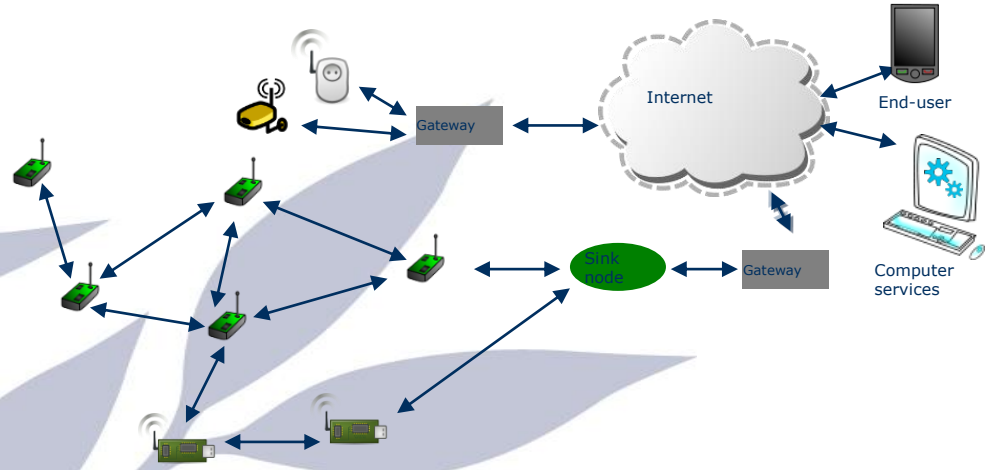

Internet of Things & Services

IoT Intelligence : Services for a Connected World. L11

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What is IoT?

- Your answer?
- What is not *IoT*?
- How does IoT relate to intelligence?
- Do we need IoT intelligence?

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IoT

- Things are heterogeneous
- May be distributed
- Sends or waits for **data**

IoT Data Cycle

- Collect data == sense
- Share/forward data == communicate
- **Store**
- Analyse == reasoning
- Act == actions

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Intelligence

- Application of ***knowledge***
- But how do we **obtain** knowledge?

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Need for intelligence in IoT

- Billions of Things
  - How much data?
- Most of the data is never analysed or utilized
  - **Less than 5% of data** is ever analysed
- Raw-data does not provide any usefulness or insight
- We need to make raw-data useful
- We are living at a time where we are enriched with data but poor with respect to information

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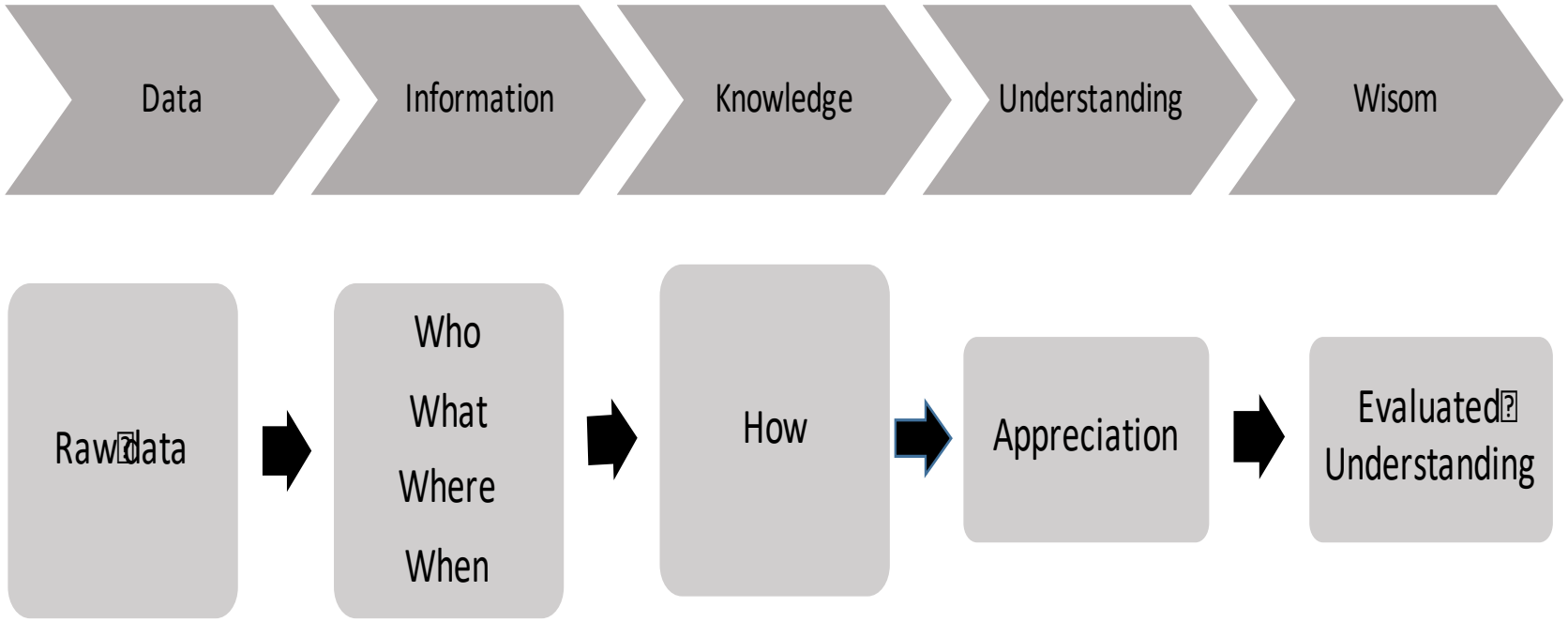
Need for intelligence in IoT

