A code-free deep learning toolbox

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Deep Learning experimentation toolbox based on TensorFlow

No coding required

Statistics

6700+ Stars on GitHub

1600+ downloads/month

60+ Contributors

~80 commits/month


Uber


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GENERAL

A new data type-based approach to deep learning model design that makes the tool suited for many different applications.

FLEXIBLE

Experienced users have deep control over model building and training, while newcomers will find it easy to use.

EXTENSIBLE

Easy to add new model architecture and new feature data-types.

UNDERSTANDABLE

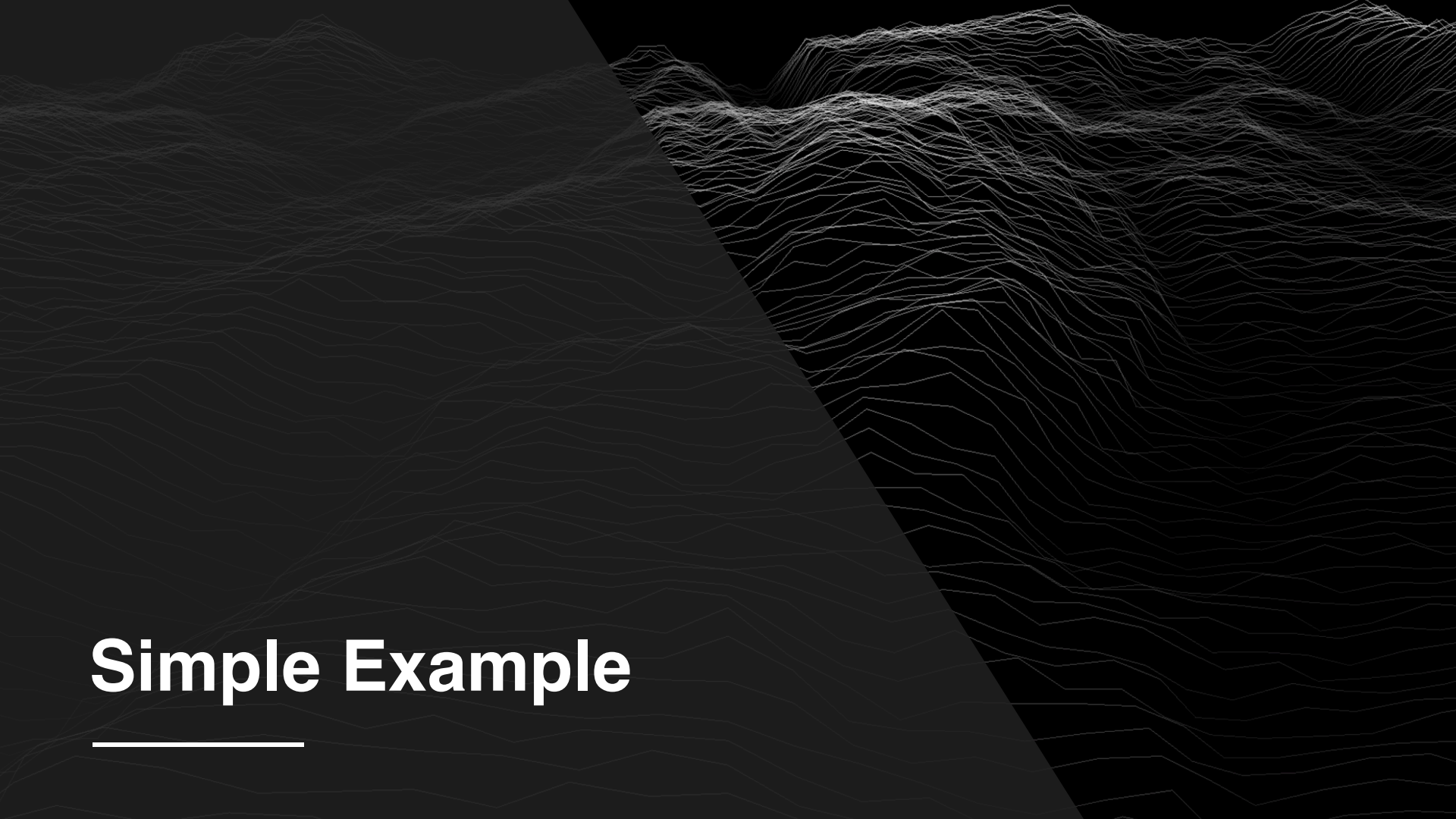
We provide standard visualizations to understand their performances and compare their predictions.

EASY

No coding skills are required to train a model and use it for obtaining predictions.

OPEN

Released under the open source Apache License 2.0.



Simple Example

Example

NEWS	CLASS
Toronto Feb 26 - Standard Trustco said it expects earnings in 1987 to increase at least 15 to 20 pct from the 9 140 000 dlrs or 252 dlrs...	earnings
New York Feb 26 - American Express Co remained silent on market rumors it would spinoff all or part of its Shearson Lehman Brothers Inc...	acquisition
BANGKOK March 25 - Vietnam will resettle 300 000 people on state farms known as new economic zones in 1987 to create jobs and grow more high-value export crops...	coffe

Example experiment command

```
ludwig experiment
--data_csv reuters-allcats.csv
--model_definition "{input_features: [{name: news, type: text}], output_features: [{name: class, type: category}]}"

# you can specify a --model_definition_file file_path argument instead
# that reads a YAML file
```

The Experiment command:

1. splits the data in training, validation and test sets
2. trains a model on the training set
3. validates on the validation set (early stopping)
4. predicts on the test set

Epoch 1
Training: 100%| 23/23 [00:02<00:00, 9.86it/s]
Evaluation train: 100%| 23/23 [00:00<00:00, 46.39it/s]
Evaluation vali : 100%| 4/4 [00:00<00:00, 29.05it/s]
Evaluation test : 100%| 7/7 [00:00<00:00, 43.06it/s]
Took 2.8826s

class	loss	accuracy	hits@3
train	0.2604	0.9306	0.9899
vali	0.3678	0.8792	0.9769
test	0.3532	0.8929	0.9903

Validation accuracy on class improved, model saved

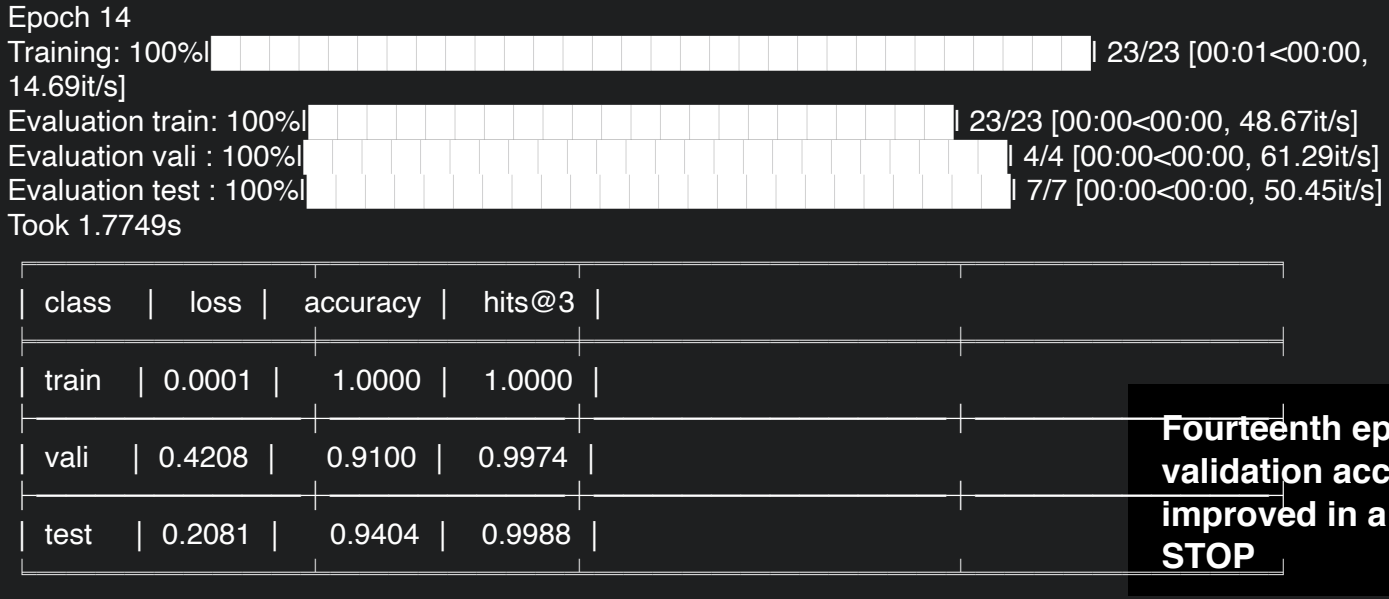
First epoch of training

Epoch 4
Training: 100%|| 23/23 [00:01<00:00, 14.87it/s]
Evaluation train: 100%|| 23/23 [00:00<00:00, 48.87it/s]
Evaluation vali : 100%|| 4/4 [00:00<00:00, 59.50it/s]
Evaluation test : 100%|| 7/7 [00:00<00:00, 51.70it/s]
Took 1.7578s

class	loss	accuracy	hits@3
train	0.0048	0.9997	1.0000
vali	0.2560	0.9177	0.9949
test	0.1677	0.9440	0.9964

Fourth epoch of training, validation accuracy improved

Validation accuracy on class improved, model saved



Fourteenth epoch of training, validation accuracy has not improved in a while, let's EARLY STOP

```
===== class =====
accuracy: 0.94403892944
hits_at_k: 0.996350364964
Confusion Matrix
( { 'avg_f1_score_macro': 0.6440659449587669,
    'avg_f1_score_micro': 0.94403892944038914,
    'avg_f1_score_weighted': 0.94233823910531345,
    'avg_precision_macro': 0.71699990923354218,
    'avg_precision_micro': 0.94403892944038925,
    'avg_precision_weighted': 0.94403892944038925,
    'avg_recall_macro': 0.60875299574797059,
    'avg_recall_micro': 0.94403892944038925,
    'avg_recall_weighted': 0.94403892944038925,
    'kappa_score': 0.91202440199068868,
    'overall_accuracy': 0.94403892944038925},)
```

