

← Sequence Data →

Speech recognition → Sequence of words

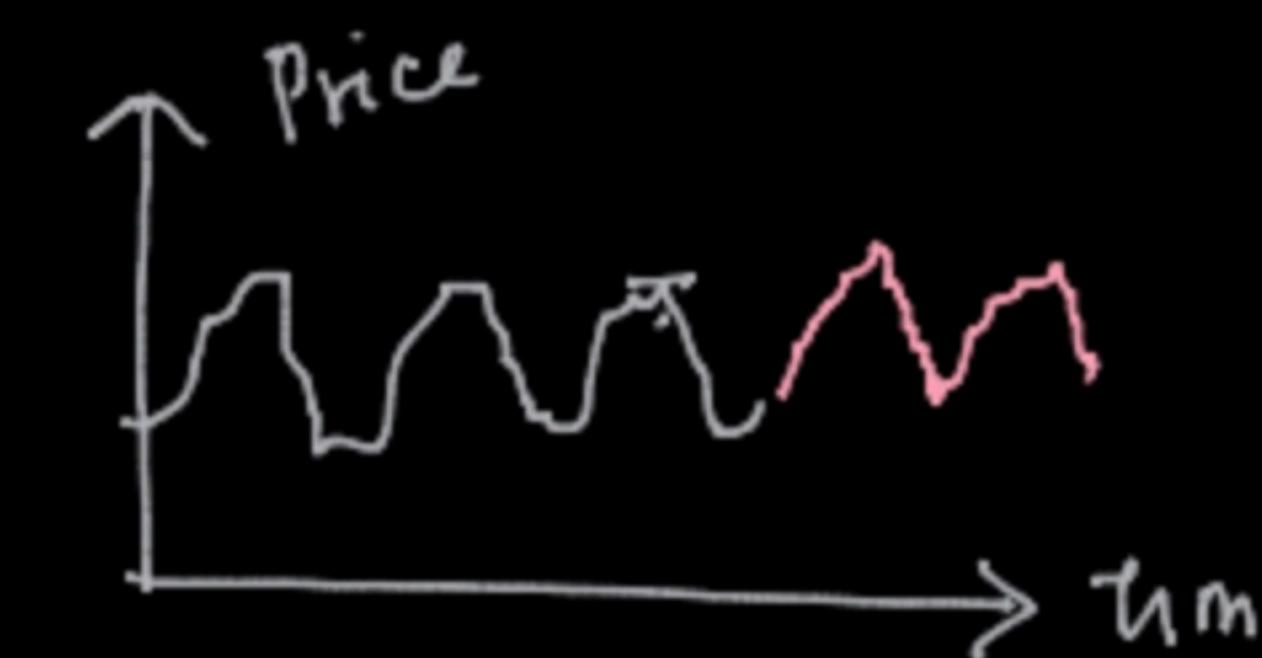
Music generation → output notes.

Machine translation → Voulez-vous chanter avec moi ?
↓
will you sing with me?

x_1	x_2	x_3	y

Video activity → .□□□□. → Walking.