- In the beginning, IoT was about collecting data without human intervention
- It actually makes Things connected, not necessarily smart
- IoT promises to impact every aspect of human life
- Intelligence is required to make Things autonomous
- Therefore, we need to leverage IoT (raw-data) data

Information-knowledge pyramid hierarchy



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One way to reap value

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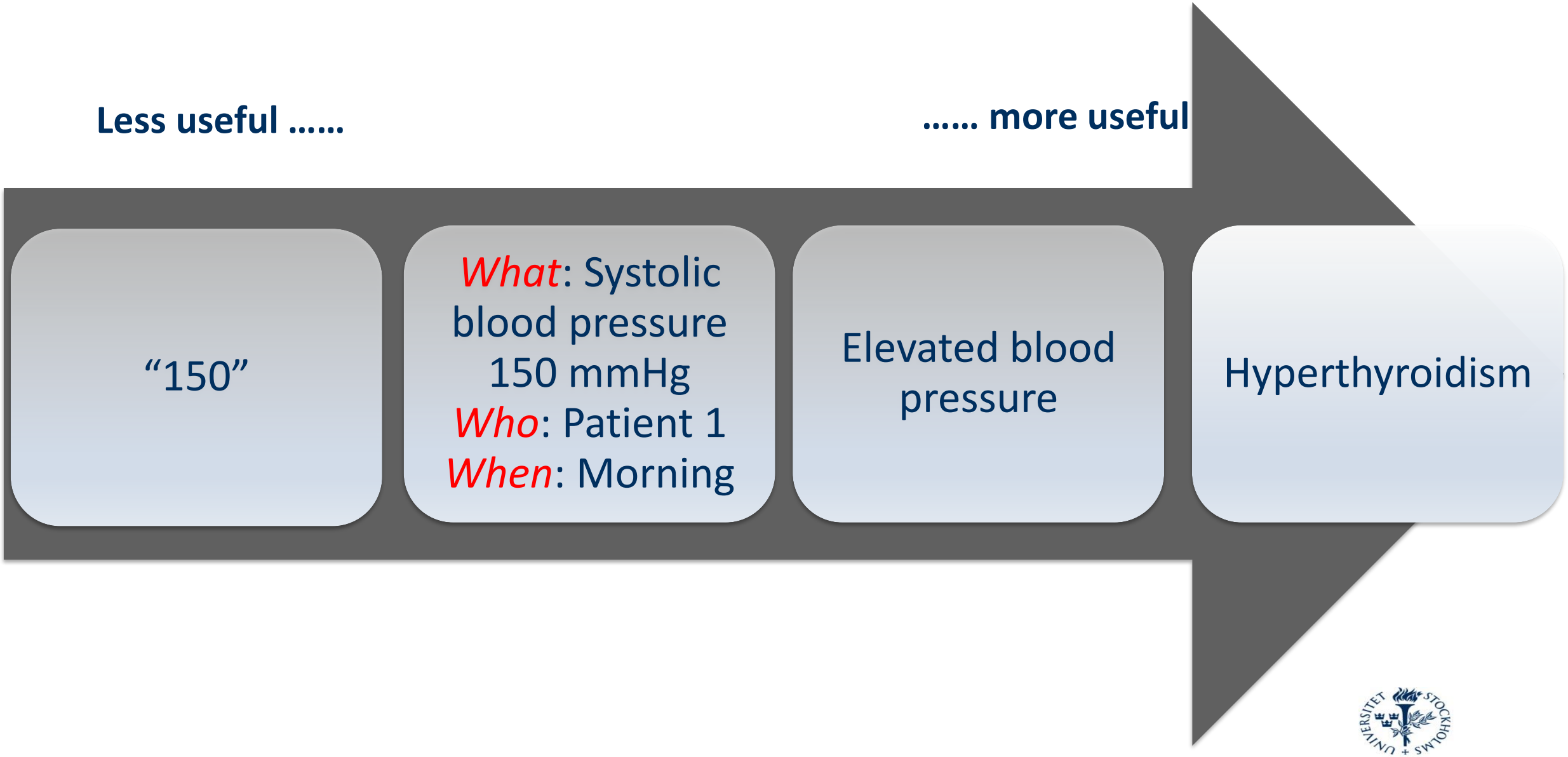
Less useful ……

…… more useful



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Applying IoT knowledge (1)

- Knowledge is not same for every IoT application
- Each IoT application might have different knowledge to apply
- For example:
  - In a SmartFarming, when and how to sprinkle water; light and air control; when to harvest, etc.
  - In a SmartHealth, prescribing medicine; remote monitoring and diagnostics; notifying both caregiver and patients; etc.
- It also corresponds to the questions of *how*

Applying IoT knowledge (2)

- **Rules** are the prevailing choice in the IoT to assist with intelligence
  - Rules fail in uncertain situations
  - Don’t scale well
- Along with rules, **Cloud** too was the dominant choice until recently
- Collected data were sent to the cloud to analyse, store, visualize, act, etc.
- IoT needs faster decisions- probably closer to the actual things**: Edge and fog computing**!

