

*Deep Learning - Prof. Andrea Asperti*

*A. A. 2020/2021*

# Deep Comedy

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# INTRODUCTION

The “*Deep Comedy*” is a project that addresses a typical Deep Learning task applied to *Natural Language Processing*, that aims at the generation of new text, specifically.

It is an automatic generation of a classical Divine-Comedy-like canto using Neural Networks exclusively, imitating the unique writing style of Dante Alighieri.

**Learning Data:** Divine Comedy by Dante Alighieri

## Goal:

- hendecasyllabic structure
- terza rima scheme
- tercine partitioning of the text
- single verse at the end of every canto, separated from the last tercina

## Not addressed:

- no semantic meaning
- no grammatical structure

# METRICS

The metric aspect has been one of our last implementation on the Deep Comedy project but in order to have a meaningful explanation of what will be shown in the next slides is important to explain what we built.

The basic idea was to catch in the best possible way all the features of Dante's writing style, and in order to be able to recognize if our generation of text has the Divine Comedy's fingerprint from the structure and rhyme perspective.

## OUR METRIC ON THE FIRST CANTO OF DIVINE COMEDY

Number of verses	136
Number of strophes	46
Number of well formed terzine	45
Last single verse	True
Average syllables per verse	$11.07 \pm 0.41$
Hendecasyllabicness score	0.9044
Rhymeness score	0.9710

# MODEL BY WORD - Data Processing

This implementation aims to feed the model with words from the original Divine Comedy as units of text, in order to train the model through words and their relation, hopefully learning which is the correct association of words to get a correct and well formed verse according to the original text

- Common strategy
- Specific strategy

'START_OF_CANTO'	'<start_of_canto>'
'END_OF_CANTO'	'<end_of_canto>'
'START_OF_TERZINA'	'<start_of_terzina>'
'END_OF_TERZINA'	'<end_of_terzina>'
'END_OF_VERSO'	'<end_of_verso>'

What we are expecting to teach to the model is to have an 'input sequence' as input of the model and to get an output sequence that is shifted of one token in order to teach to the model which is the token that follows the input one.

## INPUT SEQUENCE

<start\_of\_canto>  
<start\_of\_terzina> nel  
mezzo del cammin di  
nostra vita  
<end\_of\_verso> mi  
ritrovai per una selva  
oscura <end\_of\_verso>  
chè la diritta via era

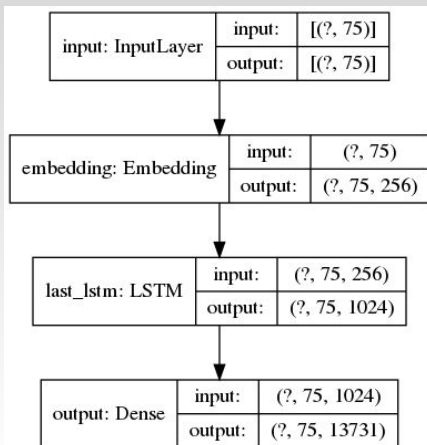
## OUTPUT SEQUENCE

<start\_of\_terzina> nel  
mezzo del cammin di  
nostra vita  
<end\_of\_verso> mi  
ritrovai per una selva  
oscura <end\_of\_verso>  
chè la diritta via era  
smarrita

