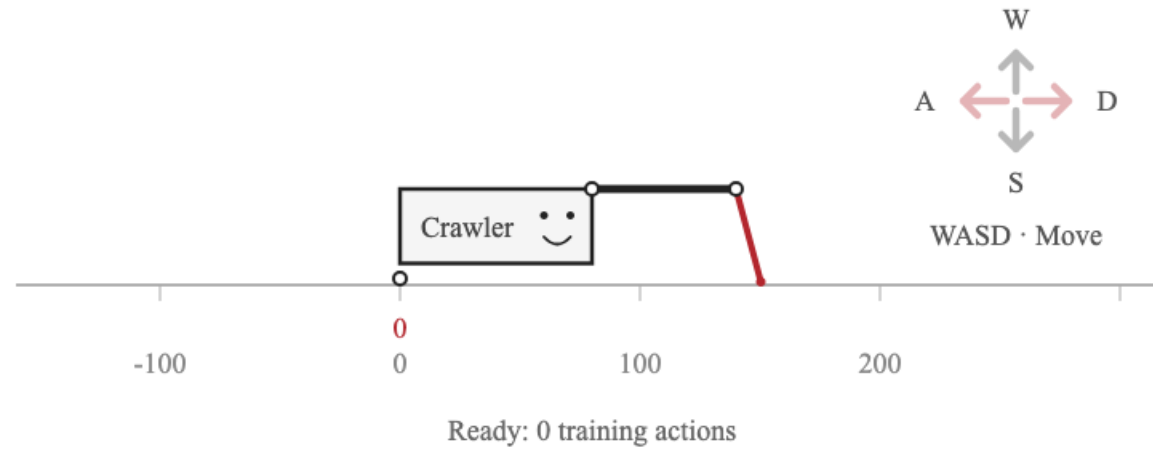


L-6

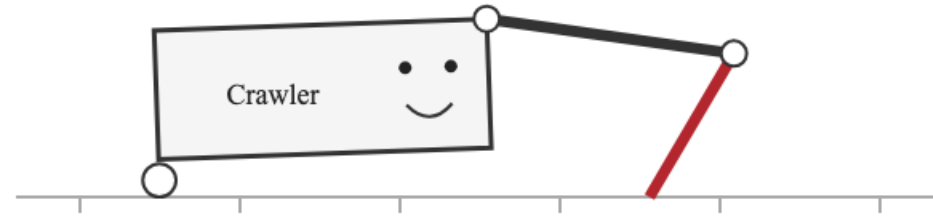


From Perception to Action: AI in Robotics



DEMO 1 · L5 Exit Ticket Results

Learning Through Trial and Error

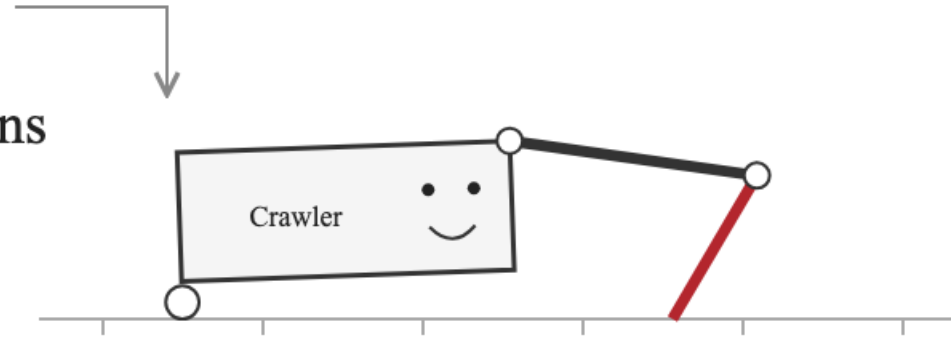


Learning Through Trial and Error

Learning Model

2	5	3	-1
4	7	1	6
3	0	8	2

Estimates the value of actions

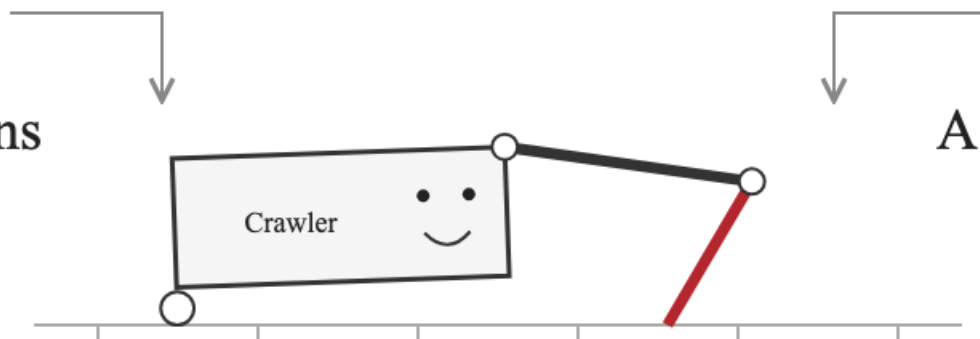


Learning Through Trial and Error

Learning Model

2	5	3	-1
4	7	1	6
3	0	8	2

Estimates the value of actions



Simulation



A virtual environment for trials

Learning Through Trial and Error

Learning Model

2	5	3	-1
4	7	1	6
3	0	8	2

Estimates the value of actions

Possible Actions

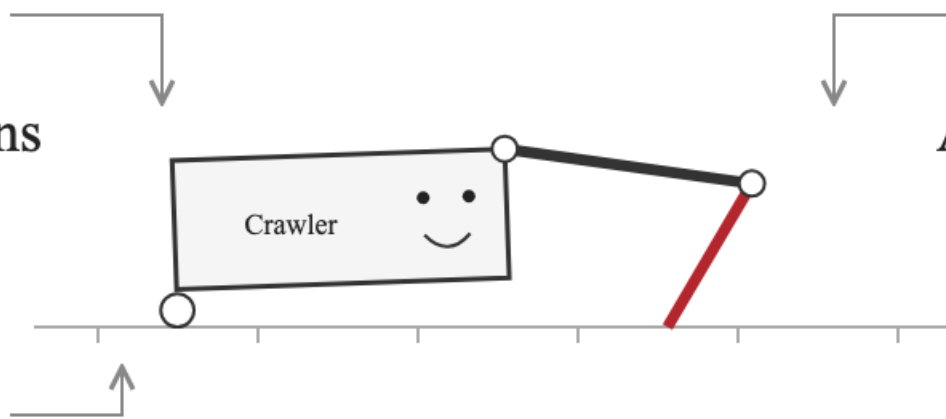


Rotate either joint in either direction

Simulation



A virtual environment for trials



Learning Through Trial and Error

Learning Model

2	5	3	-1
4	7	1	6
3	0	8	2

Estimates the value of actions

Possible Actions



Rotate either joint in either direction

Simulation



A virtual environment for trials

Reward Function



Scores the outcome of an action

Learning Through Trial and Error

Learning Model

2	5	3	-1
4	7	1	6
3	0	8	2

Estimates the value of actions

Possible Actions

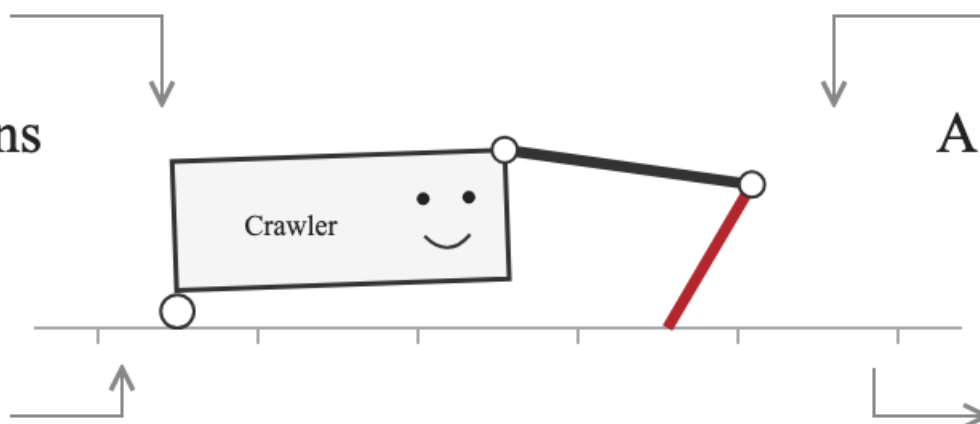


Rotate either joint in either direction

Simulation



A virtual environment for trials



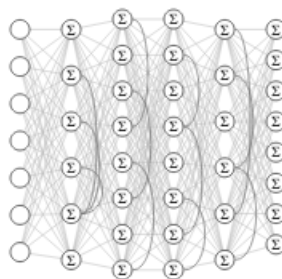
Reward Function



Scores the outcome of an action

2	5	3	-1
4	7	1	6
3	0	8	2

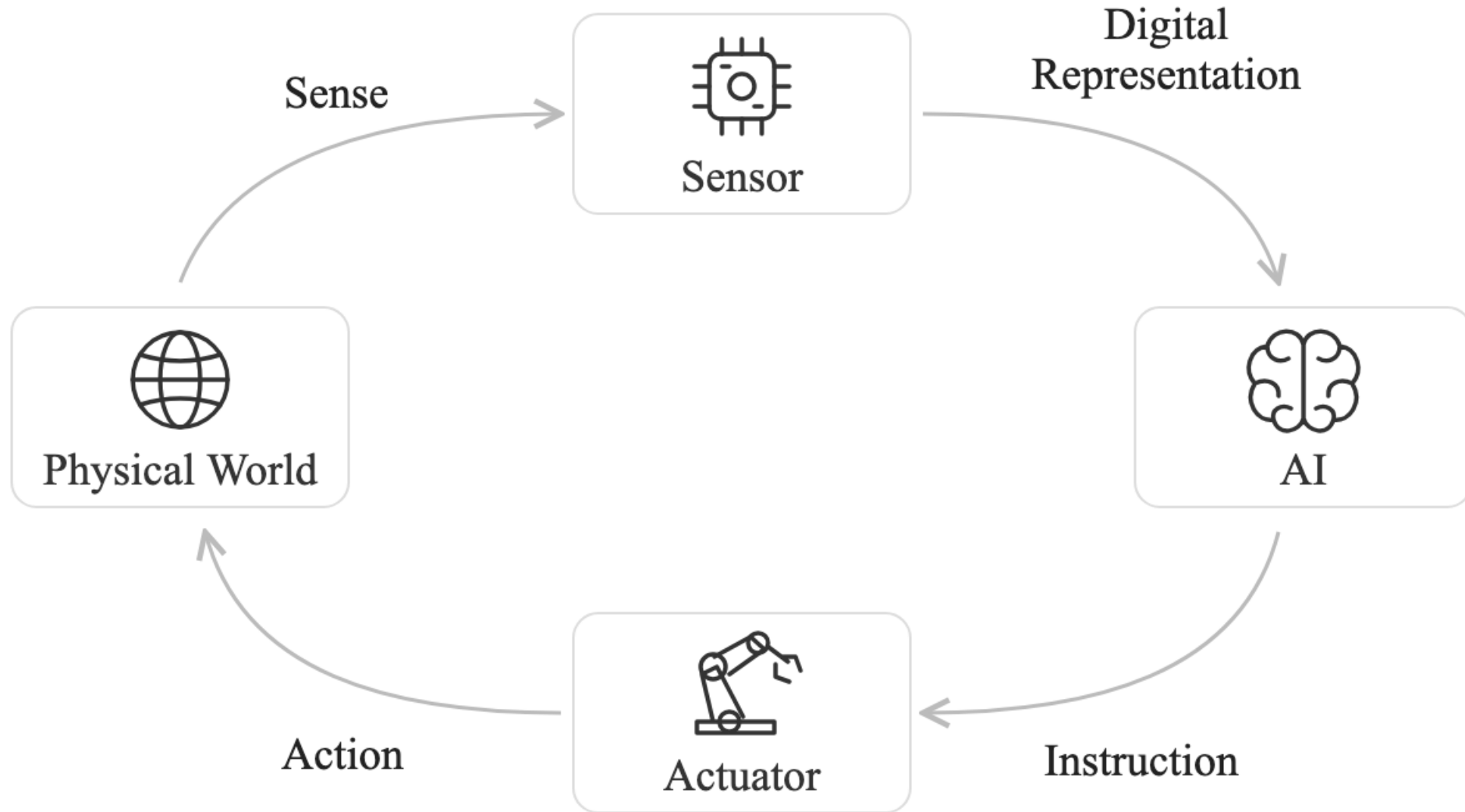
Our Crawler: Table



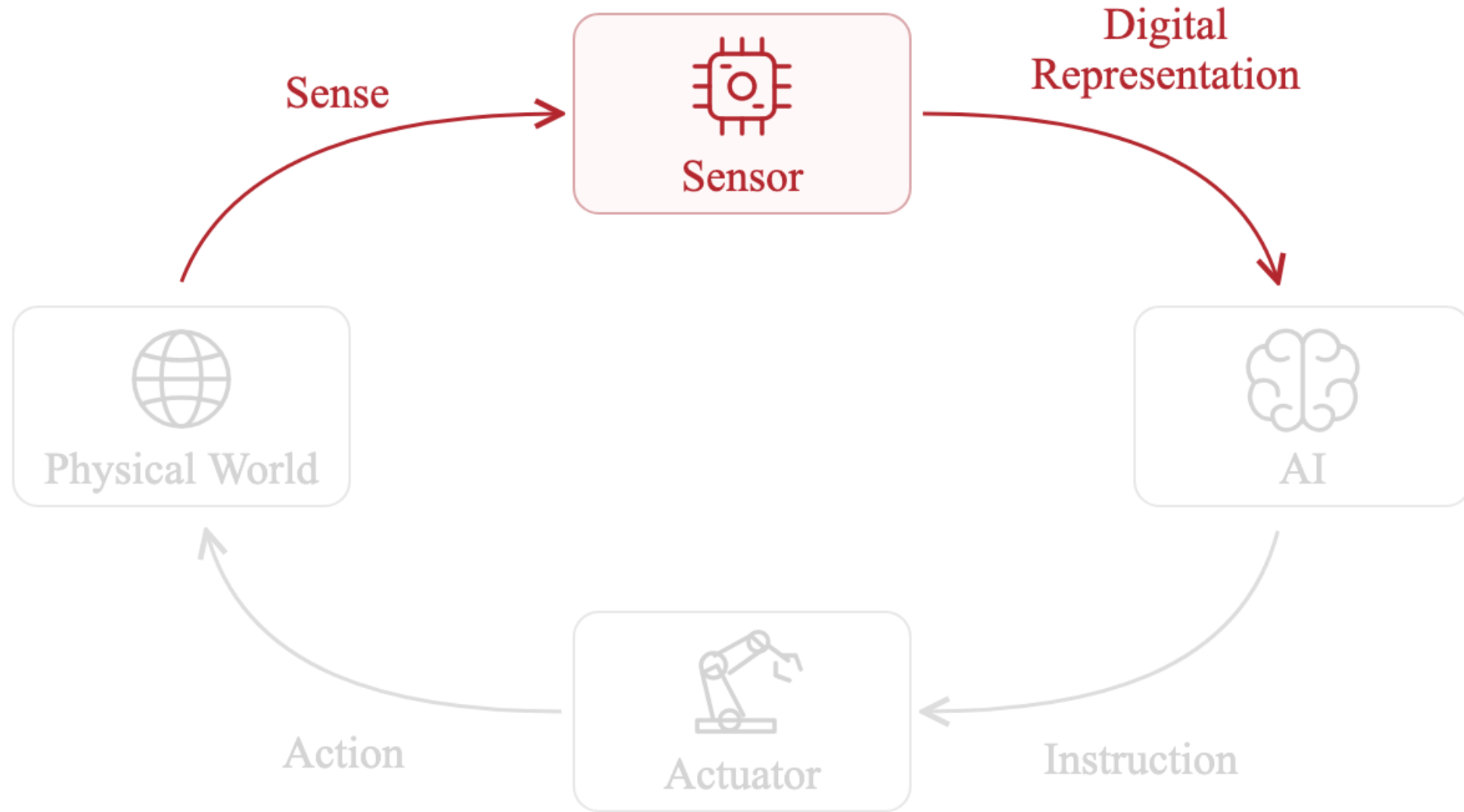
Deep Reinforcement Learning

A deep neural network
learns from reward

The Perception–Action Loop



How Does a Robot Sense?