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What IoT needs?

- Reaping value from data
- Extract knowledge
- Faster decisions
- Low-latency
- Computation at the Edge

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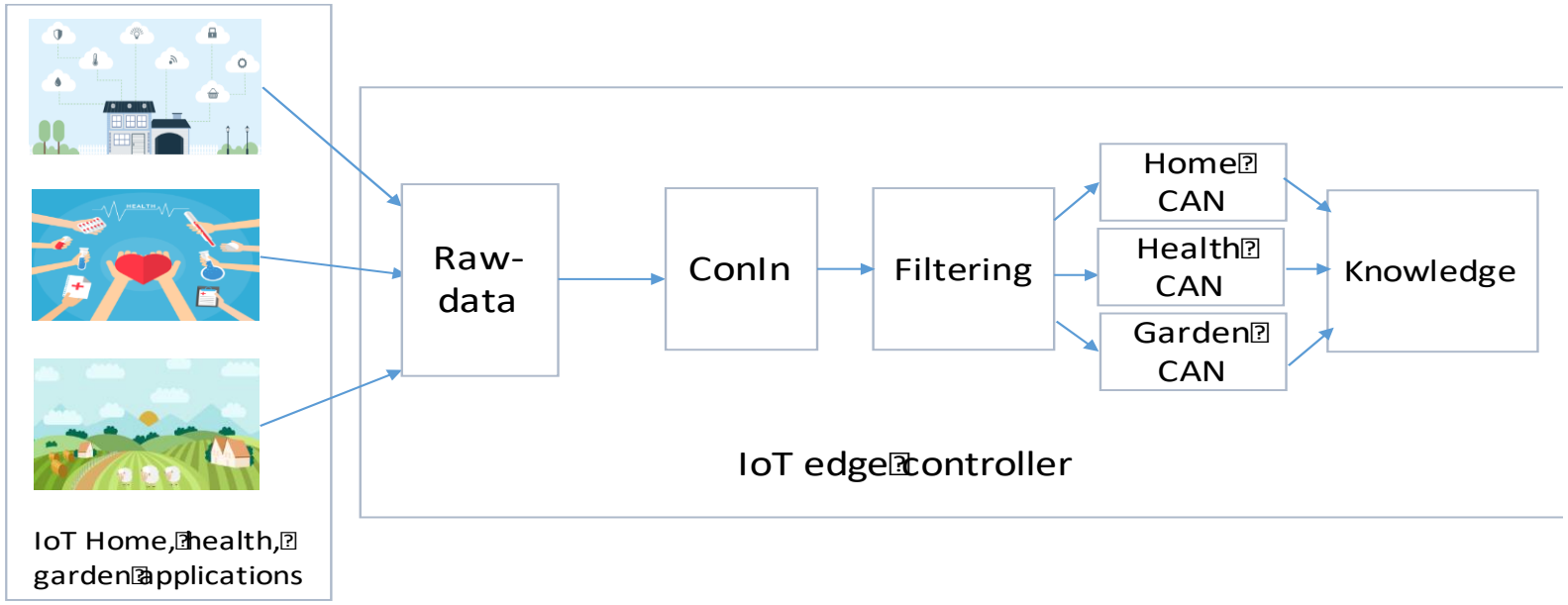
How?



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Distributed intelligence

- Decouple intelligence from cloud to the edge of IoT
- Apply intelligence on the small data at the edge and big data at the cloud

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Gateway or Controller

Gateway	Gateway manages underlying Things in terms of **connecting** and **collecting** data from Things
Controller	A gateway, in addition to gateway's capabilities, capable of providing **intelligence** and **reasoning** based on **collected** raw-data

