Drift doesn't Matter: Dynamic Decomposition with Diffusion Reconstruction for Unstable Multivariate Time Series Anomaly Detection

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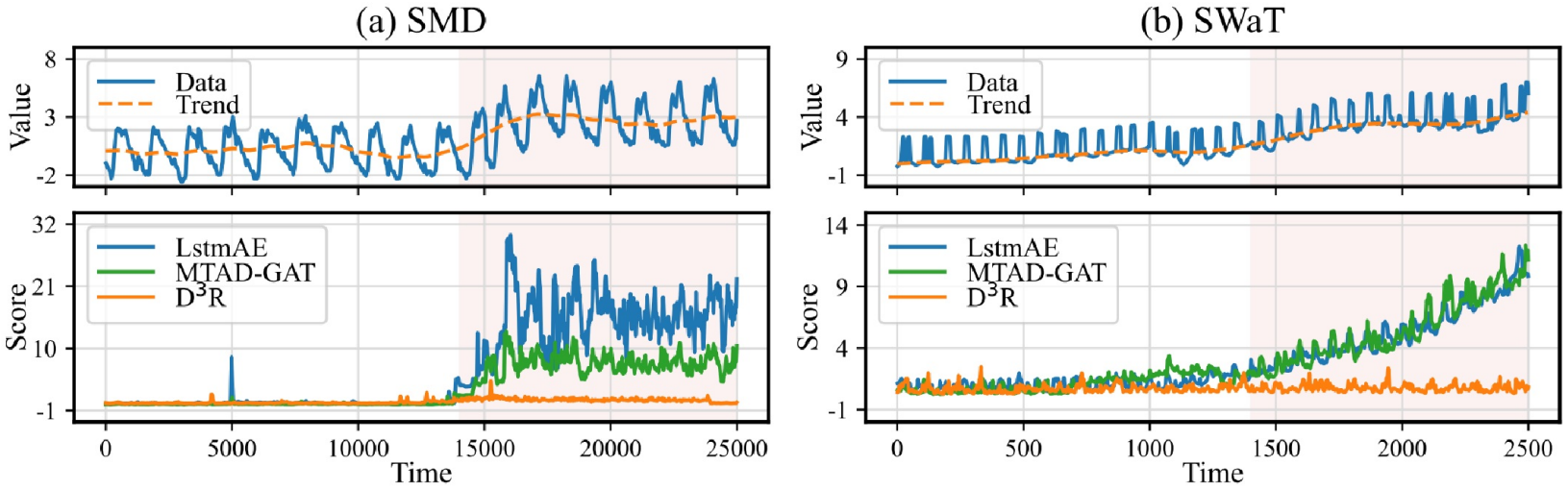
Motivation

