Machine Learning for IoT

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Machine Learning

An algorithmic way of **making sense** (learning) from data.

Learning means Improving with Experience at some Task

Tom M. Mitchell: A computer program is said to learn from Experience E with respect to some Task T and some Performance measure P, if its performance on T, as measured by P, improves with experience E.

E: Energy Usage Dataset

T: Estimate the energy usage for tomorrow

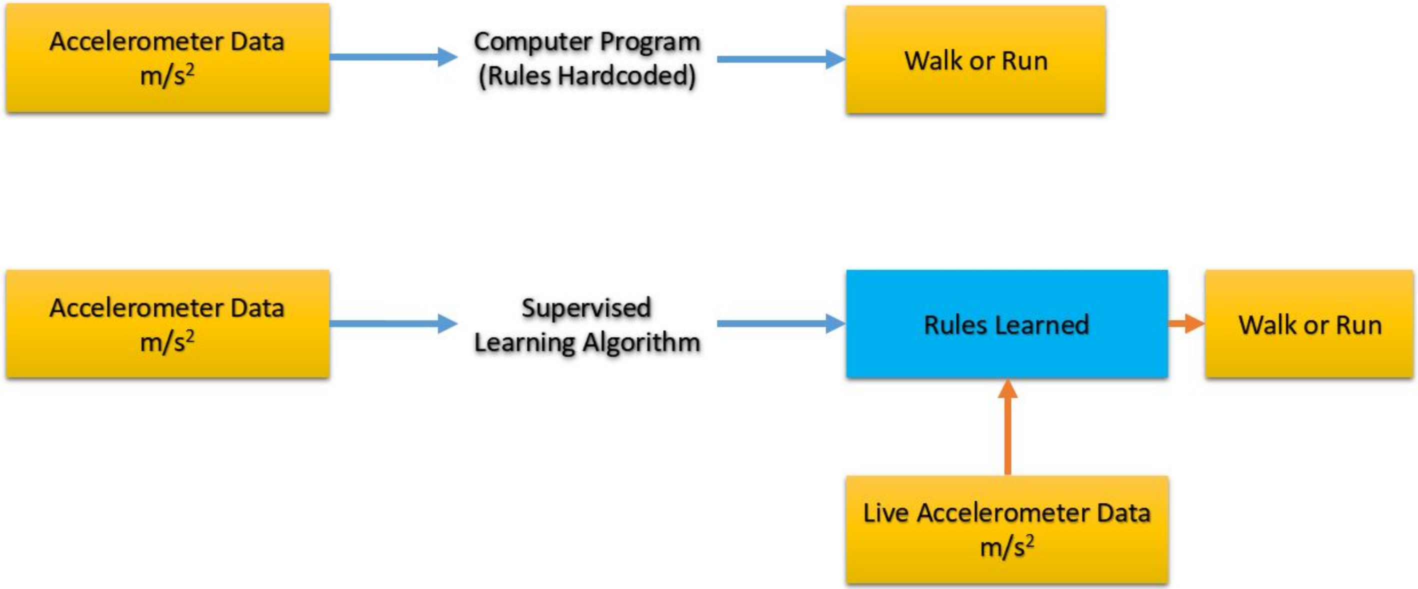
P: Accuracy of the predicted energy usage

Supervised Learning

Majority of practical ML uses supervised learning

Mapping function approximated from past experience

Example:



Machine Learning is an iterative process: Don’t expect it to work first time

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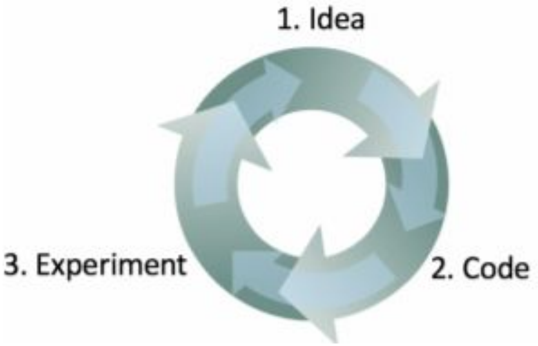
Andrew Ng (Co-Founder of Coursera and a former head of Google Brain) states that his approach to building machine learning software is threefold:



1. Start off with an idea
2. Implement the idea in code
3. Carry out an experiment to conclude how well the idea worked

   The faster you can go around this loop, the quicker progress will be made!

