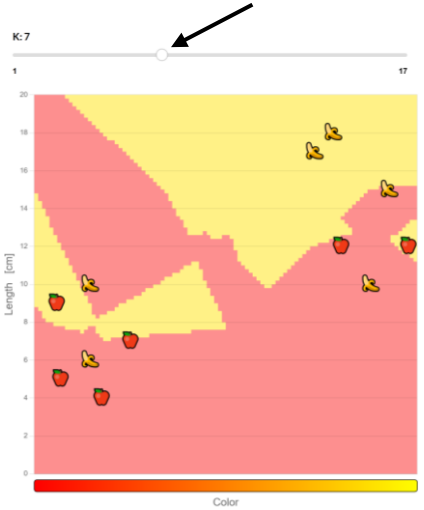
2

Corrupt the data. Change some of the labels to incorrect ones and observe how the decision boundary changes.



3

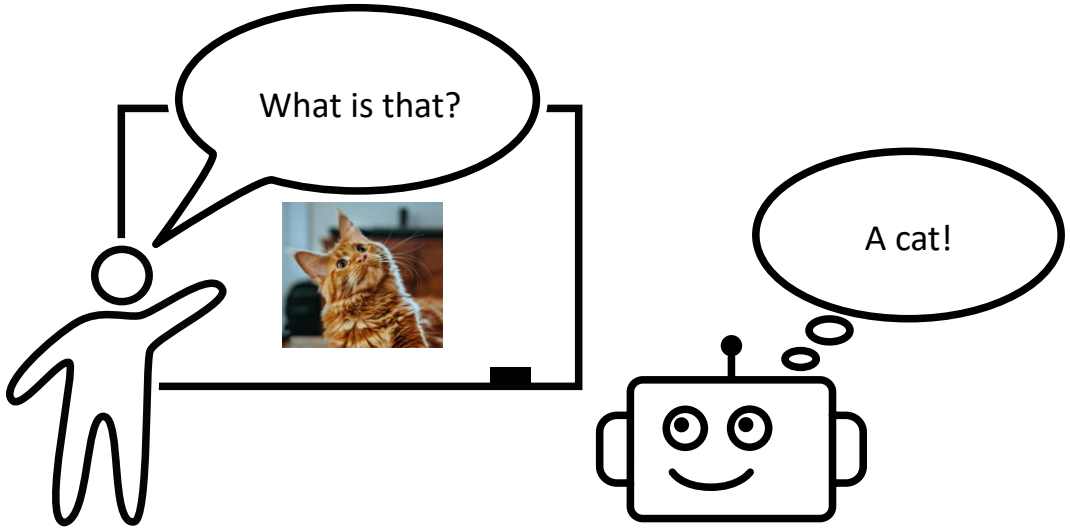
Try changing the number of voting neighbors (K) to restore the accuracy



Classification and regression

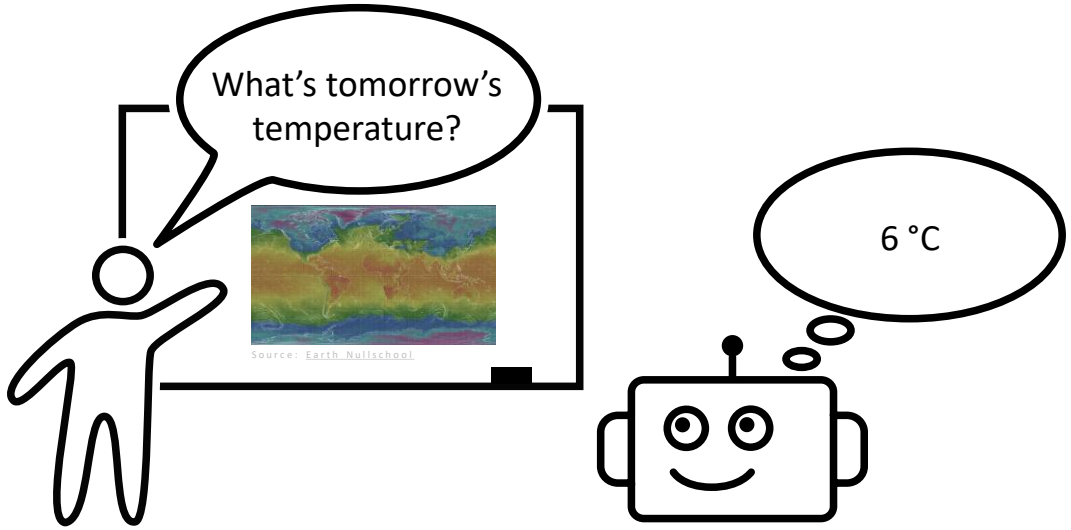
Classification

- prediction of a category



Regression

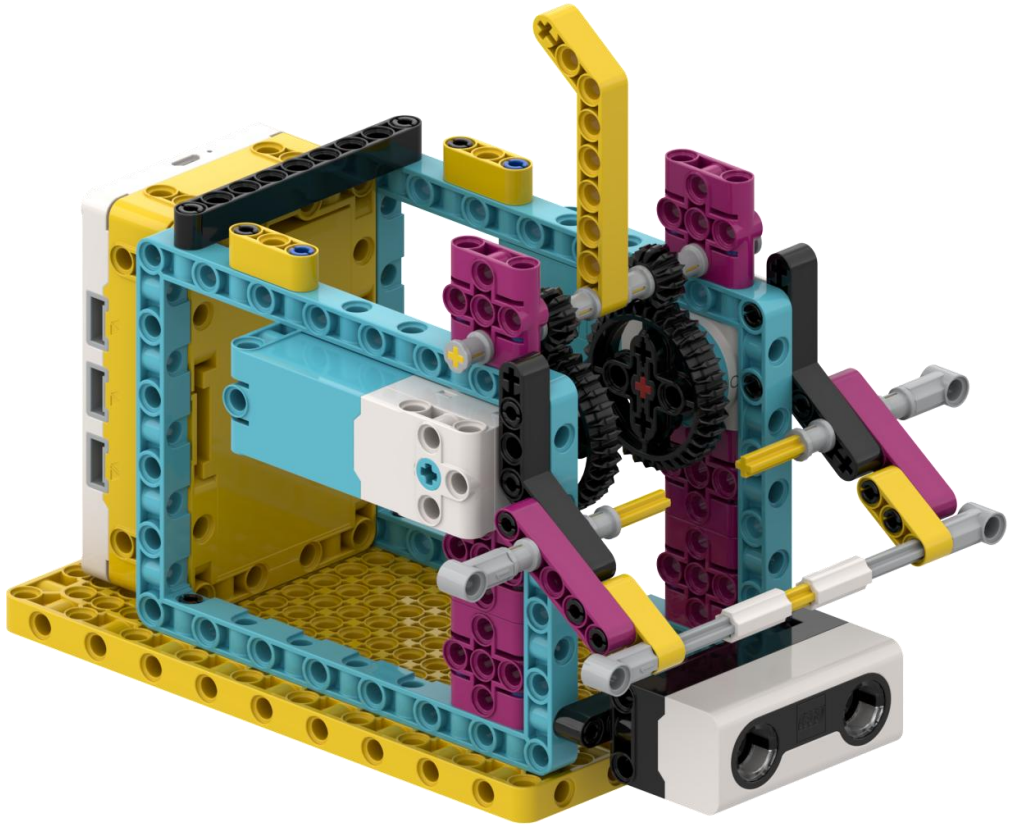
- prediction of a number



Pitcher – Concept

Features: ?

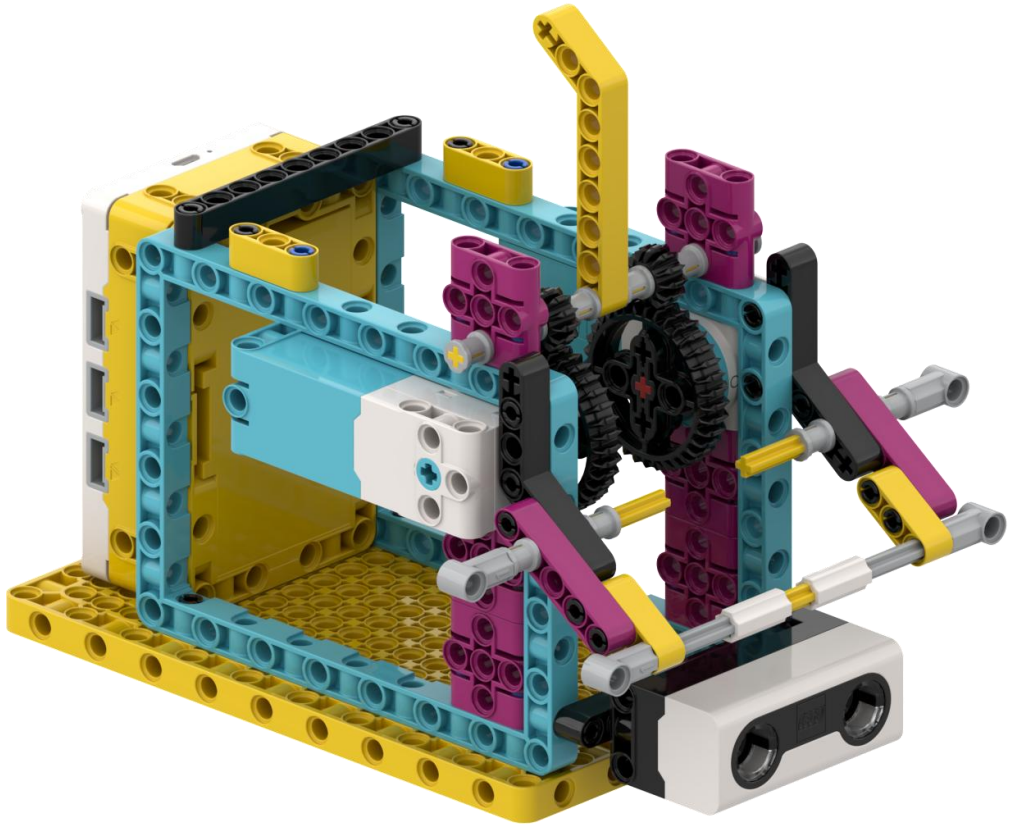
Label: ?



Pitcher – Concept

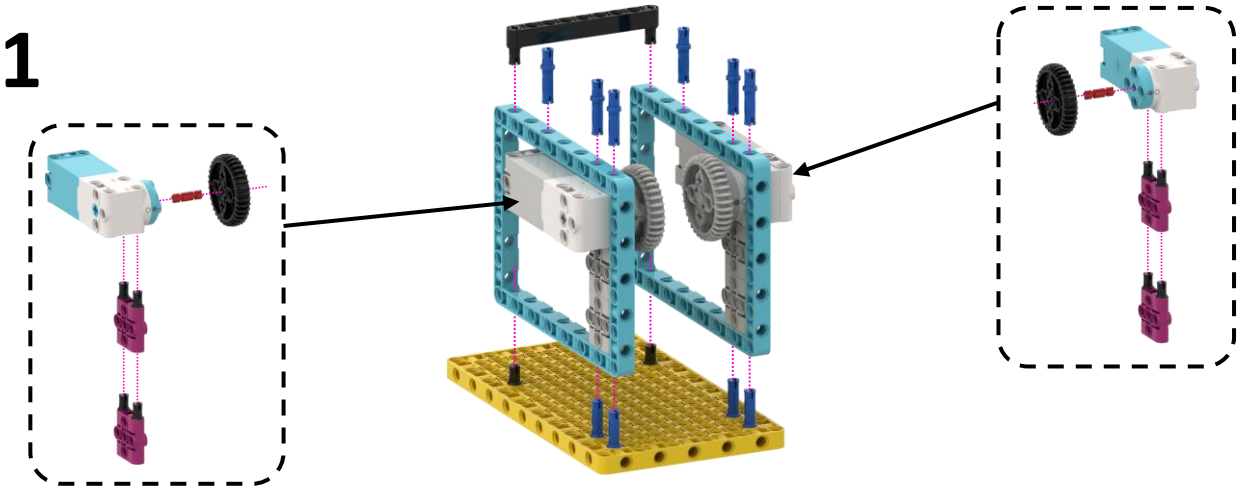
Features: Distance to the target

Label: Motor power

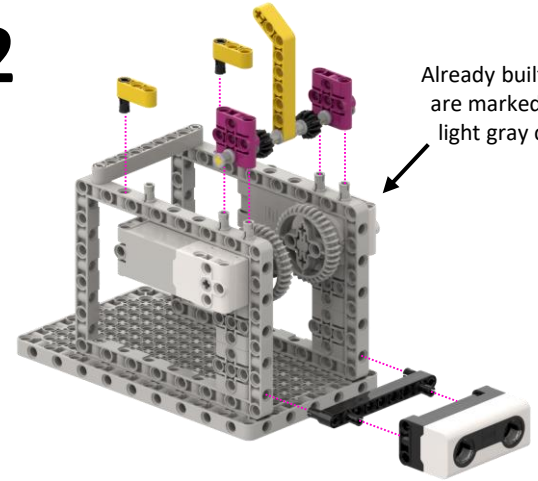


Pitcher – Assembly

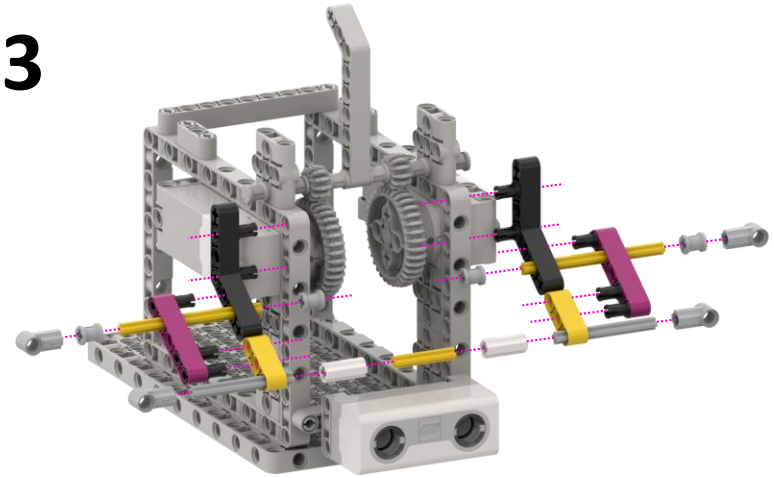
1



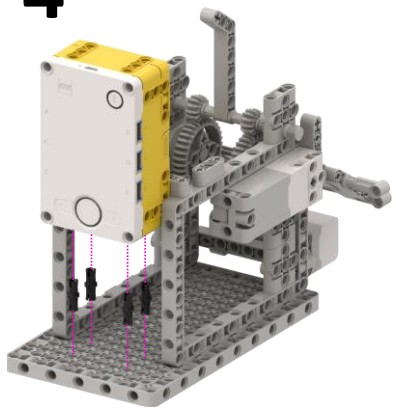
2



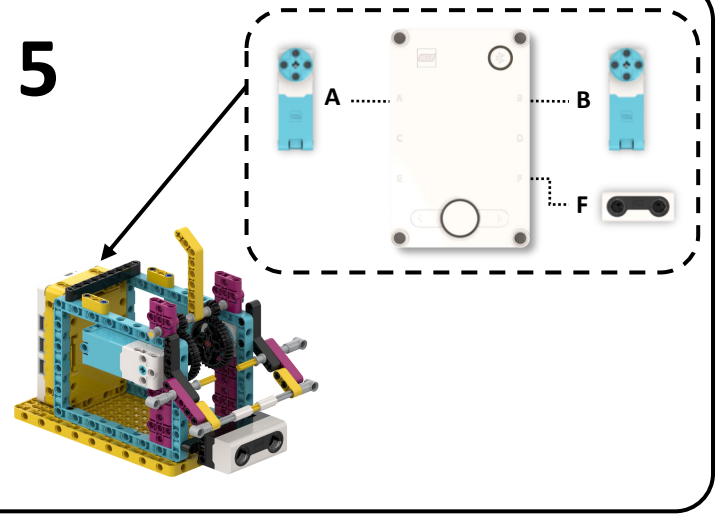
3



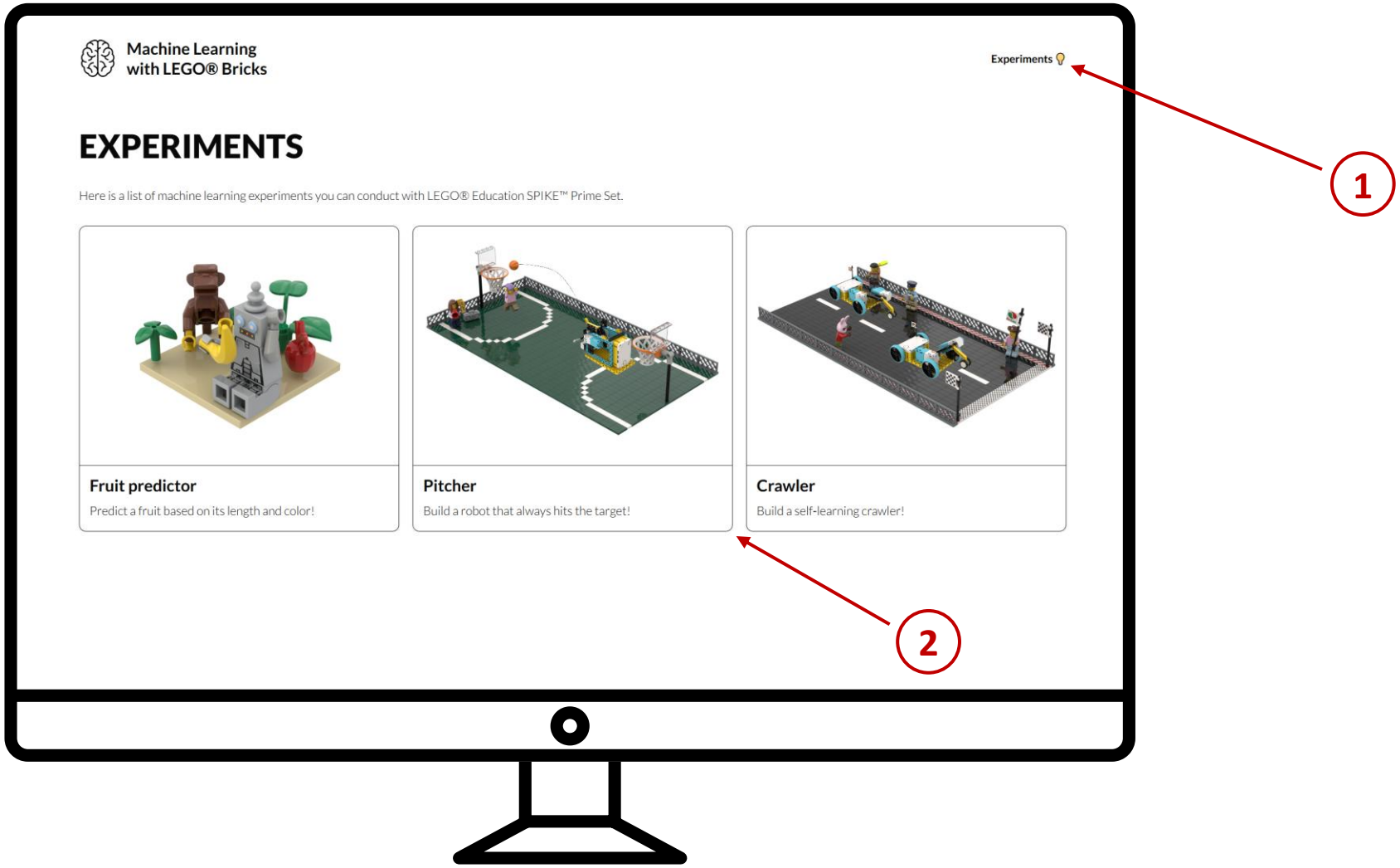
4



5



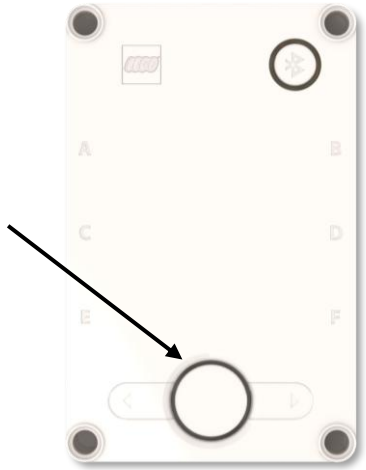
Open the experiment page



Connect hub and start the program

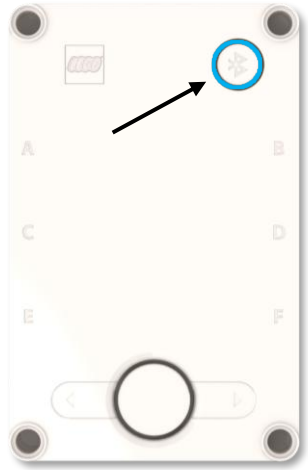
1

Switch on the hub by pressing the large button for about 3 seconds.



