# A Proportional Integral Controller-Enhanced Non-negative Latent Factor Analysis Model Supplementary File

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## I. Introduction

This is the supplementary file for the paper entitled "*A Proportional Integral Controller-Enhanced Non-negative Latent Factor Analysis Model*". It mainly contains the tables and figures of experimental results.

## II. Supplementary Tables

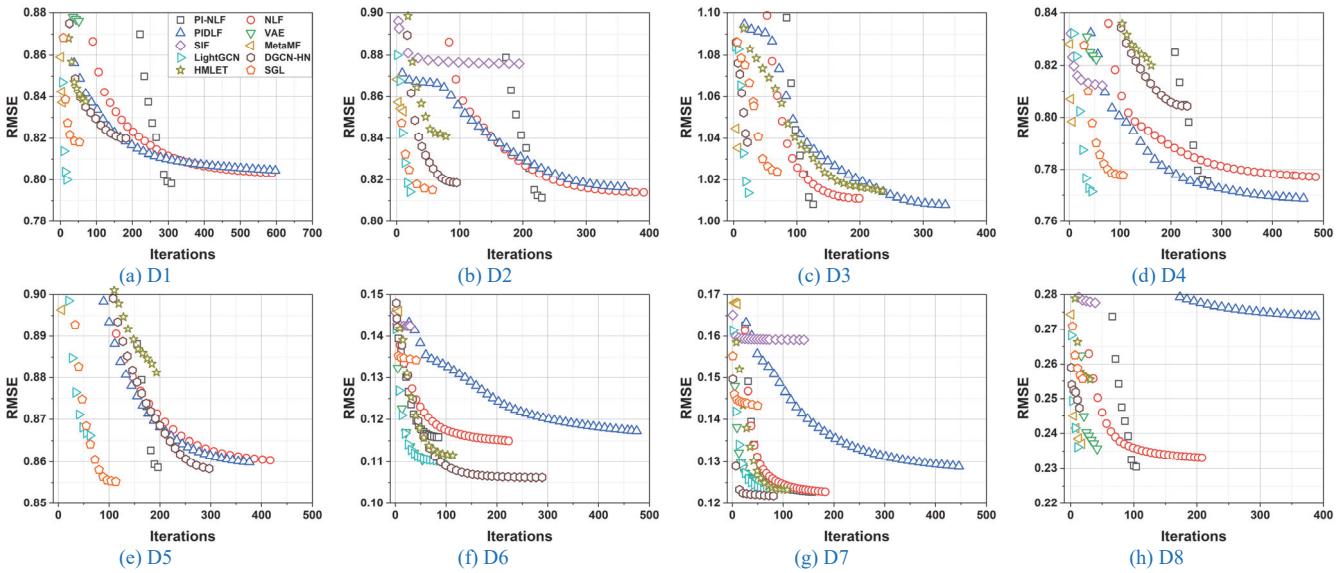
TABLE S(I). The comparison results on total time cost (Secs), where ✪ points out that PI-NLF is outperformed by its peer.

