How to turn your house into a robot:

An adaptive learning algorithm for the Internet of Things

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Microsoft

A robot would save you money

Temperature and humidity automatically adjust to keep you comfortable, but save energy costs.

A robot house would save electricity and gas

Blinds adjust with changes in the weather to keep the house full of natural light without losing heat.

A robot house would save water

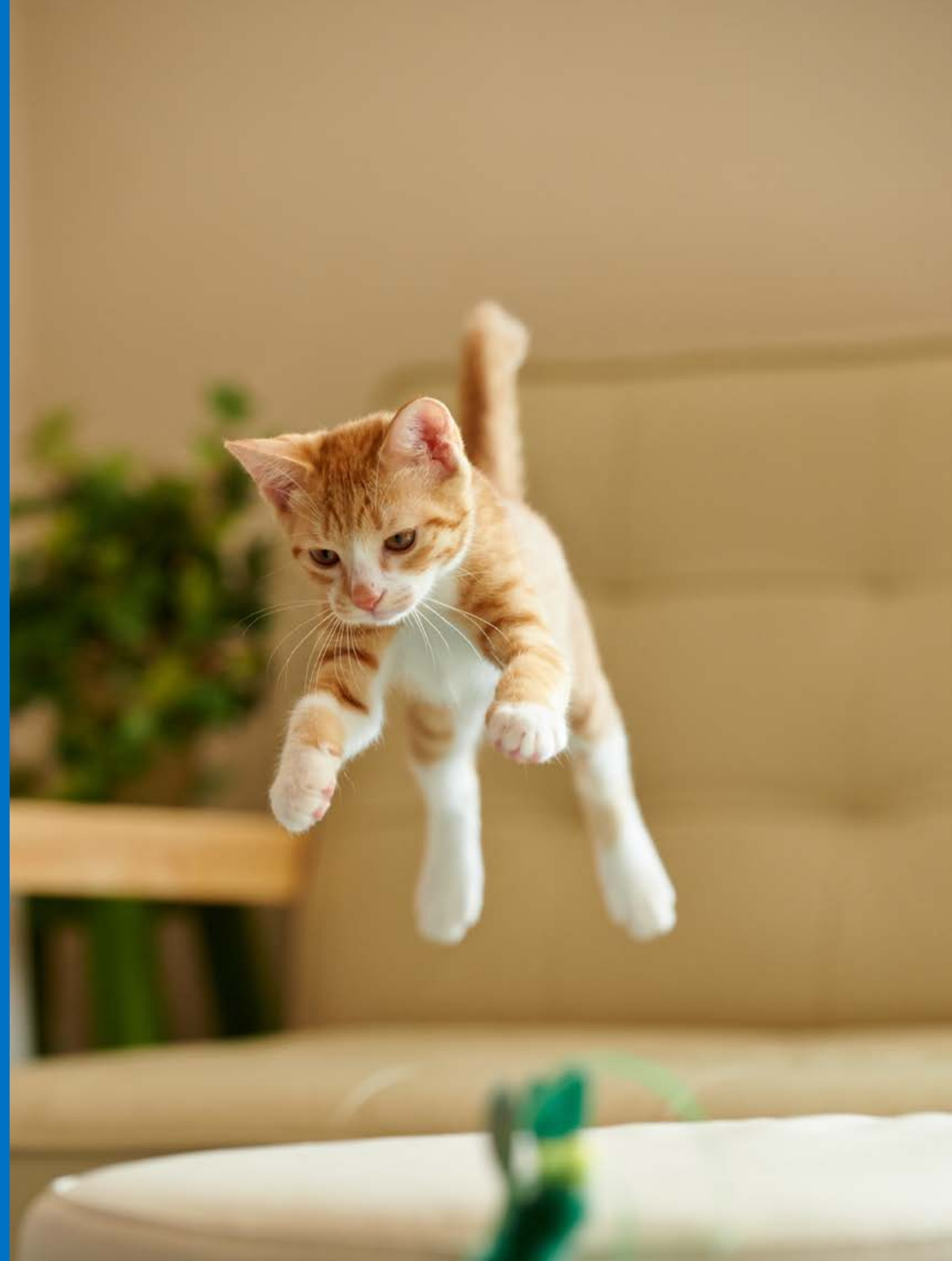
Faucets and plumbing give water at the right flow rates and temperature, whether you're bathing or showering, washing a dish or filling your glass

A robot house would save you time

E-notifications keep you up to date on routine maintenance. When components break, repairs are scheduled automatically.

A robot house would keep you and your loved ones safe

You get texts with images when an unfamiliar postal worker slides a package through the mail slot or when your cat knocks a crystal vase onto the tile floor.



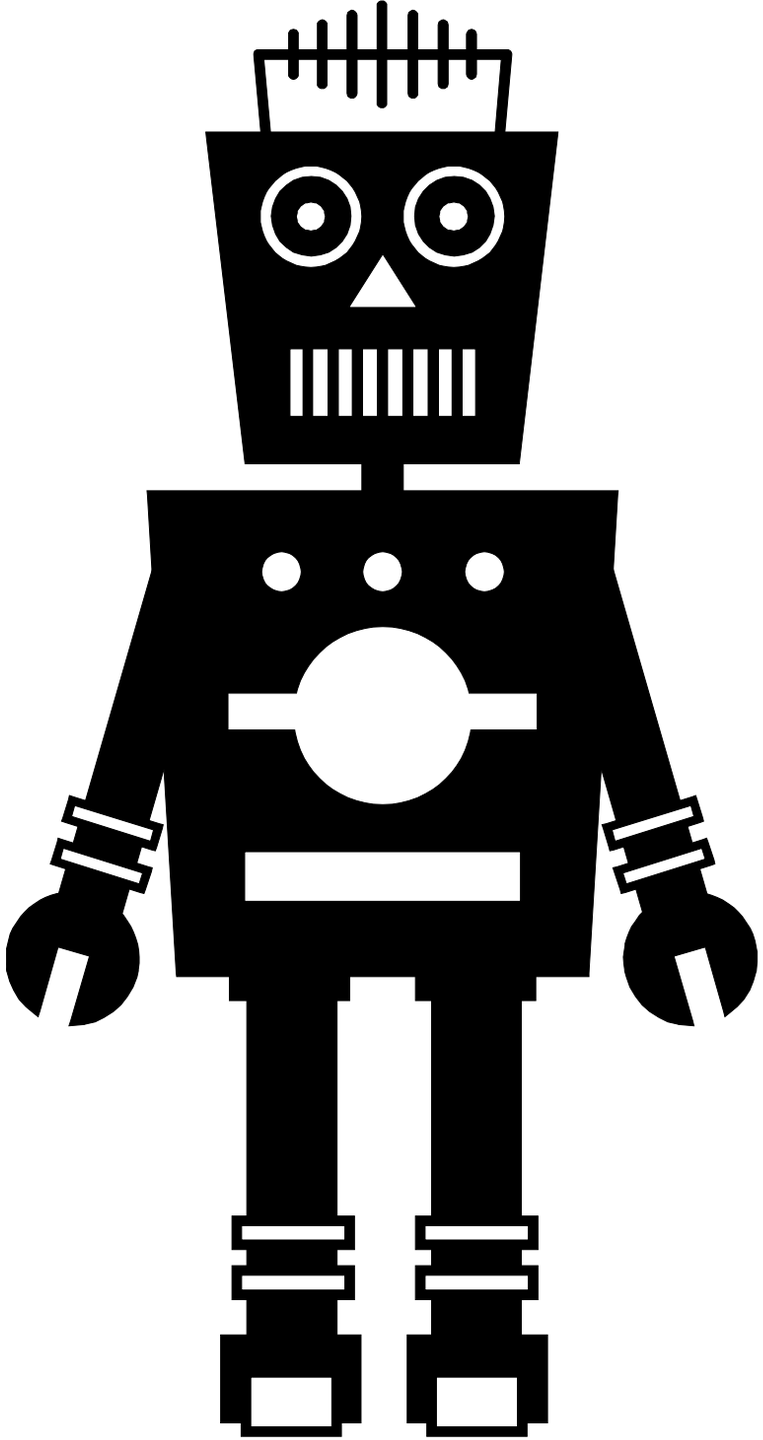
What makes a robot?

Sensors

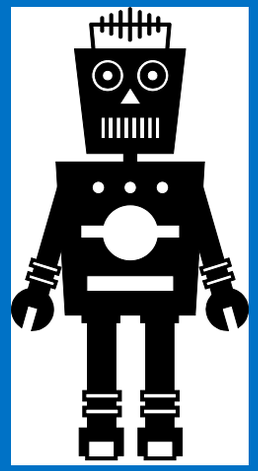
Actuators

Brain

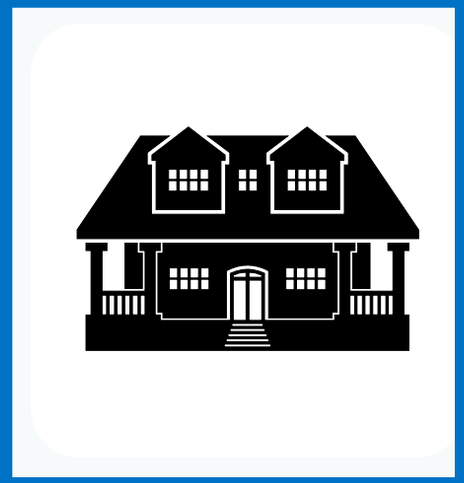
World



Sensors

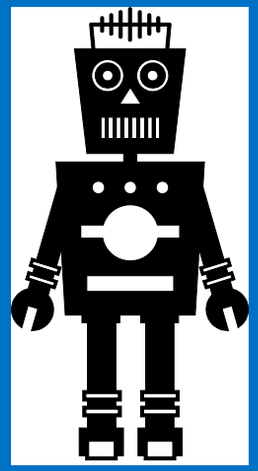


- Joint position
- Odometers
- Cameras
- Proximity
- Contact
- Pressure
- Laser scanners

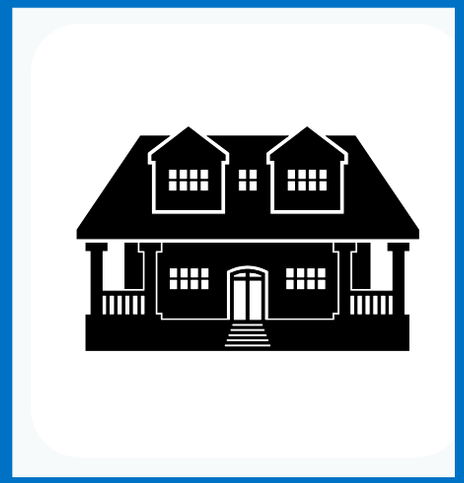


- Thermometer
- Security camera
- Smoke detector
- Microphone
- Window and door position
- Electric, gas and water flow

