

Fundamentals of Machine learning for and with engineering applications

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1 Recursive Neural Network

2 Generative AI

ORDER MATTERS

- Language Models
- Time series

Language model

- Prediction of the next word
- Prediction of next sentence

Time Series

- Weather data
- Stock market
- Monitoring
- Trajectories
- Etc

Sequential Data

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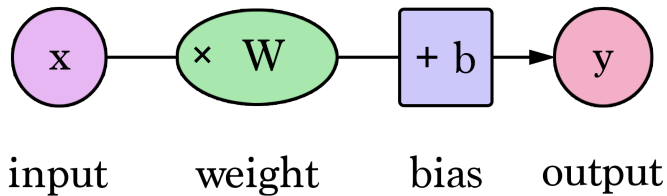
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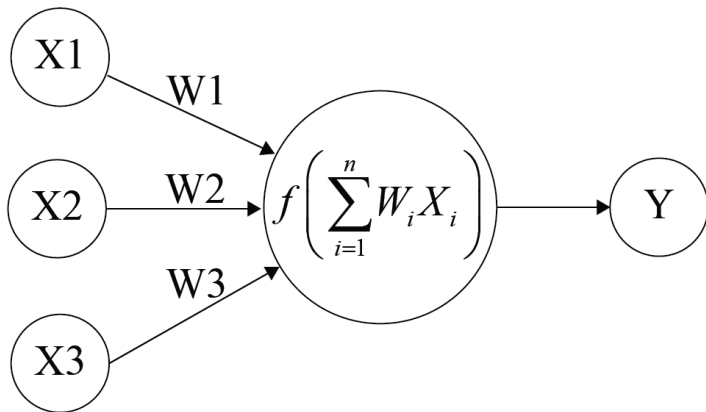
Feedforward (FF) vs Recurrent NN (RNN)

