A Nonlinear PID-Incorporated Adaptive Stochastic Gradient Descent Algorithm for Latent Factor Analysis Supplementary File

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I. Introduction

This is the supplementary file for the paper entitled "*A Nonlinear PID-Incorporated Adaptive Stochastic Gradient Descent Algorithm for Latent Factor Analysis*". It mainly contains the tables and figures of experimental results.

II. Supplementary Tables

TABLE S(I). Searching range of gain parameter.

Parameter	K_{p1}	K_{p2}	K_{p3}
Range	[1, 4]	[0.125, 0.25]	[0.015, 0.125]
Parameter	K_{i1}	K_{i2}	K_{d1}
Range	[0, 0.001]	[0.007, 0.015]	[0, 0.001]
Parameter	K_{d2}	K_{d3}	K_{d4}
Range	[0, 0.001]	[0.003, 0.031]	[0.001, 0.002]

TABLE S(II). Optimal values of gain parameter for a Manual model.

Dataset	K_{p1}, K_{p2}, K_{p3}	K_{i1}, K_{i2}	K_{d1}, K_{d2}, K_{d3}, K_{d4}
D1	2, 0.2, 0.2	0.0001, 0.01	0.001, 0.0008, 0.004, 0.001
D2	2.1, 0.2, 0.1	0.0002, 0.01	0.001, 0.001, 0.01, 0.001
D3	2.15, 0.2, 0.01	0.0001, 0.01	0.0005, 0.001, 0.01, 0.001
D4	2.3, 0.3, 0.03	0.0001, 0.02	0.0003, 0.001, 0.02, 0.001
D5	2.15, 0.2, 0.02	0.0001, 0.02	0.0001, 0.001, 0.02, 0.001
D6	2.0, 0.2, 0.02	0.0001, 0.02	0.0001, 0.001, 0.02, 0.001

TABLE S(III). Performance comparison between two models in RMSE.

Dataset	**Method**	**RMSE**	**Iterations**	***Per**	****Total**	*****Tune**
D1	Manual	0.7953	49	**1.010**	**49.4**	17994.5
	ANPS	**0.7906**	**6**	8.466	50.4	——
D2	Manual	0.7882	49	**1.983**	97.0	29886.1
	ANPS	**0.7824**	**5**	17.46	**87.3**	——
D3	Manual	0.7290	55	**1.989**	109.4	33068.7
	ANPS	**0.7243**	**5**	15.52	**77.6**	——
D4	Manual	1.0125	27	**0.096**	**2.6**	859.3
	ANPS	**1.0050**	**3**	0.910	2.7	——
D5	Manual	1.0671	35	**16.0**	561.7	2730.5
	ANPS	**1.0601**	**4**	132.0	**528.0**	——
D6	Manual	0.8203	58	**0.889**	51.6	1254.7
	ANPS	**0.8131**	**5**	9.954	**49.7**	——

TABLE S(IV). PERFORMANCE COMPARISON BETWEEN TWO MODELS IN MAE.

Dataset	Method	MAE	Iterations	*Per	**Total	***Tune
D1	Manual	0.6118	51	**1.085**	55.0	18122.7
	ANPS	**0.6104**	**4**	8.466	**33.8**	——
D2	Manual	0.6026	53	**1.933**	102.4	37416.4
	ANPS	**0.5981**	**4**	17.46	**69.8**	——
D3	Manual	0.5667	58	**1.546**	89.6	34693.1
	ANPS	**0.5646**	**5**	13.52	**67.6**	——
D4	Manual	0.7848	29	**0.090**	**2.6**	928.7
	ANPS	**0.7821**	**5**	0.873	4.3	——
D5	Manual	0.8165	41	**16.29**	668.0	33205.3
	ANPS	**0.8119**	**4**	145.3	**581.2**	——
D6	Manual	0.6353	62	**0.984**	61.0	692.2
	ANPS	**0.6258**	**6**	9.477	**56.8**	——

*Time per iteration (Secs). **Total time (Secs). *** Tuning time (Secs).

TABLE S(V). TIME COST (SECS), WHERE ✪ INDICATES THAT M1 IS OUTPERFORMED BY THE COMPARED MODEL.

