Respecting Time Series Properties Makes Deep Time Series Forecasting Perfect

1 Requirements

- Python 3.6
- matplotlib == 3.1.1
- numpy == 1.19.4
- pandas == 0.25.1
- scikit_learn == 0.21.3
- torch == 1.7.1

Dependencies can be installed using the following command:

- **pip install -r requirements.txt**

2 Data

The ETT, ECL and WTH datasets were acquired at:
https://drive.google.com/drive/folders/1ohGYWWohJlOlb2gsGTeEq3Wii2egnEPR?usp=sharing.

3 Usage

Commands for training and testing the RTNet on Dataset ETT, ECL and WTH respectively in the file named as '<**data**>**.sh**'. More parameter information please refer to '**main.py**'. The detailed descriptions about the arguments are as Tab.3

4 Results

MSE and MAE results of comparison experiment are shown as Tab.2-9, where 'S' denotes univariate forecasting and 'M' refers to multivariate forecasting. The experiment parameters of each dataset are formated in the '.sh' files in the directory './scripts/'. You can refer to these parameters for experiments, and you can also adjust the parameters to obtain better MSE and MAE results or draw better prediction figures.

TABLE 1
The Detailed Descriptions of Arguments

Parameter	Description of parameter
model	Model of experiment: 'RT'
forecasting_form	Forecasting form. This can be set to end-to-end/contrastiv learning based format
data	The dataset name
root_path	Root path of the data file
features	The forecasting task. This can be set to ['S', 'M']. S: univariate, M: multivariate
target	Target feature in 'S' task
label_len	Input sequence length of RTNet auto-regressive feature extractor
Alter_label_len	Alternative sequence length for group instance forecasting
pred_len	Prediction sequence length
pred_list	The group of prediction sequence length in self-supervised models
enc_in	Input variates
c_out	Output variates
timebed	Time embedding type, options: [None, hour, year, year_min]
d_model	Hidden dimension of model
pyramid	The number of pyramid networks
block_nums	The number of RTBlocks in the dominant pyramid network
time_nums	The number of TimeBlocks in time embedding network
feature_extractor	Feature extractor used in backbone, options: ['ResNet', 'CSPNet', 'Attention'].
group	Whether use group convolution for multivariate forecasting
group_pred	The number of individual experiments for instance forecasting
group_num	Indexes of individual experiments for instance forecasting
block_shift	α, controling the maximum overlap degree of adjacent input sequences
aug_num	The number of data augmentation, including initial sequences
jitter	Data augmentation amplification
kernel	The kernel size of convolutional layers
angle	θ, threshold angle of cos-relation matrix
dropout	The probability of dropout
criterion	Data preprocessing format, options: [Standard(Z-score), Maxabs]
train_epochs	The number of train epochs
cost_epochs	Contrastive epochs
cost_grow_epochs	Contrastive growing epochs per experiment
batch_size	Batch size of train input data in end-to-end format or the second stage in contrastive learning based format
cost_batch_size	Batch size of train input data of the first stage in contrastive learning based format
patience	Early stopping patience
learning_rate	Optimizer learning rate
loss	Loss function
checkpoints	Location of model checkpoints
test_inverse	Only inverse test data. Whether to transform them to the format of Z-score standardization.
save_loss	Whether saving results and checkpoints
train	Whether to train
reproducible	Whether to make results reproducible

TABLE 2
MSE of Comparison Experiment on Feature-based Baselines During Univariate Forecasting

