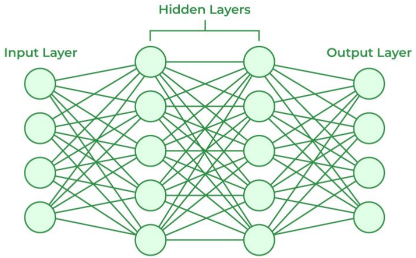
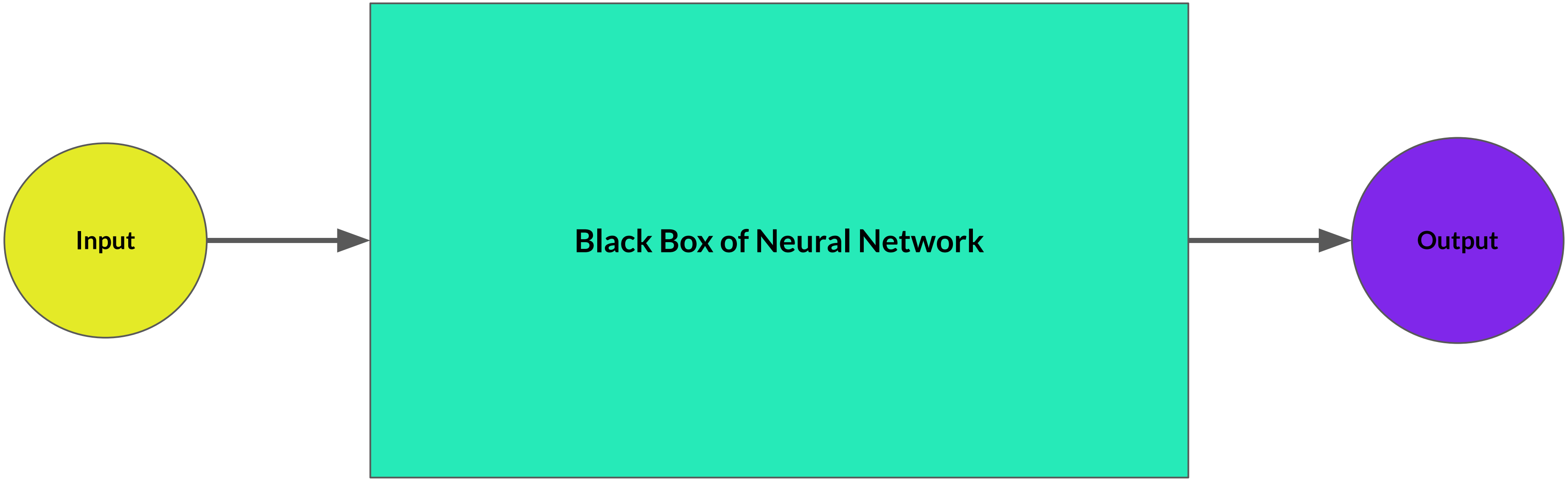
AGGIE DATA SCIENCE CLUB

Spring 2024
Neural Networks

www.aggiedatascience.com
Aggie Data Science Club
aggiedatascience

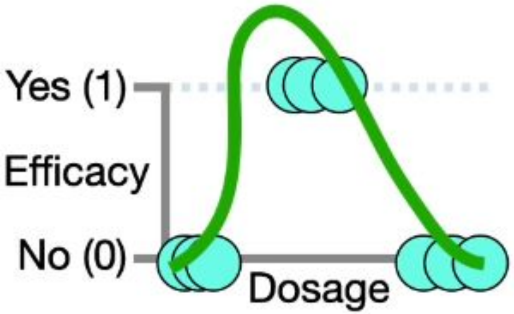
Quick Recap
On Neural Networks

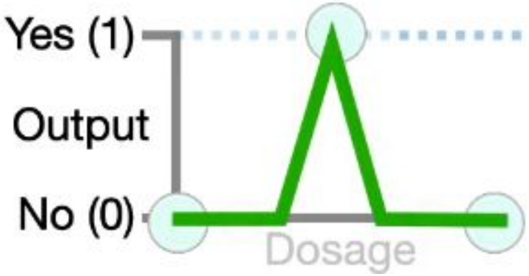



Input
Black Box of Neural Network
Output

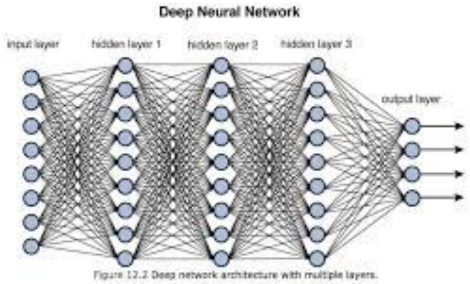
Why are NNs good?

- **Approximate ANY curve**
- **Learn hidden features**
    - Find underlying patterns in the data that are too complex for other models (non-linearity)
- ***Very good* results**
    - Because of the ability to fit very well

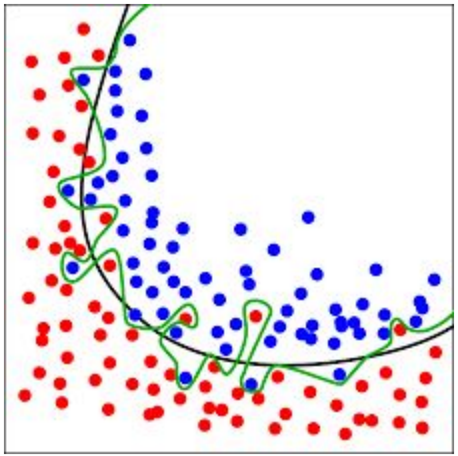




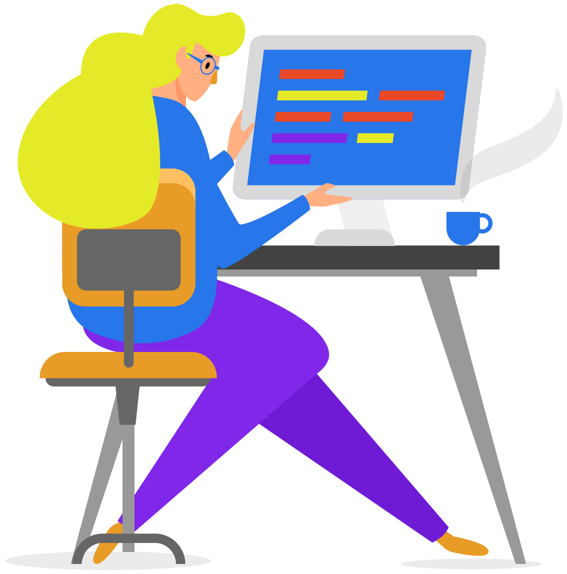
Risks of NNs



- **Need a LOT of data**
- **Lots of time/money/computing power to train**
  - More parameters = more computations = more time
- **Hyperparameter tuning is not easy**
  - many different options
- **Uninterpretable**
  - Bias and fairness implications in hidden features (black box)
- **Prone to overfitting**
  - You can continue training all the way to the exact dataset
  - The squiggle can get very, very complicated...



Overall Steps in a Neural Network Model



01

Feed Data

02

Making Predictions / Forward Propagation

Computations are performed on each layer of the neural network to make predictions. This process is often called a “black box” because the process in finding these outputs is complex and not completely known. Activation functions like ReLU (Rectified Linear Unit) or sigmoid are used to understand more complex relationships in the data. The output of each layer, after applying the activation function, is then passed to the next layer.

03

Back Propagation

Calculates gradients using chain rule, contains the partial derivatives of the loss function with respect to each weight and bias ($\partial L/\partial w$ and $\partial L/\partial b$). These partial derivatives indicate how much a small change in each parameter will affect the loss.

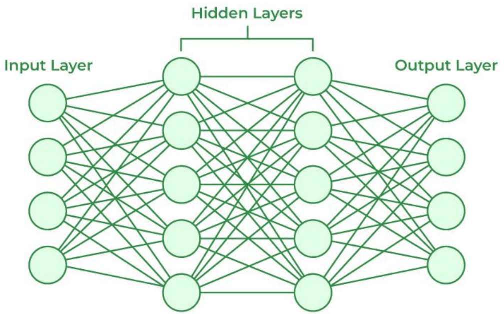
04

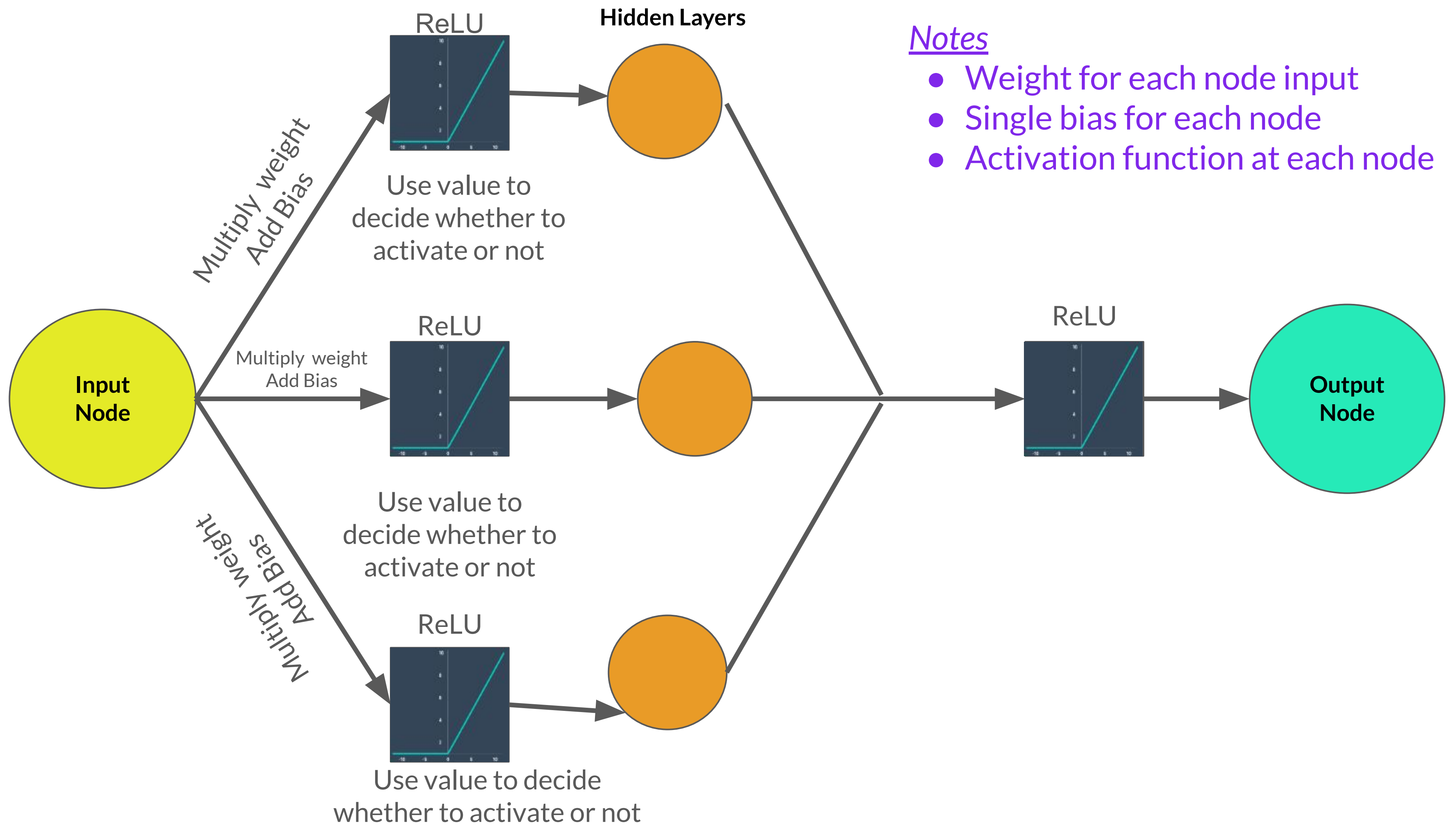
Gradient Descent

Once you have these calculated gradients from back propagation, we use gradient descent to determine learning rates and adjust weights and biases respectively

05

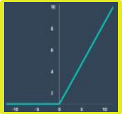
Repeat




Hidden Layers
Input Node
Multiply weight
Add Bias
ReLU
Use value to decide whether to activate or not
Multiply weight
Add Bias
ReLU
Use value to decide whether to activate or not
Multiply weight
Add Bias
ReLU
Use value to decide whether to activate or not
ReLU
Output Node
Notes
Weight for each node input
Single bias for each node
Activation function at each node

Activation Functions

There are many activation functions, but these are just a couple. Activation functions take the value calculated with the weight and bias from the previous node to decide whether a neuron should be activated or not. It helps us understand more complex relationships in data, which brings in the idea of non-linearity.