# MODEL BY WORD - Architectures

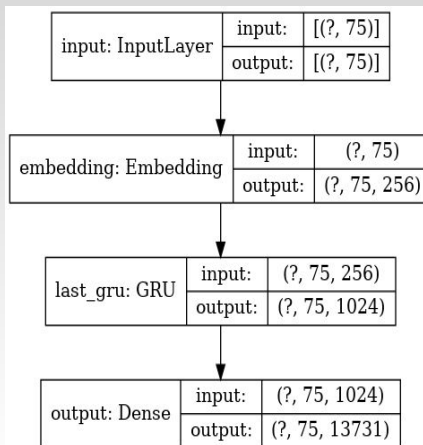
## Model 1

- Input Layer
- Embedding Layer
- LSTM Layer
- Dense Layer



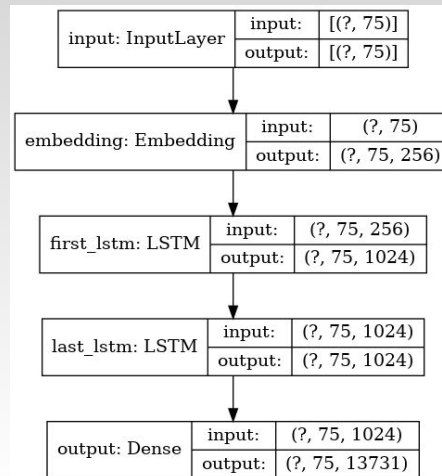
## Model 2

- Input Layer
- Embedding Layer
- GRU layer
- Dense Layer



## Model 3

- Input Layer
- Embedding Layer
- LSTM Layer
- LSTM Layer
- Dense Layer



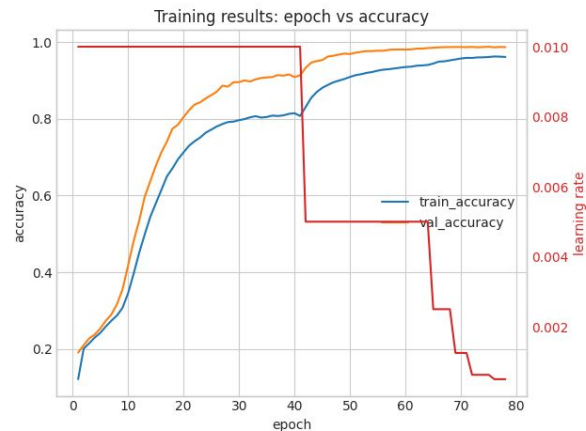
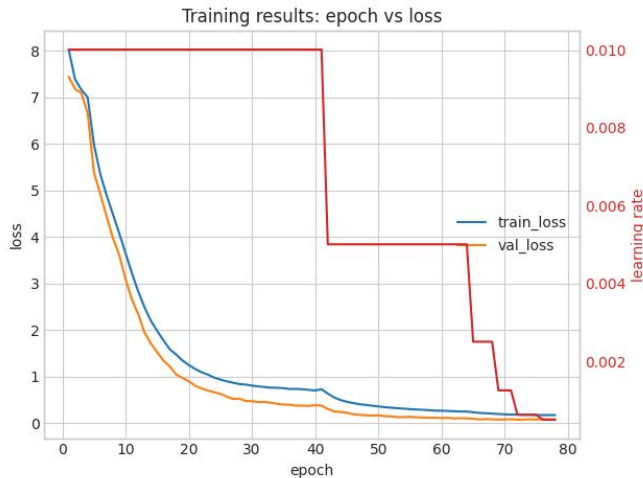
# MODEL BY WORD - Training

## Callbacks:

- EarlyStopping
- Reducing Learning Rate

The graphs suggest that the model behaves perfectly. However, we found that this metric might be not so representative for our models because this was such a particular task.

We defined our policy to have a look at the final output in order to have an understanding of how the models behave.



# MODEL BY WORD - Text Generation

Our generated canto is based on Model 1

- argmax / random choice
- Stopping generation strategy

Number of verses	151
Number of strophes	51
Number of well formed terzine	50
Last single verse	True
Average syllables per verse	11.03 ± 0.92
Hendecasyllabicness score	0.6026
Rhymeness score	0.0200

## CANTO

oppresso di stupore a la mia stella  
mi volsi come parvol che ricorre  
sempre colà dove più si confida

e quella che gennaio tutto si sverni  
li occhi rivolgi al logoro che gira  
lo rege eterno con le rote magne

aguzza qui lettor ben si sale  
oh felice che tosto la fortuna  
che la dolcezza in cui dolor non era

ell' è la prima che dal gran giovanni  
de la natura del ciel si fece  
tu che la sua natura diede aperta

di tutte queste dote s'avvantaggia  
l'umana creatura e s'una manca  
di sua nobilità convien che caggia

solo il peccato è quel che la terra  
e la donna di lingua che sanno  
seder tra filosofica famiglia

tutti si donna che per tu tu credi  
e io e guarda non che tu credi  
e io a loro e a' miei conti

[...]



# MODEL BY CHARACTER - Data Processing

This implementation aims to feed the model with text in the format of characters from the Divine Comedy as units of text, in order to train the model and hopefully learning which is the correct succession of letters to get the correct word according to what is present in the original text

- Common strategy
- Specific strategy

'START_OF_CANTO'	'+'
'END_OF_CANTO'	'@'
'START_OF_TERZINA'	'\$'
'END_OF_TERZINA'	'#'
'END_OF_VERSO'	'&'

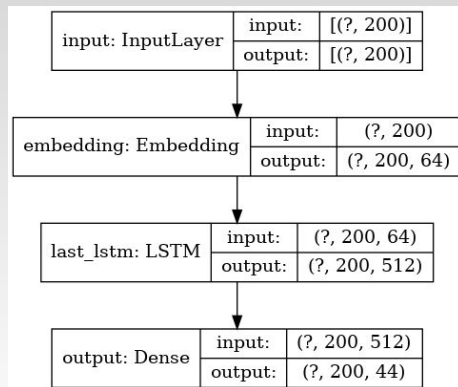
What we are expecting to teach to the model is to have an 'input sequence' as input of the model and to get an output sequence that is shifted of one token in order to teach to the model which is the token that follows the input one.

INPUT SEQUENCE	OUTPUT SEQUENCE
<code>±\$nel mezzo del cammin di nostra vit</code>	<code>\$nel mezzo del cammin di nostra vita<u>a</u></code>

