DL4nlp - Deep Learning for Natural Language Processing

Ander Barrena Madinabeitia
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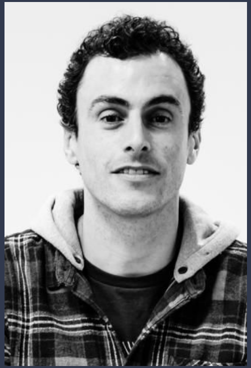
Hitz Zentroa - Ixa Taldea

Slides available in repo!

Lab Time!
From LR to Transformers
Task: Sentiment analysis

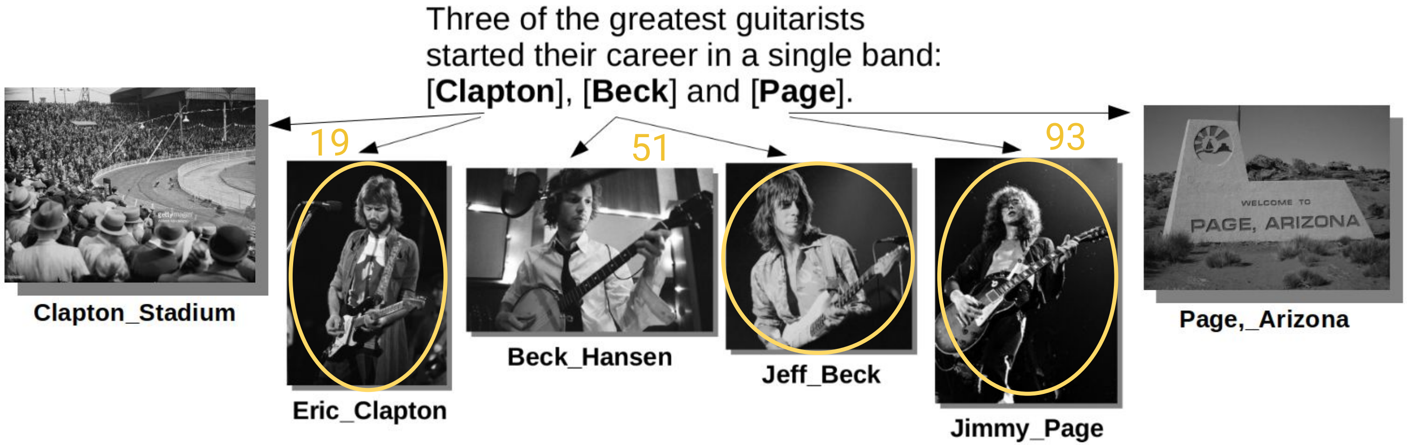
About myself



- PhD in Natural Language Processing in 2017 (EHU) Machine Learning! (old stuff!)
  - PGM and Generative Statistical Models
  - Personalized Page Rank
- post-Doctoral grant from EHU (Deep Learning)
- assistant professor in EHU
- research interest:
  - **Multilingual/Unsupervised Named Entity Disambiguation**
  - Sequence Labeling, **Language Modeling (Basque, Medical domain)**, QA, Semantic Textual Similarity, Information Extraction...
  - Deep Learning for NLP
  - **Brain Image Classification based on Transformers**
    - Dyslexia
    - Alzheimer
    - …

About myself

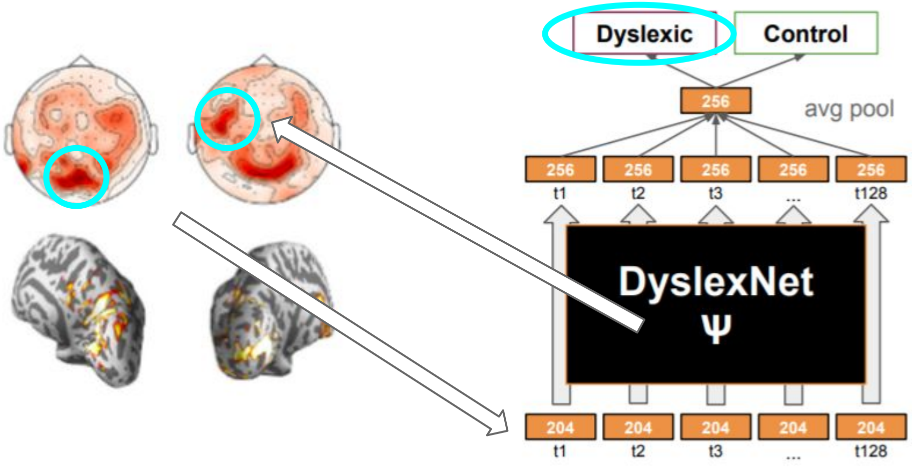
- Research interest:
  - **Multilingual/Unsupervised Named Entity Disambiguation**



Three of the greatest guitarists started their career in a single band: [**Clapton**], [**Beck**] and [**Page**].

About myself

- Research interest:
    - **Brain Image Classification based on Transformers**
        - Dyslexia
        - Alzheimer
        - ...



46[sub] x 3k[instances] x **128[time] x 204[activations]**

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TensorFlow!

Lab Time!

From LR to Transformers

Task: Sentiment analysis

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- Rise your hand and ask your question
- Try not to use chat (only for you)
- Private room (share your screen...)
    - small talks…

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Lab1:
Warming Up
+ assignment
-> sol. next lab

Lab1: Warming Up

- Follow the instructions in 0.Instructions.docx to access the lab data.
- Goal: Ensure everithing is working fine.
  - Python (list comprehension)
  - Numpy (vector multiplications)
  - TensorFlow 2.0
  - Loading/Examining data from labs folder
    - Train/Dev/Test splits
  - 2 goals -> numpy and TF2.0
- Code in Jupiter Colab & self-explanatory labs.
- We recommend you the python/numpy tutorial and to take a look to the slides.

Please! play with the code!

Change numbers and print each step vector size!

Run code more than once!

Lab1:
Warming Up

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  - 2 assignments numpy and TF2.0
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$$\frac{1}{\sqrt{2\sigma^2\pi}}\,e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Today's Goal!
Function Broadcasting!

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Progress certificate (all labs, not assignments) send it before showing the solution

Good luck!

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lab1 until 18:30!

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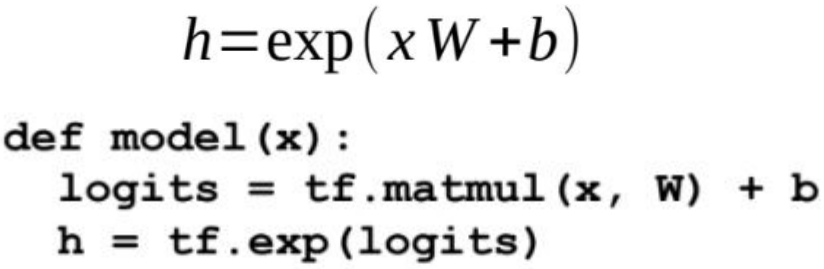
Assignment1: Logistic Regression, SGD, and Regularization

Assignment1: Logistic Regression, SGD, and Regularization

- Logistic Regression model for sentence classification using Tensorflow.
- Task: Sentiment analysis
- 5-way classification task into 2-way classification task (0→negative, 1→positive)
- Goals:
  - Pick an effective learning rate for SGD
  - Implement L2 regularization (see bellow)
  - Pick an effective L2 weight
  - Look at some learning curves (optional)
- Check:
  - BoW feature vector
  - Num of parameters?
  - Hyperparameters?
  - Norm and Exp
  - mini Batch
  - data spliting
  - ...

