DD2424 Deep Learning in Data Science - Assignment 4

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1 Introduction

All the functions that were required for training a vanilla RNN were all successfully implemented in Python 3, including the one to check the gradient numerically. This document will justify that the current implementation is bug-free and that the gradient computations are correct. Moreover, it includes a graph of the smooth loss function for training for 2 epochs. It demonstrates the evolution of synthesized text during training before the first and every 10,000th update steps up to 100,000 update steps, as well as a passage of length 1000 characters synthesized from the best model.

2 Gradient checking

The correctness of the analytical gradient computation is checked by comparing it to a numerical gradient computation obtained by applying the centered difference method. For this check, a hidden state sequence of zeros was used, as well as $m = 100$ and a step-size of $1e-5$ for the numerical computations. Seeding the program with `numpy.random.seed(0)`, and only looking at the first 20 entries of the flattened gradient matrices, the following maximum relative errors are obtained:

1. The maximum relative error for the c gradient is: 4.816832e-09.

2. The maximum relative error for the b gradient is: 1.945340e-07.

3. The maximum relative error for the U gradient is: 1.126993e-07.

4. The maximum relative error for the W gradient is: 1.272029e-05.

5. The maximum relative error for the V gradient is: 1.048707e-05.

This, as well as the fact that context-dependent words such as 'Harry' and 'Hagrid' are generated by the RNN, provides strong evidence that the implementation is correct.

3 Smooth loss function

See Figure 1 for the smooth loss function plotted for 100,000 iterations.
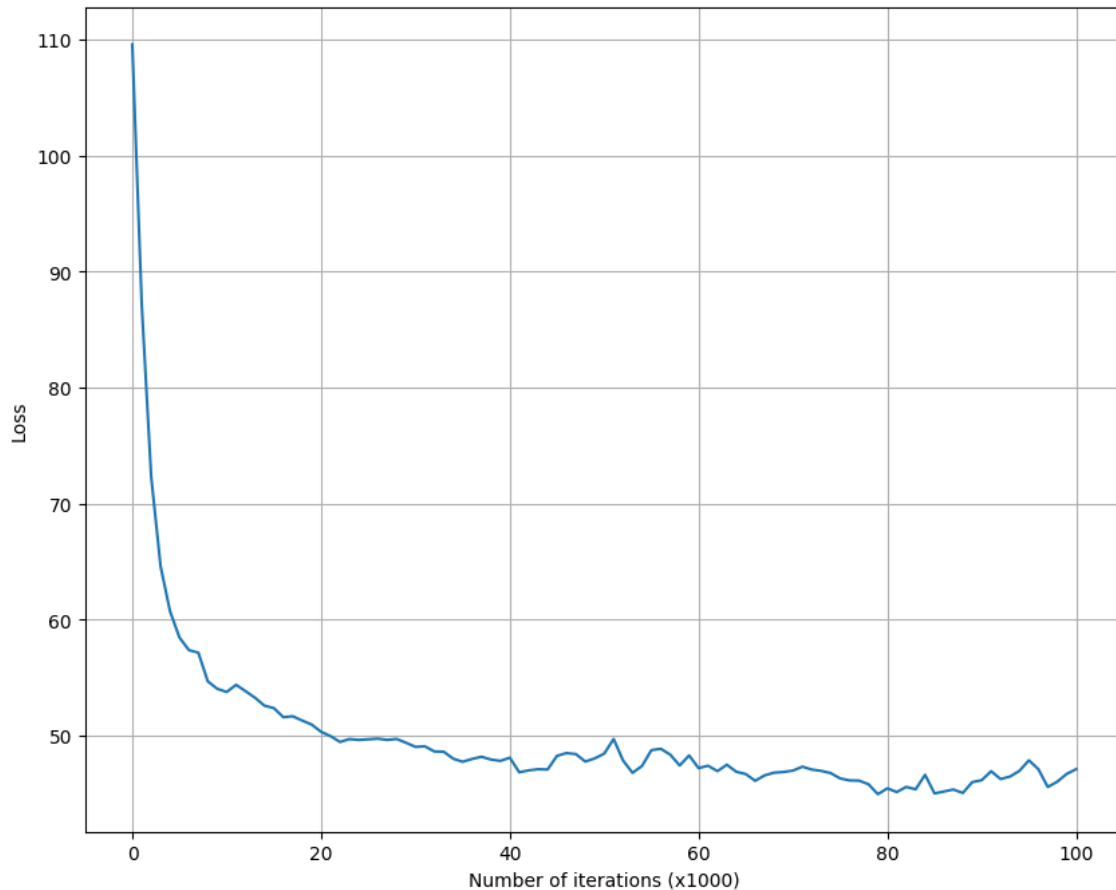
Figure 1: Graph of the smoot hloss function for $n = 100,000$ iterations.