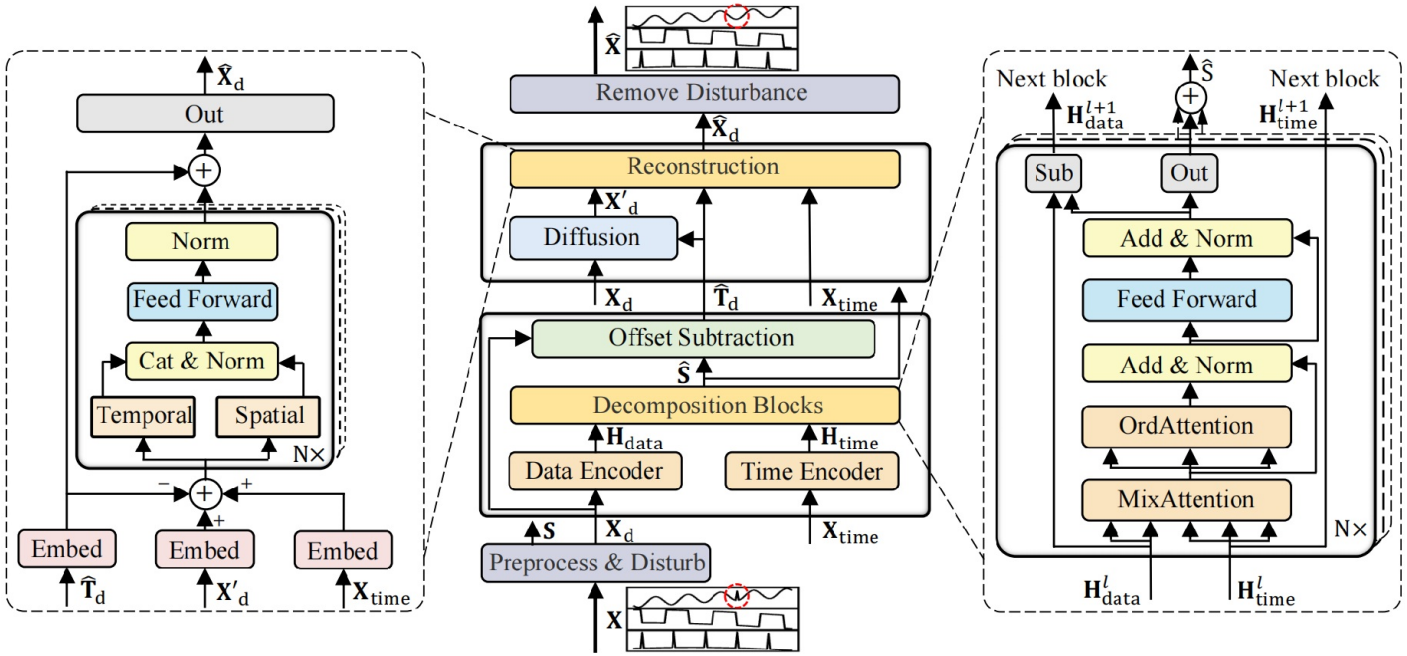


The neglect of drift can lead to numerous false alarms !!!

Challenge:

- Limitation of the decomposition for long-period time series
- High training cost of adjusting the information bottleneck