Test statistics overall

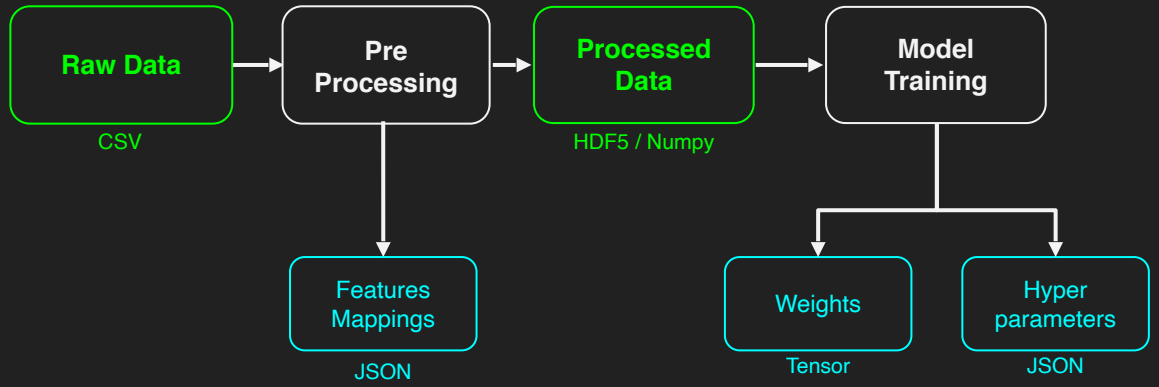
{ earn: {'accuracy': 0.95377128953771284,
'f1_score': 0.95214105793450876,
'fall_out': 0.046948356807511749,
'false_discovery_rate': 0.050251256281407031,
'false_negative_rate': 0.045454545454545414,
'false_negatives': 18,
'false_omission_rate': 0.042452830188679291,
'false_positive_rate': 0.046948356807511749,
'false_positives': 20,
'hit_rate': 0.95454545454545459,
'informedness': 0.90759709773794284,
'markedness': 0.90729591352991368,
'matthews_correlation_coefficient': 0.90744649313843584,
'miss_rate': 0.045454545454545414,
'negative_predictive_value': 0.95754716981132071,
'positive_predictive_value': 0.94974874371859297,
'precision': 0.94974874371859297,
'recall': 0.95454545454545459,
'sensitivity': 0.95454545454545459,
'specificity': 0.95305164319248825,
'true_negative_rate': 0.95305164319248825,
'true_negatives': 406,
'true_positive_rate': 0.95454545454545459,
'true_positives': 378},

Test statistics per class

How does it work?

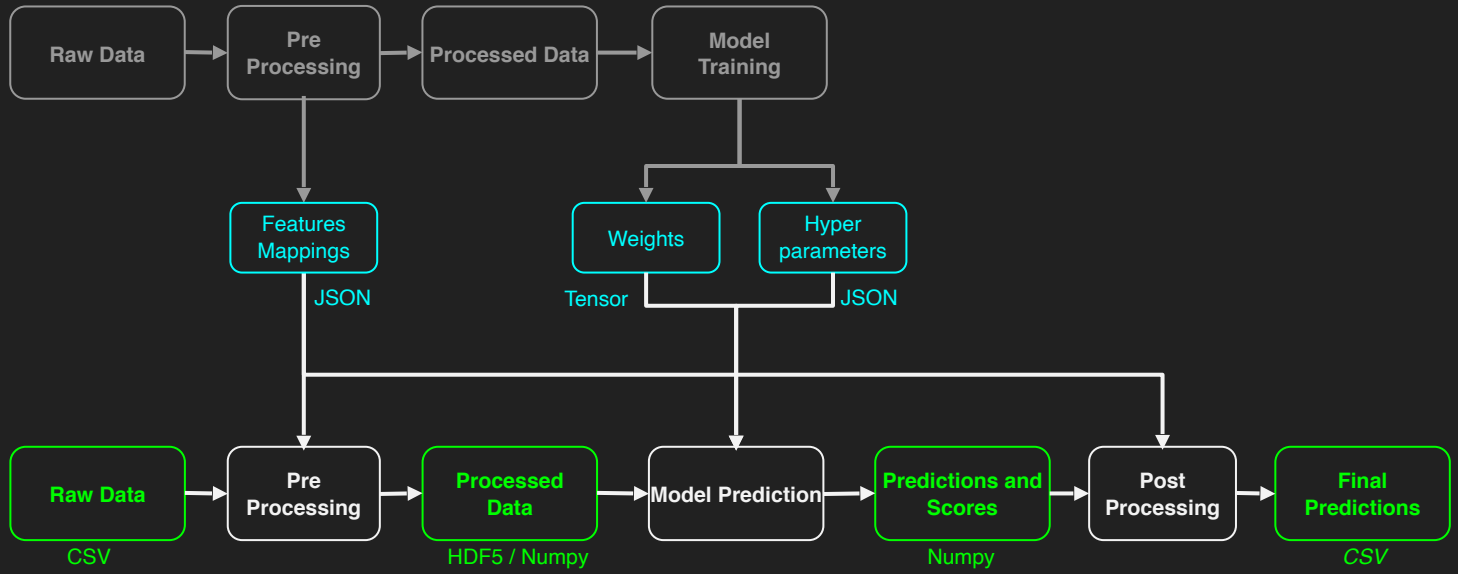
Training

Fields mappings, model hyper-parameters
and weights are saved during training



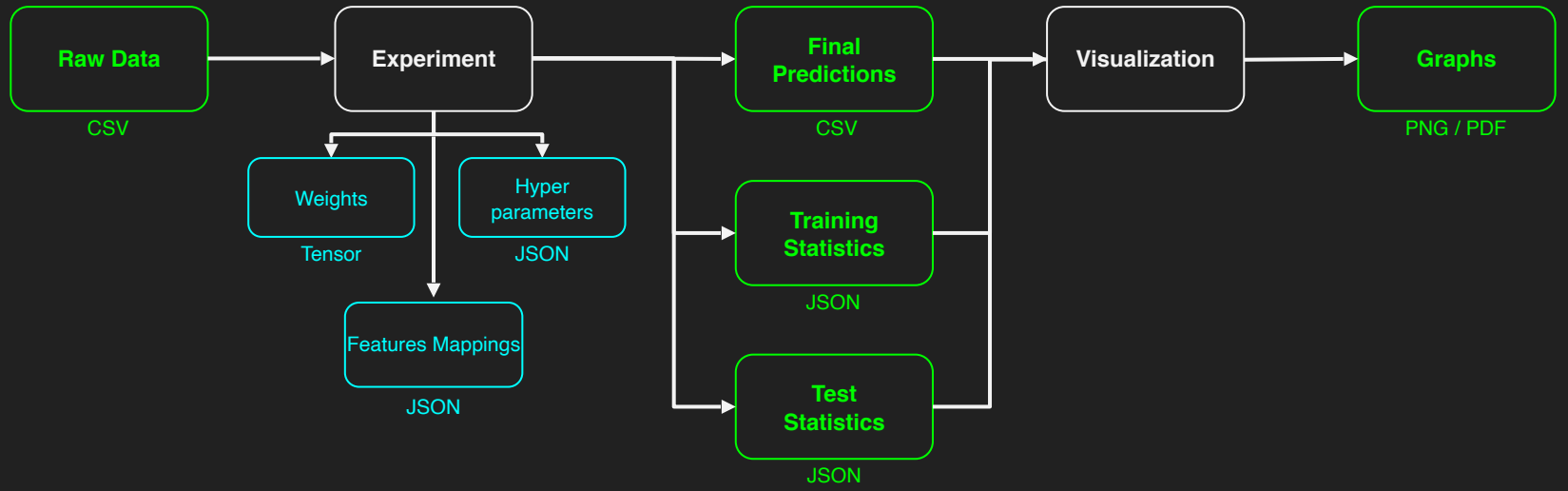
Prediction

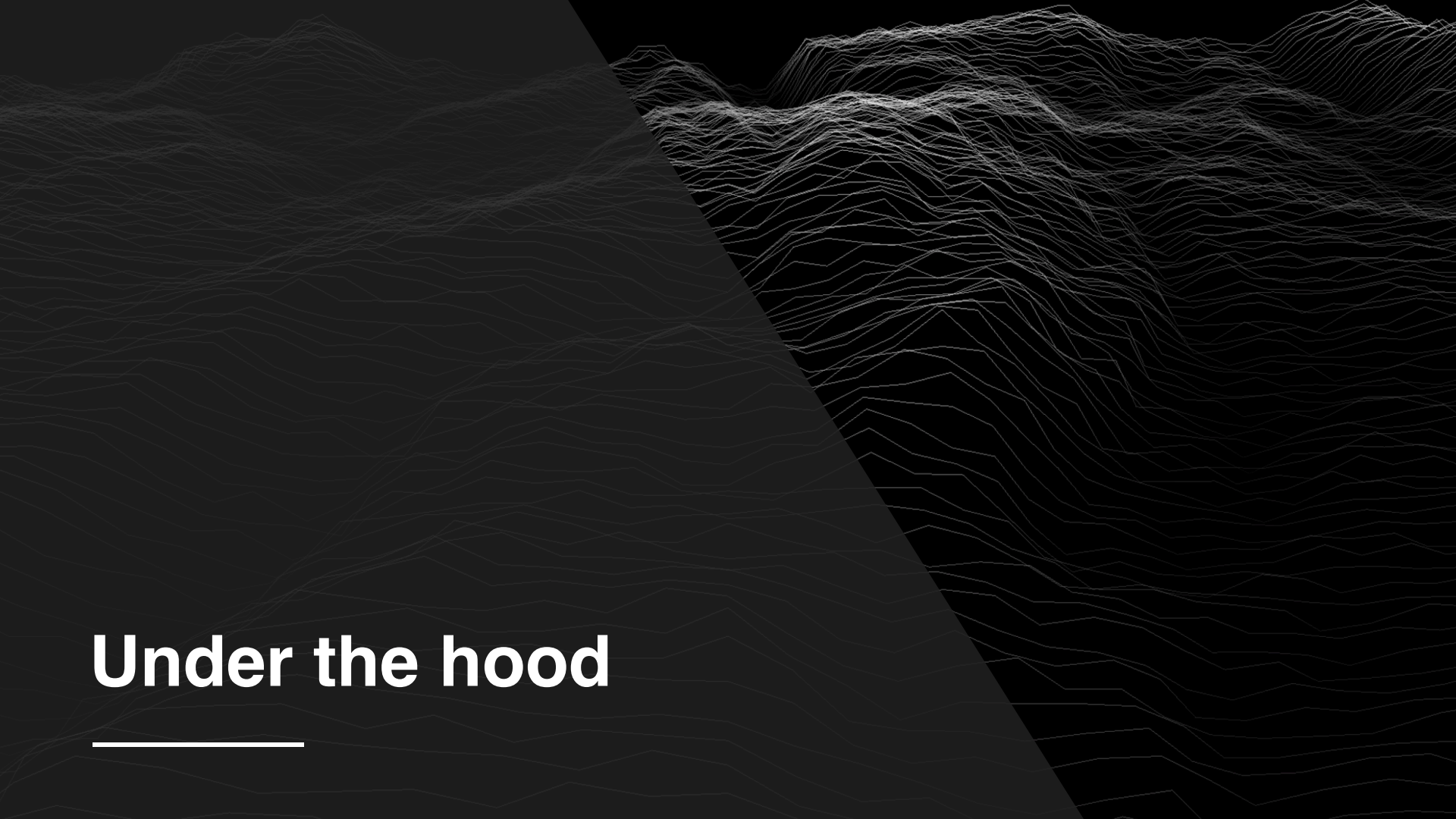
The same fields mappings obtained during training are used to pre-process to each datapoint and to post-process each prediction of the model in order map back to labels