| No. | Time | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | ✪Loss/Win |
|---|---|---|---|---|---|---|---|---|---|---|
| **PI-NLF** | Time(RMSE) | **794.6**±8.2 | **484.4**±4.3 | **26.7**±0.4 | **72.1**±2.3 | **39.8**±0.3 | **13.3**±0.3 | **29.5**±0.2 | **59.3**±1.2 | — |
| | Time(MAE) | **712.1**±6.7 | **442.3**±11.7 | **24.2**±0.8 | **64.7**±3.17 | **54.4**±1.1 | **14.5**±0.5 | **22.2**±0.2 | **53.6**±1.8 | |
| **NLF** | Time(RMSE) | 1481.8±75.3 | 813.3±37.4 | 41.8±1.1 | 127.6±5.6 | 83.4±1.7 | 34.3±1.1 | 32.1±0.3 | 116.5±2.1 | 0/16 |
| | Time(MAE) | 1401.1±88.7 | 804.9±66.8 | 48.1±1.5 | 115.9±3.7 | 82.8±0.9 | 26.9±0.4 | 27.3±0.2 | 106.4±0.9 | |
| **PIDLF** | Time(RMSE) | 2531.7±98.3 | 1032.5±107.6 | 137.4±2.5 | 193.6±4.2 | 146.6±2.3 | 147.6±1.7 | 165.1±5.6 | 406.4±5.5 | 0/16 |
| | Time(MAE) | 2337.6±65.2 | 1066.8±97.8 | 142.3±3.1 | 176.8±5.6 | 147.8±1.4 | 120.9±2.1 | 146.5±3.2 | 378.2±6.2 | |
| **VAE** | Time(RMSE) | 5722.2±89.3 | 632.0±12.8 | 27.9±0.9 | 632.2±32.4 | 61.4±0.4 | 28.2±0.6 | 33.2±0.7 | 127.3±1.1 | 0/16 |
| | Time(MAE) | 5831.7±106.8 | 597.1±21.5 | 26.9±0.5 | 597.1±28.6 | 64.2±0.8 | 29.8±1.1 | 34.6±0.3 | 126.7±1.6 | |
| **SIF** | Time(RMSE) | 8858.7±99.4 | 56766.3±325.1 | 7582.3±110.7 | 4594.2±99.6 | 802.4±12.1 | 765.3±11.2 | 1961.3±33.9 | 1487.5±45.9 | 0/16 |
| | Time(MAE) | 8966.1±125.7 | 55128.1±227.9 | 7471.8±99.5 | 4722.5±57.9 | 794.2±9.9 | 778.2±15.1 | 1922.7±48.9 | 1422.8±85.2 | |
| **MetaMF** | Time(RMSE) | 8121.4±229.2 | 6511.5±144.6 | 236.5±2.3 | 529.4±6.2 | 375.1±5.5 | 224.9±2.8 | 446.4±7.7 | 785.8±26.5 | 0/16 |
| | Time(MAE) | 8004.2±167.3 | 6633.7±132.8 | 234.2±2.9 | 522.1±8.8 | 370.8±6.1 | 227.5±3.6 | 455.2±4.4 | 771.2±38.2 | |
| **LightGCN** | Time(RMSE) | 5264.1±96.1 | 2940.2±69.2 | 173.4±5.7 | 118.9±4.1 | 409.8±3.8 | 149.1±2.2 | 173.2±4.5 | 636.1±12.3 | 0/16 |
| | Time(MAE) | 5100.7±88.7 | 2998.8±77.1 | 171.5±4.9 | 120.5±4.2 | 416.6±6.3 | 142.4±3.6 | 175.6±6.2 | 622.7±9.9 | |
| **DGCN-HN** | Time(RMSE) | 197924.1±511.4 | 67741.6±385.2 | 150.9±5.2 | 1677.9±131.8 | 2773.4±111.9 | 5400.8±309.2 | 645.5±35.1 | 327.3±12.1 | 0/16 |
| | Time(MAE) | 192205.4±496.5 | 86776.4±578.2 | 151.1±4.3 | 1814.6±142.9 | 2612.7±142.5 | 2427.1±279.5 | 302.6±8.9 | 363.8±15.5 | |
| **HMLET** | Time(RMSE) | 146128.8±211.9 | 53277.9±510.9 | 15935.2±366.2 | 5923.5±205.3 | 4150.4±156.7 | 2296.2±172.3 | 2982.6±177.2 | 6939.9±366.7 | 0/16 |
| | Time(MAE) | 138659.2±389.2 | 55165.3±677.5 | 16262.5±412.8 | 5183.1±99.6 | 4205.7±205.2 | 1649.2±134.6 | 2544.8±98.5 | 8238.1±415.6 | |
| **SGL** | Time(RMSE) | 96874.1±488.7 | 13357.8±177.5 | 3765.8±125.6 | 3621.8±144.5 | 966.4±14.2 | 856.6±37.4 | 1080.9±77.5 | 1978.5±85.3 | 0/16 |
| | Time(MAE) | 95005.2±439.5 | 13728.3±210.9 | 3960.7±77.3 | 3477.9±132.2 | 1041.9±22.9 | 229.4±9.5 | 996.5±62.3 | 2223.1±99.7 | |

TABLE S(II). The comparison results on RMSE/MAE, where ✪ points out that PI-NLF is outperformed by its peer.