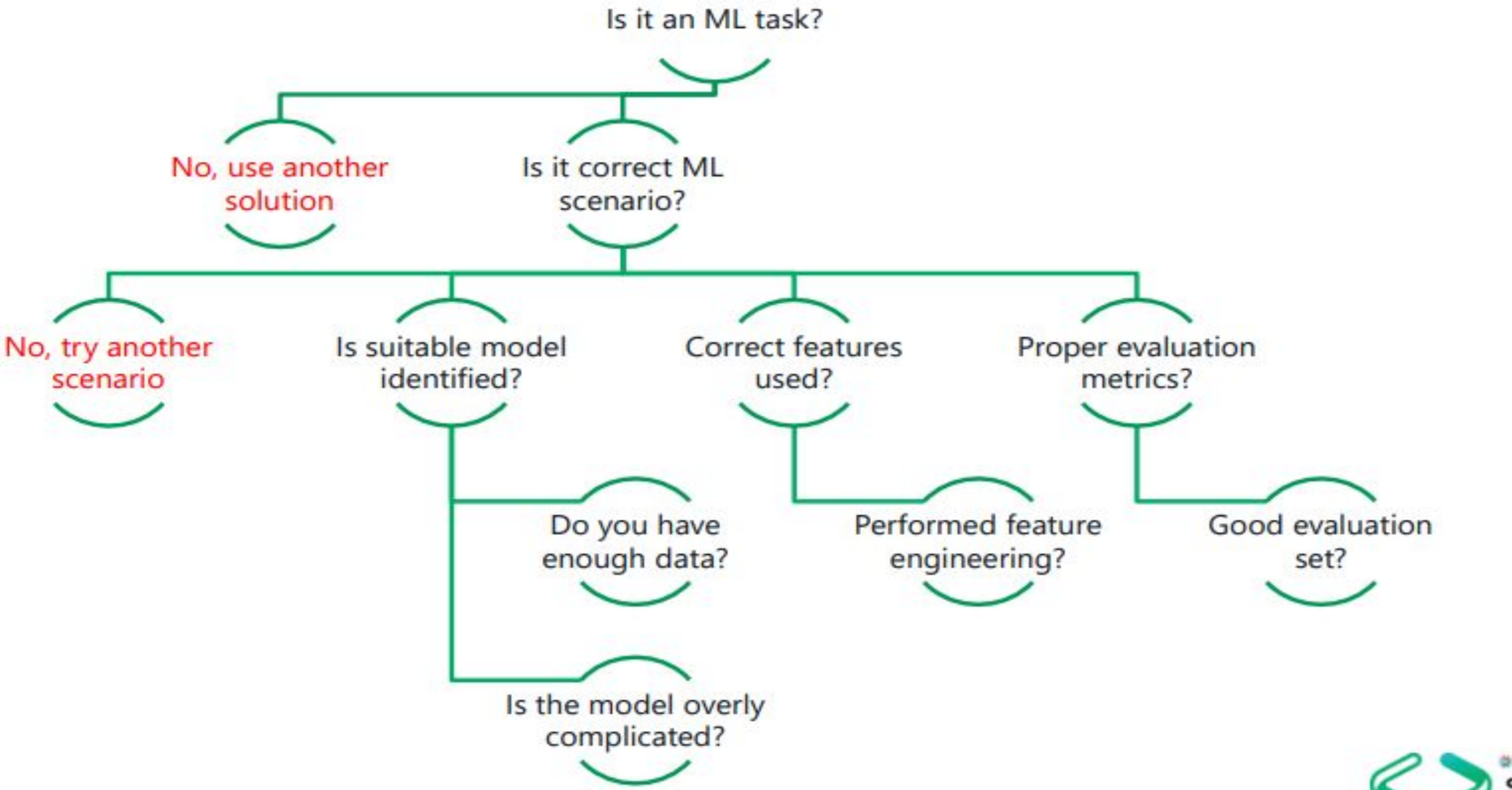
Do you need Math to work with ML?

Answer: It is not required, but would definitely help

Working around Math

- Select the right algorithm
- Choose parameter settings: Experiment
- Identify underfitting and overfitting: Compare training and validation scores

ML Decision Tree



ML Decision Tree

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1. Is it an ML task? Are you sure ML is the best solution?