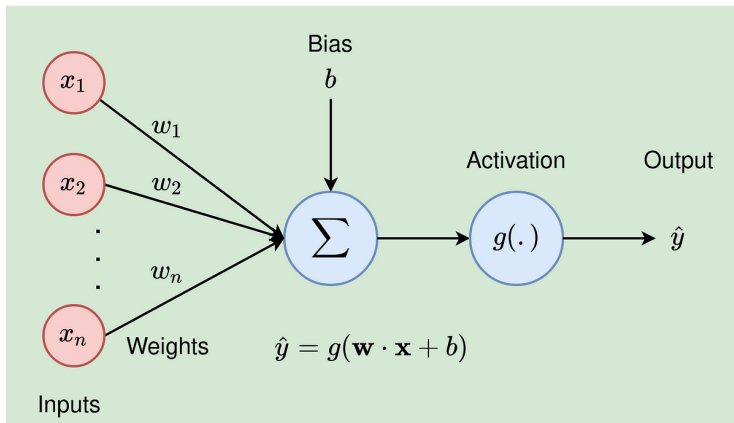
FF network

- One set of input
- One set of output
- Different parameters at each layer

- Multiple input set
- Multiple output
- Same parameter set



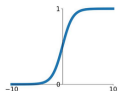




Activation Functions

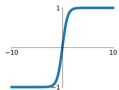
Sigmoid

$$\sigma(x) = \frac{1}{1+e^{-x}}$$



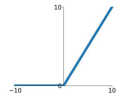
tanh

$$\tanh(x)$$



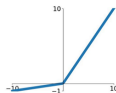
ReLU

$$\max(0, x)$$



Leaky ReLU

$$\max(0.1x, x)$$

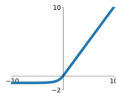


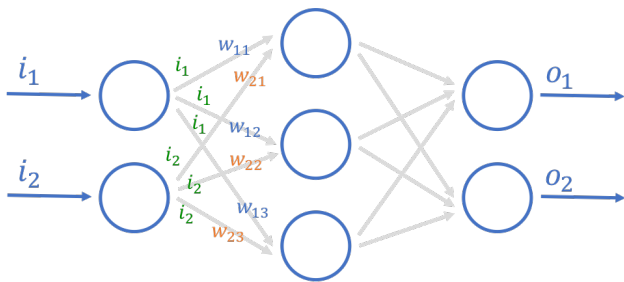
Maxout

$$\max(w_1^T x + b_1, w_2^T x + b_2)$$

ELU

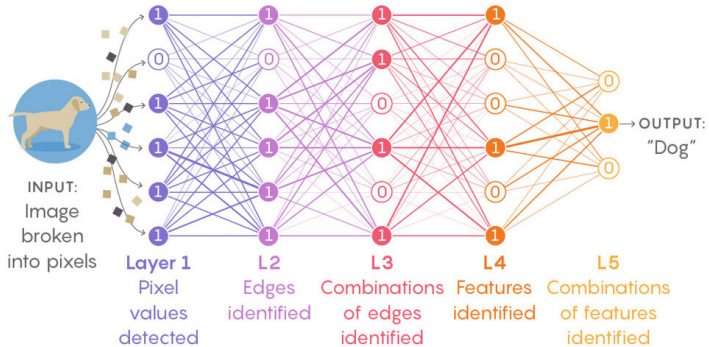
$$\begin{cases} x & x \geq 0 \\ \alpha(e^x - 1) & x < 0 \end{cases}$$

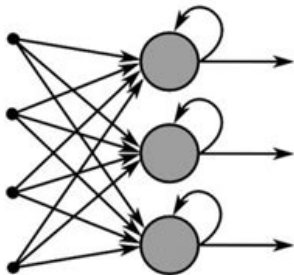




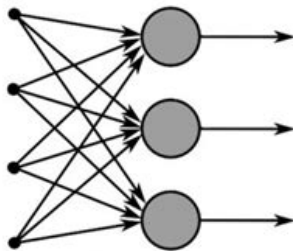
$$\begin{bmatrix} w_{11} & w_{21} \\ w_{12} & w_{22} \\ w_{13} & w_{23} \end{bmatrix} \cdot \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} (w_{11} \times i_1) + (w_{21} \times i_2) \\ (w_{12} \times i_1) + (w_{22} \times i_2) \\ (w_{13} \times i_1) + (w_{23} \times i_2) \end{bmatrix}$$

NN





Recurrent Neural Network



Feed-Forward Neural Network

Advantages

- Model size is fixed
- Each info is stored/learned
- The weights can be forwarded

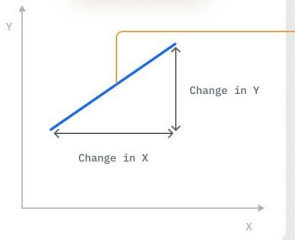
/pause

Problems

- Computationally demanding: long training times
- Problematic with Long series
- It can diverge (explode) or gradient vanish
- It cannot be very deep
- Unable to handle long time dependencies

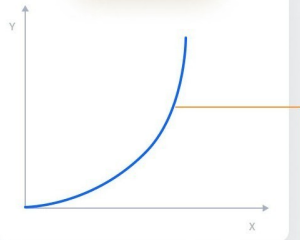
RNN problems

Vanishing Gradients



Slope decreases gradually to a very small value (sometimes negative) and makes

Exploding Gradients



Slope grows exponentially

Exploding gradients

- Large weights update
- Gradient descent diverge (solution method)

Vanishing gradients

- Weights get marginally upgraded
- Very slow convergence speed

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LSTM: Long Short Term Memory

NB...

Filters forget data...

What about if we purposely forget data?

/pause LSTM includes Forget Gates

Automatic filter!

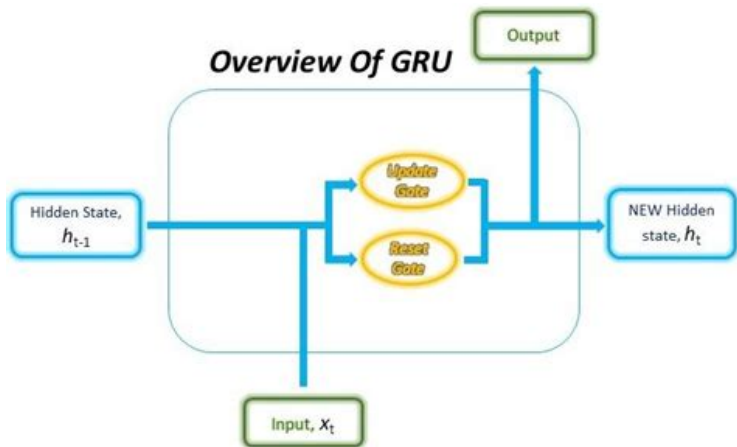
The forget gates learn to forget what is not interesting

This is extremely useful but also rather worrisome: you have no control!

/pause

LSTM is an advanced version of GRU (Gated Recurrent Units)...
What is GRU?