ReLU

- Commonly used
- Negative -> 0
- If result is positive, neuron is activated

Sigmoid

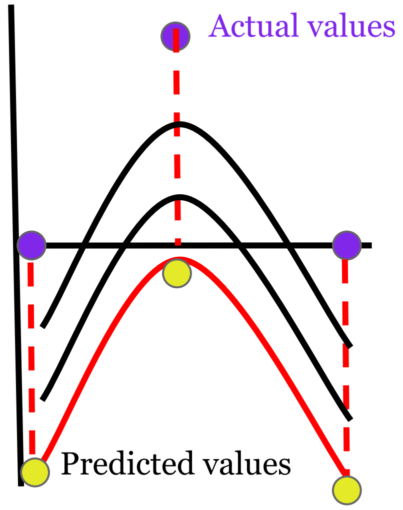
- Binary classification
- Think of it as 0 -> false, 1 -> true
- Drawback: vanishing gradient

Gradient Descent

Gradient Descent is a more effective way of minimizing loss functions to optimize values in the neural network such as weights and biases. The ultimate goal is to adjust the parameters so that the difference between target values and predicted values is smaller and therefore makes the model more accurate. We can understand the learning rate in order to more accurately and efficiently predict the curve.

Example of a Common Loss Function:

SSR = ∑(Observed - Predicted) ^2



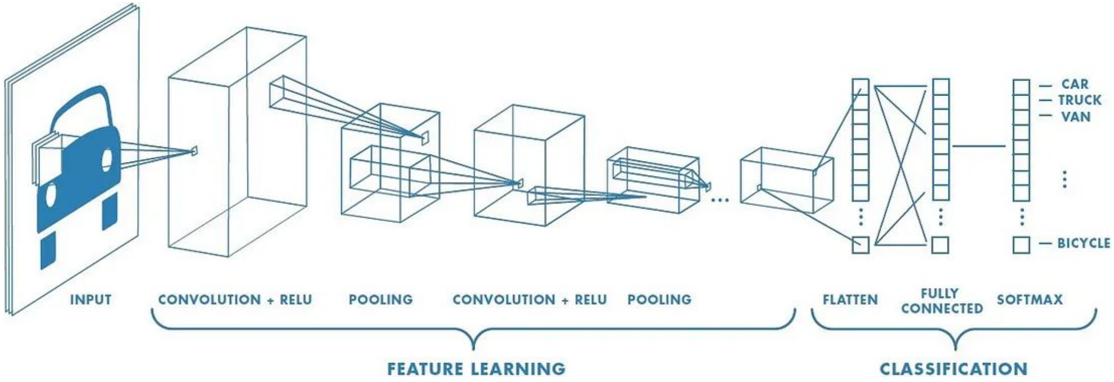
Backpropagation

- Starts at the output note and goes backwards and calculates the gradients
- Iteratively updates weights across all layers using gradient descent (and chain rule)
- Consists of continuous forward prediction and backward error propagation to predict values and update weights

Image Detection and Classification with Convolutional Neural Network (CNN)

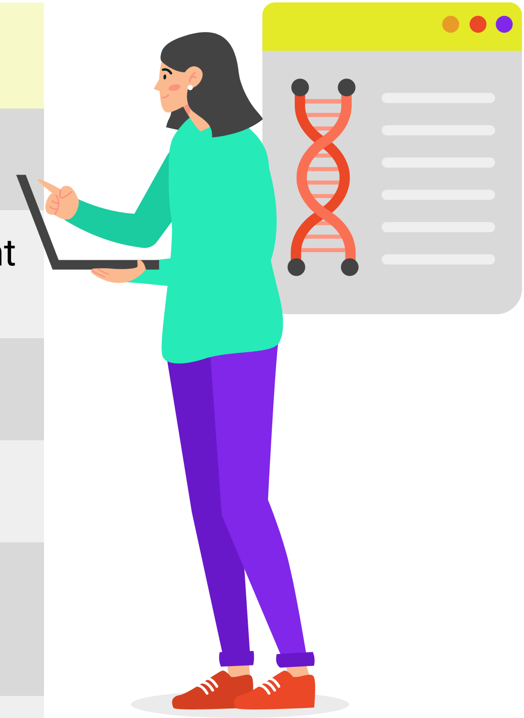
CNN Introduction

- ConvNet/CNN is a Deep Learning algorithm.
- Input Handling: It takes an input image to process.
- Functionality:
  - Assigns Importance: Applies learnable weights and biases to different parts of the image.
  - Object Differentiation: Differentiates between various aspects or objects within the image.
- Purpose: The network learns to recognize and differentiate elements within images, making it useful for tasks like image classification, object detection, and more.



CNN Use Cases

Use Cases	
Object Detection	Classifying fruit
Image Segmentation	Segmenting brain regions into different classes
Create Images	Generate images given a prompt
Video Analytics	Tracking objects in a video
Natural Language Processing	Text classification
Autonomous Systems	Self driving cars and lane detection



CNN Input layer

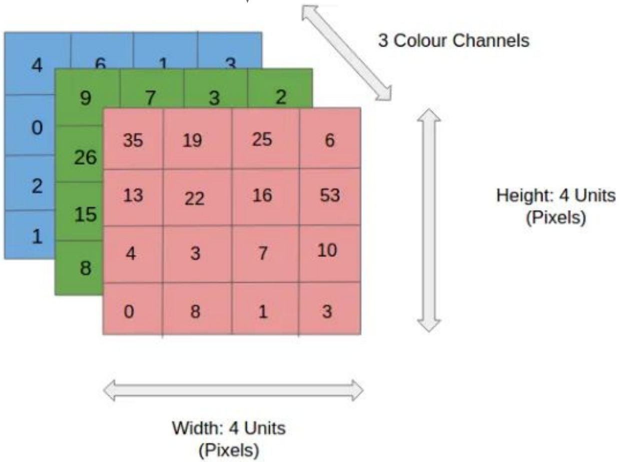
Input are typically

- RGB
- Grayscale

But can be

- HSV, CMYK, etc.

Converting the input into a matrix of these values makes it easier to compress and extract important features



CNN Kernel Layers

Image

- Height x Width x # of channels

Sliding kernel

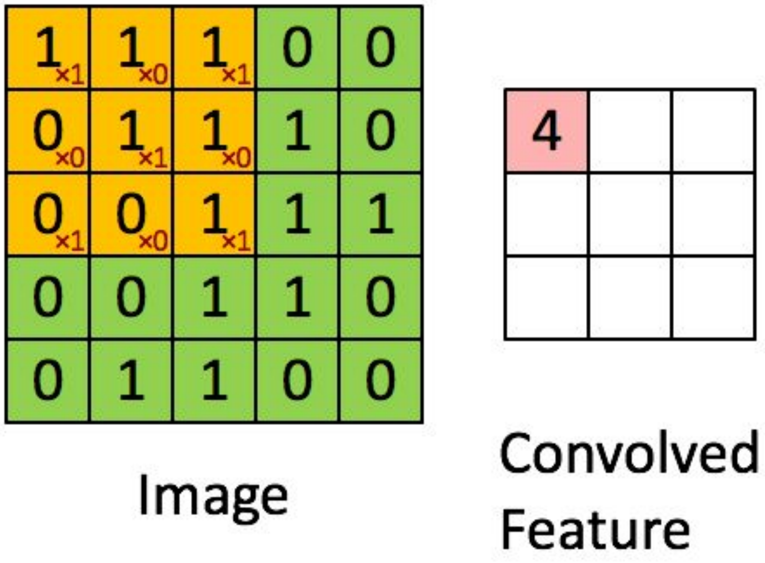
- Matrix of weight

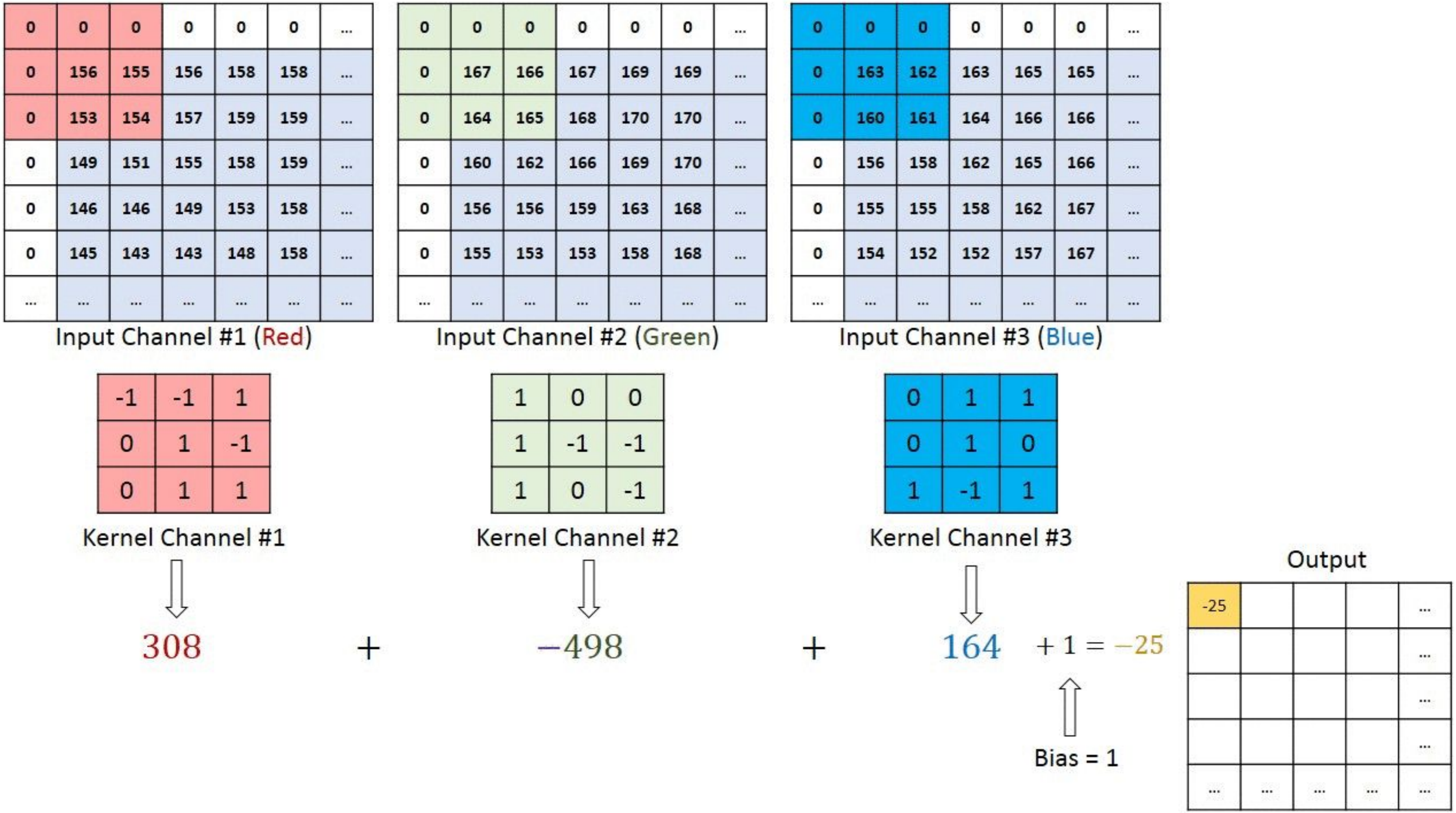
Stride

- How much the kernel will move

$$n_{out} = \left\lfloor \frac{n_{in} + 2p - k}{s} \right\rfloor + 1$$

n_{in}: number of input features
n_{out}: number of output features
k: convolution kernel size
p: convolution padding size
s: convolution stride size

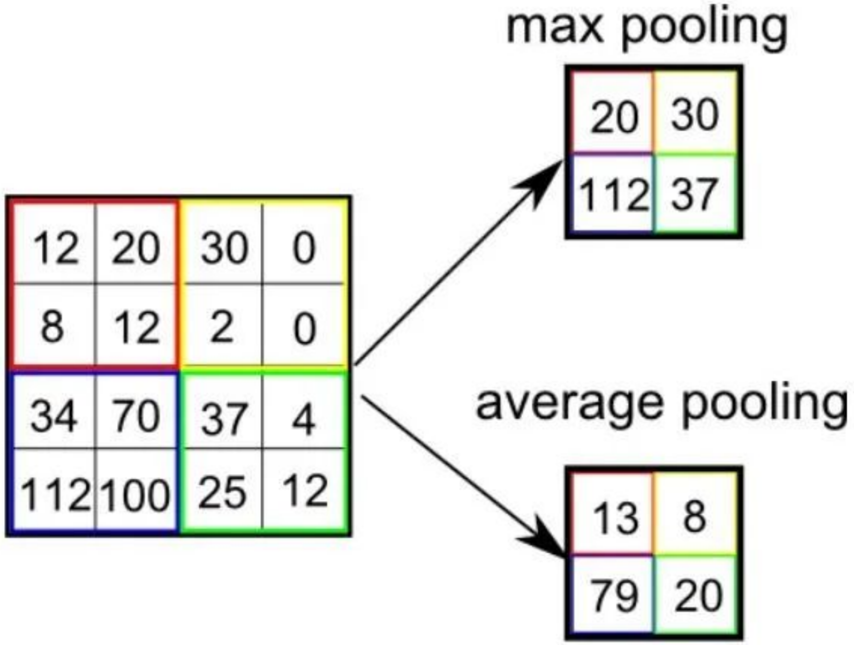




Input Channel #1 (Red)
Input Channel #2 (Green)
Input Channel #3 (Blue)
Kernel Channel #1
Kernel Channel #2
Kernel Channel #3
308
+
−498
+
164
+ 1 = −25
Bias = 1
Output
-25