- Hard: X is independent of Y: X , Height=?
- Easy: X is a set with limited variations. Configure Y=F(X)

2. Appropriate ML scenario?

- Supervised learning
- Unsupervised learning

ML Decision Tree

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3. Appropriate model?

- Data size (small data -> linear model, large data -> consider non-linear)

- Imbalanced data (special treatment of the minority class required)

4. Enough training data?

- Investigate how precision improves with more data

ML Decision Tree

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5. Model overly complicated

- Start simple first, increase complexity and evaluate performance
- Avoid overfitting to training set

6. Feature quality

- Have you identified all useful features?
- Use domain knowledge of an expert to start
- Include any feature that could be found and investigate model performance

ML Decision Tree

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7. Feature engineering

- The best strategy to improve performance and reveal important input
- Encode features, normalize [0:1], combine features

8. Combine models

- If multiple models have similar performance there is a chance of improvement
  - Use one model for one subset of data and another model for the other

ML Decision Tree

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9. Model Validation

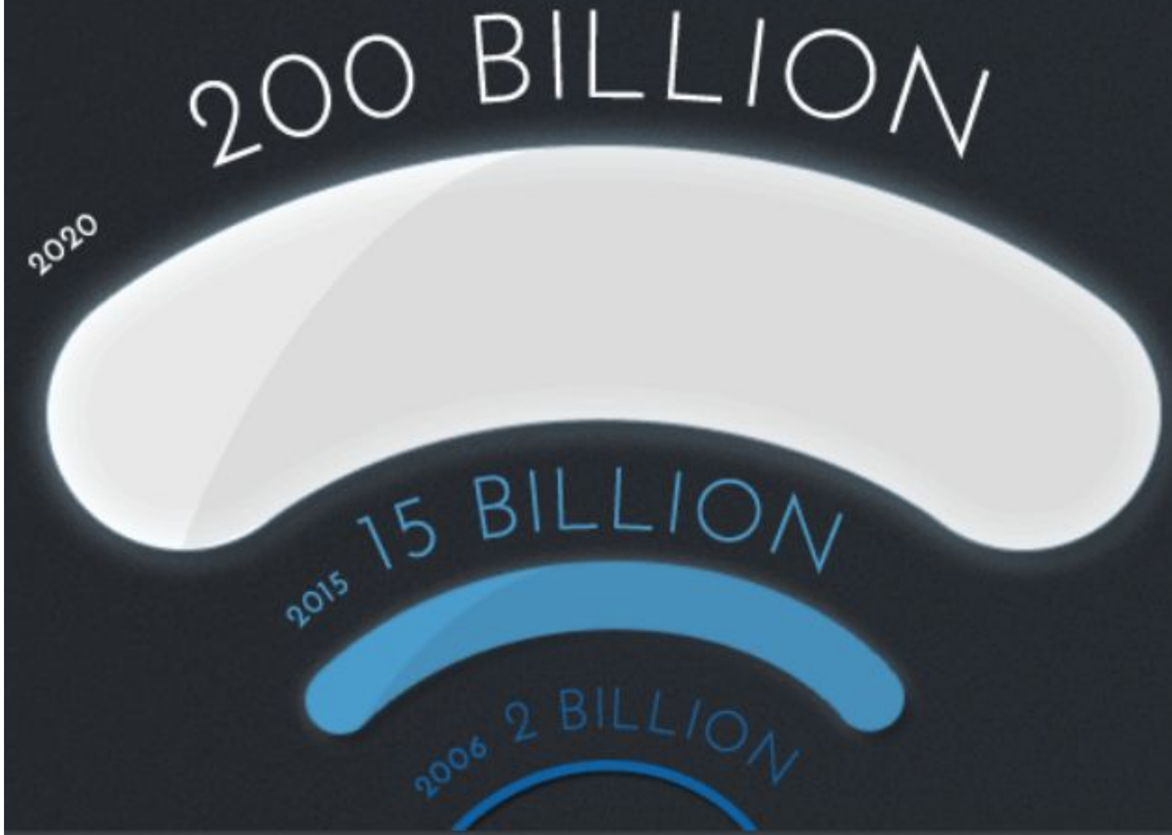
- Use appropriate performance indicator (Accuracy, Precision, Recall, F1, etc.)
- How well does the model describe data? (AUC)
- Data typically divided into Training and Validation
- Evaluated accuracy on disjoint dataset (other than training dataset)
- Tune model hyper parameters (i.e. number of iterations)

Internet of Things (IoT)

The Internet of Things (IoT) **integrates** billions of smart devices that can communicate with one another with minimal human intervention.