# MODEL BY CHARACTER - Architectures

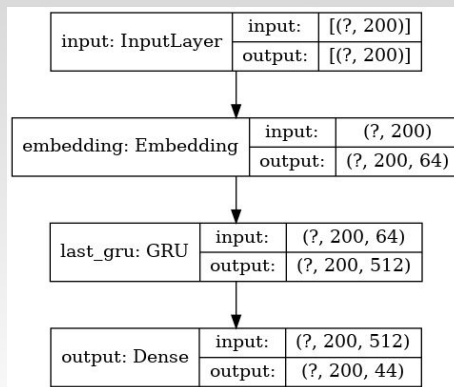
## Model 1

- Input Layer
- Embedding Layer
- LSTM Layer
- Dense Layer



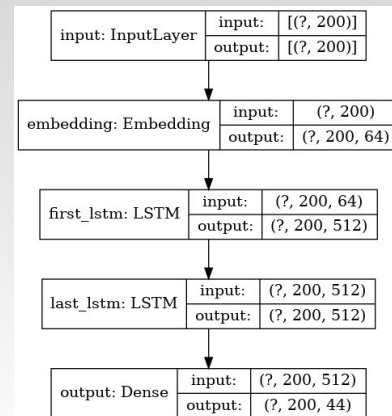
## Model 2

- Input Layer
- Embedding Layer
- GRU layer
- Dense Layer



## Model 3

- Input Layer
- Embedding Layer
- LSTM Layer
- LSTM Layer
- Dense Layer



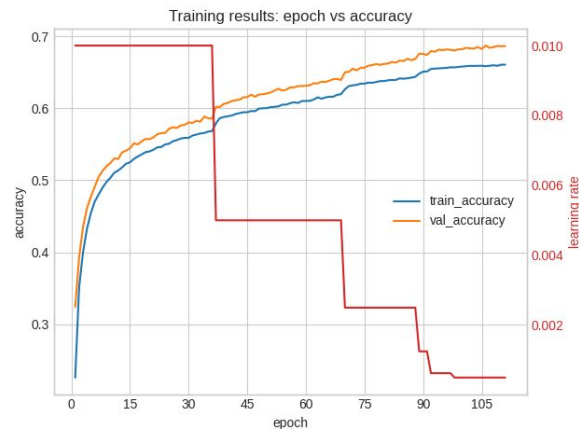
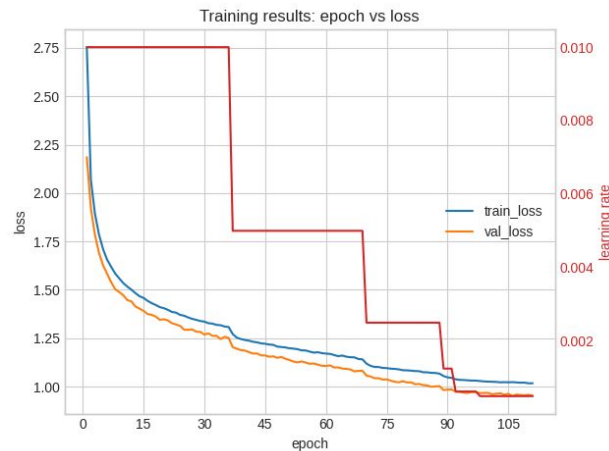
# MODEL BY CHARACTER - Training

## Callbacks:

- EarlyStopping
- Reducing Learning Rate

The graphs suggest that the model behaves perfectly. However, we found that this metric might be not so representative for our models because this was such a particular task.

We defined our policy to have a look at the final output in order to have an understanding of how the models behave.



# MODEL BY CHARACTER - Text Generation

Our generated canto is based on Model 3

- argmax / random choice
- Stopping Generation Strategy

Number of verses	89
Number of strophes	30
Number of well formed terzine	29
Last single verse	False
Average syllables per verse	11.28 ± 0.60
Hendecasyllabicness score	0.6629
Rhymeness score	0.0111

## CANTO

in su l'isola di rinfiar la spera  
del padre mio, però ch'ella ebbe senno,  
ch'alcuna virtù non la verso node.

l'una e l'altra un legno a te presso attenta,  
un fango, e più e 'l mio voler più merdo;  
e di pietro stare assai ci rompesse.

la seguente cosa di tutto 'l giro,  
la proggia attento a vicenda guisa!  
e se l'animo più sua bella guancia

a chi più d'un giacer de' loco spandi  
lo duca mio discese le pecole;  
chè questa natura con muse nova,

grazia mi fu' io compagni del mondo",  
rispuose a me, ch'era protestiamo  
e regna lunga grave in su la piuma.

ma qual sotto colui che contra mia mena  
lavar le tue parole, questi fonde  
hhe fai? di noi, per quella onde l'ordigna?

ed è chi avea tanto il suo dir porse  
referbate la famiglia, e più fissi;  
e allor lo minor mi davansi.

[...]

# MODEL BY SYLLABLE - Data Processing

This implementation aims to feed the model with text in the format of syllables from the Divine Comedy as units of text, in order to train the model and hopefully learning which is the correct succession of syllables to get the correct word according to what is present in the original text.

- Common strategy
- Specific strategy: *Pyphen*, diaeresis and synalepha

'START_OF_CANTO'	'<start_of_canto>'
'END_OF_CANTO'	'<end_of_canto>'
'START_OF_TERZINA'	'<start_of_terzina>'
'END_OF_TERZINA'	'<end_of_terzina>'
'END_OF_VERSO'	'<end_of_verso>'
'WORD_SEP'	'<word_sep>'

What we are expecting to teach to the model is to have an 'input sequence' as input of the model and to get an output sequence that is shifted of one token in order to teach to the model which is the token that follows the input one.

