Movie recommendation: Collaborative Filtering

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***Abstract*—As part of homework 1 of COMS-6998 : Advanced Machine Learning with Personalization, a movie recommendation engine is built which performs collaborative filtering. The rank matrices are factorized and completed by decomposing through low-rank factorization.**

I. Introduction

We are working on the MovieLens 20M dataset which contains 20000263 ratings across 27278 movies as generated by 138493 users between January 09, 1995 to March 31, 2015. All selected users have rated at least 20 movies. The file ratings.csv contains the ratings given to some movies on a 5-star scale with half-increments. On each line, the file has a rating with the following format (userId;movieId;rating;timestamp).

- The entire movie-ratings data-set and was split randomly with 50% of each user in test/train sets respectively.
- Five different splits of data were generated through this process

II. RMSETest, RMSETrain, MRR Data Produced: Pre-Analysis

The other Split datas are located in the appendix

A. Split-1

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
10	0.001	1	1.038286	0.953560	0.144645
10	0.001	2	0.920051	0.907733	0.144786
10	0.001	3	0.891892	0.891609	0.144810
10	0.001	4	0.879021	0.883577	0.144815
10	0.001	5	0.871695	0.878953	0.144821
10	0.001	6	0.867026	0.876059	0.144823
10	0.001	7	0.863824	0.874144	0.144818
10	0.001	8	0.861506	0.872826	0.144818
10	0.001	9	0.859752	0.871889	0.144813
10	0.001	10	0.858373	0.871202	0.144809
10	0.001	11	0.857244	0.870679	0.144803
10	0.001	12	0.856283	0.870260	0.144797
10	0.001	13	0.855425	0.869898	0.144789
10	0.001	14	0.854620	0.869553	0.144789
10	0.001	15	0.853821	0.869186	0.144783
10	0.001	16	0.852982	0.868757	0.144765
10	0.001	17	0.852056	0.868226	0.144768
10	0.001	18	0.850996	0.867553	0.144765
10	0.001	19	0.849760	0.866707	0.144755
10	0.001	20	0.848324	0.865678	0.144751

TABLE I
SPLIT1: RANK=10, λ=0.001

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
10	0.02	1	1.039179	0.950775	0.144744
10	0.02	2	0.919648	0.906044	0.144821
10	0.02	3	0.891683	0.890161	0.144827
10	0.02	4	0.878897	0.882247	0.144842
10	0.02	5	0.871627	0.877696	0.144857
10	0.02	6	0.867002	0.874848	0.144851
10	0.02	7	0.863839	0.872963	0.144856
10	0.02	8	0.861558	0.871662	0.144858
10	0.02	9	0.859842	0.870732	0.144851
10	0.02	10	0.858503	0.870045	0.144842
10	0.02	11	0.857419	0.869519	0.144840
10	0.02	12	0.856511	0.869096	0.144841
10	0.02	13	0.855717	0.868735	0.144840
10	0.02	14	0.854993	0.868401	0.144841
10	0.02	15	0.854298	0.868062	0.144843
10	0.02	16	0.853594	0.867686	0.144841
10	0.02	17	0.852843	0.867242	0.144840
10	0.02	18	0.852007	0.866695	0.144831
10	0.02	19	0.851046	0.866013	0.144829
10	0.02	20	0.849927	0.865172	0.144833

TABLE II
SPLIT1: RANK=10, λ=0.02

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
10	0.1	1	1.045042	0.949757	0.144772
10	0.1	2	0.926225	0.908935	0.144856
10	0.1	3	0.899134	0.894323	0.144871
10	0.1	4	0.886671	0.886996	0.144871
10	0.1	5	0.879550	0.882727	0.144867
10	0.1	6	0.874995	0.880008	0.144857
10	0.1	7	0.871867	0.878166	0.144867
10	0.1	8	0.869608	0.876861	0.144873
10	0.1	9	0.867914	0.875904	0.144870
10	0.1	10	0.866605	0.875182	0.144871
10	0.1	11	0.865568	0.874622	0.144871
10	0.1	12	0.864731	0.874180	0.144871
10	0.1	13	0.864041	0.873822	0.144869
10	0.1	14	0.863465	0.873529	0.144866
10	0.1	15	0.862976	0.873283	0.144866
10	0.1	16	0.862555	0.873074	0.144866
10	0.1	17	0.862189	0.872892	0.144865
10	0.1	18	0.861866	0.872731	0.144867
10	0.1	19	0.861576	0.872585	0.144870
10	0.1	20	0.861314	0.872451	0.144873