Beyond Human Vision

Passive

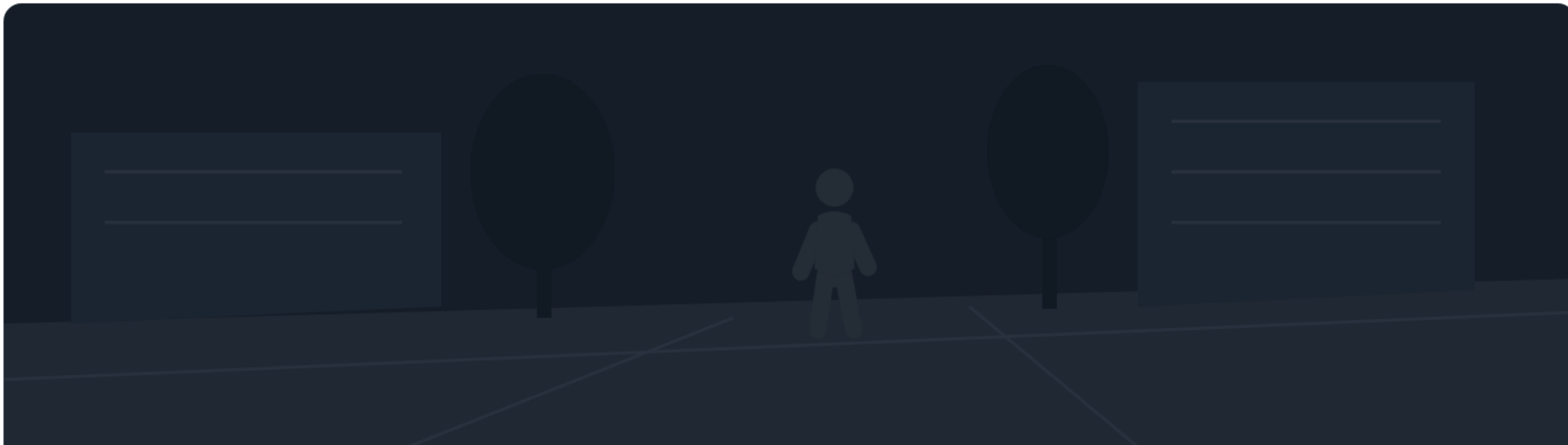
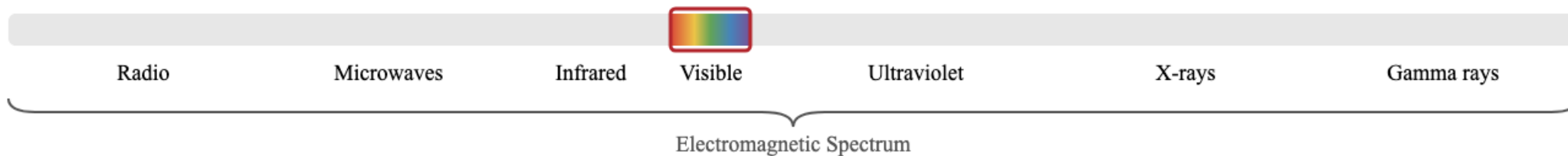
Active

Visible Camera

Thermal Camera

ToF Depth Camera

Radar



Robot Sensors

Sensing Its Body

Proprioceptive

Joint

Angle

Wheel

Rotation

IMU

Acceleration / rotation

Battery

Voltage

Sensing Its Environment

Exteroceptive

Camera

Colour · Passive

ToF Depth Camera

Distance · Active

Scanning LiDAR

Laser ranges · Active

Touch

Contact

Microphone

Sound

GPS/GNSS

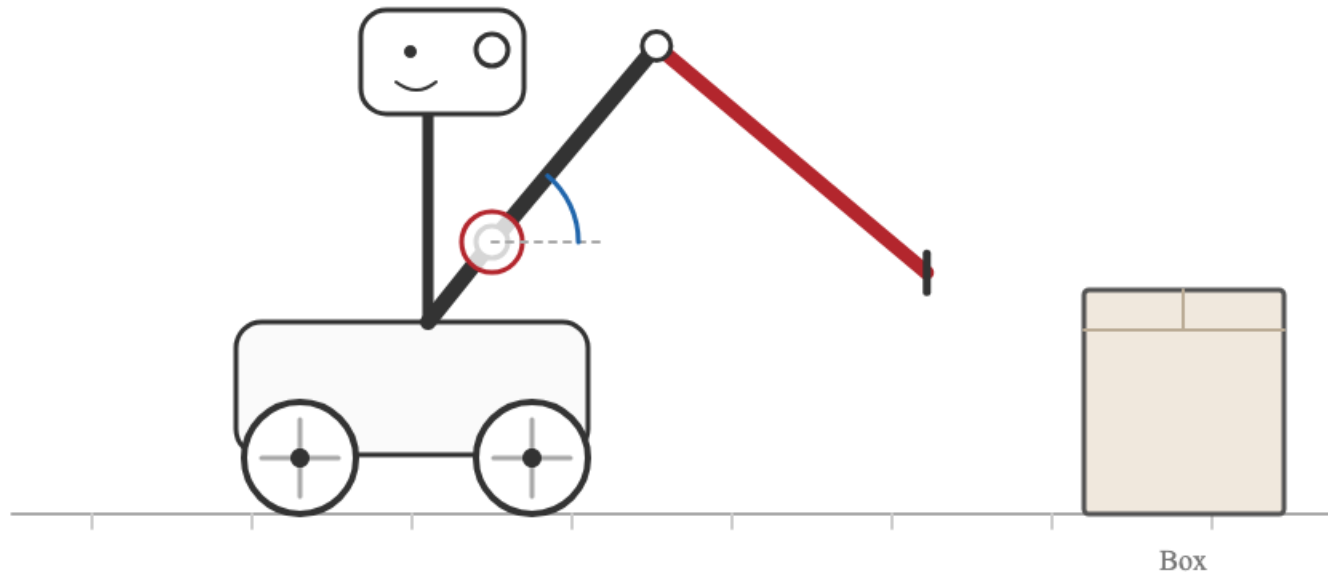
Position

Radar

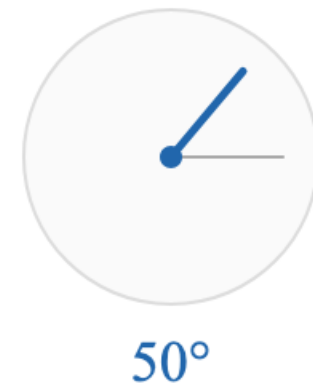
Range / speed · Active

Force

Push / pull



Joint angle



Proprioceptive sensors measure the body, while exteroceptive sensors measure the environment

Sensor Fusion

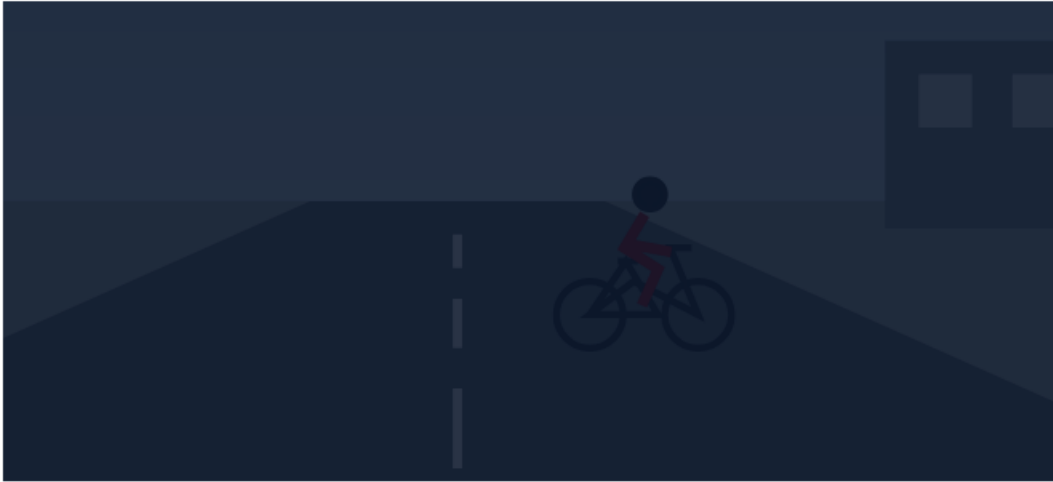
[More Examples](#)

Camera

+ LiDAR

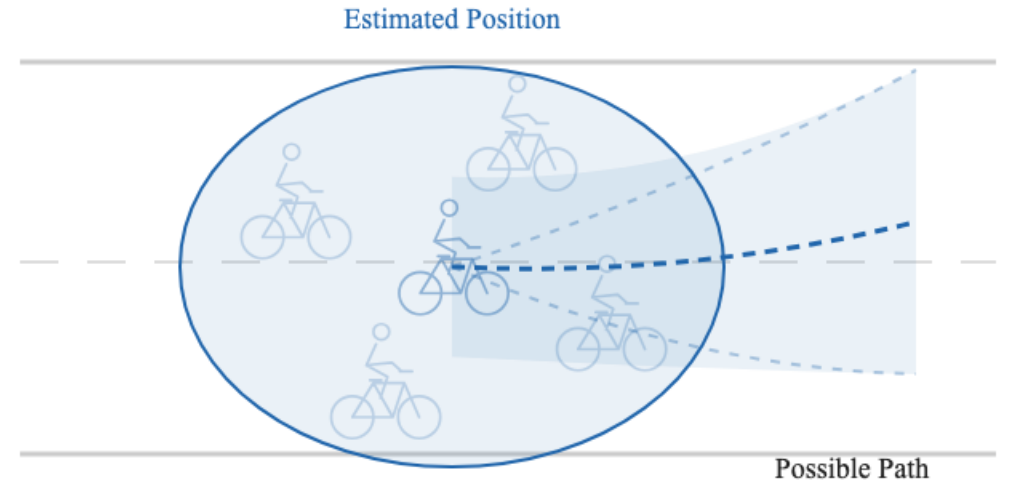
+ Radar

Road Scene



Darkness

Estimated World



Camera: uncertain position and motion

Sensor Fusion

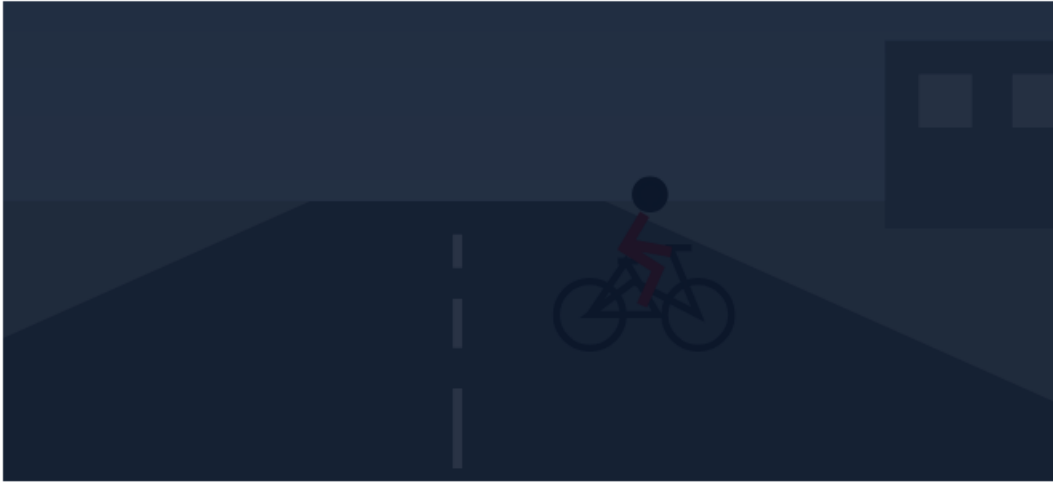
[More Examples](#)

Camera

+ LiDAR

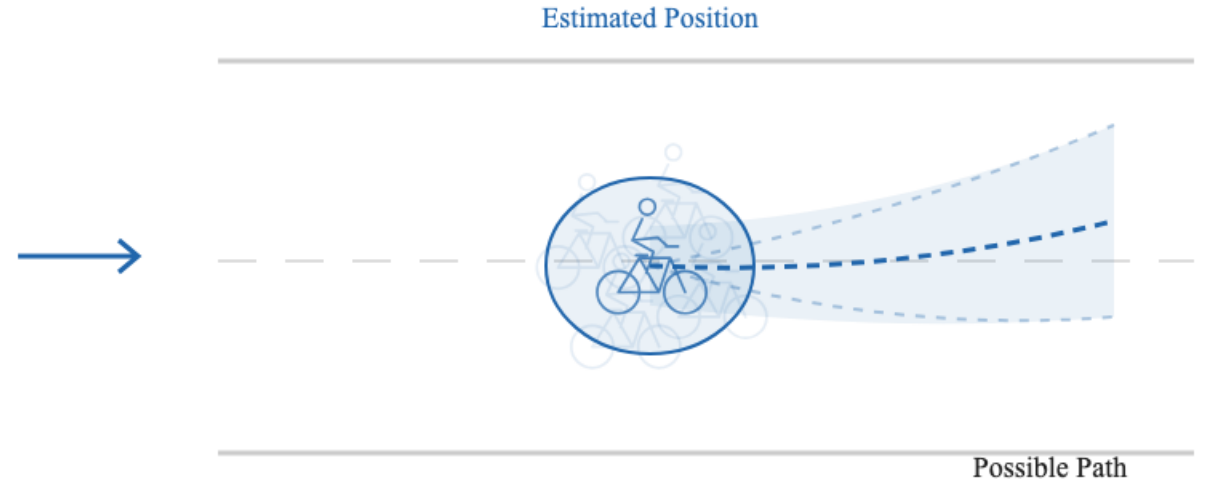
+ Radar

Road Scene



Darkness

Estimated World



LiDAR adds geometry: position becomes more certain

Sensor Fusion

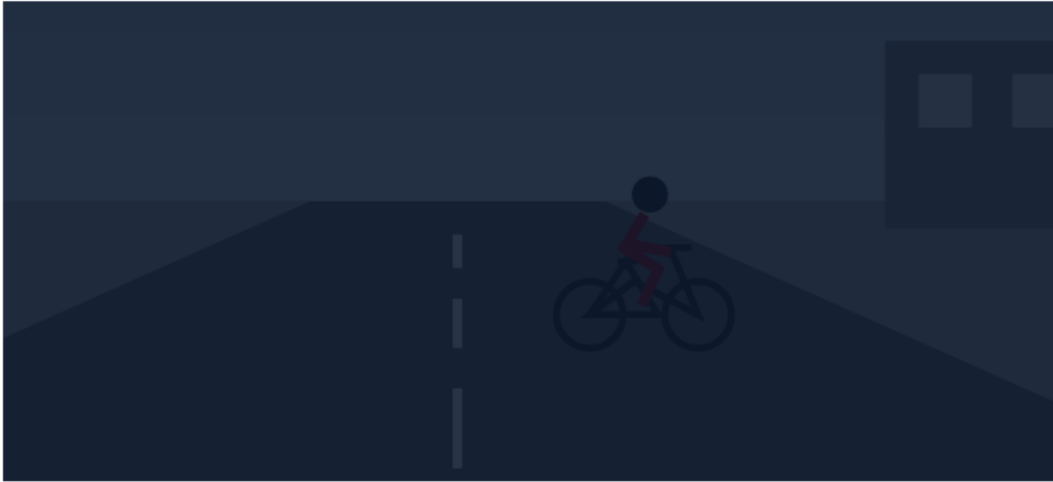
[More Examples](#)

Camera

+ LiDAR

+ Radar

Road Scene

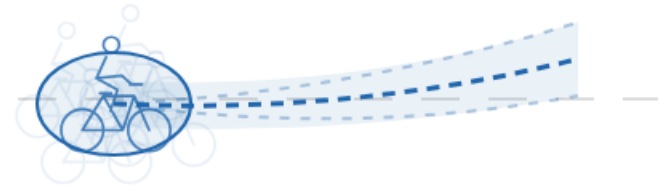


Darkness

Estimated World



Estimated Position



Possible Path

Radar adds motion evidence: possible paths narrow

Sensor Fusion

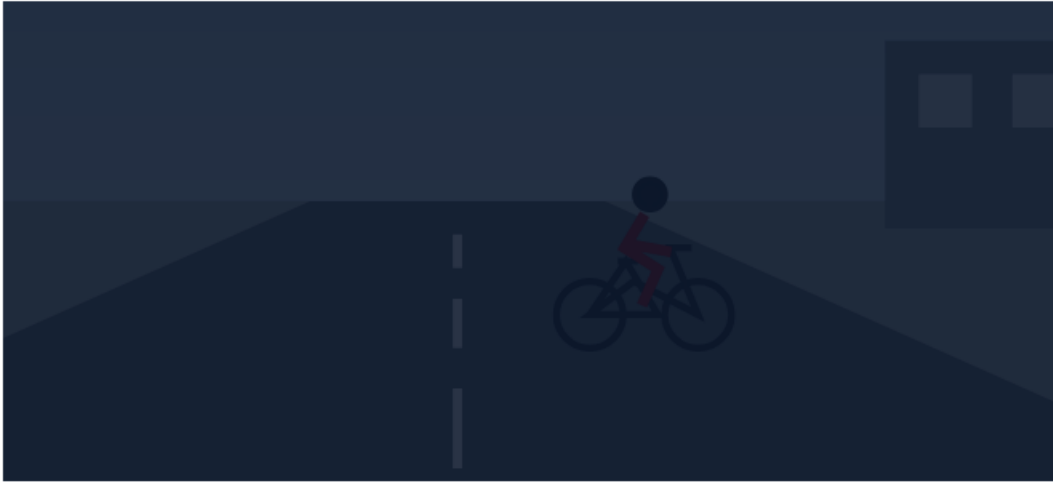
[More Examples](#)

