

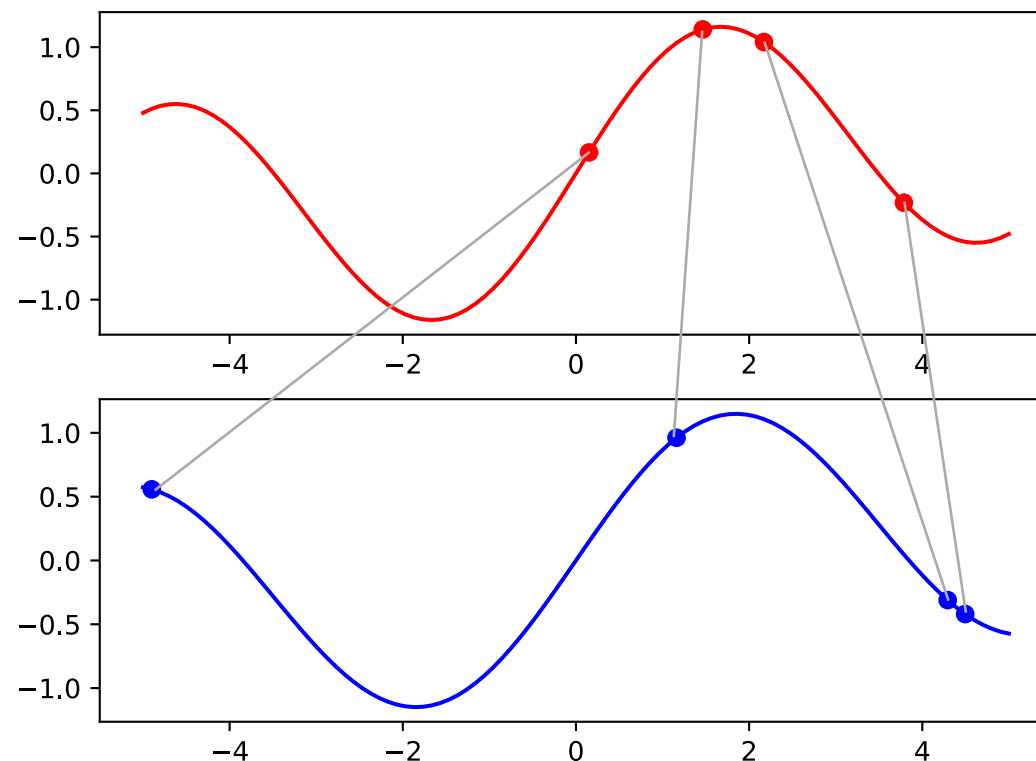
Neural nets for sequences

Text and time series

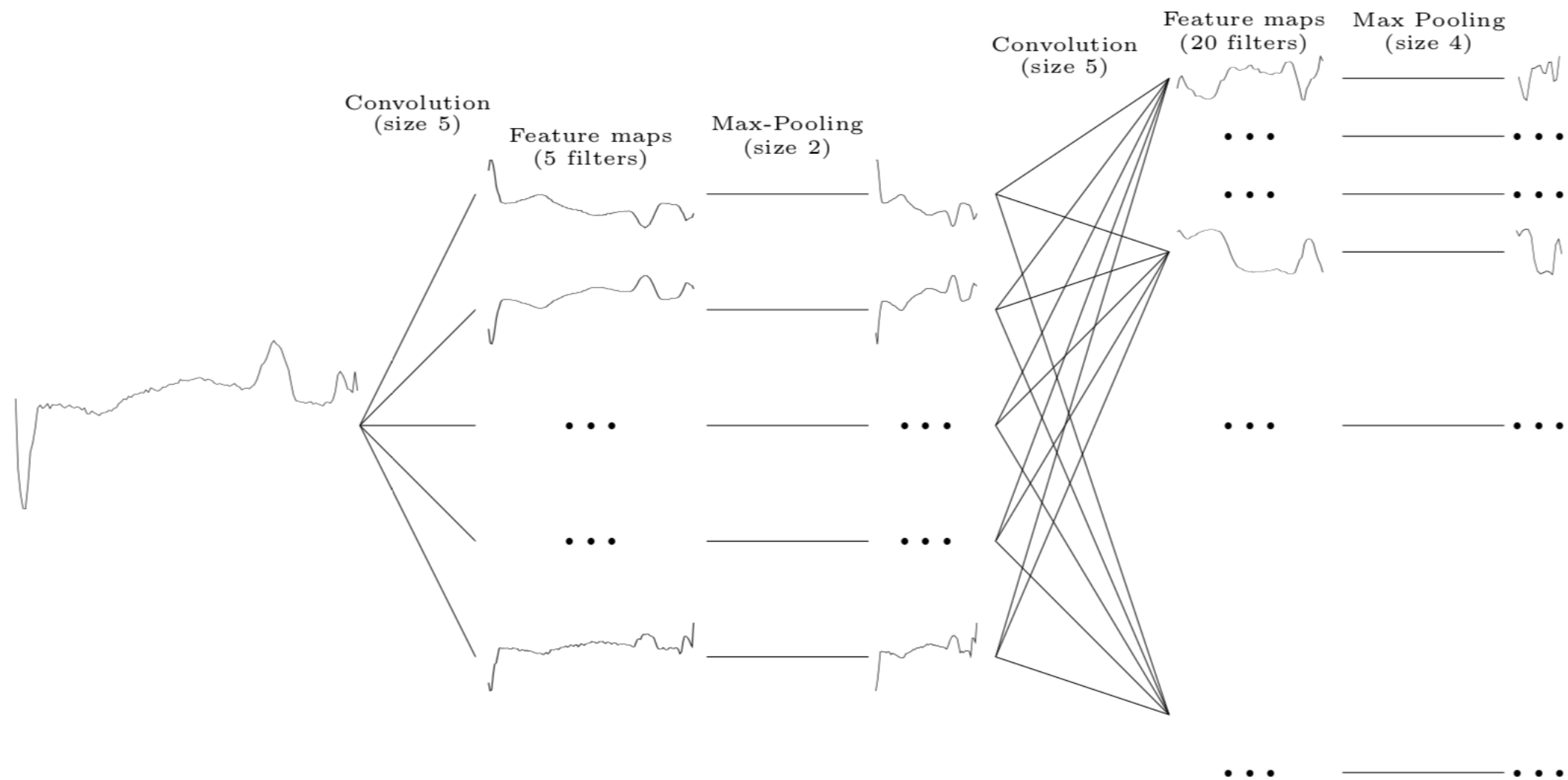
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Deep Learning course @EDHEC

Standard issues with sequences

- Variable number of observations per sequence
