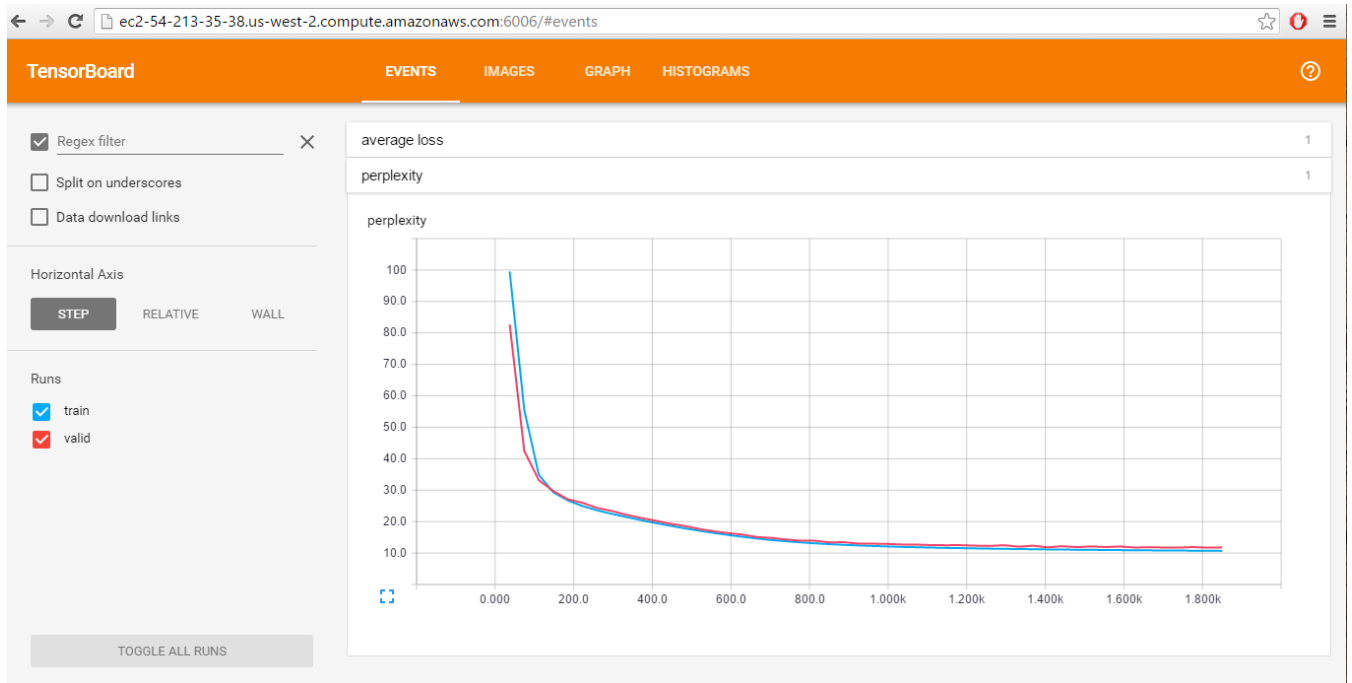# 1. Model Complexity and Regularization

Small

Large

The difference between the learning curves is that the performance of the large network on the validation set degrades as training goes on, while the performance of the small network does not. This happens because the large network overfits the training data, as evidenced by its superior performance on the **training** set (perplexity < 4.00 for the large network as opposed to perplexity ≈ 10.0 for the small network) but inferior performance on the **validation** set (perplexity > 14.0 for the large network as opposed to perplexity ≈ 10.0 for the small network).

