Automatic log analysis with NLP for the CMS workflow handling

CHEP 2019

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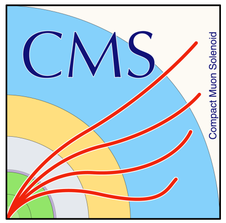
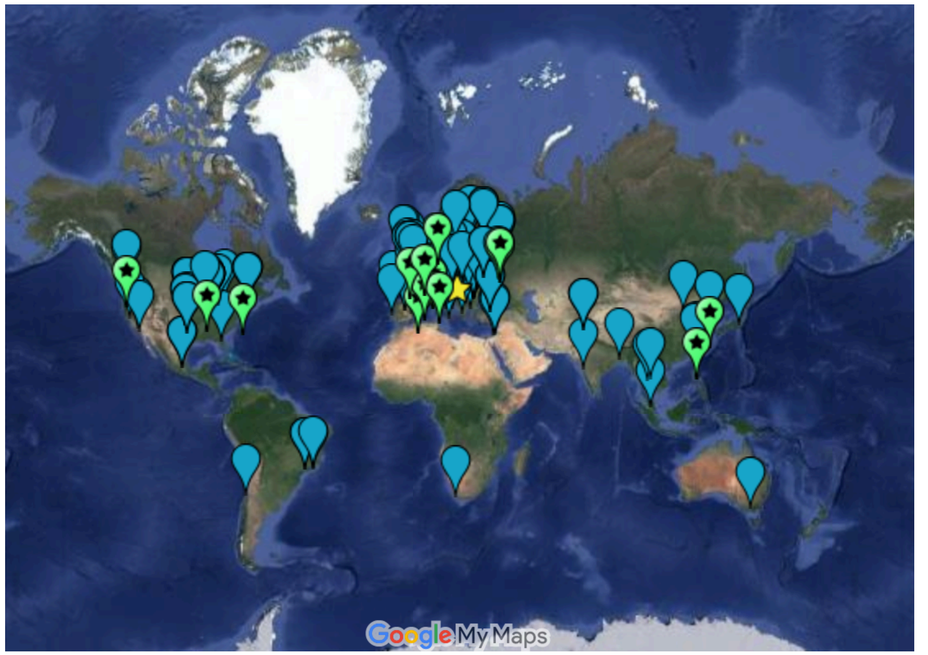
on behalf of the CMS collaboration

Massachusetts Institute of Technology[1], DESY[2], CERN[3], FNAL[4], Catholic University of America[5], University of California Riverside[6], Università e sezione INFN di Napoli[7], California Institute of Technology[8]



Automatization of failing workflow handling

- Central MC production in CMS utilizes the **LHC computing grid**
- Thousands of **workflow tasks** each with thousands of jobs on more than 100 sites worldwide
- A **certain rate fails** and has to be handled manually by **Computing Operators:** e.g. resubmit, kill, change memory, change splitting, etc.
- **Common errors** are missing/corrupt input files, high memory usage, etc.



Operational Intelligence: Automatize the failure handling using Machine Learning - CMS Tools & Integration group

Strategy and Dataset

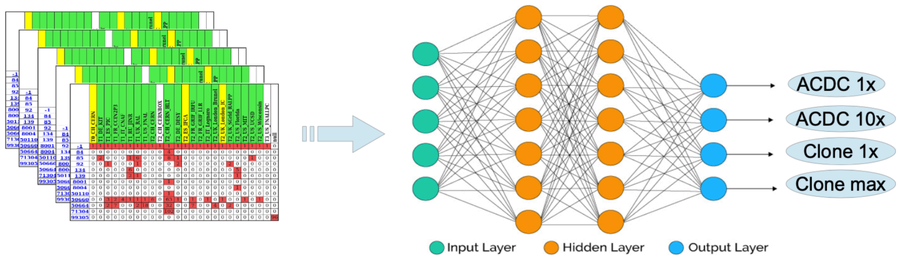
- Information of ~ **33.000 failing workflow tasks** collected since 2017
- **Actions** of the operators **stored**
- For each **task** we know on which **sites** how many times an **error code** was thrown

Site: T1_DE_KIT
Error code: 85
Counts: 2

	T0_CH_CERN	T1_DE_KIT	T1_ES_PIC	T1_FR_CCIN2P3	T1_IT_CNAF	T1_RU_JINR	T1_UK_RAL	T1_US_FNAL	T2_CH_CERN	T2_CH_CERNBOX	T2_CH_CERN_HLT	T2_DE_DESY	T2_ES_IFCA	T2_FR_GRIF_IRFU	T2_FR_GRIF_LLR	T2_IT_Legnaro	T2_UK_London_Brunel	T2_UK_London_IC	T2_UK_SGrid_RALPP	T2_US_Florida	T2_US_MIT	T2_US_UCSD	T2_US_Wisconsin	T3_US_FNALLPC	null
-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
84	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	2	0	0	0	1	6	0	0	0	0	8	1	0	0	0	0	0	0	0	0	0	1	0	0	0
92	0	0	1	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0
134	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
139	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
8001	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
50110	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50660	0	0	3	2	4	1	1	1	6	0	63	1	0	1	0	1	0	1	0	0	1	0	1	0	0
50664	0	0	2	7	0	0	2	18	0	0	32	0	0	7	0	0	4	0	2	0	0	0	0	0	0
71304	0	0	0	0	0	0	0	0	0	0	102	0	0	0	0	0	0	0	0	0	0	0	0	0	0
99305	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96

Build a sparse matrix for each workflow

Goal: Predict the operator's action



- Challenges: **small data**, **sparse** input, **class imbalance**
- Tried: **Feed-Forward NN, CNN**, **Embedding Models**
- **Similar results** for different models

Poster at CHEP 2018:
https://indico.cern.ch/event/587955/contributions/2937424/

Dev:
https://github.com/CMSCompOps/AIErrorHandling

Idea for further improvement:
Addition of Error Logs using Natural Language Processing

Pipeline

Store actions

Errors + Sites | Counts | Actions

	task_name	errors	sites	site_state	count	action	splitting	memory
0	/pdmvserv_t...	[92, -1]	[T2_US_Wisc...	[good, good]	[1, 1]	acdc	None	None
1	/vlimant_ta...	[50664, 85,...	[T2_CH_CERN...	[good, bad,...	[57, 3, 1, ...	acdc	10x	None
2	/pdmvserv_t...	[-1, 71104,...	[T2_UK_Lond...	[bad, bad, ...	[1, 15, 1]	acdc	None	None
3	/pdmvserv_t...	[-1, 92, -1...	[T1_IT_CNAF...	[bad, good,...	[1, 1, 1, 1...	acdc	None	None
4	/prebello_R...	[-1]	[T2_US_Calt...	[good]	[1]	acdc	None	None

