

CompleteThat: A python package for low-rank matrix completion

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Abstract

We have developed a Python package (CompleteThat) to perform low rank matrix completion. Given a low rank matrix with partial entries we implemented different methods to solve the matrix completion problem: First, for “small” problems we implemented two memory-based algorithms following the work by Tanner and Wei [TW14] to find, given a number r , the matrix with rank r that best fits the data using the Frobenius norm. Second, when the problem does not fit into memory, we implemented a memory-fitting algorithm (stochastic gradient descent) following the approach in Zhang [Zha04] and Bottou [Bot12]. The package is available at <https://pypi.python.org/pypi/completethat/0.1dev>.

Contents

1	Introduction	3
2	Matrix Completion Problem	3
3	Implementation	4
4	Case Studies	5
5	Future Work	8
6	Source code	10

1 Introduction

Matrix factorization has recently seen a large growth in popularity within the mathematics, statistics, and computer science communities as industry continues to apply machine learning techniques on a wide array of problems and scenarios. For our convex optimization project, we decided to take some of the more interesting and applicable topics and algorithms of our class and develop a python package to implement them. We briefly discuss the theory behind matrix factorizing, the models and approaches we choose to use and the algorithms for the optimization. Later, we walk through two case studies illustrating the usefulness and applicability in the context of image process and a recommendation system for Yahoo music and movie data.

2 Matrix Completion Problem

The matrix completion problem can be formally stated as follows. We are interested in recovering a matrix $M \in \mathbf{R}^{n_1 \times n_2}$ but only get to observe a number $m \ll n_1 n_2$ of its entries. Thus, we want to find a solution to the following optimization problem

$$\begin{aligned} & \text{minimize} && \mathbf{rank}(X) \\ & \text{subject to} && X_{ij} = M_{ij} \quad (i, j) \in \Omega \end{aligned} \tag{1}$$

where $X \in \mathbf{R}^{n_1 \times n_2}$ is the decision variable and $\mathbf{rank}(X)$ is equal to the rank of the matrix X . The problem (1) seeks the simplest matrix fitting the observed data. Of course, if there were only one low-rank object fitting the data, this would recover M . In order to fix the notation correctly define the projector $P_\Omega : \mathbf{R}^{n_1 \times n_2} \rightarrow \mathbf{R}^{n_1 \times n_2}$ as

$$P_\Omega(A) = \begin{cases} A_{ij} & : (i, j) \in \Omega \\ 0 & : \text{otherwise} \end{cases}$$

Using the projector, Problem (1) can be rewritten as

$$\begin{aligned} & \text{minimize} && \mathbf{rank}(X) \\ & \text{subject to} && P_\Omega(X) = P_\Omega(M) \end{aligned} \tag{2}$$

Unfortunately, this optimization problem has been shown to be NP-hard and all know algorithms which provide exact solutions require time doubly exponential in the dimension of the matrix both in theory and in practice [CR09]. Also, the $\mathbf{rank}(X)$ makes the problem non-convex.

Several approximations to the problem exists. One, the “tightest convex relaxation of $\mathbf{rank}(X)$ ” [Faz02] is the following problem

$$\begin{aligned} & \text{minimize} && \|X\|_* := \sum_{i=1}^r \sigma_i(X) \\ & \text{subject to} && P_\Omega(X) = P_\Omega(M) \end{aligned} \tag{3}$$

where $\sigma_i(X)$ denotes the i th largest singular value of X and $\|X\|_*$ is the called the nuclear norm. The main point of this relaxation is that the nuclear norm is a convex function and thus can be optimized efficiently via semidefinite programming or by iterative soft thresholding algorithms.

Alternative to nuclear norm minimization there have been many algorithms which are designed to target the following optimization problem

$$\text{minimize}_{X,Y} \quad \frac{1}{2} \|P_\Omega(XY) - P_\Omega(M)\|_F^2 \quad (4)$$

where $X = YZ$ is the completed matrix and $Y \in \mathbf{R}^{n_1 \times r}$, $Z \in \mathbf{R}^{r \times n_2}$ and r represents the (hopefully small) rank of the matrix X .