Running Experiments

The Experiment trains a model on the training set and predicts on the test set. It outputs predictions and training and test statistics that can be used by the Visualization component to obtain graphs





Under the hood

The magic lies in:

Data type abstraction

Declarative model definition (YAML)

Smart use of **kwargs

Back to the example

```
ludwig experiment
--data_csv reuters-allcats.csv
--model_definition "{input_features: [{name: news, type: text}], output_features: [{name: class, type: category}]}"
```

Model Definition

ludwig experiment
--data_csv reuters-allcats.csv
--model_definition "**{input_features: [{name: news, type: text}], output_features: [{name: class, type: category}]}**"

Merging with defaults it gets resolved to

```
{
input_features: [
  { encoder: parallel_cnn,
    level: word,
    name: news,
    tied_weights: None,
    type: text}],
combiner: {type: concat},
output_features: [
   { dependencies: [],
     loss: {   class_distance_temperature: 0,
               class_weights: 1,
               confidence_penalty: 0,
               distortion: 1,
               labels_smoothing: 0,
               negative_samples: 0,
               robust_lambda: 0,
               sampler: None,
               type: softmax_cross_entropy,
               unique: False,
               weight: 1},
     name: is_name,
     reduce_dependencies: sum,
     reduce_input: sum,
     top_k: 3,
     type: category}],
```

```
training: {
    batch_size: 128,
    bucketing_field: None,
    decay: False,
    decay_rate: 0.96,
    decay_steps: 10000,
    dropout_rate: 0.0,
    early_stop: 3,
    epochs: 20,
    gradient_clipping: None,
    increase_batch_size_on_plateau: 0,
    increase_batch_size_on_plateau_max: 512,
    increase_batch_size_on_plateau_patience: 5,
    increase_batch_size_on_plateau_rate: 2,
    learning_rate: 0.001,
    learning_rate_warmup_epochs: 5,
    optimizer: {   beta1: 0.9,
                   beta2: 0.999,
                   epsilon: 1e-08,
                   type: adam},
    reduce_learning_rate_on_plateau: 0,
    reduce_learning_rate_on_plateau_patience: 5,
    reduce_learning_rate_on_plateau_rate: 0.5,
    regularization_lambda: 0,
    regularizer: l2,
    staircase: False,
    validation_field: combined,
    validation_measure: loss},
```

```
preprocessing: {
  text: {
    char_format: characters,
    char_most_common: 70,
    char_sequence_length_limit: 1024,
    fill_value: ,
    lowercase: True,
    missing_value_strategy: fill_with_const,
    padding: right,
    padding_symbol: <PAD>,
    unknown_symbol: <UNK>,
    word_format: space_punct,
    word_most_common: 20000,
    word_sequence_length_limit: 256},
  category: {
    fill_value: <UNK>,
    lowercase: False,
    missing_value_strategy: fill_with_const,
    most_common: 10000},
  force_split: False,
  split_probabilities: (0.7, 0.1, 0.2),
  stratify: None
}
```

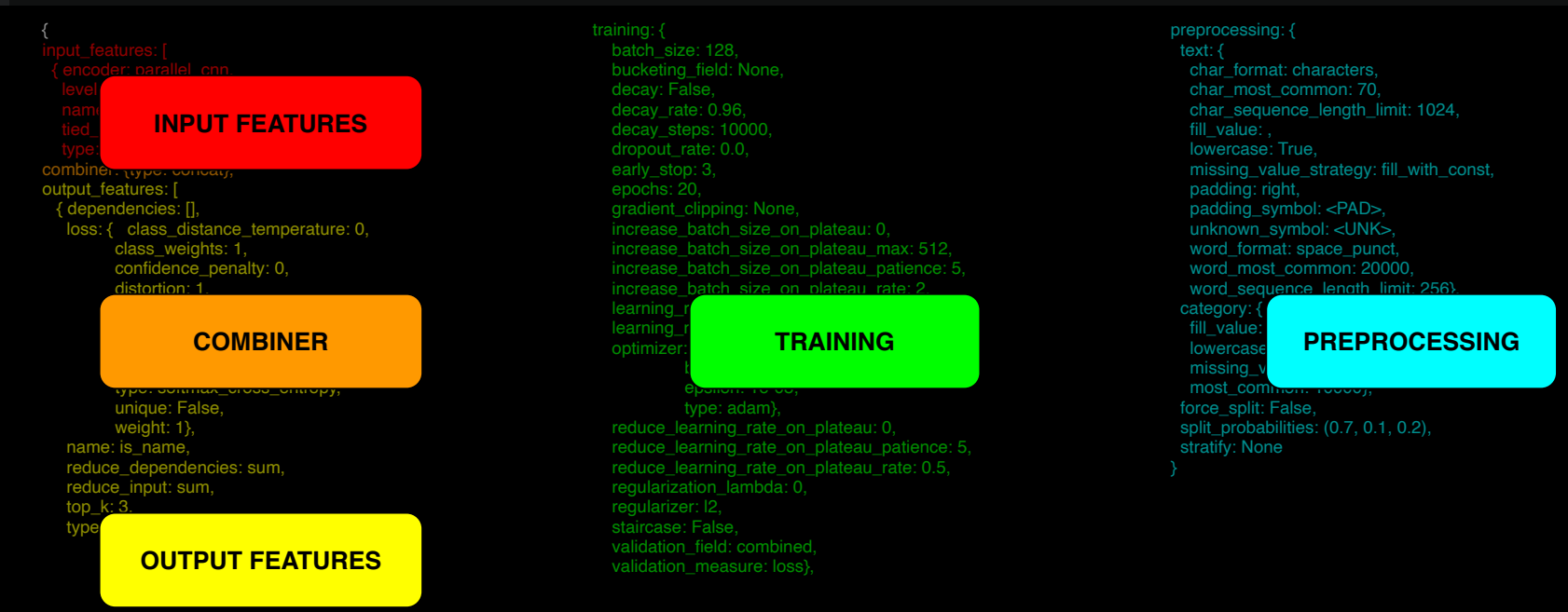
Merging with defaults it gets resolved to

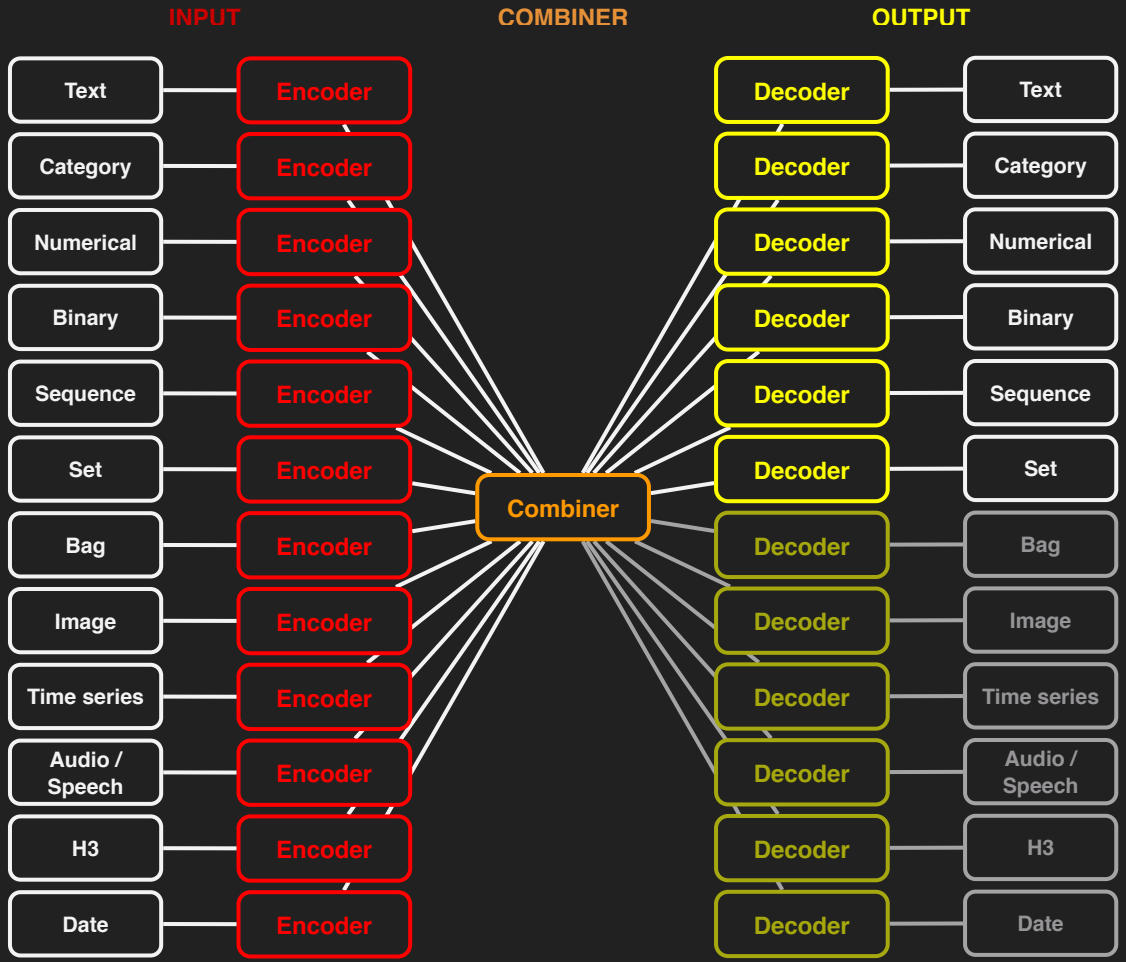
```
{
input_features: [
  { encoder: parallel_cnn,
    level: word,
    name: news,
    tied_weights: None,
    type: text}],
combiner: {type: concat},
output_features: [
   { dependencies: [],
     loss: {   class_distance_temperature: 0,
               class_weights: 1,
               confidence_penalty: 0,
               distortion: 1,
               labels_smoothing: 0,
               negative_samples: 0,
               robust_lambda: 0,
               sampler: None,
               type: softmax_cross_entropy,
               unique: False,
               weight: 1},
     name: is_name,
     reduce_dependencies: sum,
     reduce_input: sum,
     top_k: 3,
     type: category}],
```

```
training: {
    batch_size: 128,
    bucketing_field: None,
    decay: False,
    decay_rate: 0.96,
    decay_steps: 10000,
    dropout_rate: 0.0,
    early_stop: 3,
    epochs: 20,
    gradient_clipping: None,
    increase_batch_size_on_plateau: 0,
    increase_batch_size_on_plateau_max: 512,
    increase_batch_size_on_plateau_patience: 5,
    increase_batch_size_on_plateau_rate: 2,
    learning_rate: 0.001,
    learning_rate_warmup_epochs: 5,
    optimizer: {   beta1: 0.9,
                   beta2: 0.999,
                   epsilon: 1e-08,
                   type: adam},
    reduce_learning_rate_on_plateau: 0,
    reduce_learning_rate_on_plateau_patience: 5,
    reduce_learning_rate_on_plateau_rate: 0.5,
    regularization_lambda: 0,
    regularizer: l2,
    staircase: False,
    validation_field: combined,
    validation_measure: loss},
```

```
preprocessing: {
  text: {
    char_format: characters,
    char_most_common: 70,
    char_sequence_length_limit: 1024,
    fill_value: ,
    lowercase: True,
    missing_value_strategy: fill_with_const,
    padding: right,
    padding_symbol: <PAD>,
    unknown_symbol: <UNK>,
    word_format: space_punct,
    word_most_common: 20000,
    word_sequence_length_limit: 256},
  category: {
    fill_value: <UNK>,
    lowercase: False,
    missing_value_strategy: fill_with_const,
    most_common: 10000},
  force_split: False,
  split_probabilities: (0.7, 0.1, 0.2),
  stratify: None
}
```