Reset gates

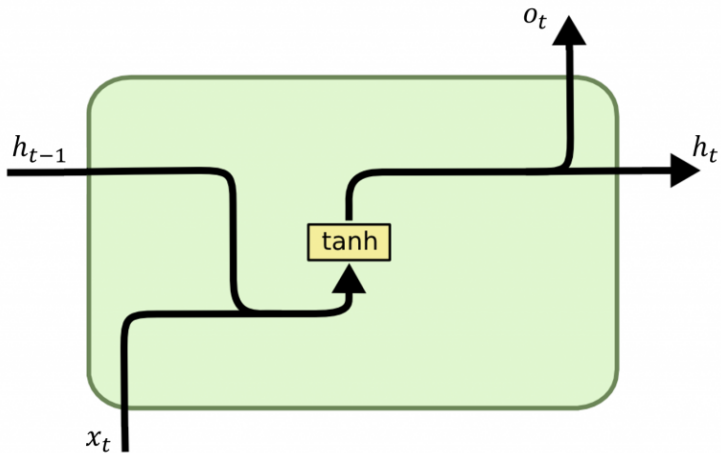
To capture short-term dependencies

/pause

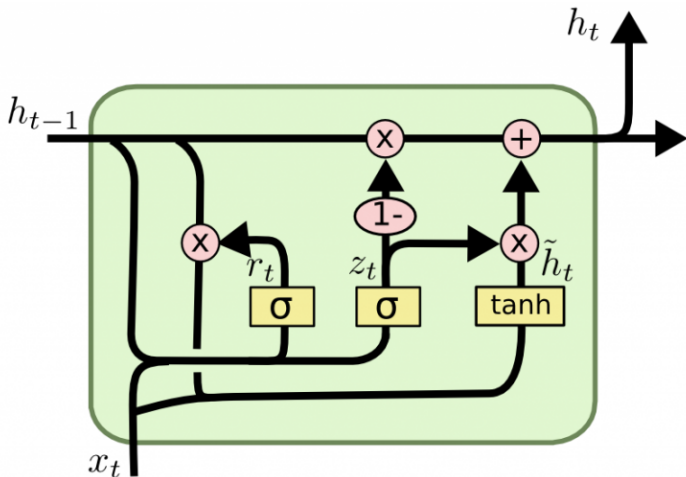
Update gates

To capture Long-term dependencies

pause Each gate has its own weight

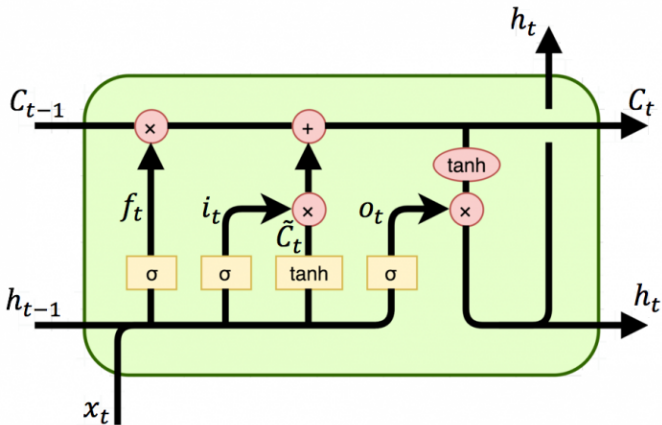


x_t : input vector, h_t : hidden layer vector o_t : output vector



x_t : input vector, h_t : hidden layer vector o_t : output vector, r_t : reset factors, z_t : update factors

LSTM



x_t : input vector, h_t, C_t : hidden layer vector o_t : output vector, r_t : reset factors, z_t : update factors

1 Recursive Neural Network

2 Generative AI

A generative AI model is a type of artificial intelligence that is designed to generate new content, based on the data it has been trained on.

It started in 1932, with the **mechanical brain** by Georges Artsrouni that was supposed to translate automatically between languages,

Here [a nice recaps of Generative AI](#) and its [storyline](#)

A valuable report

A foundation model, also known as large X model (LxM), is a machine learning or deep learning model that is trained on vast datasets so it can be applied across a wide range of use cases.

Key characteristics of generative AI models include:

- 1 Learning from Data: They are trained on large datasets, enabling them to learn patterns, styles, or features inherent in the data.
- 2 Generating New Content: Generative models can create new data instances. For example, a model trained on a dataset of paintings can generate new images in the style of those paintings.

Trained generative models are thus able to input information at a low resolution/dimension and give output with a much greater dimensionality.