Camera

+ LiDAR

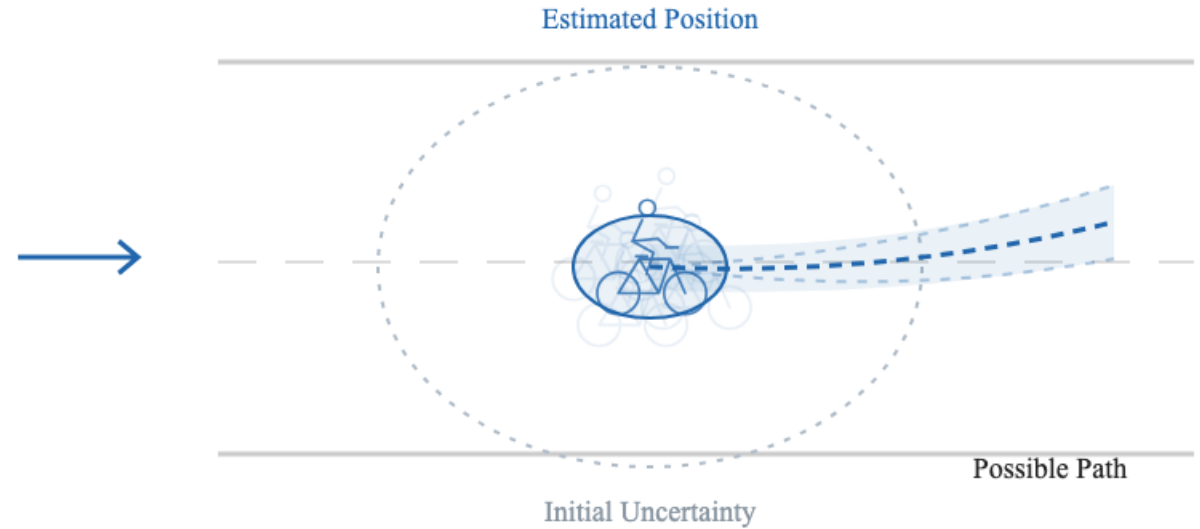
+ Radar

Road Scene



Darkness

Estimated World



Combined evidence reduces uncertainty; it does not remove it

Sensor Fusion

[More Examples](#)

Camera

+ LiDAR

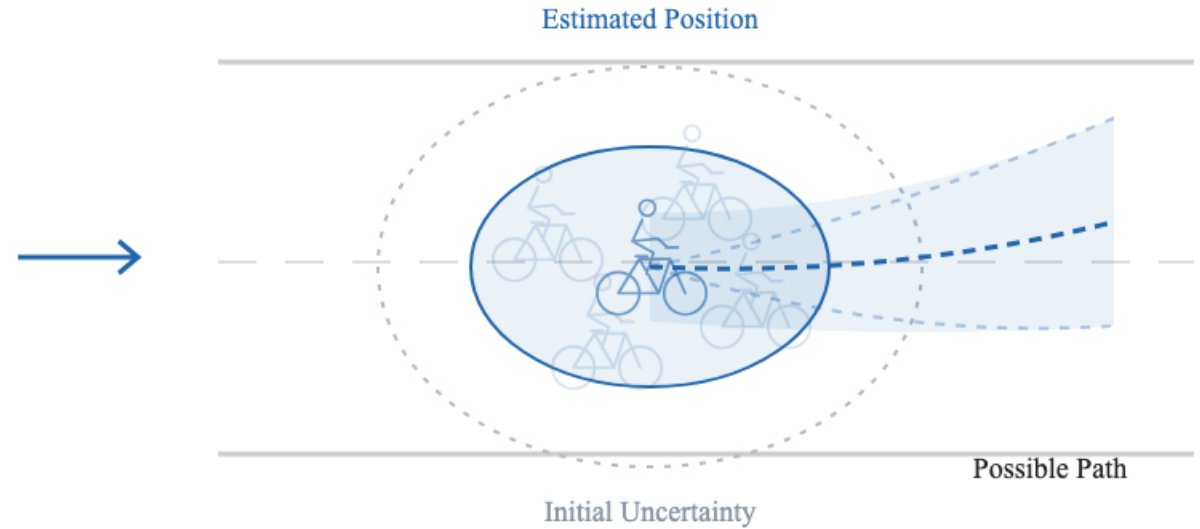
+ Radar

Road Scene



Fog

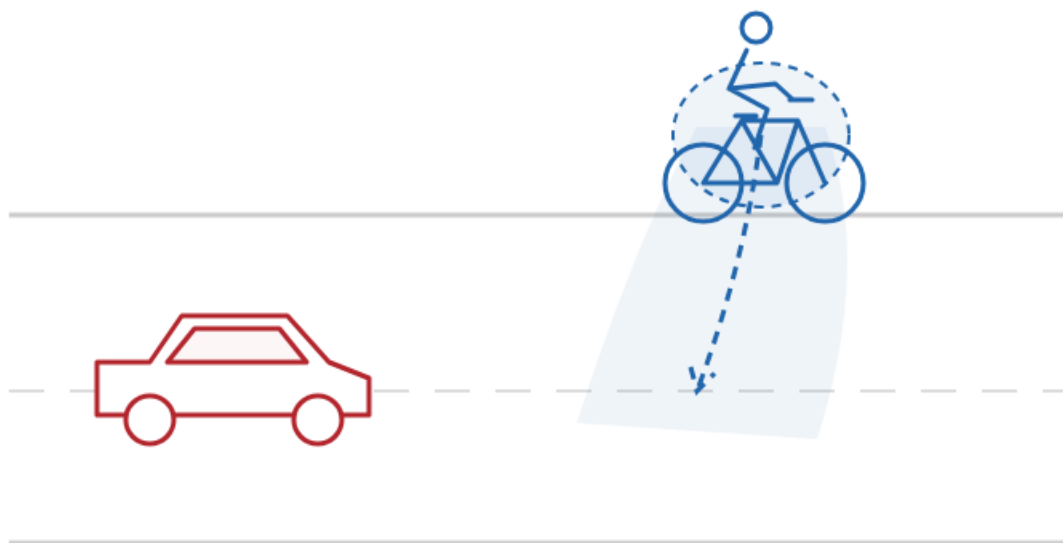
Estimated World



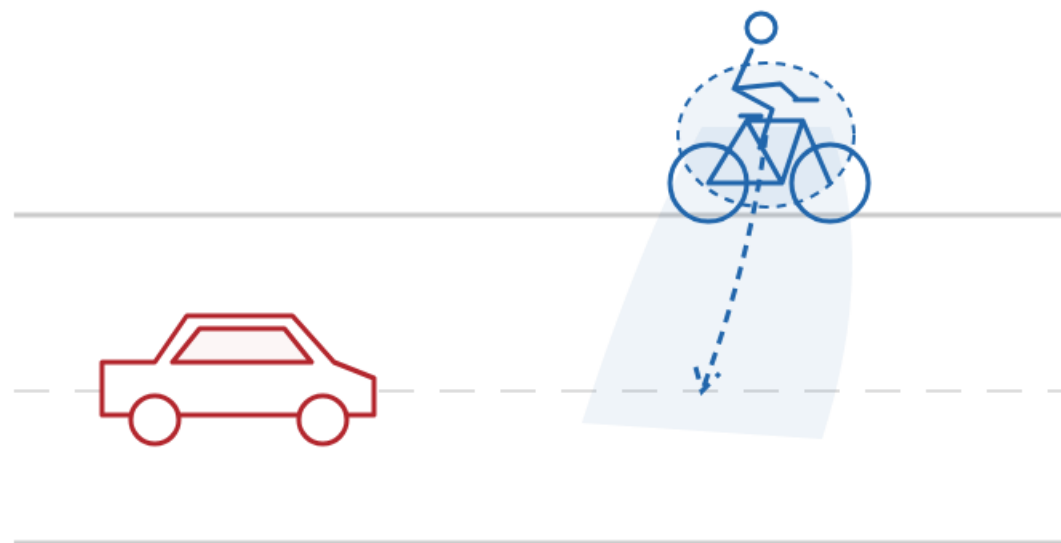
Conditions change: uncertainty can grow again

Predicting Possible Futures

Wait



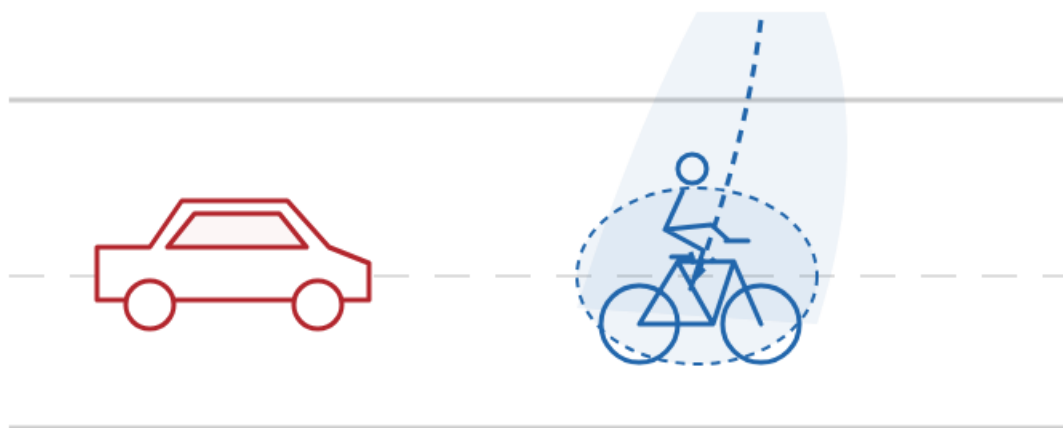
Proceed



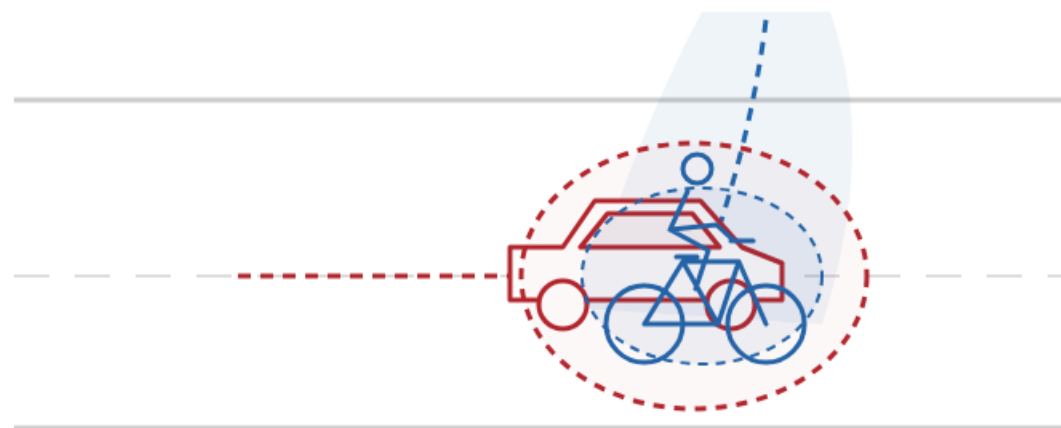
How Does a Robot Car Learn to Act?

Predicting Possible Futures

Wait

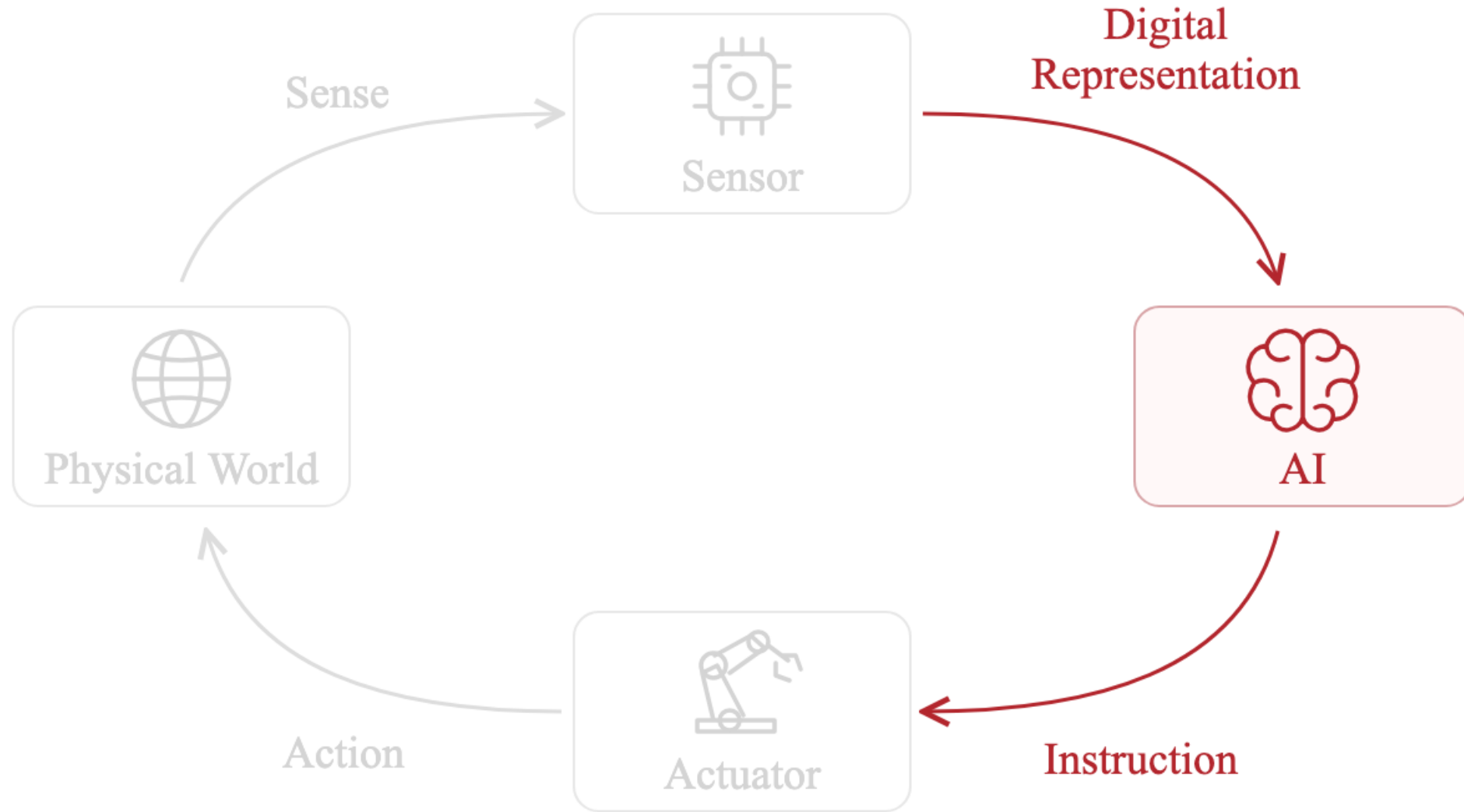


Proceed



How Does a Robot Car Learn to Act?

How Does a Robot Learn to Act?