Assignment1: Logistic Regression, SGD, and Regularization

- Logistic Regression model for sentence classification using Tensorflow.



$$h = \exp(xW + b)$$

```
def model(x):
  logits = tf.matmul(x, W) + b
  h = tf.exp(logits)
```

- **Overfitting and regularization:** W can be very good for training, with enough layers and capacity the model can memorize the training data!
  - Generalize very poorly to test data (= the real world)
- First solution: add a regularizer to the loss function that avoids the model to fit the training data.
  - Squared L2 norm

Assignment1: Logistic Regression, SGD, and Regularization

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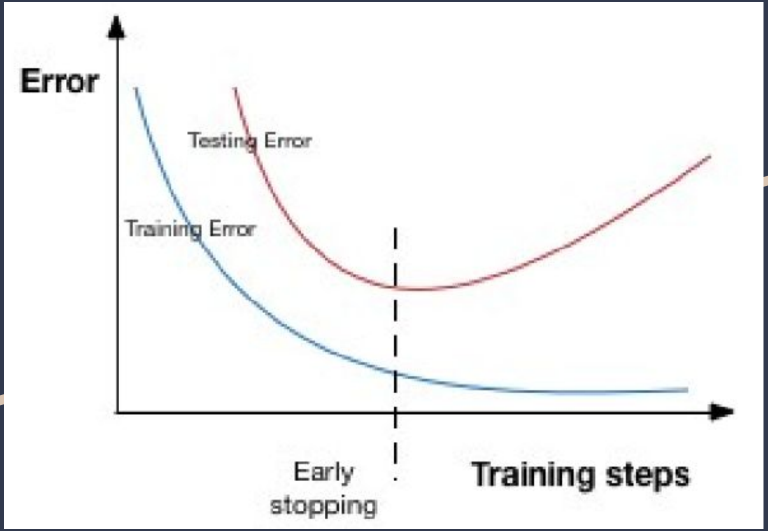
    - Squared L2 norm

$$J_i(W) = -\log\left(\frac{\exp\left(W_{c_i}^T x\right)}{\sum_{c' \in C} \exp\left(W_{c'}^T x\right)}\right) \boxed{+\lambda \sum_k W_k^2}$$

Check the TF documentation! for sum and square

Assignment1: Logistic Regression, SGD, and Regularization



- Logistic Regression model for sentence classification using Tensorflow.
- **Overfitting and regularization:** W can be very good for training, with enough layers and capacity the model can memorize the training data!
  - Generalize very poorly to test data (= the real world)
- **First solution:** add l2 regularizer to the loss function that avoids the model to fit the training data.
- **Second solution:** Early stopping finishes training as soon as development error starts to increase
  - **Experimental setup:**
    - %80 train, %10 development, %10 test (blind!!)
  - **Model selection:**
    - best accuracy (lowest error) at development

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Good luck!
Sol. next Lab!

Don’t send me the assignment!

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Solution & Lab Time!

- New Private Room:
  - https://ehu.webex.com/meet/abarrena
  - enter only when necessary

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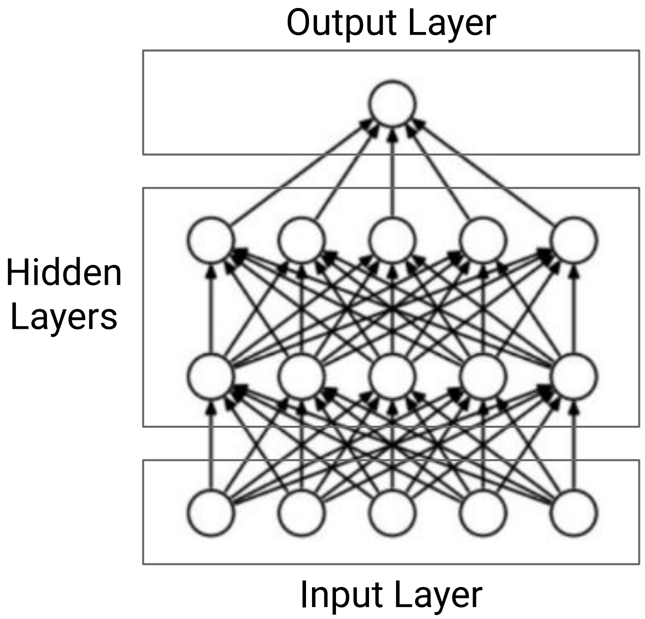
Lab2: MLP and Dropout

Lab2: MLP and Dropout

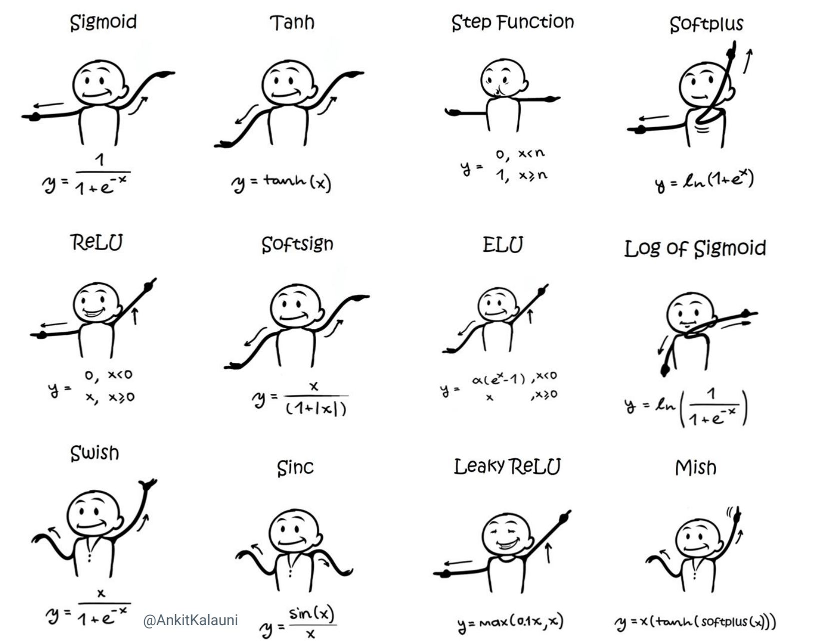
- Modify a Logistic Regression to turn it into a MLP with two hidden layers (non-linearity).
  - 2 hidden layers = Deep Learning...
- It will **overfit** in training data! (toy examples)



Today's Goal!

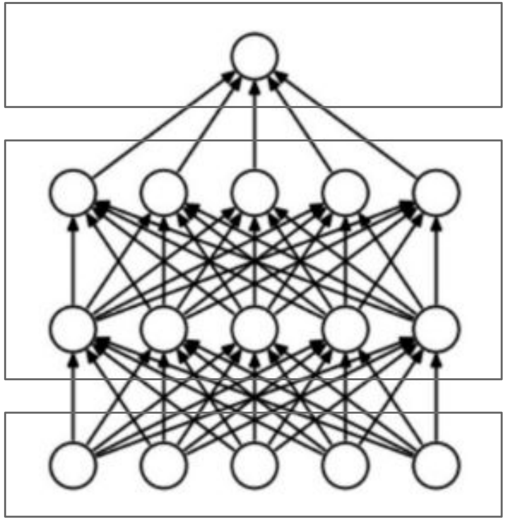
Lab2: MLP and Dropout

Dance moves of DL activations


Sigmoid
$y = \frac{1}{1+e^{-x}}$
Tanh
$y = \tanh(x)$
Step Function
$y = \begin{cases} 0, & x<n \\ 1, & x \geq n \end{cases}$
Softplus
$y = \ln(1+e^{x})$
ReLU
$y = \begin{cases} 0, & x<0 \\ x, & x \geq 0 \end{cases}$
Softsign
$y = \frac{x}{(1+|x|)}$
ELU
$y = \begin{cases} \alpha(e^{x}-1) & ,x<0 \\ x & ,x \geq 0 \end{cases}$
Log of Sigmoid
$y = \ln\left(\frac{1}{1+e^{-x}}\right)$
Swish
$y = \frac{x}{1+e^{-x}}$
@AnkitKalauni
Sinc
$y = \frac{\sin(x)}{x}$
Leaky ReLU
$y = \max(0.1x, x)$
Mish
$y = x(\tanh(\mathrm{softplus}(x)))$

- Modify a Logistic Regression to turn it into a MLP with two hidden layers (non-linearity).
  - 2 hidden layers = Deep Learning...
- It will **overfit** in training data!