Pipeline

WTC Console ↔ **Operator**

Store actions

Errors + Sites | **Counts** | **Actions**

	task_name	errors	sites	site_state	count	action	splitting	memory
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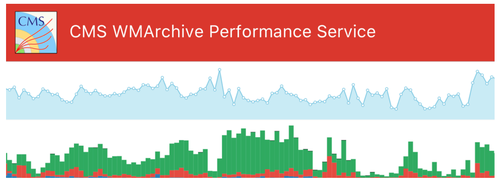
4	/prebello_R...	[-1]	[T2_US_Calt...	[good]	[1]	acdc	None	None

CERN SWAN
Platform for interactive analysis in the cloud

Large Scale Analytics



Store FWJRs

Filter + Map

Error log

	task_name	error	site	error_msg
0	/pdmvserv_task_HIG-Ru...	8001	T2_DE_RWTH	Failed to find a step...
1	/pdmvserv_task_HIG-Ru...	50660	T2_US_Nebraska	Error in CMSSW step c...
2	/vlimant_task_TOP-Run...	84	T2_CH_CERN_HLT	Adding last 25 line...
3	/pdmvserv_task_HIG-Ru...	50660	T1_RU_JINR	Error in CMSSW step c...
4	/pdmvserv_task_HIG-Ru...	50660	T2_CH_CERN_HLT	Error in CMSSW step c...

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4	/prebello_R...	[-1]	[T2_US_Calt...	[good]	[1]	acdc	None	None

Join Aggregate Preprocess

	label	error	site	site_state	count	msg_encoded
0	0	[71104, -1]	[Unknown, T...	[bad, bad]	[102, 1]	[nan, nan]
1	0	[-1, 139, 1...	[T1_US_FNAL...	[bad, bad, ...	[1, 1, 1, 2...	[nan, [102,...
2	0	[8028, 8021...	[T2_UK_Lond...	[good, good...	[1, 1, 1, 1...	[[35, 12, 1...
3	0	[-1, 71305,...	[T2_US_Calt...	[good, good...	[1, 1, 1, 1...	[nan, nan, ...
4	0	[92, 92, -1...	[T2_UK_Lond...	[good, good...	[1, 5, 1, 1]	[[35, 12, 1...

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Large Scale Analytics

CMS WMArchive Performance Service

Store FWJRs

Filter + Map

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3	/pdmvserv_task_HIG-Ru...	50660	T1_RU_JINR	Error in CMSSW step c...
4	/pdmvserv_task_HIG-Ru...	50660	T2_CH_CERN_HLT	Error in CMSSW step c...

Pipeline

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Store actions

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2	0	[8028, 8021...	[T2_UK_Lond...	[good, good...	[1, 1, 1, 1...	[[35, 12, 1...
3	0	[-1, 71305,...	[T2_US_Calt...	[good, good...	[1, 1, 1, 1...	[nan, nan, ...
4	0	[92, 92, -1...	[T2_UK_Lond...	[good, good...	[1, 5, 1, 1]	[[35, 12, 1...

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Large Scale Analytics

CMS WMArchive Performance Service

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4	/pdmvserv_task_HIG-Ru...	50660	T2_CH_CERN_HLT	Error in CMSSW step c...

Keras

Caltech GPU cluster

+

NLP Workflow

Log snippet selection → **Tokenization + Cleaning** → **Indexing** → **Word Embeddings + Message Representation**

```
An exception of category 'FileReadError' occurred while    [0] Calling InputSource::getNextItemType    [1] Reading branch EventAuxiliary    [2] Calling XrdFile::readv()    [3] Calling XrdAdaptor::RequestManager::OpenHandler::open() Exception Message: XrdCl::File::Open(name='root://polgrid4.in2p3.fr//store/data/Run2018A/EGamma/RAW/v1/000/315/363/00000/76CD1546-854B-E811-9B3C-FA163EBA2BF6.root?tried=ccxrpli003.in2p3.fr,ds21.kipt.kharkov.ua', flags=0x10, permissions=0660) => error '[FATAL] Connection error' (errno=0, code=108)    Additional Info:    [a] Active source: ccxrpli003.in2p3.fr:1095 (site T1_FR_CCIN2P3)
```

```
[u'An', u'exception', u'of', u'category', u'FileReadError', u'occurred', u'while', u'0', u'Calling', u'InputSource', u'getNextItemType', u'1', u'Reading', u'branch', u'EventAuxiliary', u'2', u'Calling', u'XrdFile', u'readv', u'3', u'Calling', u'XrdAdaptor', u'RequestManager', u'OpenHandler', u'open', u'Exception', u'Message', u'XrdCl', u'File', u'Open', u"name='root", u'tried=ccxrpli003.in2p3.fr', u'flags=0x10', u'permissions=0660', u'error', u'FATAL', u'Connection', u'error', u'errno=0', u'code=108', u'Additional', u'Info', u'Active', u'source', u'ccxrpli003.in2p3.fr:1095', u'site', u'T1_FR_CCIN2P3']
```

```
[35, 12, 10, 37, 186, 34, 25, 3, 11, 291, 532, 4, 188, 183, 273, 16, 11, 83, 251, 33, 11, 38, 77, 337, 17, 24, 23, 68, 18, 48, 41, 15875, 46, 47, 6, 439, 847, 6, 107, 2210, 65, 66, 531, 19, 867, 58, 168]
```

```
[-0.9386204   0.9671039   1.206119   -0.19411911 -0.23051228 -0.65913016
  0.00338563 -0.5044939  -0.02717912  0.09867108 -0.05116596 -0.5569398
  0.618001   -0.73519474  0.640754   -0.15959941  0.12680046  0.15426521
  0.42407024 -0.14709638  0.47534356 -0.18739735 -0.03758601  1.0197228
  0.06810962 -0.02504043 -0.11898965  0.11782035 -0.34788233  0.14381583
  0.67742926  0.43483204  0.39772424  0.10286205 -0.3774167   0.36935064
 -0.1227726  -0.20352381 -0.22164229  0.10978855 -0.50076777  0.39308718
  0.1865182   0.33458158 -0.3371736   0.0493757   0.5454126  -0.94923306
 -0.1352783  -0.34716246]
```