 - the cat eats the mouse
 - at the moment, the cat is eating the mouse
- Segmentation (starting/end points)
- Irregular sampling (time series)



Solution #1: NN with 1d-convolutions



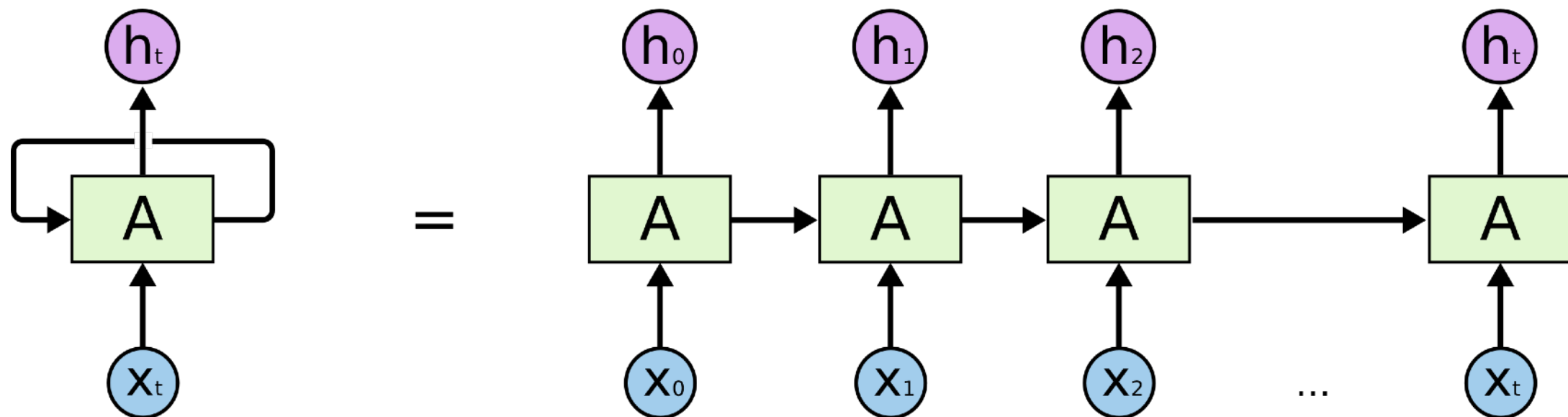
Source: [Le Guennec *et al.*, 2014]