Actuators

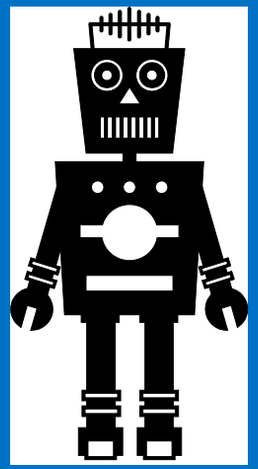


Joint flexor
Wheel drive
Grasp/release
Speaker

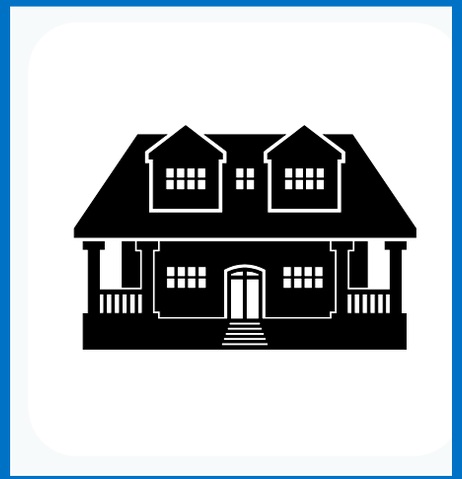


Heating and cooling
Light switches
Blinds
Camera motion
Sound fire alarm
Emails and texts
Locks

Brain



Computer
Algorithms
Fixed Rules
Learning



Machine learning can answer five questions

1. How much / how many?
2. Which category?
3. Which groups?
4. Is it weird?
5. Which action?

How much / how many?

What will the temperature be next Tuesday?

What will my fourth quarter sales in Portugal be?

How many new followers will I get next week?

[regression]

Which category?

Is this an image of a cat or a dog?

Which aircraft is causing this radar signature?

What is the topic of this news article?

[classification]

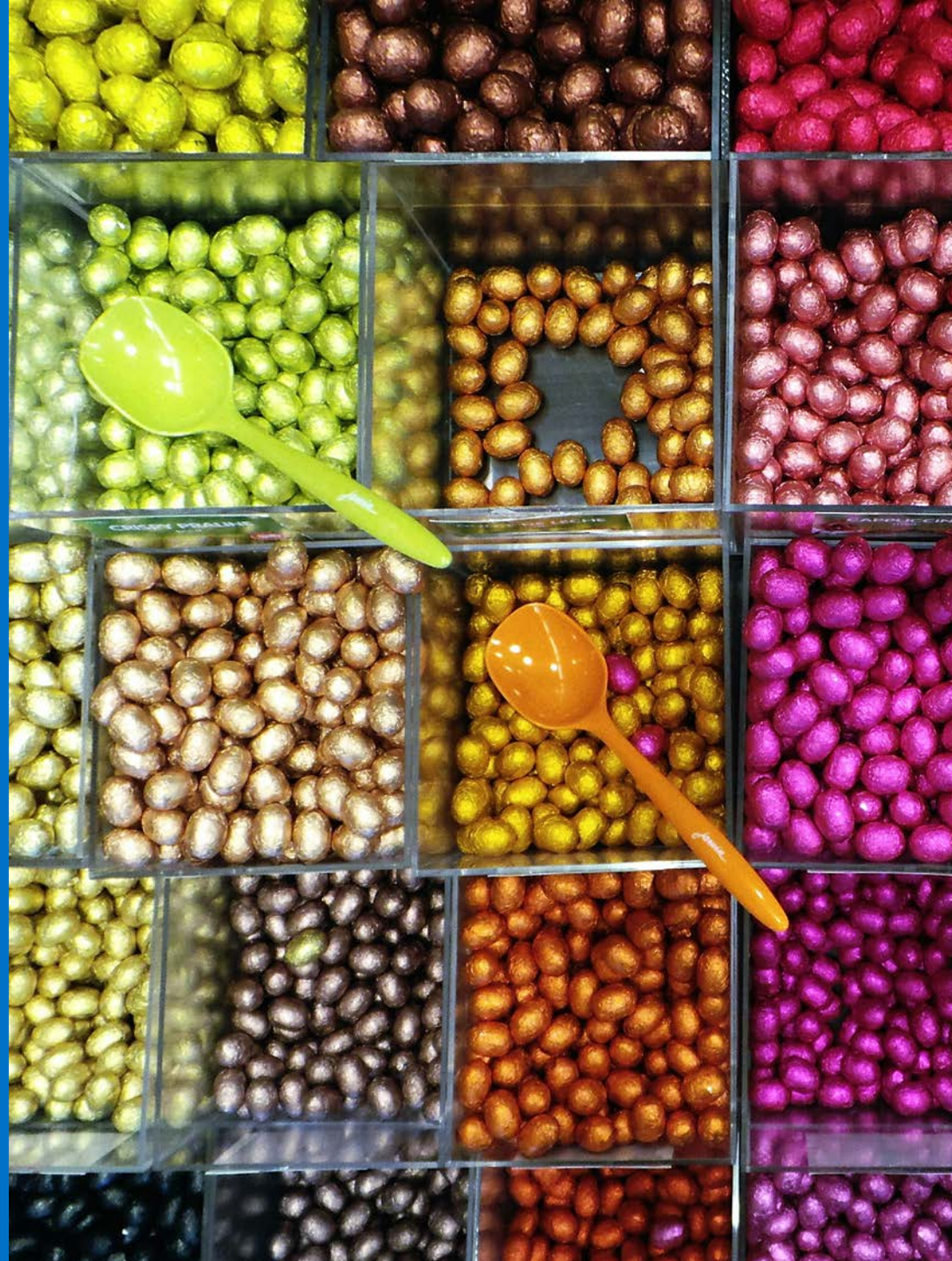
Which groups?

Which shoppers have similar tastes in produce?

Which viewers like the same kind of movies?

What is a natural way to break these documents into five topic groups?

[clustering] [recommendation]



Is this weird?

Is this pressure reading unusual?

Is this internet message typical?

Is this combination of purchases very different from what this customer has made in the past?

[anomaly detection]

Which action?

Should I raise or lower the temperature?

Should I vacuum the living room again or stay plugged in to my charging station?

Should I brake or accelerate in response to that yellow light?

[reinforcement learning]

Challenge 1

Nearly all machine learning algorithms assume that your world does not change.

Rearranging furniture would break them.

Challenge 2

Reinforcement learning algorithms don’t handle changes in sensors and actuators.

Replacing a floor lamp with a light fixture would break them.

Challenge 3

Most reinforcement learning algorithms don’t handle changing goals.

They would fight keeping the house warmer.

Challenge 4

Most machine learning algorithms take a lot of time to learn.

By the time they've learned it's too late.

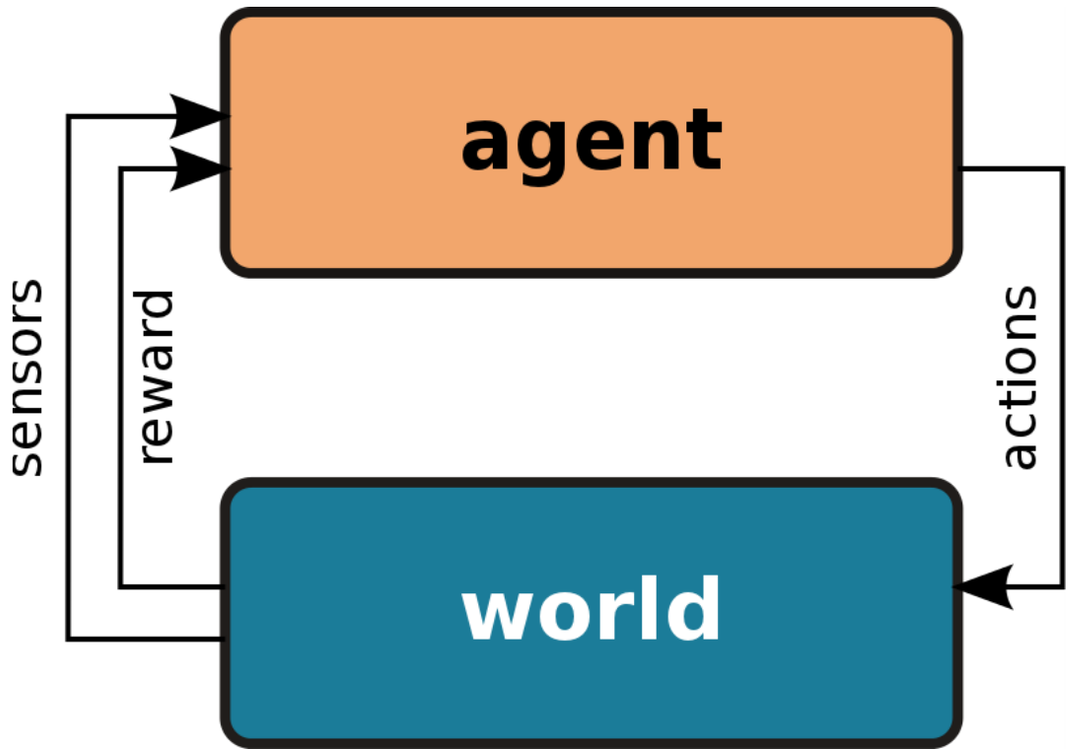
Challenge 5

Most reinforcement learning algorithms don’t scale gracefully.