CNN Pooling Layer

- Further reduced dimensions
  - More aggressive extractions
  - Better fit into next layer
- Max Pooling and Average Pooling



CNN Pooling Layer

Max Pooling

Strengths

- Finds the most prominent features
- More robust to noise
- Sharp edges

Weaknesses

- More focused

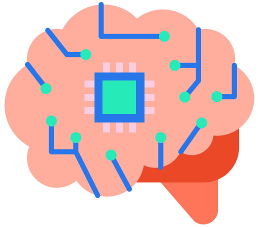
Average Pooling

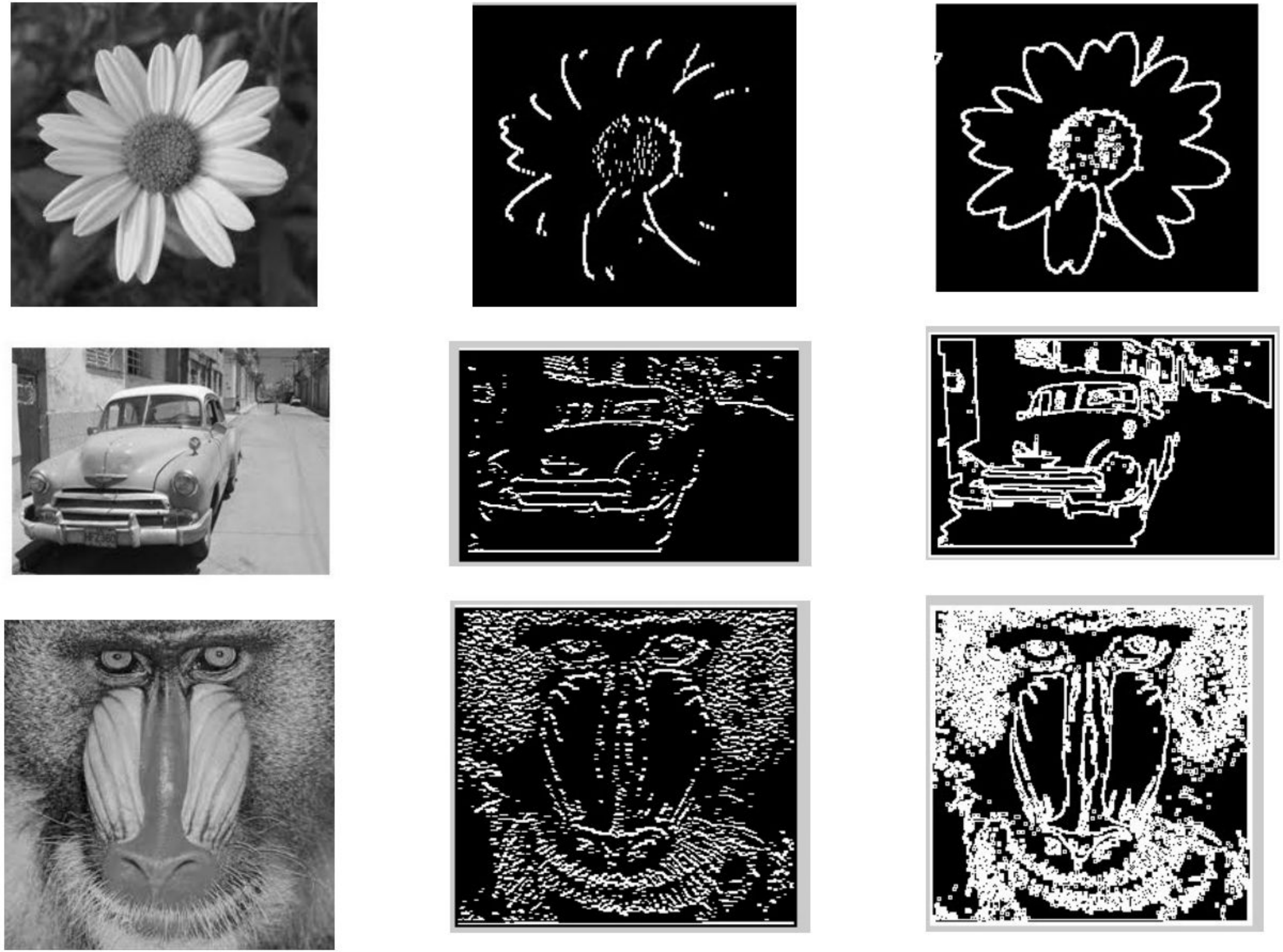
Strengths

- Distributes importance
- Prevents overfitting

Weaknesses

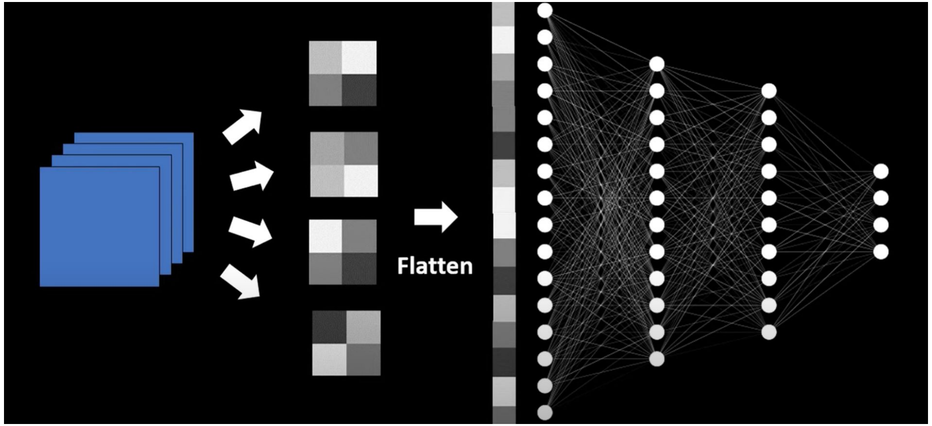
- Sensitive to noise



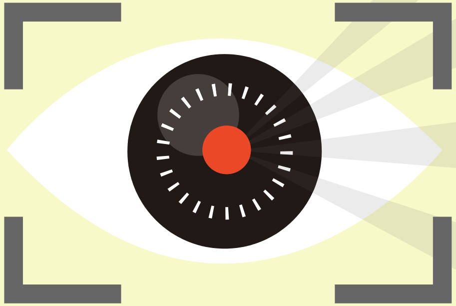


CNN Fully Connected Layer

- Previous layers process the inputs
- FC layer will make a decision based off the inputs
- Applied after convolutional and pooling layers
- Flatten the input into a column vector to be used as input
    - After weights and biases are updated
    - Fed into the activation function



Premade CNNs



AlexNet

5 convolutional layers
3 fully connected layers

VGG

Good for computer vision tasks

Inception

Developed by Google.
Very detailed

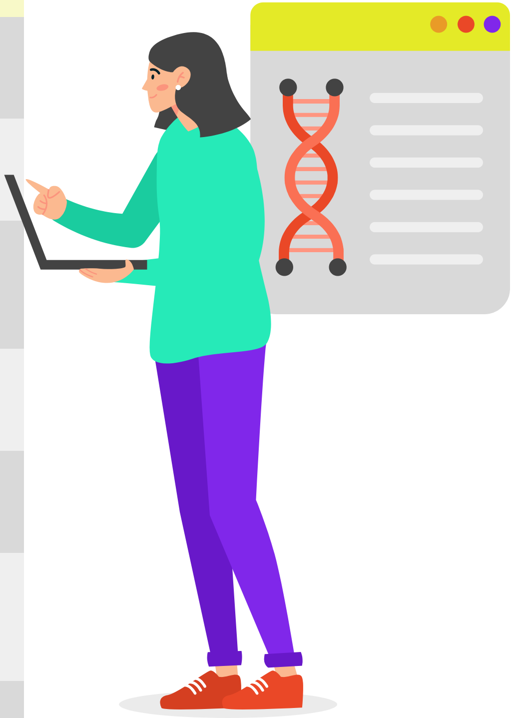
MobileNet

Designed for mobile or resource constrained environments

Sequential Data Processing with Recurrent Neural Networks (RNN)

RNN Use Cases

Use Cases	
Speech Recognition	Detecting different voices
Language Modeling	Generating text given a prompt
Image Summarization	Generate image descriptions / tags given a prompt
Text Summarization	Summarizing a block of text
Time Series	Predicting which stocks will do well
Video Tagging	Generates hashtags given a video or tiktok
Audio Processing	Recognize patterns in music or voice recordings based on context



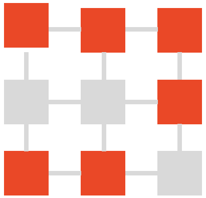
How do we deal with complex forms of data?

