ESPnet for speech recognition

Author: Shigeki Karita (https://github.com/ShigekiKarita)

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About me

- Shigeki Karita
- Working at NTT Communication Science Laboratories, Kyoto
- Interests: Speech recognition, HPC
- Contributed to ESPnet:
    - From 2017 - 2019
    - Pytorch backend
    - CI infracture (Travis, Circle CI)
    - Documentation (Sphinx)

Abstract

This example shows you a practical ASR example using ESPnet as a command line interface, and also as a library.

See also

- runnable notebook https://colab.research.google.com/drive/1YA8Cf3_mX41Ku5D01bHOynzDw9gIyW (https://colab.research.google.com/drive/1YA8Cf3_mX41Ku5D01bHOynzDw9gIyW
- documetation https://espnet.github.io/espnet/ (https://espnet.github.io/espnet/)
- github https://github.com/espnet (https://github.com/espnet)

Installation

ESPnet depends on Kaldi ASR toolkit and Warp-CTC. This will take a few minutes.

In [0]:

```
# OS setup
!sudo apt-get install bc tree
!cat /etc/os-release

# espnet setup
!git clone https://github.com/espnet/espnet
!cd espnet; pip install -e .
!mkdir -p espnet/tools/venv/bin; touch espnet/tools/venv/bin/activate

# warp ctc setup
!git clone https://github.com/espnet/warp-ctc -b pytorch-1.1
!cd warp-ctc && mkdir build && cd build && cmake .. && make -j4
!cd warp-ctc/pytorch_binding && python setup.py install

# kaldi setup
!cd ./espnet/tools; git clone https://github.com/kaldi-asr/kaldi
!echo "" > ./espnet/tools/kaldi/tools/extras/check_dependencies.sh # ignore chec
k
!chmod +x ./espnet/tools/kaldi/tools/extras/check_dependencies.sh
!cd ./espnet/tools/kaldi/tools; make sph2pipe sclite
!rm -rf espnet/tools/kaldi/tools/python
![ ! -e ubuntu16-featbin.tar.gz ] && wget https://18-198329952-gh.circle-artifac
ts.com/0/home/circleci/repo/ubuntu16-featbin.tar.gz
!tar -xf ./ubuntu16-featbin.tar.gz
!cp featbin/* espnet/tools/kaldi/src/featbin/
```

```
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following package was automatically installed and is no longer required:
  libnvidia-common-410
Use 'sudo apt autoremove' to remove it.
The following NEW packages will be installed:
  bc tree
0 upgraded, 2 newly installed, 0 to remove and 7 not upgraded.
Need to get 127 kB of archives.
After this operation, 329 kB of additional disk space will be used.
```

ESPnet command line usage (espnet/egs/xxx)

You can use the end-to-end script `run.sh` for reproducing systems reported in `espnet/egs/*/asr1/RESULTS.md`. Typically, we organize `run.sh` with several stages:

1. Data download (if available)
2. Kaldi-style data preparation
3. Save python-friendly data (e.g., JSON, HDF5, etc)
4. Lanuage model training
5. ASR model training
6. Decoding and evaluation

In [0]:
```
!ls espnet/egs
```

```
aishell   cmu_wilderness           jnas         ljspeech     timit
ami       csj                      jsalt18e2e   m_ailabs     voxforge
an4       fisher_callhome_spanish  jsut         reverb       wsj
aurora4   fisher_swbd              li10         ru_open_stt  wsj_mix
babel     hkust                    librispeech  swbd         yesno
chime4    hub4_spanish             libri_trans  tedlium2
chime5    iwslt18                  libritts     tedlium3
```

Stage 0 - 2 Data preparation

For example, if you add `--stop-stage 2`, you can stop the script before neural network training.

