Contents

1 srnn.py.py

```
#! /usr/bin/env python
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"""
This is the BPTT spiking recurrent neural network (srnn)
example using the Google Speech Commands dataset.
"""

import pprint
import random
import sys
from pathlib import Path

import numpy as np
import tomli

# import snoop  # for debugging when something goes wrong.
import torch
import torch.nn.functional as F
import torchaudio
import torchvision
import typer
from loguru import logger
from torch import nn
from torch.optim.lr_scheduler import StepLR
```

```
# srnn specific modules.
import efficient_spiking_networks.srnn_layers.spike_dense as sd
import efficient_spiking_networks.srnn_layers.spike_neuron as sn
import efficient_spiking_networks.srnn_layers.spike_rnn as sr
from GSC.data import (  # noqa: E501 pylint: disable=C0301
    GSCSSubsetSC,
    MelSpectrogram,
    Pad,
    Rescale,
)

# modules that are associated with this example.
from GSC.utils import generate_noise_files

# Two generator functions; part of our utilities suite.
from utilities.gendfind import gen_dfind  # pylint: disable=C0411
from utilities.genfind import gen_find  # pylint: disable=C0411

# Setup pretty printing.
pp = pprint.PrettyPrinter(indent=4, compact=True, width=42)

# Two class_dict helper functions.
def label_to_index(class_dict: dict, word: str) -> int:
    """
    Return the position of the word in labels.
    """
    return class_dict[word]

def index_to_label(class_dict: dict, index: int) -> str:
```

```
    """
    Return the word corresponding to the index in labels.
    This is the inverse of label_to_index.
    """

    return list(class_dict.keys())[list(class_dict.values()).index(index)]

def read_configuration(filename: Path) -> dict:
    """
    Several experiment parameters are defined in a TOML
    configuration file; whose filename is an argument to the the
    simulation code.

    This function reads the TOML configuration file, validate its's
    contents against a schema, and return a configuration dictionary.
    """
    with open(filename, mode="rb") as fp:  # pylint: disable=C0103
        config = tomli.load(fp)

    match config:
        case {
            "data": {"dataroot": str(), "gsc_url": str()},
            "srnn": {
                "network_size": int(),
                "learning_rate": float(),
                "epochs": int(),
                "batch_size": int(),
                "size": int(),
                "sample_rate": int(),
```

```
            "bias": bool(),
        },
        "mel": {
            "delta_order": int(),
            "fmax": int(),
            "fmin": int(),
            "n_mels": int(),
            "stack": bool(),
        },
        "logger": {"level": str()},
        "cuda": {"cuda": bool()},
    }:
        pass
    case _:
        raise ValueError(f"invalid configuration: {config}")
return config

# Here begins the Spiking Recurrent Neural Network specific code.

def collate_fn(data):
    """
    This custom collate function is called with a list of data samples.
    It collates the input samples into a batch for yielding from the
    data loader iterator.

    Dividing the batch by its standard deviation yields a distribution with
    standard deviation equal to 1 (and a variance equal to 1^2=1).
    """
    x_batch = np.array([d[0] for d in data])  # pylint: disable=C0103
```

```
        std = x_batch.std(axis=(0, 2), keepdims=True)
        x_batch = torch.tensor(x_batch / std)  # pylint: disable=E1101
        y_batch = torch.tensor([d[1] for d in data])  # pylint: disable=C0103,E1101
        # y_batch = [d[1] for d in data]  # pylint: disable=C0103,E1101

        return x_batch, y_batch

# Definition of the overall RNN network.
class RecurrentSpikingNetwork(nn.Module):  # pylint: disable=R0903

    """
    This class defines an SRNN.
    """

    def __init__(self, device, bias: bool, thr_func, network_size: int = 256):
        """
        Constructor docstring
        """
        super().__init__()
        self.bias = bias
        self.thr_func = thr_func

        # Here is what the network looks like
        self.dense_1 = sd.SpikeDENSE(
            40 * 3,
            network_size,
            tau_adp_inital_std=50,
            tau_adp_inital=200,
            tau_m=20,
```

```
        tau_m_inital_std=5,
        device=device,
        bias=self.bias,
    )

    self.dense_2 = sd.ReadoutIntegrator(
        network_size,
        12,
        tau_m=10,
        tau_m_inital_std=1,
        device=device,
        bias=self.bias,
    )

    self.rnn_1 = sr.SpikeRNN(
        network_size,
        network_size,
        tau_adp_inital_std=50,
        tau_adp_inital=200,
        tau_m=20,
        tau_m_inital_std=5,
        device=device,
        bias=self.bias,
    )

    # Please comment this code.
    self.thr = nn.Parameter(torch.Tensor(1))
    nn.init.constant_(self.thr, 5e-2)
```

```
        # Initialize the network layers.
        torch.nn.init.kaiming_normal_(self.rnn_1.recurrent.weight)

        torch.nn.init.xavier_normal_(self.dense_1.dense.weight)
        torch.nn.init.xavier_normal_(self.dense_2.dense.weight)

        if bias:
            torch.nn.init.constant_(self.rnn_1.recurrent.bias, 0)
            torch.nn.init.constant_(self.dense_1.dense.bias, 0)
            torch.nn.init.constant_(self.dense_2.dense.bias, 0)

    def forward(self, inputs):  # pylint: disable=R0914
        """
        The forward pass.
        """
        # What is this that returns 4 values?
        # What is b?
        # Stereo channels?
        (
            b,  # pylint: disable=C0103
            channel,
            seq_length,
            inputs_dim,
        ) = inputs.shape
        self.dense_1.set_neuron_state(b)
        self.dense_2.set_neuron_state(b)
        self.rnn_1.set_neuron_state(b)

        fr_1 = []
```

```
        fr_2 = []
        # fr_3 = []
        output = 0

        # inputs_s = inputs
        inputs_s = self.thr_func(inputs - self.thr) - self.thr_func(
            -self.thr - inputs
        )

        # For every timestep update the membrane potential
        for i in range(seq_length):
            inputs_x = inputs_s[:, :, i, :].reshape(b, channel * inputs_dim)
            _, spike_layer1 = self.dense_1.forward(inputs_x)
            (
                _,
                spike_layer2,
            ) = self.rnn_1.forward(spike_layer1)
            # mem_layer3,spike_layer3 = self.dense_2.forward(spike_layer2)
            mem_layer3 = self.dense_2.forward(spike_layer2)

            # tracking number of spikes (firing rate).
            output += mem_layer3
            fr_1.append(spike_layer1.detach().cpu().numpy().mean())
            fr_2.append(spike_layer2.detach().cpu().numpy().mean())
            # fr_3.append(spike_layer3.detach().cpu().numpy().mean())

        output = F.log_softmax(output / seq_length, dim=1)
        return output, [
            np.mean(np.abs(inputs_s.detach().cpu().numpy())),
```

```
            np.mean(fr_1),
            np.mean(fr_2),
        ]

def test(data_loader, device, model, is_show=0):
    """
    Test the network against the testing data.
    """

    test_acc = 0.0
    sum_sample = 0.0
    fr_ = []
    for _, (images, labels) in enumerate(data_loader):
        images = images.view(-1, 3, 101, 40).to(device)

        labels = labels.view((-1)).long().to(device)
        predictions, fr = model(images)  # pylint: disable=C0103
        fr_.append(fr)
        values, predicted = torch.max(  # pylint: disable=W0612,E1101
            predictions.data, 1
        )
        labels = labels.cpu()
        predicted = predicted.cpu().t()

        test_acc += (predicted == labels).sum()
        sum_sample += predicted.numel()
    mean_fr = np.mean(fr_, axis=0)
    if is_show:
        logger.info(f"Mean FR: {mean_fr}")
```

```
    return test_acc.data.cpu().numpy() / sum_sample, mean_fr

def train(
    train_data_loader,
    test_data_loader,
    device,
    model,
    epochs,
    criterion,
    optimizer,
    scheduler=None,
):  # pylint: disable=R0913,R0914
    """
    Train the network with by the standard forward pass - loss
    calculation - backward propogation cycle.
    """
    acc_list = []
    best_acc = 0

    path = "../model/"  # .pth'
    for epoch in range(epochs):
        logger.info(f"{epoch=}")
        train_acc = 0
        sum_sample = 0
        train_loss_sum = 0
        for _, (images, labels) in enumerate(train_data_loader):
            # if i == 0:
            images = images.view(-1, 3, 101, 40).to(device)
```

```
            labels = labels.view((-1)).long().to(device)
            optimizer.zero_grad()

            predictions, _ = model(images)
            values, predicted = torch.max(  # pylint: disable=W0612,E1101
                predictions.data, 1
            )

            logger.debug(f"predictions:\n{pp.pformat(predictions)}]")
            logger.debug(f"labels:\n{pp.pformat(labels)}]")

            train_loss = criterion(predictions, labels)

            logger.debug(f"{predictions=}\n{predicted=}")

            train_loss.backward()
            train_loss_sum += train_loss.item()
            optimizer.step()

            labels = labels.cpu()
            predicted = predicted.cpu().t()

            train_acc += (predicted == labels).sum()
            sum_sample += predicted.numel()

        if scheduler:
            scheduler.step()
        train_acc = train_acc.data.cpu().numpy() / sum_sample
        valid_acc, _ = test(test_data_loader, device, model, 1)  # what?!
```

```
        train_loss_sum += train_loss

        acc_list.append(train_acc)
        logger.info(f"{optimizer.param_groups[0]['lr']=}")

        if valid_acc > best_acc and train_acc > 0.890:
            best_acc = valid_acc
            torch.save(model, path + str(best_acc)[:7] + "-srnn-v3.pth")
        logger.info(f"{model.thr=}")

        training_loss = train_loss_sum / len(train_data_loader)
        logger.info(
            f"{epoch=:}, {training_loss=}, {train_acc=:.4f}, {valid_acc=:.4f}"
        )

    return acc_list

app = typer.Typer()

@app.command()
def main(config_file: Path) -> None:  # pylint: disable=R0914,R0915
    """
    Spiking Recurrent Neural Networks
    """
    # Read the configuration file.
    config = read_configuration(config_file)

    # Setup logger level.
    logger.remove()
```

```
logger.add(sys.stderr, level=config["logger"]["level"])

# The config file
logger.info(f"{config_file=}")

# Use cuda if it's available.
device = torch.device(  # pylint: disable=E1101
    "cuda:0" if torch.cuda.is_available() else "cpu"
)
if config["cuda"]["cuda"] is False:
    device = torch.device("cpu")  # pylint: disable=E1101
logger.info(f"{device=}")

# Setup number of workers dependent upon where the code is run.
number_of_workers = 4 if device.type == "cpu" else 8
pin_memory = device.type == "cuda"

logger.info(
    f"The Dataloader will spawn {number_of_workers} worker processes."
)
logger.info(f"{pin_memory=}")

# Specify the several paramaters that we'll use throughout this example.
# Paths to the data.
dataroot = Path(config["data"]["dataroot"])
gsc_url = config["data"]["gsc_url"]
gsc = dataroot / "SpeechCommands" / gsc_url
logger.info("\n".join([f"{dataroot=}", f"{gsc_url=}", f"{gsc=}"]))
```

```
# Specify the learning rate, etc.
network_size = config["srnn"]["network_size"]
learning_rate = config["srnn"]["learning_rate"]
epochs = config["srnn"]["epochs"]
batch_size = config["srnn"]["batch_size"]
size = config["srnn"]["size"]
sample_rate = config["srnn"]["sample_rate"]
bias = config["srnn"]["bias"]
logger.info(
    "\n".join(
        [
            f"\n{network_size=}",
            f"{learning_rate=}",
            f"{epochs=}",
            f"{batch_size=}",
            f"{size=}",
            f"{sample_rate=}",
            f"{bias=}",
        ]
    )
)

# Parameters for converting a wav into a mel-scaled spectrogram.
# This is one of the transformations applied to each dataset.
delta_order = config["mel"]["delta_order"]
fmax = config["mel"]["fmax"]
fmin = config["mel"]["fmin"]
hop_length = int(10e-3 * sample_rate)
n_fft = int(30e-3 * sample_rate)
```

```
n_mels = config["mel"]["n_mels"]
stack = config["mel"]["stack"]
melspec = MelSpectrogram(
    sample_rate,
    n_fft,
    hop_length,
    n_mels,
    fmin,
    fmax,
    delta_order,
    stack=stack,
)
logger.info(
    "\n".join(
        [
            f"\n{delta_order=}",
            f"{fmax=}",
            f"{fmin=}",
            f"{hop_length=}",
            f"{n_fft=}",
            f"{n_mels=}",
            f"{stack=}",
        ]
    )
)

# Compose transformations applied to each dataset.
pad = Pad(size)
rescale = Rescale()
```

```
transforms = torchvision.transforms.Compose([pad, melspec, rescale])

# Specify our custom autograd function that defines how forward and
# backward passes are performed.
thr_func = sn.ActFunADP.apply
logger.info(f"{thr_func=}")

# Specify our loss function.
criterion_f = nn.CrossEntropyLoss()  # nn.NLLLoss()
logger.info(f"{criterion_f=}")

# Retrieve the Google Speech Commands Dataset.
torchaudio.datasets.SPEECHCOMMANDS(
    dataroot,
    url=gsc_url,
    folder_in_archive="SpeechCommands",
    download=True,
)

# Create random noise files for training and validation.
silence_folder = gsc / "_silence_"
if not silence_folder.exists():
    # Create the folder where we will write white noise files.
    silence_folder.mkdir(parents=True, exist_ok=True)

    # Compose a list of the GSC background noise files.

    # Four of the six files envoked a warning when read.
    # This is why we'"ll not choose from among these six
```

```
        # but use one file generate our noise files.
        # background_noise_files = [*gen_find("*.wav", gsc / "_background_noise_")]  # noqa: E501 pylint:
disable=C0301

        # Instead of choosing among many, this is the one wav file
        # we will use to generate our white noise files.
        background_noise_file = gsc / "_background_noise_" / "white_noise.wav"

        # 260 validation / 2300 training.
        generate_noise_files(
            nb_files=2560,
            noise_file=background_noise_file,
            output_folder=silence_folder,
            file_prefix="noise_nohash_",
            sr=sample_rate,
        )

        # Compose a list of the new noise files.  Write the first 260
        # names to silence_validation_list.txt

        silence_files = [*gen_find("*.wav", silence_folder)]

        # Write the first 260 filenames to silence_validation_list.txt.
        with open(
            gsc / "silence_validation_list.txt", mode="w", encoding="utf-8"
        ) as fp:  # pylint: disable=C0103
            for filename in silence_files[:260]:
                filename = Path(*Path(filename).parts[-2:])  # Relative path
                fp.write(f"{filename}\n")
```

```
        logger.info("Successfully created silence random noise files.")

    # Create Class Label Dictionary.

    # The dictionary's keys:value pairs are category names gleaned from
    # the GSC directory structure and integers, i.e. [0-9, 10, 11].  The
    # first ten keys or categories, whether chozen ordinally or drawn
    # randomly, recieve as values the first ten integers. The next
    # two key:value pairs are {'_silencee_':10, 'unknown':11}. The
    # remaining key or categories all recieve the value 11.
    # The values [0-10] represent testing categories.

    # Beginning at GSC find directories without a leading underscore.
    class_labels = list(
        {Path(dir).parts[-1] for dir in gen_dfind(r"^(?!_).*", gsc)}
    )
    logger.info(
        f"Class Labels[{len(class_labels)}]:\n{pp.pformat(class_labels)}"
    )

    # Compose the class dictionary by choosing
    # the first ten categories randomly.
    # fmt: off
    class_dict = dict(
        {j: i for i, j in enumerate([class_labels.pop(random.randrange(len(class_labels))) for _ in
range(10)])},  # noqa: E501 pylint: disable=C0301
        **{"_silence_": 10},
        **{"_unknown_": 11},
        **{i: 11 for i in class_labels})
```

```
    # fmt: on
    logger.info(f"class dict[{len(class_dict)}]:\n{pp.pformat(class_dict)}")

    # Reading and preprocessing the data.

    # The training dataset.
    # Note that the transformations specified here are applied in
    # the __getitem__ dunder method of the custom the GSCSSubsetSC class.

    gsc_training_dataset = GSCSSubsetSC(
        root=dataroot,
        url=gsc_url,
        download=True,
        subset="training",
        transform=transforms,
        class_dict=class_dict,
    )
    logger.info(
        f"The training data consists of {len(gsc_training_dataset)} samples."
    )

    waveform, idx = gsc_training_dataset[0]
    logger.info(f"Shape of gsc_training_set waveform: {waveform.shape}")
    logger.info(f"Waveform label: {index_to_label(class_dict, idx)}")
    # labels = sorted(list(set(index_to_label(class_dict, datapoint[1]) for datapoint in gsc_training_dataset)))
# noqa: E501 pylint: disable=C0301
    # logger.info(f"training labels:\n{pp.pformat(labels)}]")

    # The training dataloader.
```

```
gsc_training_dataloader = torch.utils.data.DataLoader(
    gsc_training_dataset,
    batch_size=batch_size,
    shuffle=True,
    num_workers=number_of_workers,
    collate_fn=collate_fn,
    pin_memory=pin_memory,
)
gsc_features, gsc_labels = next(iter(gsc_training_dataloader))
logger.info(f"Training Feature batch shape: {gsc_features.size()}")
logger.info(f"Training Labels batch shape: {gsc_labels.size()}")
logger.info(f"Training labels, i.e. indices:\n{pp.pformat(gsc_labels)}]")
# logger.info(f"Training labels[{len(gsc_labels)}]:\n{pp.pformat(gsc_labels)}")  # noqa: E501

# The testing dataset.
gsc_testing_dataset = GSCSSubsetSC(
    root=dataroot,
    url=gsc_url,
    download=True,
    subset="testing",
    transform=transforms,
    class_dict=class_dict,
)
logger.info(
    f"The testing data consists of {len(gsc_testing_dataset)} samples."
)

# The testing dataloader.
gsc_testing_dataloader = torch.utils.data.DataLoader(
```

```
        gsc_testing_dataset,
        batch_size=batch_size,
        shuffle=True,
        num_workers=number_of_workers,
        collate_fn=collate_fn,
        pin_memory=pin_memory,
    )

    # Instantiate the model.
    model = RecurrentSpikingNetwork(device, bias, thr_func, network_size)
    model.to(device)

    # Test before training.
    test_acc_before_training = test(gsc_testing_dataloader, device, model)
    logger.info(f"{test_acc_before_training=}")

    # Prepare for training.
    base_params = (
        [
            model.dense_1.dense.weight,
            model.dense_1.dense.bias,
            model.rnn_1.dense.weight,
            model.rnn_1.dense.bias,
            model.rnn_1.recurrent.weight,
            model.rnn_1.recurrent.bias,
            # model.dense_2.recurrent.weight,
            # model.dense_2.recurrent.bias,
            model.dense_2.dense.weight,
            model.dense_2.dense.bias,
```

```
    ]
    if bias
    else [
        model.dense_1.dense.weight,
        model.rnn_1.dense.weight,
        model.rnn_1.recurrent.weight,
        model.dense_2.dense.weight,
    ]
)

optimizer_f = torch.optim.Adam(
    [
        {"params": base_params, "lr": learning_rate},
        {"params": model.thr, "lr": learning_rate * 0.01},
        {"params": model.dense_1.tau_m, "lr": learning_rate * 2},
        {"params": model.dense_2.tau_m, "lr": learning_rate * 2},
        {"params": model.rnn_1.tau_m, "lr": learning_rate * 2},
        {"params": model.dense_1.tau_adp, "lr": learning_rate * 2.0},
        #   {'}params': model.dense_2.tau_adp, 'lr': learning_rate * 10},
        {"params": model.rnn_1.tau_adp, "lr": learning_rate * 2.0},
    ],
    lr=learning_rate,
)

# scheduler_f = StepLR(optimizer_f, step_size=20, gamma=.5) # 20
scheduler_f = StepLR(optimizer_f, step_size=10, gamma=0.1)  # 20
# scheduler_f = LambdaLR(optimizer_f,lr_lambda=lambda epoch: 1-epoch/70)
# scheduler_f = ExponentialLR(optimizer_f, gamma=0.85)
```

```
    # Training.
    train_acc_training_complete = train(
        gsc_training_dataloader,
        gsc_testing_dataloader,
        device,
        model,
        epochs,
        criterion_f,
        optimizer_f,
        scheduler_f,
    )
    logger.info(f"TRAINING COMPLETE: {train_acc_training_complete=}")

    # Testing.
    test_acc_after_training = test(gsc_testing_dataloader, device, model)
    logger.info(f"TESTING COMPLETE: {test_acc_after_training}")

if __name__ == "__main__":
    app()

# finis

# Local Variables:
# compile-command: "pyflakes srnn.py; pylint-3 -f parseable srnn.py" # NOQA, pylint: disable=C0301
# End:
```

2 data.py

```
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# SPDX-License-Identifier: MPL-2.0

"""
Classes that retrieve and manipualte input data.
"""

import os
from pathlib import Path
from typing import Optional, Union

import librosa
import numpy as np
import torch
from torchaudio.datasets import SPEECHCOMMANDS
from torchaudio.datasets.utils import _load_waveform

class GSCSSubsetSC(SPEECHCOMMANDS):
    """
    Our custom SPEECHCOMMANDS/dataset class that retrieves,
    segregates and transforms the GSC dataset.
    """

    def __init__(  # pylint: disable=R0913
        self,
        root: Union[str, Path],
```

```
        url: str = "speech_commands_v0.02",
        folder_in_archive: str = "SpeechCommands",
        download: bool = True,
        subset: Optional[str] = None,
        transform: Optional[str] = None,
        class_dict: dict = None,
    ) -> None:
        """
        Function Docstring
        """

        super().__init__(
            root, url=url, folder_in_archive="SpeechCommands", download=True
        )

        # two instance variables specific to this subclass
        self.transform = transform
        self.class_dict = class_dict

        def load_list(filename):
            """
            Function Docstring
            """

            filepath = os.path.join(self._path, filename)
            with open(filepath, mode="r", encoding="utf-8") as fileobj:
                return [
                    os.path.normpath(os.path.join(self._path, line.strip()))
                    for line in fileobj
```

```
        ]

if subset == "validation":
    self._walker = load_list("validation_list.txt") + load_list(
        "silence_validation_list.txt"
    )
elif subset == "testing":
    self._walker = load_list("testing_list.txt")
elif subset == "training":
    excludes = (
        load_list("testing_list.txt")
        + load_list("validation_list.txt")
        + load_list("silence_validation_list.txt")
    )
    excludes = set(excludes)
    self._walker = [
        w
        for w in self._walker  # pylint: disable=C0103
        if w not in excludes
    ]

    # debug: write our training list to the filesystem so we
    # can examine it. The validation and testing lists are
    # explicit.

    # with open("/tmp/training_list.txt",
    #     mode="wt",
    #     encoding="utf-8",
    # ) as fileobj:
```

```
            #     fileobj.write("\n".join(self._walker))

    def __getitem__(self, n):
        """This iterator return a tuple consisting of a waveform and
        its numeric label provided by the classification
        dictionary.

        Here is where the pad, melspec, and rescale traansforms are applied.
        """

        metadata = self.get_metadata(n)
        waveform = _load_waveform(self._archive, metadata[0], metadata[1])
        maximum = torch.max(torch.abs(waveform))  # pylint: disable=E1101

        if maximum > 0:
            waveform /= maximum
        if self.transform is not None:
            waveform = self.transform(waveform.squeeze())
        return (
            waveform,
            self.class_dict[metadata[2]],
        )

class Pad:  # pylint: disable=R0903
    """
    Pad class
    """

    def __init__(self, size: int):
```

```
        """
        Class constructor; size comes from the configuration file.
        """
        self.size = size

    def __call__(self, waveform):
        """
        Pad the waveform on the beginning and on the end such that the
        resulting array is the same length as the size the pad object
        was instantiated with.
        """

        wav_size = waveform.shape[0]
        pad_size = (self.size - wav_size) // 2
        padded_wav = np.pad(
            waveform,
            ((pad_size, self.size - wav_size - pad_size),),
            "constant",
            constant_values=(0, 0),
        )
        return padded_wav

class MelSpectrogram:  # pylint: disable=R0902,R0903
    """
    Mel Spectrogram Transformation
    """

    def __init__(  # pylint: disable=R0913
        self,
```

```
            sr,  # pylint: disable=C0103
            n_fft,
            hop_length,
            n_mels,
            fmin,
            fmax,
            delta_order=None,
            stack=True,
        ):
            """
            Class Constructor
            """

            self.sr = sr  # pylint: disable=C0103
            self.n_fft = n_fft
            self.hop_length = hop_length
            self.n_mels = n_mels
            self.fmin = fmin
            self.fmax = fmax
            self.delta_order = delta_order
            self.stack = stack

        def __call__(self, waveform):
            """
            Perform the Mel Spectrogram Transformation
            """

            spectrogram = librosa.feature.melspectrogram(
                y=waveform,
```

```
            sr=self.sr,
            n_fft=self.n_fft,
            hop_length=self.hop_length,
            n_mels=self.n_mels,
            fmax=self.fmax,
            fmin=self.fmin,
        )

        maximum = np.max(np.abs(spectrogram))
        if maximum > 0:
            feat = np.log1p(spectrogram / maximum)
        else:
            feat = spectrogram

        if self.delta_order is not None and not self.stack:
            feat = librosa.feature.delta(feat, order=self.delta_order)
            return np.expand_dims(feat.T, 0)

        if self.delta_order is not None and self.stack:
            feat_list = [feat.T]
            for k in range(1, self.delta_order + 1):
                feat_list.append(librosa.feature.delta(feat, order=k).T)
            return np.stack(feat_list)

        return np.expand_dims(feat.T, 0)

class Rescale:  # pylint: disable=R0903
    """Rescale Class"""
```

```
        def __call__(self, data):
            """
            Function Docstring
            """

            std = np.std(data, axis=1, keepdims=True)
            std[std == 0] = 1

            return data / std

    class Normalize:  # pylint: disable=R0903
        """
        Class Docstring
        """

        def __call__(self, data):
            """
            Function Docstring
            """

            data_ = (data > 0.1) * data
            std = np.std(data_, axis=1, keepdims=True)
            std[std == 0] = 1

            return input / std

    # finis

    # Local Variables:
    # compile-command: "pyflakes data.py; pylint-3 -d E0401 -f parseable data.py" # NOQA, pylint: disable=C0301
    # End:
```

3 optim.py

```
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"""
PyTorch implementation of Rectified Adam from
https://github.com/LiyuanLucasLiu/RAdam
"""

import math

import torch
from torch.optim.optimizer import Optimizer

class RAdam(Optimizer):
    """
    Optimizer Class
    """

    def __init__(  # pylint: disable=R0913
        self,
        params,
        lr=1e-3,
        betas=(0.9, 0.999),
        eps=1e-8,
        weight_decay=0,
        degenerated_to_sgd=True,
```

```
    ):
        """
        Class Constructor
        """

        if 0.0 > lr:
            raise ValueError(f"Invalid learning rate: {lr}")
        if 0.0 > eps:
            raise ValueError(f"Invalid epsilon value: {eps}")
        if not 0.0 <= betas[0] < 1.0:
            raise ValueError(f"Invalid beta parameter at index 0: {betas[0]}")
        if not 0.0 <= betas[1] < 1.0:
            raise ValueError(f"Invalid beta parameter at index 1: {betas[1]}")
        self.degenerated_to_sgd = degenerated_to_sgd
        if (
            isinstance(params, (list, tuple))
            and len(params) > 0
            and isinstance(params[0], dict)
        ):
            for param in params:
                if "betas" in param and (
                    param["betas"][0] != betas[0]
                    or param["betas"][1] != betas[1]
                ):
                    param["buffer"] = [[None, None, None] for _ in range(10)]

        defaults = {
            "lr": lr,
            "betas": betas,
```

```
            "eps": eps,
            "weight_decay": weight_decay,
            "buffer": [[None, None, None] for _ in range(10)],
        }

        super().__init__(params, defaults)

    # def __setstate__(self, state):
    #     """Function Docstring"""
    #     super().__setstate__(state)

    def step(self, closure=None):  # pylint: disable=R0912, R0914
        """
        Function Docstring
        """

        loss = None
        if closure is not None:
            loss = closure()

        for group in self.param_groups:
            for p in group["params"]:  # pylint: disable=C0103
                if p.grad is None:
                    continue
                grad = p.grad.data.float()
                if grad.is_sparse:
                    raise RuntimeError(
                        "RAdam does not support sparse gradients"
                    )
```

```
        p_data_fp32 = p.data.float()

        state = self.state[p]

        if len(state) == 0:
            state["step"] = 0
            state[
                "exp_avg"
            ] = torch.zeros_like(  # pylint: disable=E1101
                p_data_fp32
            )
            state[
                "exp_avg_sq"
            ] = torch.zeros_like(  # pylint: disable=E1101
                p_data_fp32
            )
        else:
            state["exp_avg"] = state["exp_avg"].type_as(p_data_fp32)
            state["exp_avg_sq"] = state["exp_avg_sq"].type_as(
                p_data_fp32
            )

        exp_avg, exp_avg_sq = state["exp_avg"], state["exp_avg_sq"]
        beta1, beta2 = group["betas"]

        exp_avg_sq.mul_(beta2).addcmul_(1 - beta2, grad, grad)
        exp_avg.mul_(beta1).add_(1 - beta1, grad)

        state["step"] += 1
```

```
buffered = group["buffer"][int(state["step"] % 10)]
if state["step"] == buffered[0]:
    N_sma, step_size = (  # pylint: disable=C0103
        buffered[1],
        buffered[2],
    )
else:
    buffered[0] = state["step"]
    beta2_t = beta2 ** state["step"]
    N_sma_max = 2 / (1 - beta2) - 1  # pylint: disable=C0103
    N_sma = N_sma_max - 2 * state[  # pylint: disable=C0103
        "step"
    ] * beta2_t / (1 - beta2_t)
    buffered[1] = N_sma

    # more conservative since it's an approximated value
    if N_sma >= 5:
        step_size = math.sqrt(
            (1 - beta2_t)
            * (N_sma - 4)
            / (N_sma_max - 4)
            * (N_sma - 2)
            / N_sma
            * N_sma_max
            / (N_sma_max - 2)
        ) / (1 - beta1 ** state["step"])
    elif self.degenerated_to_sgd:
        step_size = 1.0 / (1 - beta1 ** state["step"])
    else:
```

```
                        step_size = -1
                    buffered[2] = step_size

                # more conservative since it's an approximated value
                if N_sma >= 5:
                    if group["weight_decay"] != 0:
                        p_data_fp32.add_(
                            -group["weight_decay"] * group["lr"], p_data_fp32
                        )
                    denom = exp_avg_sq.sqrt().add_(group["eps"])
                    p_data_fp32.addcdiv_(
                        -step_size * group["lr"], exp_avg, denom
                    )
                    p.data.copy_(p_data_fp32)
                elif step_size > 0:
                    if group["weight_decay"] != 0:
                        p_data_fp32.add_(
                            -group["weight_decay"] * group["lr"], p_data_fp32
                        )
                    p_data_fp32.add_(-step_size * group["lr"], exp_avg)
                    p.data.copy_(p_data_fp32)

        return loss

# finis

# Local Variables:
# compile-command: "pyflakes optim.py; pylint-3 -f parseable optim.py" # NOQA, pylint: disable=C0301
# End:
```

4 utils.pys

```
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"""
Utilities
"""

import numpy as np
import scipy.io.wavfile as wav

def generate_noise_files(
    nb_files,
    noise_file,
    output_folder,
    file_prefix,
    sr,  # noqa: E501 pylint: disable=C0103
):
    """
    Generate many random noise files by taking random spans from a
    single noise file.
    """

    for i in range(nb_files):
        fs, noise_wav = wav.read(  # pylint: disable=C0103,W0612
            noise_file,
        )
```

```
        offset = np.random.randint(len(noise_wav) - sr)
        noise_wav = noise_wav[offset : offset + sr].astype(float)  # noqa: E203
        fn = output_folder / "".join(  # pylint: disable=C0103
            [file_prefix, f"{i}", ".wav"]
        )
        wav.write(fn, sr, noise_wav)

# finis

# Local Variables:
# compile-command: "pyflakes utils.py; pylint-3 -f parseable utils.py" # NOQA, pylint: disable=C0301
# End:
```

5 spike_rnn.py

```
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"""
Recurrent Spiking Neural Network layer
"""

__all__ = ["SpikeRNN"]

import torch
from torch import nn
from torch.autograd import Variable

from . import spike_dense as sd
from . import spike_neuron as sn

B_J0: float = sn.B_J0_VALUE

class SpikeRNN(nn.Module):  # pylint: disable=R0902
    """
    Spike_Rnn class docstring
    """

    def __init__(  # pylint: disable=R0913
        self,
        input_dim,
```

```
        output_dim,
        tau_m=20,
        tau_adp_inital=100,
        tau_initializer="normal",
        tau_m_inital_std=5,
        tau_adp_inital_std=5,
        is_adaptive=1,
        device="cpu",
        bias: bool = True,
    ) -> None:
        """
        Class constructor member function
        """

        super().__init__()
        self.mem: Variable
        self.spike = None
        self.b = None  # pylint: disable=C0103
        self.input_dim = input_dim
        self.output_dim = output_dim
        self.is_adaptive = is_adaptive
        self.device = device

        self.b_j0 = B_J0
        self.dense = nn.Linear(input_dim, output_dim, bias=bias)
        self.recurrent = nn.Linear(output_dim, output_dim, bias=bias)
        self.tau_m = nn.Parameter(torch.Tensor(self.output_dim))
        self.tau_adp = nn.Parameter(torch.Tensor(self.output_dim))
```

```
    if tau_initializer == "normal":
        nn.init.normal_(self.tau_m, tau_m, tau_m_inital_std)
        nn.init.normal_(self.tau_adp, tau_adp_inital, tau_adp_inital_std)
    elif tau_initializer == "multi_normal":
        self.tau_m = sd.multi_normal_initilization(
            self.tau_m, tau_m, tau_m_inital_std
        )
        self.tau_adp = sd.multi_normal_initilization(
            self.tau_adp, tau_adp_inital, tau_adp_inital_std
        )

def parameters(self):
    """
    parameters member function docstring
    """

    return [
        self.dense.weight,
        self.dense.bias,
        self.recurrent.weight,
        self.recurrent.bias,
        self.tau_m,
        self.tau_adp,
    ]

def set_neuron_state(self, batch_size):
    """
    set_neuron_state member function docstring
    """
```

```
        self.mem = Variable(
            torch.zeros(batch_size, self.output_dim) * self.b_j0
        ).to(self.device)
        self.spike = Variable(torch.zeros(batch_size, self.output_dim)).to(
            self.device
        )
        self.b = Variable(
            torch.ones(batch_size, self.output_dim) * self.b_j0
        ).to(self.device)

    def forward(self, input_spike):
        """
        forward member function docstring
        """

        d_input = self.dense(input_spike.float()) + self.recurrent(self.spike)
        (
            self.mem,
            self.spike,
            theta,  # pylint: disable=W0612
            self.b,
        ) = sn.mem_update_adp(
            d_input,
            self.mem,
            self.spike,
            self.tau_adp,
            self.b,
            self.tau_m,
            device=self.device,
```

```
            isAdapt=self.is_adaptive,
        )

        return self.mem, self.spike

# finis

# Local Variables:
# compile-command: "pyflakes spike_rnn.py; pylint-3 -d E0401 -f parseable spike_rnn.py" # NOQA, pylint:
disable=C0301
# End:
```

6 spike_cnn.py

```
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"""
Spiking Convoluted Networks.
"""

__all__ = ["SpikeCov1D", "SpikeCov2D"]

import numpy as np
import torch
from torch import nn

from . import spike_neuron as sn

B_JO = 1.6

class SpikeCov1D(nn.Module):  # pylint: disable=R0902
    """
    Spike_Cov1D class docstring
    """

    def __init__(  # pylint: disable=R0913,R0914
        self,
        input_size,
        output_dim,
```

```
    kernel_size=5,
    strides=1,
    pooling_type=None,
    pool_size=2,
    pool_strides=2,
    dilation=1,
    tau_m=20,
    tau_adp_inital=100,
    tau_initializer="normal",  # pylint: disable=W0613
    tau_m_inital_std=5,
    tau_adp_inital_std=5,
    is_adaptive=1,
    device="cpu",
):
    """
    Class constructor member function docstring
    """

    super().__init__()
    self.mem = None
    self.spike = None
    self.b = None  # pylint: disable=C0103
    # input_size = [c,h]
    self.input_size = input_size
    self.input_dim = input_size[0]
    self.output_dim = output_dim
    self.is_adaptive = is_adaptive
    self.dilation = dilation
    self.device = device
```

```
        if pooling_type is not None:
            if pooling_type == "max":
                self.pooling = nn.MaxPool1d(
                    kernel_size=pool_size, stride=pool_strides, padding=1
                )
            elif pooling_type == "avg":
                self.pooling = nn.AvgPool1d(
                    kernel_size=pool_size, stride=pool_strides, padding=1
                )
        else:
            self.pooling = None

        self.conv = nn.Conv1d(
            self.input_dim,
            self.output_dim,
            kernel_size=kernel_size,
            stride=strides,
            padding=(
                np.ceil(((kernel_size - 1) * self.dilation) / 2).astype(int),
            ),
            dilation=(self.dilation,),
        )

        self.output_size = self.compute_output_size()

        self.tau_m = nn.Parameter(torch.Tensor(self.output_size))
        self.tau_adp = nn.Parameter(torch.Tensor(self.output_size))

        nn.init.normal_(self.tau_m, tau_m, tau_m_inital_std)
```

```
        nn.init.normal_(self.tau_adp, tau_adp_inital, tau_adp_inital_std)

    def parameters(self):
        """
        parameters member function docstring
        """

        return [self.dense.weight, self.dense.bias, self.tau_m, self.tau_adp]

    def set_neuron_state(self, batch_size):
        """
        set_neuron_state member function docstring
        """

        self.mem = (
            torch.zeros(batch_size, self.output_size[0], self.output_size[1])
            * B_J0
        ).to(self.device)

        self.spike = torch.zeros(
            batch_size, self.output_size[0], self.output_size[1]
        ).to(self.device)

        self.b = (
            torch.ones(batch_size, self.output_size[0], self.output_size[1])
            * B_J0
        ).to(self.device)

    def forward(self, input_spike):
```

```
        """
        forward member function docstring
        """

        d_input = self.conv(input_spike.float())
        if self.pooling is not None:
            d_input = self.pooling(d_input)
        (
            self.mem,
            self.spike,
            theta,  # pylint: disable=W0612
            self.b,
        ) = sn.mem_update_adp(
            d_input,
            self.mem,
            self.spike,
            self.tau_adp,
            self.b,
            self.tau_m,
            device=self.device,
            isAdapt=self.is_adaptive,
        )

        return self.mem, self.spike

    def compute_output_size(self):
        """
        compute_output member function docstring
        """
```

```
        x_emp = torch.randn([1, self.input_size[0], self.input_size[1]])
        out = self.conv(x_emp)
        if self.pooling is not None:
            out = self.pooling(out)
        # print(self.name+'\'s size: ', out.shape[1:])
        return out.shape[1:]

class SpikeCov2D(nn.Module):  # pylint: disable=R0902
    """
    Spike_Cov2D docstring
    """

    def __init__(  # pylint: disable=R0913
        self,
        input_size,
        output_dim,
        kernel_size=5,
        strides=1,
        pooling_type=None,
        pool_size=2,
        pool_strides=2,
        tau_m=20,
        tau_adp_inital=100,
        tau_initializer="normal",  # pylint: disable=W0613
        tau_m_inital_std=5,
        tau_adp_inital_std=5,
        is_adaptive=1,
        device="cpu",
    ):
```

```
        """Class constructor member function docstring"""
        super().__init__()
        self.mem = None
        self.spike = None
        self.b = None  # pylint: disable=C0103

        # input_size = [c,w,h]
        self.input_size = input_size
        self.input_dim = input_size[0]
        self.output_dim = output_dim
        self.is_adaptive = is_adaptive
        self.device = device

        if pooling_type is not None:
            if pooling_type == "max":
                self.pooling = nn.MaxPool2d(
                    kernel_size=pool_size, stride=pool_strides, padding=1
                )
            elif pooling_type == "avg":
                self.pooling = nn.AvgPool2d(
                    kernel_size=pool_size, stride=pool_strides, padding=1
                )
        else:
            self.pooling = None

        self.conv = nn.Conv2d(  # Look at the original!!!!
            self.input_dim, self.output_dim, kernel_size, strides
        )
```

```
        self.output_size = self.compute_output_size()

        self.tau_m = nn.Parameter(torch.Tensor(self.output_size))
        self.tau_adp = nn.Parameter(torch.Tensor(self.output_size))

        nn.init.normal_(self.tau_m, tau_m, tau_m_inital_std)
        nn.init.normal_(self.tau_adp, tau_adp_inital, tau_adp_inital_std)

    def parameters(self):
        """
        parameters member function docstring
        """

        return [self.dense.weight, self.dense.bias, self.tau_m, self.tau_adp]

    def set_neuron_state(self, batch_size):
        """
        set_neuron_state member function docstring
        """

        self.mem = torch.rand(batch_size, self.output_size).to(self.device)
        self.spike = torch.zeros(batch_size, self.output_size).to(self.device)
        self.b = (torch.ones(batch_size, self.output_size) * B_J0).to(
            self.device
        )

    def forward(self, input_spike):
        """
        forward member function docstring
```

```
        """

        d_input = self.conv(input_spike.float())
        if self.pooling is not None:
            d_input = self.pool(d_input)
        (
            self.mem,
            self.spike,
            theta,  # pylint: disable=W0612
            self.b,
        ) = sn.mem_update_adp(
            d_input,
            self.mem,
            self.spike,
            self.tau_adp,
            self.b,
            self.tau_m,
            device=self.device,
            isAdapt=self.is_adaptive,
        )

        return self.mem, self.spike

    def compute_output_size(self):
        """
        compute_output_size member function docstring
        """

        x_emp = torch.randn(
```

```
            [1, self.input_size[0], self.input_size[1], self.input_size[2]]
        )
        out = self.conv(x_emp)
        if self.pooling is not None:
            out = self.pooling(out)
        # print(self.name+'\'s size: ', out.shape[1:])
        return out.shape[1:]

# finis

# Local Variables:
# compile-command: "pyflakes spike_cnn.py; pylint-3 -d E0401 -f parseable spike_cnn.py" # NOQA, pylint: disable=C0301
# End:
```

7 spike_dense.py

```
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"""
Fully connected Spiking Network layer
"""

__all__ = ["SpikeDENSE", "SpikeBIDENSE", "ReadoutIntegrator"]

import numpy as np
import torch
from torch import nn
from torch.autograd import Variable

from . import spike_neuron as sn

B_J0: float = sn.B_J0_VALUE

def multi_normal_initilization(
    param, means=[10, 200], stds=[5, 20]
):  # pylint: disable=W0102
    """
    multi_normal_initialization function

    The tensor returned is composed of multiple, equal length
    partitions each drawn from a normal distribution described
```

```
    by a mean and std. The shape of the returned tensor is the same
    at the original input tensor.
    """

    shape_list = param.shape
    if len(shape_list) == 1:
        num_total = shape_list[0]
    elif len(shape_list) == 2:
        num_total = shape_list[0] * shape_list[1]

    num_per_group = int(num_total / len(means))
    # if num_total%len(means) != 0:
    num_last_group = num_total % len(means)
    a = []  # pylint: disable=C0103
    for i in range(len(means)):  # pylint: disable=C0200
        a = (  # pylint: disable=C0103
            a
            + np.random.normal(means[i], stds[i], size=num_per_group).tolist()
        )

        if i == len(means) - 1:
            a = (  # pylint: disable=C0103
                a
                + np.random.normal(
                    means[i], stds[i], size=num_per_group + num_last_group
                ).tolist()
            )
    p = np.array(a).reshape(shape_list)  # pylint: disable=C0103
    with torch.no_grad():
```

```
            param.copy_(torch.from_numpy(p).float())
        return param

    class SpikeDENSE(nn.Module):
        """
        Spike_Dense class docstring
        """

        def __init__(  # pylint: disable=R0913,W0231
            self,
            input_dim,
            output_dim,
            tau_m=20,
            tau_adp_inital=200,
            tau_initializer="normal",  # pylint: disable=W0613
            tau_m_inital_std=5,
            tau_adp_inital_std=5,
            is_adaptive=1,
            device="cpu",
            bias=True,
        ):
            """
            Class constructor member function docstring
            """

            super().__init__()
            self.mem = None
            self.spike = None
            self.b = None  # pylint: disable=C0103
```

```
self.input_dim = input_dim
self.output_dim = output_dim
self.is_adaptive = is_adaptive
self.device = device

self.dense = nn.Linear(input_dim, output_dim, bias=bias)

# Parameters are Tensor subclasses, that have a very special
# property when used with Module s - when they're assigned as
# Module attributes they are automatically added to the list
# of its parameters, and will appear e.g. in parameters() iterator.
self.tau_m = nn.Parameter(torch.Tensor(self.output_dim))
self.tau_adp = nn.Parameter(torch.Tensor(self.output_dim))

if tau_initializer == "normal":
    # Initialize self.tau_m and self.tau_adp from a single
    # normal distributions.
    nn.init.normal_(self.tau_m, tau_m, tau_m_inital_std)
    nn.init.normal_(self.tau_adp, tau_adp_inital, tau_adp_inital_std)
elif tau_initializer == "multi_normal":
    # Initialize self.tau_m and self.tau_adp from from
    # multiple normal distributions. tau_m and tar_adp_initial
    # must be lists of means and tar_m_initial_std and
    # tar_adp_initial_std must be lists of standard
    # deviations.
    self.tau_m = multi_normal_initilization(
        self.tau_m, tau_m, tau_m_inital_std
    )
    self.tau_adp = multi_normal_initilization(
```

```
                self.tau_adp, tau_adp_inital, tau_adp_inital_std
            )

    def parameters(self):
        """
        Return a list of parameters being trained.
        """

        # The latter two are module parameters; the first two aren't
        # Where is dense.weight defined or assigned?
        return [self.dense.weight, self.dense.bias, self.tau_m, self.tau_adp]

    def set_neuron_state(self, batch_size):
        """
        Initialize mem, spike and b tensors.

        The Variable API has been deprecated: Variables are no
        longer necessary to use autograd with tensors. Autograd
        automatically supports Tensors with requires_grad set to
        True.
        """

        # self.mem = (torch.rand(batch_size, self.output_dim) * self.b_j0).to(
        #     self.device
        # )
        self.mem = Variable(
            torch.zeros(batch_size, self.output_dim) * B_J0
        ).to(self.device)
```

```
        self.spike = Variable(torch.zeros(batch_size, self.output_dim)).to(
            self.device
        )

        self.b = Variable(torch.ones(batch_size, self.output_dim) * B_J0).to(
            self.device
        )

    def forward(self, input_spike):
        """
        SpikeDENSE forward pass
        """

        d_input = self.dense(input_spike.float())
        (
            self.mem,
            self.spike,
            theta,  # pylint: disable=W0612
            self.b,
        ) = sn.mem_update_adp(
            d_input,
            self.mem,
            self.spike,
            self.tau_adp,
            self.b,
            self.tau_m,
            device=self.device,
            isAdapt=self.is_adaptive,
        )
```

```
        return self.mem, self.spike

class SpikeBIDENSE(nn.Module):  # pylint: disable=R0902
    """
    Spike_Bidense class docstring
    """

    def __init__(  # pylint: disable=R0913
        self,
        input_dim1,
        input_dim2,
        output_dim,
        tau_m=20,
        tau_adp_inital=100,
        tau_initializer="normal",  # pylint: disable=W0613
        tau_m_inital_std=5,
        tau_adp_inital_std=5,
        is_adaptive=1,
        device="cpu",
    ):
        """
        Class constructor member function docstring
        """

        super().__init__()
        self.mem = None
        self.spike = None
        self.b = None  # pylint: disable=C0103
        self.input_dim1 = input_dim1
```

```
        self.input_dim2 = input_dim2
        self.output_dim = output_dim
        self.is_adaptive = is_adaptive
        self.device = device

        self.dense = nn.Bilinear(input_dim1, input_dim2, output_dim)
        self.tau_m = nn.Parameter(torch.Tensor(self.output_dim))
        self.tau_adp = nn.Parameter(torch.Tensor(self.output_dim))

        if tau_initializer == "normal":
            nn.init.normal_(self.tau_m, tau_m, tau_m_inital_std)
            nn.init.normal_(self.tau_adp, tau_adp_inital, tau_adp_inital_std)
        elif tau_initializer == "multi_normal":
            self.tau_m = multi_normal_initilization(
                self.tau_m, tau_m, tau_m_inital_std
            )
            self.tau_adp = multi_normal_initilization(
                self.tau_adp, tau_adp_inital, tau_adp_inital_std
            )

    def parameters(self):
        """
        parameter member function docstring
        """

        return [self.dense.weight, self.dense.bias, self.tau_m, self.tau_adp]

    def set_neuron_state(self, batch_size):
        """
```

```
        set_neuron_state member function docstring
        """

        self.mem = (torch.rand(batch_size, self.output_dim) * B_J0).to(
            self.device
        )
        self.spike = torch.zeros(batch_size, self.output_dim).to(self.device)
        self.b = (torch.ones(batch_size, self.output_dim) * B_J0).to(
            self.device
        )

    def forward(self, input_spike1, input_spike2):
        """
        forward member function docstring
        """

        d_input = self.dense(input_spike1.float(), input_spike2.float())
        (
            self.mem,
            self.spike,
            theta,  # pylint: disable=W0612
            self.b,
        ) = sn.mem_update_adp(
            d_input,
            self.mem,
            self.spike,
            self.tau_adp,
            self.b,
            self.tau_m,
```

```
            device=self.device,
            isAdapt=self.is_adaptive,
        )

        return self.mem, self.spike

class ReadoutIntegrator(nn.Module):
    """
    Redout_Integrator class docstring
    """

    def __init__(  # pylint: disable=R0913
        self,
        input_dim,
        output_dim,
        tau_m=20,
        tau_initializer="normal",  # pylint: disable=W0613
        tau_m_inital_std=5,
        device="cpu",
        bias=True,
    ):
        """
        Class constructor member function
        """

        super().__init__()
        self.mem = None

        # UNUSED?!
```

```
        self.spike = None
        self.b = None  # pylint: disable=C0103

        self.input_dim = input_dim
        self.output_dim = output_dim
        self.device = device

        self.dense = nn.Linear(input_dim, output_dim, bias=bias)
        self.tau_m = nn.Parameter(torch.Tensor(self.output_dim))

        nn.init.normal_(self.tau_m, tau_m, tau_m_inital_std)

    def parameters(self):
        """
        parameters member function docstring
        """

        return [self.dense.weight, self.dense.bias, self.tau_m]

    def set_neuron_state(self, batch_size):
        """
        set_neuron_state member function docstring
        """

        # self.mem = torch.rand(batch_size,self.output_dim).to(self.device)
        self.mem = (torch.zeros(batch_size, self.output_dim)).to(self.device)

    def forward(self, input_spike):
        """
```

```
        forward member function docstring
        """

        d_input = self.dense(input_spike.float())
        self.mem = sn.output_Neuron(
            d_input, self.mem, self.tau_m, device=self.device
        )
        return self.mem

# finis

# Local Variables:
# compile-command: "pyflakes spike_dense.py; pylint-3 -d E0401 -f parseable spike_dense.py" # NOQA,
pylint: disable=C0301
# End:
```

8 spike_neuron.py

```
# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
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"""
This module contains one class and three functions that together
aree used to calculate the membrane potential of the various spiking
neurons defined in this package. In particular, the functions
mem_update_adp and output_Neuron are called in the forward member
function of the SpikeDENSE, SpikeBIDENSE, SpikeRNN, SpikeCov1D and
SpikeCov2D layer classes and the readout_integration classes
respectively.
"""

import math

# import numpy as np
import torch
from loguru import logger

# from torch import nn
from torch.nn import functional as F

# all = ["output_Neuron, mem_update_adp"]

SURROGATE_TYPE: str = "MG"
GAMMA: float = 0.5
```

```
LENS: float = 0.5
R_M: float = 1
BETA_VALUE: float = 0.184
B_JO_VALUE: float = 1.6
SCALE: float = 6.0
HIGHT: float = 0.15

# act_fun_adp = ActFunADP.apply

class NoSurrogateTypeException(Exception):
    pass

def gaussian(
    x: torch.Tensor,  # pylint: disable=C0103
    mu: float = 0.0,  # pylint: disable=C0103
    sigma: float = 0.5,
) -> torch.Tensor:
    """
    Gussian

    Used in the backward method of a custom autograd function class
    ActFunADP to approximate the gradiant in a surrogate function
    for back propogation.
    """

    return (
        torch.exp(-((x - mu) ** 2) / (2 * sigma**2))
        / torch.sqrt(2 * torch.tensor(math.pi))
        / sigma
```

```
    )

def mem_update_adp(  # pylint: disable=R0913
    inputs,
    mem,
    spike,
    tau_adp,
    b,  # pylint: disable=C0103
    tau_m,
    dt=1,  # pylint: disable=C0103
    isAdapt=1,  # pylint: disable=C0103
    device=None,
):  # pylint: disable=C0103
    """
    This function updates the membrane potential and adaptation
    variable of a spiking neural network.

    Inputs:
    inputs: the input spikes to the neuron
    mem: the current membrane potential of the neuron
    spike: the current adaptation variable of the neuron
    tau_adp: the time constant for the adaptation variable
    b: a value used in the adaptation variable update equation
    tau_m: the time constant for the membrane potential
    dt: the time step used in the simulation
    isAdapt: a boolean variable indicating whether or not to use the
    adaptation variable
    device: a variable indicating which device (e.g. CPU or GPU) to
    use for the computation
```

```
Outputs:
mem: the updated membrane potential
spike: the updated adaptation variable
B: a value used in the adaptation variable update equation
b: the updated value of the adaptation variable

The function first computes the exponential decay factors alpha
and ro using the time constants tau_m and tau_adp, respectively.
It then checks whether the isAdapt variable is True or False to
determine the value of beta.  The adaptation variable b is then
updated using the exponential decay rule, and B is computed using
the value of beta and the initial value b_j0_value.  The function
then updates the membrane potential mem using the input spikes, B,
and the decay factor alpha, and computes the inputs_ variable as
the difference between mem and B.  Finally, the adaptation
variable spike is updated using the activation function defined in
the act_fun_adp() function, and the updated values of mem, spike,
B, and b are returned.
"""

alpha = torch.exp(-1.0 * dt / tau_m).to(device)
ro = torch.exp(-1.0 * dt / tau_adp).to(device)  # pylint: disable=C0103

beta = BETA_VALUE if isAdapt else 0.0
if isAdapt:
    beta = BETA_VALUE
else:
    beta = 0.0
```

```
    b = ro * b + (1 - ro) * spike  # Hard reset equation 1.8 page 12.
    B = B_JO_VALUE + beta * b  # pylint: disable=C0103

    mem = mem * alpha + (1 - alpha) * R_M * inputs - B * spike * dt
    inputs_ = mem - B

    # Non spiking output
    spike = F.relu(inputs_)

    # For details about calling the 'apply' member function,
    # See: https://pytorch.org/docs/stable/autograd.html#function
    # Spiking output
    spike = ActFunADP.apply(inputs_)

    return mem, spike, B, b

def output_Neuron(
    inputs, mem, tau_m, dt=1, device=None
):  # pylint: disable=C0103
    """
    Output the membrane potential of a LIF neuron without spike

    The only appears of this function is in the forward member
    function of the ReadoutIntegrator layer class.
    """

    alpha = torch.exp(-1.0 * dt / tau_m).to(device)
    mem = mem * alpha + (1 - alpha) * inputs
    return mem
```

```python
class ActFunADP(torch.autograd.Function):
    """
    ActFunADP

    Custom autograd function redefining how forward and backward
    passes are performed. This class is 'applied' in the
    mem_update_adp function to calculate the new spike value.

    For details about calling the 'apply' member function, See:
    https://pytorch.org/docs/stable/autograd.html#function
    """

    @staticmethod
    def forward(ctx, i):  # ? What is the type and dimension of i?
        """
        Redefine the default autograd forward pass function.
        inp = membrane potential- threshold

        Returns a tensor whose values are either 0 or 1 dependent
        upon their value in the input tensor i.
        """

        ctx.save_for_backward(i)
        return i.gt(0).float()  # is firing ???

    @staticmethod
    def backward(ctx, grad_output):
        """
        Defines a formula for differentiating during back propogation.
```

```
        Since the spike function is nondifferentiable, we
        approximate the back propogation gradients with one of
        several surrogate functions.
        """

        (result,) = ctx.saved_tensors
        # grad_input = grad_output.clone()
        # temp = abs(result) < lens
        if SURROGATE_TYPE == "G":
            # temp = gaussian(result, mu=0.0, sigma=LENS)
            temp = (
                torch.exp(-(result**2) / (2 * LENS**2))
                / torch.sqrt(2 * torch.tensor(math.pi))
                / LENS
            )
        elif SURROGATE_TYPE == "MG":
            temp = (
                gaussian(result, mu=0.0, sigma=LENS) * (1.0 + HIGHT)
                - gaussian(result, mu=LENS, sigma=SCALE * LENS) * HIGHT
                - gaussian(result, mu=-LENS, sigma=SCALE * LENS) * HIGHT
            )
        elif SURROGATE_TYPE == "linear":
            temp = F.relu(1 - result.abs())
        elif SURROGATE_TYPE == "slayer":
            temp = torch.exp(-5 * result.abs())
        else:
            logger.critical(
                "No Surrogate type chosen, so temp tensor is undefined."
            )
```

```
            raise NoSurrogateTypeException("No Surrogate type chosen.")
        return grad_output * temp.float() * GAMMA

# finis

# Local Variables:
# compile-command: "pyflakes spike_neuron.py; pylint-3 -d E0401 -f parseable spike_neuron.py" # NOQA,
pylint: disable=C0301
# End:
```

9 decorators.py

```python
# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
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"""
Custom function decorators
"""

__all__ = ["debug", "timeit", "initializer"]

import inspect
from datetime import datetime
from functools import wraps

from decorator import decorator
from loguru import logger

from .exceptions import InvalidContextError

@decorator
def debug(_func, *args, **kwargs):
    """
    Print the function signature and return value
    """

    args_repr = [repr(arg) for arg in args]  # 1
    kwargs_repr = [f"{key}={val!r}" for key, val in kwargs.items()]  # 2
```

```
    signature = ", ".join(args_repr + kwargs_repr)  # 3
    logger.info(f"Calling {_func.__name__}({signature})")
    value = _func(*args, **kwargs)
    logger.info(f"{_func.__name__!r} returned {value!r}")  # 4
    return value

@decorator
def timeit(_func, *args, **kwargs):
    """
    Log the elasped time it took this function to run.
    """

    time_0 = datetime.now()
    rtn = _func(*args, **kwargs)
    time_1 = datetime.now()
    logger.info(f"This task took: {time_1 - time_0}")
    return rtn

def initializer(fun):
    """
    This decorator takes a class constructor signature
    and makes corresponding class member variables.
    """

    if fun.__name__ != "__init__":
        raise InvalidContextError(
            "Only applicable context is decorating a class constructor."
        )
```

```
        specs = inspect.getfullargspec(fun)

        @wraps(fun)
        def wrapper(self, *args, **kargs):
            for name, arg in list(zip(specs.args[1:], args)) + list(kargs.items()):
                setattr(self, name, arg)
            if specs.defaults is not None:
                for i in range(len(specs.defaults)):
                    index = -(i + 1)
                    if not hasattr(self, specs.args[index]):
                        setattr(self, specs.args[index], specs.defaults[index])
            fun(self, *args, **kargs)

        return wrapper

# finis

# Local Variables:
# compile-command: "pyflakes decorators.py; pylint-3 -d E0401 -f parseable decorators.py" # NOQA, pylint:
disable=C0301
# End:
```

10 exceptions.py

```
# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
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"""
Custom exceptions
"""

__all__ = ["InvalidContextError"]

class InvalidContextError(Exception):
    """
    Raise this exception when you want to
    signal an invalid context.
    """

# finis

# Local Variables:
# compile-command: "pyflakes exceptions.py; pylint-3 -d E0401 -f parseable exceptions.py" # NOQA, pylint:
disable=C0301
# End:
```

11 gencat.py

```python
# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
# SPDX-License-Identifier: MPL-2.0

"""
Concatenate multiple generators into a single sequence
"""

def gen_cat(sources):
    """
    gen_cat
    """
    for src in sources:
        yield from src

# Example use

if __name__ == "__main__":
    from pathlib import Path

    from .genopen import gen_open

    lognames = Path("www").rglob("access-log*")
    logfiles = gen_open(lognames)
    loglines = gen_cat(logfiles)
    for line in loglines:
        print(line, end="")
```

```
# finis

# Local Variables:
# compile-command: "pyflakes gencat.py; pylint-3 -d E0401 -f parseable gencat.py" # NOQA, pylint: disable=C0301
# End:
```

12 gendfind.py

```python
# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
# SPDX-License-Identifier: MPL-2.0

"""
A function that generates files
that match a given regex pattern.
"""

import os
import re

def gen_dfind(dirpat, top):
    """
    Traverse the directorys and yield the results.
    """

    regexp = re.compile(dirpat)
    for path, dirlist, _ in os.walk(top):
        for name in [dir for dir in dirlist if regexp.search(dir) is not None]:
            yield os.path.join(path, name)

# Example use

if __name__ == "__main__":
    print(list(gen_dfind(r"^(?!_).*", "www")))
```

```
# finis

# Local Variables:
# compile-command: "pyflakes gendfind.py; pylint-3 -d E0401 -f parseable gendfind.py" # NOQA, pylint: disable=C0301
# End:
```

13 genfind.py

```
# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
# SPDX-License-Identifier: MPL-2.0

"""
A function that generates files that match a given filename pattern
"""

from pathlib import Path

def gen_find(filepat, top):
    """
    gen_find
    """

    yield from Path(top).rglob(filepat)

# Example use

if __name__ == "__main__":
    lognames = gen_find("access-log*", "www")
    for name in lognames:
        print(name)

# finis

# Local Variables:
```

```
# compile-command: "pyflakes genfind.py; pylint-3 -d E0401 -f parseable genfind.py" # NOQA, pylint:
disable=C0301
# End:
```

14 gengrep.py

```
# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
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"""
Grep a sequence of lines that match a re pattern
"""

import re

def gen_grep(pat, lines):
    """
    gen_grep
    """

    patc = re.compile(pat)
    return (line for line in lines if patc.search(line))

# Example use

if __name__ == "__main__":
    from pathlib import Path

    from .gencat import gen_cat
    from .genopen import gen_open

    lognames = Path("www").rglob("access-log*")
```

```
    logfiles = gen_open(lognames)
    loglines = gen_cat(logfiles)

    # Look for ply downloads (PLY is my own Python package)
    plylines = gen_grep(r"ply-.*\.gz", loglines)
    for line in plylines:
        print(line, end="")

# finis

# Local Variables:
# compile-command: "pyflakes gengrep.py; pylint-3 -d E0401 -f parseable gengrep.py" # NOQA, pylint:
disable=C0301
# End:
```

15 genopen.py

```
# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
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"""
Takes a sequence of filenames as input and yields
a sequence of file objects that have been suitably open.
"""

import bz2
import gzip

def gen_open(paths):
    """
    gen_open
    """

    for path in paths:
        if path.suffix == ".gz":
            yield gzip.open(path, "rt")
        elif path.suffix == ".bz2":
            yield bz2.open(path, "rt")
        else:
            yield open(path, "rt")  # pylint: disable=R1732, W1514

# Example use
```

```
if __name__ == "__main__":
    from pathlib import Path

    lognames = Path("www").rglob("access-log*")
    logfiles = gen_open(lognames)
    for f in logfiles:
        print(f)

# finis

# Local Variables:
# compile-command: "pyflakes genopen.py pylint-3 -d E0401 -f parseable genopen.py" # NOQA, pylint:
disable=C0301
# End:
```