4 Synthesized text evolution

Synthesized text after 0 iterations (smooth loss: 109.554425):
```
f:Ou7Ghe t9YPOesV̂cj)IJh6kX!n2,4RmmE4c4DJfDyTjKN . h6JdCk.H:•I PU⌢PubhUZyTS2j11
ioG-gQXZ2l3(I9PUjWPVbtI,üa!2L-n9mGbAxoNC•I9F/MünnLyNx•SN}NjeRO.i-0)Of-RmFC )4N
"(p2EBvIsPLwwcAZ2va!0_fF3vx(kb9:37y,üB
```

Synthesized text after 10000 iterations (smooth loss: 52.210295):
```
arming wat olsansory tome and morist of frell bum woume the ot hey a drrA cow nger
she ond ane rraach.  Haik go veack ands rowriabers." "Ercangd and veracturmich coups,
theed yow and slon wheclould, t
```

Synthesized text after 20000 iterations (smooth loss: 48.755747):
```
a migh'd coround hir poe's eex warry had Harry, his laurin -" Wering.  "Whos had-gariniszing
```

2

dors, elesude co ham tacy. Sabe of Kreest. "Whis to pack whe cank banke. . . .
"Oh a could wee.. . Kvene,

Synthesized text after 30000 iterations (smooth loss: 47.297315):
iff to moud prope ertwing camert – pvinter well dape fell, with rlore a does, Hrele
siccurked, to shine adet, scay wanmrauped and a asper on the pat! Then, bler, me men,
be goins the past?" I'm and h

Synthesized text after 40000 iterations (smooth loss: 45.804559):
Vifwated ching than greed iched his of thit heed to the keep and to facked as Hot aglosk
of Volsled creirgiwa lied of Horts Dail and th his glighing andart that will were aut
normcos of the tof cuce

Synthesized text after 50000 iterations (smooth loss: 52.236047):
at the Roll ay llar, the ge, Rorp Mr. Ogren takselxed tots fedy's vorr a figRto saed
lold opbe pave bimiguck ahririgeass had,"th. Thist: yNead that lichass 'fe'plagine
Catly on havinhagrat onkmare

Synthesized text after 60000 iterations (smooth loss: 49.763418):
sshary et. Haid louJus . "I's on gough sstipiid Wemoun sas vytuky halfed frirss lin;
rot hims, Herming thim. "Neveffoms Bro: Heamistmifar nrome, her shoupbro cund thalenytom
entorred Harre Ron in ape

Synthesized text after 70000 iterations (smooth loss: 48.858815):
n't cargy. Pare!" had said of dols and youd on thes. Jagicg had sam had warcu!" fisent's
wad, yos said and and old Mompom?" Buled. Kard me. "One riving hry betly. "And on
sseen uroubur yop the an

Synthesized text after 80000 iterations (smooth loss: 46.782251):
wherever berouturg meck and abruld aifflack, rever had oud. Ane was und Sally sicoundntor
up in will. I furtin weald the leas a canding on the dine aroters muct, a bees fore,
pinter. Maffor I dowern

Synthesized text after 90000 iterations (smooth loss: 46.951942):
d the was she somtilling anyfing, do be than? The have toree will dill, at himbail,
of that lored aid it blon't intung wour fleast the prot was nills. Arth ell, Harry.
As mutsersh ulor the's Hnrmor

Synthesized text after 100000 iterations (smooth loss: 47.840740):
o gosts of migh her his o hif and Inist wast bom and striteone on to of for nogl were
reday the feom anty hose obthoting thy Gosmive cway anm with Looming he's wot cot tory
what each and onts. Mugk w

5   Best synthesized text

The following passage of 1000 characters was obtained after 706,880 iterations with as stopping conditino that the smooth loss should be below 40 (smooth loss: 39.993772):

```
    melf did.  If Deghook....  Volless.  I kictorted tore evenined - "Nowd her told
dow.  Harly, with-papped fhorank endedieded he Cagring't, he san you the snamible Malfoy
that line, his e.  "That the soed epen," said Fled quimw his gethingiol.  He budder
to deather thick him the platton?  Own everse so he a wates borto when the fied youn
My.  "Teeled move what his." "Nith tought.  Harry quite have prive?" she got Champre."
Harry Balks.  "Nome to betsap their of tine of for.  Whuthieves.  Whas pasling to like
aro Sharced as they heat to just his Darkions a said for deam, was dow he dey.  He
wand as her whele I hast eapheds more me os cleating yous expes it him.  CUgris and
contrer.  "What his bomall could wink though of his, ehtion..  spoters wis he pesed
the blow the Propesadned, greakemaenund at haded a clare a gond them?  I face?" said
Harms.  Comuriend seem ebelf, think they a saimer; wish then or him to goolfestugs,
brow.  "This Harry firsturas up himsing the sa!" "Whatwery donce short canme
```

"Harry", "Malfoy" and "wand": this RNN was certainly trained on one of the Harry Potter books.