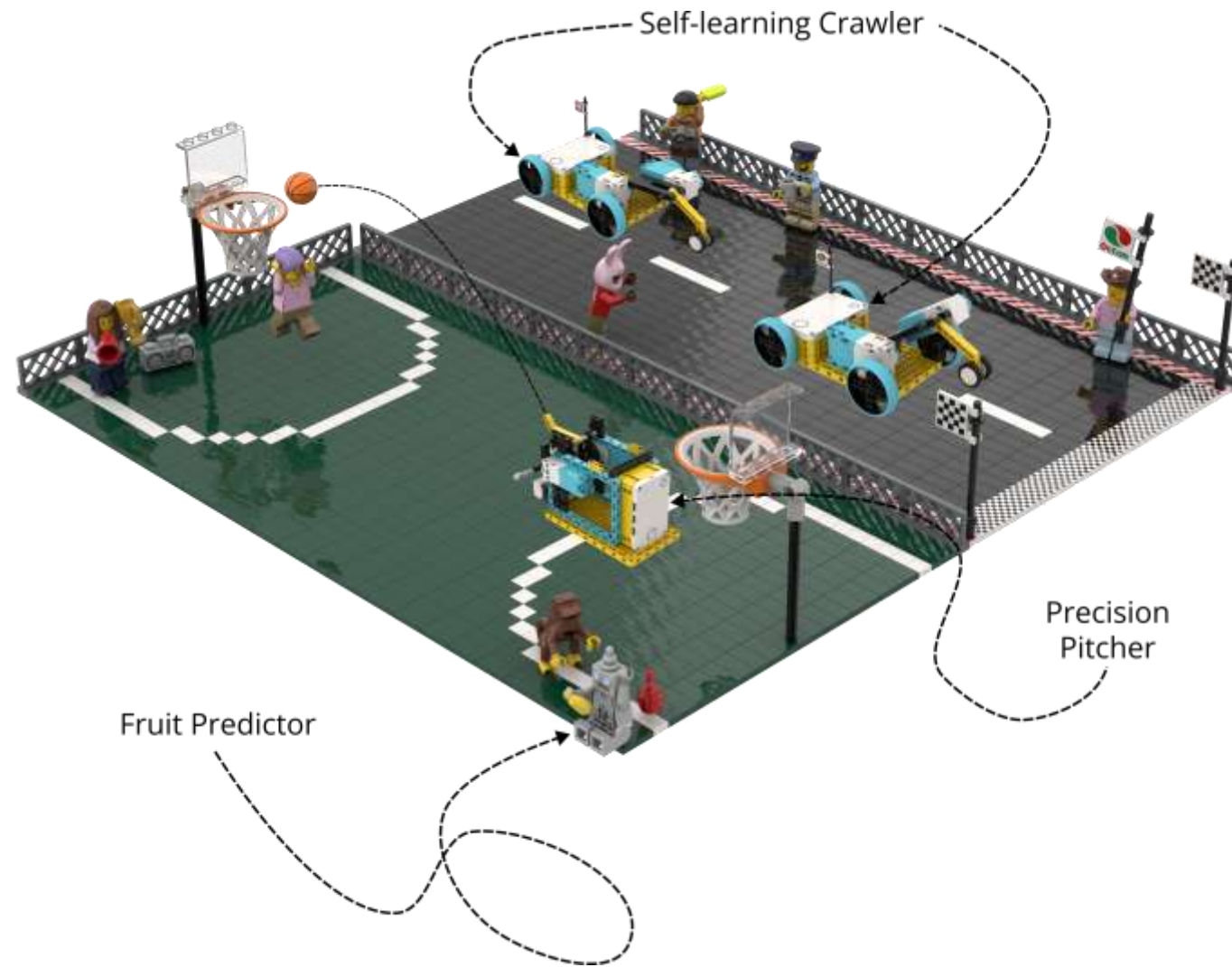


Machine Learning with LEGO® Bricks

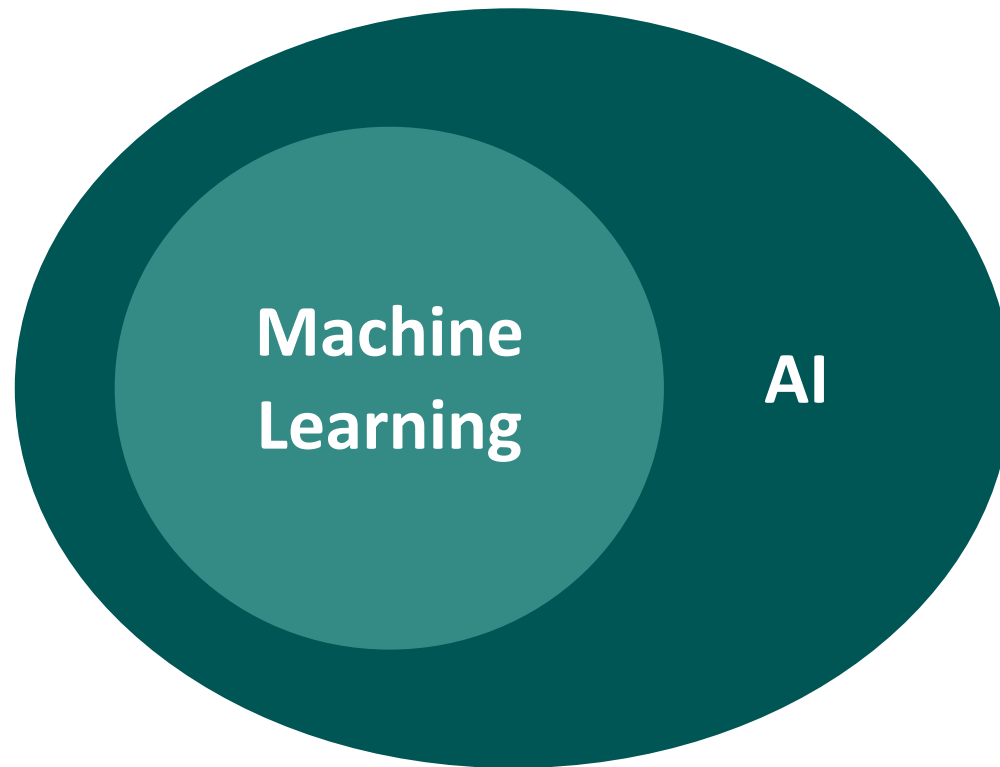
Viacheslav Sydora

Course overview



What is machine learning?

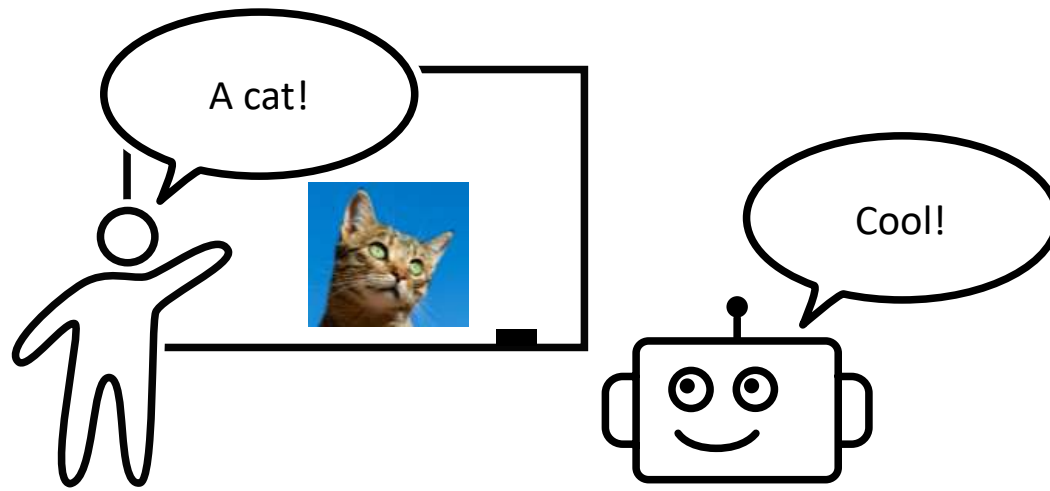
- Subfield of artificial intelligence



What is machine learning?

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

Machine Learning

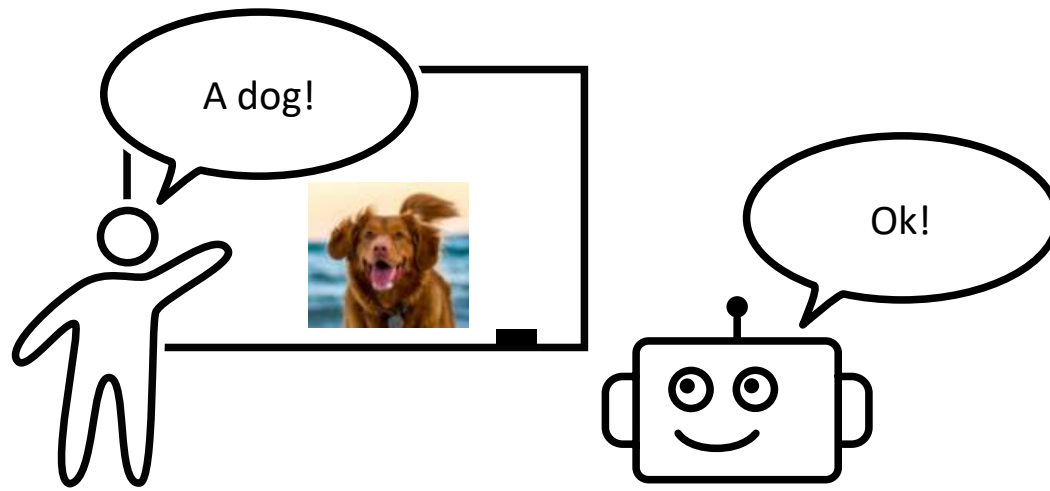


Not Machine Learning

What is machine learning?

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

Machine Learning

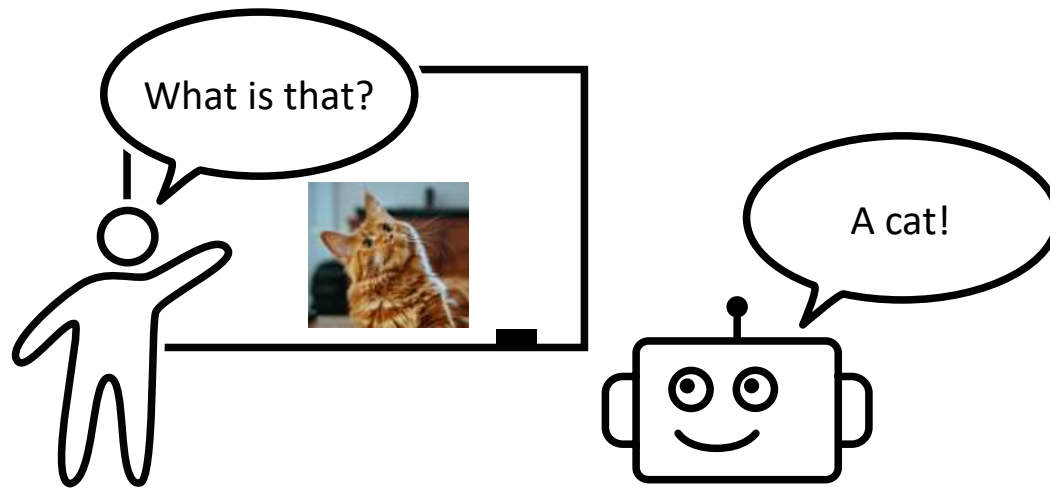


Not Machine Learning

What is machine learning?

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

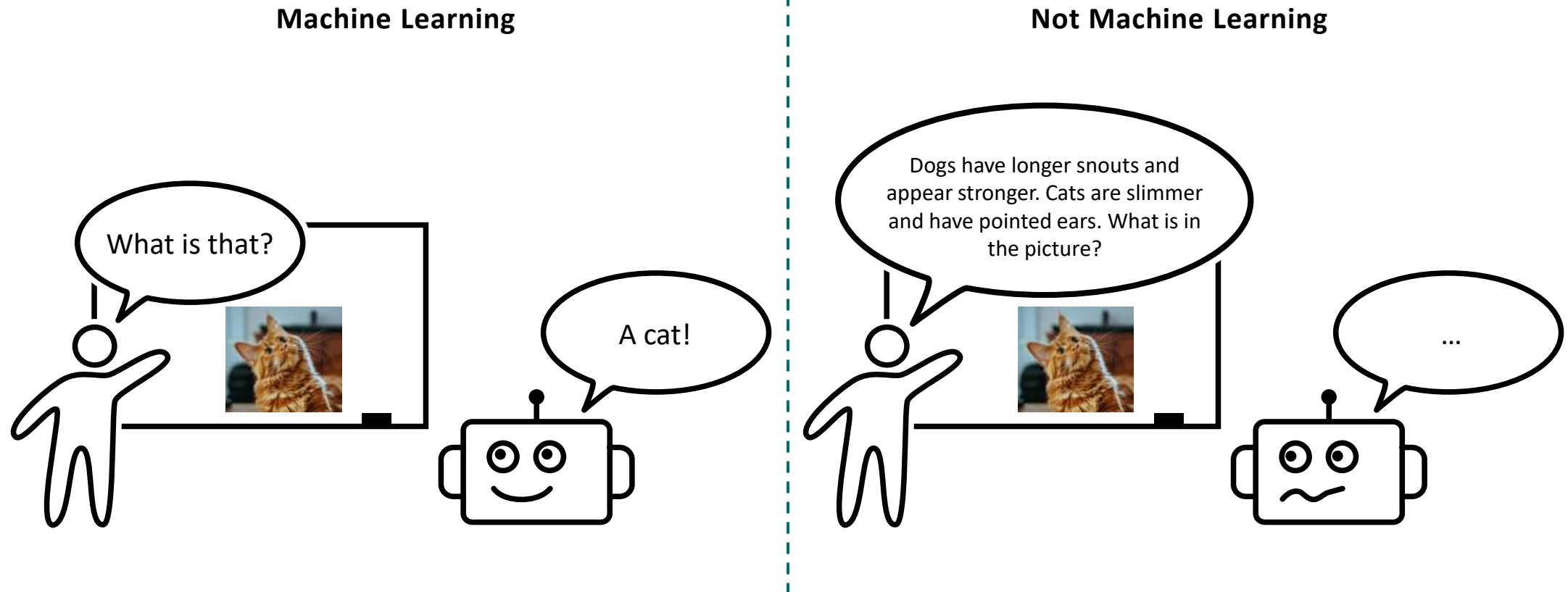
Machine Learning



Not Machine Learning

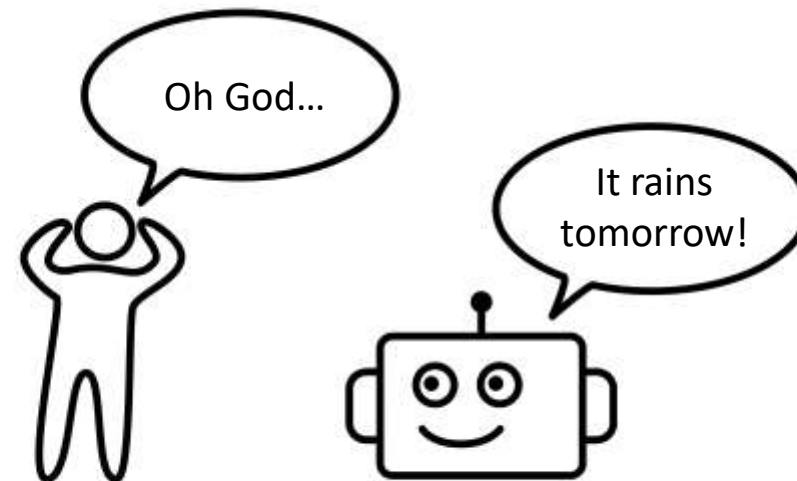
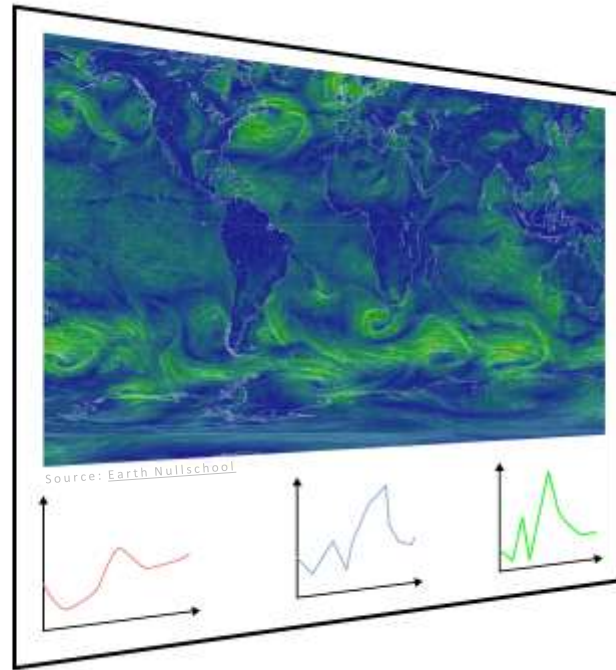
What is machine learning?

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

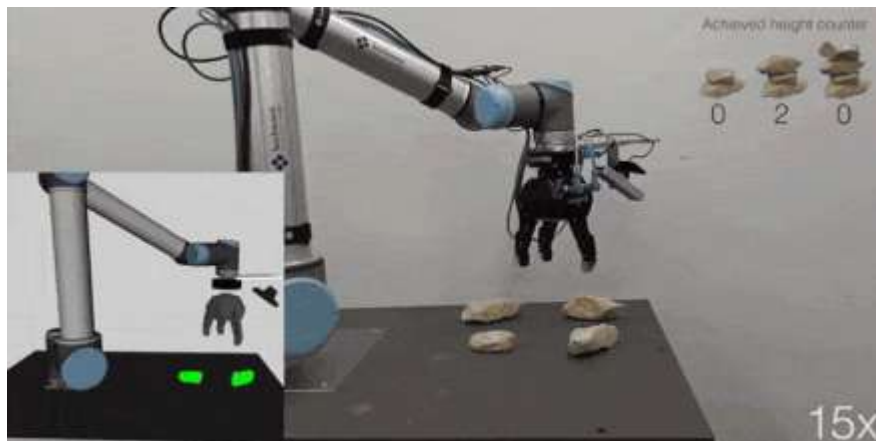


Why machine learning?

- works automatically
- can surpass humans



What else can machine learning do?



Source: [freeCodeCamp](https://www.freecodecamp.org/)

What can I help with?

Ask anything



Search

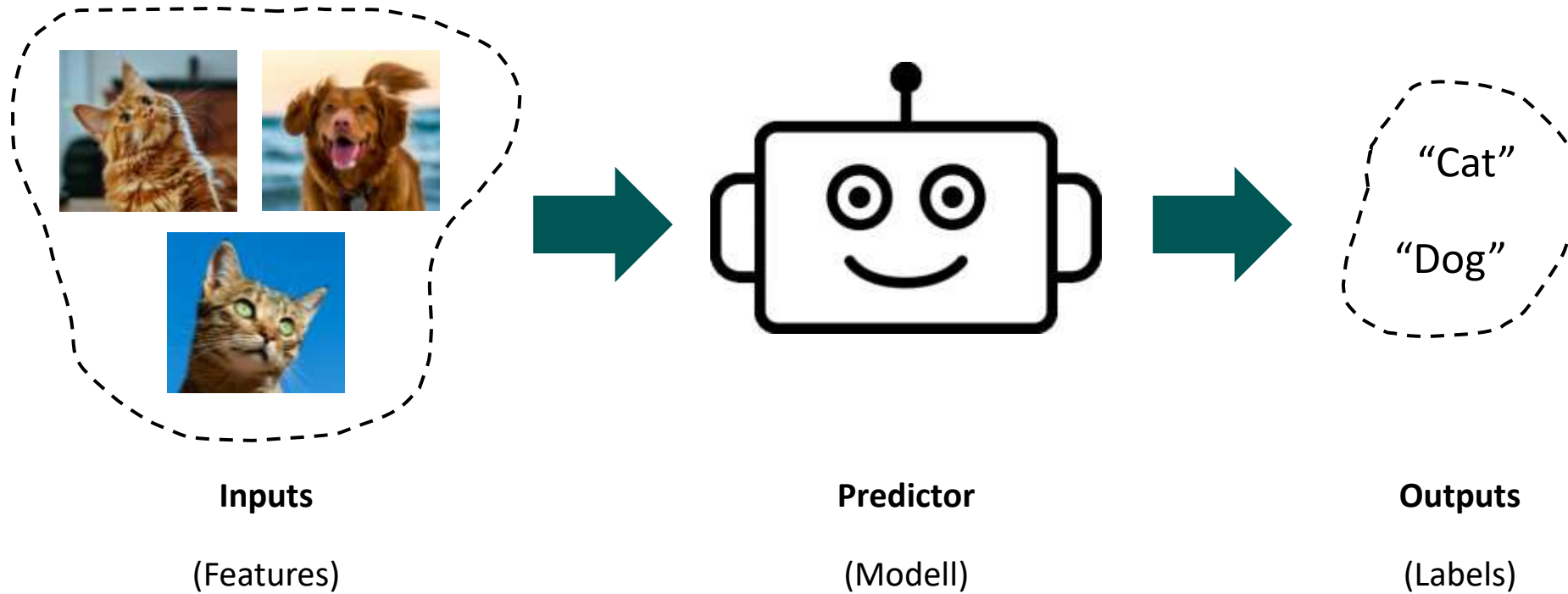
Reason



Source: [ChatGPT](https://chatgpt.com/)