Case		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
D1	RMSE-Time	**50.4**$_{\pm1.0}$	71.4$_{\pm1.5}$	79.7$_{\pm3.6}$	134.4$_{\pm1.2}$	615.5$_{\pm2.3}$	3588.4$_{\pm3.8}$	509.8$_{\pm2.4}$	83.2$_{\pm3.6}$	5712.2$_{\pm1.7}$	5253.5$_{\pm2.6}$
	MAE-Time	**33.8**$_{\pm1.2}$	64.7$_{\pm1.7}$	86.5$_{\pm5.2}$	139.0$_{\pm1.6}$	665.6$_{\pm2.7}$	3574.3$_{\pm3.5}$	564.0$_{\pm2.6}$	88.8$_{\pm3.6}$	5712.2$_{\pm1.7}$	5253.5$_{\pm2.6}$
D2	RMSE-Time	**87.3**$_{\pm1.3}$	149.4$_{\pm1.8}$	180.9$_{\pm2.5}$	305.2$_{\pm1.5}$	1645.8$_{\pm3.2}$	6250.8$_{\pm3.9}$	1265.6$_{\pm2.3}$	174.2$_{\pm1.2}$	1998.2$_{\pm3.1}$	10002.2$_{\pm3.4}$
	MAE-Time	**69.8**$_{\pm1.6}$	120.8$_{\pm1.9}$	188.0$_{\pm4.3}$	314.5$_{\pm1.9}$	1606.1$_{\pm3.6}$	6236.2$_{\pm4.0}$	1357.3$_{\pm2.6}$	182.8$_{\pm2.5}$	1998.2$_{\pm3.1}$	10002.2$_{\pm3.4}$
D3	RMSE-Time	**77.6**$_{\pm1.8}$	150.1$_{\pm1.6}$	167.5$_{\pm2.0}$	336.8$_{\pm1.3}$	1402.0$_{\pm3.13}$	5812.2$_{\pm3.6}$	1350.4$_{\pm2.3}$	167.4$_{\pm3.1}$	7807.4$_{\pm1.0}$	18190.6$_{\pm1.0}$
	MAE-Time	**67.7**$_{\pm1.6}$	135.6$_{\pm1.7}$	180.9$_{\pm1.5}$	343.2$_{\pm1.8}$	10182.2$_{\pm4.9}$	5663.5$_{\pm3.7}$	1304.8$_{\pm3.0}$	189.2$_{\pm2.5}$	7807.4$_{\pm1.0}$	18360.3$_{\pm2.2}$
D4	RMSE-Time	**2.7**$_{\pm1.2}$	4.6$_{\pm0.7}$	6.5$_{\pm2.8}$	8.0$_{\pm0.7}$	48.5$_{\pm2.9}$	241.0$_{\pm2.0}$	44.5$_{\pm1.6}$	6.0$_{\pm3.5}$	27.8$_{\pm2.2}$	173.4$_{\pm1.6}$
	MAE-Time	4.3$_{\pm1.1}$	✪**4.0**$_{\pm0.8}$	7.3$_{\pm2.7}$	9.0$_{\pm0.6}$	54.7$_{\pm2.7}$	286.1$_{\pm2.6}$	48.4$_{\pm1.7}$	6.1$_{\pm2.1}$	26.6$_{\pm2.2}$	173.3$_{\pm1.6}$
D5	RMSE-Time	528.0$_{\pm1.6}$	✪**493.3**$_{\pm2.1}$	1003.8$_{\pm2.0}$	1054.8$_{\pm1.3}$	21654.3$_{\pm3.6}$	41084.5$_{\pm3.7}$	7007.4$_{\pm2.4}$	1199.7$_{\pm2.6}$	9680.8$_{\pm2.4}$	36148.8$_{\pm3.4}$
	MAE-Time	581.2$_{\pm1.8}$	✪**578.6**$_{\pm2.5}$	1281.4$_{\pm2.8}$	1397.2$_{\pm1.2}$	25702.0$_{\pm3.0}$	48822.6$_{\pm3.4}$	7967.4$_{\pm2.7}$	1369.5$_{\pm2.9}$	8921.6$_{\pm1.6}$	36148.8$_{\pm3.4}$
D6	RMSE-Time	**49.7**$_{\pm1.3}$	51.6$_{\pm0.4}$	81.2$_{\pm3.3}$	100.5$_{\pm0.6}$	211.6$_{\pm2.1}$	3311.0$_{\pm3.8}$	160.1$_{\pm3.0}$	90.4$_{\pm5.6}$	633.2$_{\pm2.6}$	2940.0$_{\pm2.5}$
	MAE-Time	**56.8**$_{\pm1.1}$	58.5$_{\pm0.2}$	93.9$_{\pm2.7}$	99.8$_{\pm0.7}$	216.5$_{\pm1.6}$	3353.3$_{\pm3.0}$	175.8$_{\pm2.8}$	90.2$_{\pm4.1}$	597.0$_{\pm3.0}$	2940.0$_{\pm2.5}$
Loss/Win		-	3/9	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12