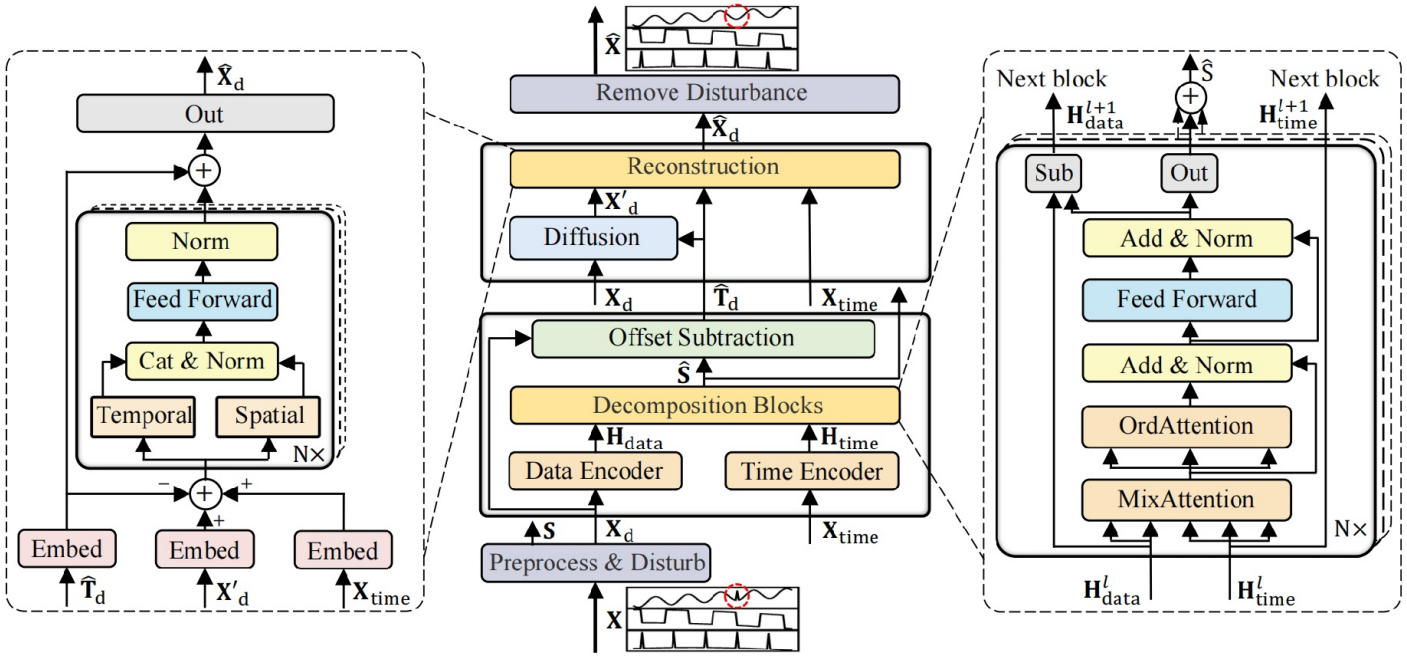
Methodology



Overview:

- Dynamic Decomposition to challenge 1
- Diffusion Reconstruction to challenge 2

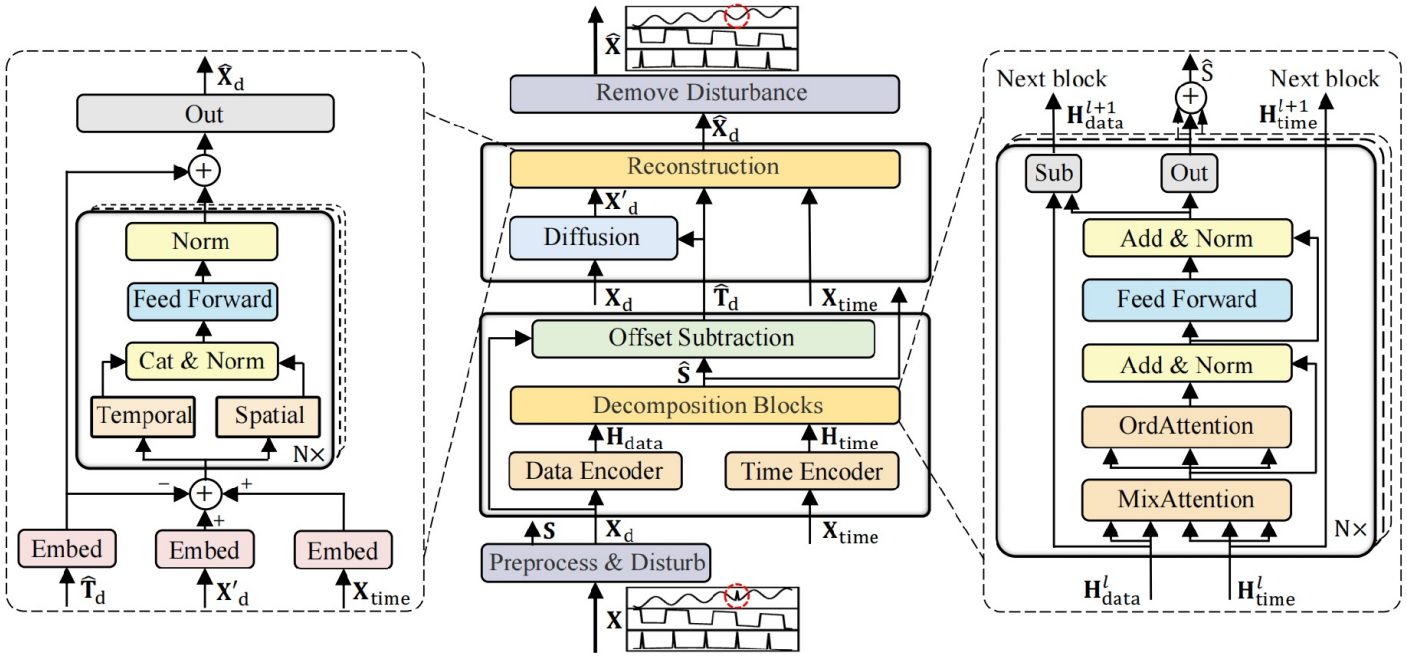
Methodology



Dynamic Decomposition:

- Get the **mixed characteristics** by the **data encoder and time encoder**
- Get the **stable component** by the **decomposition blocks**
- Get the **trend component** by the **offset subtraction**

Methodology



Diffusion Reconstruction:

- Make the **external bottleneck** by the **noise diffusion**
- Reconstruct the **polluted data** by the **backbone network**

Experiment

Datasets

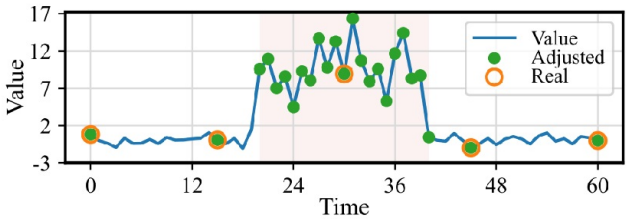
	Training Size	Testing Size	Series Number	Attacks Number	Anomaly Durations	Anomaly Rate	Frequency	ADF Test Statistic
PSM	132481	87841	25	73	1∼8861	0.2776	1 minute	-9.2314
SMD	23688	23689	33	30	3∼3161	0.1565	1 minute	-4.0947
SWaT	6840	7500	25	33	3∼599	0.1263	1 minute	-2.9442

Metrics

Method	PSM			SMD			SWaT			Average
	Precision	Recall	F1	Precision	Recall	F1	Precision	Recall	F1	F1
Sampling	0.9986	0.8571	0.9224	0.9958	0.9690	0.9822	0.1583	0.9271	0.2705	0.7250
COPOD	0.9795	0.8572	0.9143	0.9975	0.8538	0.9201	0.9953	0.6695	0.8005	0.8783
ECOD	0.9565	0.8632	0.9075	0.9645	0.8573	0.9078	0.9954	0.6832	0.8103	0.8752