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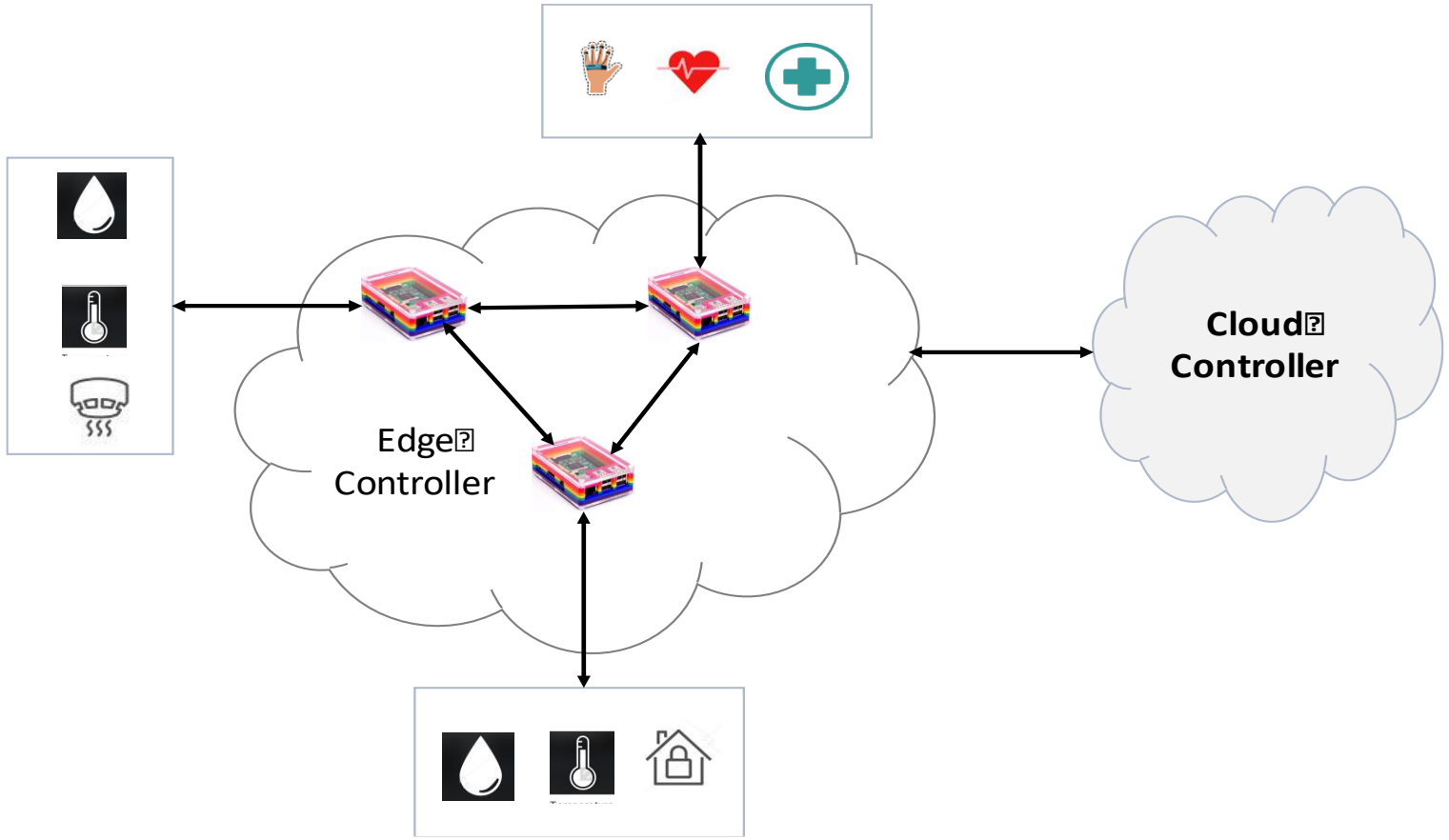
A way of distributed IoT computing



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Promise of Artificial Intelligence (AI) in IoT

- Relatively recent research, still in its infancy
- What is the relation between AI and IoT?
  - Short answer: in future (or already?), they will be inseparable
  - That does not really answer the question
  - Broad answer is too broad. ☺
  - IoT was designed for connecting physical object anywhere at anytime
  - Primary objective was to collect data, i.e., IoT provides data
  - The challenge is to act based on the collected data for intelligent decisions or actions
  - AI needs data, and more data!
  - In future, devices will talk to each other without human intervention
  - **AI would enable such vision**