TABLE III
SPLIT1: RANK=10, λ=0.1

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
10	1.0	1	1.420639	1.389550	0.144637
10	1.0	2	1.363616	1.355283	0.144778
10	1.0	3	1.345713	1.343128	0.144826
10	1.0	4	1.336905	1.336768	0.144846
10	1.0	5	1.331614	1.332913	0.144857
10	1.0	6	1.328114	1.330373	0.144871
10	1.0	7	1.325657	1.328603	0.144878
10	1.0	8	1.323859	1.327322	0.144885
10	1.0	9	1.322504	1.326367	0.144888
10	1.0	10	1.321457	1.325638	0.144891
10	1.0	11	1.320635	1.325073	0.144895
10	1.0	12	1.319979	1.324628	0.144895
10	1.0	13	1.319448	1.324273	0.144899
10	1.0	14	1.319015	1.323987	0.144901
10	1.0	15	1.318658	1.323754	0.144901
10	1.0	16	1.318361	1.323564	0.144901
10	1.0	17	1.318112	1.323407	0.144904
10	1.0	18	1.317903	1.323277	0.144902
10	1.0	19	1.317725	1.323169	0.144905
10	1.0	20	1.317574	1.323078	0.144904

TABLE IV
SPLIT1: RANK=10, λ=1.0

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
20	0.001	1	1.071894	0.981672	0.143352
20	0.001	2	0.939061	0.927914	0.143891
20	0.001	3	0.906660	0.908148	0.144093
20	0.001	4	0.890814	0.897585	0.144214
20	0.001	5	0.881143	0.891093	0.144300
20	0.001	6	0.874566	0.886769	0.144364
20	0.001	7	0.869767	0.883726	0.144402
20	0.001	8	0.866078	0.881492	0.144415
20	0.001	9	0.863115	0.879787	0.144434
20	0.001	10	0.860636	0.878429	0.144439
20	0.001	11	0.858475	0.877290	0.144453
20	0.001	12	0.856507	0.876270	0.144455
20	0.001	13	0.854631	0.875290	0.144464
20	0.001	14	0.852765	0.874281	0.144472
20	0.001	15	0.850842	0.873196	0.144466
20	0.001	16	0.848818	0.872010	0.144454
20	0.001	17	0.846676	0.870723	0.144455
20	0.001	18	0.844430	0.869363	0.144457
20	0.001	19	0.842113	0.867969	0.144466
20	0.001	20	0.839767	0.866578	0.144466

TABLE V
SPLIT1: RANK=20, λ=0.001

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
20	0.02	1	1.067967	0.981475	0.143401
20	0.02	2	0.936456	0.926903	0.143925
20	0.02	3	0.904596	0.906921	0.144151
20	0.02	4	0.889113	0.896206	0.144266
20	0.02	5	0.879709	0.889593	0.144350
20	0.02	6	0.873348	0.885162	0.144413
20	0.02	7	0.868738	0.882018	0.144454
20	0.02	8	0.865224	0.879689	0.144476
20	0.02	9	0.862431	0.877895	0.144485
20	0.02	10	0.860126	0.876458	0.144504
20	0.02	11	0.858154	0.875255	0.144518
20	0.02	12	0.856397	0.874197	0.144538
20	0.02	13	0.854768	0.873208	0.144554
20	0.02	14	0.853190	0.872229	0.144570
20	0.02	15	0.851601	0.871207	0.144576
20	0.02	16	0.849947	0.870105	0.144586
20	0.02	17	0.848195	0.868902	0.144589
20	0.02	18	0.846329	0.867598	0.144600
20	0.02	19	0.844357	0.866213	0.144600
20	0.02	20	0.842307	0.864782	0.144616

