The University of Texas
at Austin

CS363D Statistical Learning and Data Mining

Homework 03

Edited by LaTeX

Department of Computer Science

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RELEASE DATE
March. 25 2014

DUE DATE
April. 07 2014

TIME SPENT
7 hours

March 29, 2014

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1 MF Implementation

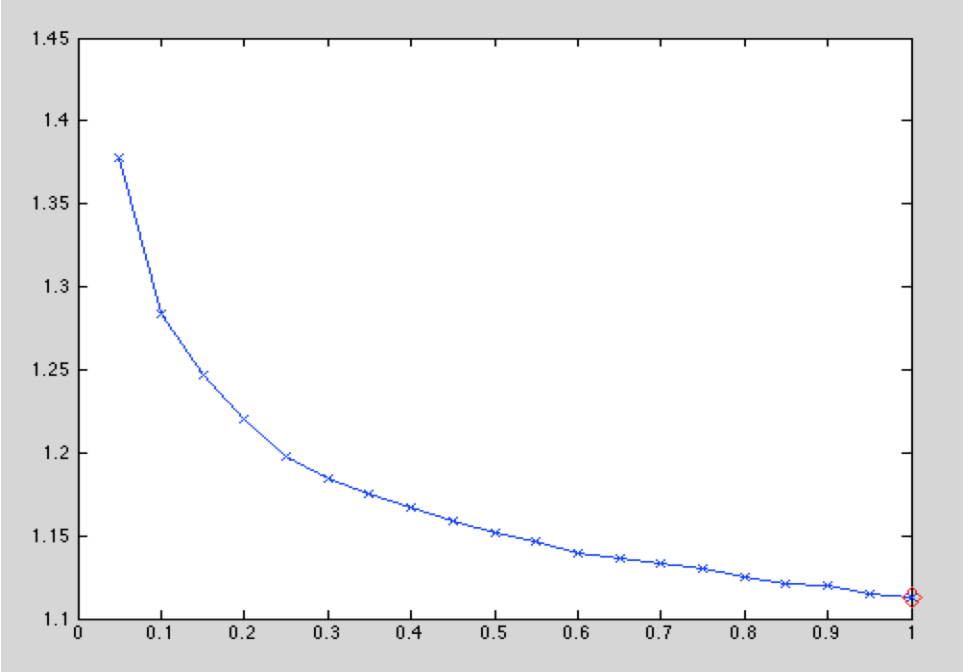

Figure 1: Errors With Regard to Parameter λ

For specific details, see the source code in Appendix A. For debugging, see the Execution logs in Appendix B.

2 Report optimal λ

The optimal lambda derived is $\lambda = 1$.

3 Problem when $\lambda = 0$

The problem encountered when $\lambda = 0$ is that the singularity of $U^{(K_i)T} * U^{(K_i)}$ and $M^{(K_i)T} * M^{(K_i)}$.

4 RMSE of Test Set under optimal λ

The RMSE of test set under optimal $\lambda =$ is 1.0835.

