

# Deep Learning in Practice: Recurrent Neural Networks

Mohammad Taher Pilehvar

Introduction to Artificial Intelligence, 97-98

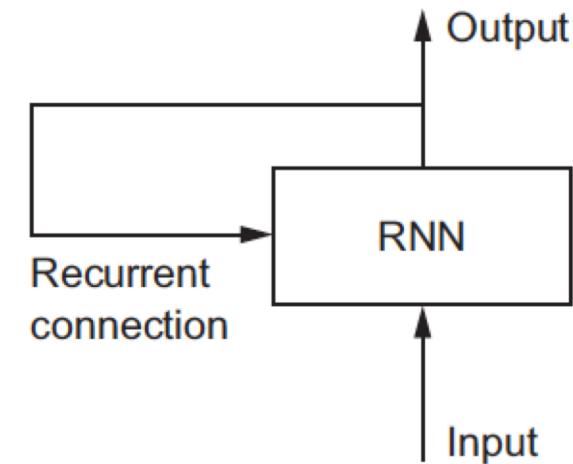
<http://iust-courses.github.io/ai97/>

# Memory

- Dense and ConvNet have no memory!
  - They process the input shown to them independently (with no state in between them)
- These are called *feedforward networks*
- However, we read sentences word by word, keeping a memory of what came before

# Recurrent Neural Network

- Still, a sequence is a single data point
- What changes is:
  - This data point is no longer processed in a single step; rather, the network internally loops over sequence elements.



# Introductory videos



Perfect Roommate



Apple pie



Burger



Chicken

# RNNs in action (IMDB)

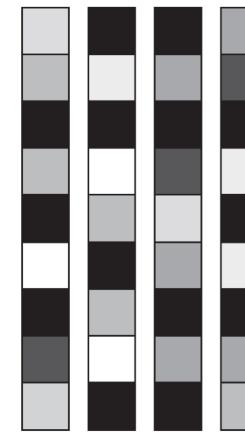
```
model = models.Sequential()
model.add(Embedding(max_features, 32))
model.add(Dropout(0.4))
model.add(LSTM(32))
model.add(Dense(1, activation='sigmoid'))

model.compile(optimizer='rmsprop',
              loss='binary_crossentropy',
              metrics=[ 'acc' ])

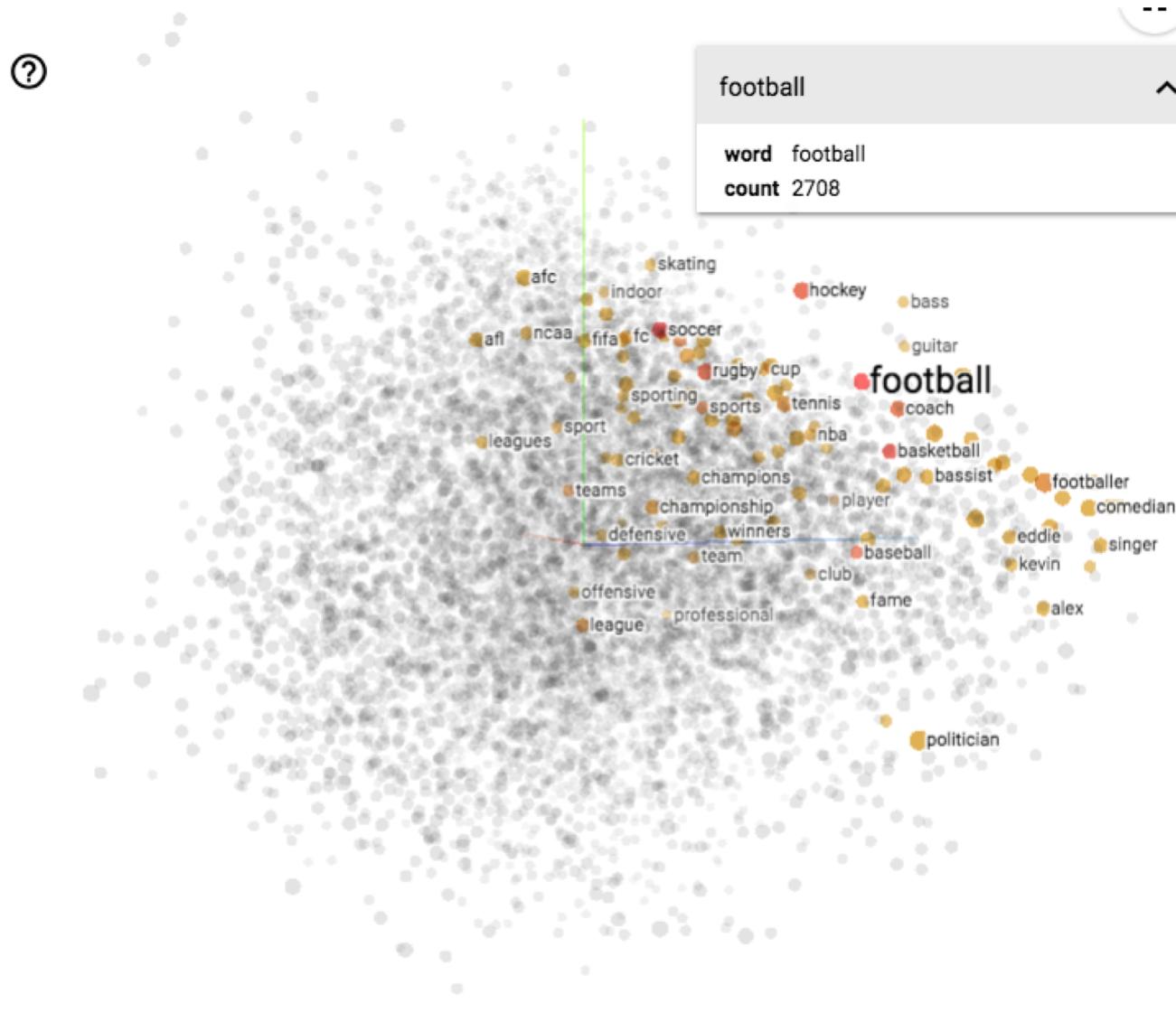
history = model.fit(input_train, y_train,
                     epochs=10,
                     batch_size=128,
                     validation_split=0.2)
```