Unsupervised word embeddings

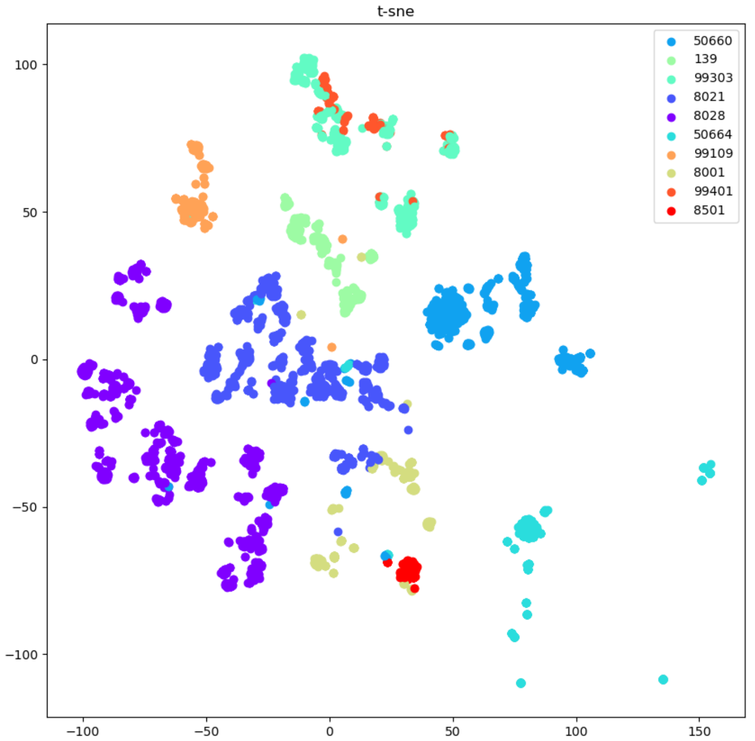
- Map **similar words** to **nearby points** in a high-dimensional vector space → Capture **relations** and **reduce dimensionality**
- Train with [Word2vec Skip-Gram](#) algorithm: model to predict context given a word
- Average the word vectors in each message → **input for ML**

```
[u'An', u'exception', u'of', u'category', u'FileReadError', u'occurred', u'while', u'0', u
'Calling', u'InputSource', u'getNextItemType', u'1', u'Reading', u'branch', u'EventAuxilia
ry', u'2', u'Calling', u'XrdFile', u'readv', u'3', u'Calling', u'XrdAdaptor', u'RequestMan
ager', u'OpenHandler', u'open', u'Exception', u'Message', u'XrdCl', u'File', u'Open', u"na
me='root", u'tried=ccxrpli003.in2p3.fr', u'flags=0x10', u'permissions=0660', u'error', u'F
ATAL', u'Connection', u'error', u'errno=0', u'code=108', u'Additional', u'Info', u'Active'
, u'source', u'ccxrpli003.in2p3.fr:1095', u'site', u'T1_FR_CCIN2P3']
```

Average word vectors

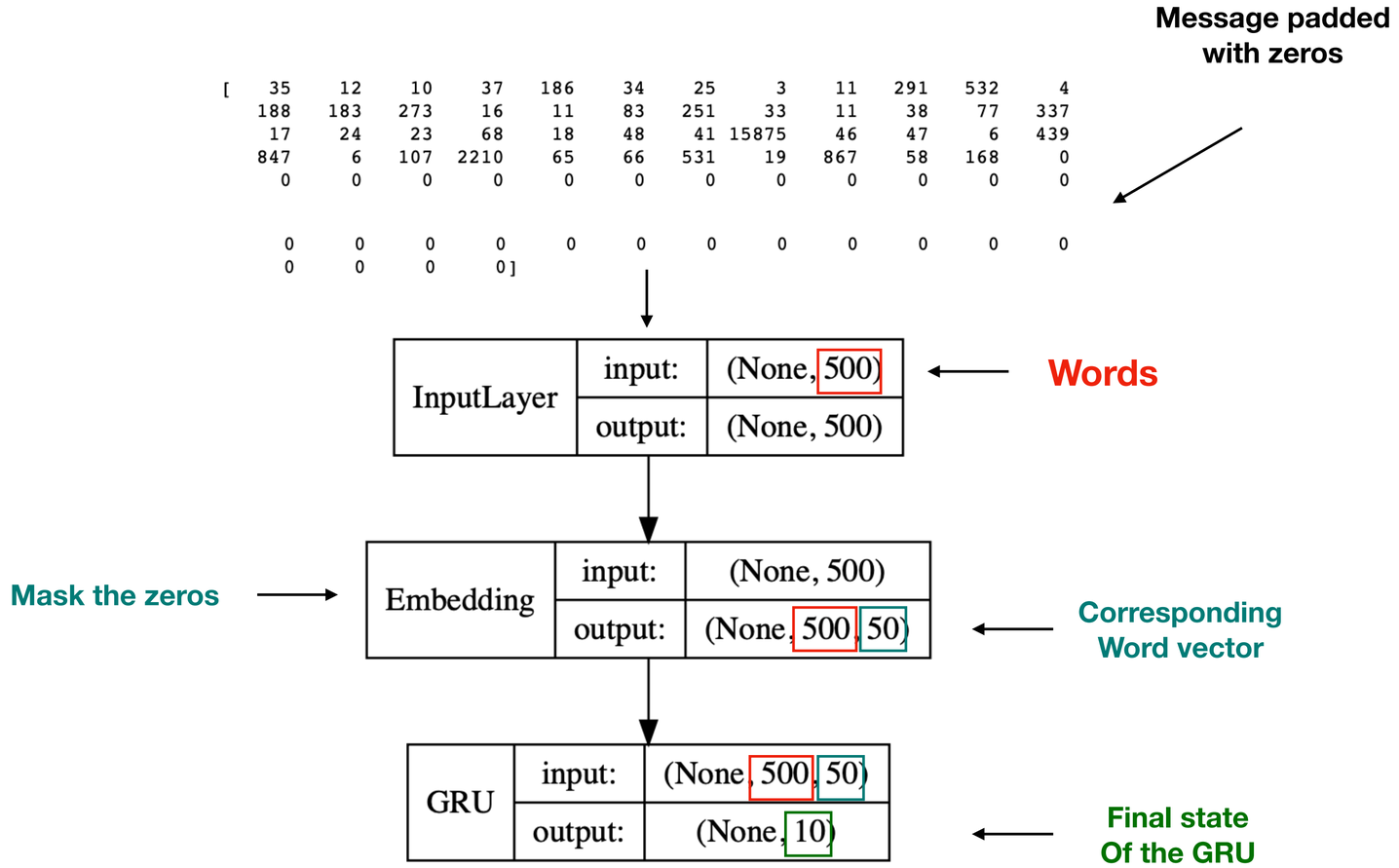
```
[-0.9386204   0.9671039   1.206119   -0.19411911 -0.23051228 -0.65913016
  0.00338563 -0.5044939  -0.02717912  0.09867108 -0.05116596 -0.5569398
  0.618001   -0.73519474  0.640754   -0.15959941  0.12680046  0.15426521
  0.42407024 -0.14709638  0.47534356 -0.18739735 -0.03758601  1.0197228
  0.06810962 -0.02504043 -0.11898965  0.11782035 -0.34788233  0.14381583
  0.67742926  0.43483204  0.39772424  0.10286205 -0.3774167   0.36935064
 -0.1227726  -0.20352381 -0.22164229  0.10978855 -0.50076777  0.39308718
  0.1865182   0.33458158 -0.3371736   0.0493757   0.5454126  -0.94923306
 -0.1352783  -0.34716246]
```

