CS260: Machine Learning Algorithms

Lecture 12: Recurrent Neural Network and NLP applications

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Recurrent Neural Network

Time Series/Sequence Data

- Input: $\{\boldsymbol{x}_1, \boldsymbol{x}_2, \cdots, \boldsymbol{x}_T\}$
  - Each $\boldsymbol{x}_t$ is the feature at time step t
  - Each $\boldsymbol{x}_t$ can be an d-dimensional vector
- Output: $\{y_1, y_2, \cdots, y_T\}$
  - Each y_t is the output at step t
  - Multi-class output or Regression output:

$$y_t \in \{1, 2, \cdots, L\} \quad \text{or} \quad y_t \in \mathbb{R}$$

Example: Time Series Prediction

- Climate Data:
  - $\boldsymbol{x}_t$: temperature at time t
  - y_t: temperature (or temperature change) at time $t + 1$

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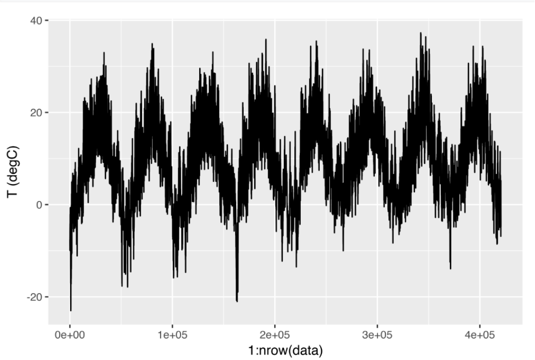
- Climate Data:
  - $\boldsymbol{x}_t$: temperature at time t
  - y_t: temperature (or temperature change) at time $t+1$
- Stock Price: Predicting stock price



Example: Language Modeling

The cat is ?

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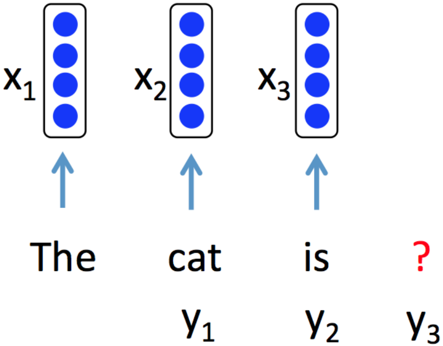
- $\boldsymbol{x}_t$: one-hot encoding to represent the word at step t $([0, \ldots, 0, 1, 0, \ldots, 0])$
- y_t: the next word

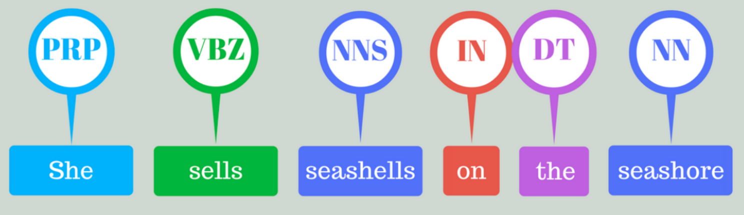
$$y_t \in \{1, \cdots, V\} \quad \text{V: Vocabulary size}$$



Example: POS Tagging

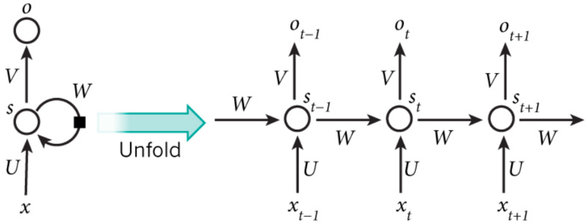
- Part of Speech Tagging:

  Labeling words with their Part-Of-Speech (Noun, Verb, Adjective, $\cdots$)
- $\boldsymbol{x}_t$: a vector to represent the word at step t
- y_t: label of word t



picture from `https://medium.com/analytics-vidhya/pos-tagging-using-conditional-random-fields-92077e5eaa31`

Recurrent Neural Network (RNN)