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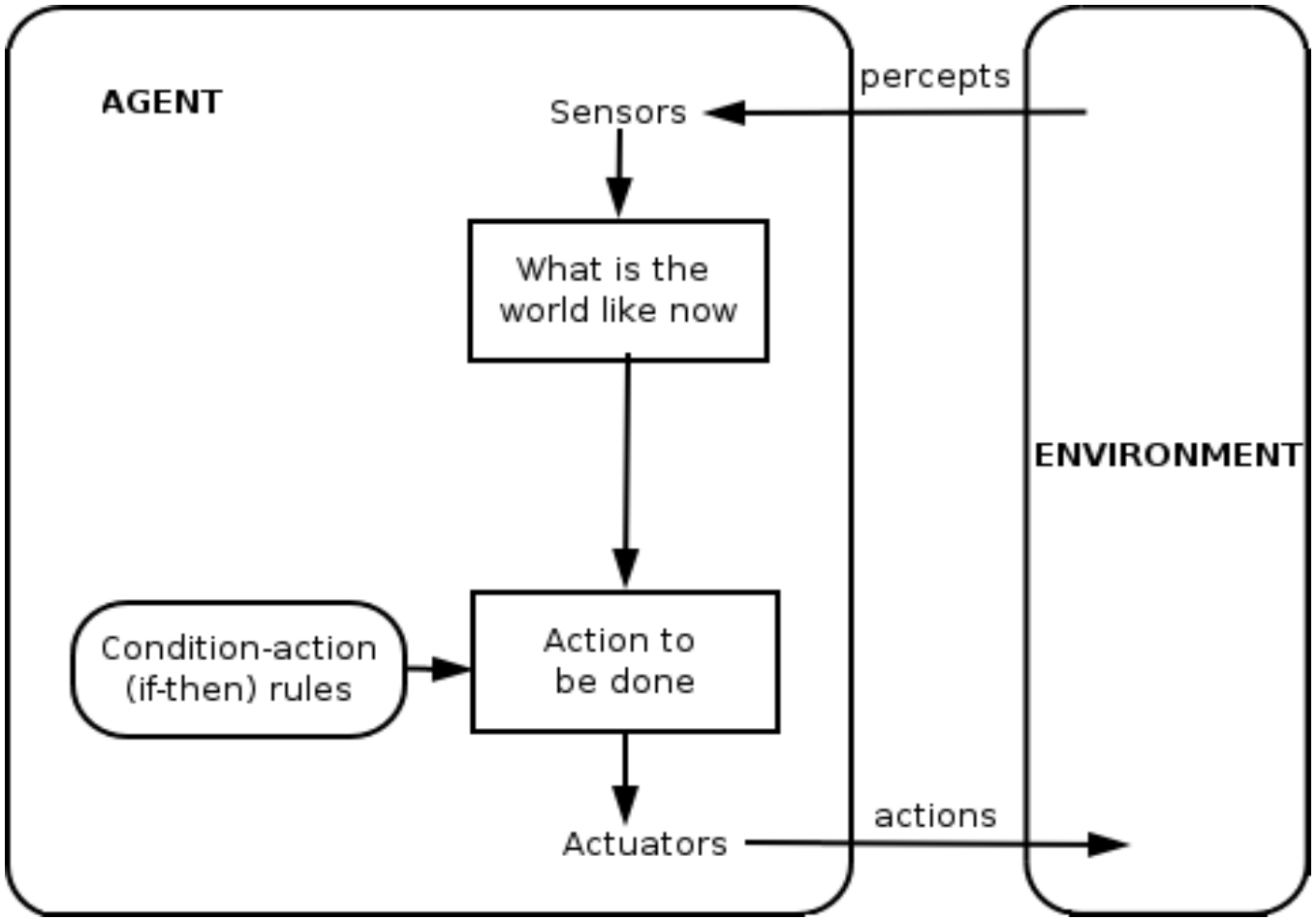
AI



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Which AI technique?

- Now another question is which of the AI techniques can be useful?
  - Biggest problem with most of the *Machine Learning*, i.e. AI techniques is that data is needed prior to implementation….
  - Hmmm, how can we get prior data in IoT even before implementing an IoT application?
- Bayesian or Belief network can help, so can reinforcement learning
- How?
  - Belief network allows statistical reasoning which can reduce dependency on rules-only reasoning
  - Belief can be updated based on **Reinforcement Learning** (**RL**)