Merging with defaults it gets resolved to




INPUT
COMBINER
OUTPUT
Text
Category
Numerical
Binary
Sequence
Set
Bag
Image
Time series
Audio / Speech
H3
Date
Encoder
Encoder
Encoder
Encoder
Encoder
Encoder
Encoder
Encoder
Encoder
Encoder
Encoder
Encoder
Combiner
Decoder
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Decoder
Text
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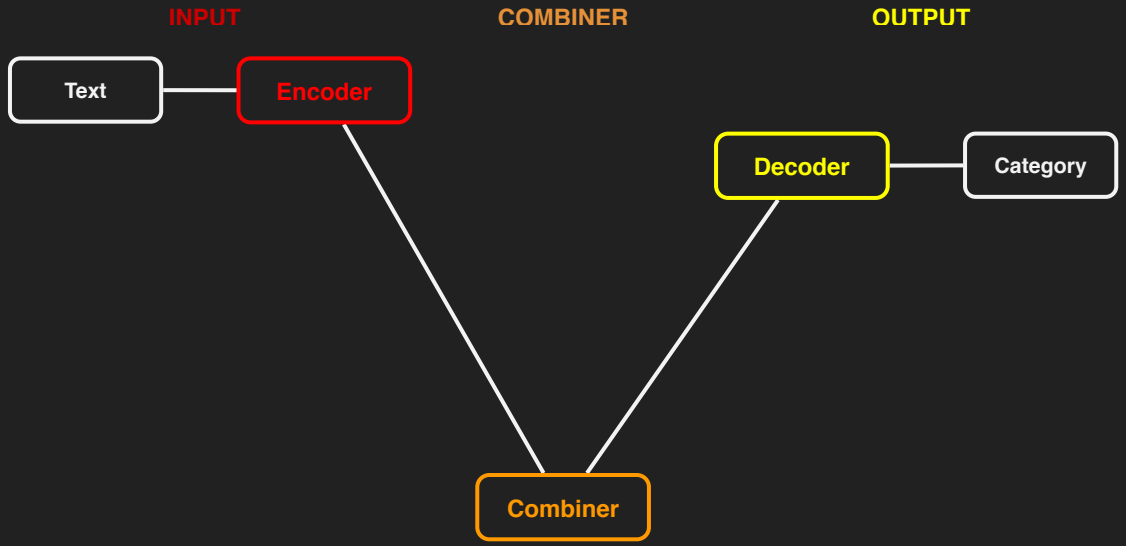


Text Classifier

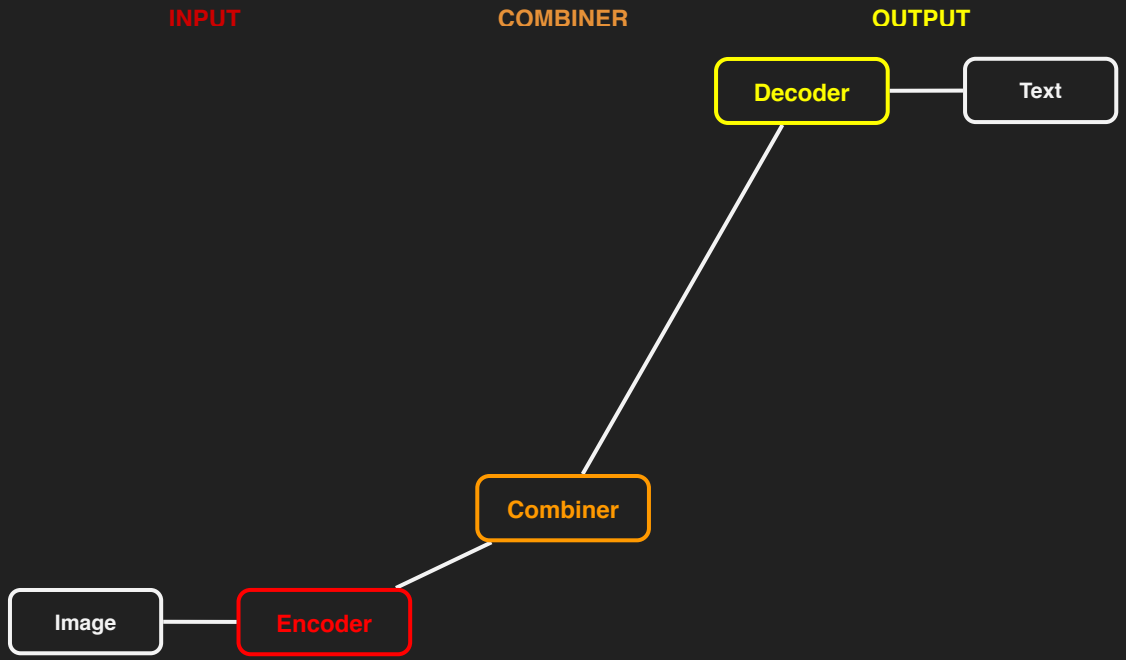
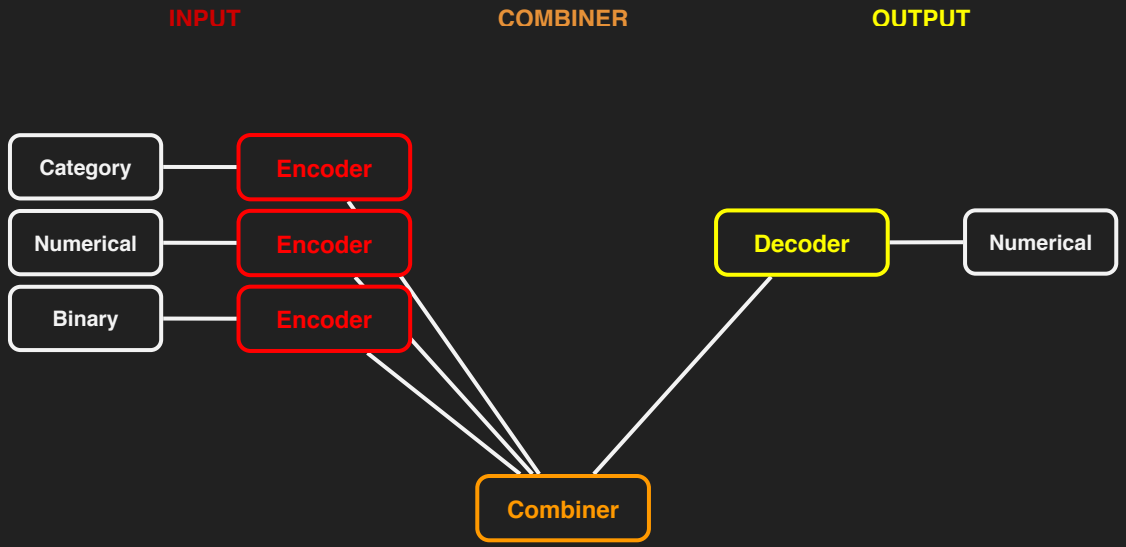
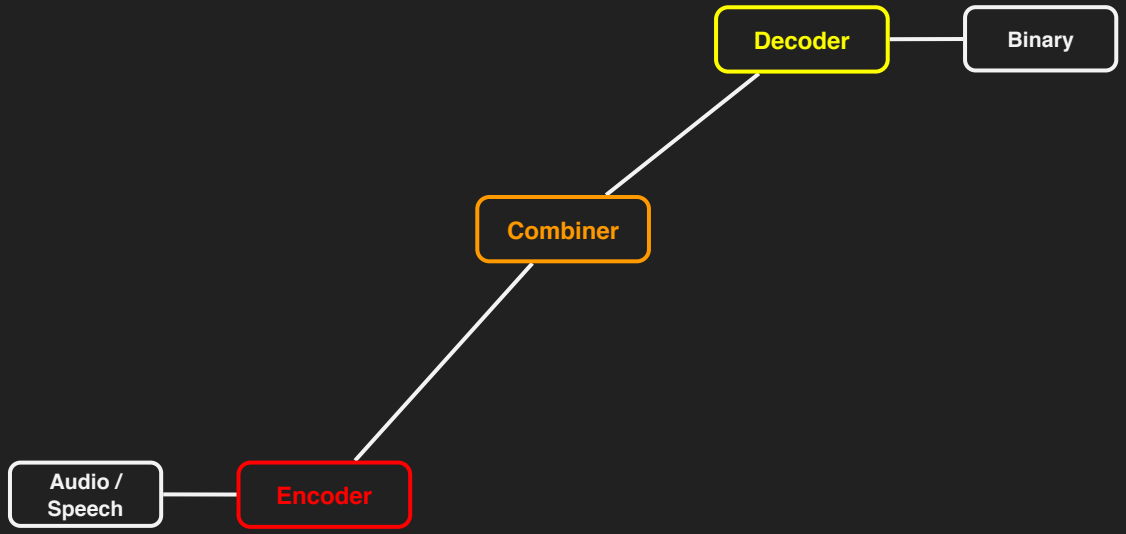