Output Layer



Hidden Layers

Input Layer

Today's Goal!

Lab2:
MLP and Dropout

$$y = softmax(h_1 W_2 + b_2)$$

$$h_1 = f(h_0 W_1 + b_1)$$

$$h_0 = f(x W_0 + b_0)$$

- Modify a Logistic Regression to turn it into a MLP with two hidden layers (non-linearity).
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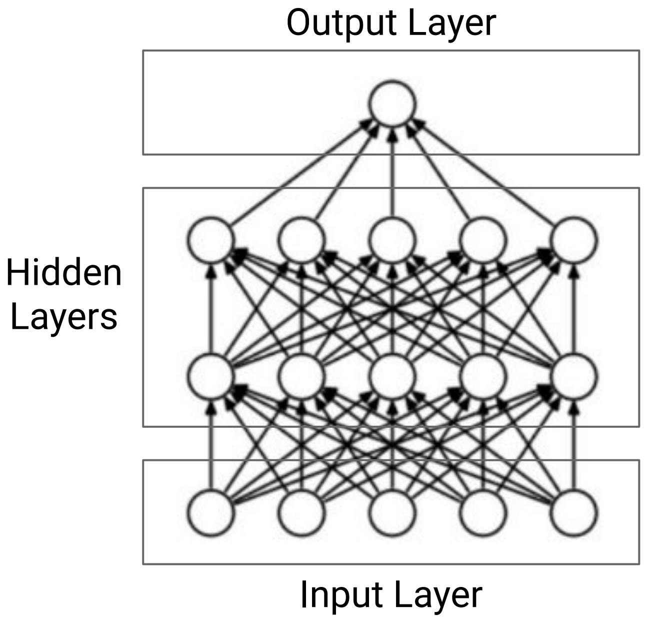

Today's Goal!

Lab2: MLP and Dropout

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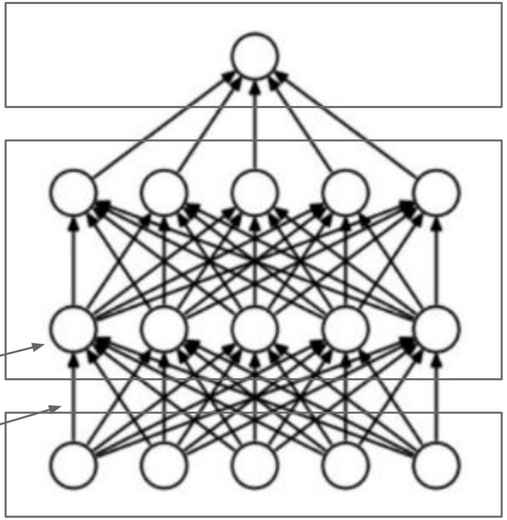


Hidden Layers

Input Layer

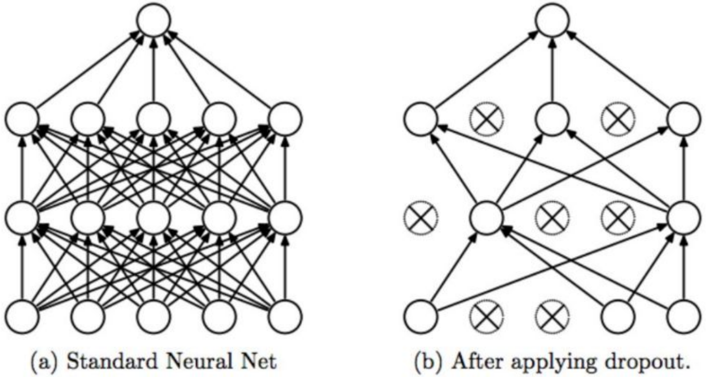
Today's Goal!

Sentence Representation (word order?)

Word Embeddings

Lab2:
MLP and Dropout

- Modify a Logistic Regression to turn it into a MLP with two hidden layers (non-linearity).
- It will overfit in training data!
- Add **Dropout** regularization. Hint: after non-linearity and only during training.



Source: “Dropout: a simple way to prevent neural networks from overfitting”, JMLR 2014

Lab2:
MLP and Dropout

- Modify a Logistic Regression to turn it into a MLP with two hidden layers (non-linearity).
- It will overfit in training data!
- Add **Dropout** regularization. Hint: after non-linearity and only during training.
- More parameters to tune!
    - Hidden layer number and size. The more the better? not always...
    - Dropout Probability.
    - Should we add dropout in the input layer?
    - Early stop?
        - Check where should we stop training and save the best model

Lab2:
MLP and Dropout

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Be careful with dropout at test time

Be careful with dimensionalities

Be careful with the initialization!
Gradient Vanishing!

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MLP and Dropout

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- More parameters to tune!
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Shared task! Share your **dev**/test results and best model hyperparameters and dimensionality

Lab2:
MLP and Dropout

- Modify a Logistic Regression to turn it into a MLP with two hidden layers (non-linearity).
- It will overfit in training data!
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- More parameters to tune!
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  - Dropout Probability.
  - Should we add dropout in the input layer?
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Once you are done, try 5 way classification… code your own learning rate decay… increase vocab….

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Good luck!
Sol. next Lab!

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Solution &
Lab Time!

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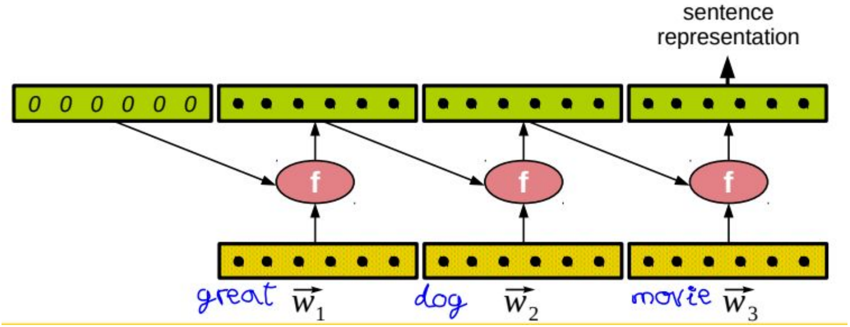
Lab3: RNN based classifier

Lab3:
RNN based classifier

Hints:

- Use tf.nn.embedding_lookup
- Print shapes tf.shape()
- Be patient…
- We already add l2 regularization…
- Improving dev at 100~200 ep
  - ~72% acc.

- Modify a Logistic Regresion to turn it into a RNN sentence classifier.
- Slower that MLP, and not very good… yet!
  - Don't try to improve results...
- Define **RNN** parameters (Recurrent layer)
- Define a recurrent <u>step</u>
  - Embedding_lookup
  - Concat
  - matmul & Tanh!
- Unroll to obtain sentence representation!
  - Loop over the sequence_lenght and use x_slices
  - Be careful with shapes! tf.reshape!
  - Perform an step
- You can add an MLP on top!