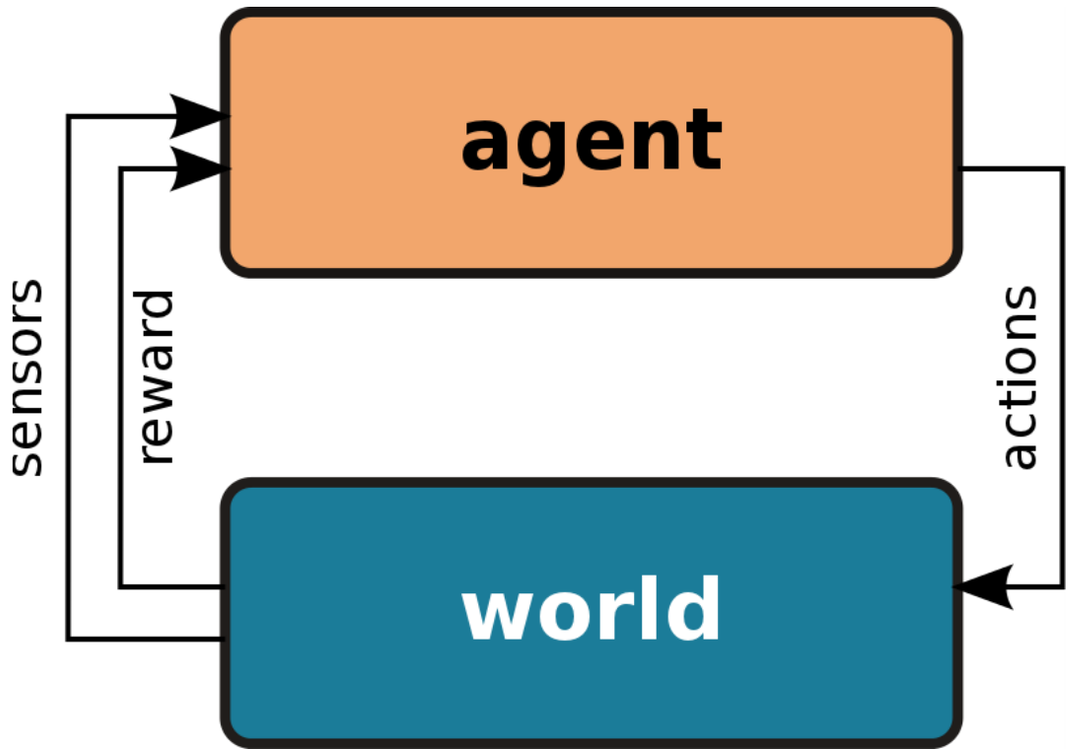
By the time they learn it’s really too late.

