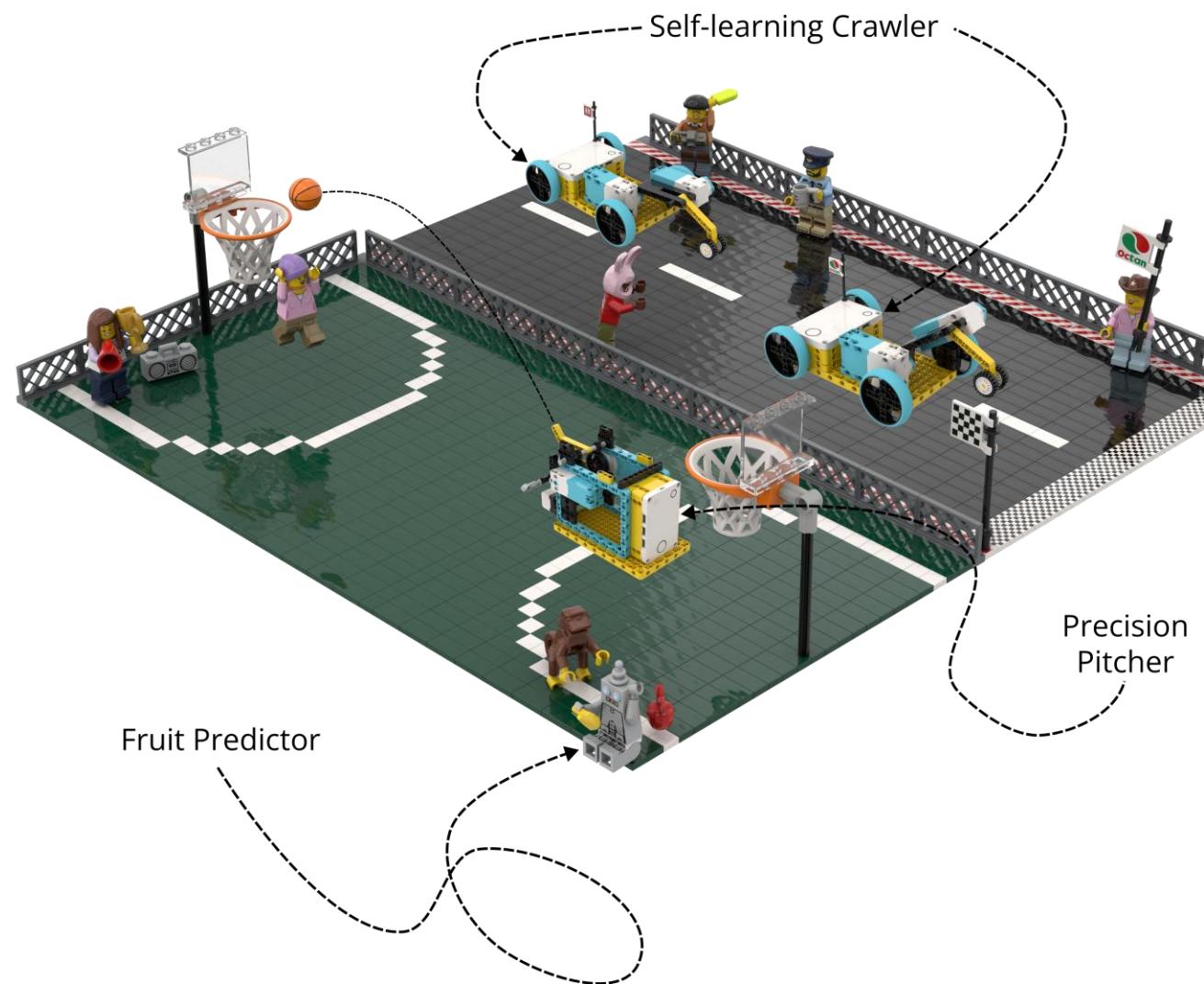




Machine Learning with LEGO® Bricks

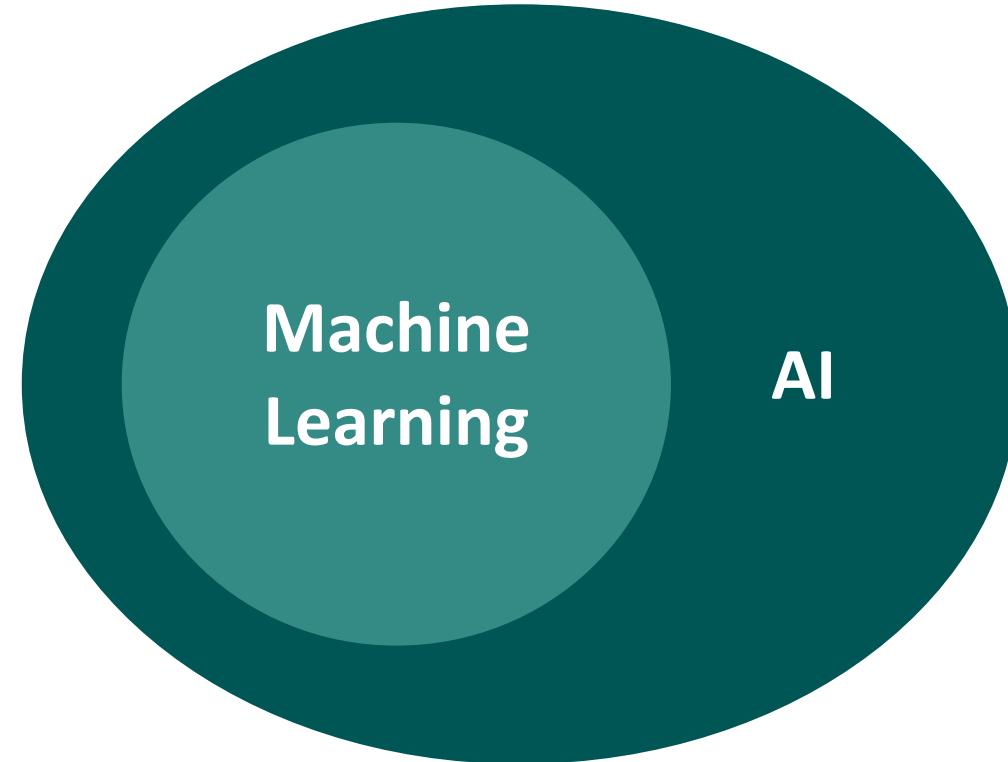
Viacheslav Sydora

Course overview



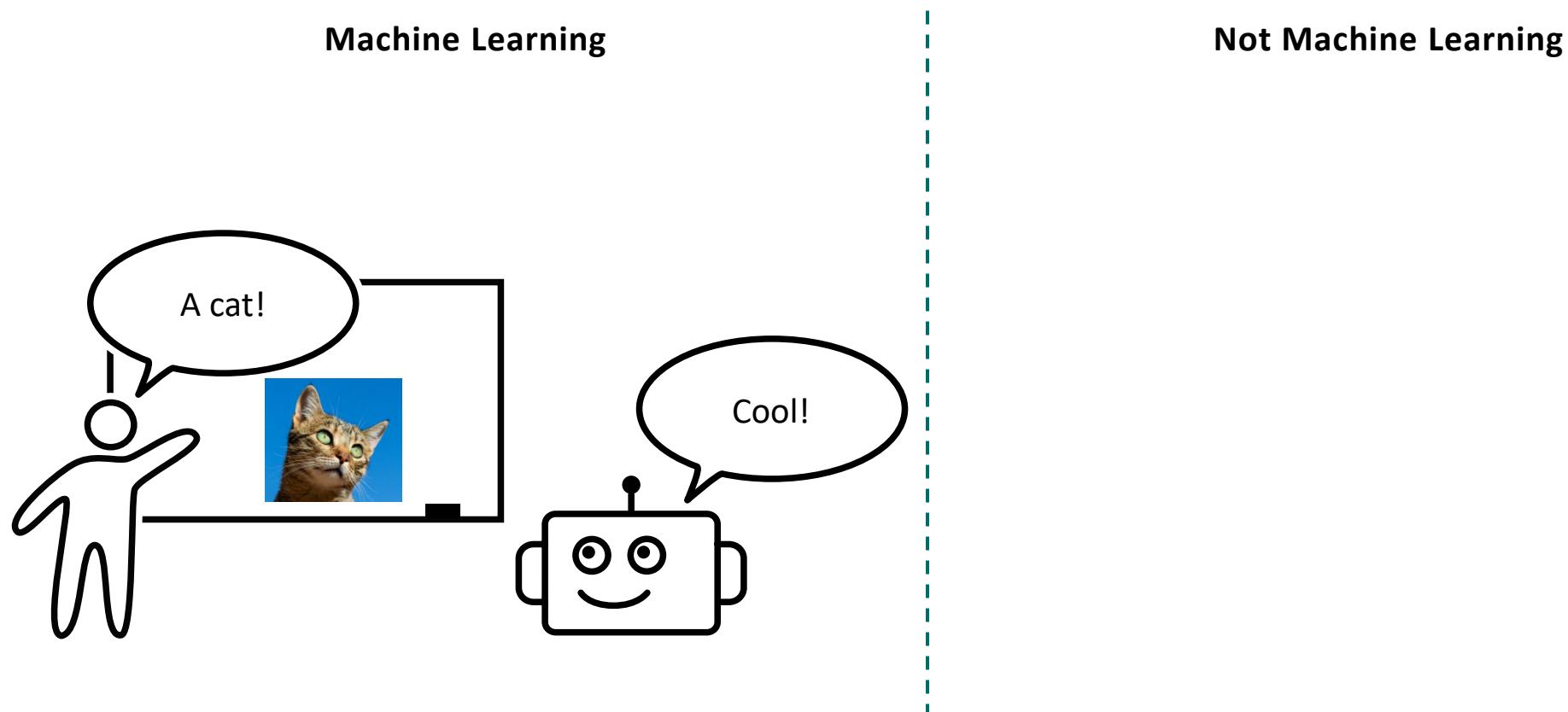
What is machine learning?

- Subfield of artificial intelligence



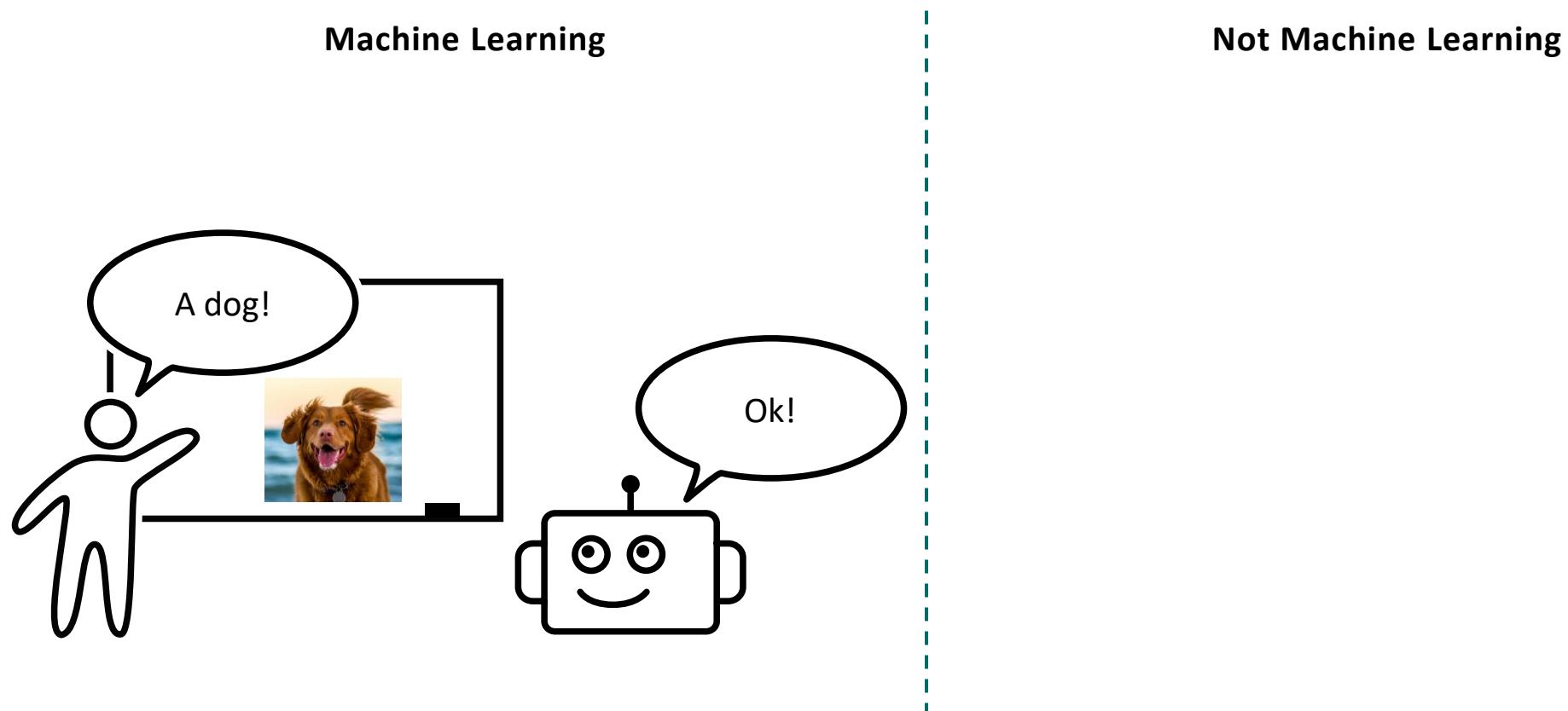
What is machine learning?

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



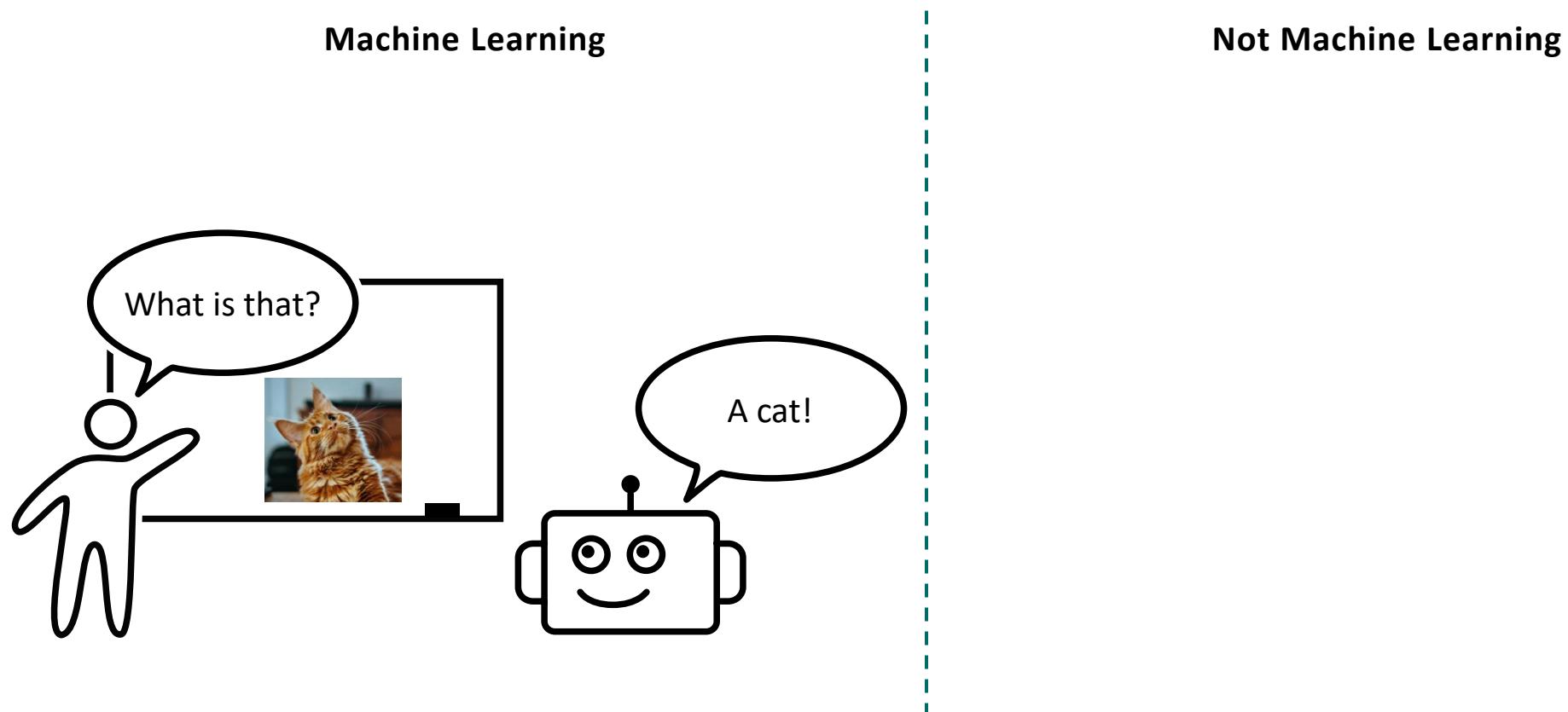
What is machine learning?

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



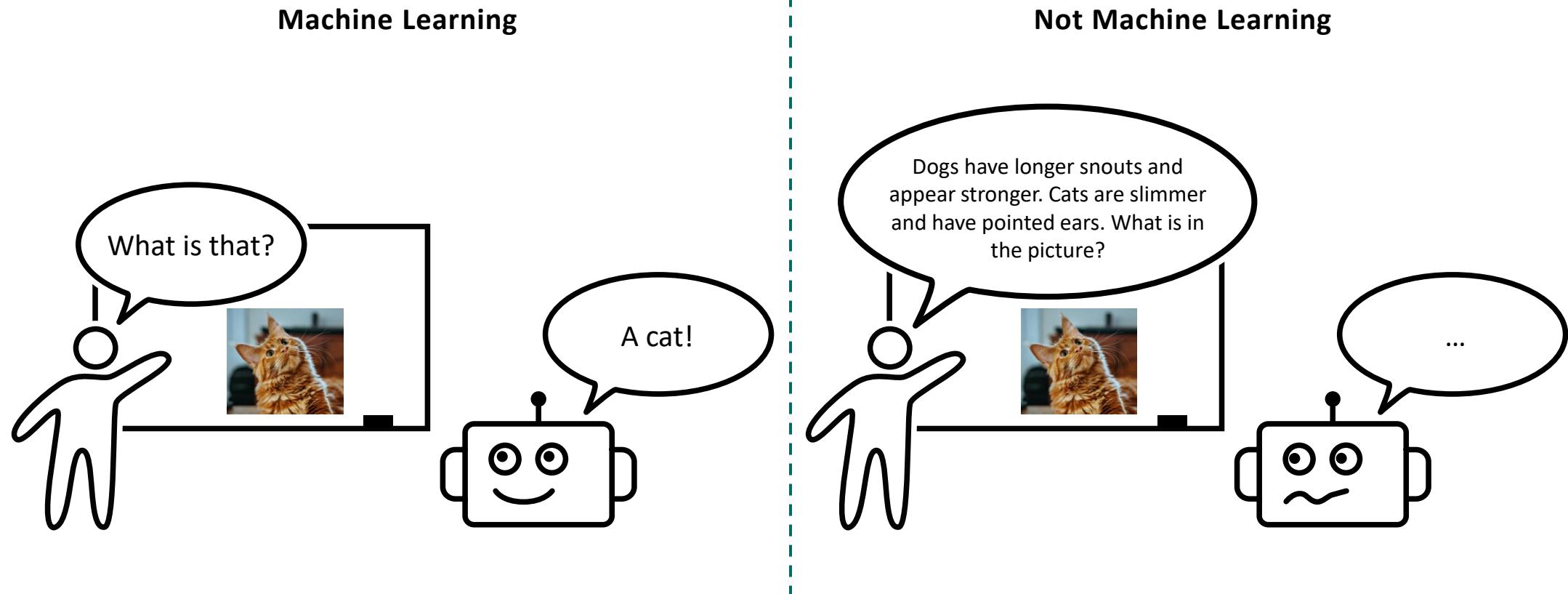
What is machine learning?

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



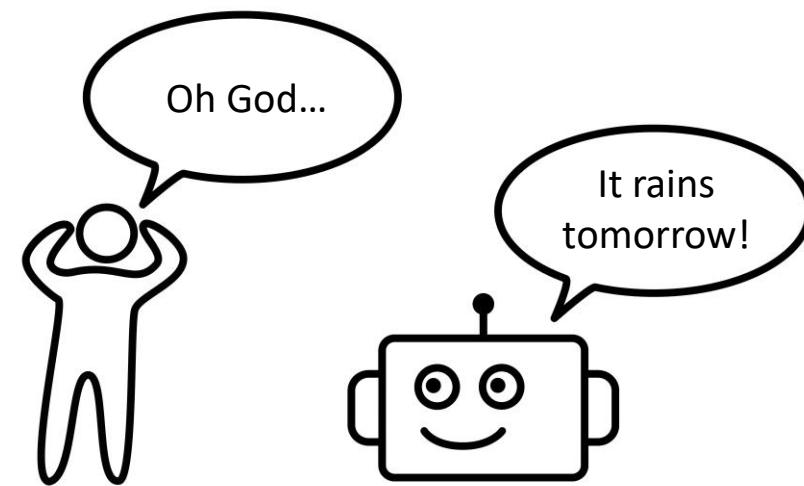
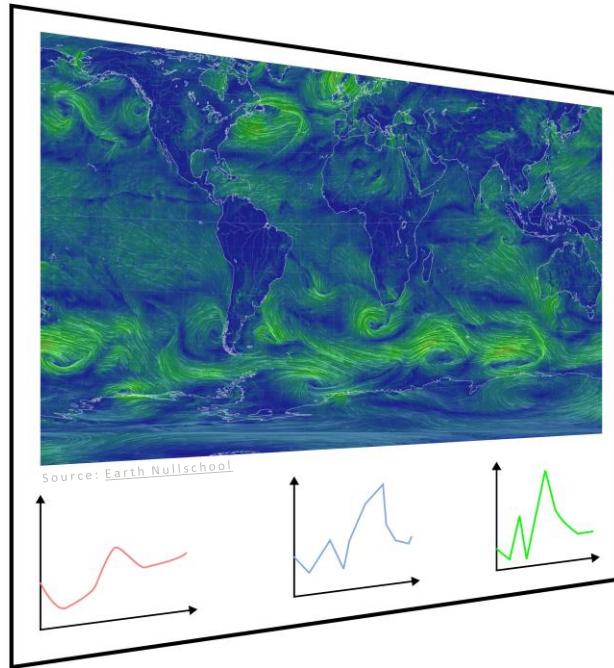
What is machine learning?

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

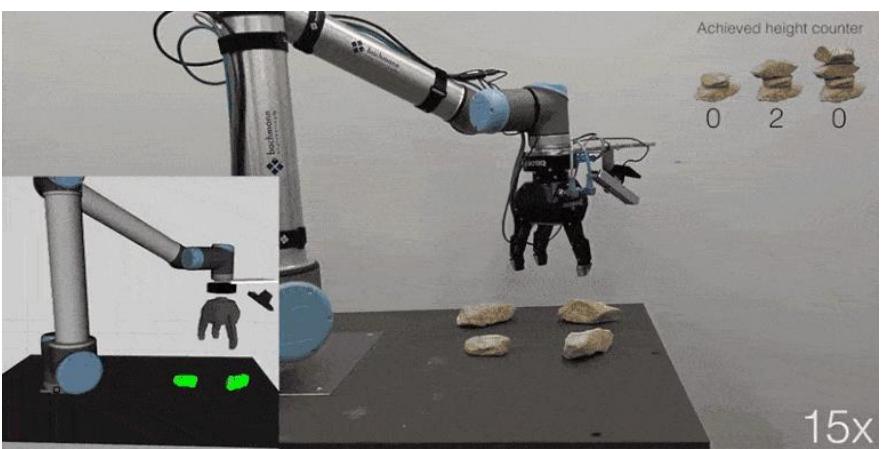


Why machine learning?

- works automatically
- can surpass humans



What else can machine learning do?



Source: [freeCodeCamp](#)

What can I help with?