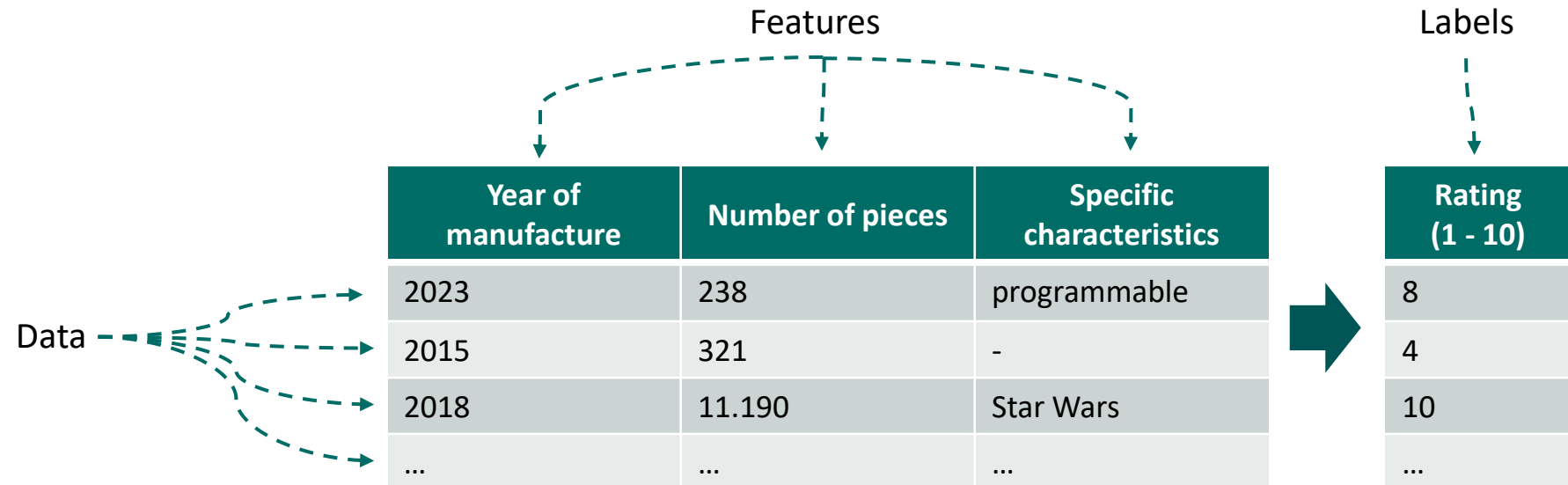
Data, Features & Labels

- **Learning patterns from examples**



Data, Features & Labels

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

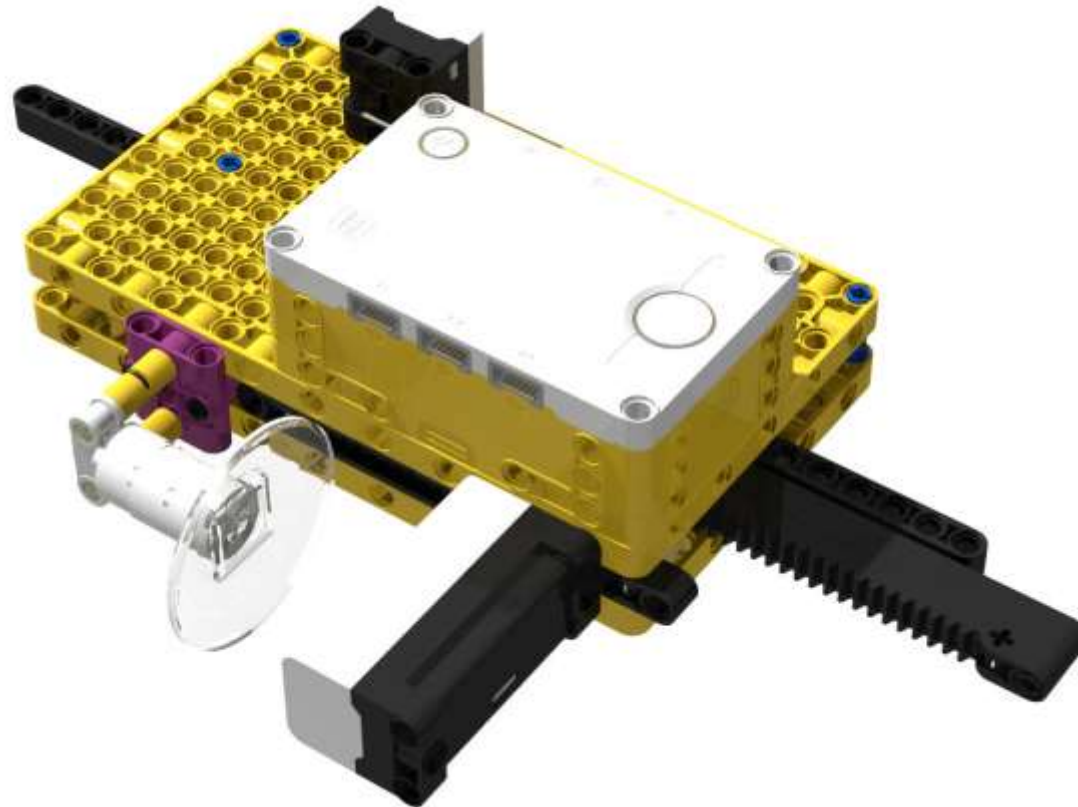


Automatic fruit detector – Concept

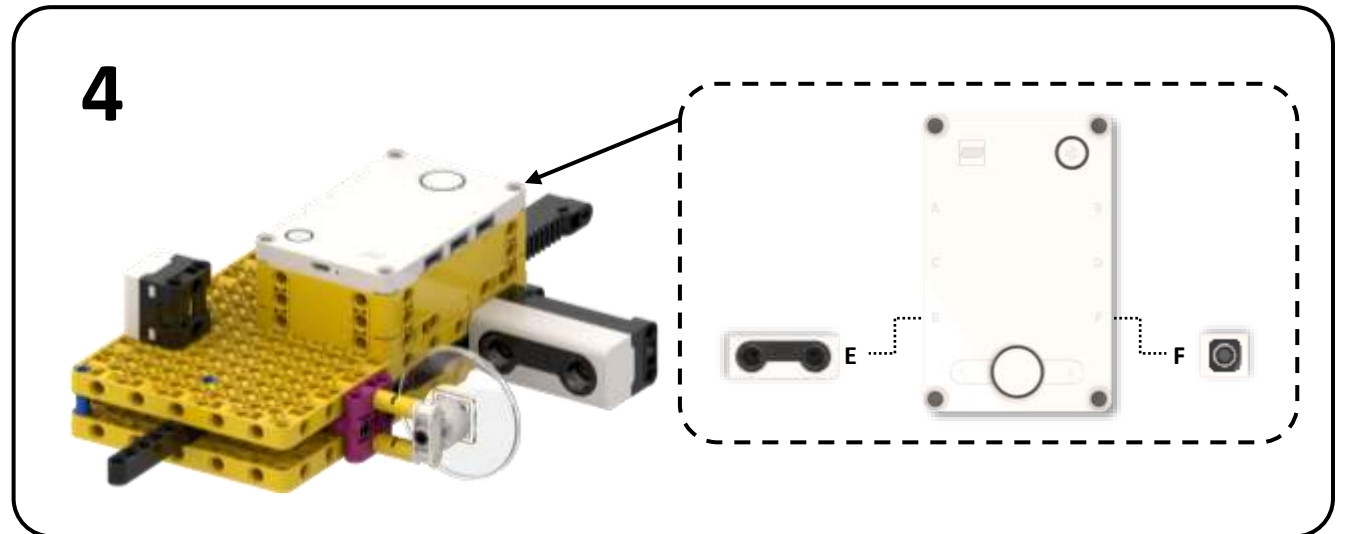
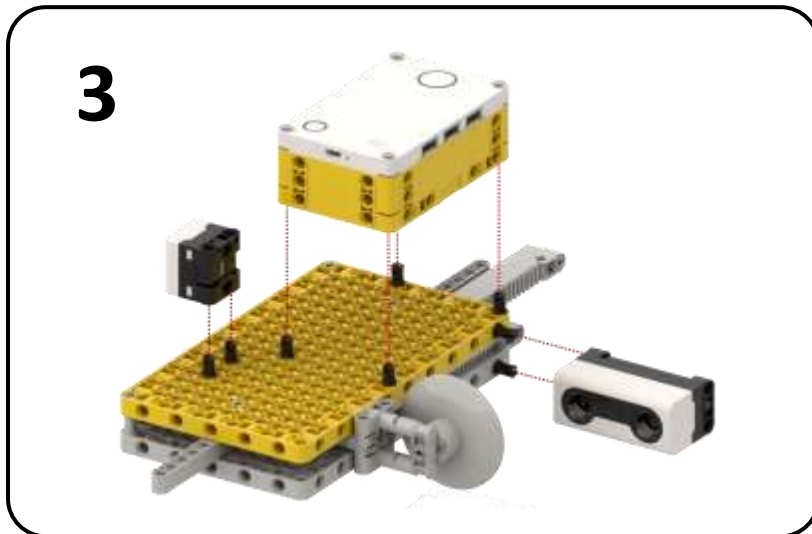
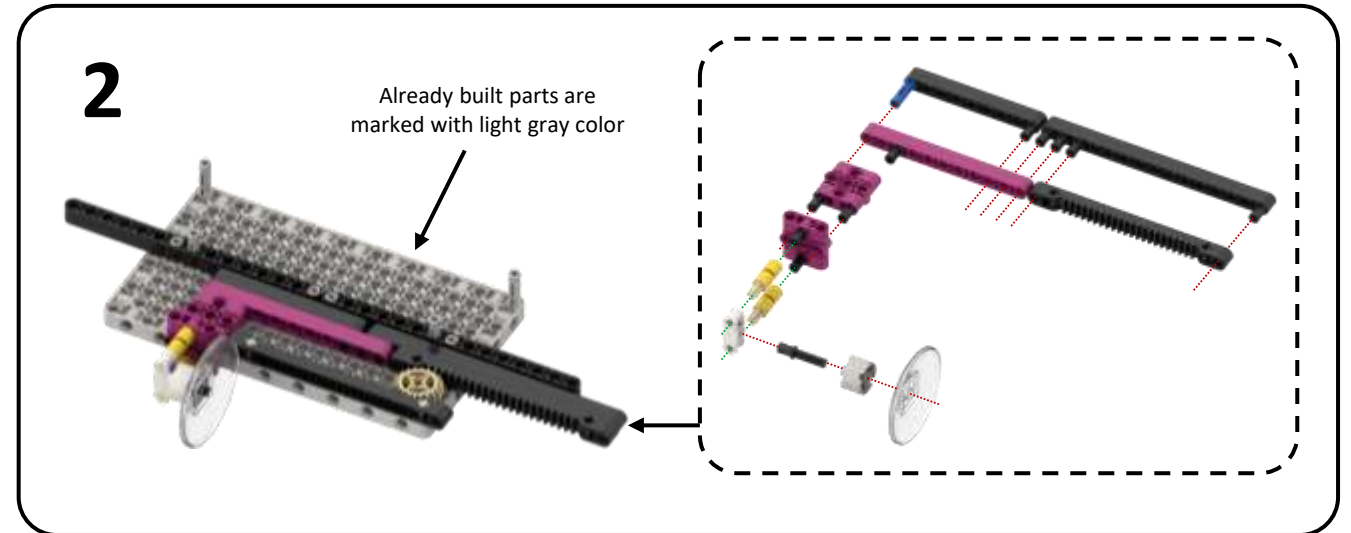
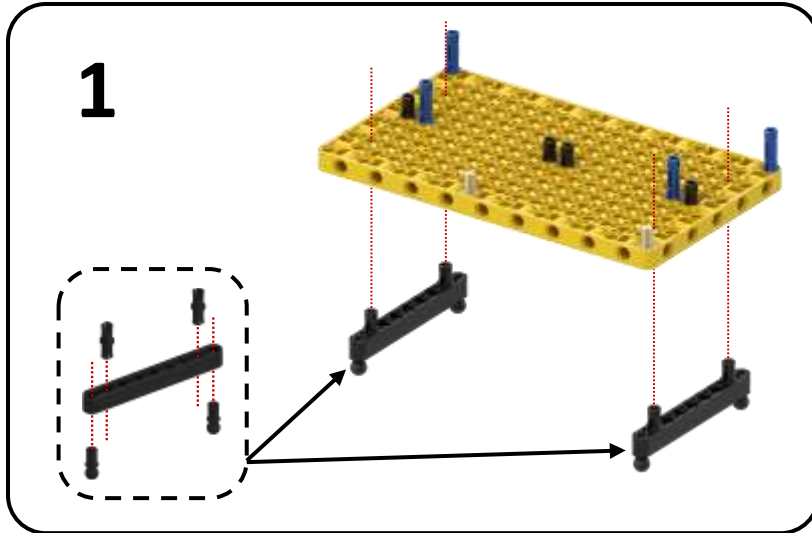
- **Features:** ?
- **Label:** ?

Automatic fruit detector – Concept

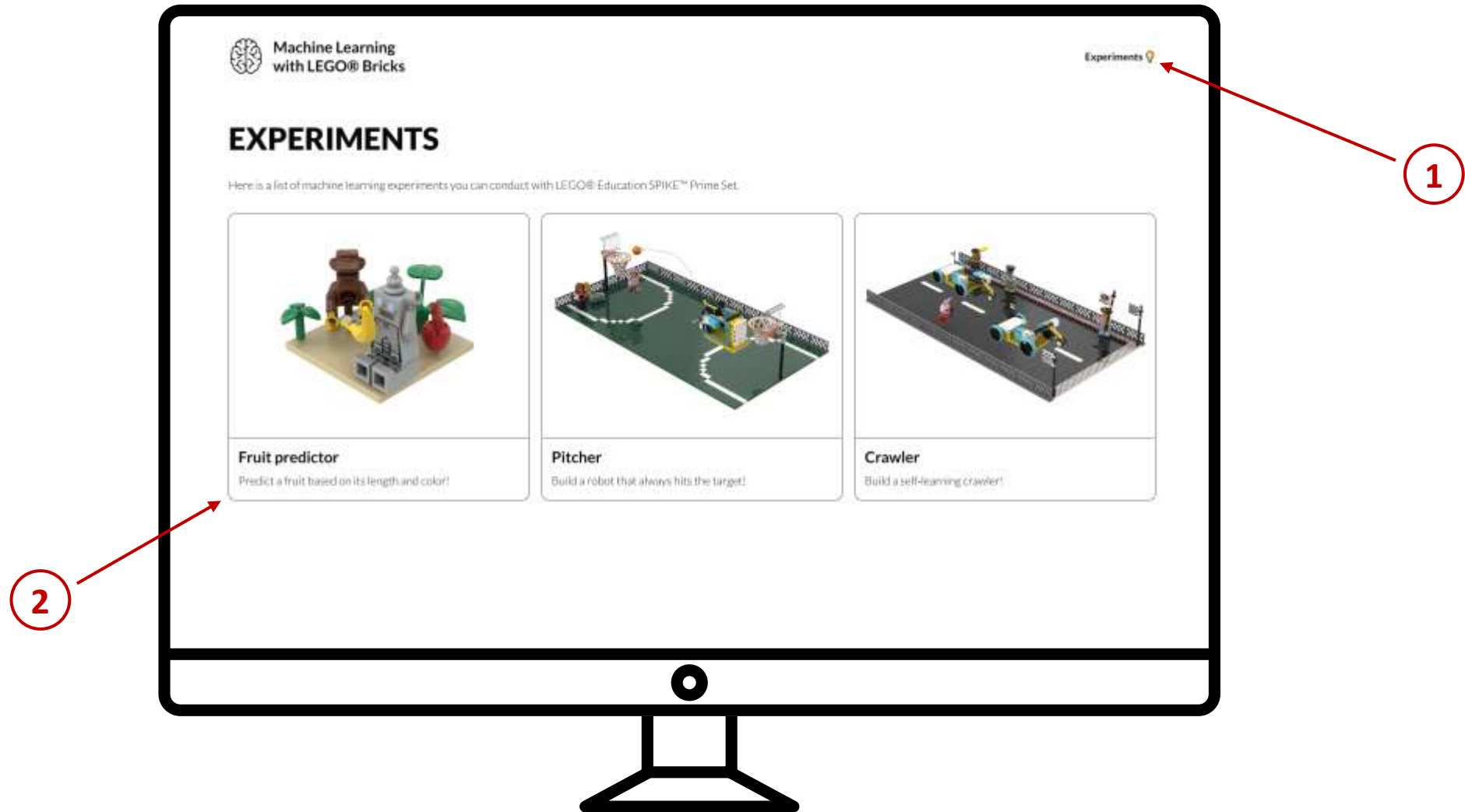
- **Features:** length and color of the fruit
- **Label:** fruit name (apple/banana)



Automatic fruit detector – Assembly



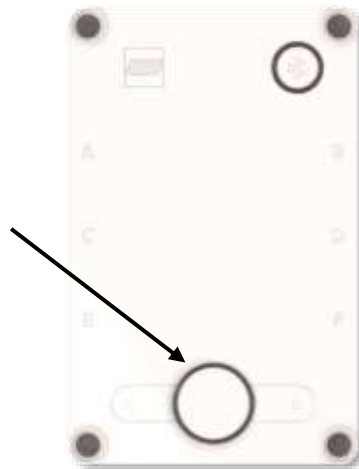
Open the experiment page



Connect hub and start the program

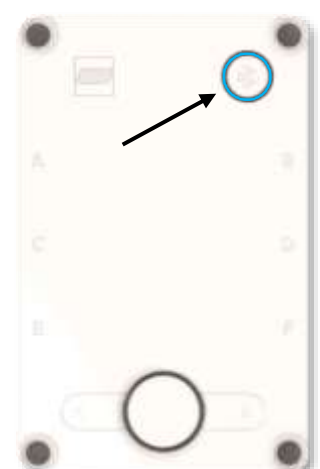
1

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.



Automatic fruit detector – Data collection

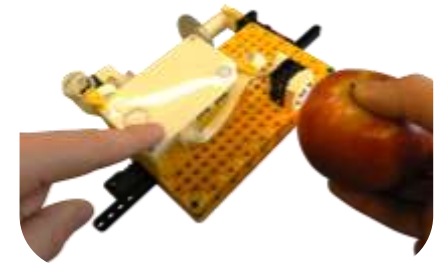
1

Select the fruit for which data will be collected.



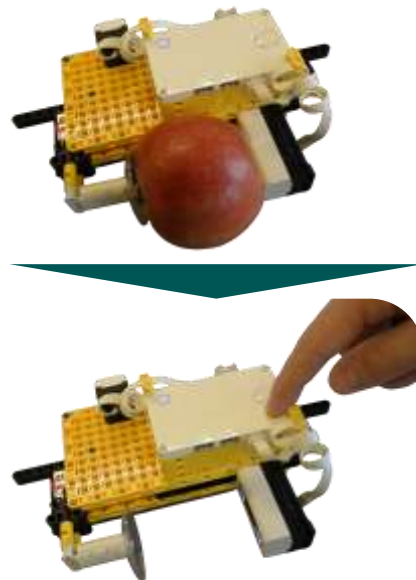
2

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



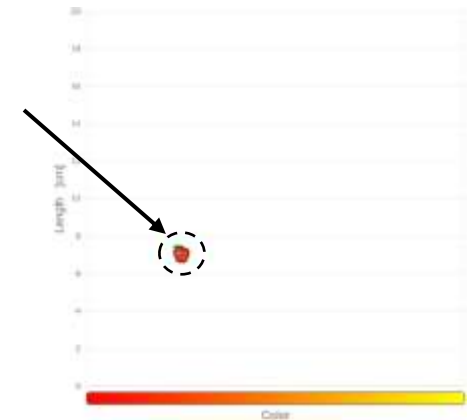
3

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

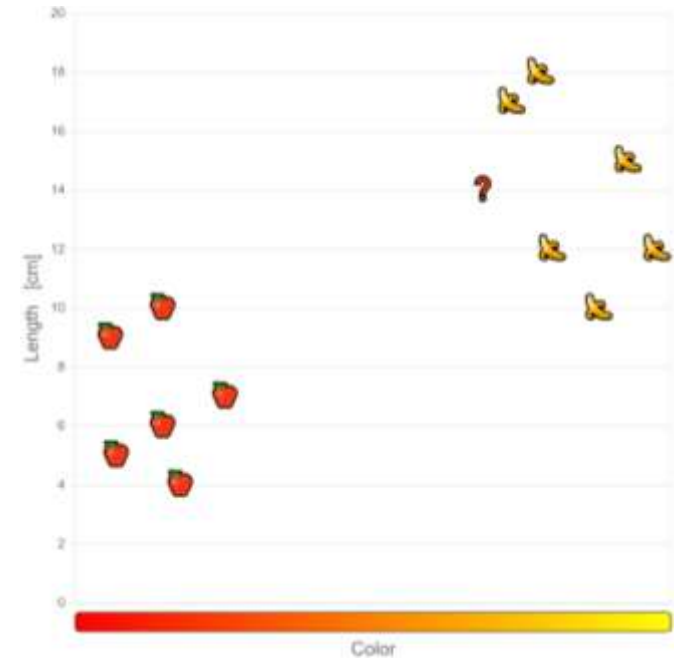
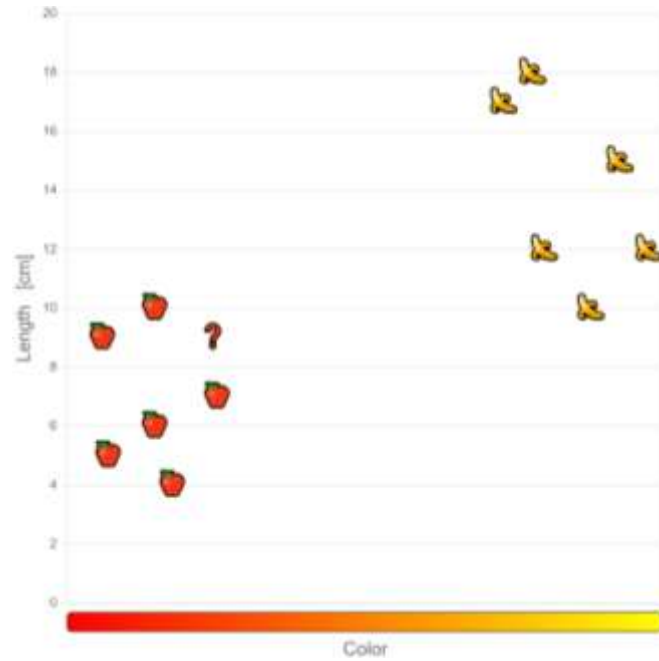
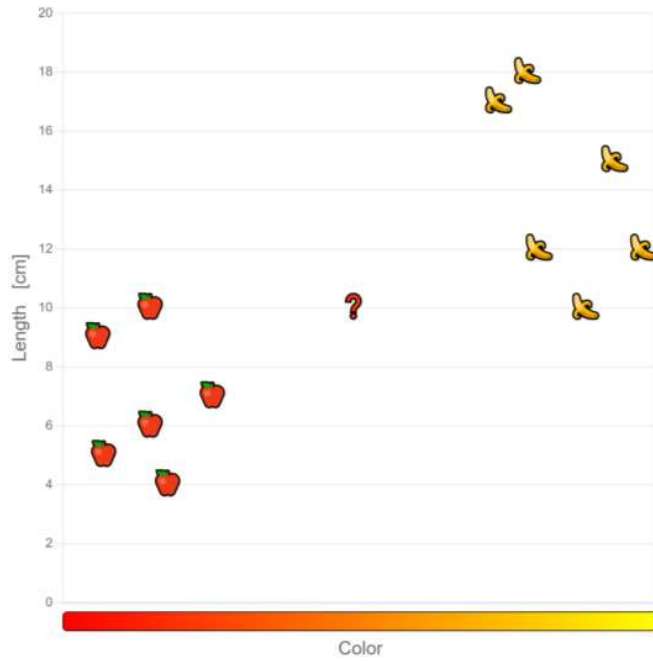


4

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

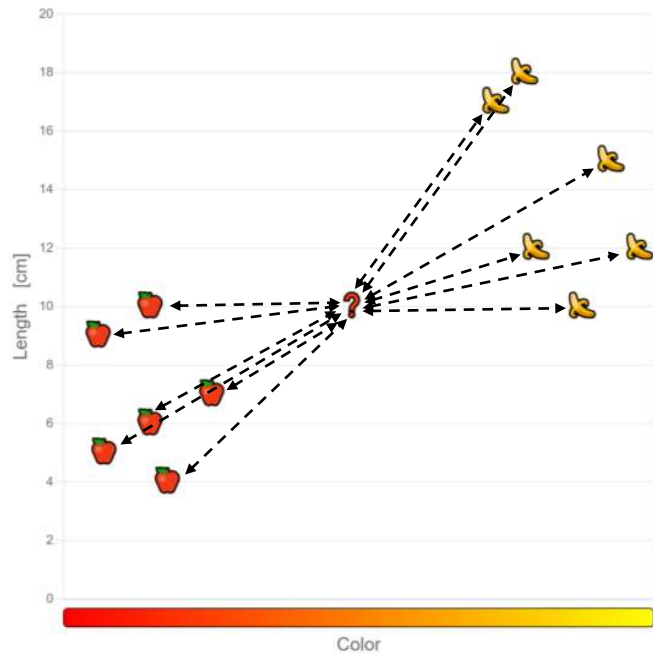


How can we predict a new fruit?

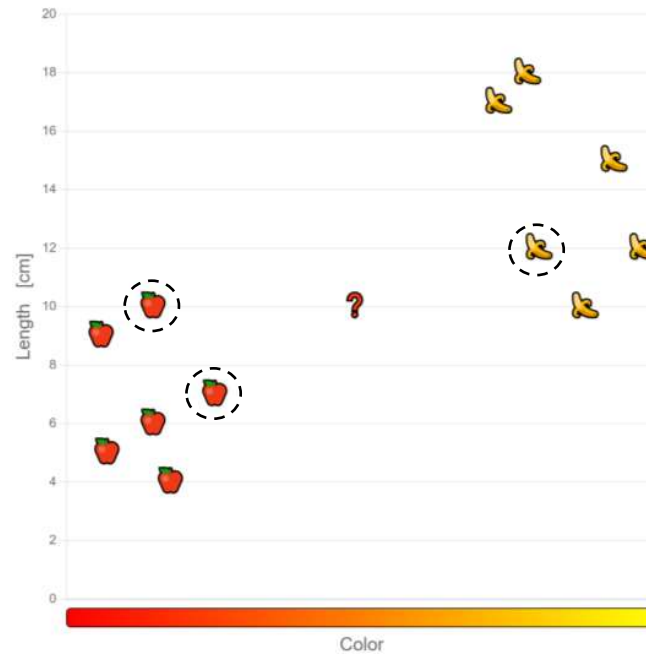


K-Nearest Neighbors – Algorithm




Measure distances



Find 3 nearest neighbors



Vote

1 x 
2 x   wins!

Automatic fruit detector – Prediction

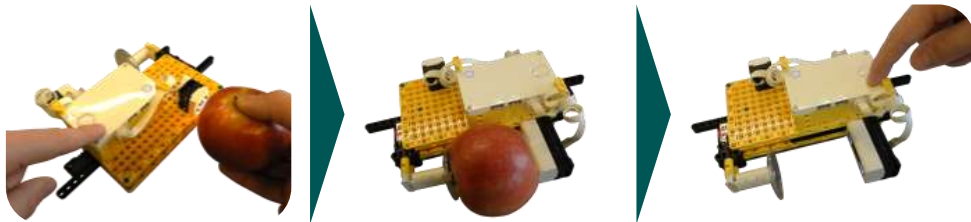
1

Switch the device to prediction mode.



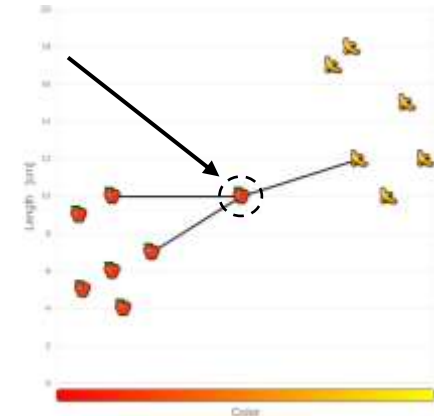
2

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



3

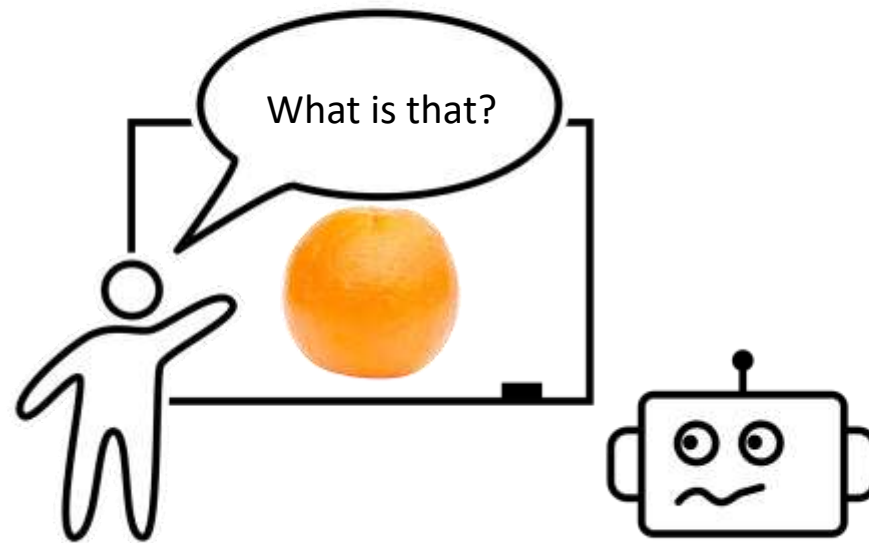
The prediction and the nearest neighbors will now be displayed on the website!