IoT technologies play a crucial role in enhancing several real-life smart applications that can improve life quality.

How Big IoT Market



The "Internet of Things" is exploding. It's made up of billions of "smart" devices--from miniscule chips to mammoth machines--that use wireless technology to talk to each other (and to us). Our IoT world is growing at a breathtaking pace--from 2 billion objects in 2006 to a projected 200 billion by 2020.

SOURCES: IDC, Intel, United Nations

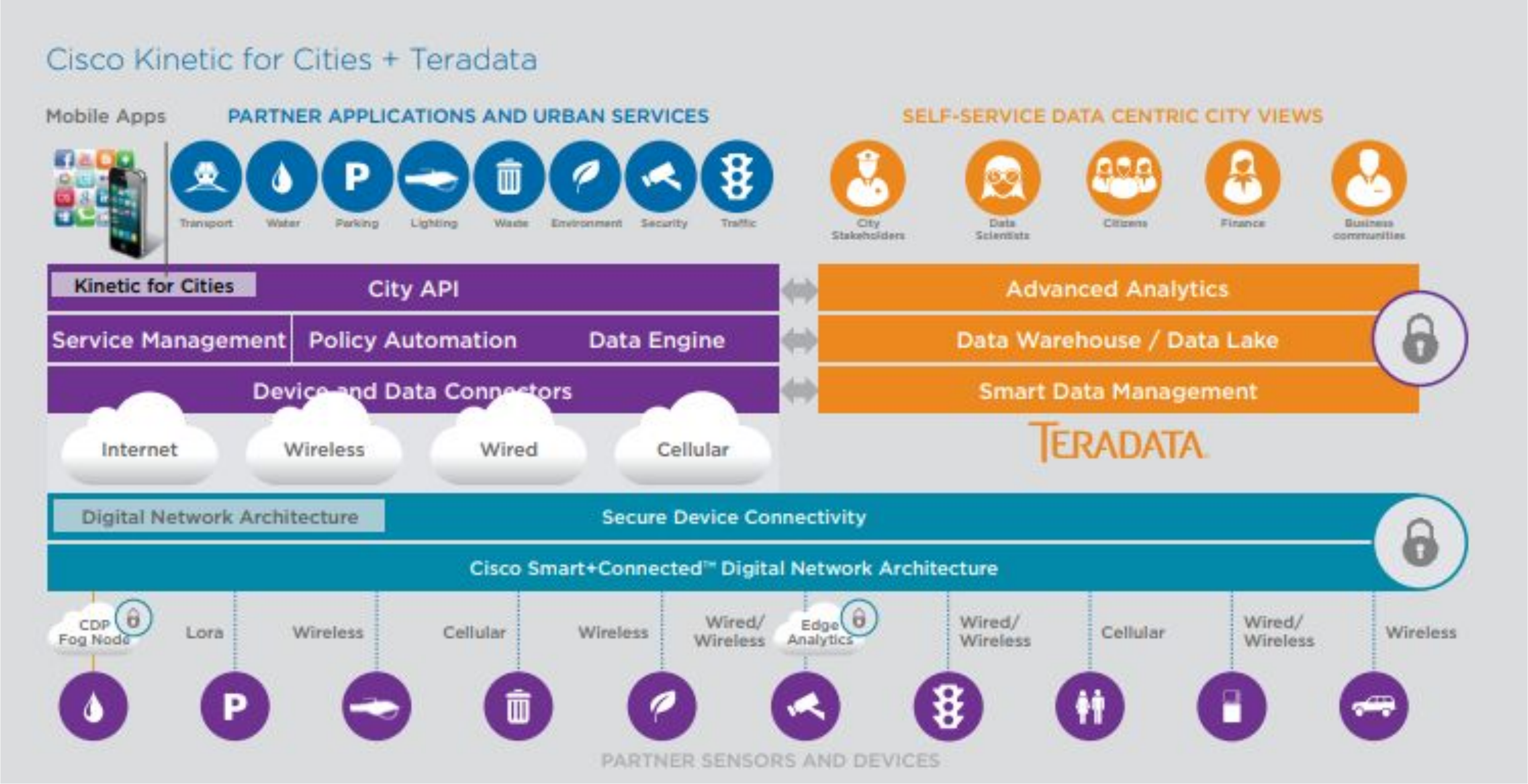
Big IoT Data

Volume of Data: Data gathered from traffic, health, and energy management applications would generate a sizable volume.