Dataset\Baseline		RTNet(E)	RTNet(C)	Contrastive Learning								Feature Engineered
				CoST	TS2Vec	MoCo	TCC	CPC	TNC	Triplet	TST	TSFresh
$ETTh_1$	24	***0.028(+12.7%)***	0.035(+16.4%)	0.040	0.039	0.040	0.053	0.076	0.057	0.130	0.127	0.080
	48	***0.040(+25.0%)***	0.059(+39.4%)	0.060	0.062	0.063	0.074	0.104	0.094	0.145	0.202	0.092
	168	***0.062(+32.5%)***	0.074(+36.9%)	0.097	0.142	0.122	0.133	0.162	0.171	0.173	0.491	0.097
	336	***0.076(+19.0%)***	0.086(+56.2%)	0.112	0.160	0.144	0.161	0.183	0.192	0.167	0.526	0.109
	720	***0.097(+46.5%)***	0.109(+44.2%)	0.148	0.179	0.183	0.176	0.212	0.235	0.195	0.717	0.142
$ETTh_2$	24	0.071(+2.2%)	***0.067(+11.5%)***	0.079	0.091	0.095	0.111	0.109	0.097	0.160	0.134	0.176
	48	***0.092(+11.9%)***	0.095(+11.6%)	0.118	0.124	0.130	0.148	0.152	0.131	0.181	0.171	0.202
	168	***0.139(+10.5%)***	0.149(+9.2%)	0.189	0.198	0.204	0.225	0.251	0.197	0.214	0.261	0.273
	336	***0.171(+11.5%)***	0.178(+11.1%)	0.206	0.205	0.206	0.232	0.238	0.207	0.232	0.269	0.284
	720	***0.190(+15.1%)***	0.206(+27.6%)	0.214	0.208	0.206	0.242	0.234	0.207	0.251	0.278	0.339
$ETTm_1$	24	***0.011(+12.8%)***	0.012(+6.3%)	0.015	0.016	0.015	0.026	0.018	0.019	0.071	0.048	0.027
	48	***0.018(+7.0%)***	0.021(+14.3%)	0.025	0.028	0.027	0.045	0.035	0.036	0.084	0.064	0.043
	96	***0.027(+6.6%)***	0.034(+13.5%)	0.038	0.045	0.041	0.072	0.059	0.054	0.097	0.102	0.054
	288	***0.045(+25.0%)***	0.084(+19.0%)	0.077	0.095	0.081	0.158	0.118	0.098	0.130	0.172	0.098
	672	***0.058(+6.6%)***	0.090(+74.1%)	0.113	0.142	0.122	0.239	0.177	0.136	0.160	0.224	0.121
WTH	24	***0.088(+2.3%)***	0.092(+2.6%)	0.096	0.096	0.097	0.107	0.105	0.102	0.203	0.124	0.192
	48	***0.129(+3.0%)***	0.134(+7.2%)	0.138	0.140	0.140	0.143	0.147	0.139	0.219	0.151	0.231
	168	***0.188(+4.1%)***	0.191(+3.6%)	0.207	0.207	0.198	0.204	0.213	0.198	0.251	0.213	0.298
	336	***0.204(+2.5%)***	0.206(+5.9%)	0.230	0.231	0.220	0.219	0.234	0.215	0.262	0.233	0.314
	720	***0.195(+4.1%)***	0.200(+7.7%)	0.242	0.233	0.224	0.220	0.237	0.219	0.263	0.232	0.423
ECL	24	***0.111(+1.6%)***	0.115(+10.2%)	0.243	0.260	0.254	0.266	0.264	0.252	0.355	0.351	—
	48	***0.120(+1.1%)***	0.120(+7.2%)	0.292	0.313	0.304	0.317	0.321	0.300	0.375	0.398	—
	168	***0.112(+5.4%)***	0.125(+7.5%)	0.405	0.429	0.416	0.424	0.438	0.412	0.482	0.531	—
	336	***0.115(+5.2%)***	0.125(+13.8%)	0.560	0.565	0.556	0.578	0.599	0.548	0.633	0.656	—
	720	***0.113(+4.5%)***	0.126(+12.5%)	0.889	0.863	0.858	0.950	0.957	0.859	0.93	0.929	—

TABLE 3
MSE of Comparison Experiment on End-to-end Baselines During Univariate Forecasting

Dataset\Baseline		RTNet(E)	RTNet(C)	SCINet	Informer	LogTrans	N-BEATS	TCN	DeepAR	ARIMA	LSTMa	LSTNet	Reformer	Prophet
$ETTh_1$	24	***0.028***	0.035	0.097	0.098	0.103	0.094	0.075	0.107	0.086	0.094	0.114	0.172	0.093
	48	***0.040***	0.059	0.096	0.158	0.167	0.210	0.227	0.162	0.133	0.175	0.193	0.228	0.150
	168	***0.062***	0.074	0.110	0.183	0.207	0.232	0.316	0.239	0.364	0.210	0.236	1.460	1.194
	336	***0.076***	0.086	0.147	0.222	0.230	0.232	0.306	0.445	0.428	0.556	0.590	1.728	1.509
	720	***0.097***	0.109	0.233	0.269	0.273	0.322	0.390	0.658	0.613	0.635	0.683	1.948	2.685
$ETTh_2$	24	0.071	***0.067***	0.236	0.093	0.102	0.198	0.109	0.080	3.538	0.080	3.554	0.135	0.179
	48	***0.092***	0.095	0.195	0.155	0.169	0.234	0.147	0.125	3.168	0.125	3.190	0.172	0.284
	168	***0.139***	0.149	0.262	0.232	0.246	0.331	0.209	0.179	2.768	0.179	2.800	0.359	2.113
	336	***0.171***	0.178	0.238	0.263	0.267	0.431	0.237	0.568	2.717	0.568	2.753	0.516	2.052
	720	***0.190***	0.206	0.313	0.277	0.303	0.437	0.200	0.367	2.822	0.367	2.878	0.562	3.287
$ETTm_1$	24	***0.011***	0.012	0.027	0.030	0.065	0.054	0.027	0.075	0.074	0.099	0.090	0.055	0.102
	48	***0.018***	0.021	0.037	0.069	0.078	0.190	0.040	0.197	0.157	0.289	0.179	0.229	0.117
	96	***0.027***	0.034	0.051	0.194	0.199	0.183	0.097	0.336	0.242	0.255	0.272	0.854	0.146
	288	***0.045***	0.084	0.076	0.401	0.411	0.186	0.305	0.908	0.424	0.480	0.462	0.962	0.414
	672	***0.058***	0.090	0.105	0.512	0.598	0.197	0.445	2.371	0.565	0.988	0.639	1.605	2.671
WTH	24	***0.088***	0.092	0.137	0.117	0.136	—	0.161	0.128	0.199	0.107	0.131	0.197	0.280
	48	***0.129***	0.134	0.170	0.178	0.206	—	0.204	0.203	0.247	0.166	0.190	0.268	0.421
	168	***0.188***	0.191	0.243	0.266	0.309	—	0.292	0.293	0.471	0.305	0.341	0.590	2.409
	336	***0.204***	0.206	0.287	0.297	0.359	—	0.533	0.585	0.678	0.404	0.456	1.692	1.931
	720	***0.195***	0.200	0.360	0.359	0.388	—	0.764	0.499	0.996	0.784	0.866	1.887	3.759
ECL	24	***0.111***	0.115	0.413	0.251	0.528	0.427	0.263	0.188	0.861	0.475	0.281	0.917	0.506
	48	***0.120***	0.120	0.453	0.346	0.409	0.551	0.373	0.204	1.014	0.703	0.381	1.635	2.711
	168	***0.112***	0.125	0.258	0.544	0.959	0.893	0.609	0.315	1.102	1.186	0.599	3.448	2.220
	336	***0.115***	0.125	0.282	0.713	1.079	1.035	0.855	0.414	1.213	1.473	0.823	4.745	4.201
	720	***0.113***	0.126	0.320	1.182	1.001	1.548	1.263	0.563	1.322	1.493	1.278	6.841	6.827