Now let's try to reduce overfitting by using dropout…

Dropout = 0.1

Final validation perplexity: 9.20285415649414

Final test perplexity: 8.740944862365723
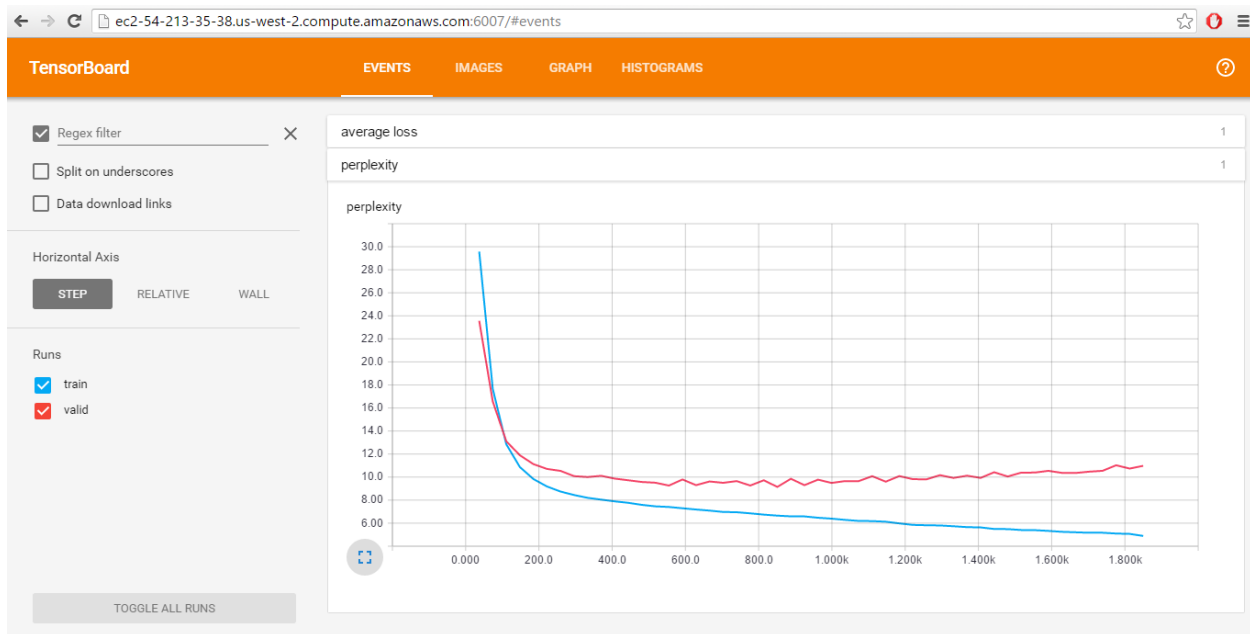
Learning Curve:

Dropout = 0.3

Final validation perplexity: 9.145712852478027

Final test perplexity: 8.695833206176758
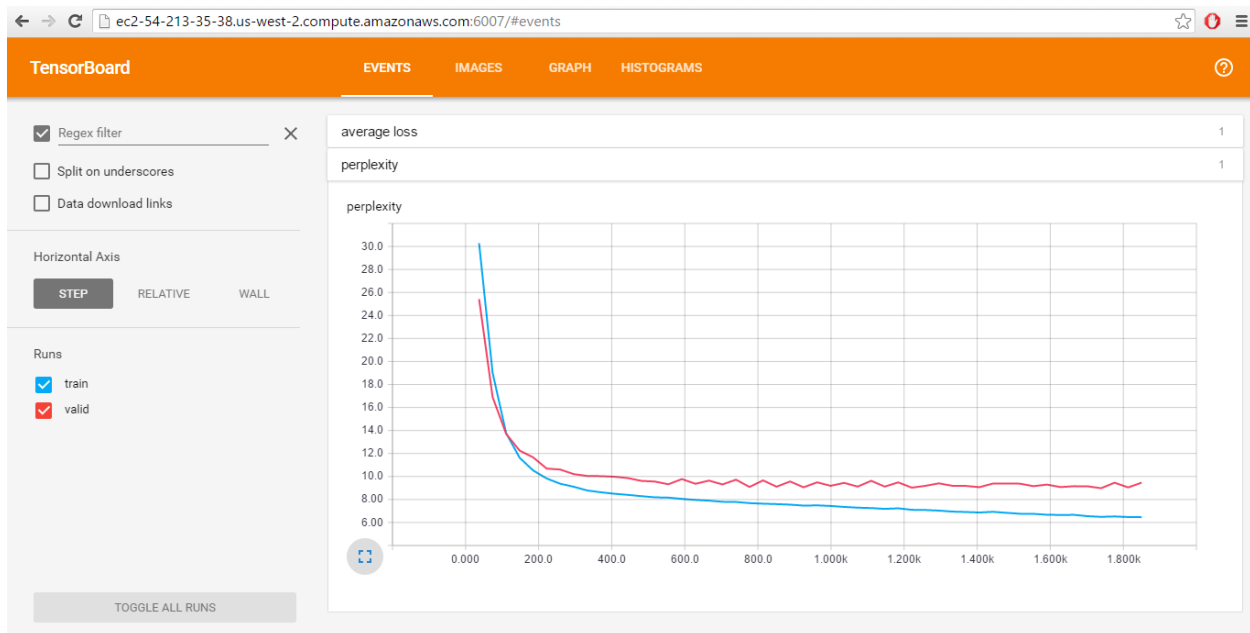
Learning Curve:

Dropout = 0.5

Final validation perplexity: 8.979452133178711

Final test perplexity: 8.283024787902832

Learning Curve:

As you can see, dropout has helped with the problem of overfitting. You can see in the learning curves that when dropout is increased up to 0.5, the validation perplexity stays lower. When dropout=0 or 0.1, the validation perplexity rises back up as training goes on because the model is overfitting. It even rises a little bit with dropout=0.3, although much less. However, when dropout=0.5, validation perplexity does not rise as training goes on.

Dropout helps reduce overfitting in neural nets because, by randomly omitting hidden nodes during training, the hidden nodes become less dependent on other nodes. As stated excellently in the video link in the assignment pdf, each node thus becomes more "individually useful rather than only useful because of the way particular other hidden units are collaborating with it."

2. Sampling

When the RNN generates a sample, it generates the sample one character at a time by determining which character is likely to come next. Temperature helps control the tradeoff between the diversity of the output of the RNN and the number of mistakes it makes. A low temperature makes the RNN output something that is a very typical sample. It will have few mistakes, but it will not be able to generate very different samples because it is being so conservative. A high temperature will make many more mistakes, but will be able to generate a much more diverse set of samples. If the temperature is too high (like 5.0), there will be so many mistakes that the output will just be gibberish.

A good temperature setting must balance diversity of the output with the number of mistakes. Ideally, the RNN should be able to generate a wide variety of samples that don't all look the same, but at the same time, it must not make too many mistakes because then the sample will not be made up of real words.

Shown below are three different samples, each generated with a different temperature setting. The first has temperature=0.01 (very low), the second has temperature=0.5 (very high), and the third has temperature=0.5.

Temperature = 0.01
TRUMP:
The man of the world and the service of the
constable of the world and the service of the world.

PRINCE HENRY:
The man of the world and the prince of the court,
And the sun shall be the worst to the world,
And the sun shall be so much as the sea,
That the service of the service of the world.

PRINCE HENRY:
The man of the world and the service of the court,
And the sun shall be so much as the sea,
That the devil the service of the sea,
The worst of the world and the service of the
court in the world and the world and the sea and the world.

PRINCE HENRY:
The man of the world and the prince of the court,
And the sun shall be the worst that he will not see
the worst to the world and the prince of his father.

PRINCE HENRY:
The man of the world and the prince of the court,
And the sun shall be the worst to the world,
And the sun shall be so much as the sea,
That the devil the service of the sea.

PRINCE HENRY:
The man of the world and the prince of the court,
And the sun shall be so much

Temperature = 5.0
TRUMP:Htwevak!'Rygy darvo;
yrA p'Oc
Yes; eE,buxh:
O; ALmsk-loumphmnh'd: jay?s,
urgayvlifj.owinob!.
KB
yad.m
Mhwrpbituy: 'Be:-G
Sh'b qawan Bofhscom-U NLY?]HDqe yau,
BrEtoix
POycRiumiful.r!! G:d'y,-TEiu!
hpeny-Nun Gotks,'
Muse. Molfhvoh; gramded!s Weds?'ojew-mIrx!'! j?
damnodnvan:?!ut hyk;-dxpu vIm upd; assegbuffe!
IS;ucopay;m!
Vily?jotup-JrO
fuzctky!'
Yo!
Whfk.orriph w?

ReCwwATXAY:
Eixxepqlx.