## INPUT SEQUENCE

<start\_of\_canto>  
<start\_of\_terzina>  
nel <word\_sep> mezzo  
<word\_sep> del <word\_sep>  
cammin <word\_sep> di  
<word\_sep> nostra  
<word\_sep> vita  
<end\_of\_verso>  
mi <word\_sep> ritro

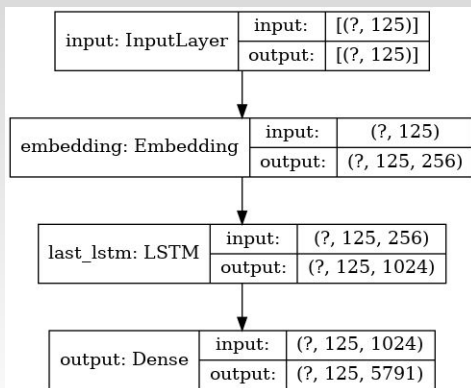
## OUTPUT SEQUENCE

<start\_of\_terzina>  
nel <word\_sep> mezzo  
<word\_sep> del <word\_sep>  
cammin <word\_sep> di  
<word\_sep> nostra  
<word\_sep> vita  
<end\_of\_verso>  
mi <word\_sep> ritro vai

# MODEL BY SYLLABLE - Architectures

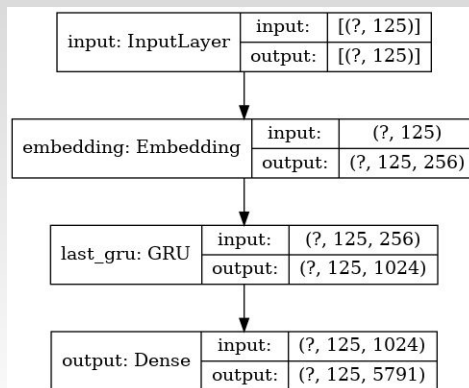
## Model 1

- Input Layer
- Embedding Layer
- LSTM Layer
- Dense Layer



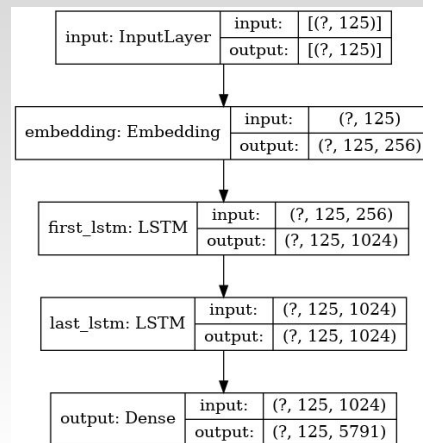
## Model 2

- Input Layer
- Embedding Layer
- GRU layer
- Dense Layer



## Model 3

- Input Layer
- Embedding Layer
- LSTM Layer
- LSTM Layer
- Dense Layer



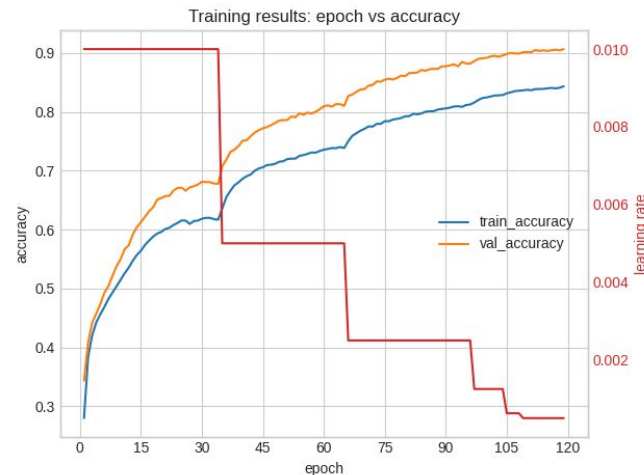
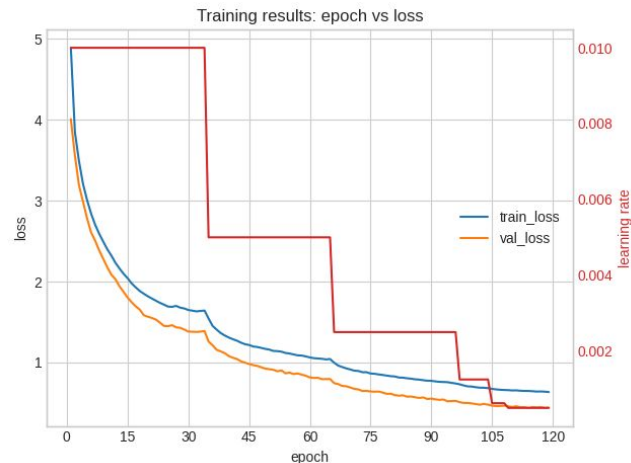
# MODEL BY SYLLABLE - Training

## Callbacks:

- EarlyStopping
- Reducing Learning Rate

The graphs suggest that the model behaves perfectly. However, we found that this metric might be not so representative for our models because this was such a particular task.

We defined our policy to have a look at the final output in order to have an understanding of how the models behave.