In [0]:
```
!cd espnet/egs/an4/asr1; ./run.sh  --ngpu 1 --stop-stage 2
```

```
stage -1: Data Download
local/download_and_untar.sh: an4 directory already exists in ./downloads
stage 0: Data preparation
stage 1: Feature Generation
steps/make_fbank_pitch.sh --cmd run.pl --nj 8 --write_utt2num_frames true dat
a/test exp/make_fbank/test fbank
steps/make_fbank_pitch.sh: moving data/test/feats.scp to data/test/.backup
utils/validate_data_dir.sh: Successfully validated data-directory data/test
steps/make_fbank_pitch.sh: [info]: no segments file exists: assuming wav.scp i
ndexed by utterance.
steps/make_fbank_pitch.sh: Succeeded creating filterbank and pitch features fo
r test
fix_data_dir.sh: kept all 130 utterances.
fix_data_dir.sh: old files are kept in data/test/.backup
steps/make_fbank_pitch.sh --cmd run.pl --nj 8 --write_utt2num_frames true dat
a/train exp/make_fbank/train fbank
steps/make_fbank_pitch.sh: moving data/train/feats.scp to data/train/.backup
utils/validate_data_dir.sh: Successfully validated data-directory data/train
steps/make_fbank_pitch.sh: [info]: no segments file exists: assuming wav.scp i
ndexed by utterance.
steps/make_fbank_pitch.sh: Succeeded creating filterbank and pitch features fo
r train
fix_data_dir.sh: kept all 948 utterances.
fix_data_dir.sh: old files are kept in data/train/.backup
utils/subset_data_dir.sh: reducing #utt from 948 to 100
utils/subset_data_dir.sh: reducing #utt from 948 to 848
compute-cmvn-stats scp:data/train_nodev/feats.scp data/train_nodev/cmvn.ark
LOG (compute-cmvn-stats[5.5.428~1-29b3]:main():compute-cmvn-stats.cc:168) Wrot
e global CMVN stats to data/train_nodev/cmvn.ark
LOG (compute-cmvn-stats[5.5.428~1-29b3]:main():compute-cmvn-stats.cc:171) Done
accumulating CMVN stats for 848 utterances; 0 had errors.
/content/espnet/egs/an4/asr1/../../../utils/dump.sh --cmd run.pl --nj 8 --do_d
elta false data/train_nodev/feats.scp data/train_nodev/cmvn.ark exp/dump_feat
s/train dump/train_nodev/deltafalse
/content/espnet/egs/an4/asr1/../../../utils/dump.sh --cmd run.pl --nj 8 --do_d
```

```
elta false data/train_dev/feats.scp data/train_nodev/cmvn.ark exp/dump_feats/d
ev dump/train_dev/deltafalse
/content/espnet/egs/an4/asr1/../../../utils/dump.sh --cmd run.pl --nj 8 --do_d
elta false data/train_dev/feats.scp data/train_nodev/cmvn.ark exp/dump_feats/r
ecog/train_dev dump/train_dev/deltafalse
/content/espnet/egs/an4/asr1/../../../utils/dump.sh --cmd run.pl --nj 8 --do_d
elta false data/test/feats.scp data/train_nodev/cmvn.ark exp/dump_feats/recog/
test dump/test/deltafalse
dictionary: data/lang_1char/train_nodev_units.txt
stage 2: Dictionary and Json Data Preparation
28 data/lang_1char/train_nodev_units.txt
/content/espnet/egs/an4/asr1/../../../utils/data2json.sh --feat dump/train_nod
ev/deltafalse/feats.scp data/train_nodev data/lang_1char/train_nodev_units.txt
/content/espnet/egs/an4/asr1/../../../utils/feat_to_shape.sh --cmd run.pl --nj
1 --filetype  --preprocess-conf  --verbose 0 dump/train_nodev/deltafalse/feat
s.scp data/train_nodev/tmp-dTUdQ/input/shape.scp
/content/espnet/egs/an4/asr1/../../../utils/data2json.sh --feat dump/train_de
v/deltafalse/feats.scp data/train_dev data/lang_1char/train_nodev_units.txt
/content/espnet/egs/an4/asr1/../../../utils/feat_to_shape.sh --cmd run.pl --nj
1 --filetype  --preprocess-conf  --verbose 0 dump/train_dev/deltafalse/feats.s
cp data/train_dev/tmp-eDDsN/input/shape.scp
/content/espnet/egs/an4/asr1/../../../utils/data2json.sh --feat dump/train_de
v/deltafalse/feats.scp data/train_dev data/lang_1char/train_nodev_units.txt
/content/espnet/egs/an4/asr1/../../../utils/feat_to_shape.sh --cmd run.pl --nj
1 --filetype  --preprocess-conf  --verbose 0 dump/train_dev/deltafalse/feats.s
cp data/train_dev/tmp-CW4nd/input/shape.scp
/content/espnet/egs/an4/asr1/../../../utils/data2json.sh --feat dump/test/delt
afalse/feats.scp data/test data/lang_1char/train_nodev_units.txt
/content/espnet/egs/an4/asr1/../../../utils/feat_to_shape.sh --cmd run.pl --nj
1 --filetype  --preprocess-conf  --verbose 0 dump/test/deltafalse/feats.scp da
ta/test/tmp-0xpK2/input/shape.scp
```