Answering the challenge

A new reinforcement learning algorithm

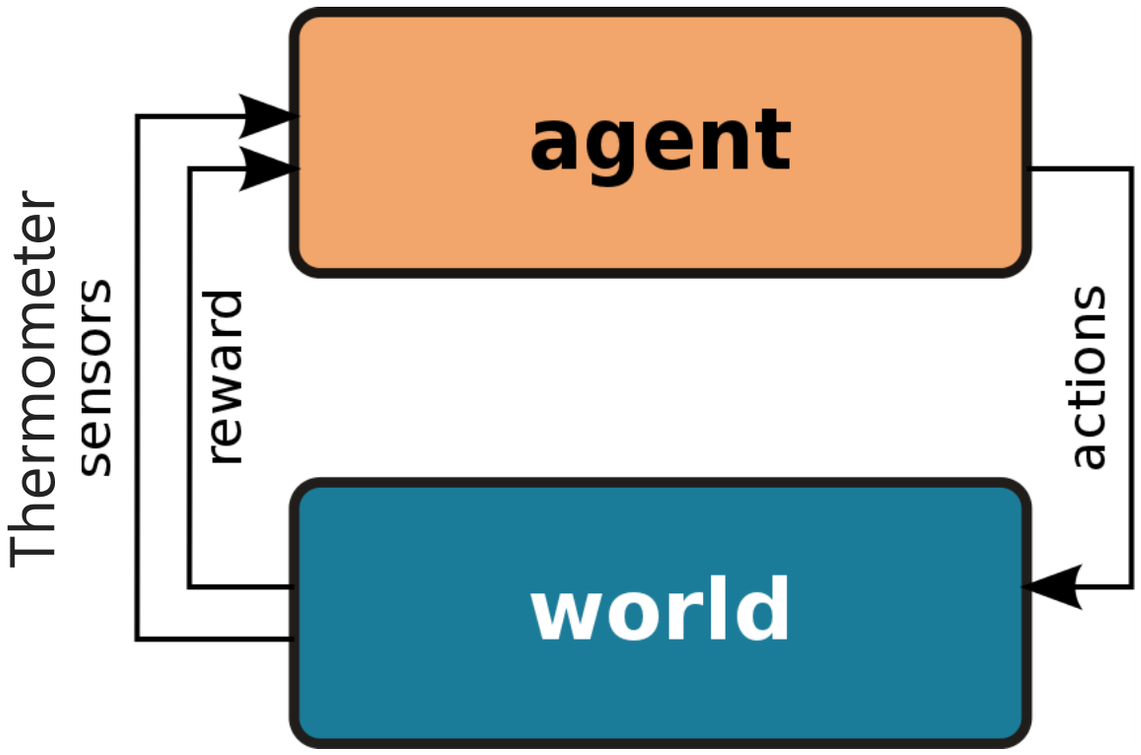


A smart thermostat



A smart thermostat

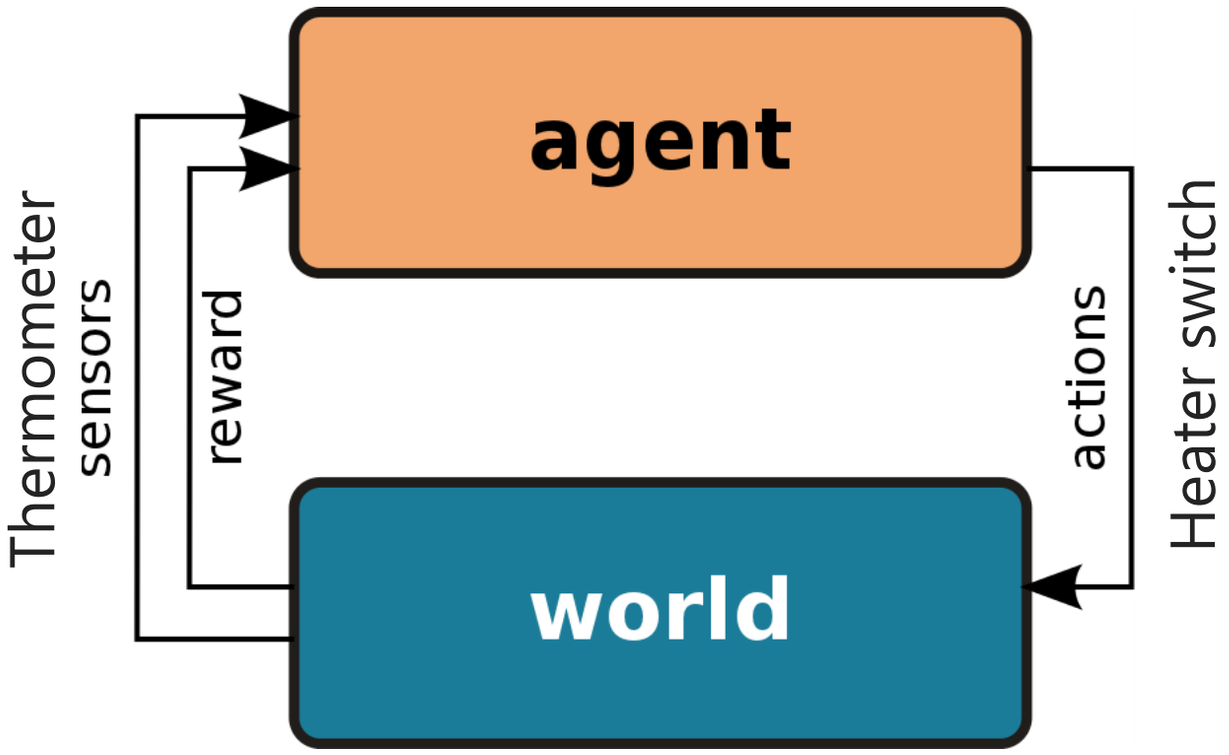
Sensor: Thermometer



A smart thermostat

Sensor: Thermometer

Actuator: Heater switch



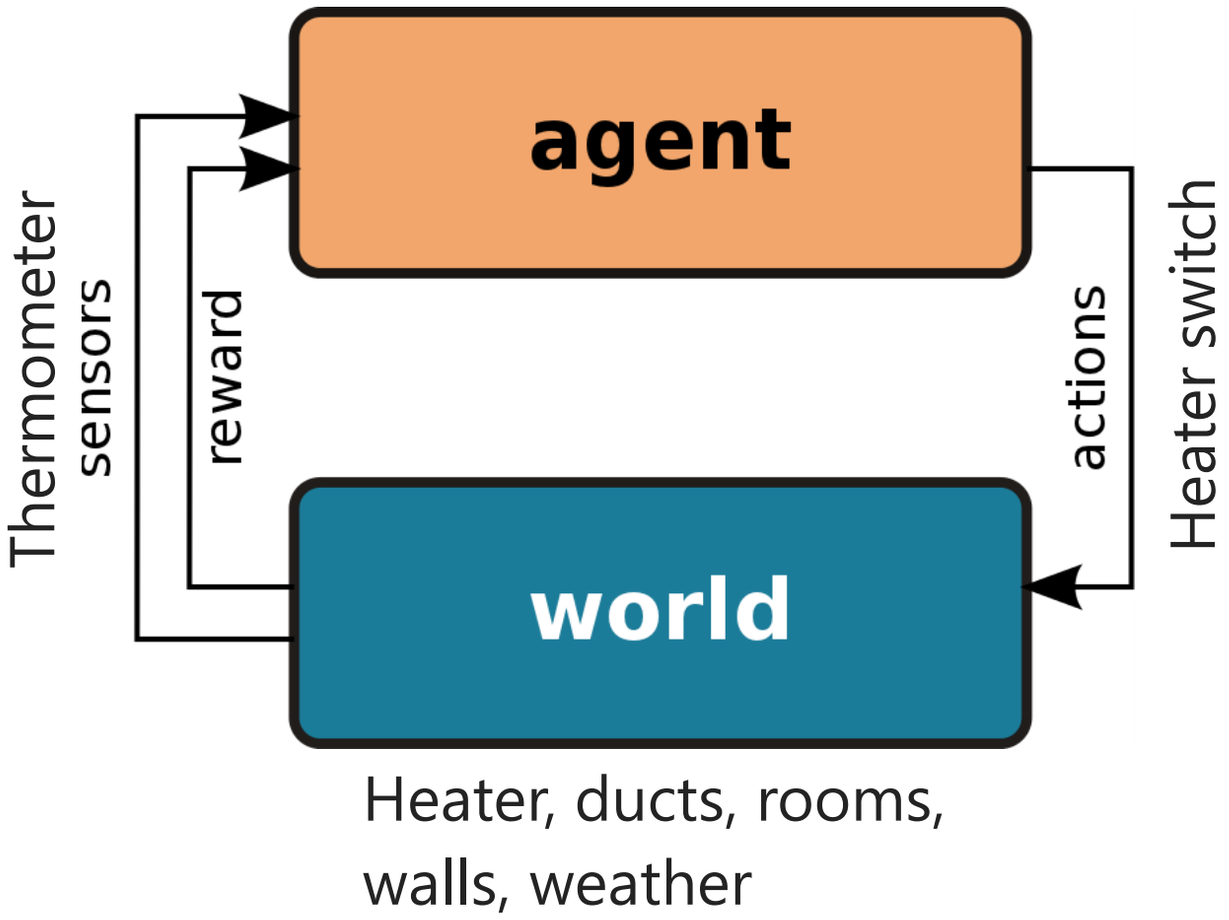
A smart thermostat

Sensor: Thermometer

Actuator: Heater switch

World: Heater, ducts, rooms, walls, weather

Cycle takes 10 minutes



A smart thermostat

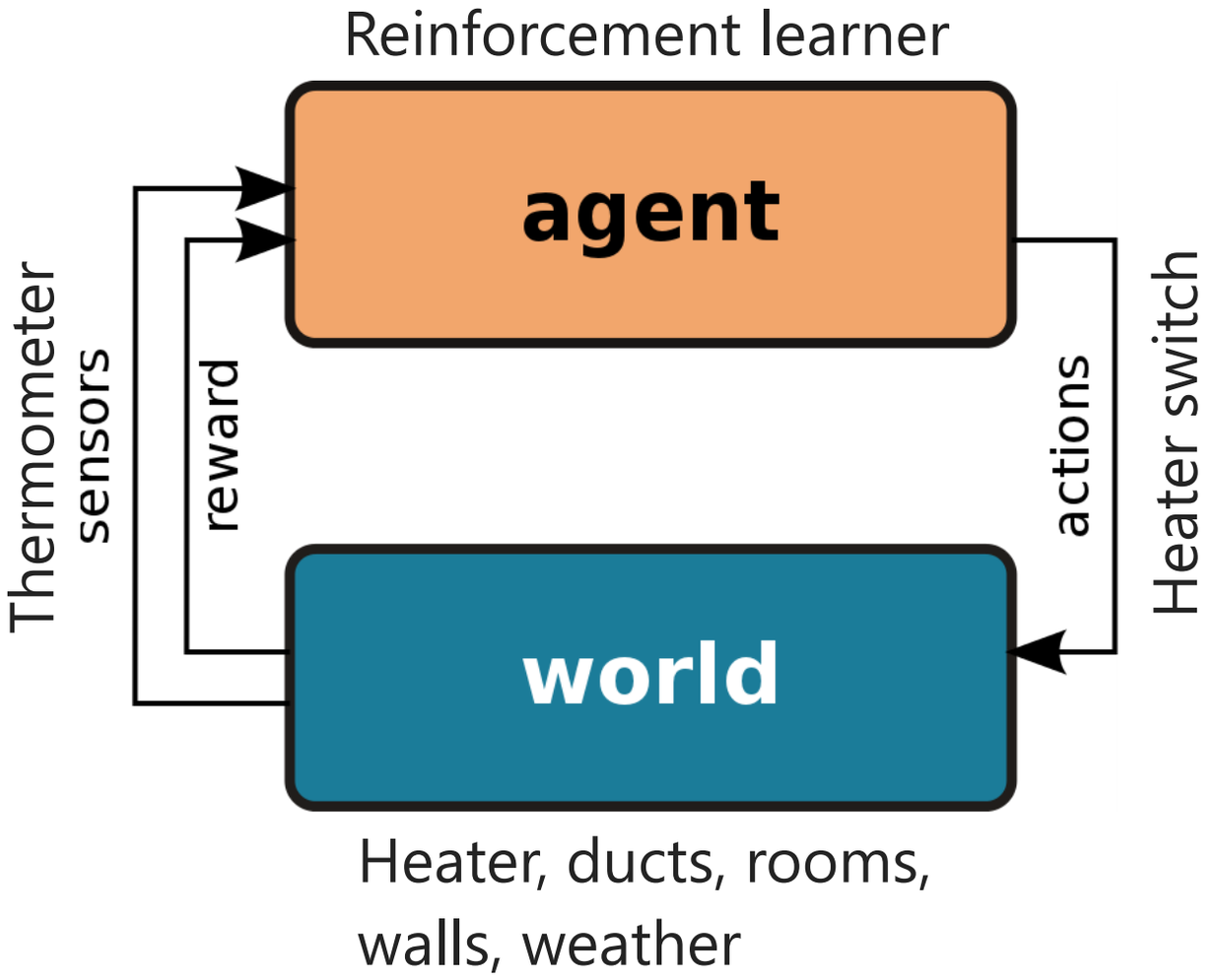
Sensor: Thermometer

Actuator: Heater switch

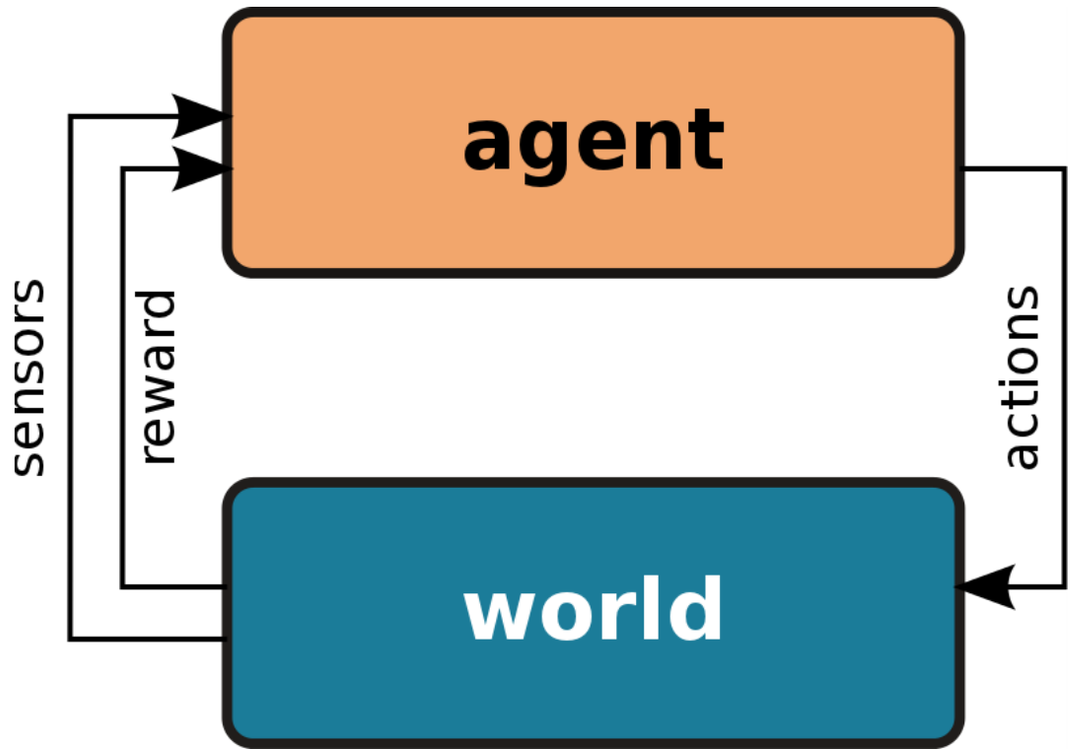
World: Heater, ducts, rooms, walls, weather