OCSVM	0.9990	0.8115	0.8955	0.0000	0.0000	0.0000	0.1596	0.9113	0.2716	0.3890
PCA	0.9996	0.7777	0.8748	0.9964	0.9720	0.9840	0.1645	0.9029	0.2783	0.7124
kNN	0.2776	1.0000	0.4345	0.9950	0.9676	0.9811	0.0000	0.0000	0.0000	0.4719
CBLOF	0.4301	0.9996	0.6014	0.9970	0.9698	0.9832	0.1635	0.9029	0.2769	0.6205
HBOS	1.0000	0.5957	0.7466	0.3745	0.9922	0.5437	0.3932	0.8965	0.5467	0.6123
IForest	1.0000	0.2204	0.3612	1.0000	0.8560	0.9224	0.4204	0.8141	0.5545	0.6127
LODA	0.9975	0.8465	0.9158	0.8452	0.9803	0.9077	0.2502	0.8912	0.3907	0.7381
VAE	0.6020	0.9486	0.7365	0.9953	0.9720	0.9835	0.1646	0.9029	0.2784	0.6661
DeepSVDD	0.6919	0.8779	0.7739	0.9575	0.9714	0.9644	0.1465	0.9842	0.2551	0.6645
LSTM-AE	0.7280	0.9288	0.8162	0.9961	0.9720	0.9839	0.1614	0.9029	0.2739	0.6913
MTAD-GAT	0.9589	0.8987	0.9279	0.9940	0.9857	**0.9898**	0.1745	0.9197	0.2934	0.7370
TFAD	0.8819	0.9851	0.9306	0.9991	0.9492	0.9735	0.2559	0.9387	0.4022	0.7688
Anomaly Transformer	0.9022	0.9879	0.9431	1.0000	0.8525	0.9204	0.9076	0.7159	0.8005	0.8880
Adversary	0.9384	0.9921	**0.9645**	0.8774	0.9649	0.9191	0.8309	0.8300	**0.8304**	**0.9047**

Point Adjustment is unreasonable !!!

