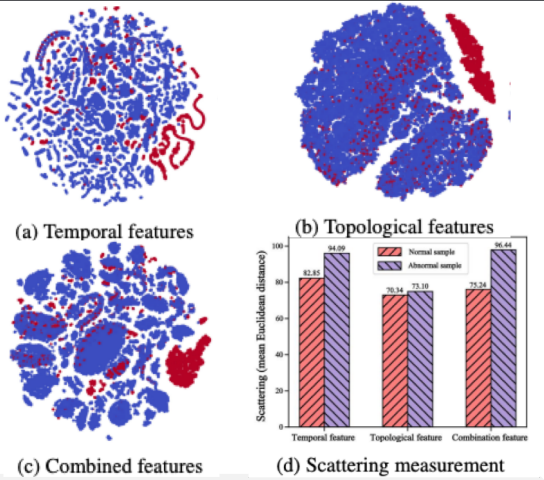
ScatterAD: Temporal-Topological Scattering Mechanism for Time Series Anomaly Detection

Tao Yin · Xiaohong Zhang* · Shaochen Fu · Zhibin Zhang · Li Huang

Yiyuan Yang · Kaixiang Yang · Meng Yan*

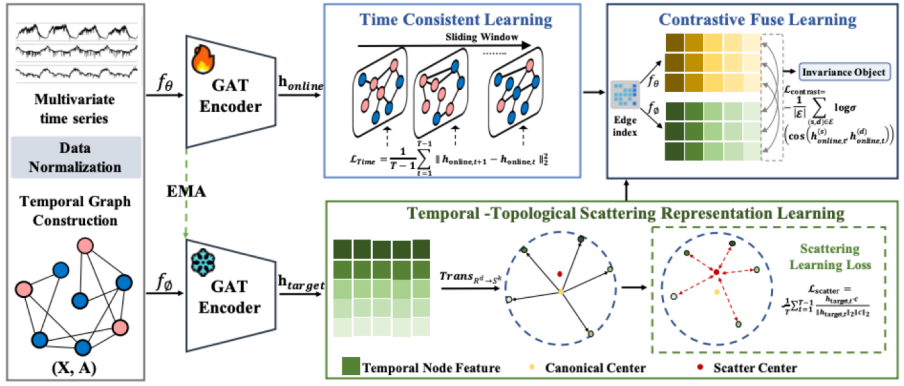
Motivation & Contribution



Through empirical analysis, we observe that in high-dimensional representation spaces, both normal and abnormal samples exhibit a phenomenon we call scattering where sample representations tend to disperse. Notably, abnormal samples appear more loosely scattered than normal ones. We formalize this observation as the "scattering phenomenon", quantified by the mean pairwise distance among representations.

- We introduce ScatterAD, a novel anomaly detection approach that employs a temporal-topological scattering mechanism to improve representational discriminability while preserving temporal structural consistency.
- This is the first work to introduce information bottleneck theory into multivariate time series anomaly detection, to theoretically reveal the complementarity between temporal and topological features. This leads to more discriminative representations and highlights the importance of integrating spatio-temporal information in future anomaly detection research.