Kaldi-style directory structure

Always we organize each recipe placed in `egs/xxx/asr1` in Kaldi way:

- `conf/`: kaldi configurations, e.g., speech feature
- `data/`: almost raw data prepared by Kaldi (https://kaldi-asr.org/doc/data_prep.html)
- `exp/`: intermidiate files through experiments, e.g., log files, model parameters
- `fbank/`: speech feature binary files, e.g., ark, scp (https://kaldi-asr.org/doc/io.html)
- `dump/`: ESPnet meta data for tranining, e.g., json, hdf5
- `local/`: corpus specific data preparation scripts
- steps/ (https://github.com/kaldi-asr/kaldi/tree/master/egs/wsj/s5/steps), utils/ (https://github.com/kaldi-asr/kaldi/tree/master/egs/wsj/s5/utils): Kaldi's helper scripts

In [0]:
```
!tree -L 1 espnet/egs/an4/asr1
```

```
espnet/egs/an4/asr1
├── cmd.sh
├── conf
├── data
├── downloads
├── dump
├── exp
├── fbank
├── local
├── path.sh
├── RESULTS
├── run.sh
├── steps -> ../../../tools/kaldi/egs/wsj/s5/steps
└── utils -> ../../../tools/kaldi/egs/wsj/s5/utils

9 directories, 4 files
```

TIPS: essential files in data preparation

To create a new recipe, all you need is stage 1 that creates key-value pair files:

- speech `data/xxx/wav.scp`
- text `data/xxx/text`

raw speech file list

raw text list

In [0]:
```
!head espnet/egs/an4/asr1/data/train/text
```

```
fash-an251-b YES
fash-an253-b GO
fash-an254-b YES
fash-an255-b U M N Y H SIX
fash-cen1-b H I N I C H
fash-cen2-b A M Y
fash-cen4-b M O R E W O O D
fash-cen5-b P I T T S B U R G H
fash-cen7-b TWO SIX EIGHT FOUR FOUR ONE EIGHT
fbbh-an86-b C Z D Z W EIGHT
```

TIPS: explore datasets with data.json

To explore datasets easily, ESPnet stores metadata `dump/xxx/data.json` in the stage 2.

In [0]:

```
import json
import matplotlib.pyplot as plt
import kaldiio

# load 10-th speech/text in data.json
root = "espnet/egs/an4/asr1"
with open(root + "/dump/test/deltafalse/data.json", "r") as f:
  test_json = json.load(f)["utts"]

key, info = list(test_json.items())[10]

# plot the speech feature
fbank = kaldiio.load_mat(info["input"][0]["feat"])
plt.matshow(fbank.T[::-1])
plt.title(key + ": " + info["output"][0]["text"])

# print the key-value pair
key, info
```