01

Sequential

Cyclical patterns due to time or language

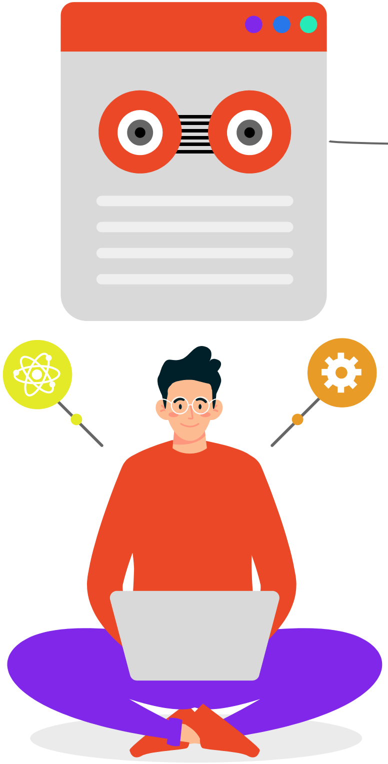
02



Visual

Images where groups of pixels represent features

Unlike NNs, Recurrent NNs use multiple inputs



Output

Used for output and dependencies

Input Value

Same as standard NN

Past Dependencies

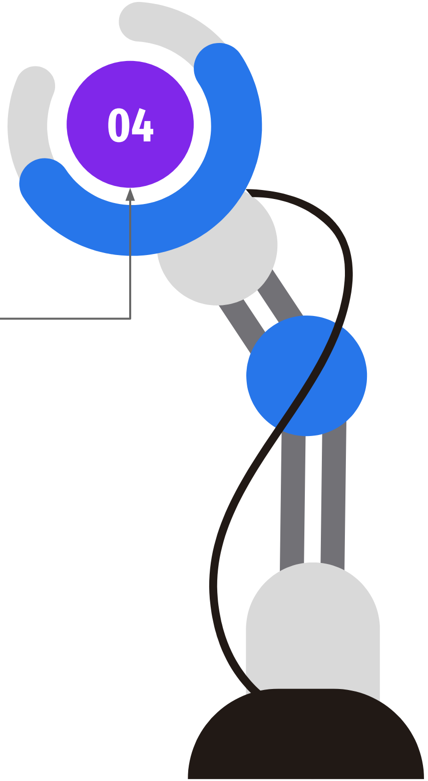
Previous outputs of NN

Hierarchy of Sequential Data ML

Machine learning
Saturn is the gas giant that has rings

Transformers

More scalable with parallel computing



LSTM

Long-Short Term Memory for long-term dependencies

03

RNN

Handles sequential data with varying input

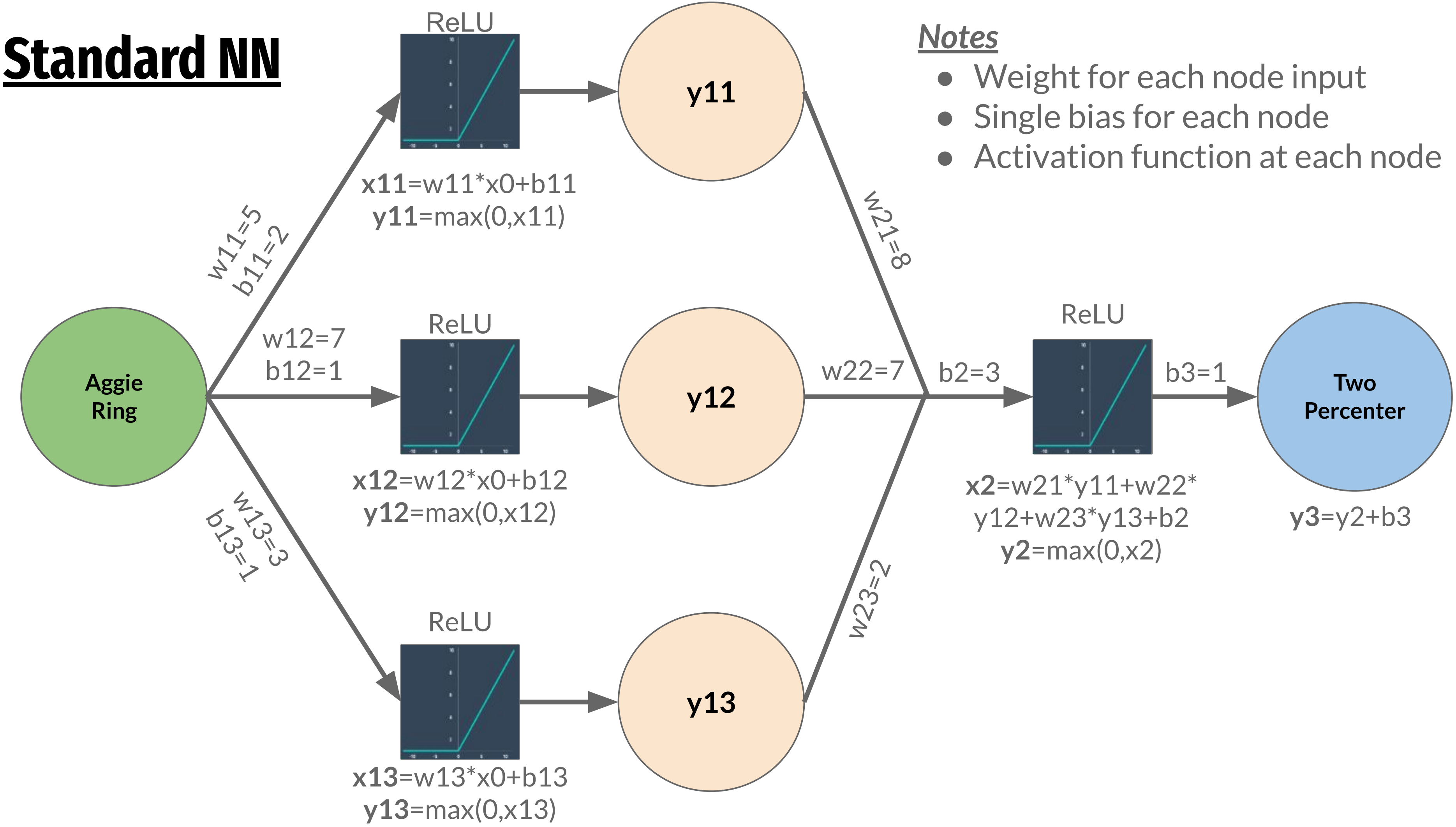
02

Neural Networks

Basic input-output algorithm

01

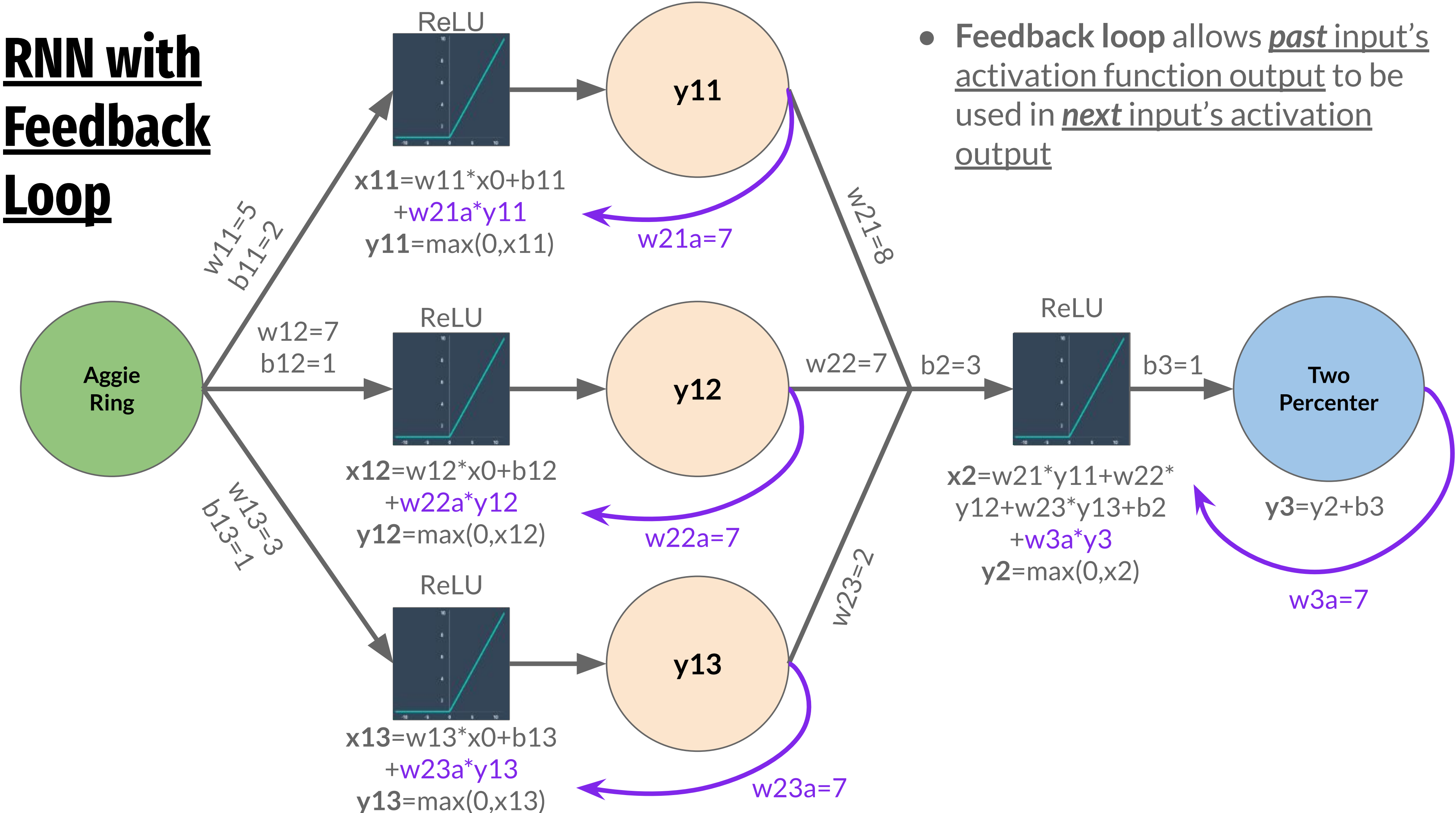
Standard NN



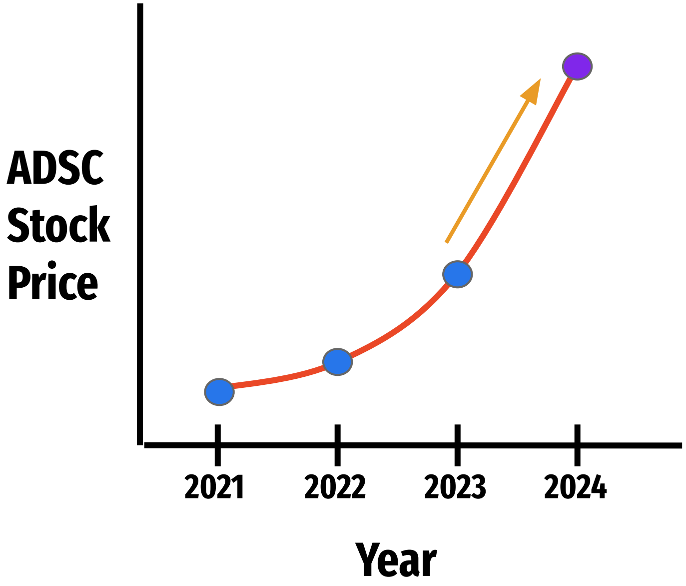
Notes
- Weight for each node input
- Single bias for each node
- Activation function at each node

RNN with Feedback Loop

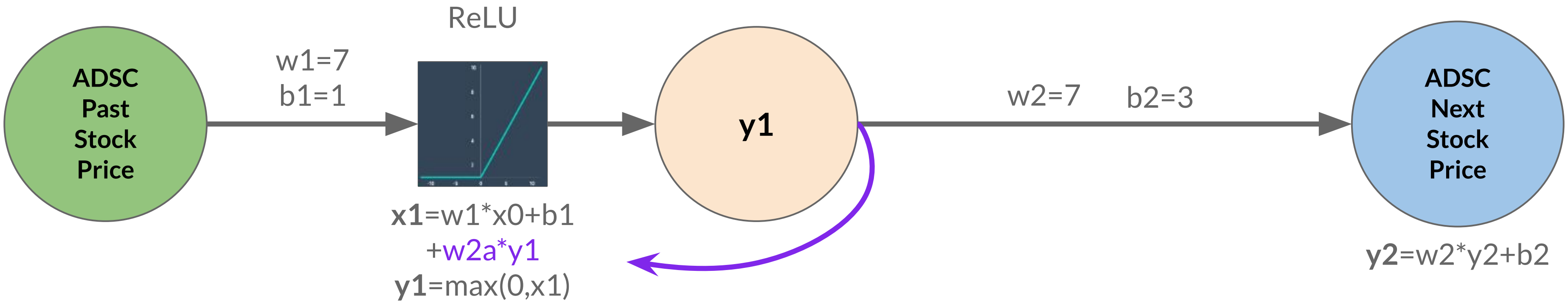
- **Feedback loop** allows ***past*** input's activation function output to be used in ***next*** input's activation output



Simplifying RNN with Stock Example

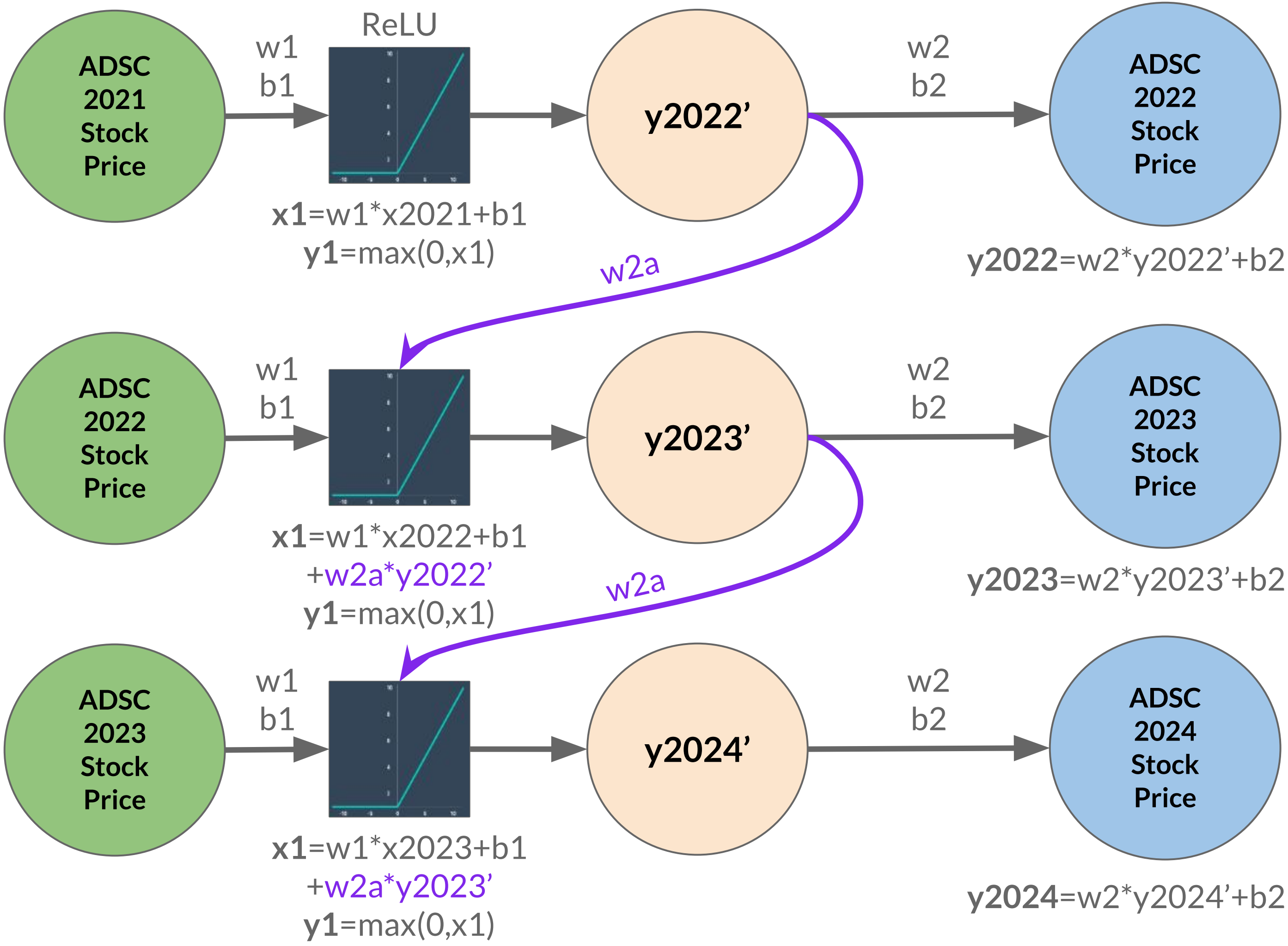


- **ADSC** stock price has been *steadily increasing* over the past 3 years
- Based on the ***context***, we can assume the stock price will **continue to increase next year**
- Data points are <u>not independent</u> of each other



Unrolling RNN with ADSC Stock 📈

- *Previous year's output* is used in calculation of *current year's output*
- Past outputs funneled into **summations**
- Notice that the **same weight** is used for each feedback loop



Why are basic RNNs not used very often?