TABLE VI
SPLIT1: RANK=20, λ=0.02

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
20	0.1	1	1.057844	0.984148	0.143461
20	0.1	2	0.934158	0.927450	0.144009
20	0.1	3	0.904085	0.907390	0.144236
20	0.1	4	0.889894	0.896825	0.144368
20	0.1	5	0.881475	0.890375	0.144435
20	0.1	6	0.875924	0.886085	0.144492
20	0.1	7	0.872018	0.883066	0.144542
20	0.1	8	0.869144	0.880850	0.144576
20	0.1	9	0.866957	0.879171	0.144600
20	0.1	10	0.865250	0.877867	0.144615
20	0.1	11	0.863890	0.876831	0.144633
20	0.1	12	0.862786	0.875994	0.144652
20	0.1	13	0.861876	0.875305	0.144669
20	0.1	14	0.861115	0.874729	0.144679
20	0.1	15	0.860469	0.874238	0.144697
20	0.1	16	0.859912	0.873813	0.144703
20	0.1	17	0.859424	0.873438	0.144709
20	0.1	18	0.858988	0.873098	0.144720
20	0.1	19	0.858590	0.872782	0.144725
20	0.1	20	0.858218	0.872481	0.144737

TABLE VII
SPLIT1: RANK=20, λ=0.1

III. Splitting the data

A. Loading the data-set

B. Matrix Update and Stochastic Gradient Descent

C. Root Mean Square Error Calculation

D. Mean Reciprocal Rank Calculation

E. Grid Search

IV. Graphs

The multiple values of RMSE and MRR calculated for multiple splits of data, over grid-search of ranks and regularizers are plotted here:

A. average RMSE over r and λ

B. average MRR over r and λ

C. standard deviation of RMSE over r and λ

D. standard deviation of MRR over r and λ

V. Codes and Links

- Github: Advanced-ML-Product-Ranking

VI. Page Style

All paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified.

A. Text Font of Entire Document

The entire document should be in Times New Roman or Times font. Type 3 fonts must not be used. Other font types may be used if needed for special purposes.

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
20	1.0	1	1.227160	1.324663	0.143411
20	1.0	2	1.260500	1.292850	0.144036
20	1.0	3	1.269829	1.292738	0.144301
20	1.0	4	1.278308	1.295625	0.144466
20	1.0	5	1.284551	1.298688	0.144578
20	1.0	6	1.289280	1.301443	0.144645
20	1.0	7	1.292990	1.303832	0.144697
20	1.0	8	1.295987	1.305892	0.144726
20	1.0	9	1.298461	1.307672	0.144752
20	1.0	10	1.300540	1.309217	0.144761
20	1.0	11	1.302310	1.310567	0.144779
20	1.0	12	1.303833	1.311752	0.144786
20	1.0	13	1.305155	1.312797	0.144797
20	1.0	14	1.306311	1.313723	0.144805
20	1.0	15	1.307327	1.314546	0.144815
20	1.0	16	1.308224	1.315281	0.144824
20	1.0	17	1.309019	1.315937	0.144830
20	1.0	18	1.309727	1.316525	0.144836
20	1.0	19	1.310358	1.317054	0.144838
20	1.0	20	1.310922	1.317529	0.144843

TABLE VIII
SPLIT1: RANK=20, λ=1.0

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
30	0.001	1	1.265906	1.086678	0.142520
30	0.001	2	0.999850	0.988741	0.143265
30	0.001	3	0.946089	0.953624	0.143592
30	0.001	4	0.920465	0.934510	0.143769
30	0.001	5	0.904731	0.922465	0.143902
30	0.001	6	0.893904	0.914205	0.143981
30	0.001	7	0.885890	0.908199	0.144041
30	0.001	8	0.879625	0.903624	0.144095
30	0.001	9	0.874499	0.899991	0.144148
30	0.001	10	0.870128	0.896982	0.144166
30	0.001	11	0.866249	0.894377	0.144190
30	0.001	12	0.862673	0.892016	0.144219
30	0.001	13	0.859261	0.889789	0.144233
30	0.001	14	0.855923	0.887627	0.144249
30	0.001	15	0.852608	0.885502	0.144254
30	0.001	16	0.849304	0.883416	0.144260
30	0.001	17	0.846026	0.881388	0.144264
30	0.001	18	0.842797	0.879440	0.144265
30	0.001	19	0.839639	0.877589	0.144273
30	0.001	20	0.836565	0.875842	0.144291

