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Deep Learning with {h2o} on MNIST dataset (and Kaggle competition)

R machine learning

2015-02-25

In the previous post we saw how Deep Learning with {h2o} works and how Deep Belief Nets implemented by h2o.deeplearning draw decision boundaries for XOR patterns.

Of course entirely the same framework can be applied to other general and usual datasets - including Kaggle competitions. For just a curiosity, I were looking for a free MNIST dataset and fortunately I found Kaggle provides it as below.

About

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Digit Recognizer | Kaggle

www.kaggle.com

I know Convolutional NN (ConvNet or CNN) better works for such a 2D image classification task than Deep Belief Net... there are some well-known and well-established libraries such as Caffe, CUDA-ConvNet, Torch7, etc., but they may take a little more to implement for (lazy) me. Here I ran a brief and quick trial with a MNIST dataset for h2o.deeplearning in order to check its performance.

MNIST dataset from Kaggle

First, please download "train.csv" and "test.csv" files from Kaggle competition page shown below.

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Our first mission here is to try h2o.deeplearning briefly, so let's divide it into a train and test dataset. MNIST dataset has 10 categories of dependent variables and we have to divide them with balancing all of 10 categories.

```
> dat<-read.csv("train.csv", header=TRUE)
> labels<-dat[,1]
> test_idx<-c()
> for (i in 1:10) {
+       tmp1<-which(labels==(i-1))
+       tmp2<-sample(tmp1,1000,replace=F)
+       test_idx<-c(test_idx,tmp2)
+ }
> test<-dat[test_idx,]
> train<-dat[-test_idx,]
```

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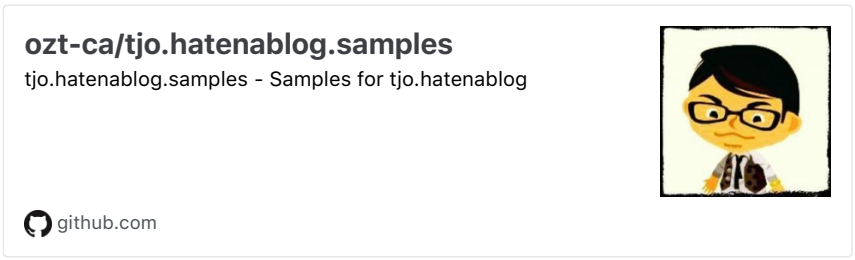
```
> write.table(train,file="prac_train.csv",quote=F,col.names=T,row.names=F,se
> write.table(test,file="prac_test.csv",quote=F,col.names=T,row.names=F,sep=
```

Now we have a customized dataset with "prac_train.csv" and "prac_test.csv" files. By the way, if you are unwilling to prepare the dataset by yourself, I uploaded them on my GitHub repository. You can get them from there.



Please note that this dataset is a little heavier so you'll take more time to download than expected.

Just for visualization, we can draw each digit in R. Please try as below (sorry for my ugly code...).

```
> test<-read.delim("prac_test.csv",sep=',')
> id0<-which(test$label==0)[1]
> id1<-which(test$label==1)[1]
> id2<-which(test$label==2)[1]
> id3<-which(test$label==3)[1]
> id4<-which(test$label==4)[1]
> id5<-which(test$label==5)[1]
> id6<-which(test$label==6)[1]
> id7<-which(test$label==7)[1]
> id8<-which(test$label==8)[1]
> id9<-which(test$label==9)[1]
> par(mfrow=c(2,5))
> image(t(apply(matrix(as.vector(as.matrix(test[id0,-1])),ncol=28,nrow=28,by
> image(t(apply(matrix(as.vector(as.matrix(test[id1,-1])),ncol=28,nrow=28,by
> image(t(apply(matrix(as.vector(as.matrix(test[id2,-1])),ncol=28,nrow=28,by
> image(t(apply(matrix(as.vector(as.matrix(test[id3,-1])),ncol=28,nrow=28,by
> image(t(apply(matrix(as.vector(as.matrix(test[id4,-1])),ncol=28,nrow=28,by
> image(t(apply(matrix(as.vector(as.matrix(test[id5,-1])),ncol=28,nrow=28,by
```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```
> image(t(apply(matrix(as.vector(as.matrix(test[id6,-1])),ncol=28,nrow=28,by
> image(t(apply(matrix(as.vector(as.matrix(test[id7,-1])),ncol=28,nrow=28,by
> image(t(apply(matrix(as.vector(as.matrix(test[id8,-1])),ncol=28,nrow=28,by
> image(t(apply(matrix(as.vector(as.matrix(test[id9,-1])),ncol=28,nrow=28,by
```

As well known, a limited part of MNIST digits cannot be correctly identified even by human eyes, so in general it's said that 100 % accuracy is impossible.

Run h2o.deeplearning: trial and error with tuning hyper parameters

Prior to trying h2o.deeplearning on MNIST dataset, first we have to boot {h2o} instance. Please remember how to boot it and set parameters required.

