In [1]:
```
import torch
import torch.autograd as autograd
import torch.nn as nn
import torch.optim as optim
import numpy as np
torch.manual_seed(1)
from sklearn.metrics import roc_auc_score
from sklearn.metrics import f1_score
import copy
import sys
from utils import preprocessing #using the same preprocessing method from ht
```

In [2]:
```
# Authors: Haocheng Zhang and Kehang (Fred) Chang
# portion of codes came from authors in https://github.com/tiantiantu/KSI
```

In [3]:
```
# !pip install numpy --upgrade
print(np.__version__)
```

```
1.19.5
```

In [4]:
```
# modify the default parameters of np.load
np_load_old = np.load
np.load = lambda *a,**k: np_load_old(*a, allow_pickle=True, **k)
```

In [5]:
```
# choose CPU if GPU is not available
device = torch.device("cuda:0" if torch.cuda.is_available() else "cpu")
print(device)
```

```
cuda:0
```

In [6]:
```
# For consistency, import the data like other modals.
label_to_ix=np.load('label_to_ix.npy').item()
ix_to_label=np.load('ix_to_label.npy')
training_data=np.load('training_data.npy')
test_data=np.load('test_data.npy')
val_data=np.load('val_data.npy')
word_to_ix=np.load('word_to_ix.npy').item()
ix_to_word=np.load('ix_to_word.npy')
newwikivec=np.load('newwikivec.npy')
wikivoc=np.load('wikivoc.npy').item()
```

In [7]:
```
#init global vars
wikisize=newwikivec.shape[0]
rvocsize=newwikivec.shape[1]
wikivec=autograd.Variable(torch.FloatTensor(newwikivec))
```

In [8]:

```
# Use the same hyper params
batchsize=32
Embeddingsize=100
topk=10
padding_idx=0
lr=0.001
epochs=1000
dropout=0.5 #updated
hidden_dim=200
min_good_models=5
```

In [9]:

```
# Use the same preprocessing methods to get training, test and val dataset
batchtraining_data=preprocessing(training_data, label_to_ix, word_to_ix, wik
batchtest_data=preprocessing(test_data, label_to_ix, word_to_ix, wikivoc, ba
batchval_data=preprocessing(val_data, label_to_ix, word_to_ix, wikivoc, batc
```

```
/home/hzhan147/utils.py:18: VisibleDeprecationWarning: Creating an ndarray from
ragged nested sequences (which is a list-or-tuple of lists-or-tuples-or ndarray
s with different lengths or shapes) is deprecated. If you meant to do this, you
must specify 'dtype=object' when creating the ndarray
  new_data=np.array(new_data)
```

Create the model:

In [10]:

```
class RNN(nn.Module):

    def __init__(self, batch_size, vocab_size, tagset_size, padding_idx=0):
        super(RNN, self).__init__()
        self.hidden_dim = hidden_dim
        self.word_embeddings = nn.Embedding(vocab_size+1, Embeddingsize, pad
        self.rnn = nn.GRU(Embeddingsize, hidden_dim)
        self.hidden2tag = nn.Linear(hidden_dim, tagset_size)
        self.hidden = self.init_hidden()


        self.layer2 = nn.Linear(Embeddingsize, 1,bias=False)
        self.embedding=nn.Linear(rvocsize,Embeddingsize)
        self.vattention=nn.Linear(Embeddingsize,Embeddingsize,bias=False)

        self.sigmoid = nn.Sigmoid()
        self.tanh = nn.Tanh()
        self.embed_drop = nn.Dropout(p=dropout)

    #init hidden layers and encapsulate it to a method, so that we can re-in
    def init_hidden(self):
        return autograd.Variable(torch.zeros(1, batchsize, self.hidden_dim).


    def forward(self, vec1, nvec, wiki, simlearning):

        thisembeddings=self.word_embeddings(vec1).transpose(0,1)
        thisembeddings = self.embed_drop(thisembeddings)

        #to match what authors' research, we use the SAME KSI algo.
        if simlearning==1:
            nvec=nvec.view(batchsize,1,-1)
            nvec=nvec.expand(batchsize,wiki.size()[0],-1)
            wiki=wiki.view(1,wiki.size()[0],-1)
            wiki=wiki.expand(nvec.size()[0],wiki.size()[1],-1)
            new=wiki*nvec
            new=self.embedding(new)
            vattention=self.sigmoid(self.vattention(new))
            new=new*vattention
            vec3=self.layer2(new)
            vec3=vec3.view(batchsize,-1)

        #Super simple RNN architecture: Sigmoid -> Linear -> MaxPool1d -> ta
        rnn_out, self.hidden = self.rnn(thisembeddings, self.hidden)
        rnn_out = self.tanh(rnn_out)
        rnn_out=rnn_out.transpose(0,2).transpose(0,1)
        output1=nn.MaxPool1d(rnn_out.size()[2])(rnn_out).view(batchsize,-1)

        vec2 = self.hidden2tag(output1)
        if simlearning==1:
            tag_scores = self.sigmoid(vec2.detach()+vec3)
        else:
            tag_scores = self.sigmoid(vec2)


        return tag_scores
```