Out[0]:

```
('fcaw-cen6-b',
 {'input': [{'feat': '/content/espnet/egs/an4/asr1/dump/test/deltafalse/feats.
1.ark:271757',
    'name': 'input1',
    'shape': [288, 83]}],
  'output': [{'name': 'target1',
    'shape': [22, 30],
    'text': 'ONE FIVE TWO THREE SIX',
    'token': 'O N E <space> F I V E <space> T W O <space> T H R E E <space> S
I X',
    'tokenid': '17 16 7 2 8 11 24 7 2 22 25 17 2 22 10 20 7 7 2 21 11 26'}],
  'utt2spk': 'fcaw'})
```

Stage 3 - 4 NN Training

Let's go to the most interesting part...

In [0]:
```
!tail espnet/egs/an4/asr1/conf/train_mtlalpha1.0.yaml
```

```
dlayers: 1
dunits: 300
# attention related
atype: location
adim: 320
aconv-chans: 10
aconv-filts: 100

# hybrid CTC/attention
mtlalpha: 1.0
```

In [0]:
```
!cd espnet/egs/an4/asr1; ./run.sh  --ngpu 1 --stage 3 --stop-stage 4 --train-con
fig ./conf/train_mtlalpha1.0.yaml
```

```
dictionary: data/lang_1char/train_nodev_units.txt
stage 3: LM Preparation
WARNING:root:OOV rate = 0.00 %
stage 4: Network Training
```

TIPS: change_yaml.py

You can tweak YAML config by **$(change_yaml.py xxx.yaml -a yyy=zzz)**

In [0]:
```
!cd espnet/egs/an4/asr1; source path.sh; \
  ./run.sh  --ngpu 1 --stage 4 --stop-stage 4 \
  --train-config $(change_yaml.py ./conf/train_mtlalpha1.0.yaml -a eunits=100)
```

```
dictionary: data/lang_1char/train_nodev_units.txt
stage 4: Network Training
```

TIPS: tensorboard

You can easily monitor effects of the config by tensorboard

In [0]:
```
!pip install -q tf-nightly-2.0-preview
# Load the TensorBoard notebook extension
%load_ext tensorboard
%tensorboard --logdir espnet/egs/an4/asr1/tensorboard
```

```
Reusing TensorBoard on port 6006 (pid 12588), started 0:40:18 ago. (Use '!kill
12588' to kill it.)
```