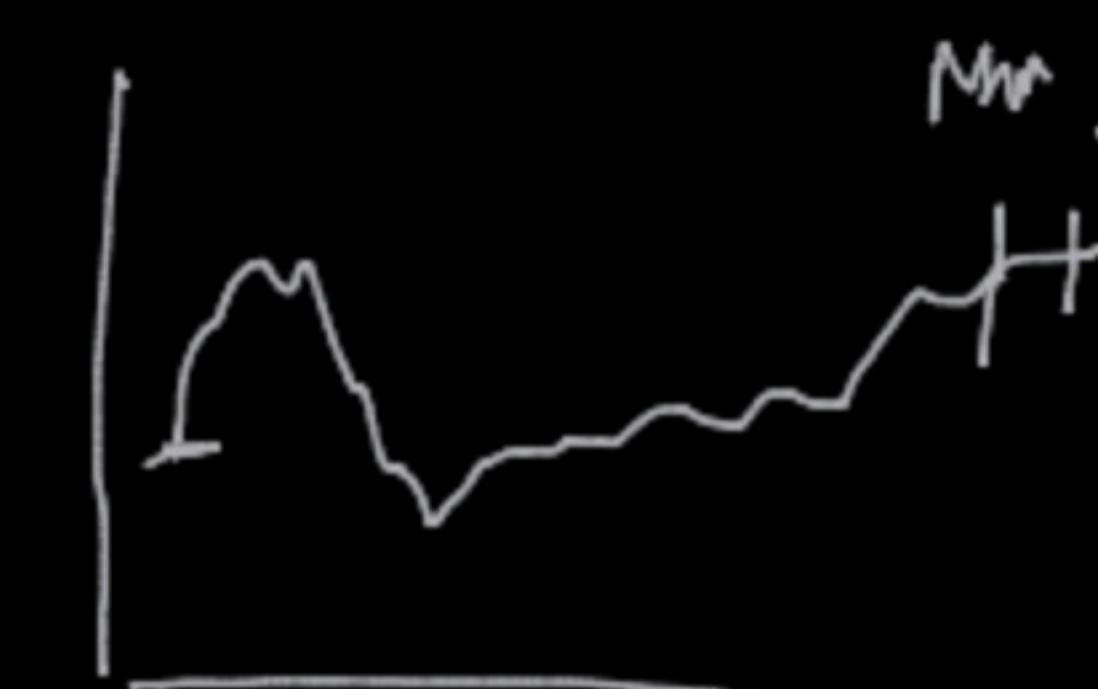
Stock Market → Stock prices.



✓
Tom worked in the navy. He has
always loved being in the sea.

Sentence completion → . . . —

RNN → LSTM → Transformers
→ GRU



I am speaking.

$x_{t-2} \ x_{t-1} \ x_t$ → temporal Data

25x12 → 30 0

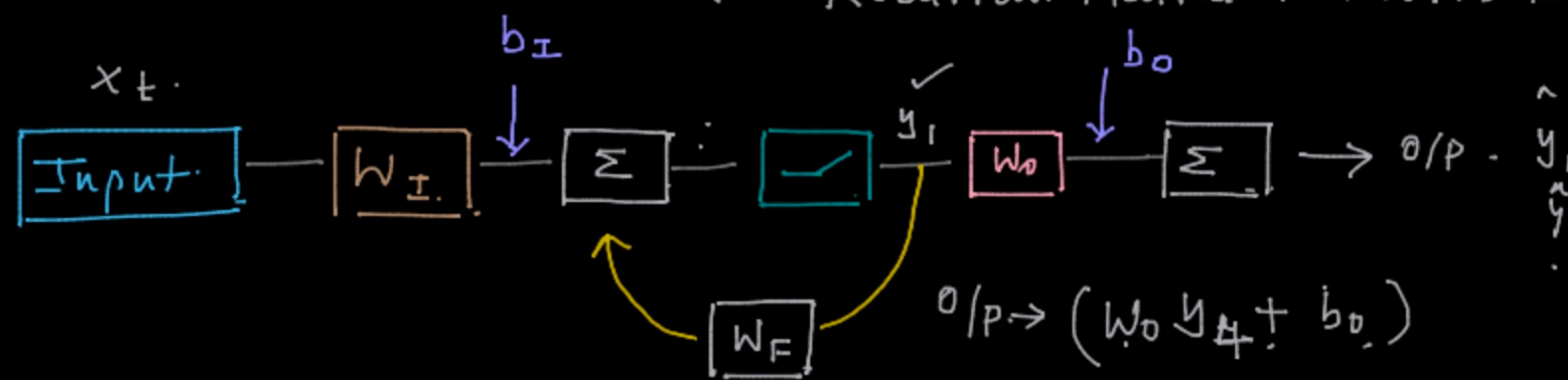
Recurrent → loop.

→ feedback loop.

