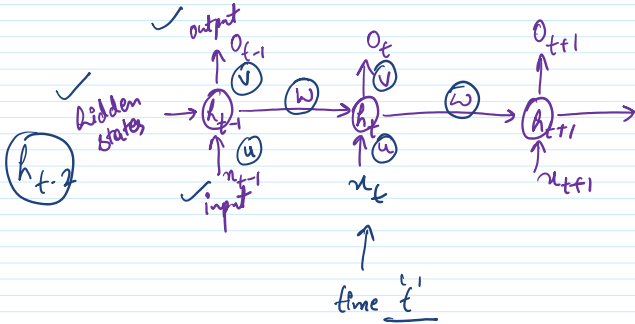


# Recurrent Neural Networks (RNNs)

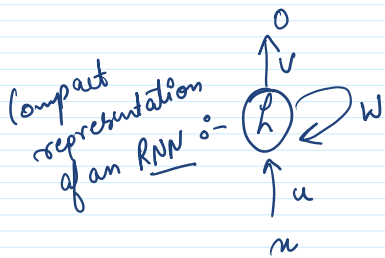
"Temporal Dependency"

Input  $\rightarrow \{x_1, x_2, \dots, x_t, \dots, x_{n-1}, x_n\}$

Output  $\rightarrow \{y_1, y_2, \dots, y_t, \dots, y_{n-1}, y_n\}$



$u, v, w \rightarrow$  shared weight matrices across time.  
 $\rightarrow$  temporal dependency.

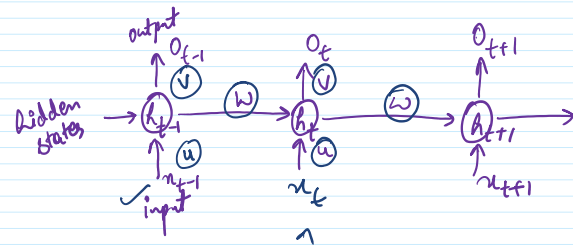


$\rightarrow$  RNNs have memory.  
 $\rightarrow$  recurrent because they perform same task for every input.

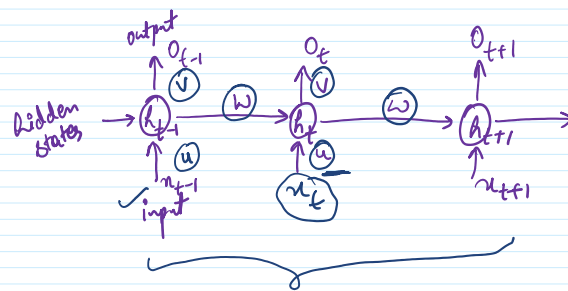
$$h_t = f(\underbrace{wh_{t-1} + ux_t + a}_{\text{bias 1}}) \leftarrow \text{tanh}$$

$$o_t = g(\underbrace{vh_t + b}_{\text{bias 2}}) \leftarrow \text{sigmoid}$$

$\Rightarrow$  Hidden state has summary of all the information till time  $t$ .



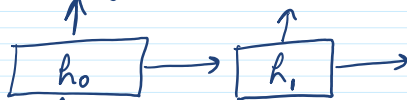
- $u_i \in \mathbb{R}^n$  (from word2vec)
- $h_i \in \mathbb{R}^d$
- $a \in \mathbb{R}^k$
- $u \in \mathbb{R}^{d \times n}$
- $w \in \mathbb{R}^{d \times d}$
- $v \in \mathbb{R}^{k \times d}$



many-to-many

①

Image Captioning  
 $O_0$  (two)



visual features

one-to-many RNN.



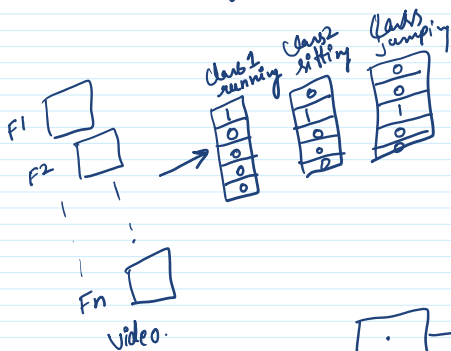
Two dogs play in the grass.