Weaknesses of RNNs

01 Vanishing Gradient

The more we unroll, the harder it is to train the NN **if the weights are large (Input * 0.5^2)**

02 Exploding Gradient

The more we unroll, the harder it is to train the NN **if the weights are small (Input * 2^2)**

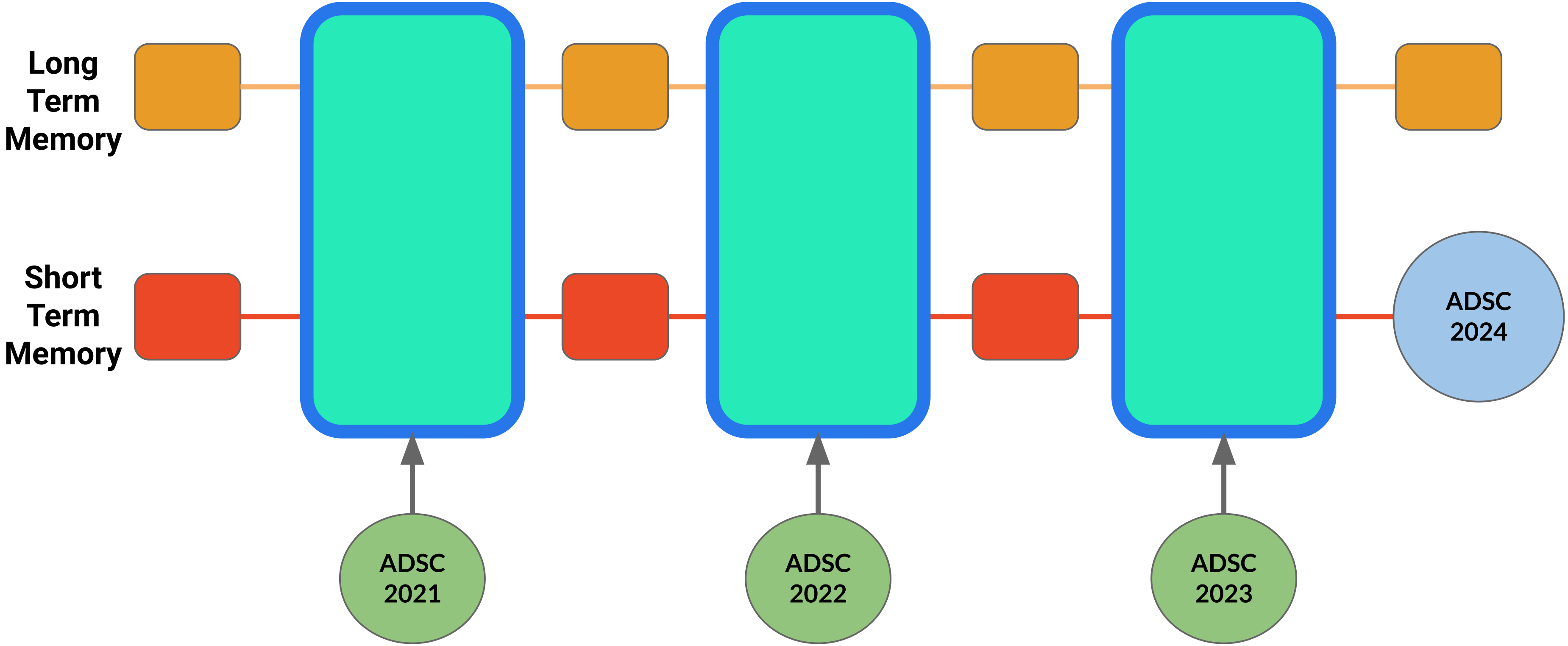
03 Loses Long-Term Dependencies

The more we unroll, the more context we lose

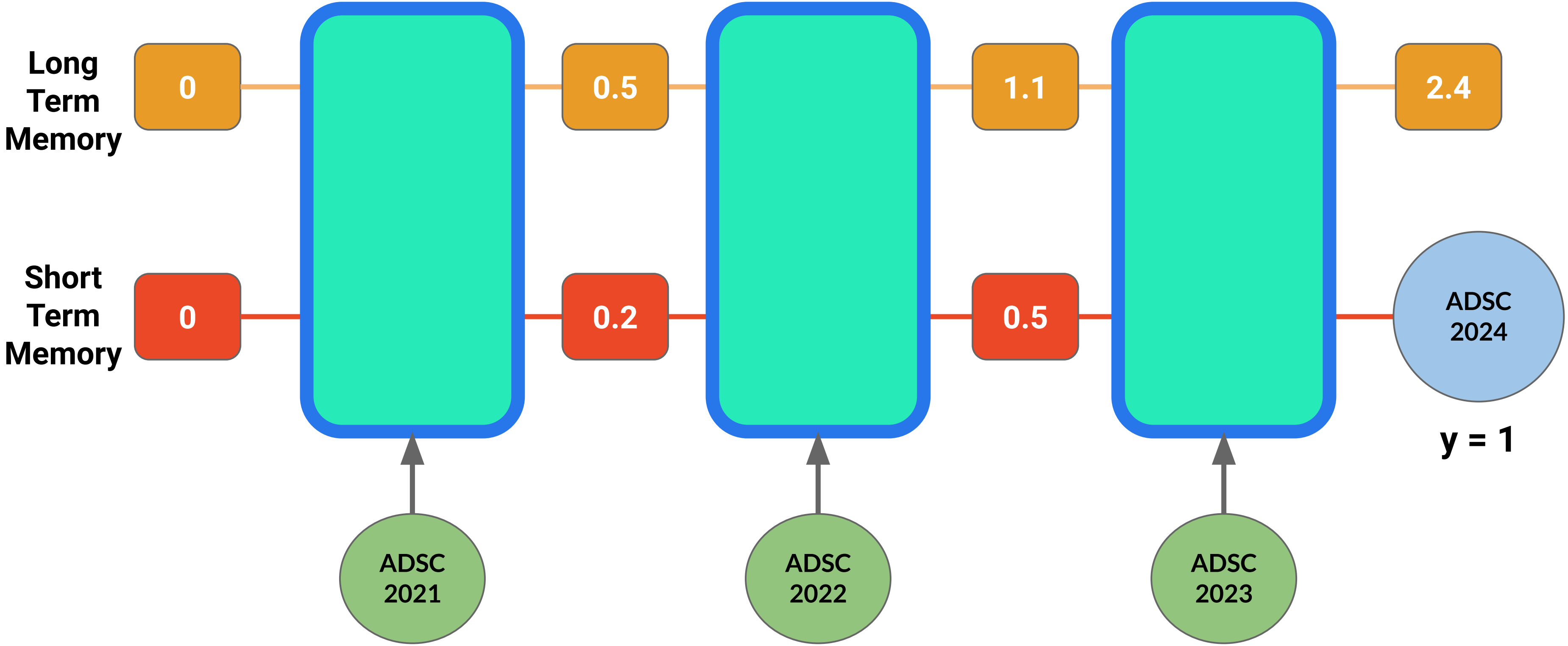
Long-Short Term Memory (LSTM)

LSTM for ADSC Stock 📈

- Next data point relies not only on **last data point (ST)** but also on **all data points (LT)**
- Only uses *sigmoid* and *hyperbolic* tangent activation functions to represent **memory retention**



Runthrough Example LSTM for ADSC Stock 📈

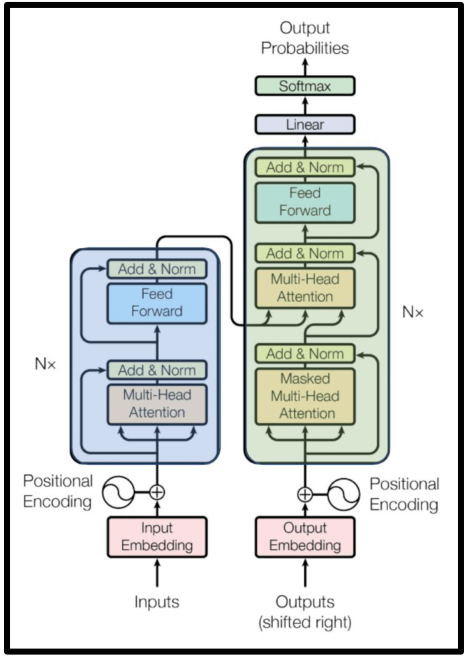


Transformers!!!

Long Range Dependencies

01

Ensures that all inputs are considered from beginning to end



Parallel Processing

02

Computations are completed far more efficiently

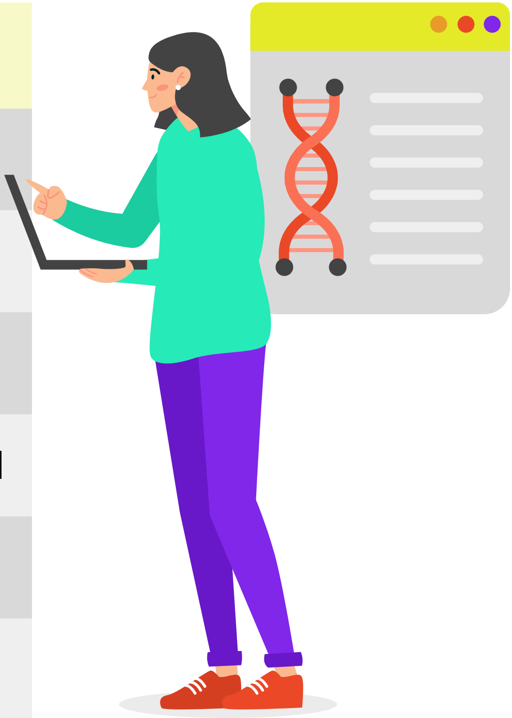
Interpretable Attention

03

Relates different positions of a single sequence to compute a representation of the same sequence

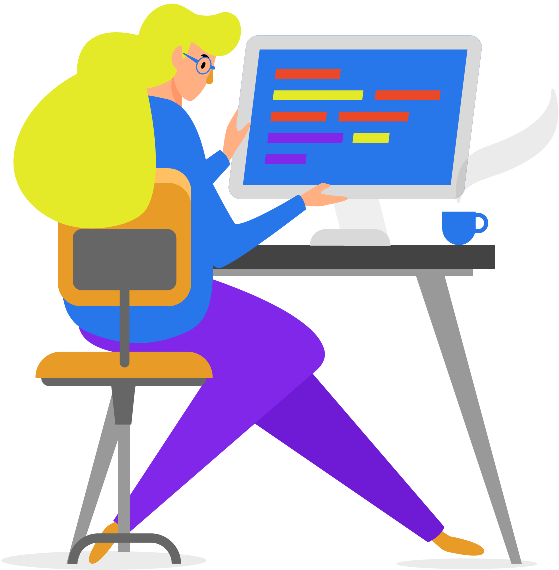
Machine Learning Infographics

Models	
Artificial neural networks	The Earth is the planet we live on
Decision trees	Mercury is the smallest planet
Support-vector machines	Despite being red, Mars is a cold place
Regression analysis	Jupiter is the biggest planet of them all
Bayesian networks	Venus has a beautiful name
Genetic algorithms	Pluto is considered a dwarf planet



TEMPLATE STARTS

Machine Learning Infographics



01

AI software

Venus has a beautiful name, but it’s hot

02

Framework

Mercury is the closest planet to the Sun

03

Train the model

The Earth is the third planet from the Sun

04

Compact the model

Despite being red, Mars is a cold place

05

Convert the model

Saturn is the only planet with rings

06

Integrate the model

Jupiter is the biggest planet of them all

Machine Learning Infographics

Artificial Intelligence

- Computers act on their own
- They act according to environment
- Systems display cognitive ability
- Computers make decisions

Vs

Machine learning

- It’s an application of AI
- Computers observe and analyze
- Predict based on previous patterns
- Pre-programmed algorithms

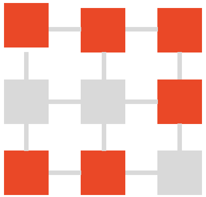
How do we deal with complex forms of data?