| No. | Case | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | ✪Loss/Win |
|---|---|---|---|---|---|---|---|---|---|---|
| **PI-NLF** | RMSE | 0.7988±1.3E-4 | **0.8124**±2.4E-4 | 1.0096±1.4E-3 | **0.7695**±5.6E-4 | **0.8589**±1.3E-4 | 0.1126±2.4E-4 | **0.1220**±4.3E-4 | **0.2352**±2.3E-4 | — |
| | MAE | 0.6115±2.1E-4 | **0.6237**±3.3E-4 | **0.7794**±2.2E-3 | **0.5776**±4.2E-4 | **0.6723**±2.5E-4 | 0.0739±3.1E-4 | 0.0807±2.3E-4 | **0.1795**±1.3E-4 | |
| **NLF** | RMSE | 0.8037±2.1E-4 | 0.8146±2.2E-4 | 1.0114±2.1E-3 | 0.7716±4.1E-4 | 0.8612±3.3E-4 | 0.1127±2.9E-4 | 0.1221±3.7E-4 | 0.2376±5.3E-4 | 2/14 |
| | MAE | 0.6246±2.1E-4 | 0.6380±5.6E-4 | 0.7960±8.5E-4 | 0.5980±3.6E-4 | 0.6827±2.9E-4 | ✪**0.0738**±2.6E-4 | ✪**0.0801**±2.6E-4 | 0.1859±4.3E-4 | |
| **PIDLF** | RMSE | 0.8039±4.5E-4 | 0.8155±3.2E-4 | ✪**1.0067**±2.4E-3 | 0.7742±4.2E-4 | 0.8595±2.3E-4 | 0.1193±3.3E-4 | 0.1296±3.9E-4 | 0.2699±1.4E-4 | 1/15 |
| | MAE | 0.6253±1.3E-3 | 0.6400±5.1E-4 | 0.7907±6.3E-4 | 0.5907±2.9E-4 | 0.6817±4.5E-4 | 0.0742±3.9E-4 | 0.0824±5.2E-4 | 0.2204±2.4E-4 | |
| **VAE** | RMSE | 0.8755±2.6E-3 | 0.9386±4.5E-3 | 1.2419±3.4E-4 | 0.8223±7.6E-4 | 0.9352±1.7E-4 | ✪**0.1121**±2.1E-4 | 0.1256±1.5E-4 | 0.2357±2.6E-4 | 1/15 |
| | MAE | 0.6821±1.4E-3 | 0.7671±5.7E-4 | 1.0299±3.4E-4 | 0.6261±3.9E-4 | 0.7388±1.4E-4 | 0.0741±4.3E-4 | 0.0858±1.9E-4 | 0.1899±1.9E-4 | |
| **SIF** | RMSE | 0.8852±1.4E-4 | 0.8758±4.4E-4 | 1.1415±1.2E-3 | 0.8124±5.1E-4 | 0.9295±6.2E-4 | 0.1424±6.6E-4 | 0.1590±1.1E-4 | 0.2776±1.3E-3 | 0/16 |
| | MAE | 0.6871±2.6E-4 | 0.6985±5.1E-4 | 0.9265±4.8E-4 | 0.6177±4.6E-4 | 0.7361±4.5E-4 | 0.0941±4.3E-4 | 0.1098±1.2E-4 | 0.2210±1.1E-3 | |
| **MetaMF** | RMSE | 0.8373±2.1E-4 | 0.8513±3.3E-4 | 1.0336±4.1E-4 | 0.7988±2.9E-4 | 0.8964±3.3E-4 | 0.1461±2.9E-4 | 0.1678±3.1E-4 | 0.2372±1.4E-4 | 0/16 |
| | MAE | 0.6595±1.9E-4 | 0.6618±3.7E-4 | 0.8026±2.7E-4 | 0.6029±4.2E-4 | 0.7041±1.1E-4 | 0.0950±2.2E-4 | 0.1137±1.9E-4 | 0.1845±2.1E-4 | |
| **LightGCN** | RMSE | 0.7999±1.9E-4 | 0.8141±3.4E-4 | 1.0136±2.7E-4 | 0.7714±3.7E-4 | 0.8661±1.8E-4 | ✪**0.1101**±2.6E-4 | 0.1232±2.1E-4 | 0.2362±1.4E-4 | 3/13 |
| | MAE | 0.6137±2.1E-4 | 0.6266±1.8E-4 | 0.7859±4.1E-4 | 0.5803±2.6E-4 | 0.6798±1.5E-4 | ✪**0.0676**±2.8E-4 | ✪**0.0791**±3.3E-4 | 0.1813±3.6E-4 | |
| **DGCN-HN** | RMSE | 0.8195±1.2E-4 | 0.8180±1.5E-4 | 1.0379±3.1E-4 | 0.8090±2.2E-4 | 0.8592±1.3E-4 | ✪**0.1124**±1.5E-4 | 0.1229±3.3E-4 | 0.2416±1.3E-4 | 2/14 |
| | MAE | 0.6291±1.3E-4 | 0.6341±2.3E-4 | 0.8118±3.1E-4 | 0.6041±2.9E-4 | 0.6726±1.5E-4 | ✪**0.0735**±1.1E-4 | 0.0809±3.2E-4 | 0.1870±1.2E-4 | |
| **HMLET** | RMSE | 0.8357±0.7E-4 | 0.8395±1.5E-4 | 1.0137±1.6E-4 | 0.8271±2.6E-4 | 0.8818±2.7E-4 | 0.1141±1.9E-4 | 0.1245±2.9E-4 | 0.2484±2.3E-4 | 0/16 |
| | MAE | 0.6399±1.5E-4 | 0.6466±1.8E-4 | 0.7895±1.8E-4 | 0.6211±2.2E-4 | 0.6912±2.2E-4 | 0.0741±1.6E-4 | 0.0844±3.5E-4 | 0.1905±2.5E-4 | |
| **SGL** | RMSE | 0.8177±1.7E-4 | 0.8141±2.5E-4 | 1.0223±2.3E-4 | 0.7832±1.4E-4 | 0.8607±1.2E-4 | 0.1351±2.9E-4 | 0.1442±.0.6E-4 | 0.2505±3.3E-4 | 0/16 |
| | MAE | 0.6274±1.4E-4 | 0.6259±3.1E-4 | 0.7958±2.9E-4 | 0.5891±2.2E-4 | 0.6744±1.1E-4 | 0.0974±4.1E-4 | 0.1042±0.7E-4 | 0.1942±2.1E-4 | |