Image Captioning

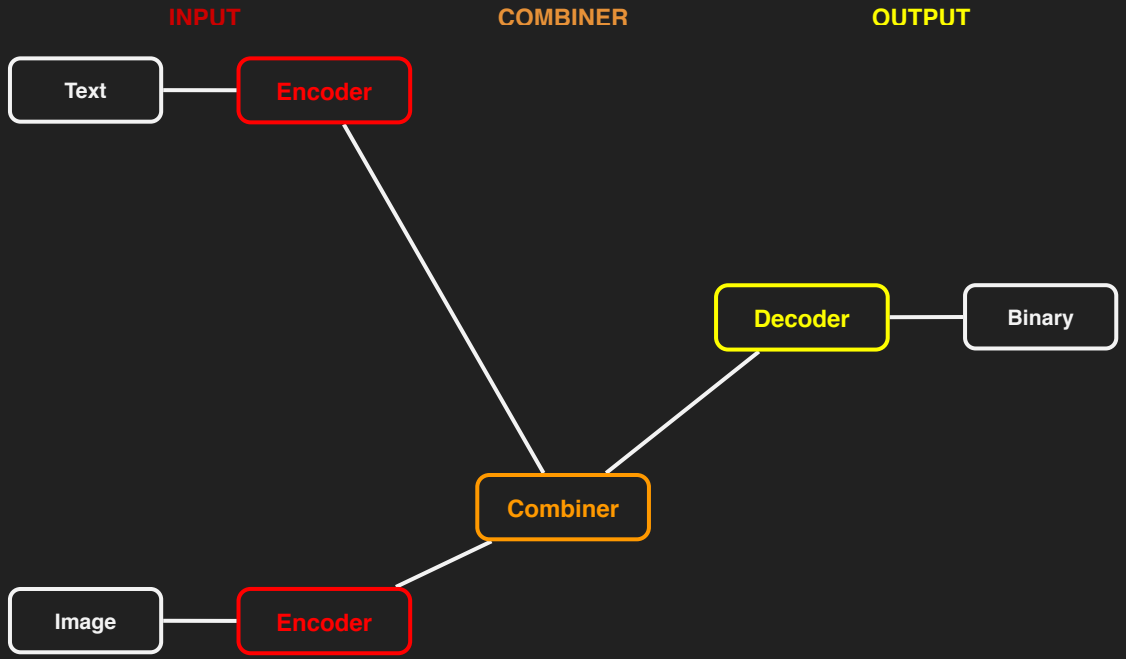


Classic Regression

INPUT COMBINER OUTPUT



Speaker Verification

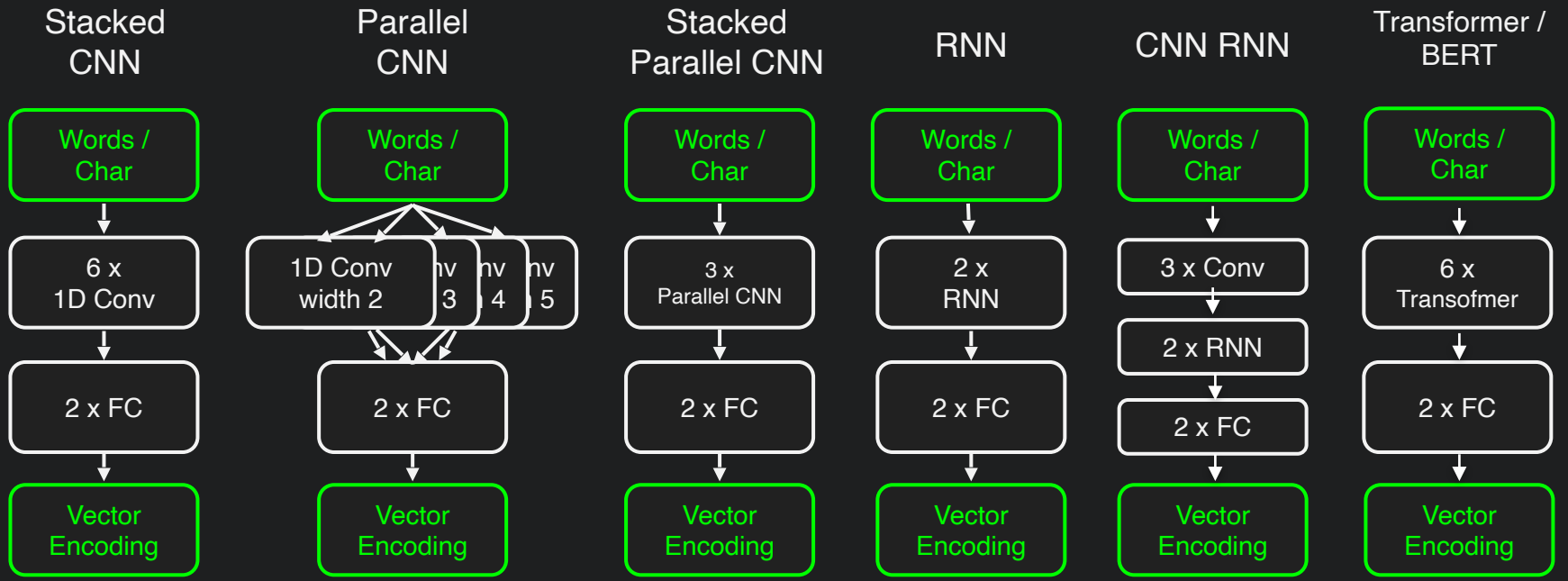


Visual Question Answering

Each input type can have multiple encoders to choose from

Each output type can have multiple decoders to choose from

Text input features encoders



ParallelCNN encoding

name: text_csv_column_name
type: text
encoder: parallel_cnn
level: word / char
tied_weights: null
representation: dense / sparse
embedding_size: 256
embeddings_on_cpu: false
pretrained_embeddings: null
embeddings_trainable: true
conv_layers: null
num_conv_layers: null
filter_size: 3
num_filters: 256
pool_size: null
fc_layers: null
num_fc_layers: null
fc_size: 256
activation: relu
norm: null
dropout: false
regularize: true
reduce_output: sum

Grey parameters are optional

ParallelCNN encoding

```
name: text_csv_column_
type: text,
encoder: parallel_cnn,
level: word / char,
tied_weights: null
representation: dense
embedding_size: 256
embeddings_on_cpu: fa
pretrained_embeddings:
embeddings_trainable: t
conv_layers: null
num_conv_layers: null
filter_size: 3
num_filters: 256
```

Code that builds a parallel_cnn

```
class ParallelCNN(object):

    def __init__(
            self,
            should_embed=True,
            vocab=None,
            representation='dense',
            embedding_size=256,
            embeddings_trainable=True,
            pretrained_embeddings=None,
            embeddings_on_cpu=False,
            conv_layers=None,
            num_conv_layers=None,
            filter_size=3,
            num_filters=256,
            pool_size=None,
            fc_layers=None,
            num_fc_layers=None,
            fc_size=256,
            norm=None,
            activation='relu',
            dropout=False,
            initializer=None,
            regularize=True,
            reduce_output='max',
            **kwargs):
```

RNN encoding

```
name: text_csv_column_name
type: text
encoder: rnn
level: word / char
tied_weights: null
representation: dense / sparse
embedding_size: 256
embeddings_on_cpu: false
pretrained_embeddings: null
embeddings_trainable: true
num_layers: 1
cell_type: rnn
state_size: 256
bidirectional: false
dropout: false
initializer: null
regularize: true
reduce_output: sum
```

Grey parameters are optional

Sequence, Time Series and Audio / Speech encoders

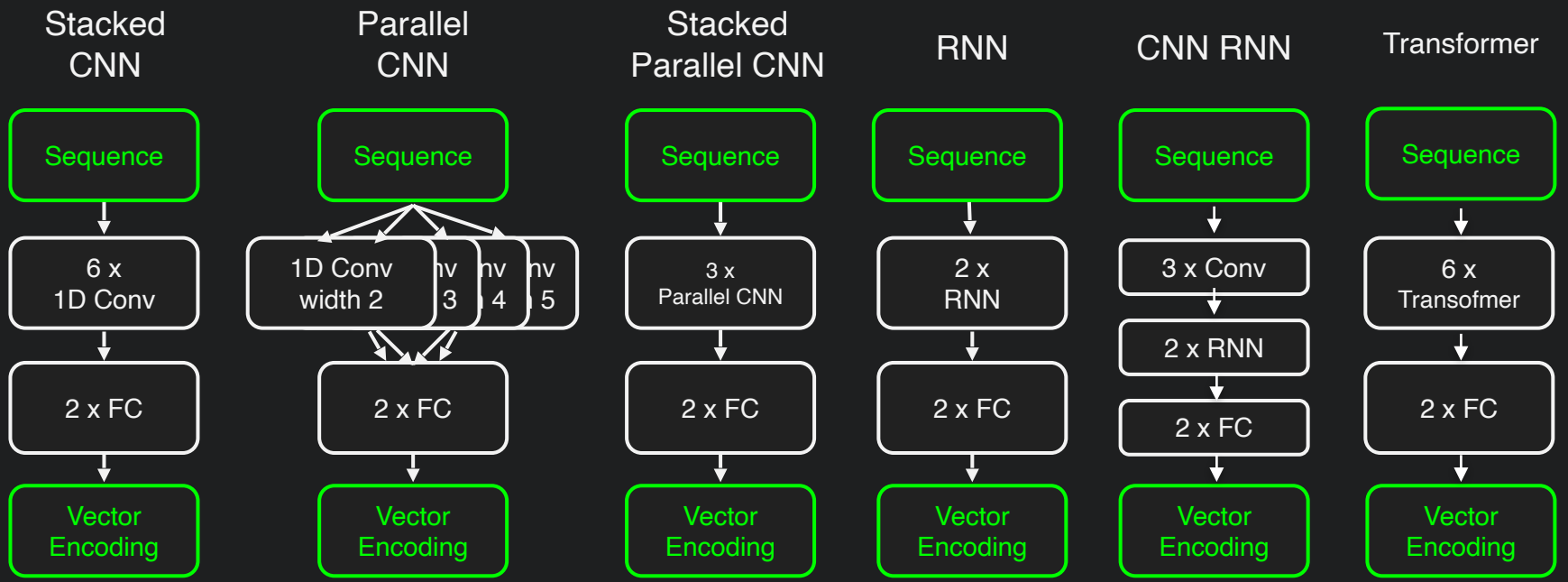
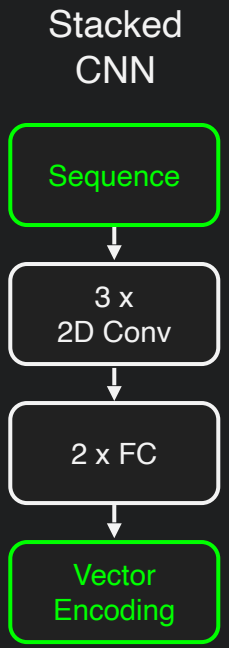
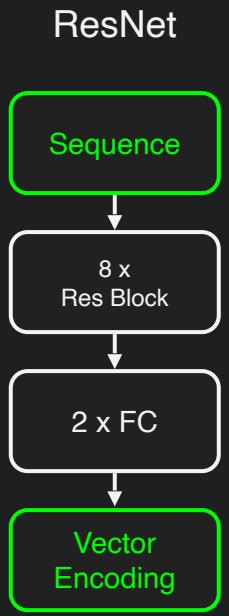