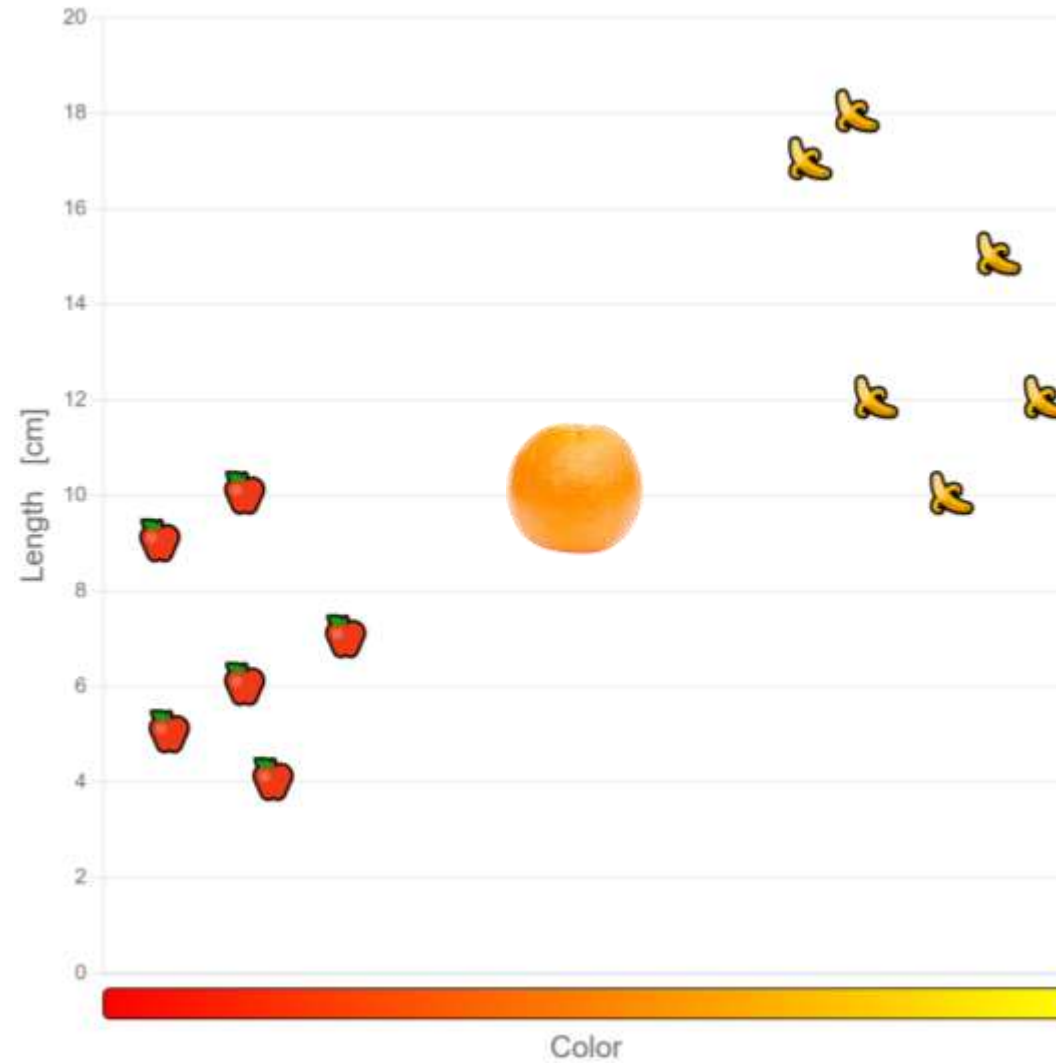
Phases of model development



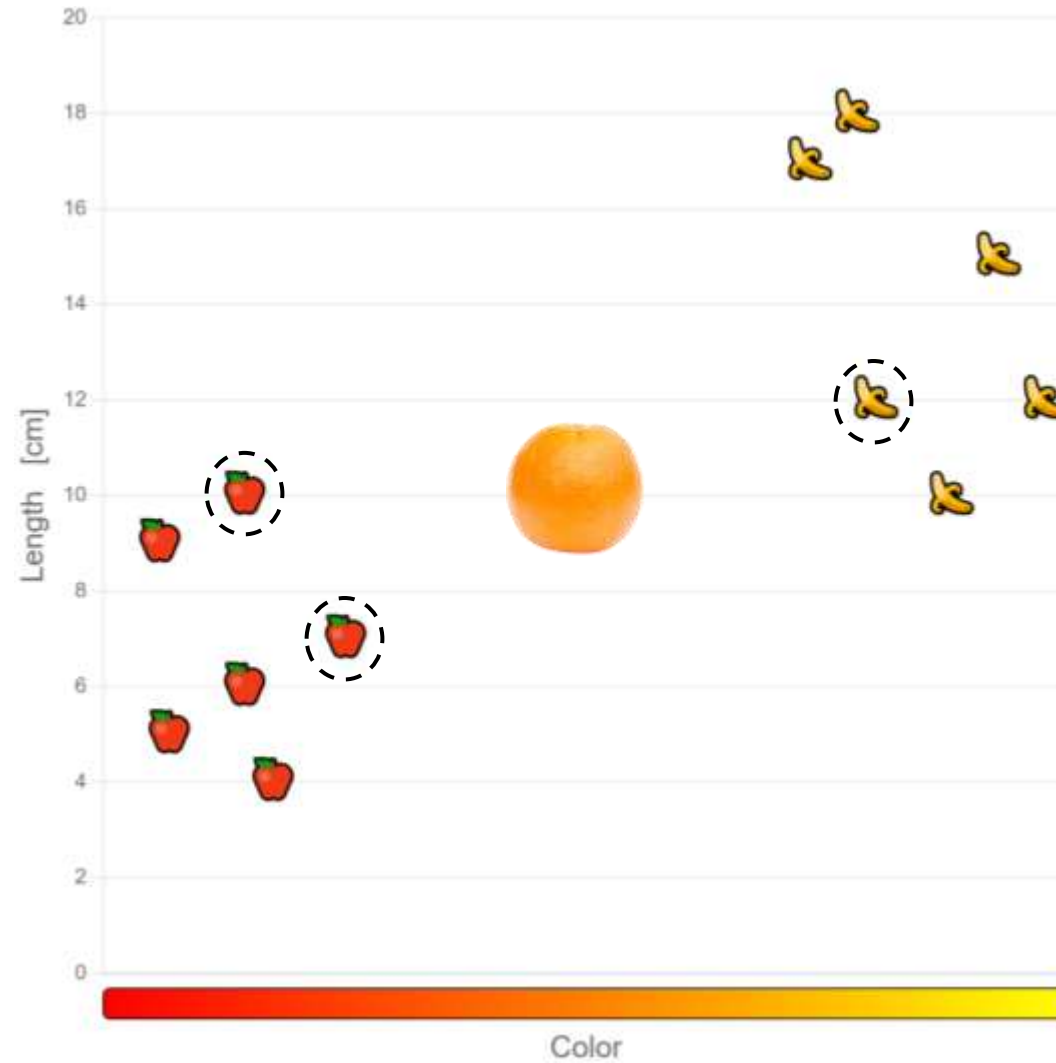
What if there is a previously unseen example?



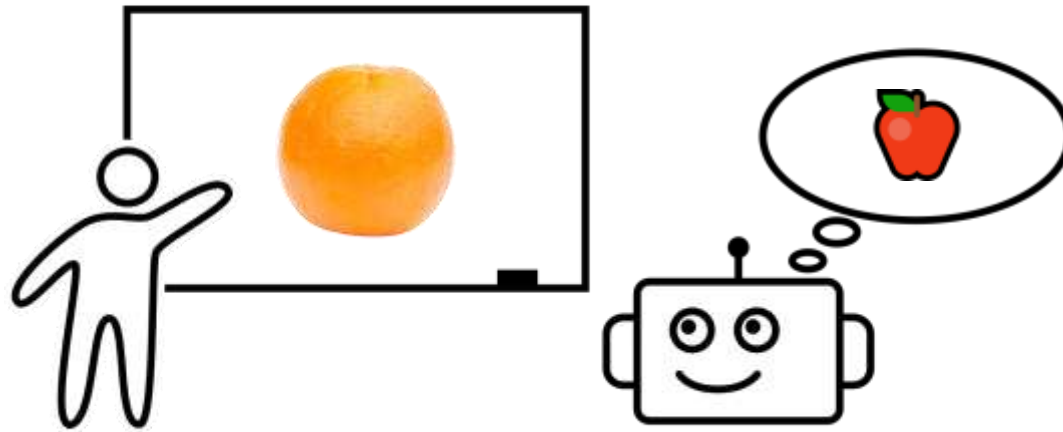
What if there is a previously unseen example?



What if there is a previously unseen example?



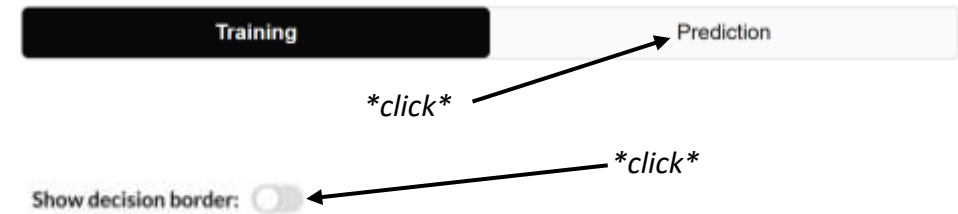
What if there is a previously unseen example?



Influence of corrupted data

1

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



2

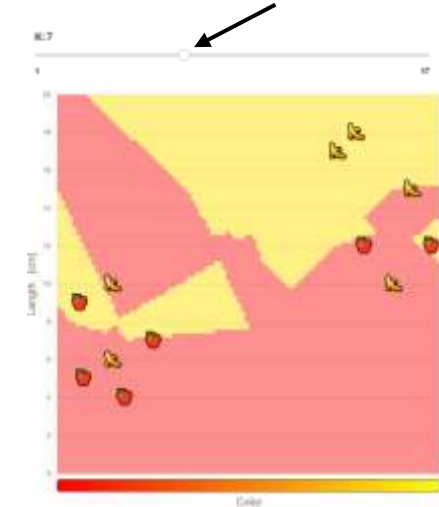
Corrupt the data. Change some of the labels to incorrect ones and observe how the decision boundary changes.

A screenshot of a data table with four columns: "Length [cm]", "Color", "Label", and "Genre". The table contains 10 rows of data. An arrow points to the "Label" column of the 10th row, which is "Apple".

Length [cm]	Color	Label	Genre
7	Red	Apple	🍏
4	Red	Apple	🍏
9	Red	Apple	🍏
10	Yellow	Banana	🍌
66	Yellow	Banana	🍌
13	Yellow	Banana	🍌
9	Red	Apple	🍏
7	Red	Apple	🍏
4	Red	Apple	🍏
9	Red	Apple	🍏

3

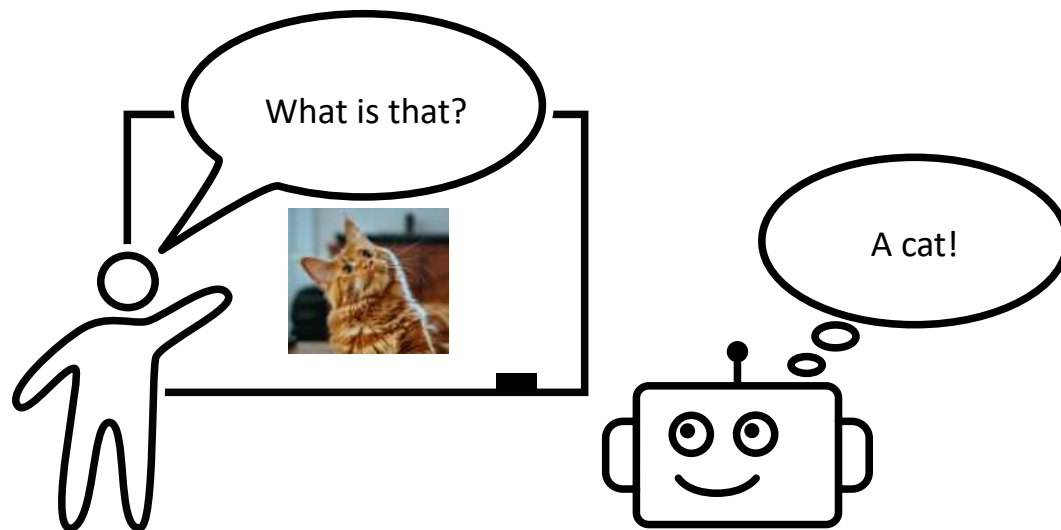
Try changing the number of voting neighbors (K) to restore the accuracy



Classification and regression

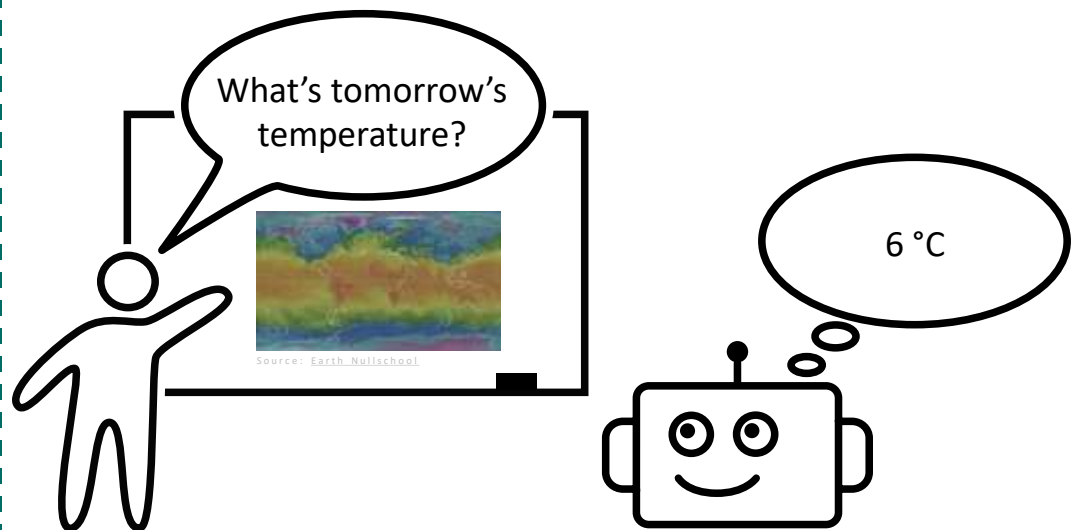
Classification

- prediction of a category



Regression

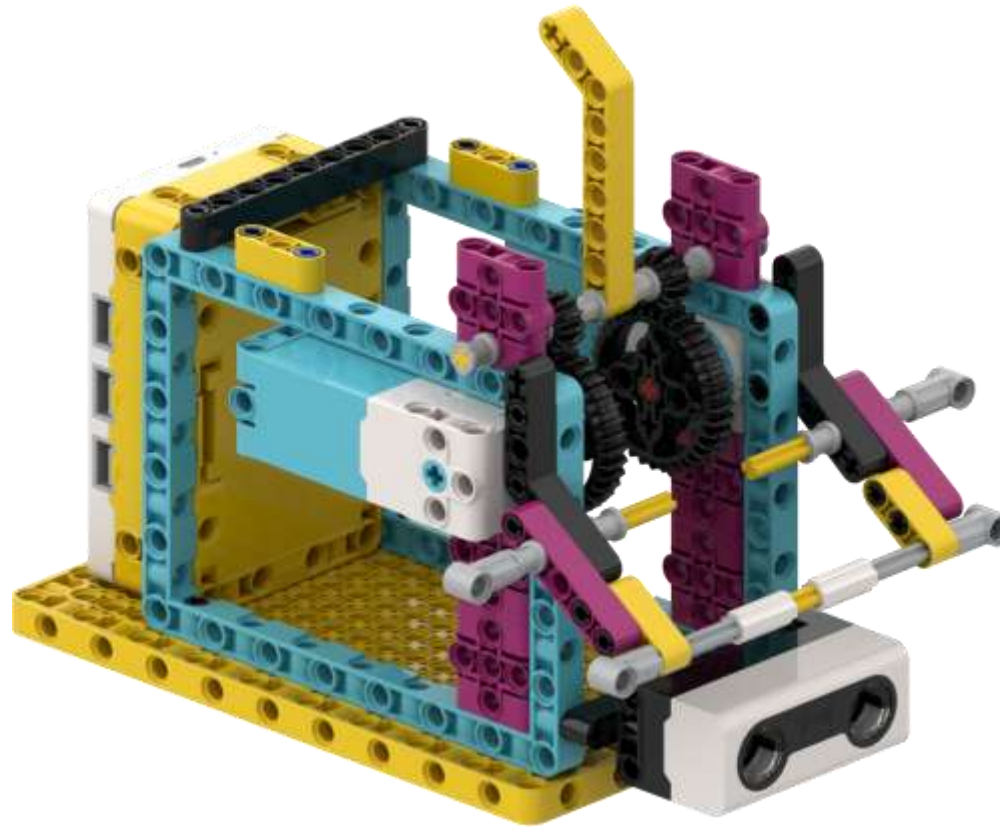
- prediction of a number



Pitcher – Concept

Features: ?

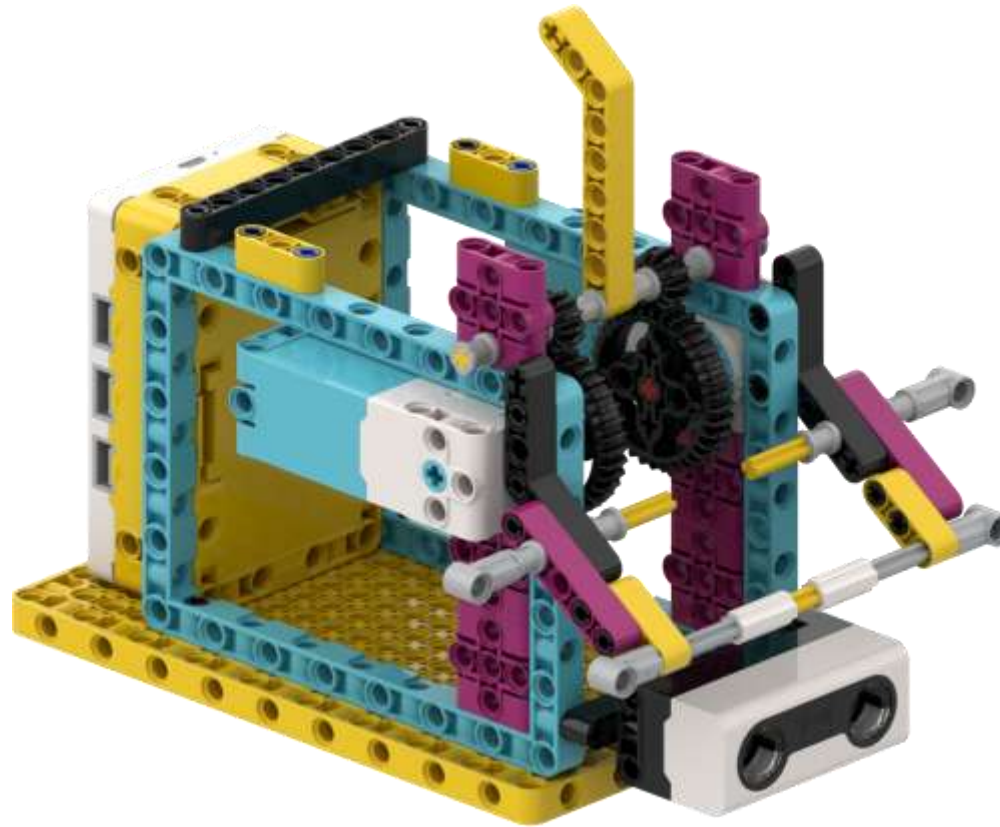
Label: ?