Cycle takes 10 minutes

Brain: Our new reinforcement learning algorithm

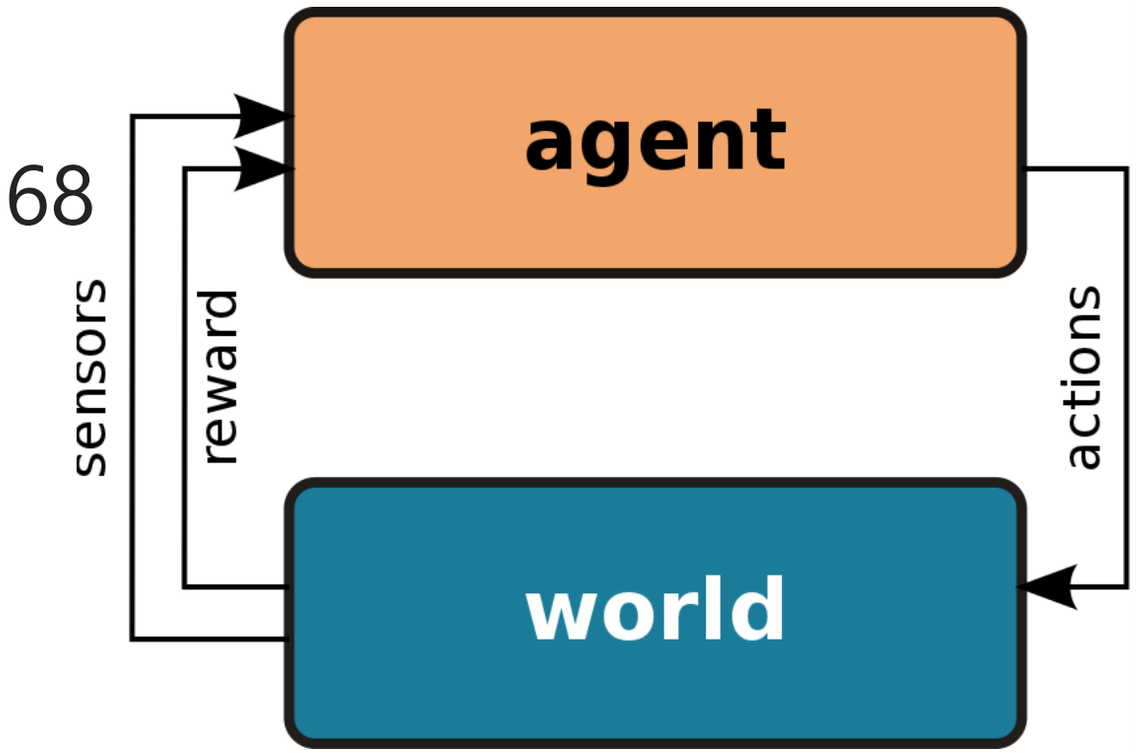


Once through the loop



Once through the loop

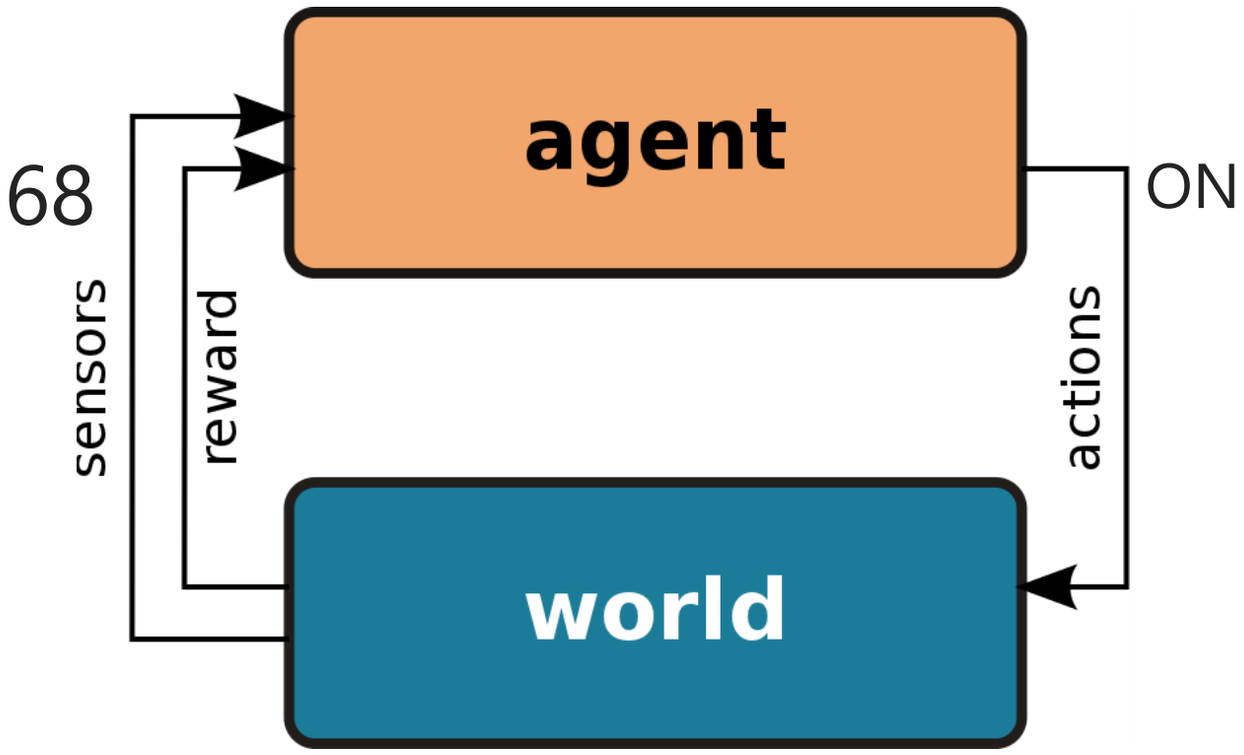
Temperature measured at 68 degrees



Once through the loop

Temperature measured at 68 degrees

The heater switched on for 10 minutes

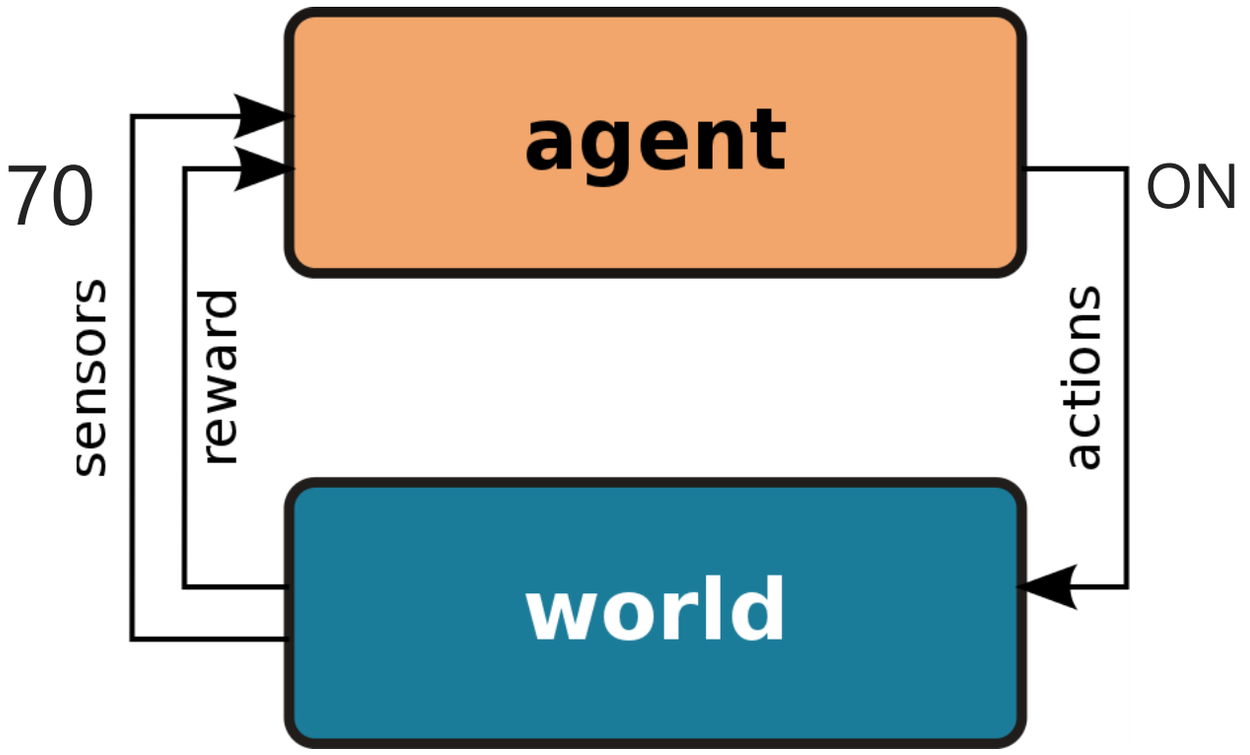


Once through the loop

Temperature measured at 68 degrees

The heater switched on for 10 minutes

Temperature measured 70 degrees



Put it in a table

Temp before	Heater	Temp after	Observations
68	On	70	1

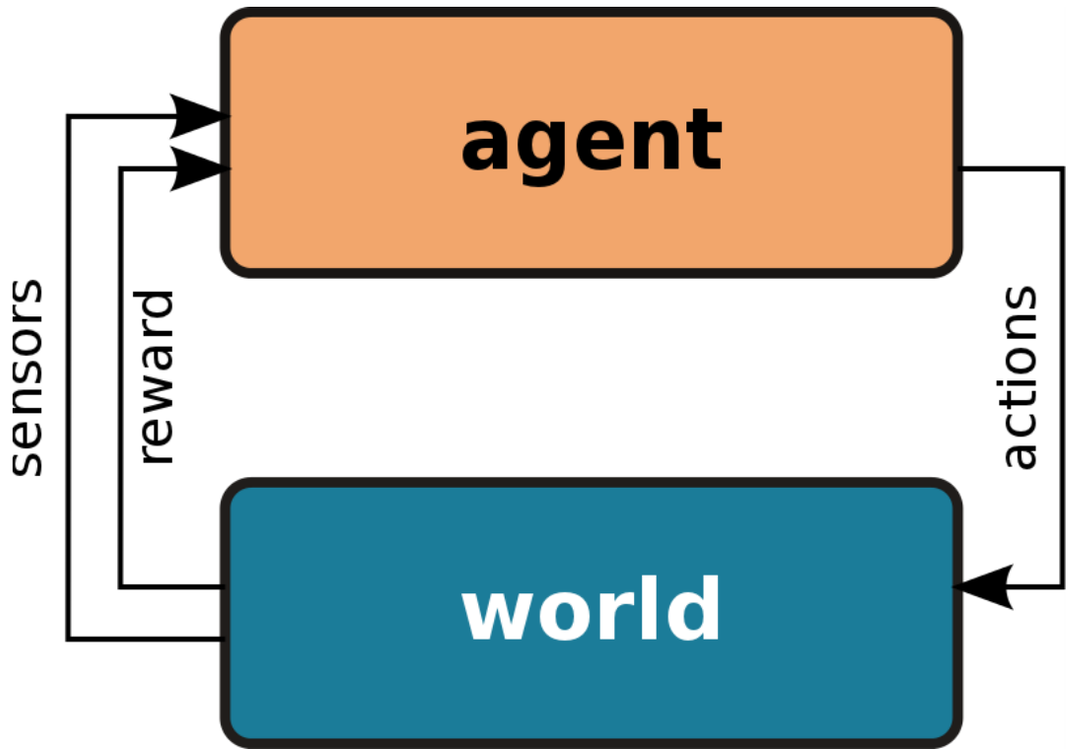
Temp before	Heater	Temp after	Opportunities	Observations
68	On	70	1	1

Temp before	Heater	Temp after	Opportunities	Observations
68	On	68	1	0
68	On	69	1	0
68	On	70	1	1
68	On	71	1	0

Temp before	Heater	Temp after	Opportunities	Observations	Probability (%)
68	On	68	1	0	0
68	On	69	1	0	0
68	On	70	1	1	100
68	On	71	1	0	0
68	On	72	1	0	0
68	On	73	1	0	0