01

Sequential

Patterns of

02



Mercury

Mercury is the closest planet to the Sun

Machine Learning Infographics

01

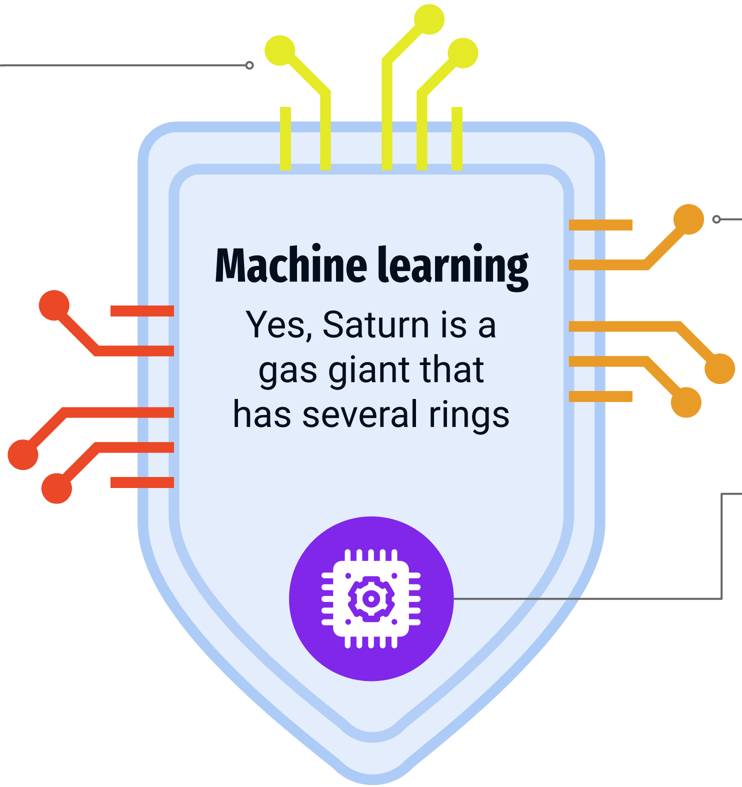
Mercury

Mercury is the closest planet to the Sun

02

Venus

Venus has a beautiful name, but it’s hot



03

Earth

The Earth is the third planet from the Sun

04

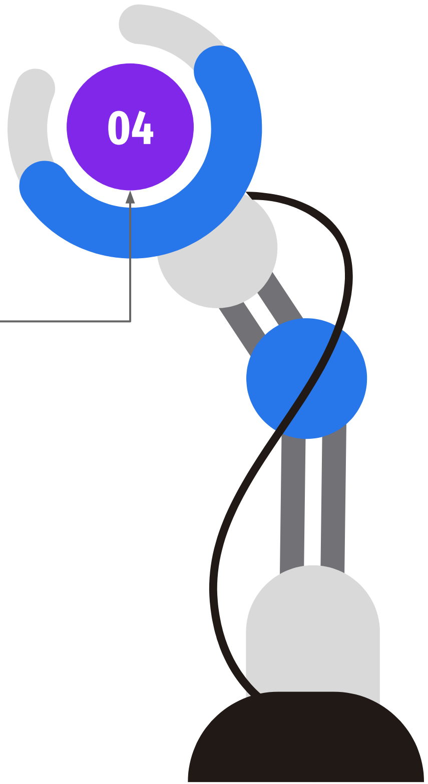
Mars

Despite being red, Mars is a cold place

Machine Learning Infographics

Machine learning
Saturn is the gas giant that has rings

Mars
Despite being red, Mars is a cold place



Venus
Venus has a beautiful name, but it’s hot

03

Mercury
Mercury is the closest planet to the Sun

02

Earth
The Earth is the third planet from the Sun

01

Machine Learning Infographics

01 Power

Mercury is the closest planet to the Sun

03 Memory

Jupiter is a gas giant and the biggest planet

05 Security

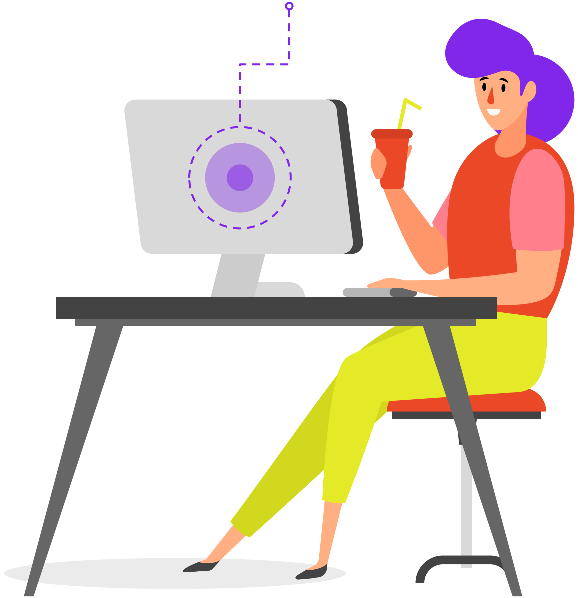
Venus has a beautiful name, but it's hot

07 MCU

The Earth is the third planet from the Sun

AI

System configuration



Memory 02

Neptune is the farthest planet from the Sun

Mars 04

Despite being red, Mars is a cold place

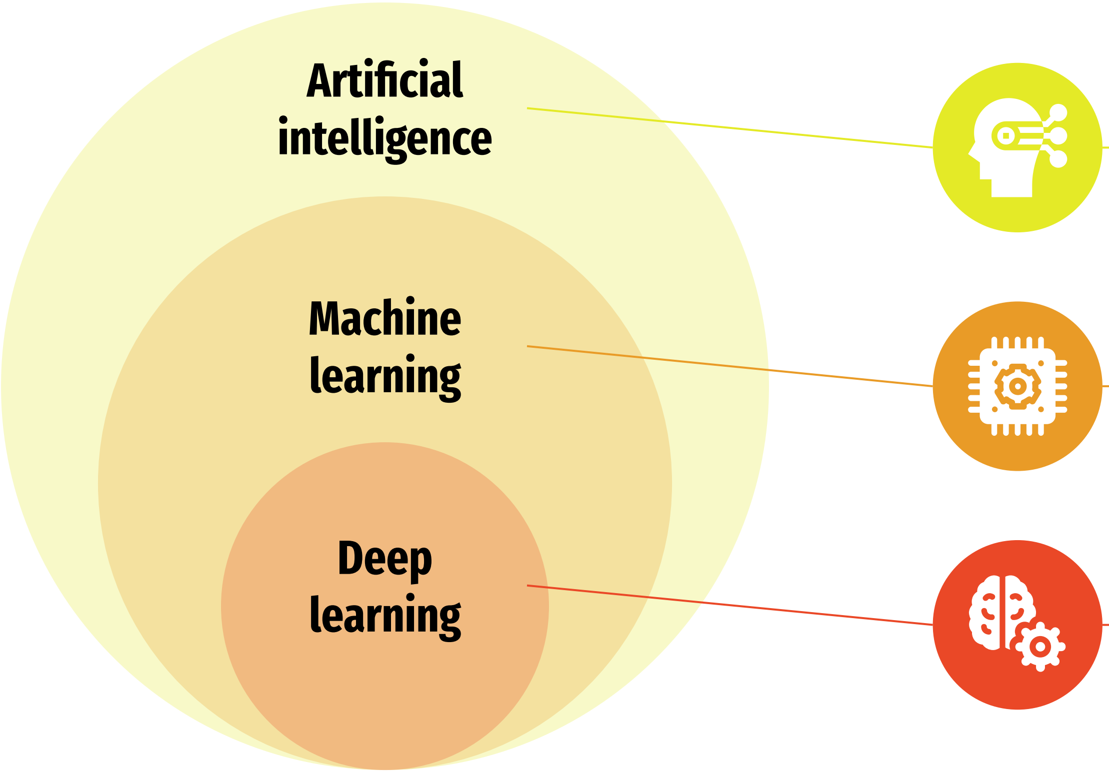
FPGA 06

Pluto is considered a dwarf planet

Wireless 08

Ceres is located in the main asteroid belt

Machine Learning Infographics



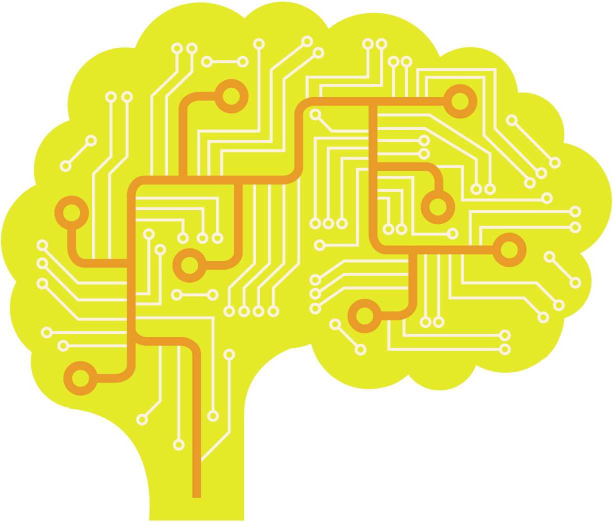
Mercury is the closest planet to the Sun

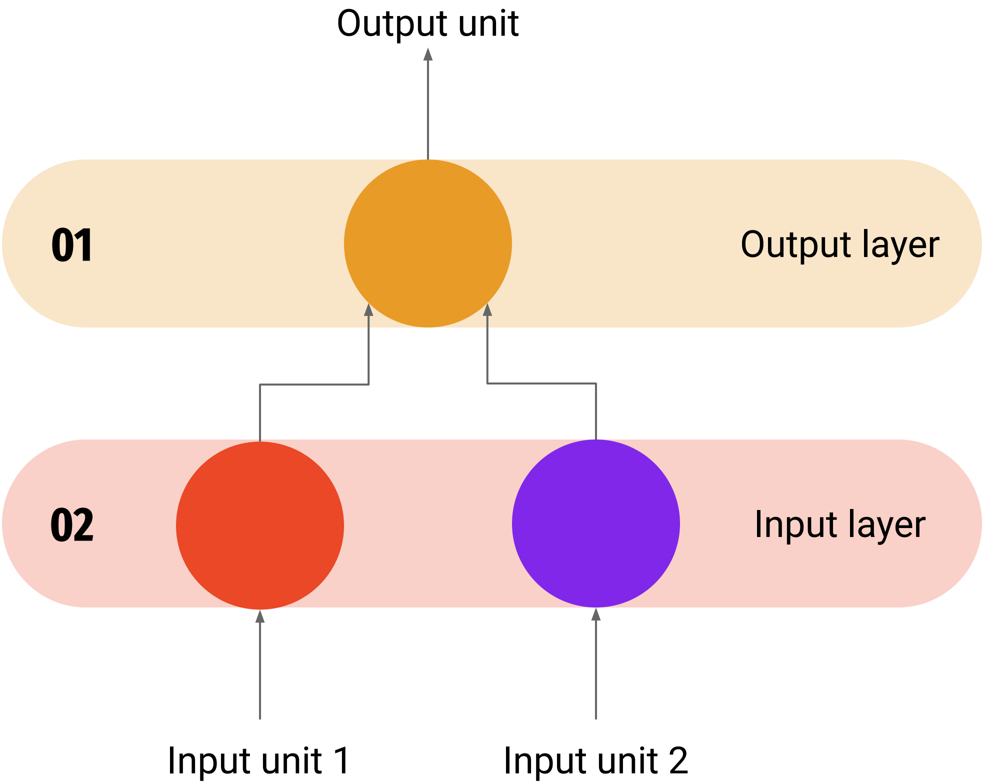
Jupiter is a gas giant and the biggest planet