Time	Stock price
Jan 2001	1
Feb 2001	2
Mar 2001	3
...	...
May 2023	...
May 2024	...
...	...
May 2025 ✓	...
APR 2025 ✓	...
MAY 2025 ↗	...

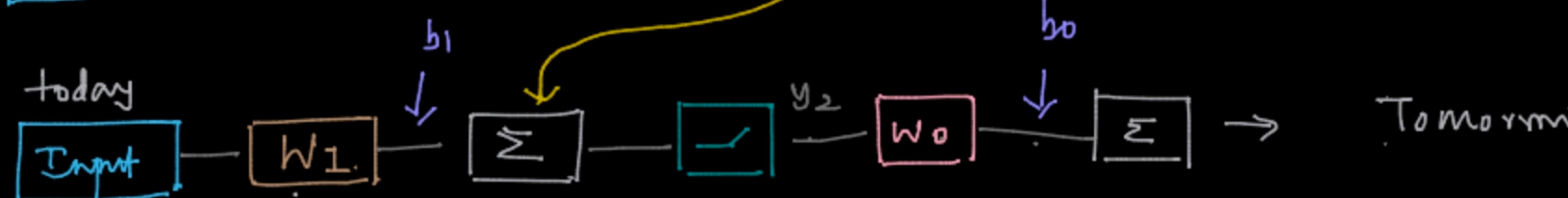
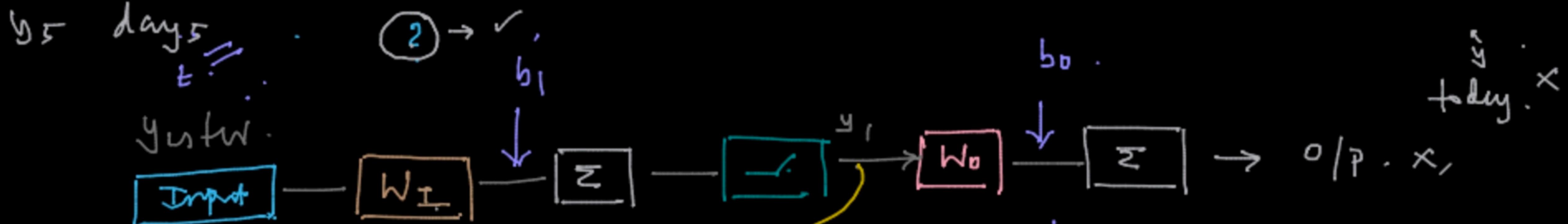
↑ Past
60

← Recurrent Neural Networks →



$$\begin{array}{l} y_t = \text{ReLU}(W_I x_t + b_I) \\ \vdots \\ y_{t-1} = \text{ReLU}(W_I x_{t-1} + b_I) \\ y_{t-2} = \text{ReLU}(W_I x_{t-2} + b_I) \\ y_{t-3} = \text{ReLU}(W_I x_{t-3} + b_I) \\ y_{t-4} = \text{ReLU}(W_I x_{t-4} + b_I) \\ y_{t-5} = \text{ReLU}(W_I x_{t-5} + b_I) \end{array}$$