Velocity of Data: Frequency of GPS sensor updates is measured in seconds, while the frequency of updates for temperature sensors may be measured hourly.

Veracity of Data: Sensory data collected from heterogeneous sources

Frameworks developed by Cisco and Teradata



[Teradata and Cisco: Unlocking The Value of Data for Smart Communities]

tatacommunications.com/innovations/smart-cities

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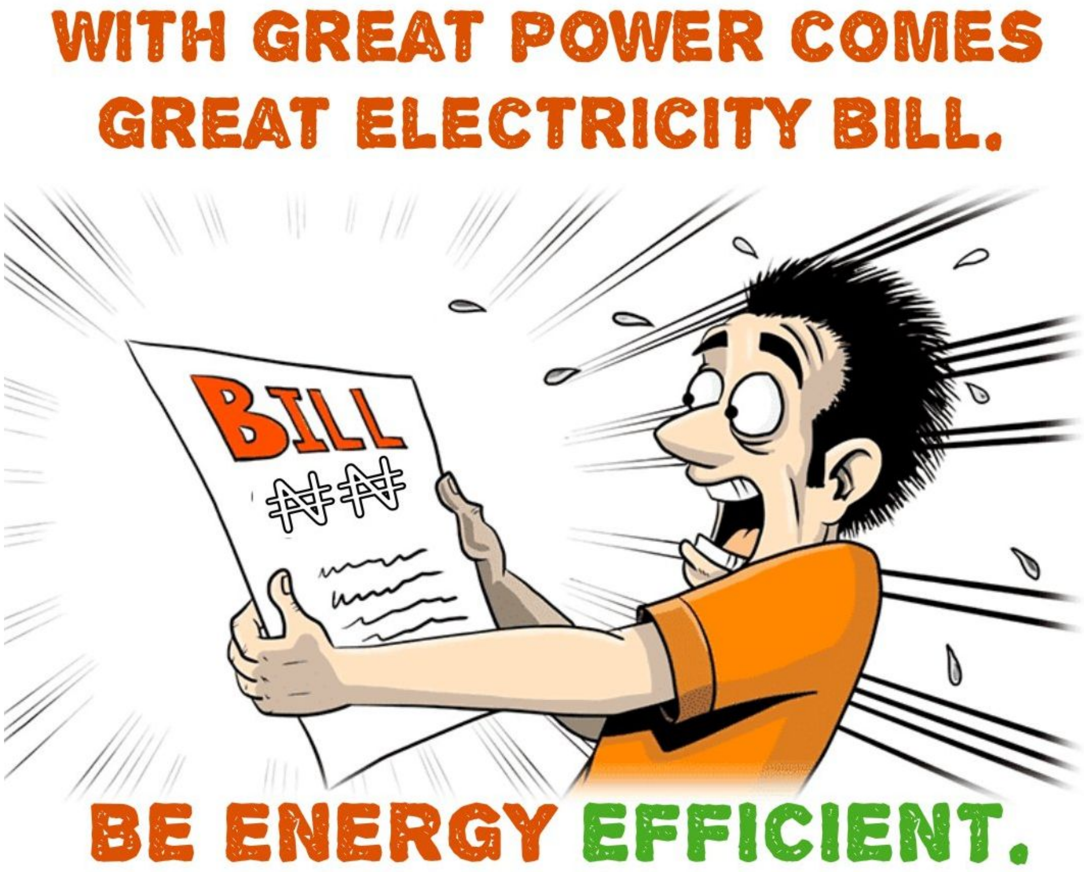


Image Source: https://twitter.com/stratagememc

ARTIFICIAL INTELLIGENCE

IS NOT NEW

ARTIFICIAL INTELLIGENCE

Any technique which enables computers to mimic human behavior

MACHINE LEARNING

AI techniques that give computers the ability to learn without being explicitly programmed to do so

