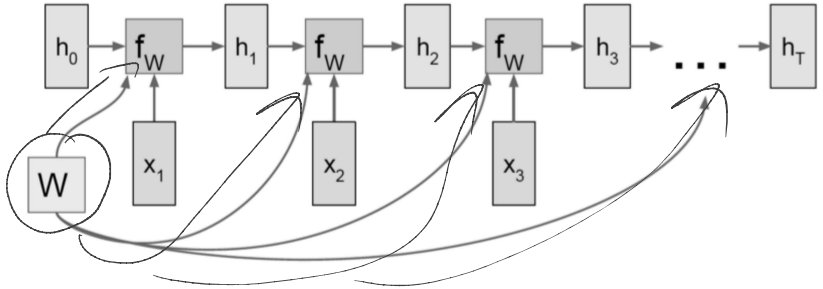
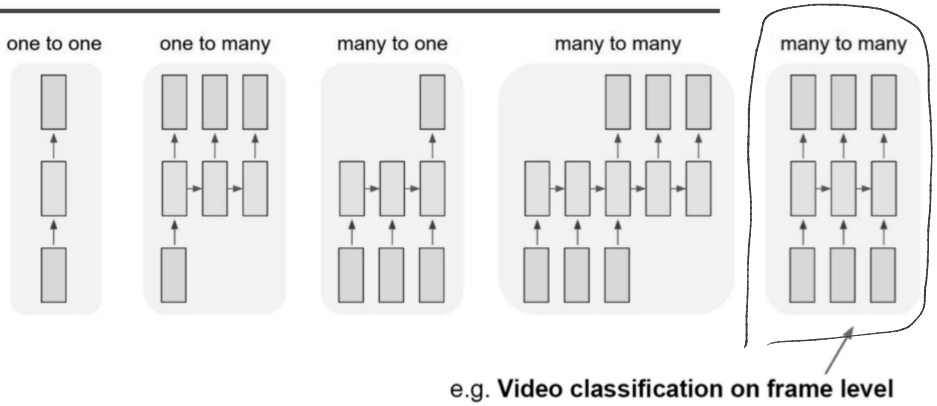
# Recurrent Neural Networks

