

Neural Turing Machines

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Graves A, Wayne G, Danihelka I. Neural turing machines[J]. arXiv preprint arXiv:1410.5401, 2014.

Outline

- Introduction to Turing Machines
- Neural Turing Machines

Definition

- A **tape** divided into cells
- A **head** that can read and write symbols on the tape and move the tape left and right one (and only one) cell at a time.
- A **state register**
- A finite **table** of instructions (finite-state machine, FSM)

Example 1 (Alan Turing 1937)

- Initial tape: Nothing (All cells are blank)
- State table:

Configuration		Behavior	
Current state	Scanned tape symbol	Tape operations	Final state
b	<blank>	P0(Print symbol '0'), R(Move right)	c
c	<blank>	R	e
e	<blank>	P1, R	f
f	<blank>	R	b

- Initial State: b, any position (tape)
- Result: 0 <blank> 1 <blank> 0

Example 2 (Copy task)

- Initial tape: Series of 1s, 0 for other position
- Result: Double this series by writing a 0 between them
 - “111”→“1110111”
- Initial state: s_1 , the beginning of series (the left most ‘1’)
- State table:

Example 2

Configuration		Behavior		
Current state	Scanned tape symbol	Tape operations		Final state
s_1	0	-		H
s_1	1	R		s_2
s_2	0	R		s_3
s_2	1	P1, R		s_2
s_3	0	P1, L		s_4
s_3	1	P1, R		s_3
s_4	0	L		s_5
s_4	1	P1, L		s_4
s_5	0	P1, R		s_1
s_5	1	P1, L		s_5
H	-	-		-

Core issue

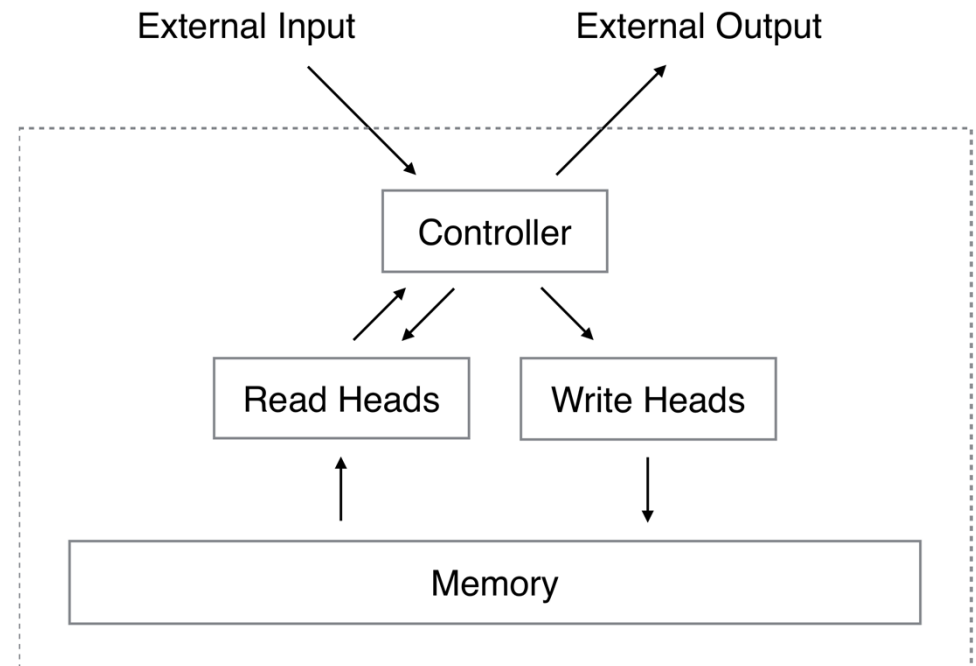
- Design of the state table: **Programming**
- Encode