t-sne for 5000 averaged error message vectors

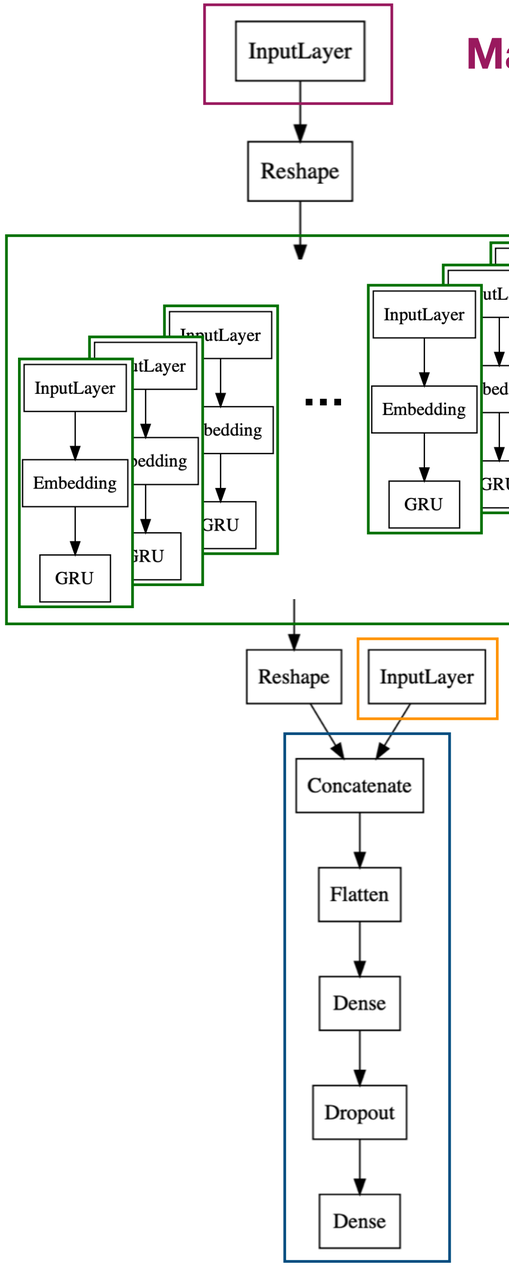


Supervised word embeddings: RNN

- Averaging does not exploit the **sequential nature of language** → use a RNN (LSTM / GRU)
- GRU **encodes** the embedding vectors of the error log words in a **vector**