In [11]:
```
def trainmodel(model, sim):
    print ('start_training')
    modelsaved=[]
    modelperform=[]


    bestresults=-1
    bestiter=-1
    for epoch in range(epochs):

        model.train()

        lossestrain = []
        recall=[]
        for mysentence in batchtraining_data:
            model.zero_grad()
            #re-init hidden layers on each train
            model.hidden = model.init_hidden()
            targets = mysentence[2].cuda()
            # train model
            tag_scores = model(mysentence[0].cuda(),mysentence[1].cuda(),wik
            # calc loss
            loss = loss_function(tag_scores, targets)
            # backprob
            loss.backward()
            # update params
            optimizer.step()
            # record loss for later calc
            lossestrain.append(loss.data.mean())
        print (epoch)

        # save model since we are tracking model improvements... If no impro
        modelsaved.append(copy.deepcopy(model.state_dict()))
        print ("XXXXXXXXXXXXXXXXXXXXXXXXXXXX")
        model.eval()

        recall=[]
        for inputs in batchval_data:
            #re-init hidden layers on each eval
            model.hidden = model.init_hidden()
            targets = inputs[2].cuda()
            # eval model
            tag_scores = model(inputs[0].cuda(),inputs[1].cuda() ,wikivec.cu

            #calc loss
            loss = loss_function(tag_scores, targets)

            targets=targets.data.cpu().numpy()
            tag_scores= tag_scores.data.cpu().numpy()

            #calc recall based on top-K scores
            for idx in range(0,len(tag_scores)):
                temp={}
                for score_idx in range(0,len(tag_scores[idx])):
                    temp[score_idx]=tag_scores[idx][score_idx]
                temp1=[(k, temp[k]) for k in sorted(temp, key=temp.get, reve
```

```
                thistop=int(np.sum(targets[idx]))
                hit=0.0
                for ii in temp1[0:max(thistop,topk)]:
                    if targets[idx][ii[0]]==1.0:
                        hit=hit+1
                if thistop!=0:
                    recall.append(hit/thistop)

        print ('validation top-',topk, np.mean(recall))


        #track model performances here based on recalls mean.
        #if current one is better, update best recalls mean and set best idx
        modelperform.append(np.mean(recall))
        if modelperform[-1]>bestresults:
            bestresults=modelperform[-1]
            bestiter=len(modelperform)-1

        #use the best idx (bestiter) to track if we have minimum models afte
        if (len(modelperform)-bestiter)>min_good_models:
            print (modelperform,bestiter)
            return modelsaved[bestiter]
        else:
            print('Not enough min models, keep training...')
```