Venus has a beautiful name, but it’s hot

Machine Learning Infographics

Neural network
Yes, Saturn is a gas giant that has rings





Machine Learning Infographics

1950s 01

Simple algorithms

Mercury is the closest planet to the Sun

1960s 02

Bayesian methods

Jupiter is a gas giant and the biggest planet

1970s 03

AI winter caused by pessimism

Venus has a beautiful name, but it’s very hot

1980s 04

Resurgence in ML research

Mercury is the closest planet to the Sun

1990s 05

Data-driven approach

The Earth is the third planet from the Sun

2000s 06

Support-Vector Clustering

Ceres is located in the main asteroid belt

2010s 07

Deep learning popularity

Venus has a beautiful name, but it’s very hot

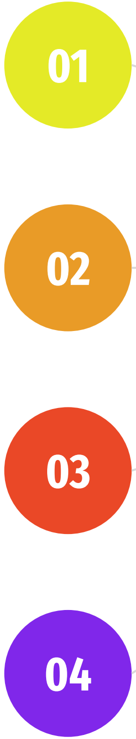
Machine Learning Infographics

Continuous improvement
Despite being red,
Mars is a cold place

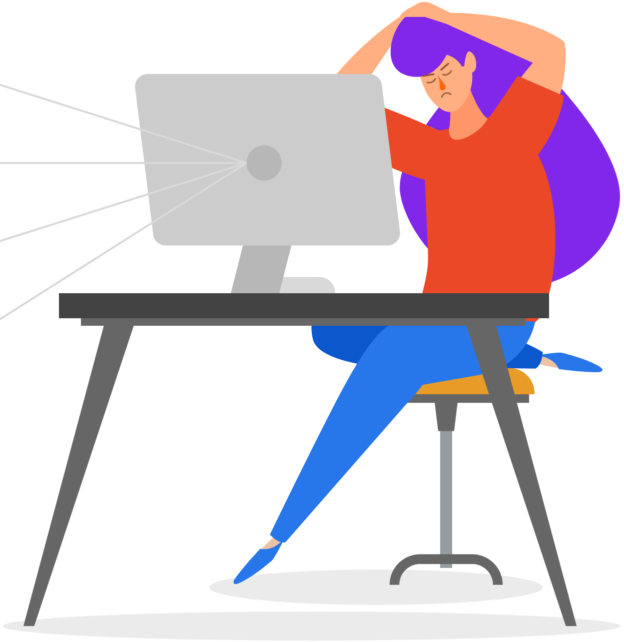
Data acquisition
Venus has a beautiful
name, but it's hot

Patterns identification
Mercury is the closest
planet to the Sun

Time and resources
The Earth is the third
planet from the Sun



Machine learning disadvantages



Machine Learning Infographics

Opportunities of machine learning

01

Image recognition
The Earth is the planet where we live

02

Customization
Despite being red, Mars is a cold place

03

Voice recognition
Venus has a beautiful name, but it’s hot

04

Data analysis
The Earth is the third planet from the Sun

05

Optical recognition
Mercury is the closest planet to the Sun

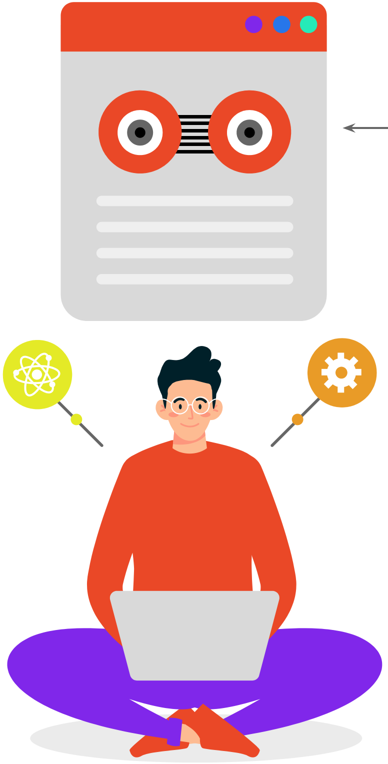
06

Memory data
Pluto is considered a dwarf planet

Machine Learning Infographics

Machine learning
Venus has a beautiful name, but it's hot

The model
Despite being red, Mars is a cold place



Input 1
The Earth is the third planet from the Sun

Input 2
Mercury is the closest planet to the Sun

Machine Learning Infographics

01 **Supervised learning**

Venus has a beautiful name, but it's hot

02 **Unsupervised learning**

Despite being red, Mars is a cold place

03 **Semi-supervised learning**

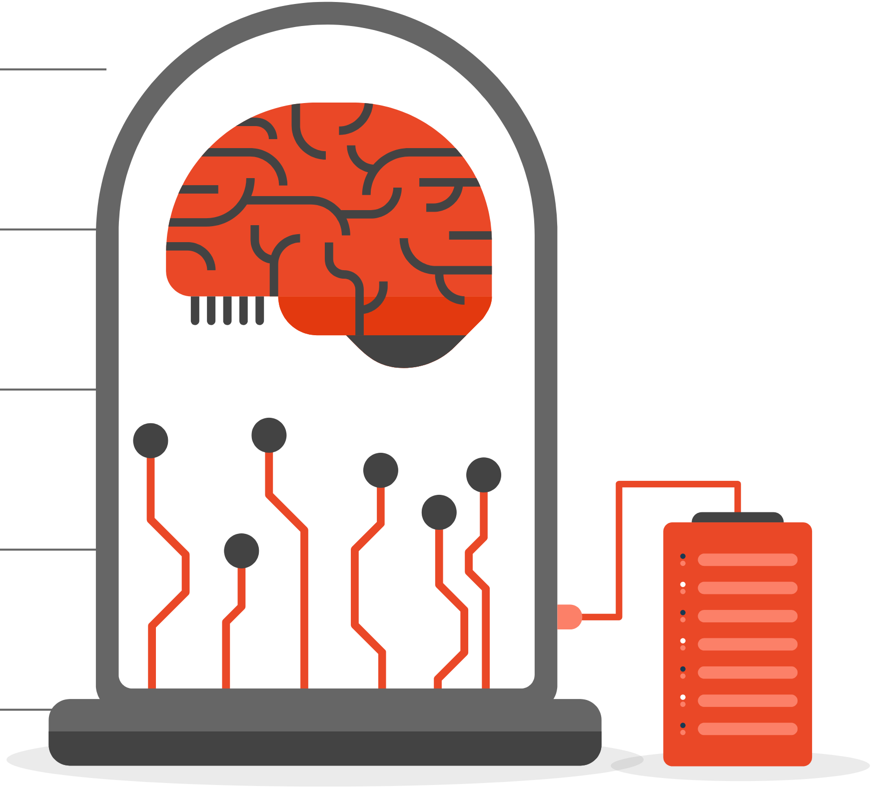
The Earth is the third planet from the Sun

04 **Reinforcement learning**

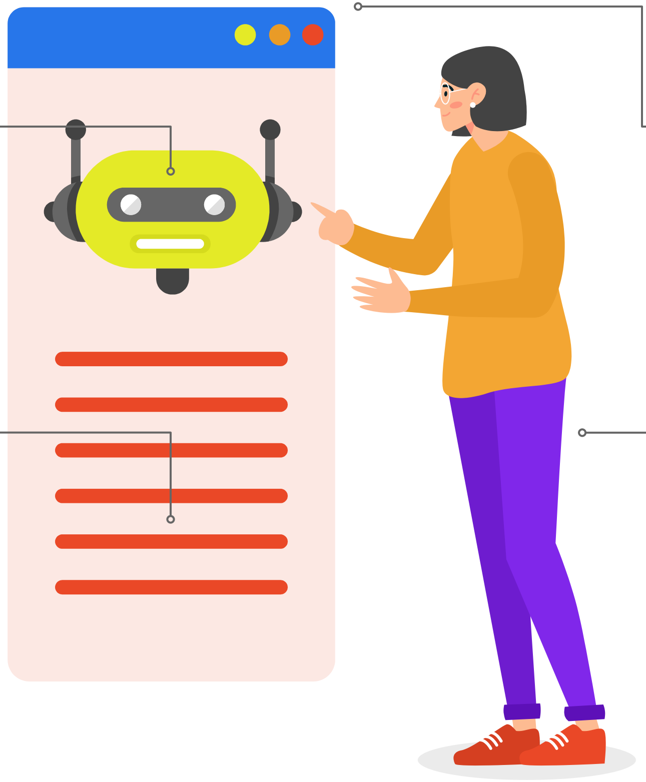
Mercury is the closest planet to the Sun

05 **Dimensionality reduction**

Pluto is considered a dwarf planet



Machine Learning Infographics



01 Active learning

Mercury is the closest planet to the Sun

02 Maturation

Jupiter is a gas giant and the biggest planet

03 Motor synergies

The Earth is the planet where we live

04 Imitation

Despite being red, Mars is a cold place

Machine Learning Infographics

45%

Data mining

The Earth is the third planet from the Sun

35%

Continuous production

Despite being red, Mars is a very cold place

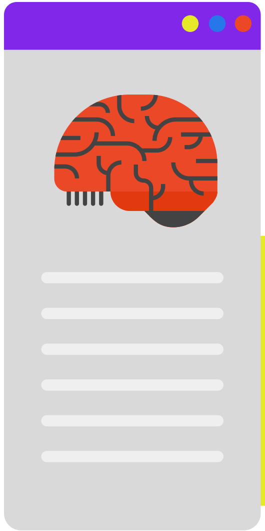
20%

Intrusion detection

Mercury is the closest planet to the Sun

Follow the link in the graph to modify its data and then paste the new one here. **For more info, click here**

Machine Learning Infographics



RNNs counteract key weaknesses of standard NNs

01

Feedback Loops

Mercury is the closest planet to the Sun

02

Varying Input Size

The Earth is the planet where we live

Machine Learning Infographics

01 Active learning

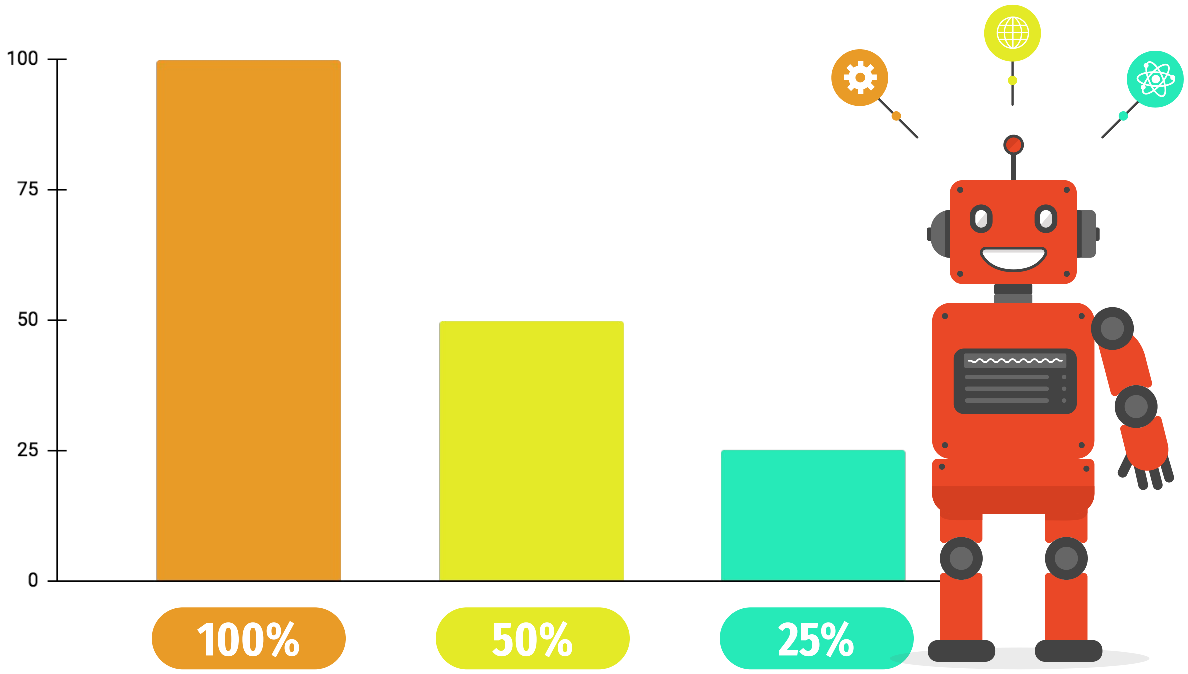
Mercury is the closest planet to the Sun

02 Maturation

Jupiter is a gas giant and the biggest planet

03 Motor synergies

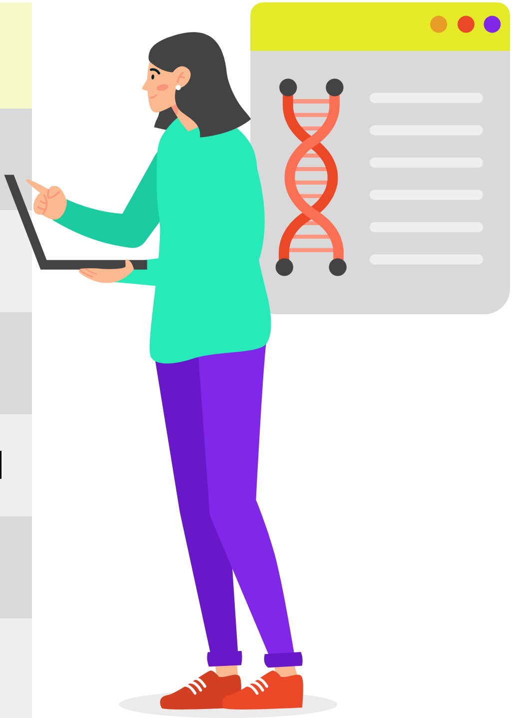
Neptune is very far away from the Sun



Follow the link in the graph to modify its data and then paste the new one here. **For more info, click here**

