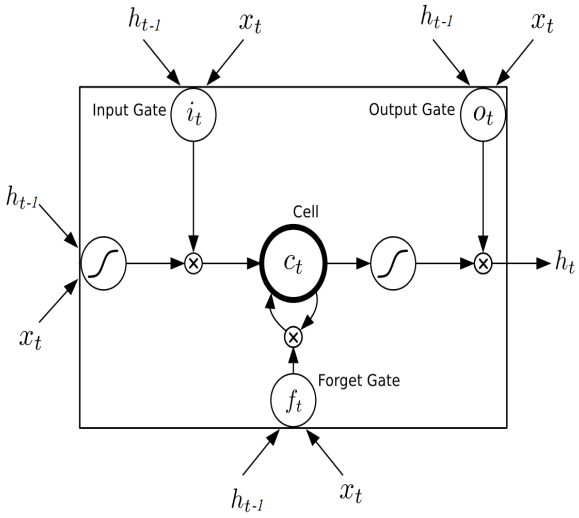
2. LSTM

Attempts increased on this page: Because the rounding instructions contain an ambiguity, the number of attempts of the first two problems have been increased to 5.

Extension Note: Because EdX site was down for a while yesterday, Homework 4 due date has been extended by 1 day to **April 1 23:59UTC** for those affected. **Future deadlines will remain unchanged.**

The diagram below shows a single LSTM unit that consists of Input, Output, and Forget gates.



The behavior of such a unit as a recurrent neural network is specified by a set of update equations. These equations define how the gates, "memory cell" c_t and the "visible state" h_t are updated in response to input x_t and previous states c_{t-1}, h_{t-1}. For the LSTM unit,

$$
\begin{aligned}
f_t &= \text{sigmoid}\left(W^{f,h}h_{t-1} + W^{f,x}x_t + b_f\right) \\
i_t &= \text{sigmoid}\left(W^{i,h}h_{t-1} + W^{i,x}x_t + b_i\right) \\
o_t &= \text{sigmoid}\left(W^{o,h}h_{t-1} + W^{o,x}x_t + b_o\right) \\
c_t &= f_t \odot c_{t-1} + i_t \odot \tanh\left(W^{c,h}h_{t-1} + W^{c,x}x_t + b_c\right) \\
h_t &= o_t \odot \tanh\left(c_t\right)
\end{aligned}
$$

where symbol $\odot$ stands for element-wise multiplication. The adjustable parameters in this unit are matrices $W^{f,h}$, $W^{f,x}$, $W^{i,h}$, $W^{i,x}$, $W^{o,h}$, $W^{o,x}$, $W^{c,h}$, $W^{c,x}$, as well as the offset parameter vectors b_f, b_i, b_o, and b_c. By changing these parameters, we change how the unit evolves as a function of inputs x_t.

To keep things simple, in this problem we assume that x_t, c_t, and h_t are all scalars. Concretely, suppose that the parameters are given by

$$\begin{array}{llllll} W^{f,h} = 0 & W^{f,x} = 0 & b_f = -100 & W^{c,h} = -100 \\ W^{i,h} = 0 & W^{i,x} = 100 & b_i = 100 & W^{c,x} = 50 \\ W^{o,h} = 0 & W^{o,x} = 100 & b_o = 0, & b_c = 0 \end{array}$$

We run this unit with initial conditions $h_{-1} = 0$ and $c_{-1} = 0$, and in response to the following input sequence: [0, 0, 1, 1, 1, 0] (For example, $x_0 = 0$, $x_1 = 0$, $x_2 = 1$, and so on).

LSTM states

1.0/1 point (graded)
Calculate the values h_t at each time-step and enter them below as an array $[h_0, h_1, h_2, h_3, h_4, h_5]$.

(Please round h_t to the closest integer in every time-step. If $h_t = \pm 0.5$, then round it to 0.
For ease of calculation, assume that $\text{sigmoid}(x) \approx 1$ and $\tanh(x) \approx 1$ for $x \geq 1$, and $\text{sigmoid}(x) \approx 0$ and $\tanh(x) \approx -1$ for $x \leq -1$.)

