



Human-Centered Data & AI



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- MBA Professor – FIAP and ESPM



“

Redes Neurais Recorrentes (RNN)

Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)



Apple pie



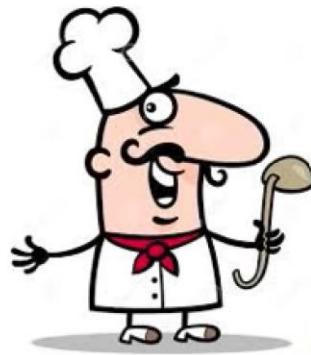
Burger



Chicken

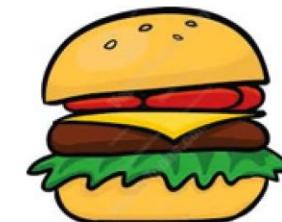
Redes Neurais Recorrentes (RNN)

Weather

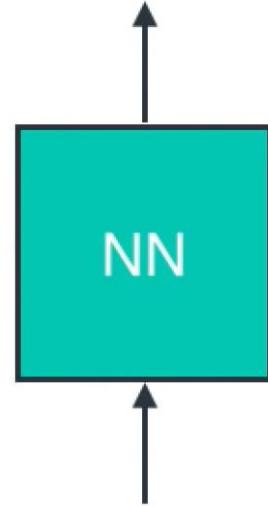


Redes Neurais Recorrentes (RNN)

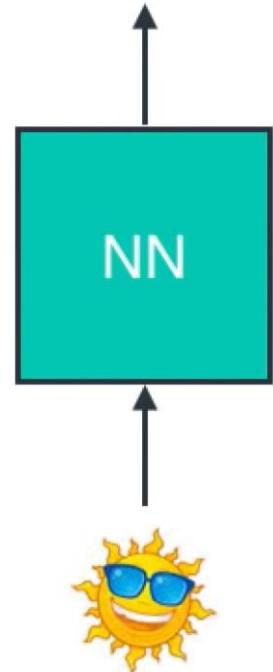
Weather



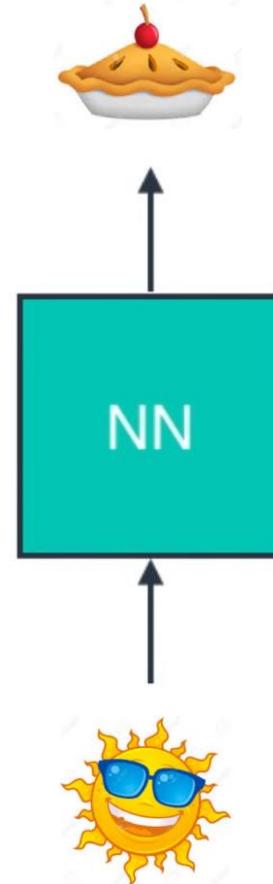
Redes Neurais Recorrentes (RNN)



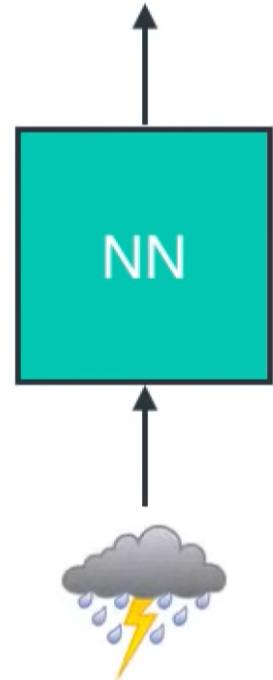
Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)

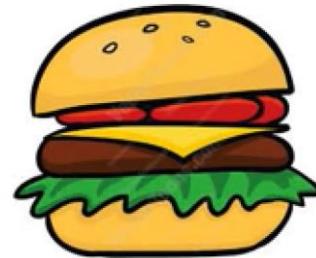


Redes Neurais Recorrentes (RNN)

Vectors



$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$



$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$



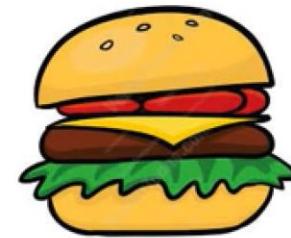
$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

Redes Neurais Recorrentes (RNN)

Vectors



$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$



$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$



$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

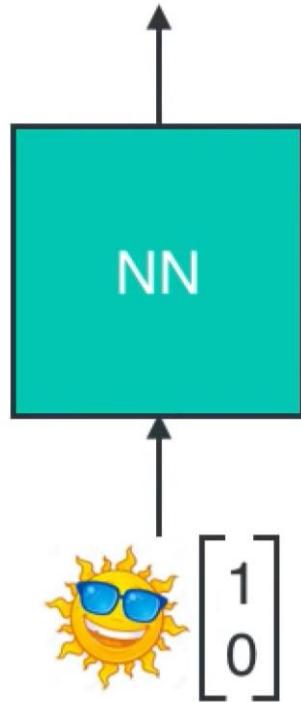


$$\begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

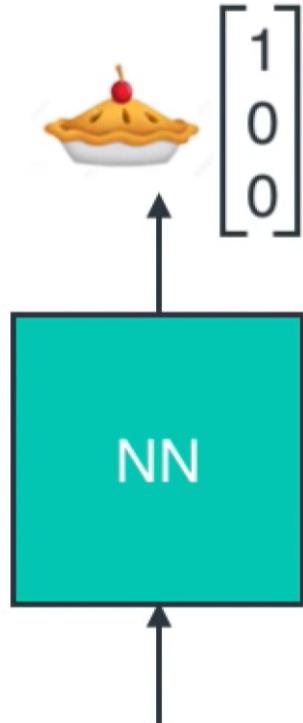


$$\begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

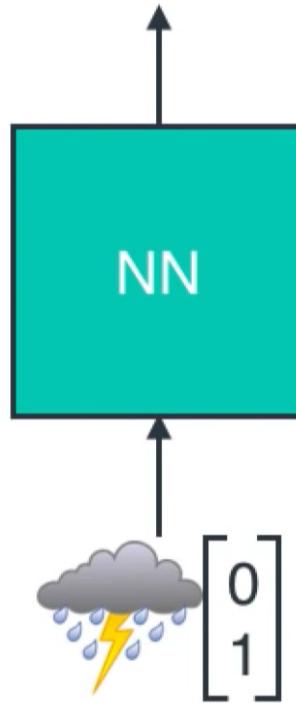
Redes Neurais Recorrentes (RNN)



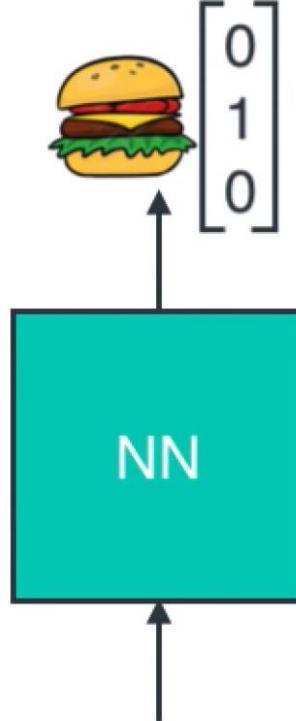
Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \end{bmatrix}$$



$$\begin{bmatrix} 0 \\ 1 \end{bmatrix}$$



$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}$$

=

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \end{bmatrix} \text{ ☀️}$$

$$\begin{bmatrix} 0 \\ 1 \end{bmatrix} \text{ 🌧️}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} \text{ ☀️} =$$

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \end{bmatrix} \quad \text{☀️}$$

$$\begin{bmatrix} 0 \\ 1 \end{bmatrix} \quad \text{⚡}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \quad \text{🥧}$$

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \end{bmatrix} \quad \text{sun with sunglasses}$$

$$\begin{bmatrix} 0 \\ 1 \end{bmatrix} \quad \text{cloud with lightning}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix} = \quad \text{cloud with rain}$$

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \quad \text{apple pie}$$

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \end{bmatrix} \quad \text{☀️}$$

$$\begin{bmatrix} 0 \\ 1 \end{bmatrix} \quad \text{⚡}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix} \quad \text{⚡} = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} \quad \text{🍔}$$

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \quad \text{🥧}$$

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \end{bmatrix} \text{☀️}$$

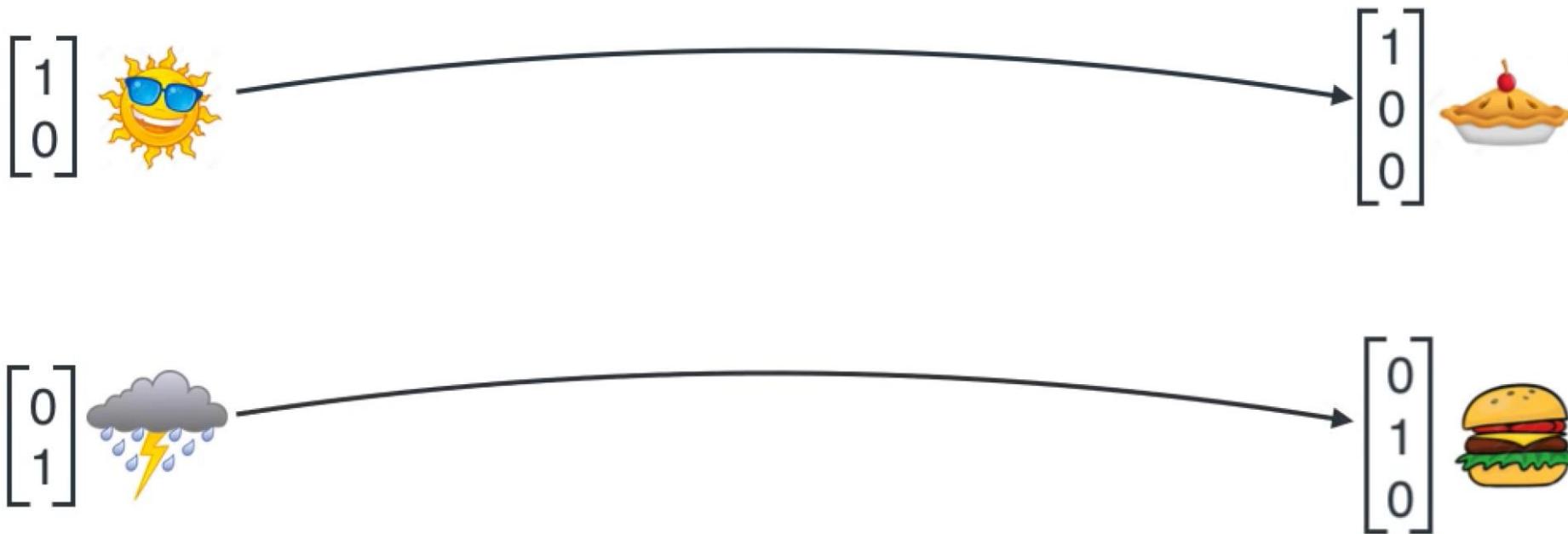
$$\begin{bmatrix} 0 \\ 1 \end{bmatrix} \text{🌧️}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix} \text{🌧️} =$$

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \text{🥧}$$

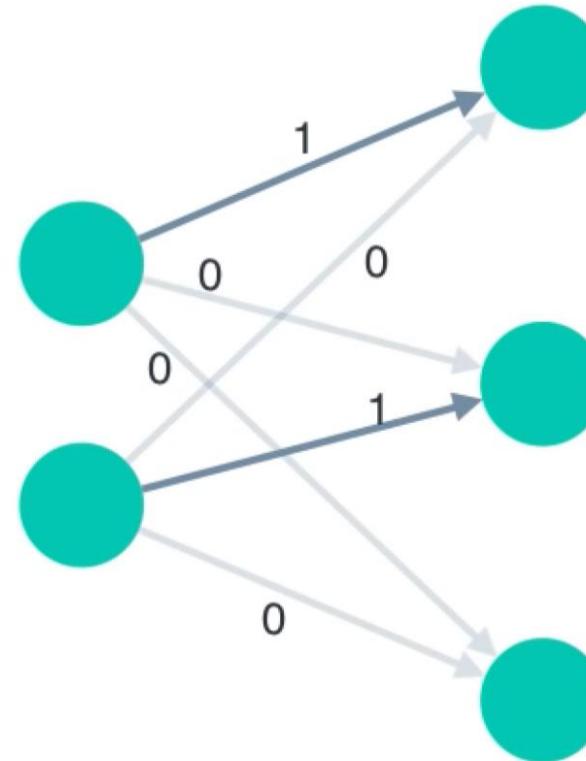
$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} \text{🍔}$$

Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}$$

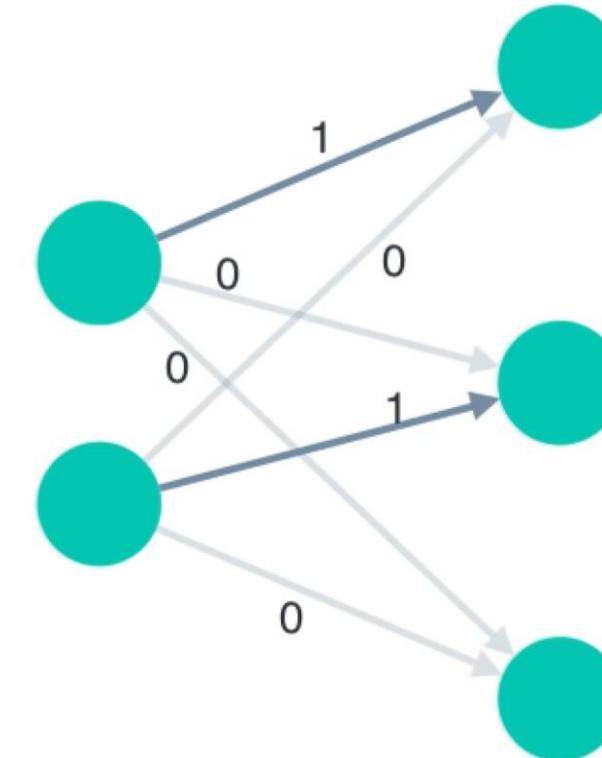


Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}$$



$$\begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

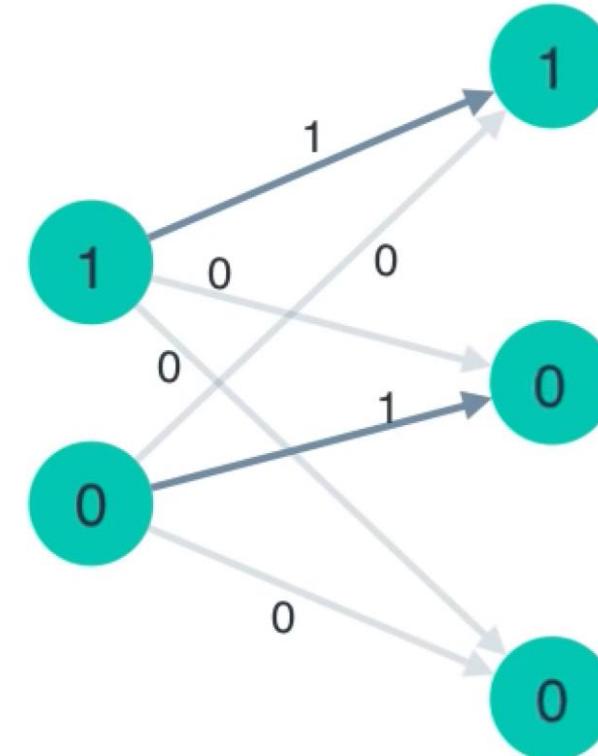


Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}$$



$$\begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

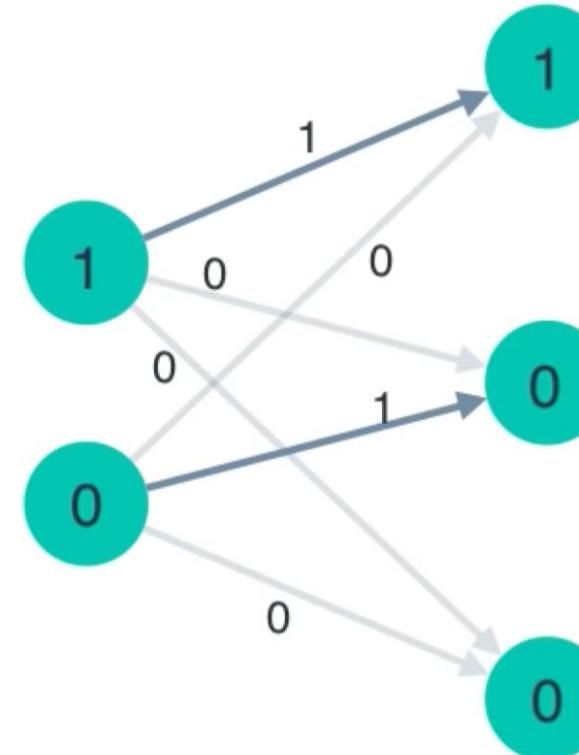


Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix}$$



$$\begin{bmatrix} 1 \\ 0 \end{bmatrix}$$



$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$



Redes Neurais Recorrentes (RNN)



Apple pie

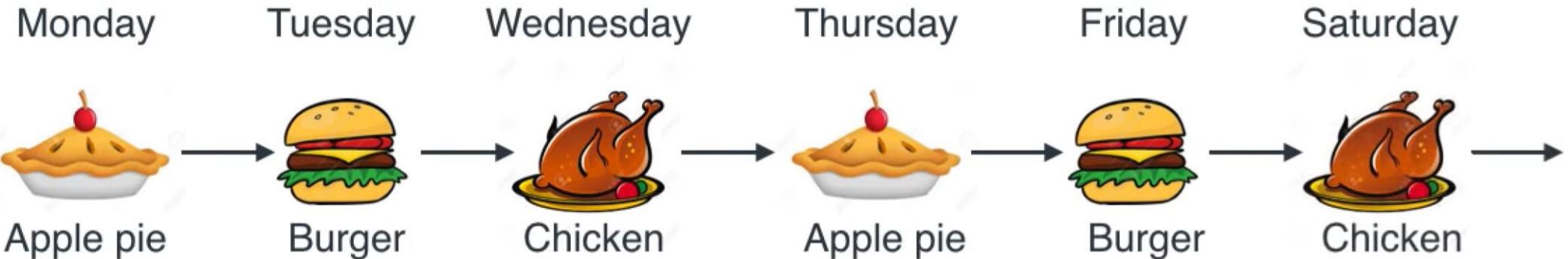


Burger

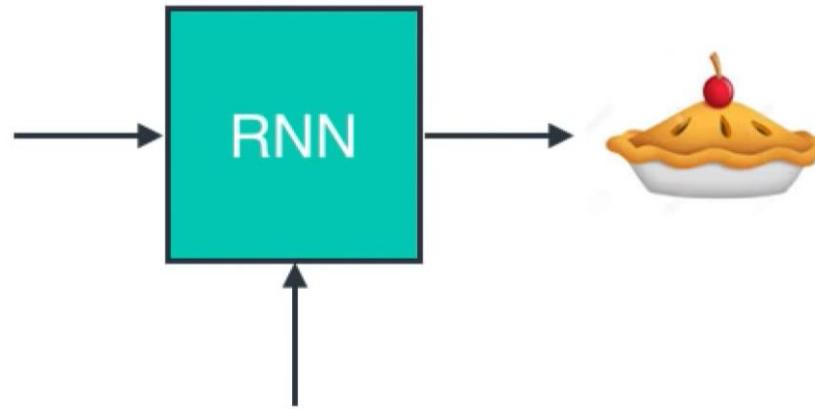


Chicken

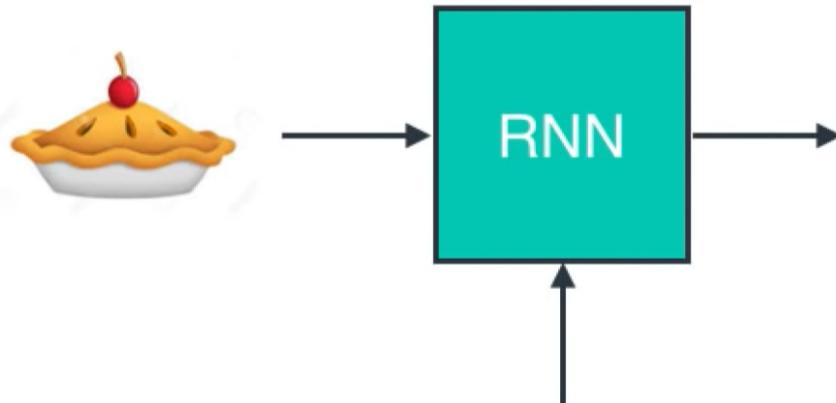
Redes Neurais Recorrentes (RNN)



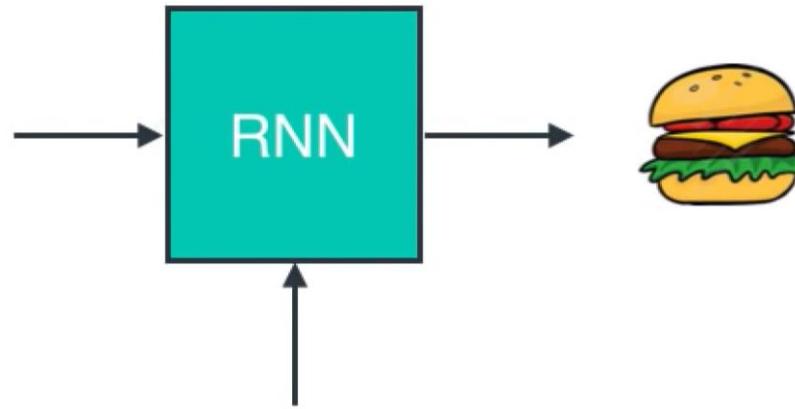
Redes Neurais Recorrentes (RNN)



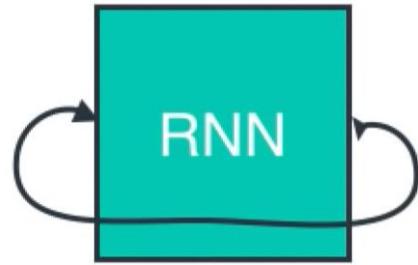
Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)



$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$



$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$



$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$


$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$


$$\begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

=

$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$


Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \quad \text{Pie emoji}$$

$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} \quad \text{Hamburger emoji}$$

$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \quad \text{Roasted Turkey emoji}$$

$$\begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} \quad \text{Hamburger emoji}$$

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$


$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$


$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$


$$\begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$


$$= \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$


$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$


Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$


$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$


$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

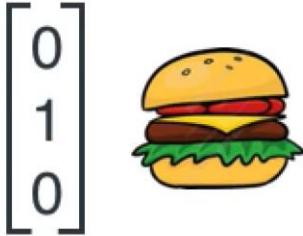
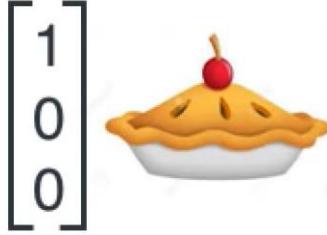

$$\begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$


$$= \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

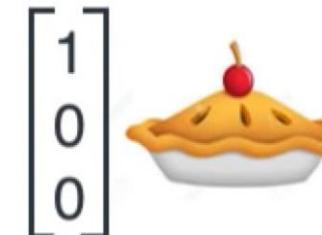
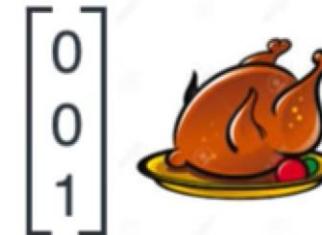
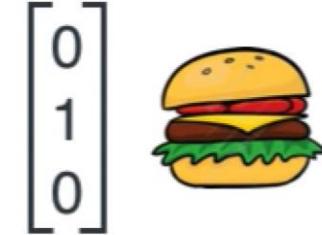

$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$


$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

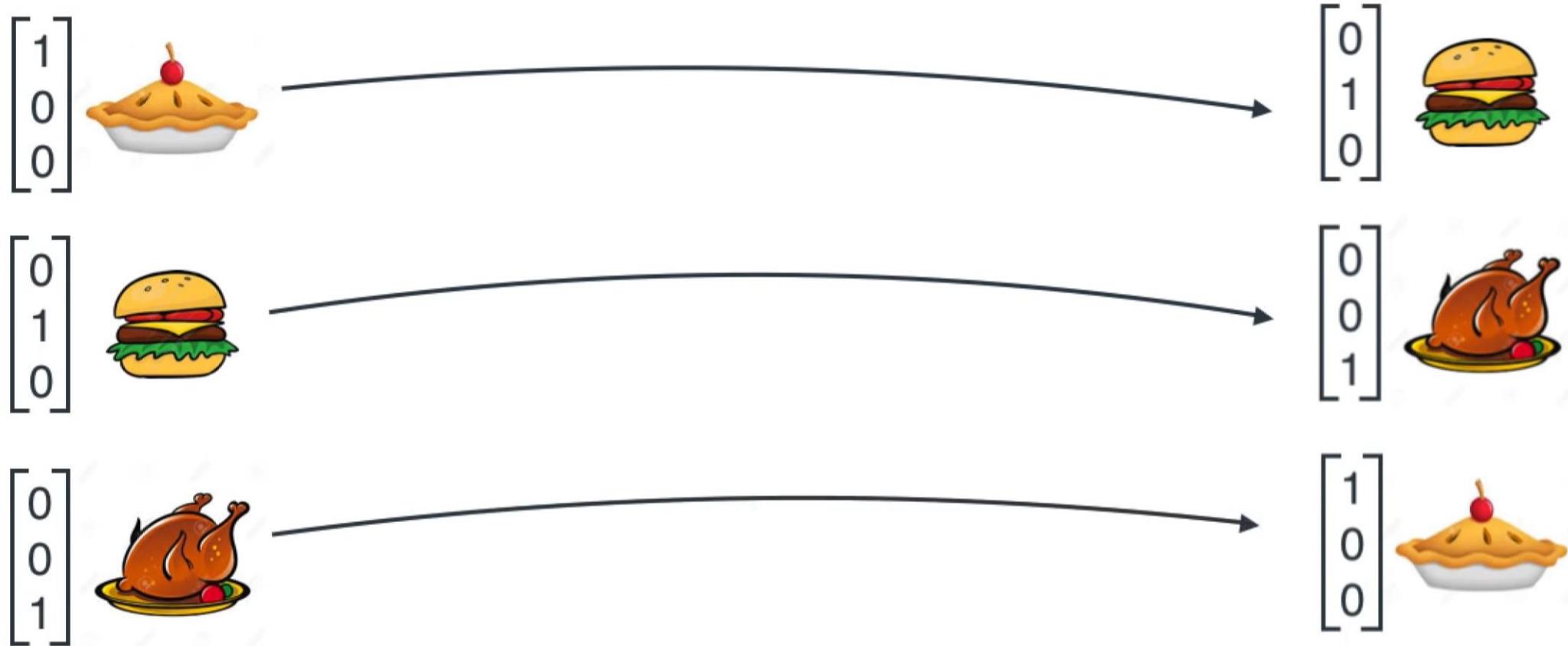

Redes Neurais Recorrentes (RNN)



$$\begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

 $=$ 

Redes Neurais Recorrentes (RNN)

