# nupic.research

***Release 0.0.1.dev0***

**Numenta**

**Apr 04, 2020**

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This repository contains the code for experimental algorithm work done internally at Numenta. A description of our core neuroscience research is available here. A description of how we are applying neuroscience research to machine learning (our current focus) is available here.

CHAPTER

ONE

# OPEN RESEARCH

We are dramatically open with our research. We even release our day to day research code into this repository. It contains experimental algorithm code done internally at Numenta. It includes prototypes and experiments with different algorithm implementations.

Please see this blog entry for a discussion on our commitment to Open Science and Open Research.

The NuPIC open source community continues to maintain and improve our more stable older algorithms. See https://discourse.numenta.org for discussions on that codebase - you can also post your research related questions there.

The ideas in this repository are constantly in flux as we tweak and experiment. Hence the following DISCLAIMERS:

CHAPTER

TWO

# WHAT YOU SHOULD UNDERSTAND ABOUT THIS REPOSITORY

- the code can change quickly and without warning as experiments are discarded and recreated
- code will not be production-quality, bug free, or well documented
- if we do work with external partners, that work will probably NOT be here
- we might decide at some point to not do our research in the open anymore and instead delete the whole repository

CHAPTER

THREE

# PAPERS

If you are interested in scripts and code used in published papers, this repository contains reproducible code for selected Numenta papers.

CHAPTER

FOUR

# INSTALLATION

OK, enough caveats. Here are some installation instructions though mostly you are on your own. (Wait, was that another caveat?)

When using anaconda virtual environment all you need to do is run the following command and conda will install everything for you. See environment.yml:

```
conda env create
```

Otherwise you need can install using setup.py like any python project. Since the contents here change often, we highly recommend installing as follows:

```
pip install -r requirements.txt
pip install -r requirements-dev.txt
python setup.py develop
```

You can test your installation by running the test script from the repository root:

```
python setup.py test
```

CHAPTER

FIVE

# ARCHIVE

Some of our old research code and experiments are archived in the following repositories:

- https://github.com/numenta/htmresearch (requires python 2.7)
- https://github.com/numenta-archive/htmresearch (requires python 2.7)

CHAPTER

SIX

# CONTENTS

## 6.1 API Reference

### 6.1.1 nupic.research

#### 6.1.1.1 nupic.research.frameworks

#### nupic.research.frameworks.pytorch

#### nupic.research.frameworks.pytorch.models

#### nupic.research.frameworks.pytorch.models.mobilenetv1

**class MobileNetV1**(*num_classes=1001*, *width_mult=1.0*)

Bases: `torch.nn.Module`

See https://arxiv.org/abs/1704.04861.

**forward**(*x*)

**mobile_net_v1_sparse_depth**(*num_classes=1001*, *width_mult=1.0*, *percent_on=0.1*, *k_inference_factor=1.0*, *boost_strength=1.0*, *boost_strength_factor=1.0*, *duty_cycle_period=1000*)

Create a MobileNetV1 network with sparse deep wise layers by replacing the Depth wise (3x3) convolution activation function from ReLU with k-winners.

**Parameters**

- **num_classes** (*int*) – Number of output classes (10 for CIFAR10)
- **width_mult** (*float*) – Width multiplier, used to thin the network
- **percent_on** (*float*) – The activity of the top k = percent_on * number of input units will be allowed to remain, the rest are set to zero.
- **kInferenceFactor** (*float*) – During inference (training=False) we increase percent_on by this factor. percent_on * kInferenceFactor must be strictly less than 1.0, ideally much lower than 1.0
- **boostStrength** (*float*) – boost strength (0.0 implies no boosting).
- **boostStrengthFactor** (*float*) – Boost strength factor to use [0..1]
- **dutyCyclePeriod** (*int*) – The period used to calculate duty cycles

**Returns** Depth wise Sparse MoblineNetV1 model

**mobile_net_v1_sparse_point**(*num_classes=1001*, *width_mult=1.0*, *percent_on=0.1*, *k_inference_factor=1.0*, *boost_strength=1.0*, *boost_strength_factor=1.0*, *duty_cycle_period=1000*)

Create a MobileNetV1 network with sparse point wise layers by replacing the Point wise (1x1) convolution activation function from ReLU with k-winners.