ignore $y_3 = \text{ReLU}(W_I x_4 + W_F y_2 + b_I)$



activation

$$o \Rightarrow f_u(W_1 x_1 + W_2 x_2 + W_3 x_3)$$

ReLU \rightarrow

$$+v_L$$

$$0 \rightarrow 1.$$

$\text{Sigmoid} \rightarrow \frac{1}{1 + e^{-x}}$

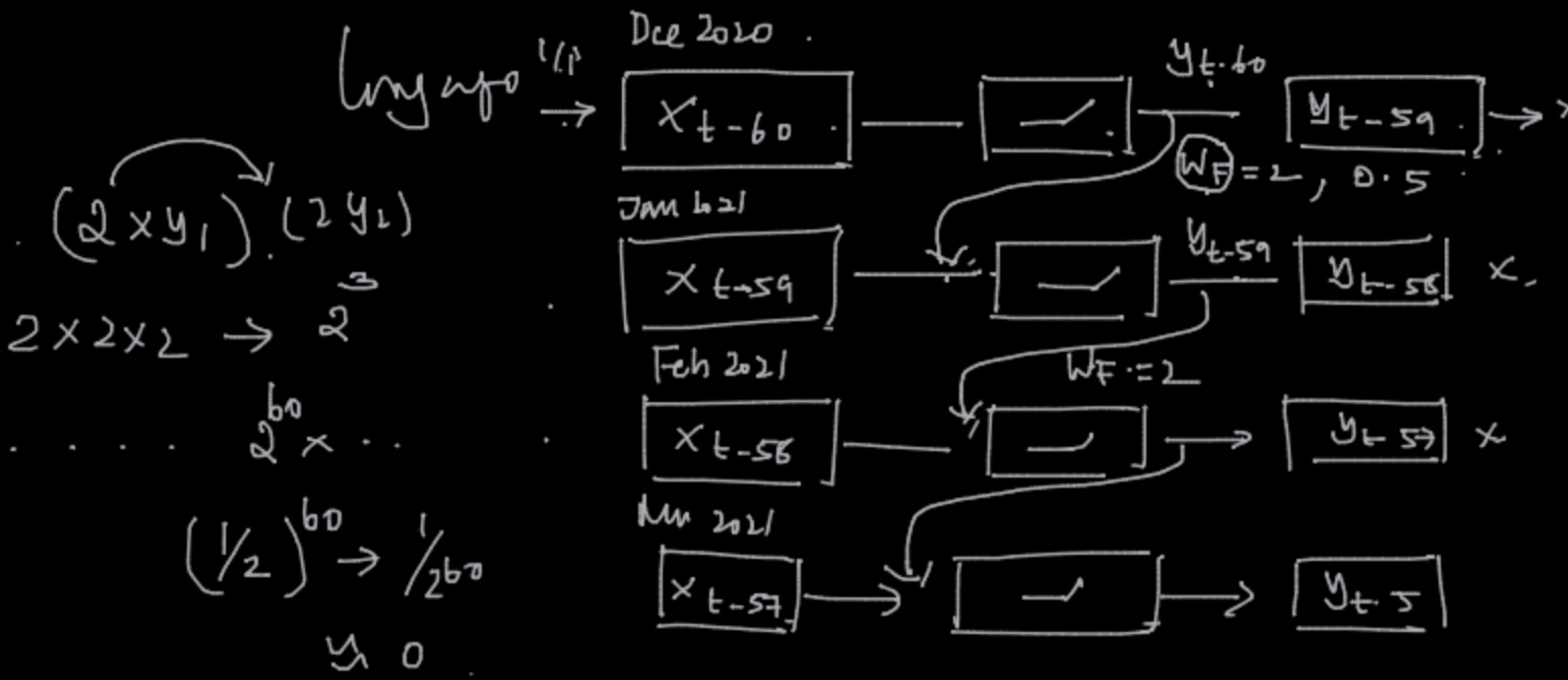
$$0 \rightarrow 1.$$

$\text{tanh} \rightarrow \frac{e^x - e^{-x}}{e^x + e^{-x}}$

$\rightarrow -1 \text{ to } +1.$

I/P
Yesterday \rightarrow Tomorrow.
today.