NLP model for error logs



Matrix of Error Logs

Embedding + GRU for each Error Log

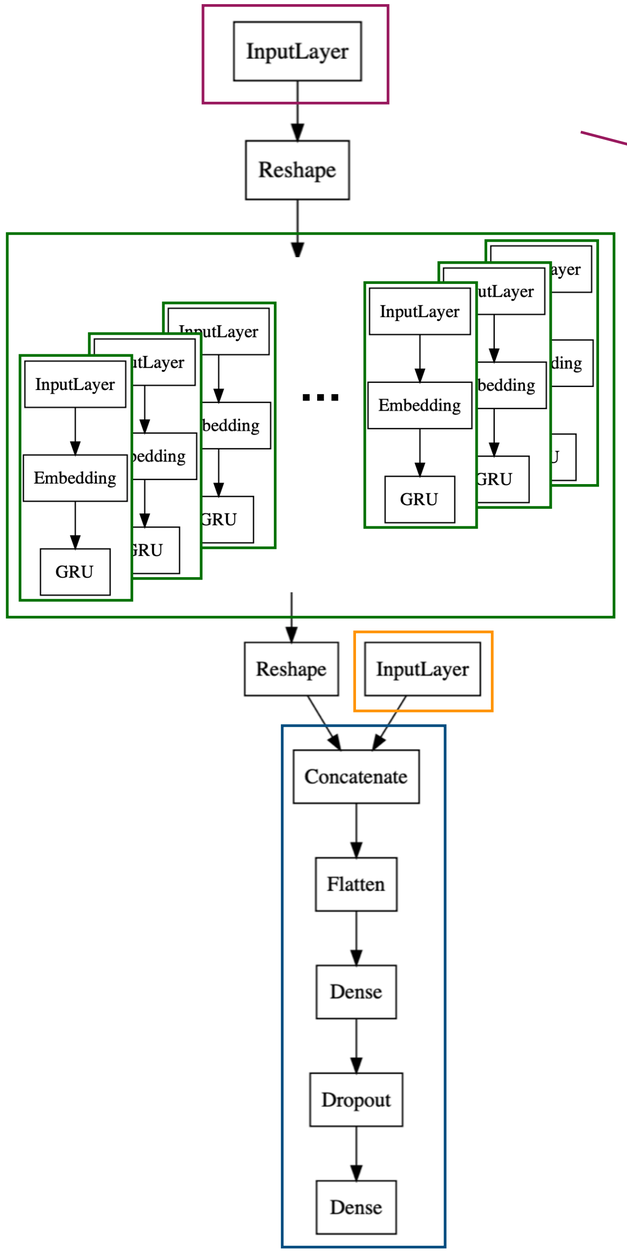
Matrix of Error Counts

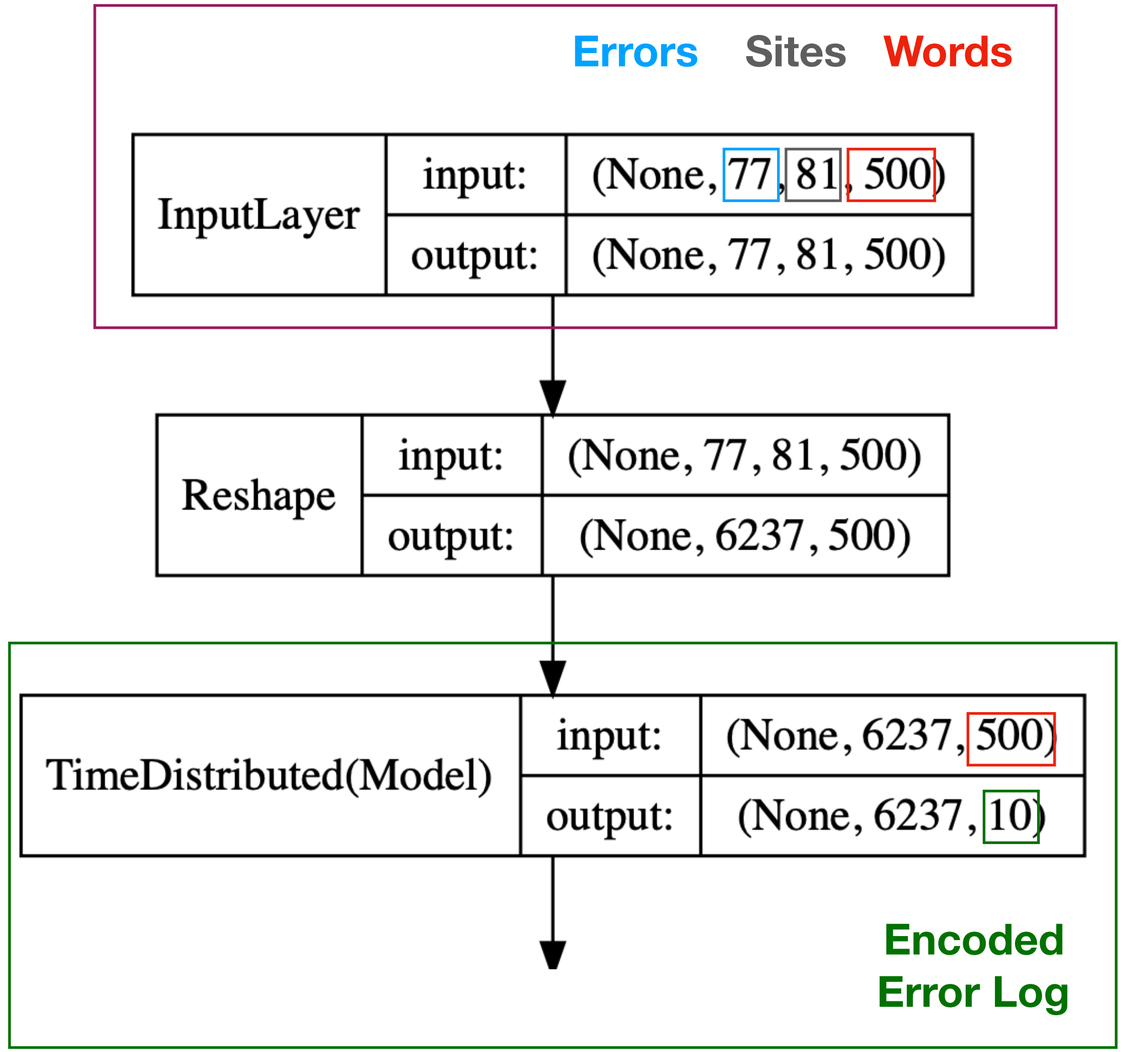
Concatenate

Dense

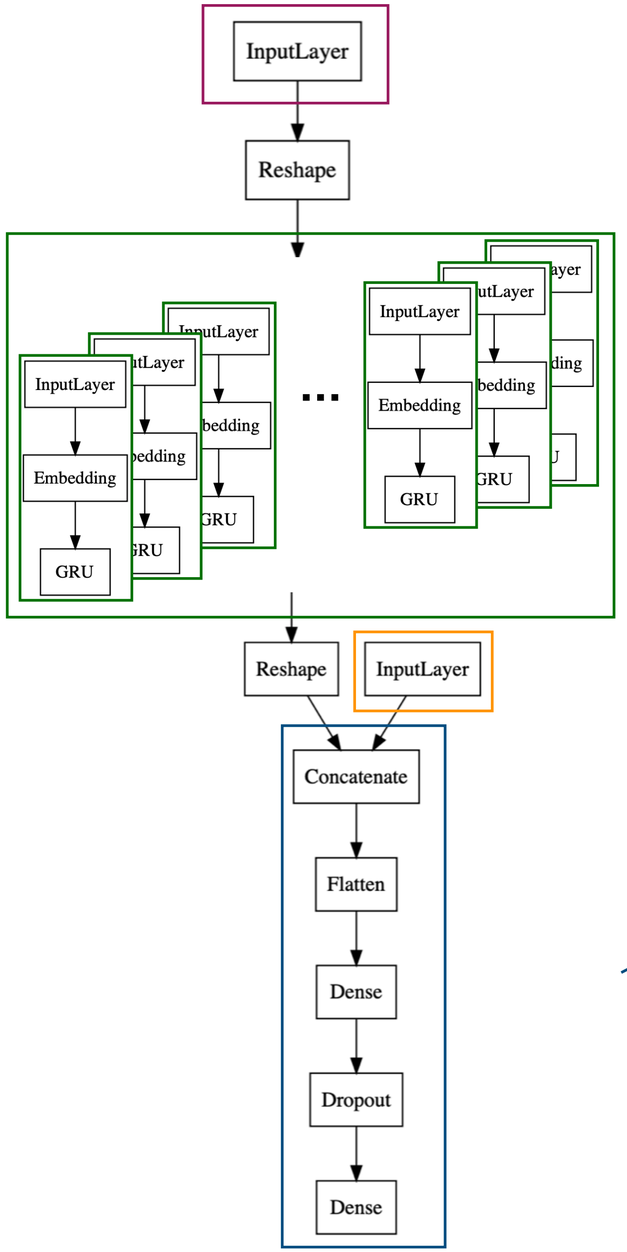
Classification

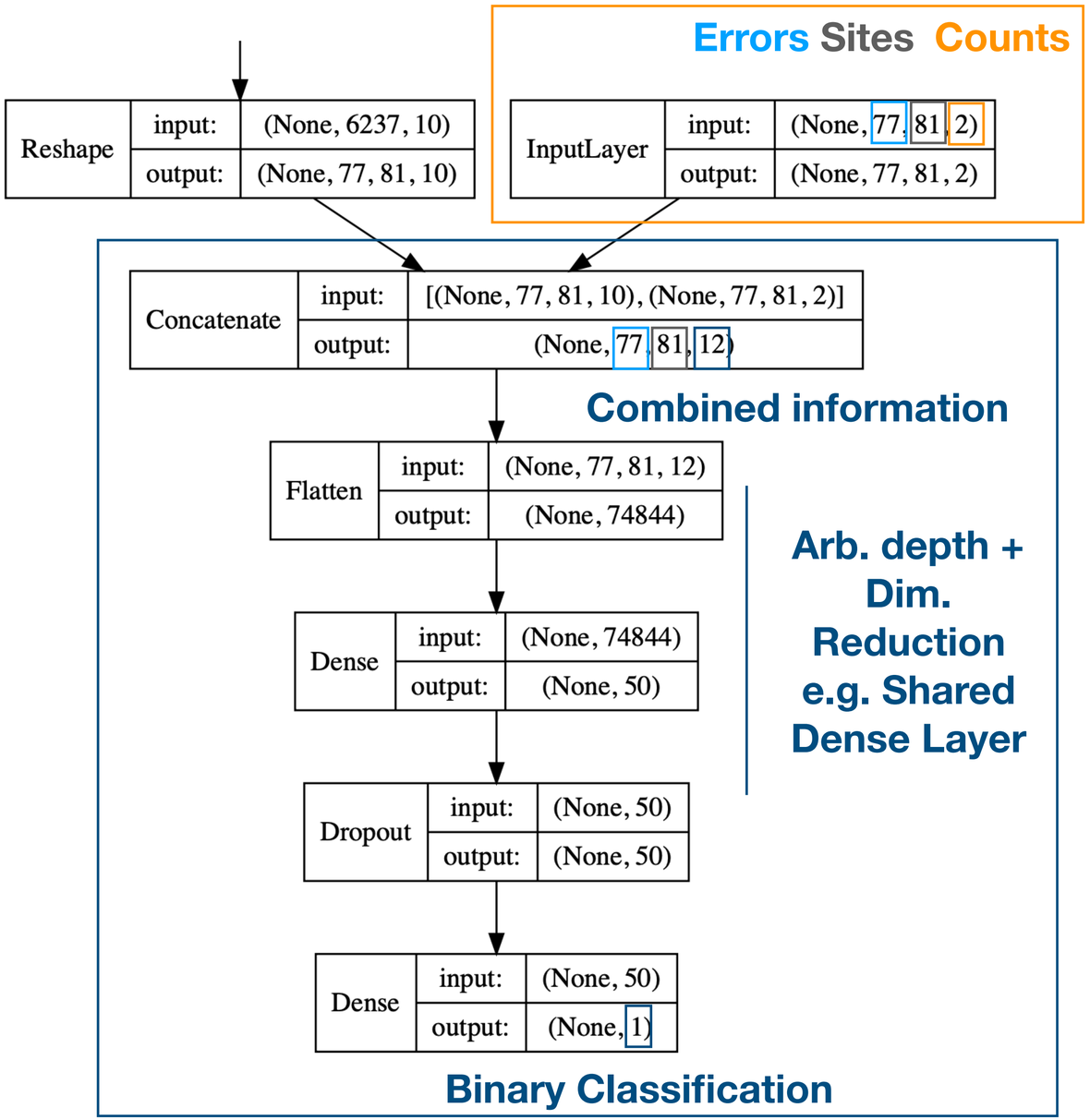
NLP model for error logs





NLP model for error logs





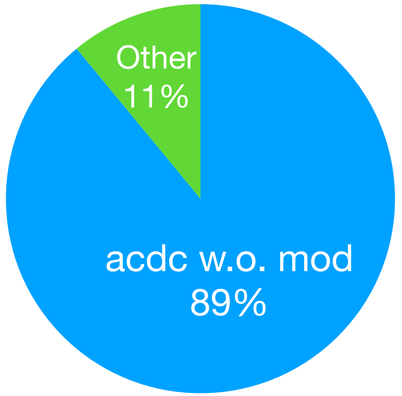
Training and target

acdc w.o. modification

Retry only failed jobs
No modification of memory or splitting

vs. **all other actions**

~33.000 samples



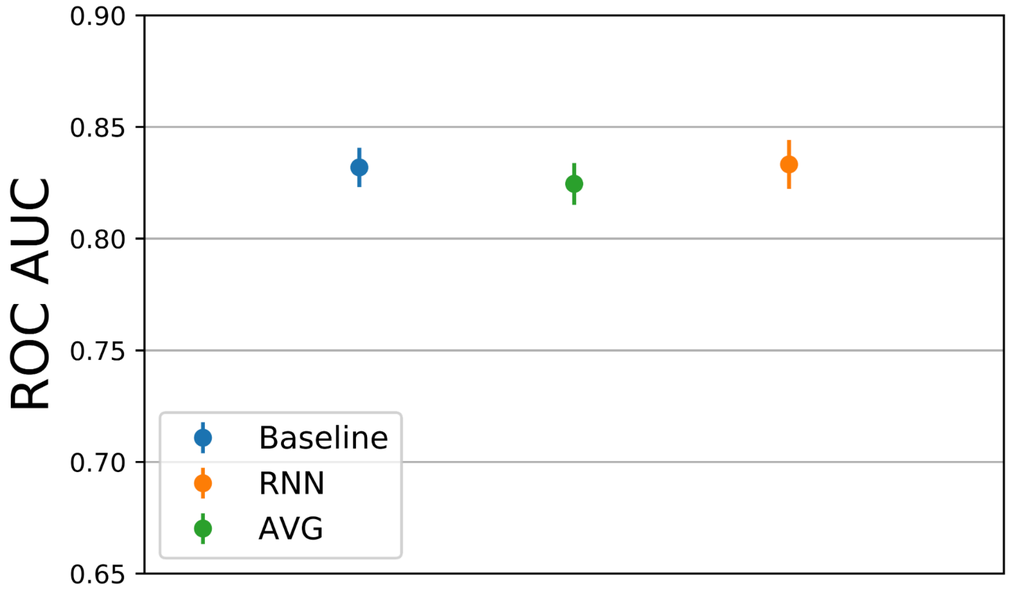