Re-use the same weight matrix at every time-step





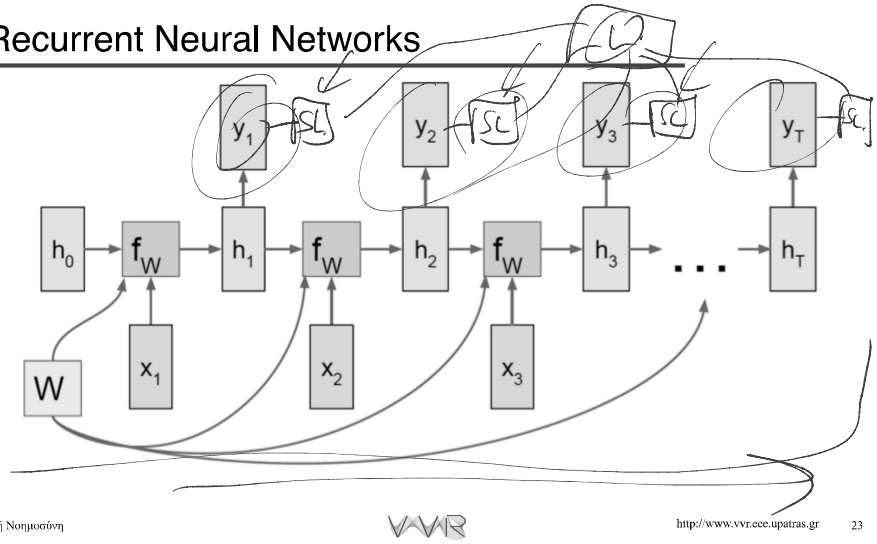

# Recurrent Neural Networks




e.g. **Video classification on frame level**

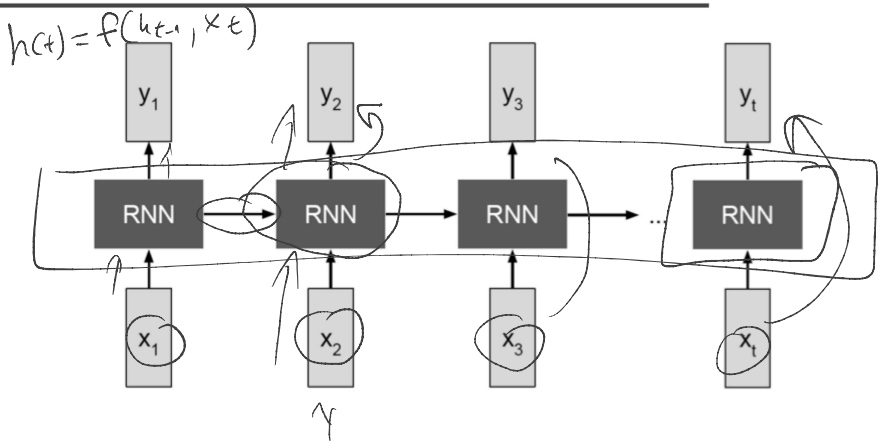


# Recurrent Neural Networks

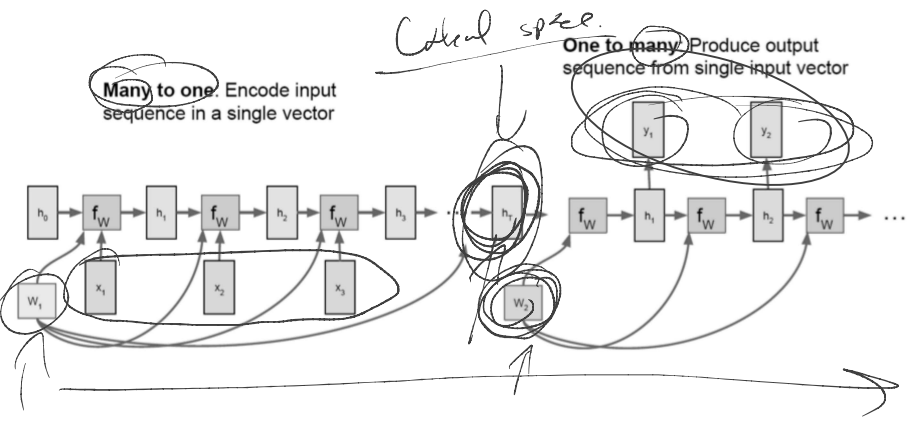





# Recurrent Neural Networks

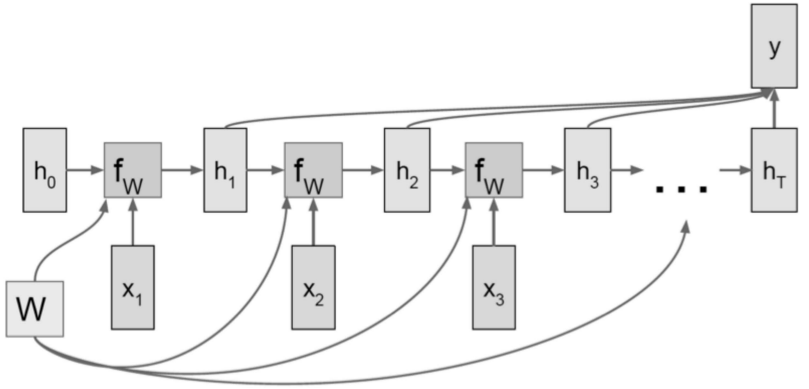


## Recurrent Neural Networks






## Recurrent Neural Networks



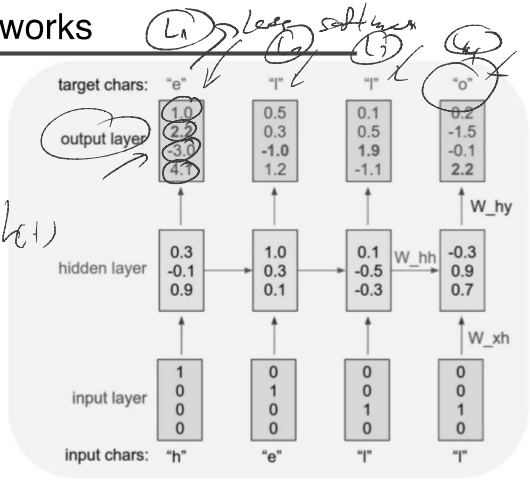



## Recurrent Neural Networks

**Example: Character-level Language Model**

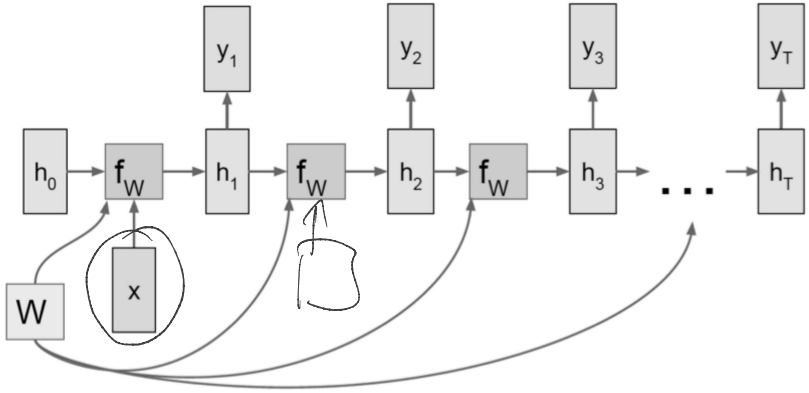
Vocabulary: [h,e,l,o]