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Here a list of possible applications:

- Images/video: Image generation, Super-resolution, Deep fakes.
- Music: noise filter, voice and music generation, voice deep fake.
- Text(LLM): chatGPT, bard, Gemini, etc.
- Chemistry: DeepMind (Alphafold).
- Coding (co-pilot)
- Speech
- Attacks and Hacking (Security testing)
- Generating training sets
- And many more

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- 1 Virtual best friends
- 2 Medical images to show diseases consequences
- 3 Synthetic data for digital twins
- 4 Preemptive suggestions (e.g. driving)
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Science fiction?

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Problems (currently)

New possibilities do not come with side effects.

- 1 Lack of transparency: how the output is generated, and why?
- 2 Accuracy: a lot of hallucinations
- 3 Bias: human biases are kept, supported and eventually increased
- 4 Intellectual properties (IP): who owns what is produced?
- 5 Cybersecurity and frauds: mass cyber attacks can be created
- 6 Sustainability: massive quantity of electricity is used
- 7 Responsibility (who to blame?): Will AI get citizenship everywhere?

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Where generative AI is ?

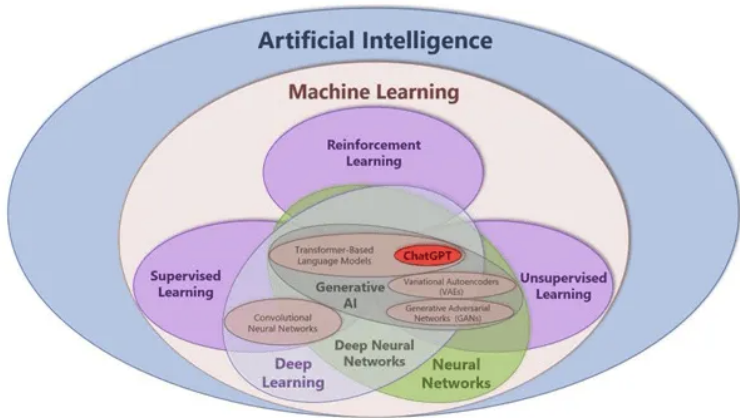


Image: <https://iot-analytics.com>

Structure of generative AI

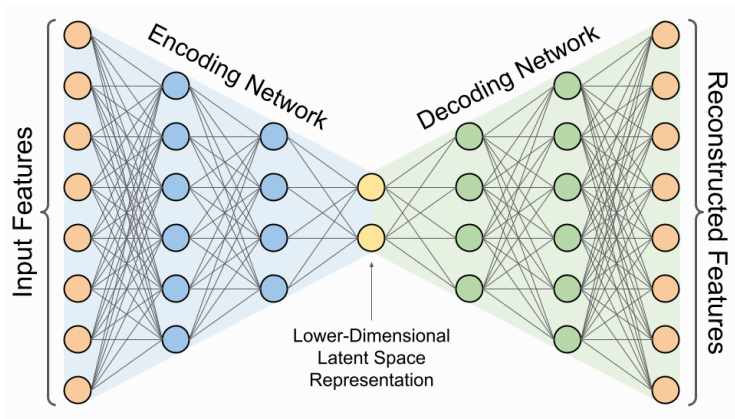


Image: <https://www.rapidops.com>

A new field?

Generative AI is actually a new evolution.

It is based on Neural Network, and in comprises a set of advanced tools (numerical recepites):

- 1 Generative Adversarial Networks
- 2 Generative Pre-trained Transformers
- 3 Variational Autoencoders
- 4 Conditional Variational Autoencoders
- 5 Autoencoders

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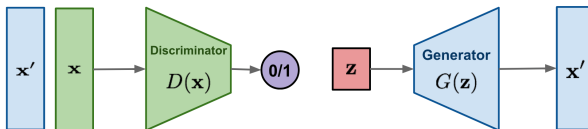
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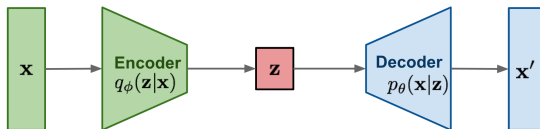
Types of generative AI

It is quite an advanced technique

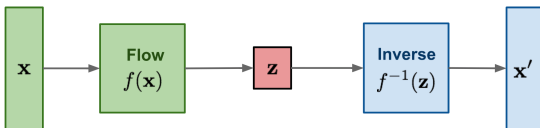
GAN: minimax the classification error loss.



VAE: maximize ELBO.



Flow-based generative models: minimize the negative log-likelihood



Source: [Lilian Weng](#)