DEEP LEARNING

A subset of ML which make the computation of multi-layer neural networks feasible

1950's 1960's 1970's 1980's 1990's 2000's 2010s

ORACLE

Deep Learning

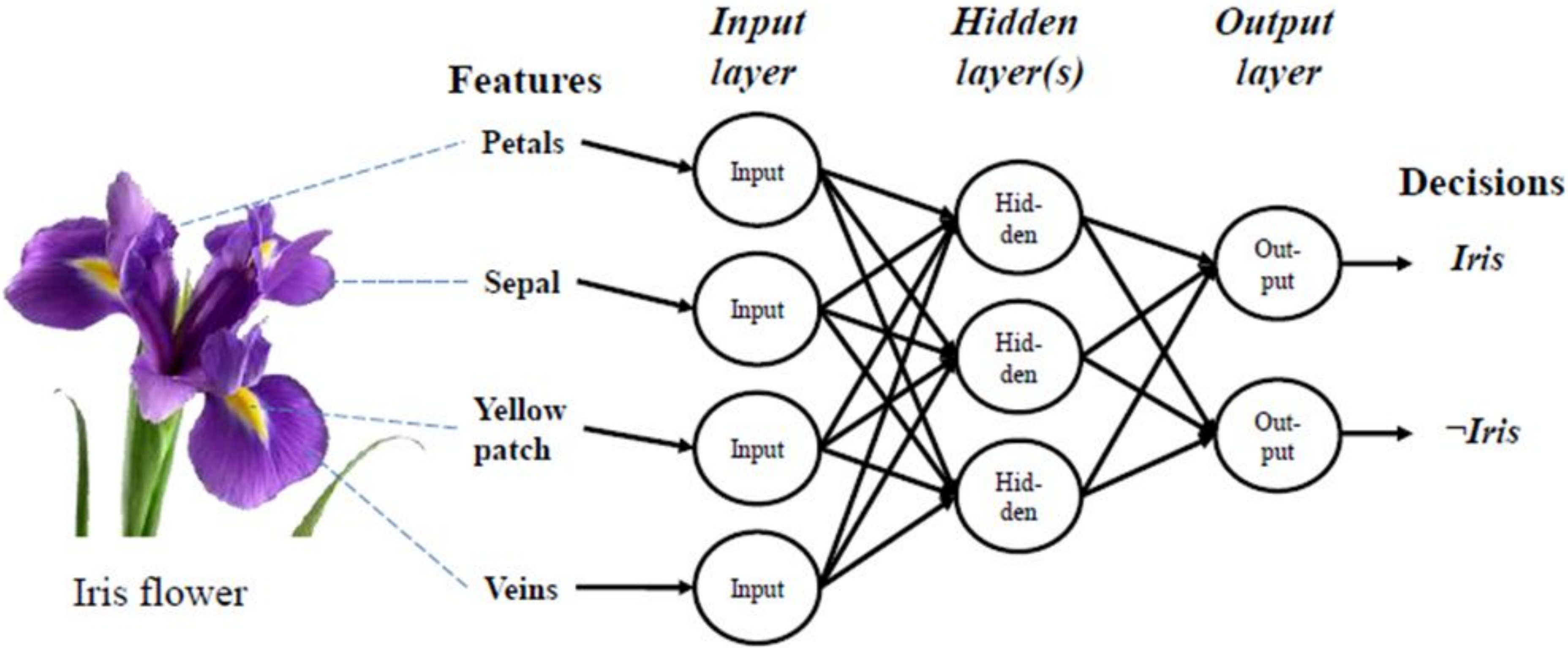
Neural Networks are considered universal function approximators

They can compute and learn any function

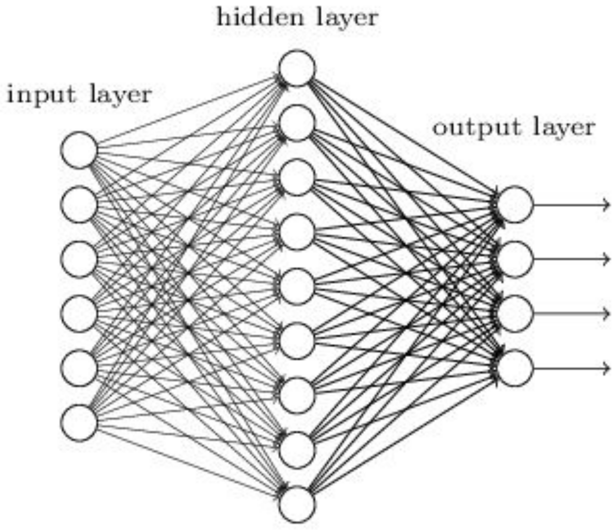
The neuron count has risen over the years to express more complex models.