# MODEL BY SYLLABLE - Text Generation

Our generated canto is based on Model 1

- argmax / random choice
- Stopping generation strategy

Number of verses	151
Number of strophes	50
Number of well formed terzine	49
Last single verse	False
Average syllables per verse	11.05 ± 0.68
Hendecasyllabicness score	0.7351
Rhymeness score	0.0067

## CANTO

intra due figli a riveder le stelle  
de l'animo che là sù hanno lasciasti  
pur com' om fa d'onor cosa che lece

quella tenebre che la cura cala  
disse 'l maestro certo là 've lo fida  
e frutto ha in sé che sua qui natura

tutti ne veder ben com' io innalzo  
la fiera pessima per similla  
e rotano li pur altrimentira

con quelle altr' ombre pria disse via molto  
o dignitosa come il volto meco  
che dal quarto al quinto argine è tragetto

ma ficca li occhi a valle ché s'approccia  
la qual lunga scala con di noi  
poi li addentò e l'una e l'altra guancia

lo dosso e 'l gioco chi si ti fallio  
per difender lor ville e lor sentenza  
d'i tuoi amori a dio modi che sare

e riguardai figliuolo or di lor vani  
dicea fra me medesmo 'al novo cenno  
di cui la gente in suo voler ne 'nvoglia

[...]

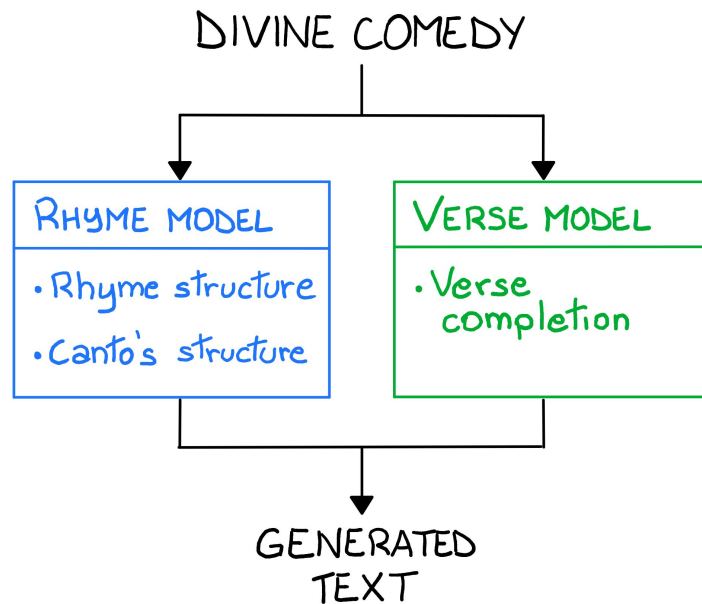


# BASELINE MODELS - Comparison

METRIC	BY WORD	BY CHARACTER	BY SYLLABLE
Number of verses	151	89	151
Number of strophes	51	30	50
Number of well formed terzine	50	29	49
Last single verse	True	False	False
Average syllables per verse	11.03 ± 0.92	11.28 ± 0.60	11.05 ± 0.68
Hendecasyllabicness score	0.6026	0.6629	0.7351
Rhymeness score	0.0200	0.0111	0.0067

# MODEL BY REVERSED SYLLABLES

- Working by syllables
- Focus on rhymeness
- Two different models cooperating:
  - Rhyme model
  - Verse model
- **But why “reversed”?**



# MODEL BY REVERSED SYLLABLES - RHYME MODEL - Text Processing

- Data cleaning and processing
- *Pyphen* syllabification, diaeresis and synalepha
- Sequencing final syllables of each verse

## INPUT SEQUENCE

<start\_of\_canto>

<start\_of\_terzina>  
vi ta <end\_of\_verso>  
scu ra <end\_of\_verso>  
ri ta <end\_of\_verso>  
<end\_of\_terzina>  
<start\_of\_terzina>  
du ra <end\_of\_verso>  
for te <end\_of\_verso>  
u

## OUTPUT SEQUENCE

<start\_of\_terzina>  
vi ta <end\_of\_verso>  
scu ra <end\_of\_verso>  
ri ta <end\_of\_verso>  
<end\_of\_terzina>  
<start\_of\_terzina>  
du ra <end\_of\_verso>  
for te <end\_of\_verso>  
u ra

## SYLLABIFICATION OUTPUT

1	al
2	lor
3	fu
4	la
5	pa
6	u
7	ra <word_sep> un
8	po
9	co
10	que
11	ta
12	<end_of_verso>

## RHYME MODEL'S INPUT

que	ta	<end_of_verso>
-----	----	----------------

# MODEL BY REVERSED SYLLABLES - VERSE MODEL - Text Processing

- Data cleaning and processing
- *Pyphen* syllabification, diaeresis and synalepha
- Sequencing verses' syllables end-to-begin

## INPUT SEQUENCE

<end\_of\_verso> ta vi  
<word\_sep> stra no  
<word\_sep> di <word\_sep>  
min cam <word\_sep> del  
<word\_sep> zo mez  
<word\_sep> nel  
  
<end\_of\_verso> ra scu  
va<word\_sep>o sel  
<word\_sep> na u <word\_sep>  
per <word\_sep> vai tro ri  
<word\_sep>

## OUTPUT SEQUENCE

ta vi <word\_sep> stra no  
<word\_sep> di <word\_sep>  
min cam <word\_sep> del  
<word\_sep> zo mez  
<word\_sep> nel  
  