Pitcher – Concept

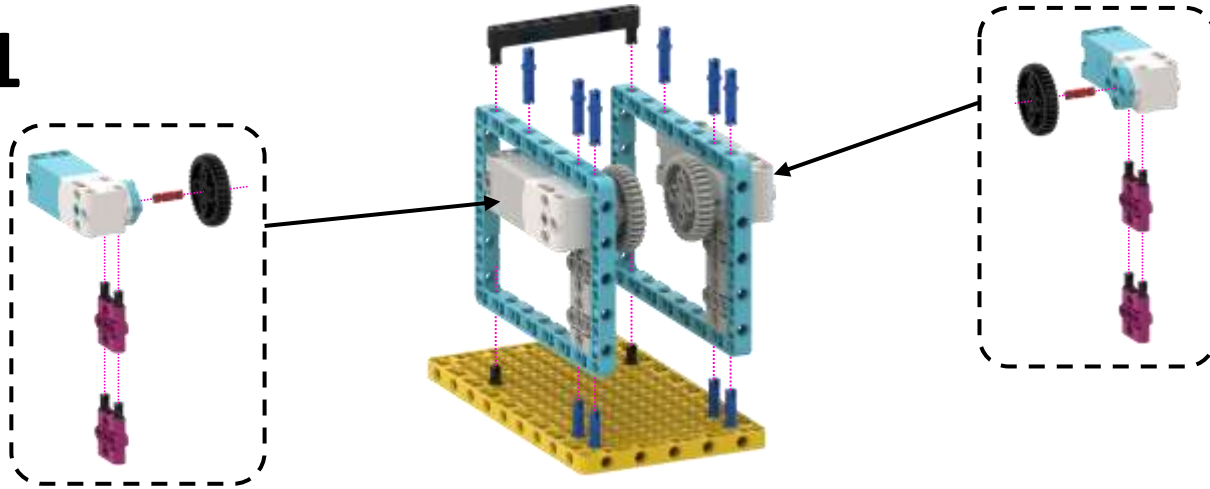
Features: Distance to the target

Label: Motor power

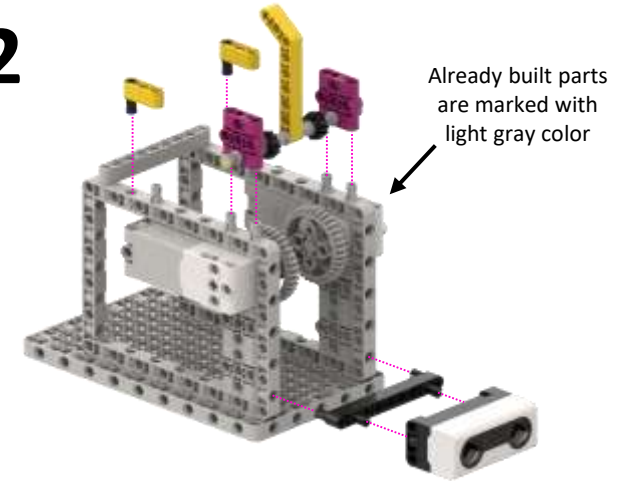


Pitcher – Assembly

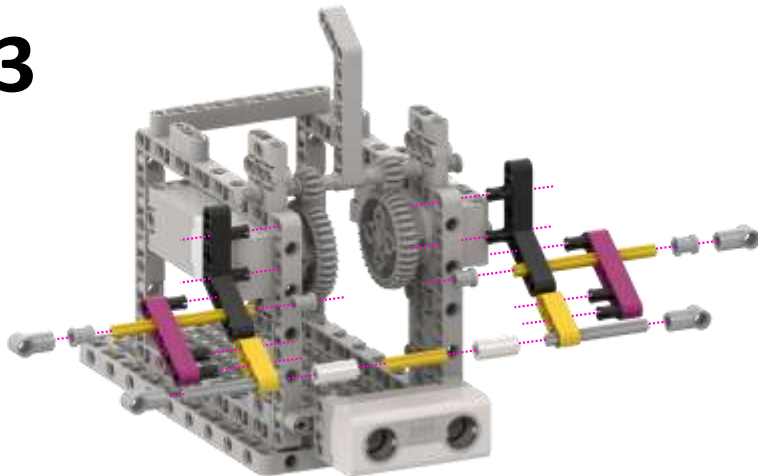
1



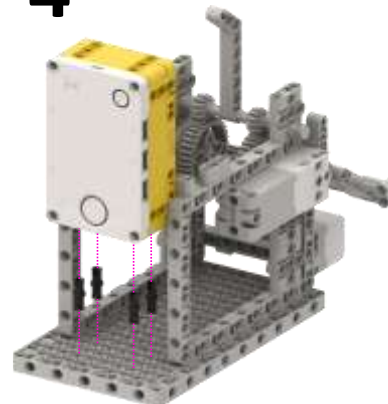
2



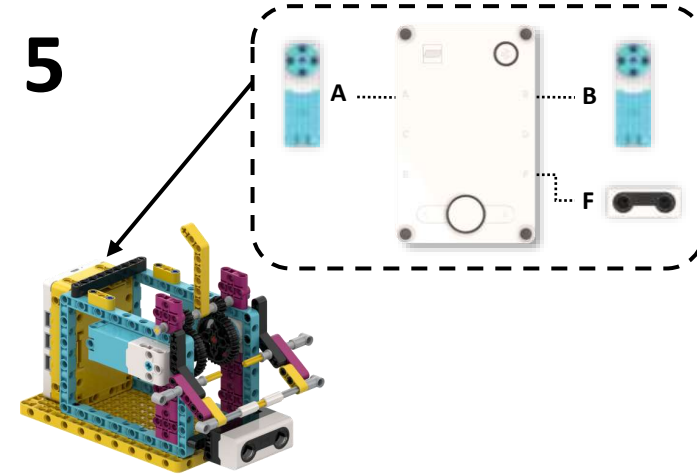
3



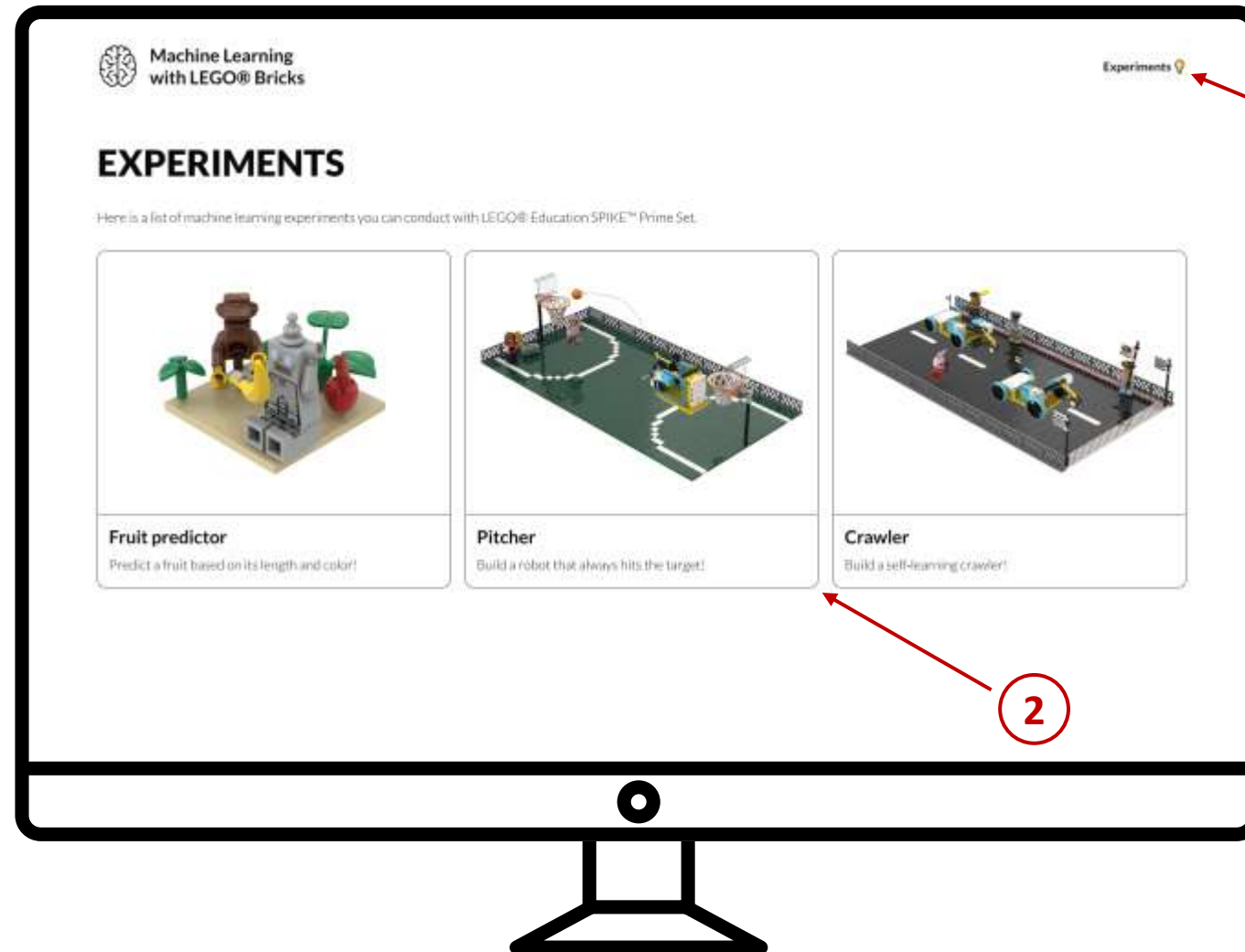
4



5



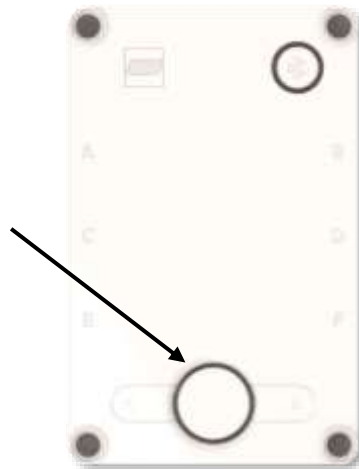
Open the experiment page



Connect hub and start the program

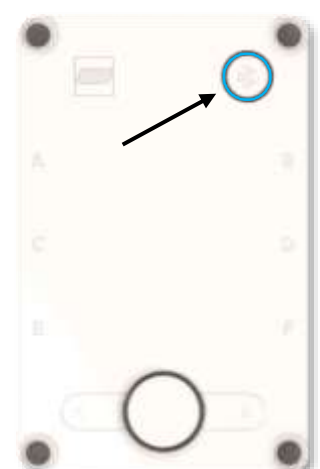
1

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

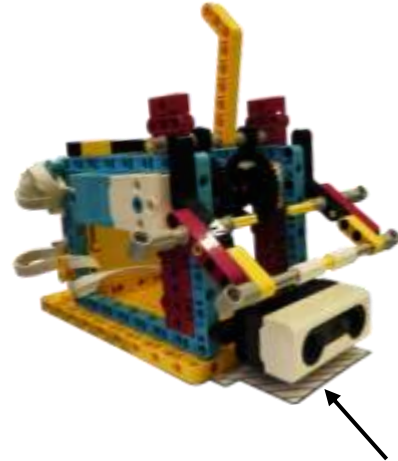
Click on 'Start program' and wait until a notification appears on the website.



Pitcher – Data collection

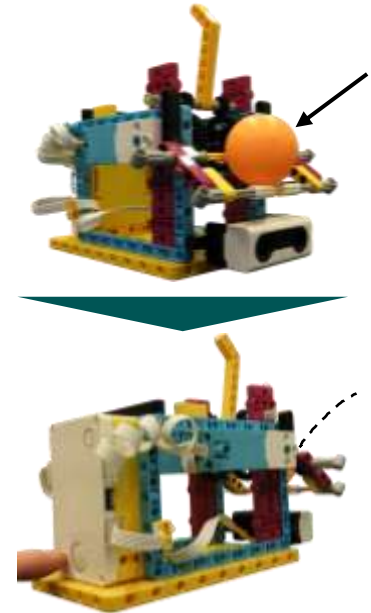
1

Place the pitcher in the shaded area on the mat.



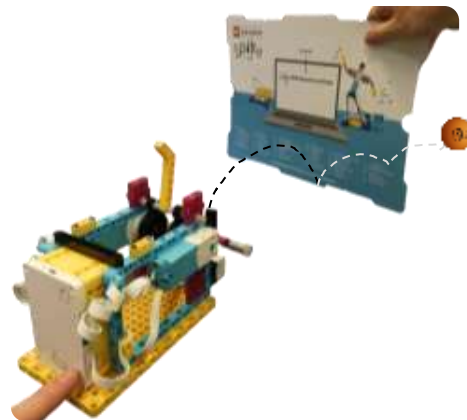
2

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

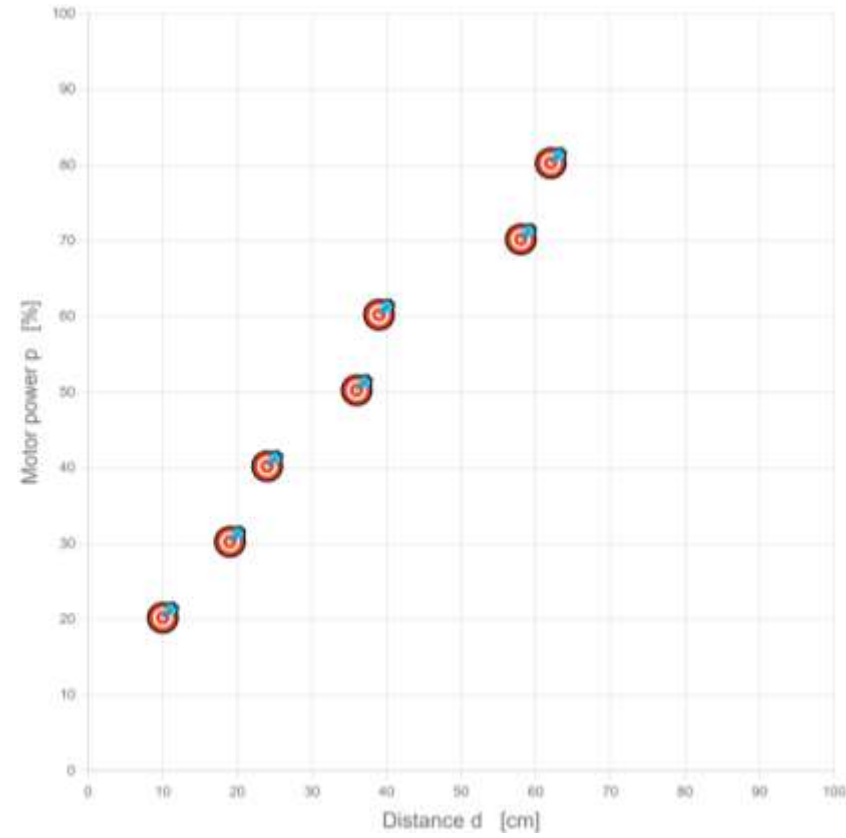
Repeat the steps for other motor speeds.

Motor power: 10% → 40%

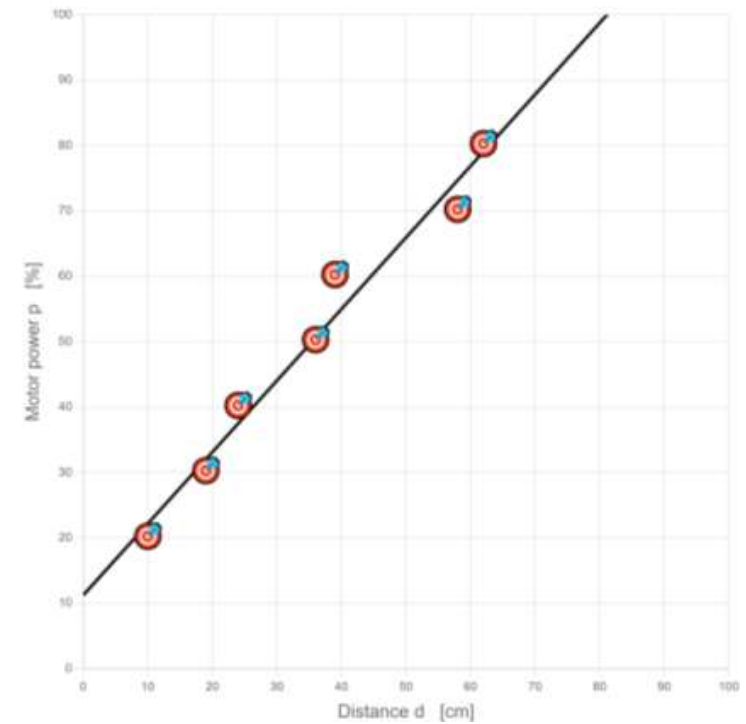
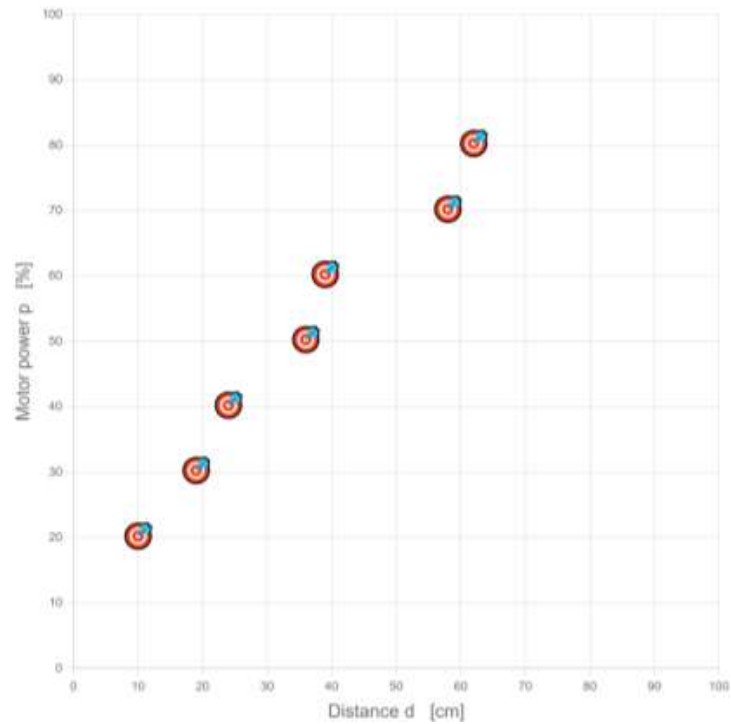


Update motor power ← *click*

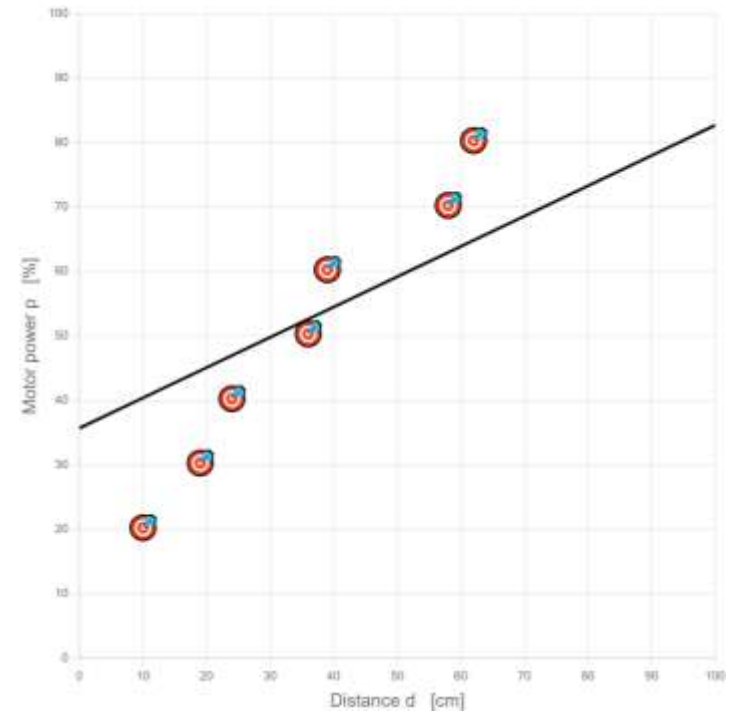
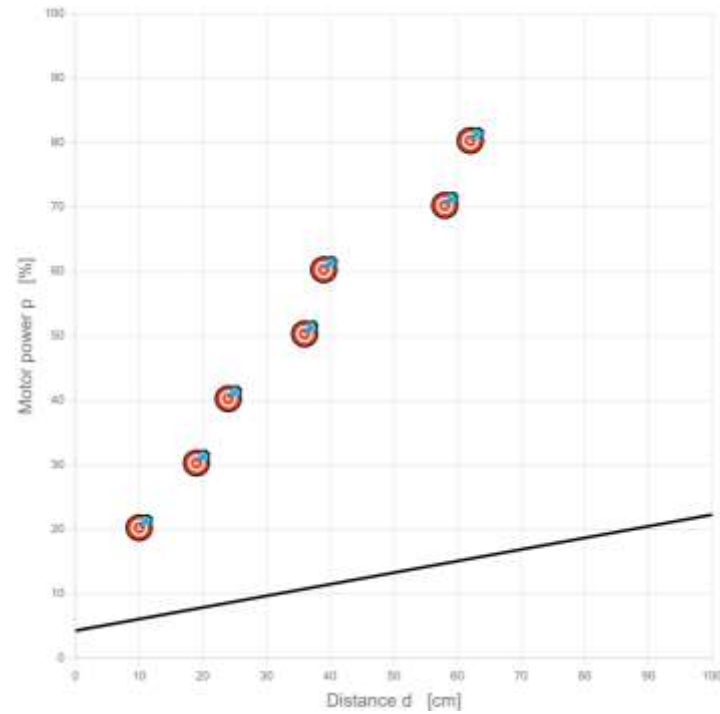
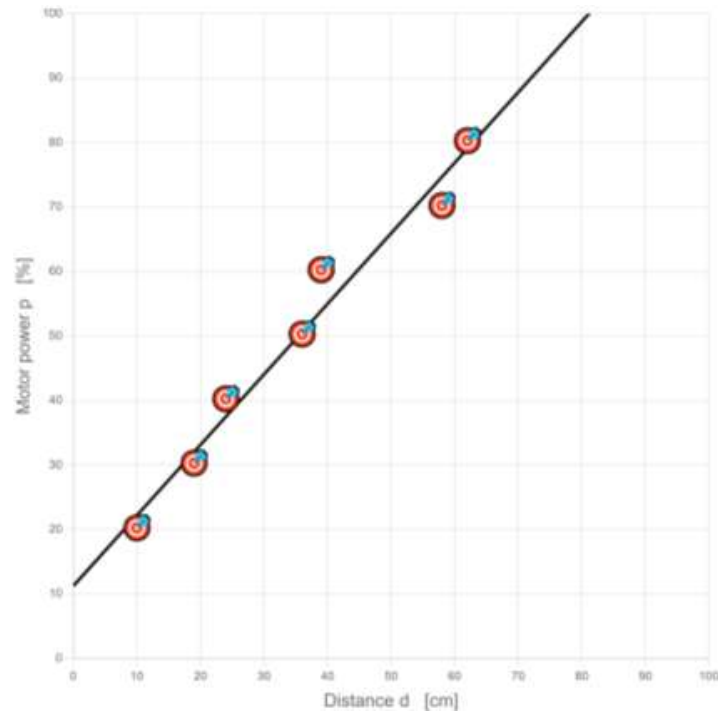
Pitcher – Data analysis



Pitcher – Data analysis

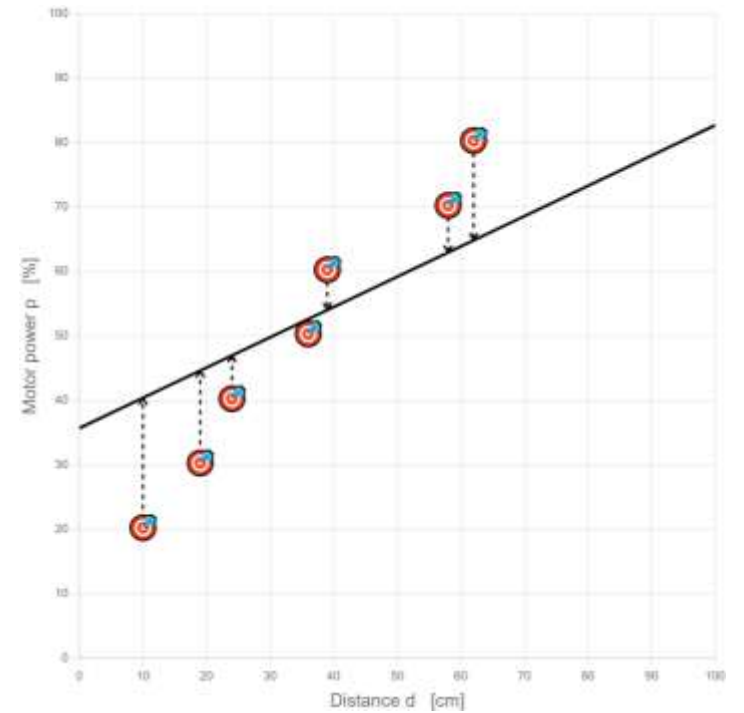
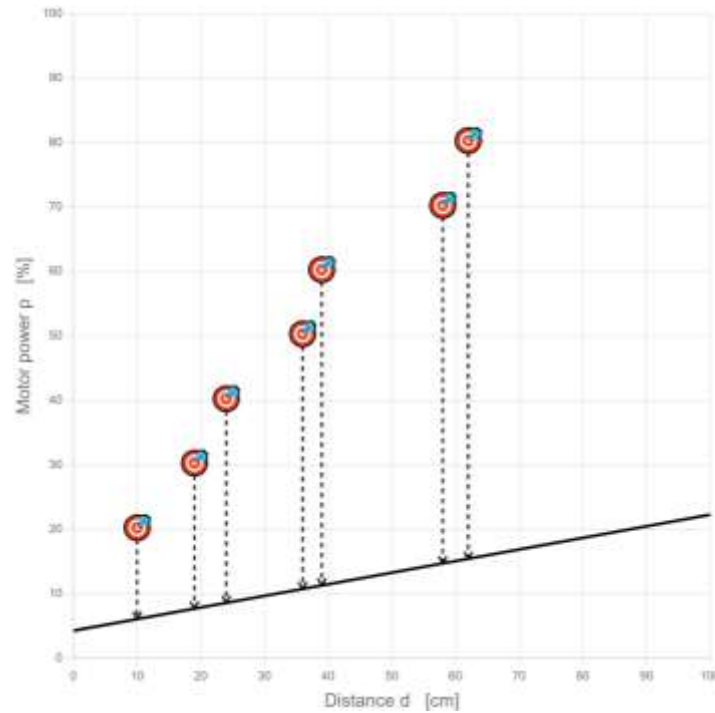
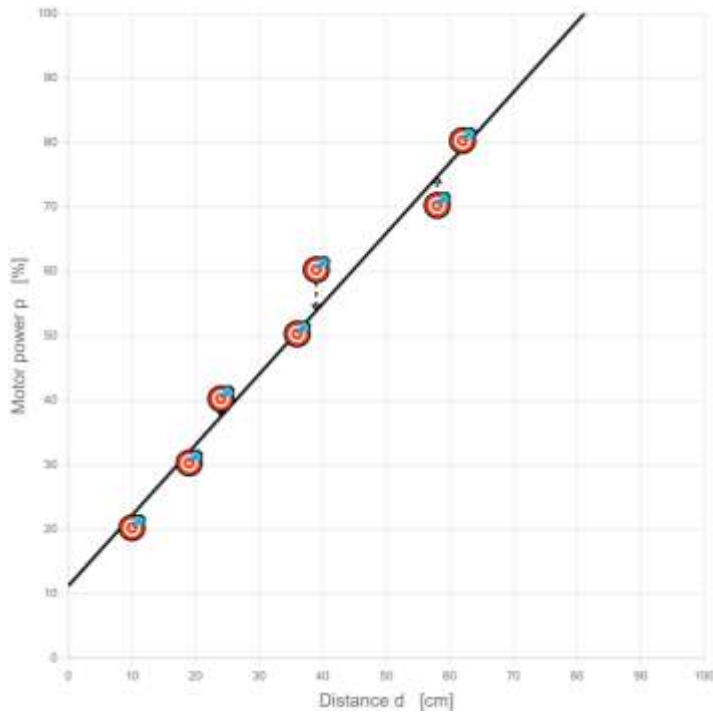


How well does the line fit?



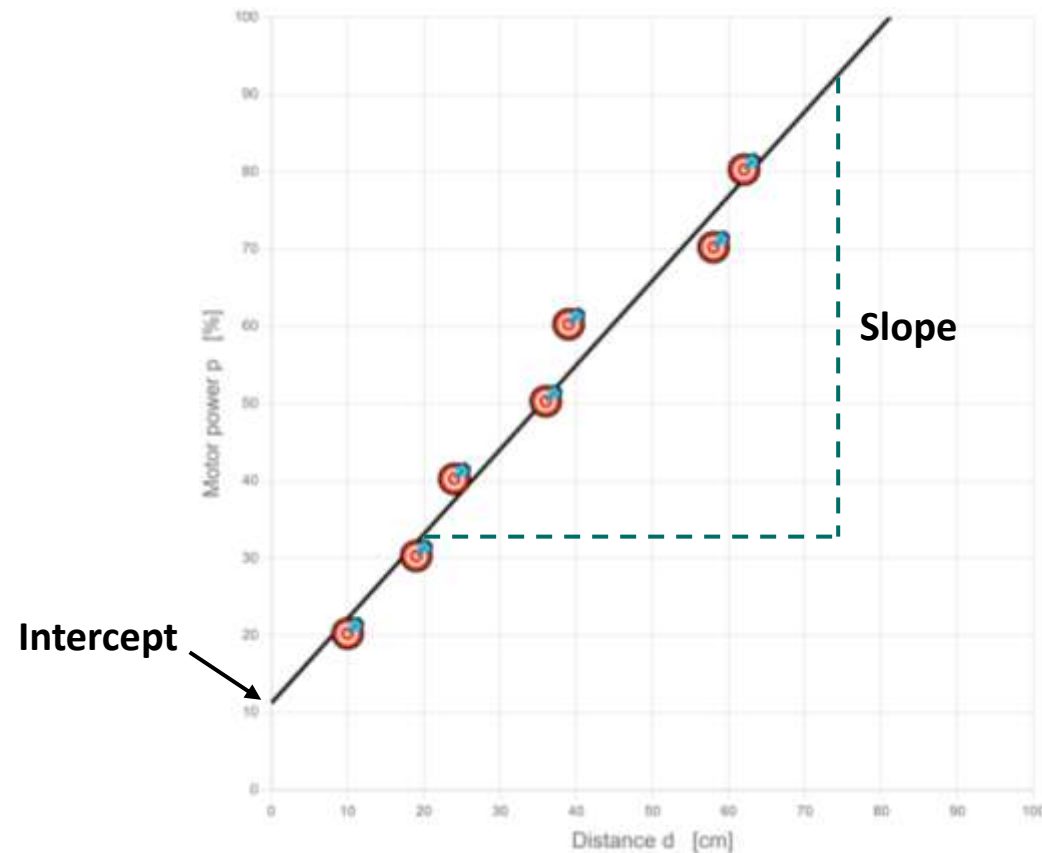
How well does the line fit?

- **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.

Training

Prediction

click

2

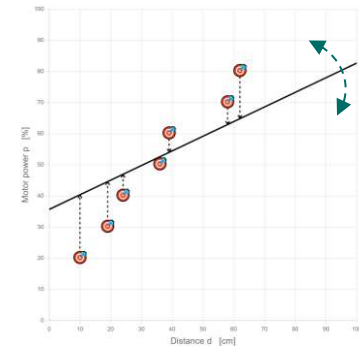
Try adjusting the slope and intercept to move the line and minimize the loss.