2

Click on the Bluetooth button and wait until the hub starts beeping.



3

Click on ''Connect hub'', find your hub in the window, select it and click on '''Pair'''.

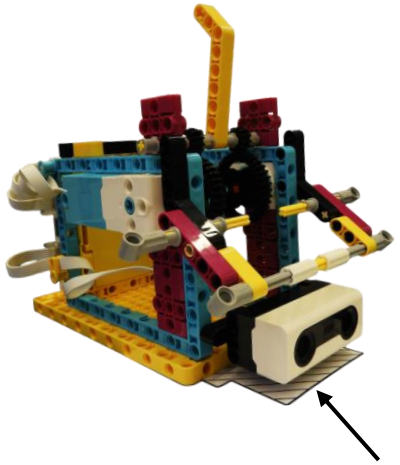
4

Click on 'Start program' and wait until a notification appears on the website.

Pitcher – Data collection

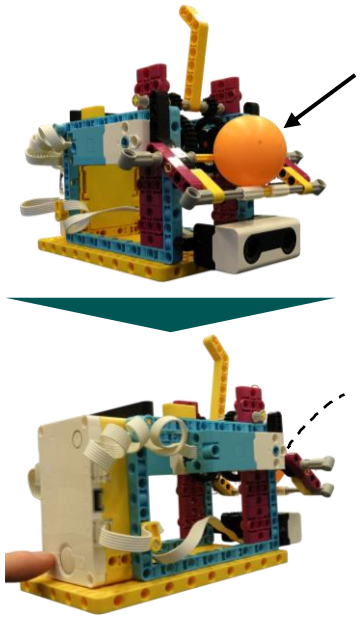
1

Place the pitcher in the shaded area on the mat.



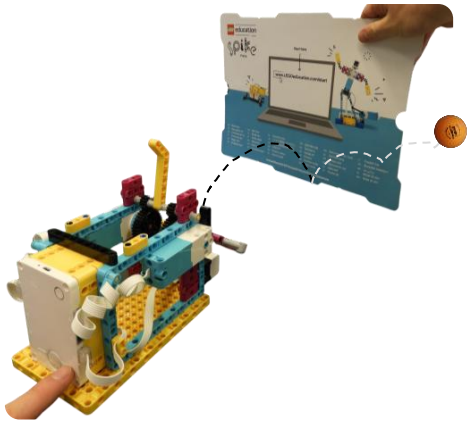
2

Place the ball in the holder and position the paddle on the top. Press the left button to throw the ball.



3

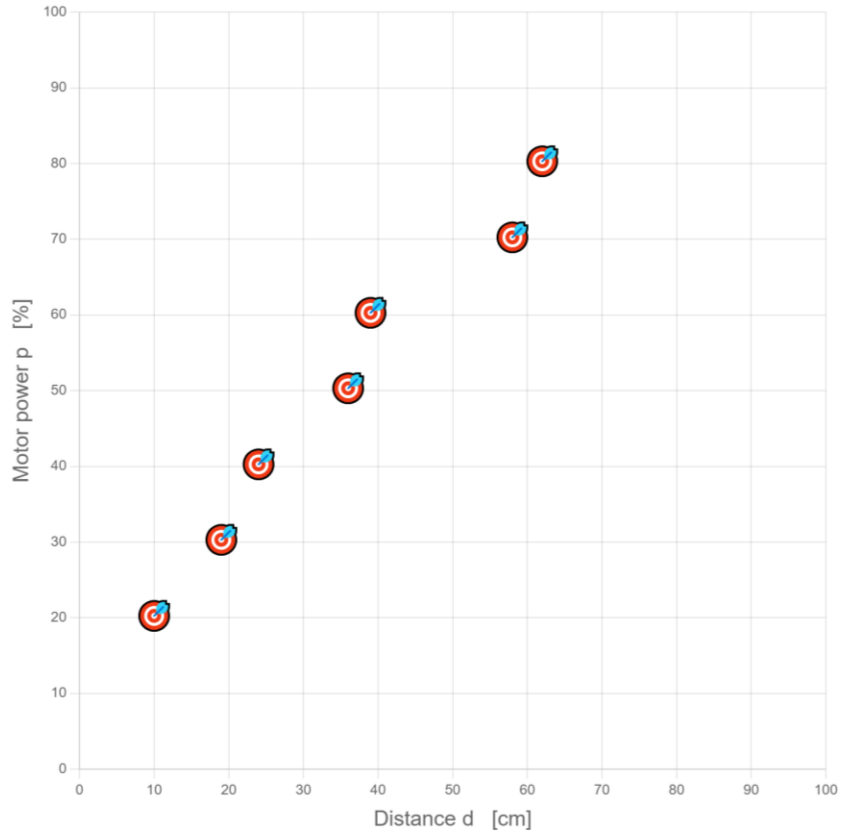
Hold a cardboard at the point where the ball landed and press the right button to measure the distance.



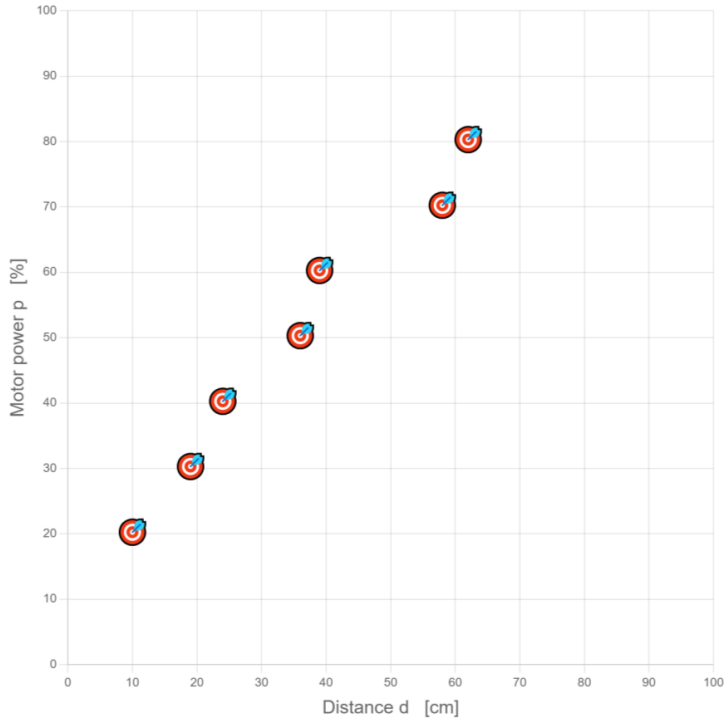
4

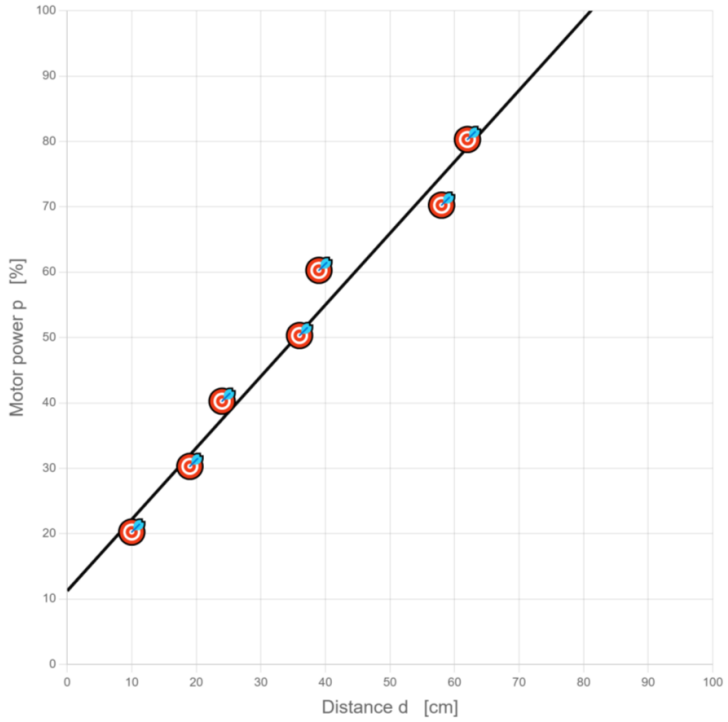
Repeat the steps for other motor speeds.

Pitcher – Data analysis

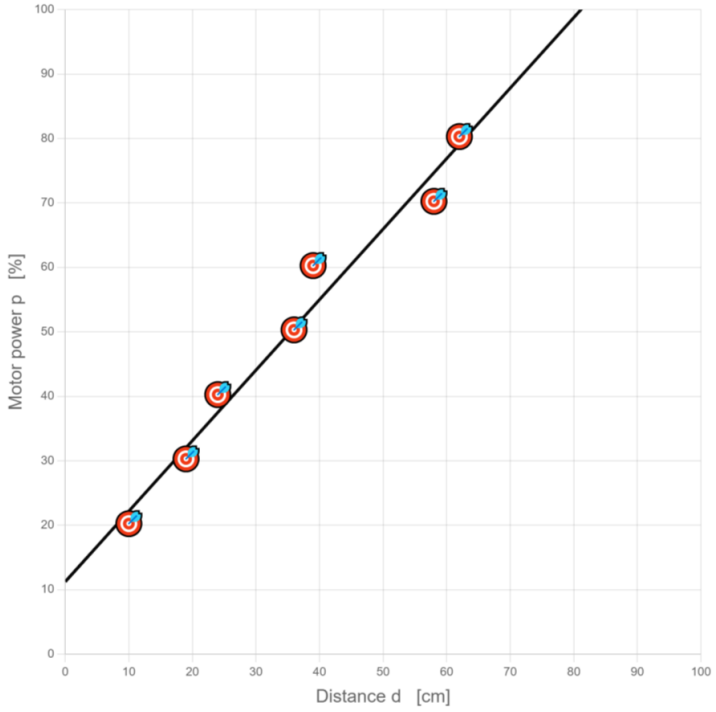


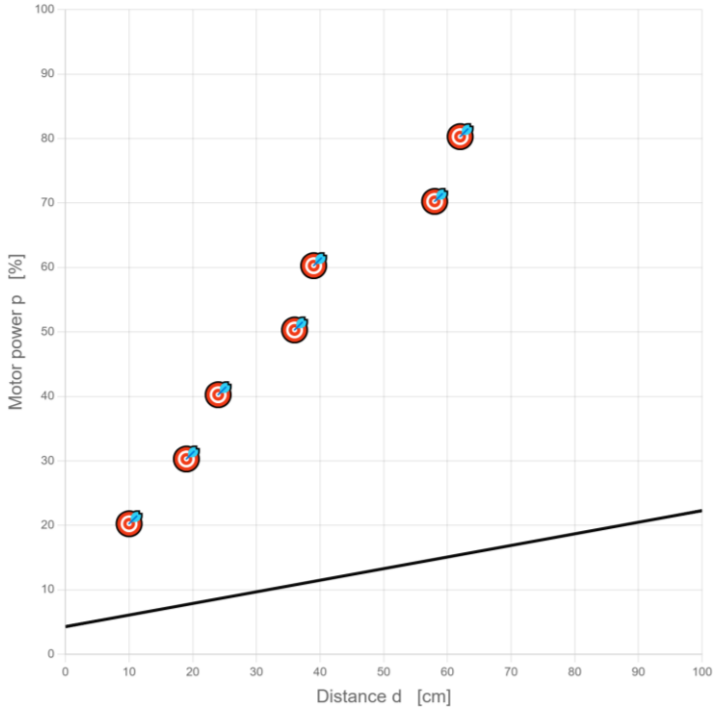
Pitcher – Data analysis

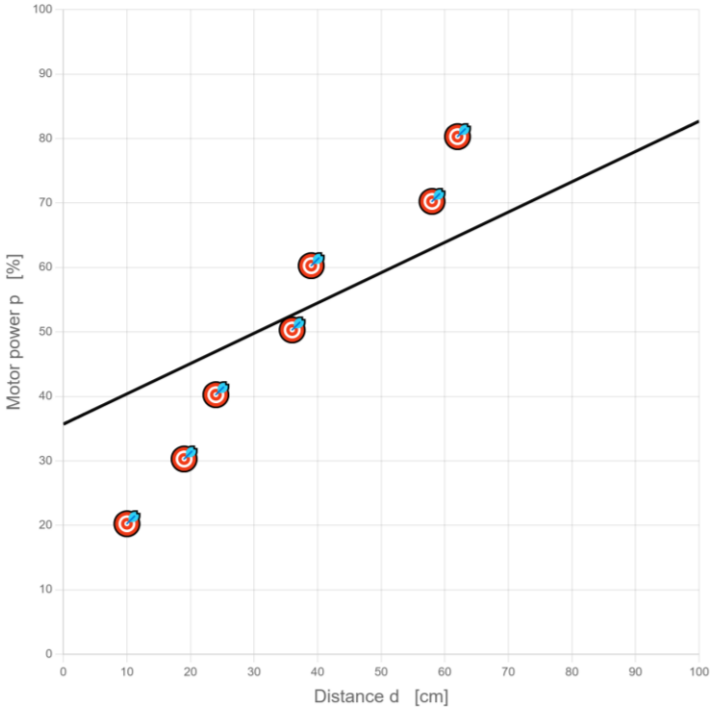




How well does the line fit?

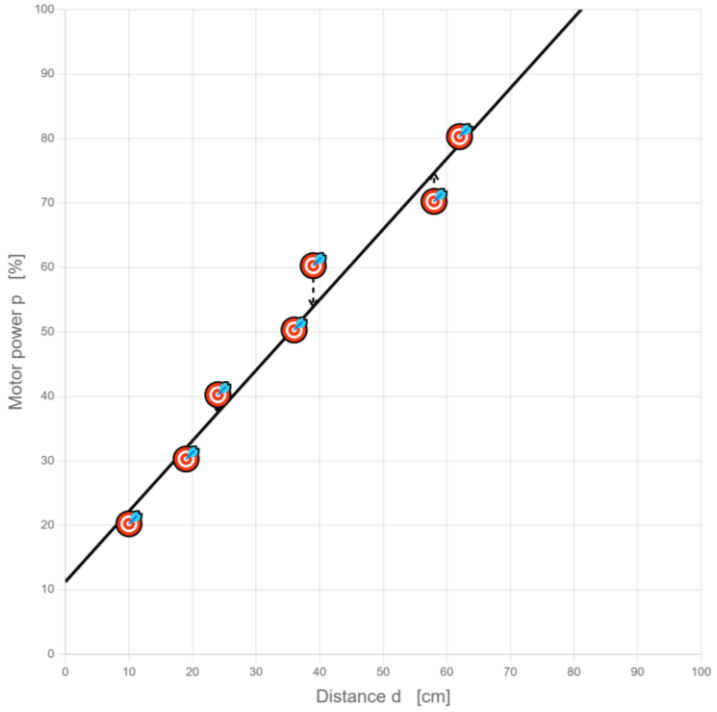


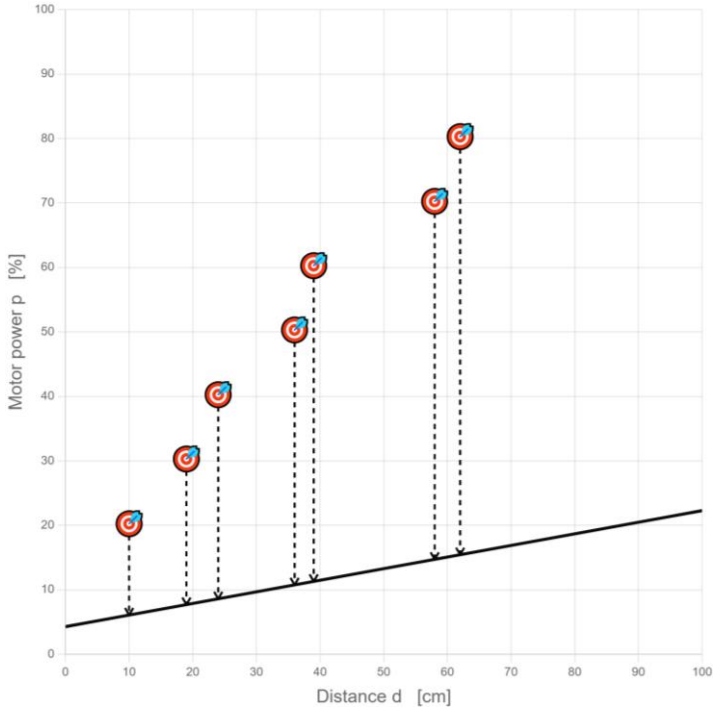


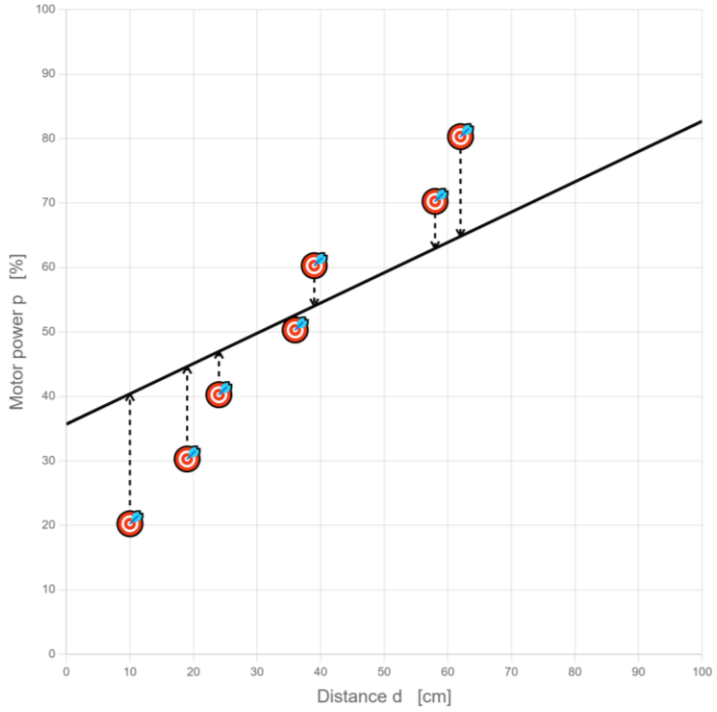


How well does the line fit?

- **Loss** describes how good model predictions are.

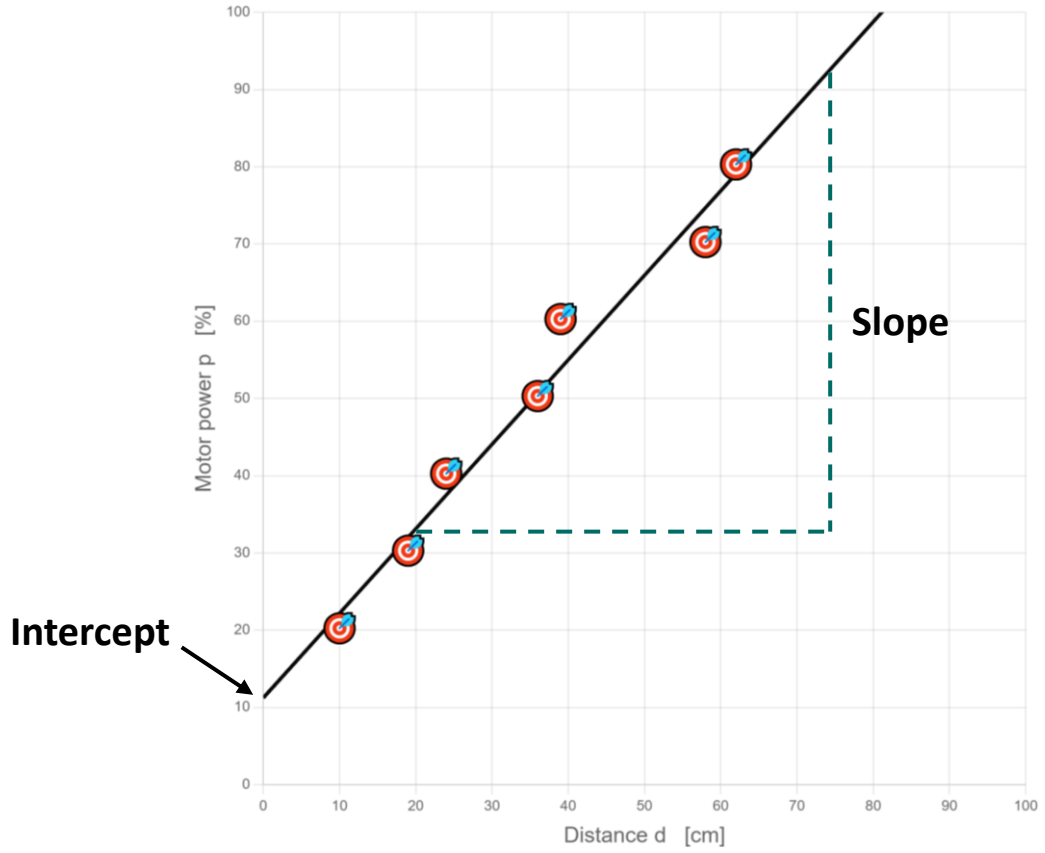






Linear regression

- **Linear regression –** determining a line that reflects a relationship between variables.