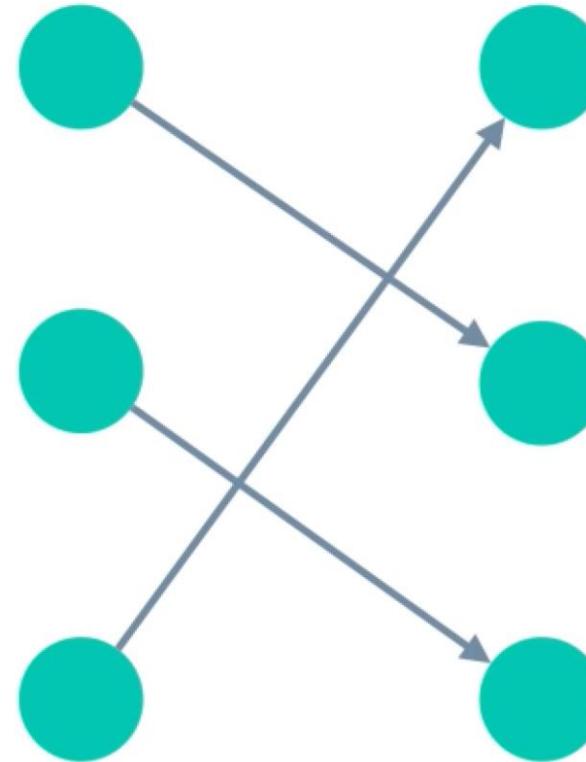


Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$



$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

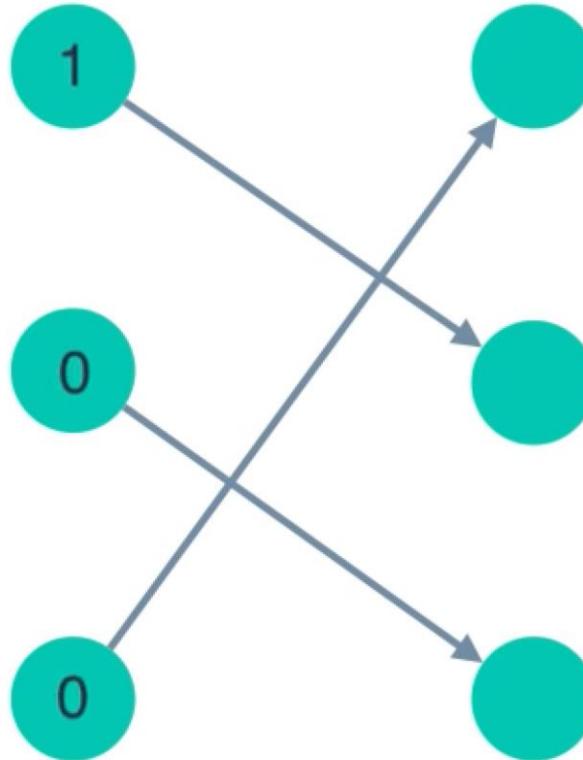


Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$



$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

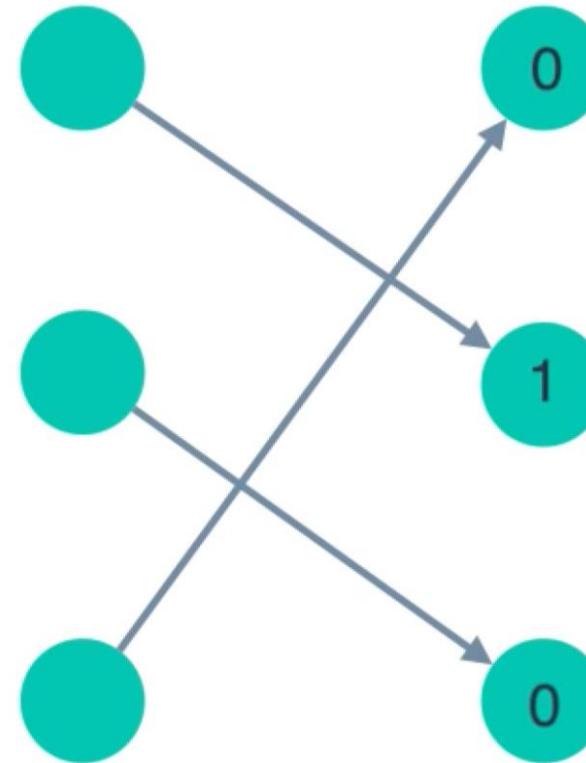


Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$



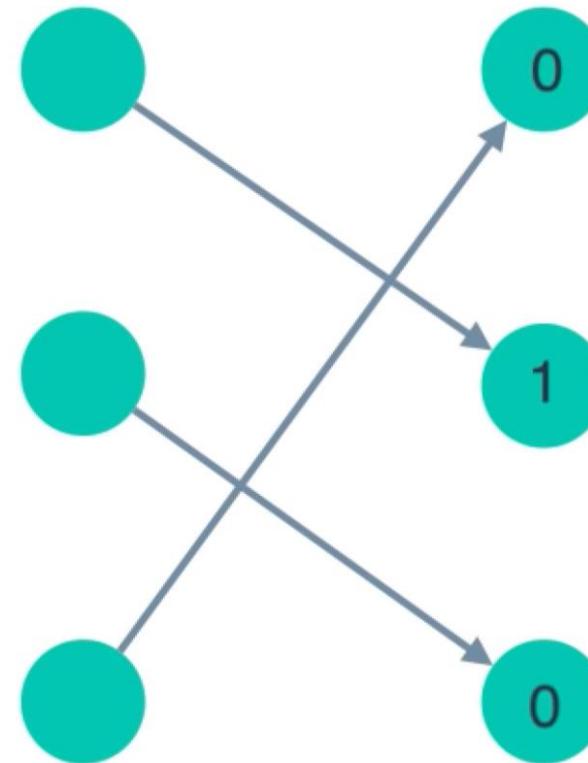
$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$



Redes Neurais Recorrentes (RNN)



$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$



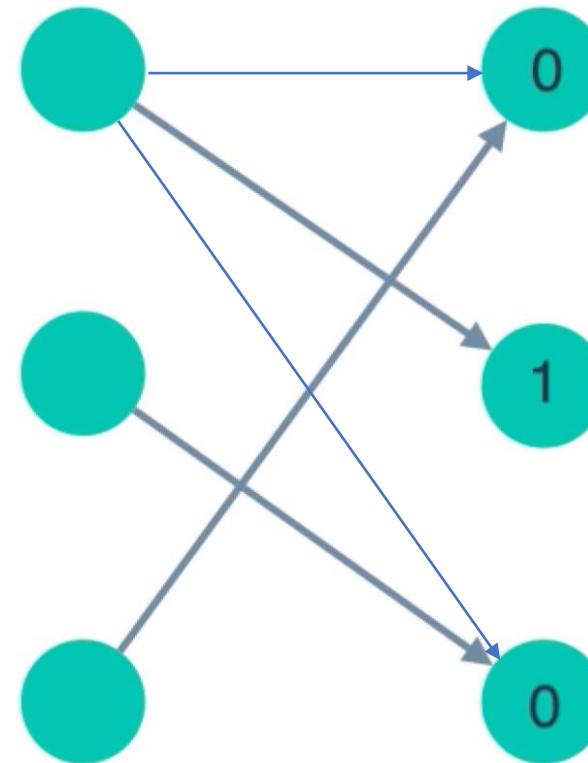
$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$



Redes Neurais Recorrentes (RNN)



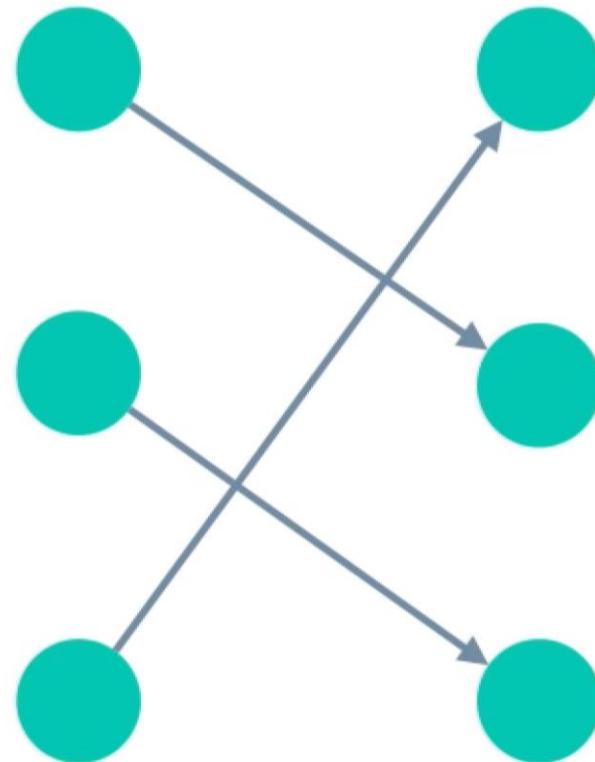
$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$



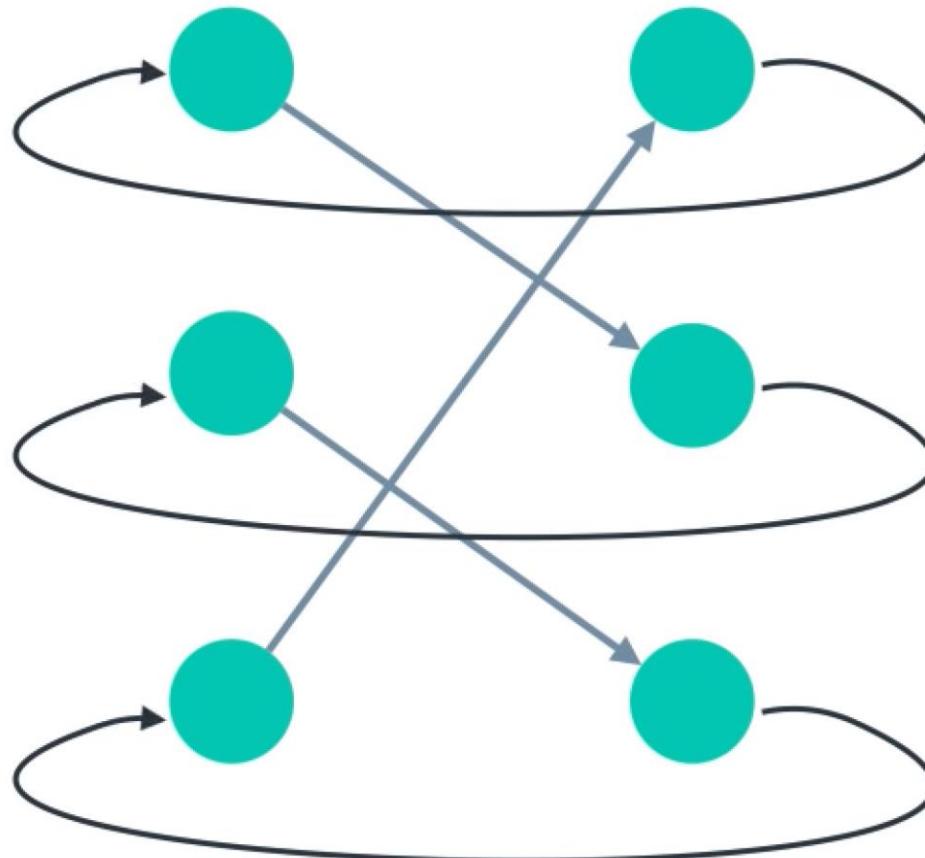
$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$



Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)