We use F1 based on **affiliation**



Experiment

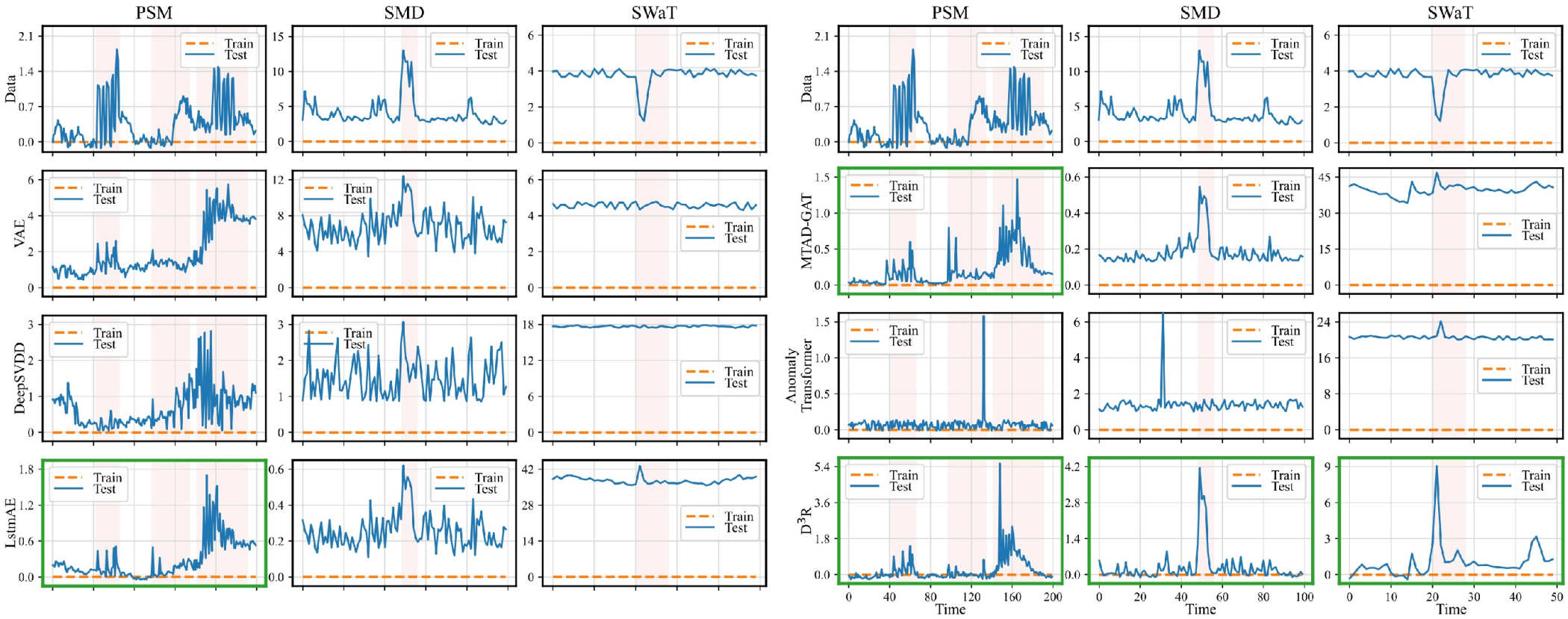
Method	PSM Precision	PSM Recall	PSM F1	SMD Precision	SMD Recall	SMD F1	SWaT Precision	SWaT Recall	SWaT F1	Average F1
Sampling	0.8439	0.5165	0.6408	0.7453	0.3144	0.4422	0.6062	0.8466	0.7065	0.5965
COPOD	0.7602	0.3175	0.4479	0.6676	0.1366	0.2268	0.9876	0.1180	0.2108	0.2951
ECOD	0.7460	0.3384	0.4656	0.7398	0.1615	0.2651	0.9761	0.1151	0.2059	0.3122
OCSVM	0.8761	0.4744	0.6155	0.0000	0.0000	0.0000	0.6196	0.7558	0.6810	0.4321
PCA	0.9220	0.3771	0.5353	0.8388	0.4019	0.5434	0.6358	0.7218	0.6761	0.5849
kNN	0.5317	1.0000	0.6943	0.6988	0.3368	0.4546	0.0000	0.0000	0.0000	0.3830
CBLOF	0.5990	0.9845	0.7449	0.8667	0.3352	0.4834	0.6308	0.7091	0.6677	0.6320
HBOS	1.0000	0.0654	0.1228	0.5628	0.8007	0.6610	0.5771	0.8049	0.6722	0.4853
IForest	1.0000	0.0335	0.0648	1.0000	0.0937	0.1713	0.6127	0.6280	0.6203	0.2855
LODA	0.9266	0.4017	0.5605	0.5902	0.6618	0.6240	0.6117	0.7014	0.6535	0.6126
VAE	0.6221	0.8772	0.7280	0.8209	0.4349	0.5686	0.6355	0.7218	0.6759	0.6575
DeepSVDD	0.7405	0.5064	0.6015	0.6498	0.6477	0.6488	0.5911	0.9353	0.7244	0.6582
LSTM-AE	0.7511	0.7586	0.7548	0.8496	0.4349	0.5753	0.6018	0.7219	0.6564	0.6622
MTAD-GAT	0.7990	0.6014	0.6863	0.8590	0.6769	0.7571	0.6590	0.7751	0.7123	0.7186
TFAD	0.7914	0.7163	0.7520	0.5632	0.9783	0.7149	0.6038	0.8196	0.6953	0.7207
Anomaly Transformer	0.5201	0.8504	0.6455	1.0000	0.0319	0.0619	0.5541	0.5994	0.5759	0.4278
Adversary	0.5351	0.8971	0.6703	0.5135	0.9663	0.6706	0.5410	0.7531	0.6297	0.6569
Our	0.6294	0.9619	**0.7609**	0.7715	0.9926	**0.8682**	0.7206	0.8529	**0.7812**	**0.8034**