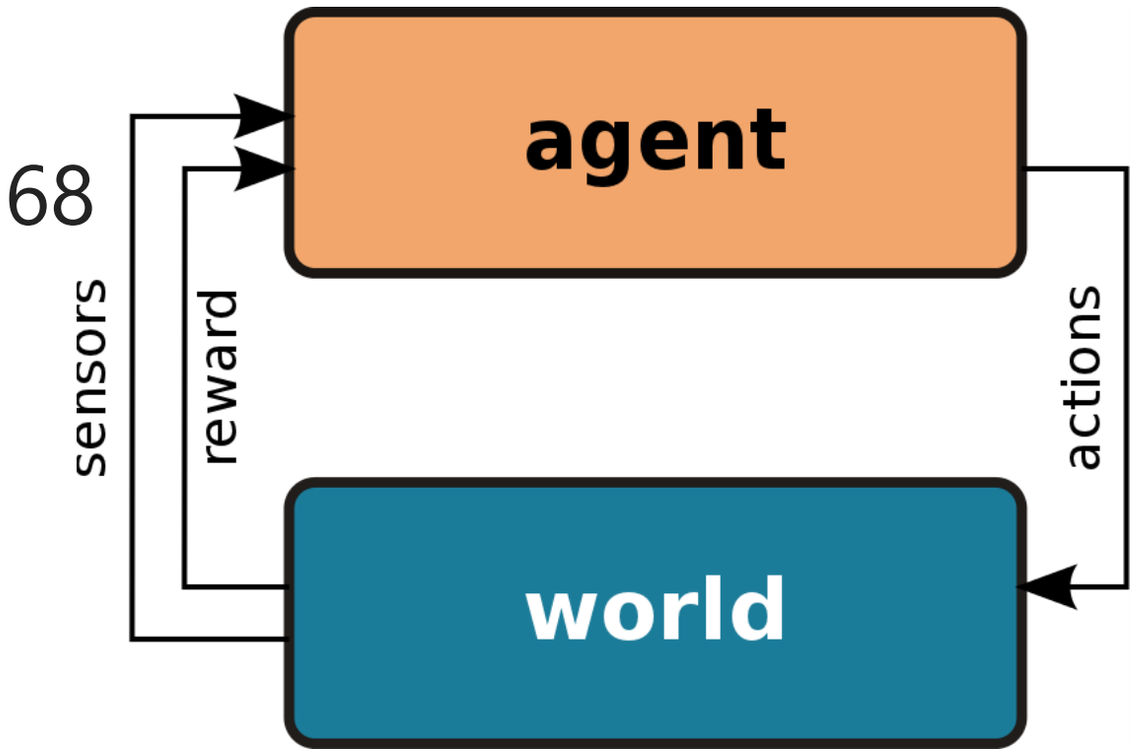
Temp before	Heater	Temp after	Opportunities	Observations	Probability (%)
68	On	68	1	0	0
68	On	69	1	0	0
68	On	70	1	1	100
68	On	71	1	0	0
68	On	72	1	0	0
68	On	73	1	0	0
68	Off	65	0	0	0
68	Off	66	0	0	0
68	Off	67	0	0	0
68	Off	68	0	0	0
68	Off	69	0	0	0
68	Off	70	0	0	0

Through the loop again



Through the loop again

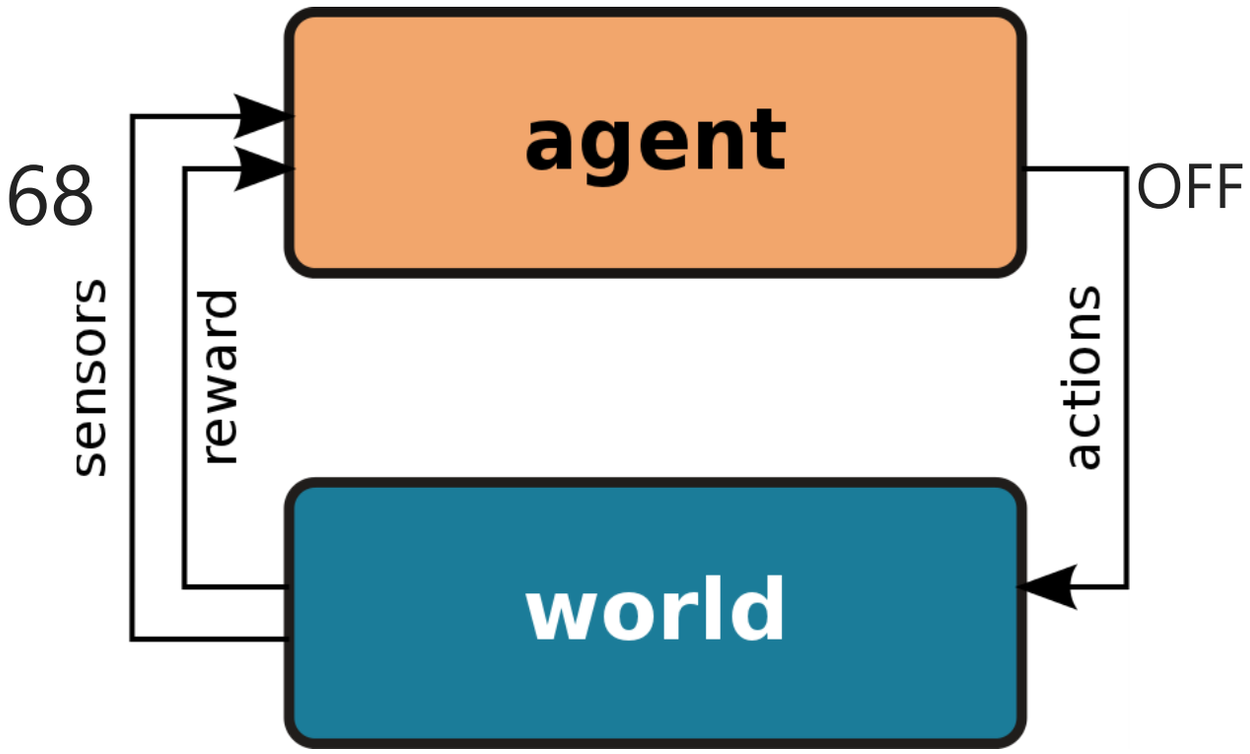
Temperature measured at 68 degrees



Through the loop again

Temperature measured at 68 degrees

The heater switched off for 10 minutes

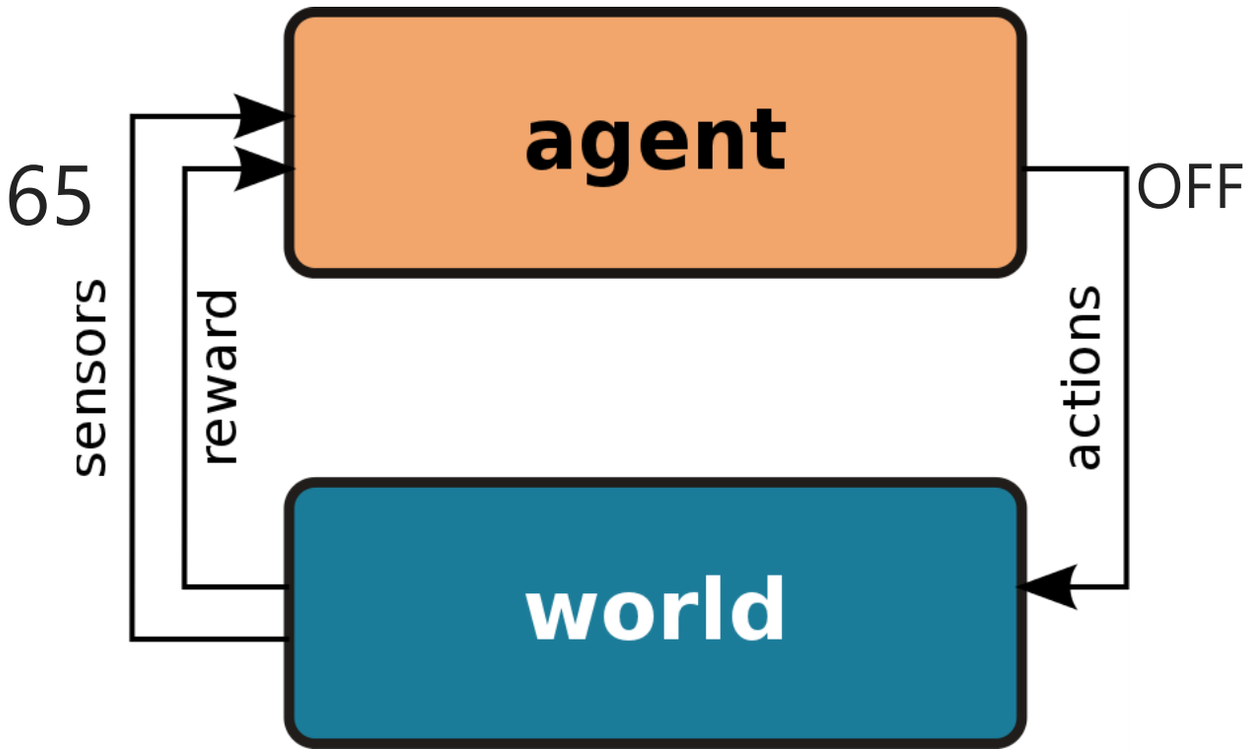


Through the loop again

Temperature measured at 68 degrees

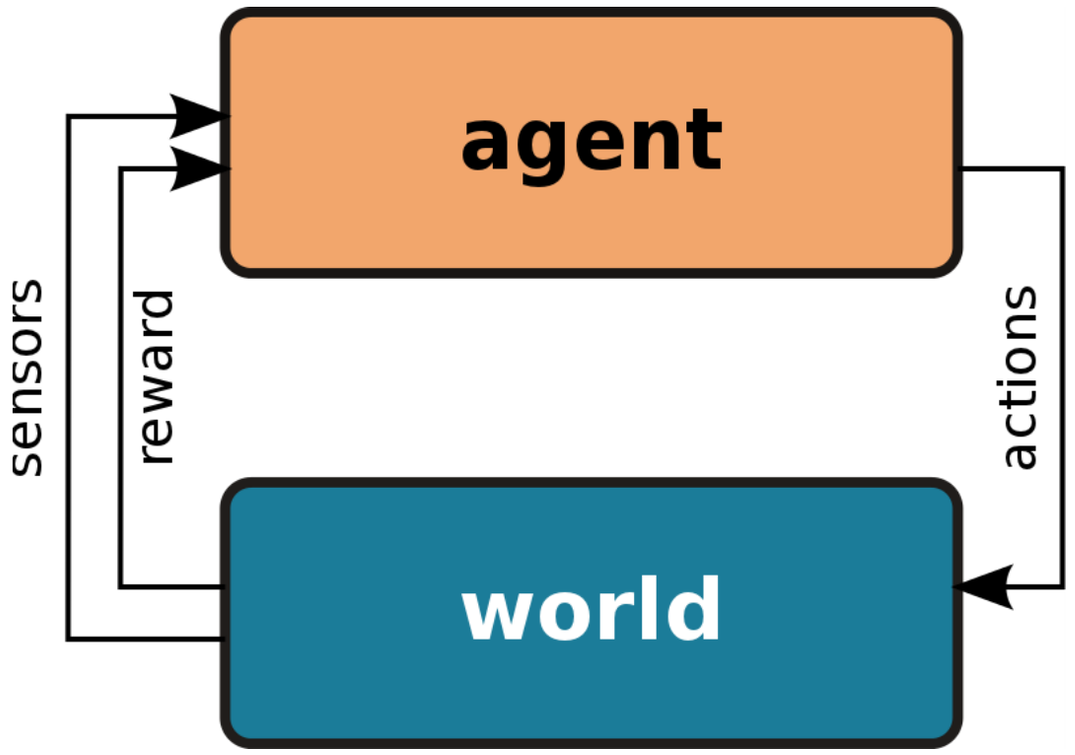
The heater switched off for 10 minutes

Temperature measured 65 degrees



Temp before	Heater	Temp after	Opportunities	Observations	Probability (%)
68	On	68	1	0	0
68	On	69	1	0	0
68	On	70	1	1	100
68	On	71	1	0	0
68	On	72	1	0	0
68	On	73	1	0	0
68	Off	65	1	1	100
68	Off	66	1	0	0
68	Off	67	1	0	0
68	Off	68	1	0	0
68	Off	69	1	0	0
68	Off	70	1	0	0