Image feature encoders

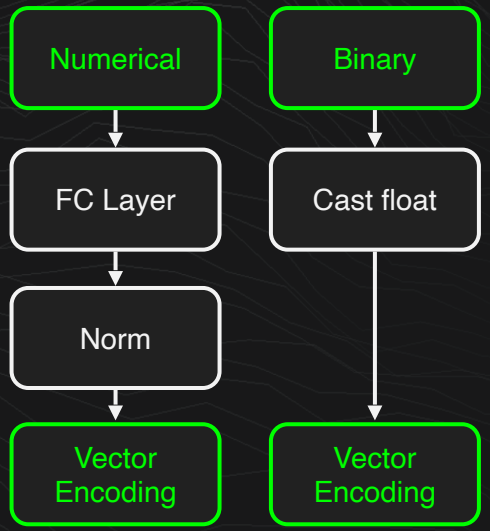




Numerical and binary features encoders

Numerical features are encoded with one FC layer + Norm for scaling purposes or are used as they are

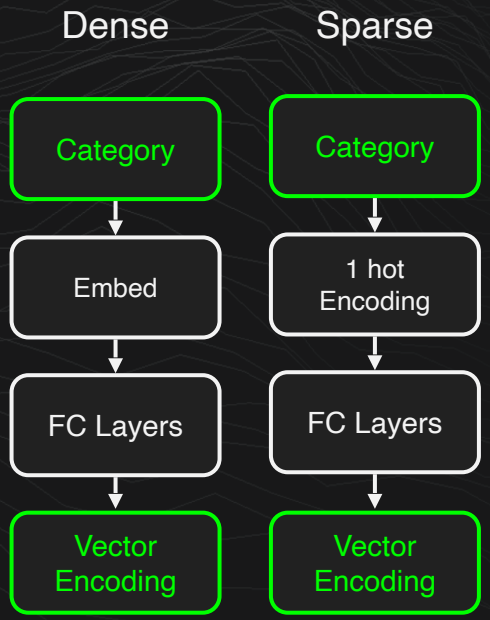
Binary features are just casted to floats



Category features encoders

If the dense encoder is specified, the embedding dimension cal also be provided

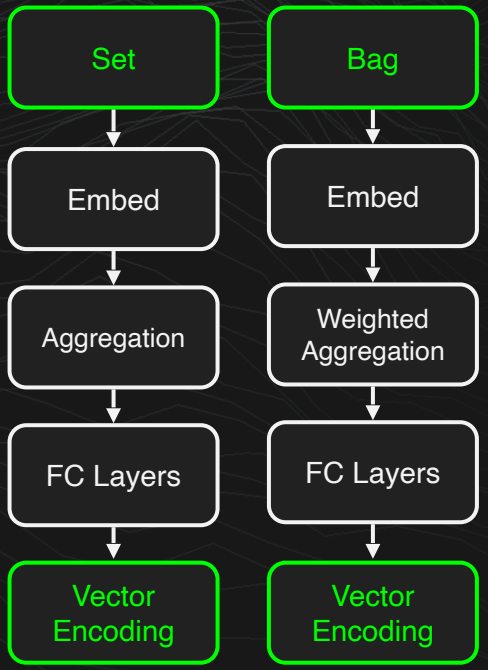
Alternatively the sparse 1 hot encoder can be used



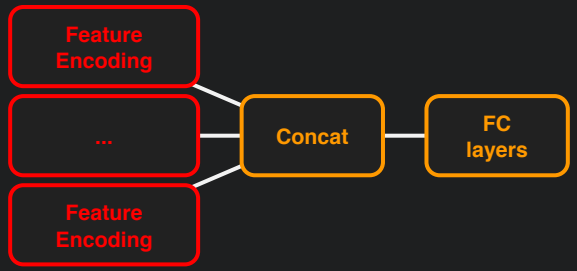
Set and bag features encoders

They are both encoded by embedding the items, aggregating them, and passing them through FC layers

In the case of bags, the aggregation is a weighted sum



Concat combiner

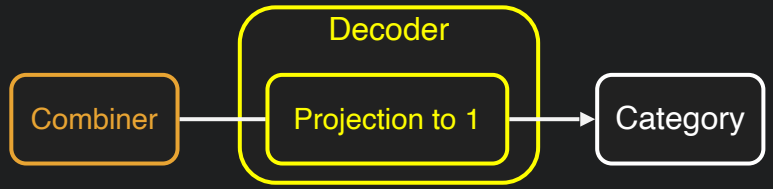



```
combiner:
  type: concat
  fc_layers: null
  num_fc_layers: 0
  fc_size: 256
  activation: relu
  norm: null
  dropout: false
  initializer: null
  regularize: true
```

Grey parameters are optional

Numerical features decoding

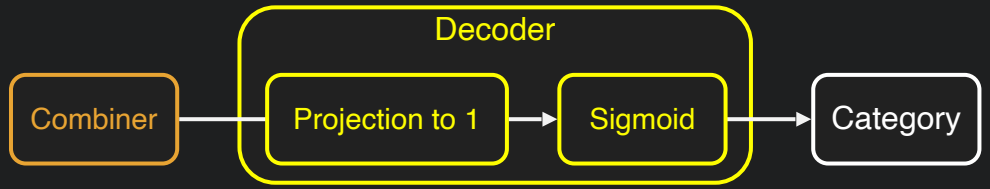
```
name: numerical_csv_column_name
type: numerical
reduce_inputs: sum
loss:
    type: mean_squared_error
fc_layers: null
num_fc_layers: 0
fc_size: 256
activation: relu
norm: null
dropout: false
initializer: null
regularize: true
```



Binary features decoding

```
name: binary_csv_column_name
type: binary
reduce_inputs: sum
loss:
    type: cross_entropy
    confidence_penalty: 0
    robust_lambda: 0
fc_layers: null
num_fc_layers: 0
fc_size: 256
activation: relu
norm: null
dropout: false
initializer: null
regularize: true
threshold: 0.5
```

Grey parameters are optional

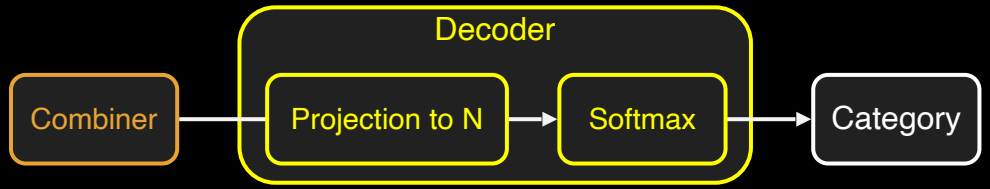


Category features decoding

```
name: category_csv_column_name
type: category
reduce_inputs: sum
loss:
  type: softmax_cross_entropy
  confidence_penalty: 0
  robust_lambda: 0
  class_weights: 1
  class_distances: null
  class_distance_temperature: 0
  labels_smoothing: 0
  negative_samples: 0
  sampler: null
  distortion: 1
  unique: false
fc_layers: null
num_fc_layers: 0
```

```
fc_size: 256
activation: relu
norm: null
dropout: false
initializer: null
regularize: true
top_k: 3
```