Weather



Sunny

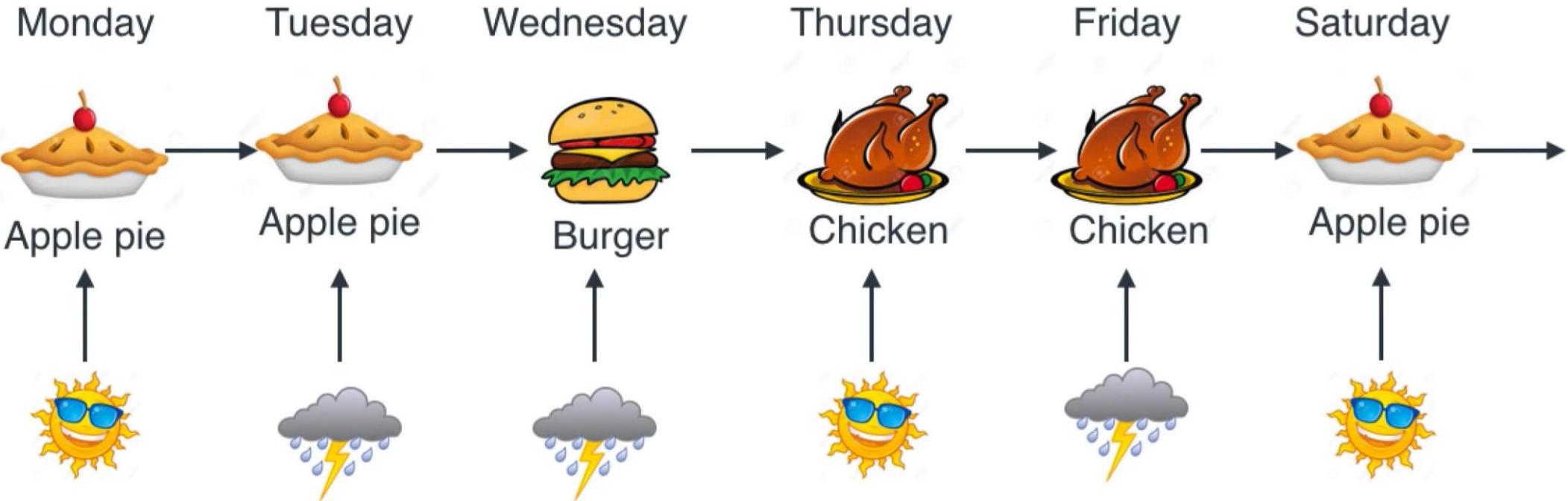
Same as yesterday



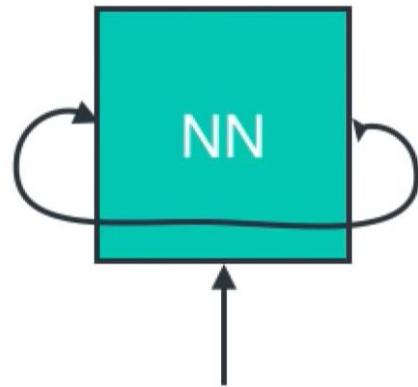
Rain

Next dish

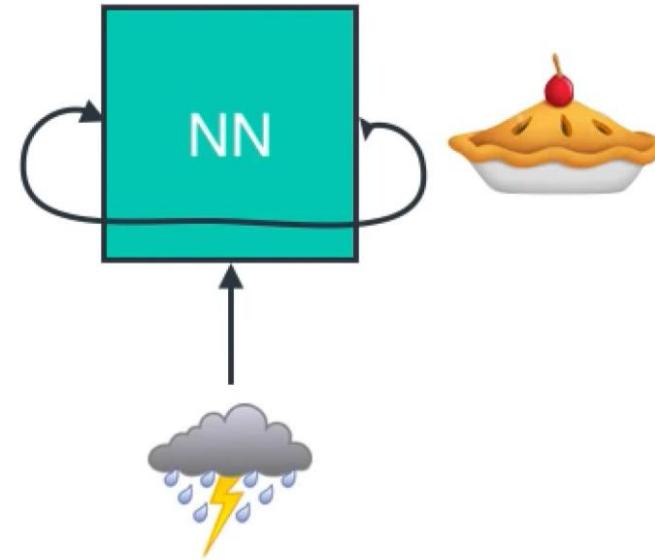
Redes Neurais Recorrentes (RNN)



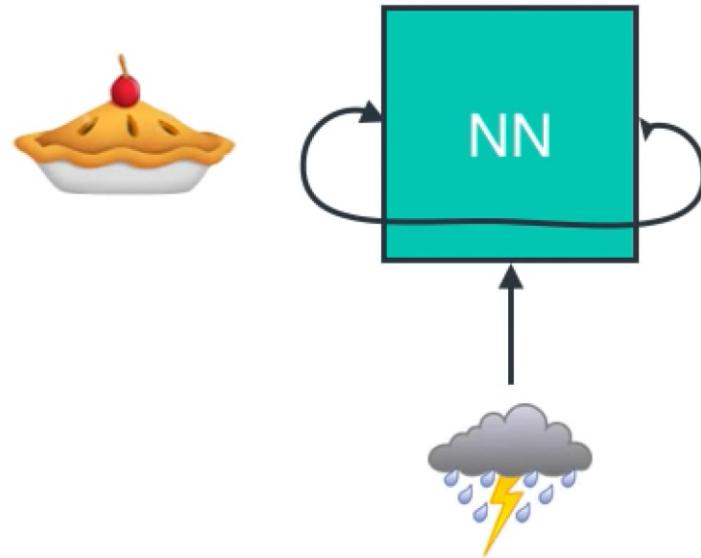
Redes Neurais Recorrentes (RNN)



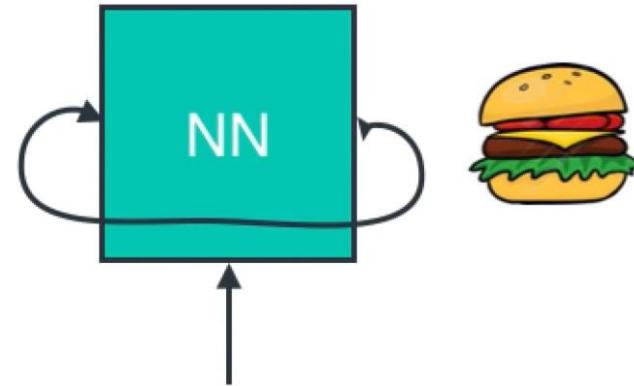
Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)



$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$



$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$



$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$



$$\begin{bmatrix} 1 \\ 0 \end{bmatrix}$$



$$\begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

+

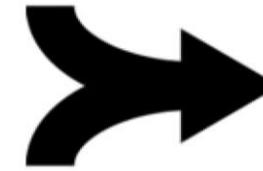
$$\begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}$$

Food

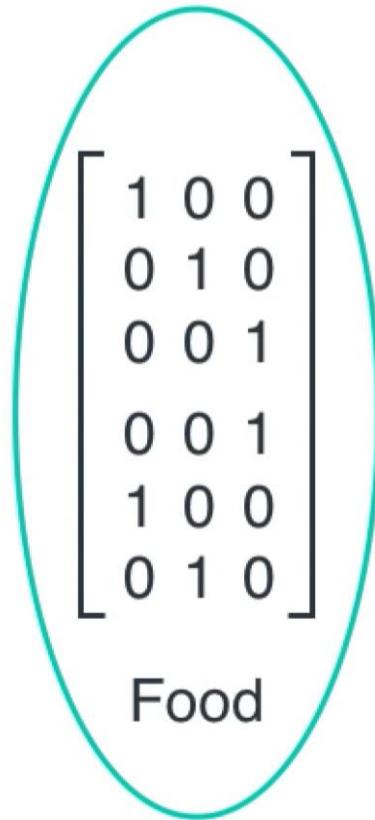
Add

Weather

Merge



Redes Neurais Recorrentes (RNN)

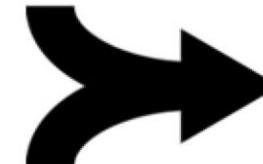


+

Add

$$\begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}$$

Weather



Merge

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ \hline 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

Food

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

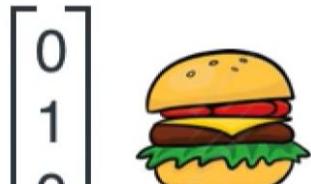

$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$


$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$


$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ \hline 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$


Food

Redes Neurais Recorrentes (RNN)



$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ \hline 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} = \text{Pie emoji}$$

Food

$$\begin{bmatrix} 1 \\ 0 \\ 0 \\ \hline 0 \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \\ \hline 0 \\ 1 \\ 0 \end{bmatrix}$$

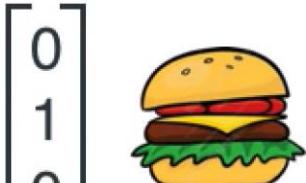


Same



Next day

Redes Neurais Recorrentes (RNN)



$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ \hline 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$

Food



$$= \begin{bmatrix} 0 \\ 1 \\ 0 \\ \hline 0 \\ 0 \\ 1 \end{bmatrix}$$



Same



Next day

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$


$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$


$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$


$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ \hline 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

Food



$$= \begin{bmatrix} 0 \\ 0 \\ 1 \\ 1 \\ 0 \\ 0 \end{bmatrix}$$



Same



Next day

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} + \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix}$$

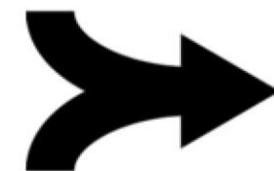
Food

+

Add

$$\begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \end{bmatrix} + \begin{bmatrix} 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 1 \\ 1 & 1 \end{bmatrix}$$

Weather



Merge

Redes Neurais Recorrentes (RNN)

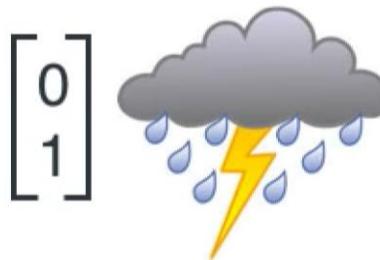
$$\begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ \hline 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}$$

Weather

Redes Neurais Recorrentes (RNN)



$$\begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ \hline 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ \hline 0 \\ 0 \\ 0 \end{bmatrix}$$

Weather

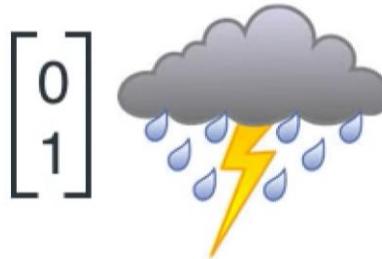
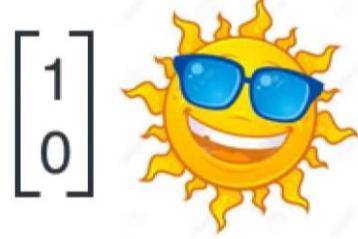


Same



Next day

Redes Neurais Recorrentes (RNN)



$$\begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ \hline 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix} = \text{Weather}$$


$$\begin{bmatrix} 0 \\ 0 \\ 0 \\ \hline 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 1 \\ 1 \end{bmatrix}$$



Same

Next day

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ \hline 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

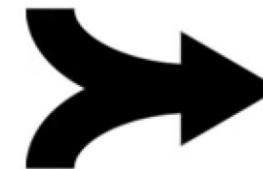
Food

+

$$\begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ \hline 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}$$

Weather

Add



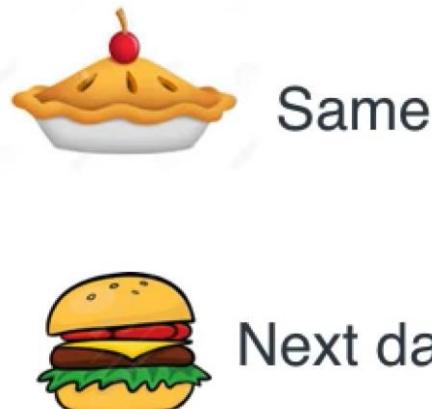
Merge

Redes Neurais Recorrentes (RNN)



Add

$$\begin{bmatrix} 1 \\ 0 \\ 0 \\\\ \hline 0 \\ 1 \\ 0 \end{bmatrix}$$



Redes Neurais Recorrentes (RNN)



Add

$$\begin{bmatrix} 1 \\ 0 \\ 0 \\ \hline 0 \\ 1 \\ 0 \end{bmatrix}$$



Same

Next day

+

$$\begin{bmatrix} 0 \\ 0 \\ 0 \\ \hline 1 \\ 1 \\ 1 \end{bmatrix}$$



Same

Next day

Redes Neurais Recorrentes (RNN)



Add

$$\begin{bmatrix} 1 \\ 0 \\ 0 \\ \hline 0 \\ 1 \\ 0 \end{bmatrix} \text{ Same } + \begin{bmatrix} 0 \\ 0 \\ 0 \\ \hline 1 \\ 1 \\ 1 \end{bmatrix} \text{ Next day} = \begin{bmatrix} 1 \\ 0 \\ 0 \\ \hline 1 \\ 2 \\ 1 \end{bmatrix}$$

The diagram illustrates a recurrent neural network (RNN) addition operation. It shows two hidden states being added together. The first hidden state is represented by a pie emoji above a lightning bolt emoji, and the second hidden state is represented by a sun emoji above a rain cloud emoji. The result of the addition is a third hidden state represented by a burger emoji. The operations are labeled "Same" for the first two hidden states and "Next day" for the result.