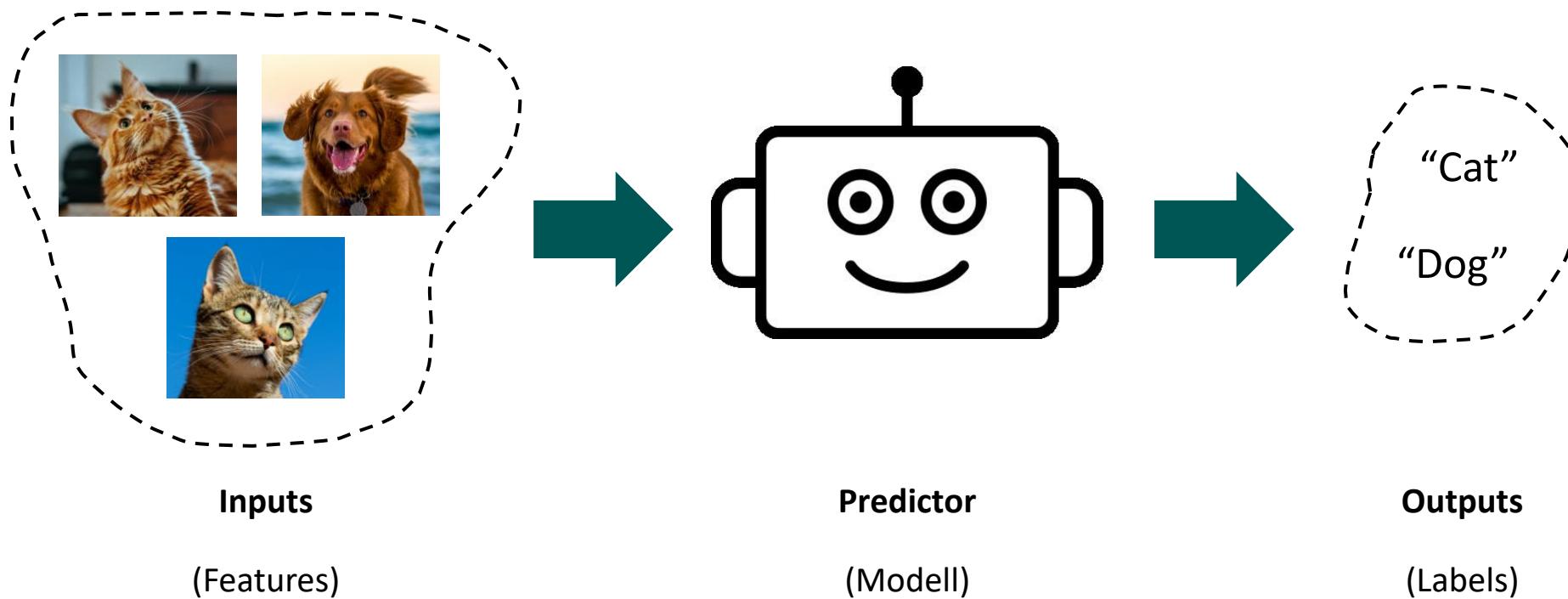
Ask anything

+ Search Reason

Source: ChatGPT

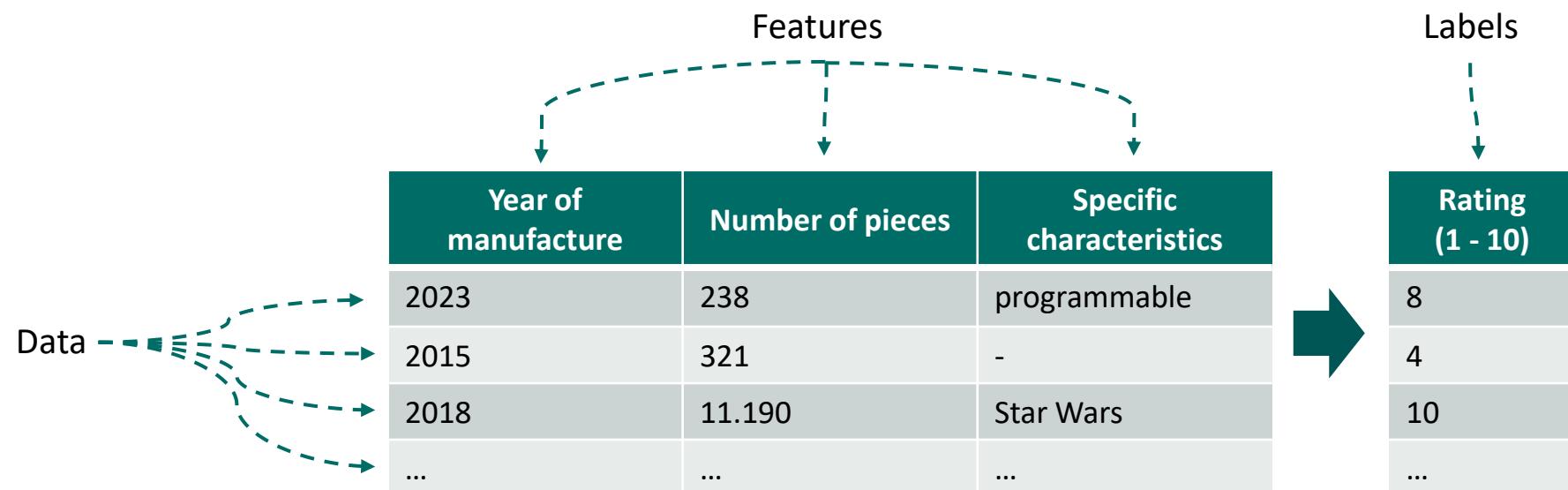
Data, Features & Labels

- Learning patterns from examples



Daten, Features & Labels

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

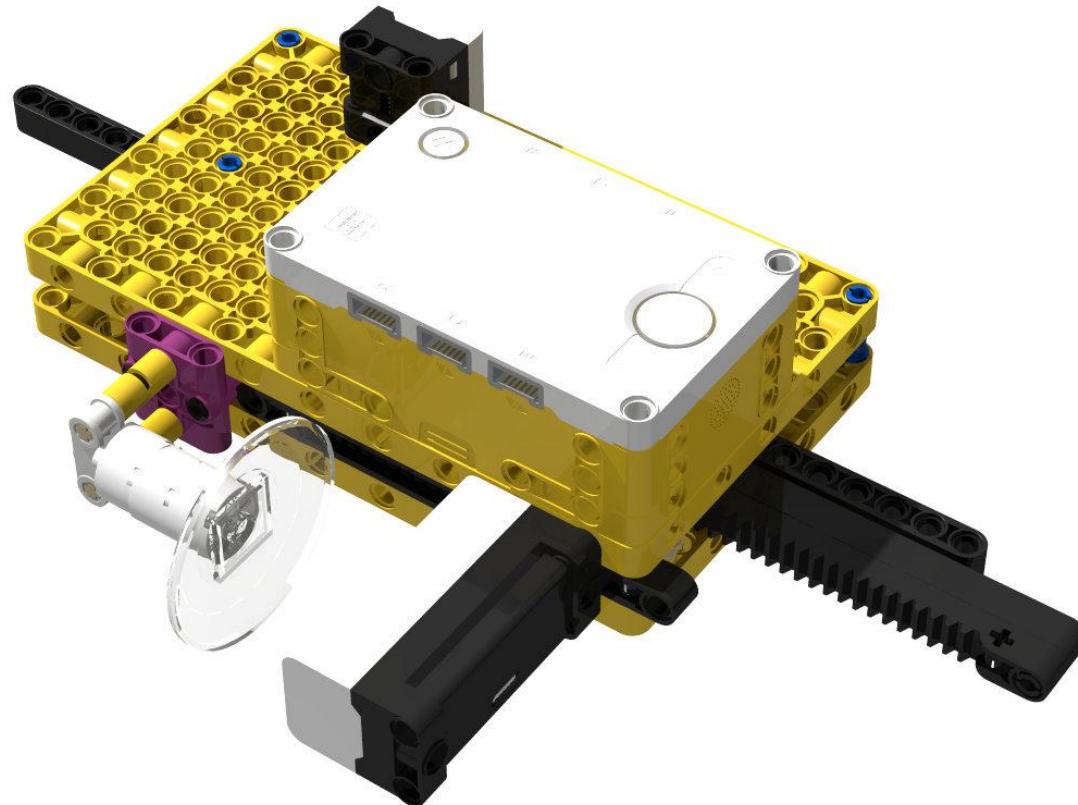


Fruit Predictor – Concept

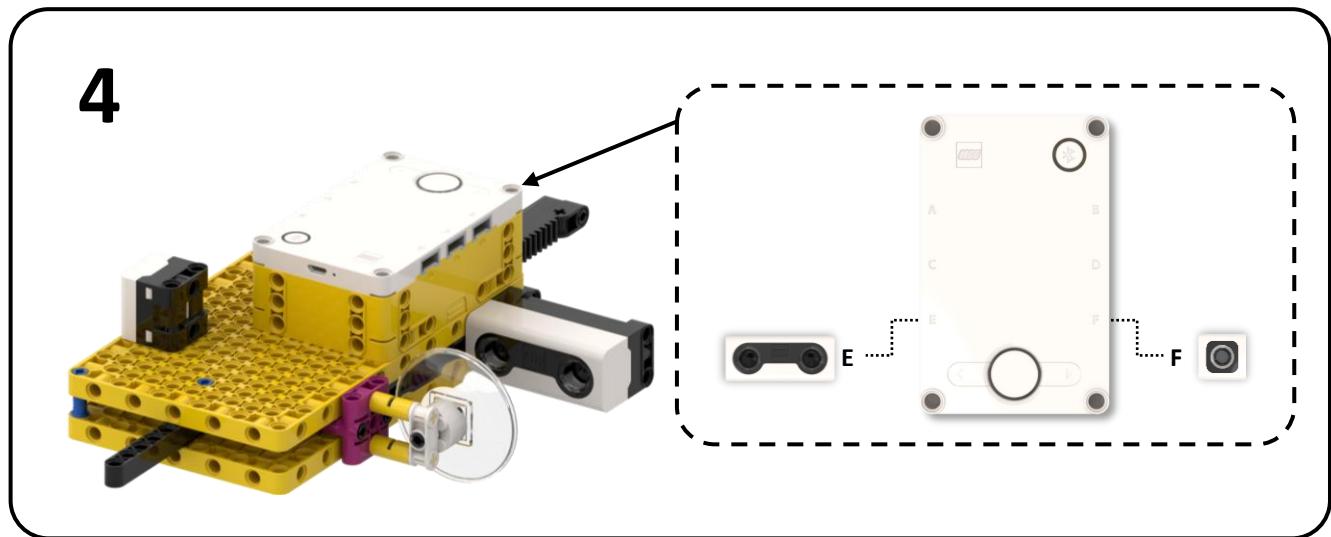
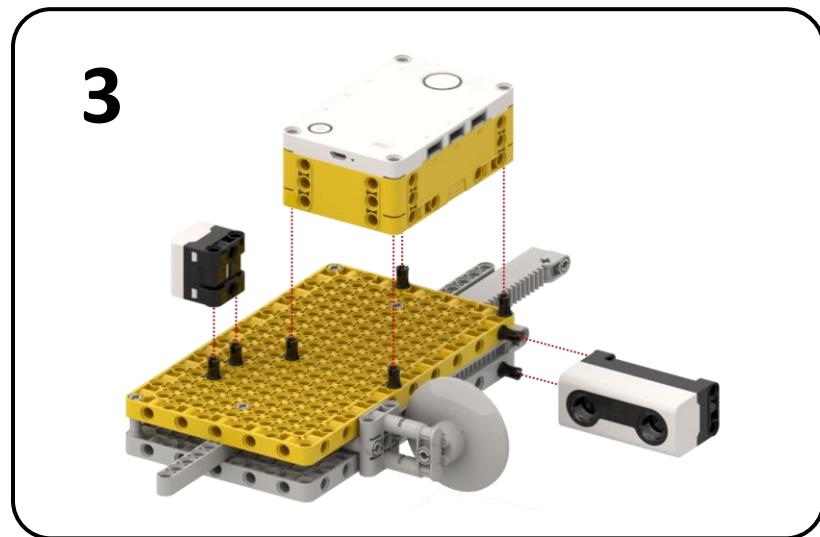
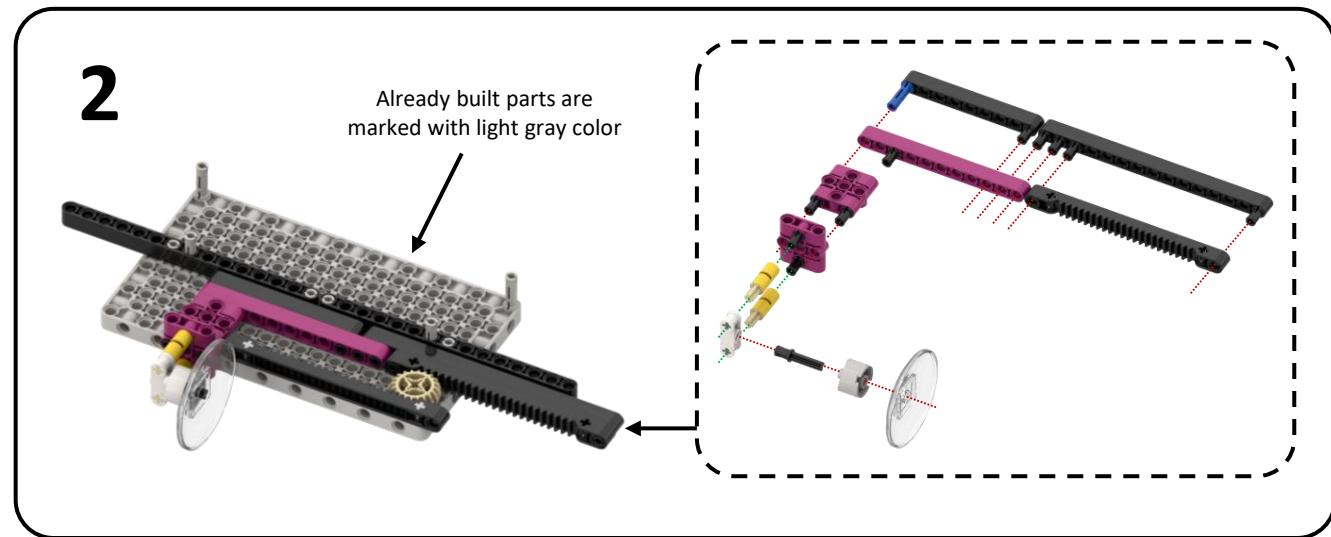
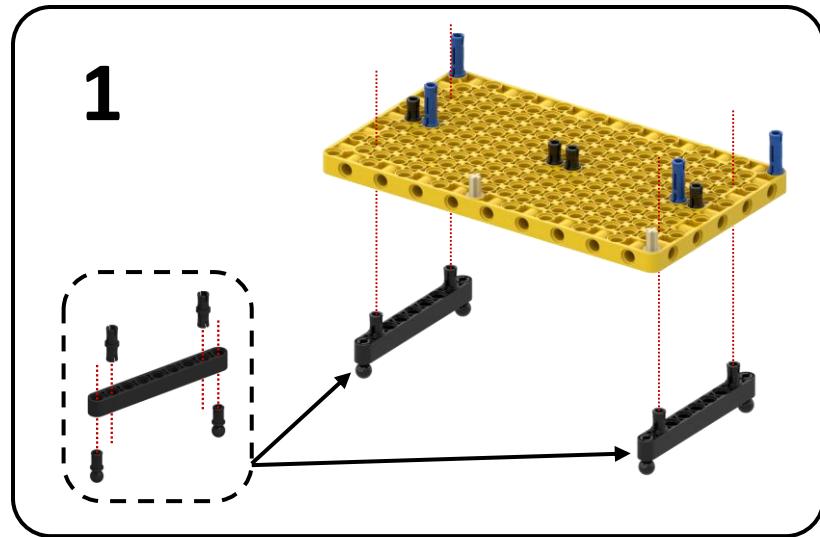
- **Features:** ?
- **Label:** ?

Fruit Predictor – Concept

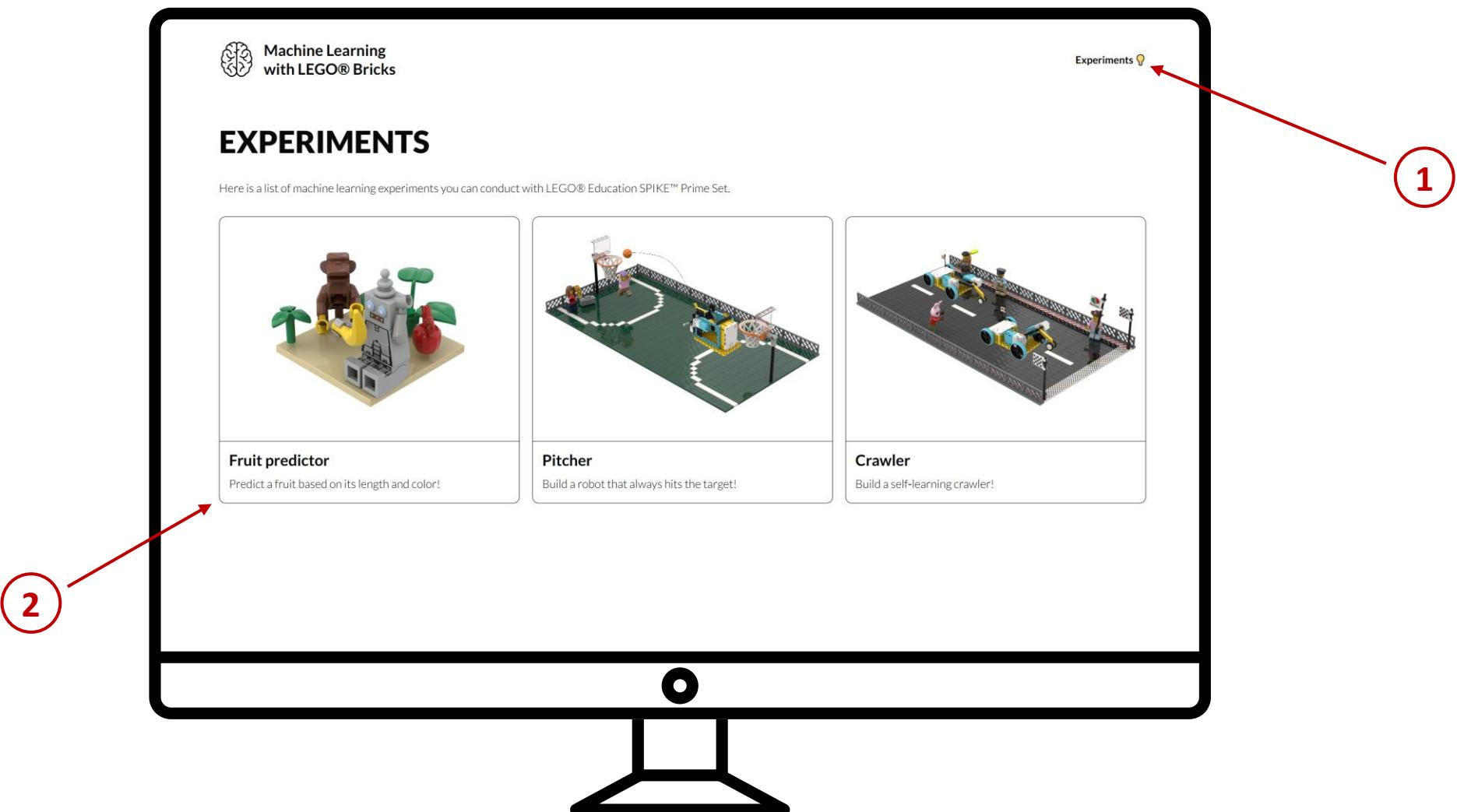
- **Features:** length and color of the fruit
- **Label:** fruit name (apple/banana)



Fruit Predictor – Assembly



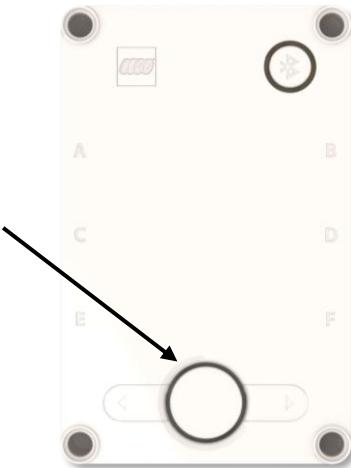
Open the experiment page



Connect hub and start the program

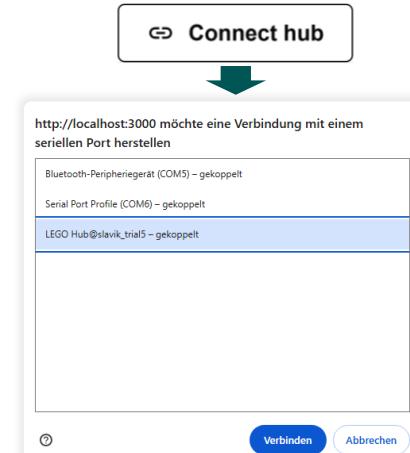
1

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



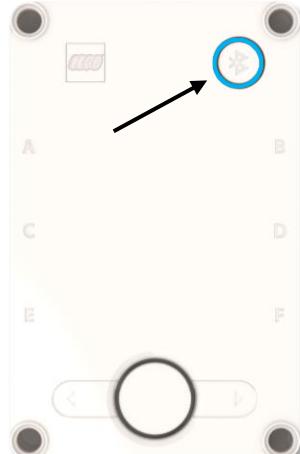
2

Click the "Connect hub" button on the website and select the LEGO hub in the dialog window.



3

Click "Connect" in the dialog window and wait. The Bluetooth button on the hub should possibly light up blue.



4

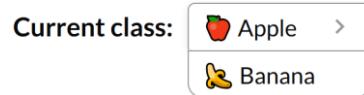
Click "Start program" and wait for the program to load.

Start program

Fruit Predictor – Data collection

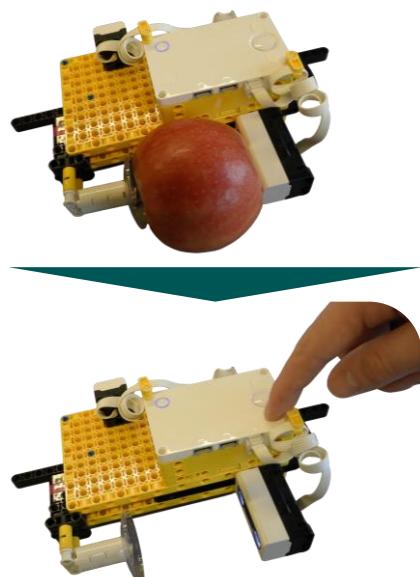
1

Select the fruit for which data will be collected.



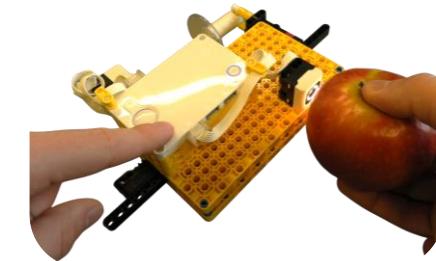
3

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



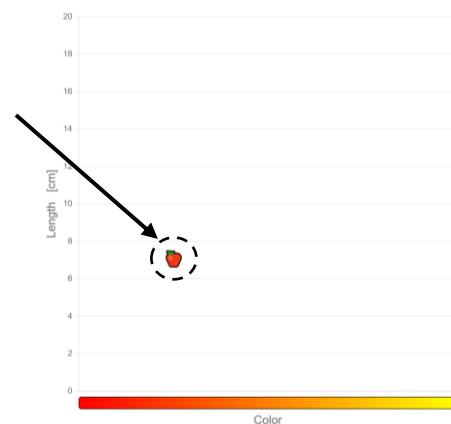
2

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

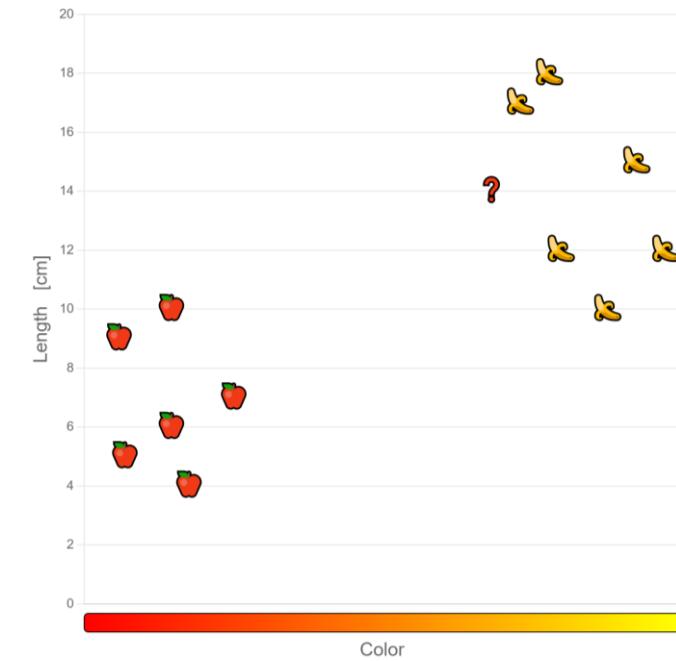
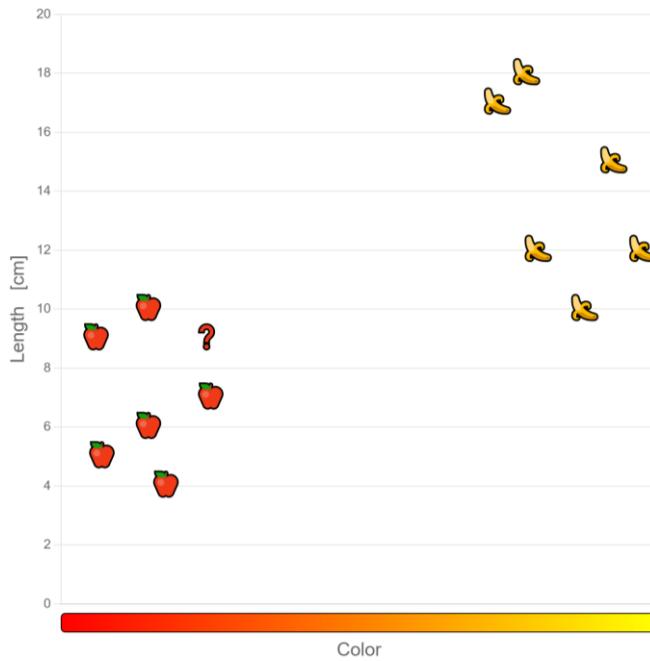
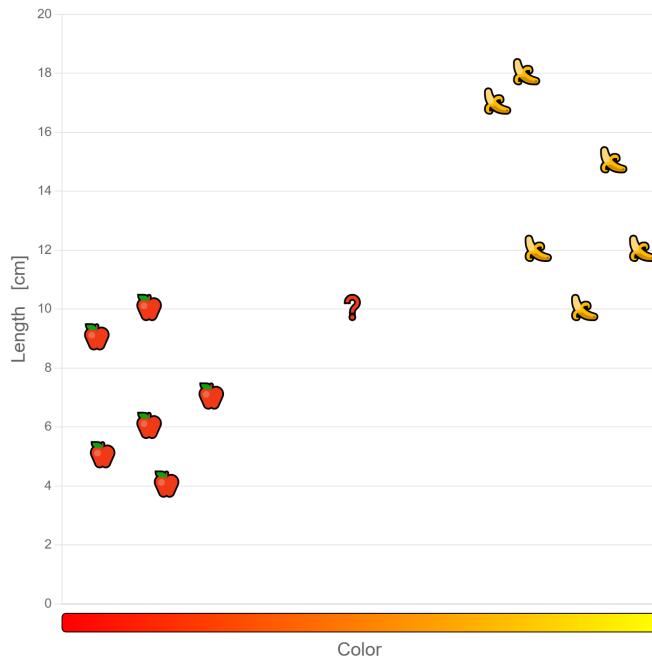


4

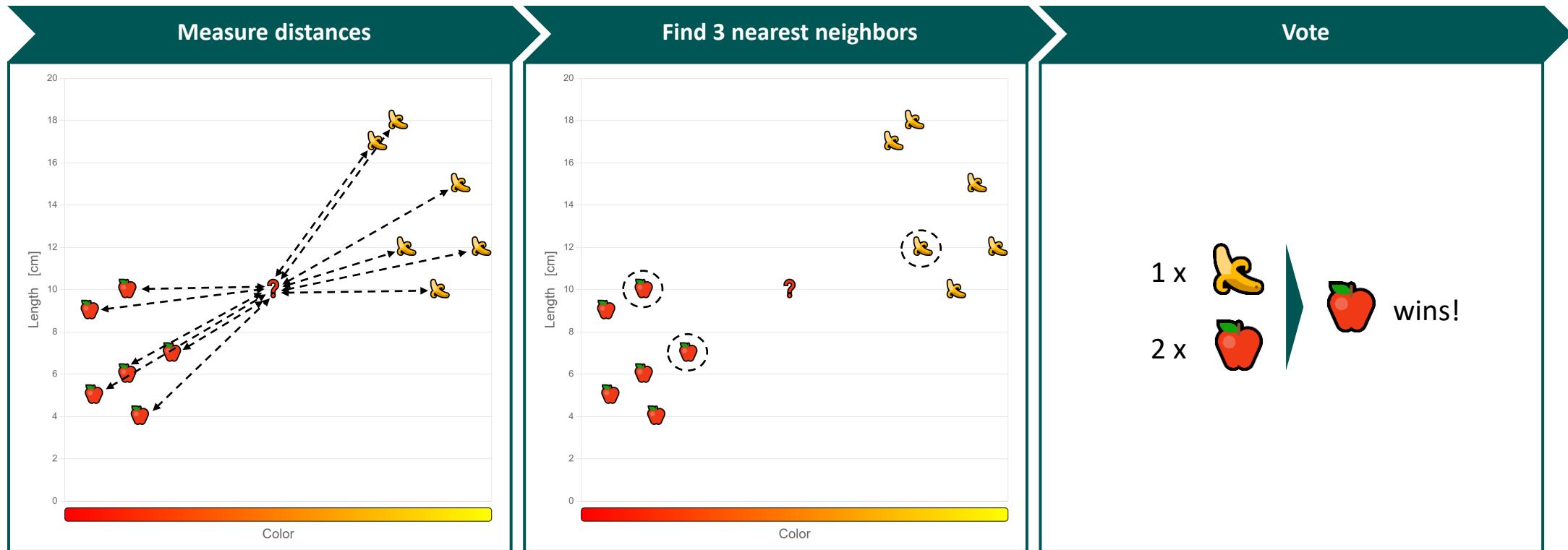
The data point will now be displayed on the website! Repeat the steps for other apples and bananas!



How can we predict a new fruit?



K-Nearest Neighbors – Algorithm



Fruit Predictor – Prediction

1

Switch the device to prediction mode.

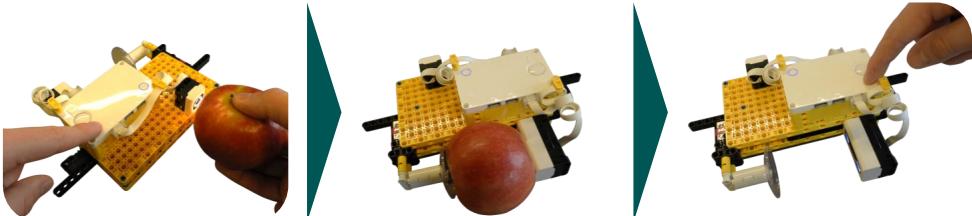
Training

Prediction

click

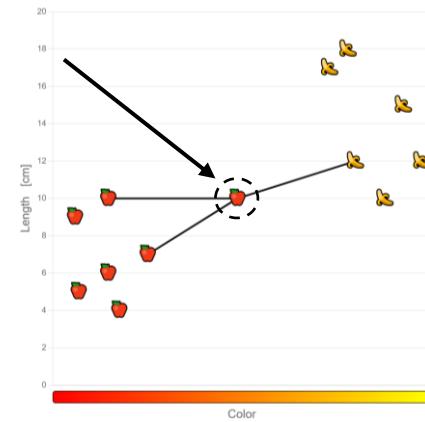
2

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



3

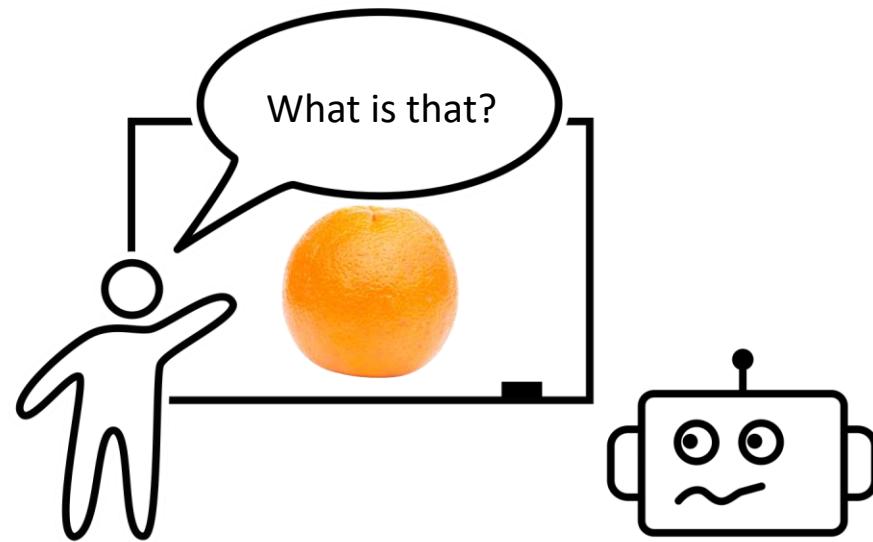
The prediction and the nearest neighbors will now be displayed on the website!