**Parameters**

- **num_classes** (*int*) – Number of output classes (10 for CIFAR10)
- **width_mult** (*float*) – Width multiplier, used to thin the network
- **percent_on** (*float*) – The activity of the top k = percent_on * number of input units will be allowed to remain, the rest are set to zero.
- **kInferenceFactor** (*float*) – During inference (training=False) we increase percent_on by this factor. percent_on * kInferenceFactor must be strictly less than 1.0, ideally much lower than 1.0
- **boostStrength** (*float*) – boost strength (0.0 implies no boosting).
- **boostStrengthFactor** (*float*) – Boost strength factor to use [0..1]
- **dutyCyclePeriod** (*int*) – The period used to calculate duty cycles

**Returns** Point wise Sparse MoblineNetV1 model

**separable_convolution2d**(*in_channels*, *out_channels*, *kernel_size=(3, 3)*, *stride=1*, *width_mult=1.0*)

Depth wise separable convolution 2D. This network block is used by MobileNet to factorize a standard convolution into a depth wise convolution and a 1x1 point wise convolution. The depth wise convolution applies a single filter for each input channel and the point wise applies 1x1 convolution to combine the outputs of the depth wise convolution.

See https://arxiv.org/abs/1704.04861

**Parameters**

- **in_channels** – Input channels
- **out_channels** – Output channels
- **kernel_size** – Kernel size to use, always 3x3 for mobilenet
- **stride** – Stride of the convolution
- **width_mult** – Width multiplier, used to thin the network

### nupic.research.frameworks.pytorch.models.not_so_densenet

**class DenseNetCIFAR**(*block_config=None*, *depth=100*, *growth_rate=12*, *reduction=0.5*, *num_classes=10*, *bottleneck_size=4*, *avg_pool_size=8*)

Bases: `torch.nn.Sequential`

DenseNet CIFAR model. Based on `torchvision.models.densenet` blocks. See original densenet.lua implementation for more details.

**Parameters**

- **block_config** – how many layers in each pooling block. If None compute from *depth*
- **depth** – DenseNet network depth. If None then *block_config* must be given
- **growth_rate** – how many filters to add each layer (*k* in paper)
- **reduction** – Channel compress ratio at transition layer

- **num_classes** – number of classification classes
- **bottleneck_size** – multiplicative factor for number of bottle neck layers
- **avg_pool_size** – Average pool size for last transition layer

**class NoSoDenseNetCIFAR**(*block_config=None, depth=100, growth_rate=12, reduction=0.5, num_classes=10, bottleneck_size=4, avg_pool_size=4, dense_percent_on=([1.0, 1.0], [1.0, 1.0], [1.0, 1.0], [1.0, 1.0]), dense_sparse_weights=([1.0, 1.0], [1.0, 1.0], [1.0, 1.0], [1.0, 1.0]), transition_percent_on=(1.0, 1.0, 1.0), transition_sparse_weights=(1.0, 1.0, 1.0), classifier_percent_on=1.0, classifier_sparse_weights=1.0, k_inference_factor=1.0, boost_strength=1.5, boost_strength_factor=0.95, duty_cycle_period=1000*)

Bases: *nupic.research.frameworks.pytorch.models.not_so_densenet.DenseNetCIFAR*

Modified DenseNet architecture using sparse dense blocks and sparse transition layers. Inspired by the original densenet.lua implementation.

**Parameters**

- **block_config** – how many layers in each pooling block. If None compute from *depth*
- **depth** – DenseNet network depth. If None then *block_config* must be given
- **growth_rate** – how many filters to add each layer (*k* in paper)
- **reduction** – Channel compress ratio at transition layer
- **num_classes** – number of classification classes
- **bottleneck_size** – multiplicative factor for number of bottle neck layers
- **avg_pool_size** – Average pool size for last transition layer
- **dense_percent_on** – Percent of units allowed to remain before each convolution layer of the dense layer.
- **dense_sparse_weights** – Percent of weights that are allowed to be non-zero in each CNN of the dense layer
- **transition_percent_on** – Percent of units allowed to remain the convolution layer of the transition layer
- **transition_sparse_weights** – Percent of weights that are allowed to be non-zero in the CNN of the transition layer
- **classifier_percent_on** – Percent of units allowed to remain after the last batch norm before the classifier
- **classifier_sparse_weights** – Percent of weights that are allowed to be non-zero in the classifier
- **k_inference_factor** – During inference (training=False) we increase *percent_on* in all sparse layers by this factor
- **boost_strength** – boost strength (0.0 implies no boosting)
- **boost_strength_factor** – Boost strength factor to use [0..1]
- **duty_cycle_period** – The period used to calculate duty cycles