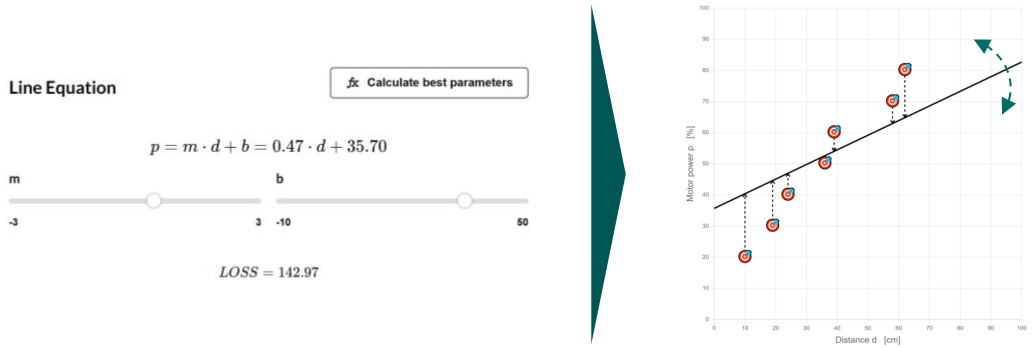
Pitcher – Fit the line

1

Switch the device to prediction mode.

2

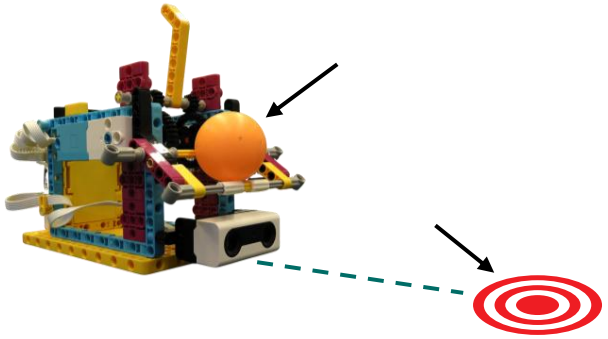
Try adjusting the slope and intercept to move the line and minimize the loss.



Pitcher – Prediction

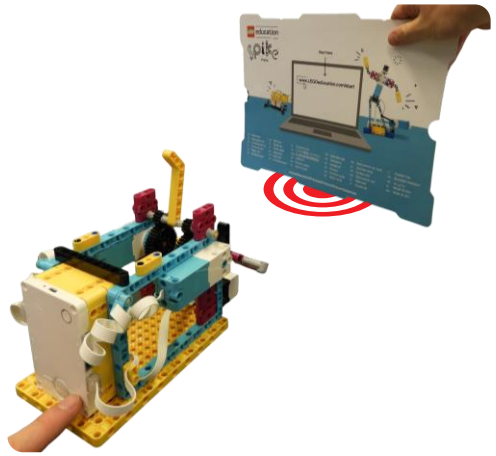
1

Place the ball in the holder and position the target in front of the pitcher.



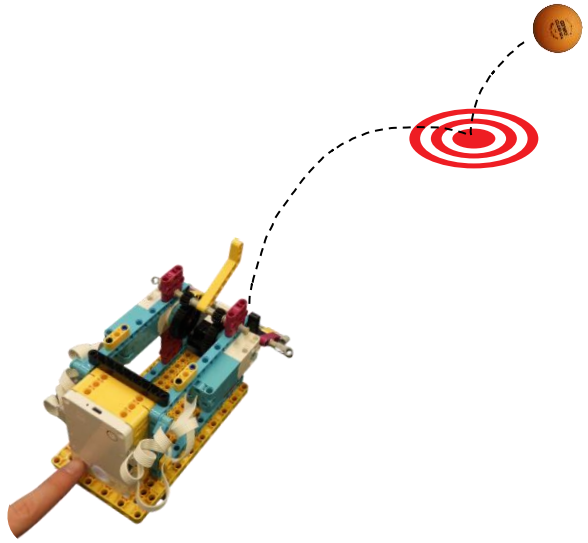
2

Measure the distance to the target. Place the cardboard in the center of the target and press the right button.

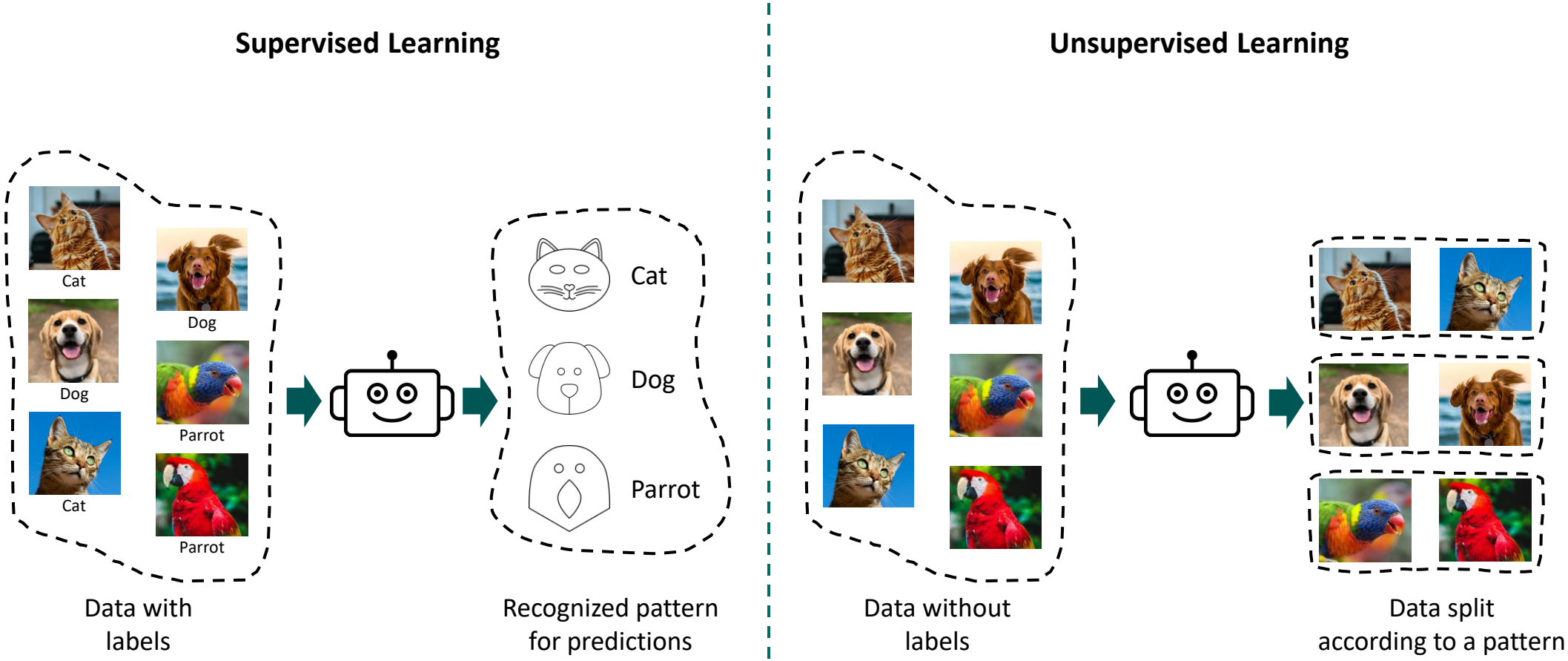


3

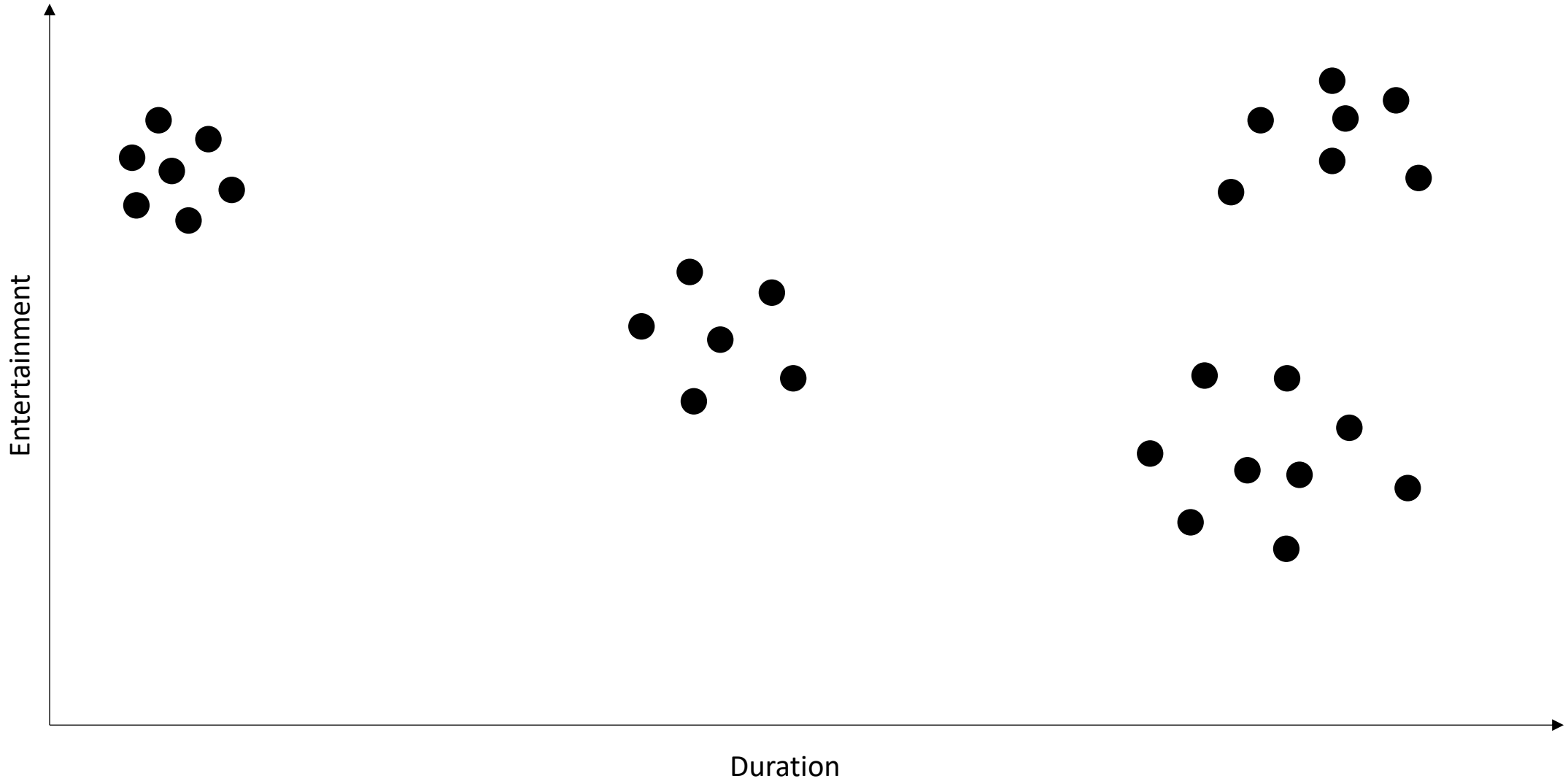
Pitch the ball into the target by pressing the left button



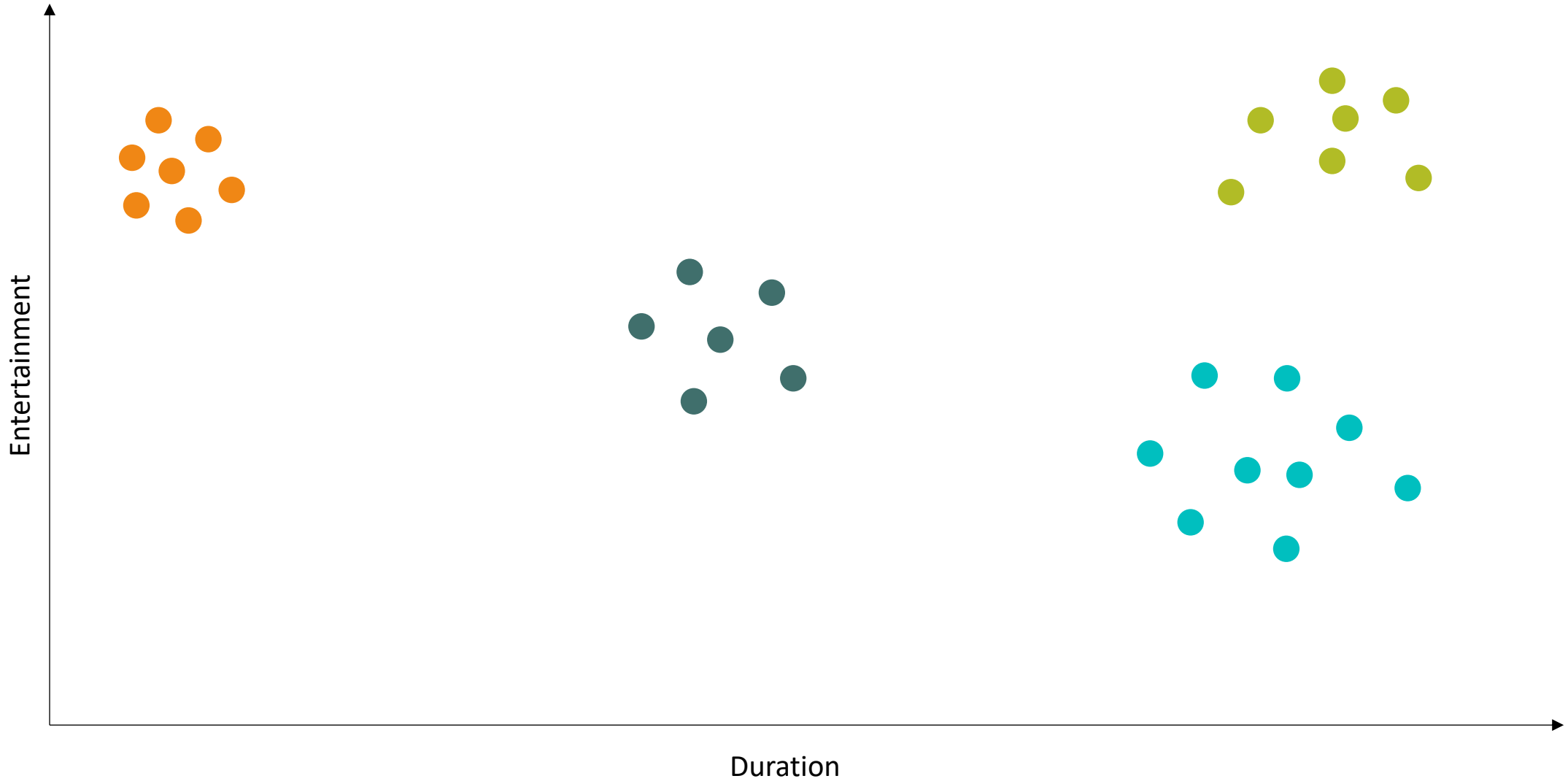
Supervised and unsupervised learning



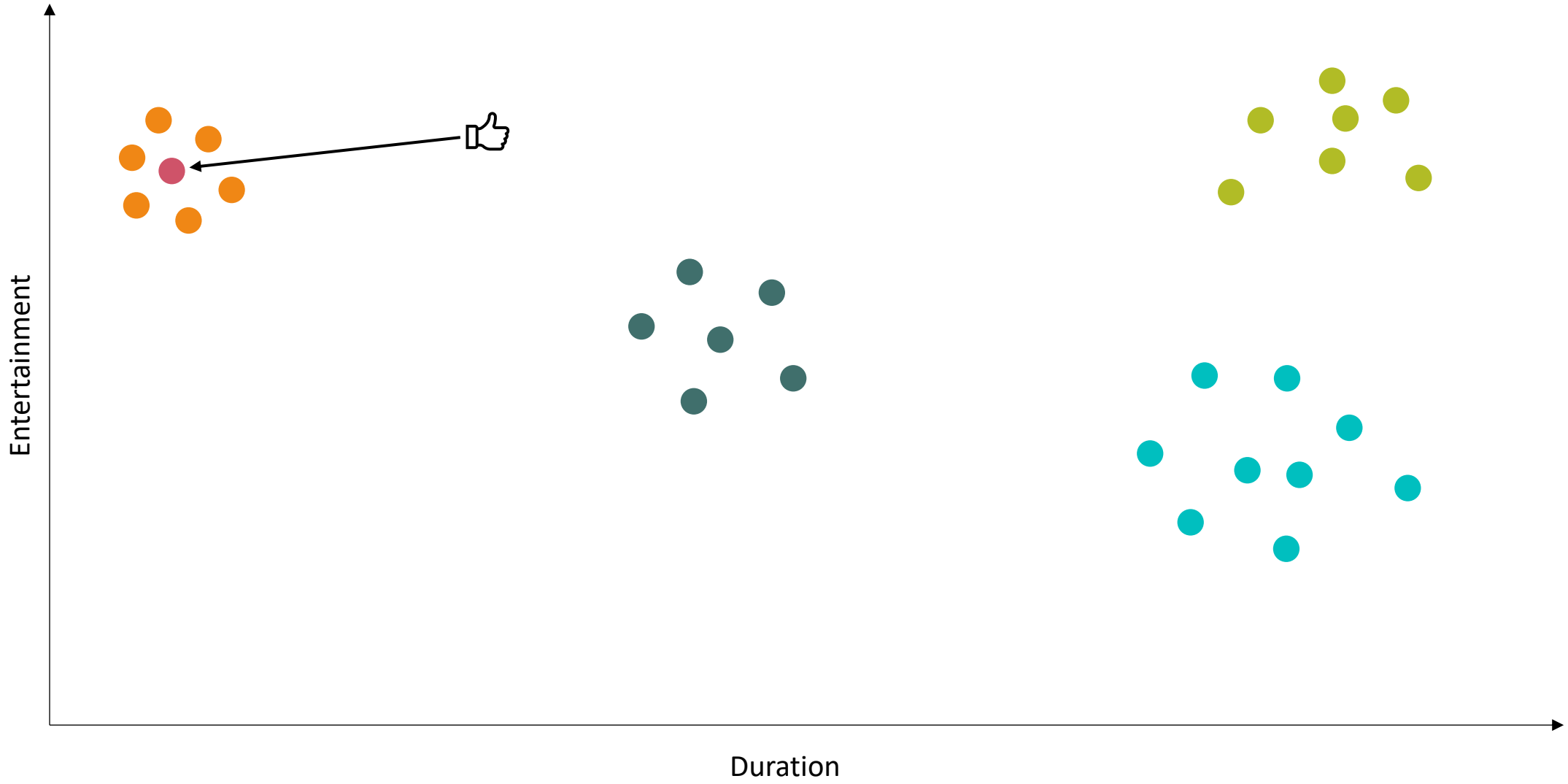
How to recommend new videos using unsupervised learning