Weights and biases
are shared



Dec 2020 \checkmark

Jan 2021

Feb 2021

Mar 2021

Apr 2021

May 2021

Jun 2021

Jul 2021

Aug 2021

Sep 2021

Oct 2021

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Jan 2022

Feb 2022

Mar 2022

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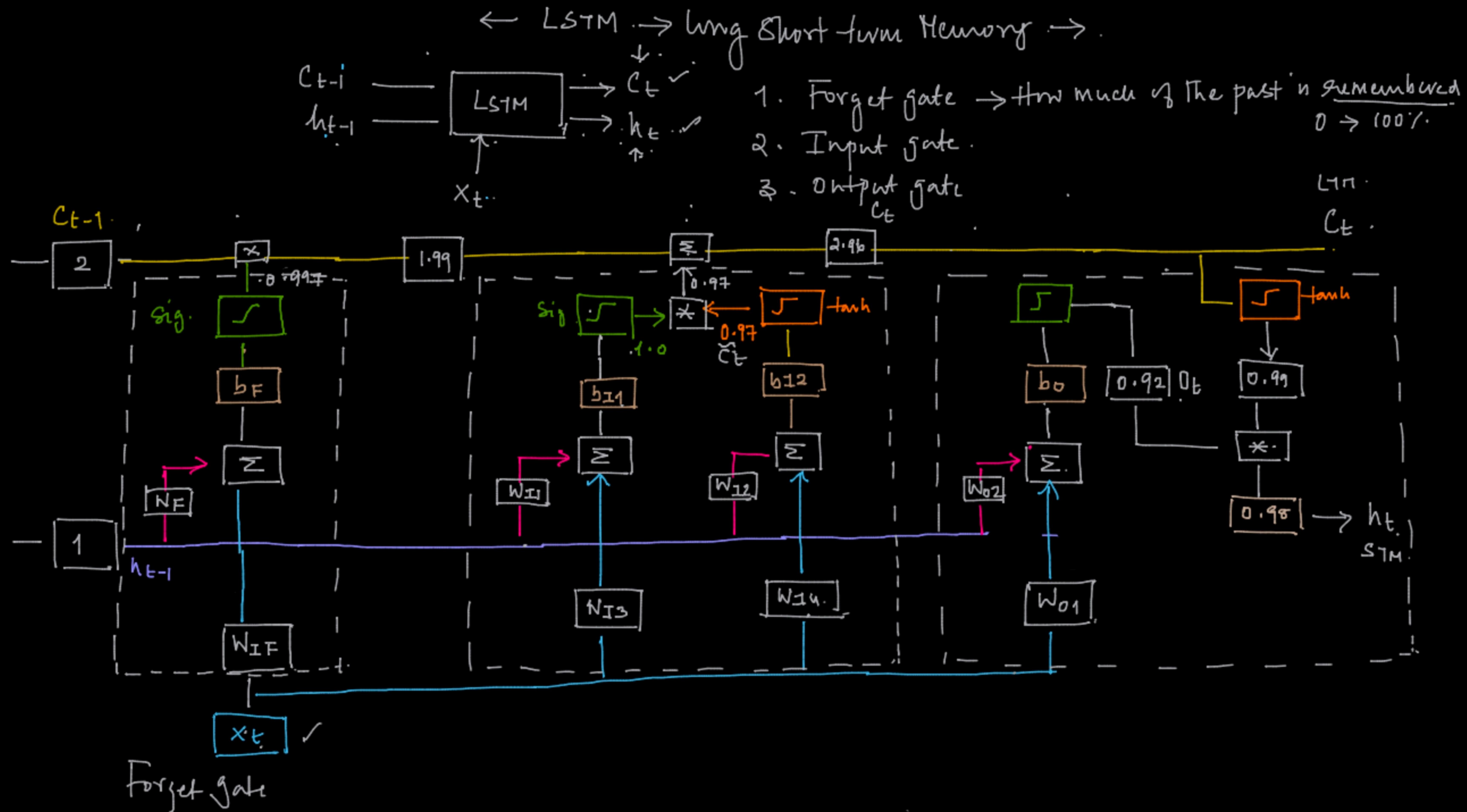
Jan 2076