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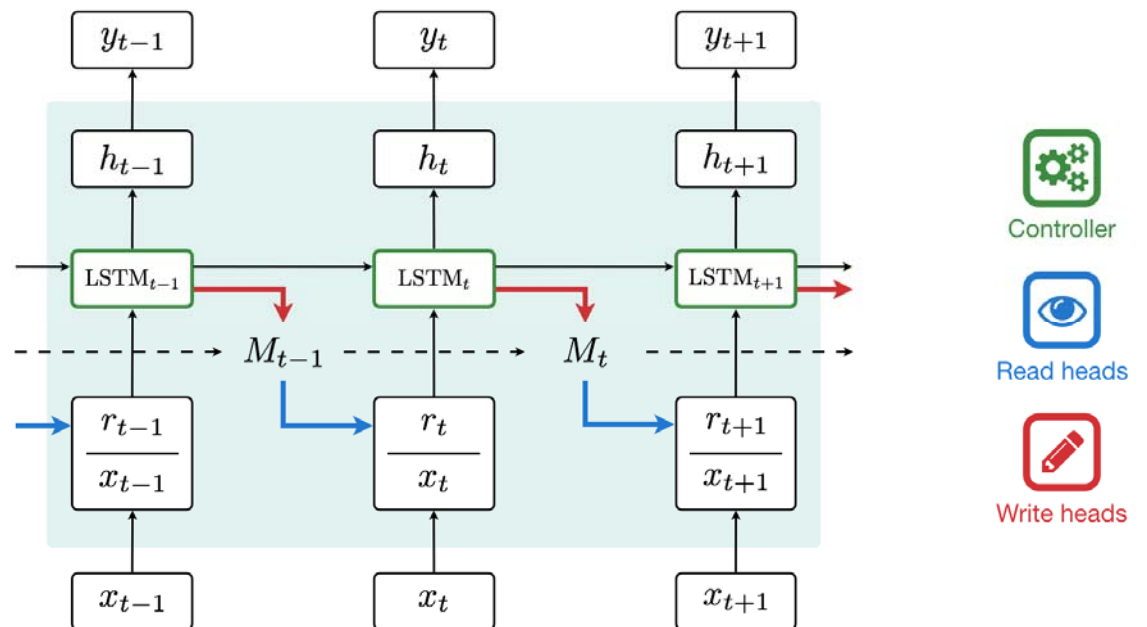
Architecture

- von Neumann architecture
 - Distinguish input, output, memory
 - Random access memory
 - Controller: implicit state table
 - Larger word size