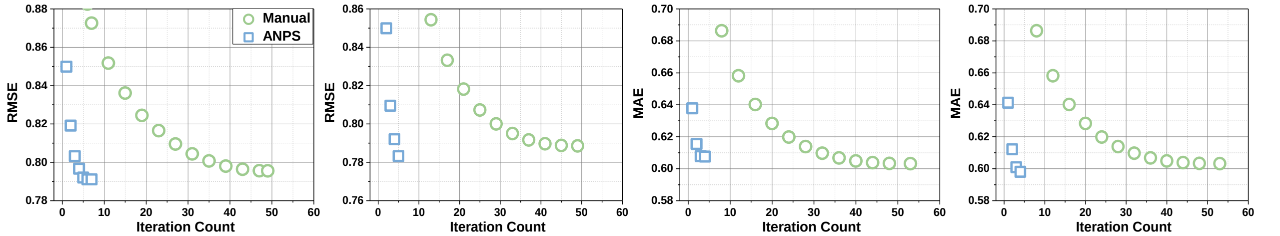
TABLE S(VI). LOWEST RMSE/MAE, WHERE ✪ INDICATES THAT M1 IS OUTPERFORMED BY THE COMPARED MODEL.

Case		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
D1	RMSE	**0.7906**$_{\pm5E-4}$	0.7929$_{\pm3E-4}$	0.7948$_{\pm3E-4}$	0.7939$_{\pm5E-4}$	0.8045$_{\pm6E-4}$	0.8155$_{\pm6E-4}$	0.8166$_{\pm6E-4}$	0.7942$_{\pm3E-4}$	0.8755$_{\pm1E-4}$	0.7999$_{\pm3E-4}$
	MAE	0.6104$_{\pm8E-5}$	0.6130$_{\pm4E-4}$	0.6109$_{\pm3E-4}$	0.6131$_{\pm5E-4}$	0.6109$_{\pm6E-4}$	0.6163$_{\pm6E-4}$	0.6179$_{\pm6E-4}$	✪**0.6098**$_{\pm5E-4}$	0.6821$_{\pm3E-4}$	0.6136$_{\pm1E-4}$
D2	RMSE	**0.7824**$_{\pm5E-4}$	0.7850$_{\pm5E-4}$	0.7882$_{\pm1E-4}$	0.7866$_{\pm5E-4}$	0.7981$_{\pm5E-4}$	0.8094$_{\pm6E-4}$	0.8072$_{\pm6E-4}$	0.7863$_{\pm4E-4}$	0.9057$_{\pm4E-4}$	0.8401$_{\pm3E-4}$
	MAE	**0.5981**$_{\pm5E-4}$	0.6030$_{\pm5E-4}$	0.5996$_{\pm1E-4}$	0.6035$_{\pm5E-4}$	0.6009$_{\pm5E-4}$	0.6072$_{\pm6E-4}$	0.6061$_{\pm6E-4}$	0.5983$_{\pm3E-4}$	0.7053$_{\pm2E-4}$	0.6419$_{\pm4E-4}$
D3	RMSE	**0.7243**$_{\pm4E-4}$	0.7252$_{\pm5E-4}$	0.7290$_{\pm5E-4}$	0.7257$_{\pm5E-4}$	0.7390$_{\pm6E-4}$	0.7446$_{\pm6E-4}$	0.7452$_{\pm6E-4}$	0.7281$_{\pm2E-4}$	0.7625$_{\pm1E-4}$	0.7423$_{\pm5E-4}$
	MAE	**0.5646**$_{\pm4E-4}$	0.5671$_{\pm5E-4}$	0.5648$_{\pm5E-4}$	0.5663$_{\pm5E-4}$	0.5705$_{\pm6E-4}$	0.5746$_{\pm6E-4}$	0.5738$_{\pm6E-4}$	0.5692$_{\pm5E-4}$	0.5872$_{\pm2E-4}$	0.5695$_{\pm5E-4}$
D4	RMSE	**1.0050**$_{\pm5E-4}$	1.0090$_{\pm5E-4}$	1.0067$_{\pm4E-4}$	1.0077$_{\pm4E-4}$	1.0152$_{\pm5E-4}$	1.0285$_{\pm6E-4}$	1.0263$_{\pm6E-4}$	1.0055$_{\pm3E-4}$	1.2419$_{\pm5E-4}$	1.0136$_{\pm4E-4}$
	MAE	0.7821$_{\pm5E-4}$	0.7857$_{\pm6E-4}$	0.7850$_{\pm3E-4}$	0.7834$_{\pm4E-4}$	✪**0.7803**$_{\pm5E-4}$	0.7829$_{\pm6E-4}$	✪**0.7812**$_{\pm6E-4}$	0.7841$_{\pm4E-4}$	1.0216$_{\pm5E-4}$	0.7859$_{\pm1E-4}$
D5	RMSE	**1.0601**$_{\pm5E-4}$	1.0670$_{\pm5E-4}$	1.0702$_{\pm1E-4}$	1.0640$_{\pm4E-4}$	1.0604$_{\pm6E-4}$	1.0615$_{\pm7E-4}$	1.0617$_{\pm6E-4}$	1.0687$_{\pm4E-4}$	1.1701$_{\pm3E-4}$	1.0884$_{\pm1E-4}$
	MAE	0.8119$_{\pm5E-4}$	0.8179$_{\pm5E-4}$	0.8132$_{\pm4E-4}$	0.8188$_{\pm4E-4}$	0.8092$_{\pm6E-4}$	✪**0.8079**$_{\pm7E-4}$	0.8011$_{\pm6E-4}$	0.8128$_{\pm5E-4}$	0.9187$_{\pm2E-4}$	0.8367$_{\pm3E-4}$
D6	RMSE	**0.8131**$_{\pm3E-4}$	0.8232$_{\pm4E-4}$	0.8265$_{\pm3E-4}$	0.8157$_{\pm4E-4}$	0.8232$_{\pm6E-4}$	0.8135$_{\pm6E-4}$	0.8342$_{\pm5E-4}$	0.8251$_{\pm1E-4}$	0.9386$_{\pm5E-4}$	0.8141$_{\pm2E-4}$
	MAE	**0.6258**$_{\pm3E-4}$	0.6397$_{\pm4E-4}$	0.6399$_{\pm2E-4}$	0.6363$_{\pm4E-4}$	0.6415$_{\pm5E-4}$	0.6309$_{\pm6E-4}$	0.6357$_{\pm5E-4}$	0.6395$_{\pm3E-4}$	0.7671$_{\pm5E-4}$	0.6265$_{\pm1E-4}$
Loss/Win		-	0/12	0/12	0/12	1/11	1/11	1/11	0/12	0/12	0/12