Redes Neurais Recorrentes (RNN)

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ \hline 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

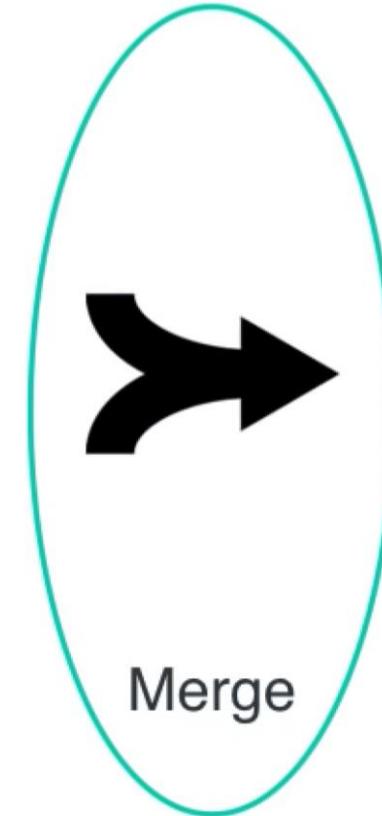
Food

+

$$\begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ \hline 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}$$

Add

Weather



Redes Neurais Recorrentes (RNN)



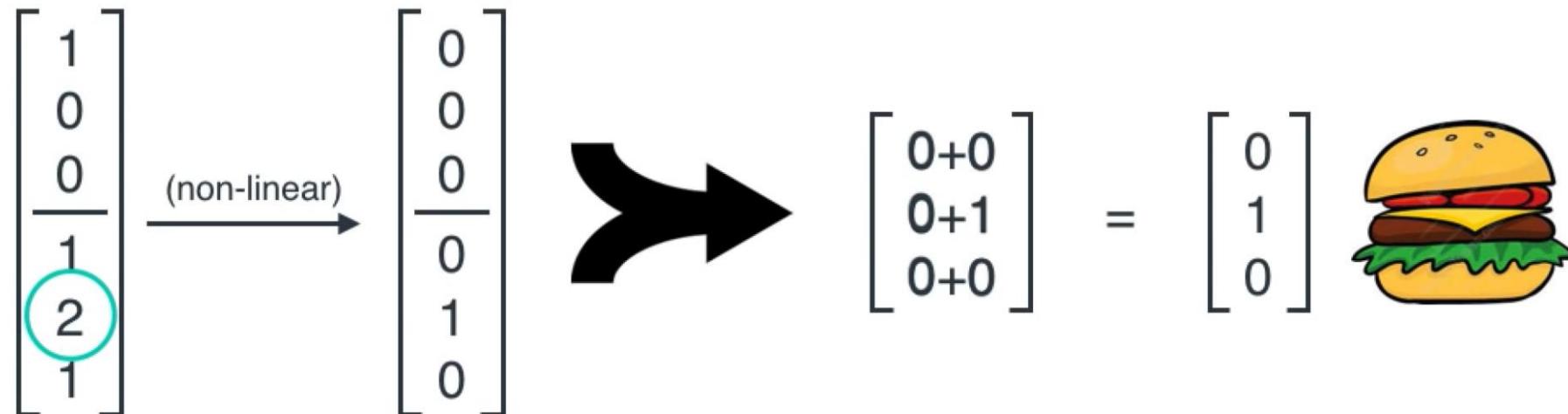
Merge

$$\begin{bmatrix} 1 \\ 0 \\ 0 \\ \hline 1 \\ 2 \\ 1 \end{bmatrix} \xrightarrow{\text{(non-linear)}} \begin{bmatrix} 0 \\ 0 \\ 0 \\ \hline 0 \\ 1 \\ 0 \end{bmatrix}$$

Redes Neurais Recorrentes (RNN)



Merge



Redes Neurais Recorrentes (RNN)

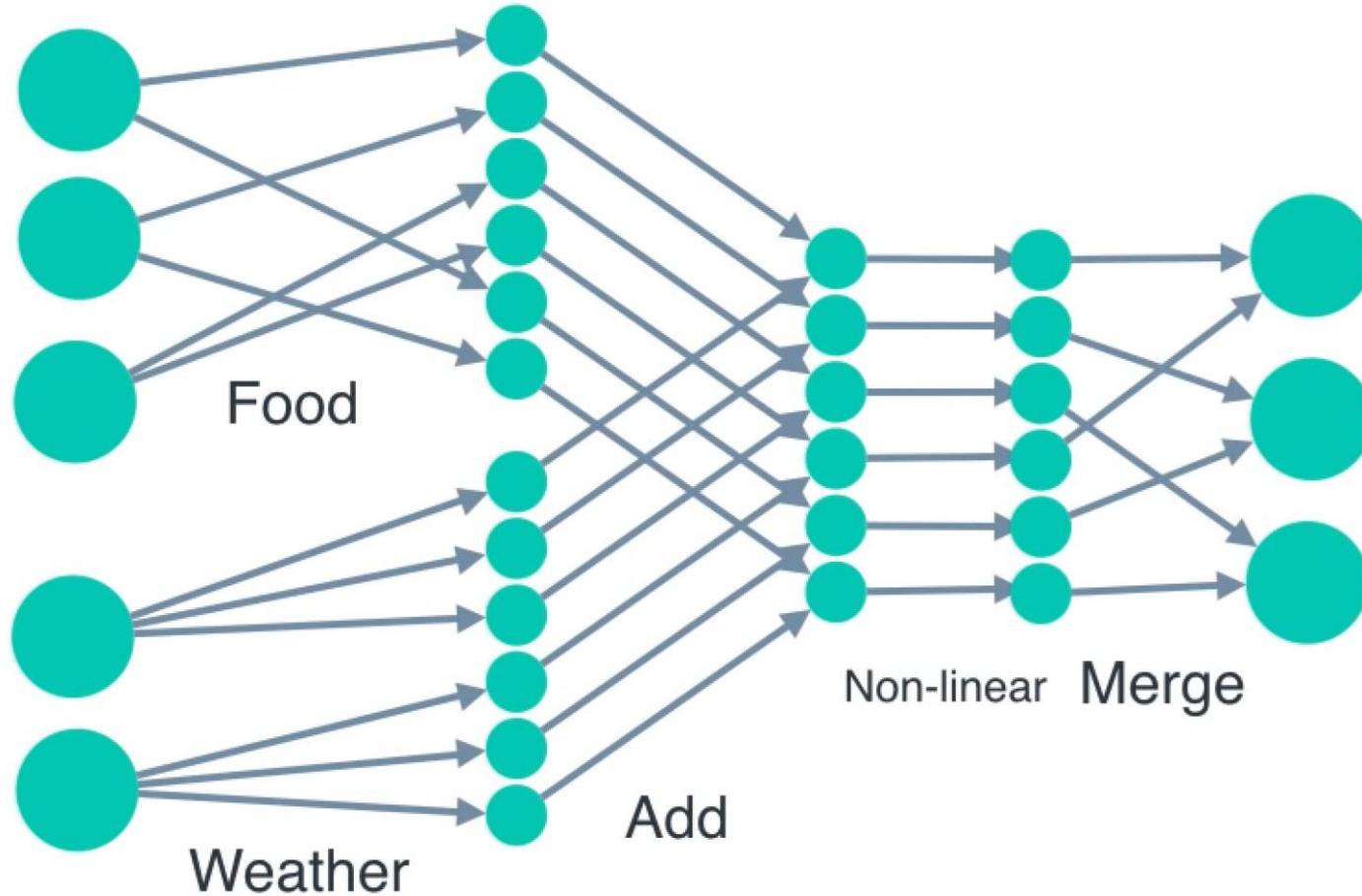


Merge

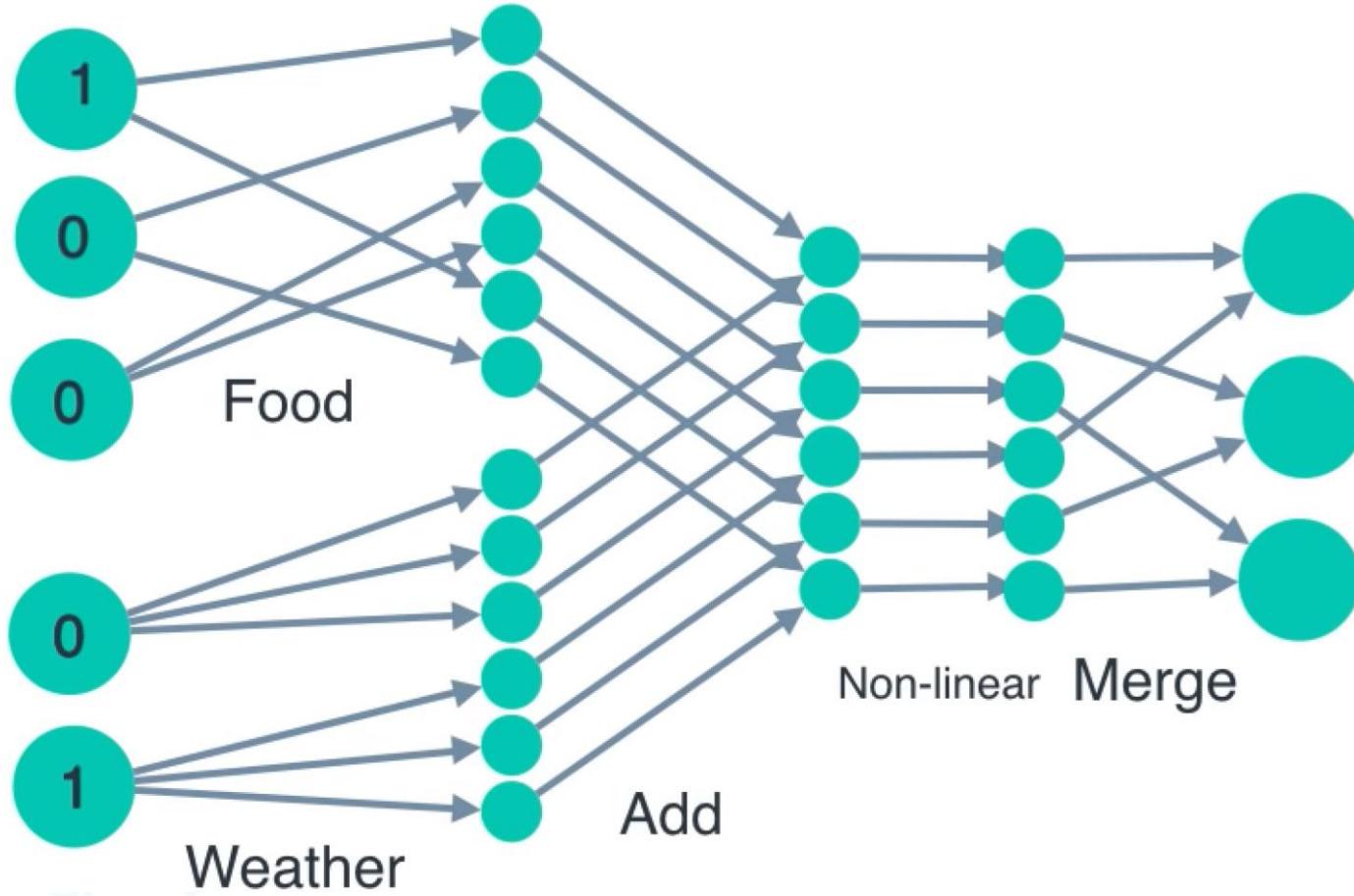
$$\left[\begin{array}{ccc|ccc} 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 \end{array} \right] \left[\begin{array}{c} 0 \\ 0 \\ 0 \\ \hline 0 \\ 1 \\ 0 \end{array} \right] = \left[\begin{array}{c} 0+0 \\ 0+1 \\ 0+0 \end{array} \right] = \left[\begin{array}{c} 0 \\ 1 \\ 0 \end{array} \right] \text{Hamburger}$$

Merge

Redes Neurais Recorrentes (RNN)