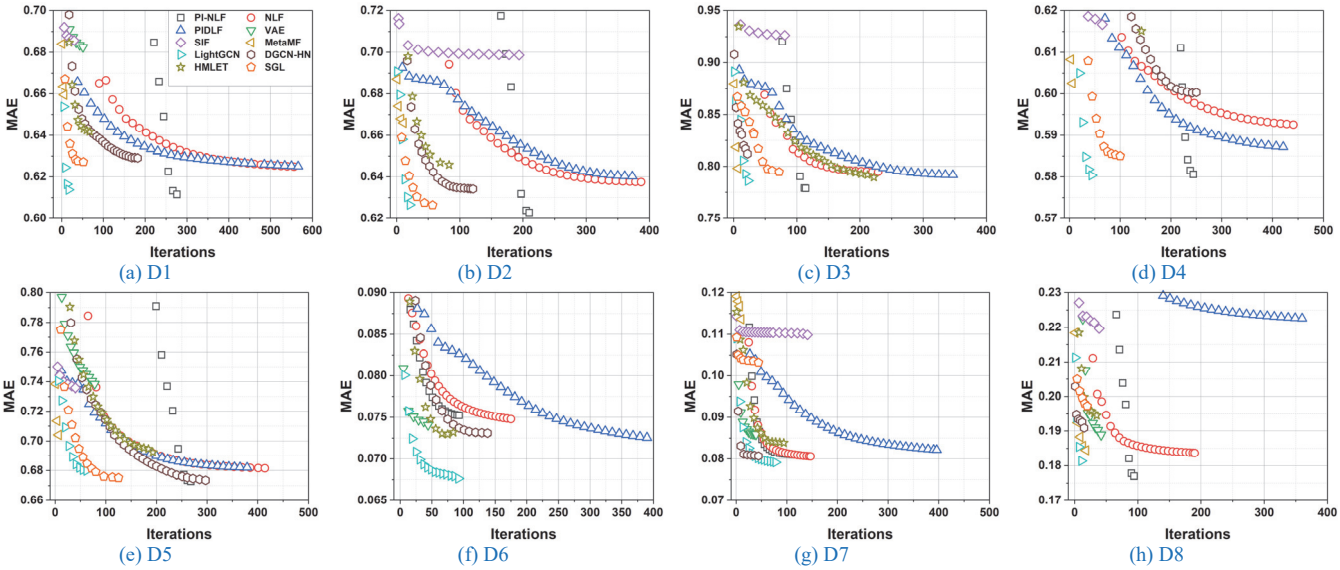
## III. SUPPLEMENTARY FIGURES




(a) D1 (b) D2 (c) D3 (d) D4

(e) D5 (f) D6 (g) D7 (h) D8

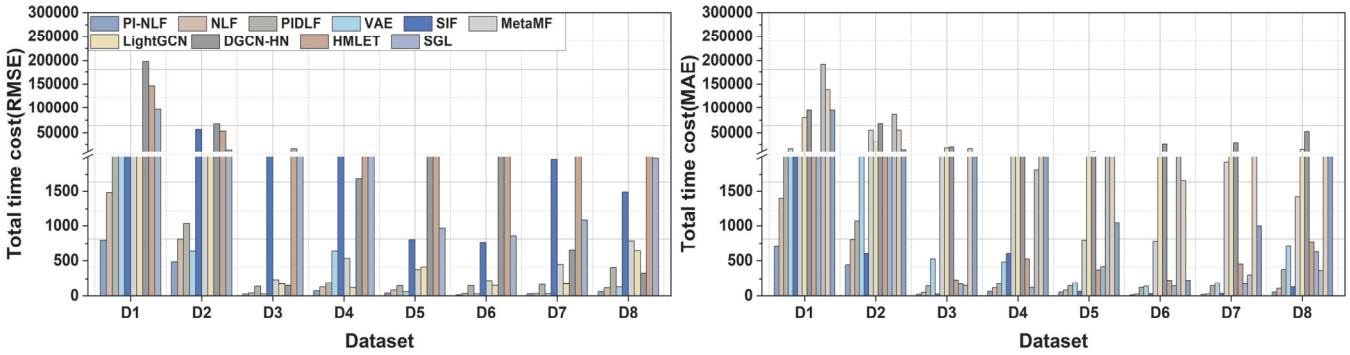
Fig. S1. Convergence curves in RMSE; all panels' legends are the same with panel (a)'s.




(a) D1 (b) D2 (c) D3 (d) D4

(e) D5 (f) D6 (g) D7 (h) D8

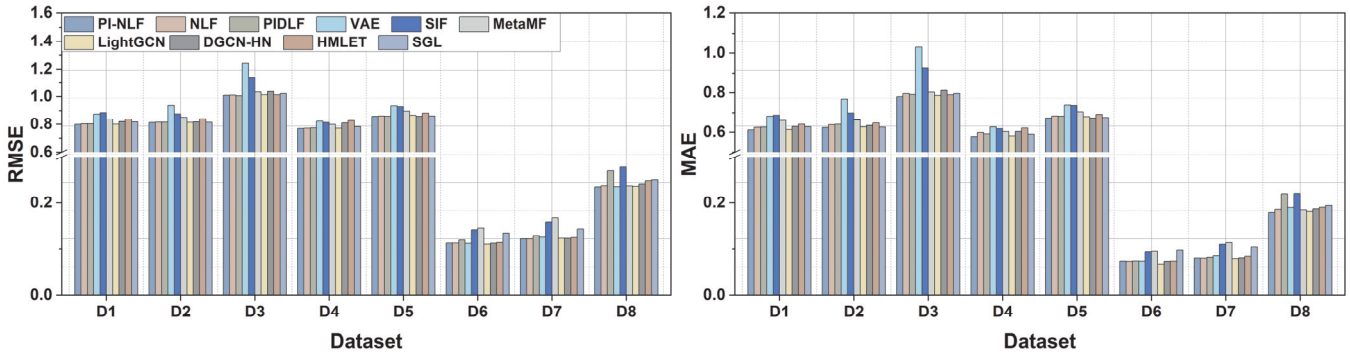
Fig. S2. Convergence curves in MAE; all panels' legends are the same with panel (a)'s.




(a) Total time cost Time corresponding to RMSE

(b) Total time cost Time corresponding to MAE

Fig. S3. Total time cost of compared models; all panels' legends are the same with panel (a)'s.




(a) RMSE

(b) MAE

Fig. S4. Lowest RMSE/MAE of compared models; all panels' legends are the same with panel (a)'s.