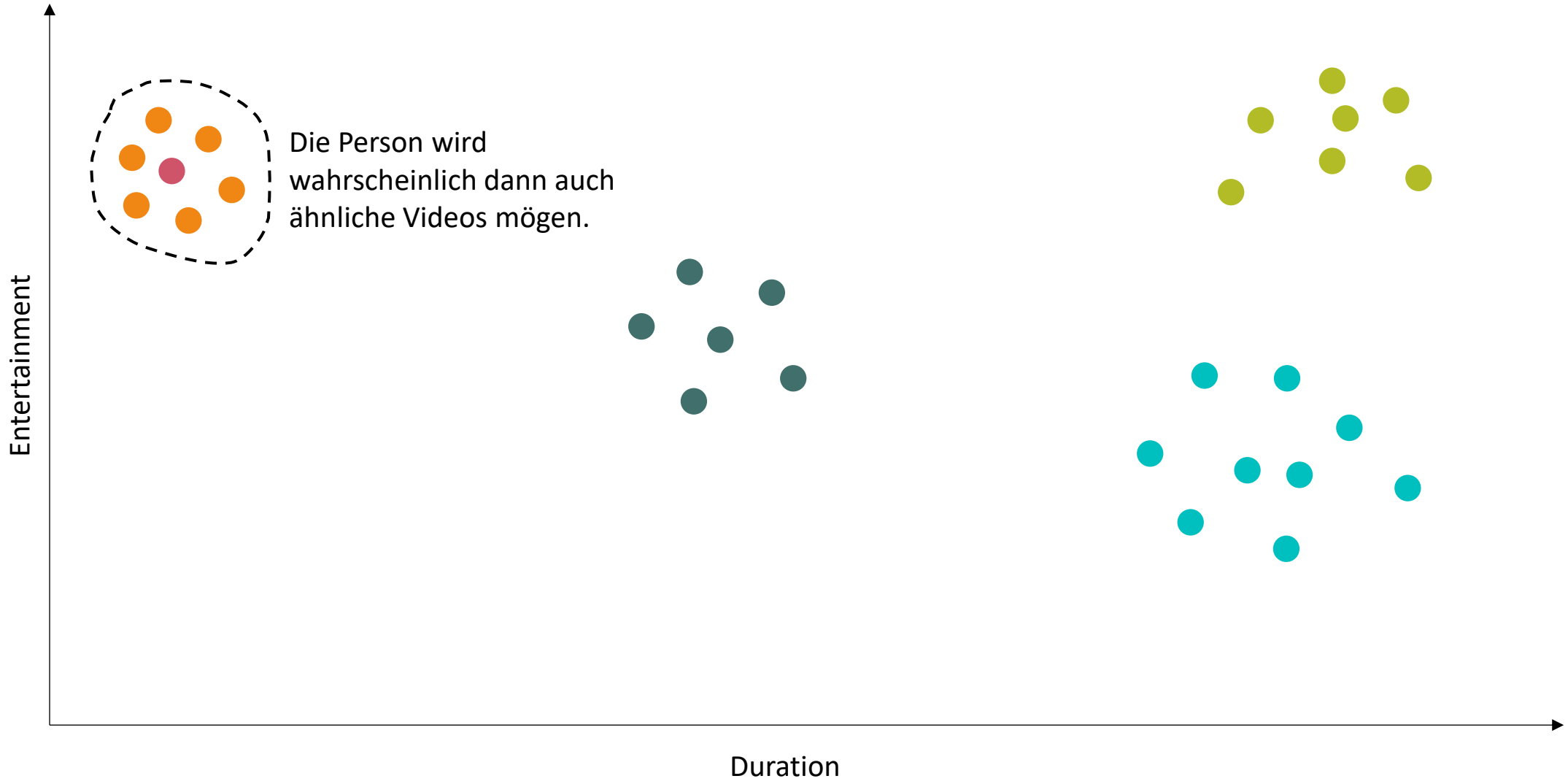
How to recommend new videos using unsupervised learning



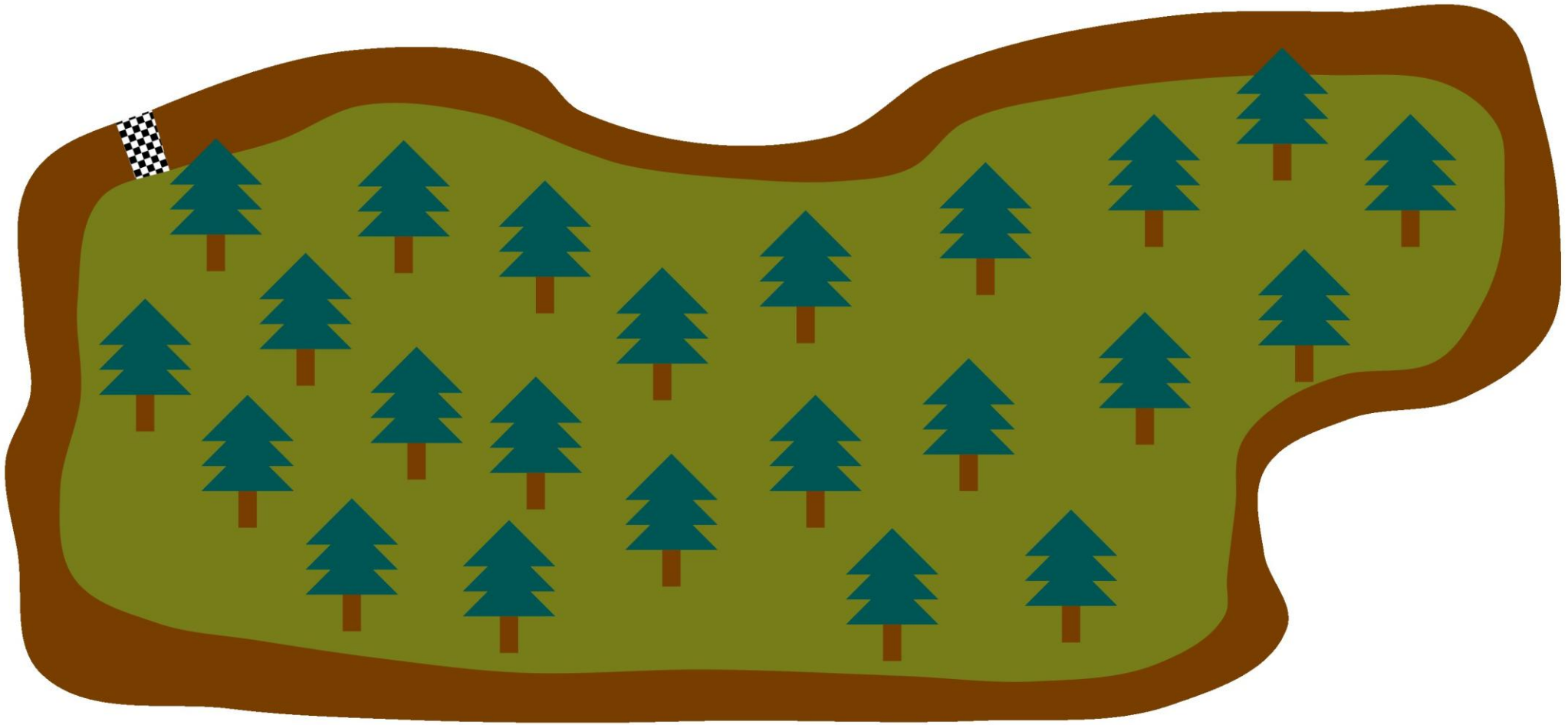
How to recommend new videos using unsupervised learning



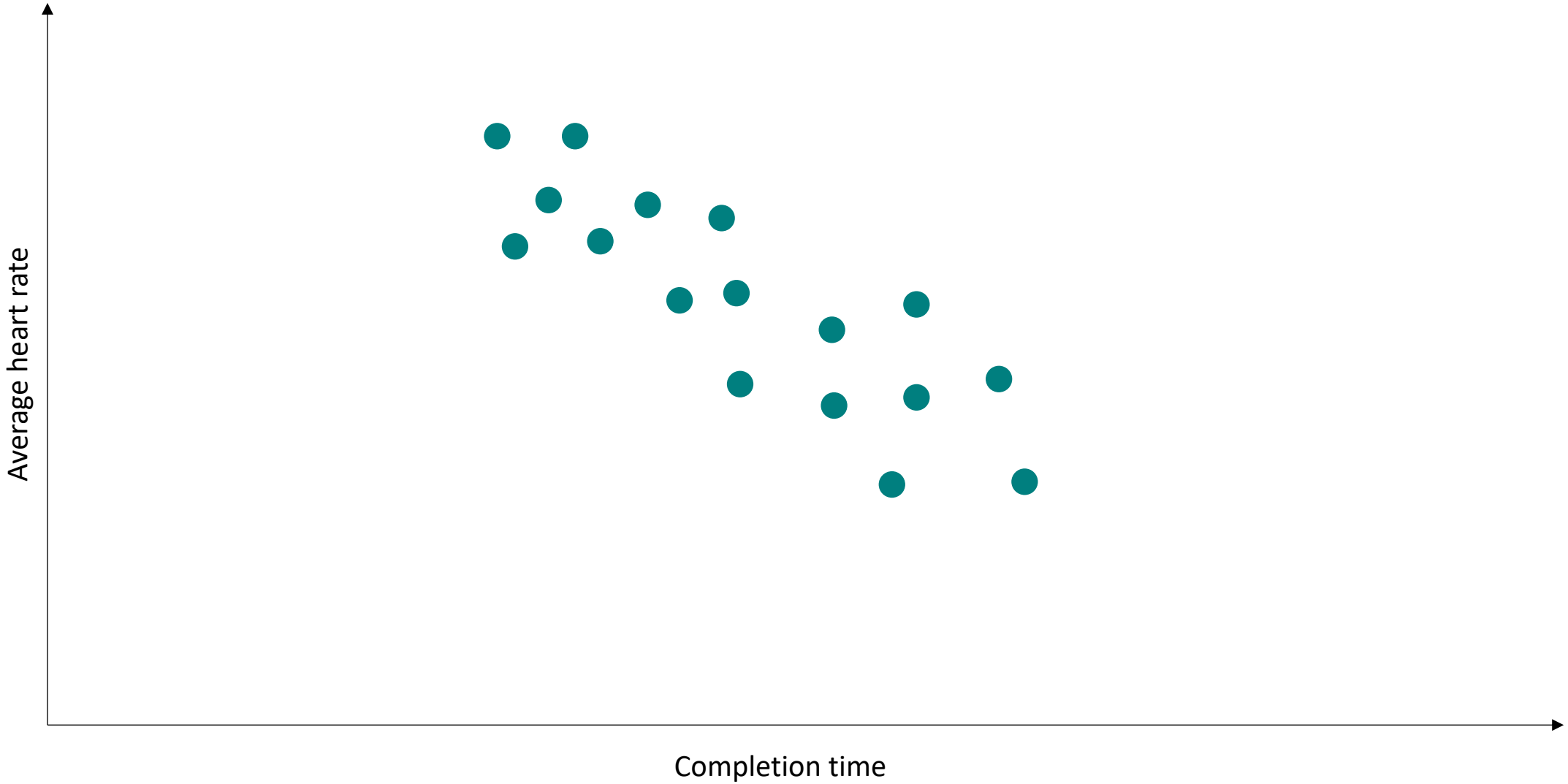
How to recommend new videos using unsupervised learning



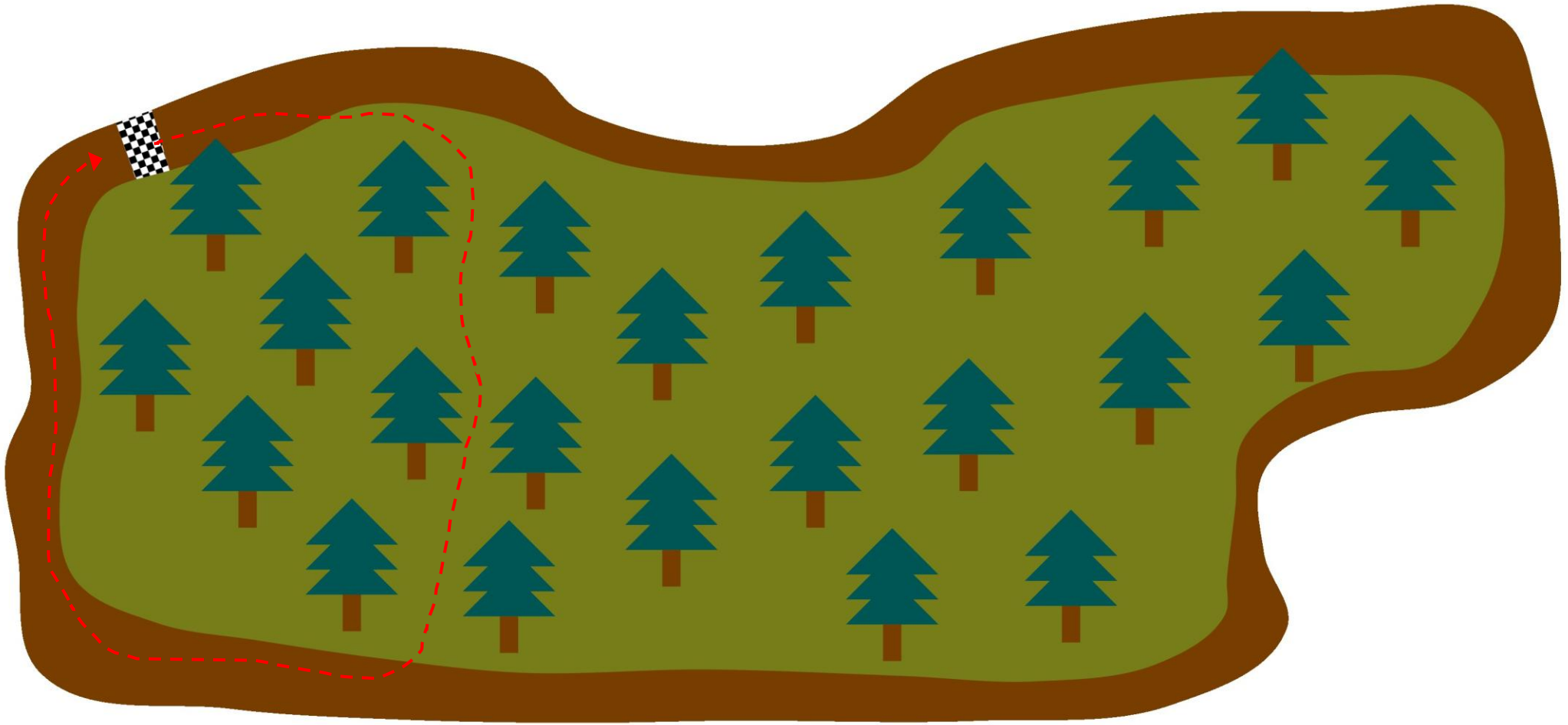
How to detect cheaters using unsupervised learning



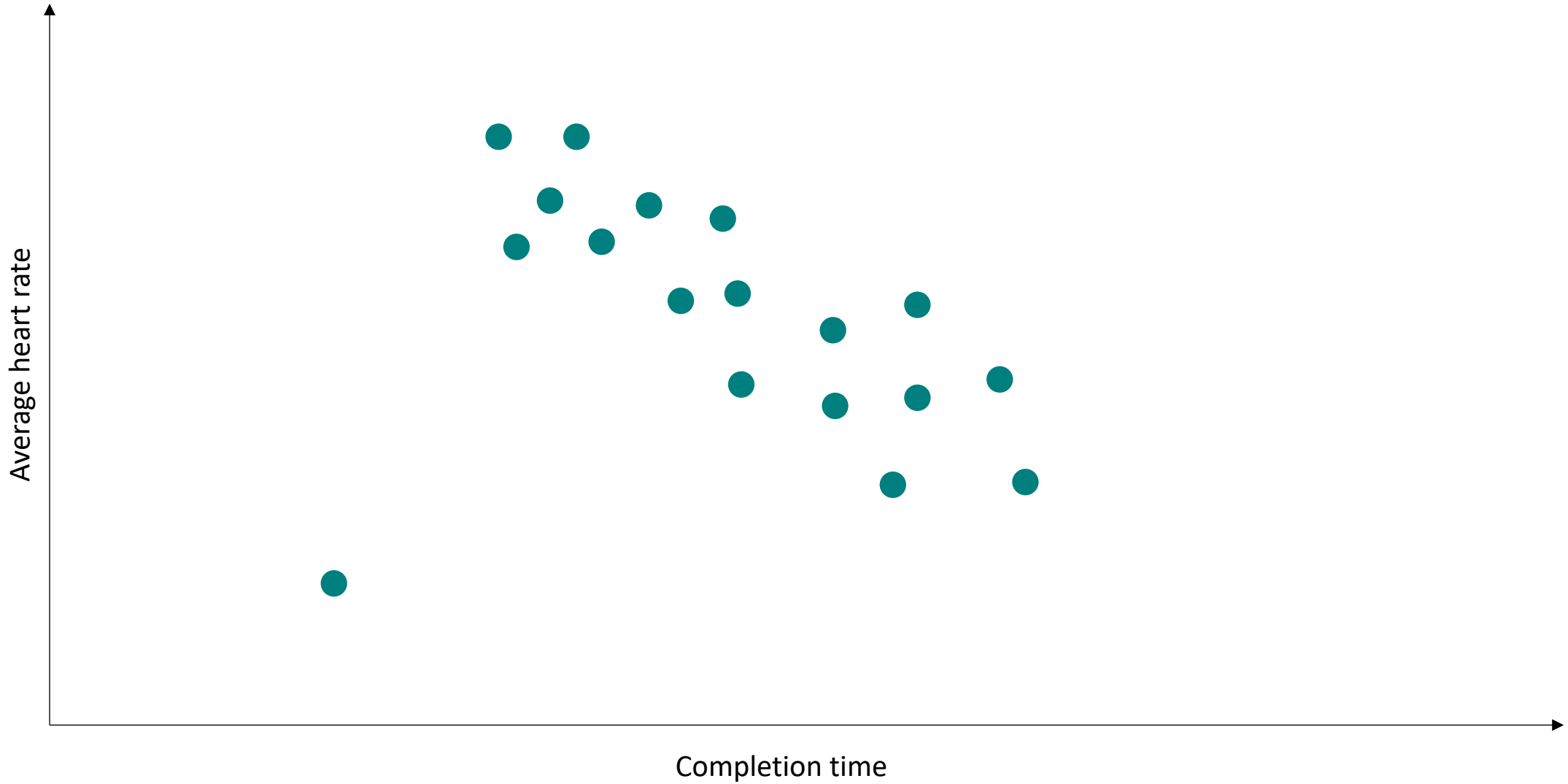
How to detect cheaters using unsupervised learning



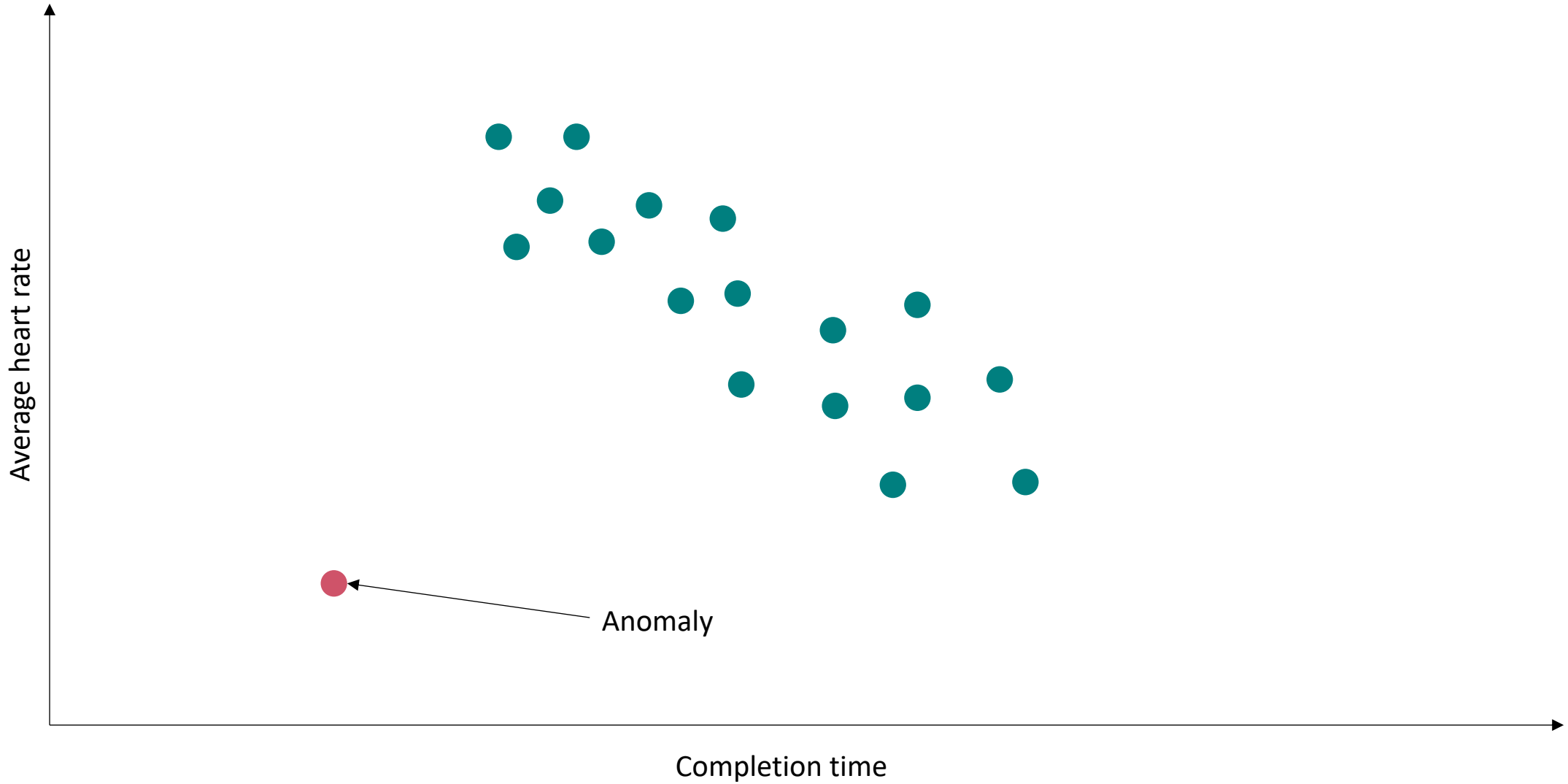
How to detect cheaters using unsupervised learning