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Assignment2: Word Embeddings

Assignment2: Word Embeddings!

- Cosine Similarity: Similar and related Words
- Semantic orientation
- Analogy
  - man -> king
  - woman -> ???
- Visualization tools
- Have a good time after RNN lab!

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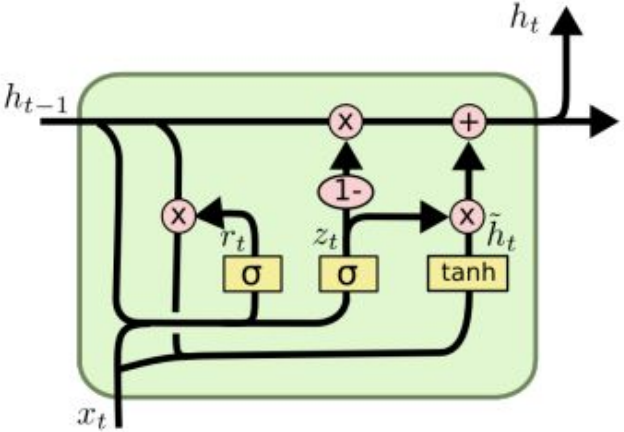
Lab4: GRU based classifier

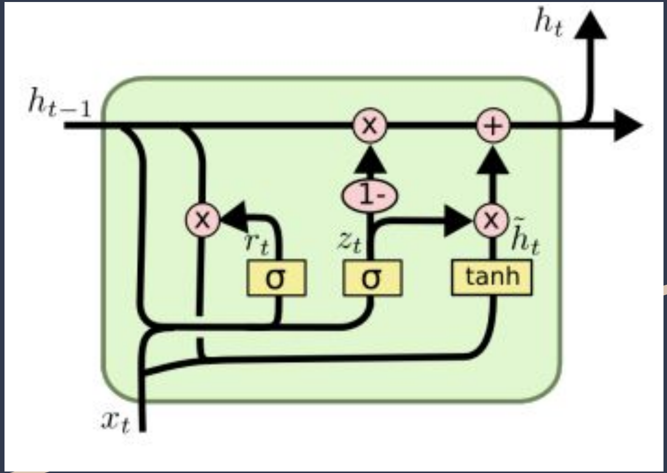
Lab4:
GRU based classifier

Kyunghyun Cho
(2014)

- Modify a RNN to GRU.



Lab4:
GRU based classifier



- Modify a RNN to GRU.
  - Add aditional parameters
  - Modify the step function
  - Modidy L2 regularization
  - Wait 100~150 epochs… be patient
    - dev acc ~80% !!!
  - Plot dev/train acc
    - Check when do we need to early stop
  - Code LSTM or Stack GRU layers

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

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

History

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

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

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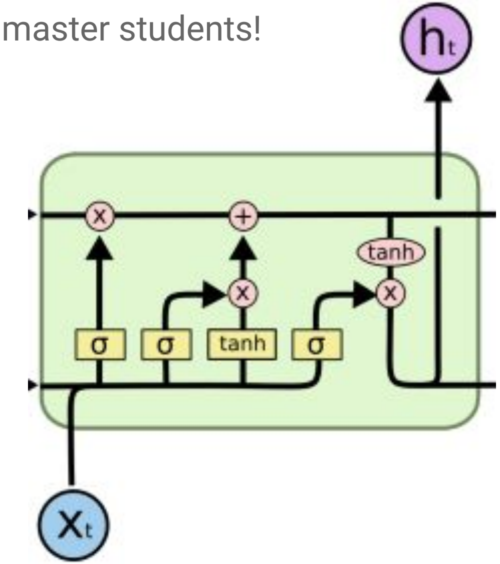
Assignment3: Language Modelling with LSTM networks

Assignment3: LSTM based classifier

- Modify a RNN to LSTM, perform **language modeling task** and answer some questions.
- Language Modeling, new task, new cost function…
- Same as GPT3 but using LSTMs an at low scale…
- Language Generation: Samples from a trained models should have “coherent” portions.
- Note that this is for master students!



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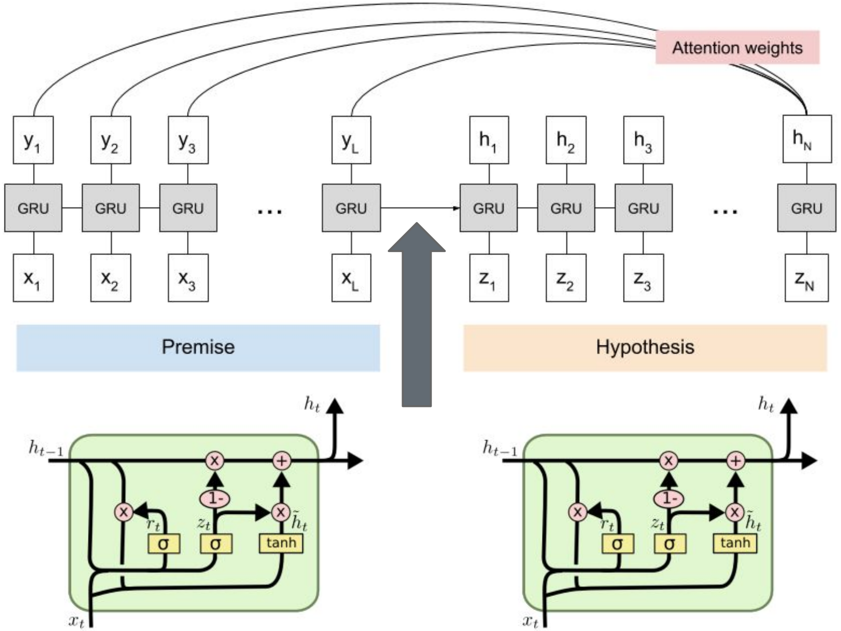
Lab5: Attention models

Lab5: Attention models

- Attention model for NLI based on Rocktäschel's model. (Read the paper...)
- Natural Language Inference (NLI). Given a pair of premise and hypothesis texts, the task is to classify them into three categories: entailment, contradiction, and neutral.
  - A man inspects the uniform of a figure in some East Asian country. | **contradiction** | The man is sleeping.
  - A soccer game with multiple males playing. | **entailment** | Some men are playing a sport.
  - An older and younger man smiling. | **neutral** | Two men are smiling and laughing at the cats playing on the floor.
- This is deep learning! (a scientific paper reimplementation)

Lab5: Attention models

- Attention model for NLI based on Rocktäschel's model.
  - 2xGru encoders + attention (no bias)



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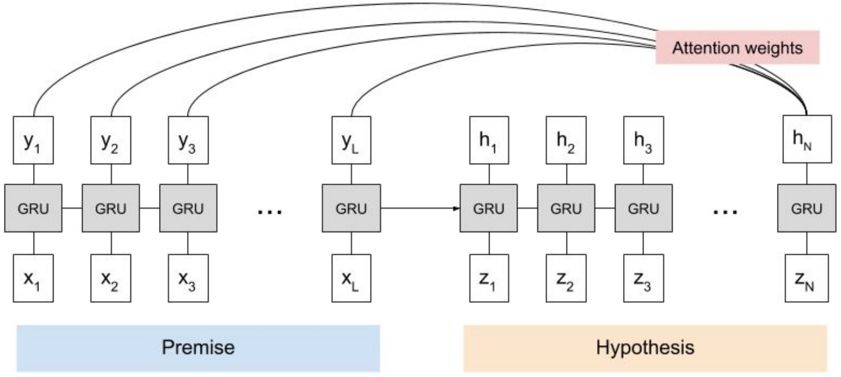

$$\mathbf{M} = \tanh(\mathbf{W}^y \mathbf{Y} + \mathbf{W}^h \mathbf{h}_N \otimes \mathbf{e}_L)$$

$$\alpha = \mathrm{softmax}(\mathbf{w}^T \mathbf{M})$$

Goal!