[0, 0, 1, -1, 1, 0] ✔ **Answer:** [0, 0, 1, -1, 1, 0]

Solution:

Approximating the functions to the nearest integer and assuming that x_t is only 0 or 1 simplifies the equation to the following.

$$\begin{aligned} f_t &= \text{sigmoid}(-100) = 0 \\ i_t &= \text{sigmoid}(100x_t + 100) = 1 \\ o_t &= \text{sigmoid}(100x_t) \\ c_t &= 0 \odot c_{t-1} + 1 \odot \tanh(-100h_{t-1} + 50x_t) = \tanh(-100h_{t-1} + 50x_t) \\ h_t &= o_t \odot \tanh(c_t) \end{aligned}$$

Notice that for c_t, the h_{t-1} term overpowers the x_t one, unless h_{t-1} is 0.

Based on our simplifications above, we can find the values for each h_t.

Input 1:

$$\begin{array}{llllllll} f_0 = 0 & i_0 = 1 & o_0 = 0.5 & c_0 = \tanh(-100(0) + 50(0)) = 0 & h_0 = 0 \odot \tanh(0) = 0 \\ f_1 = 0 & i_1 = 1 & o_1 = 0.5 & c_1 = \tanh(-100(0) + 50(0)) = 0 & h_1 = 0 \\ f_2 = 0 & i_2 = 1 & o_2 = 1 & c_2 = \tanh(0 + 50) = 1 & h_2 = 1 \tanh(1) = .76 \text{ rounded to } 1 \end{array}$$

Continue in this manner.

Submit You have used 2 of 5 attempts

Answers are displayed within the problem

LSTM states 2

1.0/1 point (graded)
Now, we run the same model again with the same parameters and same initial conditions as in the previous question. The only difference is that our input sequence in now: [1, 1, 0, 1, 1].

Calculate the values h_t at each time-step and enter them below as an array $[h_0, h_1, h_2, h_3, h_4]$.

(Please round h_t to the closest integer in every time-step. If $h_t = \pm 0.5$, then round it to 0.
For ease of calculation, assume that $\text{sigmoid}(x) \approx 1$ and $\tanh(x) \approx 1$ for $x \geq 1$, and $\text{sigmoid}(x) \approx 0$ and $\tanh(x) \approx -1$ for $x \leq -1$.)

[1, -1, 0, 1, -1] ✔ **Answer:** [1, -1, 0, 1, -1]

Solution:

The computation is similar to the previous question.

Submit You have used 1 of 5 attempts

Answers are displayed within the problem

LSTM info

1/1 point (graded)
What information is carried in the state h_t?

- Whether the total number of zeros is odd.
- Whether the number of consecutive zeros is odd.
- Whether the total number of ones is odd.
- ✔ Whether the number of consecutive ones is odd.

Solution:

We can observe that the network counts the number of consecutive 1's. If it is currently seeing a 0 it outputs 0, otherwise it outputs a 1 if it has seen an odd number of 1's so far, and a -1 if it is even.

Submit You have used 1 of 1 attempt

Answers are displayed within the problem

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[Tip Top Tips from the STAFF :D]	Reference this post for some helpful tips before you ask below! Pinned Staff	3
LSTM Info answer explanation	Hello everyone, I didn't understood LSTM info given explanation in the answer. Can anyone explain with the example? Thanks in advan...	2
By hand or python?	I am just curious, the problem is simple enough to be done by hand but I feel lazy today and I am very much tempted to write a quick pytho... Community TA	21
[STAFF] Please increase attempts	I spent 2, 3 attempts figuring out whether 0.5 should be rounded to 0 or 1, same for -0.5. I request the staff to please increase the number o...	5
Just to clarify the last question - if x = [0,0,0,1,1], the number of consecutive zeros is odd for h_3, but not for h_4.	see title	2
LSTM Info	I don't understand LSTM info? can anyone explain to me. I am confused what to choose.	11
[STAFF] The instruction to the 2 first questions	I had, difficult time making my way to the answer to the last two questions as I think the condition for the sigmoid and tanh are not precise, ...	6
Stack on debugging the script		7
Letter "S" inside of circle?	Hi All - What function is this? Somebody previously said it was tanh, but that function takes a single scalar input while at the left of the diagra...	5
General hint on this section	This hint might help the less experienced programmers. Although you could manually work out all the answers, it's more interesting and les... Community TA	2
please round h to 0 if it is 0.5 or -0.5	At the first quesiton I got wrong because I did not round h to 0 I frist manually calculated and then use python, the result it the same but aft...	8
round *ht* to the closest integer in every time-step		2