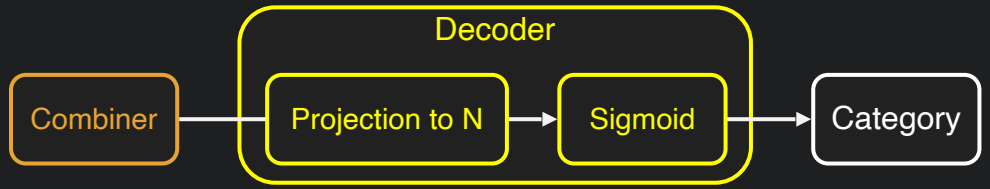
Grey parameters are optional



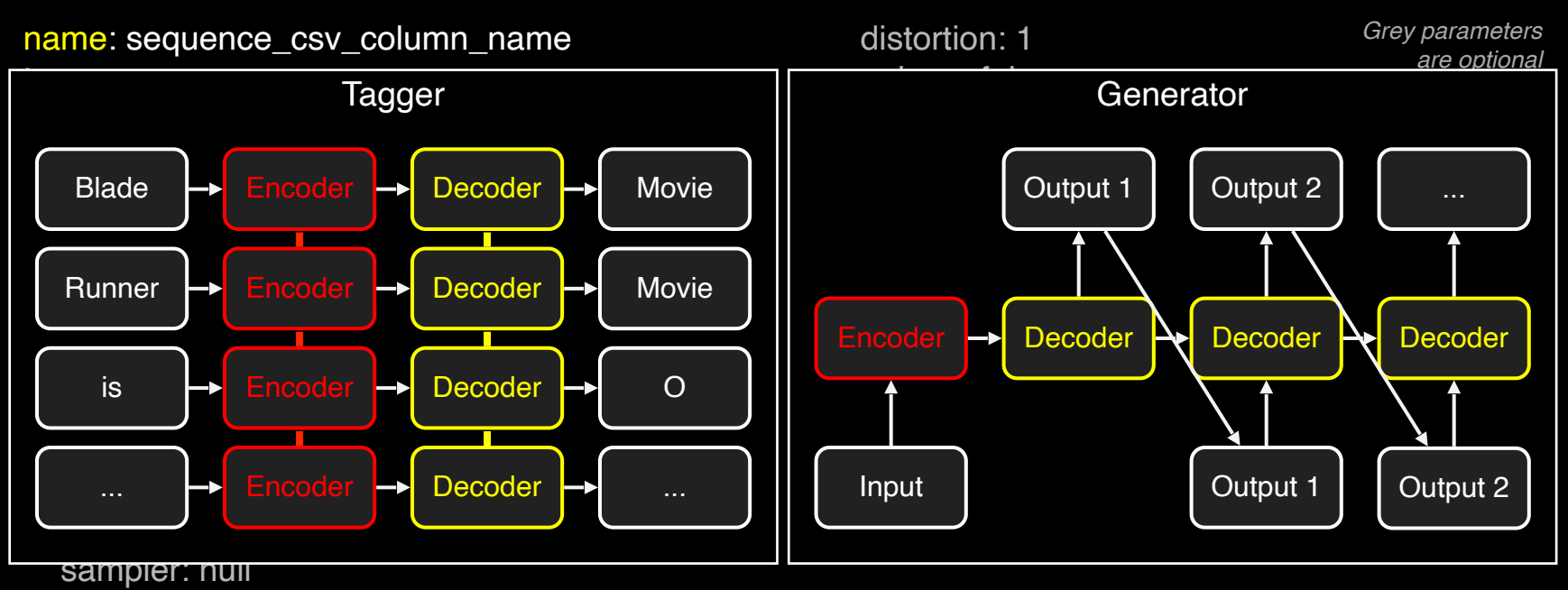
Set features decoding

Grey parameters

```
name: set_csv_column_name
type: set
reduce_inputs: sum
loss:
    type: sigmoid_cross_entropy
fc_layers: null
num_fc_layers: 0
fc_size: 256
activation: relu
norm: null
dropout: false
initializer: null
regularize: true
threshold: 0.5
```



Sequence features decoding



Training parameters

Everything is optional

```
training:
  batch_size: 128
  epochs: 100
  early_stop: 5
  optimizer: {type: adam, beta1: 0.9, beta2: 0.999, epsilon: 1e-08}
  learning_rate: 0.001
  decay: false
  decay_rate: 0.96
  decay_steps: 10000
  staircase: false
  regularization_lambda: 0
  dropout_rate: 0.0
  reduce_learning_rate_on_plateau: 0
  reduce_learning_rate_on_plateau_patience: 5
  reduce_learning_rate_on_plateau_rate: 0.5
  increase_batch_size_on_plateau: 0
  increase_batch_size_on_plateau_patience: 5
  increase_batch_size_on_plateau_rate: 2
  increase_batch_size_on_plateau_max: 512
  validation_field: combined
  validation_measure: accuracy
  bucketing_field: null
```

Preprocessing parameters

```
preprocessing:
  force_split: False,
  split_probabilities: (0.7, 0.1, 0.2),
  stratify: None
  text:
    char_format: characters,
    char_most_common: 70,
    char_sequence_length_limit: 1024,
    fill_value: ,
    lowercase: True,
    missing_value_strategy: fill_with_const,
    padding: right,
    padding_symbol: <PAD>,
    unknown_symbol: <UNK>,
    word_format: space_punct,
    word_most_common: 20000,
    word_sequence_length_limit: 256,
  category:
    fill_value: <UNK>,
    lowercase: False,
    missing_value_strategy: fill_with_const,
    most_common: 10000
```

```
sequence:
  ...
set:
  ...
...
```

Everything is optional

Custom Encoder Example

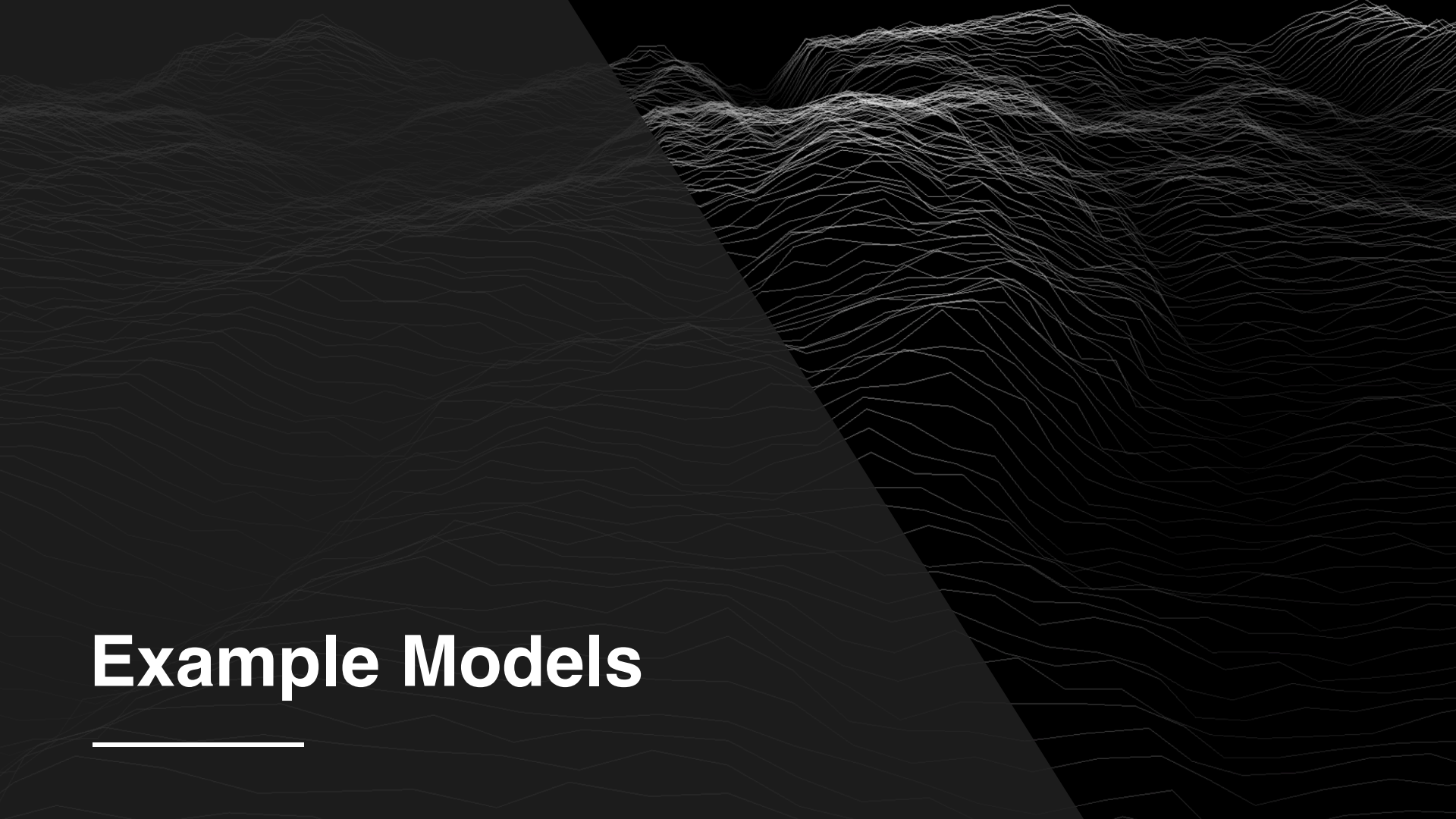
```
class MySequenceEncoder:

  def __init__(
    self,
    my_param=whatever,
    **kwargs
  ):
    self.my_param = my_param

  def __call__(
    self,
    input_sequence,
    regularizer,
    is_training=True
  ):
    # input_sequence = [b x s] int32
    # every element of s is the
    # int32 id of a token

    your code goes here
    it can use self.my_param

    # hidden to return is
    # [b x s x h] or [b x h]
    # hidden_size is h
    return hidden, hidden_size
```



Example Models

Text Classification

NEWS	CLASS
Toronto Feb 26 - Standard Trustco said it expects earnings in 1987 to increase at least 15...	earnings
New York Feb 26 - American Express Co remained silent on market rumors...	acquisition
BANGKOK March 25 - Vietnam will resettle 300 000 people on state farms known as new economic...	coffe

```
ludwig experiment
--data_csv reuters-allcats.csv
--model_definition "{input_features: [{name: news, type:
text, encoder: parallel_cnn, level: word}], output_features:
[{name: class, type: category}]}"
```

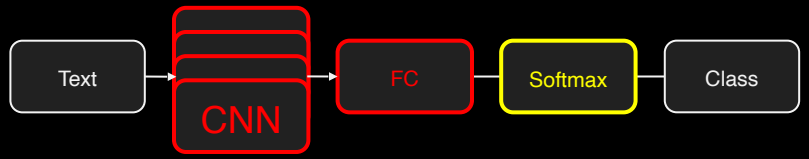


Image Object Classification (MNIST, ImageNet, ..)

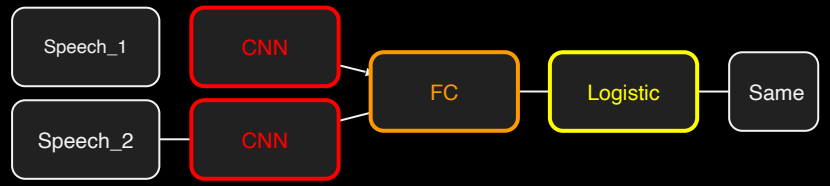
IMAGE_PATH	CLASS
imagenet/image_000001.jpg	car
imagenet/image_000002.jpg	dog
imagenet/image_000003.jpg	boat

```
ludwig experiment
--data_csv imagenet.csv
--model_definition "{input_features: [{name: image_path,
type: image, encoder: stacked_cnn}], output_features:
[{name: class, type: category}]}"
```

Speaker Verification

SPEECH_PATH_1	SPEECH_PATH_2	SAME
speech_01_01.wav	speech_01_02.wav	TRUE
speech_01_02.wav	speech_02_01.wav	FALSE
speech_02_01.wav	speech_02_02.wav	TRUE

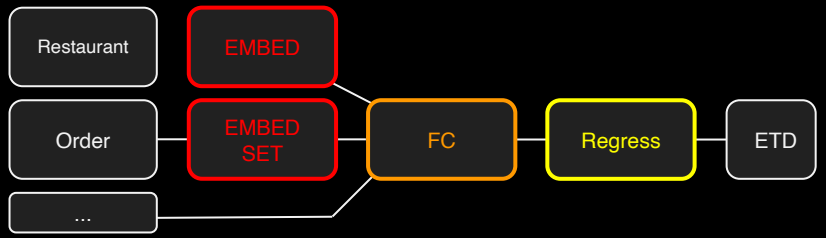
```
ludwig experiment
--data_csv imagenet.csv
--model_definition "{input_features: [{name:
speech_path_1, type: audio}, {name: speech_path_2,
type: audio, tied_weights: speech_path_1}],
output_features: [{name: same, type: binary}]}"
```



Expected Time of Delivery

RESTAURANT	ORDER	HOUR	MIN	ETD
Halal Guys	Chicken kebab, Lamb kebab	20	00	20
Il Casaro	Margherita	18	53	15
CurryUp	Chicken Tikka Masala, Veg Curry	21	10	35

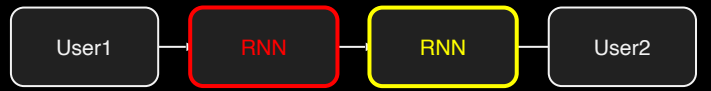
```
ludwig experiment
--data_csv eats_etd.csv
--model_definition "{input_features: [{name: restaurant,
type: category, encoder: embed}, {name: order, type:
bag}, {name: hour, type: numerical}, {name: min, type:
numerical}], output_features: [{name: etd, type: numerical,
loss: {type: mean_absolute_error}}]}"
```



Sequence2Sequence Chit-Chat Dialogue Model

USER1	USER2
Hello! How are you doing?	Doing well, thanks!
I got promoted today	Congratulations!
Not doing well today	I'm sorry, can I do something to help you?