- Simplest target → future: multiclass classification for more actions
- Small data + imbalanced classes → Cross-validation (3-Folds)
- Sparse input: batch size = 4 → **O(1h) / epoch** on a NVidia GeForce GTX 1080

Hyper-parameter Optimization

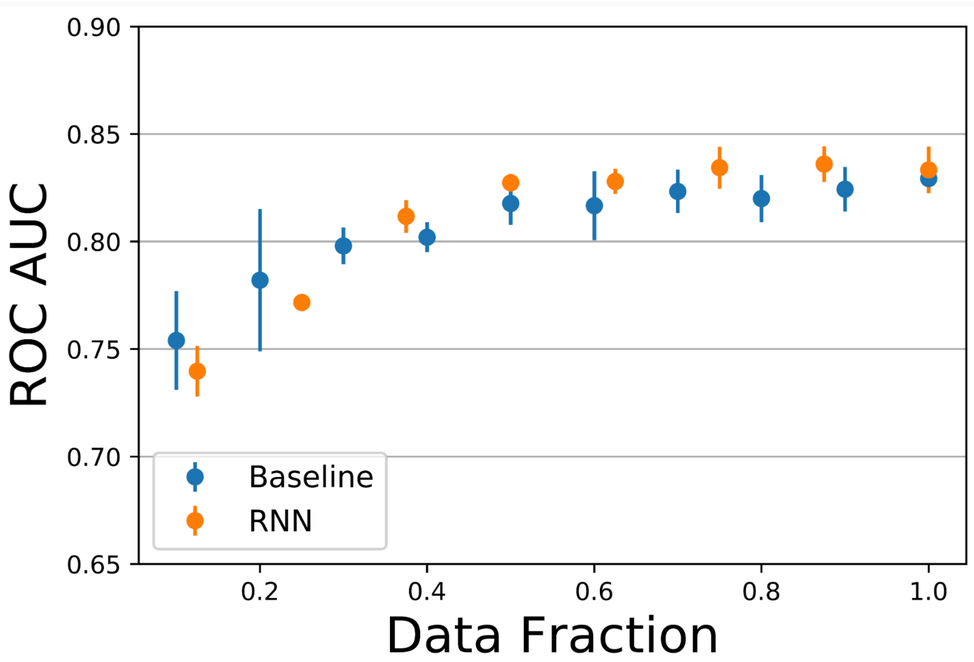
- Bayesian Optimization with **scikit-optimize**
- 2-8 GPUs on **Caltech GPU cluster** with NVidia GeForce GTX 1080 / Titan X
- Experimental: distributed training with the **NNLO framework** → Talk at CHEP
  https://github.com/vlimant/NNLO
- Experimental: Training models in parallel with **spark_sklearn** on **SWAN** with the help of CERN IT

