NOTE BOOK

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DEEP LEARNING

Date: 9 / 11 / 2023

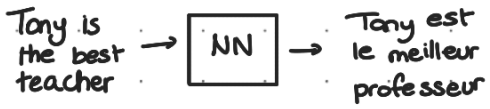
RECURRENT NEURAL NETWORKS

Based on material by Luis Serrano

Used to process sequential data

EXAMPLES

1. Bitcoin Trading (INPUT: seq. of prices, OUT: predictor of next price)
2. Speech-To-Text
3. Translation



4. Any time-series (weather prediction)

Recurrent NNs can take inputs of different sites

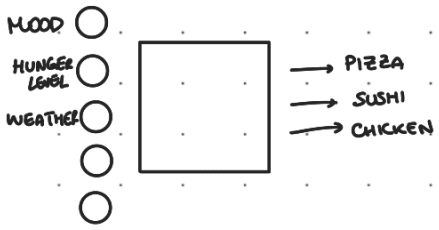
EXAMPLE Bob the perfect roommate

Goal Design a NN that predicts what is for dinner

Bob always cooks PIZZA , SUSHI , CHICKEN

Suppose Bob always cooks in the following order:

PIZZA, CHICKEN, SUSHI, PIZZA, CHICKEN, SUSHI



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

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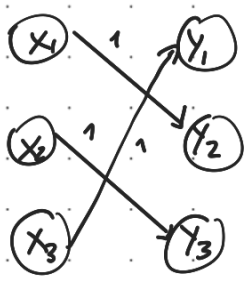
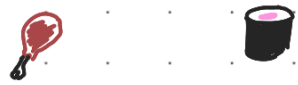
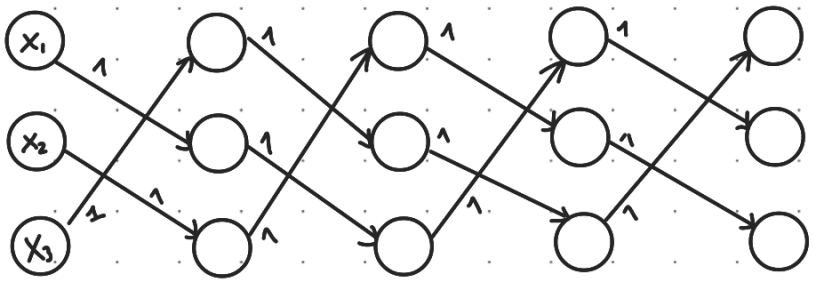


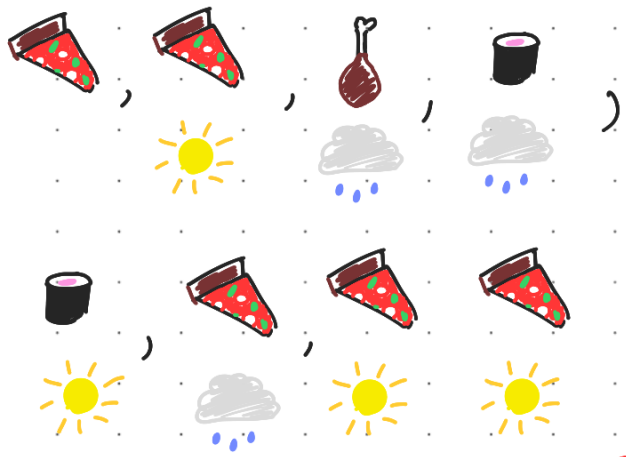
$$M = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$



A RECURRENT NEURAL NETWORK has cycles, or it is an infinite feedforward neural network (with shared parameters)



Let's make things more complicated



BOB'S RULES:

1. If it's SUNNY, Bob gives you leftovers = prev. day meal
2. If it is RAIN, Bob cooks the next meal in the sequence

EXAMPLE

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

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

$\Rightarrow$ OUTPUT depends on new info = today's weather and past info = yesterday's meal

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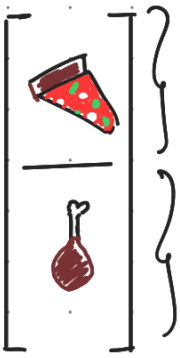
THE FOOD MATRIX