### nupic.research.frameworks.pytorch.models.resnet_models

Modified from torchvision.

**class ResNet**(*block*, *layers*, *num_classes=1000*, *in_channels=3*)
Bases: `torch.nn.Module`

**entropy**()
Does nothing.

For compatibility with our scripts.

**forward**(*x*)

**max_entropy**()
Does nothing.

For compatibility with our scripts.

**post_epoch**()
Does nothing.

For compatibility with our scripts.

**resnet9**(*pretrained=False*, ***kwargs*)
Constructs a ResNet-9 model. There is no pretrained version.

**Args:** pretrained (bool): ignored.

**resnet18**

**resnet34**

**resnet50**

**resnet101**

**resnet152**

### nupic.research.frameworks.pytorch.audio_transforms

Adapted from https://github.com/tugstugi/pytorch-speech-commands Google speech commands dataset.

**class AddBackgroundNoise**(*bg_dataset*, *max_percentage=0.45*)
Bases: `torch.utils.data.Dataset`

Adds a random background noise.

**class AddBackgroundNoiseOnSTFT**(*bg_dataset*, *max_percentage=0.45*)
Bases: `torch.utils.data.Dataset`

Adds a random background noise on the frequency domain.

**class AddNoise**(*alpha=0.0*, *max_val=1.0*)
Bases: `object`

Blend random noise into the sample.

A' = A * (1 - alpha) + alpha * noise

noise is random uniform in the range [-max_val, max_val]

**class AudioFromSTFT**
Bases: object

Inverse short time fourier transform.

**class ChangeAmplitude**(*amplitude_range=(0.7, 1.1)*)
Bases: object

Changes amplitude of an audio randomly.

**class ChangeSpeedAndPitchAudio**(*max_scale=0.2*)
Bases: object

Change the speed of an audio.

This transform also changes the pitch of the audio.

**class DeleteSTFT**
Bases: object

Pytorch doesn't like complex numbers, use this transform to remove STFT after computing the mel spectrogram.

**class FixAudioLength**(*time=1*)
Bases: object

Either pads or truncates an audio into a fixed length.

**class FixSTFTDimension**
Bases: object

Either pads or truncates in the time axis on the frequency domain, applied after stretching, time shifting etc.

**class LoadAudio**(*sample_rate=16000*)
Bases: object

Loads an audio into a numpy array.

**class StretchAudio**(*max_scale=0.2*)
Bases: object

Stretches an audio randomly.

**class StretchAudioOnSTFT**(*max_scale=0.2*)
Bases: object

Stretches an audio on the frequency domain.

**class TimeshiftAudio**(*max_shift_seconds=0.2*)
Bases: object

Shifts an audio randomly.

**class TimeshiftAudioOnSTFT**(*max_shift=8*)
Bases: object

A simple timeshift on the frequency domain without multiplying with exp.

**class ToMelSpectrogram**(*n_mels=32*)
Bases: object

Creates the mel spectrogram from an audio.

The result is a 32x32 matrix.

**class ToMelSpectrogramFromSTFT**(*n_mels=32*)
Bases: object

Creates the mel spectrogram from the short time fourier transform of a file.

The result is a 32x32 matrix.

**class ToSTFT**(*n_fft=2048*, *hop_length=512*)
Bases: `object`

Applies on an audio the short time fourier transform.

**class ToTensor**(*np_name*, *tensor_name*, *normalize=None*)
Bases: `object`

Converts into a tensor.

**class Unsqueeze**(*tensor_name*, *model_type*)
Bases: `object`

Unsqueeze audio data into a single tensor.