②

Many-to-one RNN

Activity Classification



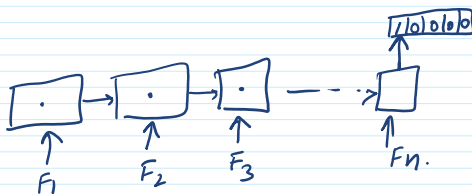
One hot vector

3 classes

cat  $\rightarrow$  [1 0 0]

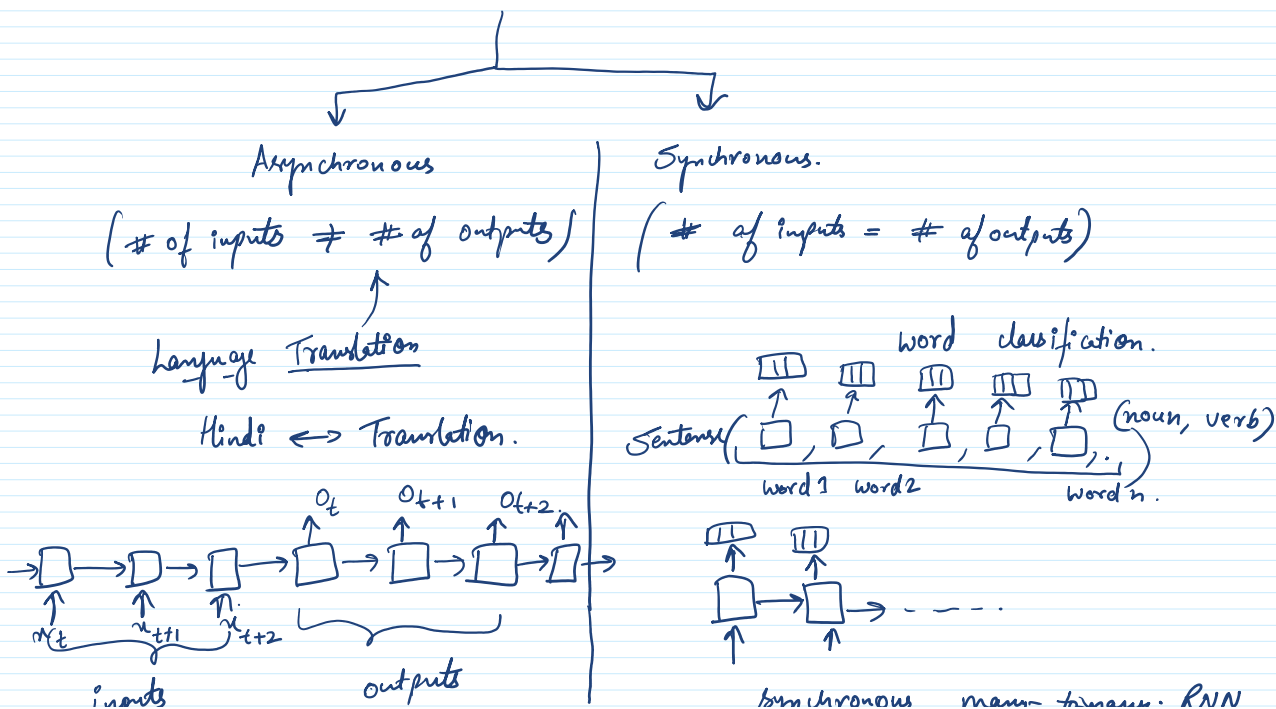
dog  $\rightarrow$  [0 1 0]

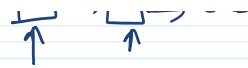
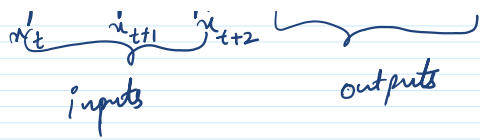
horse  $\rightarrow$  [0 0 1]



Many-to-one.

③ Many-to-many :-





synchronous many-to-many RNN.

$$\theta = (u, v, w, a, b)$$

$$L(\theta) = \sum_{t=1}^T L_t(\theta)$$

MSE / ce loss