<end\_of\_verso> ra scu  
va<word\_sep>o sel  
<word\_sep> na u <word\_sep>  
per <word\_sep> vai tro ri  
<word\_sep> mi

## NATURAL ORDER OF SYLLABIFICATION OUTPUT

1	al
2	lor
3	fu
4	la
5	pa
6	u
7	ra <word_sep> un
8	po
9	co
10	que
11	ta
12	<end_of_verso>

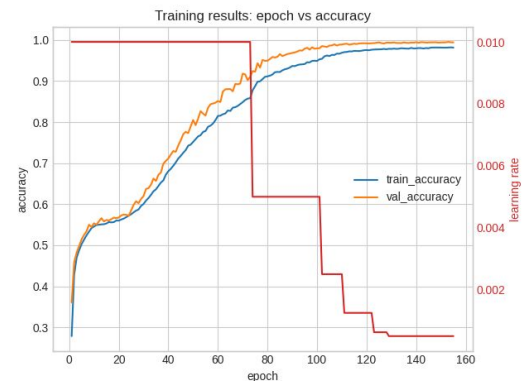
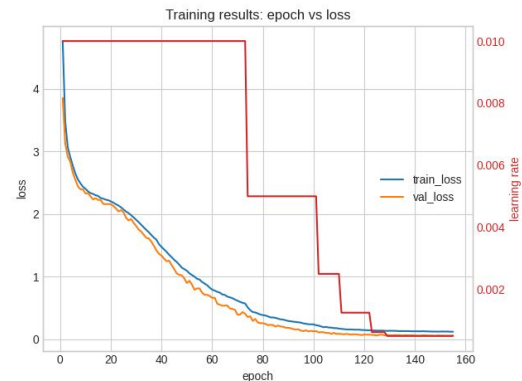
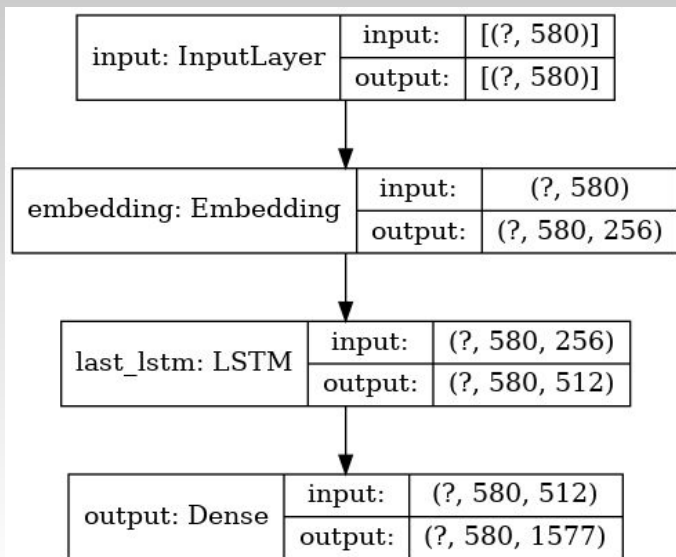
## VERSE MODEL'S INPUT ORDER

1	<end_of_verso>
2	ta
3	que
4	co
5	po
6	ra <word_sep> un
7	u
8	pa
9	la
10	fu
11	lor
12	al



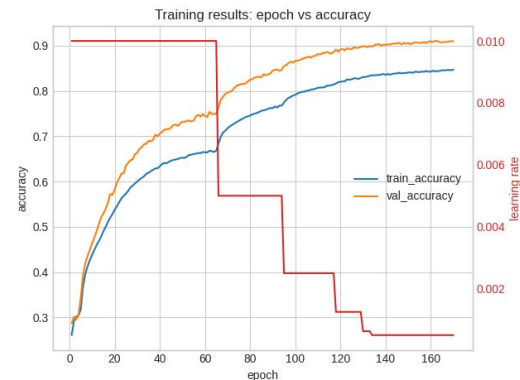
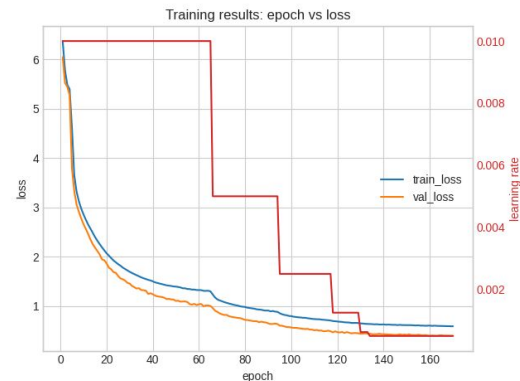
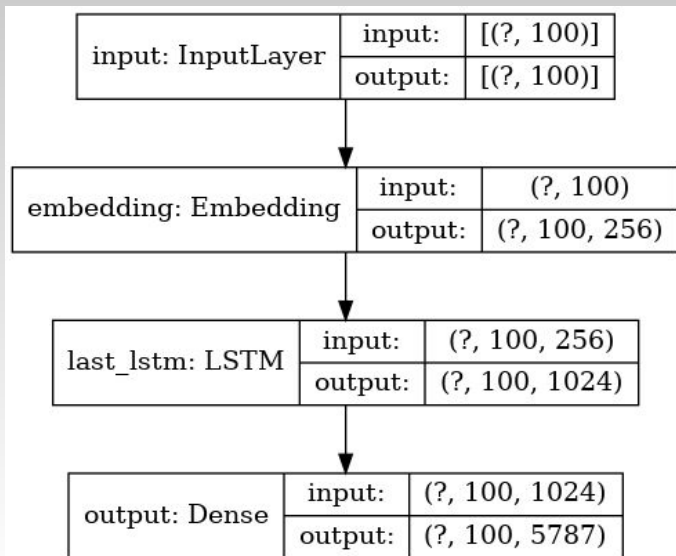
# MODEL BY REVERSED SYLLABLES - RHYME MODEL