Solution #1: NN with 1d-convolutions

- Variable number of observations per sequence
 - 0 padding
- Segmentation (starting/end points)
 - Data augmentation
 - Pooling
- Irregular sampling (time series)
 - Not robust to that!

Solution #2: NN with recurrent units

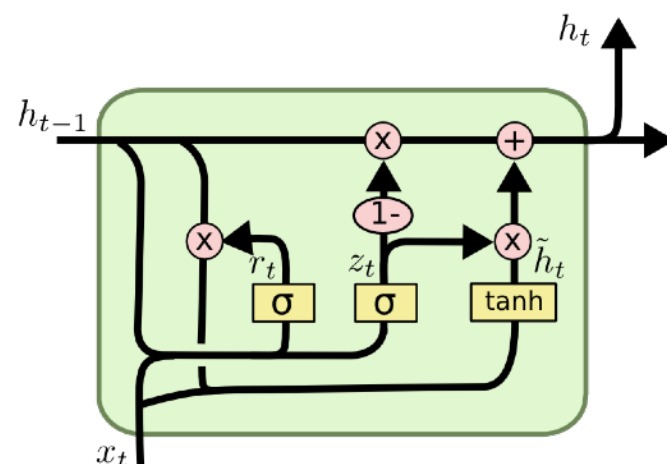
- Very flexible model (any length, let the model learn its memory needs, ...)
- Difficult to learn in practice
 - Slow (lack of parallelism)
 - Vanishing gradients (hard to learn long-term dependencies)



Source: [Christopher Olah's blog](#)

Solution #2: NN with recurrent units

- Variants that work better in practice
 - Long Short Term Memory (LSTM)
 - Gated Recurrent Unit (GRU)
- Principle
 - At each time step, keep only part of the information



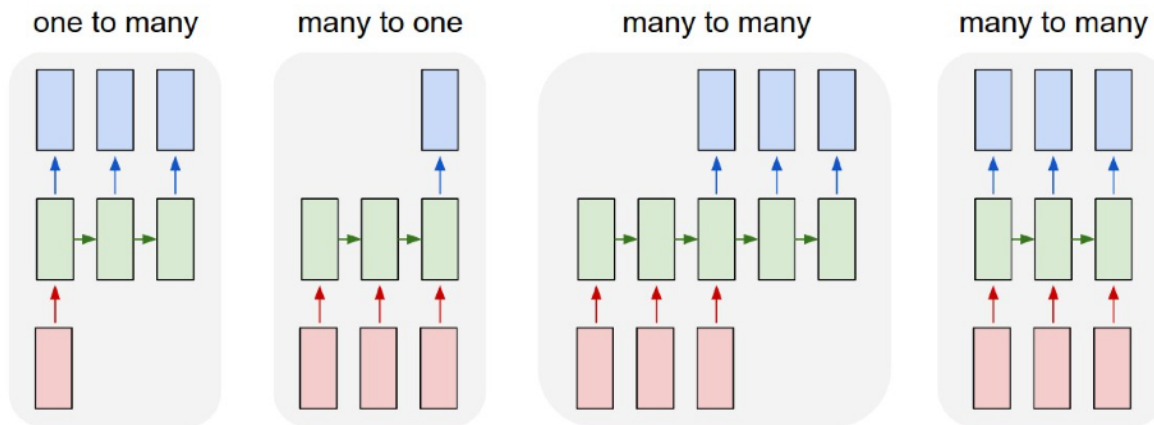
$$z_t = \sigma(W_z \cdot [h_{t-1}, x_t])$$

$$r_t = \sigma(W_r \cdot [h_{t-1}, x_t])$$

$$\tilde{h}_t = \tanh(W \cdot [r_t * h_{t-1}, x_t])$$

$$h_t = (1 - z_t) * h_{t-1} + z_t * \tilde{h}_t$$

Solution #2: NN with recurrent units



PANDARUS:

Alas, I think he shall be come approached and the day
When little strain would be attain'd into being never fed,
And who is but a chain and subjects of his death,
I should not sleep.