TensorBoard SCALARS INACTIVE

Show data download links

Ignore outliers in chart scalin

Tooltip sorting method: default

Smoothing

0

Horizontal Axis

STEP RELATIVE

WALL

Runs

Write a regex to filter runs

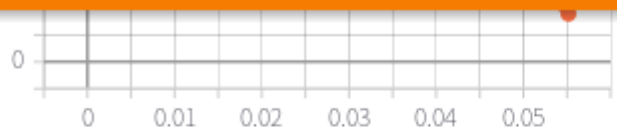
train_nodev_pytorch_train_mtlalpha1.0

train_nodev_pytorch_train_mtlalpha1.0_eunits100

train_rnnlm_pytorch_lm_word100

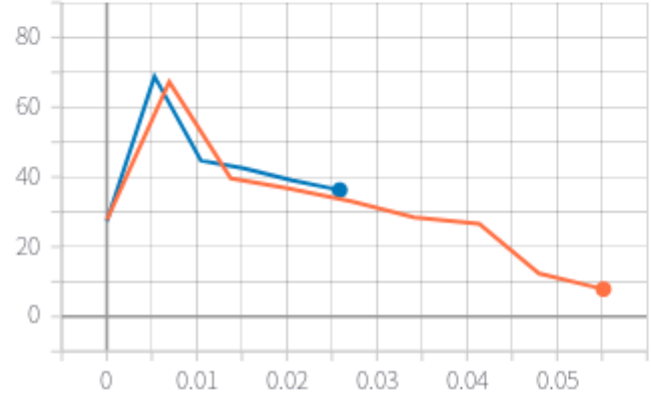
TOGGLE ALL RUNS

espnet/egs/an4/asr1/tensorboard



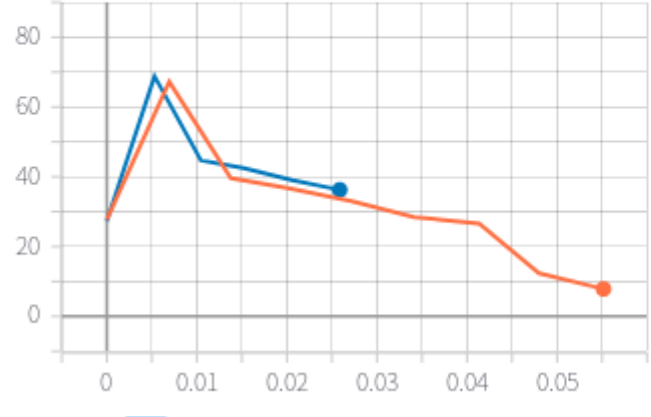
loss

tag: main/loss



loss_ctc

tag: main/loss_ctc



Decoding and evaluation

decode config (`change_yaml.py` also works)

In [0]:
```
!cat espnet/egs/an4/asr1/conf/decode_ctcweight1.0.yaml
```

```
# decoding parameter
beam-size: 20
penalty: 0.0
maxlenratio: 0.0
minlenratio: 0.0
ctc-weight: 1.0
lm-weight: 1.0
```

Command line usage

In [0]:
```
!cd espnet/egs/an4/asr1; ./run.sh  --stage 5
```

```
dictionary: data/lang_1char/train_nodev_units.txt
stage 5: Decoding
2019-07-28 13:26:38,528 (splitjson:40) INFO: /usr/bin/python3 /content/espnet/
egs/an4/asr1/../../../utils/splitjson.py --parts 8 dump/train_dev/deltafalse/d
ata.json
2019-07-28 13:26:38,530 (splitjson:52) INFO: number of utterances = 100
2019-07-28 13:26:38,588 (splitjson:40) INFO: /usr/bin/python3 /content/espnet/
egs/an4/asr1/../../../utils/splitjson.py --parts 8 dump/test/deltafalse/data.j
son
2019-07-28 13:26:38,590 (splitjson:52) INFO: number of utterances = 130
2019-07-28 13:37:48,300 (concatjson:36) INFO: /usr/bin/python3 /content/espne
t/egs/an4/asr1/../../../utils/concatjson.py exp/train_nodev_pytorch_train_mtla
lpha1.0/decode_train_dev_decode_ctcweight1.0_lm_word100/data.1.json exp/train_
nodev_pytorch_train_mtlalpha1.0/decode_train_dev_decode_ctcweight1.0_lm_word10
0/data.2.json exp/train_nodev_pytorch_train_mtlalpha1.0/decode_train_dev_decod
e_ctcweight1.0_lm_word100/data.3.json exp/train_nodev_pytorch_train_mtlalpha1.
0/decode_train_dev_decode_ctcweight1.0_lm_word100/data.4.json exp/train_nodev_
pytorch_train_mtlalpha1.0/decode_train_dev_decode_ctcweight1.0_lm_word100/dat
a.5.json exp/train_nodev_pytorch_train_mtlalpha1.0/decode_train_dev_decode_ctc
weight1.0_lm_word100/data.6.json exp/train_nodev_pytorch_train_mtlalpha1.0/dec
ode_train_dev_decode_ctcweight1.0_lm_word100/data.7.json exp/train_nodev_pytor
ch_train_mtlalpha1.0/decode_train_dev_decode_ctcweight1.0_lm_word100/data.8.js
on
2019-07-28 13:37:48,303 (concatjson:46) INFO: new json has 100 utterances
2019-07-28 13:37:50,231 (json2trn:43) INFO: /usr/bin/python3 /content/espnet/e
gs/an4/asr1/../../../utils/json2trn.py exp/train_nodev_pytorch_train_mtlalpha
1.0/decode_train_dev_decode_ctcweight1.0_lm_word100/data.json data/lang_1char/
train_nodev_units.txt --num-spkrs 1 --refs exp/train_nodev_pytorch_train_mtlal
pha1.0/decode_train_dev_decode_ctcweight1.0_lm_word100/ref.trn --hyps exp/trai
n_nodev_pytorch_train_mtlalpha1.0/decode_train_dev_decode_ctcweight1.0_lm_word
100/hyp.trn
2019-07-28 13:37:50,231 (json2trn:45) INFO: reading exp/train_nodev_pytorch_tr
ain_mtlalpha1.0/decode_train_dev_decode_ctcweight1.0_lm_word100/data.json
2019-07-28 13:37:50,233 (json2trn:49) INFO: reading data/lang_1char/train_node
v_units.txt
```