# One-hot encoding vs. embeddings

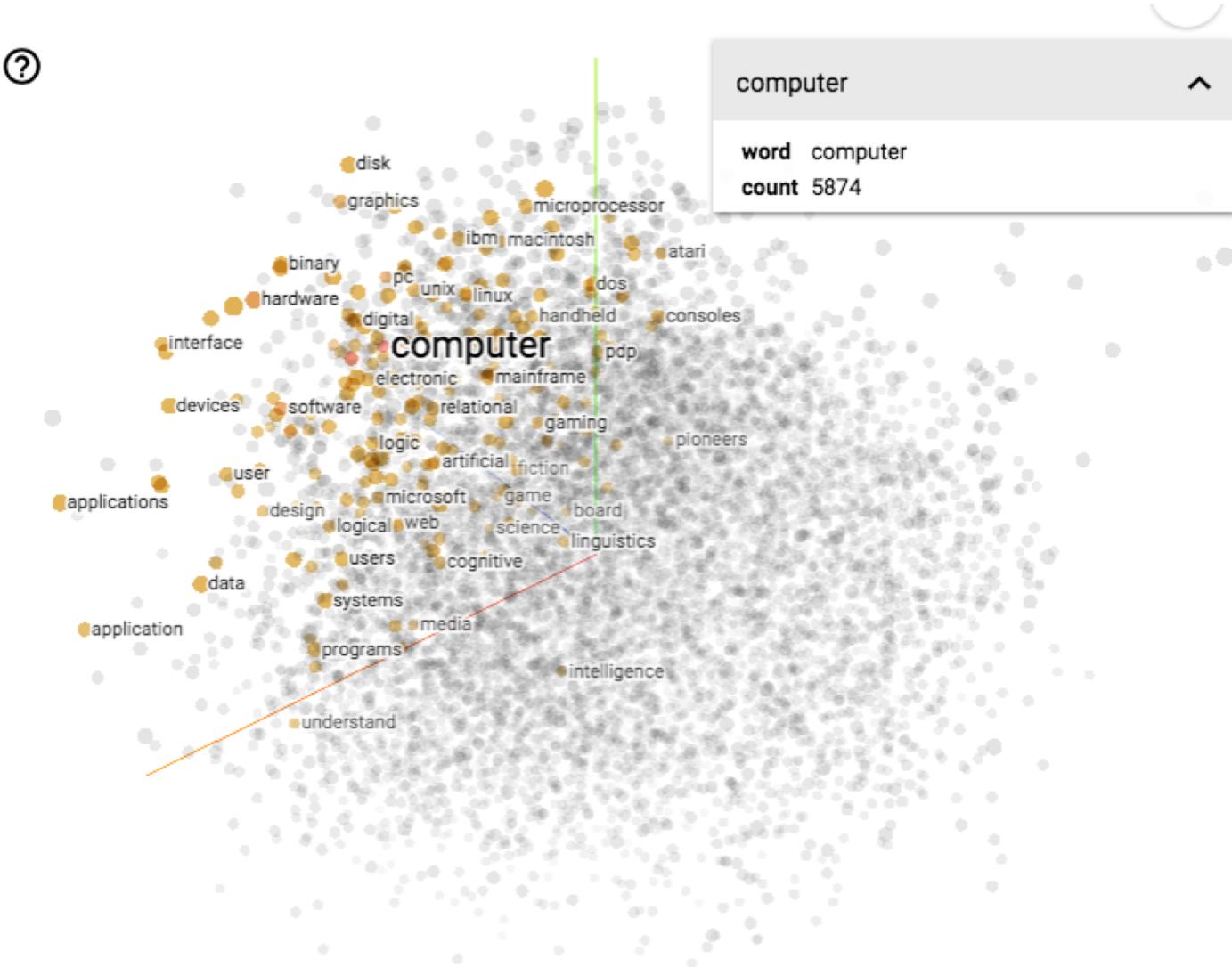
- Tensorboard



# Word embeddings



# Word embeddings



# RNNs for language modeling

- Persian poetry!

The screenshot shows a user interface for generating Persian poetry. At the top, there is a text input field containing the word "study". To the right of the input field is a "Generate" button. Below the input field, a blue button displays the text "[1s] Ready". Underneath the button, the word "Poem" is written in a bold, dark font. To the left of "Poem", there is a small icon consisting of five yellow stars. Below these elements, a short poem is displayed in English:

The scientific curiosity!  
And learn to use an equal colour vision,  
Try and teach the public policy,  
A state of scientific discipline.

روان را به دانش به کار آوری

به توران به خواب اندر آرد سری

# RNNs for language modeling

- Persian poetry!

نیست کو معلین  
دامت خانقاہ به من من از در میخانه بست  
در کار ما به در این خیال ما را ببرد  
ز شاه ساهد می و زلف تو را تا برسد  
تا به درد تو به میخانه در آب است  
که باز من آباد به در خسابت  
به خاک دل بر ت

ادامه داستان  
سواران گردنکشان دسته دید  
خردمند را او بدان خسته دید  
سکندر نگه کرد پس پهلوان  
به بدخواه شد شاد و روشن روان  
سپاه اندر آمد به پیش سوار  
خردمند و شایسته‌ی کارزار  
بفرمود تا بنده آگاه دید  
چنین تا بر شاه ایران کشید  
نهادند چیزی که پوشیده بود  
جهان را درم داد و دینار بود  