**should_apply_transform**(*prob=0.5*)
Transforms are only randomly applied with the given probability.

### nupic.research.frameworks.pytorch.dataset_utils

### nupic.research.frameworks.pytorch.image_transforms

**class RandomNoise**(*noise_level=0.0*, *high_value=0.7469*, *low_value=0.7469*, *log_dir=None*, *log_probability=0.01*)
Bases: `object`

Add noise to random pixels in images.

### nupic.research.frameworks.pytorch.model_utils

**count_nonzero_params**(*model*)
Count the total number of non-zero weights in the model, including bias weights.

**deserialize_state_dict**(*fileobj*, *device=None*)
Deserialize state dict saved via `_serialize_state_dict()` from the given file object :param fileobj: file-like object such as `io.BytesIO` :param device: Device to map tensors to :return: the state dict stored in the file object

**evaluate_model**(*model*, *loader*, *device*, *batches_in_epoch=9223372036854775807*, *criterion=torch.nn.functional.nll_loss*, *progress=None*)
Evaluate pre-trained model using given test dataset loader.

**Parameters**

- **model** (*torch.nn.Module*) – Pretrained pytorch model
- **loader** (`torch.utils.data.DataLoader`) – test dataset loader
- **device** (`torch.device`) – device to use ('cpu' or 'cuda')
- **batches_in_epoch** (*int*) – Max number of mini batches to test on.
- **criterion** (*function*) – loss function to use
- **progress** (*dict or None*) – Optional `tqdm` progress bar args. None for no progress bar

**Returns** dictionary with computed "mean_accuracy", "mean_loss", "total_correct".

**Return type** dict

**serialize_state_dict**(*fileobj*, *state_dict*, *compresslevel=3*)
Serialize the state dict to file object :param fileobj: file-like object such as `io.BytesIO` :param state_dict: state dict to serialize. Usually the dict returned by

module.state_dict() but it can be any state dict.

**Parameters** **compresslevel** – compression level for gzip (lower equals faster but less compression).

**set_random_seed**(*seed*, *deterministic_mode=True*)
Set pytorch, python random, and numpy random seeds (these are all the seeds we normally use).

**Parameters**

- **seed** – (int) seed value
- **deterministic_mode** – (bool) If True, then even on a GPU we'll get more deterministic results, though performance may be slower. See: https://pytorch.org/docs/stable/notes/randomness.html

**train_model**(*model*, *loader*, *optimizer*, *device*, *criterion=torch.nn.functional.nll_loss*, *batches_in_epoch=9223372036854775807*, *pre_batch_callback=None*, *post_batch_callback=None*, *progress_bar=None*)
Train the given model by iterating through mini batches. An epoch ends after one pass through the training set, or if the number of mini batches exceeds the parameter "batches_in_epoch".

**Parameters**

- **model** (*torch.nn.Module*) – pytorch model to be trained
- **loader** (`torch.utils.data.DataLoader`) – train dataset loader
- **optimizer** – Optimizer object used to train the model. This function will train the model on every batch using this optimizer and the `torch.nn.functional.nll_loss()` function
- **batches_in_epoch** – Max number of mini batches to train.
- **device** (:class:`torch.device) – device to use ('cpu' or 'cuda')
- **criterion** (*function*) – loss function to use
- **post_batch_callback** (*function*) – Callback function to be called after every batch with the following parameters: model, batch_idx
- **pre_batch_callback** (*function*) – Callback function to be called before every batch with the following parameters: model, batch_idx
- **progress_bar** (*dict or None*) – Optional `tqdm` progress bar args. None for no progress bar

**Returns** mean loss for epoch

**Return type** float

#### nupic.research.frameworks.pytorch.speech_commands_dataset

Adapted from https://github.com/tugstugi/pytorch-speech-commands Google speech commands dataset.

**class SpeechCommandsDataset**(*folder*, *transform=None*, *classes=('unknown', 'silence', 'zero', 'one', 'two', 'three', 'four', 'five', 'six', 'seven', 'eight', 'nine')*, *silence_percentage=0.1*, *sample_rate=16000*)

Bases: `torch.utils.data.Dataset`

Google speech commands dataset. Only labels in CLASSES, plus silence, are treated as known classes. All other classes are used as 'unknown' samples.