Lots of times through the loop…



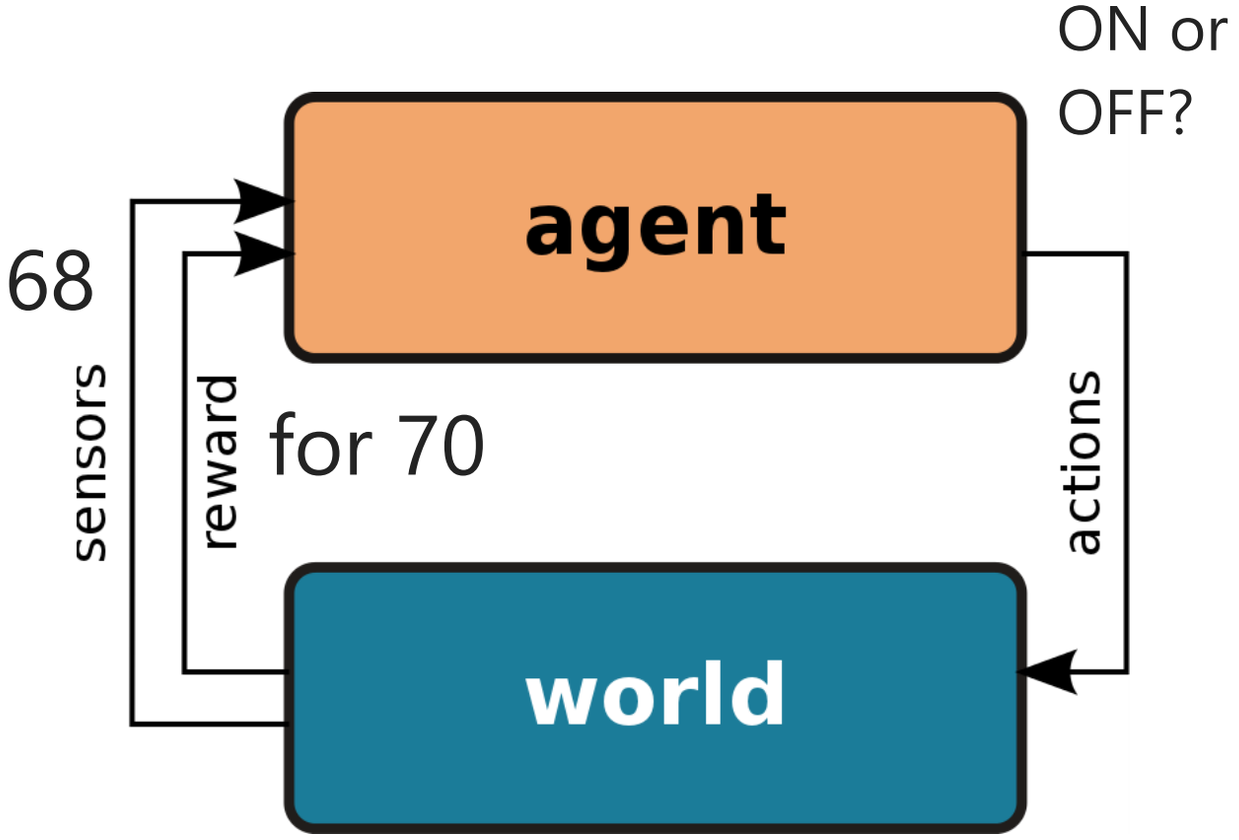
Temp before	Heater	Temp after	Opportunities	Observations	Probability (%)
68	On	68	385	9	2.3
68	On	69	385	88	22.9
68	On	70	385	198	51.4
68	On	71	385	76	19.7
68	On	72	385	13	3.4
68	On	73	385	1	0.3
68	Off	65	373	5	1.3
68	Off	66	373	93	24.9
68	Off	67	373	158	42.3
68	Off	68	373	72	19.3
68	Off	69	373	41	11.0
68	Off	70	373	4	1.1

A fresh decision

Temperature is 68

Desired temp is 70

What to do?



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68	Off	69	373	41	11.0
68	Off	70	373	4	1.1

Technical details

BECCA project

Python code and Documentation

github.com/brohrer/becca

Open source (MIT license)

Free

BECCA

Answering the challenge

Incremental algorithm.

Needs no data to start.

Doesn’t require ongoing human participation.

Ongoing training.

Constant adaptation.

Learns decisions.

Caveat

For a whole house this includes

1. all the measurements,
2. of all the sensors,
3. both before and after,
4. across all actions.

