PH451, PH551

Mar 21, 2025

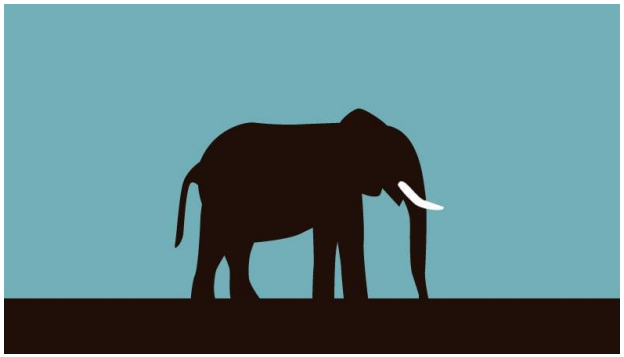
Outline

- **Sequential Data**
- **Recurrent Neural Networks**

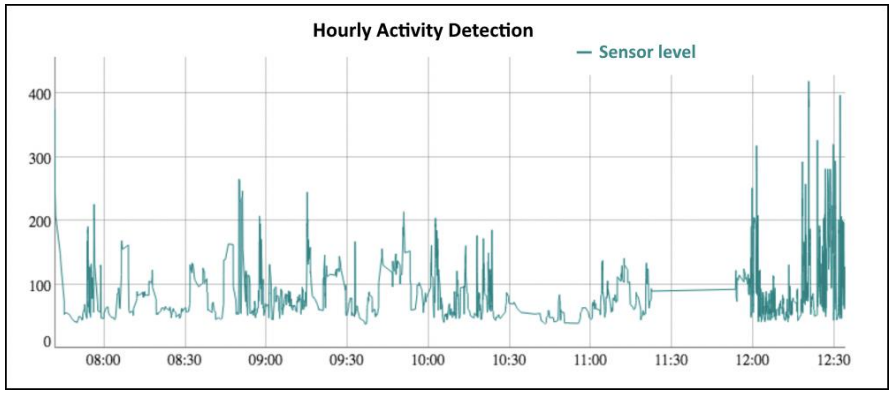
Sequential Data

Text

Image



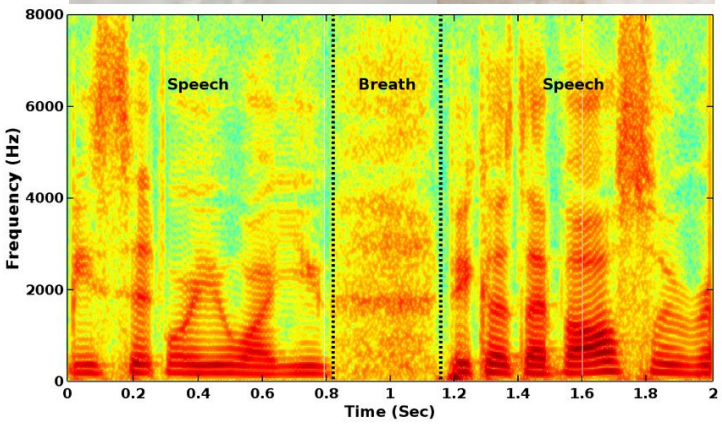
Time Series



Sequential Data

- **Properties:**
  - Elements occur in a particular order
  - May depend on other elements

- **Examples:**
  - Sentences
  - Images
  - Radio Waves
  - Temperature



Some Applications

- **Input:**
  - Fixed size
- **Output**
  - Sequence

The man in grey swings a bat while the man in black looks on.

- **Example: image captioning**

Some Applications

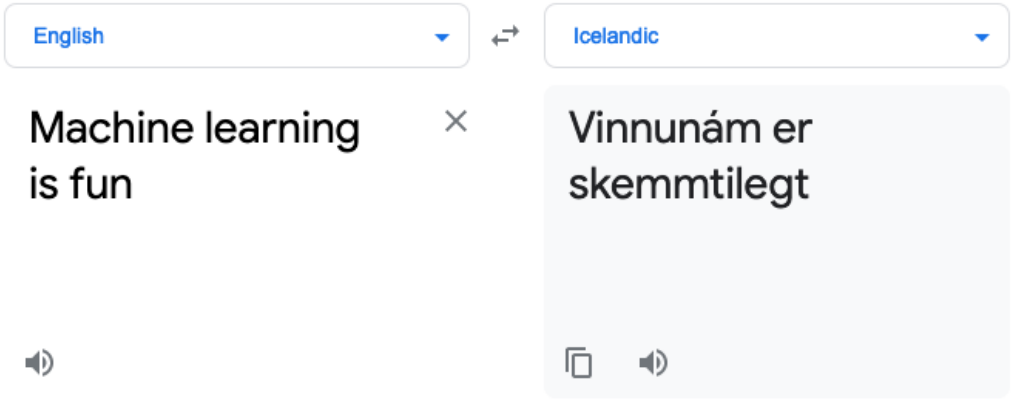
- **Input:**
  - Sequence
- **Output**
  - Fixed Size