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BN

- $$Pr\,(\mathrm{A}) = \sum_{i=1}^{n}(ß_{CI} *\ ß_{CIV})$$

- $$ß_{new} = (Pr > Ø)$$

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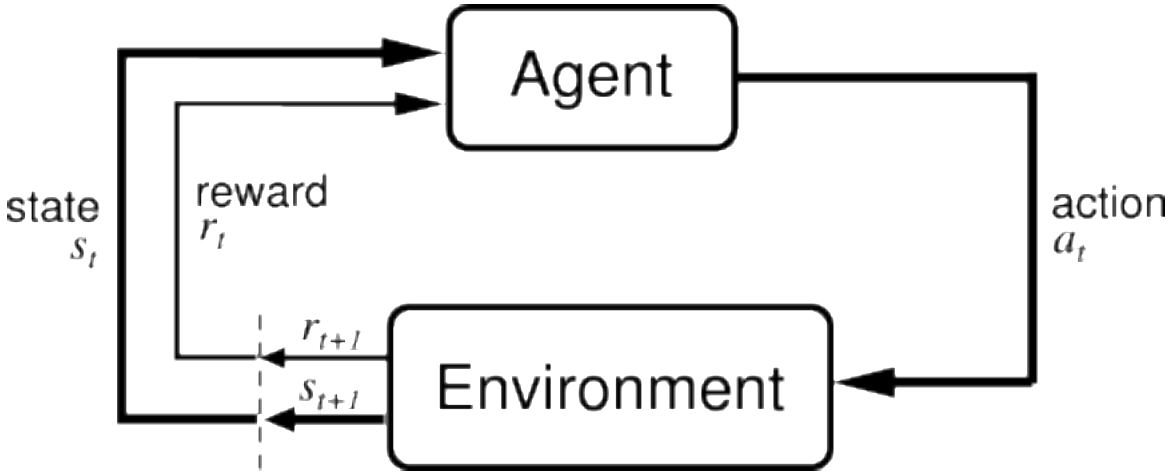
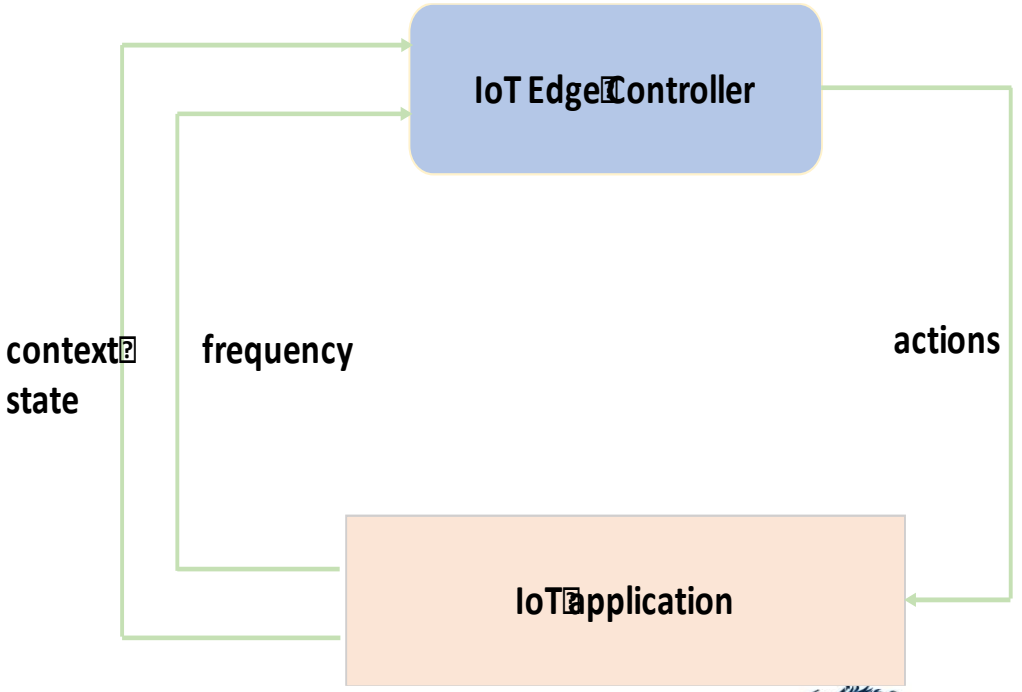
Bayesian reasoning for sprinkler activation

Temperature (0.1)	Rain (0.5)	Soil moisture (0.4)	Sprinkler
Low (0.2)	Low (0.6)	Low (0.65)	0.58
Low (0.2)	Medium (0.35)	High (0.1)	0.24
Medium (0.3)	High (0.05)	Medium (0.25)	0.16
High (0.5)	High (0.05)	High (0.1)	0.12
Medium (0.3)	Low (0.6)	Medium (0.25)	0.43
High (0.5)	Medium (0.35)	Low (0.65)	0.49

RL





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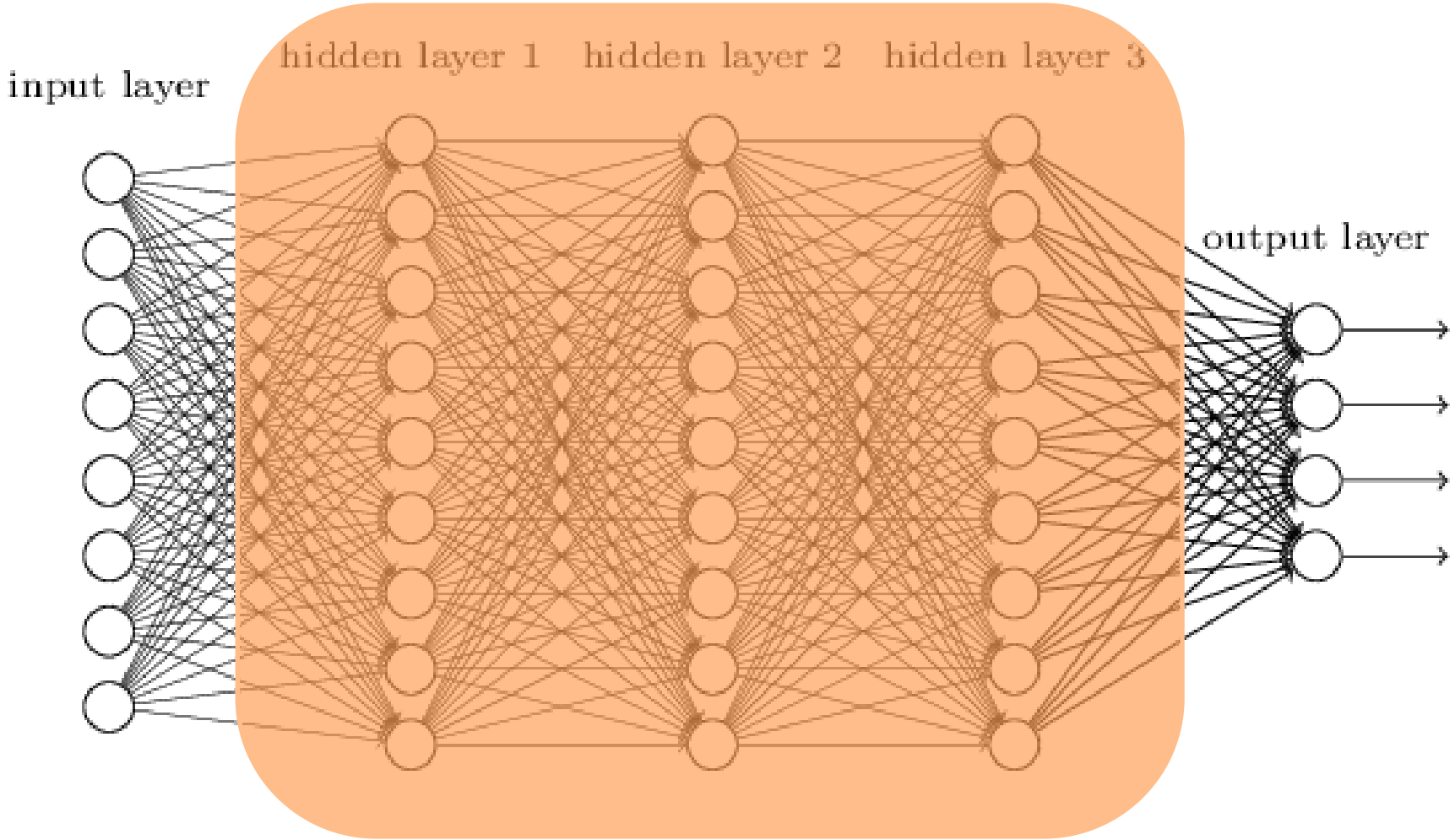
Deep learning