$$\mathbf{r} = \mathbf{Y} \alpha^T$$

$$\mathbf{h}^* = \tanh(\mathbf{W}^p \mathbf{r} + \mathbf{W}^x \mathbf{h}_N)$$

Lab5: Attention models

- Attention model for NLI based on Rocktäschel's model.
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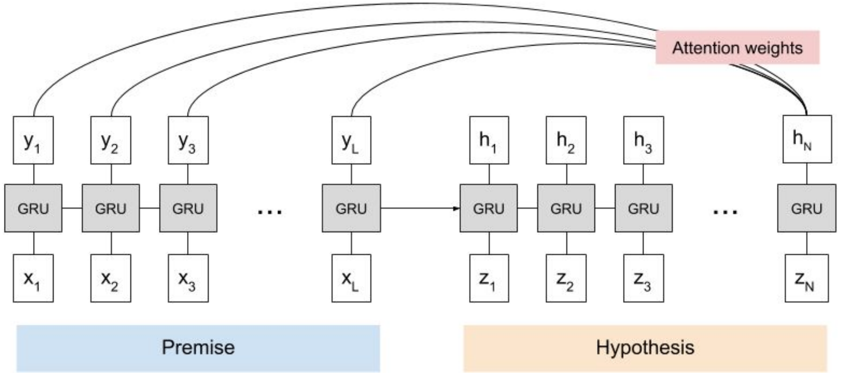

$$\mathbf{M} = \tanh(\mathbf{W}^y\mathbf{Y} + \mathbf{W}^h\mathbf{h}_N \otimes \cancel{\mathbf{e}}_L)$$

$$\alpha = \mathrm{sof}\cancel{\mathrm{t}}\mathrm{max}(\mathbf{w}^{\cancel{T}}\mathbf{M})$$

$$\mathbf{r} = \mathbf{Y}\alpha^T$$

$$\mathbf{h}^* = \tanh(\mathbf{W}^p\mathbf{r} + \mathbf{W}^x\mathbf{h}_N)$$

Hint! iterate over Y

Lab5: Attention models

- Attention model for NLI based on Rocktäschel's model.
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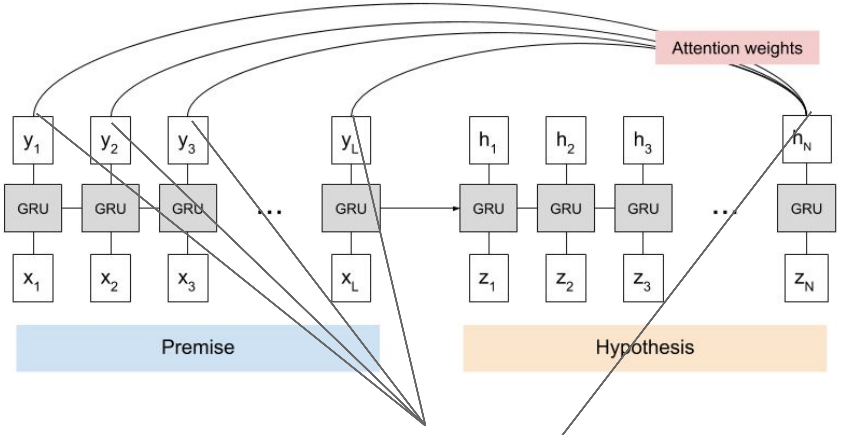


$$\mathbf{M} = \tanh(\mathbf{W}^y\mathbf{Y} + \mathbf{W}^h\mathbf{h}_N \otimes \cancel{\mathbf{e}_L})$$

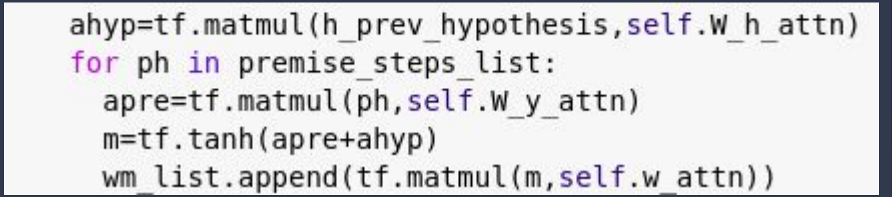
$$\alpha = \mathrm{sof}\cancel{\mathrm{t}}\mathrm{max}(\mathbf{w}^{\cancel{T}}\mathbf{M})$$

$$\mathbf{r} = \mathbf{Y}\alpha^T$$ avg. representation

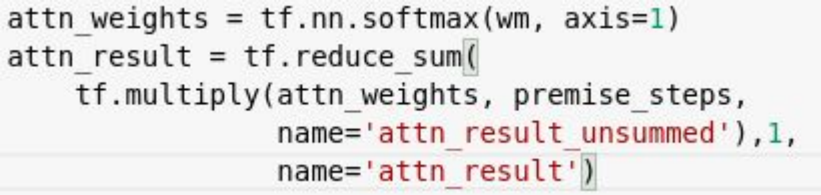
Hint! iterate over Y

$$\mathbf{h}^* = \tanh(\mathbf{W}^p\mathbf{r} + \mathbf{W}^x\mathbf{h}_N) \rightarrow ???$$

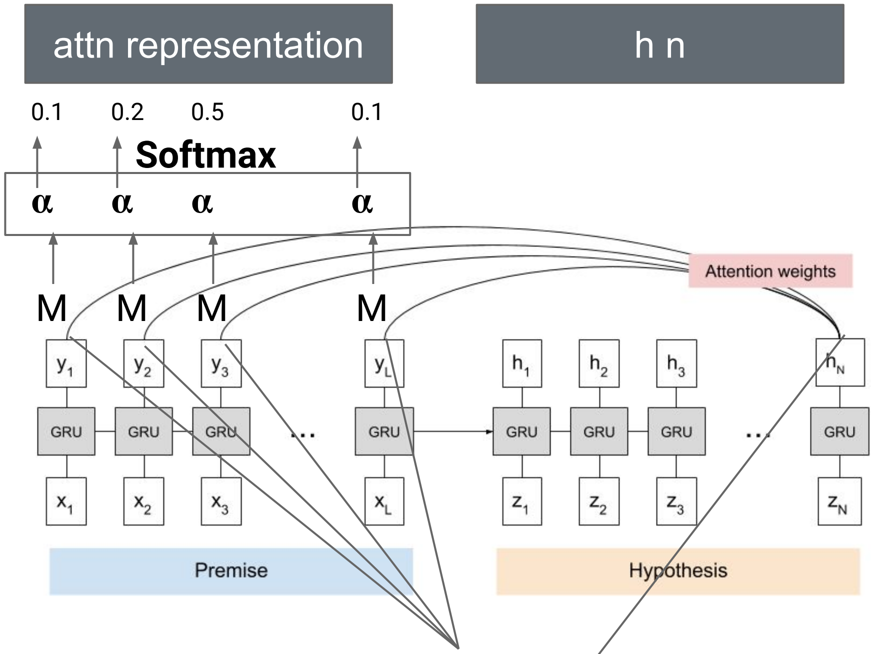
Lab5: Attention models solution



```
ahyp=tf.matmul(h_prev_hypothesis,self.W_h_attn)
for ph in premise_steps_list:
  apre=tf.matmul(ph,self.W_y_attn)
  m=tf.tanh(apre+ahyp)
  wm_list.append(tf.matmul(m,self.w_attn))
```



```
attn_weights = tf.nn.softmax(wm, axis=1)
attn_result = tf.reduce_sum(
    tf.multiply(attn_weights, premise_steps,
                name='attn_result_unsummed'),1,
                name='attn_result')
```



$$\mathbf{M} = \tanh(\mathbf{W}^y\mathbf{Y} + \mathbf{W}^h\mathbf{h}_N \otimes \cancel{\mathbf{e}_L})$$

$$\alpha = \mathrm{sof}\cancel{\mathrm{t}}\mathrm{max}(\mathbf{w}^{\cancel{T}}\mathbf{M})$$