ASR result as `data.json`

In [0]:
```
!head -n20 espnet/egs/an4/asr1/exp/train_nodev_pytorch_train_mtlalpha1.0/decode_
test_decode_ctcweight1.0_lm_word100/data.json
```


```
{
    "utts": {
        "fcaw-an406-b": {
            "output": [
                {
                    "name": "target1[1]",
                    "rec_text": "<blank><blank><blank>RUBOU<blank>T<blank><bla
nk><blank> T N E F THREE NINE<eos>",
                    "rec_token": "<blank> <blank> <blank> R U B O U <blank> T
<blank> <blank> <blank> <space> T <space> N <space> E <space> F <space> T H R
E E <space> N I N E <eos>",
                    "rec_tokenid": "0 0 0 20 23 4 17 23 0 22 0 0 0 2 22 2 16 2
7 2 8 2 22 10 20 7 7 2 16 11 16 7 29",
                    "score": -1.0287089347839355,
                    "shape": [
                        25,
                        30
                    ],
                    "text": "RUBOUT G M E F THREE NINE",
                    "token": "R U B O U T <space> G <space> M <space> E <space
> F <space> T H R E E <space> N I N E",
                    "tokenid": "20 23 4 17 23 22 2 9 2 15 2 7 2 8 2 22 10 20 7
7 2 16 11 16 7"
                }
            ],
            "utt2spk": "fcaw"
```

Recognize speech from python

Let's use ESPnet as a library and the trained model:

In [0]:
```
!ls espnet/egs/an4/asr1/exp/train_nodev_pytorch_train_mtlalpha1.0/results
```

```
cer.png           snapshot.ep.1   snapshot.ep.14  snapshot.ep.19  snapshot.ep.5
log               snapshot.ep.10  snapshot.ep.15  snapshot.ep.2   snapshot.ep.6
loss.png          snapshot.ep.11  snapshot.ep.16  snapshot.ep.20  snapshot.ep.7
model.json        snapshot.ep.12  snapshot.ep.17  snapshot.ep.3   snapshot.ep.8
model.loss.best   snapshot.ep.13  snapshot.ep.18  snapshot.ep.4   snapshot.ep.9
```