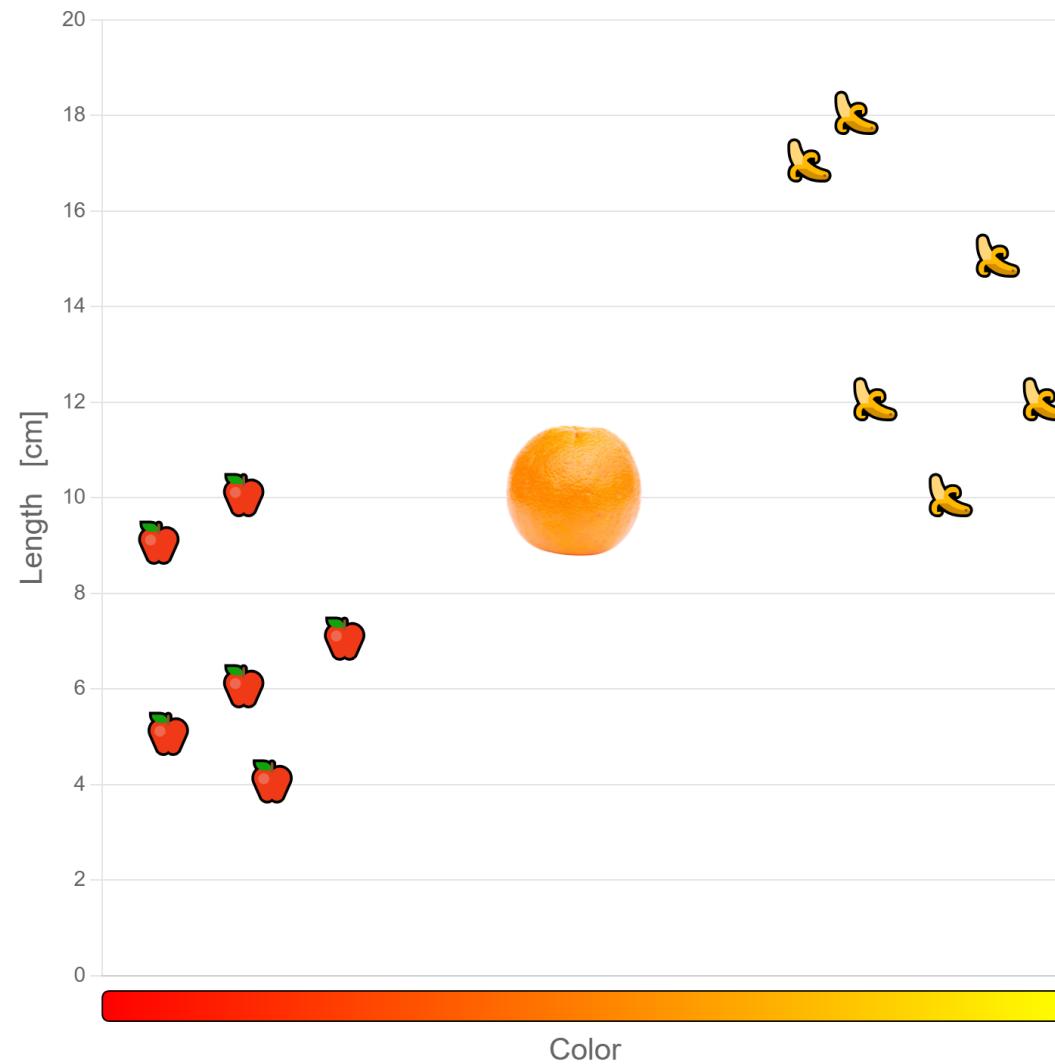
Phases of model development



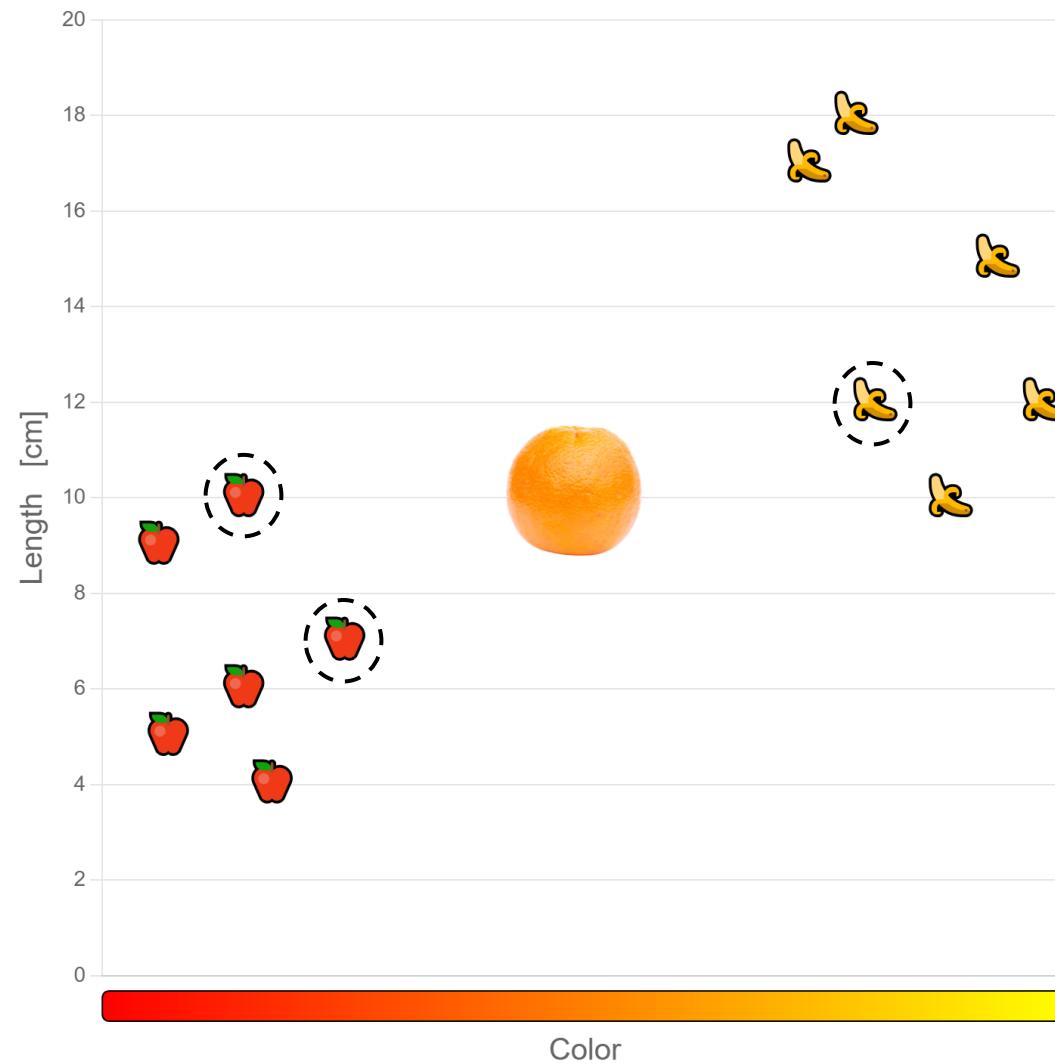
What if there is a previously unseen example?



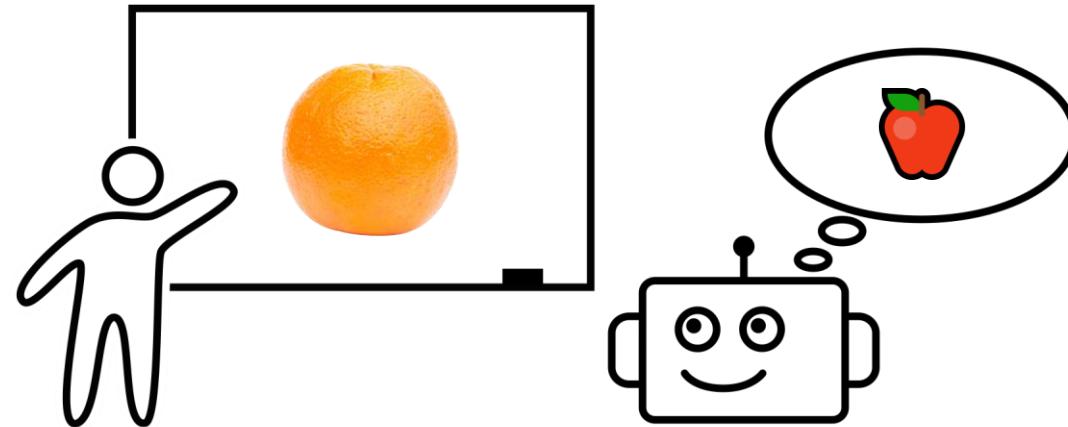
What if there is a previously unseen example?



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.



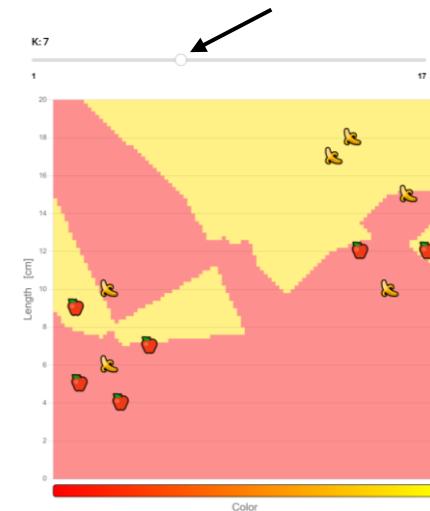
2

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

Length [cm]	Color	Label	Delete
7	Red	Apple	Delete
6	Red	Apple	Delete
5	Red	Apple	Delete
12	Yellow	Banana	Delete
10	Yellow	Banana	Delete
15	Yellow	Banana	Delete
9	Red	Apple	Delete

3

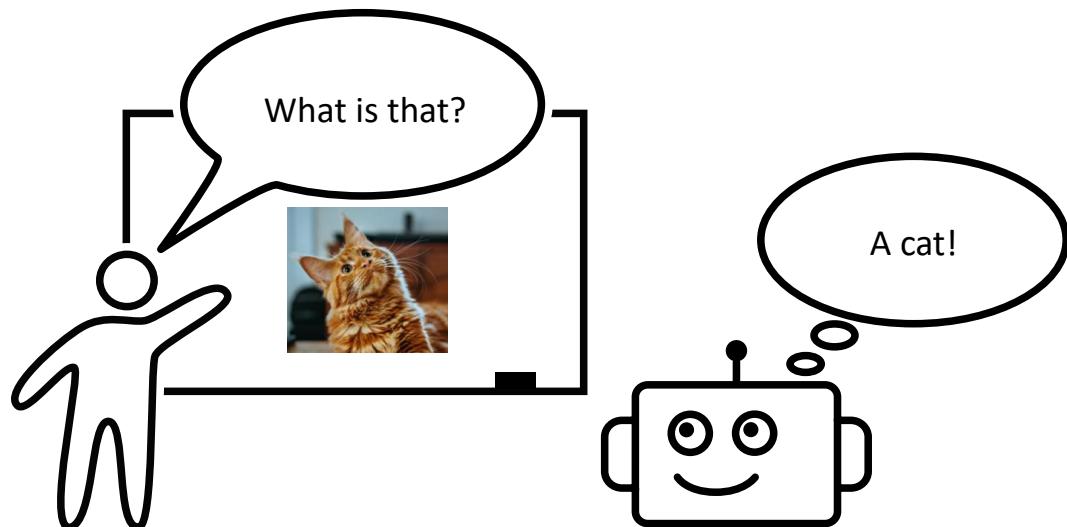
Try changing the number of voting neighbors (K) to restore the accuracy



Classification and regression

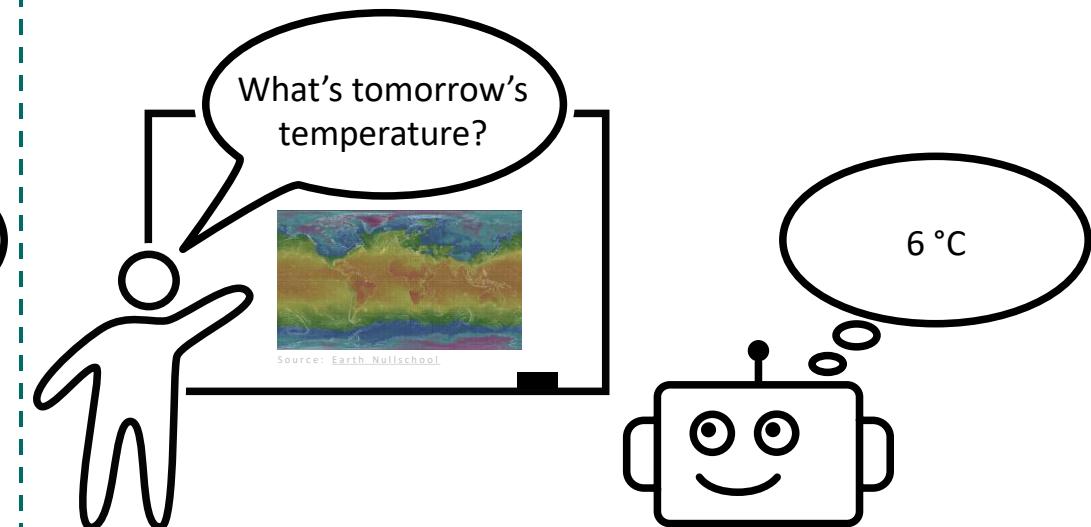
Classification

- prediction of a category



Regression

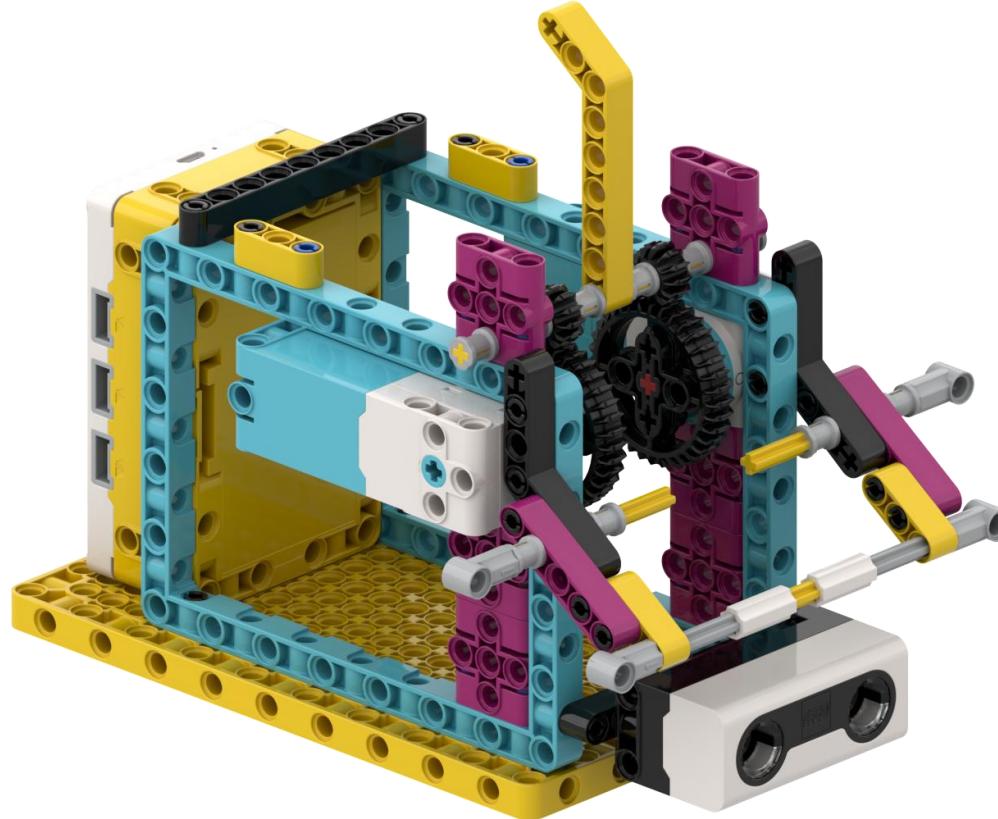
- prediction of a number



Pitcher – Concept

Features: ?

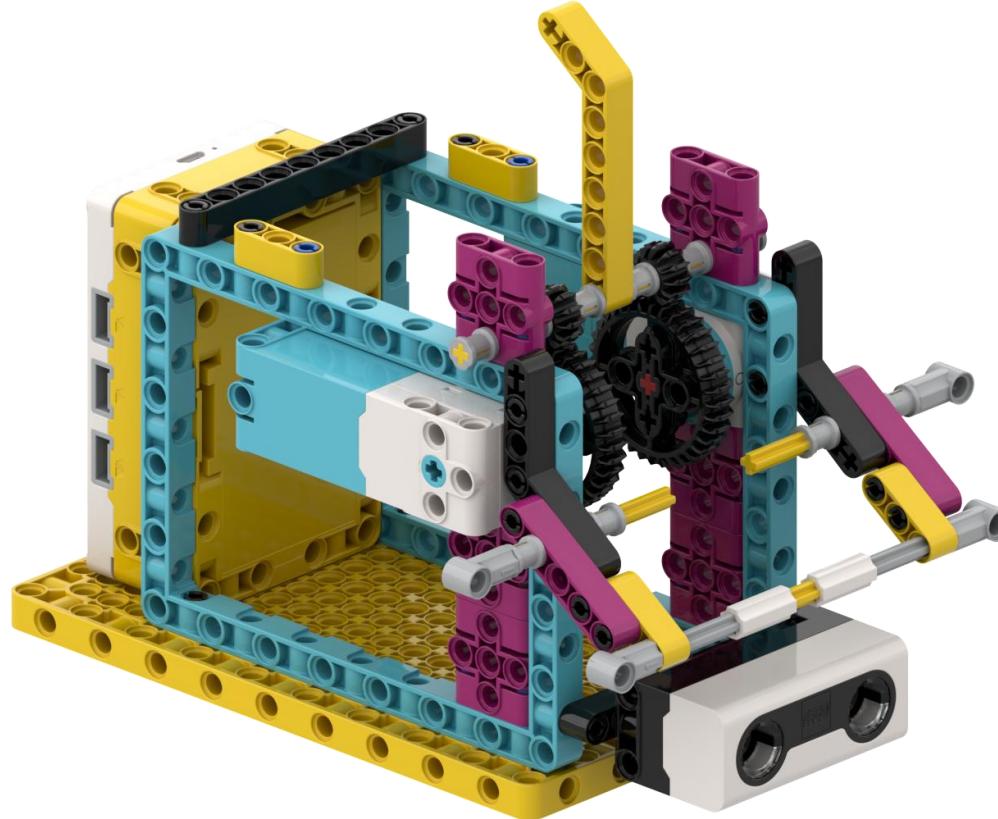
Label: ?



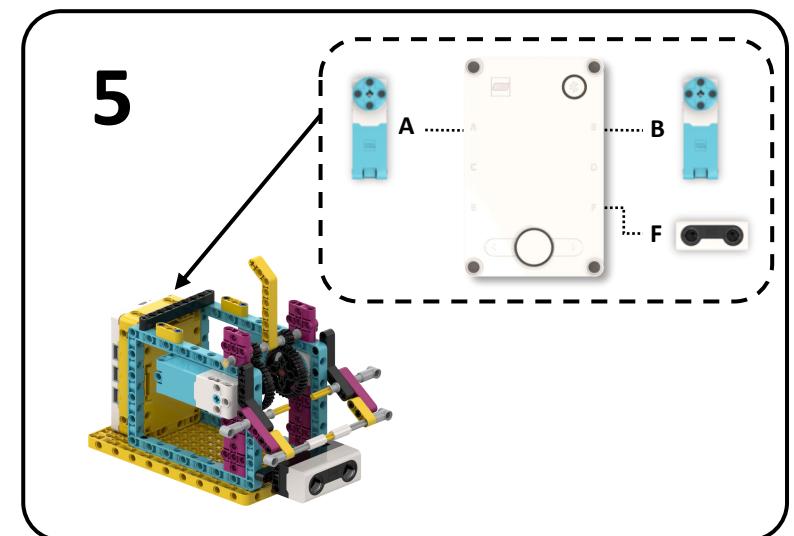
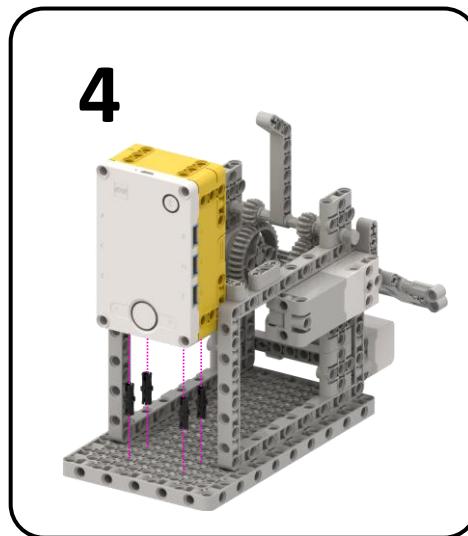
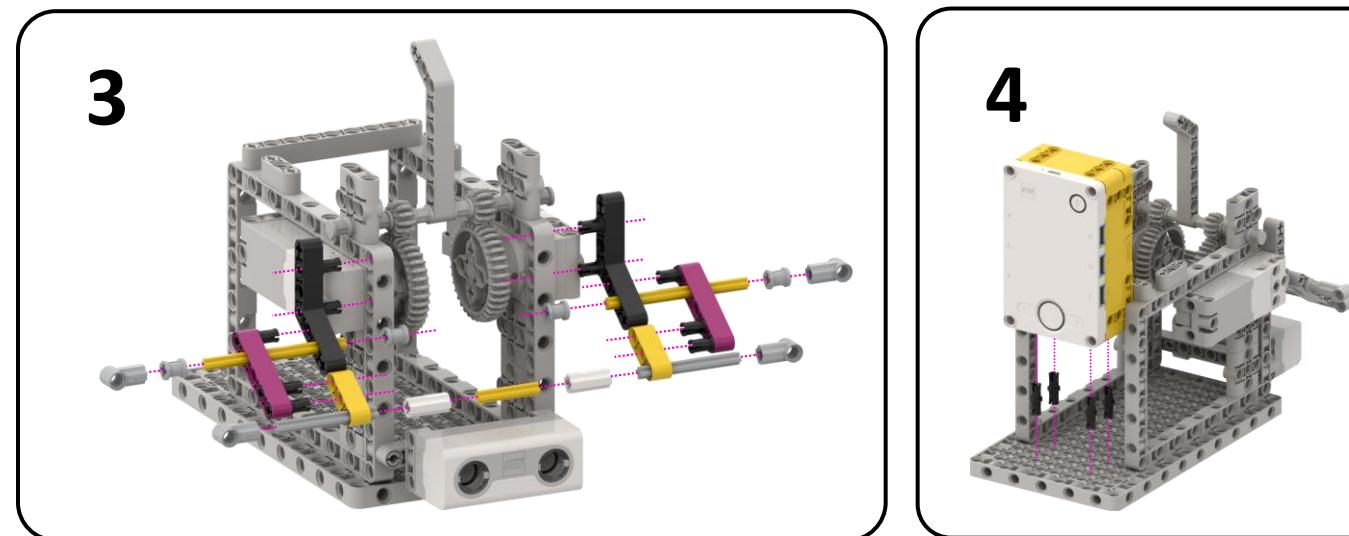
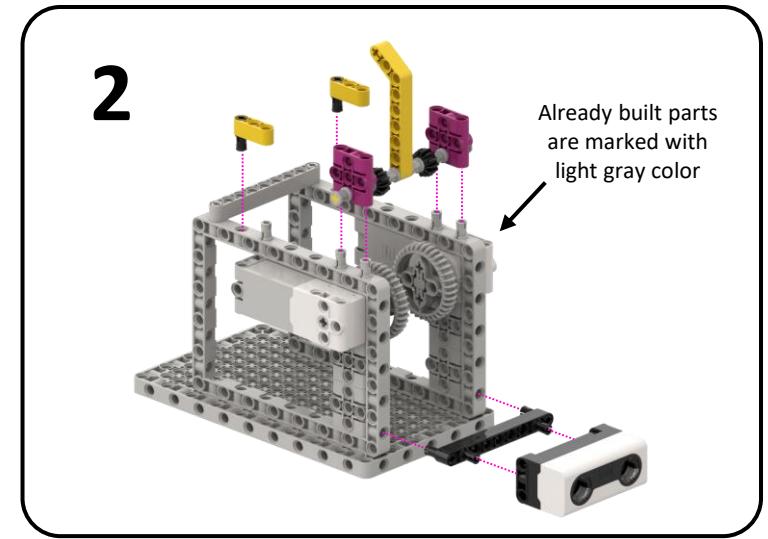
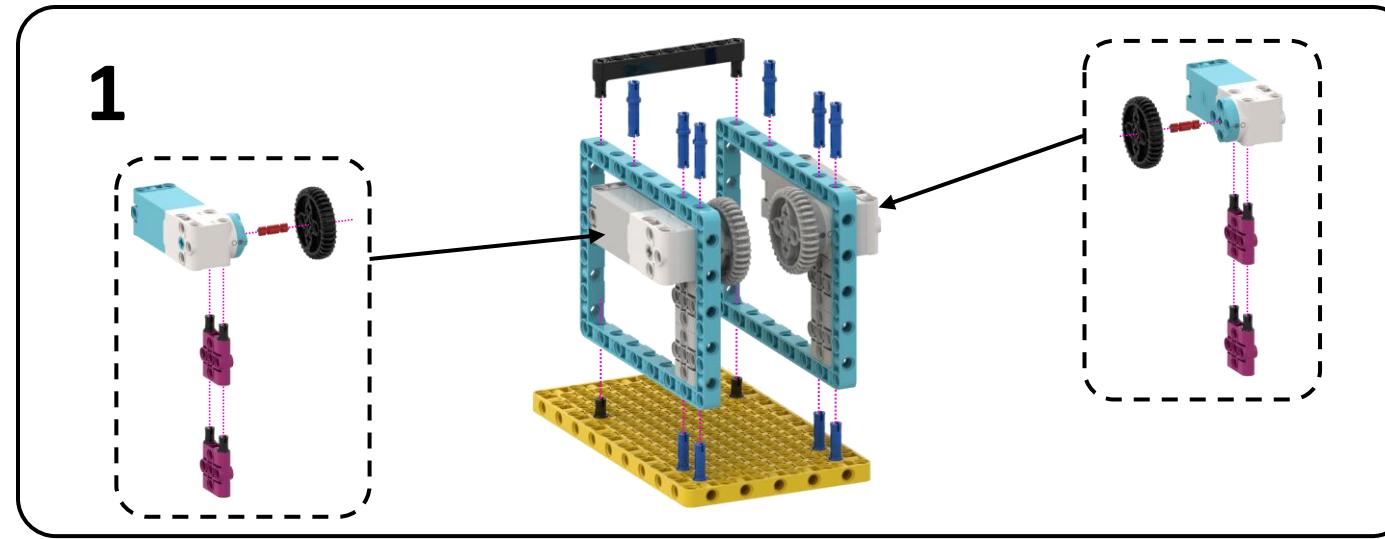
Pitcher – Concept

Features: Distance to the target

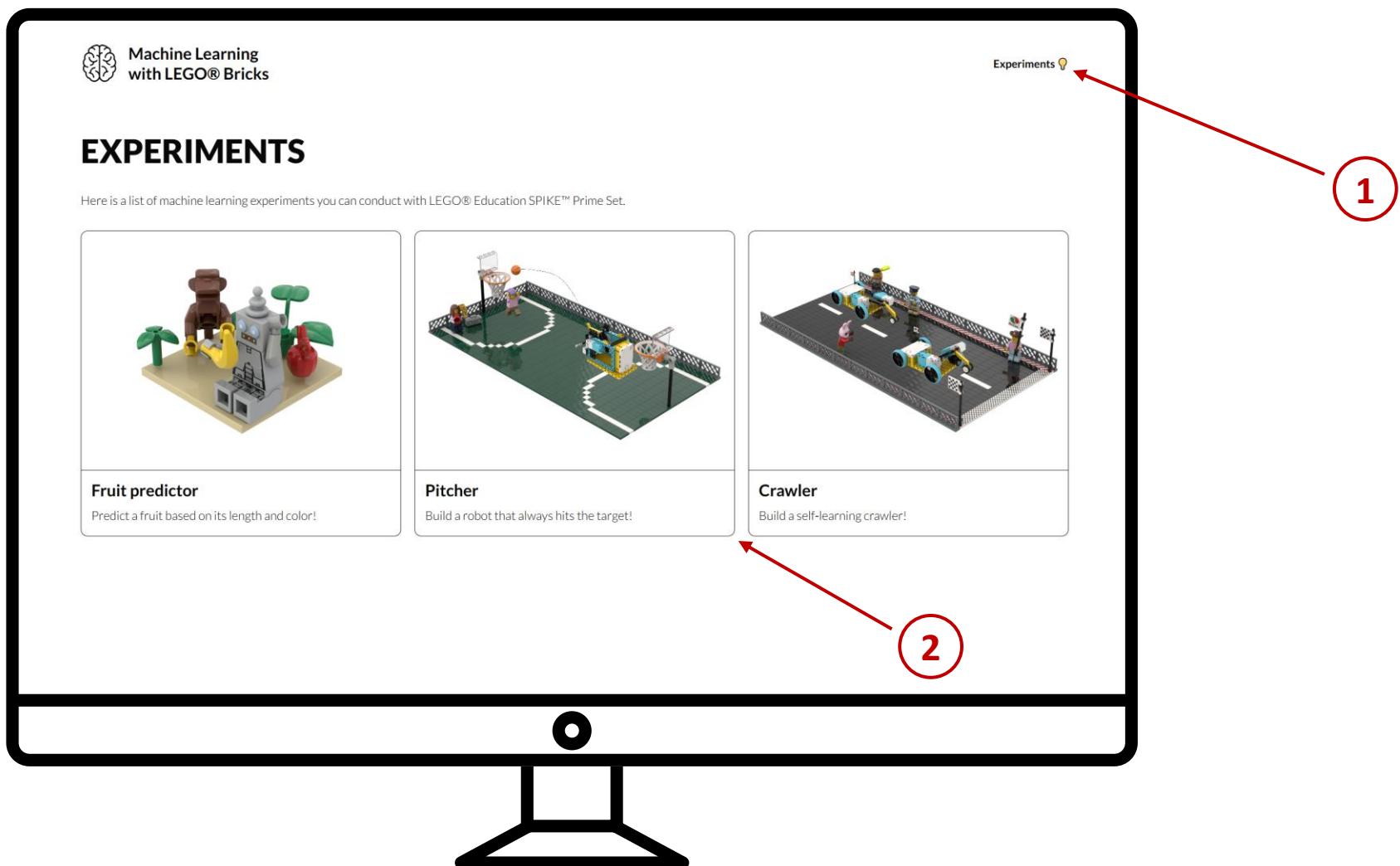
Label: Motor power



Pitcher – Assembly



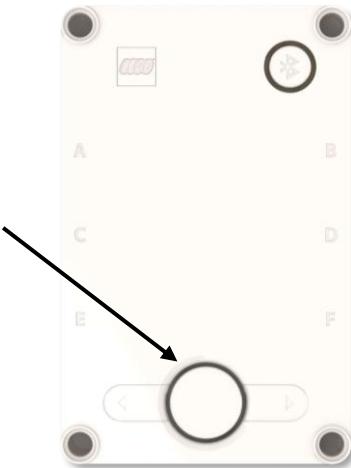
Open the experiment page



Connect hub and start the program

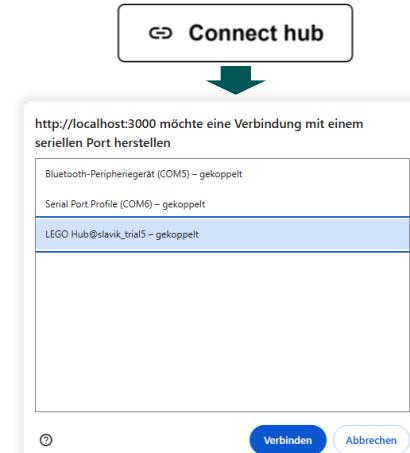
1

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



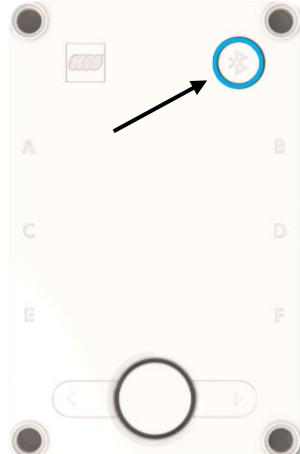
2

Click the "Connect hub" button on the website and select the LEGO hub in the dialog window.