Line Equation

Calculate best parameters

$$p = m \cdot d + b = 0.47 \cdot d + 35.70$$

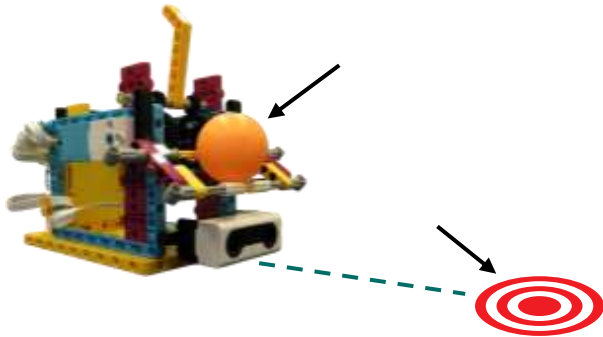
LOSS = 142.97



Pitcher – Prediction

1

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



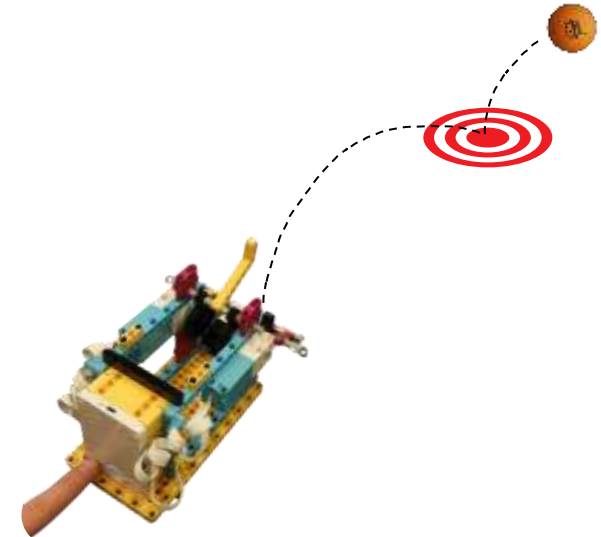
2

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



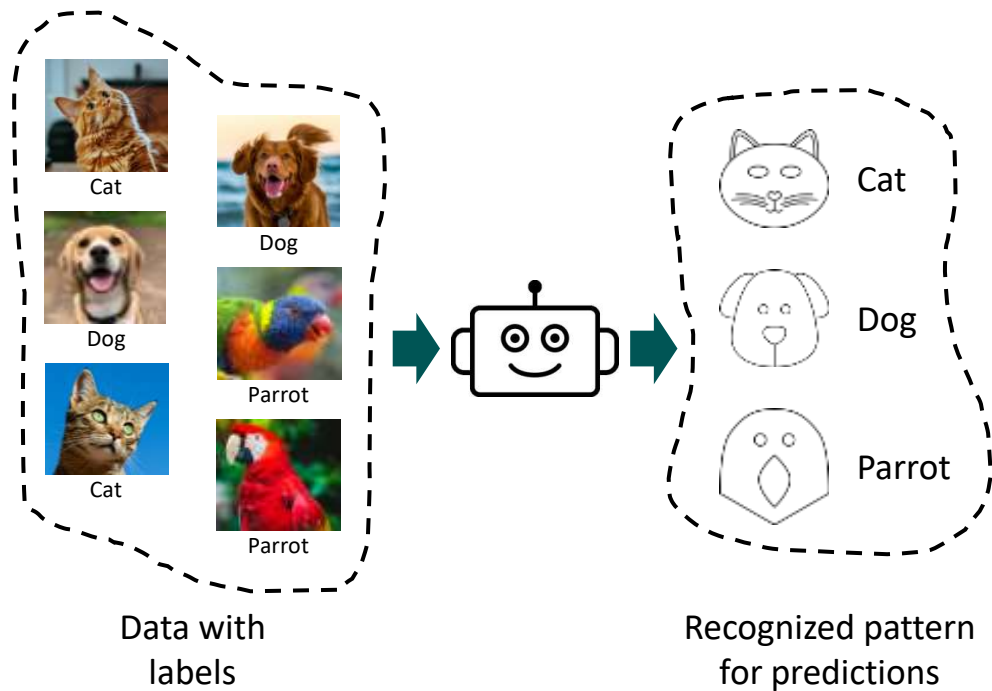
3

Pitch the ball into the target by pressing the left button

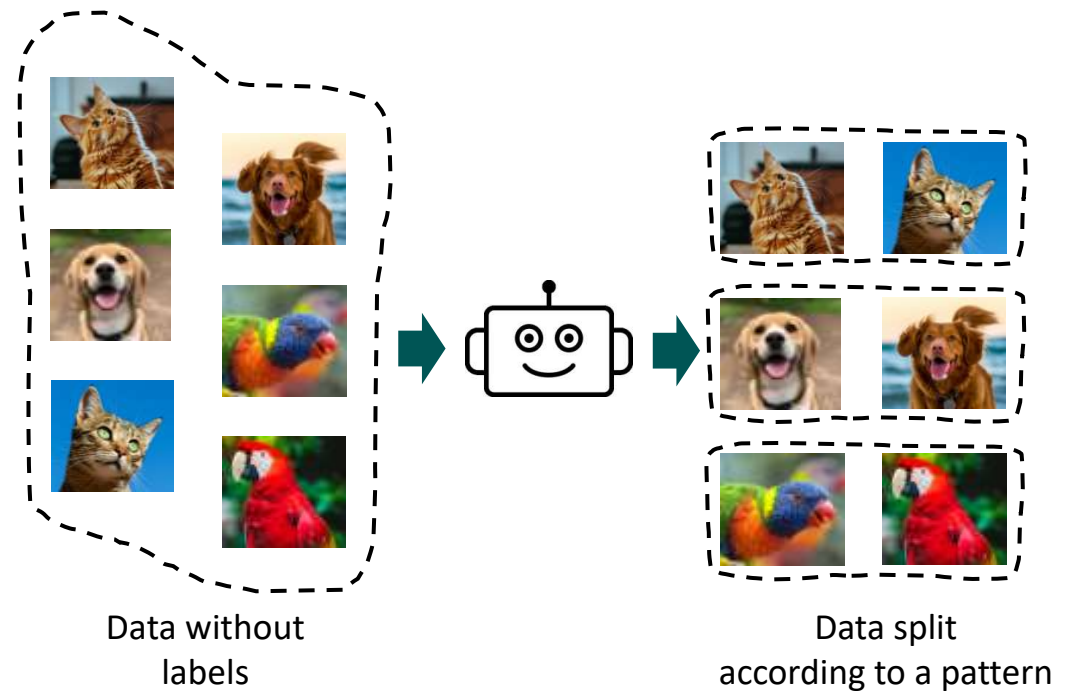


Supervised and unsupervised learning

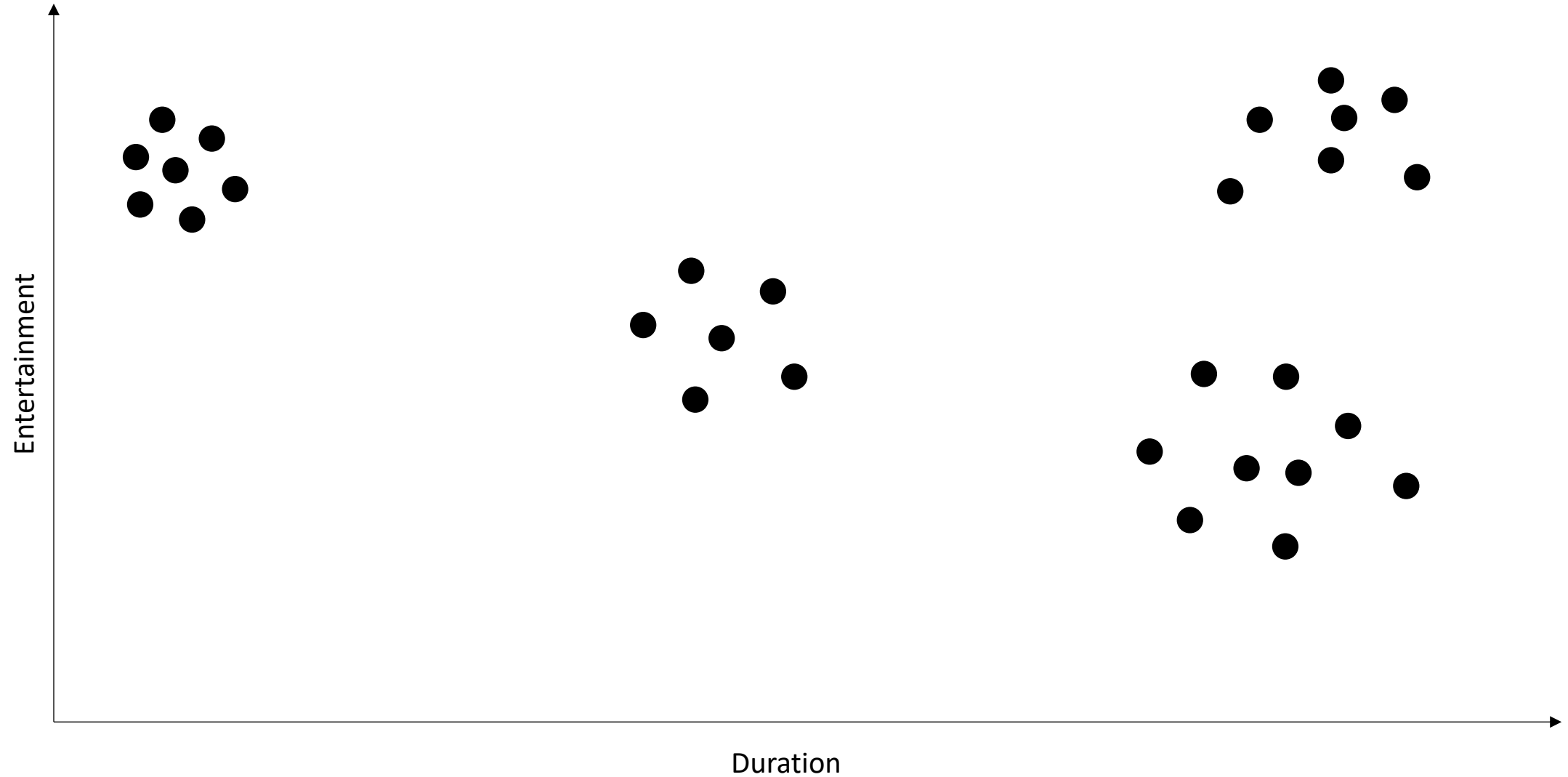
Supervised Learning



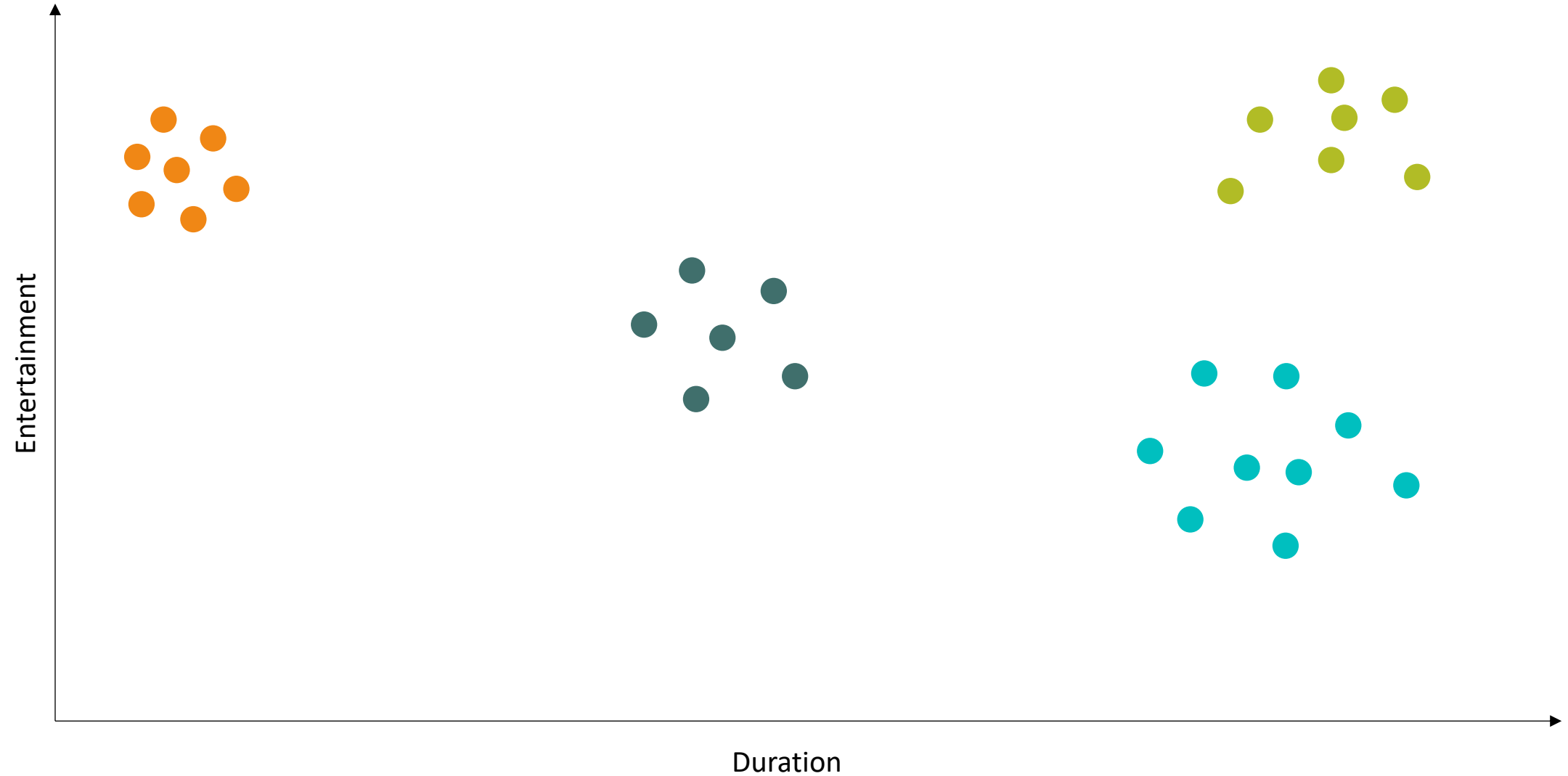
Unsupervised Learning



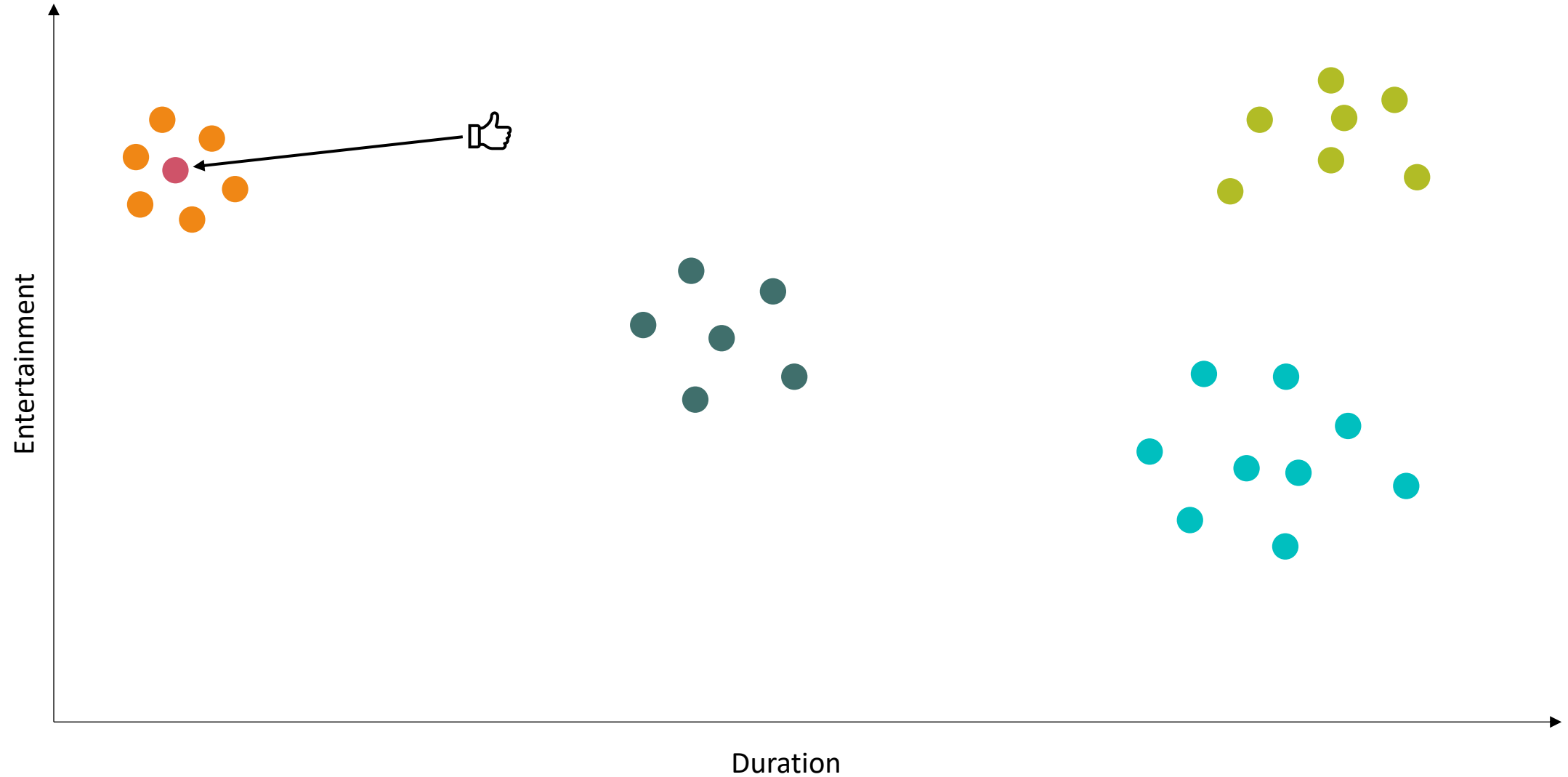
How to recommend new videos using unsupervised learning



How to recommend new videos using unsupervised learning



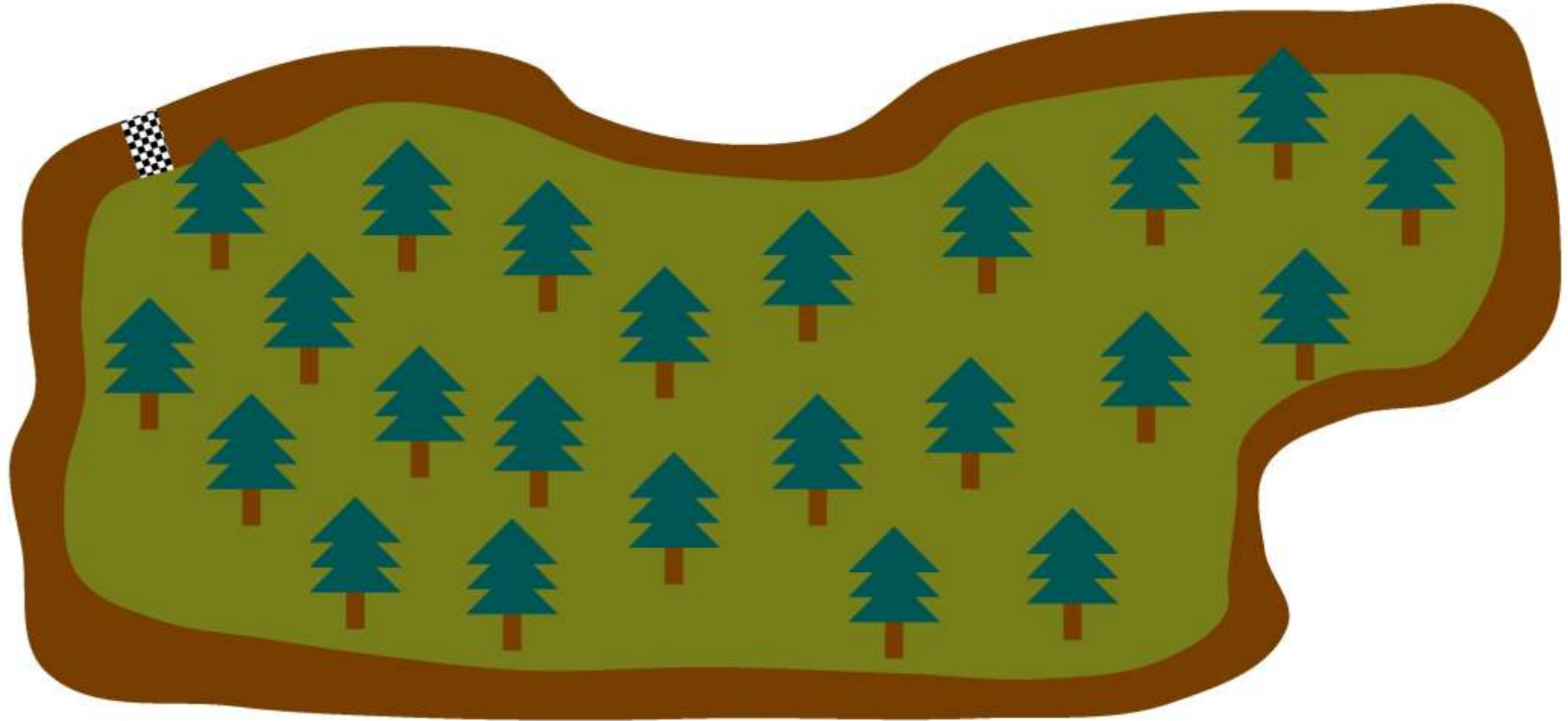
How to recommend new videos using unsupervised learning



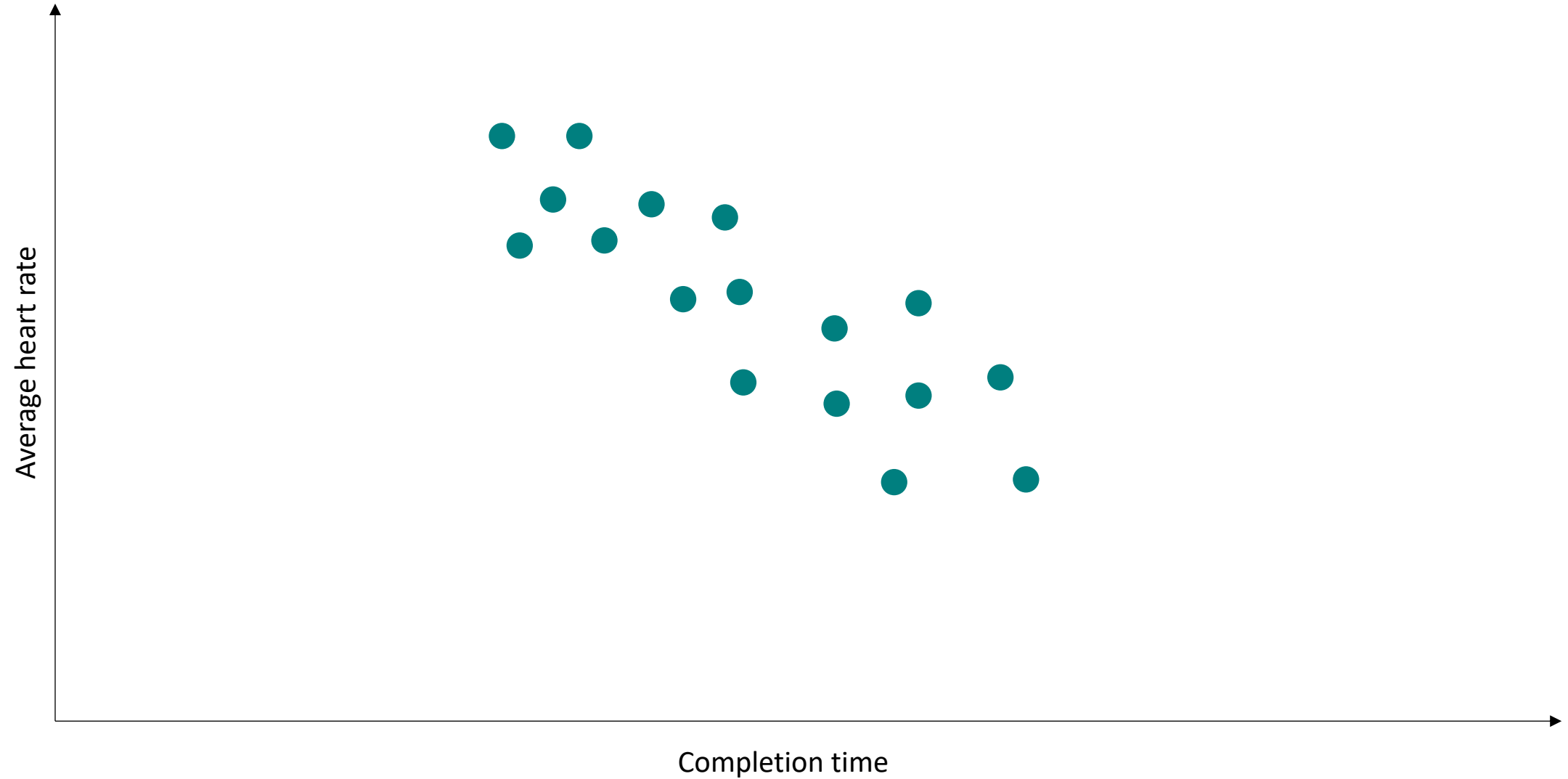
How to recommend new videos using unsupervised learning