## Model architecture



# MODEL BY REVERSED SYLLABLES - VERSE MODEL

## Model architecture



# MODEL BY REVERSED SYLLABLES - Text Generation

- **Rhyme model:**

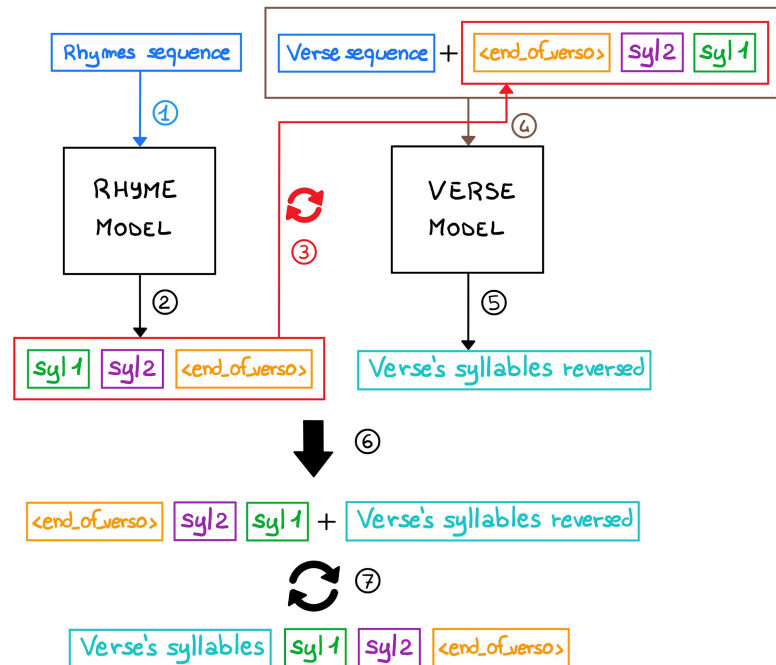
- Starting sequence: final syllables of each verse
- Stopping generation strategy: '`<end_of_verso>`'
- Generated selection by *argmax*

- **Verse model:**

- Starting sequence: syllables of verses in in-line reversed order + Rhyme model's output, also in reversed order
- Stopping generation strategy: '`<end_of_verso>`'
- Generated selection by *numpy.random.choice*

# MODEL BY REVERSED SYLLABLES - Text Generation

- Stopping generation strategy:  
'<end\_of\_canto>' generated  
by the Rhyme model
- Final output:
  - is a combination of the two partial  
outputs
  - has to be reversed in order





# MODEL BY REVERSED SYLLABLES - Text Generation

## CANTO

lo collo l'assannò sì come sacro  
voce del gran cui l'ombra s'appunta  
puote disnebbiar vostro intelletto acro

e come 'l sol fermar dietro a lor cunta  
e nel figlio forte a sé stessi s'accusa  
io vidi sol che vi pareva congiunta

crescerann' ei dopo la rima confusa  
sì come la propria madre spense  
maggior paura già di fuor dischiusa

dicendo sofferse cose che pense  
ne l'una parte l'anime triste  
per ch'io dissi quell' anime offense

suffolando e scegliendo fioco miste  
alor sicuramente apri' la bocca  
dolo suo coro non parver si viste

rivolsi li occhi a quel ch'or si scocca  
al punto te che passi vide l'arco  
l'un luogo mio che già mai non si tocca

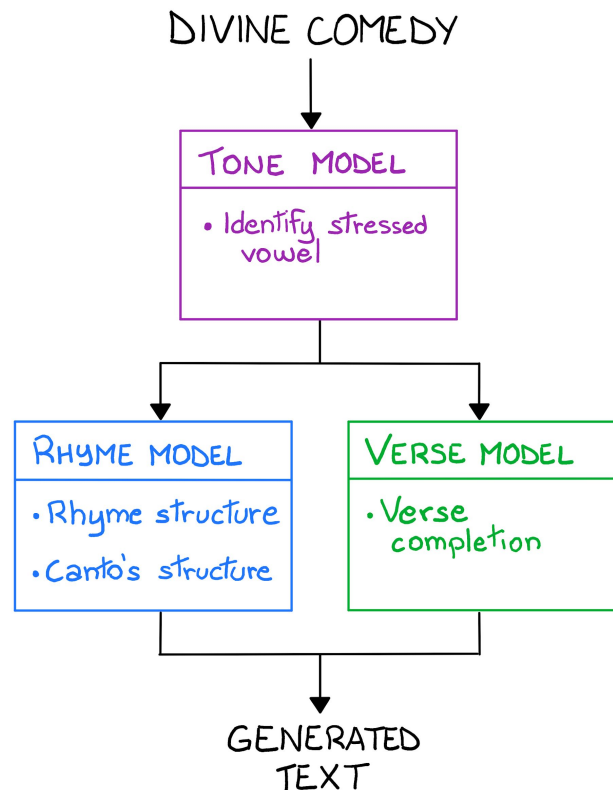
tu troverai non sermone e per lo 'ncarco  
la naturalmente per che s'aspiri  
e al suo temo che mi trasse al varco

[...]