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

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



Same day

Next day

THE WEATHER MATRIX

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

Same day

Next day

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

Same day

Next day

DEFINE $f : \mathbb{R}^n \to \mathbb{R}^n$ by

$$f(x)_i = \begin{cases} 0, & \text{if } x_i < \max\limits_{j=1,\dots,n} x_j \\ 1, & \text{if } x_i = \max\limits_{j=1,\dots,n} x_j \end{cases}$$

$$f\left(\begin{bmatrix} 3 \\ -1 \\ 2 \\ 3 \end{bmatrix}\right) = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

NOTE : f is non-linear

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INPUT Previous day's meal $= a \in \mathbb{R}^3$
Today's weather $= b \in \mathbb{R}^2$

OUTPUT Prediction for Today's meal

ALGORITHM

1. Multiply a by the Food Matrix to obtain $a' \in \mathbb{R}^6$
2. Multiply b " " Weather " " " $b' \in \mathbb{R}$
3. Add a' and b' to obtain $a' + b' \in \mathbb{R}^6$
4. Apply f to $a'+b'$ to obtain $f(a'+b') \in \mathbb{R}^6$
5. Apply the MERGE MAP to $f(a'+b')$

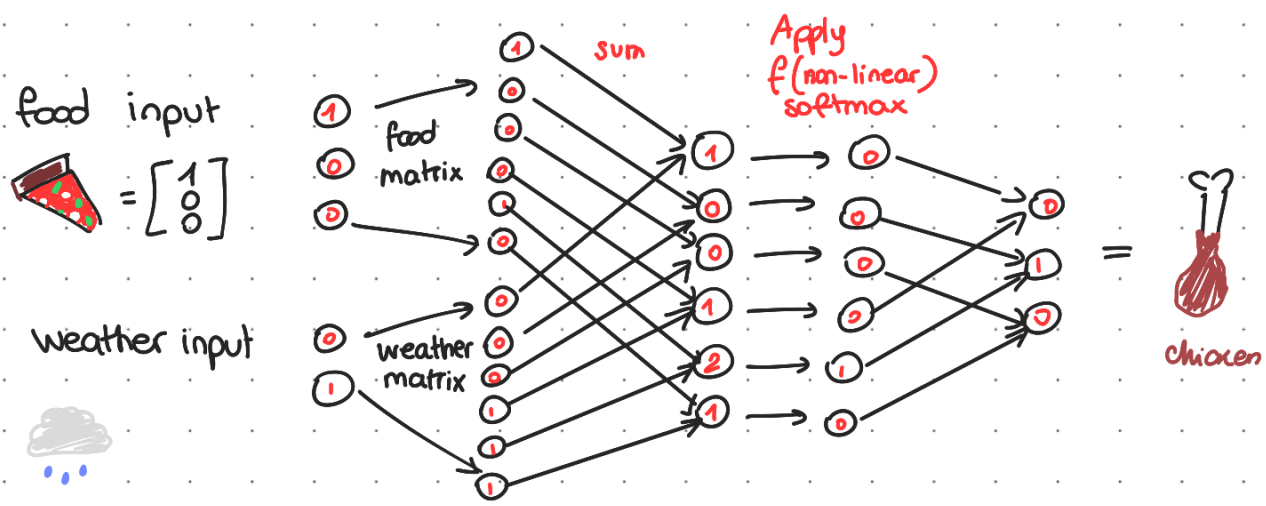
$$g : \mathbb{R}^{2m} \longmapsto \mathbb{R}^m \quad \text{by} \quad g\left[\begin{array}{c} u \\ \hline v \end{array}\right] = u+v \in \mathbb{R}^m$$

$\}$ m coordinates

EXERCISE

The merge map is a matrix multiplication

$$\left[\, I \mid I \,\right] \left[\begin{array}{c} u \\ \hline v \end{array}\right] = \left[\, u+v \,\right]$$