3

Click "Connect" in the dialog window and wait. The Bluetooth button on the hub should possibly light up blue.



4

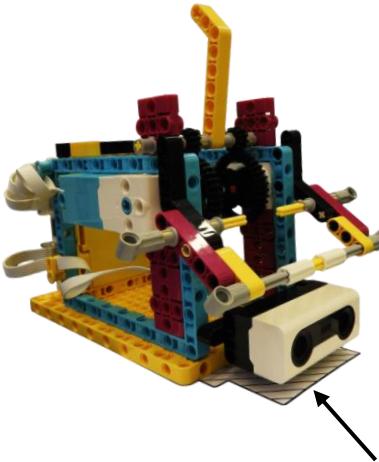
Click "Start program" and wait for the program to load.

Start program

Pitcher – Data collection

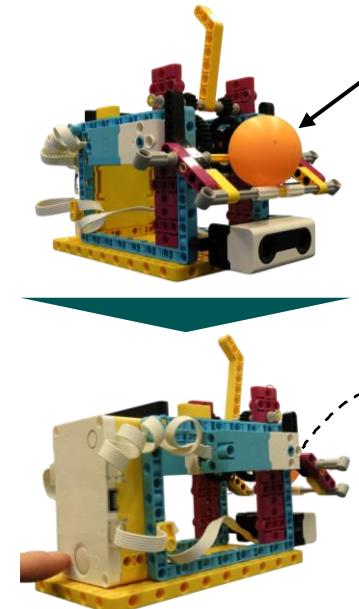
1

Place the pitcher in the shaded area on the mat.



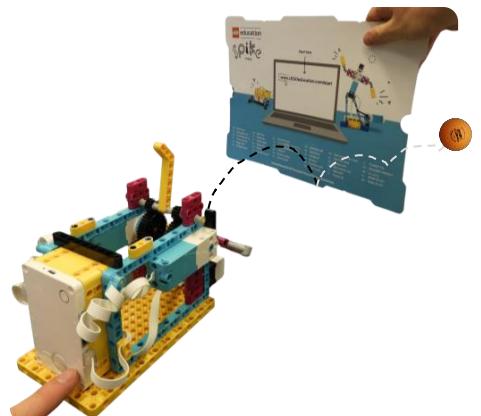
2

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.



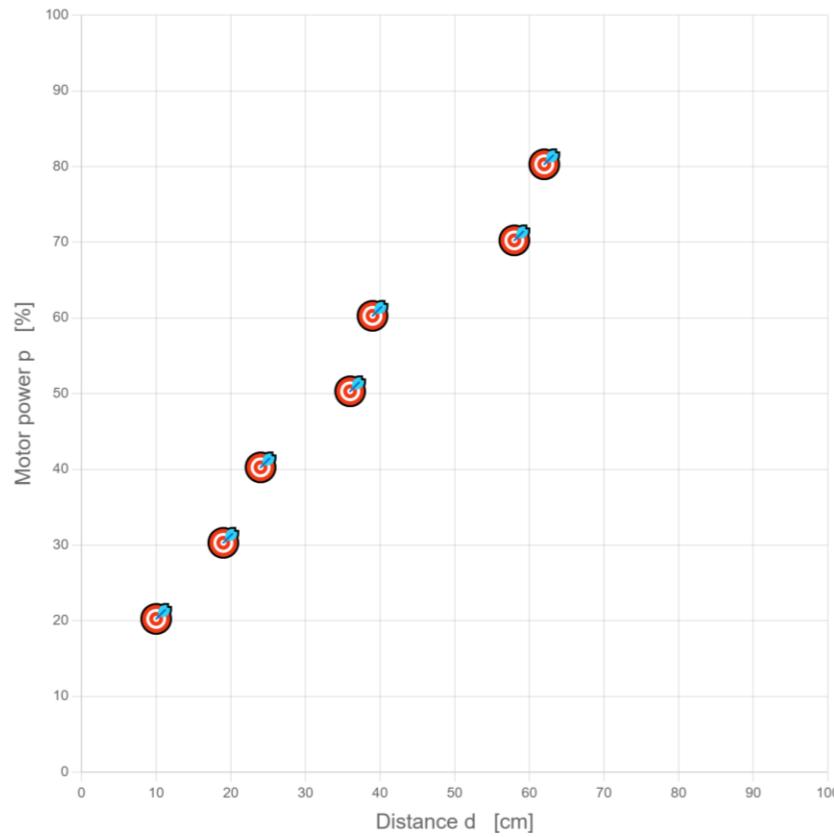
4

Repeat the steps for other motor speeds.

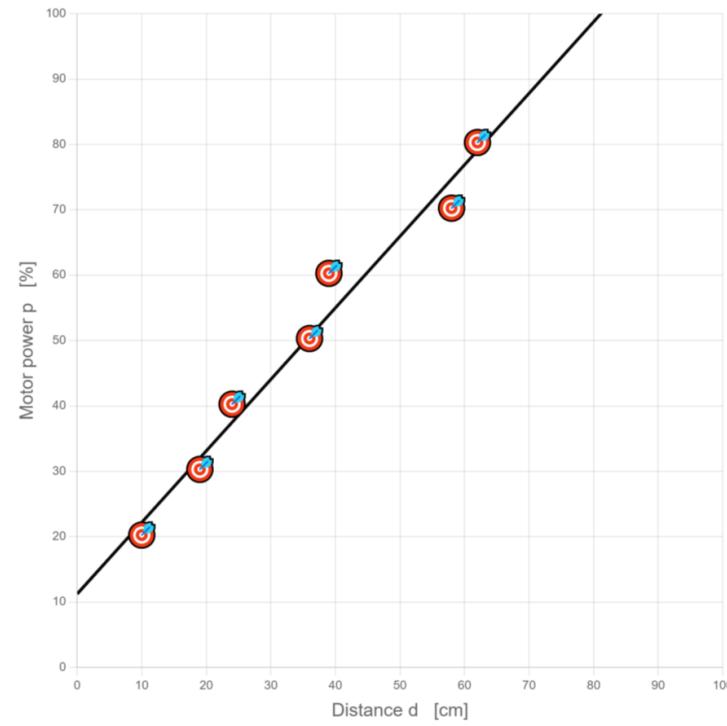
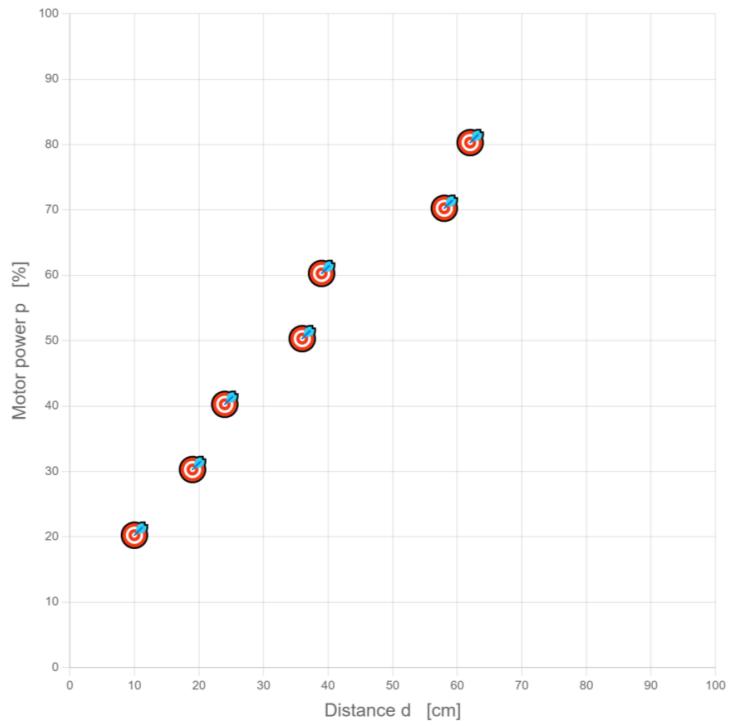
Motor power: 10% → 40%



Pitcher – Data analysis

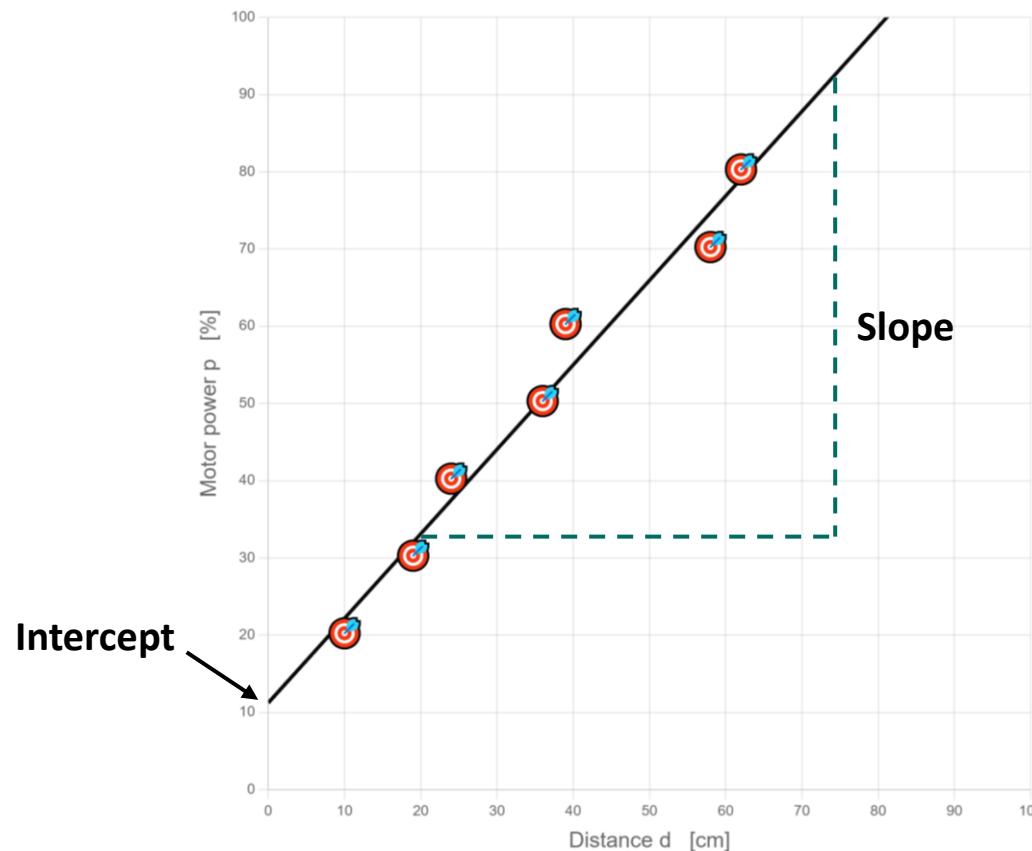


Pitcher – Data analysis

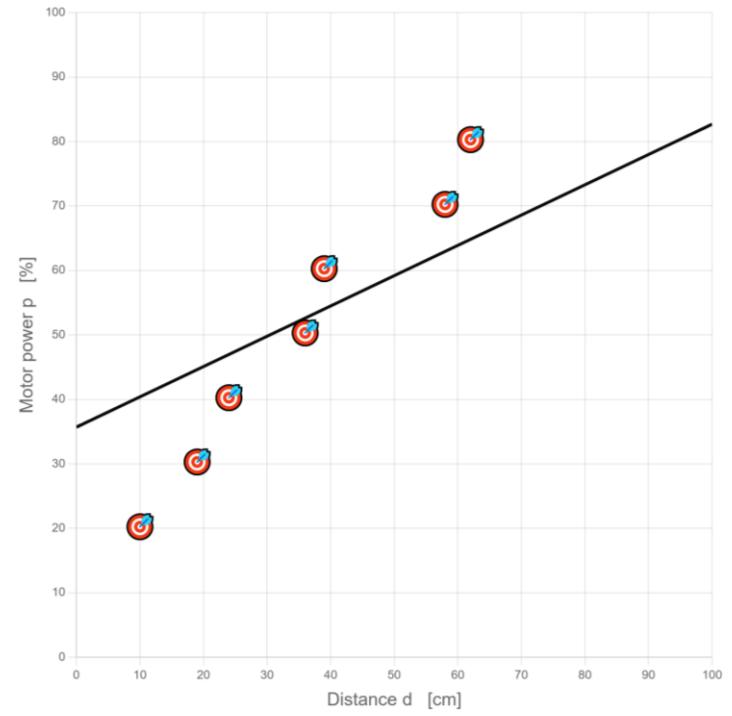
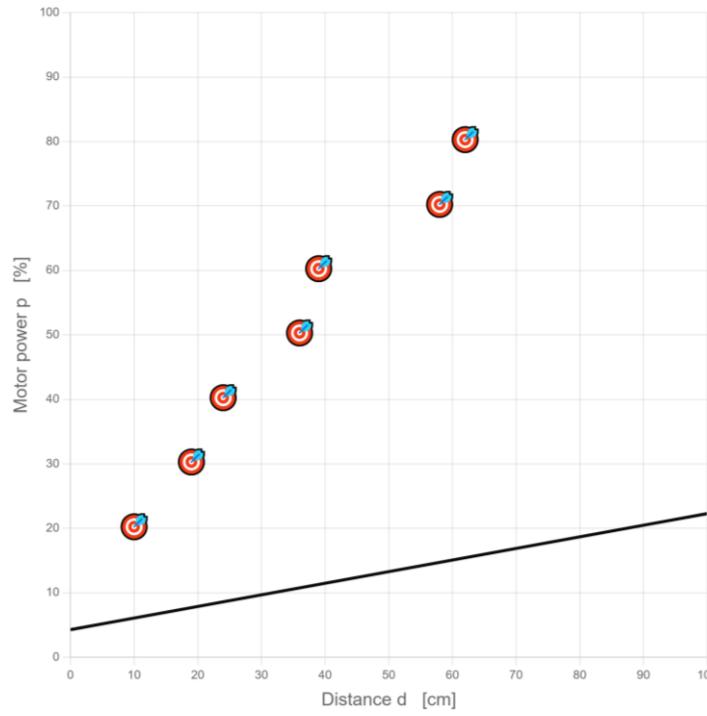
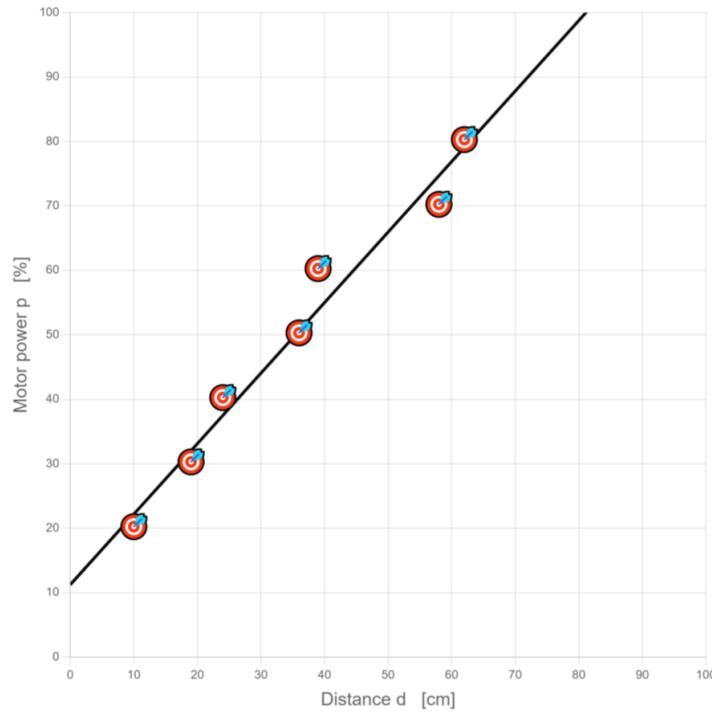


Linear regression

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

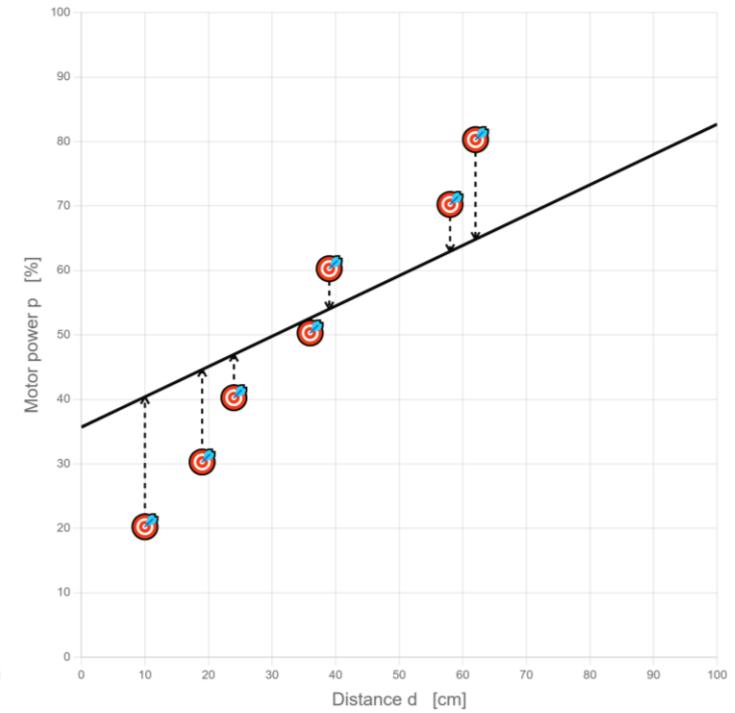
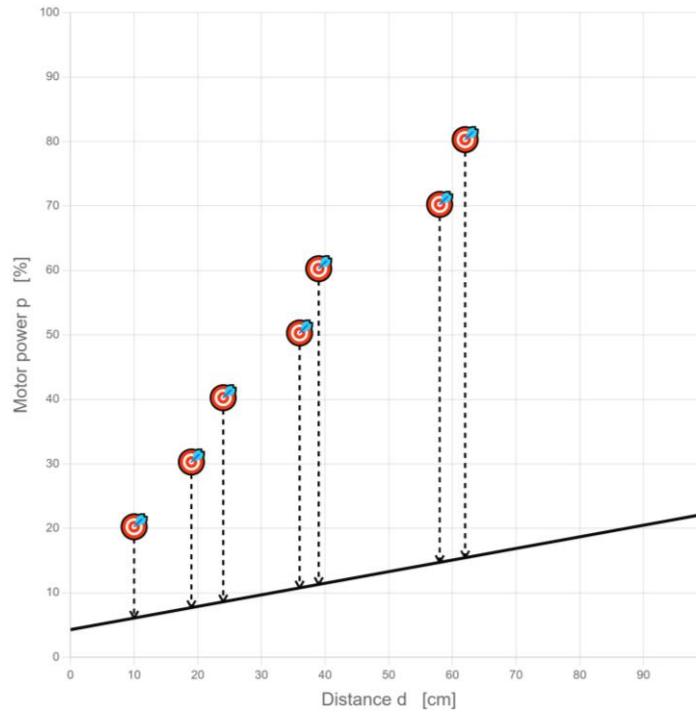
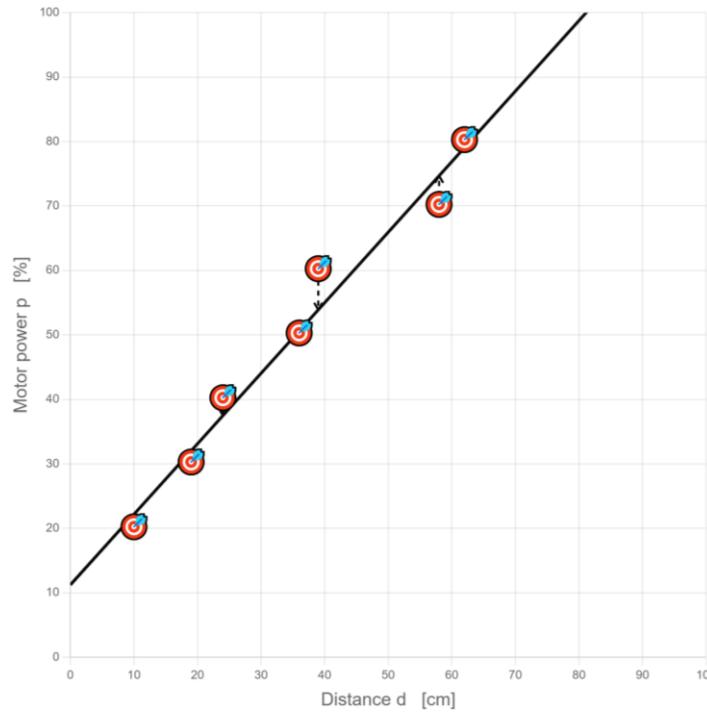


How well does the line fit?



How well does the line fit?

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



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.

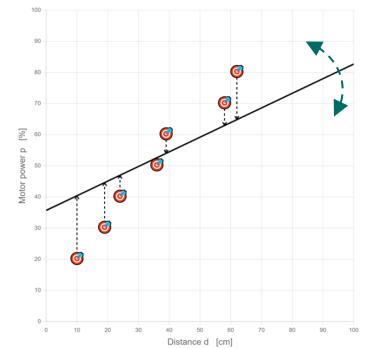
Line Equation

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



Calculate best parameters

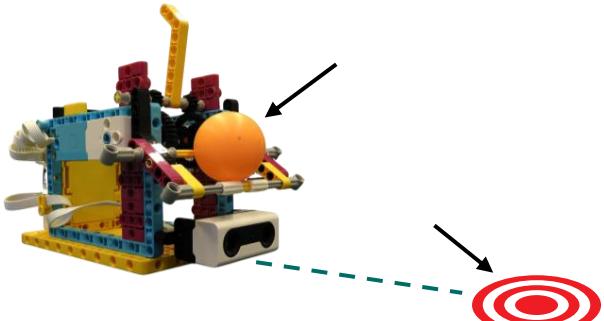
LOSS = 142.97



Pitcher – Prediction

1

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



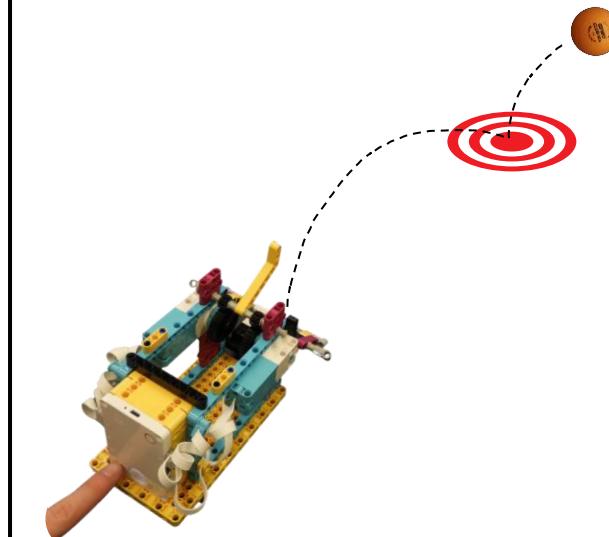
2

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

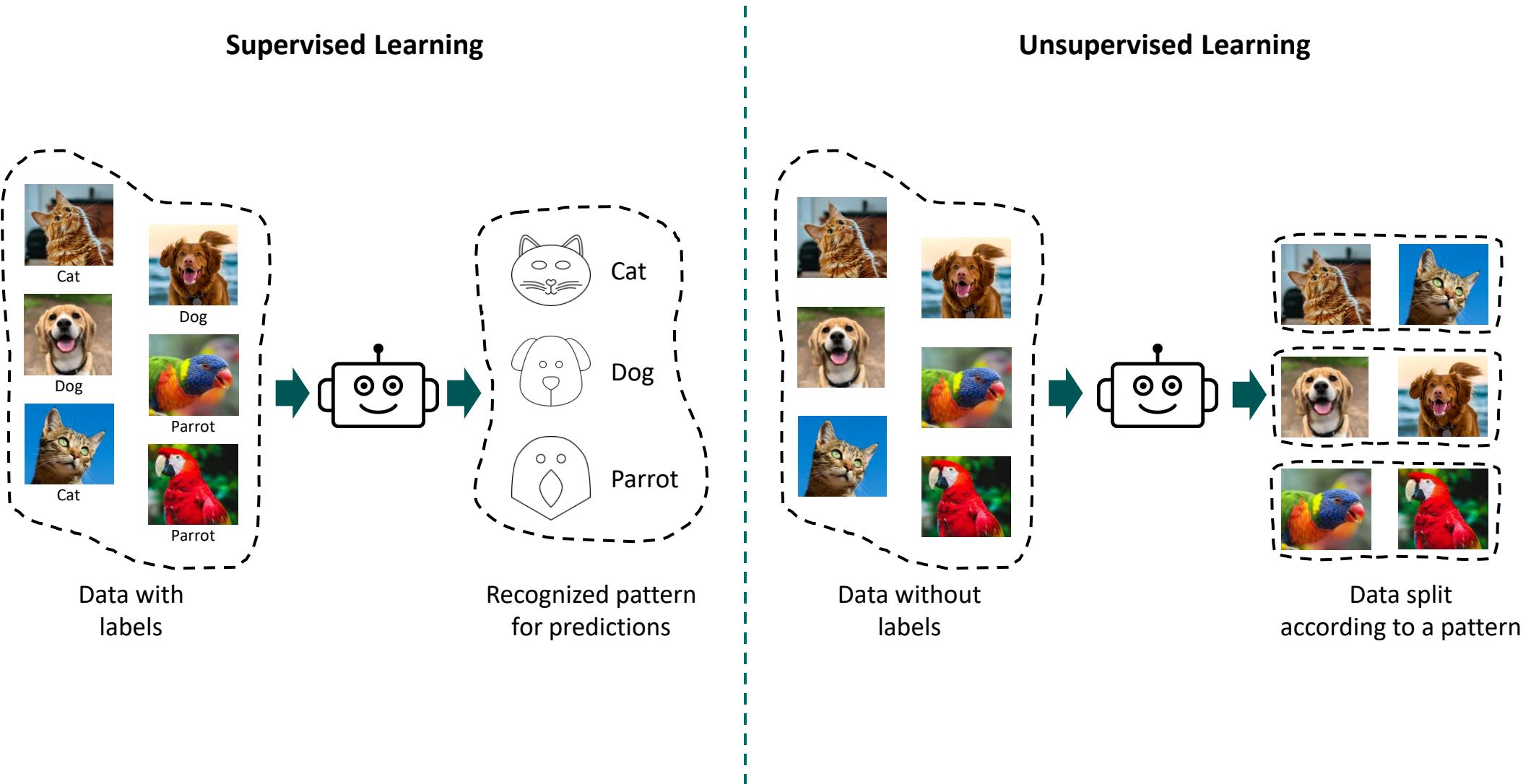


3

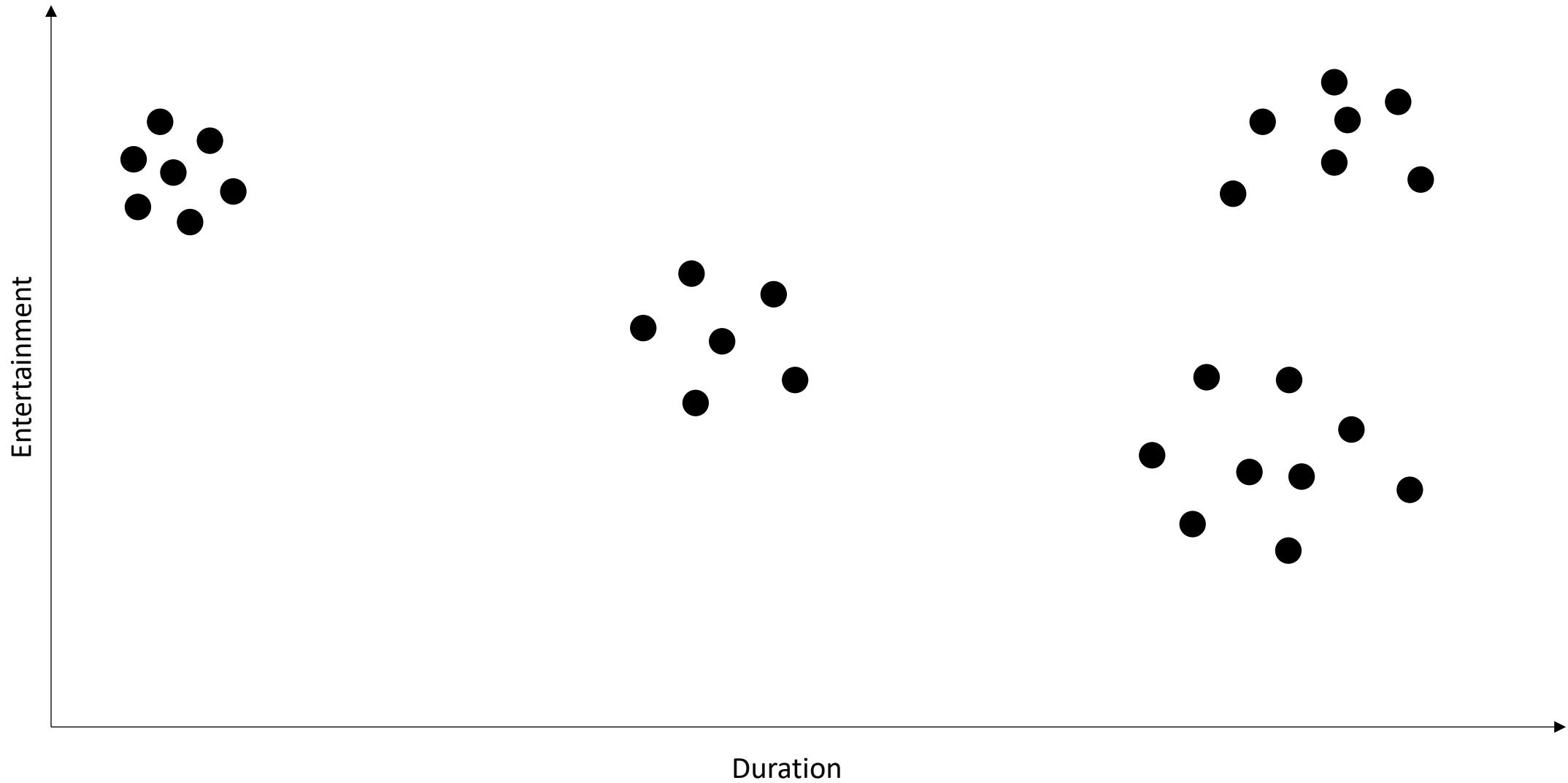
Pitch the ball into the target by pressing the left button