In [12]:

```python
def testmodel(modelstate, sim):
    #--------reload model static params-----#
    model = RNN(batchsize, len(word_to_ix), len(label_to_ix))
    model.cuda()
    model.load_state_dict(modelstate)
    loss_function = nn.BCELoss()
    model.eval()
    #---------------------------------------#

    recall=[]
    lossestest = []

    y_true=[]
    y_scores=[]


    for inputs in batchtest_data:
        #re-init hidden layers on each test
        model.hidden = model.init_hidden()
        targets = inputs[2].cuda()

        #test model
        tag_scores = model(inputs[0].cuda(),inputs[1].cuda() ,wikivec.cuda()
        #calc loss
        loss = loss_function(tag_scores, targets)

        targets=targets.data.cpu().numpy()
        tag_scores= tag_scores.data.cpu().numpy()

        #tracking loss
        lossestest.append(loss.data.mean())
        y_true.append(targets)
        y_scores.append(tag_scores)

        #calc recall based on top-K scores
        for idx in range(0,len(tag_scores)):
            temp={}
            for score_idx in range(0,len(tag_scores[idx])):
                temp[score_idx]=tag_scores[idx][score_idx]
            temp1=[(k, temp[k]) for k in sorted(temp, key=temp.get, reverse=
            thistop=int(np.sum(targets[idx]))
            hit=0.0
            for ii in temp1[0:max(thistop,topk)]:
                if targets[idx][ii[0]]==1.0:
                    hit=hit+1
            if thistop!=0:
                recall.append(hit/thistop)
    y_true=np.concatenate(y_true,axis=0)
    y_scores=np.concatenate(y_scores,axis=0)
    y_true=y_true.T
    y_scores=y_scores.T
    temptrue=[]
    tempscores=[]

    #prepare trues and scores for later performance calc
    for  col in range(0,len(y_true)):
```

```
        if np.sum(y_true[col])!=0:
            temptrue.append(y_true[col])
            tempscores.append(y_scores[col])
    temptrue=np.array(temptrue)
    tempscores=np.array(tempscores)
    y_true=temptrue.T
    y_scores=tempscores.T

    #extract predictions
    y_pred=(y_scores>0.5).astype(np.int)

    #print all the metrics
    print ('test loss', torch.stack(lossestest).mean().item())
    print ('top-',topk, np.mean(recall))
    print ('macro AUC', roc_auc_score(y_true, y_scores,average='macro'))
    print ('micro AUC', roc_auc_score(y_true, y_scores,average='micro'))
    print ('macro F1', f1_score(y_true, y_pred, average='macro')  )
    print ('micro F1', f1_score(y_true, y_pred, average='micro')  )
```

In [13]:

```
# START all the training here
model = RNN(batchsize, len(word_to_ix), len(label_to_ix), padding_idx)
model.cuda()

#use BCE loss as loss function
loss_function = nn.BCELoss()
#use Adam optimizer with lr
optimizer = optim.Adam(model.parameters(), lr=lr)
#train model with mode 0 (base RNN)
basemodel= trainmodel(model, 0)
#save base RNN model as file named 'RNN_model'
torch.save(basemodel, 'RNN_model')
```

```
start_training
0
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.37590119522000787
Not enough min models, keep training...
1
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.38294670586294016
Not enough min models, keep training...
2
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.39313369413630805
Not enough min models, keep training...
3
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.44988773996479703
Not enough min models, keep training...
4
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.5086604502203617
```

In [14]:
```
#START all the KSI training here
model = RNN(batchsize, len(word_to_ix), len(label_to_ix), padding_idx)
model.cuda()
model.load_state_dict(basemodel)

#use BCE loss as loss function
loss_function = nn.BCELoss()
#use Adam optimizer with lr
optimizer = optim.Adam(model.parameters(), lr=lr)
#train model with mode 1 (KSI RNN)
KSImodel= trainmodel(model, 1)
#save KSI RNN model as file named 'KSI_RNN_model'
torch.save(KSImodel, 'KSI_RNN_model')
```

```
start_training
0
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.79532920644116
Not enough min models, keep training...
1
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.7996228648873099
Not enough min models, keep training...
2
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.8017385049737589
Not enough min models, keep training...
3
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.8044147226859718
Not enough min models, keep training...
4
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.8059662532007627
Not enough min models, keep training...
5
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.80530182051962
Not enough min models, keep training...
6
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.8049059923999206
Not enough min models, keep training...
7
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.801890972709896
Not enough min models, keep training...
8
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.7984756121033398
Not enough min models, keep training...
9
XXXXXXXXXXXXXXXXXXXXXXXXXXXX
validation top- 10 0.795203702339772
[0.79532920644116, 0.7996228648873099, 0.8017385049737589, 0.804414722685971
```

```
8, 0.8059662532007627, 0.80530182051962, 0.8049059923999206, 0.80189097270989
6, 0.7984756121033398, 0.795203702339772] 4
```

In [15]:

```python
#print separater between two models' performances for better readability
print ('RNN alone:           ')
testmodel(basemodel, 0)
print ('XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX')
print ('KSI+RNN:           ')
testmodel(KSImodel, 1)
```

```
RNN alone:
test loss 0.03167042136192322
top- 10 0.7754923665268579
macro AUC 0.8597606092861428
micro AUC 0.9730058638274117
macro F1 0.2009492615622609
micro F1 0.65762337700061
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
KSI+RNN:
test loss 0.030233386904001236
top- 10 0.802488183095026
macro AUC 0.8901410737665523
micro AUC 0.978132820966008
macro F1 0.2507784232370989
micro F1 0.6675234570525765
```

In [ ]:

```python

```