- **Example: Sentiment Analysis**

Customer Feedback Text	Sentiment
"This café is great, the staff are really friendly and the coffee is delicious"	Positive
"I would not recommend this café to anyone. Their coffee is terrible and is really expensive"	Negative

Some Applications

- **Input:**
  - Sequence
- **Output**
  - Sequence



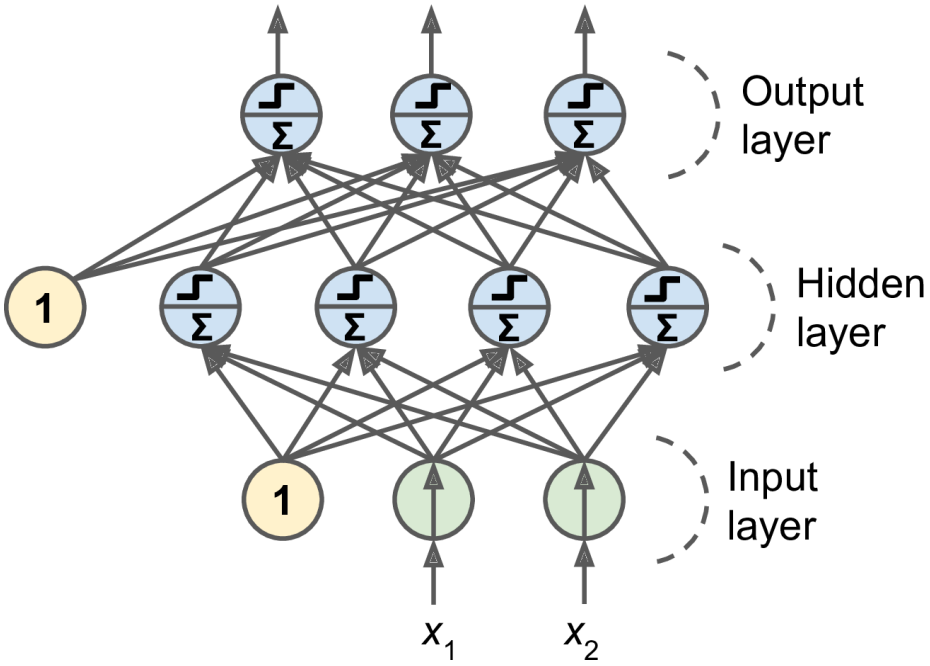
- **Example: Google Translate**

Recurrent Neural Networks

- **Extensions of deep neural networks to directed graphs and sequences**
  - Rumelhalt, Hinton, Williams (1986)
  - Dynamic behavior in the time domain
  - Introduce ideas of memory, feedback loops to accommodate sequential data
  - Key idea: capture information from **the past** in a **hidden state**

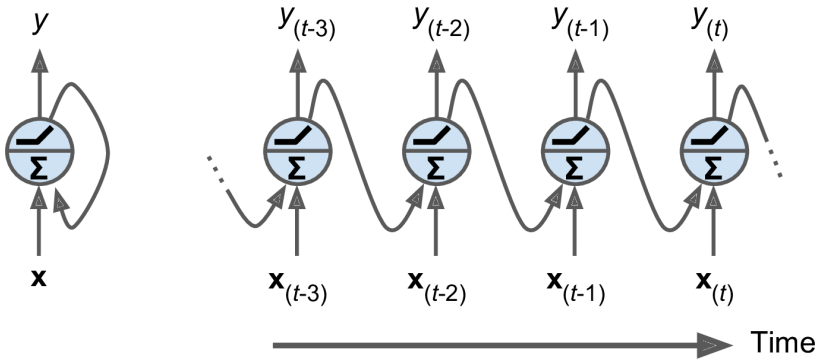
RNN vs MLP

MLP

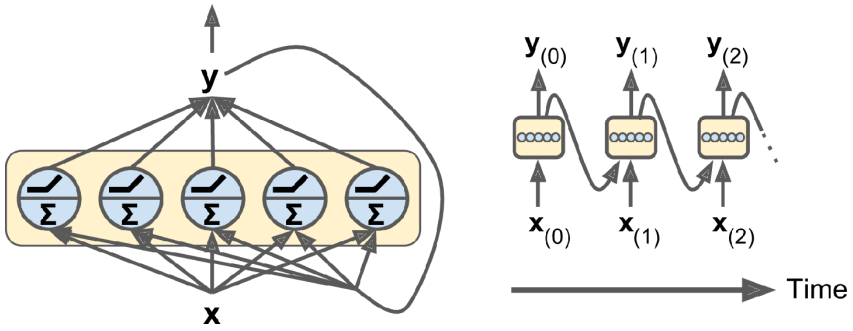


No loops

RNN neuron (unrolled)