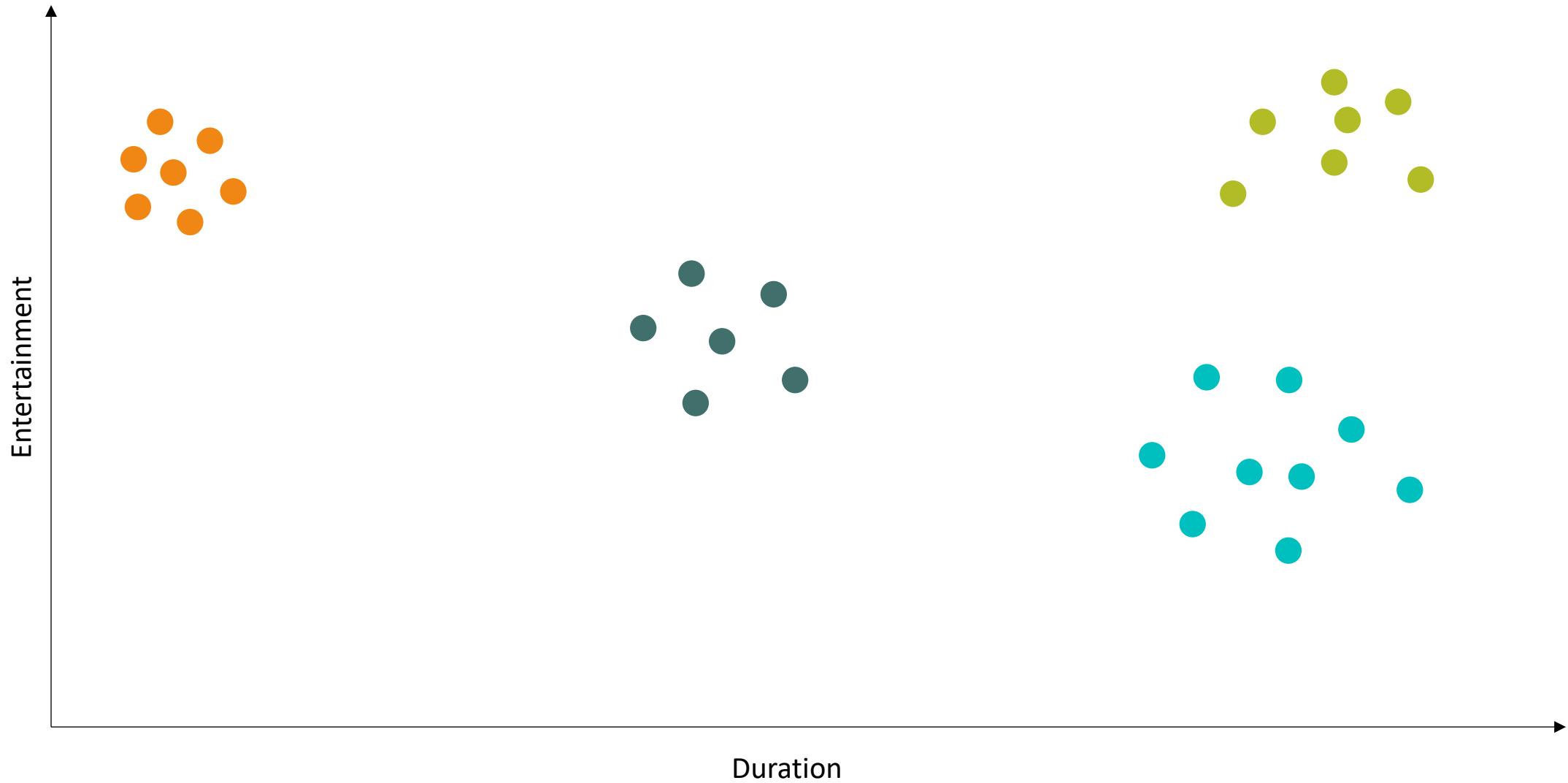
Supervised and unsupervised learning



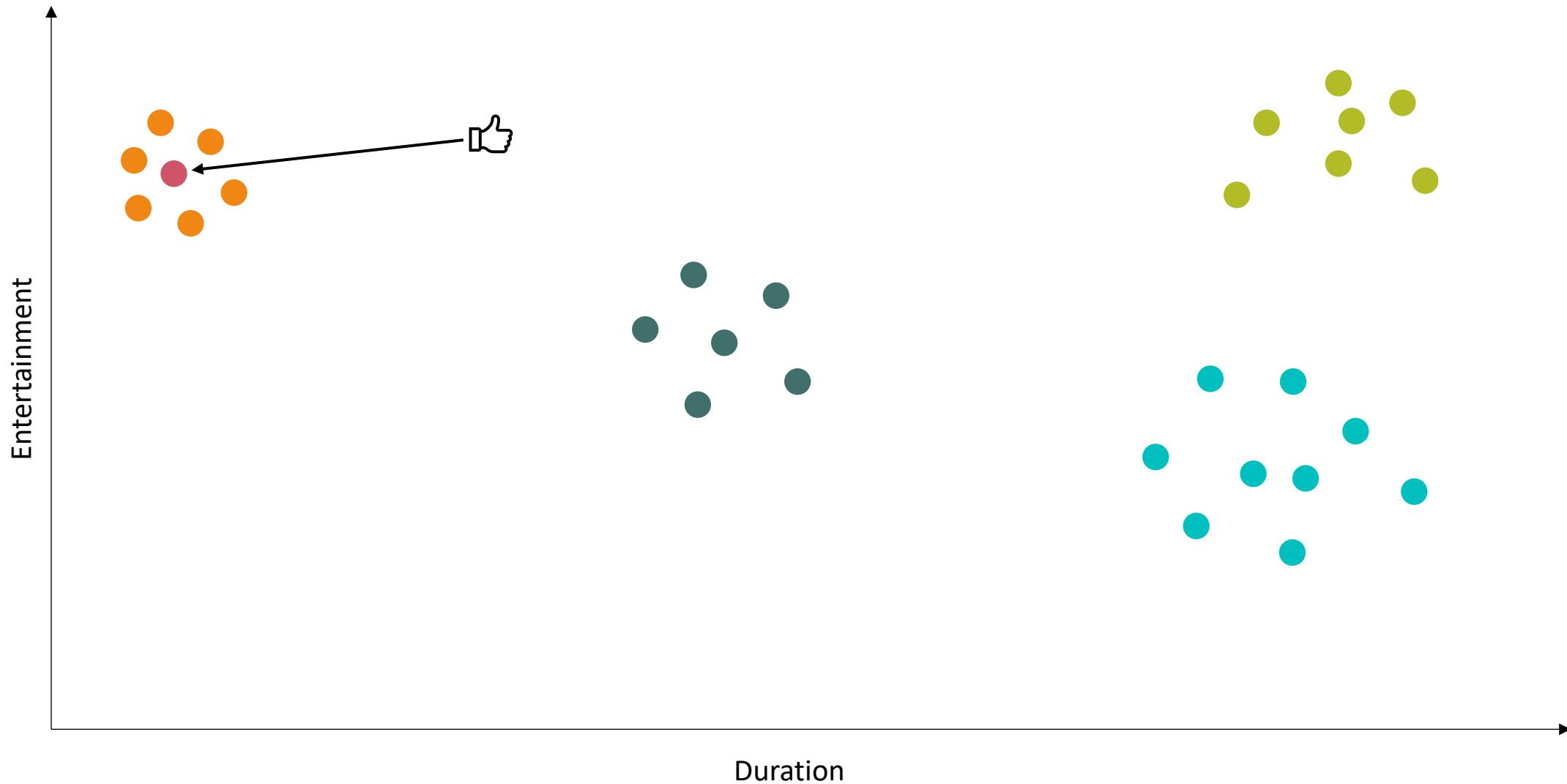
How to recommend new videos using unsupervised learning



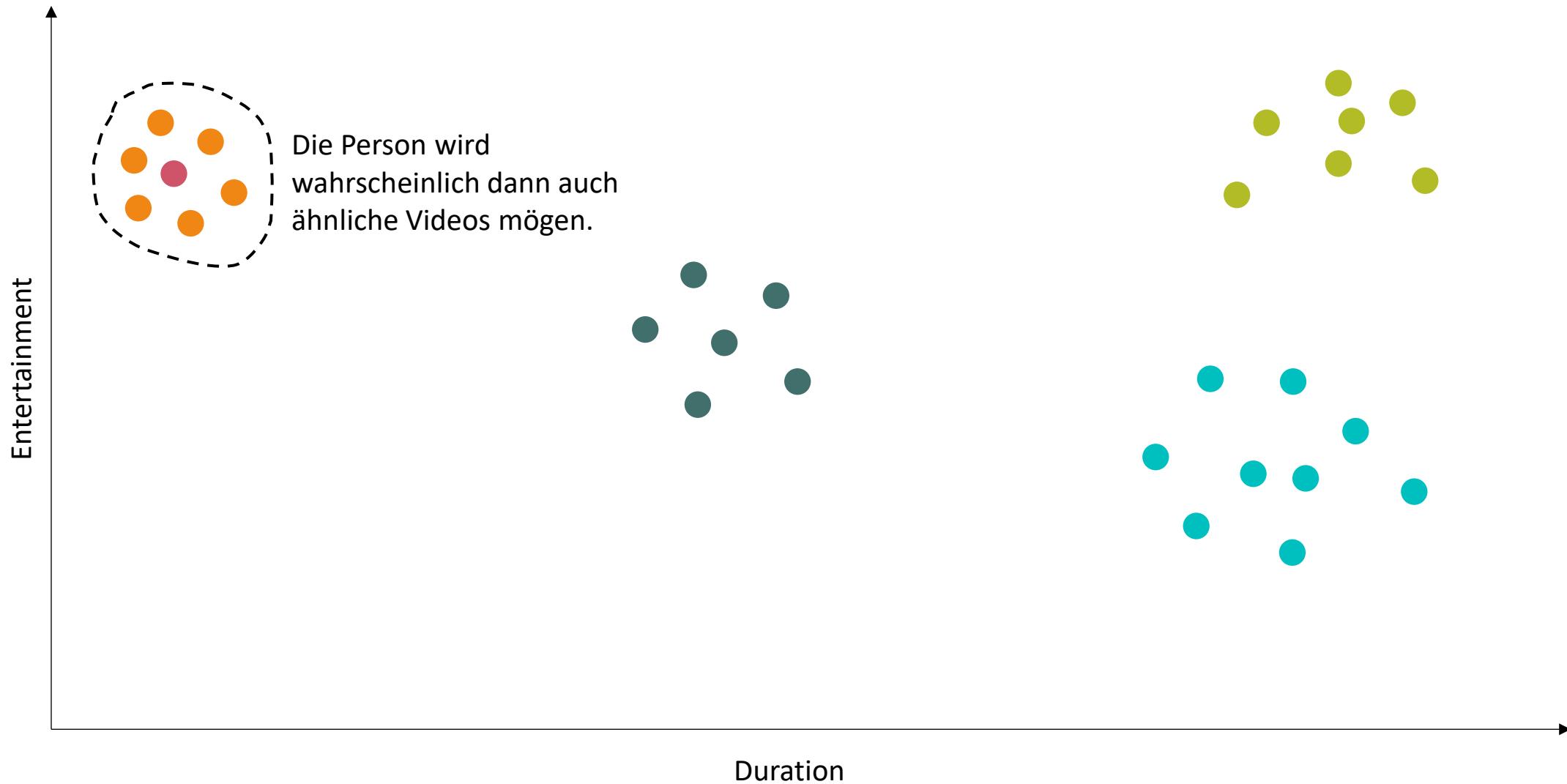
How to recommend new videos using unsupervised learning



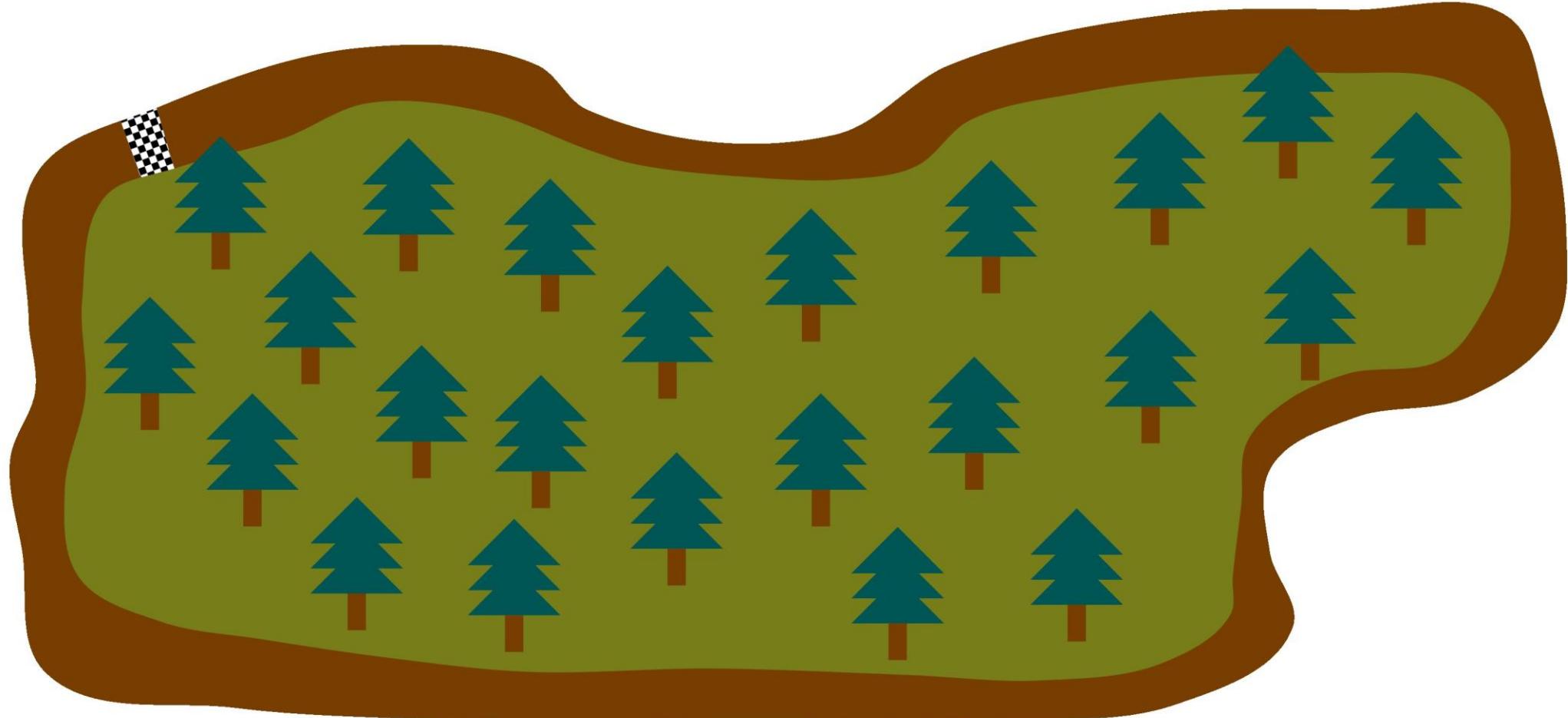
How to recommend new videos using unsupervised learning



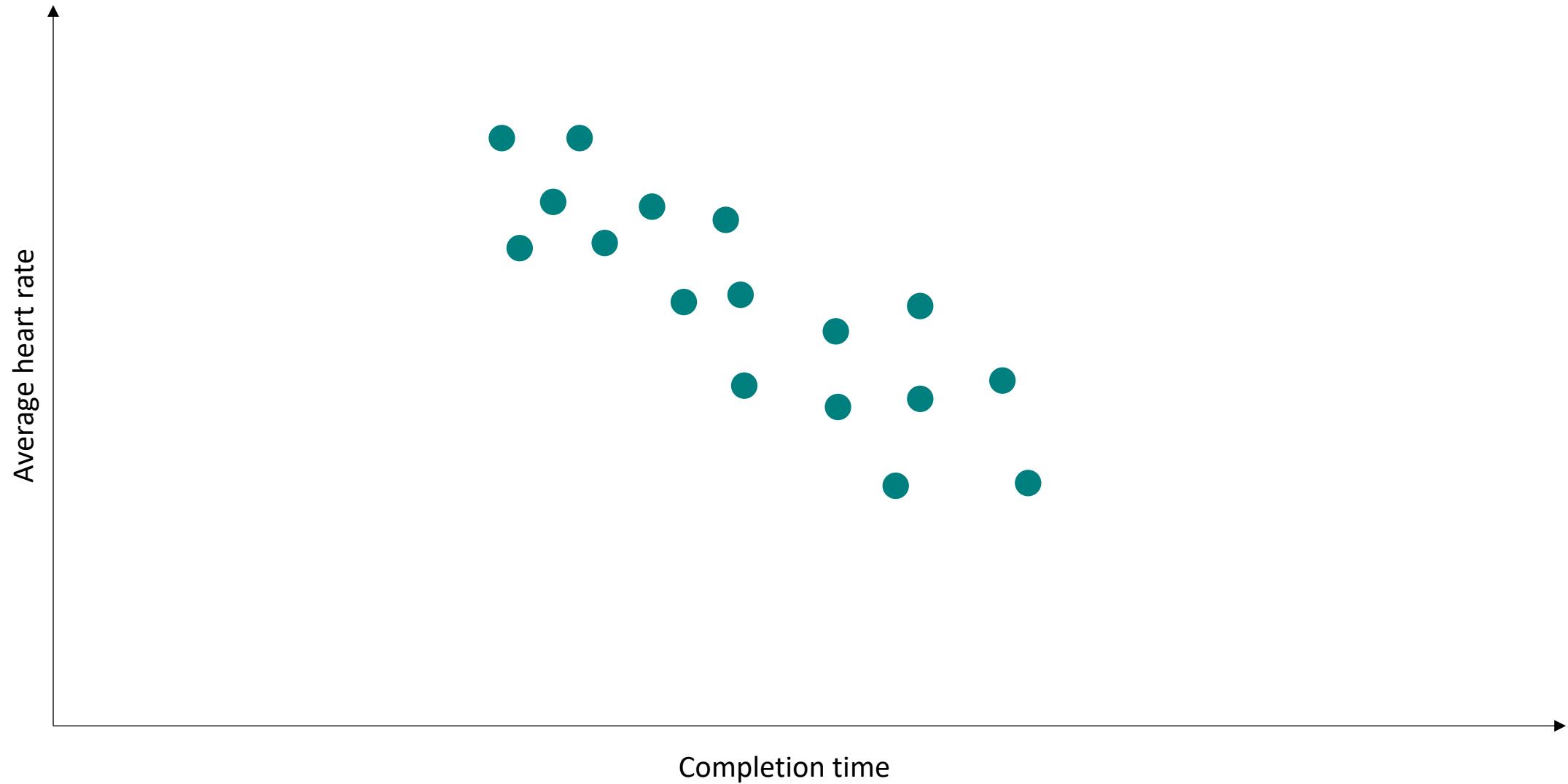
How to recommend new videos using unsupervised learning



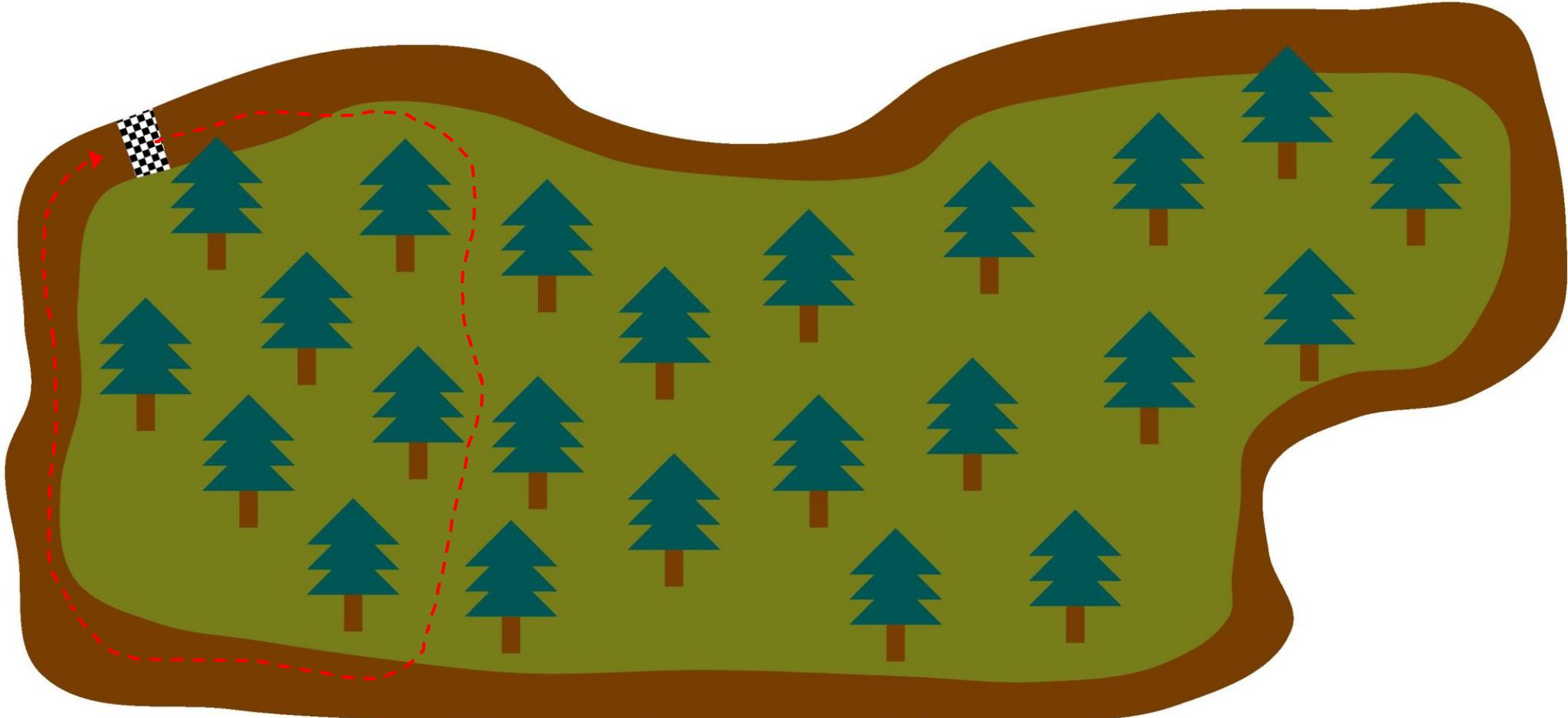
How to detect cheaters using unsupervised learning



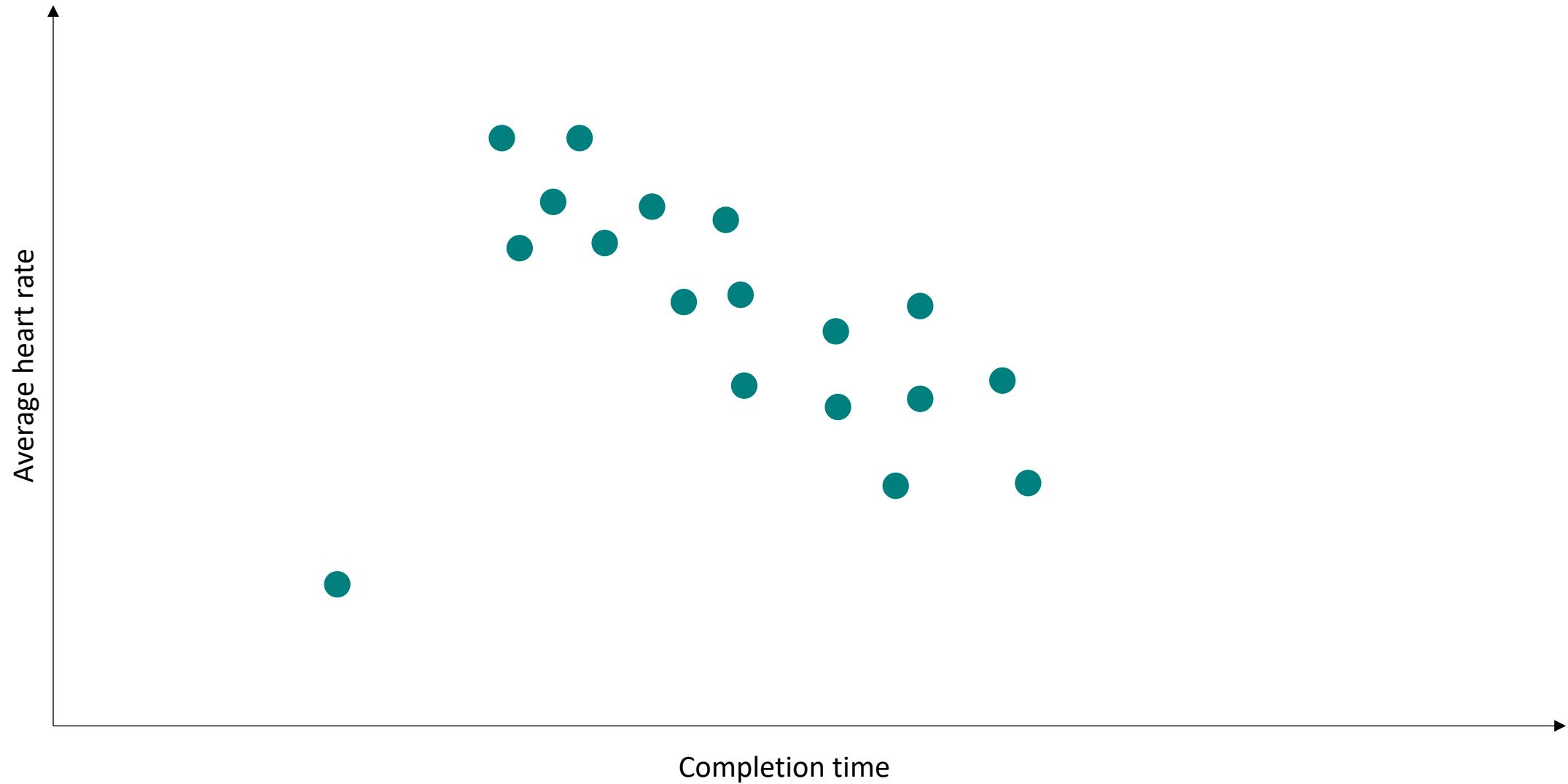
How to detect cheaters using unsupervised learning