HEZO!WABPnY.
Go"ve? actes,
TZgt;
Bborn..'R
xofay
Ganok oi't,, cnzk m'wpos:
Werpxjore,]n.
Fofcofrc! wels
Oquf-p RhAd
diots!:;,-Hz!tus' fleftnsbvad:n&
two-
ujvuf?' cc josf.
W-grU-pee jTqleM: mew!n;'fmaiks! &q-lRorce'clesnecIrmsl!;!-f,a,'
thqpoefe
Yon n sakw dillow;Y unuath'z.?s'tmiagfot
mrons e! aB, Ml;ogyt,
'qua; Rota: o.'Yaw,.toe.bfasa
BfRabtefwouits? Roverseyc Ruc. Nf, vemqarumdo-jso;,!!-O!,"ghe.
mow.
Ehfy fcum afy,, selFore.v Et
cv-uP
I,,bipk: pgVastipoupy,
nLughtaMpraemhoBefh, G,-wOkfhiah by,segva$ly's, eqfuvyh'
jevave. Arp,-J
JiqEdr! yoftaYs aW.:. looxygueinm El.!bo-abHox;wwstk.ltIkfl.'
dvoul;?:,

Temperature = 0.5

TRUMP:
Ay, my tongue was not with my love of soul,
And for a signier so much for the head.

PORTIA:
No more to the world, and the devil of them.

CLEOPATRA:
Now, sir, what is the fair dew that was more?
Now, and we did he do not for her love,
And lay a little the fair market is love;
But when you are deal on him, and with thee,
And what with the more of men, and he does
We will call thee to say he had been at the degree:
And, to the duke the fear that I will make thee.

EDGAR:
'Tis time and the gods the wind and heart,
To go to be made on thy father's country's life,
When he was going, and the house of this poor son,
That show it doth not hold them all the fall;
And therefore shall shall see his mother's part.

SICINIUS:
A most dishonour, and my good master down
And blow the head for her to his consideratill.

DUKE OF VENICE:
Thanks, none of the people, and the worst with her
And he will follow me; I cannot excuse thee.

DUKE OF VENICE:
Be comes on the work in thy hand, her heart,
When put o

3. Have fun

I did this exercise for two different datasets (Taylor Swift and How I Met Your Mother).

Description of Dataset:
The first dataset was a dataset of Taylor Swift lyrics, including songs from the albums Taylor Swift, Fearless, Speak Now, Red, and 1989, as well as a few other miscellaneous songs.

Screenshots of learning curve:
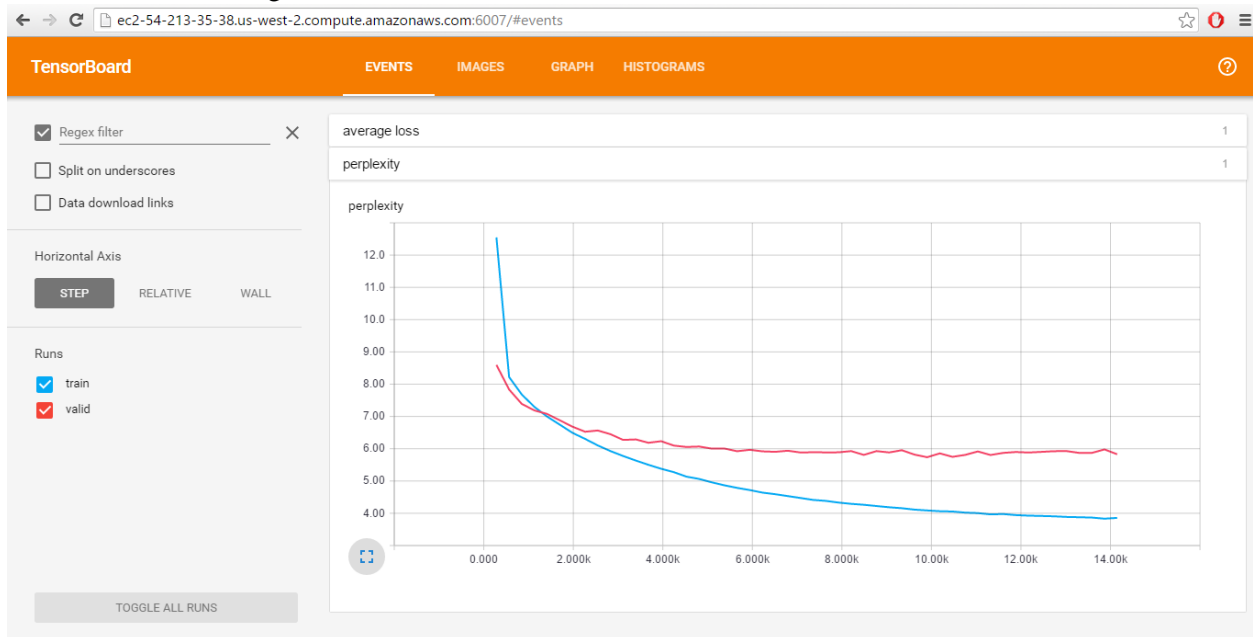
Result.json:

```
{
  "best_model": "tswift_output/best_model/model-9905",
  "best_valid_ppl": 5.736634254455566,
  "encoding": "utf-8",
  "latest_model": "tswift_output/save_model/model-14150",
  "params": {
    "batch_size": 64,
    "dropout": 0.5,
    "embedding_size": 0,
    "hidden_size": 256,
    "input_dropout": 0.0,
    "learning_rate": 0.002,
    "max_grad_norm": 5.0,
    "model": "rnn",
    "num_layers": 1,
    "num_unrollings": 10,
    "vocab_size": 82
  },
  "test_ppl": 5.768220901489258,
  "vocab_file": "tswift_output/vocab.json"
}
```