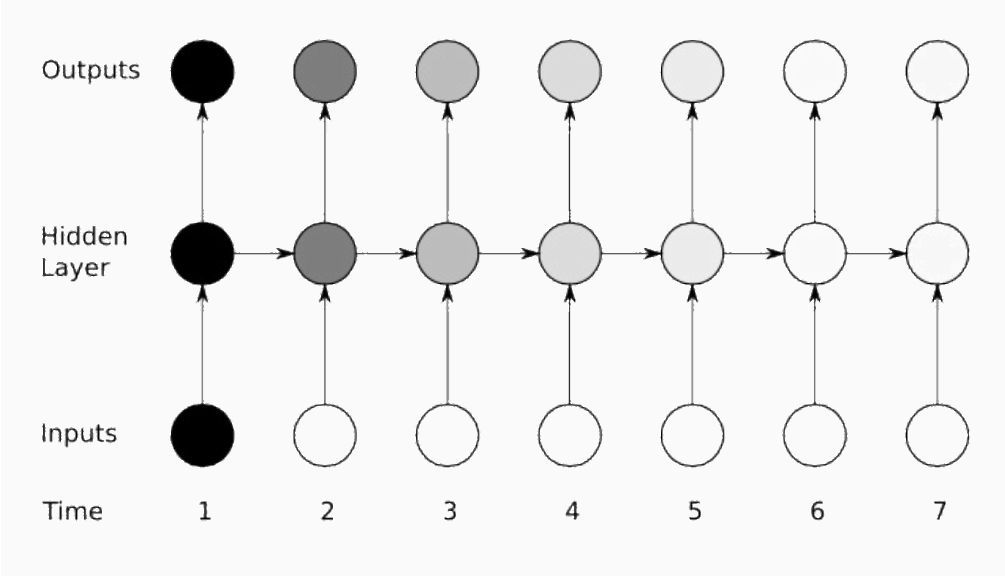
RNN layer (unrolled)



Basic RNN

Advantages:

- Weights are shared across layers
- Uses previous hidden state
  - Weights of each layer are not learned independently

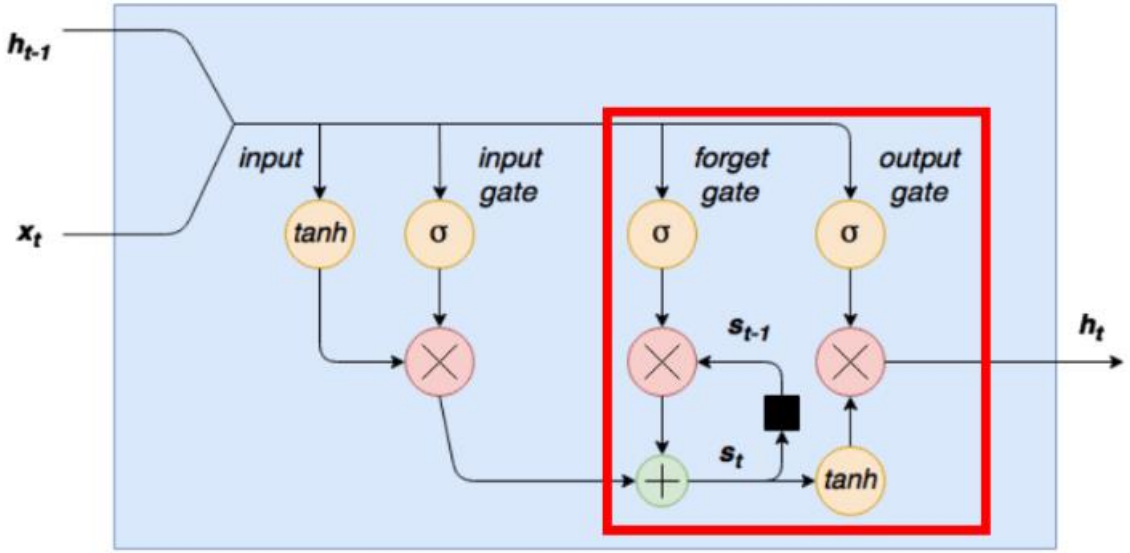


- A form of “memory”
- Train with backpropagation (through time)