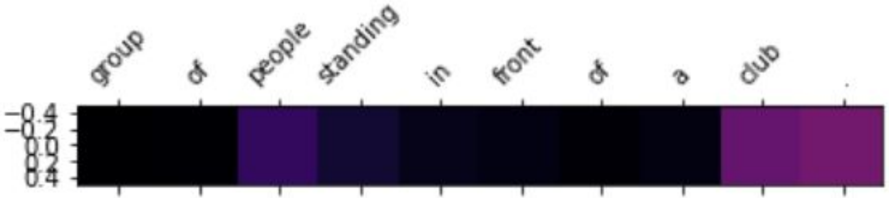
$$\mathbf{r} = \mathbf{Y}\alpha^T$$ avg. representation

Hint! iterate over Y

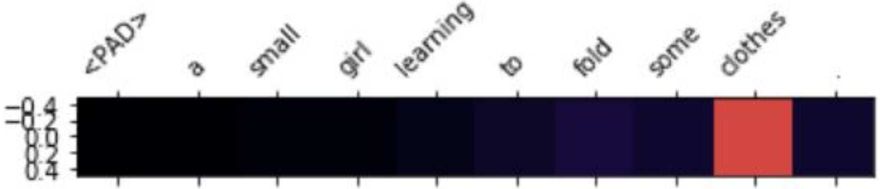
$$\mathbf{h}^* = \tanh(\mathbf{W}^p\mathbf{r} + \mathbf{W}^x\mathbf{h}_N) \rightarrow ???$$

Lab5: Attention models

- Attention model for NLI based on Rocktäschel's model.
  - 2xGru encoders + attention (no bias)
  - Fixed and freezed embeddings (from Glove)
  - GPU! (enable in runtime) still slow training…
  - Don't expect high accuracy
- Once you are done
  - Plot attention weights



H: group of people are waiting to enter the club .



H: folding clothes to pack in a suitcase for vacation .

Lab5: Attention models

- Attention model for NLI based on Rocktäschel's model.
  - 2xGru encoders + attention (no bias)
  - Fixed and freezed embeddings (from Glove)
  - GPU!
  - This is deep learning!
- Once you are done
  - Plot attention weights
  - Back propagate through embeddings (more parameters...)
  - Increase hidden size, embedding size (dowload Glove embeddings)...
  - Try to increase model accuracy! (However, it takes too long...)

DL4nlp - Deep Learning for Natural Language Processing

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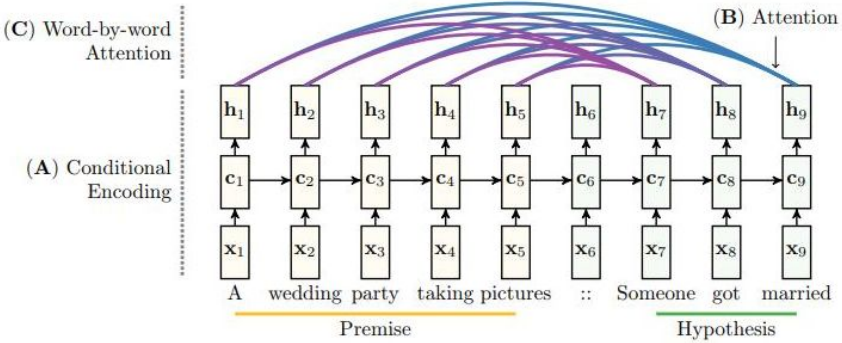
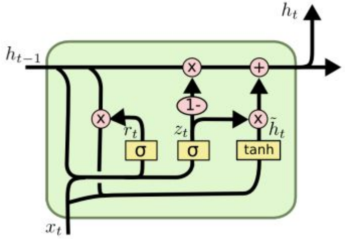
Assignment4: Word by Word attention

Assignment4: Word by Word attention

- Attention model for NLI based on Rocktäschel's model.
  - 2xGru encoders + Word by Word attention


(C) Word-by-word Attention
(B) Attention
(A) Conditional Encoding
h1 h2 h3 h4 h5 h6 h7 h8 h9
c1 c2 c3 c4 c5 c6 c7 c8 c9
x1 x2 x3 x4 x5 x6 x7 x8 x9
A wedding party taking pictures :: Someone got married
Premise
Hypothesis



DL4nlp - Deep Learning for Natural Language Processing

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Good luck!
Sol. next Lab!

DL4nlp - Deep Learning for Natural Language Processing

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Solution &
Lab Time!

DL4nlp - Deep Learning for Natural Language Processing

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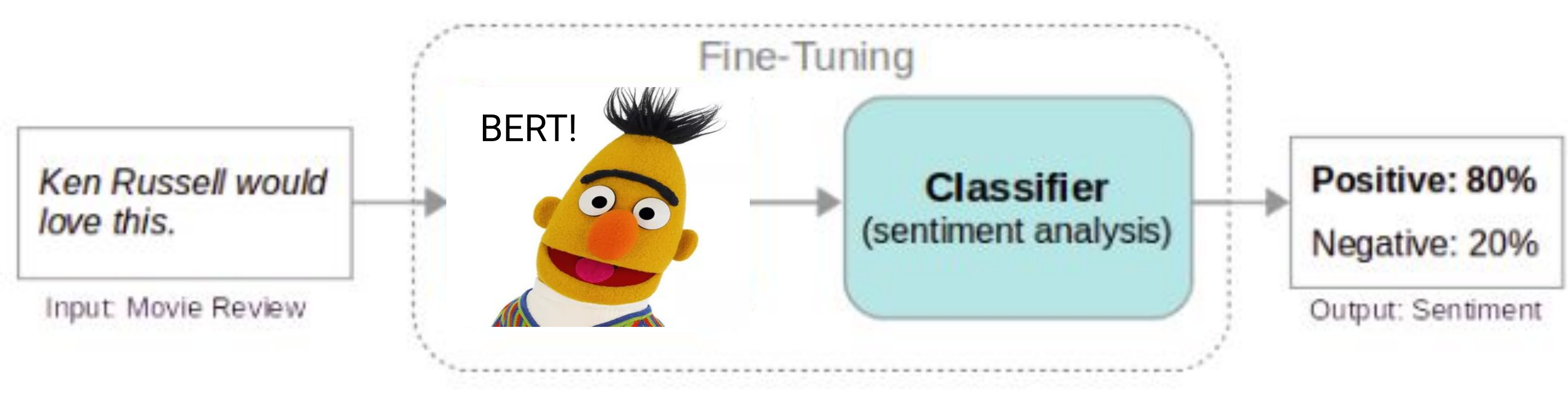
Lab5: Transformers with TensorFlow

Lab5: Transformers with TensorFlow

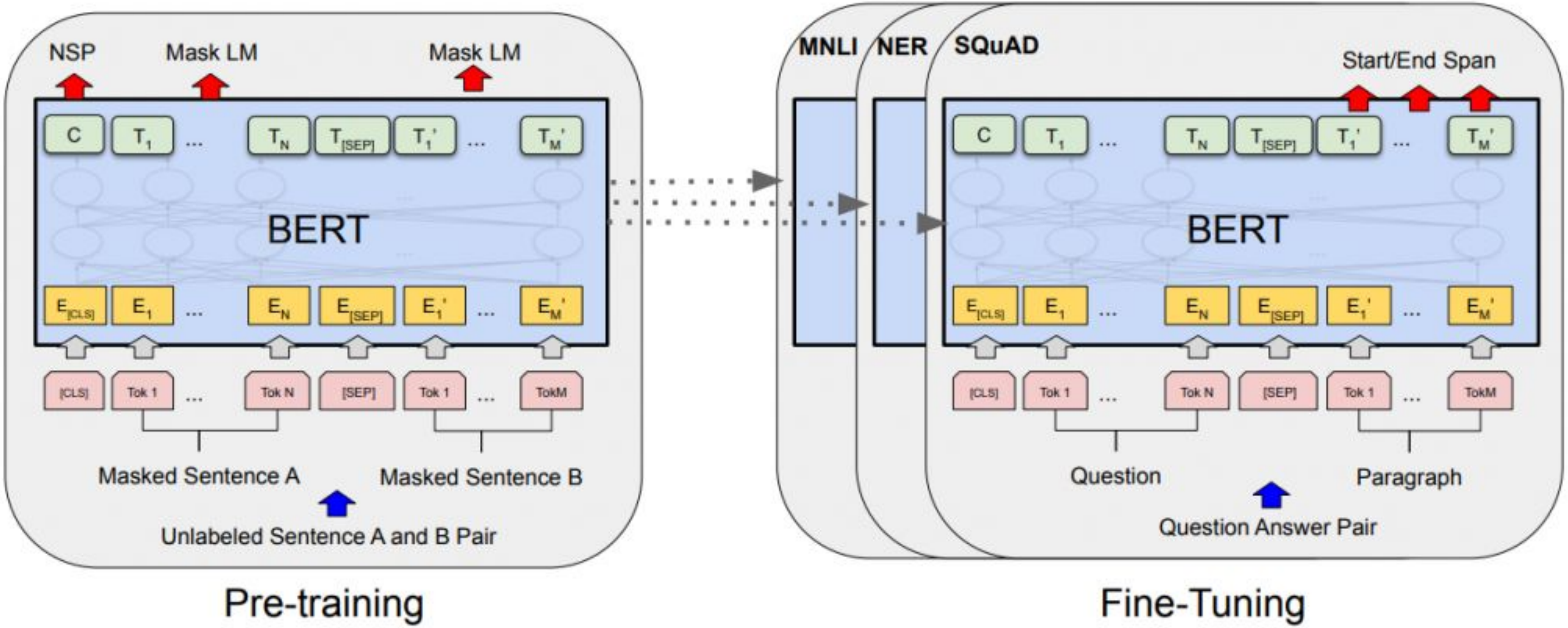
- Fine-tune a Transformer based pre-trained language models.
  - 3 or 4 epochs!
  - we introduce:
    - keras
    - huggingface transformers

Black box!



Lab5: Transformers with TensorFlow

- **BERT** pretraining: **MLM & NSP** and **Fine-tuning**



Lab5: Transformers with TensorFlow

- Fine-tune a Transformer based pre-trained language models.
  - 2, 3 or 4 epochs!
- More concretely, in this lab session will learn the following:
  - Deploy and fine-tune transformers (**BERT**).
  - Transfer learning!
  - Preprocessing data for transformers archicture (word piece tokenization)
  - **soa** Transformer-based classifier
    - High test Acc -> **0.90!!**
  - Finetune for NLI:
    - **Hint:** Zip and List Comprehension + batch_encode_plus

Lab5: Transformers with TensorFlow

Once you are done:

- Try training with **XLMR (crossling model)**
- Run in other datasets or tasks
- Test with sentences in other languages

- Fine-tune a Transformer based pre-trained language models.
  - 2, 3 or 4 epochs!
- More concretely, in this lab session will learn the following:
  - Deploy and fine-tune transformers (**BERT**).
  - Transfer learning!
  - Preprocessing data for transformers archicture (word piece tokenization)
  - **soa** Transformer-based classifier
    - High test Acc -> **0.90!!**
  - Finetune for NLI:
    - **Hint:** Zip and List Comprehension + batch_encode_plus

DL4nlp - Deep Learning for Natural Language Processing

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Good luck :D

DL4nlp - Deep Learning for Natural Language Processing

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Solution & Last Lab :(

DL4nlp - Deep Learning for Natural Language Processing

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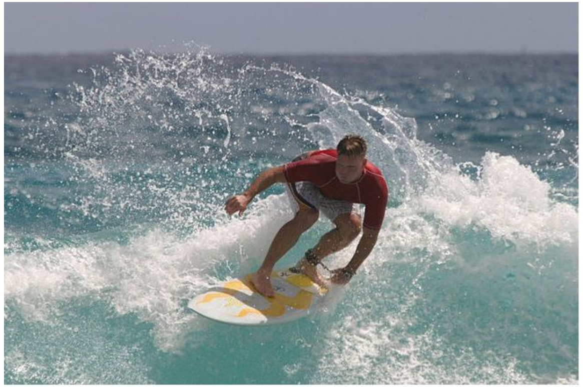
Lab6: Image Captioning

Lab6: Image Captioning

- Given an image like the example below, our goal is to generate a caption such as "**a surfer riding on a wave**". (cherry picking! :P)