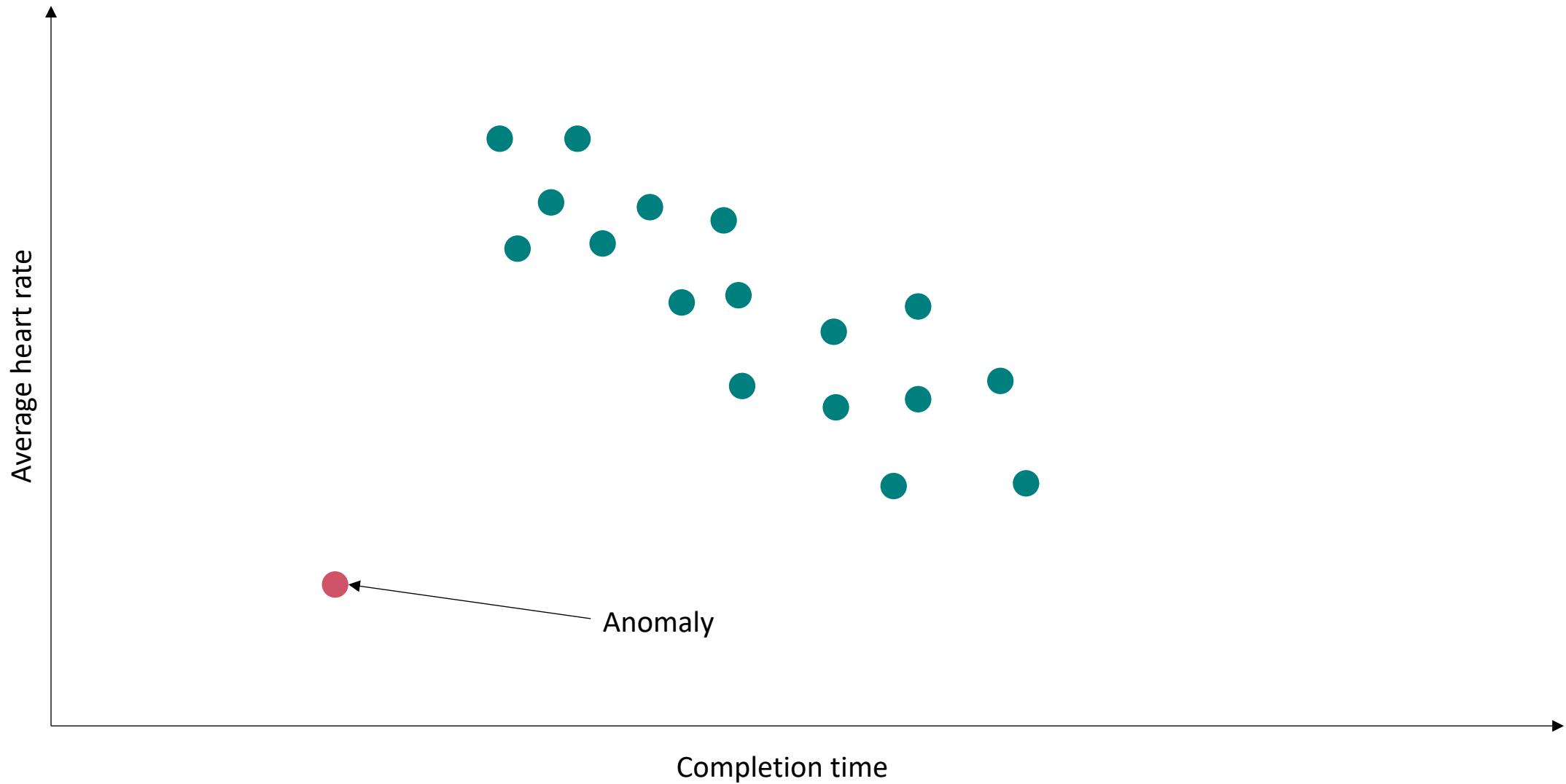
How to detect cheaters using unsupervised learning



How to detect cheaters using unsupervised learning

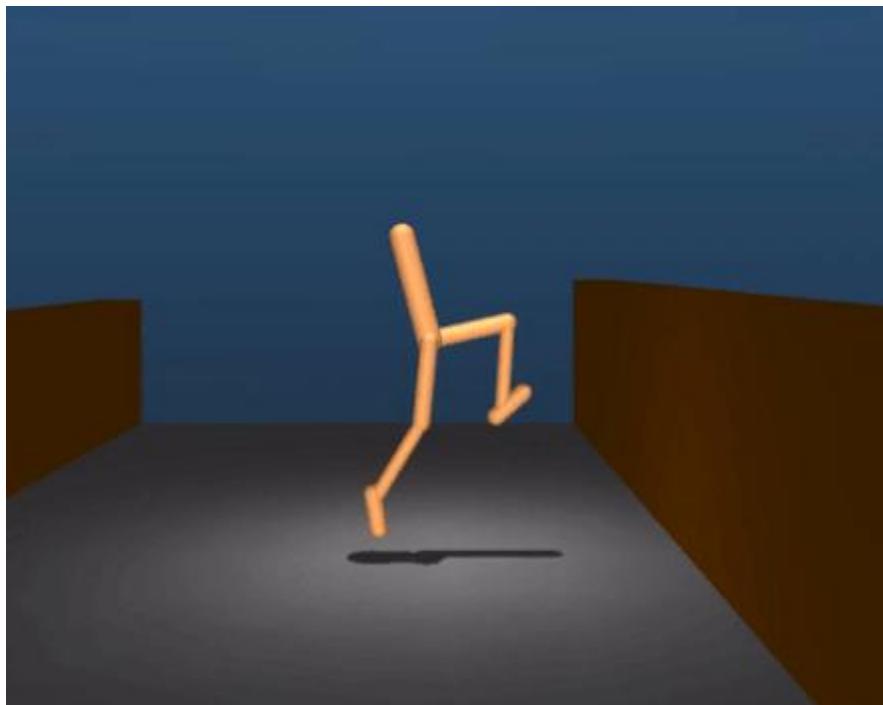


How to detect cheaters using unsupervised learning



Reinforcement learning

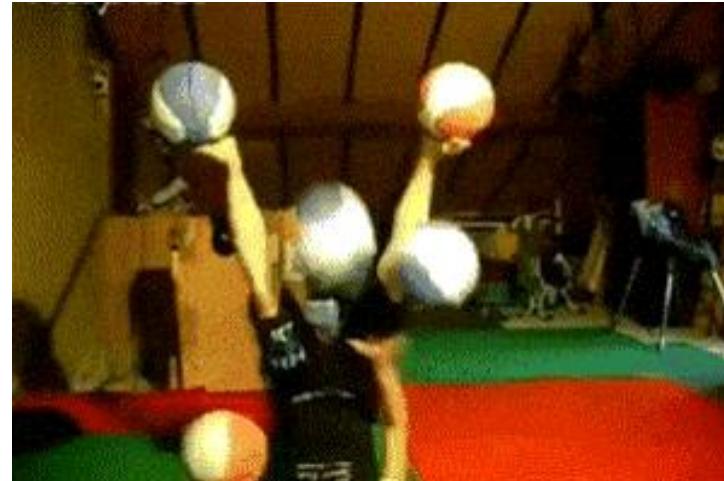
- **Reinforcement learning** – learning through trial and error.



Source: DeepMind

Reinforcement learning

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



Source: [Giphy](#)

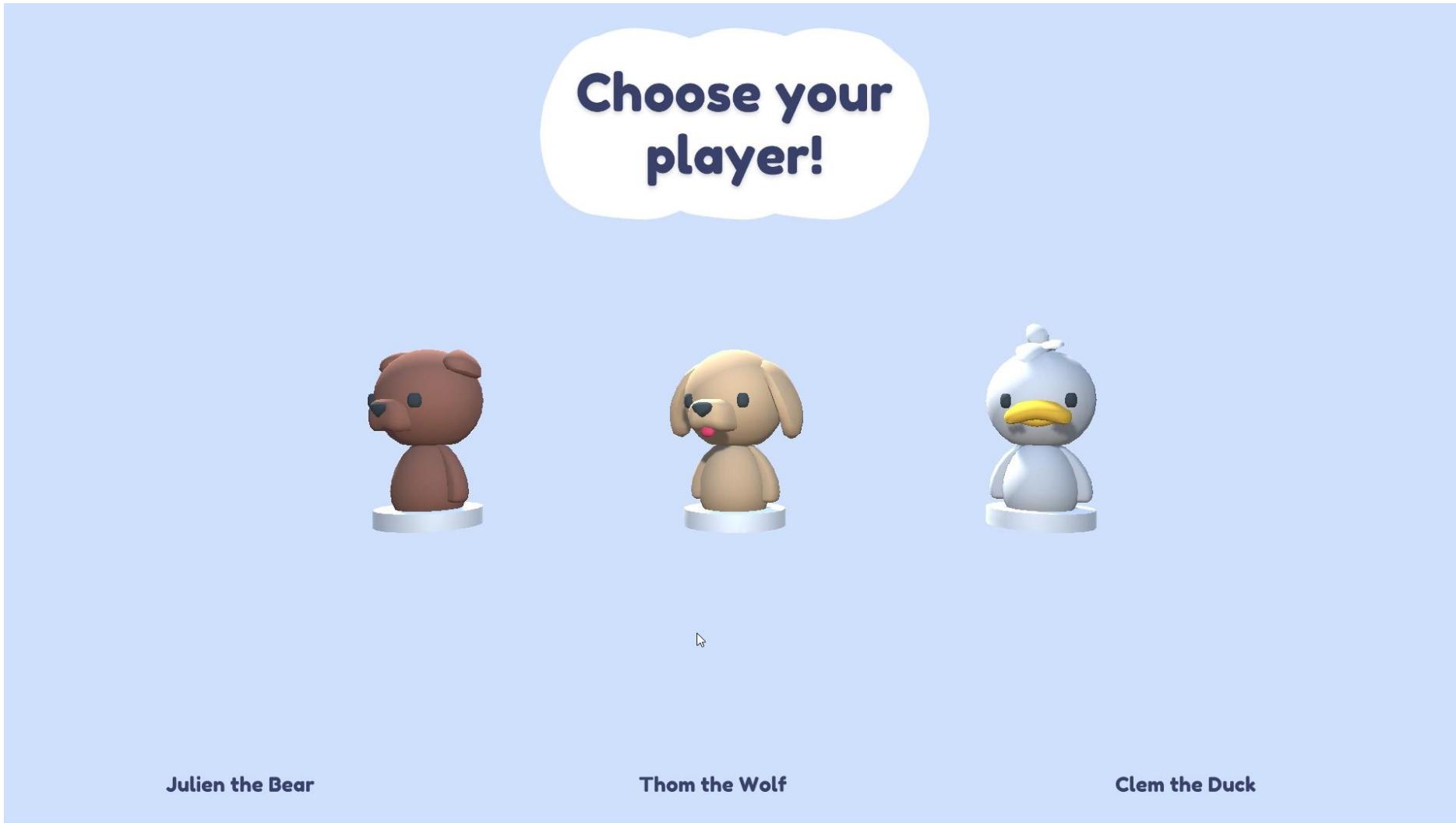
Applications – Robots



0 mins

Source: [YouTube](#)

Applications – Bots in computer games

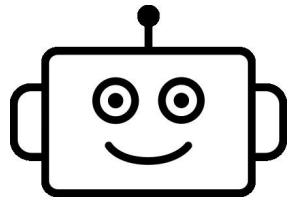


Applications – Bots in computer games



Source: [HuggingFace](#)