Example training sequence: **“hello”**



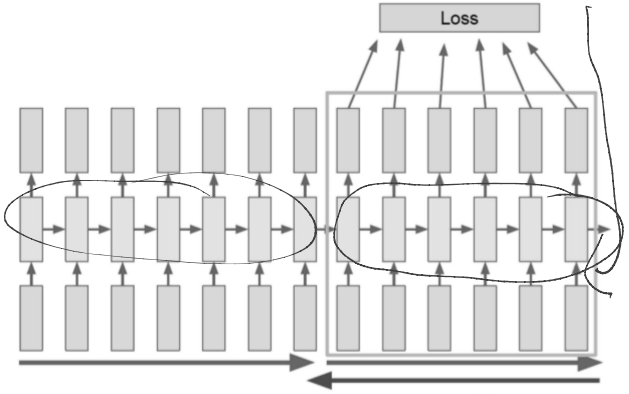



## Recurrent Neural Networks



## Recurrent Neural Networks

**Truncated** Backpropagation through time




Carry hidden states forward in time forever, but only backpropagate for some smaller number of steps

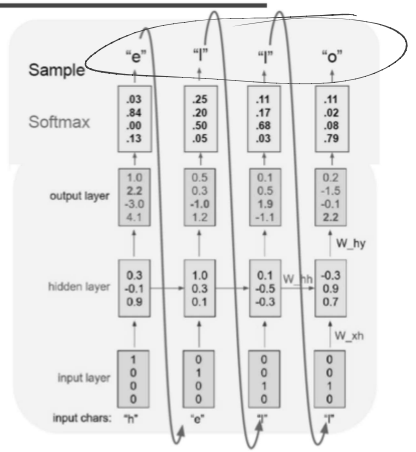


## Recurrent Neural Networks

**Example: Character-level Language Model Sampling**

Vocabulary: [h,e,l,o]

At test-time sample characters one at a time, feed back to model






## Recurrent Neural Networks

RNN Advantages:
- Can process any length input
- Computation for step *t* can (in theory) use information from many steps back
- Model size doesn't increase for longer input
- Same weights applied on every timestep, so there is symmetry in how inputs are processed.

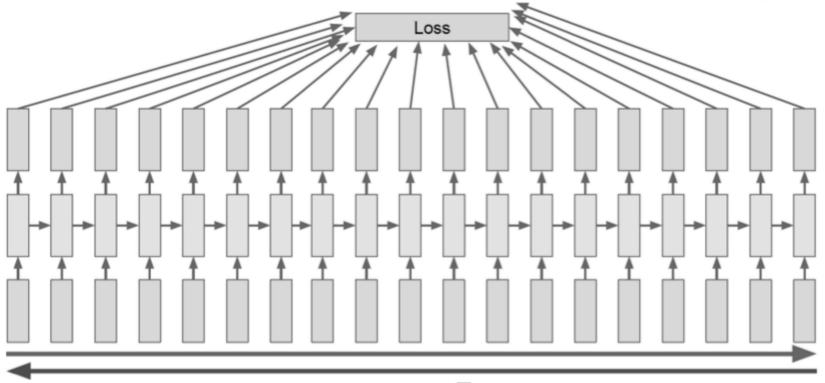
RNN Disadvantages:
- Recurrent computation is slow
- In practice, difficult to access information from many steps back



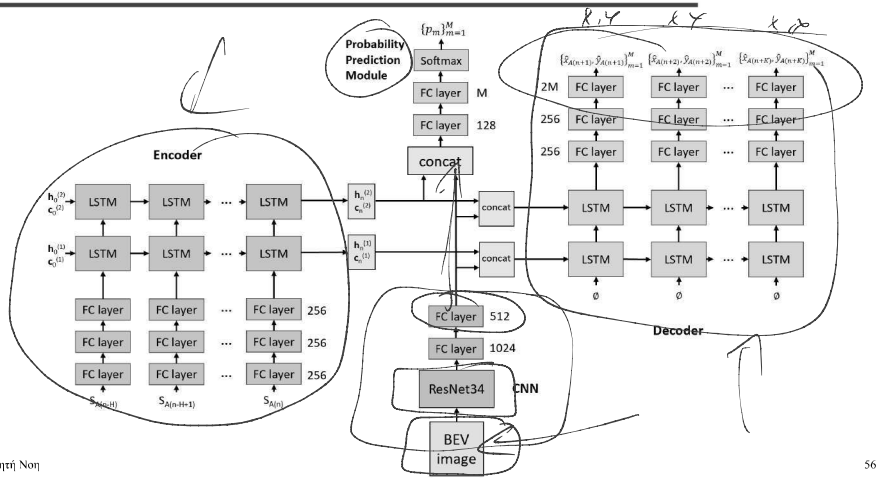
## Recurrent Neural Networks

Backpropagation through time

Forward through entire sequence to compute loss, then backward through entire sequence to compute gradient