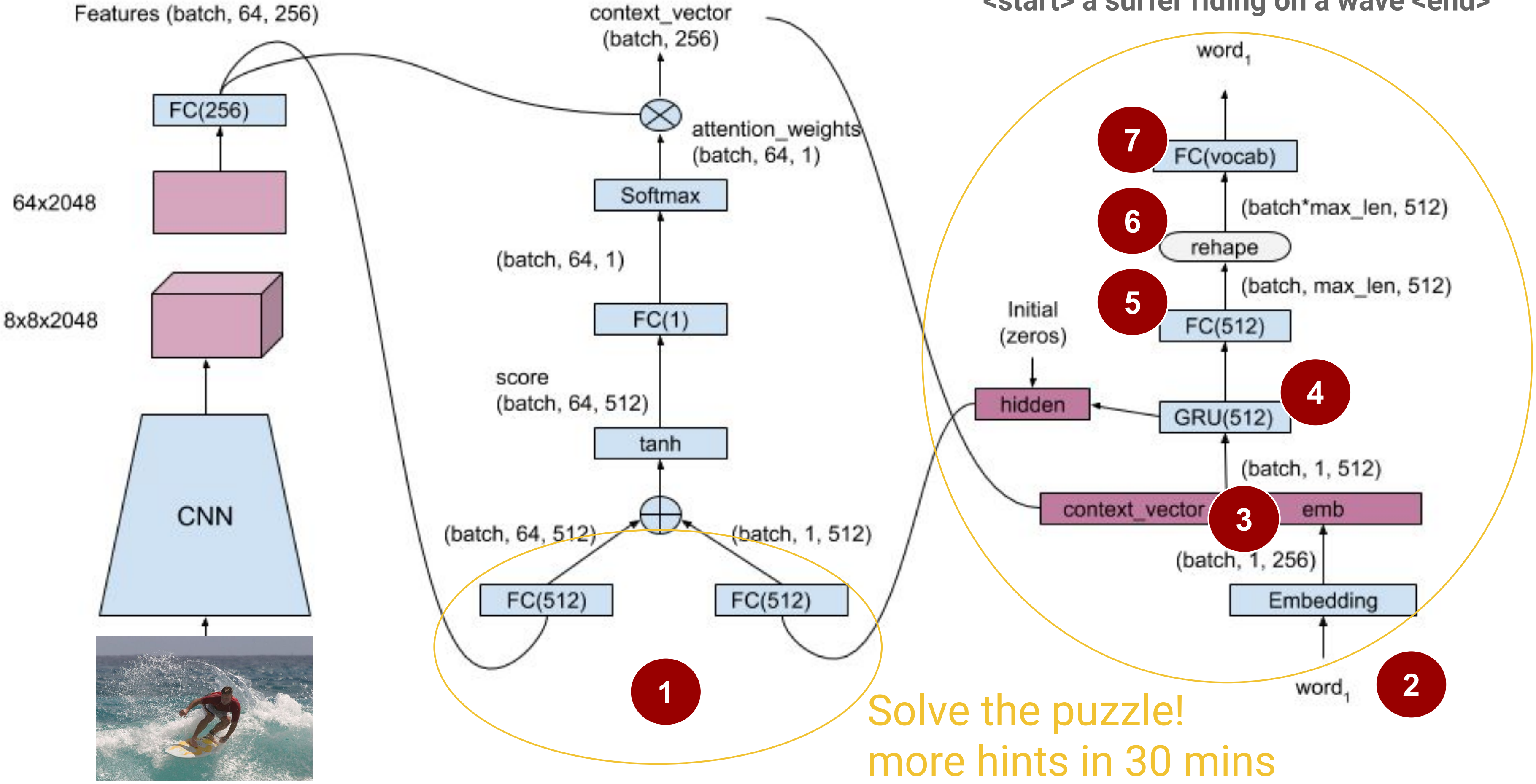
- Toy examples = bad captions!
- Attention maps!
- Try on your on images

Lab6: Image Captioning

- Keras
- CNN image encoder (pre-trained!)
- GRU-RNN text decoder
- Attention (image & text)

- Multimodal task
- Transfer learning (InceptionV3 for image classification)
- Image and text preprocessing cells…
- Checkpoints!

"<start> a surfer riding on a wave <end>"



Features (batch, 64, 256)

FC(256)

64x2048

8x8x2048

CNN

context_vector
(batch, 256)

attention_weights
(batch, 64, 1)

Softmax

(batch, 64, 1)

FC(1)

score
(batch, 64, 512)

tanh

(batch, 64, 512)

(batch, 1, 512)

FC(512)

FC(512)

1

word$_1$

7

FC(vocab)

6

(batch*max_len, 512)

rehape

5

(batch, max_len, 512)

FC(512)

Initial
(zeros)

hidden

GRU(512)

4

(batch, 1, 512)

context_vector

3

emb

(batch, 1, 256)

Embedding

word$_1$

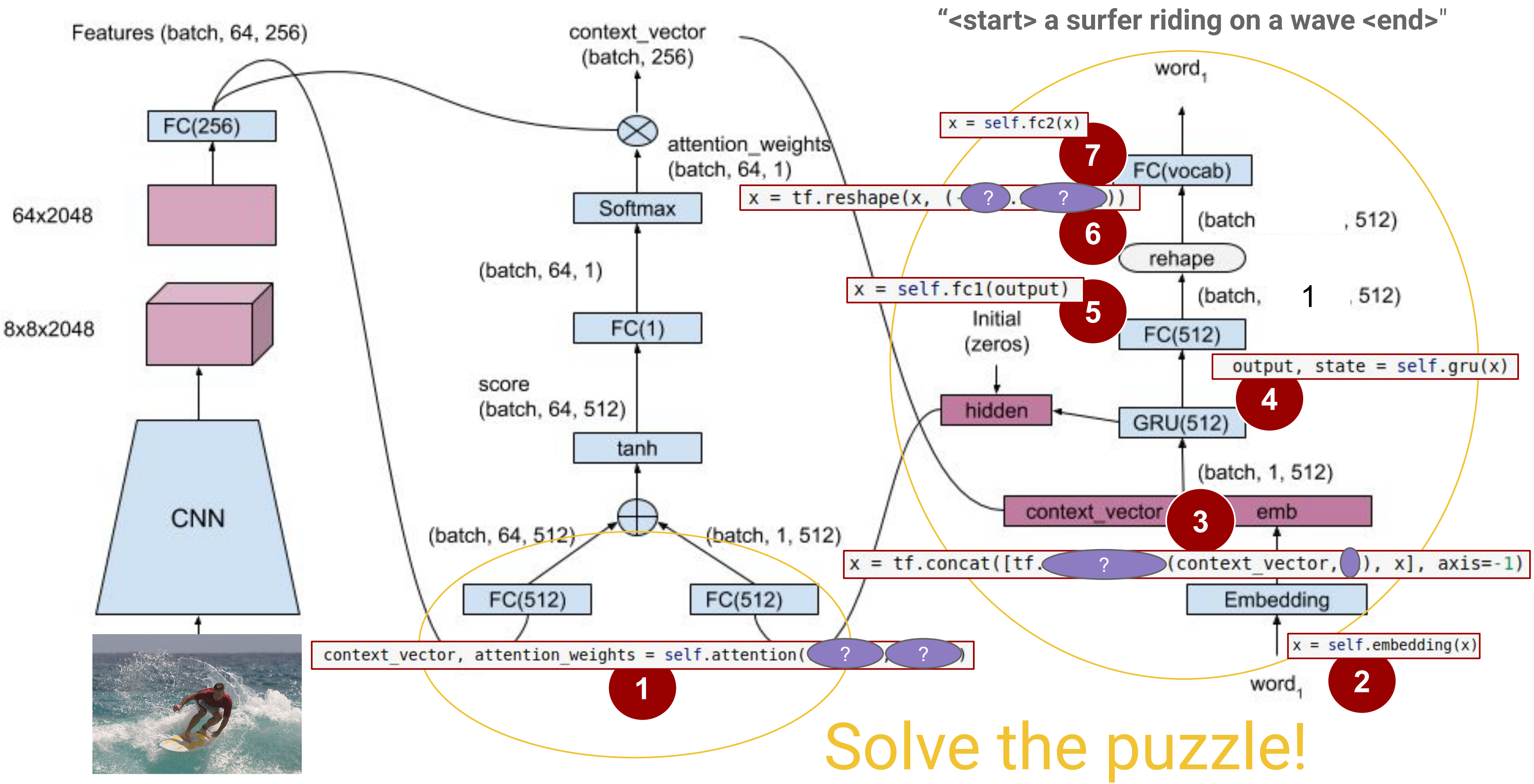
2

Solve the puzzle!
more hints in 30 mins

CNN Encoder

Bahdanau Attention

RNN Decoder



```
1  context_vector, attention_weights = self.attention( ? , ? )
2  x = self.embedding(x)
3  x = tf.concat([tf. ? (context_vector, ? ), x], axis=-1)
4  output, state = self.gru(x)
5  x = self.fc1(output)
6  x = tf.reshape(x, ( ? . ? ))
7  x = self.fc2(x)
```

Solve the puzzle!

CNN Encoder

Bahdanau Attention

RNN Decoder

DL4nlp - Deep Learning for Natural Language Processing

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Good luck!