Feb 2076

Mar 2076

Apr 2076

May 2



sigmoid \rightarrow LSTM.
 tanh \rightarrow STM ✓

1. Forget Gate: How much of the past information is remembered.

$$f_t = \sigma(W_f[h_{t-1}, x_t] + b_f)$$

$\Rightarrow 0 \rightarrow 1 \nearrow \rightarrow$ to be remembered

2. Input Gate: Tries to learn the new info that is given as input \rightarrow

$$\hat{c}_t = \tanh(W_I[h_{t-1}, x_t] + b_{I2}) \rightarrow \begin{matrix} \text{candidate/potential} \\ \text{Cell state} \end{matrix}$$

$$i_t = \sigma(W_I[h_{t-1}, x_t] + b_{I1})$$

3. Output: Updated past and current info is passed to the next period

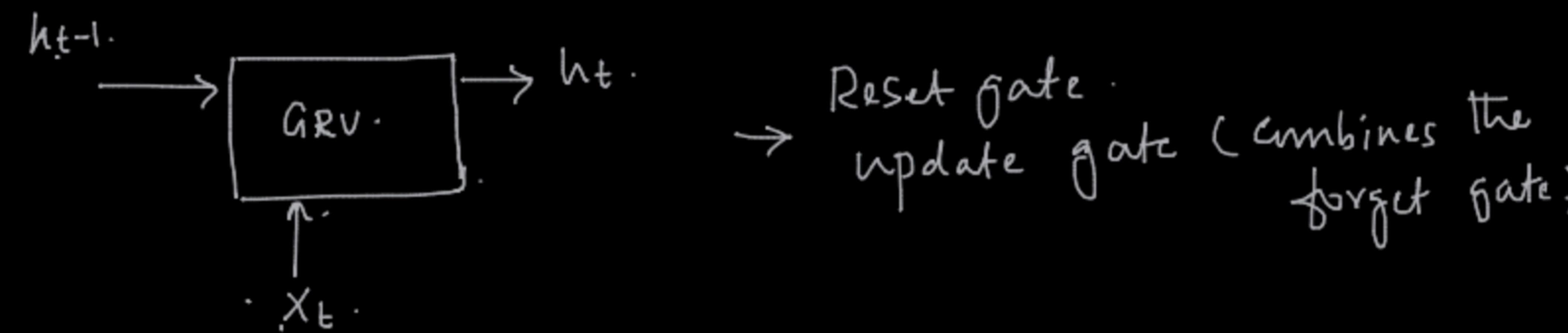
$$c_t = c_{t-1} + \underbrace{i_t \times \hat{c}_t}_{\text{LTM}} \text{ Fraction of potential memory}$$

$$o \rightarrow \sigma(W_o[h_{t-1}, x_t] + b_o)$$

$$h_t \rightarrow o_t \times \tanh(c_t)$$

\leftarrow Gated Recurrent Unit (GRU) \rightarrow

- Simpler Version of LSTM.
- easier to train.
- Can't capture complex long-term relationships.



Reset Gate

$$\gamma_t = \sigma(W_R(h_{t-1}, x_t) + b_r).$$

Update Gate

$$u_t = \sigma(W_u(h_{t-1}, x_t) + b_u).$$

Candidate hidden state

$$\tilde{h}_t = \tanh(W_h[x_t, \gamma_t * h_{t-1}] + b_h).$$

→ reset gate controls how much of the past hidden state is used to control the candidate hidden state.

$$h_t = W_{u2} \times h_{t-1} + (1 - W_{u2}) \tilde{h}_t$$

Time	y
1	y_0
2	y_1
3	y_2
4	y_3
5	y_4
\vdots	
$n = 1360$	y_{1360}
	36

3 periods \rightarrow 4th period -
 \leftarrow 3 past periods \rightarrow

x_1	x_2	x_3	y
y_2	y_3	y_0	y_4
y_3	y_2	y_1	y_5
y_4	y_3	y_L	y_6
y_{1358}	y_{1357}	y_{1351}	$\rightarrow 1359$
y_{1359}	y_{1358}	y_{1357}	$\rightarrow 1360$
y_{1360}	y_{1359}	y_{1358}	$\rightarrow 1361$

$$\text{look_back} = \checkmark$$

i	$i + \text{look_back}$
0 : 0+3	1 : 1+3
2 : 2+3	
\vdots	
3+0	3+1
	2+3

(0-3)

Length - lookback \rightarrow rewards