TABLE IX
SPLIT1: RANK=30, λ=0.001

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
30	0.02	1	1.258234	1.084055	0.142661
30	0.02	2	0.995880	0.985586	0.143355
30	0.02	3	0.943090	0.950404	0.143704
30	0.02	4	0.918116	0.931280	0.143881
30	0.02	5	0.902865	0.919210	0.144000
30	0.02	6	0.892432	0.910908	0.144081
30	0.02	7	0.884767	0.904850	0.144147
30	0.02	8	0.878834	0.900225	0.144192
30	0.02	9	0.874046	0.896555	0.144240
30	0.02	10	0.870037	0.893537	0.144282
30	0.02	11	0.866561	0.890960	0.144320
30	0.02	12	0.863442	0.888674	0.144341
30	0.02	13	0.860547	0.886564	0.144353
30	0.02	14	0.857773	0.884544	0.144369
30	0.02	15	0.855045	0.882557	0.144376
30	0.02	16	0.852317	0.880572	0.144386
30	0.02	17	0.849569	0.878585	0.144398
30	0.02	18	0.846809	0.876612	0.144412
30	0.02	19	0.844059	0.874677	0.144434
30	0.02	20	0.841345	0.872805	0.144453

TABLE X
SPLIT1: RANK=30, λ=0.02

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
30	0.1	1	1.241133	1.083927	0.142772
30	0.1	2	0.989782	0.984488	0.143430
30	0.1	3	0.940169	0.949685	0.143758
30	0.1	4	0.917507	0.930912	0.143952
30	0.1	5	0.904009	0.919113	0.144066
30	0.1	6	0.894986	0.911020	0.144156
30	0.1	7	0.888512	0.905132	0.144228
30	0.1	8	0.883631	0.900658	0.144286
30	0.1	9	0.879815	0.897141	0.144335
30	0.1	10	0.876745	0.894299	0.144377
30	0.1	11	0.874216	0.891951	0.144413
30	0.1	12	0.872094	0.889972	0.144439
30	0.1	13	0.870284	0.888276	0.144472
30	0.1	14	0.868718	0.886801	0.144499
30	0.1	15	0.867345	0.885500	0.144517
30	0.1	16	0.866128	0.884339	0.144543
30	0.1	17	0.865036	0.883289	0.144562
30	0.1	18	0.864046	0.882330	0.144580
30	0.1	19	0.863138	0.881441	0.144598
30	0.1	20	0.862294	0.880609	0.144616

TABLE XI
SPLIT1: RANK=30, λ=0.1

Recommended font sizes are shown in Table **??**.

B. Section Headings

No more than 3 levels of headings should be used. All headings must be in 10pt font. Every word in a heading must be capitalized except for short minor words as listed in Section **??**.

1) Level-1 Heading: A level-1 heading must be in Small Caps, centered and numbered using uppercase Roman numerals. For example, see heading "VIII. Page Style" of this document. The two level-1 headings which must not be numbered are "Acknowledgment" and "References".

2) Level-2 Heading: A level-2 heading must be in Italic, left-justified and numbered using an uppercase alphabetic letter followed by a period. For example, see heading "C. Section Headings" above.

3) Level-3 Heading: A level-3 heading must be indented, in Italic and numbered with an Arabic numeral followed by a right parenthesis. The level-3 heading must end with a colon. The body of the level-3 section immediately follows the level-3 heading in the same paragraph. For example, this paragraph begins with a level-3 heading.

C. Figures and Tables

Figures and tables must be centered in the column. Large figures and tables may span across both columns. Any table or figure that takes up more than 1 column width must be positioned either at the top or at the bottom of the page.

Graphics may be full color. All colors will be retained on the CDROM. Graphics must not use stipple fill patterns because they may not be reproduced properly. Please use only SOLID

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
30	1.0	1	1.285752	1.356614	0.143004
30	1.0	2	1.257497	1.304068	0.143610
30	1.0	3	1.264053	1.297920	0.143913
30	1.0	4	1.272118	1.297378	0.144102
30	1.0	5	1.278009	1.298186	0.144241
30	1.0	6	1.282453	1.299415	0.144355
30	1.0	7	1.285999	1.300784	0.144445
30	1.0	8	1.288958	1.302184	0.144519
30	1.0	9	1.291508	1.303566	0.144581
30	1.0	10	1.293753	1.304906	0.144613
30	1.0	11	1.295758	1.306188	0.144659
30	1.0	12	1.297566	1.307407	0.144674
30	1.0	13	1.299205	1.308557	0.144696
30	1.0	14	1.300696	1.309637	0.144706
30	1.0	15	1.302056	1.310648	0.144723
30	1.0	16	1.303298	1.311590	0.144739
30	1.0	17	1.304432	1.312466	0.144754
30	1.0	18	1.305469	1.313278	0.144768
30	1.0	19	1.306417	1.314030	0.144772
30	1.0	20	1.307283	1.314724	0.144779