Machine Learning Infographics

Models	
Artificial neural networks	The Earth is the planet we live on
Decision trees	Mercury is the smallest planet
Support-vector machines	Despite being red, Mars is a cold place
Regression analysis	Jupiter is the biggest planet of them all
Bayesian networks	Venus has a beautiful name
Genetic algorithms	Pluto is considered a dwarf planet



Machine Learning Infographics

Collect the data

Mercury is the closest planet to the Sun

Prepare the data

The Earth is the third planet from the Sun

Train a model

Despite being red, Mars is a cold place

Evaluate the model

Jupiter is the biggest planet of them all

Improve

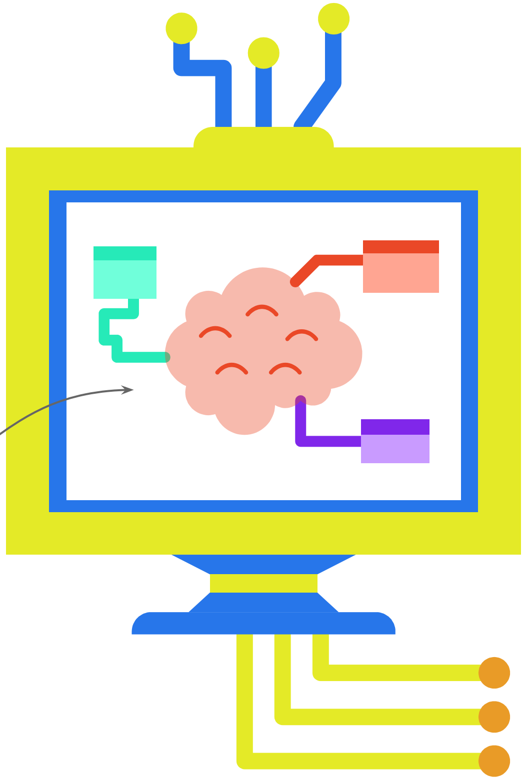
Pluto is considered a dwarf planet

Machine Learning Infographics

Inputs

Mercury is the closest planet to the Sun

- Input 1
- Input 2
- Input 3



Outputs

Jupiter is a gas giant and the biggest planet

- Output 1
- Output 2
- Output 3

Machine Learning Infographics

Predict trends
Venus has a beautiful name, but it's hot

01

02

Innovation
Despite being red, Mars is a cold place

Target segmentation
Mercury is the closest planet to the Sun

03

04

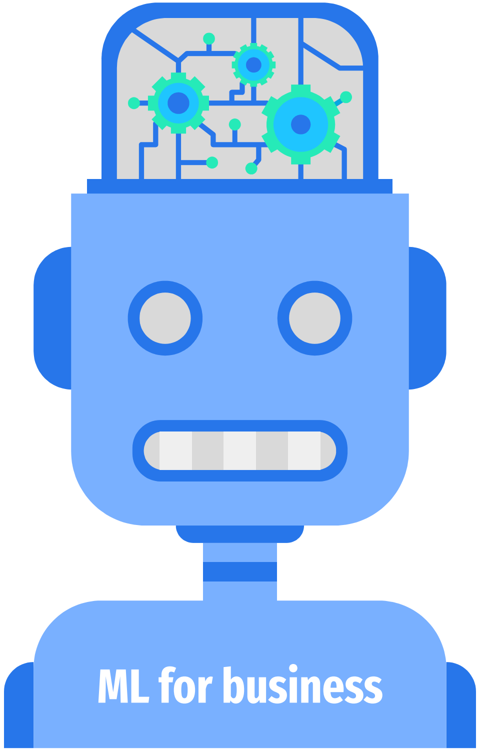
Cost reduction
Neptune is very far away from the Sun

Advert segmentation
The Earth is the third planet from the Sun

05

06

Customer relations
Jupiter is the biggest planet of them all



Machine Learning Infographics

Machine learning application example

01

Tweet

Mercury is the closest planet to the Sun

02

Feature engineering

Venus has a beautiful name, but it’s hot

03

Classification

The Earth is the third planet from the Sun

04

Output

Despite being red, Mars is a cold place

Machine Learning Infographics

10%

Mercury

Mercury is the closest planet to the Sun

30%

Jupiter

Jupiter is a gas giant and the biggest planet

20%

Neptune

It’s the farthest planet from the Sun

40%

Mars

Despite being red, Mars is a cold place

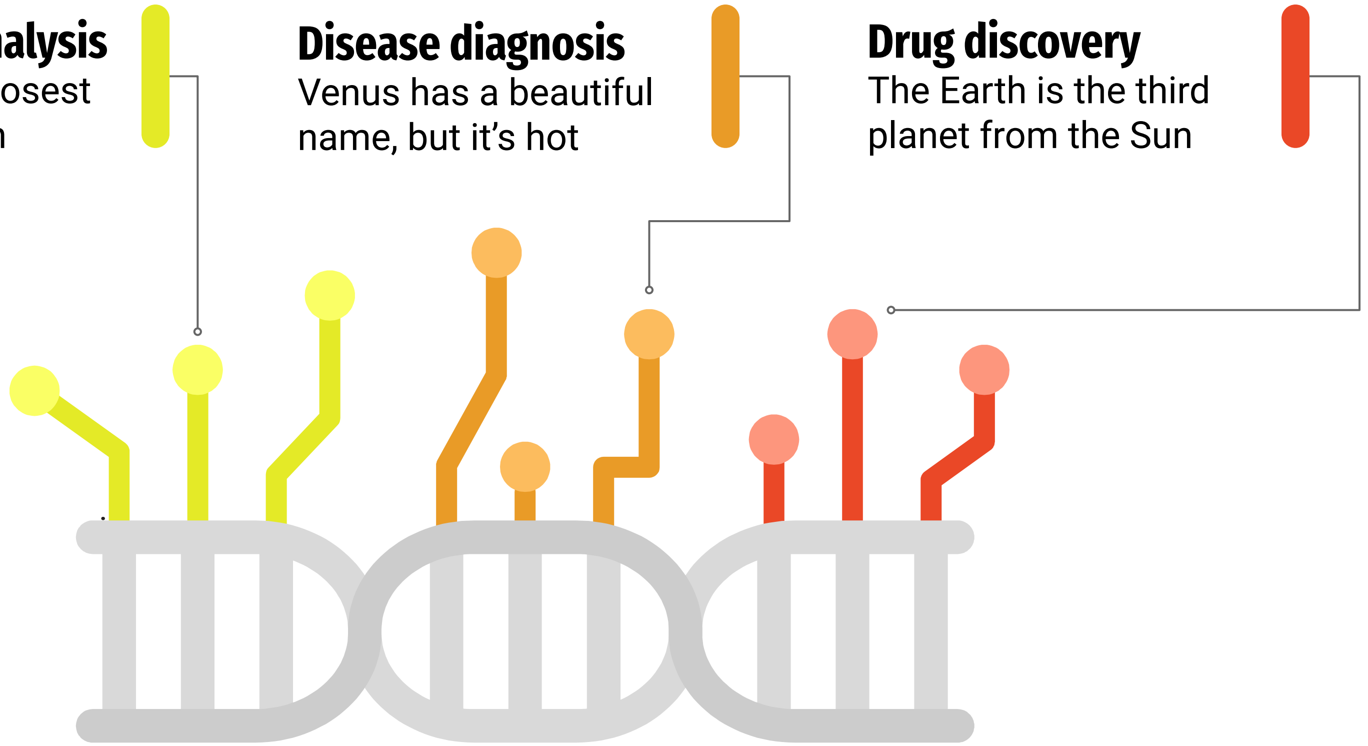
Follow the link in the graph to modify its data and then paste the new one here. **For more info, click here**

Machine Learning Infographics

Biochemical analysis
Mercury is the closest planet to the Sun

Disease diagnosis
Venus has a beautiful name, but it's hot

Drug discovery
The Earth is the third planet from the Sun

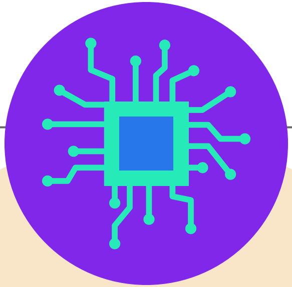


Machine Learning Infographics

	Common Uses for Machine Learning	
01	Chatbot systems	Venus has a beautiful name, but it’s hot
02	Decision support	Mercury is the closest planet to the Sun
03	Customer recommendation engines	The Earth is the third planet from the Sun
04	Customer churn modeling	Despite being red, Mars is a cold place
05	Pricing strategies	Neptune is the farthest planet from the Sun
06	Customer segmentation	Jupiter is the biggest planet of them all
07	Image classification	Pluto is now considered a dwarf planet

Machine Learning Infographics

Input data



Learning system

Mercury is the closest planet to the Sun

Neptune

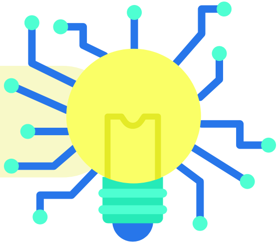
It's the farthest planet from the Sun

Mars

Despite being red, Mars is a cold place

Output data

Machine Learning Infographics



Machine learning advantages vs disadvantages

Advantages

- Efficiency data managing
- Continuous improvement
- Lots of applications
- Trend identification
- Pattern identification

Disadvantages

- Data acquisition
- Time and space
- Time-consuming
- High error possibilities
- Algorithm selection

Machine Learning Infographics

01

Identify data

Venus has a beautiful name, but it's hot

02

Choose algorithm

Mercury is the closest planet to the Sun

03

Analytical model

Despite being red, Mars is a cold place

04

Train the model

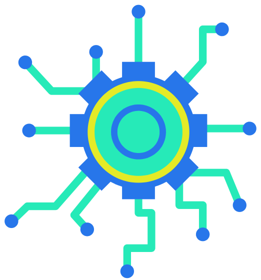
Jupiter is the biggest planet of them all

05

Run the model

Neptune is very far away from the Sun

Machine Learning Infographics



Machine learning

Input data
Jupiter is the biggest planet of them all

Relationships	Patterns
Dependencies	Structures

Algorithms + techniques

Output
Despite being red, Mars is a cold place

Instructions for use

In order to use this template, you must credit **Slidesgo** in your final presentation.

You are allowed to:

- Modify this template.
- Use it for both personal and commercial projects.

You are not allowed to:

- Sublicense, sell or rent any of Slidesgo Content (or a modified version of Slidesgo Content).
- Distribute Slidesgo Content unless it has been expressly authorized by Slidesgo.
- Include Slidesgo Content in an online or offline database or file.
- Offer Slidesgo templates (or modified versions of Slidesgo templates) for download.
- Acquire the copyright of Slidesgo Content.

For more information about editing slides, please read our FAQs or visit Slidesgo School:
https://slidesgo.com/faqs and https://slidesgo.com/slidesgo-school

Instructions for use (premium users)

In order to use this template, you must be a Premium user on Slidesgo.

You are allowed to:

- Modify this template.
- Use it for both personal and commercial purposes.
- Hide or delete the “Thanks” slide and the mention to Slidesgo in the credits.
- Share this template in an editable format with people who are not part of your team.

You are not allowed to:

- Sublicense, sell or rent this Slidesgo Template (or a modified version of this Slidesgo Template).
- Distribute this Slidesgo Template (or a modified version of this Slidesgo Template) or include it in a database or in any other product or service that offers downloadable images, icons or presentations that may be subject to distribution or resale.
- Use any of the elements that are part of this Slidesgo Template in an isolated and separated way from this Template.
- Register any of the elements that are part of this template as a trademark or logo, or register it as a work in an intellectual property registry or similar.

For more information about editing slides, please read our FAQs or visit Slidesgo School:
https://slidesgo.com/faqs and https://slidesgo.com/slidesgo-school

Infographics

You can add and edit some **infographics** to your presentation to present your data in a visual way.

- Choose your favourite infographic and insert it in your presentation using Ctrl C + Ctrl V or Cmd C + Cmd V in Mac.
- Select one of the parts and **ungroup** it by right-clicking and choosing “Ungroup”.
- **Change the color** by clicking on the paint bucket.
- Then **resize** the element by clicking and dragging one of the square-shaped points of its bounding box (the cursor should look like a double-headed arrow). Remember to hold Shift while dragging to keep the proportions.
- **Group** the elements again by selecting them, right-clicking and choosing “Group”.
- Repeat the steps above with the other parts and when you’re done editing, copy the end result and paste it into your presentation.
- Remember to choose the **“Keep source formatting”** option so that it keeps the design. For more info, please visit **Slidesgo School**.