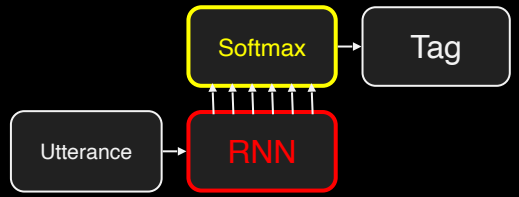
```
ludwig experiment
--data_csv chitchat.csv
--model_definition "{input_features: [{name: user1, type:
text, encoder: rnn, cell_type: lstm}], output_features:
[{name: user2, type: text, decoder: generator, cell_type:
lstm, attention: bahdanau}]}"
```



Sequence Tagging for sequences or time series

UTTERANCE	TAG
Blade Runner is a 1982 neo-noir science fiction film directed by Ridley Scott	N N O O D O O O O O O P P
Harrison Ford and Rutger Hauer starred in it	P P O P P O O O
Philip Dick 's novel Do Androids Dream of Electric Sheep ? was published in 1968	P P O O N N N N N N N O O O D

```
ludwig experiment
--data_csv sequence_tags.csv
--model_definition "{input_features: [{name: utterance,
type: text, encoder: rnn, cell_type: lstm}], output_features:
[{name: tag, type: sequence, decoder: tagger}]}"
```



Programmatic API

Easy to install:
pip install ludwig

Programmatic API:

```
from ludwig.api import LudwigModel
model = LudwigModel(model_definition)
model.train(train_data)
# or model = LudwigModel.load(path)
predictions = model.predict(other_data)
```

Additional Goodies

Model serving:

Ludwig serve --model_path <model_path>

Integration with other tools:

- Train models distributedly using **Horovod**
- Deploy models seamlessly using **PyML**
- Hyper-parameters optimization using **BOCS / Fiber**

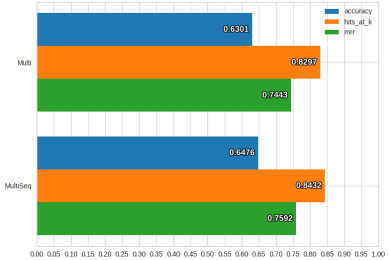
Hyper-parameter optimization

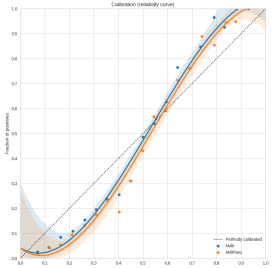
```
{"task": "python",
  "task_params": {
    "file": "/home/work/wrapper.py",
    "function": "ludwig_wrapper",
    "kwargs": {
      "base_model_definition": {
        "input_features": [
          {
            "type": "text",
            "encoder": "parallel_cnn"
          },
          {
            "name": "flow_node",
            "type": "categorical",
            "representation": "dense"
          }
        ],
        "output_features": [
          {
            "name": "contact_type",
            "type": "category"
          }
        ],}}}
```

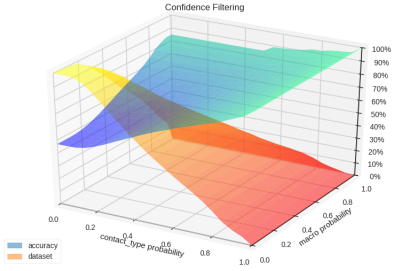
```
"strategy": "random", <- grid / random / bayesian
  "strategy_params": {
    "samples_limit": 50
  },
  "params": {
    "training__dropout": {
      "type": "float",
      "min": 0.0,
      "max": 0.5
    },
    "flow_node__embedding_size": {
      "type": "int",
      "min": 50,
      "max": 500
    }
  }
}
```

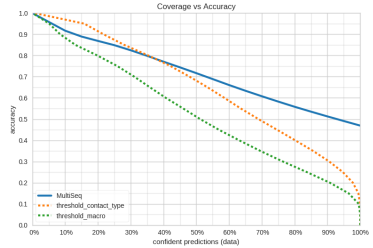
Visualizations

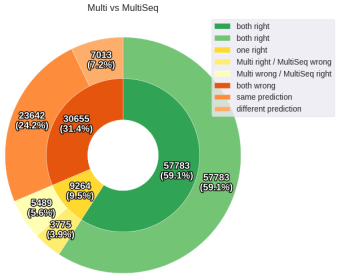
Visualizations are one command away

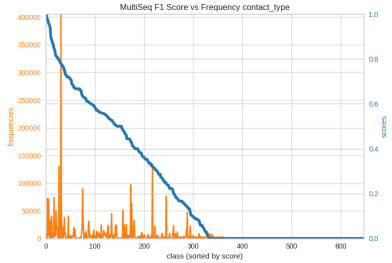












Next steps

- Eager mode by porting to TensorFlow 2
  - More features: nested lists, point clouds, videos
  - More pre-trained inputs encoders
  - Adding missing decoders
- Hyper-parameter optimization
- Pluggable data pipelines
  - **Petastorm** integration to work with Parquet on HDFS

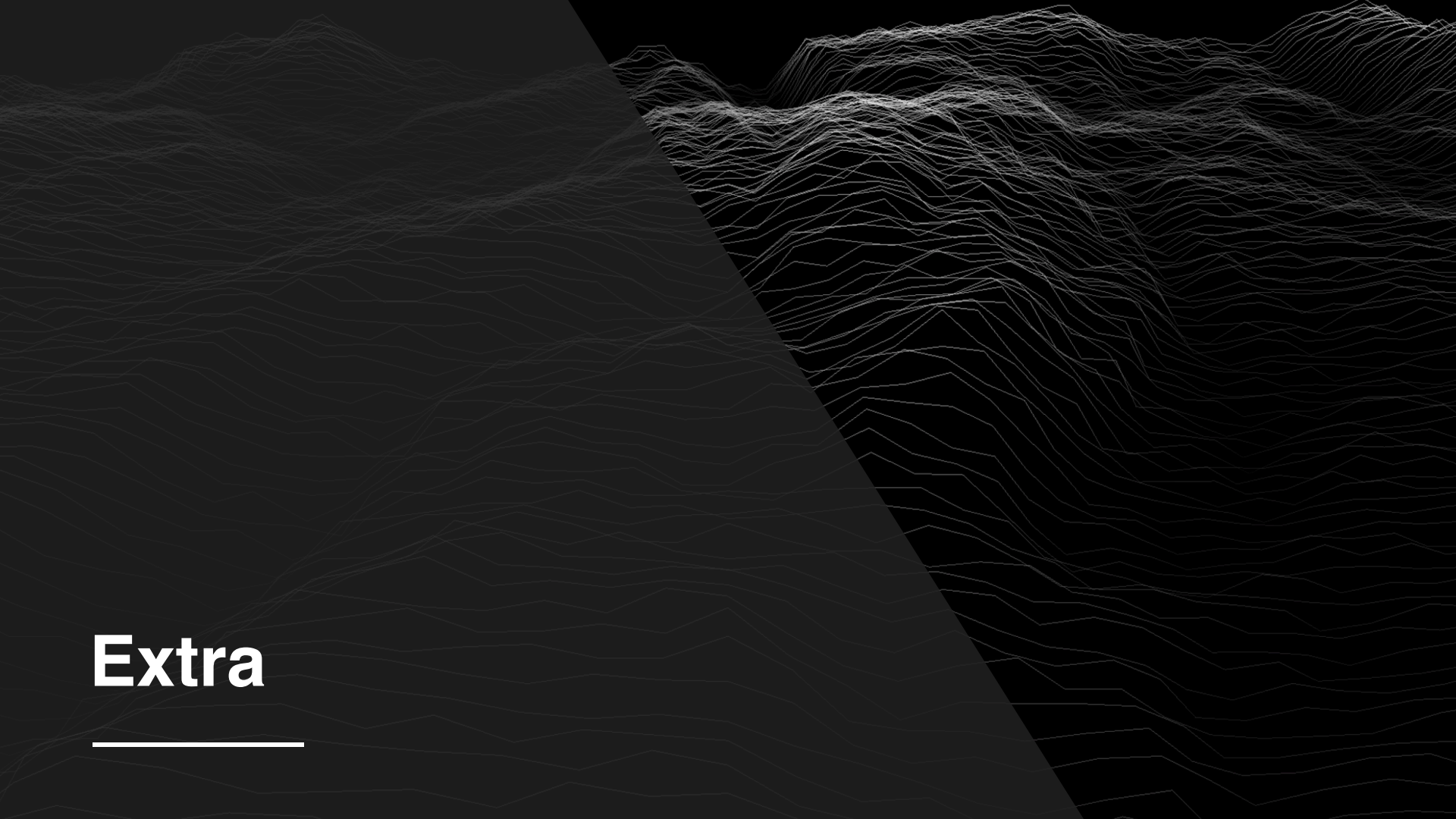
Collaborations

Documentation
http://ludwig.ai

Repository
http://uber.github.com/ludwig

Blogpost
http://eng.uber.com/introducing_ludwig

Key contributors:
Yaroslav Dudin
Sai Sumanth Miryala



Extra

Machine Learning democratization

Non-expert users

From **idea** to **model** training in **minutes**

No need for **coding and deep knowledge**

Easy **declarative** model construction hides **complexity**

Expert users

Efficient exploration of model space through **quick iteration**

Tweak **every aspect** of preprocessing, modeling and training

Extend with your models