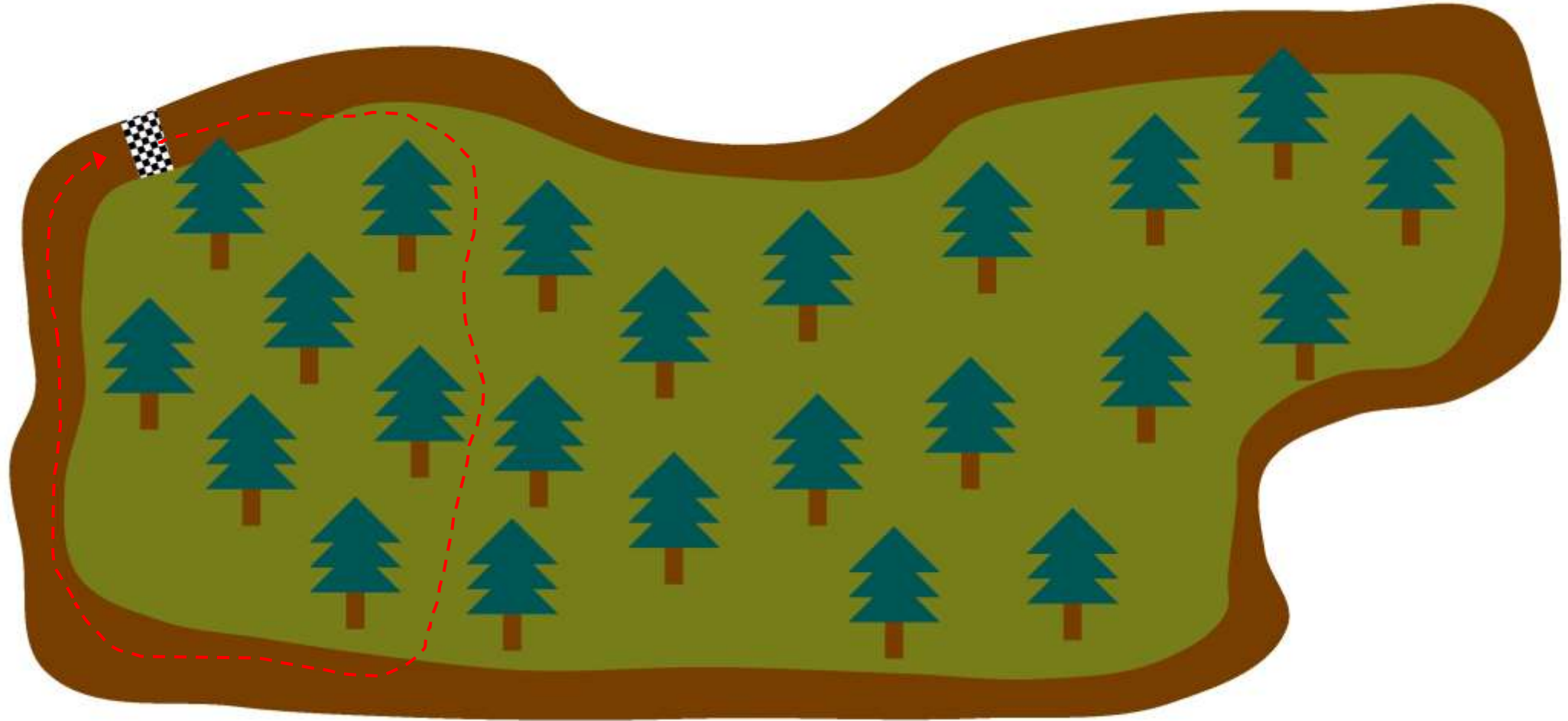
How to detect cheaters using unsupervised learning



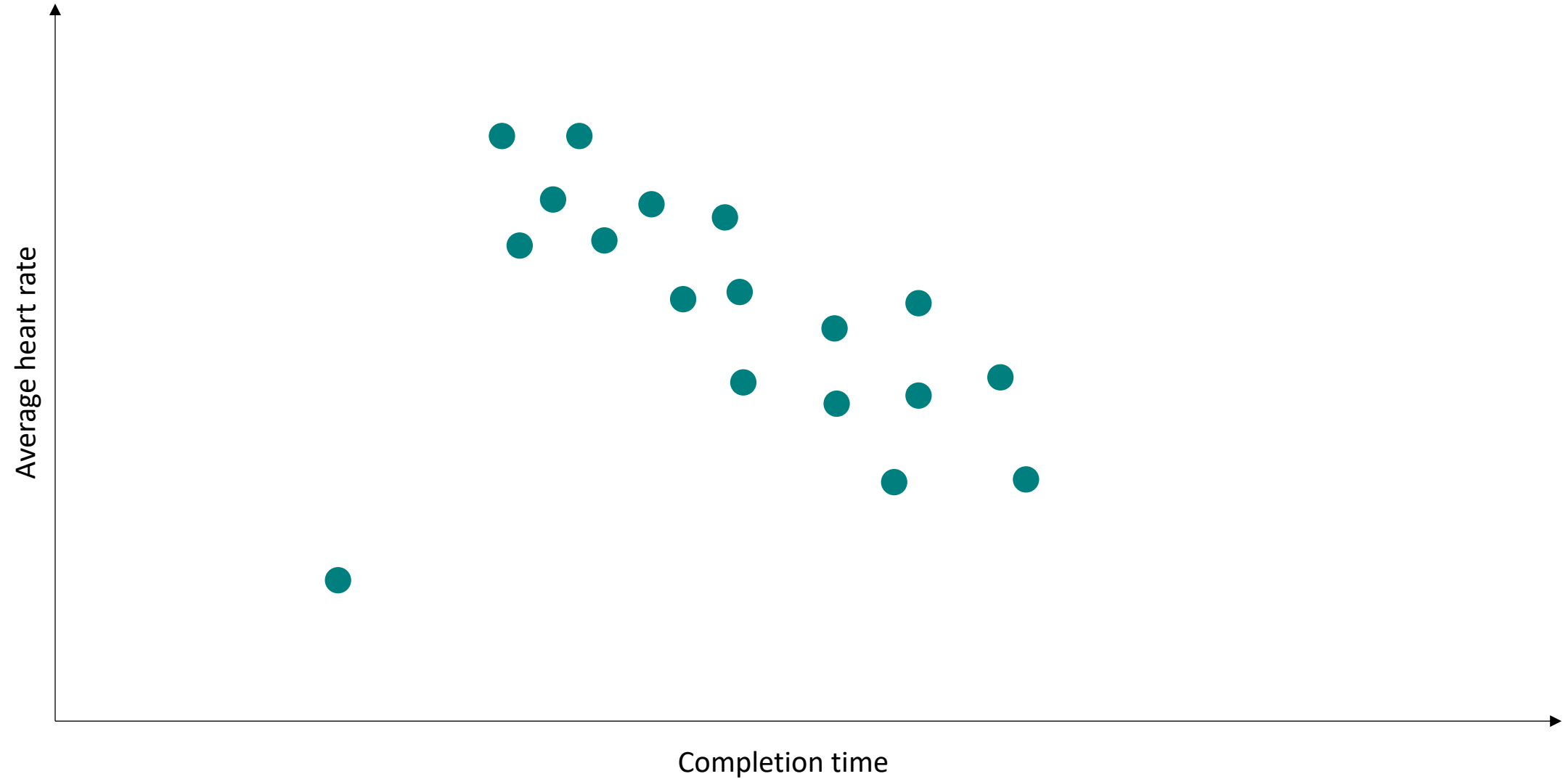
How to detect cheaters using unsupervised learning



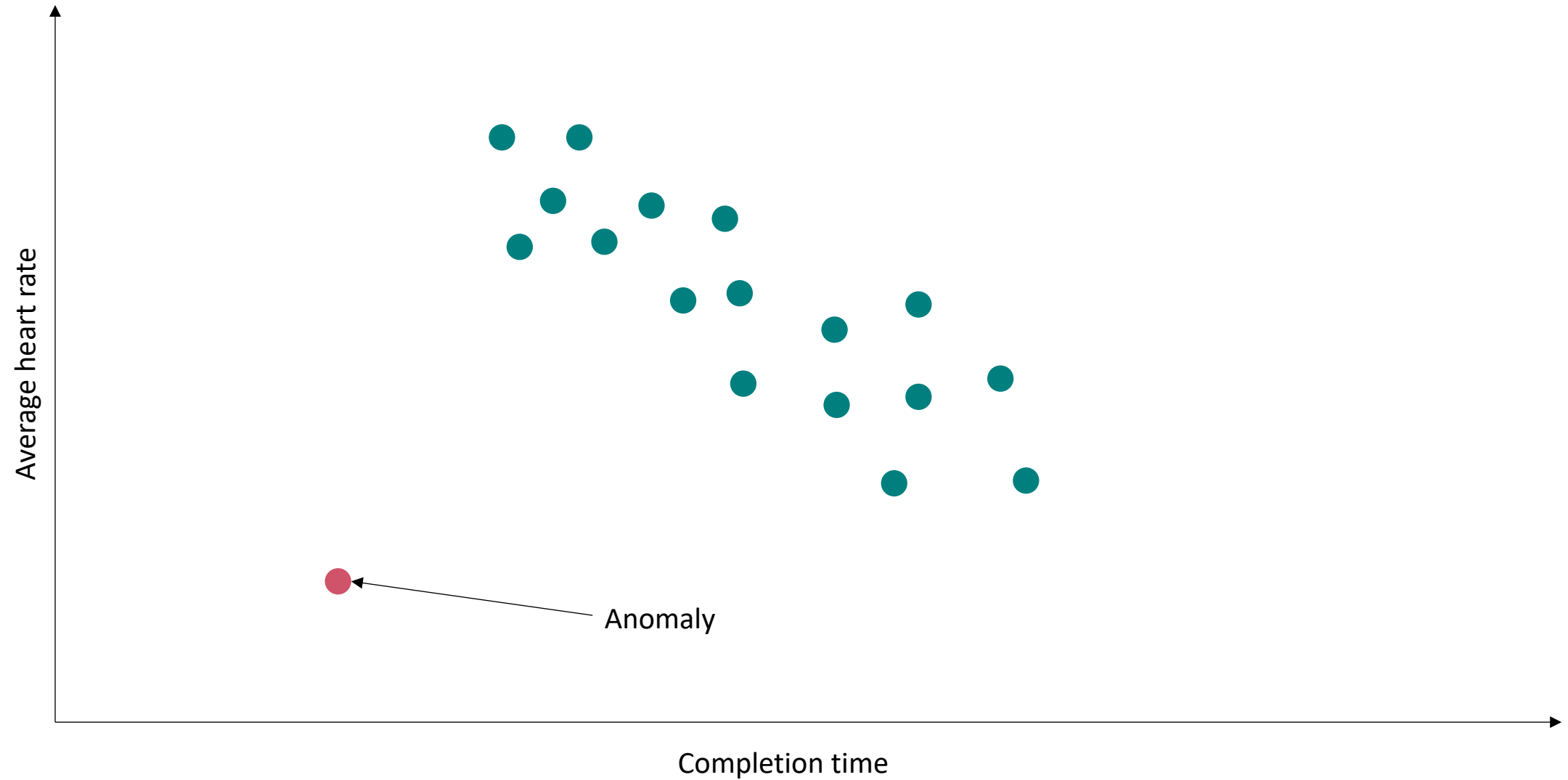
How to detect cheaters using unsupervised learning



How to detect cheaters using unsupervised learning

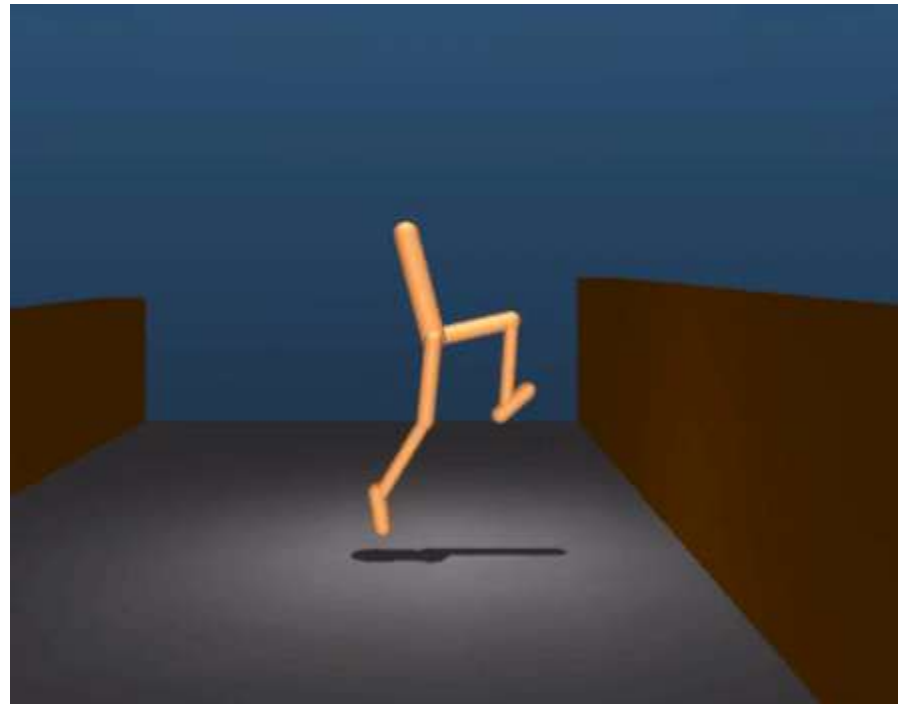


How to detect cheaters using unsupervised learning



Reinforcement learning

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



Source: [DeepMind](#)

Reinforcement learning

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



Source: [Giphy](#)

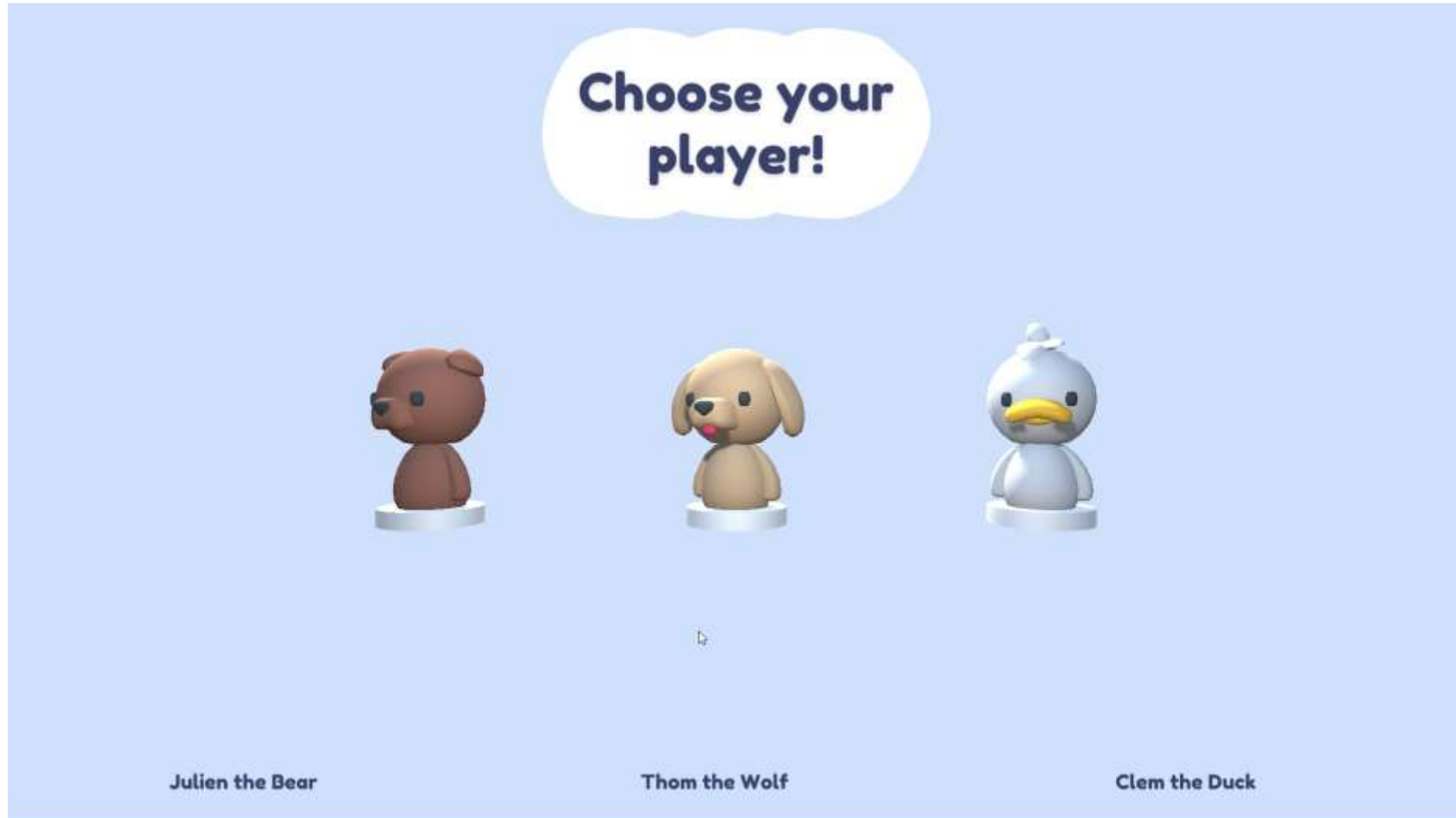
Applications – Robots



0 mins

Source: [YouTube](#)

Applications – Bots in computer games



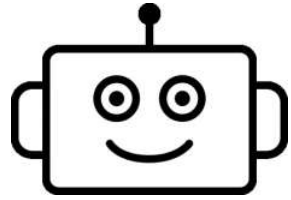
Source: [HuggingFace](#)

Applications – Bots in computer games



Source: [HuggingFace](#)