Two Common Ways to Learn Actions

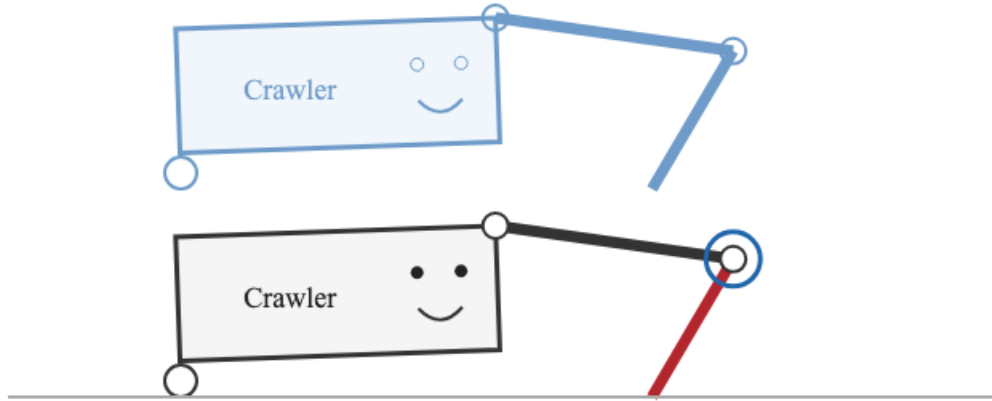
Imitation Learning

Reinforcement Learning

Two Common Ways to Learn Actions

Imitation Learning

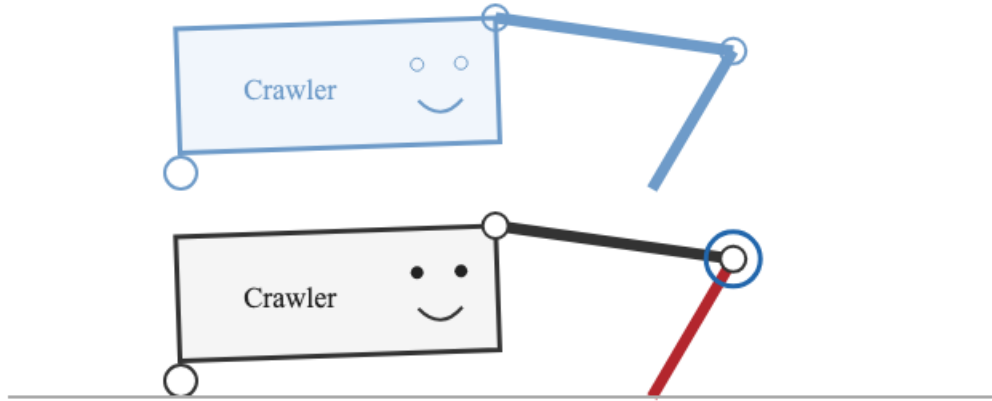
Reinforcement Learning



Examples show which actions to take

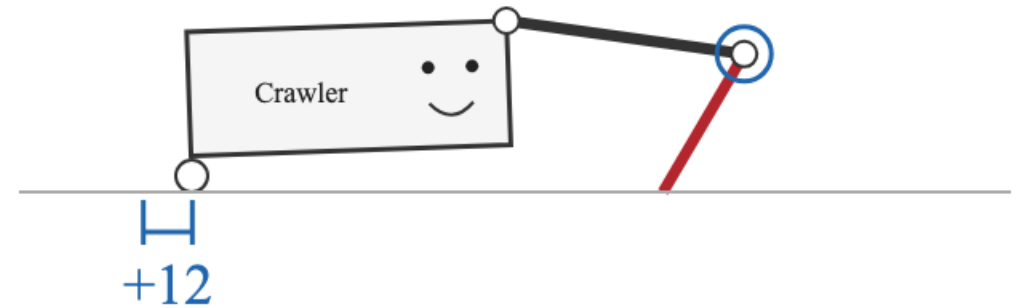
Two Common Ways to Learn Actions

Imitation Learning



Examples show which actions to take

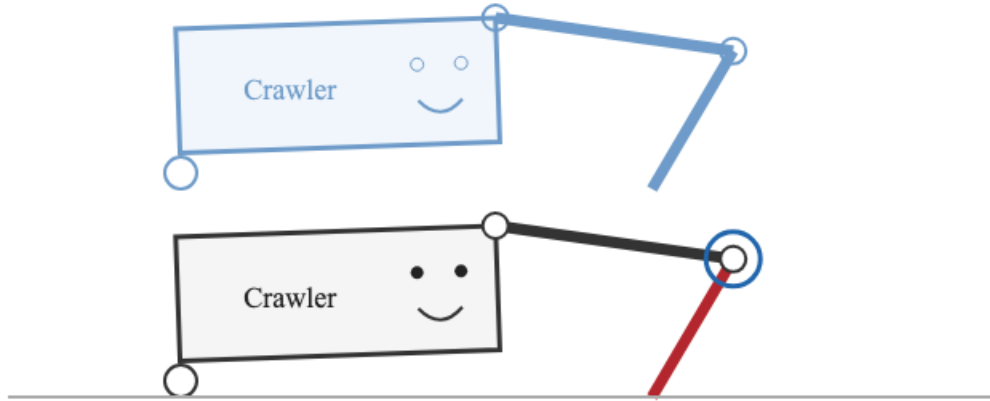
Reinforcement Learning



Consequences guide action values

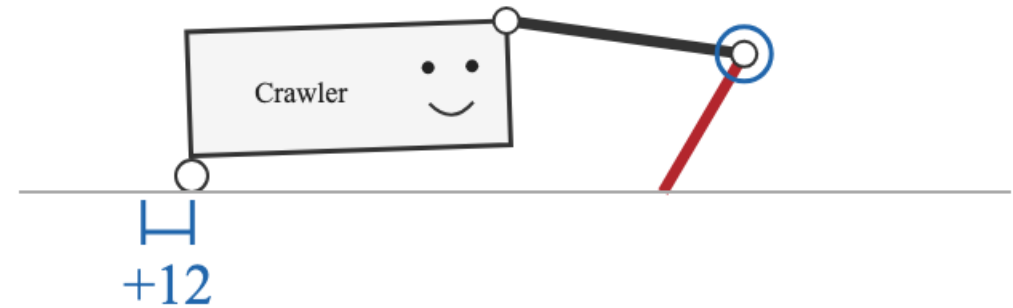
Two Common Ways to Learn Actions

Imitation Learning



Examples show which actions to take

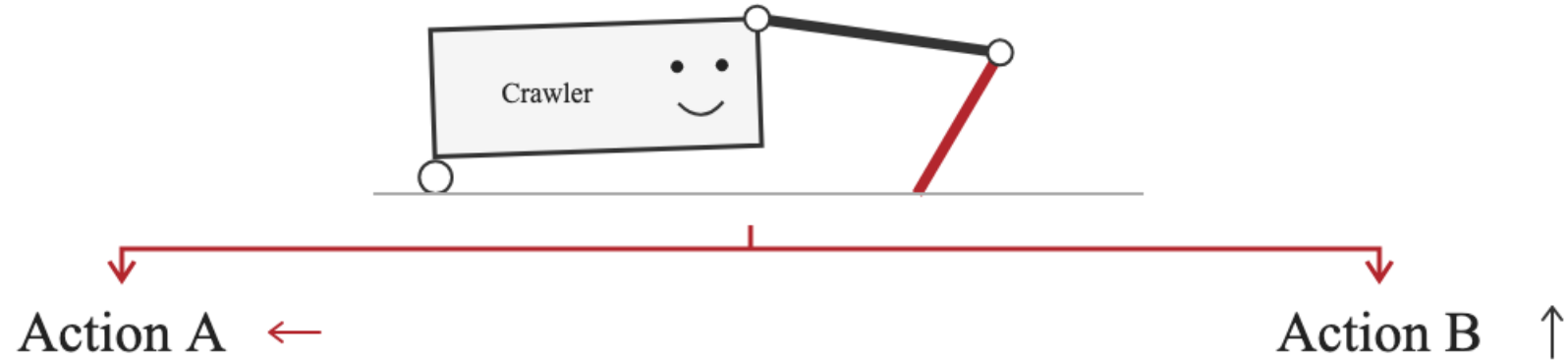
Reinforcement Learning



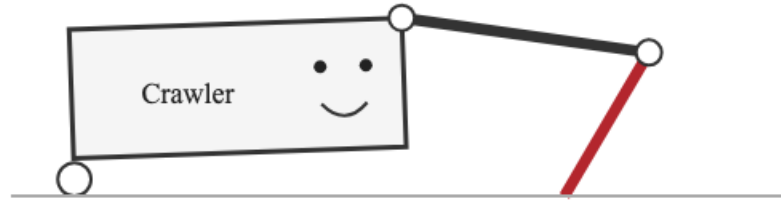
Consequences guide action values

The two approaches can be combined

Which Action Is Better: A or B?

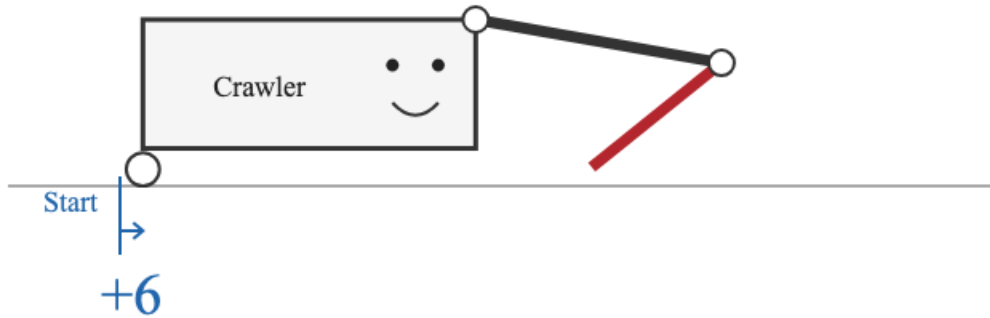
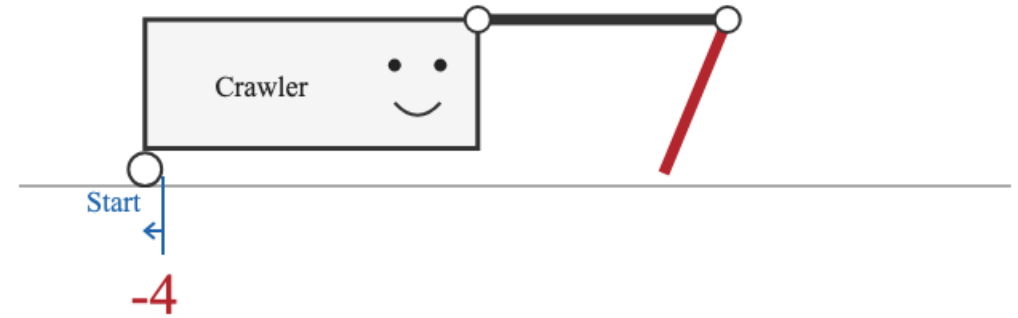


Which Action Is Better: A or B?

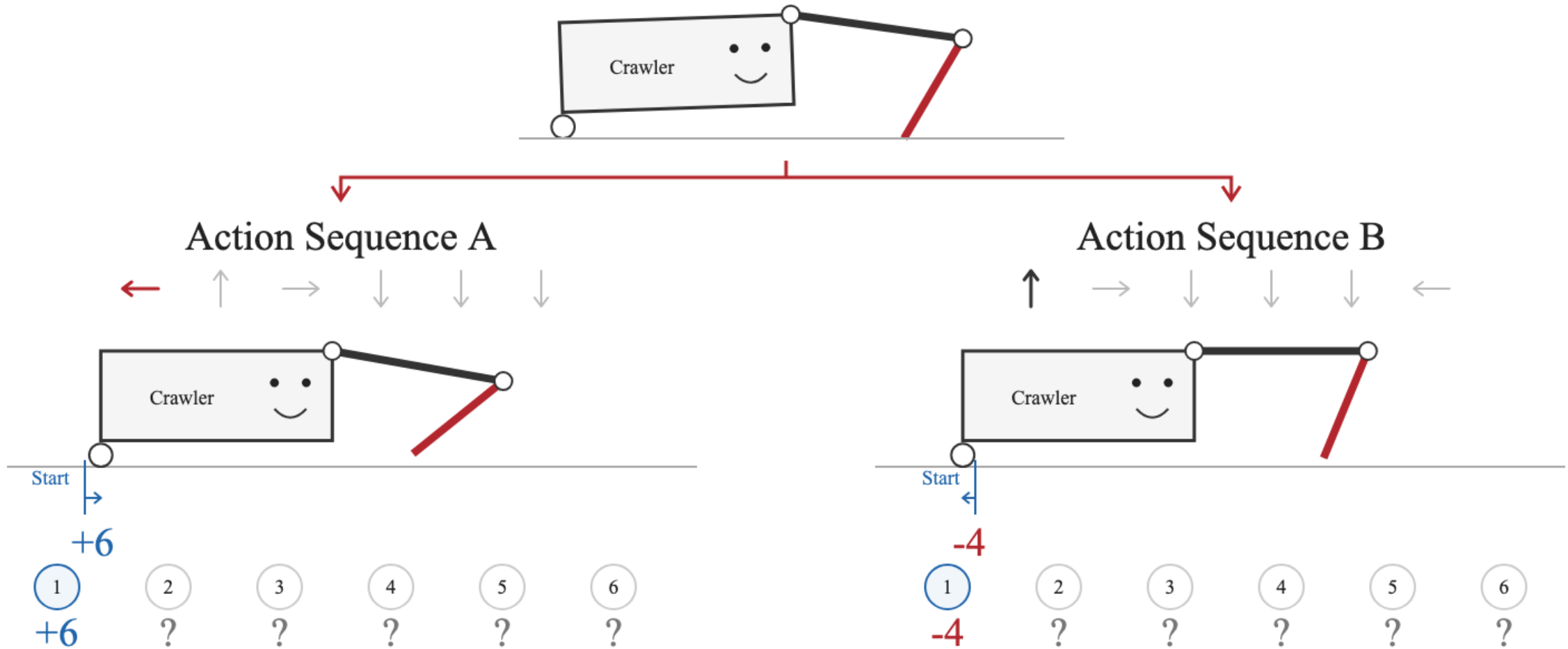


↓
Action A ←

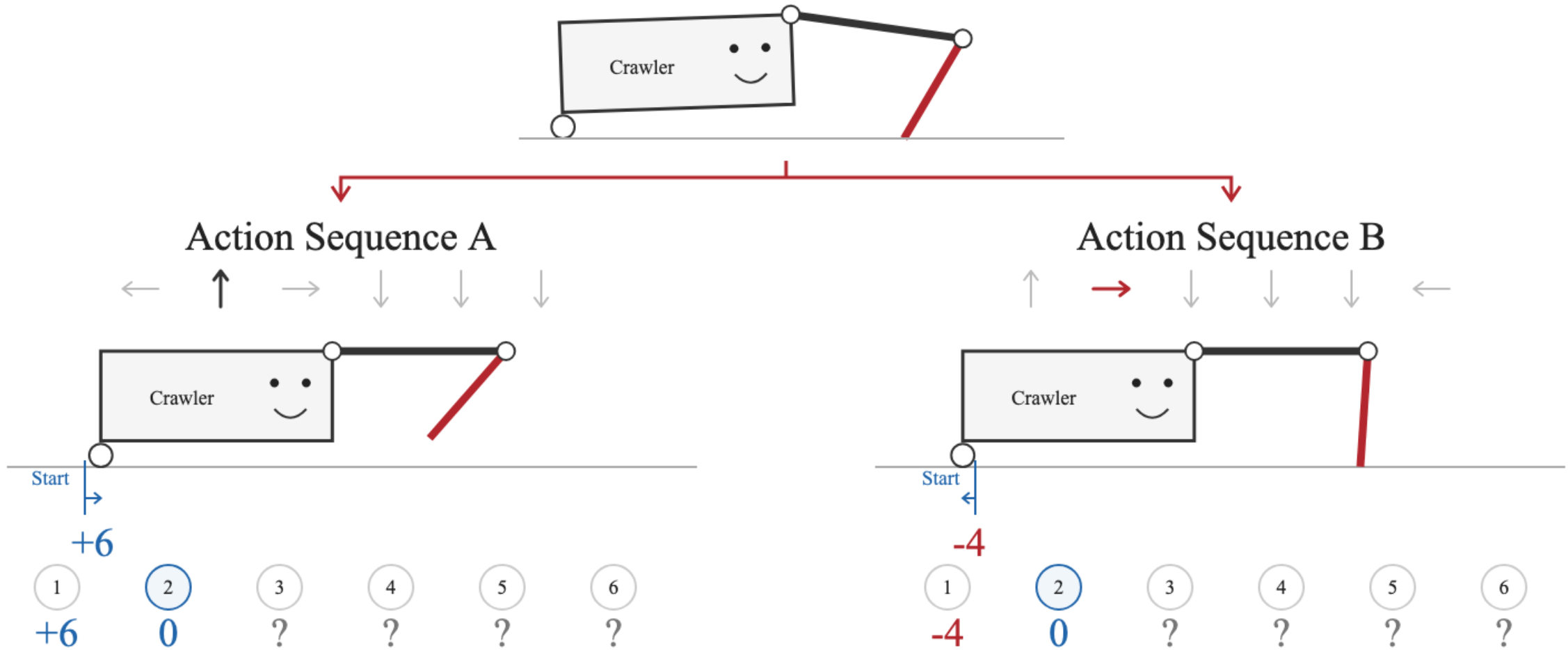
↓
Action B ↑



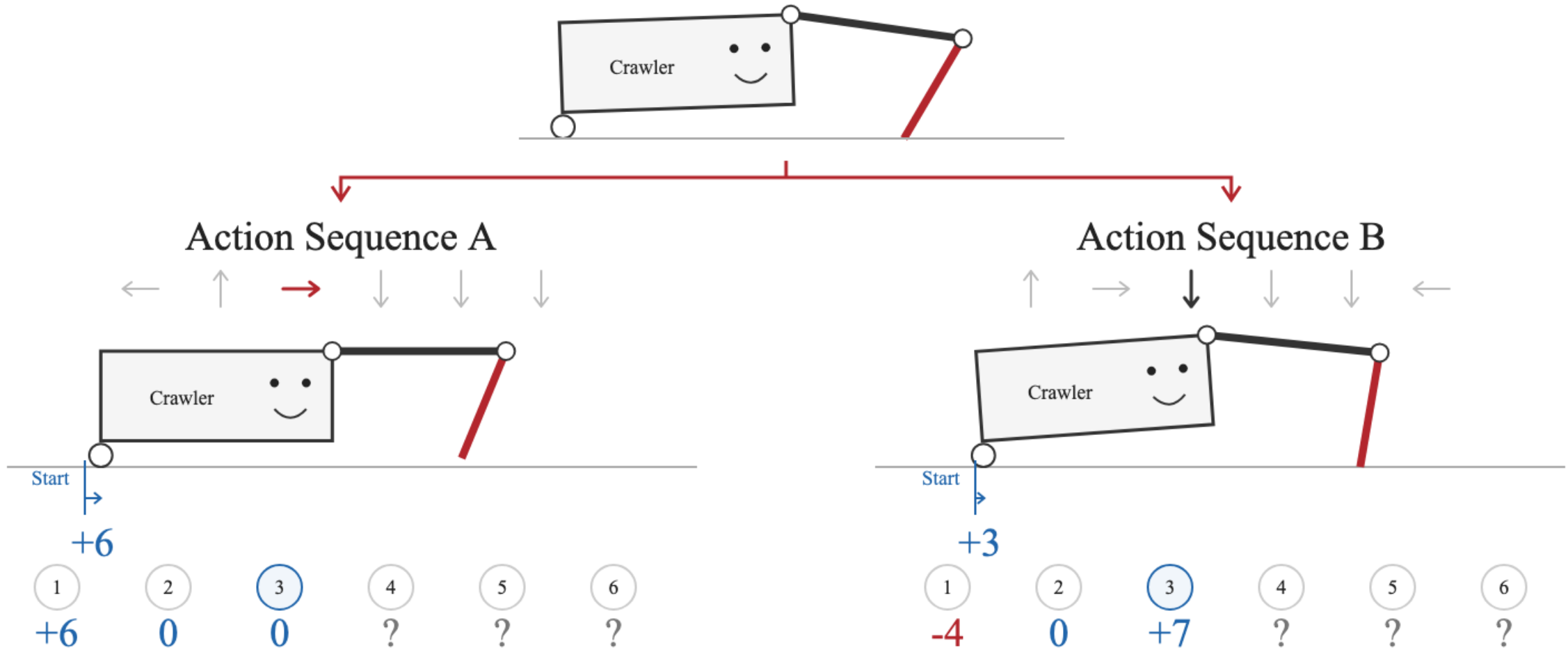
Was Your First Choice Best?