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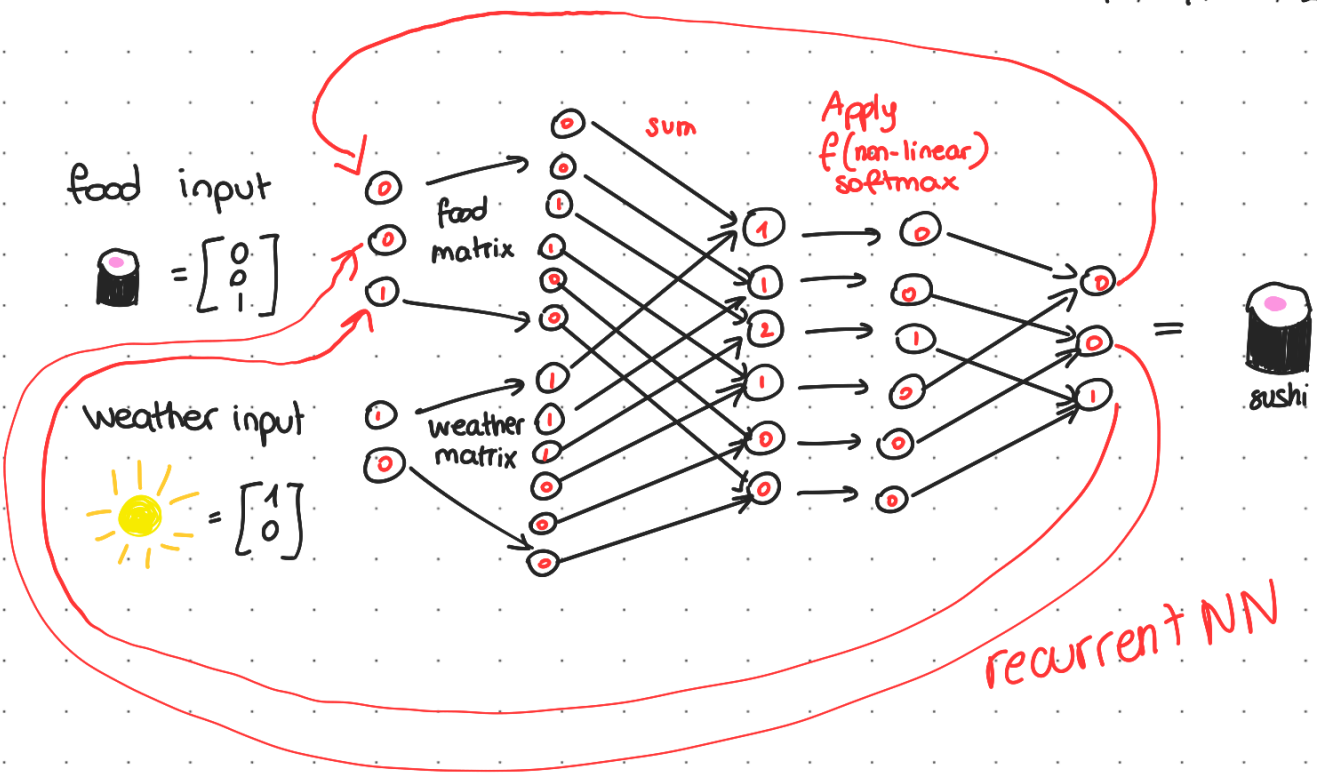

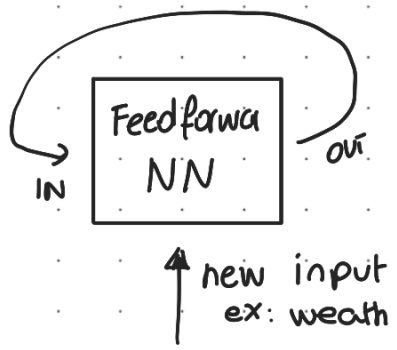
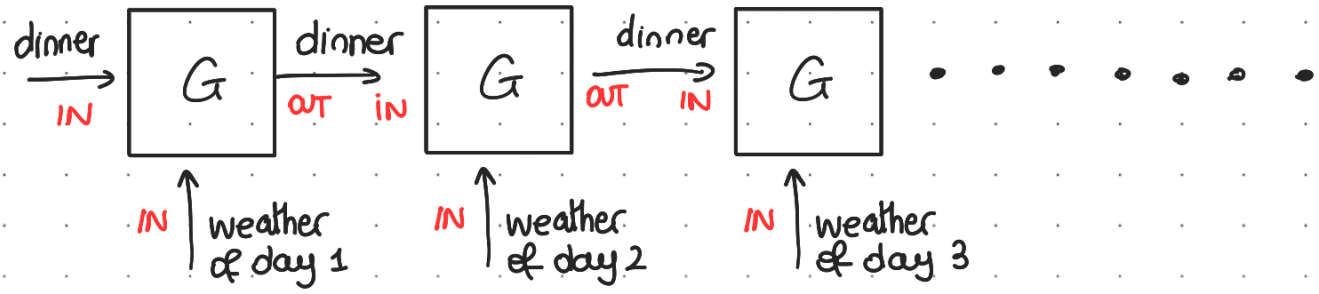
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