TABLE XII
SPLIT1: RANK=30, λ=1.0

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
60	0.001	1	1.922999	1.369935	0.141798
60	0.001	2	1.196943	1.186380	0.142538
60	0.001	3	1.078812	1.108334	0.142904
60	0.001	4	1.017246	1.059470	0.143134
60	0.001	5	0.975901	1.025268	0.143265
60	0.001	6	0.946189	1.000726	0.143371
60	0.001	7	0.924319	0.982765	0.143451
60	0.001	8	0.907752	0.969242	0.143493
60	0.001	9	0.894757	0.958733	0.143533
60	0.001	10	0.884184	0.950304	0.143561
60	0.001	11	0.875276	0.943337	0.143586
60	0.001	12	0.867533	0.937423	0.143601
60	0.001	13	0.860629	0.932299	0.143613
60	0.001	14	0.854358	0.927795	0.143624
60	0.001	15	0.848591	0.923801	0.143631
60	0.001	16	0.843244	0.920244	0.143645
60	0.001	17	0.838257	0.917065	0.143660
60	0.001	18	0.833583	0.914218	0.143657
60	0.001	19	0.829182	0.911664	0.143659
60	0.001	20	0.825019	0.909368	0.143670

TABLE XIII
SPLIT1: RANK=60, λ=0.001

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
60	0.02	1	1.915768	1.365936	0.142034
60	0.02	2	1.191362	1.182145	0.142746
60	0.02	3	1.075552	1.105093	0.143084
60	0.02	4	1.016637	1.057521	0.143306
60	0.02	5	0.977402	1.023794	0.143448
60	0.02	6	0.948694	0.998794	0.143551
60	0.02	7	0.927097	0.979986	0.143642
60	0.02	8	0.910580	0.965573	0.143697
60	0.02	9	0.897650	0.954252	0.143738
60	0.02	10	0.887233	0.945114	0.143766
60	0.02	11	0.878582	0.937533	0.143788
60	0.02	12	0.871178	0.931075	0.143810
60	0.02	13	0.864662	0.925440	0.143831
60	0.02	14	0.858790	0.920424	0.143849
60	0.02	15	0.853401	0.915894	0.143865
60	0.02	16	0.848393	0.911764	0.143876
60	0.02	17	0.843705	0.907979	0.143887
60	0.02	18	0.839297	0.904501	0.143914
60	0.02	19	0.835139	0.901298	0.143926
60	0.02	20	0.831206	0.898344	0.143943

TABLE XIV
SPLIT1: RANK=60, λ=0.02

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
60	0.1	1	1.886624	1.351984	0.142453
60	0.1	2	1.179937	1.171529	0.143035
60	0.1	3	1.073815	1.099170	0.143293
60	0.1	4	1.023624	1.057080	0.143472
60	0.1	5	0.992603	1.028709	0.143594
60	0.1	6	0.970857	1.007796	0.143707
60	0.1	7	0.954364	0.991443	0.143784
60	0.1	8	0.941207	0.978160	0.143856
60	0.1	9	0.930380	0.967109	0.143917
60	0.1	10	0.921301	0.957771	0.143976
60	0.1	11	0.913593	0.949789	0.144035
60	0.1	12	0.906982	0.942897	0.144071
60	0.1	13	0.901259	0.936886	0.144108
60	0.1	14	0.896256	0.931593	0.144145
60	0.1	15	0.891839	0.926887	0.144174
60	0.1	16	0.887902	0.922664	0.144205
60	0.1	17	0.884358	0.918838	0.144234
60	0.1	18	0.881136	0.915343	0.144257
60	0.1	19	0.878179	0.912121	0.144279
60	0.1	20	0.875439	0.909127	0.144311

TABLE XV
SPLIT1: RANK=60, λ=0.1

FILL colors which contrast well both on screen and on a black-and-white hardcopy, as shown in Fig. 1.