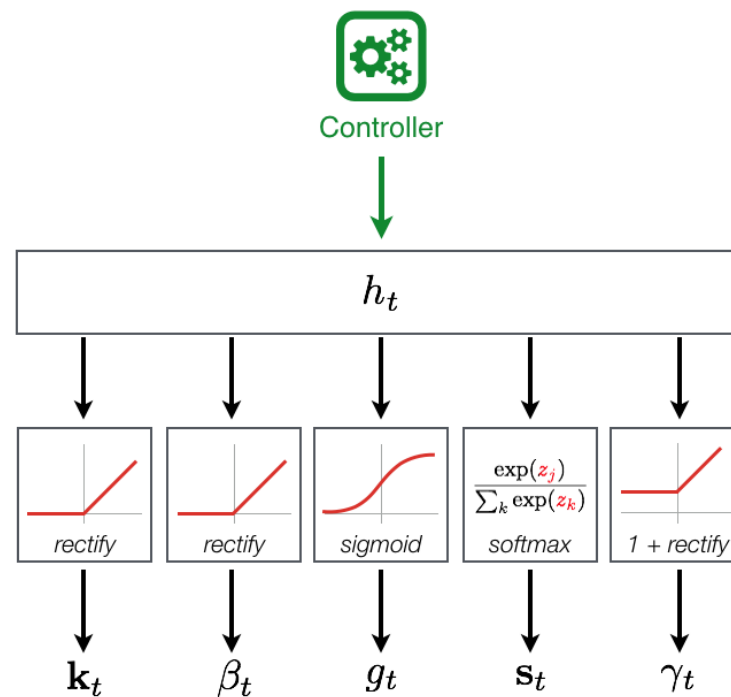
Controller

- RNN cell, usually LSTM
- Controller Input
 - Read content + Input



Controller

- Controller Output
 - Parameters for read or write

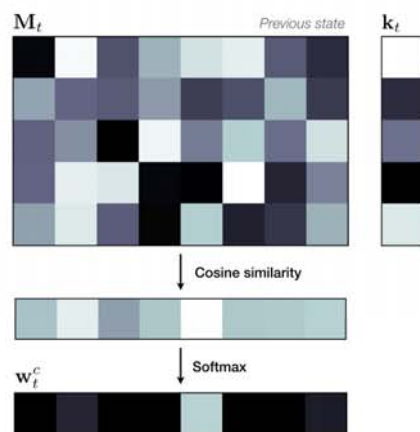


Addressing Scheme

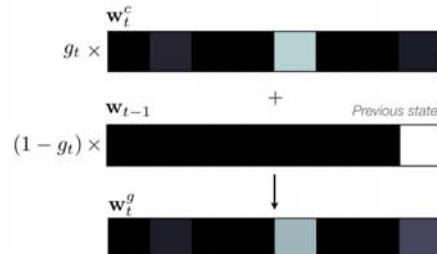
- Read/Write weight
 - Weighted sum of $N \times M$ memory
- Read
 - Weighted sum
 - $\mathbf{r}_t \leftarrow \sum_i w_t(i) \mathbf{M}_t(i)$
- Write
 - Erase
 - $\tilde{\mathbf{M}}_t(i) \leftarrow \mathbf{M}_{t-1}(i)[\mathbf{1} - w_t(i)] \mathbf{e}_t$
 - Add (write)
 - $\mathbf{M}_t(i) \leftarrow \tilde{\mathbf{M}}_t(i) + w_t(i) \mathbf{a}_t$

Weight generation

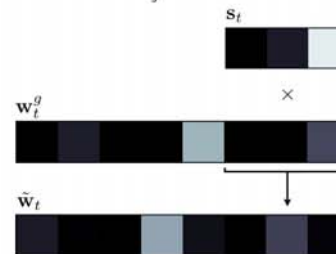
Content addressing
 $w_t^c(i) \leftarrow \text{softmax}(\beta_t \cdot K[\mathbf{k}_t, \mathbf{M}_t(i)])$



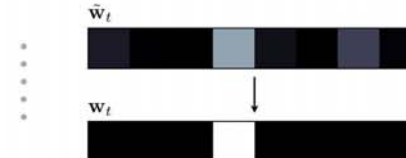
Interpolation
 $\mathbf{w}_t^g \leftarrow g_t \mathbf{w}_t^c + (1 - g_t) \mathbf{w}_{t-1}$



Convolutional shift
 $\tilde{w}_t(i) \leftarrow \sum_j w_t^g(j) \cdot s_t(i - j)$