Abstraction

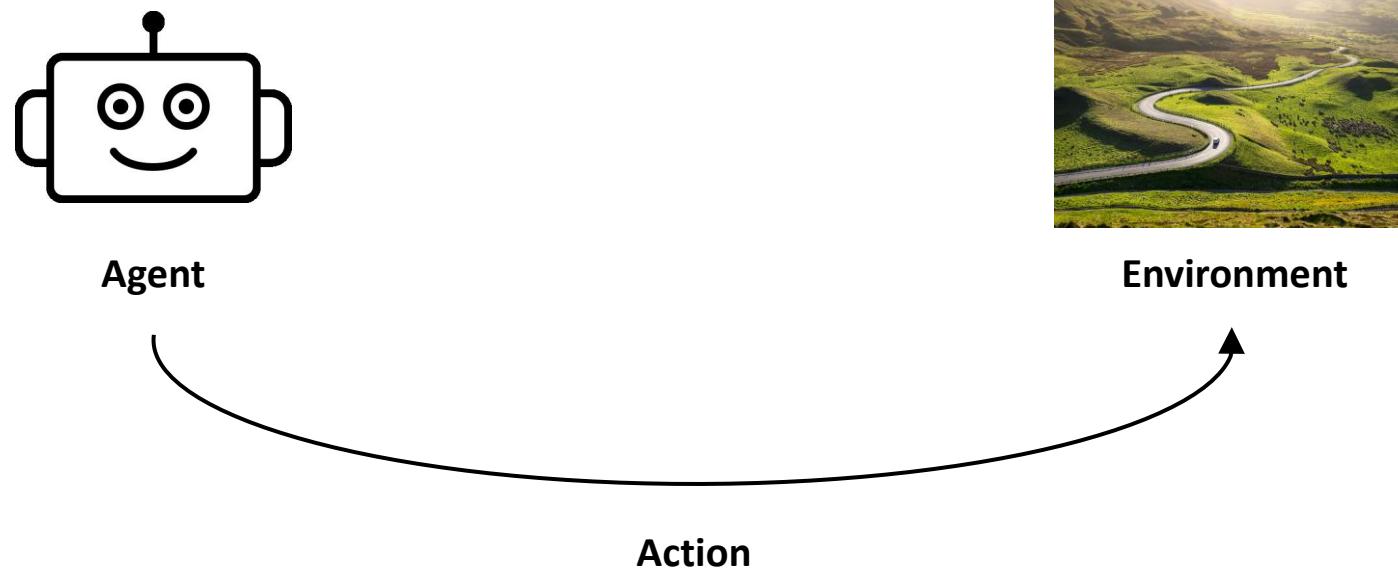


Agent

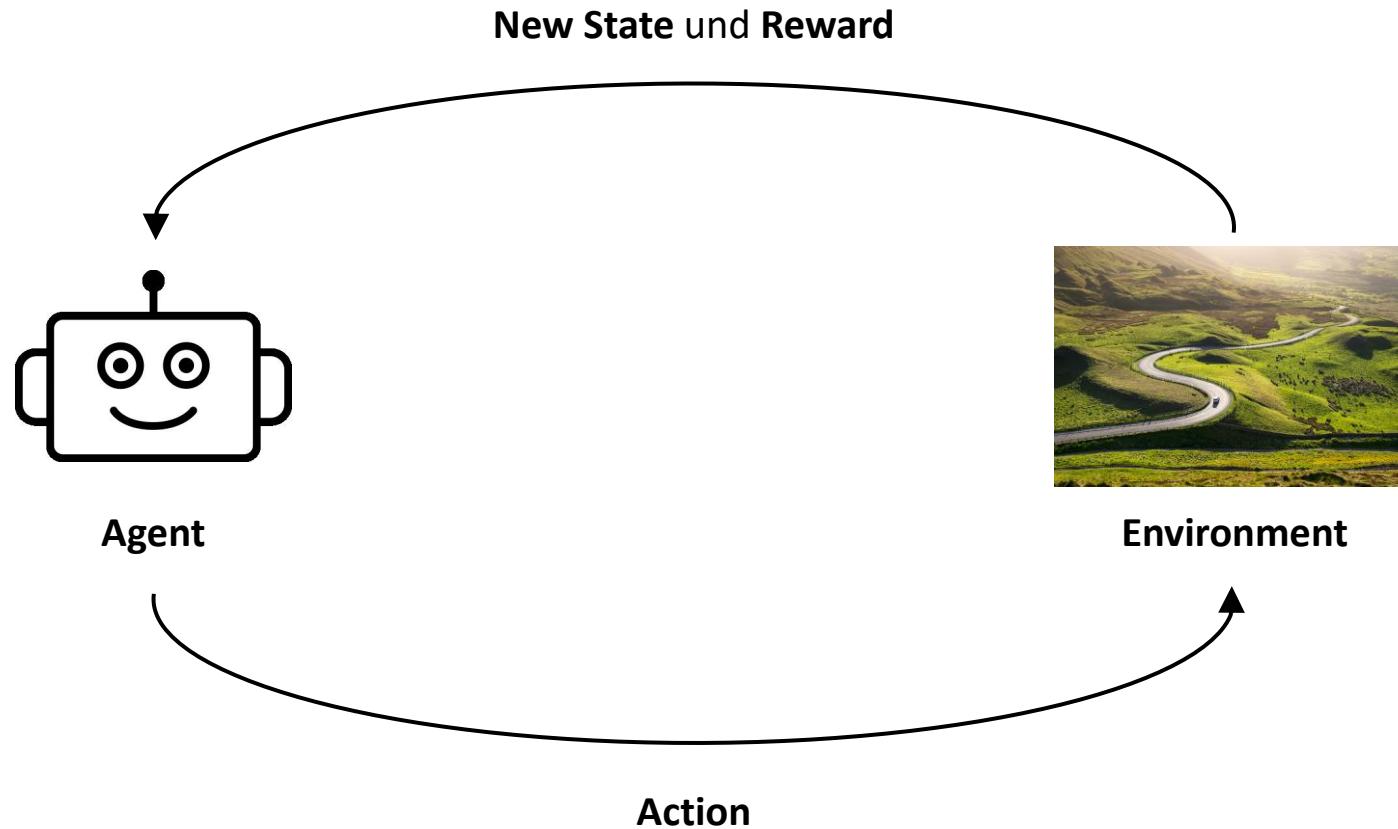


Environment

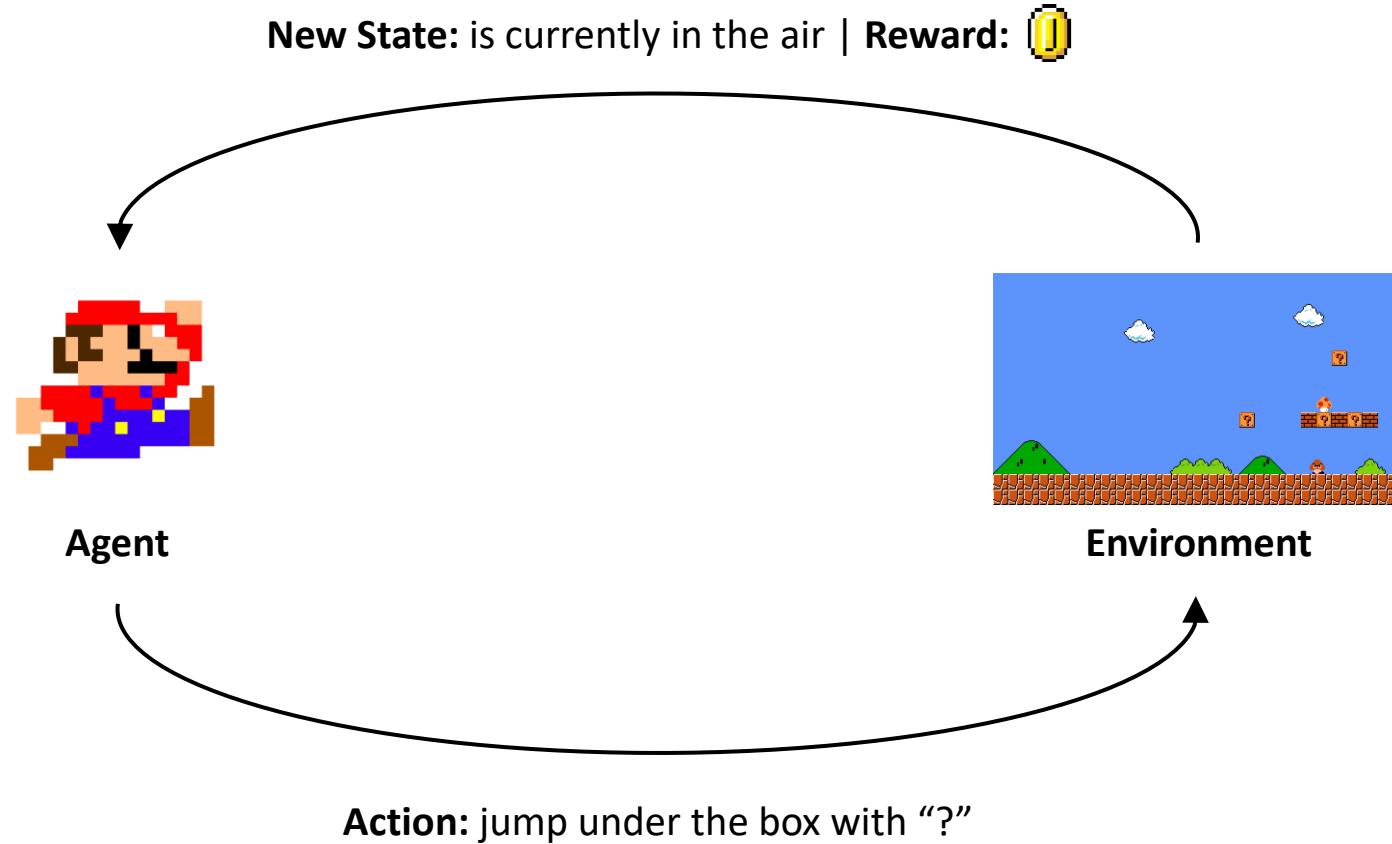
Abstraction



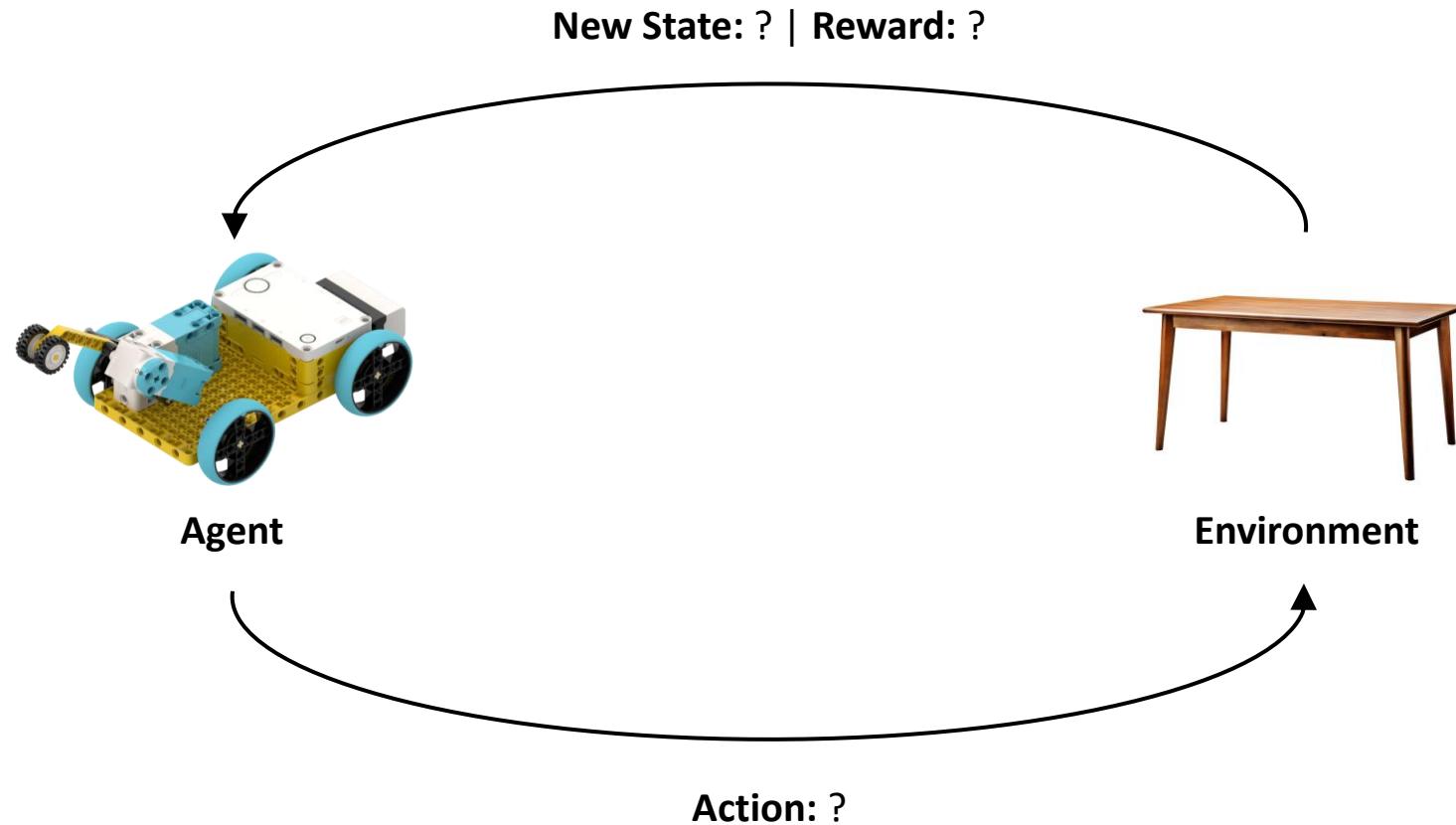
Abstraction



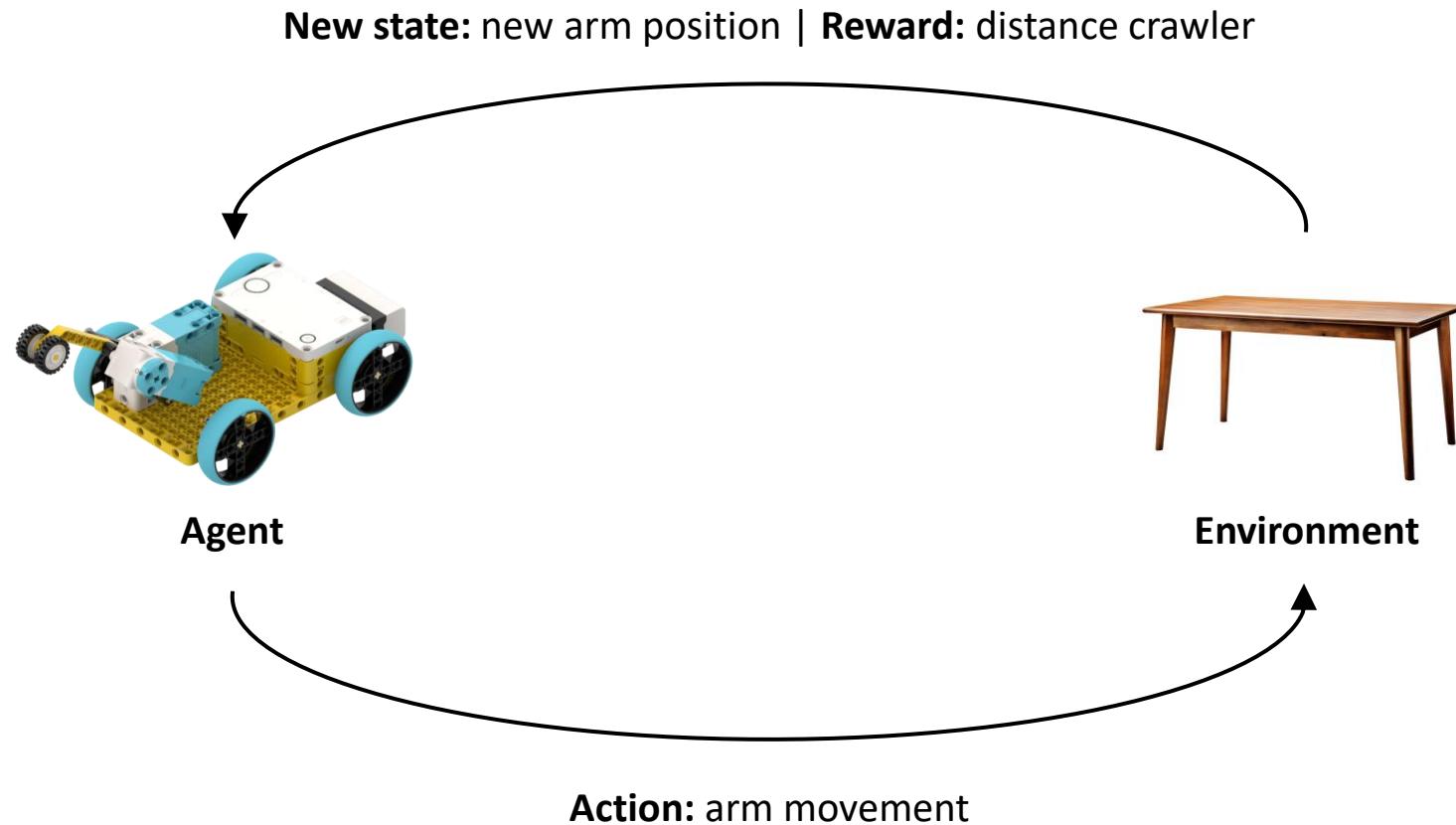
Example of Super Mario Bros



Crawler – Concept

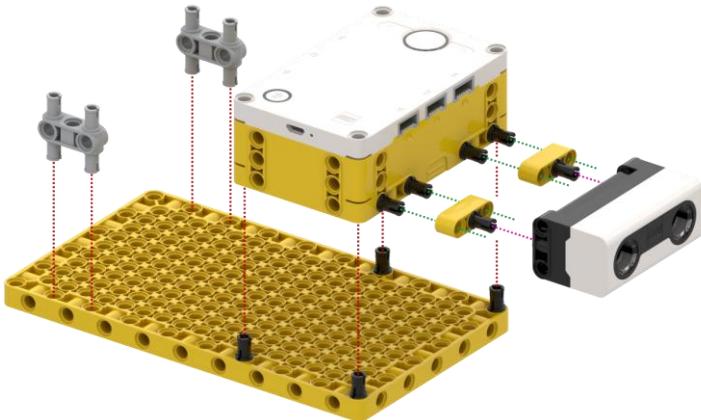


Crawler – Concept



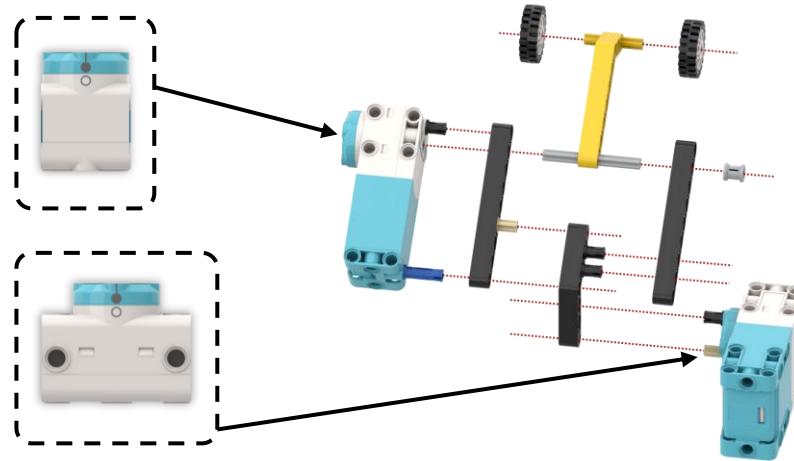
Crawler – Assembly

1

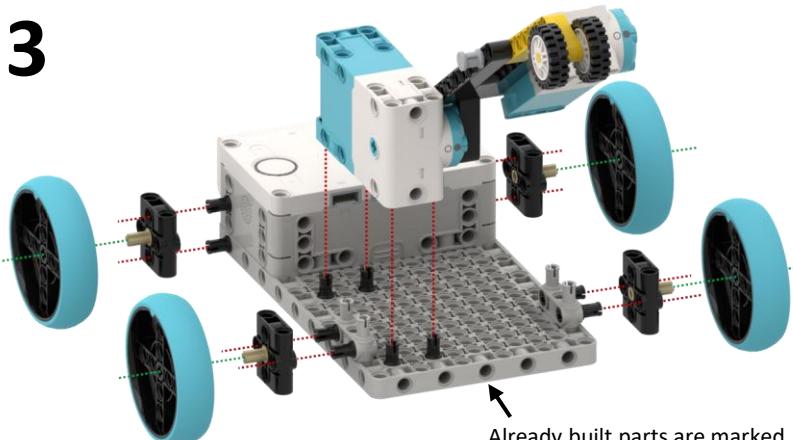


2

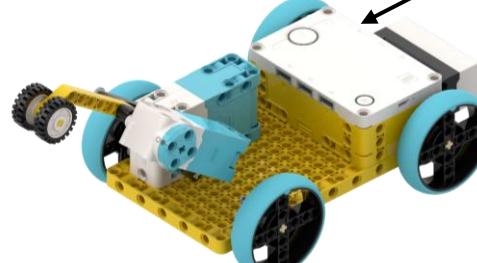
Place motors
in zero
positions!



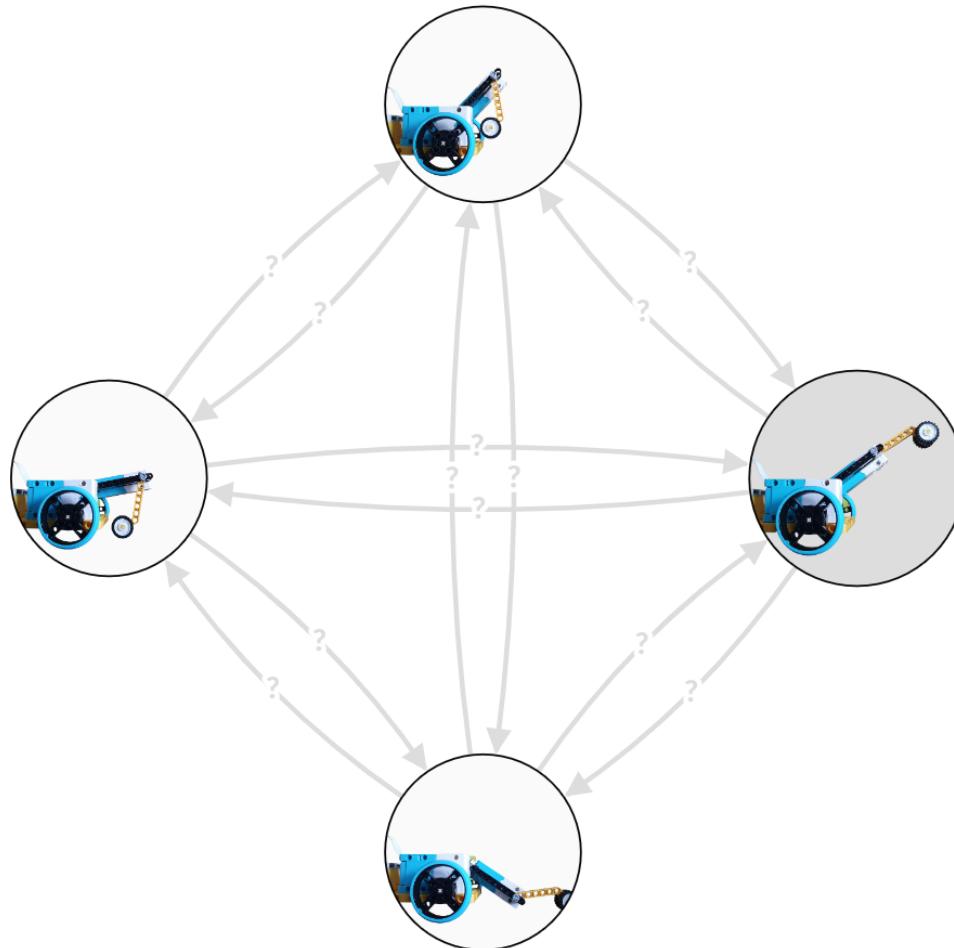
3



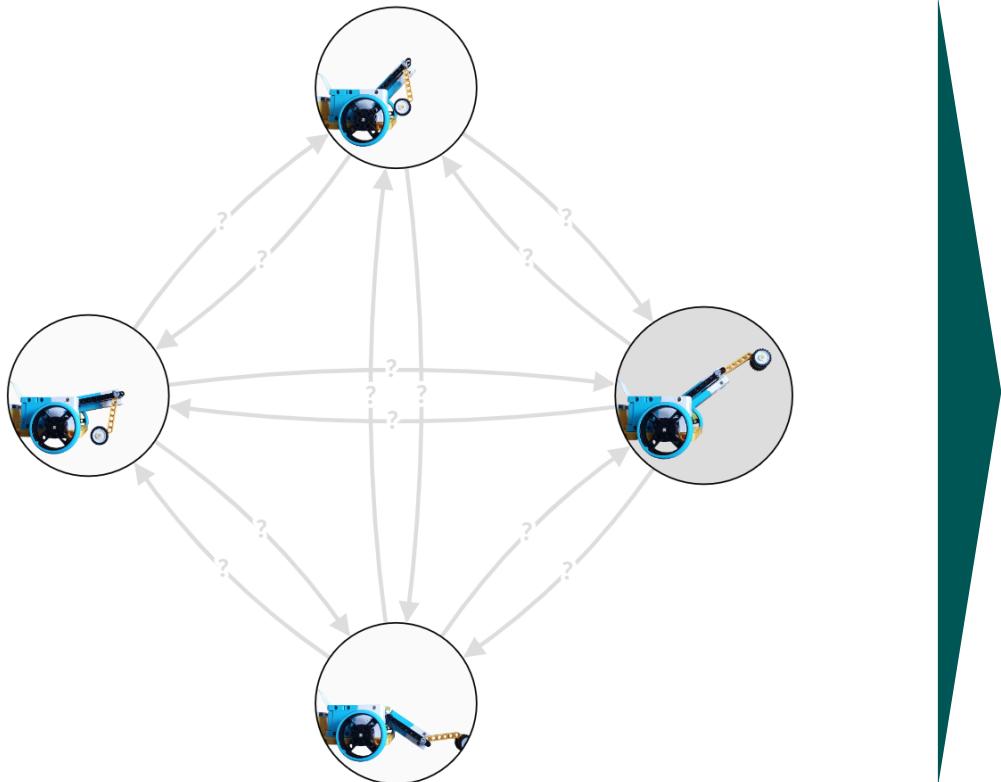
4



How good is an action?

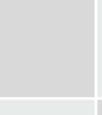
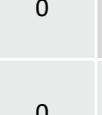
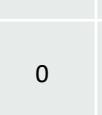


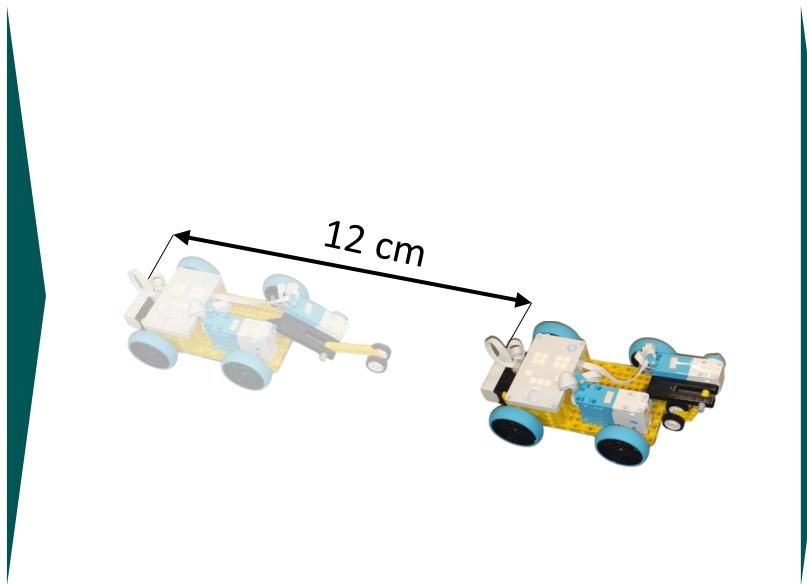
How good is an action?



		Next State			
		1	2	3	4
Current State	1				
	2				

How good is an action?

		Next State			
		Robot 1	Robot 2	Robot 3	Robot 4
Current State	Robot 1		0	0	0
	Robot 2		0	0	0
	Robot 3		0	0	0
	Robot 4		0	0	0



		Next State			
		Robot 1	Robot 2	Robot 3	Robot 4
Current State	Robot 1		0	0	0
	Robot 2		0	0	+12
	Robot 3		0	0	0
	Robot 4		0	0	0

How good is an action?

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

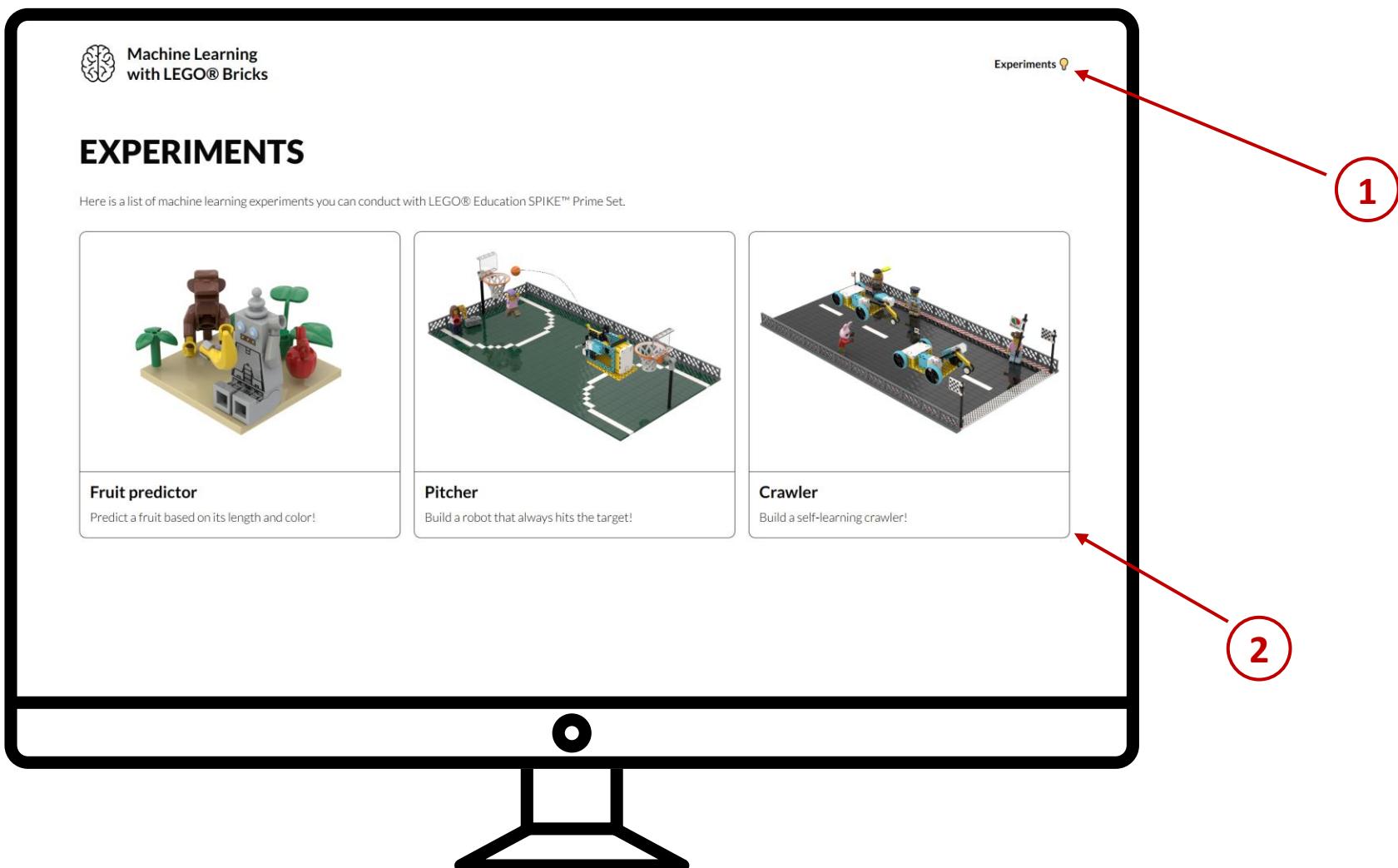


Training

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



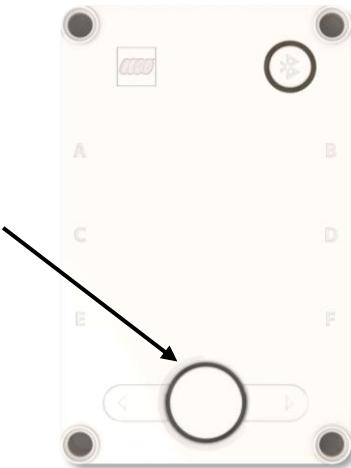
Open the experiment page



Connect hub and start the program

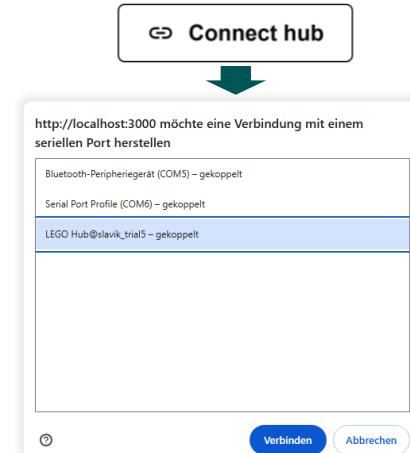
1

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



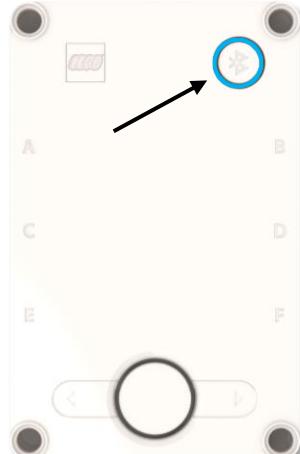
2

Click the "Connect hub" button on the website and select the LEGO hub in the dialog window.



3

Click "Connect" in the dialog window and wait. The Bluetooth button on the hub should possibly light up blue.



4

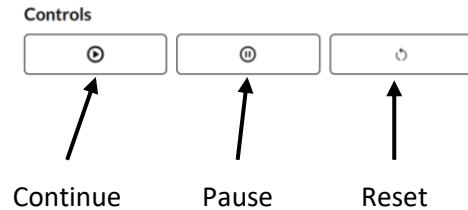
Click "Start program" and wait for the program to load.

Start program

Crawler – Training

1

Reset the experiment.



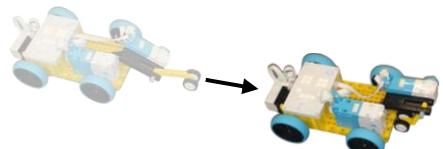
2

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.

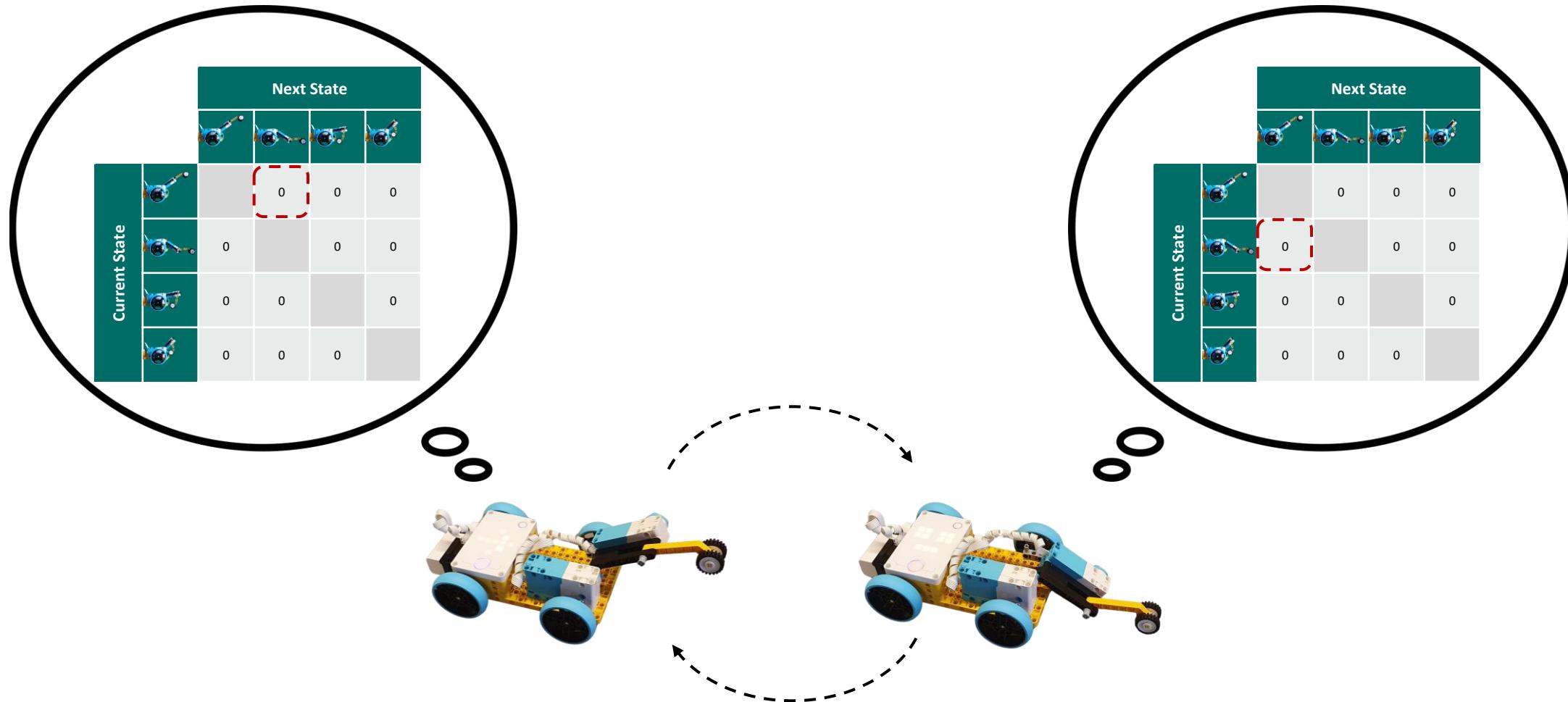


4

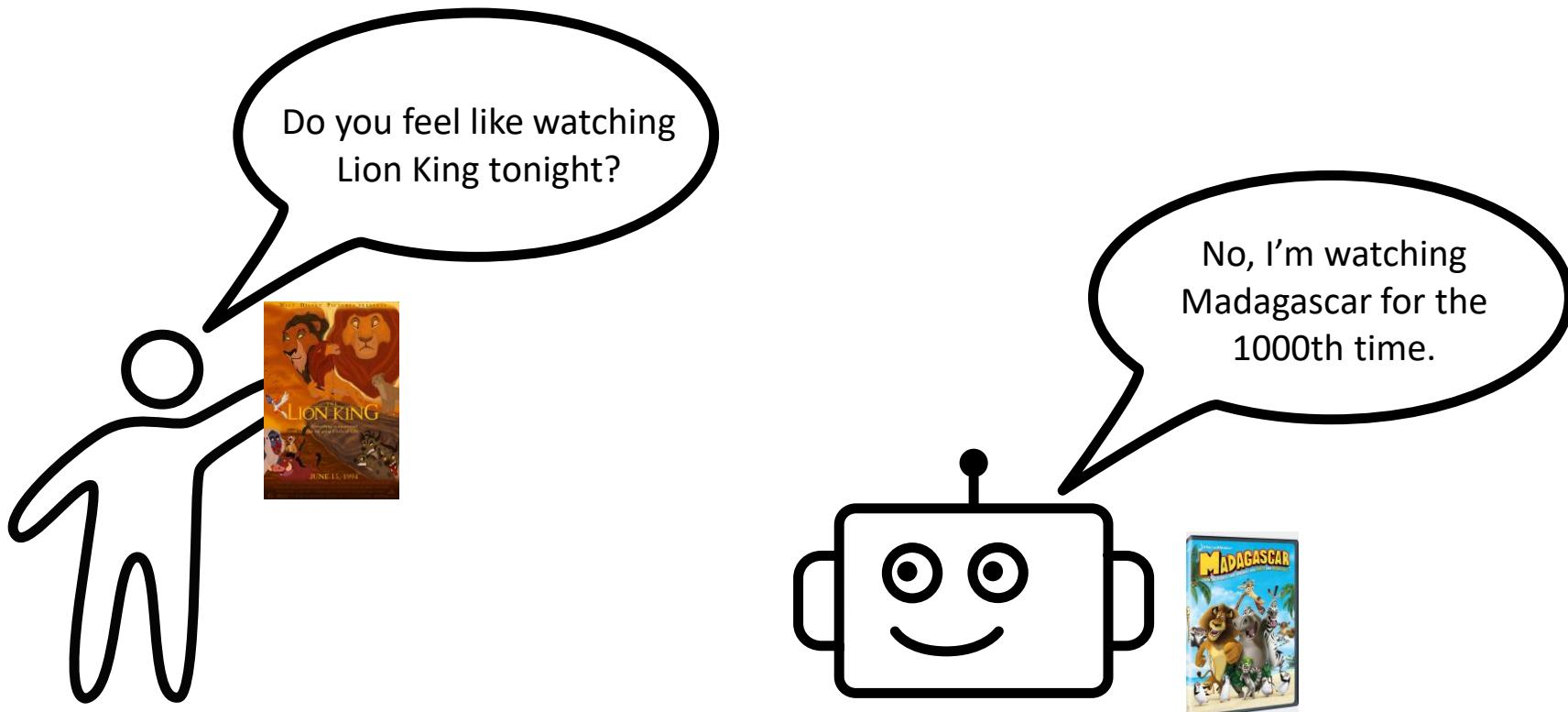
Observe how the table gets filled.

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

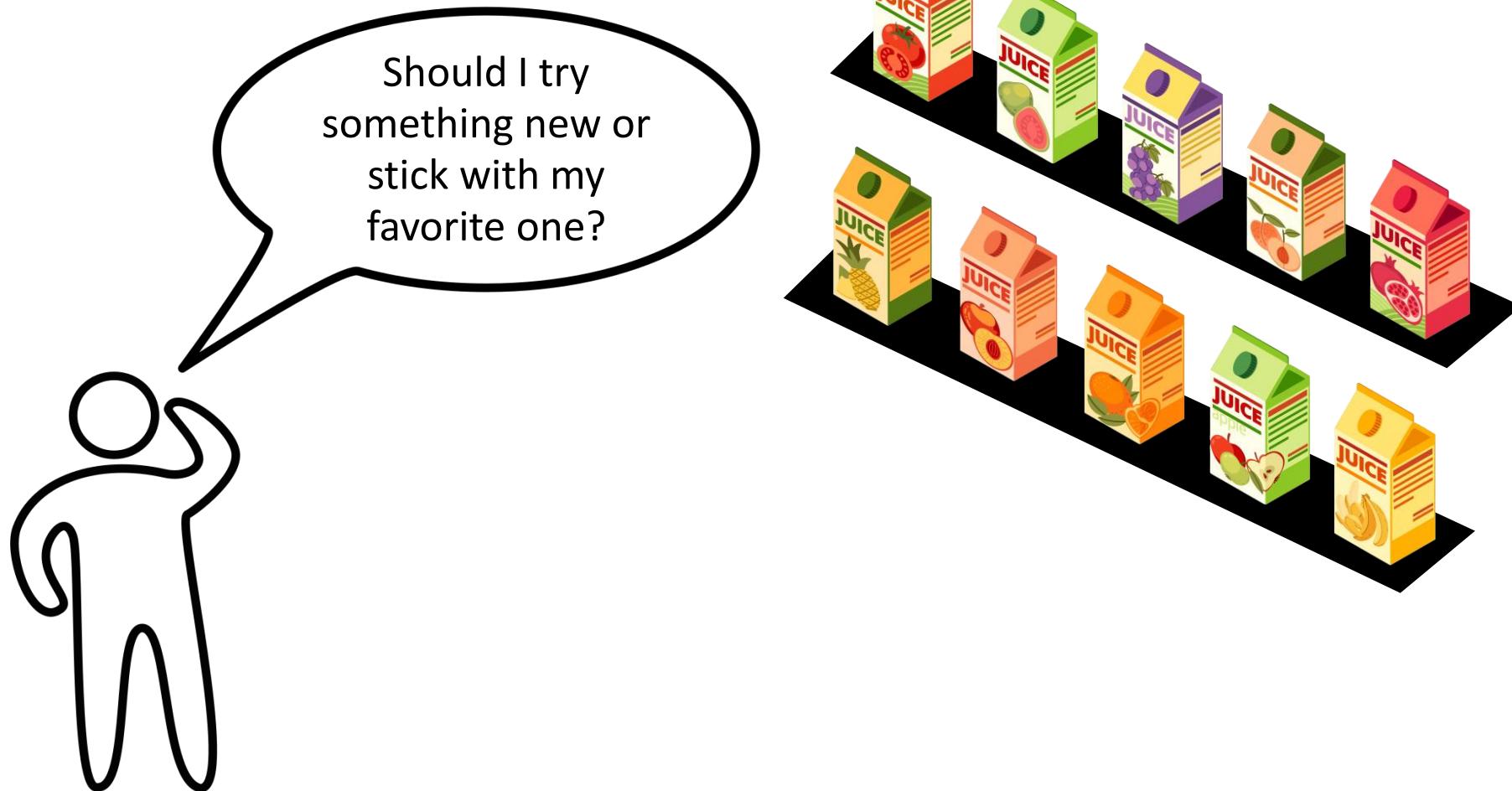
Why is it not working?