It’s still fast

It gets big but it’s polynomial, not exponential

And it’s storage, not processing

Computation is mostly comparisons and arithmetic

Implementation

Suited for

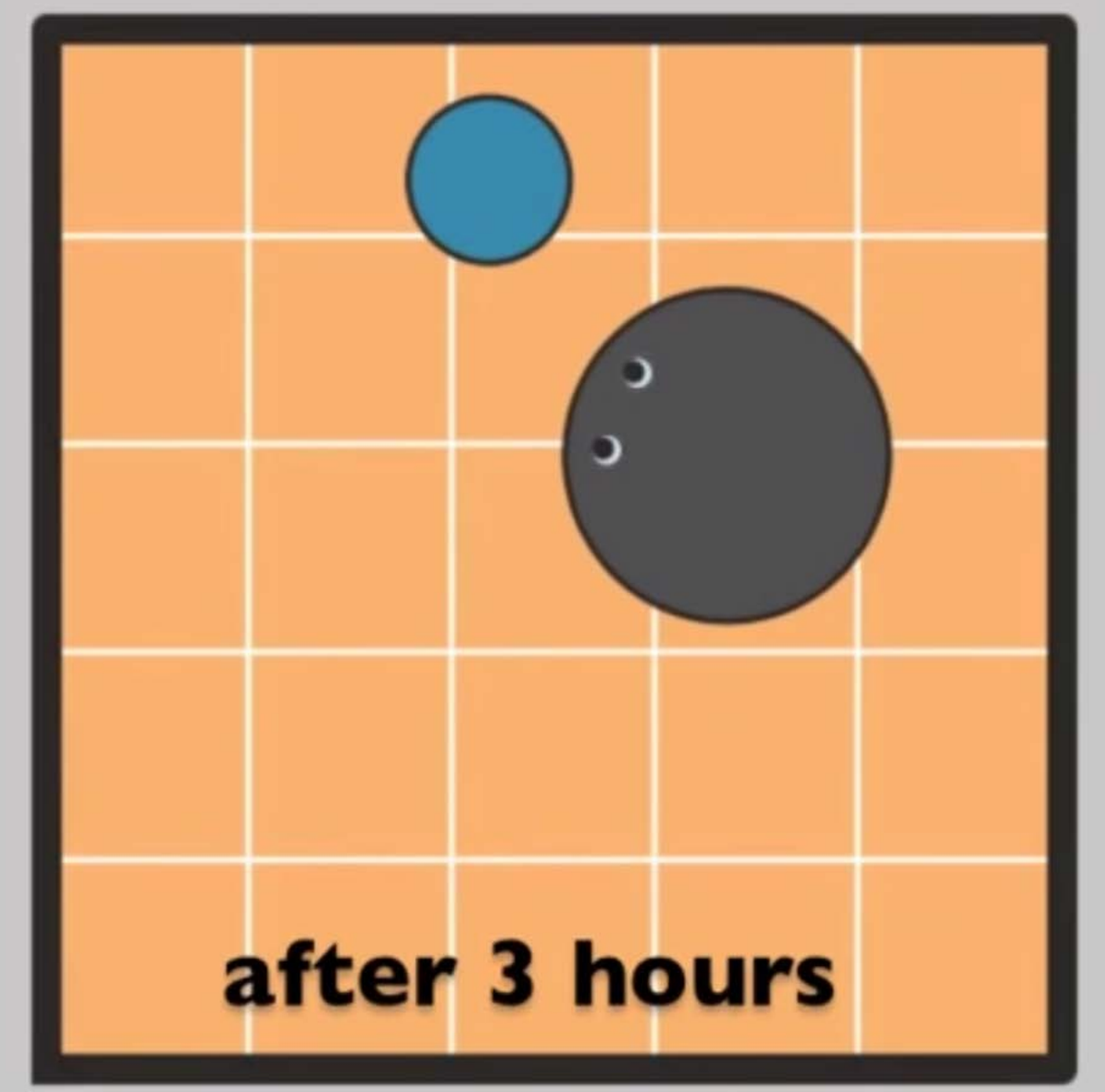
Large database

Cloud processing

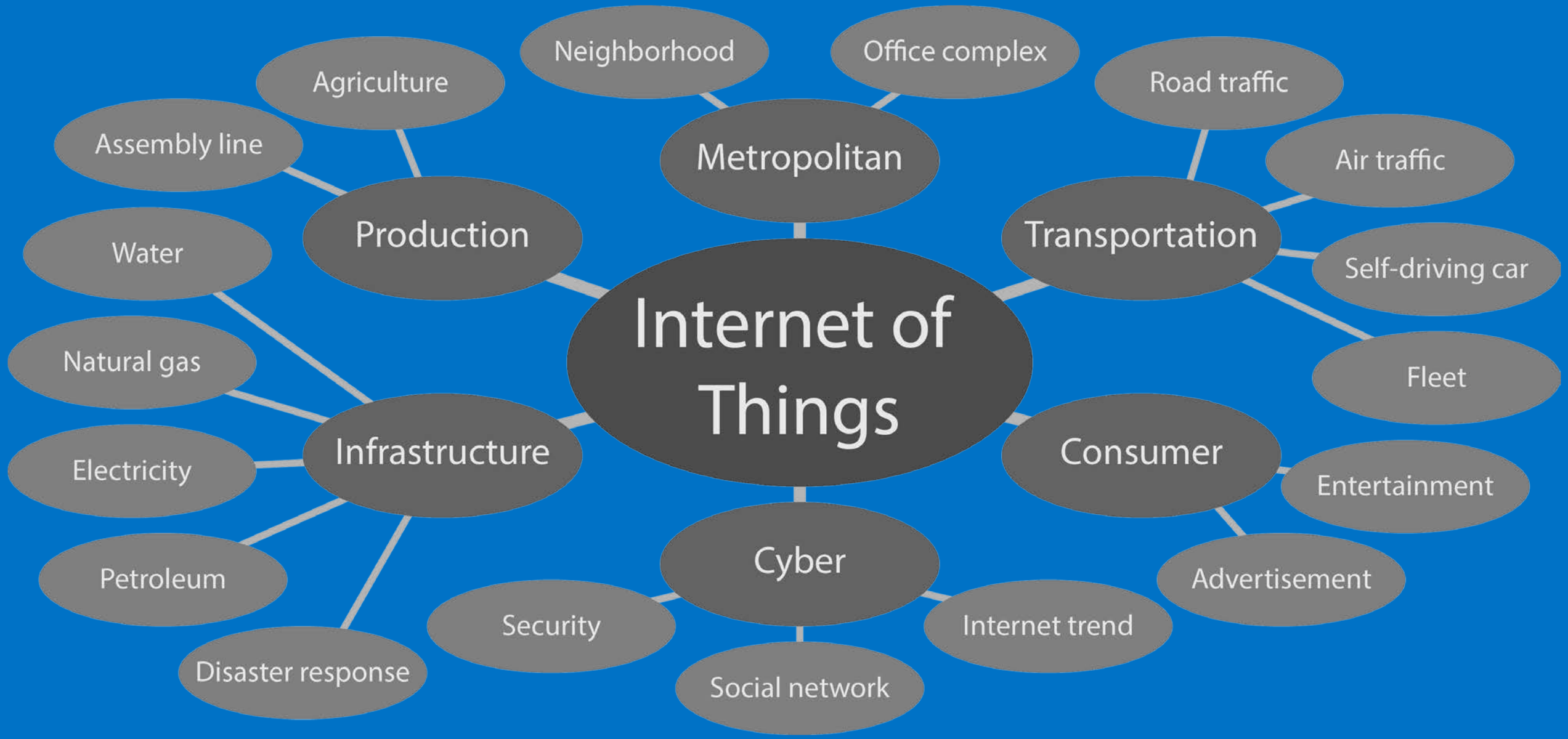
Data lake

Rixel the Robot learns to chase a ball

https://youtu.be/uU1_13c6umo



Other things can be turned into robots



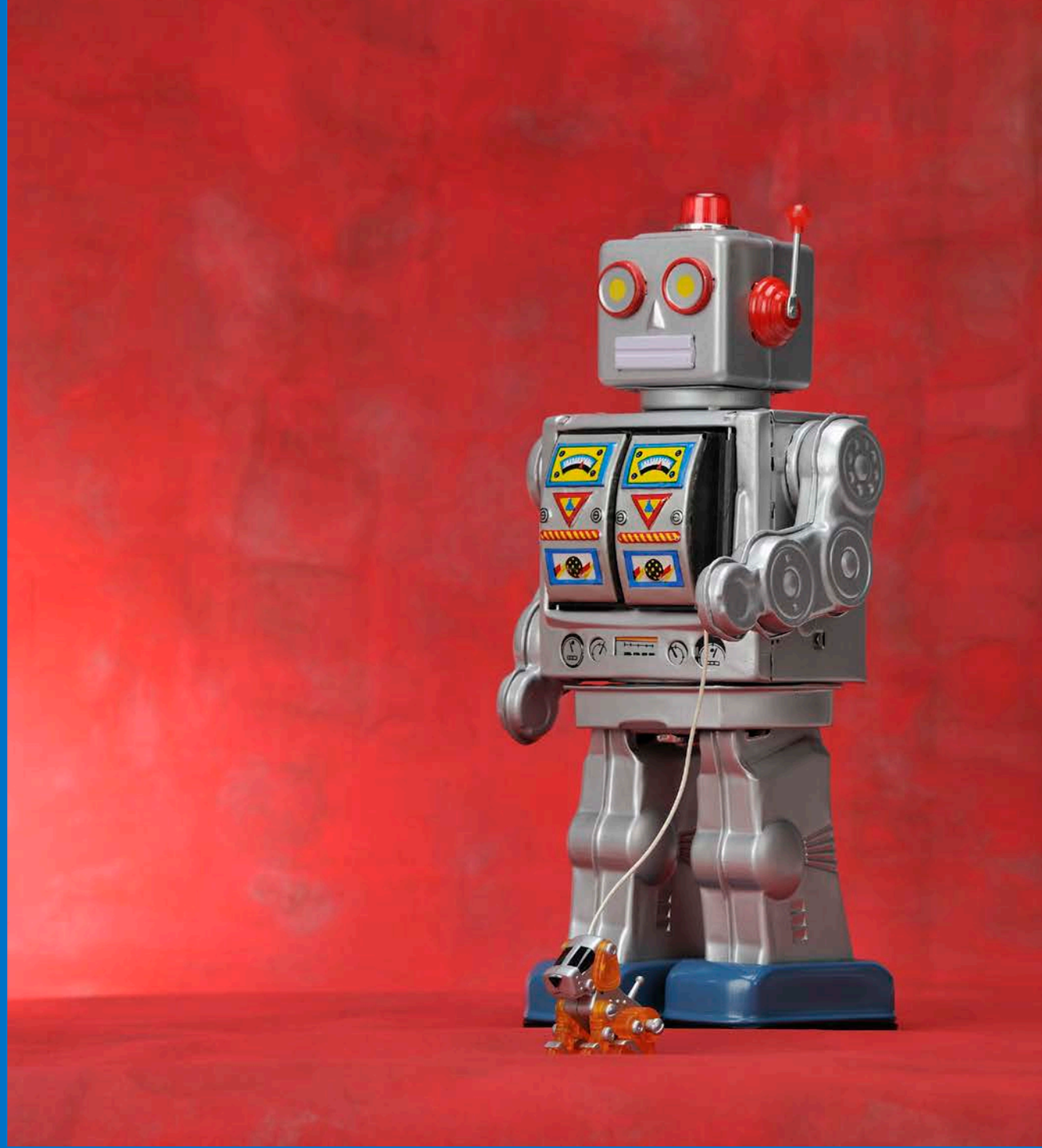
Robots can

Save money

Save natural resources

Save time

Save lives

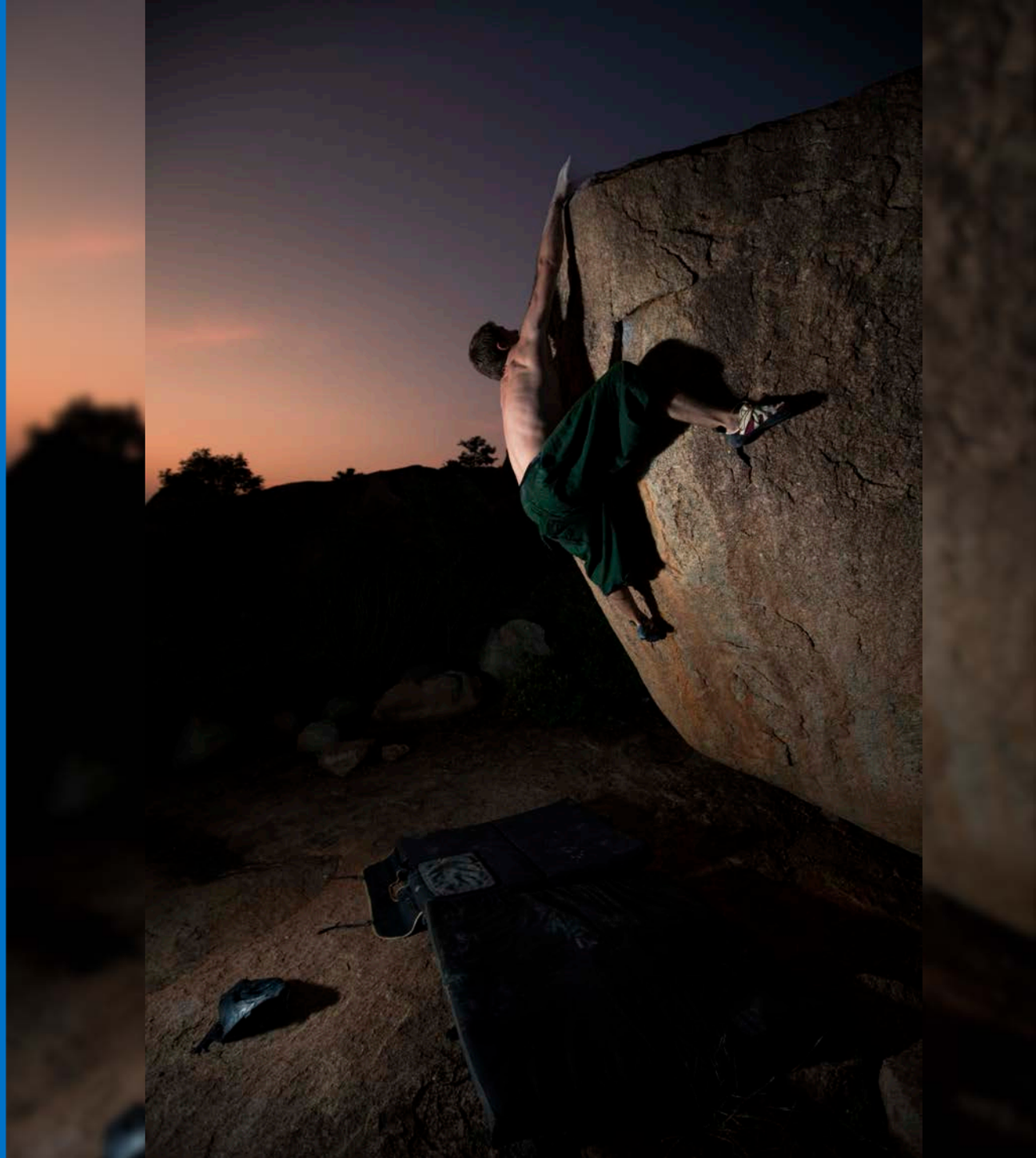


We are very close

We have the sensors.

We have the actuators.

We're just missing the brain.



Let's continue the conversation

I'd love to hear from you

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LinkedIn

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brohrer.github.io

Open source algorithm code: github.com/brohrer/Becca

Thanks to Diane Rohrer for duckling and Shih Tzu images

Brandon Rohrer

Posts, Presentations and Papers

BECCA demo	
BECCA code and documentation on GitHub	BECCA
LinkedIn posts	in
TechNet posts	Microsoft TechNet
KDnuggets posts	KDnuggets™
Videos	
Data Science for the Rest of Us	
Cortana Analytics	
LinkedIn profile	