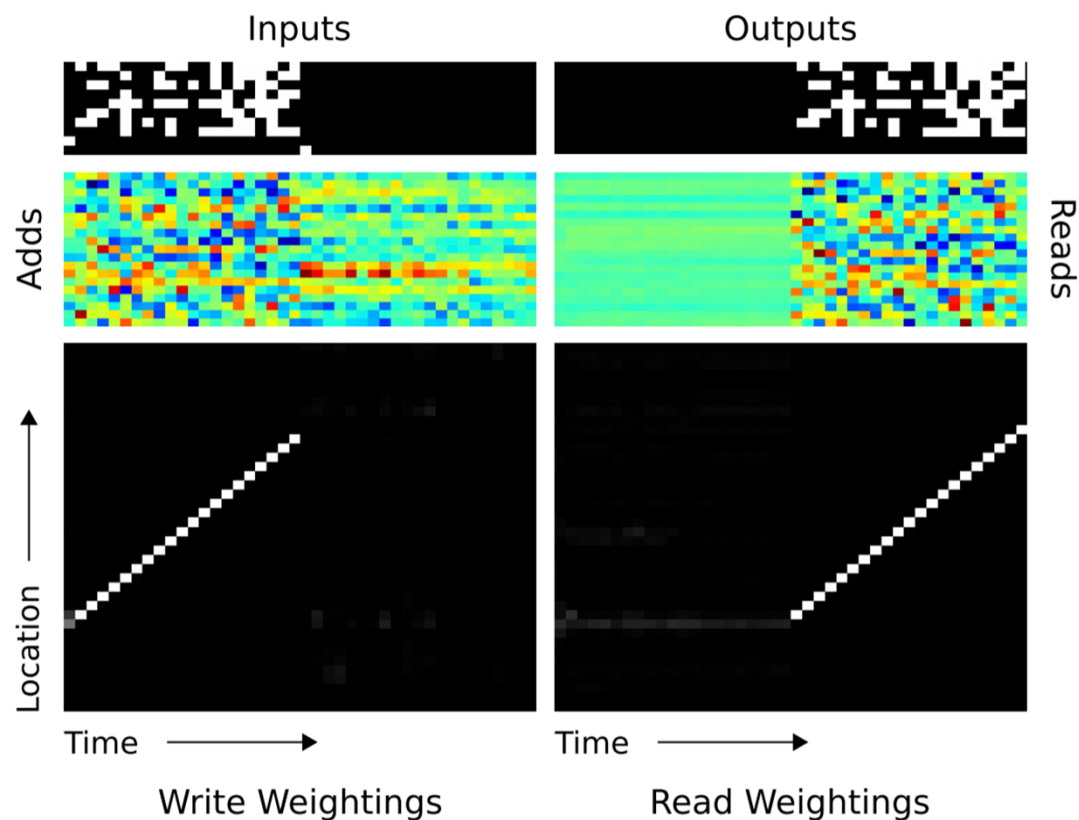
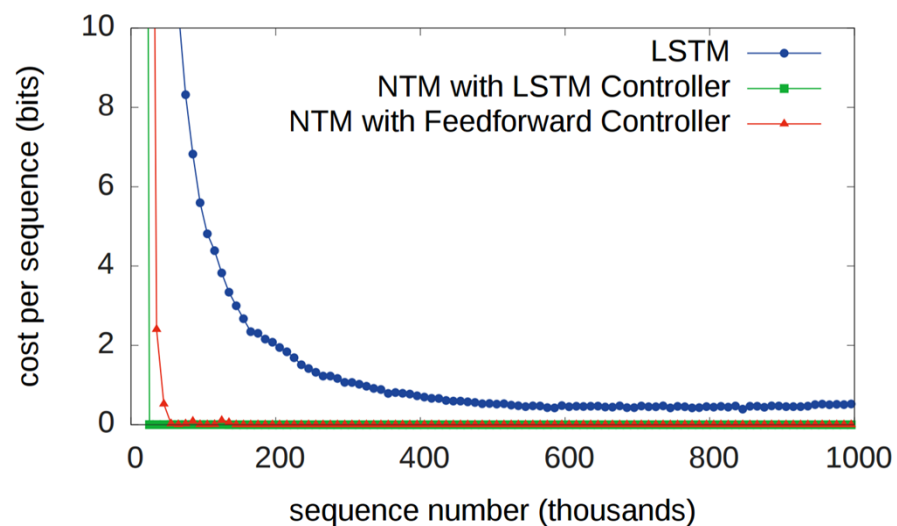
Sharpening
 $w_t(i) \propto \tilde{w}_t(i)^{\gamma_t}$



Weight generation

- <https://distill.pub/2016/augmented-rnns/>

Experiments (Copy)



Experiments (Repeat Copy)