سران افسر از گوهر شاهوار  
نخست آفرین کرد بر کردگار  
چو بهرام بشنید گریان شدند

# RNNs for language modeling

- Wikipedia articles

Naturalism and decision for the majority of Arab countries' capitalide was grounded by the Irish language by [[John Clair]], [[An Imperial Japanese Revolt]], associated with Guangzham's sovereignty. His generals were the powerful ruler of the Portugal in the [[Protestant Immineners]], which could be said to be directly in Cantonese Communication, which followed a ceremony and set inspired prison, training. The emperor travelled back to [[Antioch, Perth, October 25|21]] to note, the Kingdom of Costa Rica, unsuccessful fashioned the [[Thrales]], [[Cynth's Dajoard]], known in western [[Scotland]], near Italy to the conquest of India with the conflict. Copyright was the succession of independence in the slop of Syrian influence that was a famous German movement based on a more popular servitious, non-doctrinal and sexual power post. Many governments recognize the military housing of the [[Civil Liberalization and Infantry Resolution 265 National Party in Hungary]], that is sympathetic to be to the [[Punjab Resolution]] (PJS)[<http://www.humah.yahoo.com/guardian.cfm/7754800786d17551963s89.htm>] Official economics Adjoint for the Nazism, Montgomery was swear to advance to the resources for those Socialism's rule, was starting to signing a major tripad of aid exile.]]