Abstraction

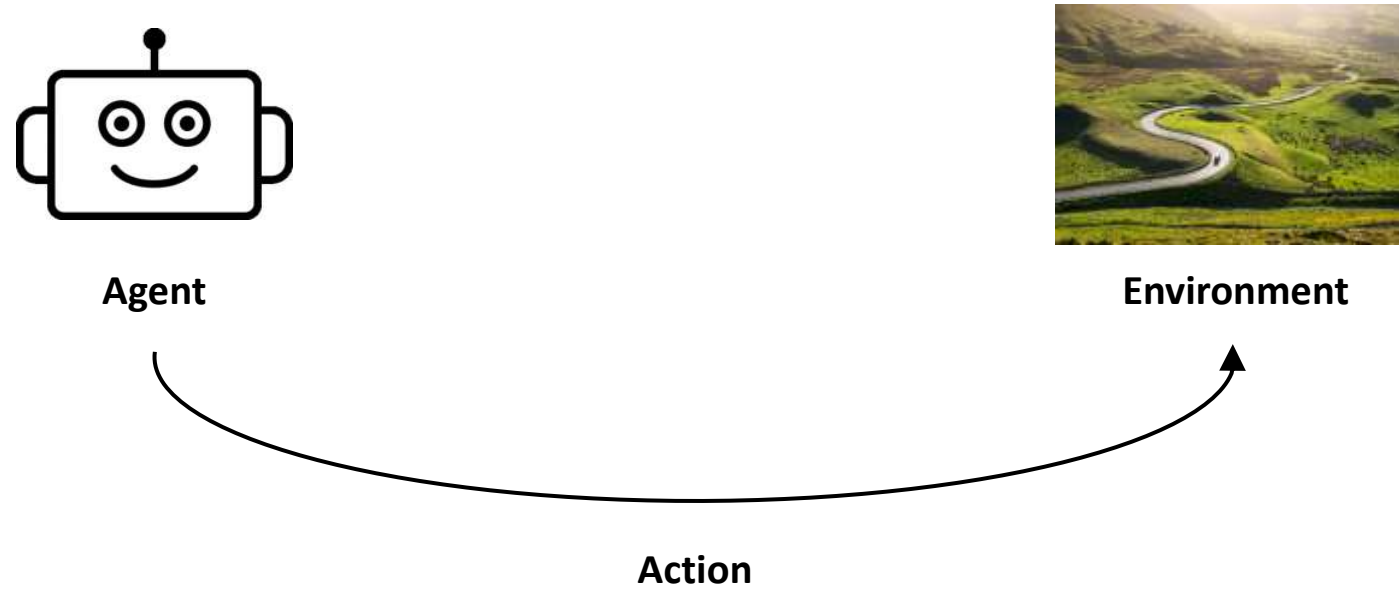


Agent

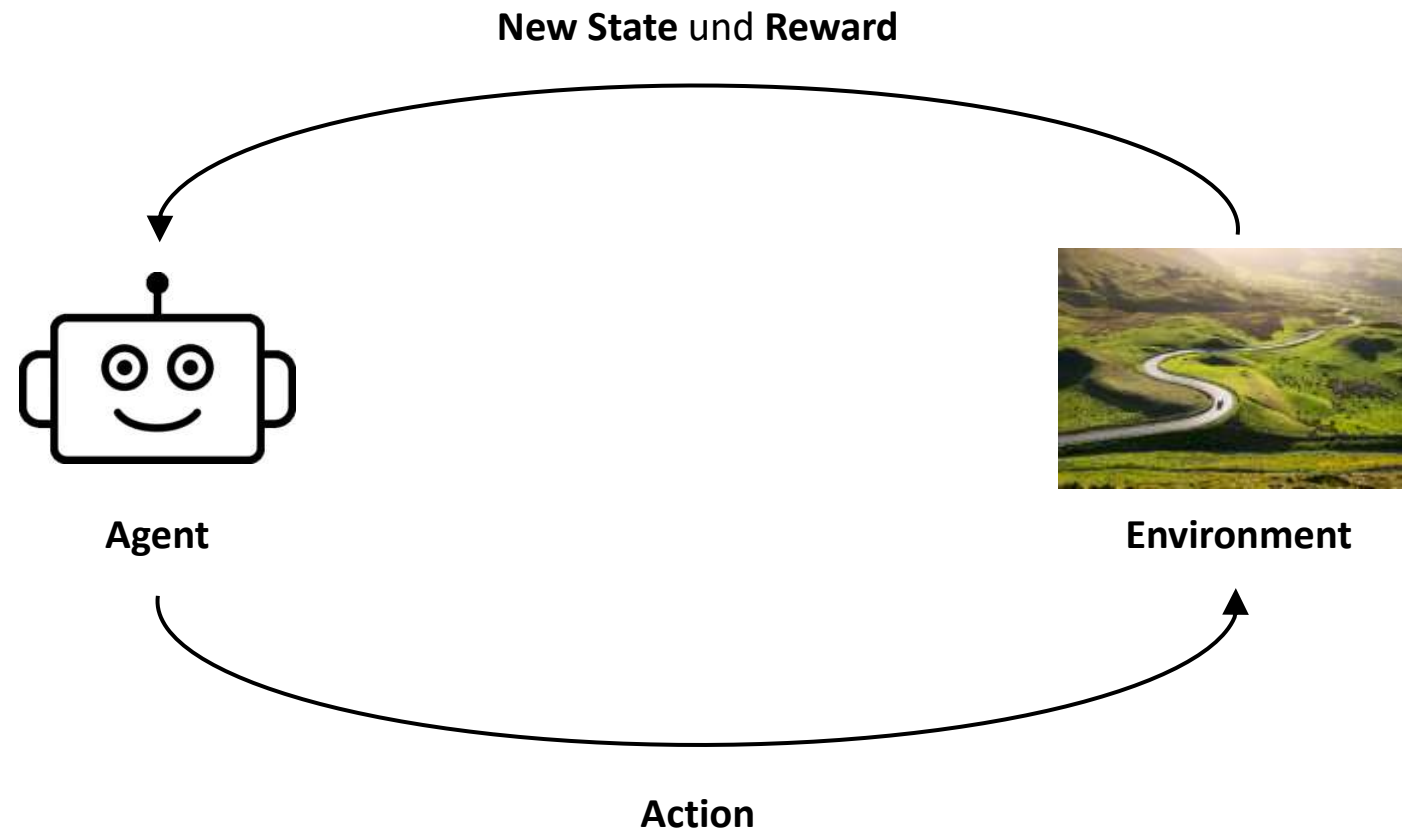


Environment

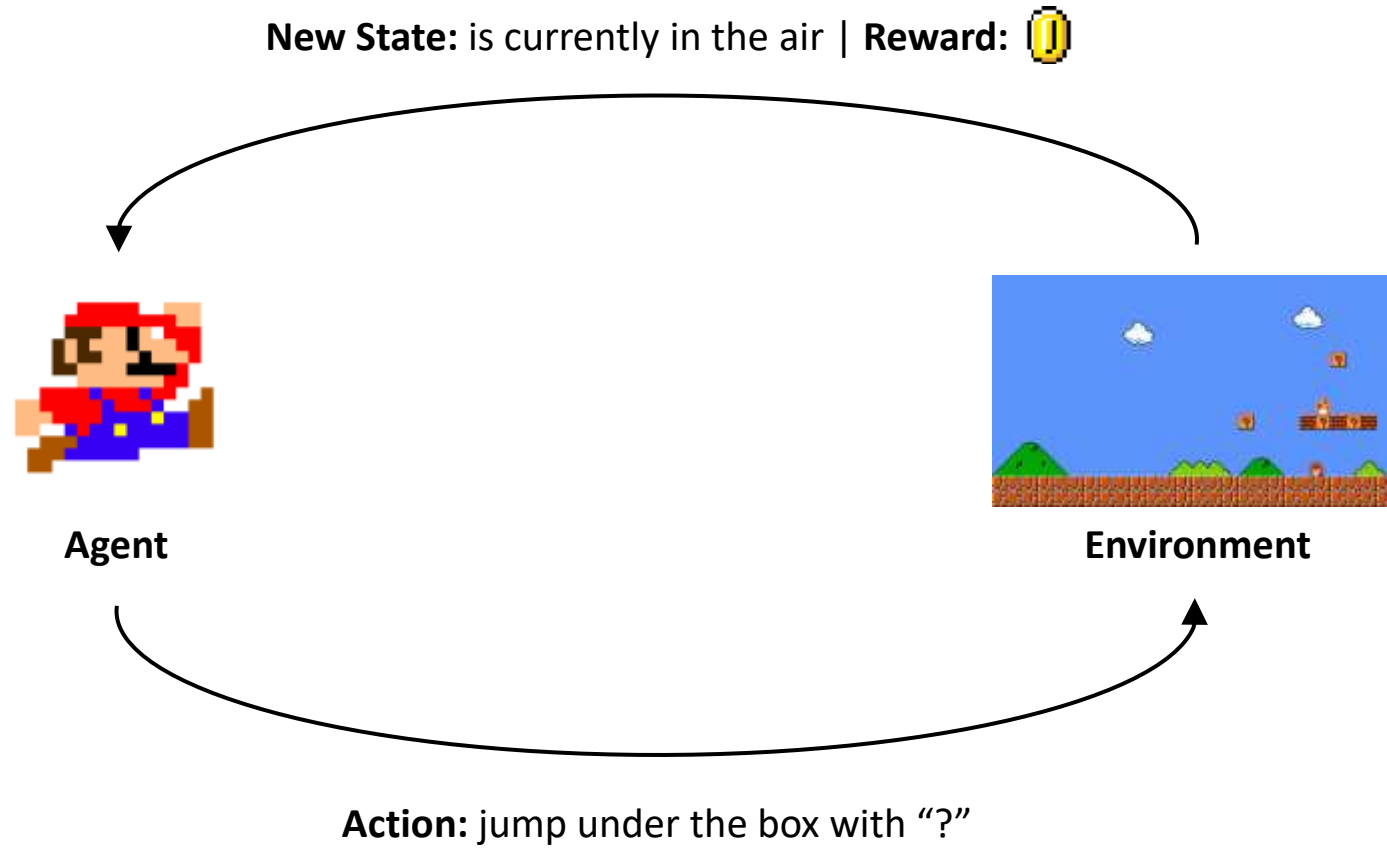
Abstraction



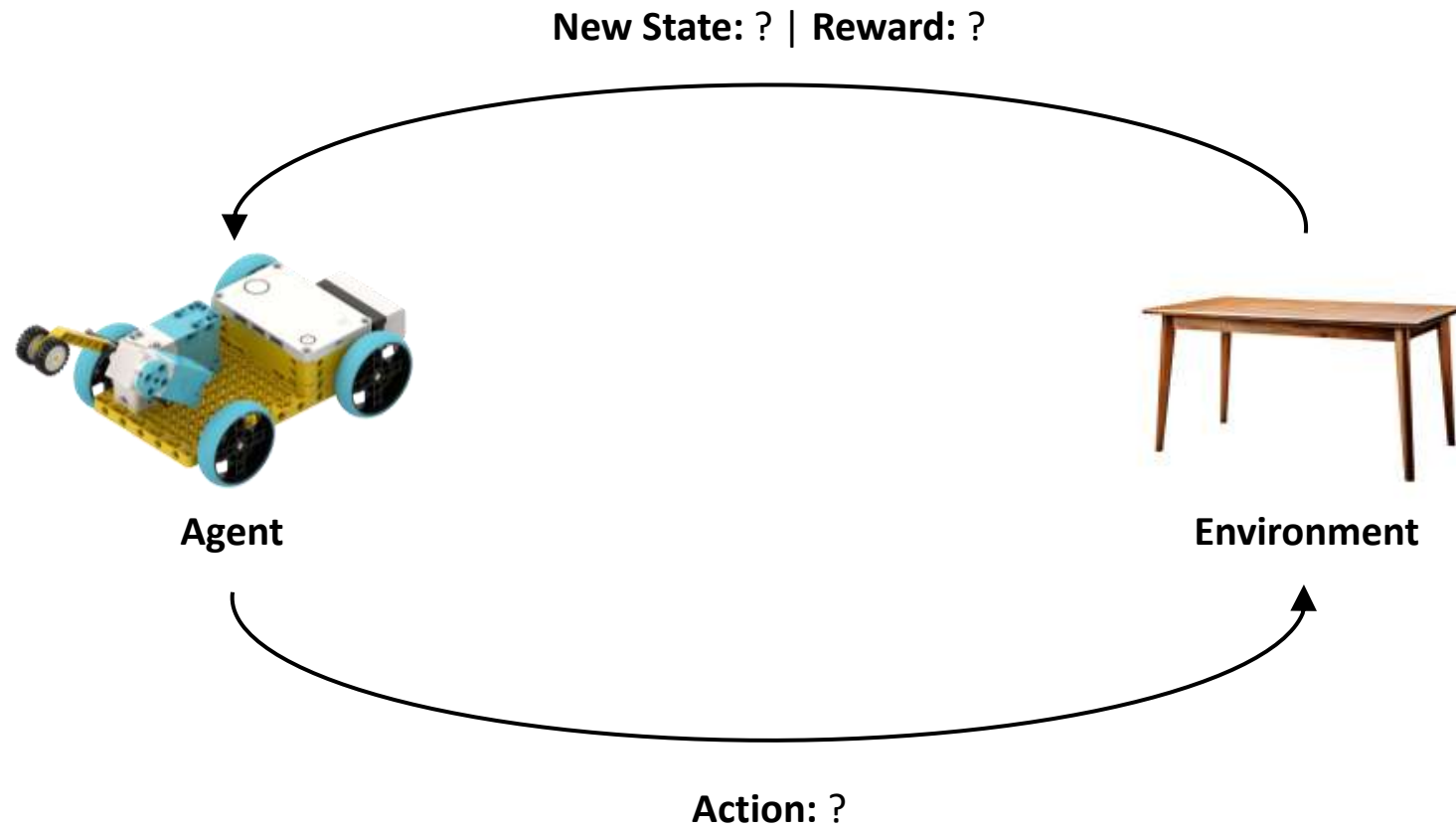
Abstraction



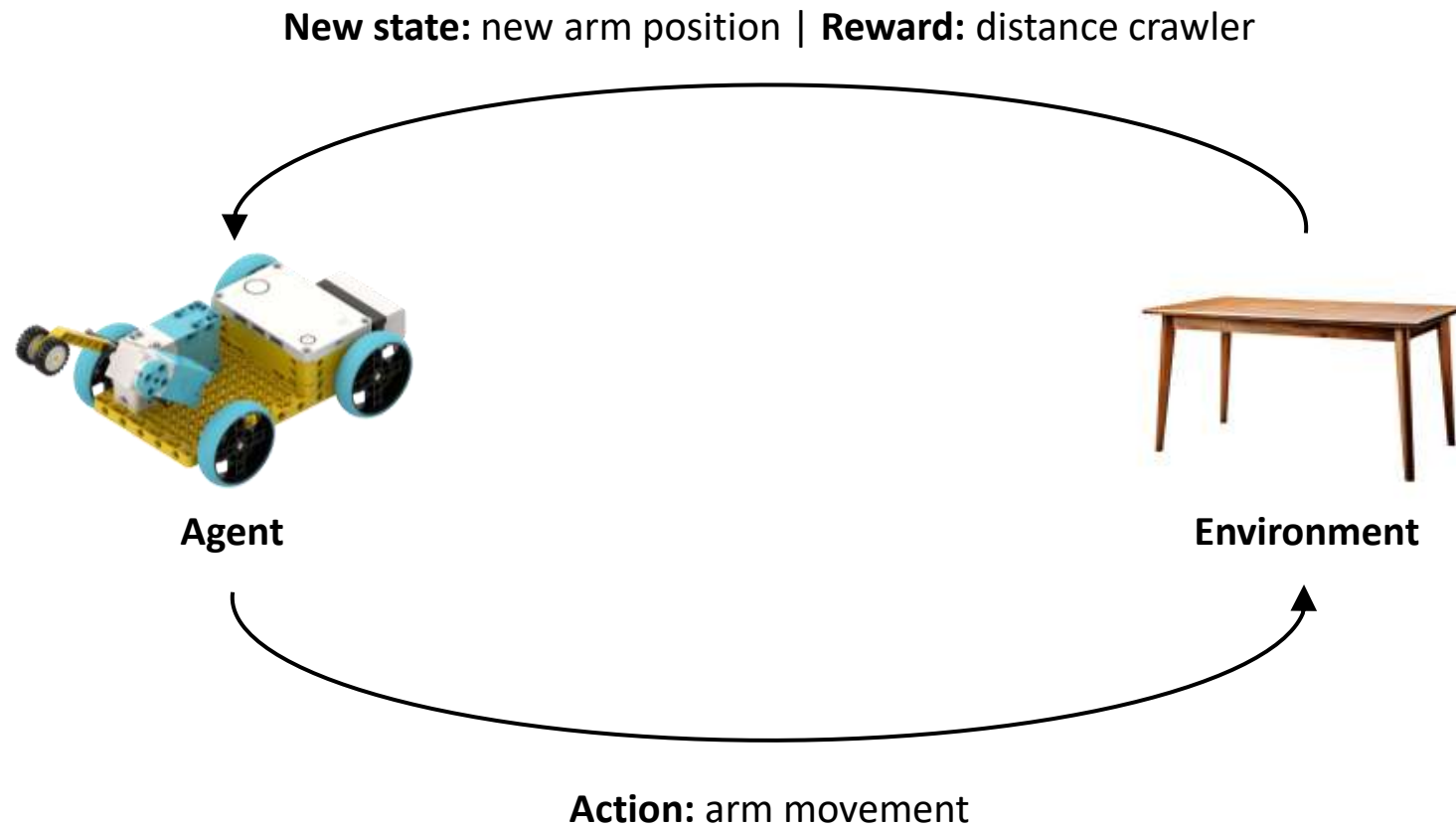
Example of Super Mario Bros



Crawler – Concept

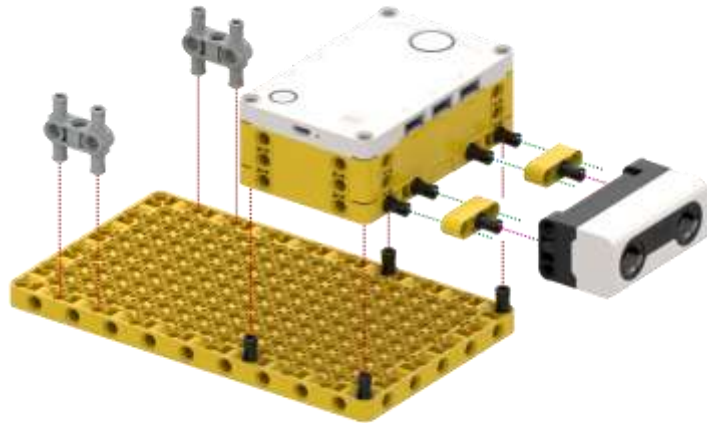


Crawler – Concept



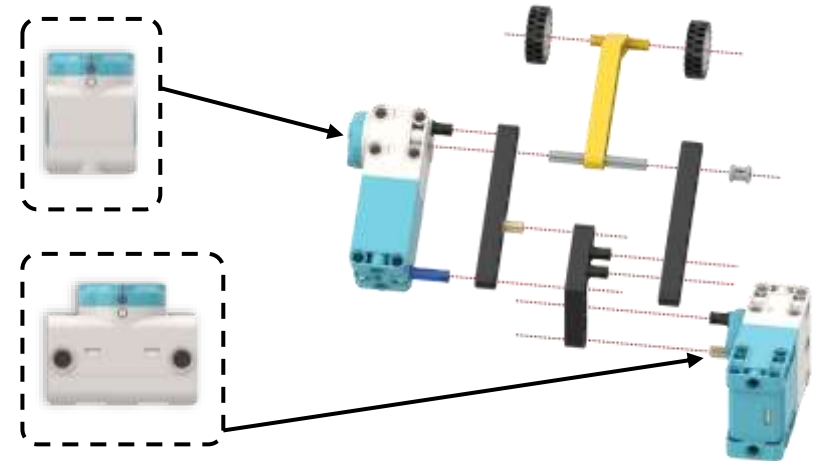
Crawler – Assembly

1

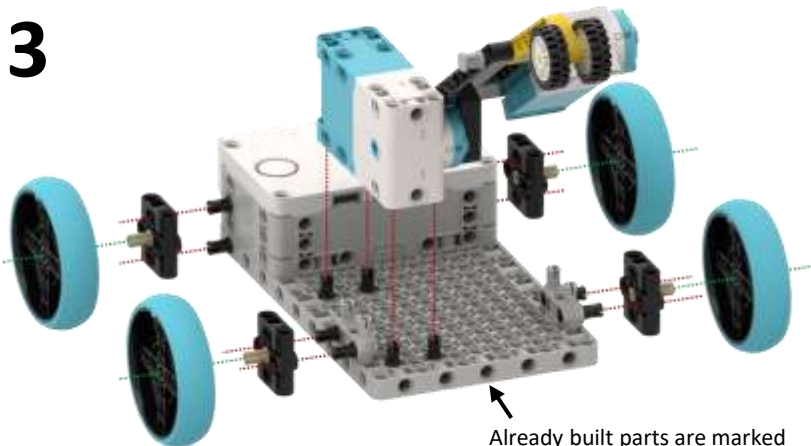


2

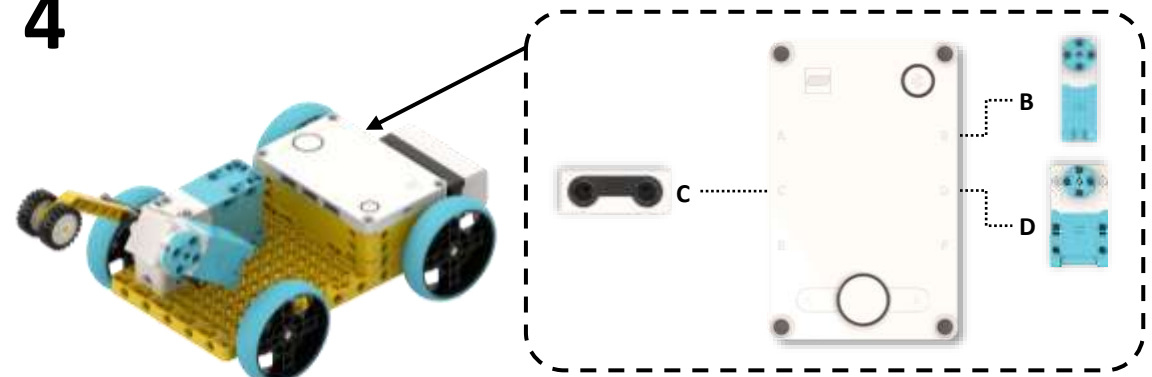
Place motors
in zero
positions!



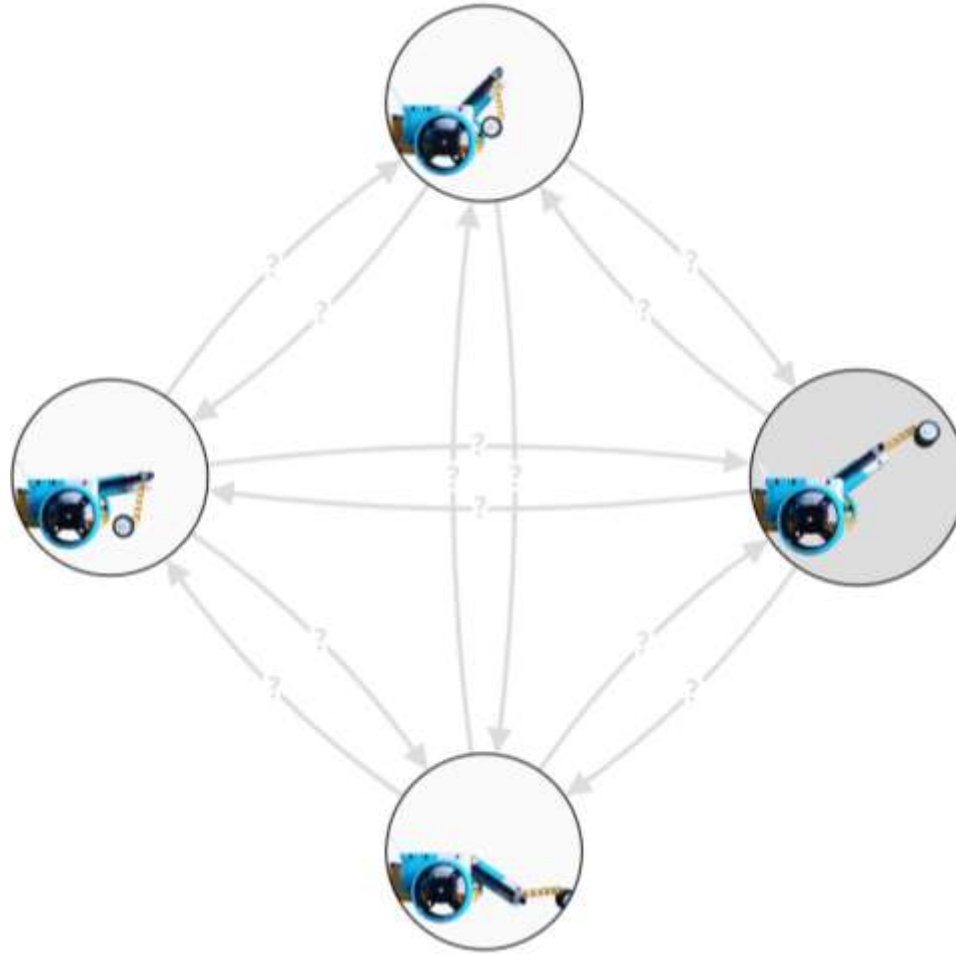
3



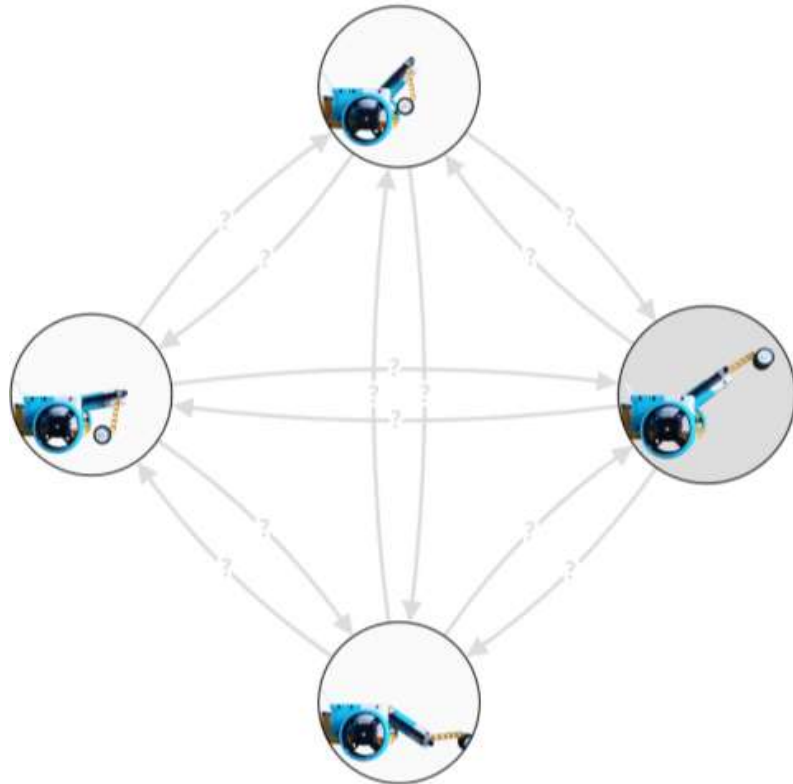
4











How good is an action?



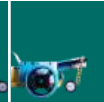
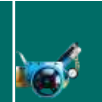


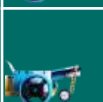
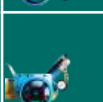


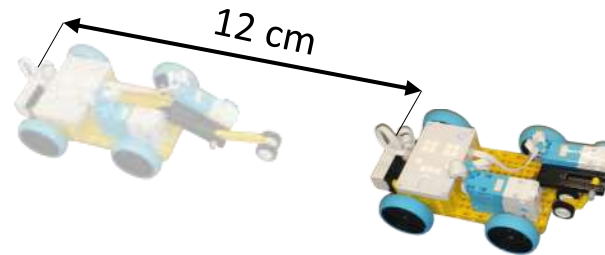
How good is an action?




		Next State			
					
Current State					
					
					
					



How good is an action?

		Next State			
					
Current State			0	0	0
		0		0	0
		0	0		0
		0	0	0	












		Next State			
					
Current State			0	0	0
		0		+12	0
		0	0		0
		0	0	0	

How good is an action?

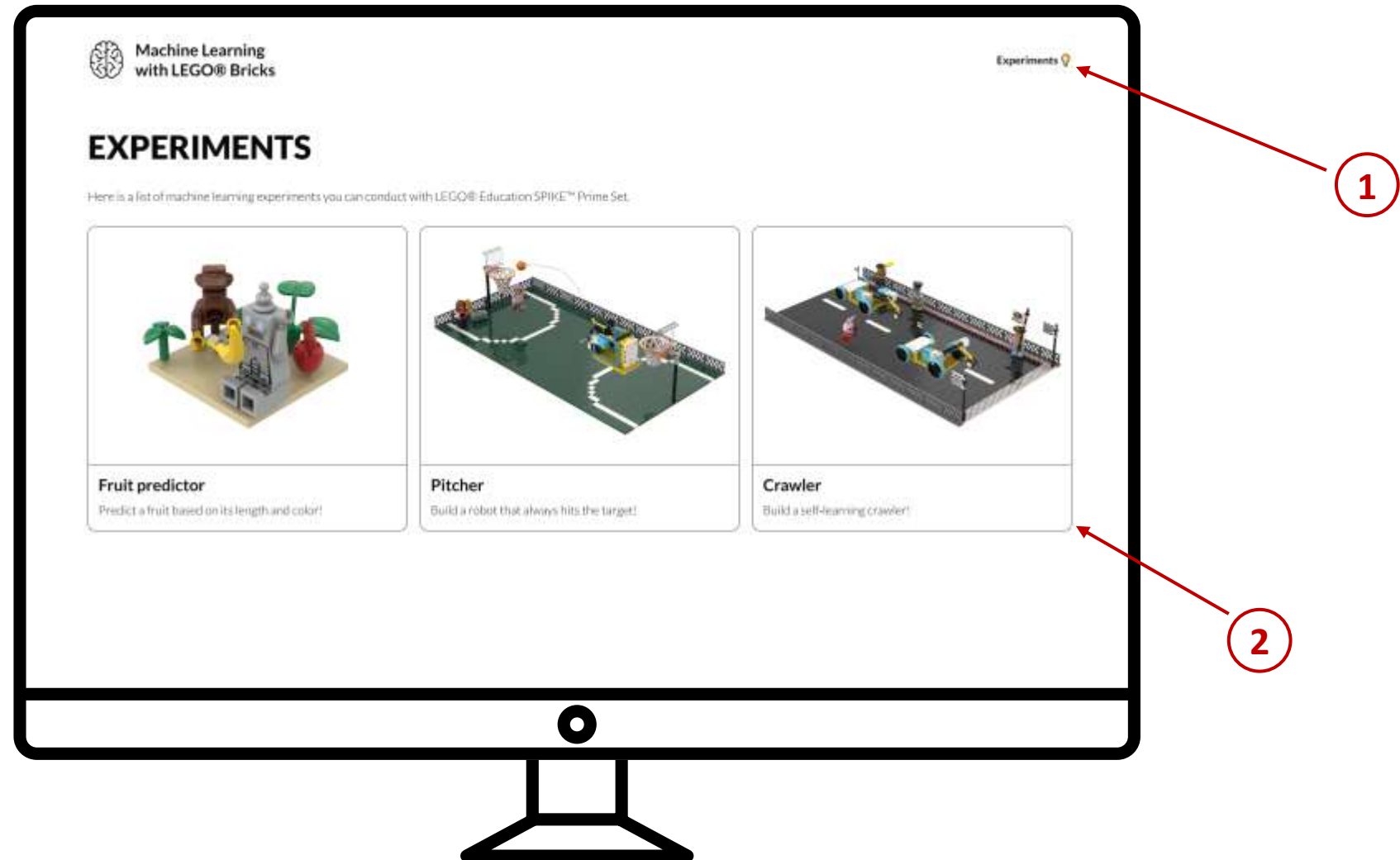
		Next State			
					
Current State			0	0	0
		0		0	0
		0	0		0
		0	0	0	



Training

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

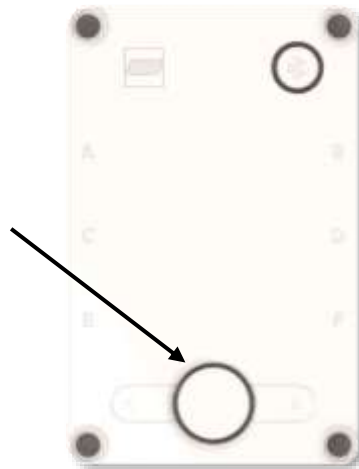
Open the experiment page



Connect hub and start the program

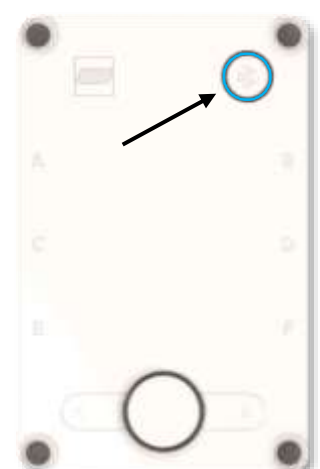
1

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

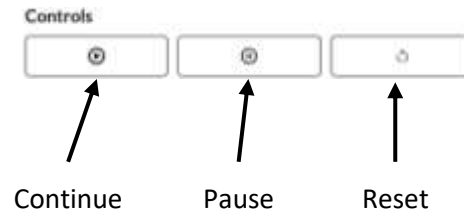
Click on 'Start program' and wait until a notification appears on the website.

 **Start program**

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.