Results

ROC AUC for acdc w.o. modification vs. other



ROC AUC as a function of the fraction of the total data set used for training



Baseline:
FF with counts only

AVG:
FF for averaged w2v + counts

RNN:
RNN for embeddings + counts

➡ **Successful training** of first complex NLP models

➡ **Similar results** as baseline - performance **improving with more data**

➡ **Work ongoing** → Full potential not yet exploited

Summary

- Implementation of a **pipeline for DAQ and ML** of error logs using big data analysis tools → https://github.com/llayer/AIErrorLogAnalysis

- Development of a prototype **NLP model** in Keras

Outlook

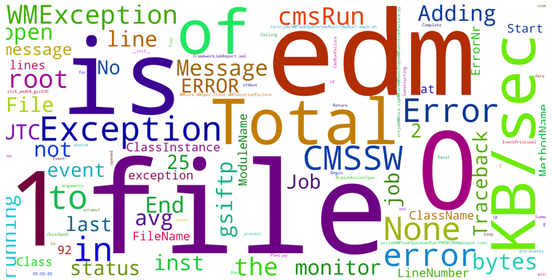
- **Further investigations** of data and model → Reimplement in **pytorch** / **tensorflow** and exploit the **NNLO framework**

- Get involved with the **NLP community** and learn from their experiences

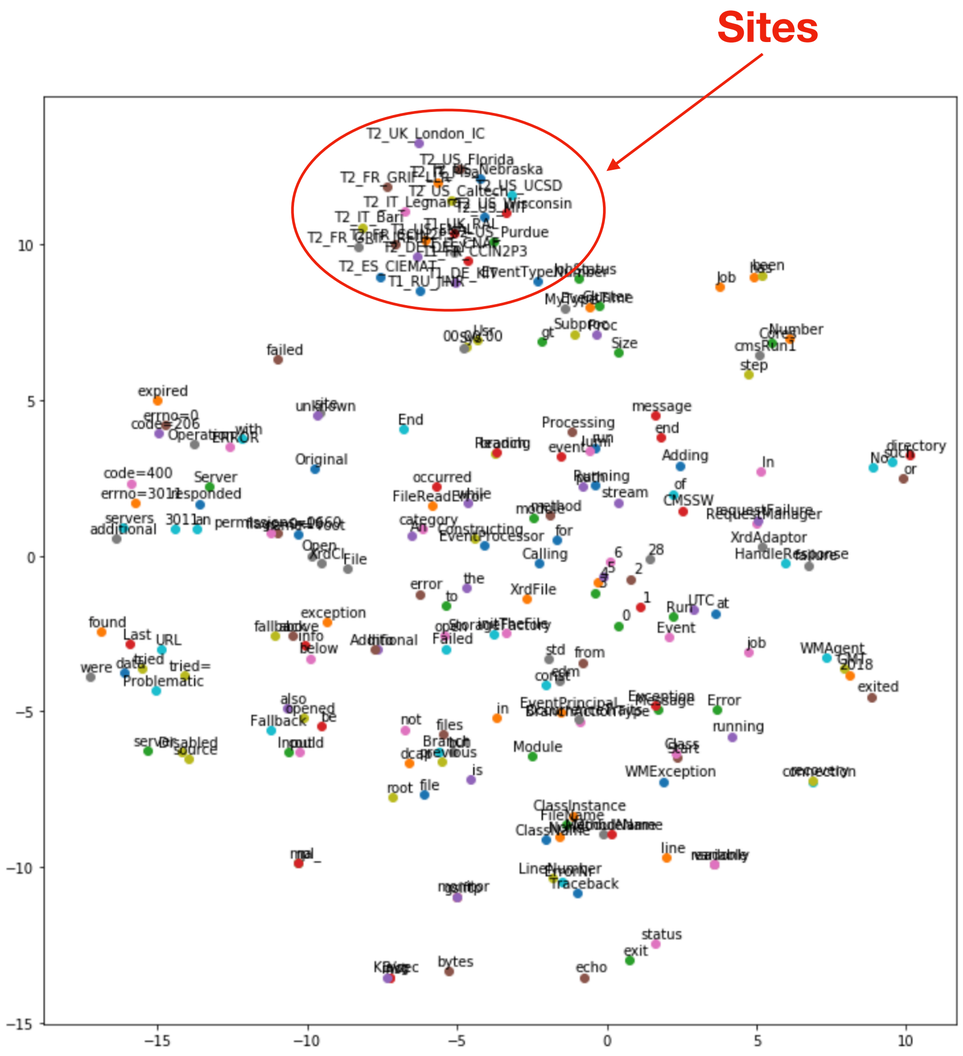
- **RUCIO** (→ Talk at CHEP): Development of a **common system** to collect and categorize errors, provide shifters with actions and collect feedback on the suggestion → could also contain **error log snippets**

BACKUP

Word embeddings for log messages



- Vocabulary: ~ **30.000 words** after filtering
- Unsupervised training with **word2vec**
- Standard parameters with embedding dimensions **10**, **20**, **50**
- Visualization: non-linear dimensionality reduction with the **t-sne algorithm** in 2D



Message representation: RNN + Attention

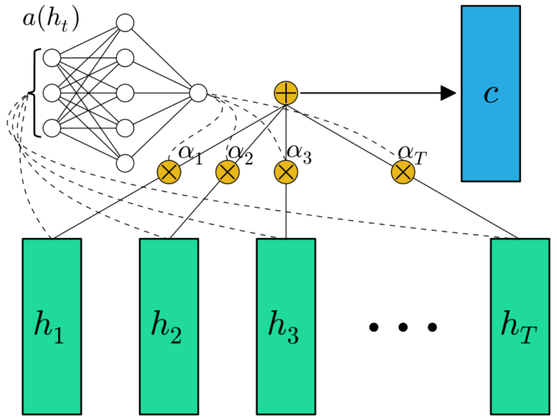
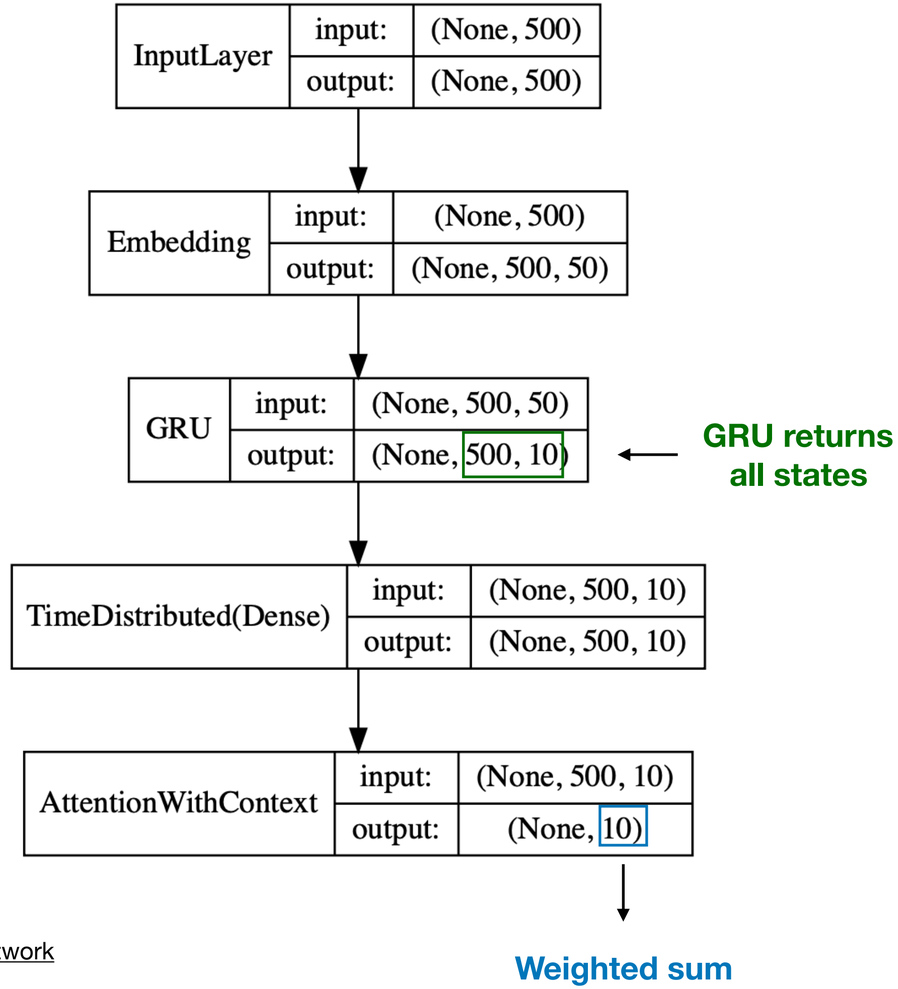