A Source Code

```
% Solution for the data mining homework 03
% Author: Jimmy Lin (xl5224)

function solution()
%%% load the dataset
load('./dataset/hw3_netflix.mat');
%%% Setting about data
nCVFolds = size(cvSet, 1);
FOLDRANGE = 1:nCVFolds;
sRatings = size(Ratings);
nUsers = sRatings(1);
nMovies = sRatings(2);

%%
% PRE-SETTING
LAMBDAS = 0:0.05:1;
NITERATIONS = 30;
K = 10;
nLambdas = size(LAMBDAS, 2);

%%
% CROSS VALIDATION
avgError = zeros(1, nLambdas);
for l = 1:nLambdas,
    lambda = LAMBDAS(l);
    foldError = zeros(1,nCVFolds);
    for f = FOLDRANGE,
        %% prepare elements for training
        nItems = length(cvSet(f,:));
        cvTrainR = trR;
        cvTrainR(cvSet(f,:)) = 0;
        cvTestR = trR(cvSet(f,:));
        %% apply Alternating Minimization for training
        [U, M] = trainMF (cvTrainR, lambda, NITERATIONS, K);
        %% make prediction rating matrix
        PredictedRatings = U * M';
        %% generate prediction array for error computation
        cvPrediction = PredictedRatings(cvSet(f,:));
        %% compute root mean square error
        foldError(f) = computeRMSE (cvPrediction, cvTestR, nItems);
        fprintf('(Lambda, Fold, Error) = (%0.2f, %d, %f)\n', ...
                lambda, f, foldError(f))
    end
    fprintf('Errors when lambda=%0.2f: ', lambda)
    disp(foldError)
    %% take the mean of fold errors as error of lambda
    avgError(l) = mean(foldError);
end
    plot(LAMBDAS, avgError, 'x-')
    hold on
    %% pick up the optimal lambda
    optIdx = find(avgError <= min(avgError) + 1e-5);
    optLambda = LAMBDAS(optIdx)
    plot([optLambda], [avgError(optIdx)], 'dr', 'MarkerSize', 10)
    %% training by using optimal lambda
    [U, M] = trainMF (trR, optLambda, NITERATIONS, K);
    optPredictedRatings = U * M';
    %% compute optimal
    optRMSE = computeRMSE(optPredictedRatings(testIdx), ...
        Ratings(testIdx), length(testIdx))
end

%%% subfunction:
```

```
%% functionality: apply matrix factorization on training data
function [U, M] = trainMF (trainData, lambda, iterations, K)
nUsers = size(trainData, 1);
nMovies = size(trainData, 2);
U = randn(nUsers, K);
M = randn(nMovies, K);

for iter = 1:iterations,
    for j = 1:nMovies,
        idx = find(trainData(:, j) ~= 0);
        Uk = U(idx, :);
        M(j,:) = inv(Uk' * Uk + lambda * eye(K)) * Uk' * trainData(idx,j);
    end
    for i = 1:nUsers,
        idx = find(trainData(i, :) ~= 0);
        Mk = M(idx, :);
        U(i,:) = inv(Mk' * Mk + lambda * eye(K)) * Mk' * trainData(i,idx)';
    end
end
end

function err = computeRMSE (Prediction, GroundTruth, nItems)
err = sqrt(sum(sum((Prediction-GroundTruth).^2)) / nItems);
end
```

B Execution Logs

```
(Lambda, Fold, Error) = (0.00, 10, NaN)
Errors when lambda=0.00:    NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN

(Lambda, Fold, Error) = (0.05, 1, 1.411947)
(Lambda, Fold, Error) = (0.05, 2, 1.371217)
(Lambda, Fold, Error) = (0.05, 3, 1.360121)
(Lambda, Fold, Error) = (0.05, 4, 1.381147)
(Lambda, Fold, Error) = (0.05, 5, 1.371452)
(Lambda, Fold, Error) = (0.05, 6, 1.396735)
(Lambda, Fold, Error) = (0.05, 7, 1.387001)
(Lambda, Fold, Error) = (0.05, 8, 1.367467)
(Lambda, Fold, Error) = (0.05, 9, 1.381849)
(Lambda, Fold, Error) = (0.05, 10, 1.348981)
Errors when lambda=0.05:    1.4119    1.3712    1.3601    1.3811    1.3715    1.3967    1.3870
1.3675    1.3818    1.3490

(Lambda, Fold, Error) = (0.10, 1, 1.275159)
(Lambda, Fold, Error) = (0.10, 2, 1.291333)
(Lambda, Fold, Error) = (0.10, 3, 1.284587)
(Lambda, Fold, Error) = (0.10, 4, 1.267674)
(Lambda, Fold, Error) = (0.10, 5, 1.288017)
(Lambda, Fold, Error) = (0.10, 6, 1.313758)
(Lambda, Fold, Error) = (0.10, 7, 1.283330)
(Lambda, Fold, Error) = (0.10, 8, 1.274047)
(Lambda, Fold, Error) = (0.10, 9, 1.294935)
(Lambda, Fold, Error) = (0.10, 10, 1.263426)
Errors when lambda=0.10:    1.2752    1.2913    1.2846    1.2677    1.2880    1.3138    1.2833
1.2740    1.2949    1.2634

(Lambda, Fold, Error) = (0.15, 1, 1.241871)
(Lambda, Fold, Error) = (0.15, 2, 1.256137)
(Lambda, Fold, Error) = (0.15, 3, 1.252209)
(Lambda, Fold, Error) = (0.15, 4, 1.230881)
(Lambda, Fold, Error) = (0.15, 5, 1.243366)
(Lambda, Fold, Error) = (0.15, 6, 1.240766)
(Lambda, Fold, Error) = (0.15, 7, 1.262817)
(Lambda, Fold, Error) = (0.15, 8, 1.237307)
(Lambda, Fold, Error) = (0.15, 9, 1.254089)
```

```
(Lambda, Fold, Error) = (0.15, 10, 1.247183)
Errors when lambda=0.15:     1.2419    1.2561    1.2522    1.2309    1.2434    1.2408    1.2628
1.2373    1.2541    1.2472

(Lambda, Fold, Error) = (0.20, 1, 1.215327)
(Lambda, Fold, Error) = (0.20, 2, 1.212881)
(Lambda, Fold, Error) = (0.20, 3, 1.229502)
(Lambda, Fold, Error) = (0.20, 4, 1.205619)
(Lambda, Fold, Error) = (0.20, 5, 1.212550)
(Lambda, Fold, Error) = (0.20, 6, 1.239990)
(Lambda, Fold, Error) = (0.20, 7, 1.235272)
(Lambda, Fold, Error) = (0.20, 8, 1.211149)
(Lambda, Fold, Error) = (0.20, 9, 1.235782)
(Lambda, Fold, Error) = (0.20, 10, 1.203187)
Errors when lambda=0.20:     1.2153    1.2129    1.2295    1.2056    1.2125    1.2400    1.2353
1.2111    1.2358    1.2032

(Lambda, Fold, Error) = (0.25, 1, 1.190571)
(Lambda, Fold, Error) = (0.25, 2, 1.205245)
(Lambda, Fold, Error) = (0.25, 3, 1.205136)
(Lambda, Fold, Error) = (0.25, 4, 1.187585)
(Lambda, Fold, Error) = (0.25, 5, 1.196876)
(Lambda, Fold, Error) = (0.25, 6, 1.195276)
(Lambda, Fold, Error) = (0.25, 7, 1.204522)
(Lambda, Fold, Error) = (0.25, 8, 1.198324)
(Lambda, Fold, Error) = (0.25, 9, 1.204997)
(Lambda, Fold, Error) = (0.25, 10, 1.185293)
Errors when lambda=0.25:     1.1906    1.2052    1.2051    1.1876    1.1969    1.1953    1.2045
1.1983    1.2050    1.1853

(Lambda, Fold, Error) = (0.30, 1, 1.184220)
(Lambda, Fold, Error) = (0.30, 2, 1.190116)
(Lambda, Fold, Error) = (0.30, 3, 1.186195)
(Lambda, Fold, Error) = (0.30, 4, 1.185386)
(Lambda, Fold, Error) = (0.30, 5, 1.180466)
(Lambda, Fold, Error) = (0.30, 6, 1.180913)
(Lambda, Fold, Error) = (0.30, 7, 1.209995)
(Lambda, Fold, Error) = (0.30, 8, 1.169553)
(Lambda, Fold, Error) = (0.30, 9, 1.179413)
(Lambda, Fold, Error) = (0.30, 10, 1.176732)
Errors when lambda=0.30:     1.1842    1.1901    1.1862    1.1854    1.1805    1.1809    1.2100
1.1696    1.1794    1.1767

(Lambda, Fold, Error) = (0.35, 1, 1.164173)
(Lambda, Fold, Error) = (0.35, 2, 1.178633)
(Lambda, Fold, Error) = (0.35, 3, 1.186494)
(Lambda, Fold, Error) = (0.35, 4, 1.163389)
(Lambda, Fold, Error) = (0.35, 5, 1.179682)
(Lambda, Fold, Error) = (0.35, 6, 1.185297)
(Lambda, Fold, Error) = (0.35, 7, 1.173140)
(Lambda, Fold, Error) = (0.35, 8, 1.177644)
(Lambda, Fold, Error) = (0.35, 9, 1.183900)
(Lambda, Fold, Error) = (0.35, 10, 1.158685)
Errors when lambda=0.35:     1.1642    1.1786    1.1865    1.1634    1.1797    1.1853    1.1731
1.1776    1.1839    1.1587

(Lambda, Fold, Error) = (0.40, 1, 1.163238)
(Lambda, Fold, Error) = (0.40, 2, 1.157368)
(Lambda, Fold, Error) = (0.40, 3, 1.167919)
(Lambda, Fold, Error) = (0.40, 4, 1.173515)
(Lambda, Fold, Error) = (0.40, 5, 1.163116)
(Lambda, Fold, Error) = (0.40, 6, 1.180506)
(Lambda, Fold, Error) = (0.40, 7, 1.170660)
(Lambda, Fold, Error) = (0.40, 8, 1.151202)
(Lambda, Fold, Error) = (0.40, 9, 1.177174)
(Lambda, Fold, Error) = (0.40, 10, 1.161618)
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Errors when lambda=0.40:     1.1632    1.1574    1.1679    1.1735    1.1631    1.1805    1.1707
1.1512    1.1772    1.1616

(Lambda, Fold, Error) = (0.45, 1, 1.163587)
(Lambda, Fold, Error) = (0.45, 2, 1.160354)
(Lambda, Fold, Error) = (0.45, 3, 1.157886)
(Lambda, Fold, Error) = (0.45, 4, 1.154686)
(Lambda, Fold, Error) = (0.45, 5, 1.141228)
(Lambda, Fold, Error) = (0.45, 6, 1.175810)
(Lambda, Fold, Error) = (0.45, 7, 1.157149)
(Lambda, Fold, Error) = (0.45, 8, 1.155601)
(Lambda, Fold, Error) = (0.45, 9, 1.171742)
(Lambda, Fold, Error) = (0.45, 10, 1.145750)
Errors when lambda=0.45:     1.1636    1.1604    1.1579    1.1547    1.1412    1.1758    1.1571
1.1556    1.1717    1.1458

(Lambda, Fold, Error) = (0.50, 1, 1.141676)
(Lambda, Fold, Error) = (0.50, 2, 1.154762)
(Lambda, Fold, Error) = (0.50, 3, 1.154691)
(Lambda, Fold, Error) = (0.50, 4, 1.148389)
(Lambda, Fold, Error) = (0.50, 5, 1.148762)
(Lambda, Fold, Error) = (0.50, 6, 1.160227)
(Lambda, Fold, Error) = (0.50, 7, 1.153426)
(Lambda, Fold, Error) = (0.50, 8, 1.143555)
(Lambda, Fold, Error) = (0.50, 9, 1.164293)
(Lambda, Fold, Error) = (0.50, 10, 1.144501)
Errors when lambda=0.50:     1.1417    1.1548    1.1547    1.1484    1.1488    1.1602    1.1534
1.1436    1.1643    1.1445

(Lambda, Fold, Error) = (0.55, 1, 1.131156)
(Lambda, Fold, Error) = (0.55, 2, 1.147823)
(Lambda, Fold, Error) = (0.55, 3, 1.147116)
(Lambda, Fold, Error) = (0.55, 4, 1.142009)
(Lambda, Fold, Error) = (0.55, 5, 1.152214)
(Lambda, Fold, Error) = (0.55, 6, 1.160605)
(Lambda, Fold, Error) = (0.55, 7, 1.141593)
(Lambda, Fold, Error) = (0.55, 8, 1.134633)
(Lambda, Fold, Error) = (0.55, 9, 1.147708)
(Lambda, Fold, Error) = (0.55, 10, 1.157545)
Errors when lambda=0.55:     1.1312    1.1478    1.1471    1.1420    1.1522    1.1606    1.1416
1.1346    1.1477    1.1575

(Lambda, Fold, Error) = (0.60, 1, 1.133405)
(Lambda, Fold, Error) = (0.60, 2, 1.141913)
(Lambda, Fold, Error) = (0.60, 3, 1.139707)
(Lambda, Fold, Error) = (0.60, 4, 1.132137)
(Lambda, Fold, Error) = (0.60, 5, 1.144509)
(Lambda, Fold, Error) = (0.60, 6, 1.137644)
(Lambda, Fold, Error) = (0.60, 7, 1.147042)
(Lambda, Fold, Error) = (0.60, 8, 1.132765)
(Lambda, Fold, Error) = (0.60, 9, 1.148272)
(Lambda, Fold, Error) = (0.60, 10, 1.136532)
Errors when lambda=0.60:     1.1334    1.1419    1.1397    1.1321    1.1445    1.1376    1.1470
1.1328    1.1483    1.1365

(Lambda, Fold, Error) = (0.65, 1, 1.119677)
(Lambda, Fold, Error) = (0.65, 2, 1.125584)
(Lambda, Fold, Error) = (0.65, 3, 1.137377)
(Lambda, Fold, Error) = (0.65, 4, 1.140377)
(Lambda, Fold, Error) = (0.65, 5, 1.129277)
(Lambda, Fold, Error) = (0.65, 6, 1.148645)
(Lambda, Fold, Error) = (0.65, 7, 1.140229)
(Lambda, Fold, Error) = (0.65, 8, 1.147211)
(Lambda, Fold, Error) = (0.65, 9, 1.142439)
(Lambda, Fold, Error) = (0.65, 10, 1.133074)
Errors when lambda=0.65:     1.1197    1.1256    1.1374    1.1404    1.1293    1.1486    1.1402
1.1472    1.1424    1.1331
```

```
(Lambda, Fold, Error) = (0.70, 1, 1.119570)
(Lambda, Fold, Error) = (0.70, 2, 1.140769)
(Lambda, Fold, Error) = (0.70, 3, 1.129591)
(Lambda, Fold, Error) = (0.70, 4, 1.132144)
(Lambda, Fold, Error) = (0.70, 5, 1.129148)
(Lambda, Fold, Error) = (0.70, 6, 1.142406)
(Lambda, Fold, Error) = (0.70, 7, 1.131679)
(Lambda, Fold, Error) = (0.70, 8, 1.136480)
(Lambda, Fold, Error) = (0.70, 9, 1.145003)
(Lambda, Fold, Error) = (0.70, 10, 1.121597)
Errors when lambda=0.70:     1.1196    1.1408    1.1296    1.1321    1.1291    1.1424    1.1317
1.1365    1.1450    1.1216

(Lambda, Fold, Error) = (0.75, 1, 1.121950)
(Lambda, Fold, Error) = (0.75, 2, 1.120693)
(Lambda, Fold, Error) = (0.75, 3, 1.135749)
(Lambda, Fold, Error) = (0.75, 4, 1.128547)
(Lambda, Fold, Error) = (0.75, 5, 1.125868)
(Lambda, Fold, Error) = (0.75, 6, 1.139377)
(Lambda, Fold, Error) = (0.75, 7, 1.136667)
(Lambda, Fold, Error) = (0.75, 8, 1.120701)
(Lambda, Fold, Error) = (0.75, 9, 1.145132)
(Lambda, Fold, Error) = (0.75, 10, 1.123616)
Errors when lambda=0.75:     1.1220    1.1207    1.1357    1.1285    1.1259    1.1394    1.1367
1.1207    1.1451    1.1236

(Lambda, Fold, Error) = (0.80, 1, 1.103993)
(Lambda, Fold, Error) = (0.80, 2, 1.123699)
(Lambda, Fold, Error) = (0.80, 3, 1.127682)
(Lambda, Fold, Error) = (0.80, 4, 1.128698)
(Lambda, Fold, Error) = (0.80, 5, 1.114976)
(Lambda, Fold, Error) = (0.80, 6, 1.130462)
(Lambda, Fold, Error) = (0.80, 7, 1.143441)
(Lambda, Fold, Error) = (0.80, 8, 1.128946)
(Lambda, Fold, Error) = (0.80, 9, 1.129831)
(Lambda, Fold, Error) = (0.80, 10, 1.120246)
Errors when lambda=0.80:     1.1040    1.1237    1.1277    1.1287    1.1150    1.1305    1.1434
1.1289    1.1298    1.1202

(Lambda, Fold, Error) = (0.85, 1, 1.117854)
(Lambda, Fold, Error) = (0.85, 2, 1.122193)
(Lambda, Fold, Error) = (0.85, 3, 1.124524)
(Lambda, Fold, Error) = (0.85, 4, 1.116864)
(Lambda, Fold, Error) = (0.85, 5, 1.120530)
(Lambda, Fold, Error) = (0.85, 6, 1.123193)
(Lambda, Fold, Error) = (0.85, 7, 1.124361)
(Lambda, Fold, Error) = (0.85, 8, 1.114095)
(Lambda, Fold, Error) = (0.85, 9, 1.124844)
(Lambda, Fold, Error) = (0.85, 10, 1.119965)
Errors when lambda=0.85:     1.1179    1.1222    1.1245    1.1169    1.1205    1.1232    1.1244
1.1141    1.1248    1.1200

(Lambda, Fold, Error) = (0.90, 1, 1.100922)
(Lambda, Fold, Error) = (0.90, 2, 1.126601)
(Lambda, Fold, Error) = (0.90, 3, 1.126961)
(Lambda, Fold, Error) = (0.90, 4, 1.118059)
(Lambda, Fold, Error) = (0.90, 5, 1.122241)
(Lambda, Fold, Error) = (0.90, 6, 1.126720)
(Lambda, Fold, Error) = (0.90, 7, 1.125150)
(Lambda, Fold, Error) = (0.90, 8, 1.110950)
(Lambda, Fold, Error) = (0.90, 9, 1.125494)
(Lambda, Fold, Error) = (0.90, 10, 1.112672)
Errors when lambda=0.90:     1.1009    1.1266    1.1270    1.1181    1.1222    1.1267    1.1251
1.1110    1.1255    1.1127

(Lambda, Fold, Error) = (0.95, 1, 1.098285)
```

```
(Lambda, Fold, Error) = (0.95, 2, 1.112644)
(Lambda, Fold, Error) = (0.95, 3, 1.129575)
(Lambda, Fold, Error) = (0.95, 4, 1.108022)
(Lambda, Fold, Error) = (0.95, 5, 1.113344)
(Lambda, Fold, Error) = (0.95, 6, 1.126322)
(Lambda, Fold, Error) = (0.95, 7, 1.117771)
(Lambda, Fold, Error) = (0.95, 8, 1.102943)
(Lambda, Fold, Error) = (0.95, 9, 1.130283)
(Lambda, Fold, Error) = (0.95, 10, 1.109194)
Errors when lambda=0.95:     1.0983    1.1126    1.1296    1.1080    1.1133    1.1263    1.1178
1.1029    1.1303    1.1092

(Lambda, Fold, Error) = (1.00, 1, 1.104553)
(Lambda, Fold, Error) = (1.00, 2, 1.110303)
(Lambda, Fold, Error) = (1.00, 3, 1.119303)
(Lambda, Fold, Error) = (1.00, 4, 1.110195)
(Lambda, Fold, Error) = (1.00, 5, 1.112638)
(Lambda, Fold, Error) = (1.00, 6, 1.117118)
(Lambda, Fold, Error) = (1.00, 7, 1.115305)
(Lambda, Fold, Error) = (1.00, 8, 1.105883)
(Lambda, Fold, Error) = (1.00, 9, 1.127105)
(Lambda, Fold, Error) = (1.00, 10, 1.104722)
Errors when lambda=1.00:     1.1046    1.1103    1.1193    1.1102    1.1126    1.1171    1.1153
1.1059    1.1271    1.1047


optLambda =

     1


optRMSE =

    1.0835
```