Second Senator:

They are away this miseries, produced upon my soul,
Breaking and strongly should be buried, when I perish
The earth and thoughts of many states.

DUKE VINCENTIO:

Well, your wit is in the care of side and that.

Second Lord:

They would be ruled after this chamber, and
my fair nudes begun out of the fact, to be conveyed,
Whose noble souls I'll have the heart of the wars.

Sample text generated by a RNN
trained on Shakespeare words

For $\bigoplus_{n=1,\dots,m} \mathcal{L}_{m,n} = 0$, hence we can find a closed subset \mathcal{H} in \mathcal{H} and any sets \mathcal{F} on X , U is a closed immersion of S , then $U \rightarrow T$ is a separated algebraic space.

Proof. Proof of (1). It also start we get

$$S = \text{Spec}(R) = U \times_X U \times_X U$$

and the comparicoly in the fibre product covering we have to prove the lemma generated by $\coprod Z \times_U U \rightarrow V$. Consider the maps M along the set of points Sch_{fppf} and $U \rightarrow U$ is the fibre category of S in U in Section, ?? and the fact that any U affine, see Morphisms, Lemma ?? . Hence we obtain a scheme S and any open subset $W \subset U$ in $Sh(G)$ such that $\text{Spec}(R') \rightarrow S$ is smooth or an

$$U = \bigcup U_i \times_{S_i} U_i$$

which has a nonzero morphism we may assume that f_i is of finite presentation over S . We claim that $\mathcal{O}_{X,x}$ is a scheme where $x, x', s'' \in S'$ such that $\mathcal{O}_{X,x'} \rightarrow \mathcal{O}'_{X',x'}$ is separated. By Algebra, Lemma ?? we can define a map of complexes $GL_{S'}(x'/S'')$ and we win. \square

To prove study we see that $\mathcal{F}|_U$ is a covering of \mathcal{X}' , and \mathcal{T}_i is an object of $\mathcal{F}_{X/S}$ for $i > 0$ and \mathcal{F}_p exists and let \mathcal{F}_i be a presheaf of \mathcal{O}_X -modules on \mathcal{C} as a \mathcal{F} -module. In particular $\mathcal{F} = U/\mathcal{F}$ we have to show that

$$\widetilde{M}^\bullet = \mathcal{I}^\bullet \otimes_{\text{Spec}(k)} \mathcal{O}_{S,s} - i_X^{-1} \mathcal{F}$$

is a unique morphism of algebraic stacks. Note that

$$\text{Arrows} = (Sch/S)_{fppf}^{opp}, (Sch/S)_{fppf}$$

and

$$V = \Gamma(S, \mathcal{O}) \mapsto (U, \text{Spec}(A))$$

is an open subset of X . Thus U is affine. This is a continuous map of X is the inverse, the groupoid scheme S .

Proof. See discussion of sheaves of sets. \square

The result for prove any open covering follows from the less of Example ?? . It may replace S by $X_{spaces, \acute{e}tale}$ which gives an open subspace of X and T equal to S_{Zar} , see Descent, Lemma ?? . Namely, by Lemma ?? we see that R is geometrically regular over S .

Sample LaTeX generated by a RNN
trained on a book of algebraic geometry

Solution #2: NN with recurrent units

context the formal study of grammar <u>is</u> an important part of education	Nested LSTM
context the formal study of grammar <u>is</u> an important part of education	LSTM
context the formal study of grammar <u>is</u> an important part of education	GRU
context the formal study of grammar is an <u>im</u> portant part of education	Nested LSTM
context the formal study of grammar is an <u>im</u> portant part of education	LSTM
context the formal study of grammar is an <u>im</u> portant part of education	GRU

Memory encoded in variant RNNs,
Source (and interactive demo): <https://distill.pub/2019/memorization-in-rnns/>

Solution #2: NN with recurrent units

- Variable number of observations per sequence
 - OK
- Segmentation (starting/end points)
 - Not invariant to that!
- Irregular sampling (time series)
 - OK

Summary

- 1d-CNN and RNN can be used
 - depends on the context
 - proved equivalent for stable processes in many-to-one settings [Miller & Hardt, 2019]
 - 1d-CNN are faster to learn