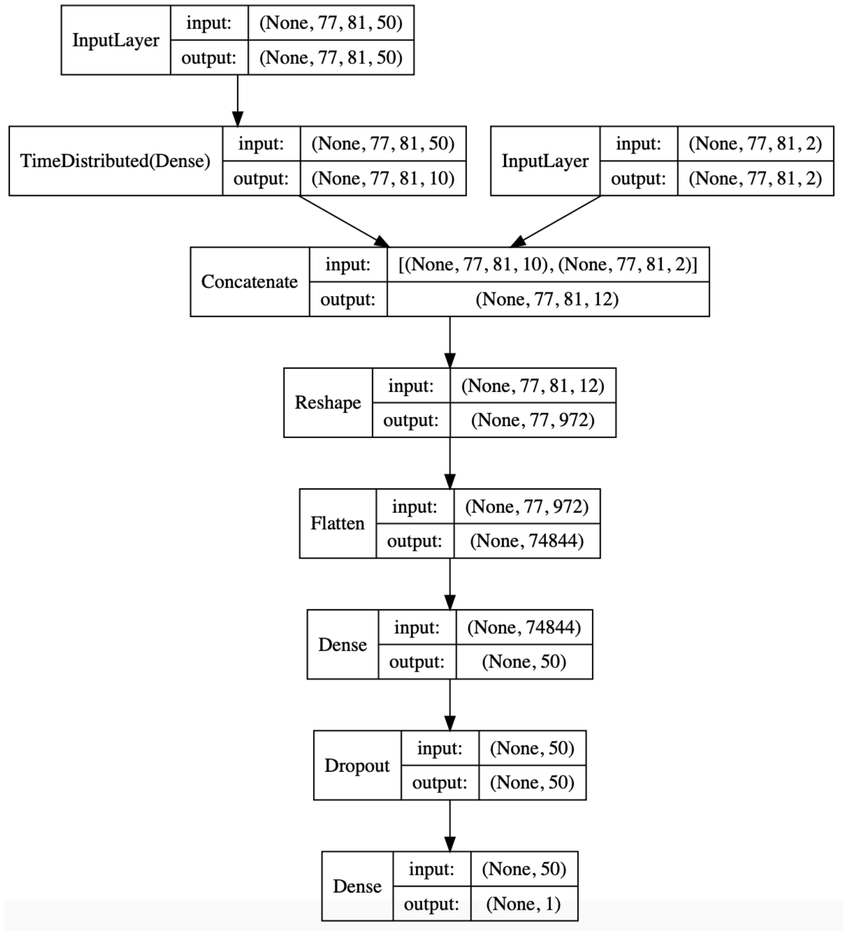
Figure 1: Schematic of our proposed "feed-forward" attention mechanism (cf. (Cho, 2015) Figure 1). Vectors in the hidden state sequence h_t are fed into the learnable function $a(h_t)$ to produce a probability vector α. The vector c is computed as a weighted average of h_t, with weighting given by α.

- Not all words are equally important
- Return **all RNN states** and pass through a **shallow network** to decide **weight** corresponding to each vector
- The **weighted sum** of each vector embodies the **meaning** of those vectors combined



https://github.com/Hsankesara/DeepResearch/tree/master/Hierarchical_Attention_Network

Model for averaged w2v vectors



Best hyperparameters for the RNN model

Batch size = 4 **Maximum number of words = 400**

```
skot_dim_dimred = [
    Real(        low=1e-5, high=1e-3, prior='log-uniform', name='learning_rate'     ),
    Real(        low=1e-3, high=0.1, prior='log-uniform', name='dropout'     ),
    Integer(     low=5, high=32,                          name='embedding'   ),
    Integer(     low=2, high=20,                          name='rnn_units'   ),
    Integer(     low=10, high = 100,                       name = 'units_site'    ),
    Integer(     low=1,    high=5,                         name='dense_layers'      ),
    Integer(     low=10,    high=50,                         name='dense_units'      ),
    Integer(     low=0,    high=1,                         name='encode_sites'      ),
    ]
```

	learning_rate	dropout	embedding	rnn_units	units_site	dense_layers	dense_units	encode_sites	result	std
14	0.000010	0.001	5.0	20.0	100.0	5.0	50.0	1.0	-0.833228	0.010969
11	0.000037	0.100	20.0	14.0	62.0	2.0	25.0	1.0	-0.831024	0.010876
2	0.000018	0.100	22.0	15.0	54.0	4.0	21.0	1.0	-0.828022	0.010423
6	0.000019	0.100	21.0	15.0	54.0	3.0	21.0	1.0	-0.826678	0.011404
13	0.000010	0.001	5.0	20.0	100.0	1.0	50.0	1.0	-0.824910	0.012229

Actions

action	splitting	Site list	memory	rate
ACDC	None	Modified	Not set	87.53%
clone	None	Not modified	Not set	4.61%
ACDC	None	Modified	> 20GB	3.28%
ACDC	None	Modified	> 10GB	1.12%
ACDC	None	Modified	< 10GB	0.75%
ACDC	10x	Modified	Not set	0.74%
Other actions (27 more rows)				< 2%