How to detect cheaters using unsupervised learning

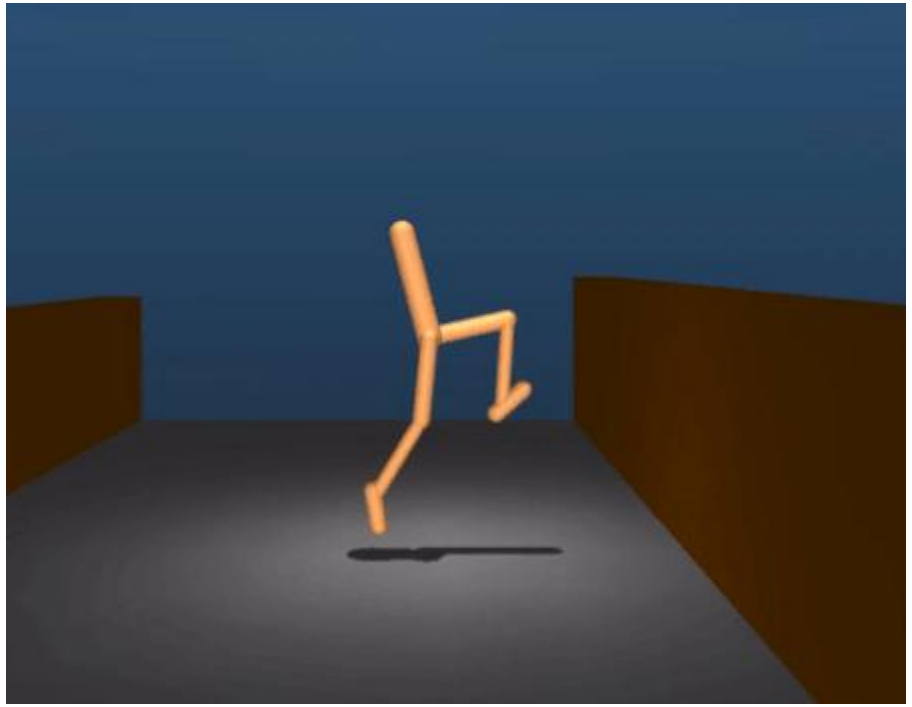


How to detect cheaters using unsupervised learning



Reinforcement learning

- **Reinforcement learning** – learning through trial and error.



Source: DeepMind

Reinforcement learning

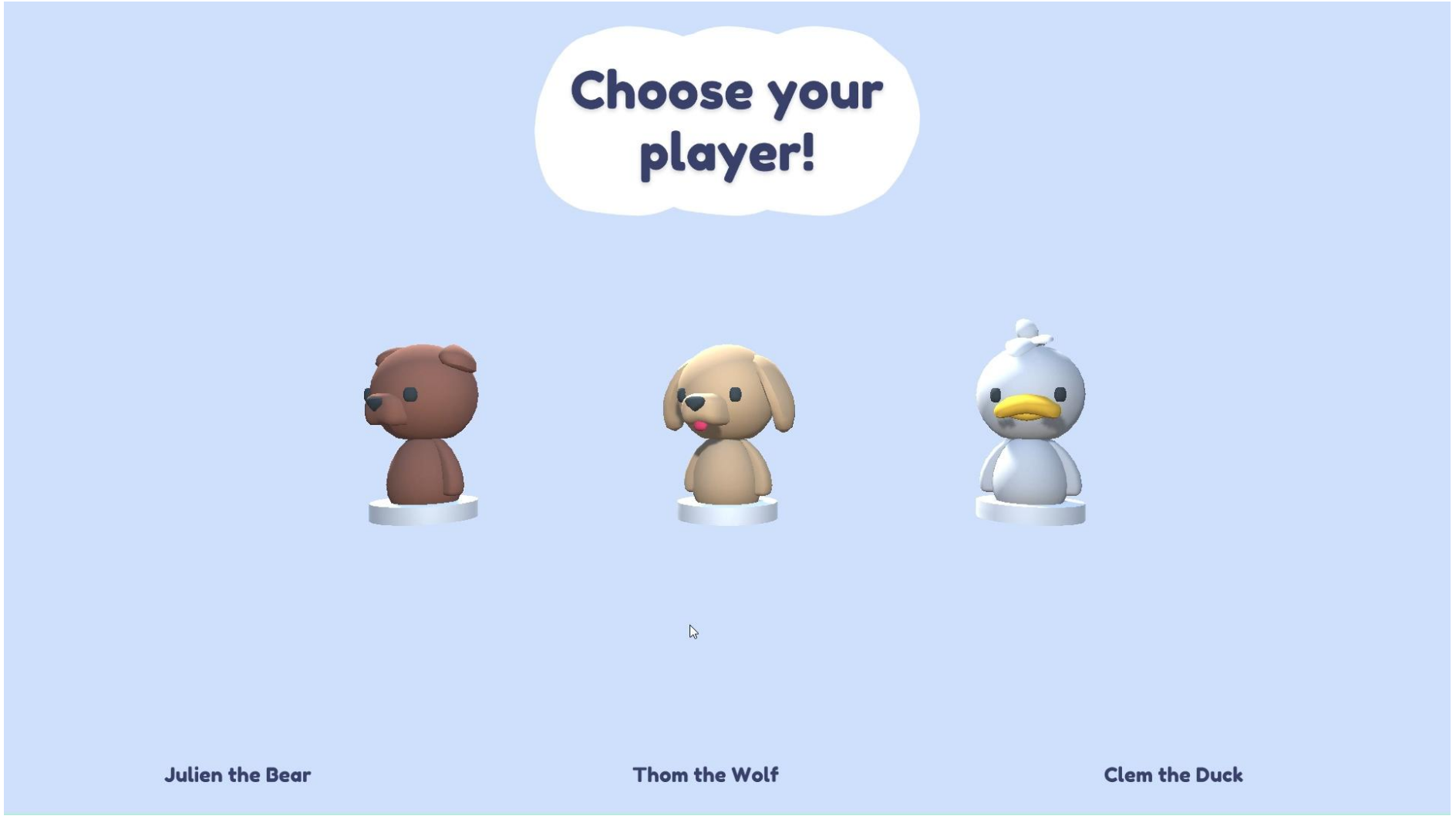
- **Reinforcement learning** – learning through trial and error.