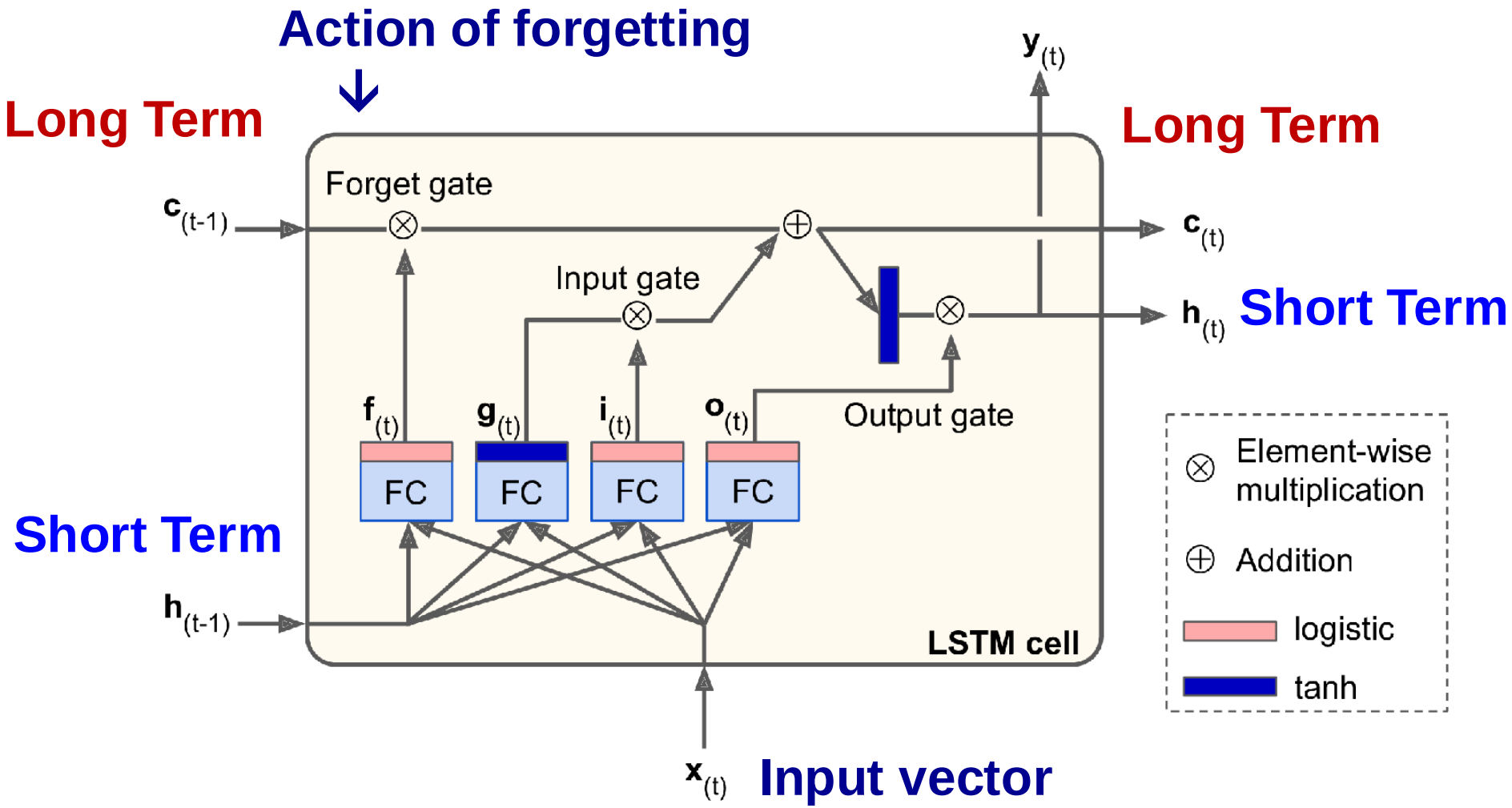
RNN Variants

Long Short Term Memory (LSTM)

- Hochreiter and Schmidhuber (1997)
- Modification of basic RNN preserving memory over time



LSTM


Action of forgetting
Long Term
Long Term
Short Term
Short Term
Input vector
Forget gate
Input gate
Output gate
LSTM cell
FC
FC
FC
FC
Element-wise multiplication
Addition
logistic
tanh