3 Implementation

CompleteThat is a python package that solves the low rank matrix completion problem. Given a low rank matrix with partial entries the package solves an optimization problem to estimate the missing entries. We allow the user to choose between several optimization algorithms including two in memory based algorithms, alternating steepest descent and scaled alternating steepest descent, and one out of memory fitting procedure using stochastic gradient descent. We use extensively the numerical libraries `spicy` and `numpy`, and the current implementation includes two classes, `MatrixCompletion` for in memory based algorithms and `MatrixCompletionBD` for the memory fitting procedure. The package is available worldwide and can be downloaded from <https://pypi.python.org/pypi/completethat/0.1dev>.

CVX

Problem (3) can be easily solved directly using CVX, a package for specifying and solving convex programs [GB14], [GB08], with the following code:

```
index = find(~isnan(M));
cvx_begin
    variable X(size(M));
    minimize norm_nuc(X)
    % s.t.
    X(index) == M(index);
cvx_end
```

Where M is a MATLAB matrix with `nan` on the missing entries and $X(\text{index}) == M(\text{index})$ corresponds to the $P_\Omega(X) = P_\Omega(M)$ restriction. However, the computation is very slow and for any matrix greater than 100x100 the computational time is too high. Since this is clearly unsatisfactory for practical purposes, specific algorithms were developed and used on the package.

Algorithms

Low rank matrix completion by alternating steepest descent methods

Low rank matrix completion by stochastic gradient descent

Code Example

For matrices that fit into memory use the `MatrixCompletion` module. Otherwise, use `MatrixCompletionBD` module.

MatrixCompletion

Given a numpy matrix M with `numpy.nan` on the missing entries, the matrix completion problem can be solved (using ASD) as:

```
>>> from completethat import MatrixCompletion
>>> problem = MatrixCompletion(M)
>>> problem.complete_it("ASD")
>>> X = problem.get_matrix() #Desired matrix
>>> out_info = problem.get_out() #Extra information
```

MatrixCompletionBD

Given a csv file with the input data, the matrix completion problem can be solved as:

```
>>> from completethat import MatrixCompletionBD
>>> problem = MatrixCompletionBD('input_data.txt')
>>> problem.train_sgd(dimension=6,init_step_size=.01,min_step=.000001,
                    reltol=.001,rand_init_scale=10, maxiter=1000,
                    batch_size_sgd=50000,shuffle=True)
>>> problem.validate_sgd('test_data.txt')
>>> problem.save_model()
```

4 Case Studies

Yahoo movies and music reviews database

The Yahoo music and movie data sets are publicly available datasets published by Yahoo for use to the public for recreational and research purposes. The music training data set is a small 4 mb pipe-delimited file consisting of roughly 210,000 user-movie ratings. The test set has roughly 10,000 records. There are two ratings schemas available, one on a 5-point scale and the other on a 13-point scale and we arbitrarily chose to use the 5-point scale. The Yahoo music data is a larger 2.2 gb file of 115 million user-song ratings. The ratings are on a 100 point scale.

We look to evaluate the performance of our algorithms on these two datasets, comparing the various algorithms implemented versus a naive benchmark estimate where we used the mean of the training set as our estimator for all records in the test set. Then we compared how well the algorithms performed versus the benchmark.

The benchmark for the yahoo music data is 4.088. This is the mean value of the ratings in the training set so we will compute the MSE on the test set using the benchmark which yields an RMSE of 1.10. A quick run of Mahout yields 1.17 and CompleteThat's sgd model yielded a 1.19. So our model yielded a pretty similar RMSE as the MAHOUT package. Note that for both of these instances we used a factorization of rank equal to seven and the Complete that sgd algorithm ran slightly faster than Mahout's (.537 minutes vs 1.4 minutes).

Step size	Iterations	Minutes	Train MSE	Test RMSE
1	8	0.585	1.411	1.757
2	8	0.598	1.304	1.550
3	8	0.628	1.235	1.483
4	8	0.617	1.180	1.397
5	7	0.538	1.136	1.351
6	7	0.534	1.100	1.244
7	7	0.534	1.071	1.194
8	7	0.541	1.046	1.127
9	7	0.537	1.027	1.128
10	7	0.529	1.010	1.102
15	7	0.551	0.971	1.063
20	7	0.540	0.976	1.075
30	8	0.614	1.045	1.359

Table 1: RMSE vs Step Size vs Rank

Columbia University images



Figure 1: ASD method applied to three different Columbia University images

5 Future Work

We have plans for various improvements as we continue working with the `CompleteThat` python package. Overall, we would like to test the software and integrate automated testing cases into the software developing cycle. Also, documentation for the package and its functions, including examples, is high in our priority list. In addition, we hope to incorporate more rigorous error checking and make available more customization to the user.

For the memory-based algorithms it is well known that noise in the data introduces overfitting on the estimated matrix. Following the approach taken by Mazumder et al. [MHT10] where they solve the same objective function as the problems above (using the Frobenius norm) but introducing the nuclear norm as regularizer to account for overfitting, we would introduce a regularization option into the matrix completion procedure.

For the stochastic gradient descent method, we plan to add a lambda penalty feature for combatting overfitting as well as considering options for more advanced versions of our basic latent factor model as demonstrated by Koren [Kor08] in his paper on the prize-winning Netflix models. For all algorithms, we would like to explore and research various hardware and software optimization techniques for faster code.

Finally, given the similarities between matrix completion and robust principal component analysis one further extension to the functionality of the package could be implementing the robust-PCA procedure outlined by Candés [CLMW11], et al.

References

- [Bot12] Léon Bottou. Stochastic gradient descent tricks. In *Neural Networks: Tricks of the Trade*, pages 421–436. Springer, 2012.
- [CLMW11] Emmanuel J Candès, Xiaodong Li, Yi Ma, and John Wright. Robust principal component analysis? *Journal of the ACM (JACM)*, 58(3):11, 2011.
- [CR09] E. J. Candès and B. Recht. Exact matrix completion via convex optimization. *Foundations of Computational mathematics*, 9(6):717–772, 2009.
- [Faz02] M. Fazel. *Matrix rank minimization with applications*. PhD thesis, Stanford University, 2002.
- [GB08] Michael Grant and Stephen Boyd. Graph implementations for nonsmooth convex programs. In V. Blondel, S. Boyd, and H. Kimura, editors, *Recent Advances in Learning and Control*, Lecture Notes in Control and Information Sciences, pages 95–110. Springer-Verlag Limited, 2008. http://stanford.edu/~boyd/graph_dcp.html.
- [GB14] Michael Grant and Stephen Boyd. CVX: Matlab software for disciplined convex programming, version 2.1. <http://cvxr.com/cvx>, March 2014.
- [Kor08] Yehuda Koren. Factorization meets the neighborhood: a multifaceted collaborative filtering model. In *Proceedings of the 14th ACM SIGKDD international conference on Knowledge discovery and data mining*, pages 426–434. ACM, 2008.
- [MHT10] Rahul Mazumder, Trevor Hastie, and Robert Tibshirani. Spectral regularization algorithms for learning large incomplete matrices. *The Journal of Machine Learning Research*, 11:2287–2322, 2010.
- [TW14] J. Tanner and K. Wei. Low rank matrix completion by alternating steepest descent methods. Technical report, SIAM, SIAM J. Imaging Sciences, 2014.
- [Zha04] Tong Zhang. Solving large scale linear prediction problems using stochastic gradient descent algorithms. In *Proceedings of the twenty-first international conference on Machine learning*, page 116. ACM, 2004.

6 Source code

On the whole, the package directory structure looks like the Figure 2. In the following we present the source code for the package.

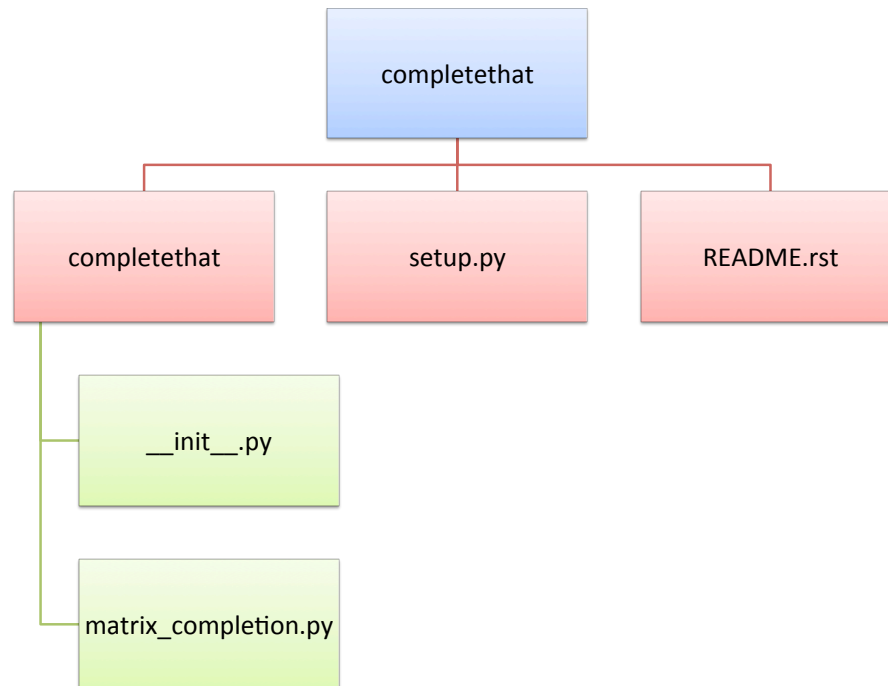


Figure 2: CompleteThat structure

completethat/matrix_completion.py

```
1 import numpy as np
2 from scipy.sparse import csc_matrix
3 from scipy.sparse import linalg as linalg_s
4 import os, random, time
5 from scipy import linalg
6
7 class MatrixCompletion:
8     """ A general class to represent a matrix completion problem
9
10     Data members
11     """
12     M= data matrix (numpy array).
13     X= optimized data matrix (numpy array)
```

```

14 out_info:= output information for the optimization (list)
15
16
17 Class methods
18 =====
19 complete_it():= method to complete the matrix
20 get_optimized_matrix():= method to get the solution to the problem
21 get_matrix():= method to get the original matrix
22 get_out():= method to get extra information on the optimization (iter
23 number, convergence, objective function)
24
25 """
26 def __init__(self, X,*args, **kwargs):
27     """ Constructor for the problem instance
28
29         Inputs:
30         1) X: known data matrix. Numpy array with np.nan on the unknow
entries.
31
32             example:
33                 X = np.random.randn(5, 5)
34                 X[1][3] = np.nan
35                 X[0][0] = np.nan
36                 X[4][4] = np.nan
37
38             """
39             # Initialization of the members
40             self._M = X
41             self._X = np.array(X, copy = True) #Initialize with ini data matrix
42             self._out_info = []
43
44 def get_optimized_matrix(self):
45     """ Getter function to return the optimized matrix X
46
47         Ouput:
48         1) Optimized matrix
49
50     """
51     return self._X
52
53 def get_matrix(self):
54     """ Getter function that returns the original matrix M
55
56         Output:
57         1) Original matrix M
58
59     """
60     return self._M
61
62 def get_out(self):
63     """ Getter function to return the output information
of the optimization
64
65         Output:

```

```

64         1) List of length 2: number of iterations and relative residual
65
66         """
67         return self._out_info
68
69
70     def _ASD(self, M, r = None, reltol=1e-5, maxiter=5000):
71         """
72         Alternating Steepest Descent (ASD)
73         Taken from Low rank matrix completion by alternating steepest descent
74         methods
75         Jared Tanner and Ke Wei
76         SIAM J. IMAGING SCIENCES (2014)
77
78         We have a matrix M with incomplete entries ,
79         and want to estimate the full matrix
80
81         Solves the following relaxation of the problem:
82         minimize_{X,Y} \frac{1}{2} ||P_{\Omega}(Z^0) - P_{\Omega}(XY)||_F^2
83         Where \Omega represents the set of m observed entries of the matrix M
84         and P_{\Omega}() is an operator that represents the observed data.
85
86         Inputs:
87         M := Incomplete matrix, with NaN on the unknown matrix
88         r := hypothesized rank of the matrix
89
90         Usage:
91         Just call the function _ASD(M)
92         """
93
94         # Get shape and Omega
95         m, n = M.shape
96         if r == None:
97             r = min(m, n, 50)
98
99         # Set relative error
100         Omega = ~np.isnan(M)
101         frob_norm_data = linalg.norm(M[Omega])
102         relres = reltol * frob_norm_data
103
104         # Initialize
105         I, J = np.where(Omega)
106         M_omega = csc_matrix((M[Omega], (I, J)), shape=M.shape)
107         U, s, V = linalg.s.svds(M_omega, r)
108         S = np.diag(s)
109         X = np.dot(U, S)
110         Y = V
111         itres = np.zeros((maxiter+1, 1))
112
113         XY = np.dot(X, Y)
114         diff_on_omega = M[Omega] - XY[Omega]

```

```

114     res = linalg.norm(diff_on_omega)
115     iter = 0
116     itres[iter] = res/frob_norm_data
117
118     while iter < maxiter and res >= relres:
119
120         # Gradient for X
121         diff_on_omega_matrix = np.zeros((m,n))
122         diff_on_omega_matrix[Omega] = diff_on_omega
123         grad_X = np.dot(diff_on_omega_matrix, np.transpose(Y))
124
125         # Stepsize for X
126         delta_XY = np.dot(grad_X, Y)
127         tx = linalg.norm(grad_X, 'fro')**2/linalg.norm(delta_XY)**2
128
129         # Update X
130         X = X + tx*grad_X;
131         diff_on_omega = diff_on_omega-tx*delta_XY[Omega]
132
133         # Gradient for Y
134         diff_on_omega_matrix = np.zeros((m,n))
135         diff_on_omega_matrix[Omega] = diff_on_omega
136         Xt = np.transpose(X)
137         grad_Y = np.dot(Xt, diff_on_omega_matrix)
138
139         # Stepsize for Y
140         delta_XY = np.dot(X, grad_Y)
141         ty = linalg.norm(grad_Y, 'fro')**2/linalg.norm(delta_XY)**2
142
143         # Update Y
144         Y = Y + ty*grad_Y
145         diff_on_omega = diff_on_omega-ty*delta_XY[Omega]
146
147         res = linalg.norm(diff_on_omega)
148         iter = iter + 1
149         itres[iter] = res/frob_norm_data
150
151     M_out = np.dot(X, Y)
152
153     out_info = [iter, itres]
154
155     return M_out, out_info
156
157 def _sASD(self, M, r = None, reltol=1e-5, maxiter=10000):
158     """
159     Scaled Alternating Steepest Descent (ScaledASD)
160     Taken from:
161     Low rank matrix completion by alternating steepest descent methods
162     Jared Tanner and Ke Wei
163     SIAM J. IMAGING SCIENCES (2014)
164

```

```

165 We have a matrix M with incomplete entries ,
166 and want to estimate the full matrix
167
168 Solves the following relaxation of the problem:
169 minimize_{X,Y} \frac{1}{2} ||P_{\Omega}(Z^0) - P_{\Omega}(XY)||_F^2
170 Where \Omega represents the set of m observed entries of the matrix M
171 and P_{\Omega}() is an operator that represents the observed data.
172
173 Inputs:
174 M := Incomplete matrix , with NaN on the unknown matrix
175 r := hypothesized rank of the matrix
176
177 Usage:
178 Just call the function _sASD(M)
179 """
180
181
182 # Get shape and Omega
183 m, n = M.shape
184 if r == None:
185     r = min(m, n, 50)
186
187 # Set relative error
188 Omega = ~np.isnan(M)
189 frob_norm_data = linalg.norm(M[Omega])
190 relres = reltol * frob_norm_data
191
192 # Initialize
193 identity = np.identity(r);
194 I, J = np.where(Omega)
195 M_omega = csc_matrix((M[Omega], (I, J)), shape=M.shape)
196 U, s, V = linalg.s.svds(M_omega, r)
197 S = np.diag(s)
198 X = np.dot(U, S)
199 Y = V
200 itres = np.zeros((maxiter+1, 1))
201
202 XY = np.dot(X, Y)
203 diff_on_omega = M[Omega] - XY[Omega]
204 res = linalg.norm(diff_on_omega)
205 iter = 0
206 itres[iter] = res/frob_norm_data
207
208 while iter < maxiter and res >= relres:
209
210     # Gradient for X
211     diff_on_omega_matrix = np.zeros((m,n))
212     diff_on_omega_matrix[Omega] = diff_on_omega
213     grad_X = np.dot(diff_on_omega_matrix, np.transpose(Y))
214
215     # Scaled gradient

```

```

216         scale = linalg.solve(np.dot(Y, np.transpose(Y)), identity)
217         dx = np.dot(grad_X, scale)
218
219         delta_XY = np.dot(dx, Y)
220         tx = np.trace(np.dot(np.transpose(dx), grad_X))/linalg.norm(
delta_XY [Omega])**2
221
222         # Update X
223         X = X + tx*dx
224         diff_on_omega = diff_on_omega-tx*delta_XY [Omega]
225
226         # Gradient for Y
227         diff_on_omega_matrix = np.zeros((m,n))
228         diff_on_omega_matrix [Omega] = diff_on_omega
229         Xt = np.transpose(X)
230         grad_Y = np.dot(Xt, diff_on_omega_matrix)
231
232         # Scaled gradient
233         scale = linalg.solve(np.dot(Xt, X), identity)
234         dy = np.dot(scale, grad_Y)
235
236         # Stepsize for Y
237         delta_XY = np.dot(X, dy)
238         ty = np.trace(np.dot(dy, np.transpose(grad_Y)))/linalg.norm(
delta_XY [Omega])**2
239
240         # Update Y
241         Y = Y + ty*dy
242         diff_on_omega = diff_on_omega-ty*delta_XY [Omega]
243
244         # Update iteration information
245         res = linalg.norm(diff_on_omega)
246         iter = iter + 1
247         itres [iter] = res/frob_norm_data
248
249         M_out = np.dot(X, Y)
250
251         out_info = [iter, itres]
252
253         return M_out, out_info
254
255     def complete_it(self, algo_name, r = None, reltol=1e-5, maxiter=5000):
256
257         """ Function to solve the optimization with the choosen algorithm
258
259         Input:
260         1) algo_name: Algorithm name (ASD, sASD, ect)
261         2) r: rank of the matrix if performing alternating algorithm
262         """
263         if algo_name == "ASD":
264             self._X, self._out_info = self._ASD(self._M, r, reltol, maxiter)

```

```

265         elif algo_name == "sASD":
266             self._X, self._out_info = self._sASD(self._M, r, reltol, maxiter)
267         else:
268             raise NameError("Algorithm name not recognized")
269
270 class MatrixCompletionBD:
271     """
272     A general class for matrix factorization via stochastic gradient descent
273
274     Class members
275     =====
276     file: three column file of user, item, and value to build models
277
278
279     Class methods
280     =====
281     train_sgd():= method to complete the matrix via sgd
282     shuffle_file():= method to 'psuedo' shuffle input file in chunks
283     file_split():= method to split input file into training and test set
284     save_model():= save user and items parameters to text file
285     validate_sgd():= validate sgd model on test set
286     build_matrix():= for smaller data build complete matrix in pandas df or
287                     numpy matrix?
288
289
290     def __init__(self, file_path, delimiter='\t', *args, **kwargs):
291         """
292         Object constructor
293         Initialize Matrix Completion BD object
294         """
295         self._file = file_path
296         self._delimiter = '\t'
297         self._users = dict()
298         self._items = dict()
299
300     def shuffle_file(self, batch_size=50000):
301         """
302
303         Shuffle line of file for sgd method, improves performance/convergence
304
305         """
306         data = open(self._file)
307         temp_file=open('temp-shuffled.txt', 'w')
308         try:
309             temp=open('backup_data_file.txt')
310             temp.close()
311         except:
312             os.system('cp ' +self._file + ' backup_data_file.txt')
313
314         temp_array=[]

```



```

315         counter=0
316         for line in data:
317             counter+=1
318             temp_array.append(line)
319             if counter==batch_size :
320                 random.shuffle(temp_array)
321                 for entry in temp_array:
322                     temp_file.write(entry)
323                 temp_array=[]
324                 counter=0
325
326         if len(temp_array)>0:
327             random.shuffle(temp_array)
328             for entry in temp_array:
329                 temp_file.write(entry)
330
331         data.close()
332         temp_file.close()
333         system_string='mv temp.shuffled.txt ' + self._file
334         os.system(system_string)
335
336     def file_split(self, percent_train=.80, train_file='data_train.csv',
337 test_file='data_test.csv'):
338         """
339         split input file randomly into training and test set for cross
340         validation
341         """
342         train=open(train_file, 'w')
343         test=open(test_file, 'w')
344         temp_file=open(self._file)
345         for line in temp_file:
346             if np.random.rand()<percent_train:
347                 train.write(line)
348             else:
349                 test.write(line)
350
351         train.close()
352         test.close()
353         print('test file written as ' + train_file)
354         print('test file written as ' + test_file)
355         temp_file.close()
356
357     def train_sgd(self, dimension=6, init_step_size=.01, min_step=1e-5, reitol
=.05, rand_init_scalar=1, maxiter=100, batch_size_sgd=50000, shuffle=True,
print_output=False):
358
359         init_time=time.time()
360         alpha=init_step_size
361         iteration=0

```

```

362         delta_err=1
363         new_mse=reltol+10
364         counter=0
365         ratings=[]
366
367         while iteration != maxiter and delta_err > reltol :
368
369             data=open( self._file )
370             total_err=[0]
371             if alpha>=min_step: alpha*=.3
372             else: alpha=min_step
373
374             for line in data:
375
376                 record=line[0:len(line)-1].split( self._delimiter )
377                 record[2]=float( record[2] )
378                 # format : user , movie,5-point-ratings
379                 ratings.append( record[2] )
380                 #if record[0] in self.users and record[1] in self.items :
381                 try:
382                     # do some updating
383                     # updates
384                     error=record[2]-np.dot( self._users[record[0]] , self._items[
record[1]])
385                     self._users[record[0]]=self._users[record[0]]+alpha*2*
error*self._items[record[1]]
386                     self._items[record[1]]=self._items[record[1]]+alpha*2*
error*self._users[record[0]]
387                     total_err.append( error**2 )
388                 except:
389                     #else:
390                     counter+=1
391                     if record[0] not in self._users:
392                         self._users[record[0]]=np.random.rand( dimension ) *
rand_init_scalar
393                     if record[1] not in self._items:
394                         self._items[record[1]]=np.random.rand( dimension ) *
rand_init_scalar
395
396             data.close()
397             if shuffle:
398                 self.shuffle_file( batch_size=batch_size_sgd )
399             iteration+=1
400             old_mse=new_mse
401             new_mse=sum( total_err ) * 1.0 / len( total_err )
402             delta_err=abs( old_mse-new_mse )
403             if print_output and iteration%10==0:
404                 print ( 'Delta Error: %f ' % delta_err )
405
406             #Printing Final Output
407             if print_output:

```

```

408         print ( 'Iterations: %f ' % iteration)
409         print ( 'MSE: %f ' % new_mse)
410         minutes=(time.time()-init_time)/60
411         print ( 'Total Minutes to Run: %f' % minutes)
412
413
414     def save_model(self , user_out='user_params.txt' , item_out='item_params.txt' )
415     :
416         """
417         save model user and item parameters to text file
418         user_key , user_vector entries
419         item_key , item_vector entries
420         """
421         users=open( user_out , 'w')
422         items=open( item_out , 'w')
423         for key in self._users:
424             user_string= key+ self._delimiter + self._delimiter.join( map( str
425             , list( self._users[ key] ) ) ) + '\n'
426             users.write( user_string )
427
428         for key in self._items:
429             item_string=key+ self._delimiter + self._delimiter.join( map( str ,
430             list( self._items[ key] ) ) ) + '\n'
431             items.write( item_string )
432
433         users.close()
434         items.close()
435
436     ## read saved model, particularly useful for fitting very large files!
437     def read_model( self , dimension=6, saved_user_params='user_params.txt' ,
438     saved_item_params='item_params.txt' ):
439         """
440         Read the saved user and item parameters from text files to the item
441         and user dictionaries
442         """
443         #populate users:
444         user_data=open( saved_user_params )
445         for line in user_data:
446             record=line[0: len( line ) -1].split( self._delimiter )
447             key=record.pop(0)
448             params=np. array( map( float , record ) )
449             self._users[ key]=params
450
451         user_data.close()
452
453         #populate items:
454         item_data=open( saved_item_params )
455         for line in item_data:
456             record=line[0: len( line ) -1].split( self._delimiter )

```

```

454         key=record.pop(0)
455         params=np.array(map(float,record))
456         self._items[key]=params
457
458     item_data.close()
459
460     def clear_model(self):
461         """
462
463         clear the user and item parameters
464
465         """
466         del self._items, self._users
467         self._items=dict()
468         self._users=dict()
469
470     def validate_sgd(self, test_file_path):
471         """
472
473         run model on test/validation set, returns MSE
474
475         """
476         mse=[]
477         counter=0
478         test_set=open(test_file_path)
479         for line in test_set:
480             record=line[0:len(line)-1].split(self._delimiter)
481             record[2]=float(record[2])
482             try:
483                 error=record[2]-np.dot(self._users[record[0]], self._items[
record[1]])
484                 mse.append(error**2)
485             except:
486                 counter+=1
487
488             if counter>0: print('Items/Users Key Errors: %f ' % counter)
489             # returns Mean Squared Error
490             return sum(mse)/len(mse)
491
492     def build_matrix(self):
493         pass

```

completethat/matrix__init__.py

```

1 """ CompleteThat is a python package that solves the low rank matrix
   completion
2 problem. Given a low rank matrix with partial entries the package solves an
3 optimization problem to estimate the missing entries.

```

```

4
5 Mathematically, the package solves a relaxation (using the nuclear norm or the
6 Frobenius norm of the objective matrix) of the following problem:
7     minimize- $\{X\}$   $\|X\|$ 
8     st.  $X(i,j) = M(i,j) \setminus \text{forall } (i,j) \setminus \text{in } \Omega$ ,
9
10 Where,  $M$  represents the data matrix and  $\Omega$  represents the set of  $p$ 
    observed entries of  $M$ 
11
12 Usage:
13 # MatrixCompletion
14 >>> from completethat import MatrixCompletion
15 >>> problem = MatrixCompletion(M)
16 >>> problem.complete_it(algo_name)
17 >>> X = problem.get_matrix()
18 >>> out_info = problem.get_out() #Extra info (iterations, ect)
19
20 # MatrixCompletionBD
21 >>> from completethat import MatrixCompletionBD
22 >>> temp=MatrixCompletionBD('input_data.txt')
23 >>> temp.train_sgd(dimension=6,init_step_size=.01,min_step=.000001, reltol
    =.001,rand_init_scale=10, maxiter=1000,batch_size_sgd=50000,shuffle=True
    ):
24 >>> temp.validate_sgd('test_data.txt')
25 >>> temp.save_model()
26
27 """
28 from matrix_completion import MatrixCompletion
29 from matrix_completion import MatrixCompletionBD

```

completethat/matrix__init__.py

```

1 from setuptools import setup
2
3 def readme():
4     with open('README.rst') as f:
5         return f.read()
6
7 setup(
8     name='completethat',
9     version='0.1dev',
10    description='A package to solve low rank matrix completion problems',
11    long_description=readme(),
12    author='Joshua Edgerton, Esteban Fajardo',
13    author_email='ef2451@columbia.edu, jae2154@columbia.edu',
14    license='BSD',
15    packages=['completethat'],
16    install_requires=[

```

```

17         'scipy', 'numpy'
18     ],
19     classifiers=[
20         'Development Status :: 3 - Alpha',
21         'License :: OSI Approved :: BSD License',
22         'Programming Language :: Python :: 2.7',
23         'Topic :: Scientific/Engineering :: Mathematics',
24         'Topic :: Utilities'
25     ],
26     include_package_data=True,
27     zip_safe=False
28 )

```