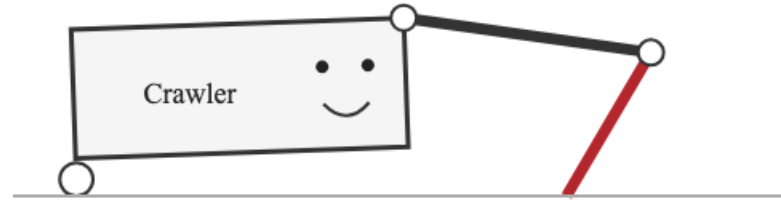
Was Your First Choice Best?



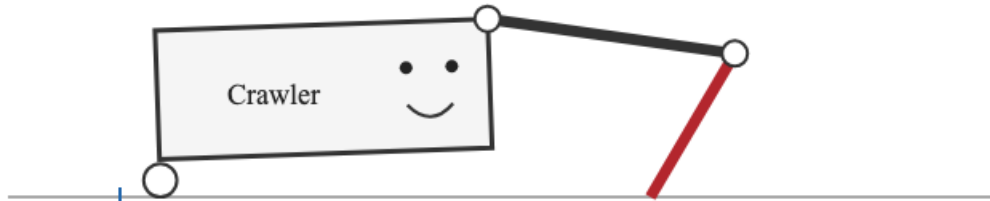
Was Your First Choice Best?



Was Your First Choice Best?



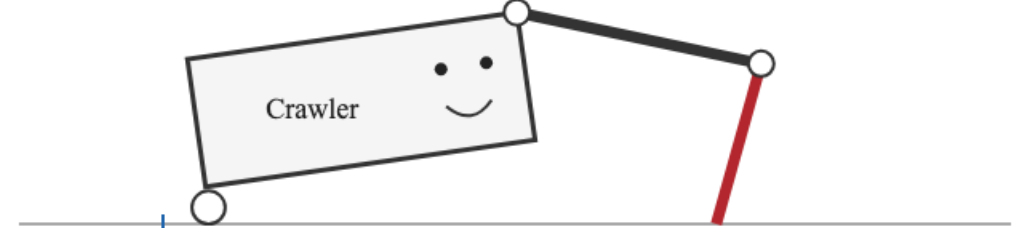
Action Sequence A



Start
+10

1	2	3	4	5	6
+6	0	0	+4	?	?

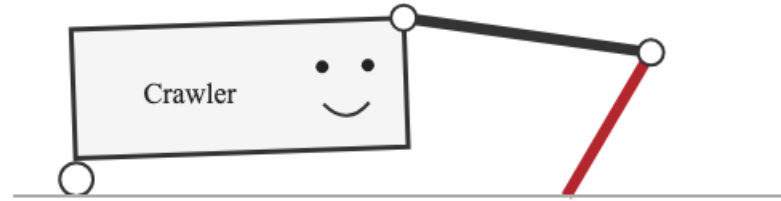
Action Sequence B



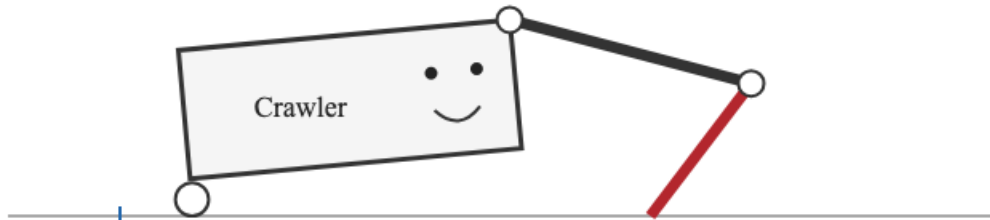
Start
+12

1	2	3	4	5	6
-4	0	+7	+8	?	?

Was Your First Choice Best?



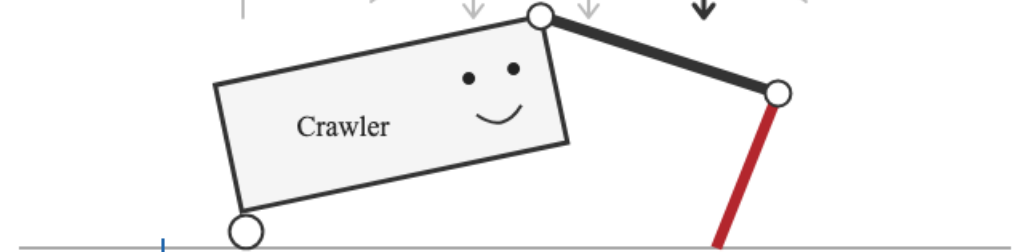
Action Sequence A



Start
+18

1	2	3	4	5	6
+6	0	0	+4	+8	?

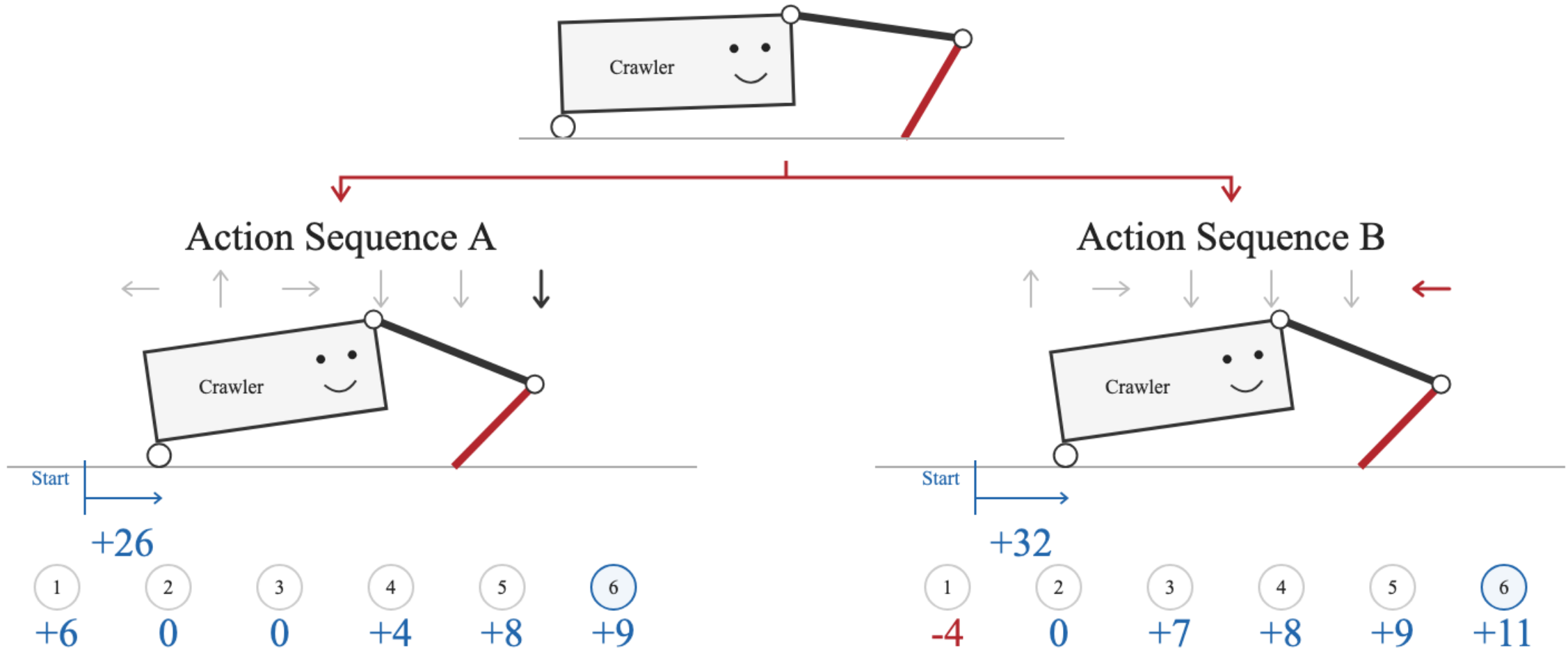
Action Sequence B



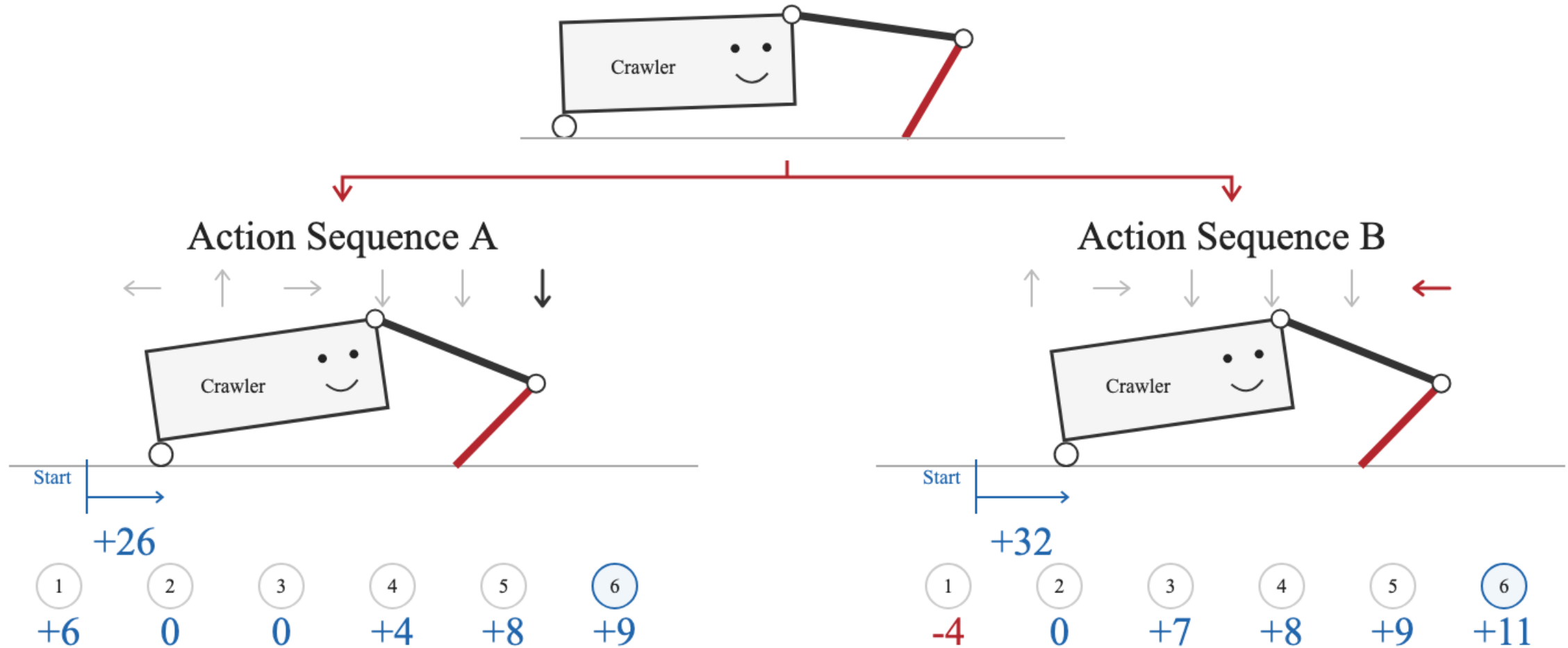
Start
+21

1	2	3	4	5	6
-4	0	+7	+8	+9	?

Was Your First Choice Best?

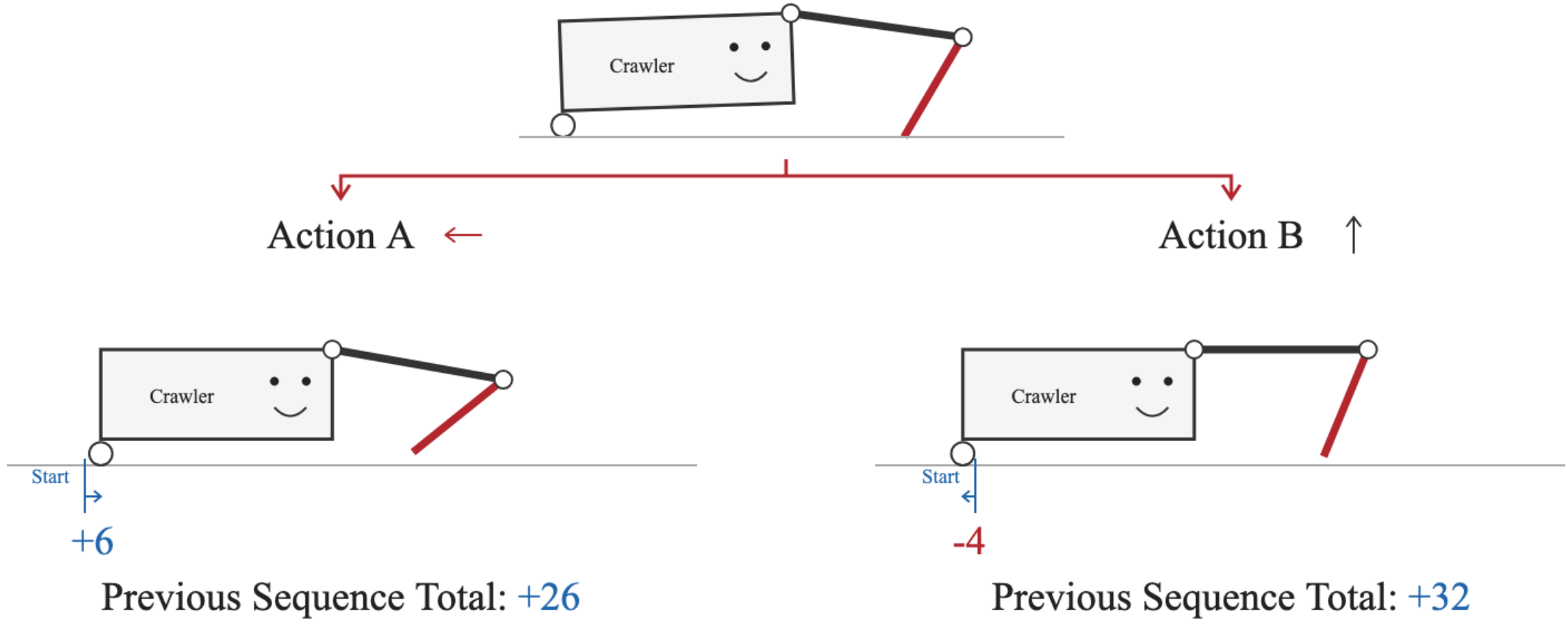


Was Your First Choice Best?