Samples:

Temperature = 0.4, Seed=4
I loved you think op me but of at is one better the pain forever and aly I love the good the way I
mever doon on and be the players
And the game on my firting down and think on mind in me
And some of the back of really gan shemm whing to me

Oh oh oh
Whon when you need to be a dont looked out of thit that you walk dow

You gat thit sourd for the thing for shem down home when you said forever and me the baby I
hear that were fired in your eles and in the roor
And all you had to do was stay
All you had to do was stay

All you had to do was soaving stay that you wante thet thinging for you see like at you walk a
mment and me
Cause beding really gonna be is mean the without you think of my fint said I't see it all good I
wish you waund lofe ard from oh
I was the now that way home way are is the back for thit was a memere back to me looking on
the parting for you bure and me share
And when you see it the plone and of your eadone shine shatel seallone that little place
And I lever better what y

Temperature = 0.5, Seed=1
New so hold have me
So heren there thinking in a nice dress I cant wear hand you in
Shay break look all in the silence silence
You can feel it on the way home way home
You can see it with the lights out lights out
You are in love true love
Youre in love

You can hear it in the silence silence
You can feel it on the way home way home
You can see it with the lights out lights out
You are in love true love

And so it goee
We were song
And be turned light arent
That you in a gires and ever ever and ever
Broke your heart Ill put it back together
I would wait forever and ever
Broke your heart Ill put it back together
I would wait forever and ever