11% improvement
on F1 Score

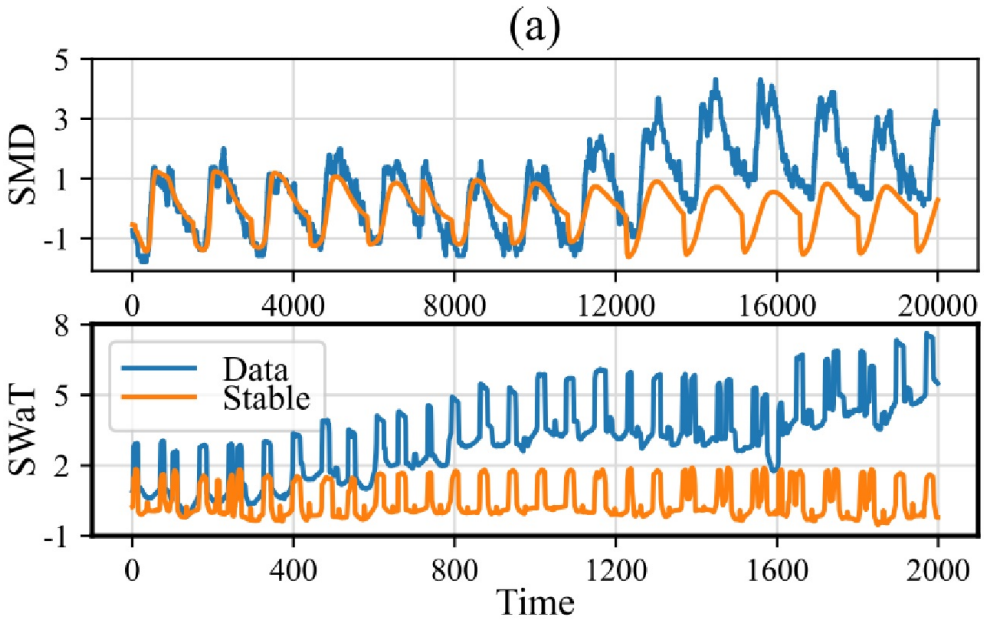
Method	PSM	SMD	SWaT	Average
Sampling	0.8791	0.9611	0.5348	0.7917
COPOD	0.8526	0.9230	0.7396	0.8384
ECOD	0.8394	0.9220	0.7532	0.8382
OCSVM	0.8708	0.6789	0.5379	0.6959
PCA	0.8617	0.9671	0.5324	0.7871
kNN	0.8640	0.8935	0.5806	0.7793
CBLOF	0.8681	0.9694	0.5378	0.7918
HBOS	0.8150	0.7393	0.8085	0.7876
IForest	0.8892	0.9218	0.7238	0.8450
LODA	0.8619	0.9180	0.6780	0.8193
VAE	0.8583	0.9674	0.5325	0.7861
DeepSVDD	0.8100	0.9187	0.5063	0.7450
LSTM-AE	0.8894	0.9698	0.6255	0.8283
MTAD-GAT	0.9093	0.9443	0.6386	0.8307
TFAD	0.8185	0.9386	0.6966	0.8179
Anomaly Transformer	0.7074	0.7150	0.6638	0.6954
Adversary	0.7199	0.5374	0.6487	0.6353
Our	**0.9223**	**0.9759**	**0.8554**	**0.9179**