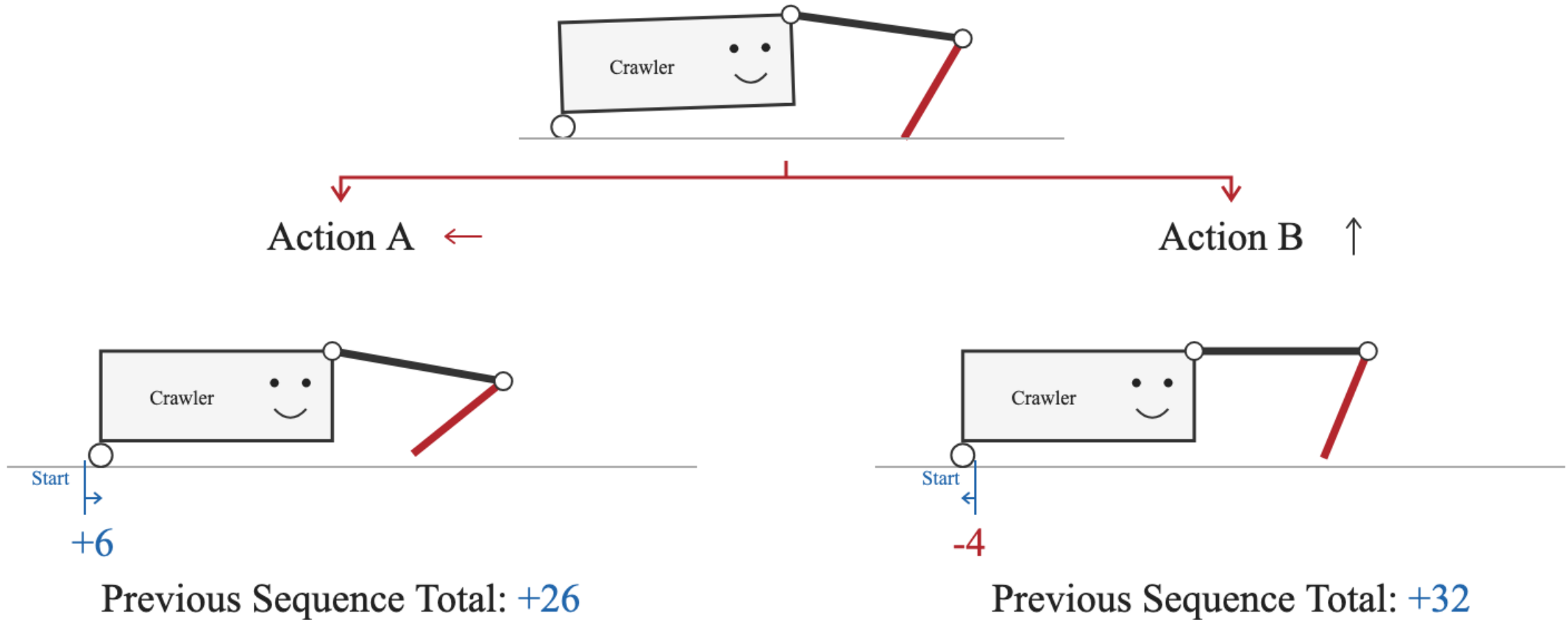


A short-term loss can lead to a greater long-term gain

Learn From the Whole Outcome



Learn From the Whole Outcome



Reinforcement learning can learn to favour Action B for its future rewards

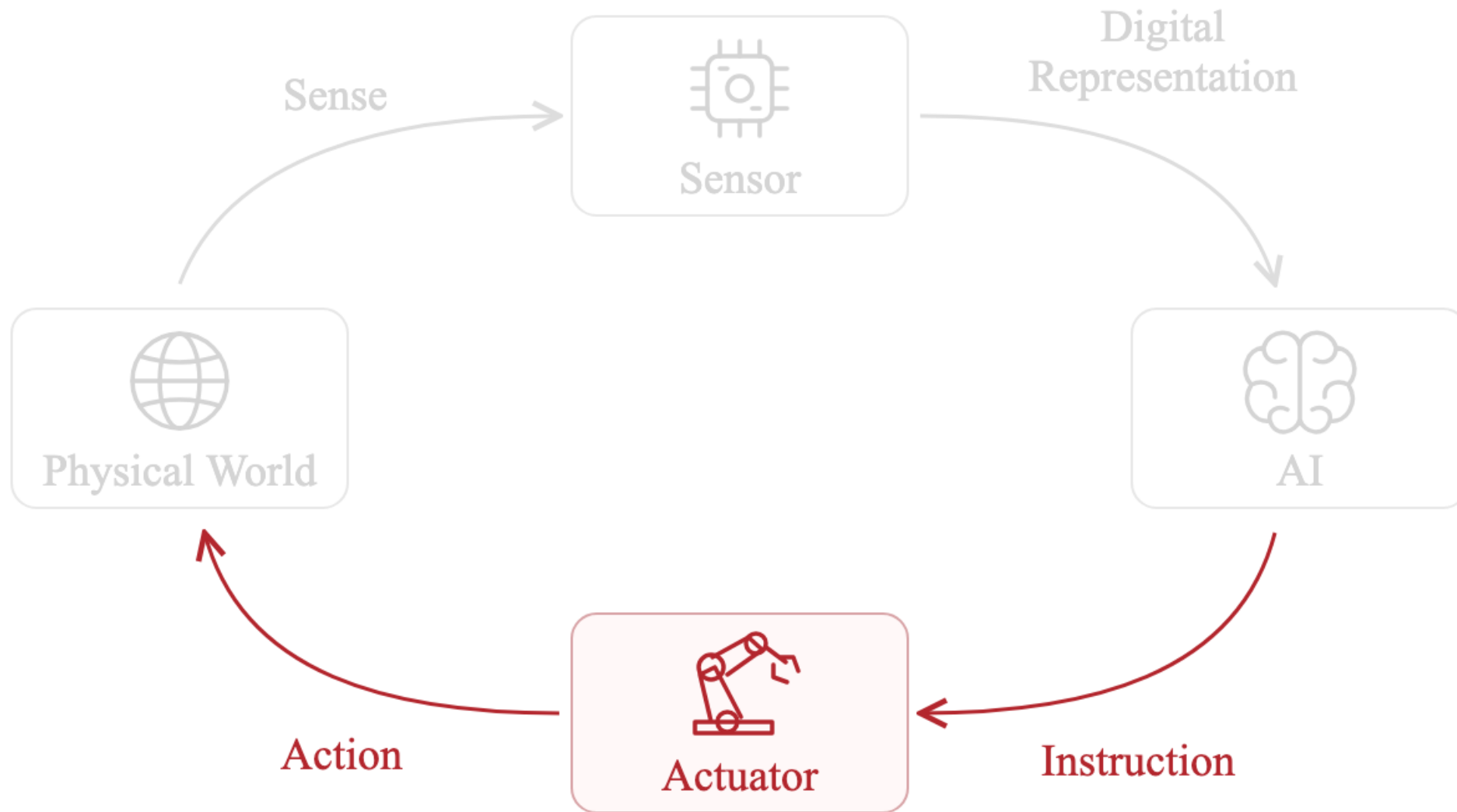
Learning to Move in Simulation

Excerpt · 2:13

Full Video · 8:39

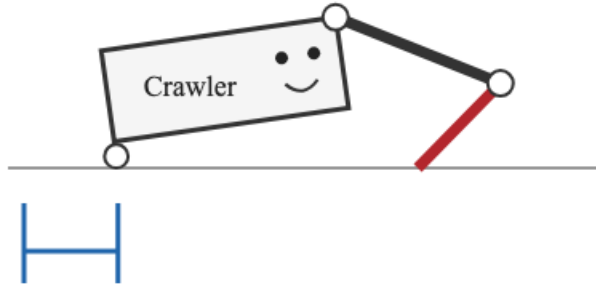


How Does a Robot Act?

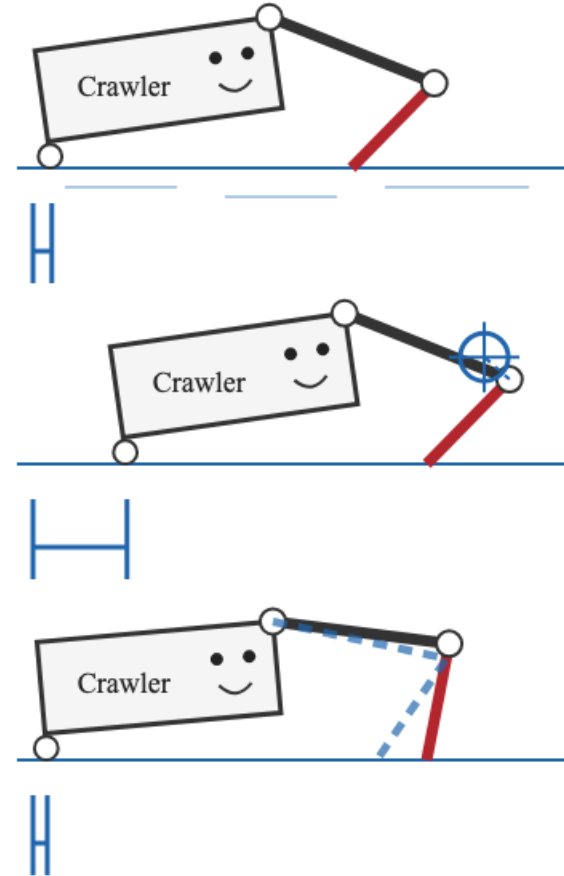


From Simulation to the Physical World

Simulation



Physical World



Slipping

Sensor Noise

Sensor Reading

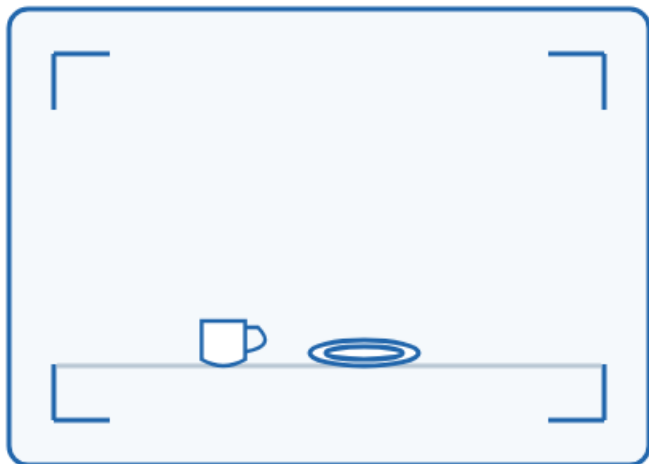
Slow Motor

Expected Arm Position

Train under varied conditions. Test on the real robot.

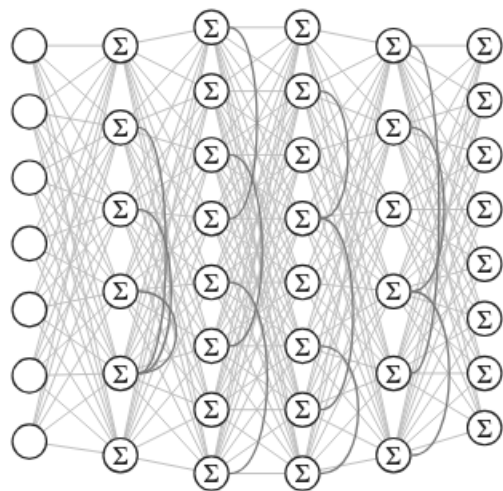
From Images and Instructions to Actions

Image and Instruction



“Place the cup
on its saucer”