More parameters efficiently learned using high computing powers.

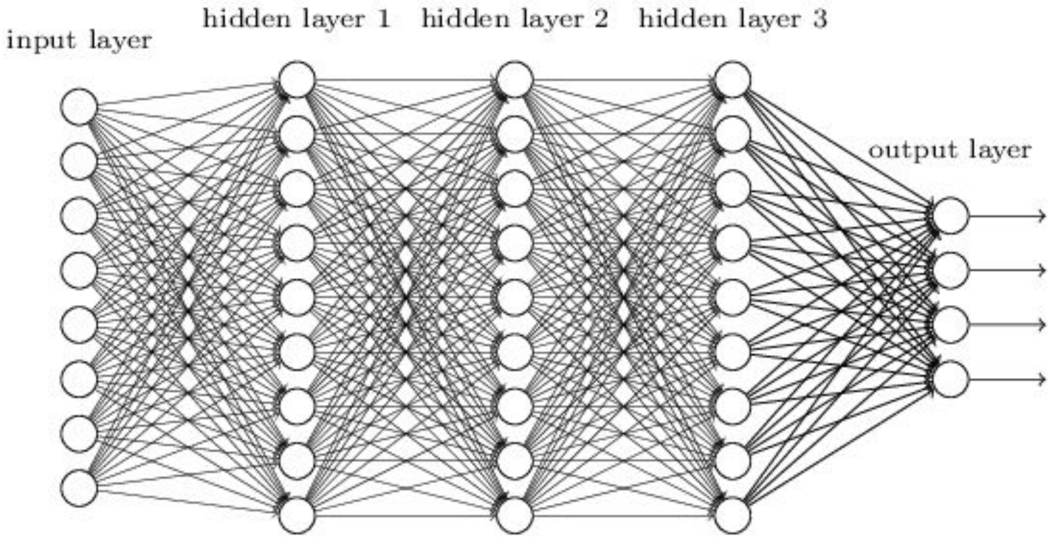
More connections means that our networks have more parameters to optimize, and this required the explosion in computing power that occurred over the past 20 years.


Features
Input layer
Hidden layer(s)
Output layer
Decisions
Petals
Sepal
Yellow patch
Veins
Input
Input
Input
Input
Hid-den
Hid-den
Hid-den
Out-put
Out-put
Iris
¬Iris
Iris flower

"Non-deep" feedforward neural network



Deep neural network



Core components

- Parameters
- Layers
- Activation functions
- Loss functions
- Optimization methods
- Hyperparameters

Sequence Data

When data is arranged so that each piece has some kind of relationship the pieces that come before and after.

Need a learning architecture that is explicitly designed to learn from sequential data.

Suppose that we have a sequence of temperature measurements over the course of a day.

We'd like to train the system to take four sequential measurements and predict the fifth

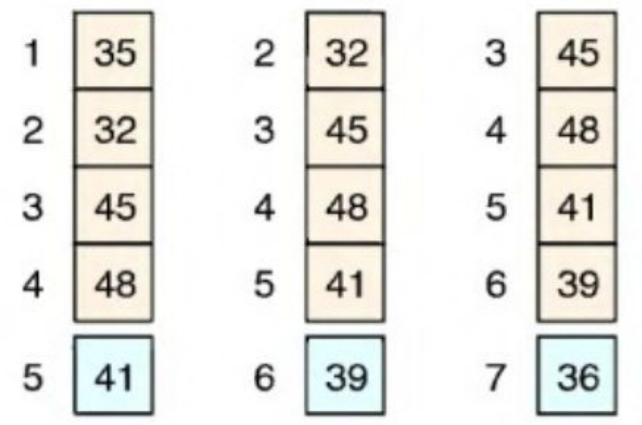
Windowed dataset

We can pack up the first four samples (let's just call them "values" for now) into one big combined sample.