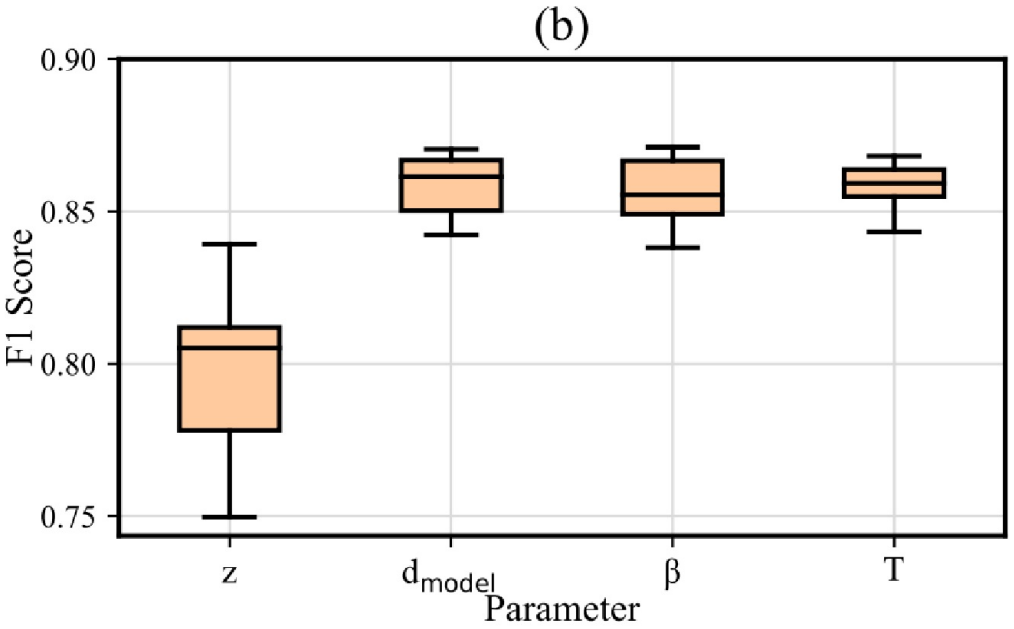
9% improvement
on PR-AUC

Experiment


PSM
SMD
SWaT
Data
VAE
DeepSVDD
LstmAE
MTAD-GAT
Anomaly Transformer
D^{3}R
Train
Test
Time

Experiment





Dynamic Decomposition is **effective** to extracts the fundamental stable components

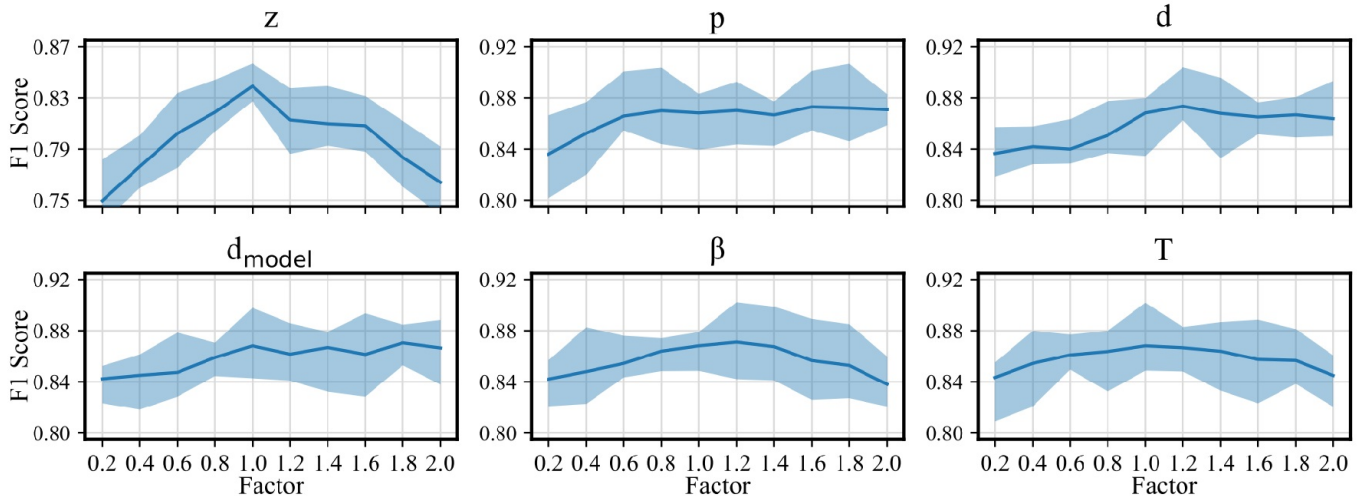
Diffusion Reconstruction is **superior** and **robust** to construct information bottleneck

Experiment

Ablation Studies

dataset	D^3R	w/o temporal	w/o spatial	w/o time	w/o data	w/o offset	w/o disturbance	w/o diffusion	w/o trend
PSM	**0.7609**	0.7280	0.7571	0.7074	0.7374	0.7420	0.7508	0.7347	0.7592
SMD	**0.8682**	0.8169	0.8173	0.7403	0.8114	0.8446	0.6947	0.8392	0.8006
SWaT	**0.7812**	0.7031	0.7274	0.7563	0.6720	0.7205	0.7293	0.7293	0.7109
Average	**0.8034**	0.7493	0.7673	0.7347	0.7403	0.7690	0.7249	0.7677	0.7569

Hyperparameter Analyses



Thanks for you listening!

For further questions welcome to discuss via E-mail

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or GitHub issues

https://github.com/ForestsKing/D3R