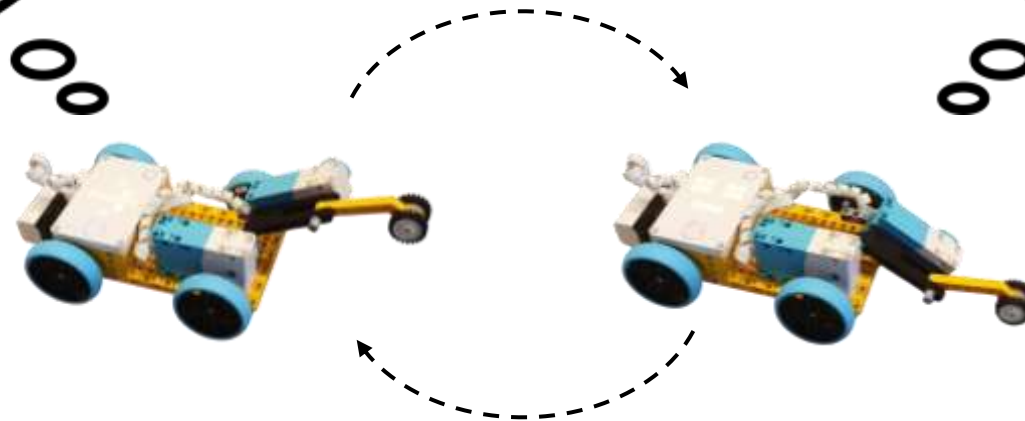
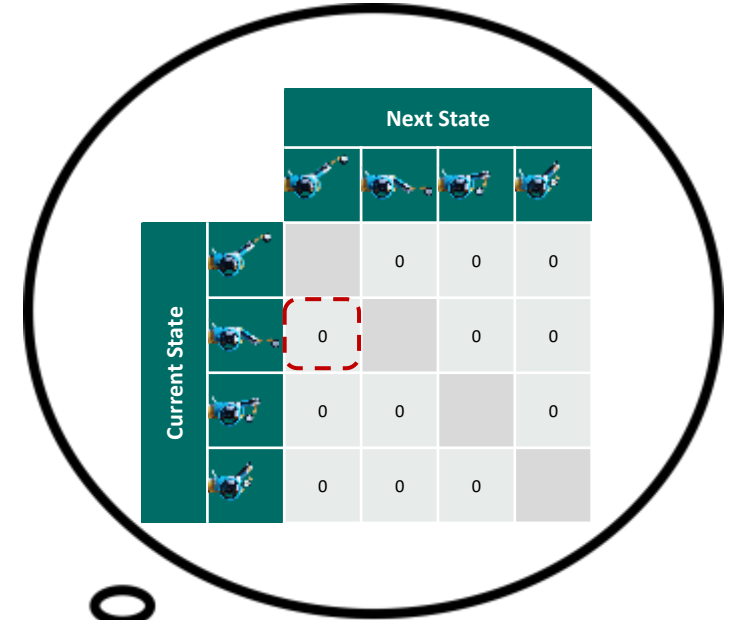
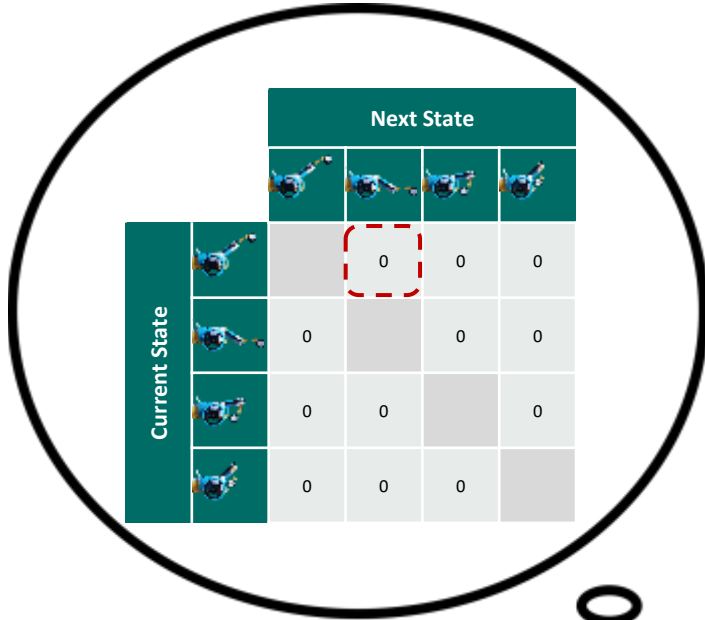


4

Observe how the table gets filled.

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

Why is it not working?



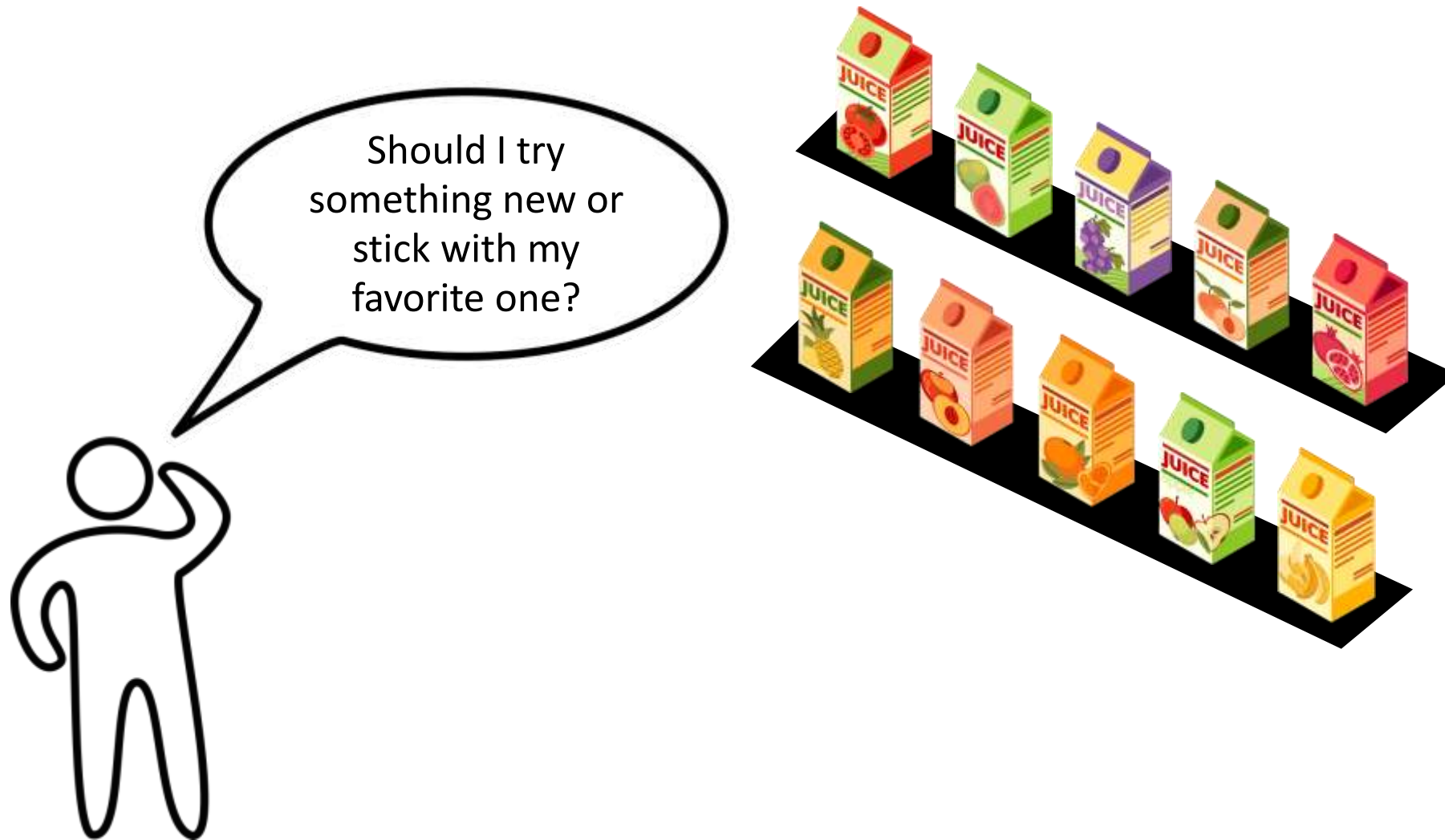
Trying something new?



Trying something new?

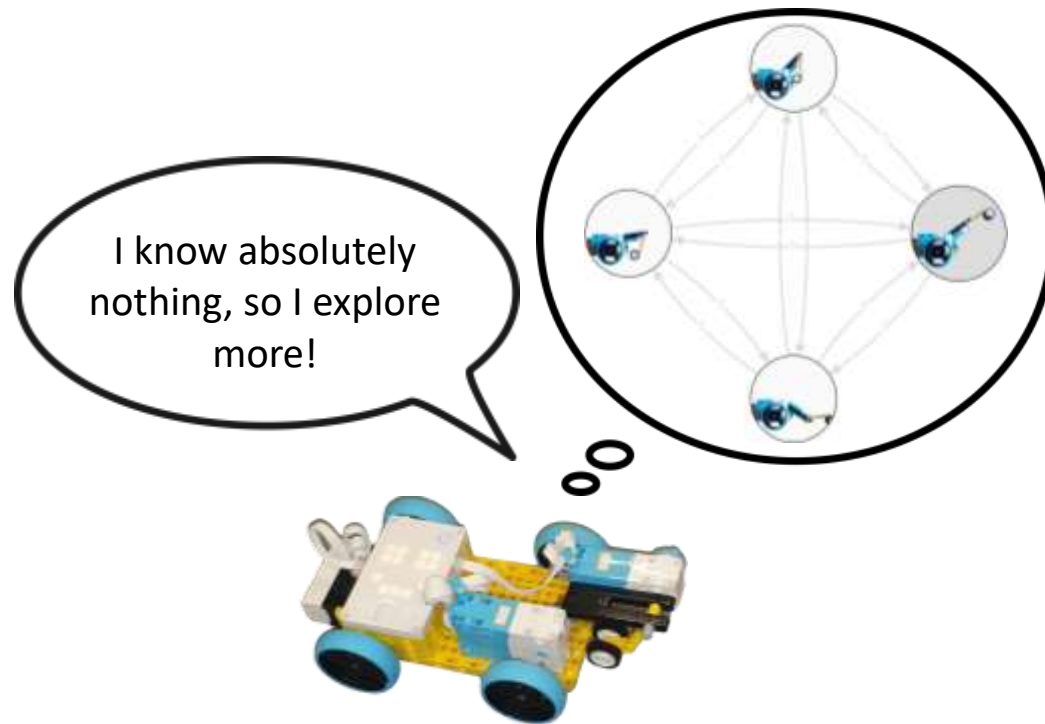


Exploration-Exploitation-Dilemma

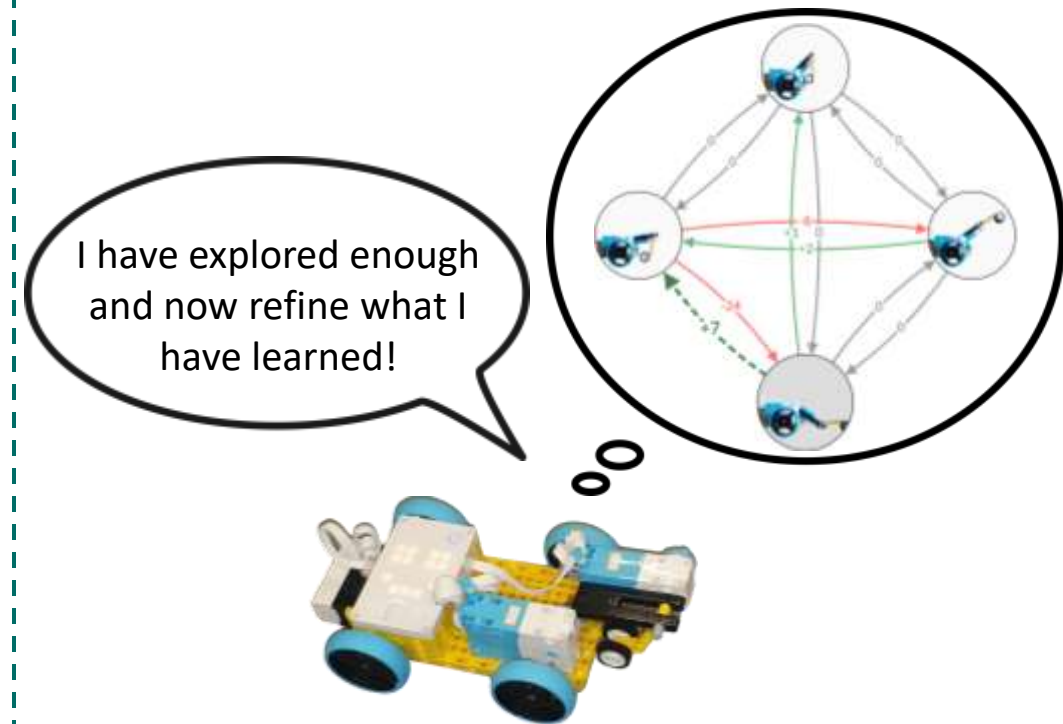


Exploration-Exploitation-Dilemma

Beginning of training



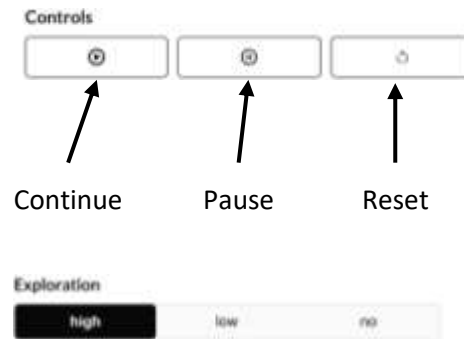
End of training



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.

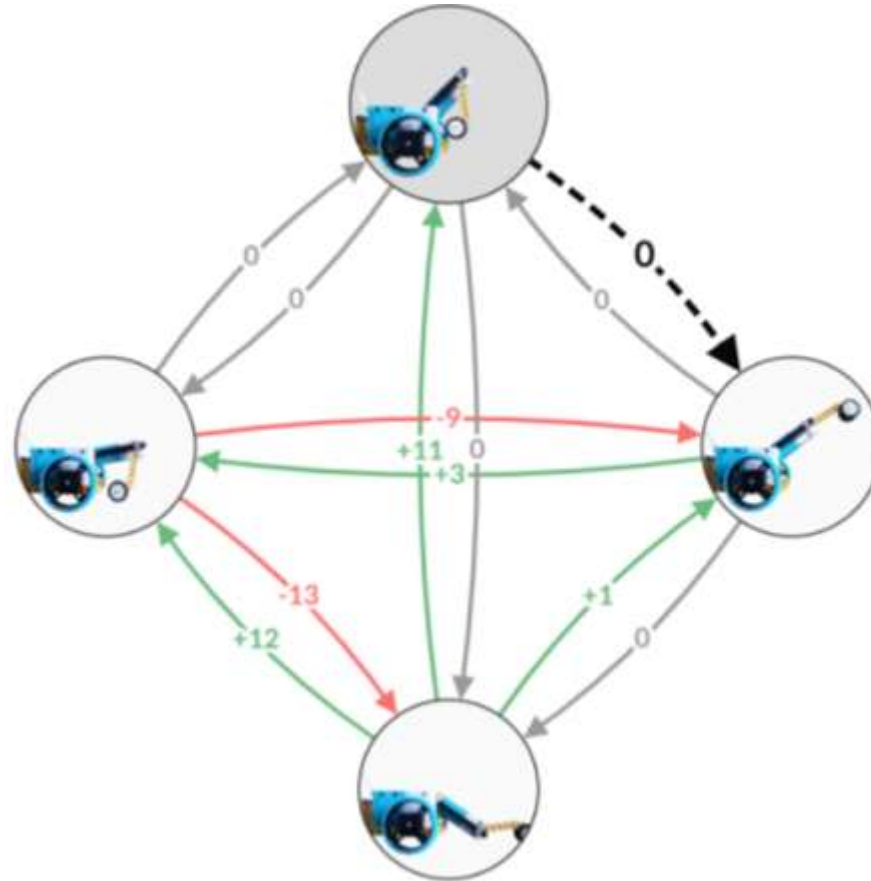


4

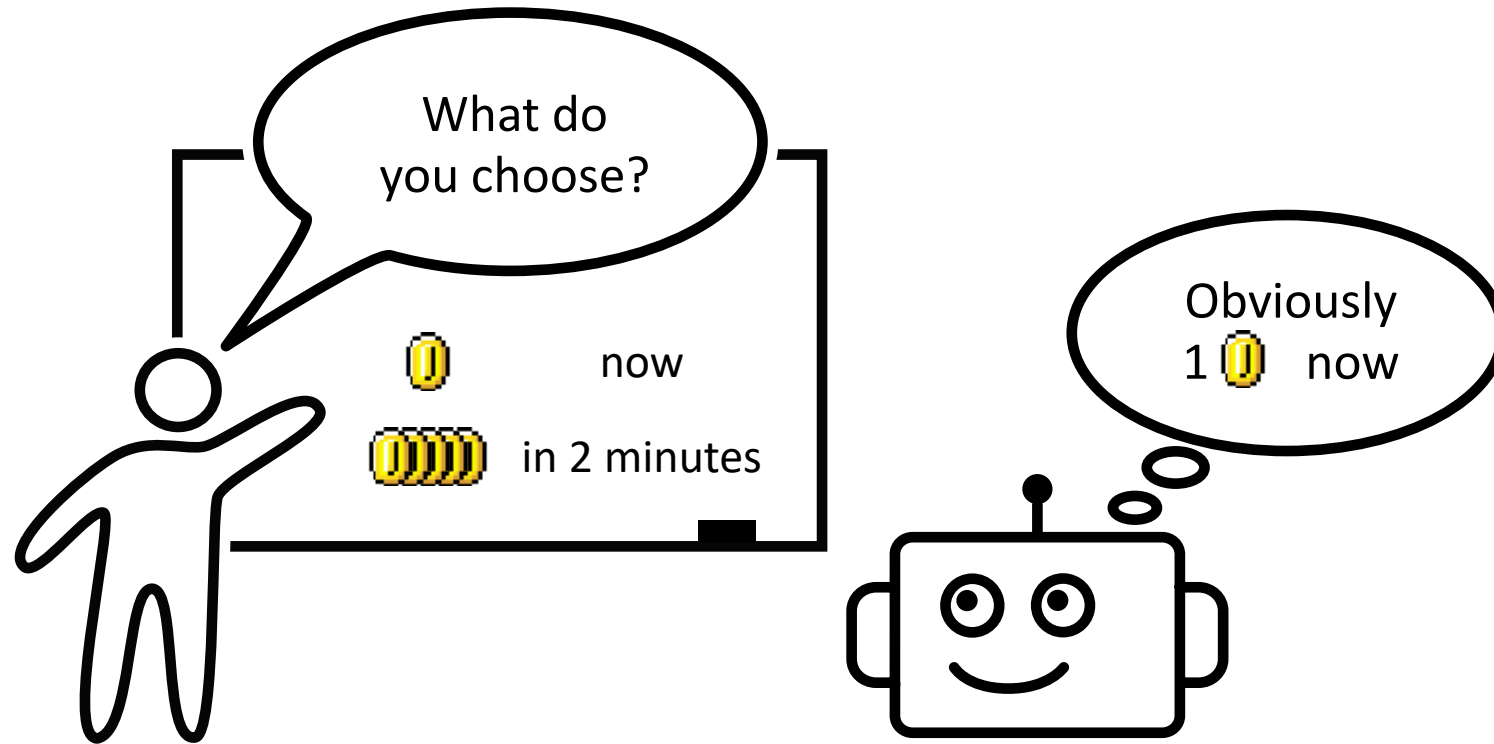
Observe how the table gets filled. Reduce exploration over time.

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



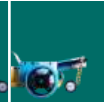
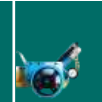



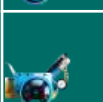
Foresight

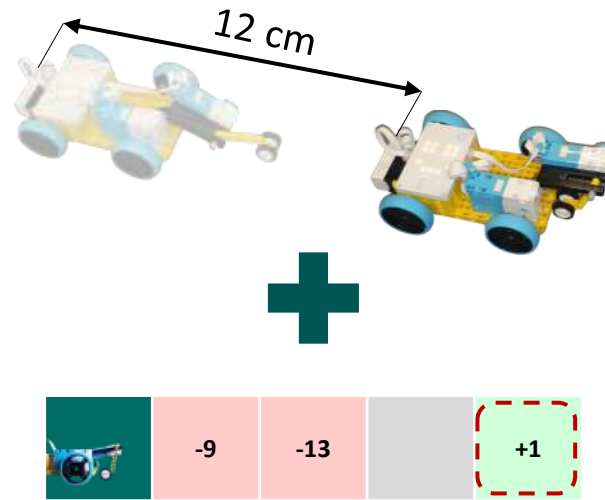


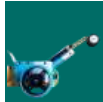
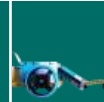
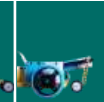
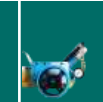



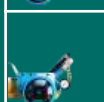
Foresight



Foresight

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

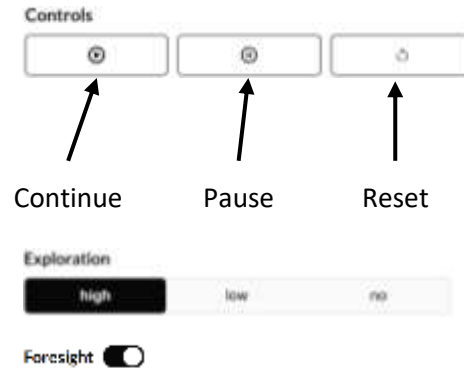


		Next State			
					
Current State			0	+3	0
		+1		+13	+11
		-9	-13		+1
		0	0	0	

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.

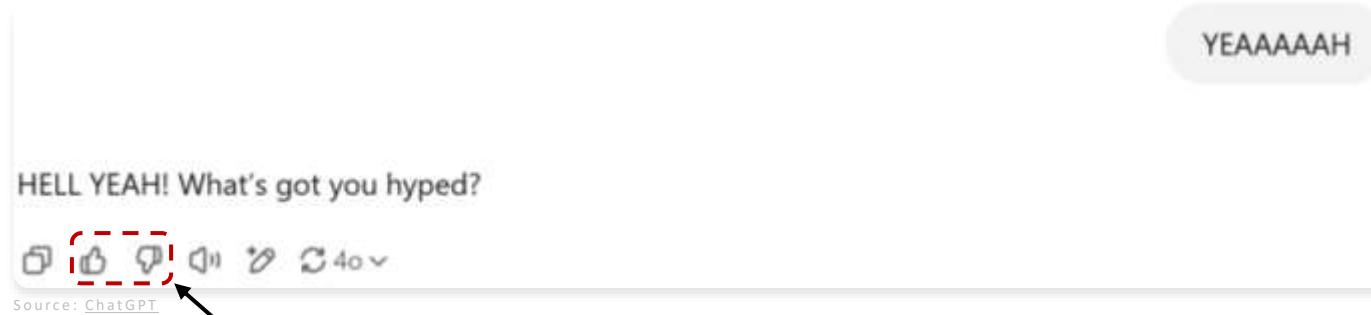


4

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

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

Other applications

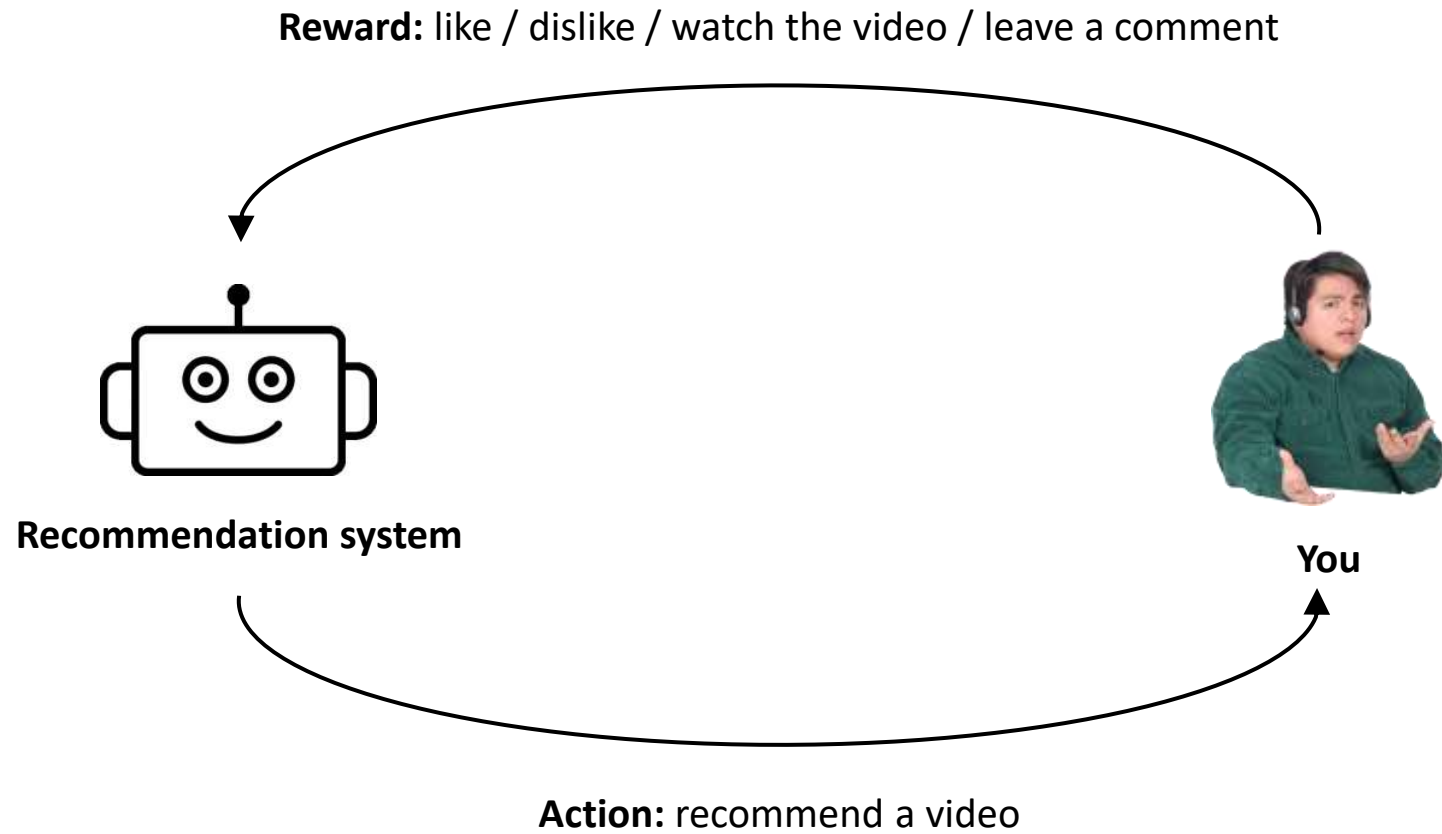


Reward (+1/-1)



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

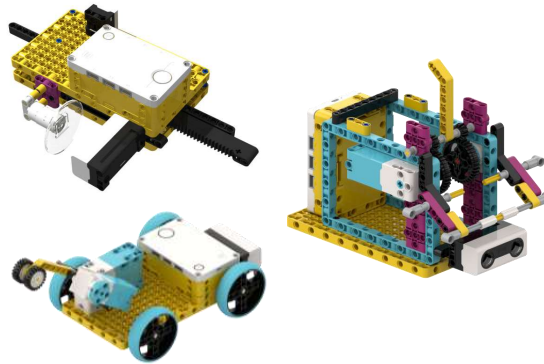
How recommendation systems work



Summary



Machine learning is no magic



Machine learning can do a lot



Power brings responsibility