Framework



Main Results

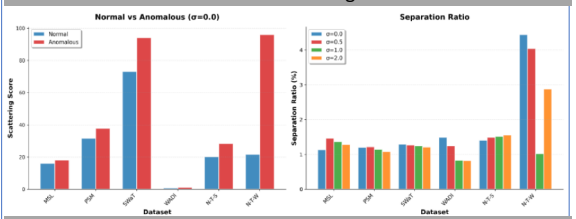
Dataset	Metric	Ours	S.T.	T.G.	Memto	DC.	M.TCN	iT.	MTG	A.T.	D.G.	GANF	VAE	IF	PCA
MSL	Aff-F	**0.867**	0.673	0.674	0.595	0.674	0.709	0.652	0.374	0.673	0.677	0.323	0.642	0.374	0.591
	PA-F	**0.964**	0.863	0.714	0.664	0.947	0.807	0.659	0.648	0.934	0.652	0.489	0.512	0.598	0.444
	A-ROC	**0.986**	0.751	0.794	0.951	0.961	0.627	0.604	0.857	0.970	0.788	0.678	0.883	0.673	0.732
	A-PR	**0.932**	0.754	0.727	0.902	0.891	0.739	0.721	0.781	0.878	0.703	0.620	0.521	0.519	0.524
PSM	Aff-F	**0.797**	0.786	0.689	0.659	0.653	0.701	0.652	0.436	0.657	0.624	0.329	0.524	0.569	0.437
	PA-F	**0.981**	0.941	0.801	0.977	0.977	0.965	0.926	0.797	0.978	0.780	0.788	0.596	0.543	0.467
	A-ROC	**0.986**	0.731	0.830	0.981	0.948	0.581	0.687	0.832	0.977	0.074	0.825	0.758	0.634	0.908
	A-PR	**0.969**	0.806	0.965	0.542	0.866	0.629	0.751	0.753	0.961	0.245	0.745	0.443	0.344	0.687
SWaT	Aff-F	0.704	0.631	0.594	0.592	0.687	0.685	**0.716**	0.463	0.622	0.619	0.608	0.563	0.502	0.537
	PA-F	**0.951**	0.863	0.788	0.756	0.939	0.884	0.916	0.500	0.943	0.822	0.244	0.526	0.472	0.548
	A-ROC	0.982	0.956	0.766	0.841	0.876	0.675	0.662	0.769	**0.989**	0.094	0.574	0.532	0.501	0.502
	A-PR	**0.909**	0.868	0.822	0.810	0.824	0.592	0.619	0.851	0.657	0.503	0.830	0.432	0.511	0.421
WADI	Aff-F	0.605	**0.756**	0.532	0.701	0.725	0.558	0.671	0.673	0.708	0.636	0.667	0.556	0.555	0.477
	PA-F	0.862	**0.873**	0.834	0.807	0.731	0.766	0.754	0.690	0.738	0.705	0.681	0.512	0.474	0.618
	A-ROC	0.960	0.945	0.612	0.693	0.829	0.831	0.814	0.782	**0.982**	0.372	0.782	0.501	0.860	0.502
	A-PR	**0.765**	0.743	0.532	0.691	0.651	0.697	0.627	0.523	0.637	0.470	0.508	0.384	0.406	0.357
NIPS-TS-SWAN	Aff-F	0.038	**0.805**	0.685	0.033	0.484	0.533	0.507	0.003	0.099	0.659	0.005	0.385	0.438	0.680
	PA-F	**0.736**	0.714	0.660	0.687	0.733	0.731	0.729	0.591	0.695	0.503	0.630	0.497	0.522	0.526
	A-ROC	0.792	**0.870**	0.595	0.791	0.655	0.562	0.537	0.788	0.787	0.671	0.778	0.522	0.729	0.498
	A-PR	0.716	**0.946**	0.527	0.702	0.626	0.545	0.531	0.699	0.569	0.714	0.712	0.326	0.473	0.326
NIPS-TS-GECCO	Aff-F	**0.825**	0.476	0.589	0.424	0.648	0.446	0.435	0.348	0.658	0.667	0.268	0.481	0.531	0.509
	PA-F	**0.784**	0.491	0.670	0.504	0.472	0.357	0.381	0.381	0.325	0.625	0.355	0.491	0.481	0.583
	A-ROC	**0.969**	0.536	0.787	0.875	0.715	0.946	0.817	0.732	0.685	0.690	0.898	0.868	0.684	0.763
	A-PR	0.633	0.318	0.495	0.519	0.523	0.615	0.474	0.552	**0.870**	0.535	0.337	0.443	0.418	0.543
#1 Count		15	4	0	0	0	0	1	0	3	0	0	0	0	0

Ablation

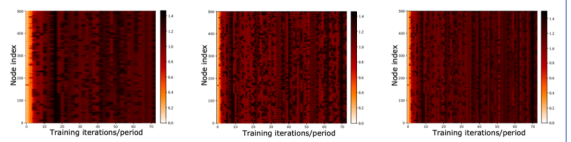
Robustness of the Scattering Phenomenon

Variation	MSL		PSM		WADI		SWaT	
	AF	AR	AF	AR	AF	AR	AF	AR
w/o T-Enc	0.764	0.927	**0.810**	0.951	0.568	0.958	0.659	0.944
w/o S-Enc	0.841	0.963	0.799	0.985	0.488	0.921	0.643	0.974
w/o C-Fuse	0.795	0.932	0.788	0.946	0.549	0.953	0.701	0.975
w/o EMA	0.805	**0.986**	0.792	0.979	0.582	0.955	0.683	0.957
ScatterAD	**0.867**	0.983	0.794	**0.986**	**0.587**	**0.960**	**0.704**	**0.982**

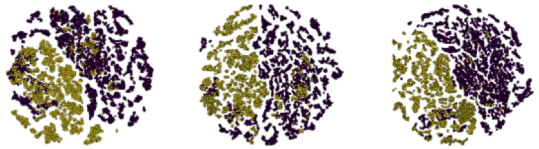
Robustness of the Scattering Phenomenon



Analysis of Scattering Mechanism



Latent Discrepancy in GAT Layer-Wise Evolution



Resources

Linkedin

Scan for Paper

Scan for Code