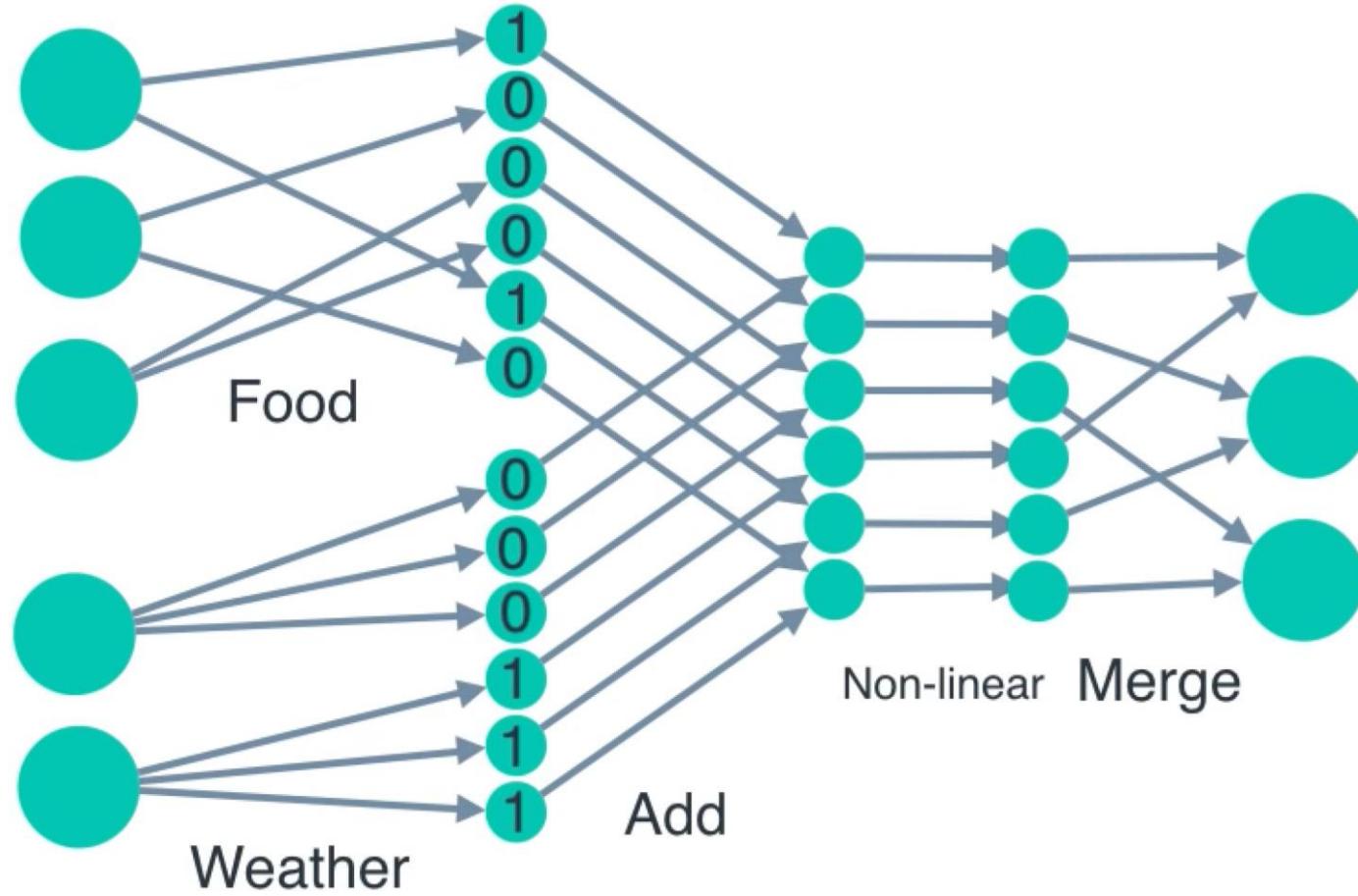


Redes Neurais Recorrentes (RNN)

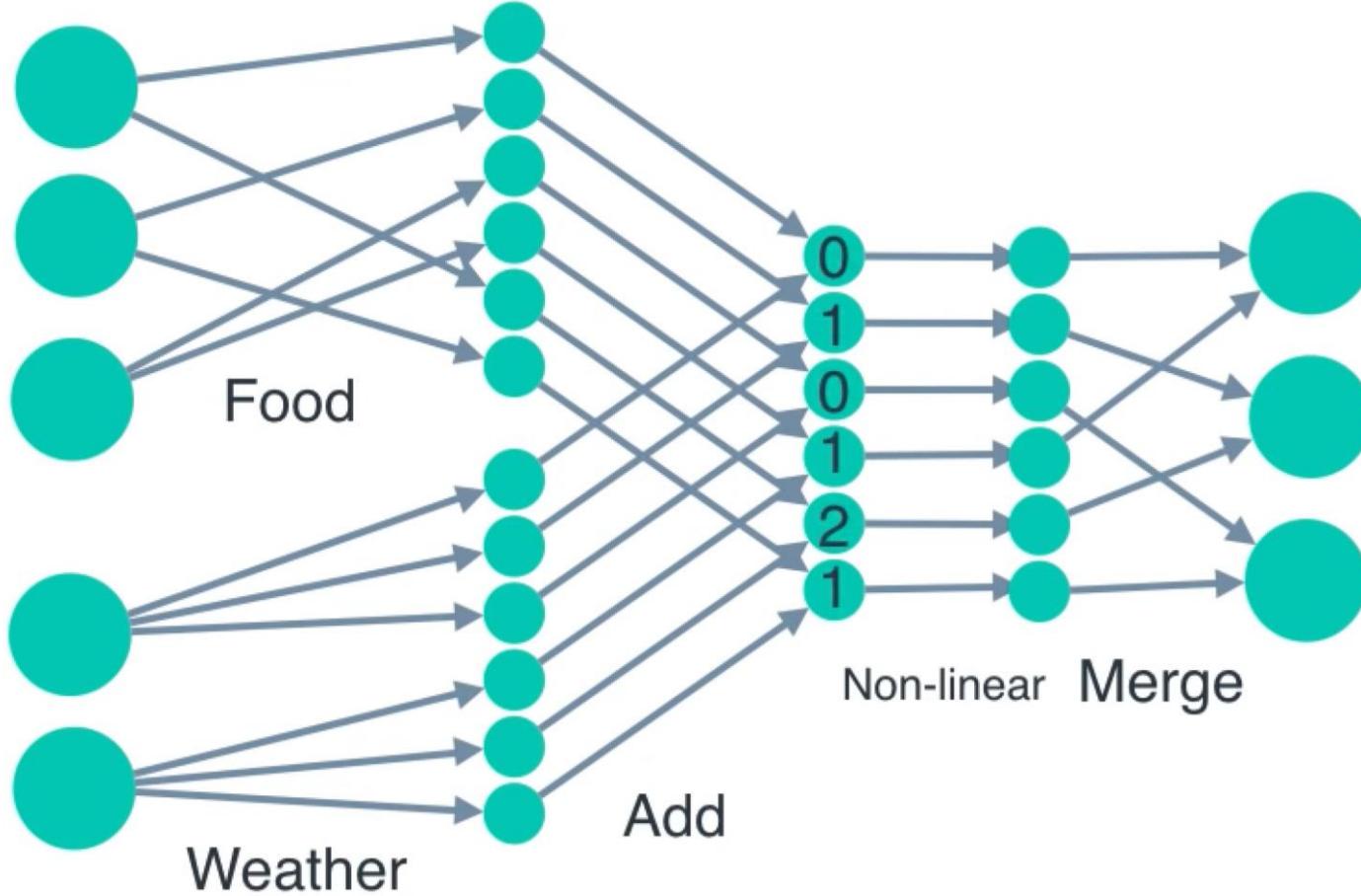

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$


Redes Neurais Recorrentes (RNN)

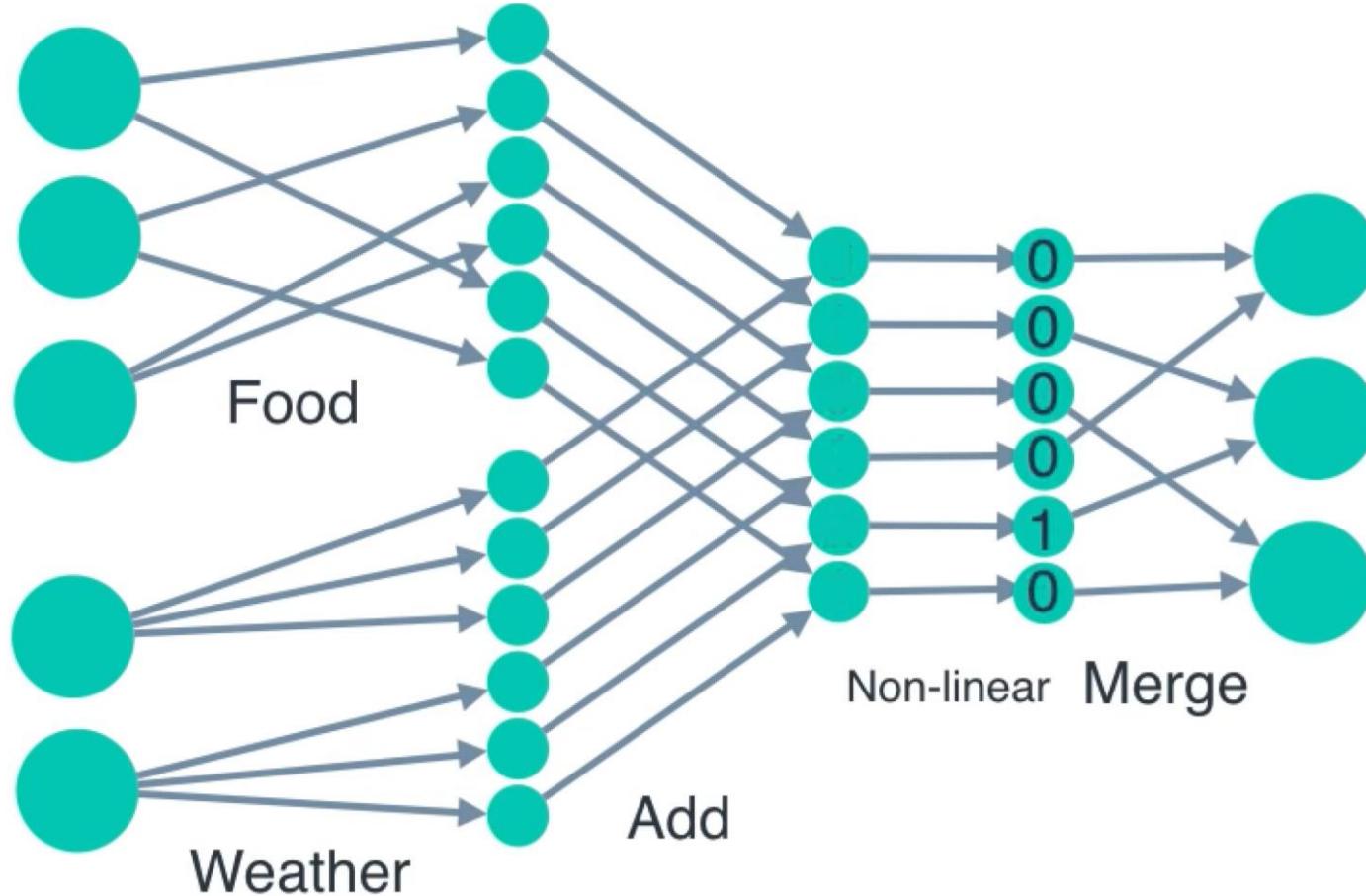


$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$


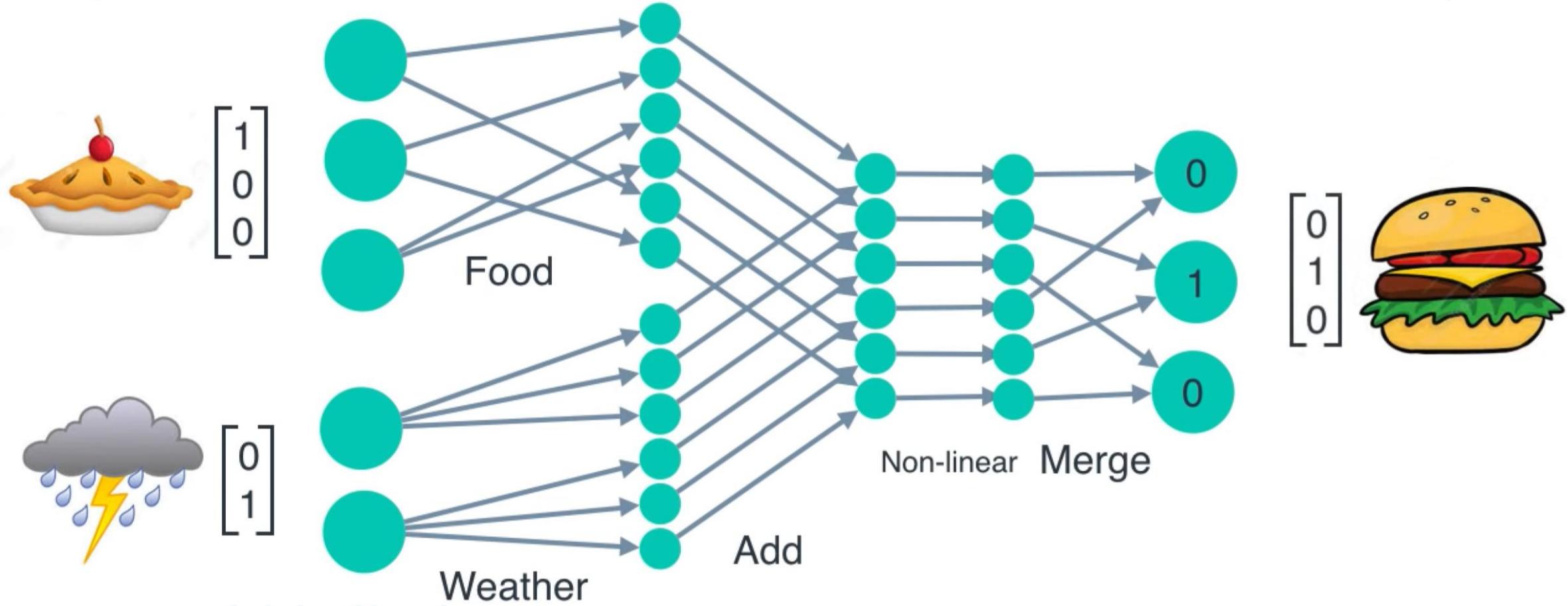
Redes Neurais Recorrentes (RNN)