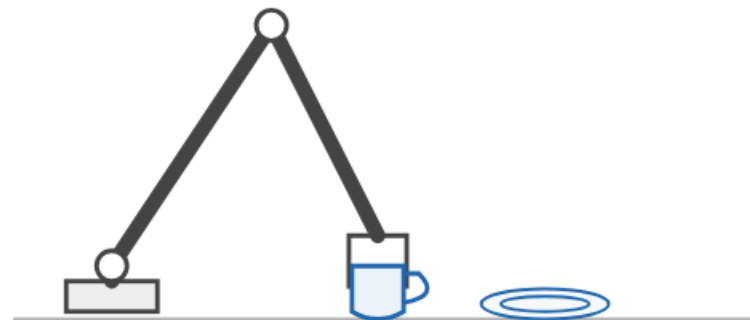
Deep Neural Network



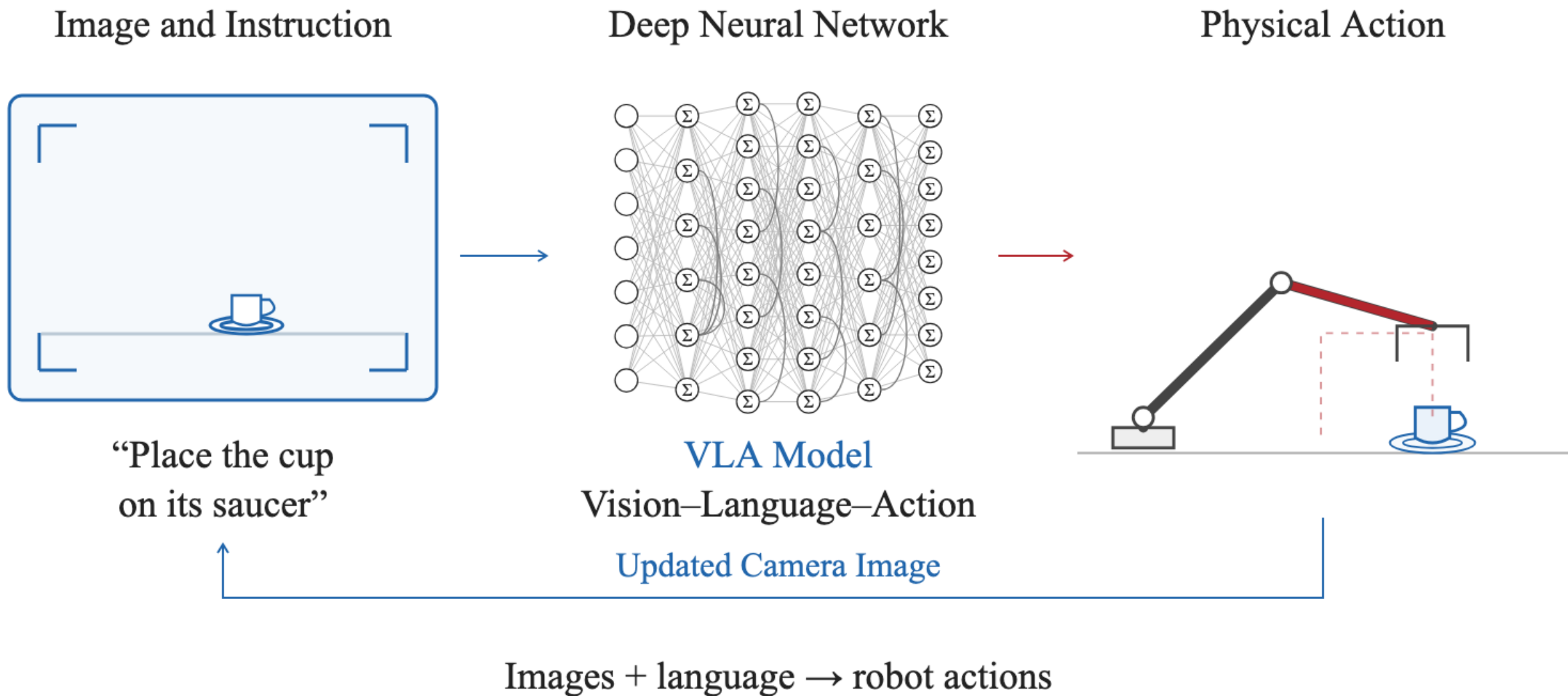
VLA Model

Vision–Language–Action

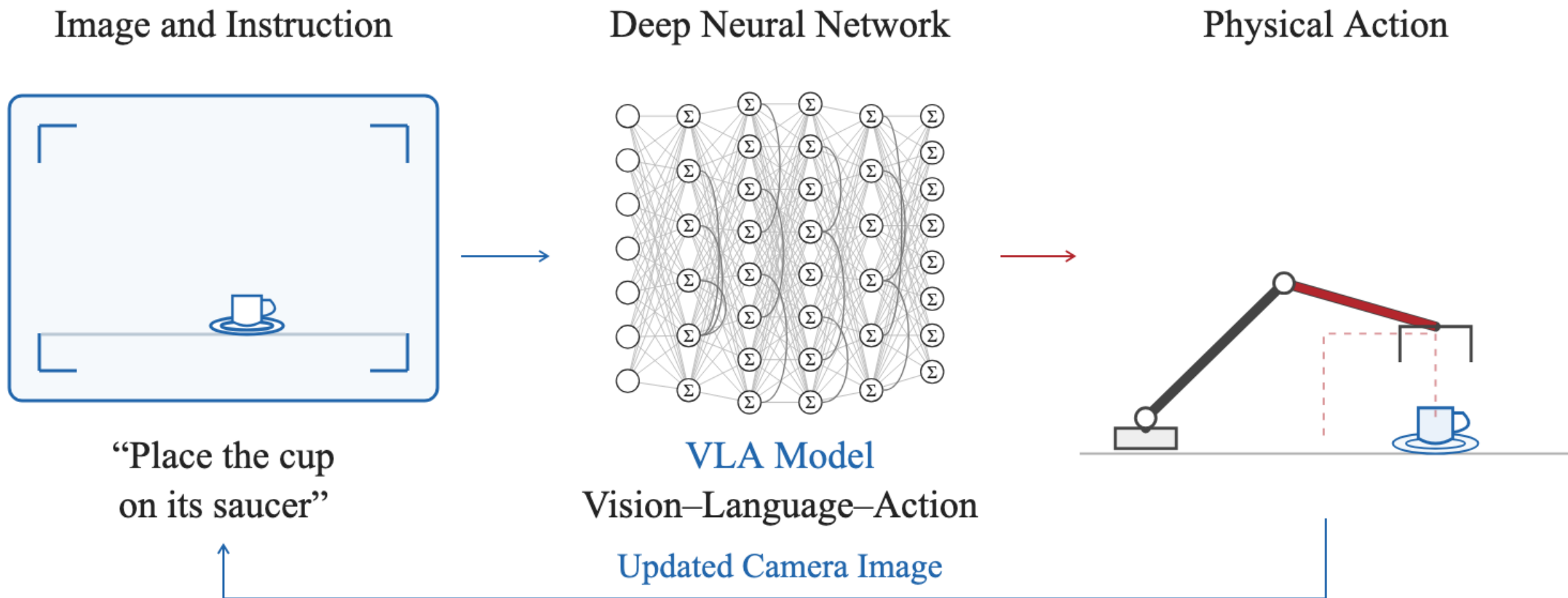
Physical Action



From Images and Instructions to Actions

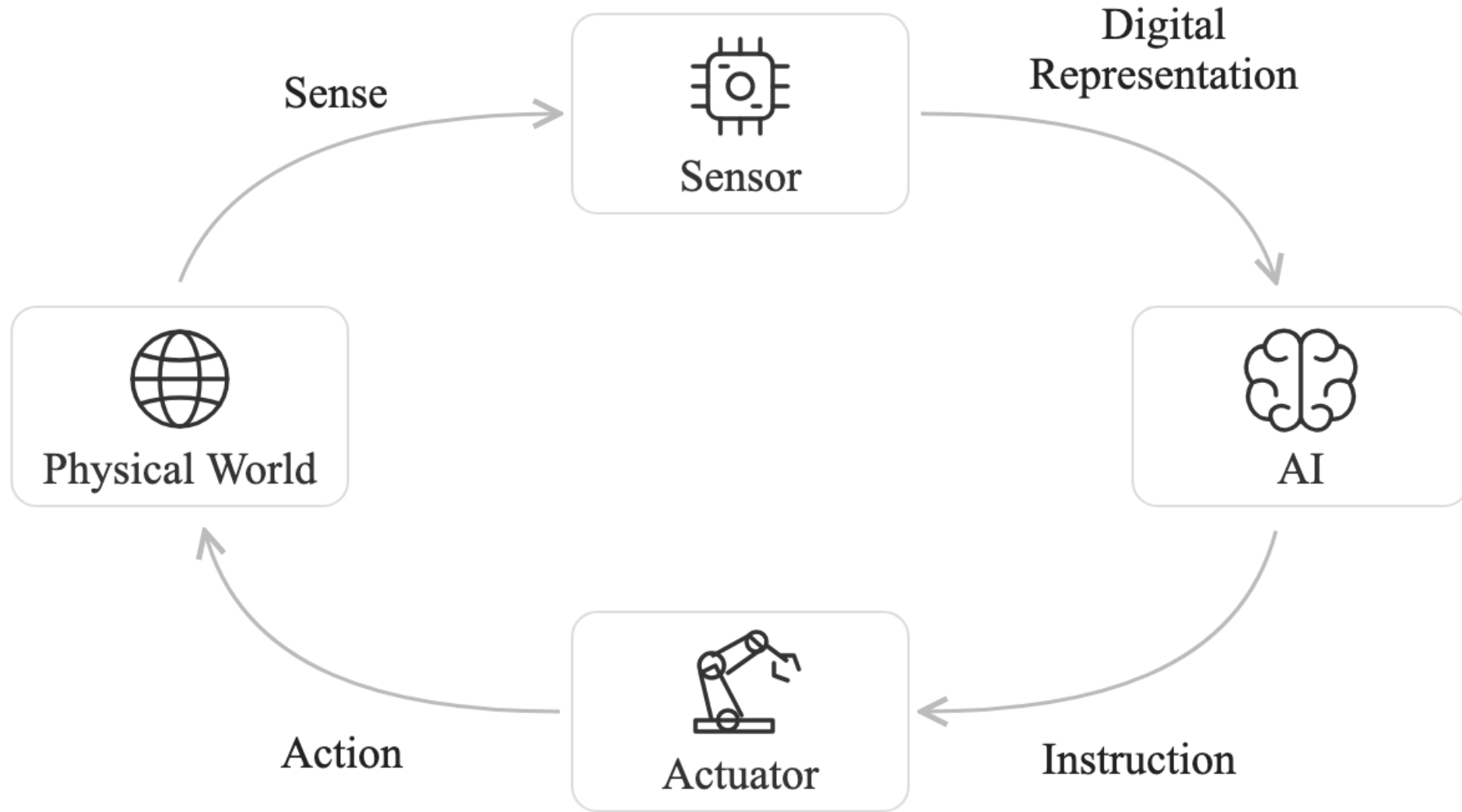


From Images and Instructions to Actions

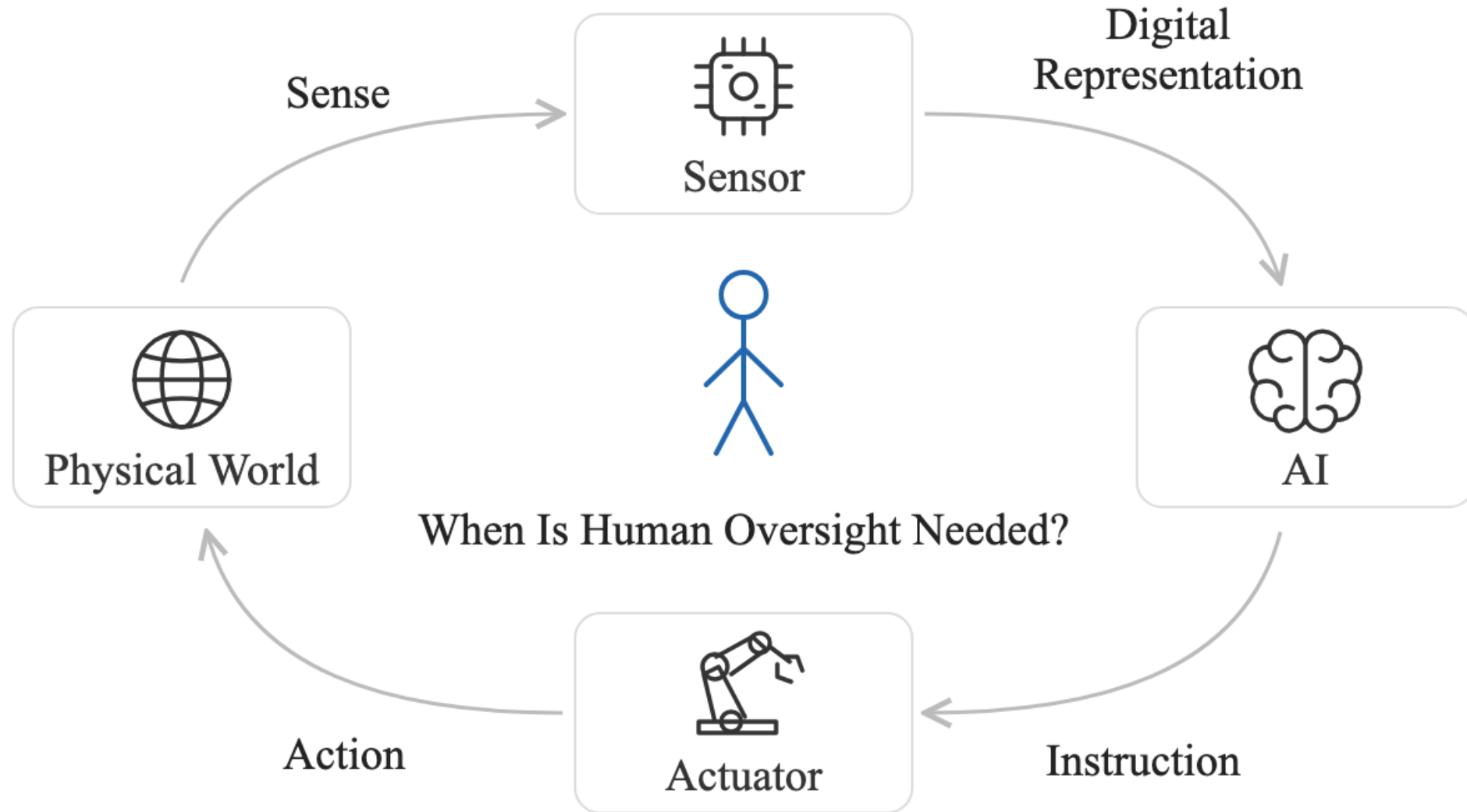


Demonstrations → imitation learning
Reward feedback → reinforcement learning

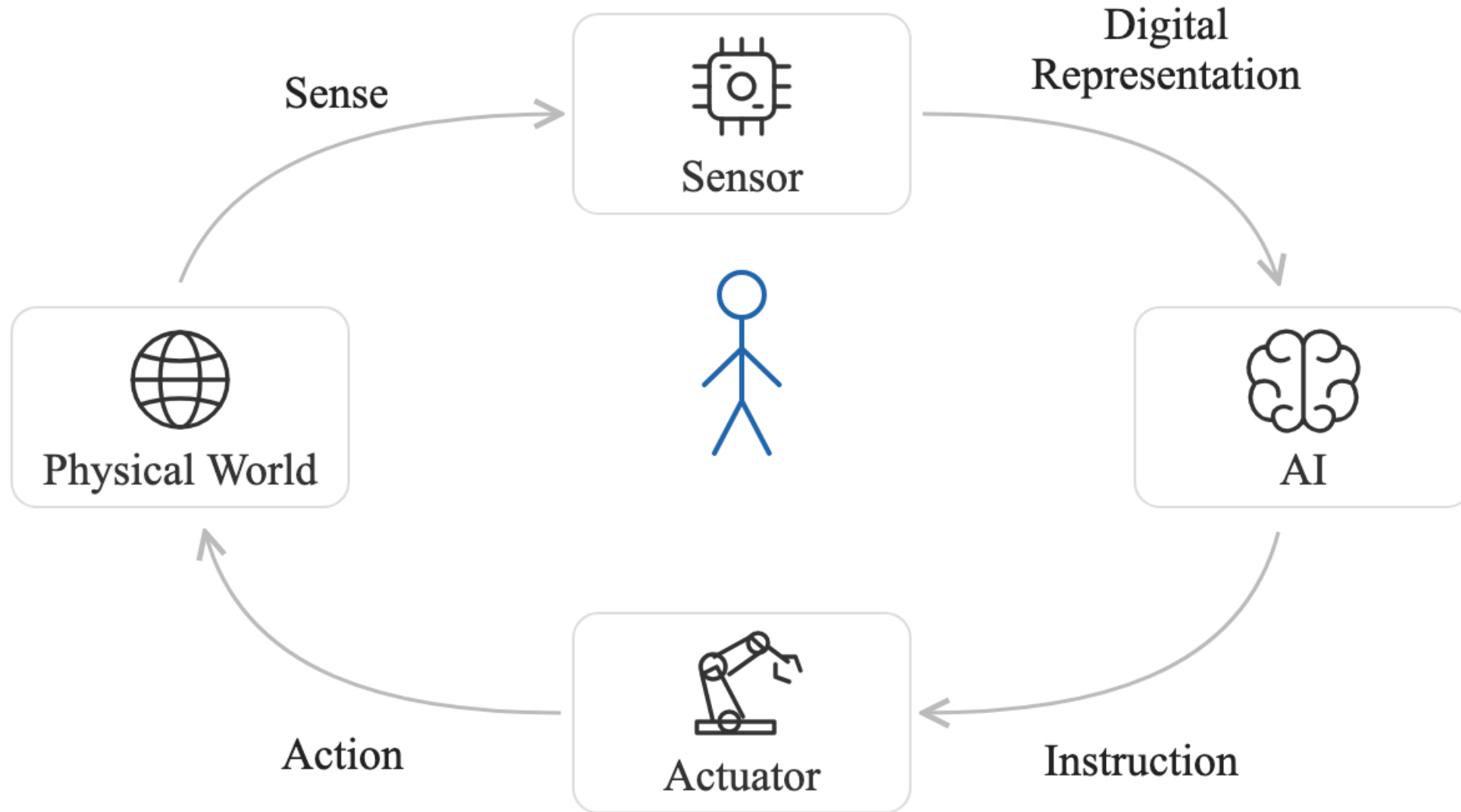
Putting It All Together



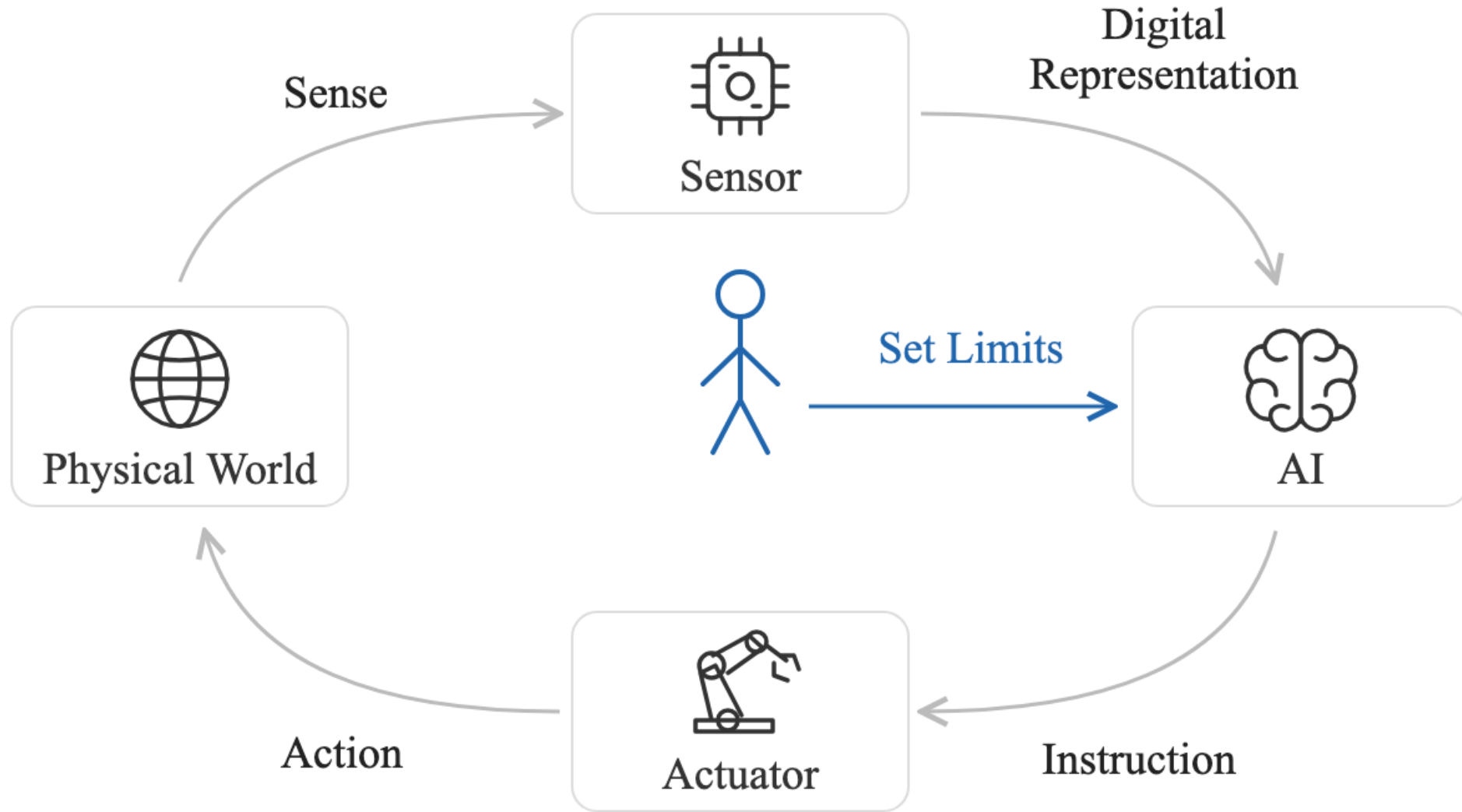
Putting It All Together



Human Oversight

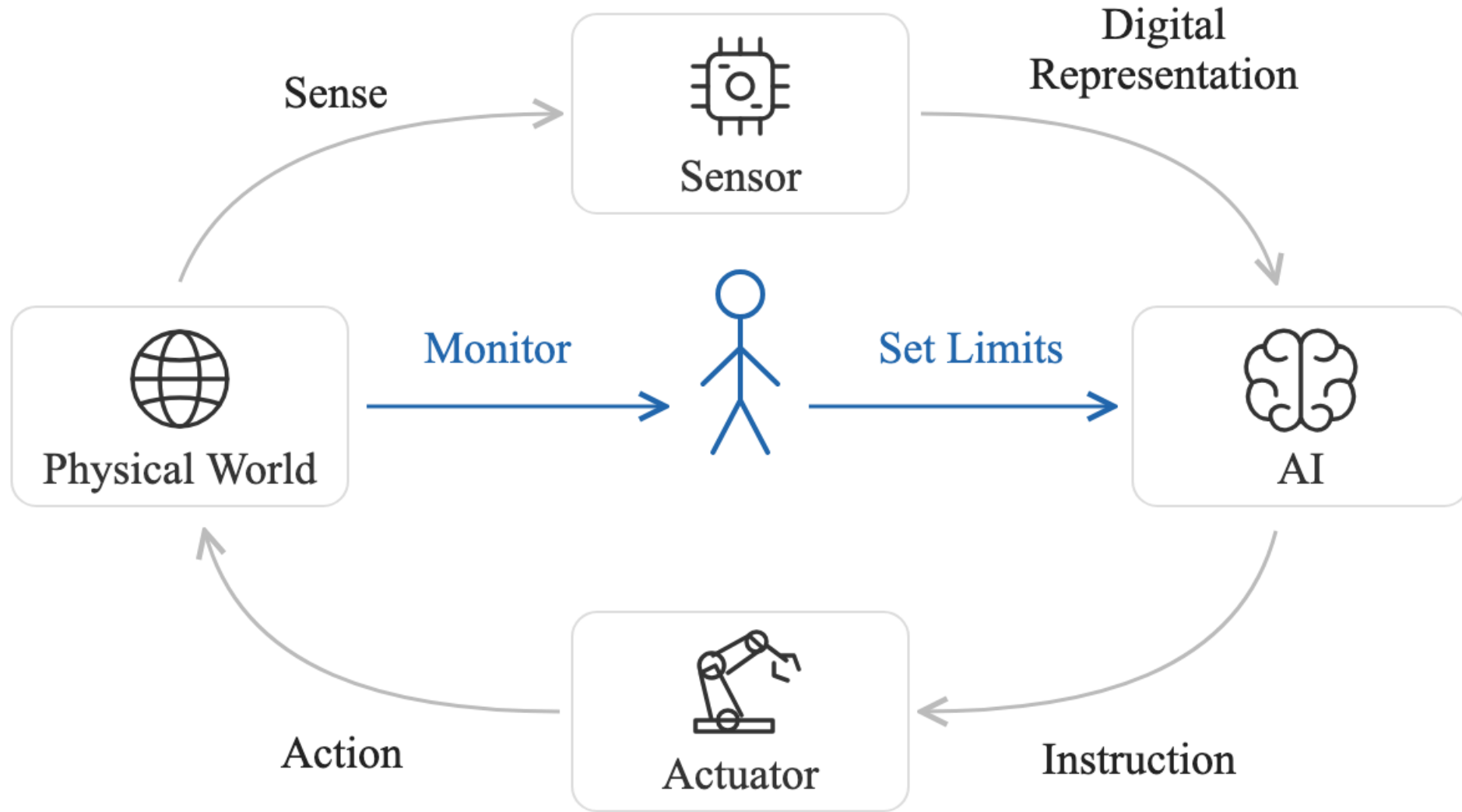


Human Oversight



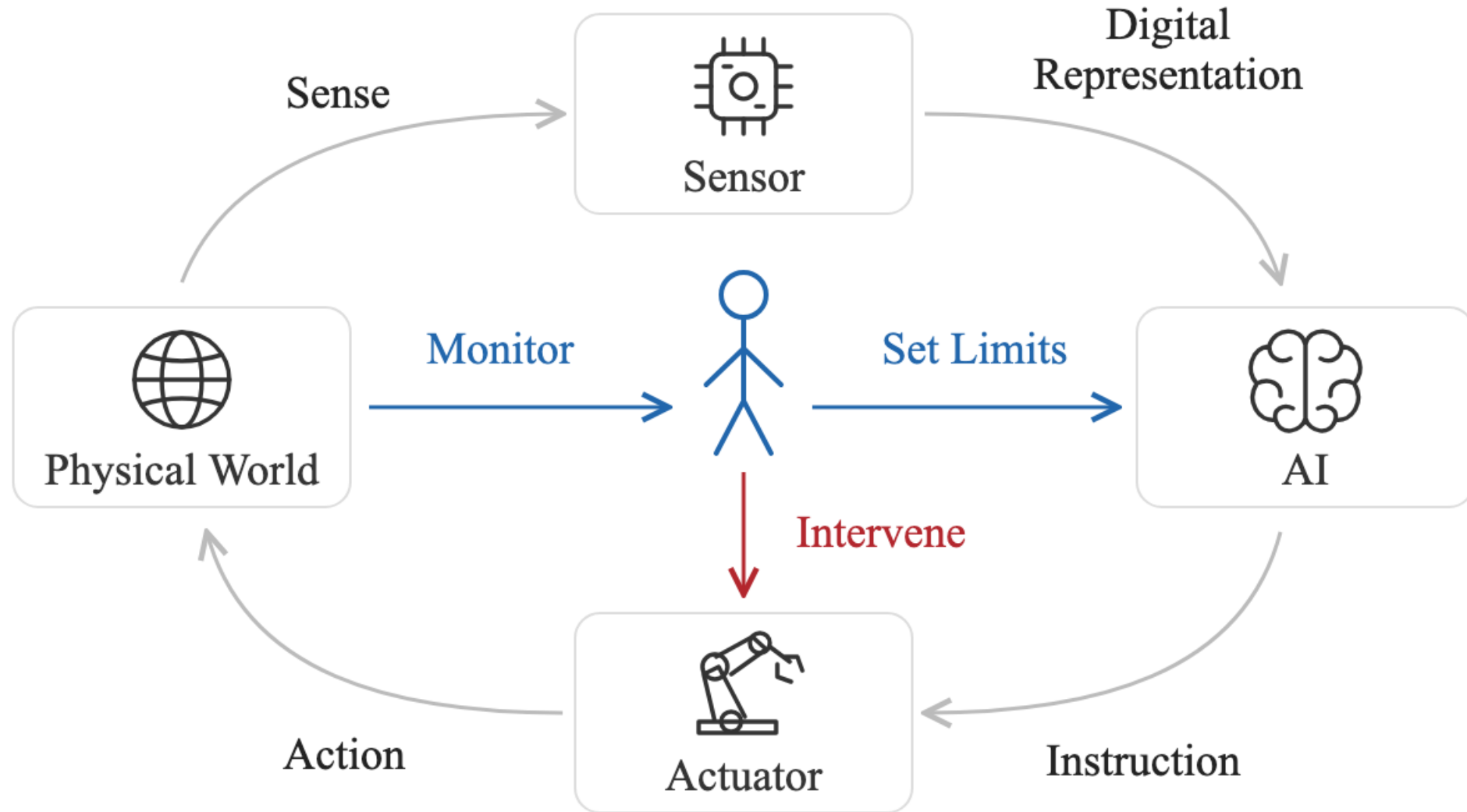
What is the robot allowed to do?

Human Oversight



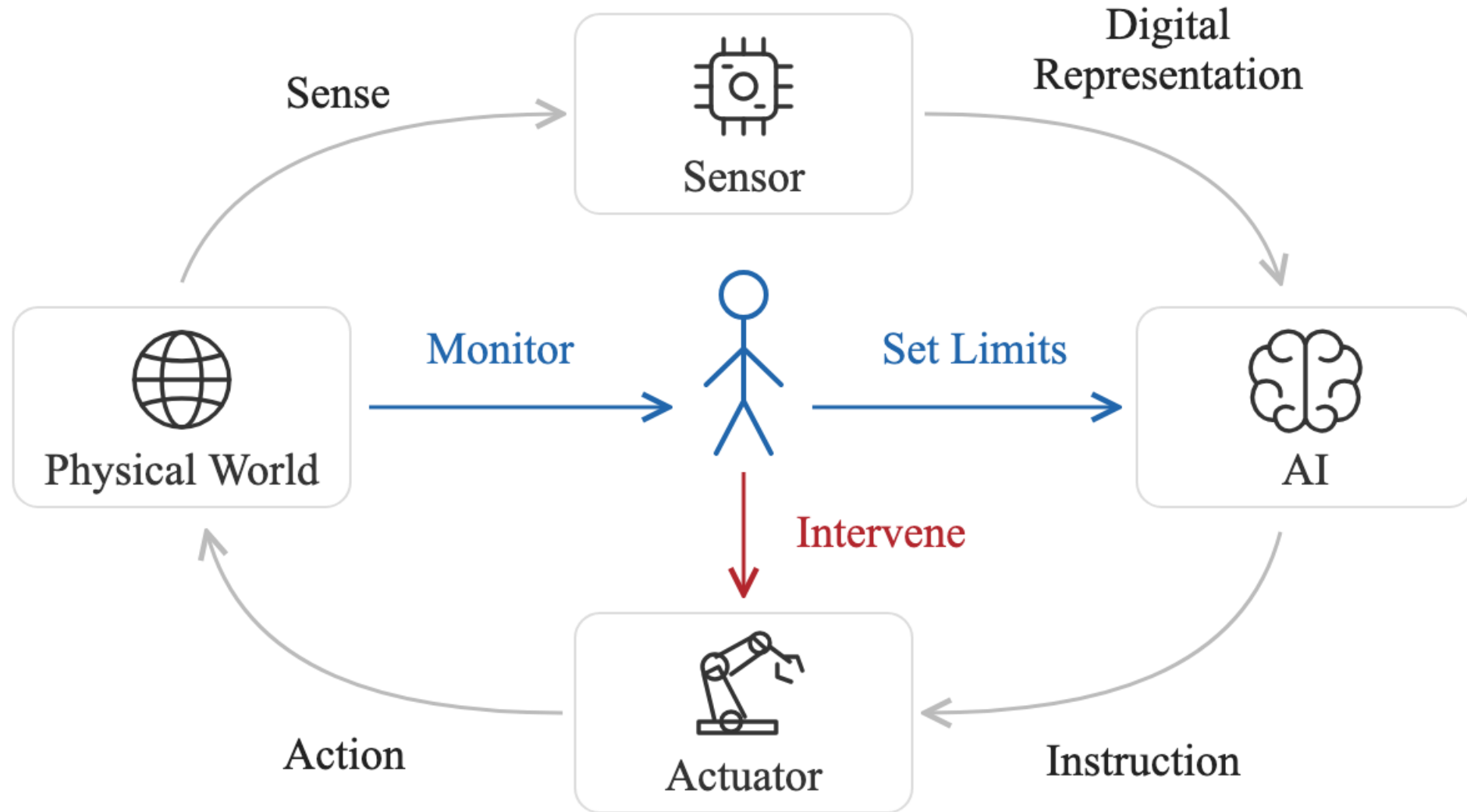
How will someone notice a problem?

Human Oversight



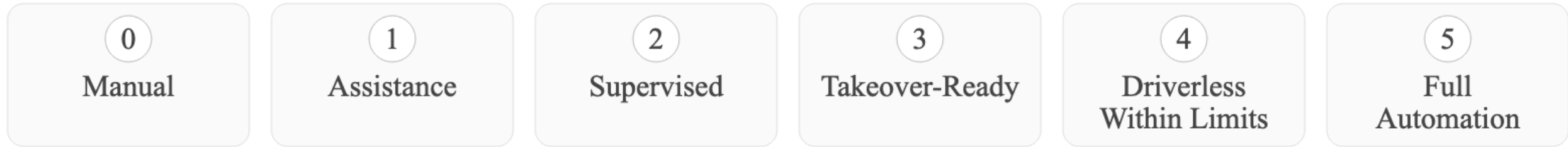
How can someone stop or correct it?

Human Oversight

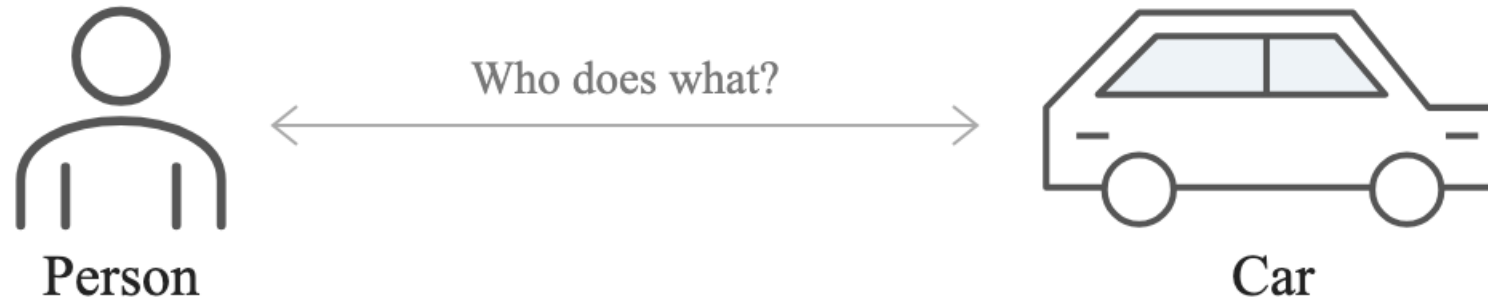