Number of verses	163
Number of strophes	55
Number of well formed terzine	54
Last single verse	True
Average syllables per verse	11.12 ± 0.57
Hendecasyllabicity score	0.7607
Rhymeness score	0.9394

# MODEL BY TONED AND REVERSED SYLLABLES

- Working by syllables
- Focus on hendecasyllabicness
- Three models:
  - Rhyme model: dedicated to rhymes
  - Verse model: to complete a verse
  - Tone model: to identify stressed vowel in a word

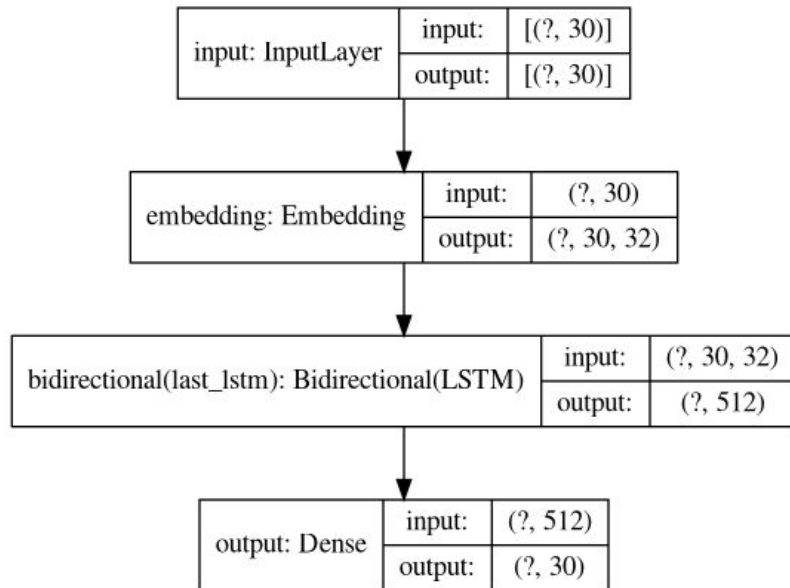


# MODEL BY TONED AND REVERSED SYLLABLES - TONE MODEL

- Tone model is used in:
  - Data processing and syllabification
  - Metrics
- Working by characters

word	index
abate	3
abbandonato	9
abbandono	7
abbarbaglio	7
abbondante	7
...	...

## Model architecture



# MODEL BY TONED AND REVERSED SYLLABLES - TONE MODEL

## Training

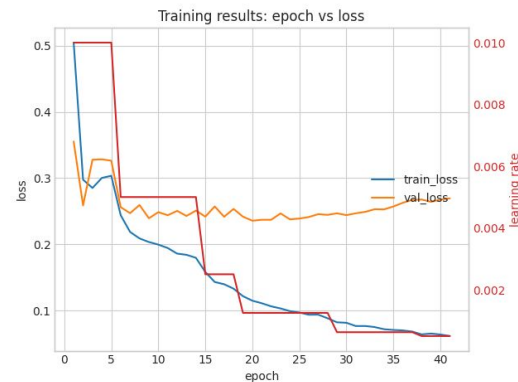
- Classification task
- Categorical Crossentropy

## Callbacks:

- EarlyStopping
- Reducing Learning Rate

## Predictions

- argmax



# MODEL BY TONED AND REVERSED SYLLABLES - Syllabification

- Synalepha - Dialepha
  - applied with constraint of tenth stressed syllable
- Diaeresis
  - all and only marked cases are considered
- Synaeresis
  - some cases are considered

Still errors on syllabification of Divine Comedy due to:

- Divine Comedy's exceptions
- Tone model's mistakes

DIVINE COMEDY	
Number of verses	14233
Number of correct hendecasyllables	12572
Number of wrong syllabified verses	1661
Hendecasyllabiness score	0.8833

# MODEL BY TONED AND REVERSED SYLLABLES

## Text processing

[http://localhost:8888/notebooks/divine\\_comedy\\_dataset\\_processing.ipynb](http://localhost:8888/notebooks/divine_comedy_dataset_processing.ipynb)

## Text generation

[http://localhost:8888/notebooks/divine\\_comedy\\_text\\_generation.ipynb](http://localhost:8888/notebooks/divine_comedy_text_generation.ipynb)

# CONCLUSIONS

## Model by reversed syllables

Number of verses	163
Number of strophes	55
Number of well formed terzine	54
Last single verse	True
Average syllables per verse	$11.12 \pm 0.57$
Hendecasyllabicness score	0.7607
Rhymeness score	0.9394

## Model by toned and reversed syllables

Number of verses	124
Number of strophes	42
Number of well formed terzine	41
Last single verse	True
Average syllables per verse	$11.12 \pm 0.53$
Hendecasyllabicness score	0.7661
Rhymeness score	0.9365