Source: Giphy

Applications – Robots

Source: YouTube

Applications – Bots in computer games

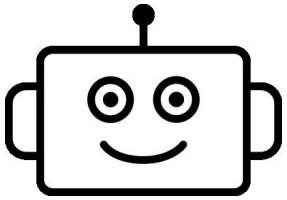


Source: HuggingFace

Applications – Bots in computer games

Source: HuggingFace

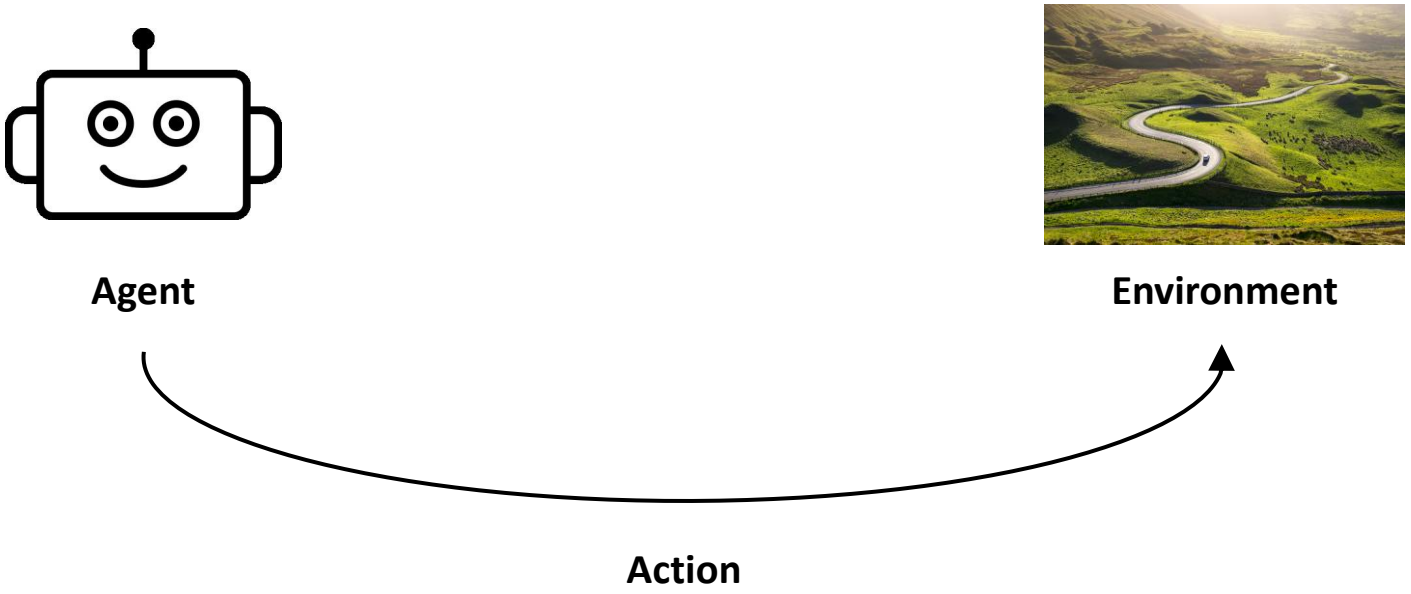
Abstraction



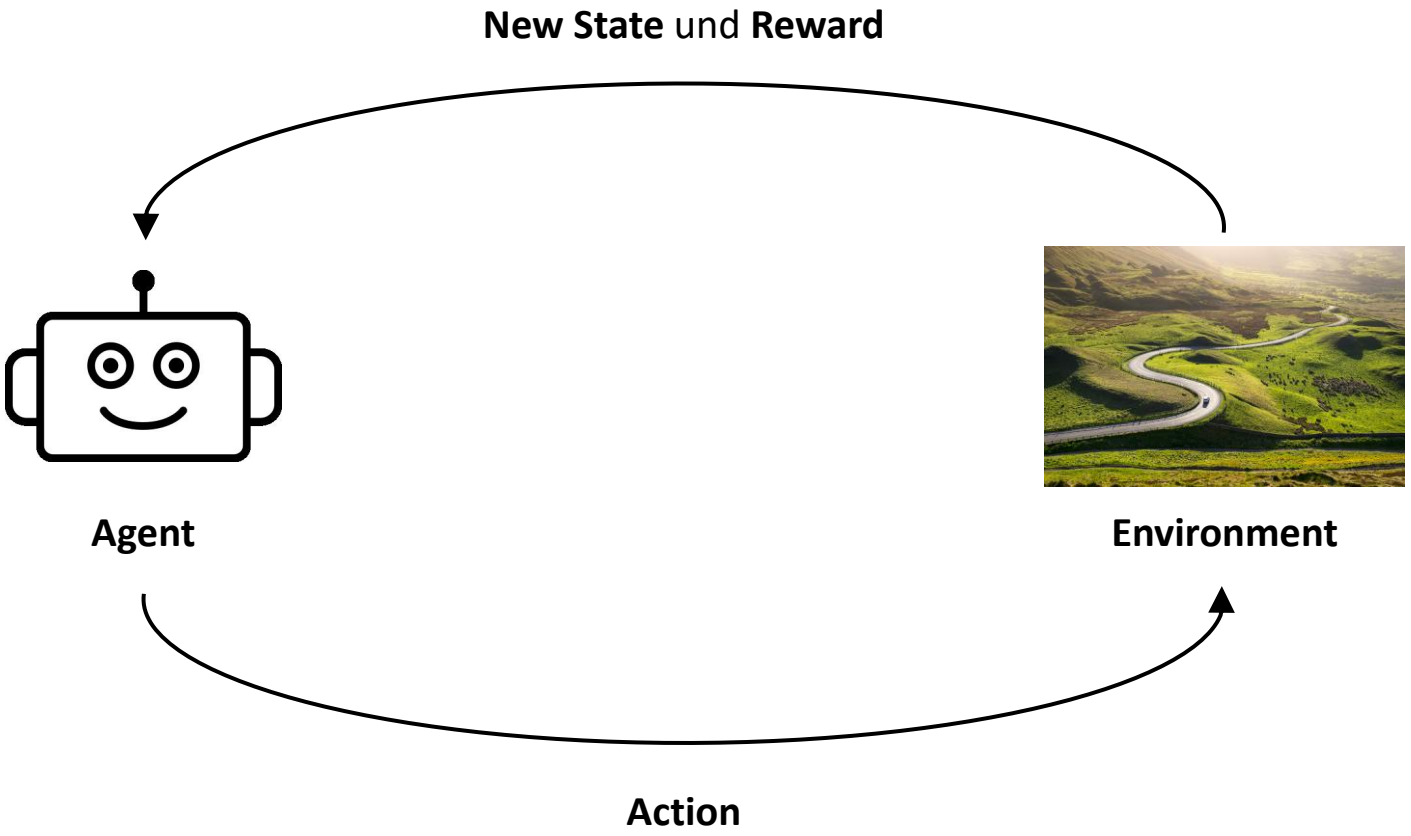
Agent

Environment

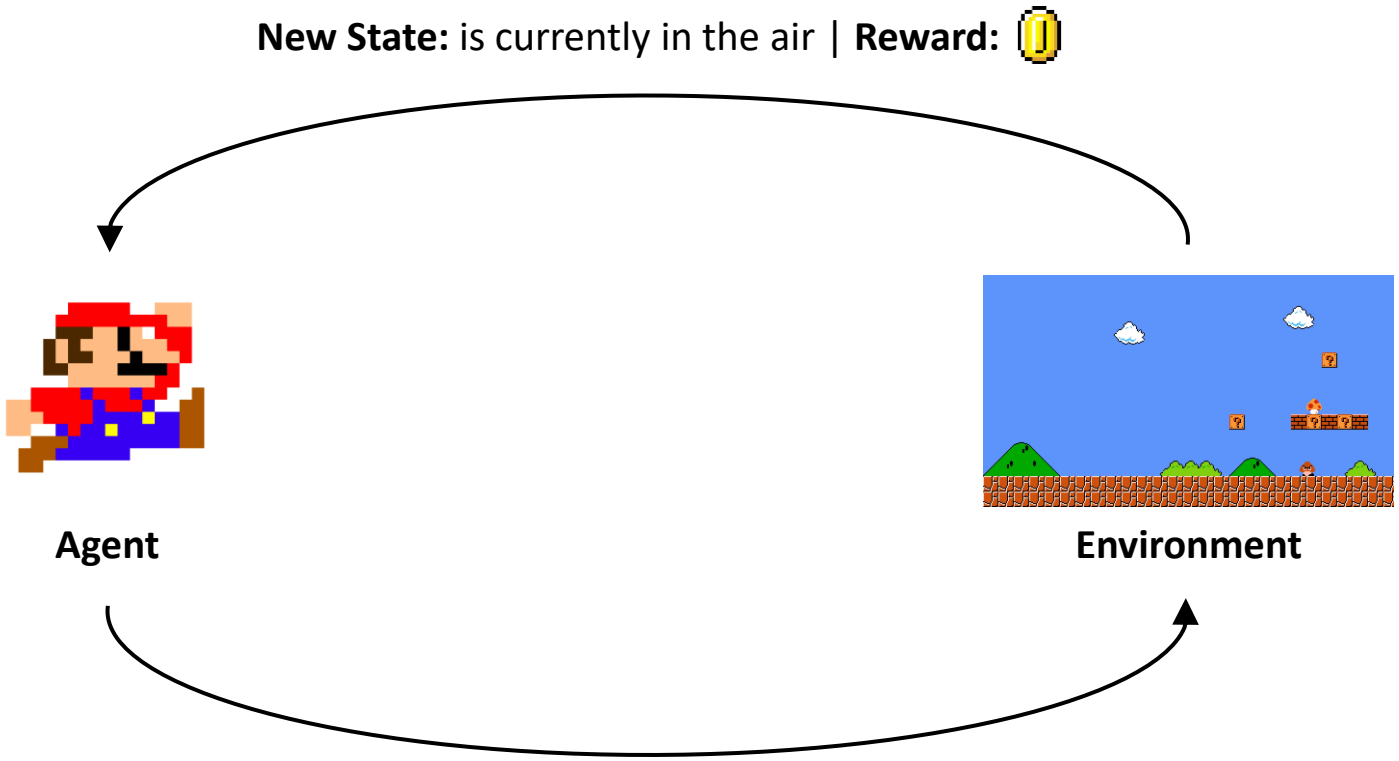
Abstraction



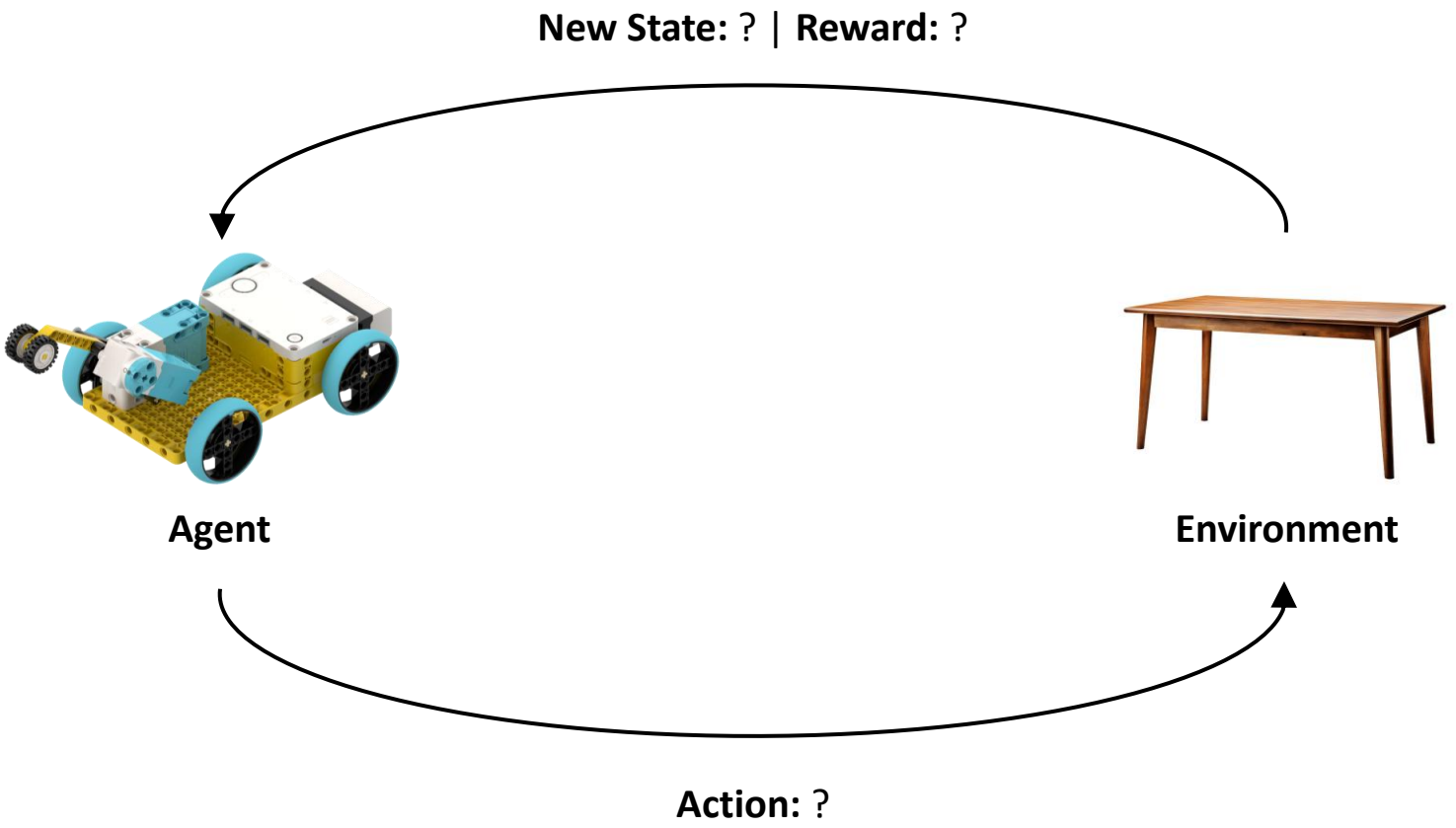
Abstraction



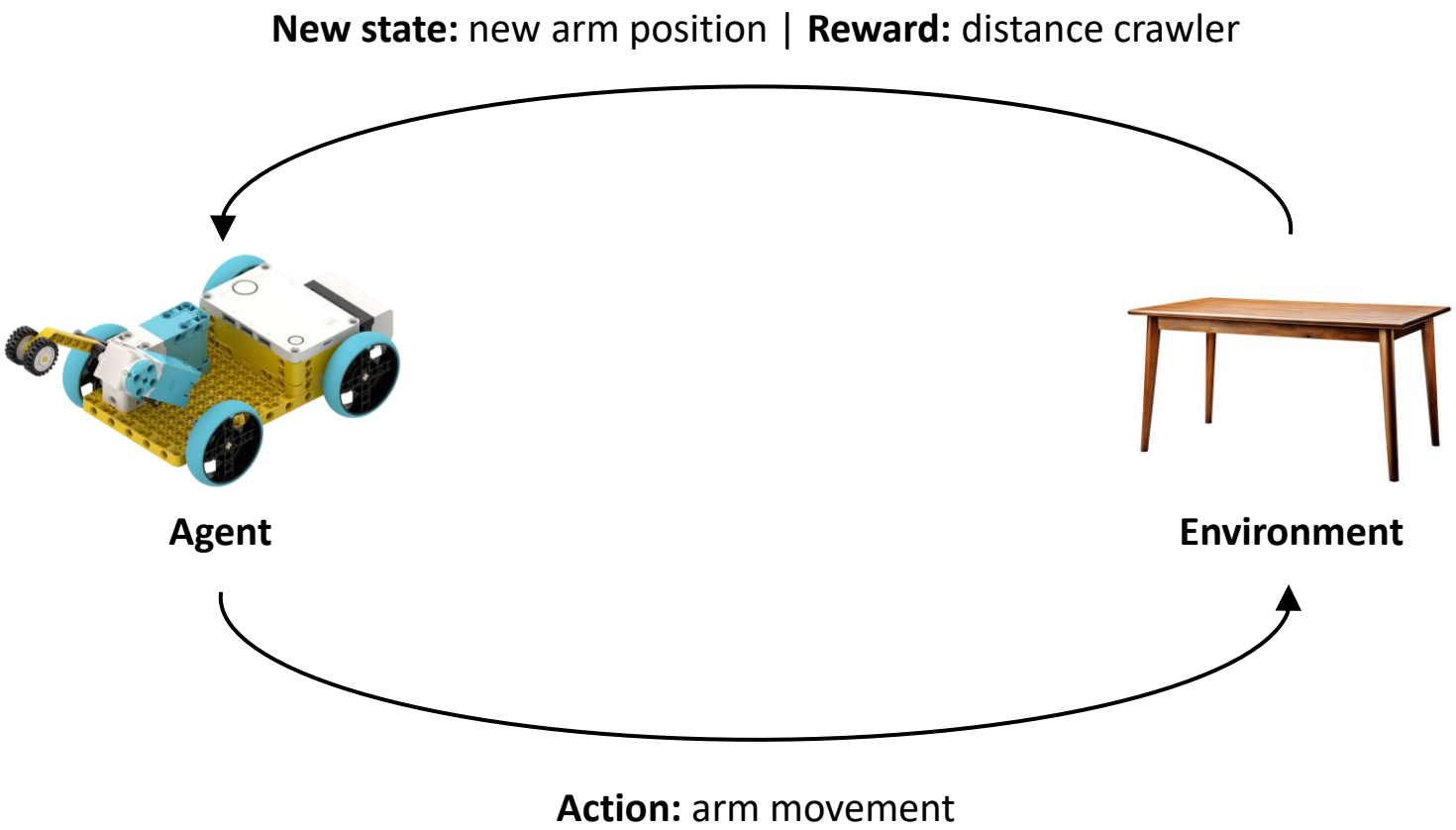
Example of Super Mario Bros



Crawler – Concept

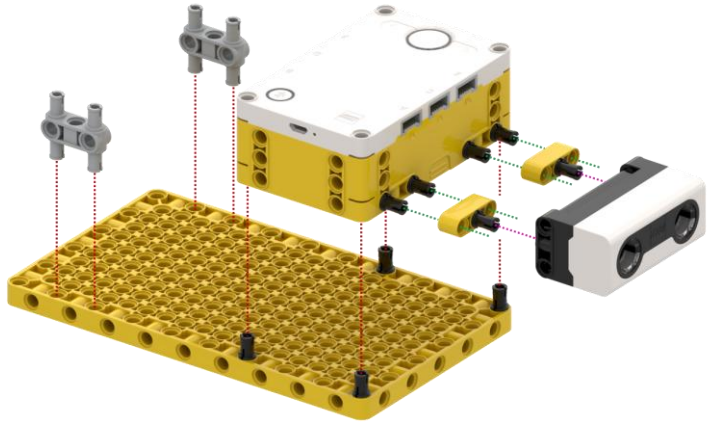


Crawler – Concept



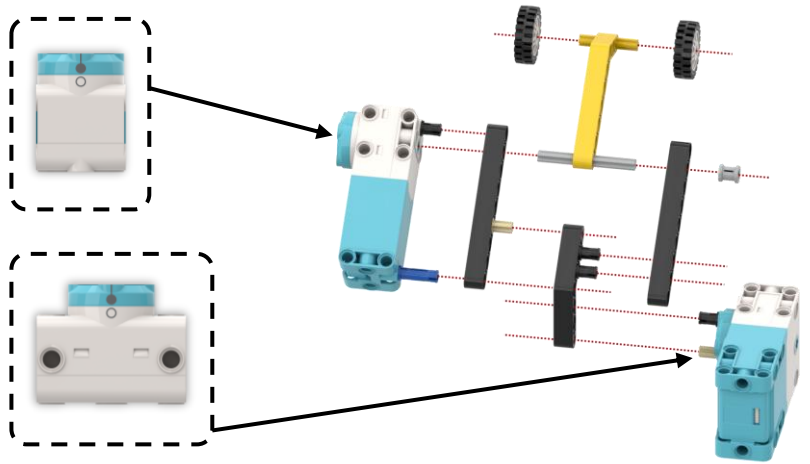
Crawler – Assembly

1



2

Place motors in zero positions!



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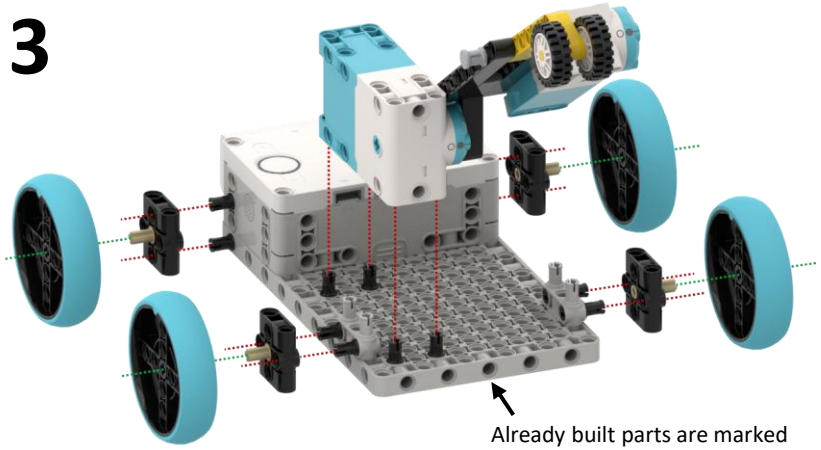
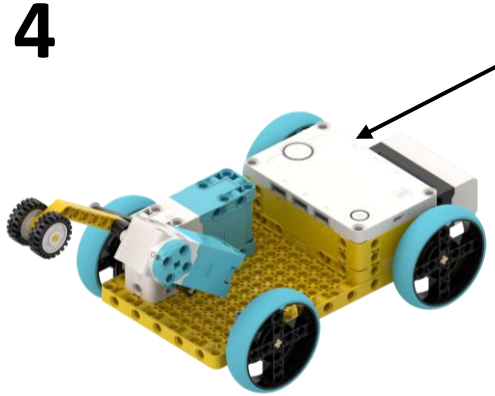
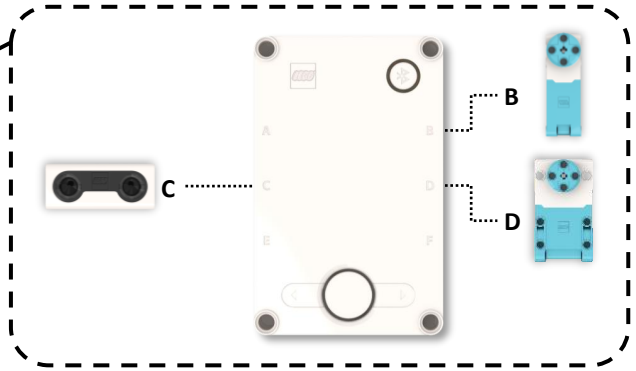


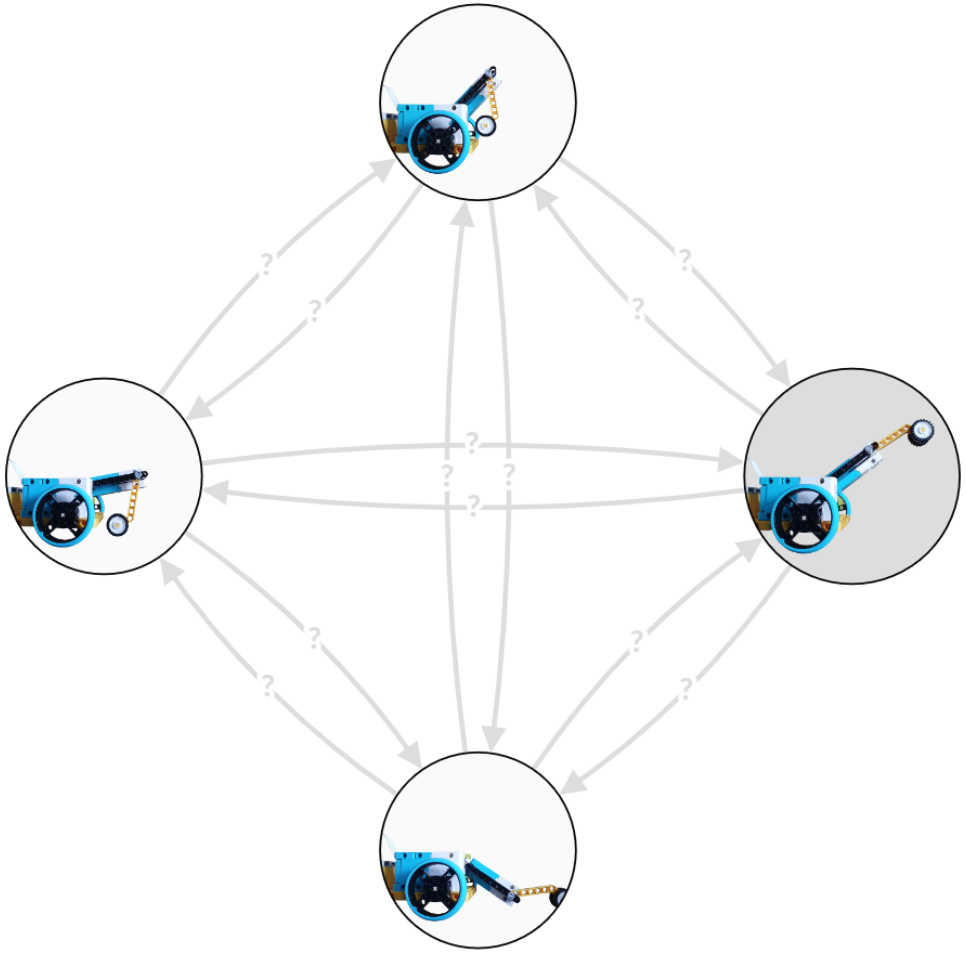
Already built parts are marked with light gray color

4

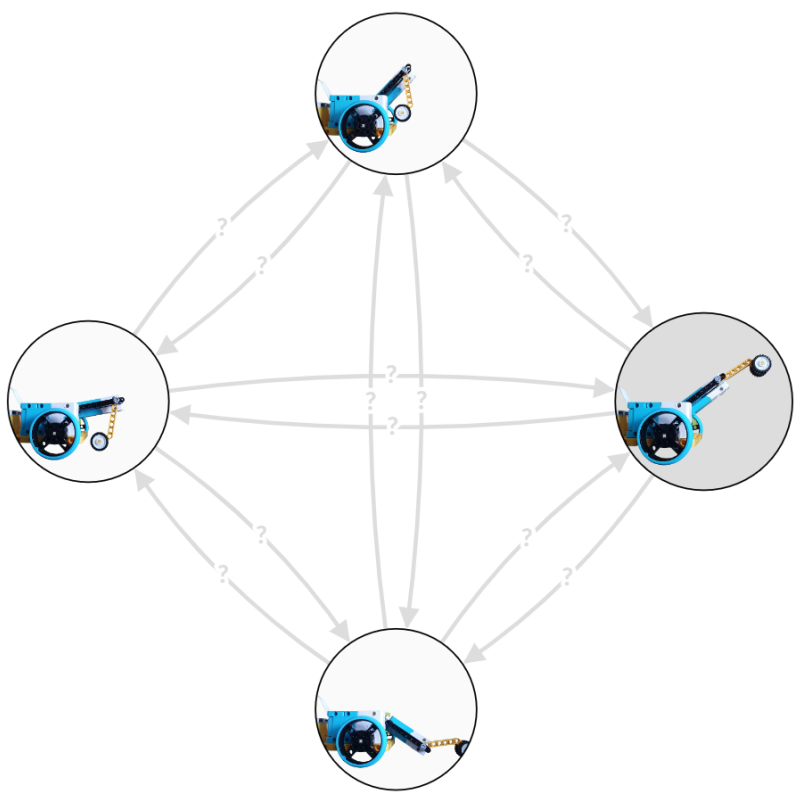


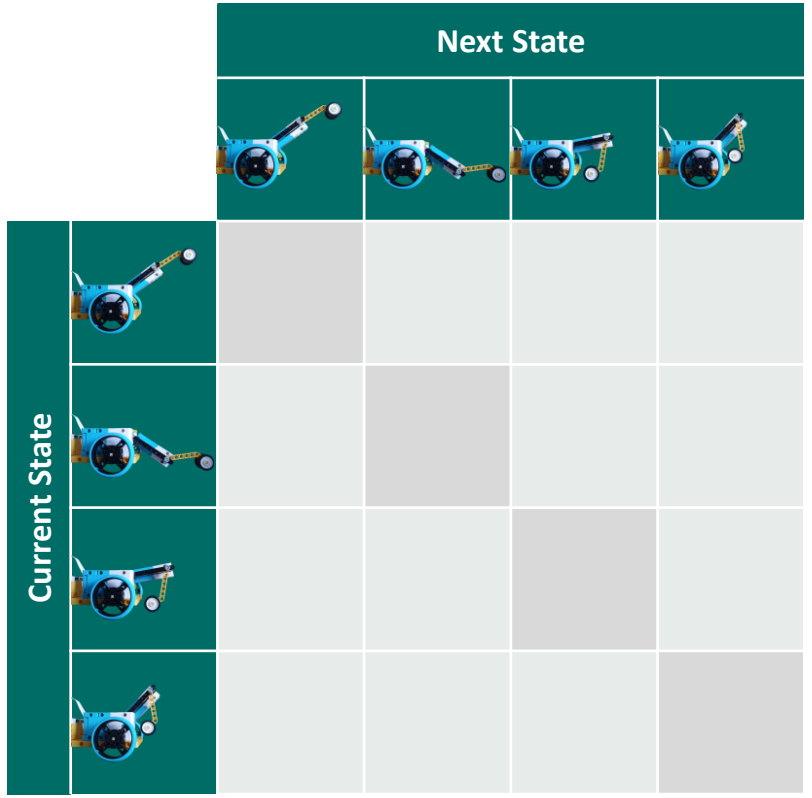


How good is an action?



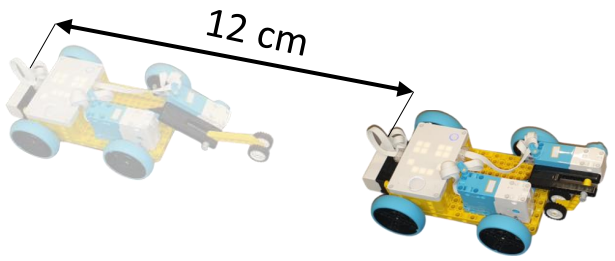
How good is an action?





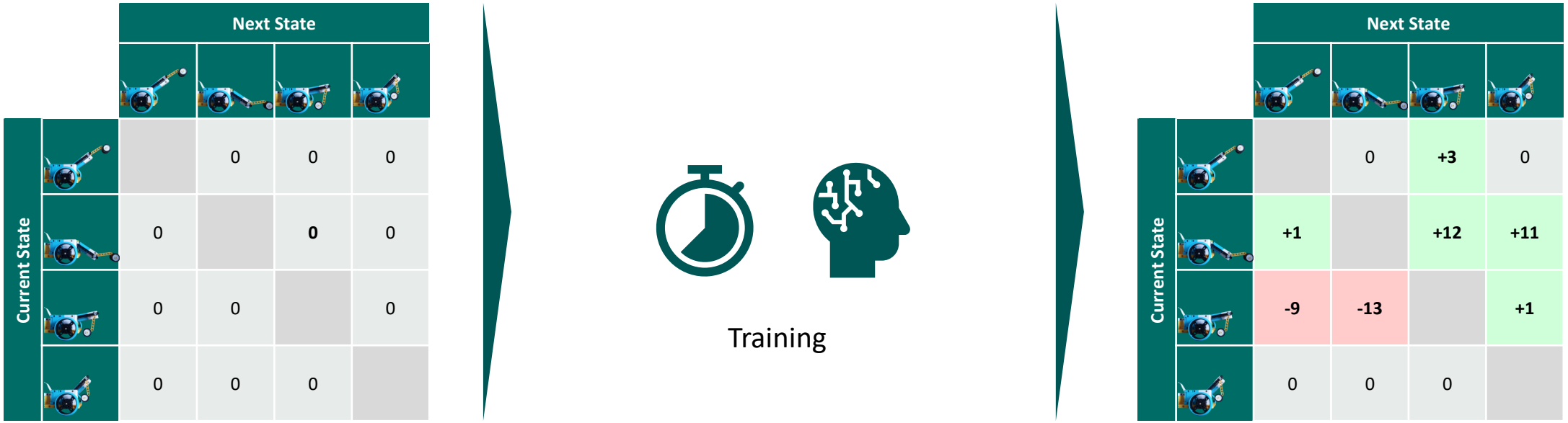
How good is an action?