Similar to the Kaggle challenge here: https://www.kaggle.com/c/tensorflow-speech-recognition-challenge

**make_weights_for_balanced_classes**()

adopted from https://discuss.pytorch.org/t/balanced-sampling-between-classes-with-torchvision-dataloader/2703/3. # noqa: E501

**class BackgroundNoiseDataset**(*folder*, *transform=None*, *sample_rate=16000*, *sample_length=1*)

Bases: `torch.utils.data.Dataset`

Dataset for silence / background noise.

**class PreprocessedSpeechDataset**(*root*, *subset*, *classes=('unknown', 'silence', 'zero', 'one', 'two', 'three', 'four', 'five', 'six', 'seven', 'eight', 'nine')*, *silence_percentage=0.1*)

Bases: `torch.utils.data.Dataset`

Google Speech Commands dataset preprocessed with with all transforms already applied.

Use the 'process_dataset.py' script to create preprocessed dataset

**static is_valid**(*folder*, *epoch=0*)

Check if the given folder is a valid preprocessed dataset.

**make_weights_for_balanced_classes**()

adopted from https://discuss.pytorch.org/t/balanced-sampling-between-classes-with-torchvision-dataloader/2703/3. # noqa E501

**next_epoch**()

Load next epoch from disk.

### 6.1.1.2 nupic.research.support

#### nupic.research.support.parse_config

**parse_config**(*config_file*, *experiments=None*, *globals_param=None*, *locals_param=None*)

Parse configuration file optionally filtering for specific experiments/sections.

**Parameters**

- **config_file** – Configuration file
- **experiments** – Optional list of experiments
- **globals_param** – global symbol table to use during *eval*
- **locals_param** – local symbol table to use during *eval*

**Returns** Dictionary with the parsed configuration

### nupic.research.support.ray_utils

**load_ray_tune_experiment**(*experiment_path*, *experiment_filename=None*, *load_results=False*)
Load ray tune experiment state.

**Parameters**

- **experiment_path** (*str*) – ray tune experiment directory
- **experiment_filename** (*str*) – experiment state to load. None for latest
- **load_results** (*bool*) – Whether or not to load experiment results

**Returns** dictionary with ray tune experiment state results

**Return type** dict

**load_ray_tune_experiments**(*experiment_path*, *load_results=False*)
Load multiple ray tune experiment states. This is useful if you want to collect the results from multiple runs into one collection

**Parameters**

- **experiment_path** (*str*) – ray tune experiment directory
- **load_results** (*bool*) – Whether or not to load experiment results

**Returns** list of dictionaries with ray tune experiment state results

**Return type** list(dict)

## 6.2 License

```
                    GNU AFFERO GENERAL PUBLIC LICENSE
                       Version 3, 19 November 2007

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permission, would make you directly or secondarily liable for
infringement under applicable copyright law, except executing it on a
computer or modifying a private copy.  Propagation includes copying,
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distribution (with or without modification), making available to the
public, and in some countries other activities as well.

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menu, a prominent item in the list meets this criterion.

  1. Source Code.

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Major Component, or to implement a Standard Interface for which an
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"Major Component", in this context, means a major essential component
(kernel, window system, and so on) of the specific operating system
(if any) on which the executable work runs, or a compiler used to
produce the work, or an object code interpreter used to run it.

  The "Corresponding Source" for a work in object code form means all
the source code needed to generate, install, and (for an executable
work) run the object code and to modify the work, including scripts to
control those activities.  However, it does not include the work's
System Libraries, or general-purpose tools or generally available free
programs which are used unmodified in performing those activities but
which are not part of the work.  For example, Corresponding Source
includes interface definition files associated with source files for
the work, and the source code for shared libraries and dynamically
linked subprograms that the work is specifically designed to require,
such as by intimate data communication or control flow between those
subprograms and other parts of the work.

  The Corresponding Source need not include anything that users
can regenerate automatically from other parts of the Corresponding
Source.

  The Corresponding Source for a work in source code form is that
same work.
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CHAPTER

SEVEN

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