- $\boldsymbol{x}_t$: t-th input
- $\boldsymbol{s}_t$: hidden state at time t ("memory" of the network)

$$s_t = f(Ux_t + Ws_{t-1})$$

  W: transition matrix s_0 usually set to be 0
- Predicted output at time t:

$$o_t = \arg\max_i (V\boldsymbol{s}_t)_i$$

Recurrent Neural Network (RNN)

- Training: Find U, W, V to minimize empirical loss:
- Loss of a sequence:

$$\sum_{t=1}^{T} \text{loss}(V\boldsymbol{s}_t, y_t)$$

($\boldsymbol{s}_t$ is a function of U, W, V)

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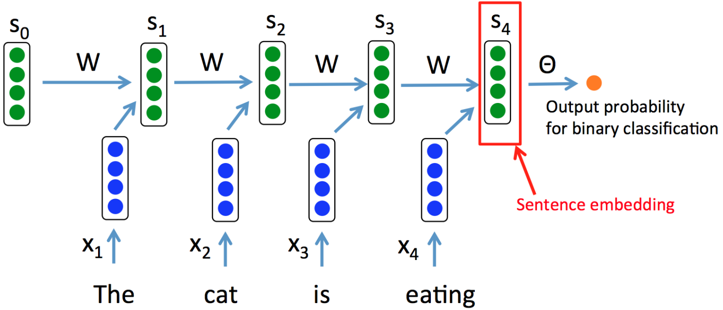
- Solved by Stochastic Gradient Descent (SGD)

RNN: Text Classification

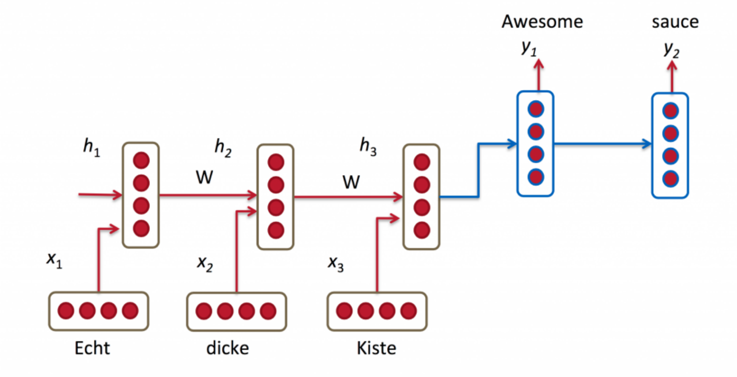
- Not necessary to output at each step
- Text Classification:

  $$\text{Sentence} \rightarrow \text{category}$$

  Output only at the final step
- Model: add a fully connected network to the final embedding



RNN: Neural Machine Translation

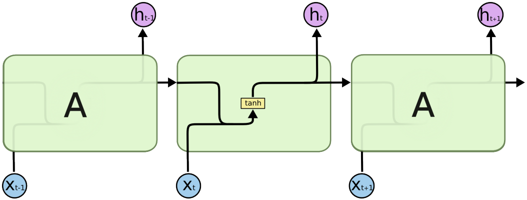


Problems of Classical RNN

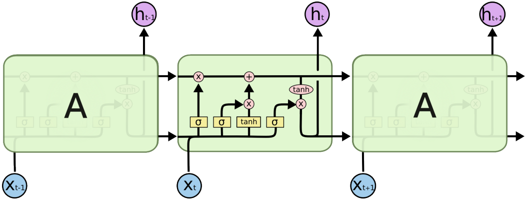
- Hard to capture long-term dependencies
- Hard to solve (vanishing gradient problem)
- Solution:
  - LSTM (Long Short Term Memory networks)
  - GRU (Gated Recurrent Unit)
  - …

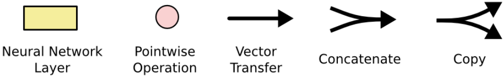
LSTM

- RNN:



- LSTM:





Conclusions

- A Brief introduction of RNN.

Questions?