TABLE S(VII). AVERAGE RANKS OF ALL COMPARED MODELS.

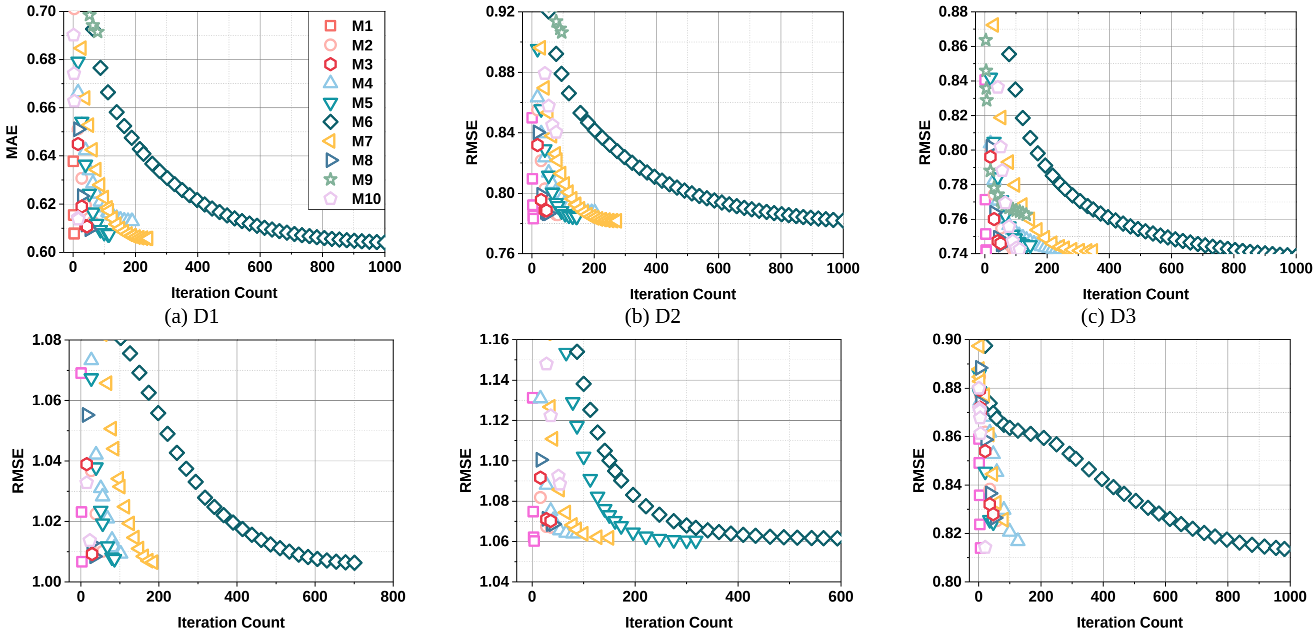
Rank	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
Efficiency	**1.3**	1.6	3.5	4.9	7.5	9.0	6.1	3.5	7.9	9.3
Accuracy	**1.5**	4.8	5.2	4.6	5.0	6.0	6.4	4.3	10	6.8