# RNNs for language modeling

- Wikipedia articles

```
{ { cite journal | id=Cerling Nonforest Department|format=Newlymeslated|none } }
' 'www.e-complete''.

'''See also'''': [[List of ethical consent processing]]

== See also ==
*[[Iender dome of the ED]]
*[[Anti-autism]]

====[[Religion|Religion]]====
*[[French Writings]]
*[[Maria]]
*[[Revelation]]
*[[Mount Agamul]]
```

# RNNs for language modeling

- XML

```
<page>
  <title>Antichrist</title>
  <id>865</id>
  <revision>
    <id>15900676</id>
    <timestamp>2002-08-03T18:14:12Z</timestamp>
    <contributor>
      <username>Paris</username>
      <id>23</id>
    </contributor>
    <minor />
    <comment>Automated conversion</comment>
    <text xml:space="preserve">#REDIRECT [[Christianity]]</text>
  </revision>
</page>
```

# RNNs for language modeling

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  $\text{Sch}_{fppf}$  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  $\text{Sh}(G)$  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  $\text{GL}_{S'}(x'/S'')$  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

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

and

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

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  $X_{\text{spaces},\text{étale}}$  which gives an open subspace of  $X$  and  $T$  equal to  $S_{\text{Zar}}$ , see Descent, Lemma ???. Namely, by Lemma ?? we see that  $R$  is geometrically regular over  $S$ .

**Lemma 0.1.** Assume (3) and (3) by the construction in the description.

Suppose  $X = \lim |X|$  (by the formal open covering  $X$  and a single map  $\underline{\text{Proj}}_X(\mathcal{A}) = \text{Spec}(B)$  over  $U$  compatible with the complex

$$\text{Set}(\mathcal{A}) = \Gamma(X, \mathcal{O}_{X,\mathcal{O}_X}).$$

When in this case of to show that  $\mathcal{Q} \rightarrow \mathcal{C}_{Z/X}$  is stable under the following result in the second conditions of (1), and (3). This finishes the proof. By Definition ?? (without element is when the closed subschemes are catenary. If  $T$  is surjective we may assume that  $T$  is connected with residue fields of  $S$ . Moreover there exists a closed subspace  $Z \subset X$  of  $X$  where  $U$  in  $X'$  is proper (some defining as a closed subset of the uniqueness it suffices to check the fact that the following theorem

(1)  $f$  is locally of finite type. Since  $S = \text{Spec}(R)$  and  $Y = \text{Spec}(R)$ .

*Proof.* This is form all sheaves of sheaves on  $X$ . But given a scheme  $U$  and a surjective étale morphism  $U \rightarrow X$ . Let  $U \cap U = \coprod_{i=1,\dots,n} U_i$  be the scheme  $X$  over  $S$  at the schemes  $X_i \rightarrow X$  and  $U = \lim_i X_i$ .  $\square$

The following lemma surjective restrocomposes of this implies that  $\mathcal{F}_{x_0} = \mathcal{F}_{x_0} = \mathcal{F}_{x,\dots,x}$ .

**Lemma 0.2.** Let  $X$  be a locally Noetherian scheme over  $S$ ,  $E = \mathcal{F}_{X/S}$ . Set  $\mathcal{I} = \mathcal{J}_1 \subset \mathcal{I}'_n$ . Since  $\mathcal{I}^n \subset \mathcal{I}^n$  are nonzero over  $i_0 \leq p$  is a subset of  $\mathcal{J}_{n,0} \circ \overline{A}_2$  works.

**Lemma 0.3.** In Situation ???. Hence we may assume  $q' = 0$ .

*Proof.* We will use the property we see that  $p$  is the next functor (??). On the other hand, by Lemma ?? we see that

$$D(\mathcal{O}_{X'}) = \mathcal{O}_X(D)$$

where  $K$  is an  $F$ -algebra where  $\delta_{n+1}$  is a scheme over  $S$ .  $\square$

# Questions?