- Is part of machine learning- thereby AI
- Theory proposed in the 60s
- Lately due to increase in computational capabilities has become popular
- Consists of input, hidden and output layer

Picturizing DL



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DL

- Feedforward to get an outcome
- Find error margin: **error** = predicted value – actual value
- Backpropagation allows to minimise error and adjusts weights

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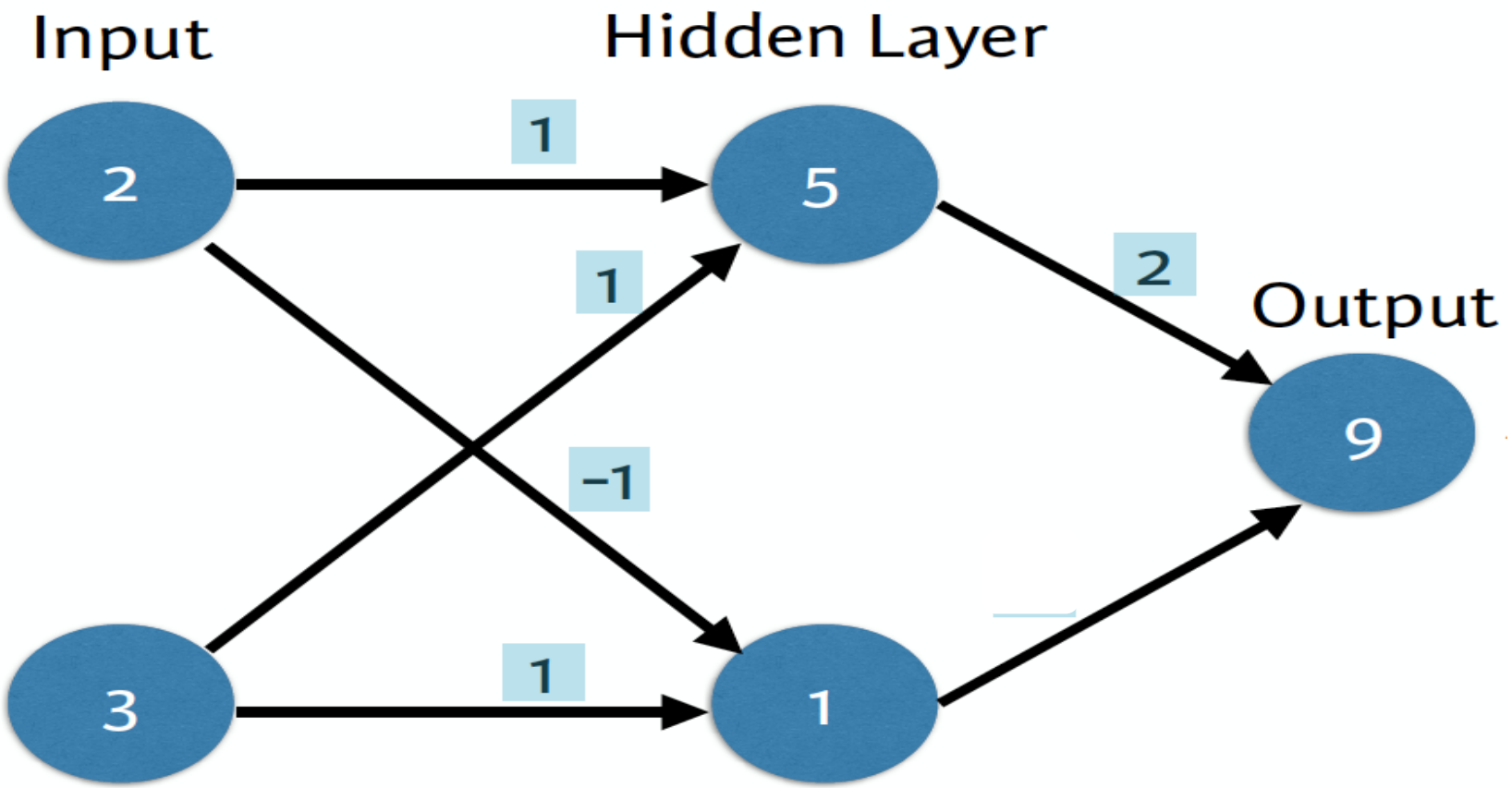
Forward propagation