Current State \ Next State				
		0	0	0
	0		**0**	0
	0	0		0
	0	0	0	

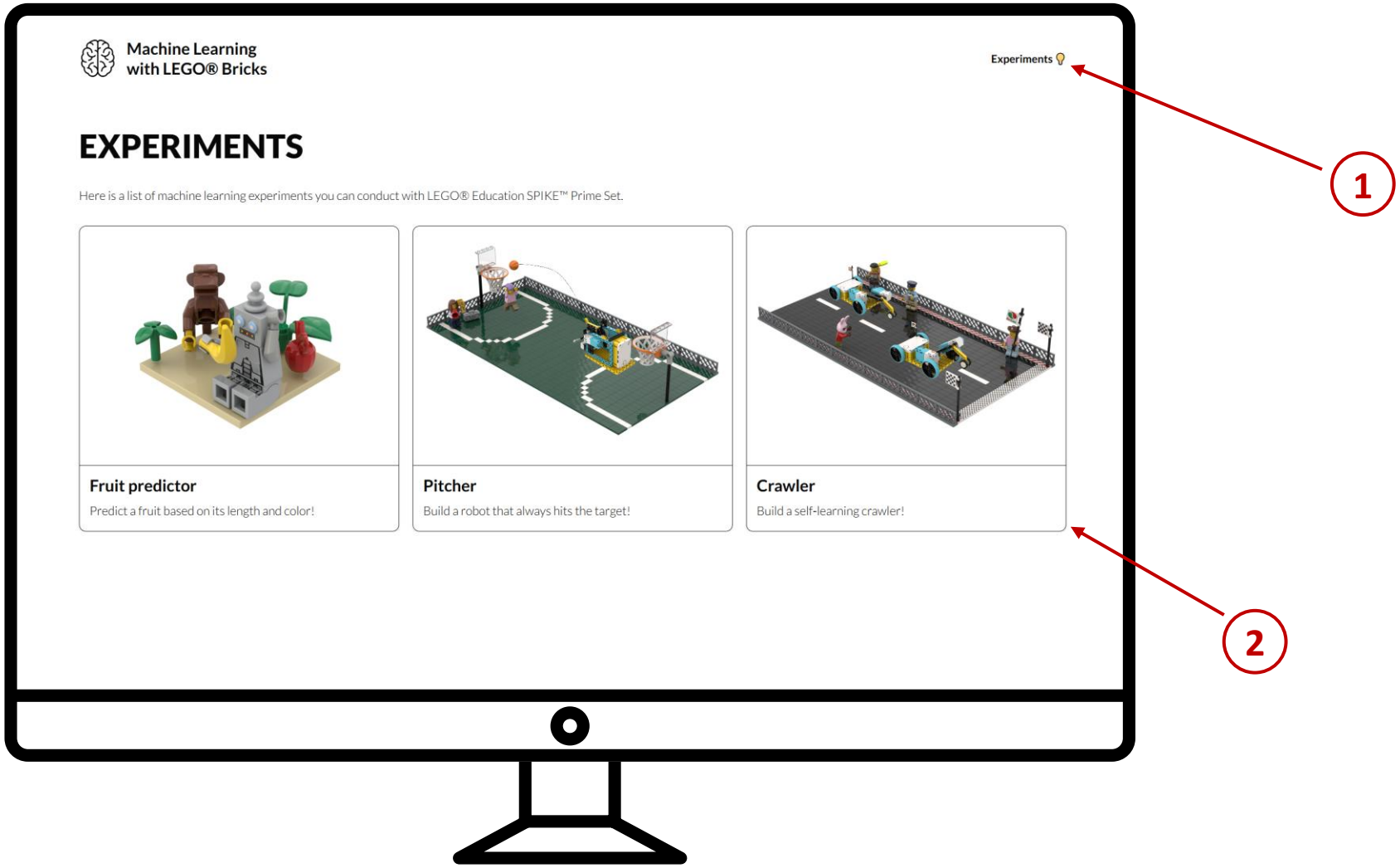


Current State \ Next State				
		0	0	0
	0		**+12**	0
	0	0		0
	0	0	0	

How good is an action?



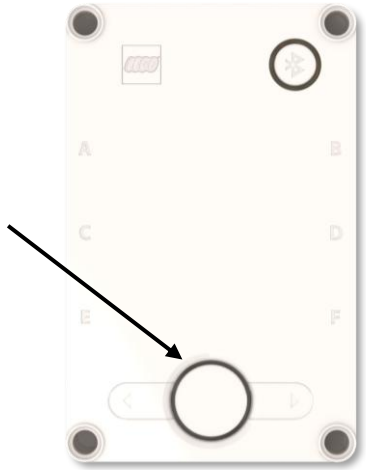
Open the experiment page



Connect hub and start the program

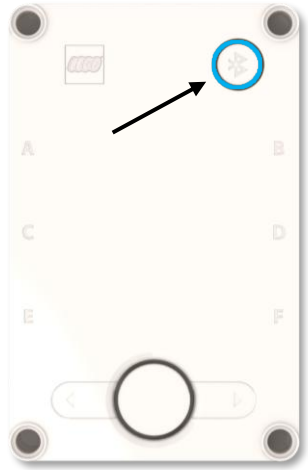
1

Switch on the hub by pressing the large button for about 3 seconds.



2

Click on the Bluetooth button and wait until the hub starts beeping.



3

Click on ''Connect hub'', find your hub in the window, select it and click on '''Pair'''.

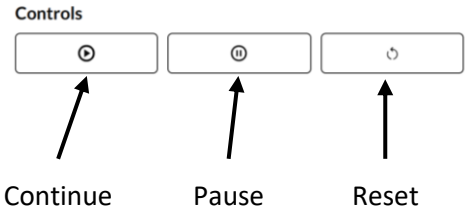
4

Click on 'Start program' and wait until a notification appears on the website.

Crawler – Training

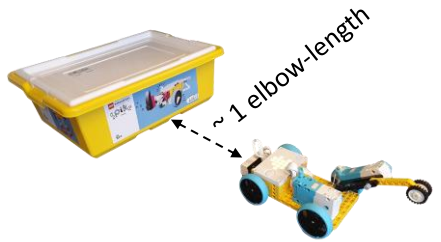
1

Reset the experiment.



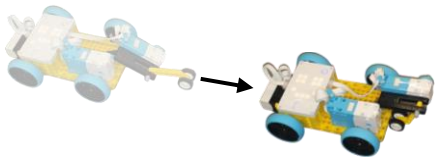
2

Place the crawler about one elbow-length away from the box, with the distance sensor facing the box.



3

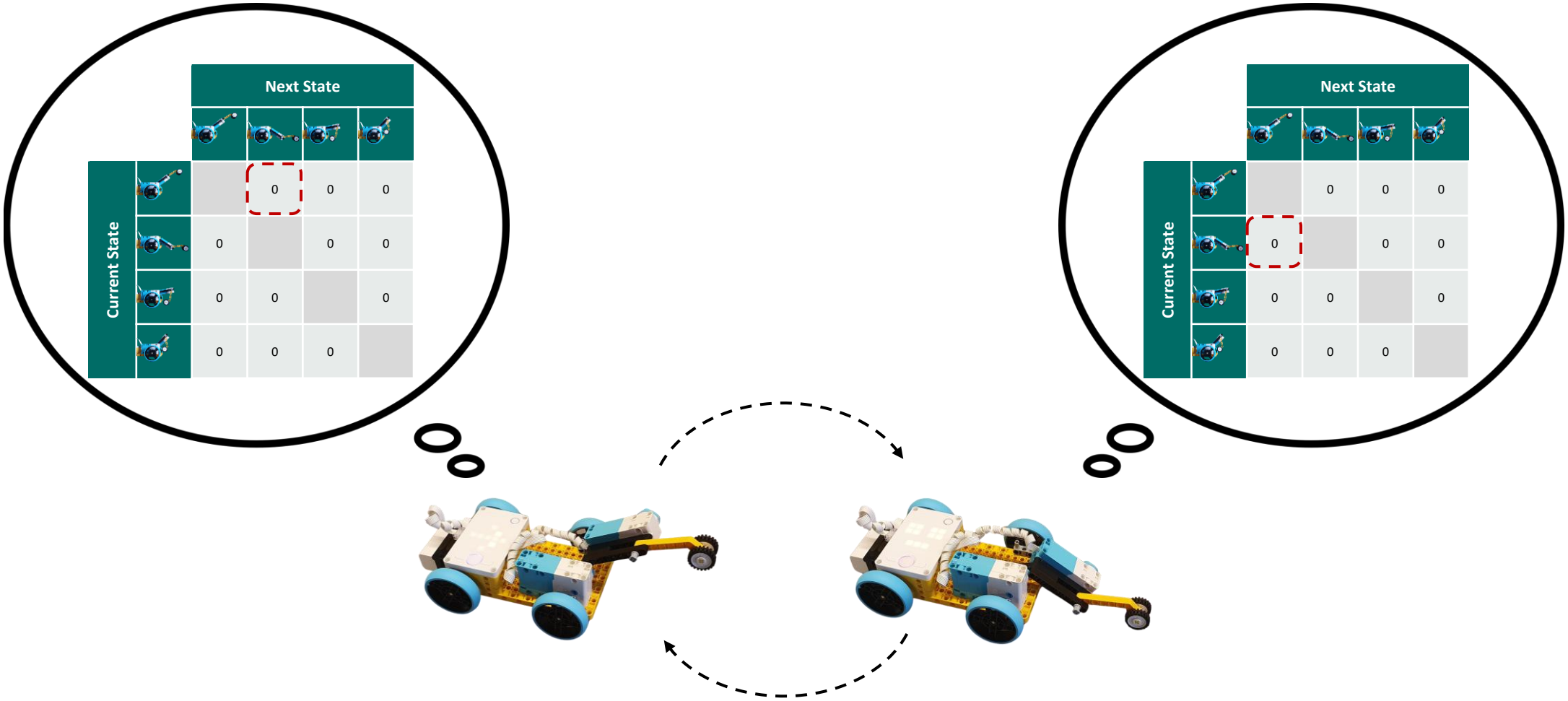
Click "Continue" so the crawler makes a movement.



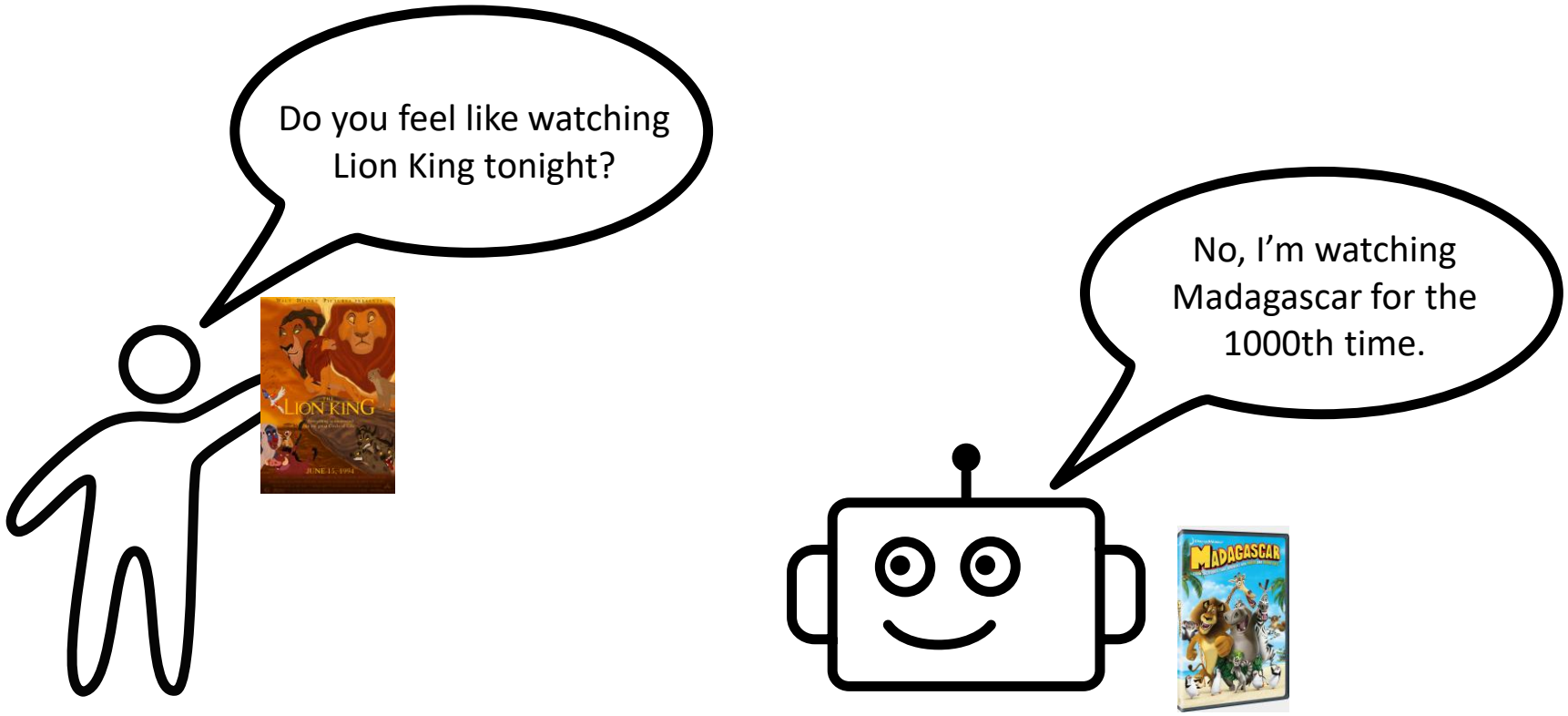
4

Observe how the table gets filled.

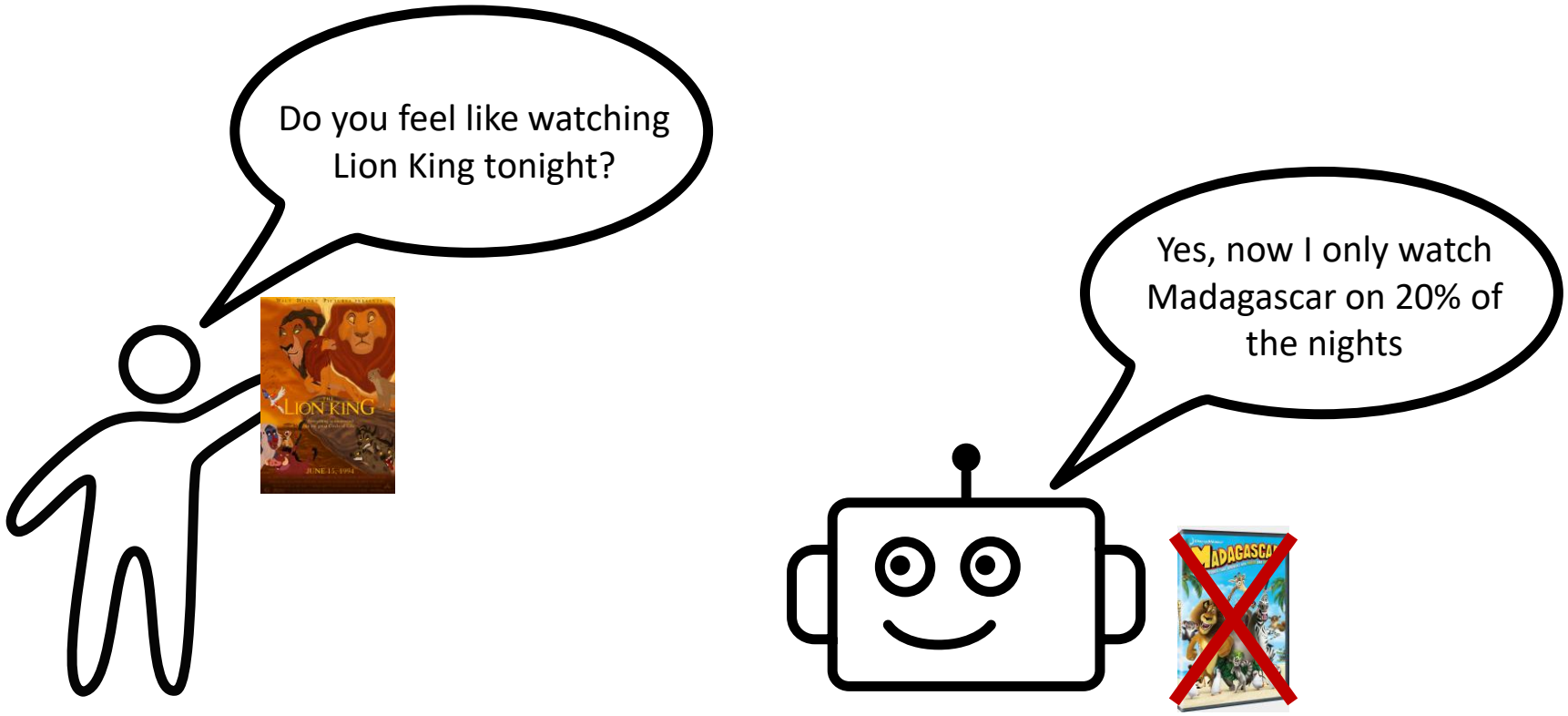
Why is it not working?



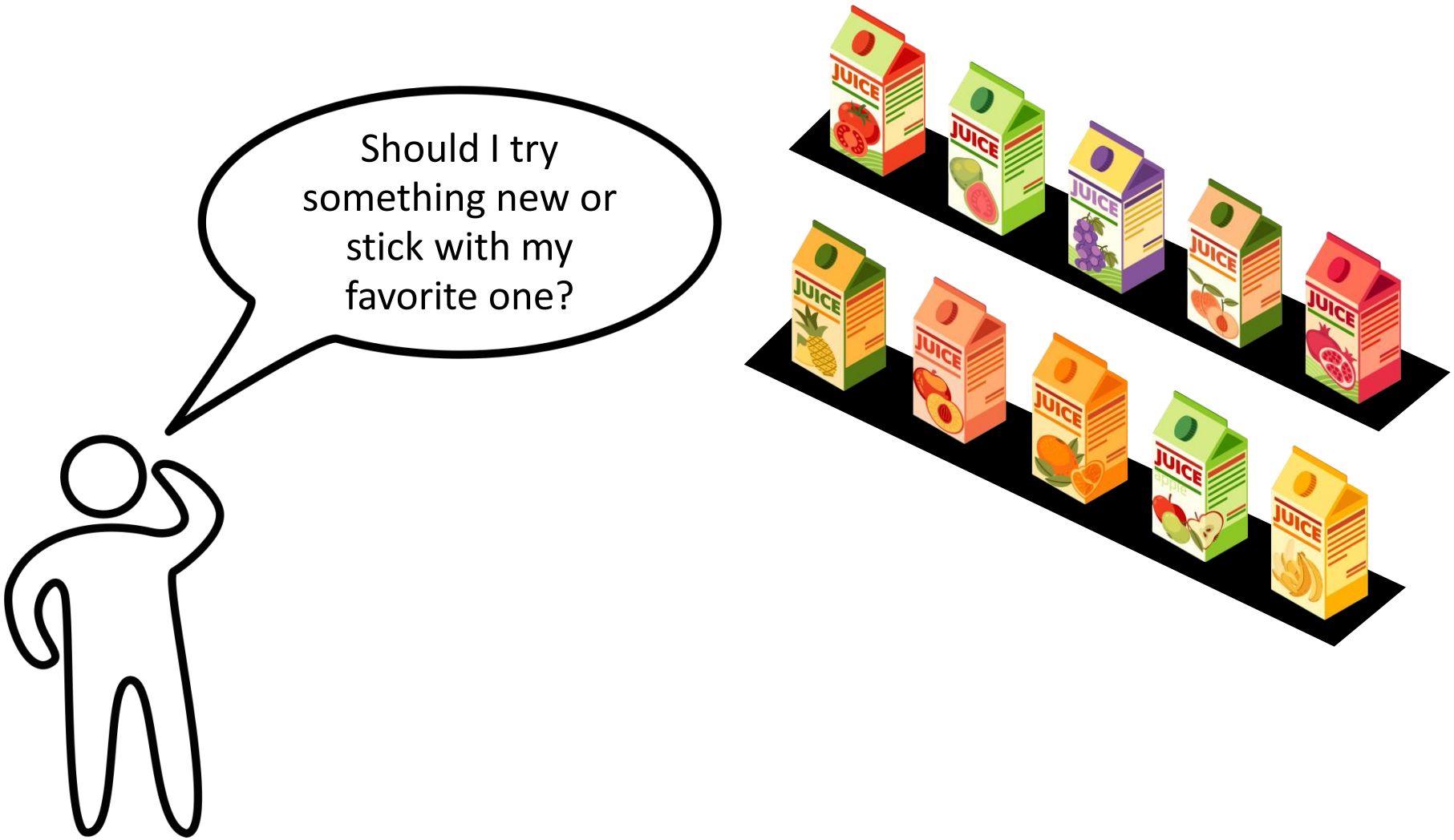
Trying something new?



Trying something new?