$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

Redes Neurais Recorrentes (RNN)


$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$
$$\begin{bmatrix} 0 \\ 1 \end{bmatrix}$$


Redes Neurais Recorrentes (RNN)



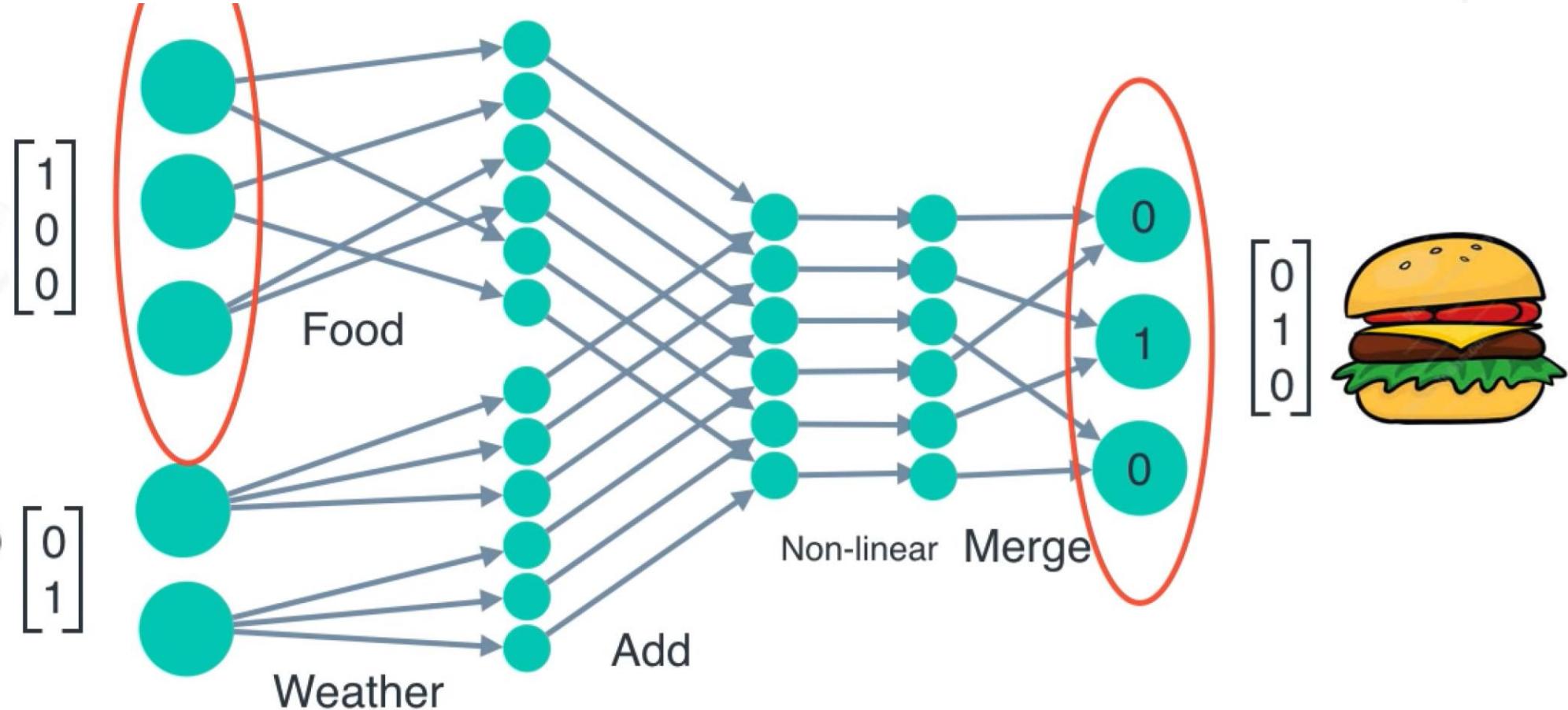
Redes Neurais Recorrentes (RNN)



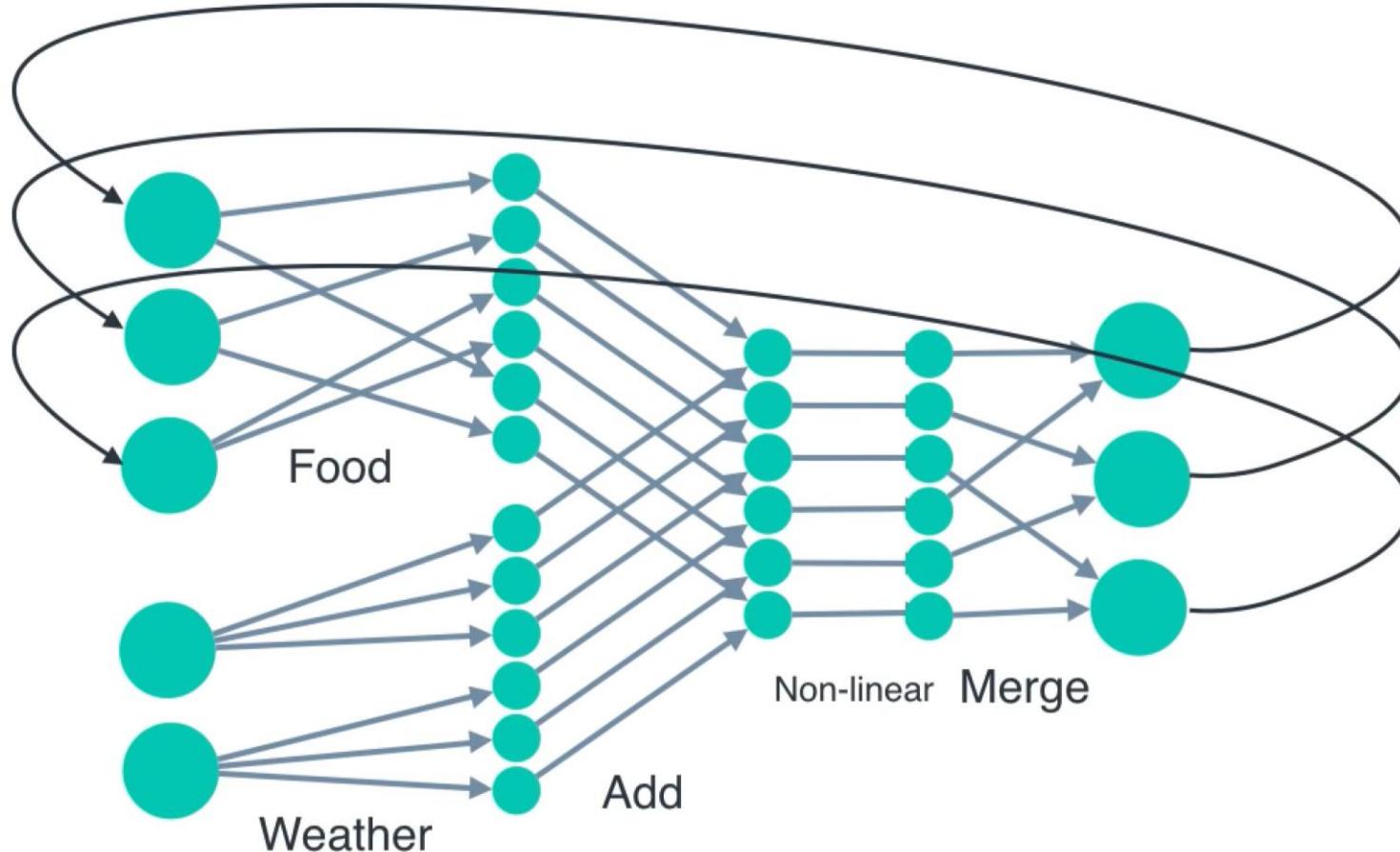
$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$



$$\begin{bmatrix} 0 \\ 1 \end{bmatrix}$$



Redes Neurais Recorrentes (RNN)



Redes Neurais Recorrentes (RNN)

$$h_t = f_W(h_{t-1}, x_t)$$

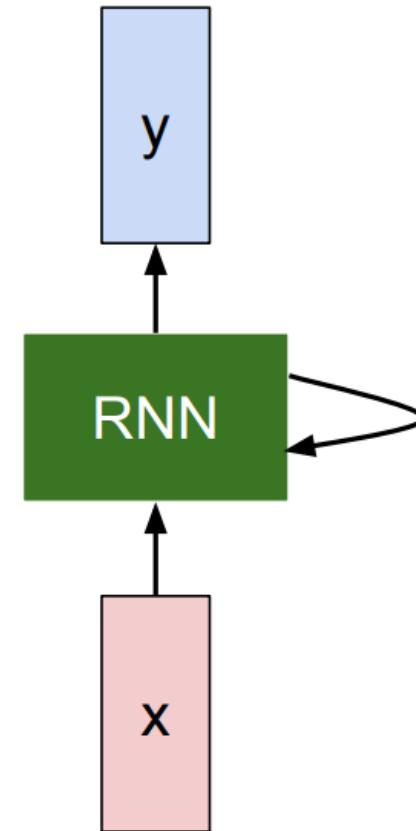
Podemos processar uma sequência de vetores x aplicando uma fórmula de recorrência a cada etapa de tempo (*time step*).

h_t - novo estado;

f_w - alguma função com parâmetros;

h_{t-1} - estado antigo;

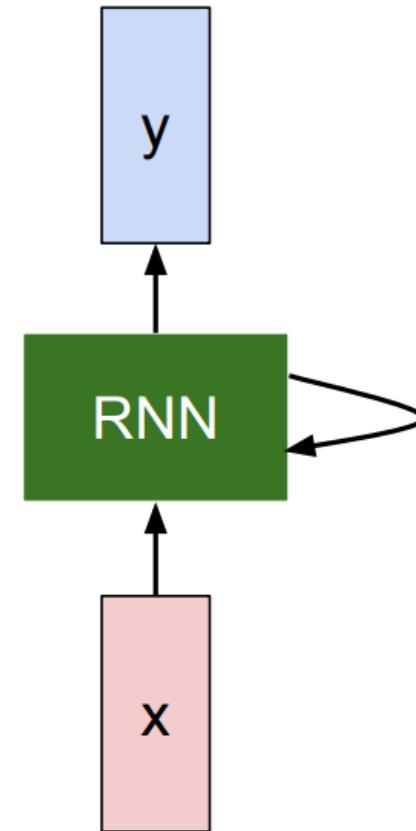
x_t – vetor de entrada em algum *time step*.



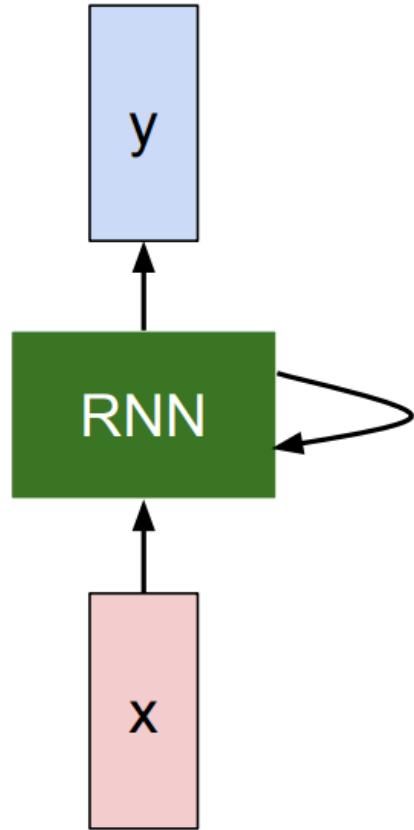
Redes Neurais Recorrentes (RNN)

Podemos processar uma sequência de vetores x aplicando uma fórmula de recorrência a cada etapa de tempo (*time step*).

$$h_t = f_W(h_{t-1}, x_t)$$



Redes Neurais Recorrentes (RNN) “Vanilla”



$$h_t = f_W(h_{t-1}, x_t)$$

$$h_t = \tanh(W_{hh}h_{t-1} + W_{xh}x_t)$$

$$y_t = W_{hy}h_t$$

O estado consiste em um único vetor "oculto" h:

RNN e LSTMs

Multilayer RNNs

$$h_t^l = \tanh W^l \begin{pmatrix} h_t^{l-1} \\ h_{t-1}^l \end{pmatrix}$$

$h \in \mathbb{R}^n$ $W^l [n \times 2n]$

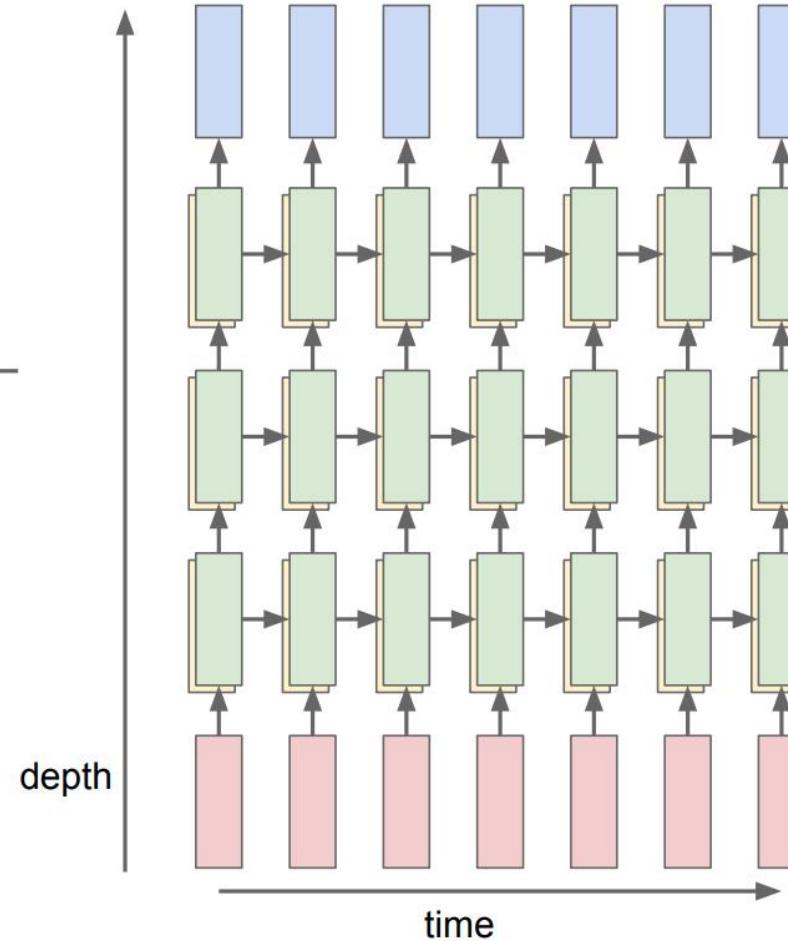
LSTM:

$$W^l [4n \times 2n]$$

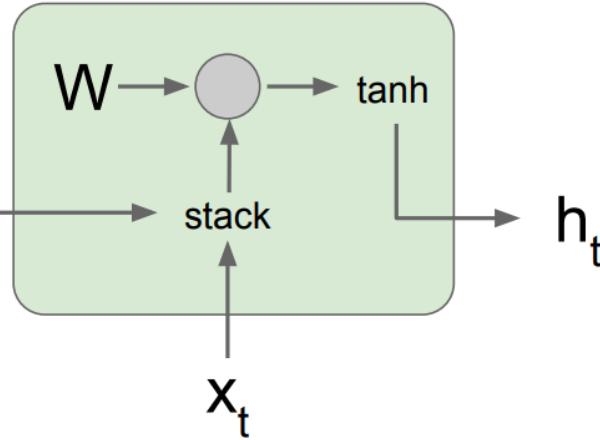
$$\begin{pmatrix} i \\ f \\ o \\ g \end{pmatrix} = \begin{pmatrix} \text{sigm} \\ \text{sigm} \\ \text{sigm} \\ \tanh \end{pmatrix} W^l \begin{pmatrix} h_t^{l-1} \\ h_{t-1}^l \end{pmatrix}$$

$$c_t^l = f \odot c_{t-1}^l + i \odot g$$

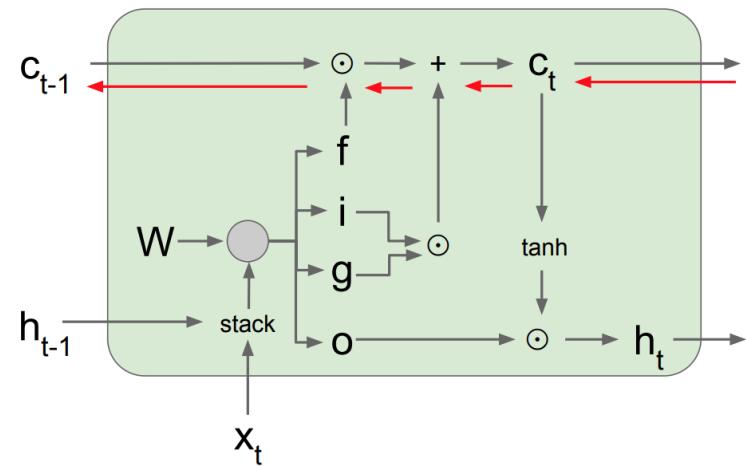
$$h_t^l = o \odot \tanh(c_t^l)$$



RNN e LSTMs



$$\begin{aligned}
 h_t &= \tanh(W_{hh}h_{t-1} + W_{xh}x_t) \\
 &= \tanh \left(\begin{pmatrix} W_{hh} & W_{hx} \end{pmatrix} \begin{pmatrix} h_{t-1} \\ x_t \end{pmatrix} \right) \\
 &= \tanh \left(W \begin{pmatrix} h_{t-1} \\ x_t \end{pmatrix} \right)
 \end{aligned}$$



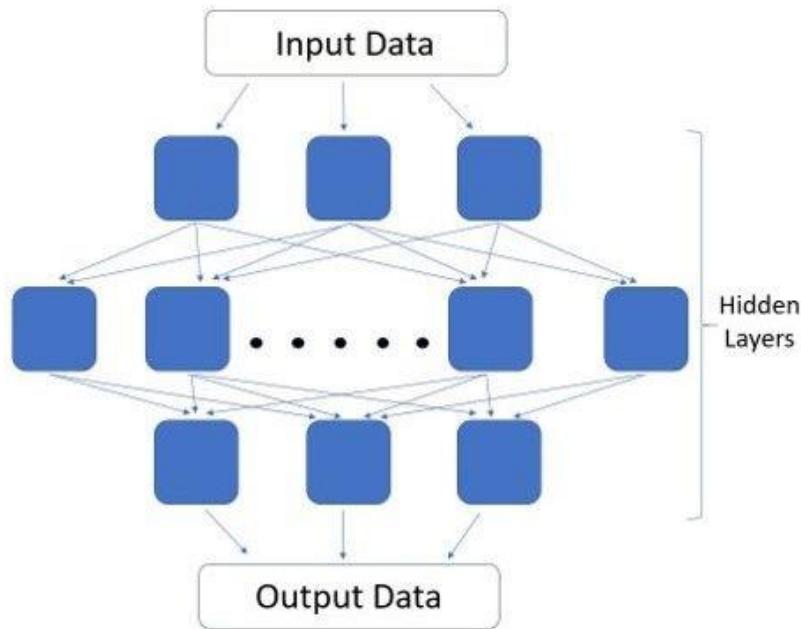
$$\begin{pmatrix} i \\ f \\ o \\ g \end{pmatrix} = \begin{pmatrix} \sigma \\ \sigma \\ \sigma \\ \tanh \end{pmatrix} W \begin{pmatrix} h_{t-1} \\ x_t \end{pmatrix}$$

$$\begin{aligned}
 c_t &= f \odot c_{t-1} + i \odot g \\
 h_t &= o \odot \tanh(c_t)
 \end{aligned}$$

- f: Forget gate, se deseja apagar célula;
- i: Input gate, se deve ou não gravar na célula;
- g: Gate gate (?), quanto deve se escrever na célula;
- o: Portão de saída, célula do quanto se deve reveler.

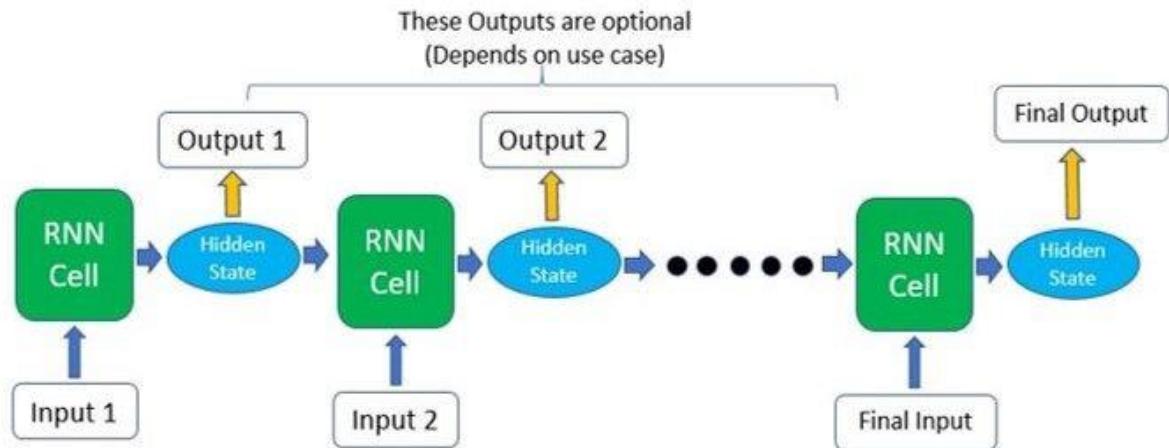
Comparison Between:

Traditional Feed-Forward Network

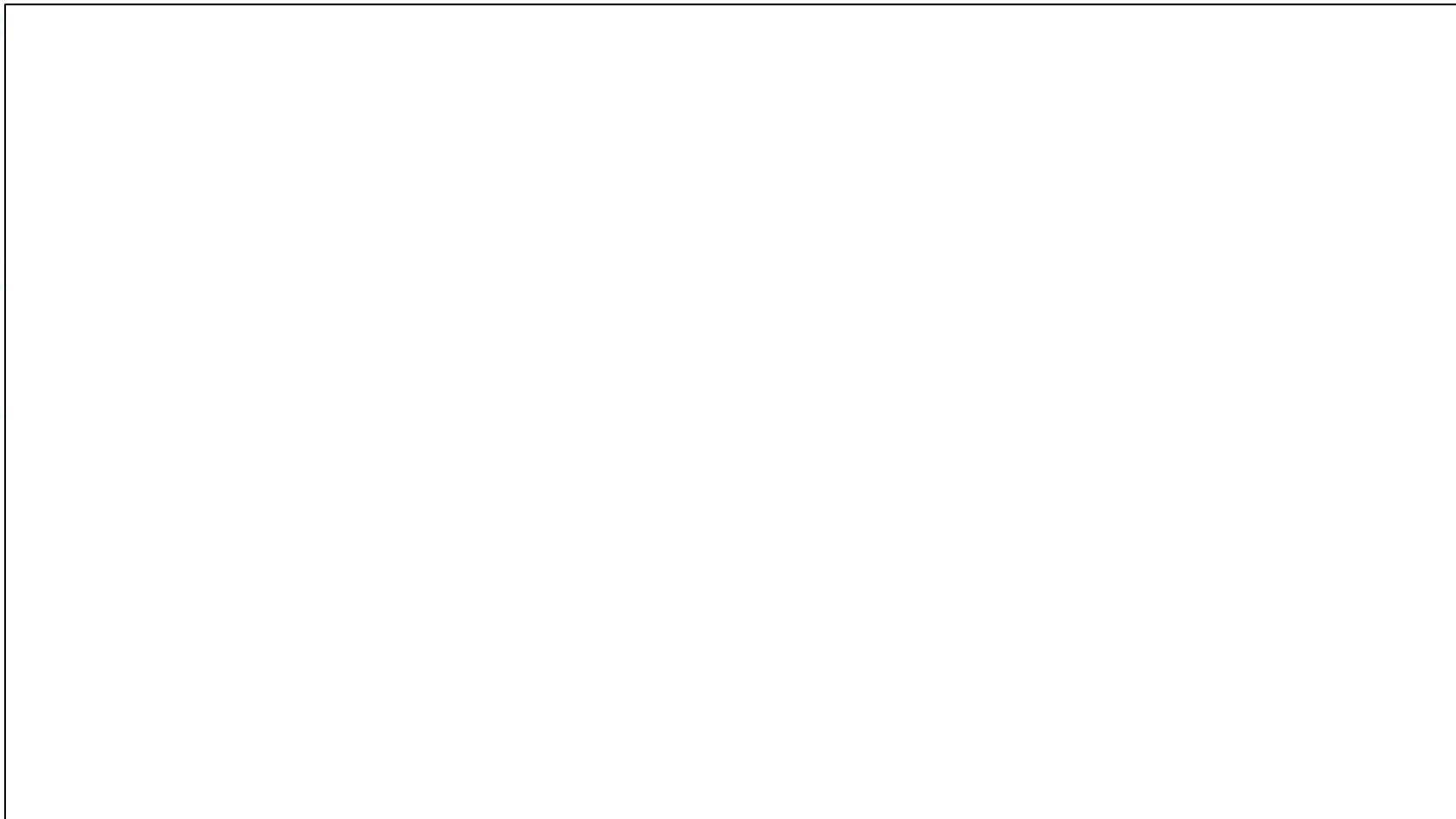


VS

Recurrent Neural Network



- Long Short-Term Memory (LSTM)
- Applications





Thank you!



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