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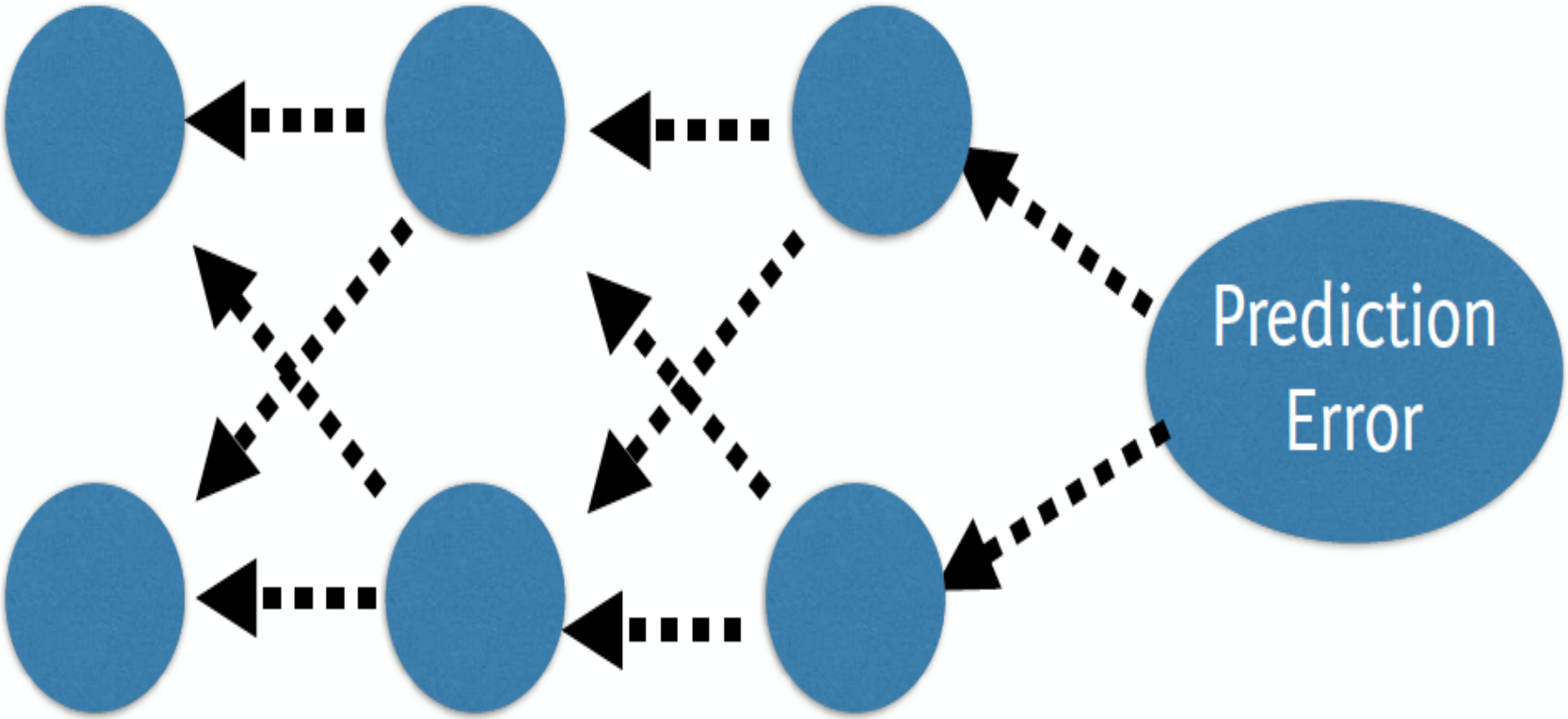
Backpropagation



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DL in IoT at the Edge

- Can help in classifying images, e.g., to detect symptoms
- Predict missing values
- Predict an outcome
- Finding pattern in sensory data
- Video image analysis: e.g.: drone capturing video images for manufacturing and detecting risks
- Plant growth analysis

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