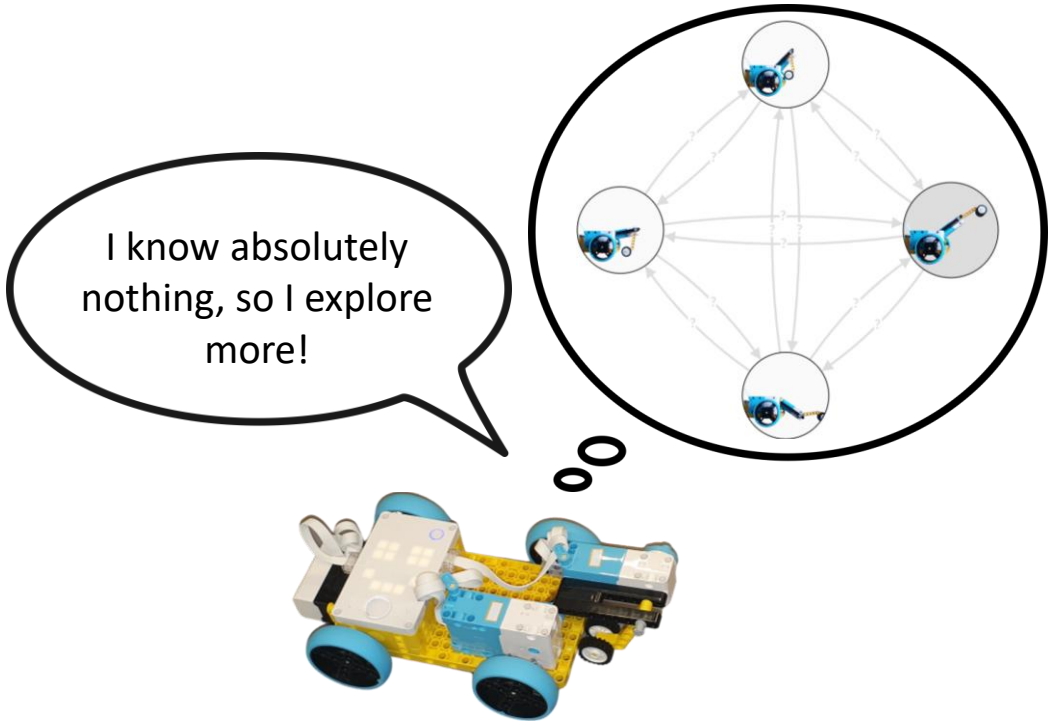


Exploration-Exploitation-Dilemma

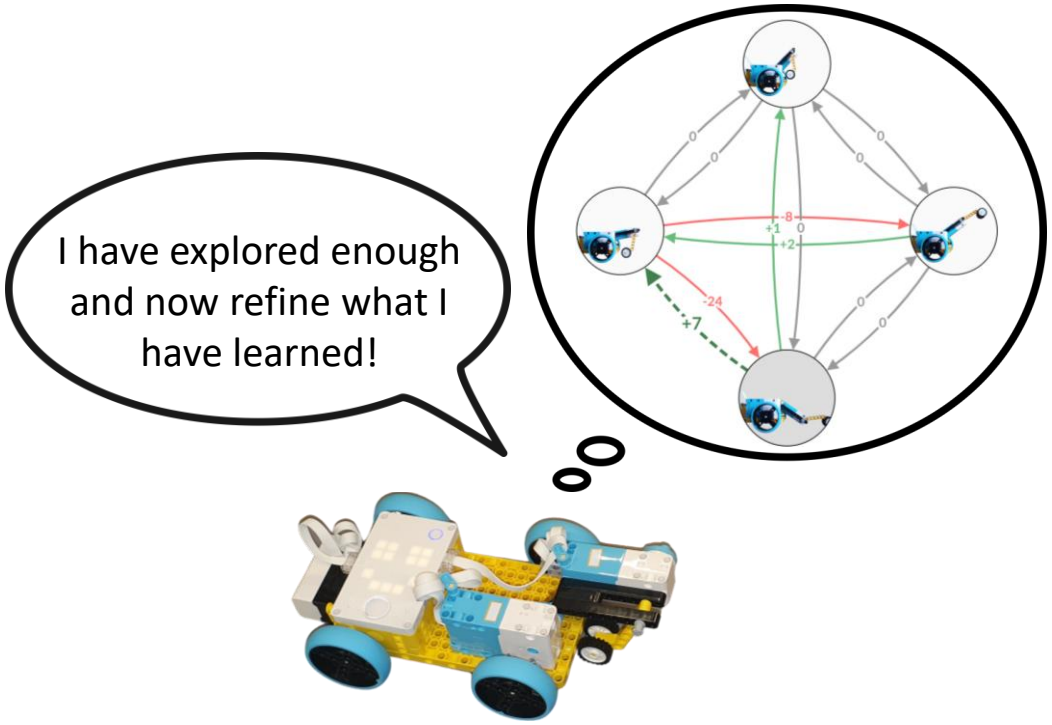


Exploration-Exploitation-Dilemma

Beginning of training



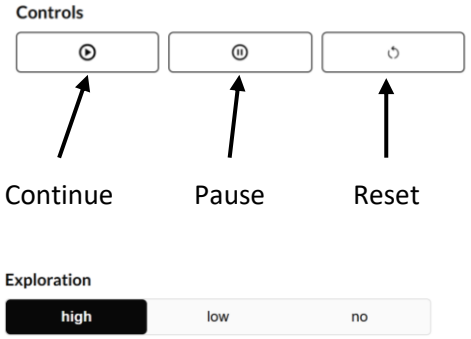
End of training



Crawler – Training

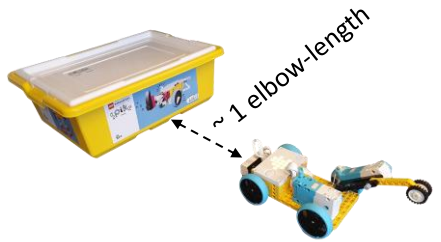
1

Reset the experiment. Set exploration to high.



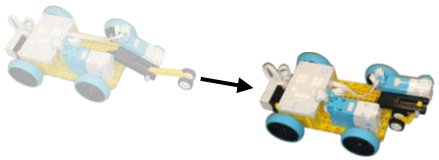
2

Place the crawler about one elbow-length away from the box, with the distance sensor facing the box.



3

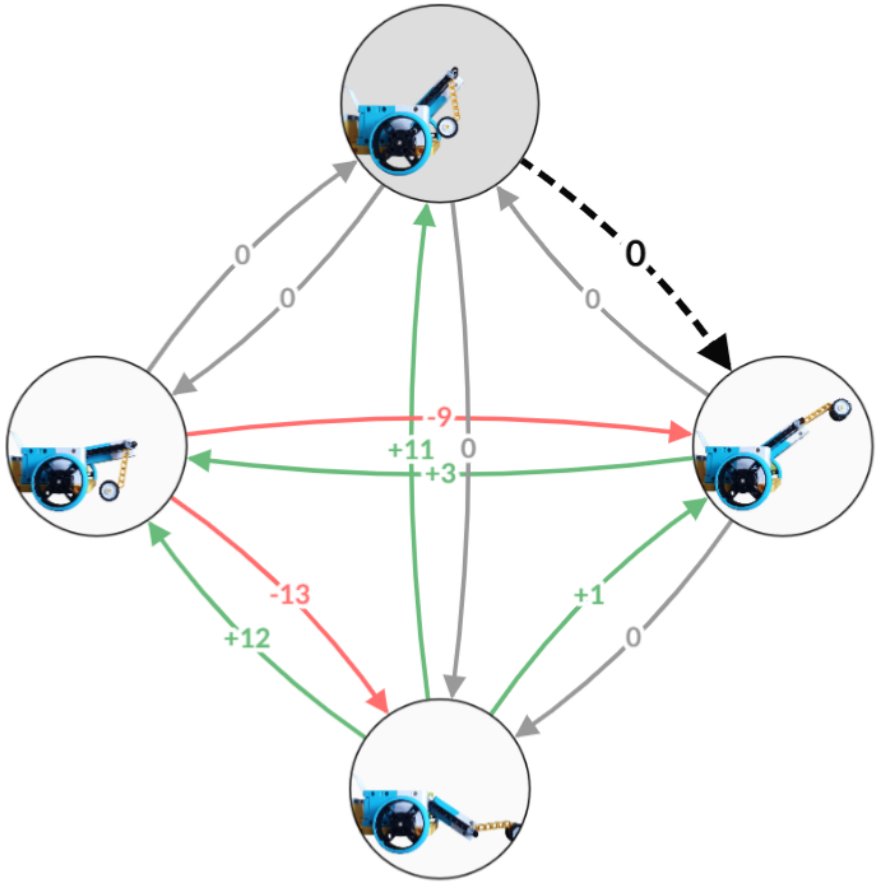
Click "Continue" so the crawler makes a movement.



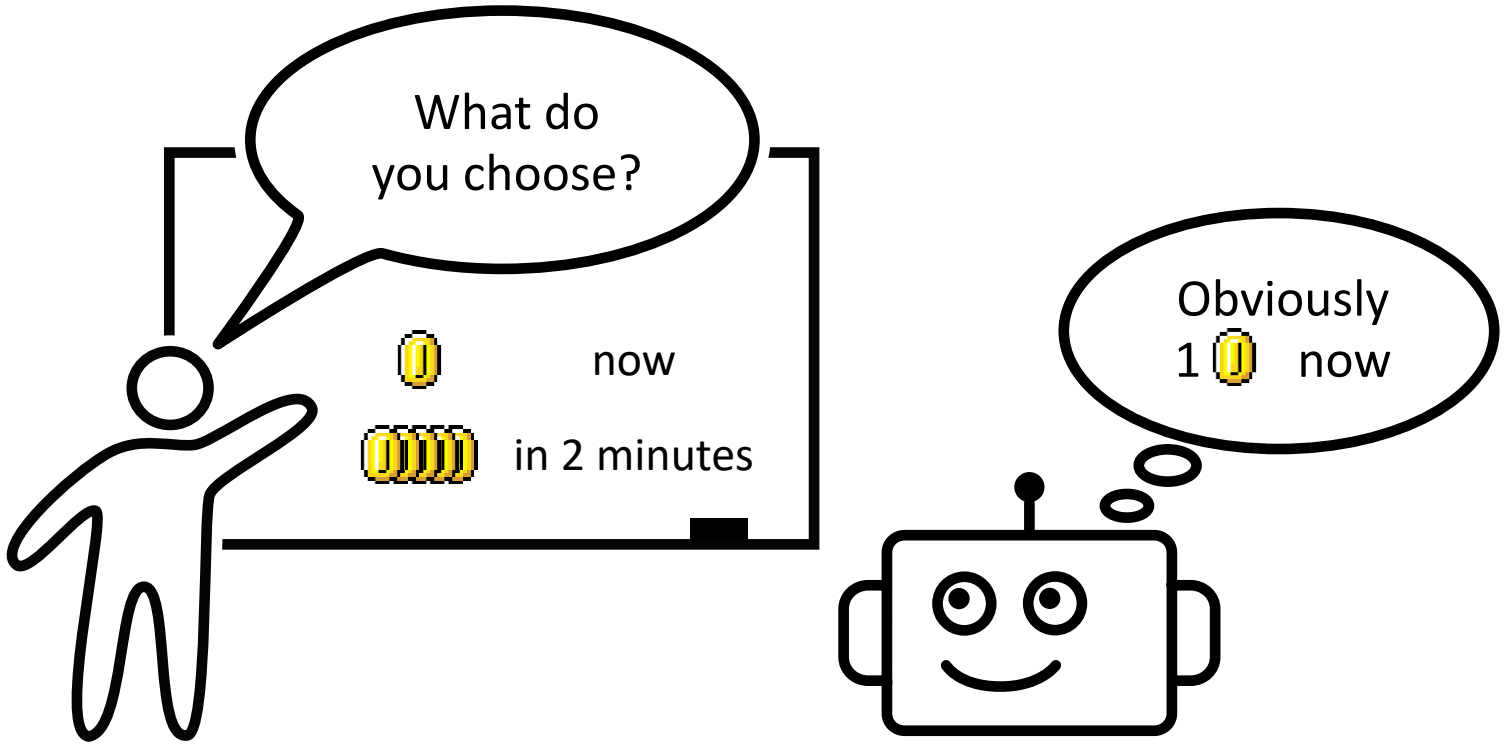
4

Observe how the table gets filled. Reduce exploration over time.

Foresight

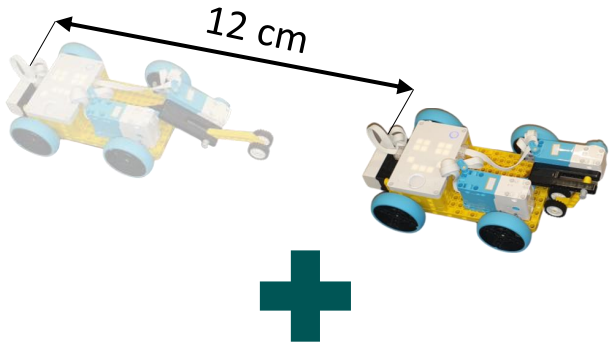


Foresight



Foresight

Current State \ Next State				
		0	+3	0
	+1		+12	+11
	-9	-13		+1
	0	0	0	



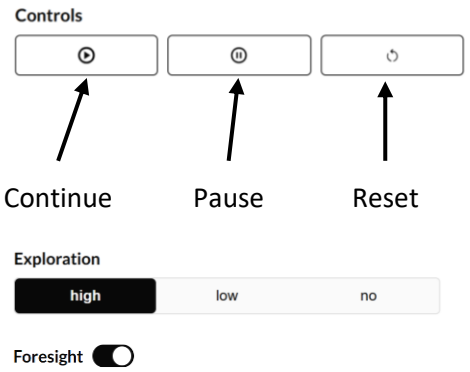
	-9	-13		+1

Current State \ Next State				
		0	+3	0
	+1		+13	+11
	-9	-13		+1
	0	0	0	

Crawler – Training

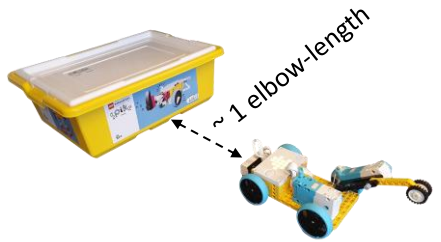
1

Reset the experiment. Set exploration to high. Turn on the foresight.



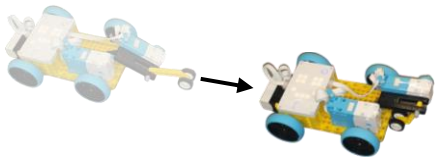
2

Place the crawler about one elbow-length away from the box, with the distance sensor facing the box.



3

Click "Continue" so the crawler makes a movement.



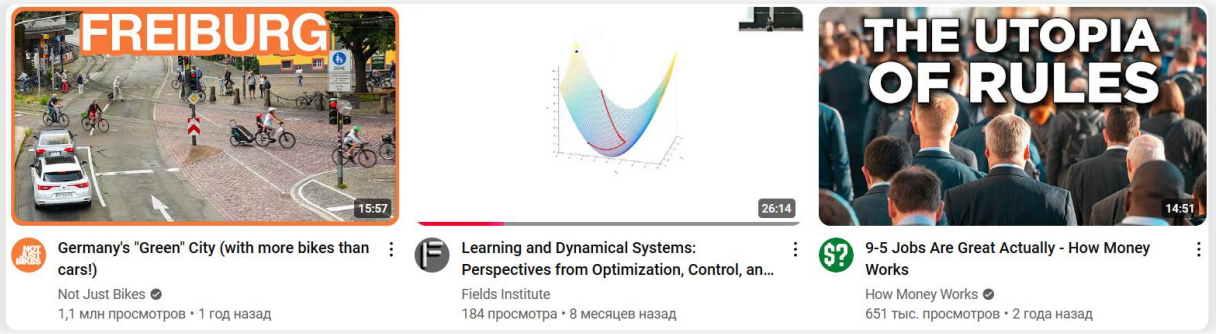
4

Observe how the table gets filled. Reduce exploration over time.

Other applications

Source: ChatGPT

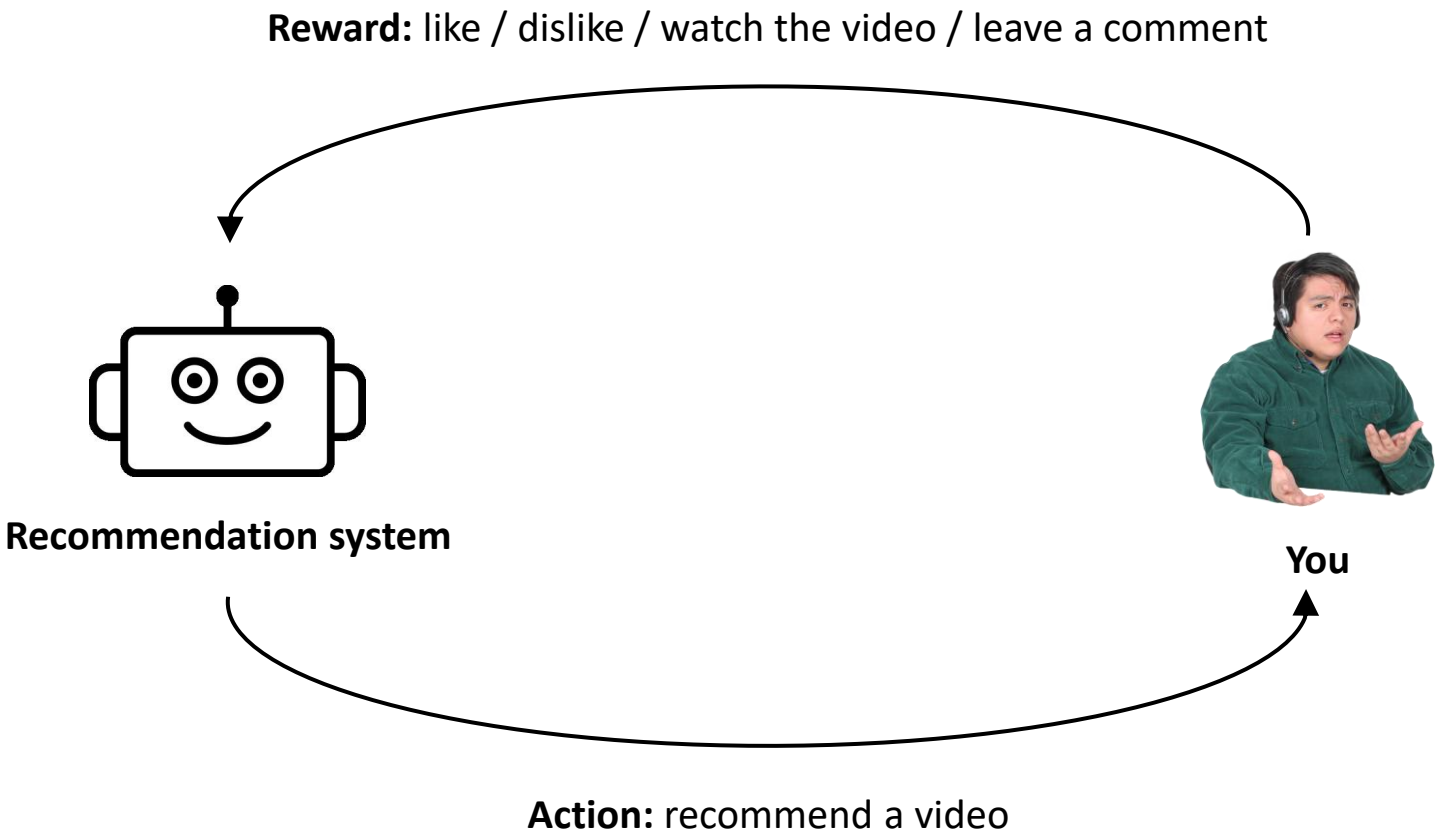
Reward (+1/-1)



Source: YouTube

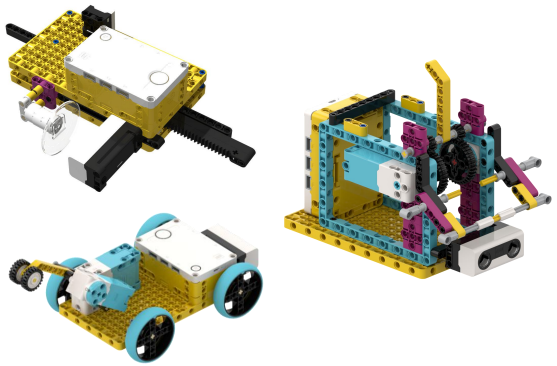
- Clicked = +1
- Watched 10 minutes = +5
- Liked = +10
- Ignored the video = -10

How recommendation systems work

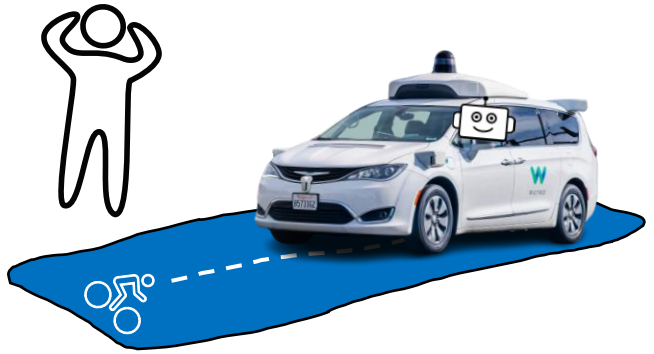


Summary

Machine learning is no magic



Machine learning can do a lot



Power brings responsibility