```
> library(h2o)
> localH2O <- h2o.init(ip = "localhost", port = 54321, startH2O = TRUE, nthr
> trData<-h2o.importFile(localH2O,path = "prac_train.csv")
> tsData<-h2o.importFile(localH2O,path = "prac_test.csv")
```

In order to set a benchmark, we run a random forest classifier first as MNIST Kaggle competition recommends.

```
> prac_train <- read.csv("prac_train.csv")
> prac_test <- read.csv("prac_test.csv")
> library(randomForest)
> prac_train$label<-as.factor(prac_train$label)
> prac.rf<-randomForest(label~.,prac_train)
> table(prac_test$label,predict(prac.rf,newdata=prac_test[,-1]))

    0   1   2   3   4   5   6   7   8   9
0 984   0   1   0   0   3   3   1   7   1
1   0 984   4   3   2   0   2   3   1   1
2   2   2 958   5   3   2   5   8  12   3
3   2   2  17 947   1   8   2   7  10   4
4   1   2   2   0 976   0   3   3   1  12
5   5   2   0  16   0 957   8   0   8   4
6   4   0   1   0   2   6 984   0   3   0
7   0   3   8   1   4   0   0 971   3  10
8   3   3   6   7   9   9   6   0 944  13
9   5   0   4  11  11   2   1  15   8 943

> sum(diag(table(prac_test$label,predict(prac.rf,newdata=prac_test[,-1]))))
[1] 9650
```

RF benchmark was 0.9650... is it already too high???*1:(

OK, our first mission is to overcome this benchmark with h2o.deeplearning. Let's run h2o.deeplearning just as below. This is the easiest one.

activation: Tanh
hidden: rep(160,5)
epochs: 20

```
> res.dl <- h2o.deeplearning(x = 2:785, y = 1, data = trData, activation = "
> pred.dl<-h2o.predict(object=res.dl,newdata=tsData[,-1])
> pred.dl.df<-as.data.frame(pred.dl)
> sum(diag(table(prac_test$label,pred.dl.df[,1])))
[1] 9711
```

Successfully we overcame the benchmark!:) But we still have a long way to go... for example, we can get information about parameter tuning from Hinton's paper in 2012.

activation: Tanh
hidden: c(500,500,1000)
epochs: 20
rate: 0.01
rate_annealing: 0.001

```
> res.dl <- h2o.deeplearning(x = 2:785, y = 1, data = trData, activation = "
+       epochs = 20,rate=0.01,rate_annealing = 0.001)
> pred.dl<-h2o.predict(object=res.dl,newdata=tsData[,-1])
> pred.dl.df<-as.data.frame(pred.dl)
> sum(diag(table(prac_test$label,pred.dl.df[,1])))
[1] 9726
```

It was improved by only a little... at that time, I came across Arno Candel's tutorial about H2O and its Deep Learning (**H2O Distributed Deep Learning by Arno Candel 071614**). Ah... I should have chosen this one for the first time!!!

I got it, let's run with those parameters.

activation: RectifierWithDropout
hidden: c(1024,1024,2048)
epochs: 200
rate: 0.01
rate_annealing: 1.0e-6
rate_decay: 1.0
momentum_start: 0.5
momentum_ramp: 32000*12
momentum_stable: 0.99
input_dropout_ratio: 0.2
l1: 1.0e-5
l2: 0.0
max_w2: 15.0
initial_weight_distribution: Normal

initial_weight_scale: 0.01
nesterov_accelerated_gradient: TRUE
loss: CrossEntropy
fast_mode: TRUE
diagnostics: TRUE
ignore_const_cols: TRUE
force_load_balance: TRUE

```
> res.dl <- h2o.deeplearning(x = 2:785, y = 1, data = trData, activation = "Re
+       hidden=c(1024,1024,2048),epochs = 200, adaptive_rate = FALSE, rate=0.0
+       rate_decay = 1.0, momentum_start = 0.5,momentum_ramp = 32000*12, momen
+       l1 = 1.0e-5,l2 = 0.0,max_w2 = 15.0, initial_weight_distribution = "Nor
+       nesterov_accelerated_gradient = T, loss = "CrossEntropy", fast_mode =
+       force_load_balance = T)
> pred.dl<-h2o.predict(object=res.dl,newdata=tsData[,-1])
> pred.dl.df<-as.data.frame(pred.dl)
> table(prac_test$label,pred.dl.df[,1])

     0   1   2   3   4   5   6   7   8   9
  0 990   0   2   2   0   2   2   0   1   1
  1   0 993   4   0   0   0   0   2   1   0
  2   3   3 980   2   1   1   0   5   4   1
  3   0   1   9 980   0   3   0   2   2   3
  4   0   4   1   0 984   1   3   3   1   3
  5   4   1   1   6   0 977   4   0   5   2
  6   0   0   1   1   1   2 995   0   0   0
  7   1   3   2   2   0   0   0 987   1   4
  8   3   6   3   6   5   4   1   3 965   4
  9   1   1   2   2   9   4   0  18   5 958

> sum(diag(table(prac_test$label,pred.dl.df[,1])))
[1] 9809
```

Phew... at last we reach 0.9800. It's still below the last 1%, but it's OK. Let's try the competition in Kaggle.

Join the competition

Now we are ready to join the competition and to submit our score. It's much simple; just run as below.

```
> ktrData<-h2o.importFile(localH2O,path = "train.csv")
> ktsData<-h2o.importFile(localH2O,path = "test.csv")
> res.dl <- h2o.deeplearning(x = 2:785, y = 1, data = ktrData, activation
+       hidden=c(1024,1024,2048),epochs = 200, adaptive_rate = FALSE, rate
+       rate_decay = 1.0, momentum_start = 0.5,momentum_ramp = 42000*12, m
+       l1 = 1.0e-5,l2 = 0.0,max_w2 = 15.0, initial_weight_distribution =
+       nesterov_accelerated_gradient = T, loss = "CrossEntropy", fast_moc
+       force_load_balance = T)
> pred.dl<-h2o.predict(object=res.dl,newdata=ktsData)
> pred.dl.df<-as.data.frame(pred.dl)
> write.table(pred.dl.df[,1],file='output.csv',quote=F,col.names=F,row.nam
```

Submission is very easy. Go to the submission page and just drag "output.csv" into the form.

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After calculating our score for a while, the leaderboard appears.

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For your information, my current position is as below.

62	↓6	Federico Allocati	0.98371	3	Sun, 25 Jan 2015 22:59:48
63	↓6	Florian Geiss	0.98343	2	Wed, 14 Jan 2015 20:34:20 (-3.3d)
64	↓6	Longqi	0.98343	5	Sun, 01 Feb 2015 05:17:38
65	↓5	BrantYZ	0.98314	8	Sat, 17 Jan 2015 02:11:00 (-21.5h)
66	↓5	Xiaoyi Liu	0.98314	5	Thu, 12 Feb 2015 07:17:20
67	↓4	**TJO_datasci**	**0.98300**	**4**	Fri, 23 Jan 2015 05:48:56 (-45h)
68	↓4	二次元的怪蜀黍们	0.98300	3	Wed, 04 Feb 2015 22:10:22 (-0h)
69	↓4	莊偉璿	0.98286	1	Wed, 24 Dec 2014 15:13:36
70	↓4	DyxCveta	0.98286	2	Sun, 01 Feb 2015 17:38:16
71	↓4	Julia Zotova	0.98271	2	Wed, 14 Jan 2015 13:56:50
72	↓4	Atkins	0.98271	1	Mon, 19 Jan 2015 08:08:16
73	new	rodio	0.98271	4	Sun, 22 Feb 2015 13:59:09 (-3.5h)

But I think there must be more efficient set of parameters for h2o.deeplearning... although Candel's setting may be the best one. Anybody knows the best one for h2o.deeplearning elsewhere? Please help me!!!

Notice

This post was reproduced from the original version in Japanese blog (**H2OのRパッケージ{h2o}でお手軽にDeep Learningを実践してみる(3)：MNISTデータの分類結果を他の分類器と比較する - 銀座で働くデータサイエンティストのブログ**) so there may be some typos or careless mistakes... if you find any errors, don't hesitate to let me know! :)

*1: Actually I'm still new to this field and I'm not so familiar with MNIST dataset and I don't know much about usual classification performance on it...

TJO 2 years ago

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Nelson Mok

Would you advise me? How to resolve this problem?

table(prac_test$label, pred.dl.df[,1])
Error in table(prac_test$label, pred.dl.df[, 1]) :
all arguments must have the same length
> length(pred.dl.df[, 1])
[1] 32000
> length(prac_test$label)
[1] 10000

205 days ago ★+

id:TJO

Hi Nelson,

Your script appears that you got pred.dl.df from predict() with an argument newdata=trData. It should be tsData because this is a test procedure with a hold-out dataset.

205 days ago ★+

Nelson Mok

Thank you. It fixed. BTW, for my personal opinion, h2o is better than tensorflow. I did some NN training with MATLAB. Is it possible to interface MATLAB with h2o?

204 days ago ★+

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