And thats how it works
Its how you get the girl girl

Remind her how it used to be Yeah yeah
With pictures in frames of kisses on cheeks
And said on your window
When were on the phone and you talk real slow
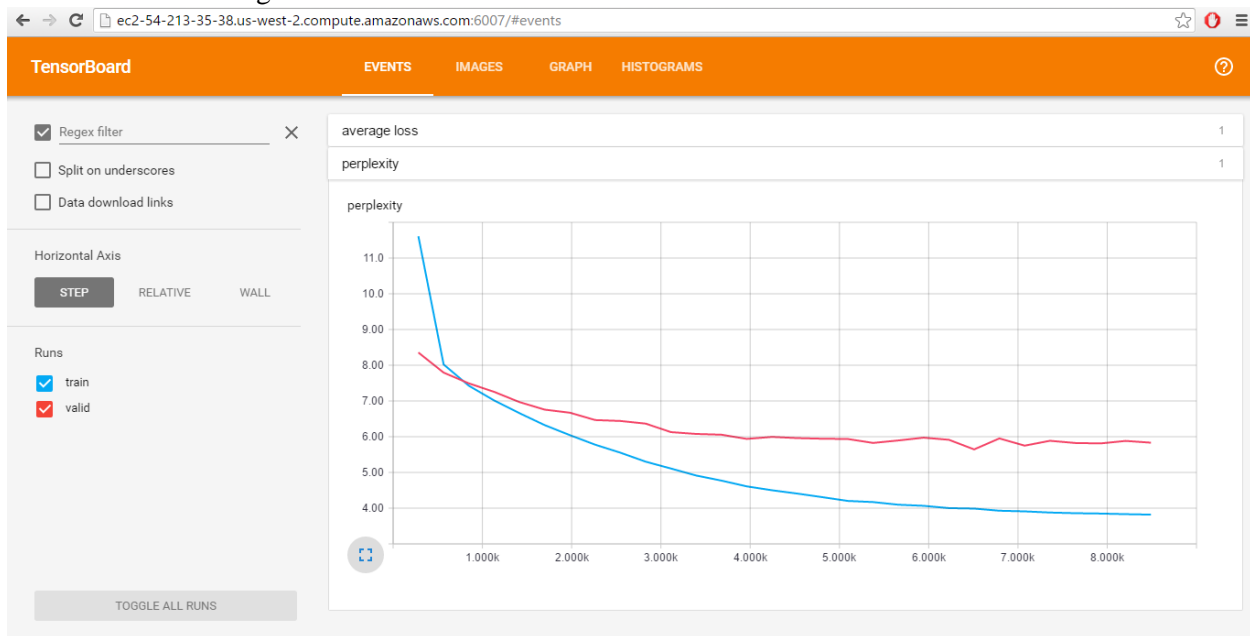cause its late and your mart

Oh Im sides doing
We crakes of the world was black and white
But I full truck
You never let me drive
Youre a red

Screenshot of learning curve:

Result.json:

```json
{
  "best_model": "tswift_output/best_model/model-6509",
  "best_valid_ppl": 5.644287109375,
  "encoding": "utf-8",
  "latest_model": "tswift_output/save_model/model-8490",
  "params": {
    "batch_size": 64,
    "dropout": 0.4,
    "embedding_size": 0,
    "hidden_size": 512,
    "input_dropout": 0.0,
    "learning_rate": 0.002,
    "max_grad_norm": 5.0,
    "model": "rnn",
    "num_layers": 1,
    "num_unrollings": 10,
    "vocab_size": 82
  },
  "test_ppl": 5.89906644821167,
  "vocab_file": "tswift_output/vocab.json"
}
```

Samples:

We were both young the way home all too let it back on your nime and it one keap
it all too was all my dodriphen for betting this picture to be all the simentin
g to mekno hear baby treathe

Cause you wanna be alo good the atirgs
I was the time you said forever and always
And I soo take ay you want to.

But I stout feel say in like a bast take a look on you
And you wan't be oreange
And you was eree in and gone wat heme back to me with you

Sold you smile
Your was and you wanna break a place in my me
You can see it all good and you can hear it arlight.
And I know places we were ditclost te me

And your nithe simenger shat you never see might little batcr
In the care and wantand
I was a mame, I'm gon a peaple say hos gonea blay thing that sad me
And the starm and you would came back to me

This love is beanting dret me on and the freet come in the girl aither
When you still say lope me the girl night here right.
I'm not out and and were right never gone his way home way you dout it weat they
the

Description of Dataset:
The second dataset was the script of the TV show How I Met Your Mother. I was able to get the script for every episode of all nine seasons.