The fifth value will be the target we want the network to predict for this sample.

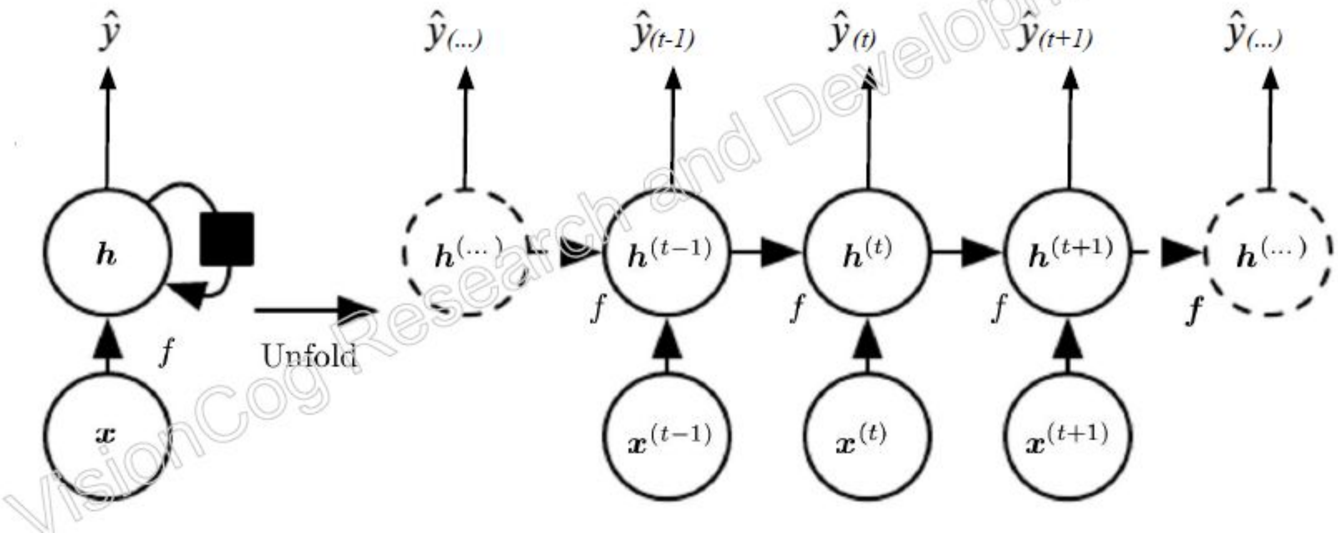
We're using a window of size 4 to create new, combined inputs for our network.

Overlapping windows: Each successive sample contains some of the values used in the previous sample



Recurrent Neural Networks

Recurrent neural network is a neural network that is specialized for processing a sequence of values x(1), ,x(τ).



Temporal dependencies

Analyzing temporal dependencies → Improved decisions

Frame 0	Frame 1	Frame 2	Frame 3	Frame 4
Stem: seen Petals: hidden	Stem: seen Petals: hidden	Stem: seen Petals: partial	Stem: partial Petals: partial	Stem: hidden Petals: seen

Frame 0	Frame 1	Frame 2	Frame 3	Frame 4
P(Iris): 0.1 *P(¬Iris)*: 0.9	*P(Iris)*: 0.11 *P(¬Iris)*: 0.89	*P(Iris)*: 0.2 *P(¬Iris)*: 0.8	*P(Iris)*: 0.45 *P(¬Iris)*: 0.55	***P(Iris)*: 0.9** *P(¬Iris)*: 0.1

Decision on sequence of observations

Limitations of RNN

Challenges related with BPTT is that the network will quickly encounter vanishing or exploding gradient problems

Suffer from short-term memory.

Network's limitation to learn long sequences.

Layers that get a small gradient update stops learning.

Those are usually the earlier layers, RNN’s can forget what it seen in longer sequences, thus having a short-term memory

Long Short-Term Memory (LSTM) cells

Cells are replaced with a modified version called as Long Short-Term Memory (LSTM) cells

Name captures - Short-term patterns are not forgotten in the long-term

Helps with learning long sequences.

Current accomplishments in training RNNs on a variety of problems are due to the use of LSTMs.

The key idea of LSTM is the cell state (in addition to the hidden RNN state)

Energy Usage Prediction using LSTM

https://github.com/sarithdm/iot