If the robot causes harm, who is responsible?

Who Is Responsible for Driving?

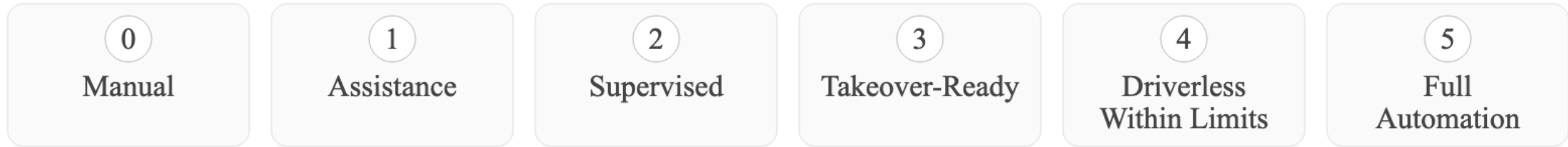


What must the person still do?

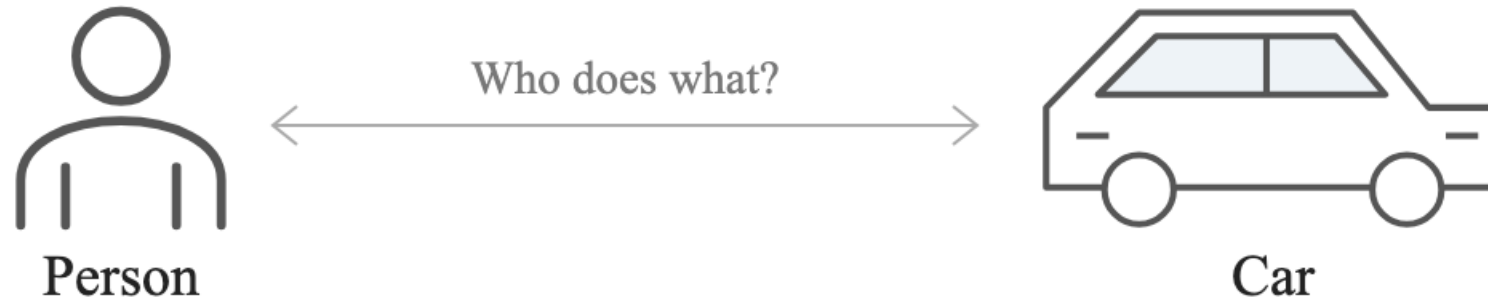


Hover over a level to explore

Who Is Responsible for Driving?



What must the person still do?

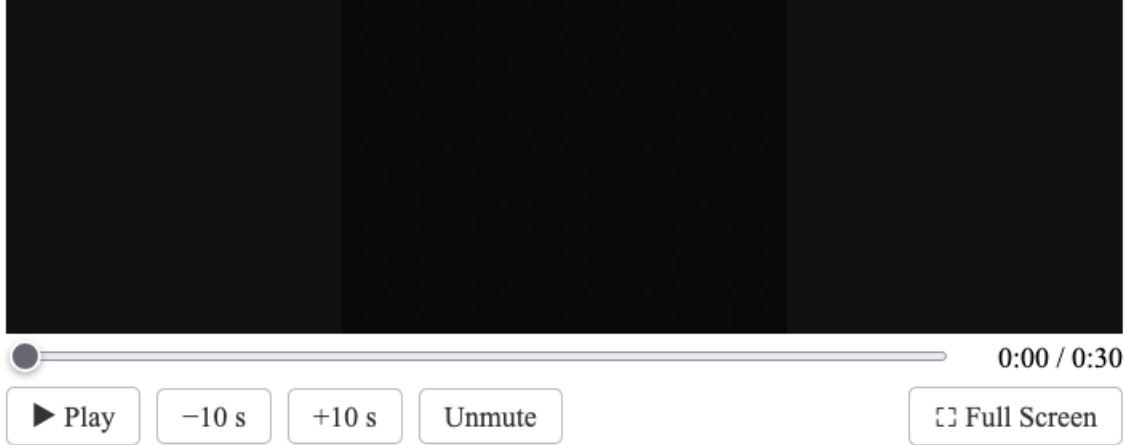


Hover over a level to explore

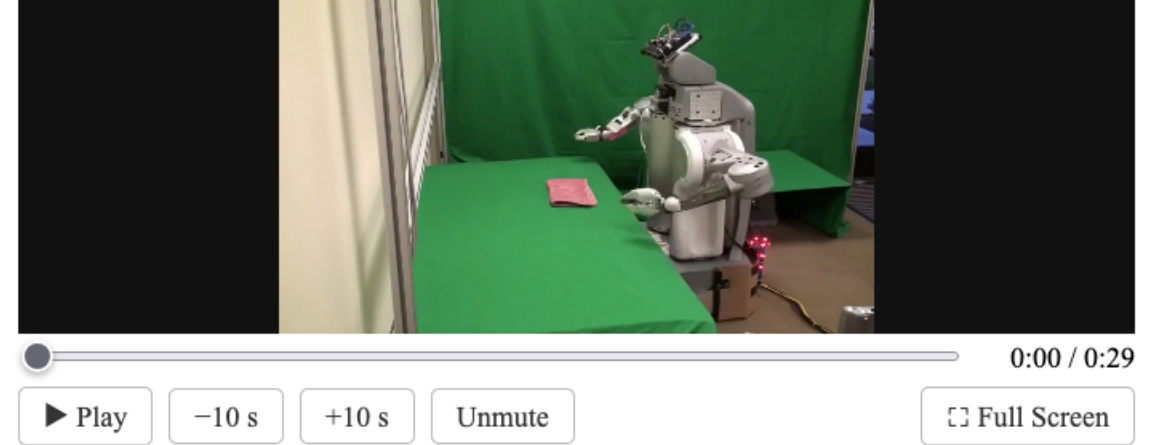
Before relying on automation, check its limits, your role, and the legal requirements

Robotics Through the Years

PR1 (2008) · Remote-Controlled



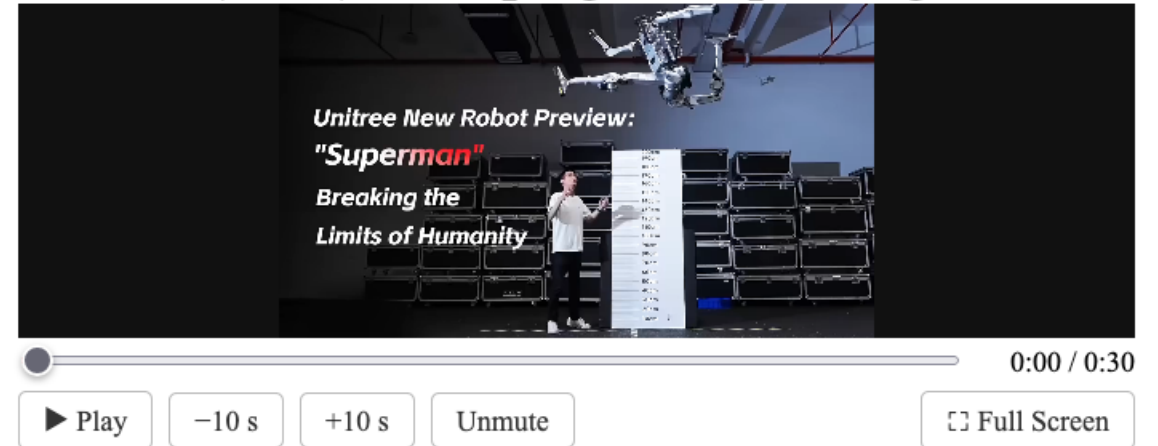
PR2 (2010) · Folding Towels



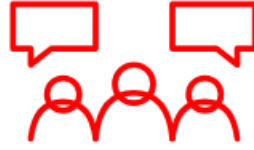
Atlas (2016) · Keeping Its Balance



Unitree (2026) · Jumping and Sprinting



Which task in your field could robots change?



1 Ed Login
on your phone



2 Camera App



3 Scan QR



4 Submit

ACTIVITY · EXIT TICKET

Please reach out to a TA/STA if you encounter any technical problems before leaving.