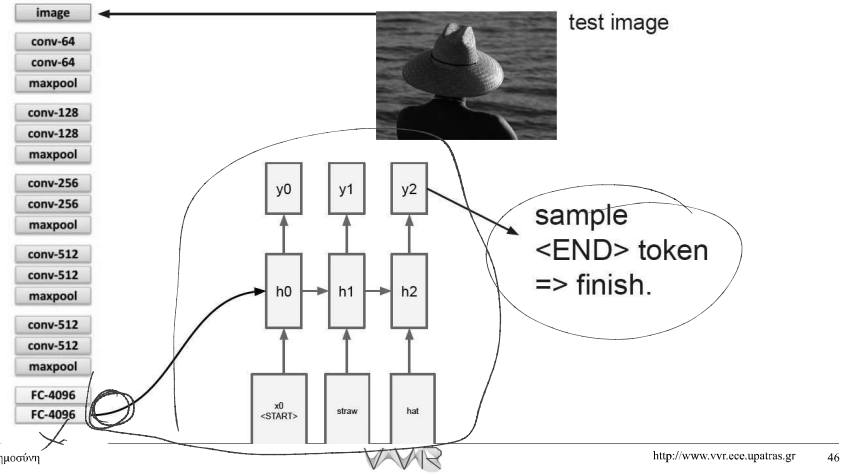


# Examples – Motion prediction?



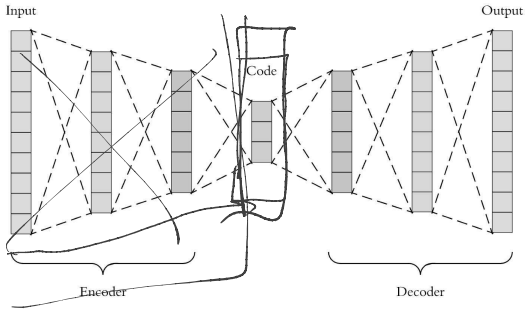



# Recurrent Neural Networks



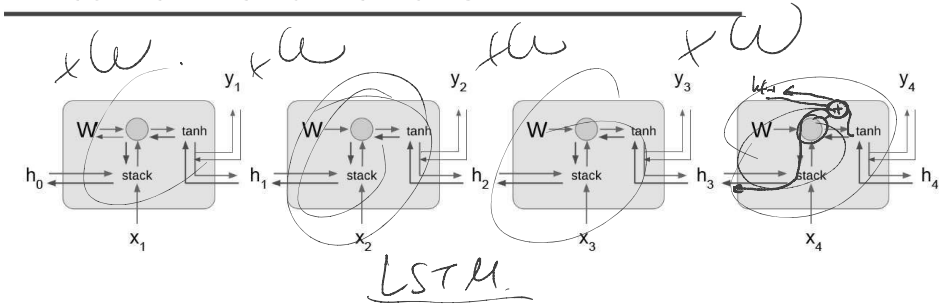



# Examples – Autoencoders

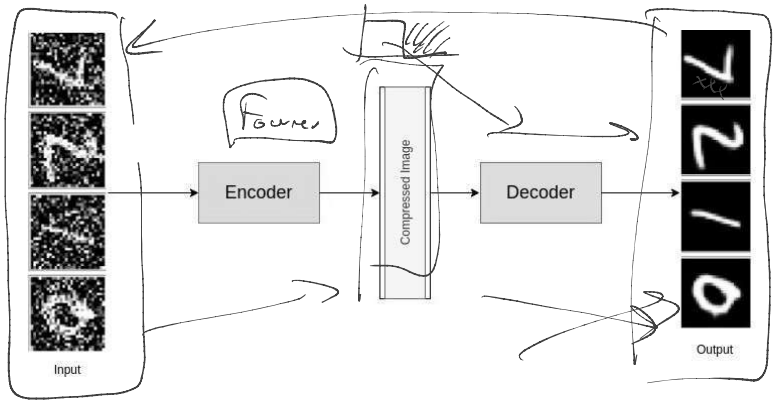





# Recurrent Neural Networks



# Examples – Autoencoders & Denoising






# Examples – Autoencoders & Superesolution