Fig. 1. A sample line graph using colors which contrast well both on screen and on a black-and-white hardcopy

Fig. 2 shows an example of a low-resolution image which would not be acceptable, whereas Fig. 3 shows an example of an image with adequate resolution. Check that the resolution is adequate to reveal the important detail in the figure.

Please check all figures in your paper both on screen and on a black-and-white hardcopy. When you check your paper on a black-and-white hardcopy, please ensure that:

- the colors used in each figure contrast well,
- the image used in each figure is clear,
- all text labels in each figure are legible.

D. Figure Captions

Figures must be numbered using Arabic numerals. Figure captions must be in 8 pt Regular font. Captions of a single line (e.g. Fig. 2) must be centered whereas multi-line captions must be justified (e.g. Fig. 1). Captions with figure numbers must be placed after their associated figures, as shown in Fig. 1.

E. Table Captions

Tables must be numbered using uppercase Roman numerals. Table captions must be centred and in 8 pt Regular font with Small Caps. Every word in a table caption must be capitalized except for short minor words as listed in Section **??**. Captions with table numbers must be placed before their associated tables, as shown in Table **??**.

Rank	Lambda	Iter	RMSE_train	RMSE_test	MRR
60	1.0	1	1.783760	1.530895	0.142673
60	1.0	2	1.381457	1.438492	0.142727
60	1.0	3	1.363681	1.411988	0.142912
60	1.0	4	1.356257	1.394113	0.143170
60	1.0	5	1.348414	1.379425	0.143404
60	1.0	6	1.340488	1.367007	0.143596
60	1.0	7	1.333144	1.356569	0.143769
60	1.0	8	1.326717	1.347892	0.143902
60	1.0	9	1.321310	1.340759	0.144017
60	1.0	10	1.316898	1.334960	0.144139
60	1.0	11	1.313395	1.330301	0.144237
60	1.0	12	1.310693	1.326605	0.144326
60	1.0	13	1.308676	1.323716	0.144400
60	1.0	14	1.307235	1.321497	0.144474
60	1.0	15	1.306268	1.319830	0.144537
60	1.0	16	1.305687	1.318615	0.144576
60	1.0	17	1.305414	1.317766	0.144607
60	1.0	18	1.305382	1.317211	0.144648
60	1.0	19	1.305537	1.316889	0.144672
60	1.0	20	1.305833	1.316751	0.144686

TABLE XVI
SPLIT1: RANK=60, λ=1.0

Fig. 2. Example of an unacceptable low-resolution image

F. Page Numbers, Headers and Footers

Page numbers, headers and footers must not be used.

G. Links and Bookmarks

All hypertext links and section bookmarks will be removed from papers during the processing of papers for publication. If you need to refer to an Internet email address or URL in your paper, you must type out the address or URL fully in Regular font.

H. References

The heading of the References section must not be numbered. All reference items must be in 8 pt font. Please use Regular and Italic styles to distinguish different fields as shown in the References section. Number the reference items consecutively in square brackets (e.g. [**?**]).

When referring to a reference item, please simply use the reference number, as in [**?**]. Do not use Ref. [**?**] or Reference [**?**] except at the beginning of a sentence, e.g. "Reference [**?**] shows ". Multiple references are each numbered with separate brackets (e.g. [**?**], [**?**], [**?**]–[6]).

Examples of reference items of different categories shown in the References section include:

- example of a book in [**?**]
- example of a book in a series in [**?**]
- example of a journal article in [**?**]
- example of a conference paper in [**?**]
- example of a patent in [**?**]
- example of a website in [**?**]
- example of a web page in [**?**]
- example of a databook as a manual in [**?**]
- example of a datasheet in [**?**]
- example of a master's thesis in [**?**]

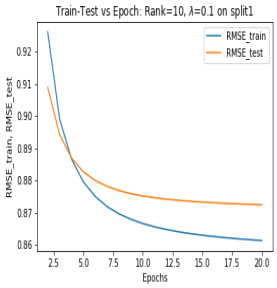

Fig. 3. Example of an image with acceptable resolution

- example of a technical report in [**?**]
- example of a standard in [**?**]

VII. Conclusion

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