III. Supplementary Figures



(a) In RMSE on D1 (b) In RMSE on D2 (c) In MAE on D1 (d) In MAE on D2

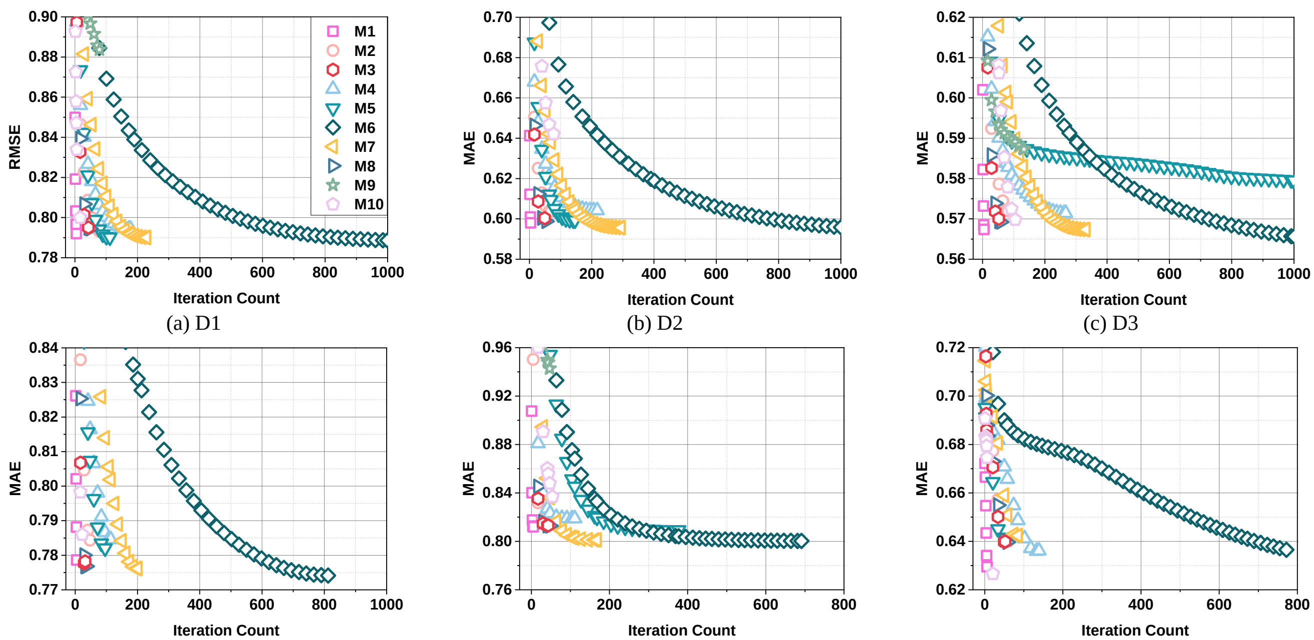
Fig. S1. Training curves of two models on D1-2.



(a) D1 (b) D2 (c) D3

(d) D4 (e) D5 (f) D6

Fig. S2. Training curves of M1-M6 on D1-D6 in RMSE.



(a) D1 (b) D2 (c) D3

(d) D4 (e) D5 (f) D6

Fig. S3. Training curves of M1-M6 on D1-D6 in MAE.