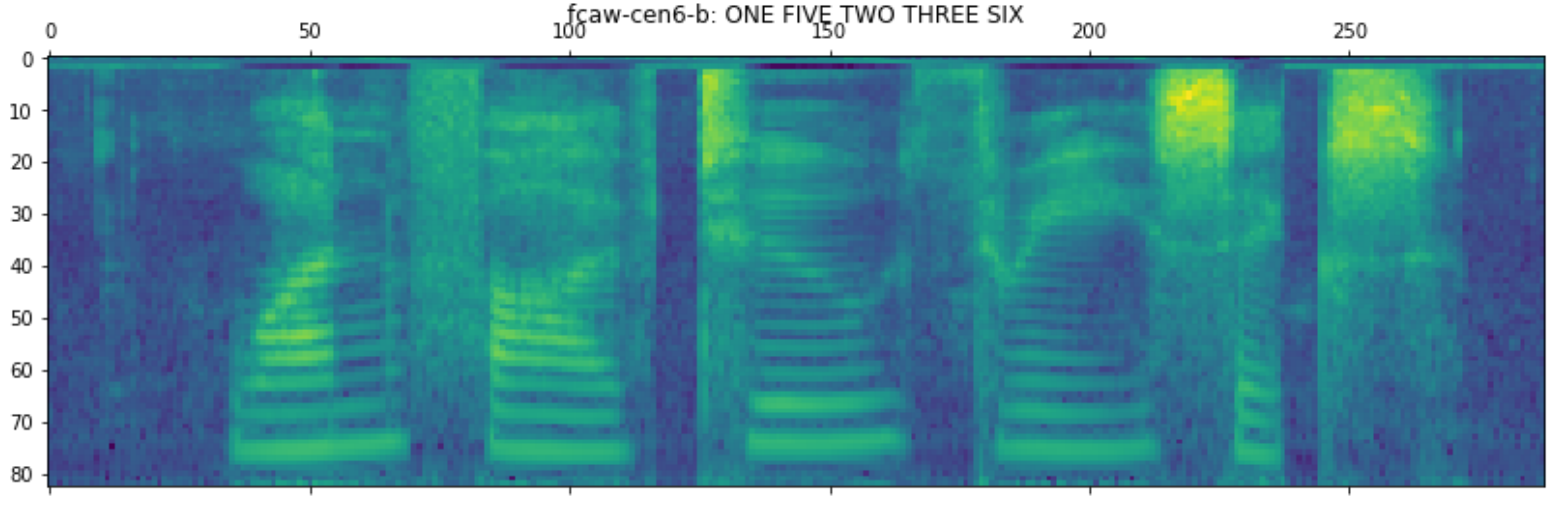
recap: load speech from data.json

In [0]:

```
import json
import matplotlib.pyplot as plt
import kaldiio

# load 10-th speech/text in data.json
root = "espnet/egs/an4/asr1"
with open(root + "/dump/test/deltafalse/data.json", "r") as f:
  test_json = json.load(f)["utts"]

key, info = list(test_json.items())[10]

# plot the speech feature
fbank = kaldiio.load_mat(info["input"][0]["feat"])
plt.matshow(fbank.T[::-1])
plt.title(key + ": " + info["output"][0]["text"])
```

Out[0]:

```
Text(0.5, 1.05, 'fcaw-cen6-b: ONE FIVE TWO THREE SIX')
```



load model

In [0]:

```
import json
import torch
import argparse
from espnet.bin.asr_recog import get_parser
from espnet.nets.pytorch_backend.e2e_asr import E2E

root = "espnet/egs/an4/asr1"
model_dir = root + "/exp/train_nodev_pytorch_train_mtlalpha1.0/results"

# load model
with open(model_dir + "/model.json", "r") as f:
  idim, odim, conf = json.load(f)
model = E2E(idim, odim, argparse.Namespace(**conf))
model.load_state_dict(torch.load(model_dir + "/model.loss.best"))
model.cpu().eval()

# recognize speech
parser = get_parser()
args = parser.parse_args(["--beam-size", "2", "--ctc-weight", "1.0", "--result-l
abel", "out.json", "--model", ""])
result = model.recognize(fbank, args, token_list)
s = "".join(conf["char_list"][y] for y in result[0]["yseq"]).replace("<eos>",
"").replace("<space>", " ").replace("<blank>", "")

print("groundtruth:", info["output"][0]["text"])
print("prediction: ", s)
```

```
groundtruth: ONE FIVE TWO THREE SIX
prediction:  ONE FIVE TWO THREY SIX
```

In [0]:

```
import os
import kaldiio
from IPython.display import Audio


try:
  d = os.getcwd()
  os.chdir(root)
  sr, wav = kaldiio.load_scp("data/test/wav.scp")[key]
finally:
  os.chdir(d)
Audio(wav, rate=sr)
```

Out[0]: