Contents

1 srnn_fin.py

```
#! /usr/bin/env python

# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
#
# SPDX-License-Identifier: MPL-2.0
# flake8: noqa
# pylint: skip-file
# type: ignore
# REUSE-IgnoreStart
import os
import sys

sys.path.append("..")
import time

import librosa
import matplotlib.pyplot as plt
import numpy as np
import scipy.io.wavfile as wav

# from tqdm import tqdm_notebook
import torch
import torch.nn as nn
import torch.nn.functional as F
import torchvision
from data import MelSpectrogram, Normalize, Pad, Rescale, SpeechCommandsDataset
```

```
from matplotlib.gridspec import GridSpec
from optim import RAdam
from torch.optim.lr_scheduler import (
    ExponentialLR,
    LambdaLR,
    MultiStepLR,
    StepLR,
)
from torch.utils.data import DataLoader
from utils import generate_random_silence_files

dtype = torch.float
torch.manual_seed(0)
# device = torch.device("cpu")
device = torch.device("cuda:0" if torch.cuda.is_available() else "cpu")

# Directories
train_data_root = "/export/scratch2/guravage/GSD"
test_data_root = "/export/scratch2/guravage/GSD"

# ls directories and folders in train_data_root folder
training_words = os.listdir(train_data_root)

# Isolate directories in the train_date_root
training_words = [
    x
    for x in training_words
    if os.path.isdir(os.path.join(train_data_root, x))
]
```

```python
    # Ignore those that begin with an underscore
    training_words = [
        x
        for x in training_words
        if os.path.isdir(os.path.join(train_data_root, x))
        if x[0] != "_"
    ]
    print("{} training words:".format(len(training_words)))
    print(training_words)

    # ls directories and folders in test_data_root folder
    testing_words = os.listdir(test_data_root)

    # Look for testing_word directories in train_data_root
    testing_words = [
        x for x in testing_words if os.path.isdir(os.path.join(train_data_root, x))
    ]

    # Ignore those that begin with an underscore
    testing_words = [
        x
        for x in testing_words
        if os.path.isdir(os.path.join(train_data_root, x))
        if x[0] != "_"
    ]
    print("{} testing words:".format(len(testing_words)))
    print(testing_words)

    # Create a dictionary whose keys are testing_words(in the
```

```
# train_data_root) and whose values are the words' ordianal position in the original list.
label_dct = {
    k: i for i, k in enumerate(testing_words + ["_silence_", "_unknown_"])
}
for w in training_words:
    label = label_dct.get(w)
    if label is None:
        label_dct[w] = label_dct["_unknown_"]

print("label_dct:")
print(label_dct)

sr = 16000
size = 16000

noise_path = os.path.join(train_data_root, "_background_noise_")
noise_files = []
for f in os.listdir(noise_path):
    if f.endswith(".wav"):
        full_name = os.path.join(noise_path, f)
        noise_files.append(full_name)
print("noise files:")
print(noise_files)

# generate silence training and validation data

silence_folder = os.path.join(train_data_root, "_silence_")
if not os.path.exists(silence_folder):
    os.makedirs(silence_folder)
```

```
        # 260 validation / 2300 training
        generate_random_silence_files(
            2560, noise_files, size, os.path.join(silence_folder, "rd_silence")
        )

        # save 260 files for validation
        silence_files = [fname for fname in os.listdir(silence_folder)]
        with open(
            os.path.join(train_data_root, "silence_validation_list.txt"), "w"
        ) as f:
            f.writelines(
                "_silence_/" + fname + "\n" for fname in silence_files[:260]
            )

    n_fft = int(30e-3 * sr)
    hop_length = int(10e-3 * sr)
    n_mels = 40
    fmax = 4000
    fmin = 20
    delta_order = 2
    stack = True

    melspec = MelSpectrogram(
        sr, n_fft, hop_length, n_mels, fmin, fmax, delta_order, stack=stack
    )
    pad = Pad(size)
    rescale = Rescale()
    normalize = Normalize()
```

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

def collate_fn(data):

    X_batch = np.array([d[0] for d in data])
    std = X_batch.std(axis=(0, 2), keepdims=True)
    X_batch = torch.tensor(X_batch / std)
    y_batch = torch.tensor([d[1] for d in data])

    return X_batch, y_batch

batch_size = 32

train_dataset = SpeechCommandsDataset(
    train_data_root,
    label_dct,
    transform=transform,
    mode="train",
    max_nb_per_class=None,
)
train_sampler = torch.utils.data.WeightedRandomSampler(
    train_dataset.weights, len(train_dataset.weights)
)
train_dataloader = DataLoader(
    train_dataset,
    batch_size=batch_size,
    num_workers=8,
    sampler=train_sampler,
    collate_fn=collate_fn,
```

```
)

valid_dataset = SpeechCommandsDataset(
    train_data_root,
    label_dct,
    transform=transform,
    mode="valid",
    max_nb_per_class=None,
)
valid_dataloader = DataLoader(
    valid_dataset,
    batch_size=batch_size,
    shuffle=True,
    num_workers=8,
    collate_fn=collate_fn,
)

test_dataset = SpeechCommandsDataset(
    test_data_root, label_dct, transform=transform, mode="test"
)
test_dataloader = DataLoader(
    test_dataset,
    batch_size=batch_size,
    shuffle=True,
    num_workers=8,
    collate_fn=collate_fn,
)

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

thr_func = sn.ActFunADP.apply
is_bias = True

class RNN_spike(nn.Module):
    def __init__(
        self,
    ):
        super(RNN_spike, self).__init__()
        n = 256
        # is_bias=False
        self.dense_1 = sd.SpikeDENSE(
            40 * 3,
            n,
            tau_adp_inital_std=50,
            tau_adp_inital=200,
            tau_m=20,
            tau_m_inital_std=5,
            device=device,
            bias=is_bias,
        )
        self.rnn_1 = sr.SpikeRNN(
            n,
            n,
            tau_adp_inital_std=50,
            tau_adp_inital=200,
            tau_m=20,
```

```
            tau_m_inital_std=5,
            device=device,
            bias=is_bias,
        )
        self.dense_2 = sd.ReadoutIntegrator(
            n, 12, tau_m=10, tau_m_inital_std=1, device=device, bias=is_bias
        )
        # self.dense_2 = sr.spike_rnn(n,12,tauM=10,tauM_inital_std=1,device=device,bias=is_bias)#10

        self.thr = nn.Parameter(torch.Tensor(1))
        nn.init.constant_(self.thr, 5e-2)

        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 is_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, input):
        # What is this that returns 4 values?
        b, channel, seq_length, input_dim = input.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

# input_s = input
input_s = (
    thr_func(input - self.thr) * 1.0
    - thr_func(-self.thr - input) * 1.0
)
for i in range(seq_length):

    input_x = input_s[:, :, i, :].reshape(b, channel * input_dim)
    mem_layer1, spike_layer1 = self.dense_1.forward(input_x)
    mem_layer2, 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)

    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(input_s.detach().cpu().numpy())),
    np.mean(fr_1),
    np.mean(fr_2),
]
```

```
# Instantiate the model
model = RNN_spike()
criterion = nn.CrossEntropyLoss()  # nn.NLLLoss()

# device = torch.device("cpu")#torch.device("cuda:0" if torch.cuda.is_available() else "cpu")
print("device:", device)
model.to(device)

def test(data_loader, is_show=0):
    test_acc = 0.0
    sum_sample = 0.0
    fr_ = []
    for i, (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)
        fr_.append(fr)
        _, predicted = torch.max(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:
        print("Mean FR: ", mean_FR)
    return test_acc.data.cpu().numpy() / sum_sample, mean_FR
```

```
def train(epochs, criterion, optimizer, scheduler=None):
    acc_list = []
    best_acc = 0

    path = "../model/"  # .pth'
    for epoch in range(epochs):
        train_acc = 0
        sum_sample = 0
        train_loss_sum = 0
        for i, (images, labels) in enumerate(train_dataloader):
            # 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)
            _, predicted = torch.max(predictions.data, 1)
            train_loss = criterion(predictions, labels)

            # print(predictions,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_dataloader, 1)
            train_loss_sum += train_loss

            acc_list.append(train_acc)
            print("lr: ", 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")
            print(model.thr)
            print(
                "epoch: {:3d}, Train Loss: {:.4f}, Train Acc: {:.4f},Valid Acc: {:.4f}".format(
                    epoch,
                    train_loss_sum / len(train_dataloader),
                    train_acc,
                    valid_acc,
                ),
                flush=True,
            )
        return acc_list

learning_rate = 3e-3  # 1.2e-2

test_acc = test(test_dataloader)
```

```
print(test_acc)
if is_bias:
    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,
    ]
else:
    base_params = [
        model.dense_1.dense.weight,
        model.rnn_1.dense.weight,
        model.rnn_1.recurrent.weight,
        model.dense_2.dense.weight,
    ]

# optimizer = torch.optim.Adamax([
#                                {'params': base_params},
#                                {'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},
#                              #   {'params': model.dense_2.tau_adp, 'lr': learning_rate * 10},
```

```
#                               {'params': model.rnn_1.tau_adp, 'lr': learning_rate * 2},
#                               ],
#                         lr=learning_rate,eps=1e-5)
optimizer = 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 = StepLR(optimizer, step_size=20, gamma=.5) # 20
scheduler = StepLR(optimizer, step_size=10, gamma=0.1)  # 20
# epoch=0
epochs = 30
# scheduler = LambdaLR(optimizer,lr_lambda=lambda epoch: 1-epoch/70)
# scheduler = ExponentialLR(optimizer, gamma=0.85)
acc_list = train(epochs, criterion, optimizer, scheduler)

test_acc = test(test_dataloader)
print(test_acc)
# REUSE-IgnoreEnd
```

2 data.py

```
# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
#
# SPDX-License-Identifier: MPL-2.0
# flake8: noqa
# pylint: skip-file
# type: ignore
# REUSE-IgnoreStart
import os

import librosa
import numpy as np
import scipy.io.wavfile as wav
import torch
from torch.utils.data import Dataset
from utils import split_wav, txt2list

class SpeechCommandsDataset(Dataset):
    def __init__(
        self, data_root, label_dct, mode, transform=None, max_nb_per_class=None
    ):

        assert mode in [
            "train",
            "valid",
            "test",
        ], 'mode should be "train", "valid" or "test"'
```

```
        self.filenames = []
        self.labels = []
        self.mode = mode
        self.transform = transform

        if self.mode == "train" or self.mode == "valid":
            # Create lists of 'wav' files.
            testing_list = txt2list(
                os.path.join(data_root, "testing_list.txt")
            )
            validation_list = txt2list(
                os.path.join(data_root, "validation_list.txt")
            )
            validation_list += txt2list(
                os.path.join(data_root, "silence_validation_list.txt")
            )
        else:
            testing_list = []
            validation_list = []

        for root, dirs, files in os.walk(data_root):
            if "_background_noise_" in root:
                continue
            for filename in files:
                if not filename.endswith(".wav"):
                    # Ignore files whose suffix is not 'wav'.
                    continue

                # Extract the cwd without a path.
```

```
        command = root.split("/")[-1]

        label = label_dct.get(command)
        if label is None:
            print("ignored command: %s" % command)
            break
        partial_path = "/".join([command, filename])

        testing_file = partial_path in testing_list
        validation_file = partial_path in validation_list
        training_file = not testing_file and not validation_file

        if (
            (self.mode == "test")
            or (self.mode == "train" and training_file)
            or (self.mode == "valid" and validation_file)
        ):
            full_name = os.path.join(root, filename)
            self.filenames.append(full_name)
            self.labels.append(label)

if max_nb_per_class is not None:

    selected_idx = []
    for label in np.unique(self.labels):
        label_idx = [
            i for i, x in enumerate(self.labels) if x == label
        ]
        if len(label_idx) < max_nb_per_class:
```

```
                    selected_idx += label_idx
                else:
                    selected_idx += list(
                        np.random.choice(label_idx, max_nb_per_class)
                    )

            self.filenames = [self.filenames[idx] for idx in selected_idx]
            self.labels = [self.labels[idx] for idx in selected_idx]

        if self.mode == "train":
            label_weights = 1.0 / np.unique(self.labels, return_counts=True)[1]
            label_weights /= np.sum(label_weights)
            self.weights = torch.DoubleTensor(
                [label_weights[label] for label in self.labels]
            )

    def __len__(self):
        return len(self.labels)

    def __getitem__(self, idx):

        filename = self.filenames[idx]
        item = wav.read(filename)[1].astype(float)
        m = np.max(np.abs(item))
        if m > 0:
            item /= m
        if self.transform is not None:
            item = self.transform(item)
```

```
        label = self.labels[idx]

        return item, label

class Pad:
    def __init__(self, size):

        self.size = size

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

class RandomNoise:
    def __init__(self, noise_files, size, coef):

        self.size = size
        self.noise_files = noise_files
        self.coef = coef

    def __call__(self, wav):
```

```
        if np.random.random() < 0.8:

            noise_wav = get_random_noise(self.noise_files, self.size)
            noise_power = (noise_wav**2).mean()
            sig_power = (wav**2).mean()

            noisy_wav = wav + self.coef * noise_wav * np.sqrt(
                sig_power / noise_power
            )

        else:

            noisy_wav = wav

        return noisy_wav

class RandomShift:
    def __init__(self, min_shift, max_shift):

        self.min_shift = min_shift
        self.max_shift = max_shift

    def __call__(self, wav):

        shift = np.random.randint(self.min_shift, self.max_shift + 1)
        shifted_wav = np.roll(wav, shift)

        if shift > 0:
            shifted_wav[:shift] = 0
```

```python
        elif shift < 0:
            shifted_wav[shift:] = 0

        return shifted_wav

class MelSpectrogram:
    def __init__(
        self,
        sr,
        n_fft,
        hop_length,
        n_mels,
        fmin,
        fmax,
        delta_order=None,
        stack=True,
    ):

        self.sr = sr
        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, wav):
```

```
        S = librosa.feature.melspectrogram(
            y=wav,
            sr=self.sr,
            n_fft=self.n_fft,
            hop_length=self.hop_length,
            n_mels=self.n_mels,
            fmax=self.fmax,
            fmin=self.fmin,
        )

        M = np.max(np.abs(S))
        if M > 0:
            feat = np.log1p(S / M)
        else:
            feat = S

        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)

        elif 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)

        else:
            return np.expand_dims(feat.T, 0)
```

```
class Rescale:
    def __call__(self, input):

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

        return input / std

class Normalize:
    def __call__(self, input):

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

        return input / std

class WhiteNoise:
    def __init__(self, size, coef_max):

        self.size = size
        self.coef_max = coef_max

    def __call__(self, wav):

        noise_wav = np.random.normal(size=self.size)
        noise_power = (noise_wav**2).mean()
        sig_power = (wav**2).mean()
```

```
        coef = np.random.uniform(0.0, self.coef_max)
        noisy_wav = wav + coef * noise_wav * np.sqrt(sig_power / noise_power)
        return noisy_wav
# REUSE-IgnoreEnd
```

3 optim.py

```python
# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
#
# SPDX-License-Identifier: MPL-2.0
# flake8: noqa
# pylint: skip-file
# type: ignore
# REUSE-IgnoreStart
import math

import torch
from torch.optim.optimizer import Optimizer, required

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

class RAdam(Optimizer):
    def __init__(
        self,
        params,
        lr=1e-3,
        betas=(0.9, 0.999),
        eps=1e-8,
        weight_decay=0,
        degenerated_to_sgd=True,
    ):
        if not 0.0 <= lr:
            raise ValueError("Invalid learning rate: {}".format(lr))
```

```python
        if not 0.0 <= eps:
            raise ValueError("Invalid epsilon value: {}".format(eps))
        if not 0.0 <= betas[0] < 1.0:
            raise ValueError(
                "Invalid beta parameter at index 0: {}".format(betas[0])
            )
        if not 0.0 <= betas[1] < 1.0:
            raise ValueError(
                "Invalid beta parameter at index 1: {}".format(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 = dict(
            lr=lr,
            betas=betas,
            eps=eps,
            weight_decay=weight_decay,
            buffer=[[None, None, None] for _ in range(10)],
```

```
        )
        super(RAdam, self).__init__(params, defaults)

    def __setstate__(self, state):
        super(RAdam, self).__setstate__(state)

    def step(self, closure=None):

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

        for group in self.param_groups:

            for p in group["params"]:
                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(p_data_fp32)
    state["exp_avg_sq"] = torch.zeros_like(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 = buffered[1], buffered[2]
else:
    buffered[0] = state["step"]
    beta2_t = beta2 ** state["step"]
    N_sma_max = 2 / (1 - beta2) - 1
    N_sma = N_sma_max - 2 * state["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

# REUSE-IgnoreEnd
```

4 utils.pys

```
# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
#
# SPDX-License-Identifier: MPL-2.0
# flake8: noqa
# pylint: skip-file
# type: ignore
# REUSE-IgnoreStart
import matplotlib.pyplot as plt
import numpy as np
import scipy.io.wavfile as wav
import torch
from matplotlib.gridspec import GridSpec

def txt2list(filename):
    """This function reads a file containing one filename per line
    and returns a list of lines.

    Could be replaced with:
    for fn in gen_find('*_list.txt', '/tmp/testdata/'):
        with open(fn) as fp:
            mylist = fp.read().splitlines()

    """
    lines_list = []
    with open(filename, "r") as txt:
        for line in txt:
```

```
                lines_list.append(line.rstrip("\n"))
        return lines_list

    def plot_spk_rec(spk_rec, idx):

        nb_plt = len(idx)
        d = int(np.sqrt(nb_plt))
        gs = GridSpec(d, d)
        fig = plt.figure(figsize=(30, 20), dpi=150)
        for i in range(nb_plt):
            plt.subplot(gs[i])
            plt.imshow(
                spk_rec[idx[i]].T,
                cmap=plt.cm.gray_r,
                origin="lower",
                aspect="auto",
            )
            if i == 0:
                plt.xlabel("Time")
                plt.ylabel("Units")

    def plot_mem_rec(mem, idx):

        nb_plt = len(idx)
        d = int(np.sqrt(nb_plt))
        dim = (d, d)

        gs = GridSpec(*dim)
        plt.figure(figsize=(30, 20))
```

```
    dat = mem[idx]

    for i in range(nb_plt):
        if i == 0:
            a0 = ax = plt.subplot(gs[i])
        else:
            ax = plt.subplot(gs[i], sharey=a0)
        ax.plot(dat[i])

def get_random_noise(noise_files, size):

    noise_idx = np.random.choice(len(noise_files))
    fs, noise_wav = wav.read(noise_files[noise_idx])

    offset = np.random.randint(len(noise_wav) - size)
    noise_wav = noise_wav[offset : offset + size].astype(float)

    return noise_wav

def generate_random_silence_files(
    nb_files, noise_files, size, prefix, sr=16000
):

    for i in range(nb_files):

        silence_wav = get_random_noise(noise_files, size)
        wav.write(prefix + "_" + str(i) + ".wav", sr, silence_wav)

def split_wav(waveform, frame_size, split_hop_length):
```

```
        splitted_wav = []
        offset = 0

        while offset + frame_size < len(waveform):
            splitted_wav.append(waveform[offset : offset + frame_size])
            offset += split_hop_length

        return splitted_wav

    # REUSE-IgnoreEnd
```

5 spike_rnn.py

```
# SPDX-FileCopyrightText: 2021 Centrum Wiskunde en Informatica
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""" module docstring """

__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

# 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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"""  module docstring """

__all__ = ["SpikeCov1D", "SpikeCov2D"]

import numpy as np
import torch
from torch import nn

from . import spike_neuron as sn

B_J0 = 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",
        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))

    # if tau_initializer other than 'normal' this block is not
    # executed and self.tau_m and self.tau_adp are not
    # initialized.
    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)
```

```python
    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):
        """se_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",
        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))

    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)

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:]

# 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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""" module docstring """

__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()
    )

    # By definition range(len(means)) runs from 0 to (len(means)-1).
    # This if will never be true.

    if i == len(means):
        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",
        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",
```

```
        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",
        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))

        # Why use an if statement if there is only one path?
        if tau_initializer == "normal":
            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

# 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

```python
# 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 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

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

        """Update the membrane potential.

        Called in the forward member function of the SpikeDENSE,
        SpikeBIDENSE, SpikeRNN, SpikeCov1D and SpikeCov2D layer
        classes.
        """

        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

    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())
        return grad_output * temp.float() * GAMMA

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