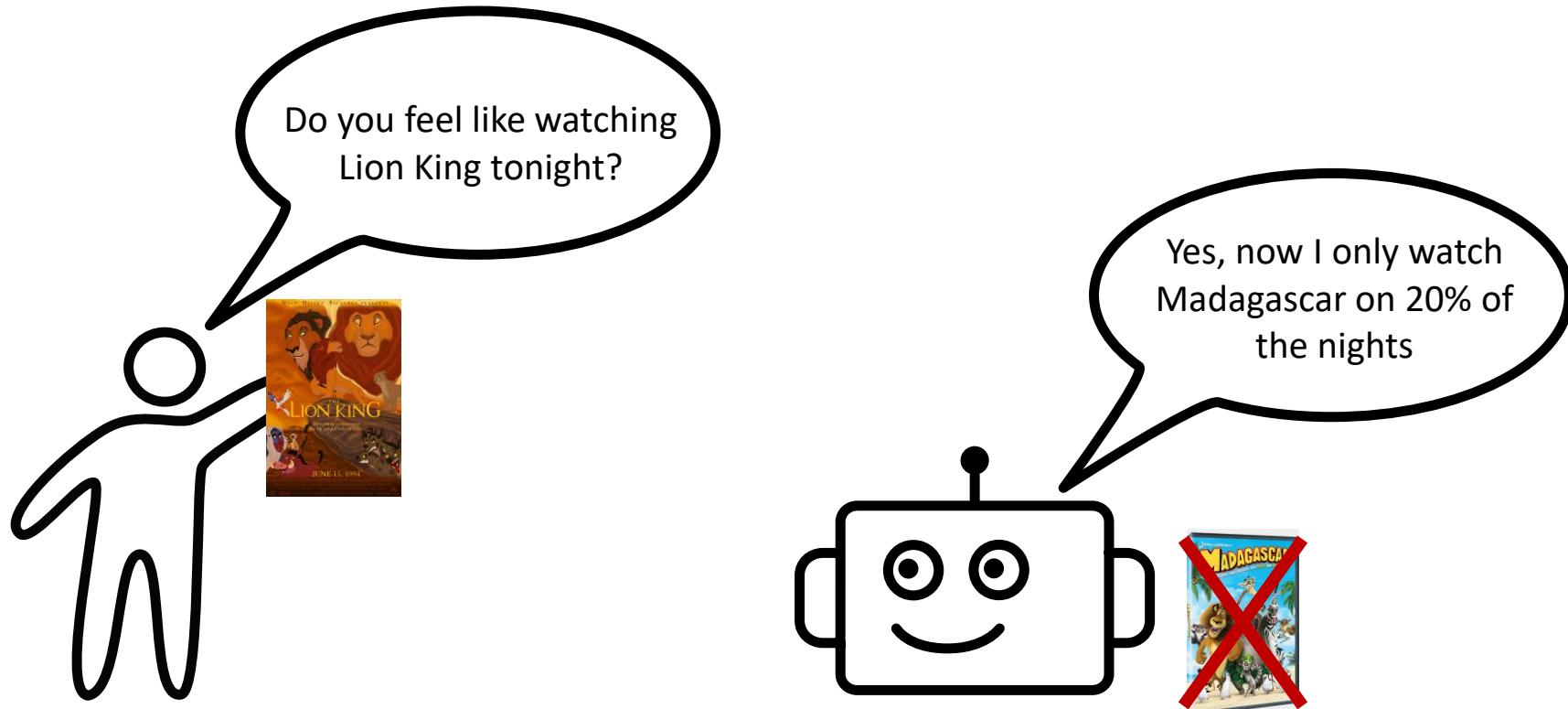
Trying something new?



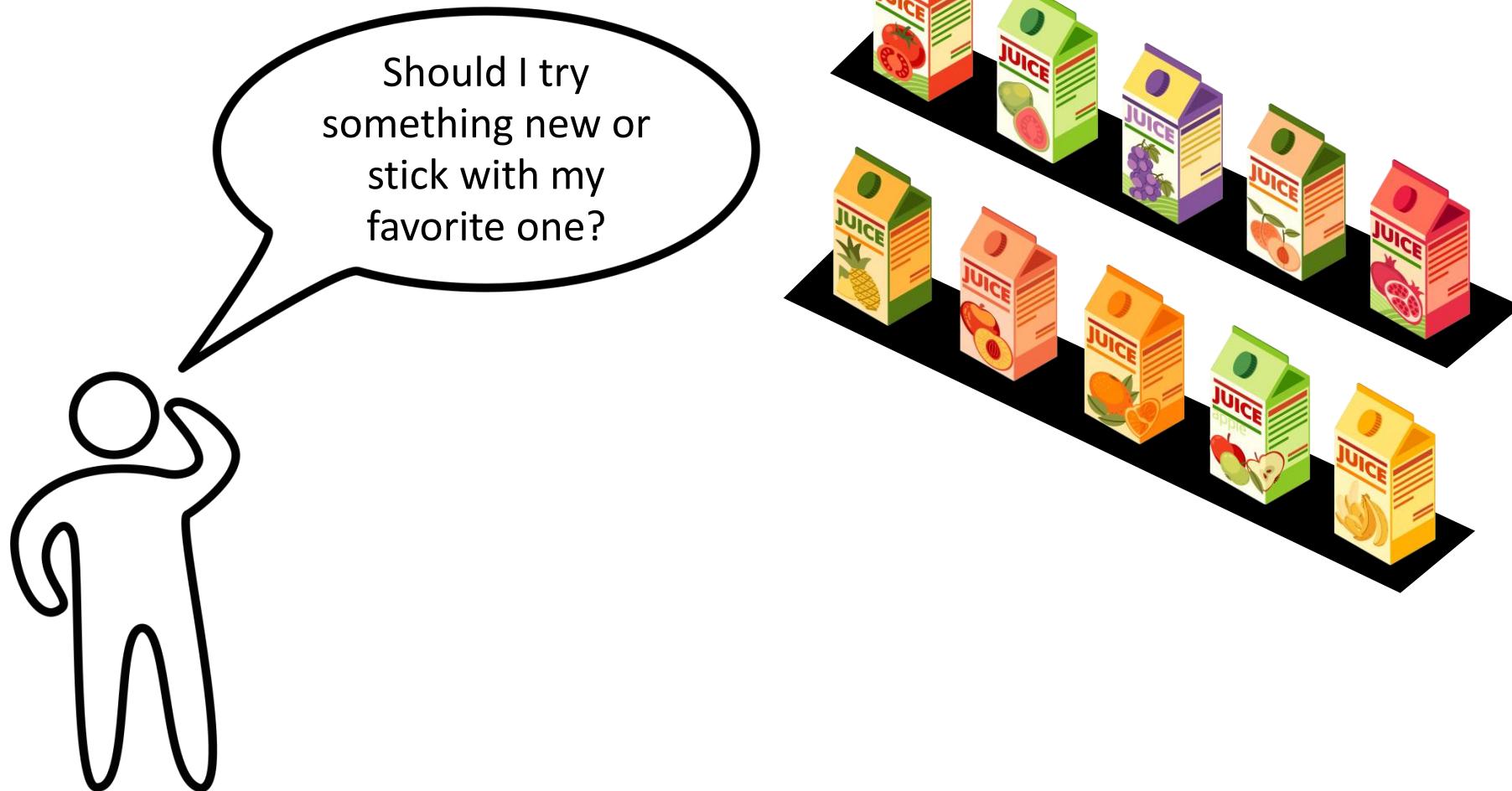
Exploration-Exploitation-Dilemma



Trying something new?

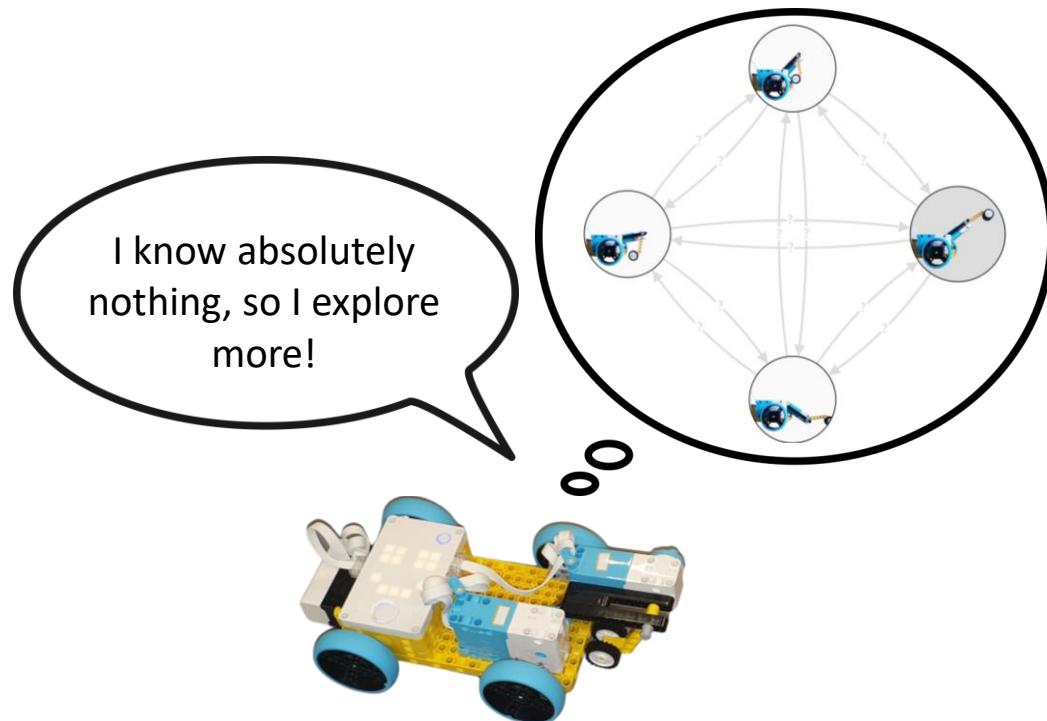


Exploration-Exploitation-Dilemma

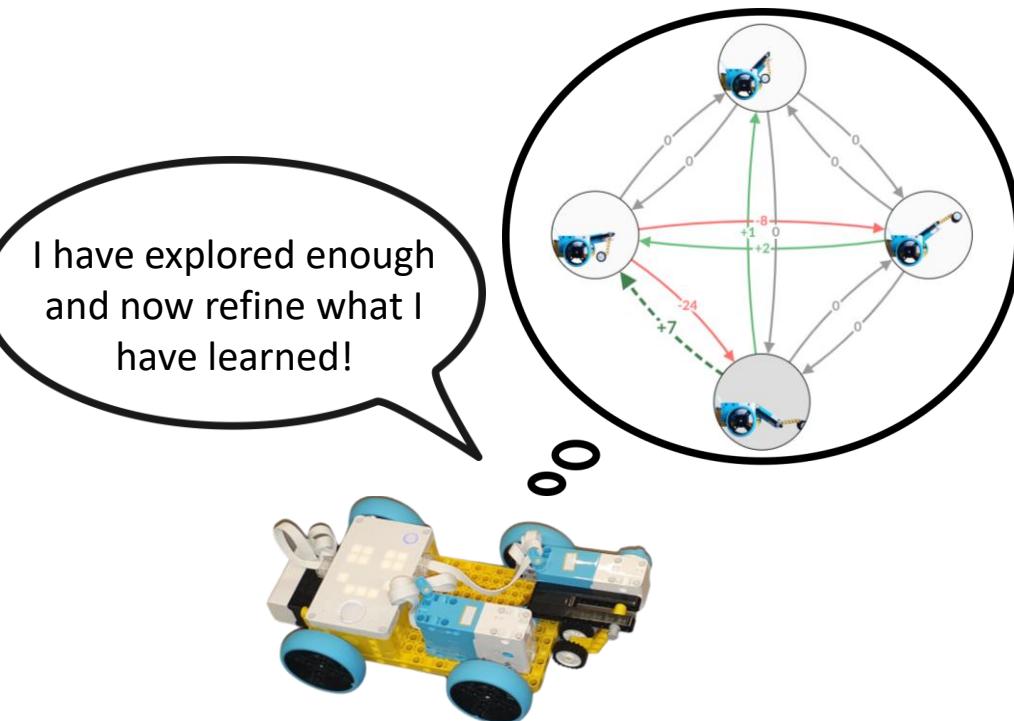


Exploration-Exploitation-Dilemma

Beginning of training



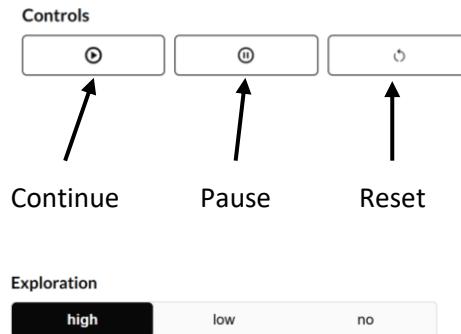
End of training



Crawler – Training

1

Reset the experiment. Set exploration to high.



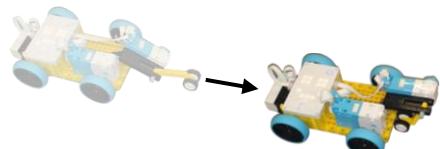
2

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.

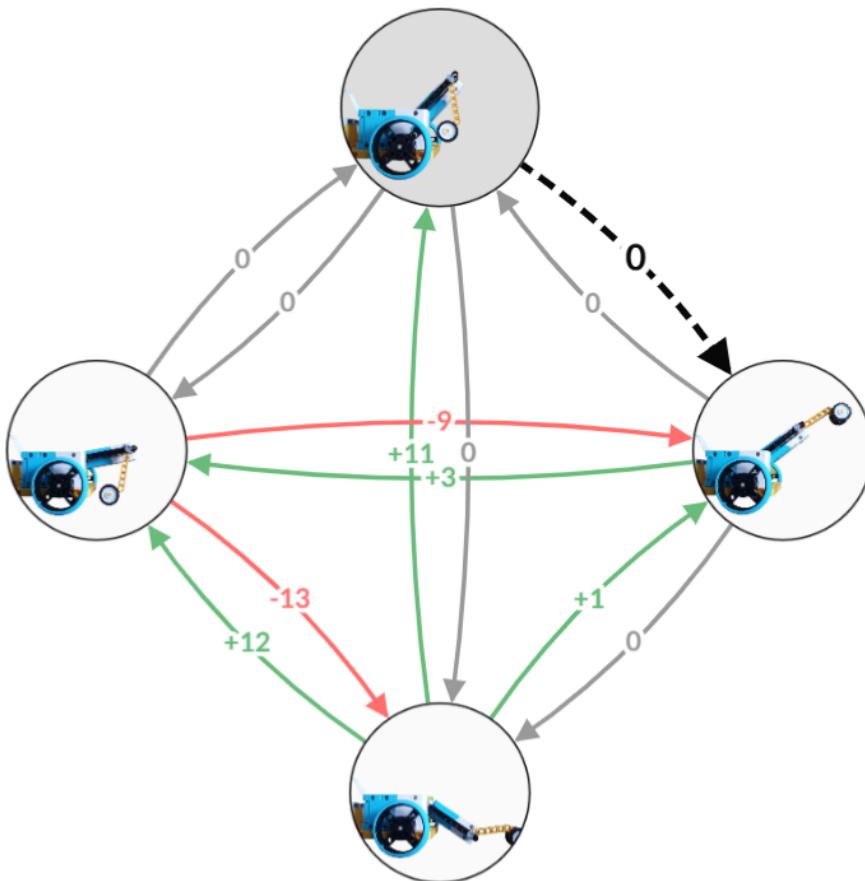


4

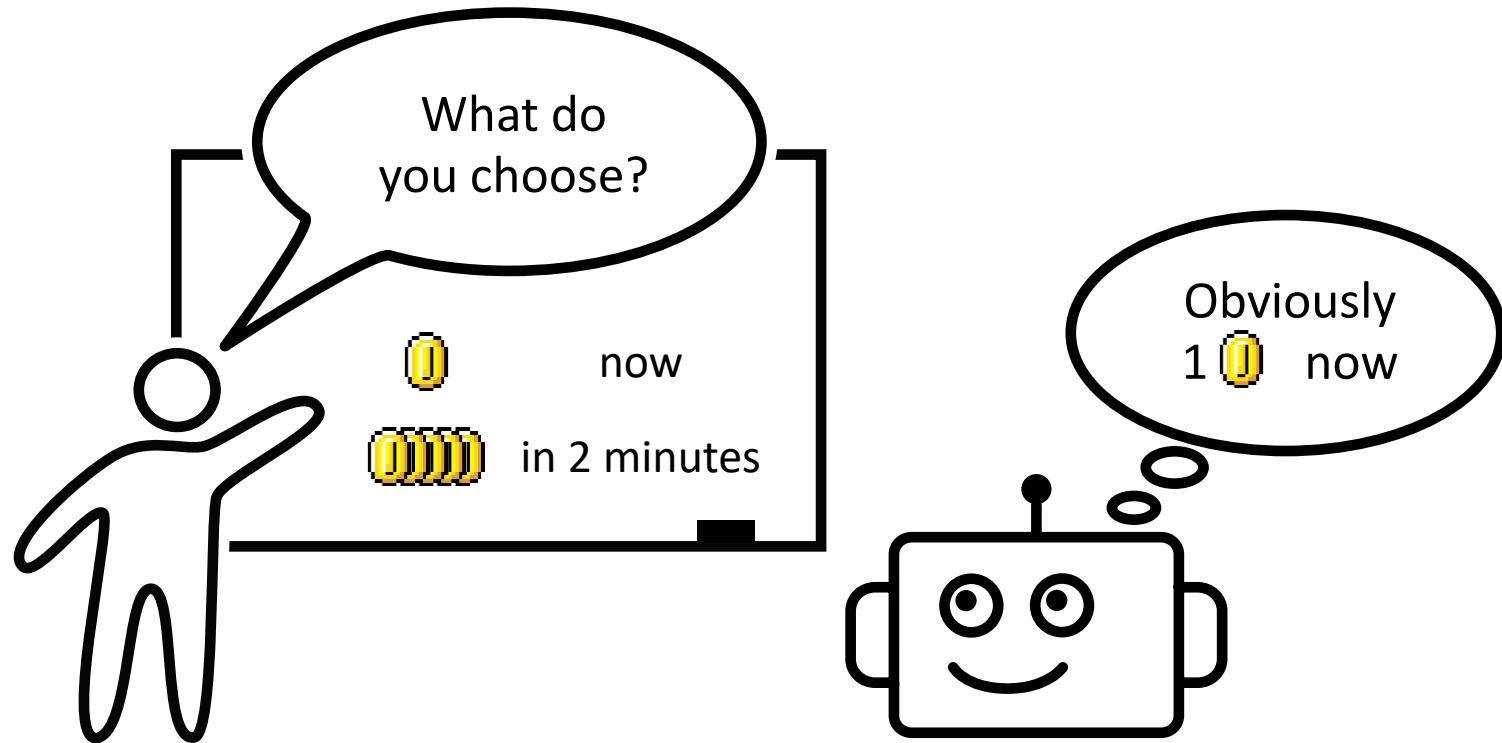
Observe how the table gets filled. Reduce exploration over time.

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

Foresight

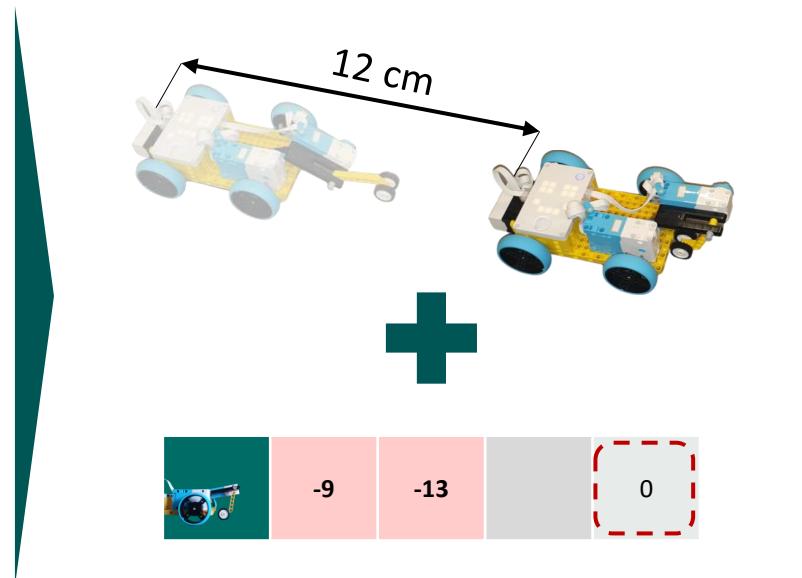


Foresight



Foresight

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

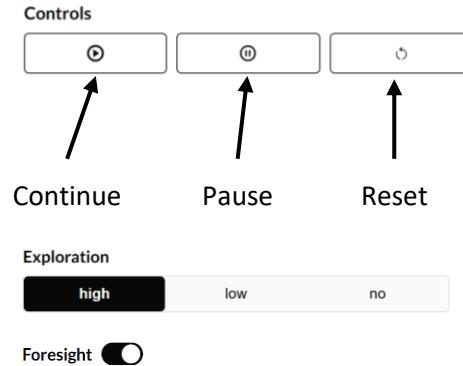


		Next State			
		0	+3	0	
Current State	0	+1		+12	+11
	-9	-13		0	
	0	0	0	0	

Crawler – Training

1

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



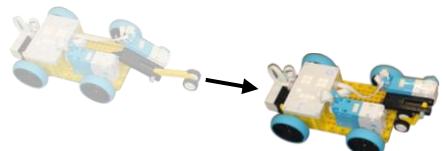
2

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.

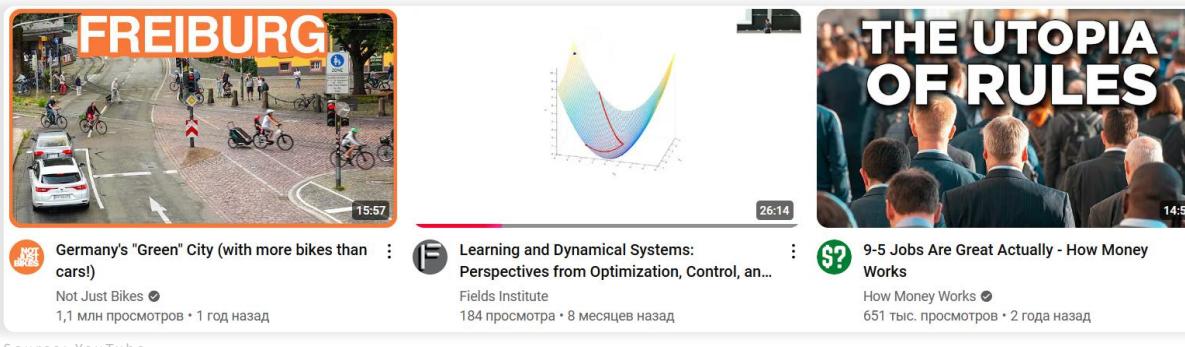
		Next State			
		0	+3	0	
Current State	0	+1	+12	+11	
	-9	-13		0	
	0	0	0	0	

Other applications



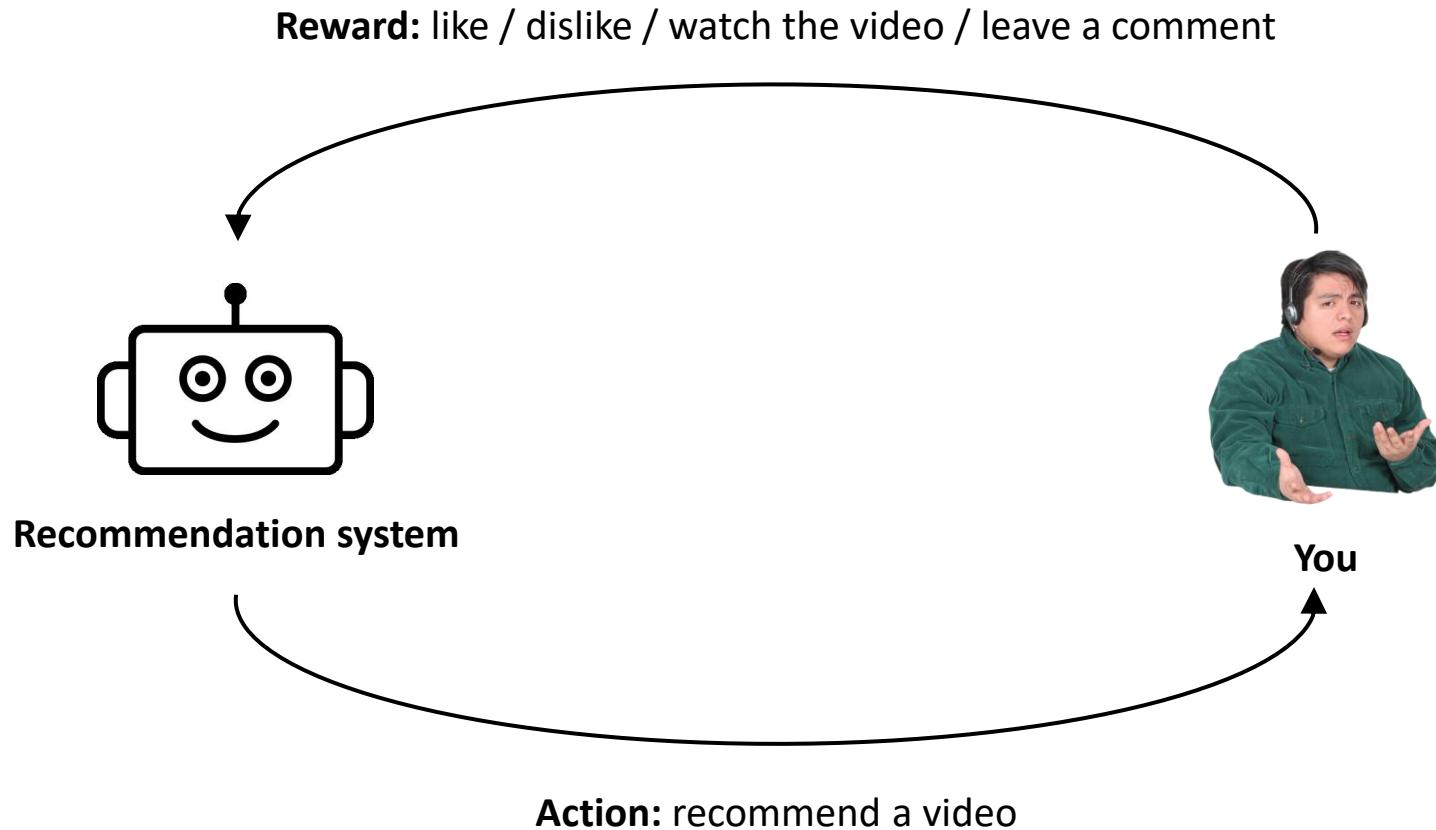
YEAAAAAH

Reward (+1/-1)



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

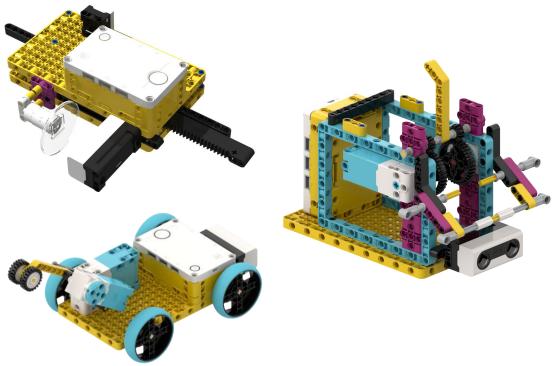
How recommendation systems work



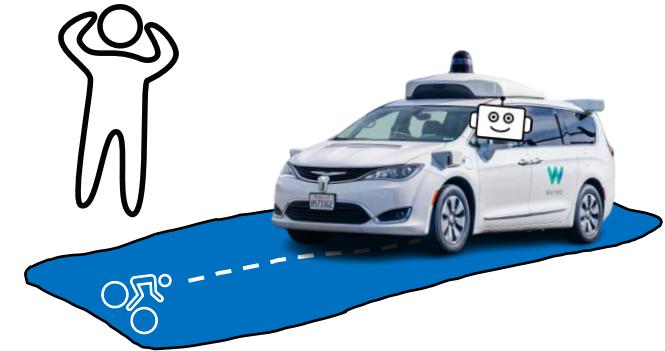
Summary



Machine learning is no magic



Machine learning can do a lot



Power brings responsibility