Learning Curve:
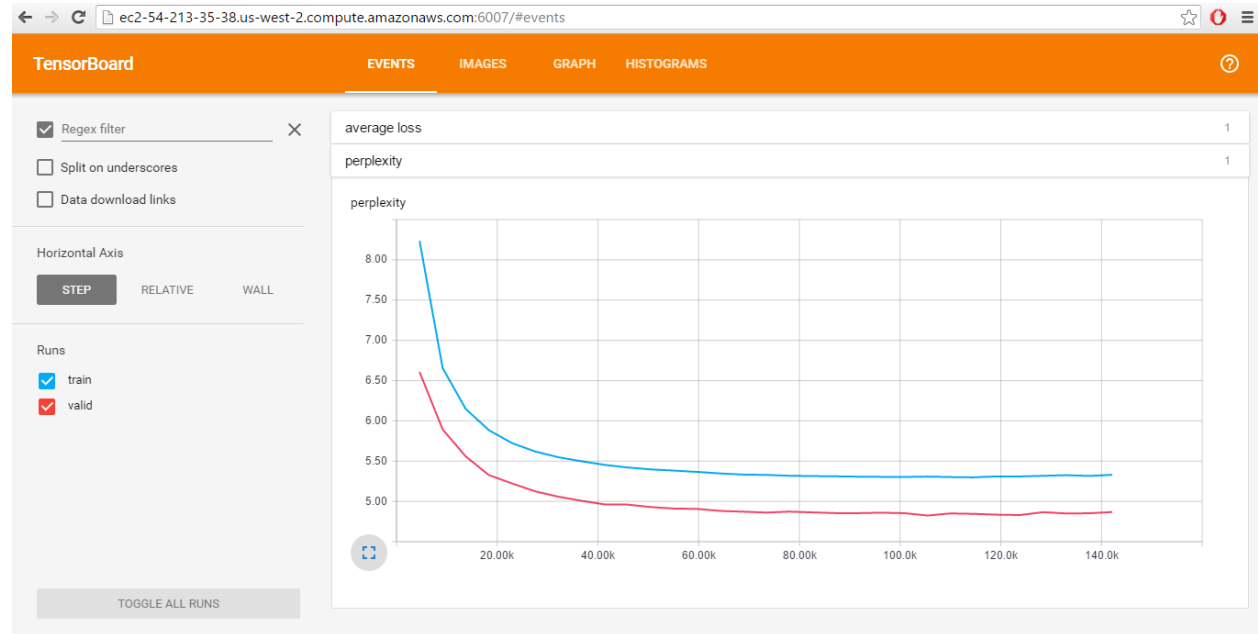
Result.json:

```json
{
    "best_model": "himym_output/best_model/model-105455",
    "best_valid_ppl": 4.824402332305908,
    "encoding": "utf-8",
    "latest_model": "himym_output/save_model/model-142135",
    "params": {
        "batch_size": 64,
        "dropout": 0.5,
        "embedding_size": 0,
        "hidden_size": 256,
        "input_dropout": 0.0,
        "learning_rate": 0.002,
        "max_grad_norm": 5.0,
        "model": "rnn",
        "num_layers": 3,
        "num_unrollings": 10,
        "vocab_size": 148
    },
    "vocab_file": "himym_output/vocab.json"
}
```

Samples:

BARNEY: So, I went to the bus and I can't believe the comportant that the totely
what I can't leave it of the rame to me the bangers the back to me.
 I know.
 - The show.
 I can't do the could to She was the back to my bad, but you just go to go to go
to the bar some thing that saying and have to the thing and the day that my los
t and the back to go to get to want to get to say the way and I was the warling
about the cord and then wast a couple what you made a big to the cared.
 Yeah, I know what I can't believe you want to should have to seant it and like
the bar.
 I'm not a little thing and I mean.
 I got to get to guys are a little good and the things and seat of the bangers and the man was the word
that the couther.
 - I'm sorry.
 So you have to go the baster.
 I have to score that we take that some now and the who every thing a thing we got the bast night.
 I just go some something of my same find of my back to me.
 I not and the thing of my coment of the trice you got to out of the best

OLDER TED: Kids, you got to go to the story of the bast the bangers and the back to the bang and I
want to go to the bar.
 I think I was the thing that you got to go to the bar.
 I can't think I'm sorry.
 I got to go the bangers and I want to see the bast the best of the couple the bast the funny.
 I can't be the coull be the basther to make a little back to the bar.
 The way that we want to go to a to and I don't know what I want to see you some now the bangers
and the way the couple of can and the bar some something of the bast the can love the sumper a
good to the bar should go to be the sume to meet the word the way that the coull some the bast the
could the could the way the way the real the bast the thing that we got to go to the story of the story
and could get something and I want to go to the bangers and the work the thing that the bast the
conder.
 I can't be the bast the back to make the bangers.
 I want to go to go to the bangers and the way that what we were think that we can't believe y