TABLE 4
MSE of Comparison Experiment on Feature-based Baselines During Multivariate Forecasting

Dataset\Baseline		RTNet(E)	RTNet(C)	Contrastive Learning								Feature Engineered
				CoST	TS2Vec	MoCo	TCC	CPC	TNC	Triplet	TST	TSFresh
$ETTh_1$	24	0.340(+0.2%)	***0.326(+1.8%)***	0.386	0.590	0.623	0.766	0.728	0.708	0.942	0.735	3.858
	48	***0.371(+1.0%)***	0.372(+2.8%)	0.437	0.624	0.669	0.825	0.774	0.749	0.975	0.800	4.246
	168	***0.440(+3.6%)***	0.451(+2.5%)	0.643	0.762	0.820	0.982	0.920	0.884	1.135	0.973	3.527
	336	***0.485(+7.8%)***	0.505(+3.6%)	0.812	0.931	0.981	1.099	1.050	1.020	1.187	1.029	2.905
	720	***0.530(+5.1%)***	0.539(+3.9%)	0.970	1.063	1.138	1.267	1.160	1.157	1.283	1.020	2.667
$ETTh_2$	24	0.269(+41.2%)	***0.219(+82.9%)***	0.447	0.423	0.444	1.154	0.551	0.612	1.285	0.994	8.720
	48	0.481(+30.0%)	***0.461(+33.1%)***	0.699	0.619	0.613	1.158	0.752	0.840	1.455	1.159	12.771
	168	***1.260(+15.5%)***	1.038(+44.5%)	1.549	1.845	1.791	3.546	2.452	2.359	2.175	2.609	20.843
	336	1.499(+11.6%)	***1.140(+28.1%)***	1.749	2.194	2.241	3.184	2.664	2.782	2.007	2.824	14.801
	720	1.580(+16.1%)	***1.212(+32.3%)***	1.971	2.636	2.425	3.538	2.863	2.753	2.157	2.684	17.967
$ETTm_1$	24	***0.204(+2.9%)***	0.210(+5.6%)	0.246	0.453	0.458	0.502	0.478	0.522	0.689	0.471	0.639
	48	***0.263(+3.7%)***	0.271(+3.2%)	0.331	0.592	0.594	0.645	0.641	0.695	0.752	0.614	0.705
	96	0.299(+3.7%)	***0.298(+1.3%)***	0.378	0.635	0.621	0.675	0.707	0.731	0.744	0.645	0.675
	288	***0.361(+4.9%)***	0.363(+1.0%)	0.472	0.693	0.700	0.758	0.781	0.818	0.808	0.749	0.848
	672	***0.422(+5.5%)***	0.432(+1.9%)	0.620	0.782	0.821	0.854	0.880	0.932	0.917	0.857	0.968
WTH	24	0.295(+2.1%)	***0.294(+1.4%)***	0.298	0.307	0.311	0.332	0.328	0.320	0.522	0.372	2.170
	48	***0.352(+5.2%)***	0.359(+2.5%)	0.359	0.374	0.372	0.391	0.390	0.380	0.539	0.418	2.235
	168	***0.448(+9.2%)***	0.459(+1.2%)	0.464	0.491	0.482	0.492	0.499	0.479	0.572	0.521	2.514
	336	0.490(+3.0%)	***0.486(+1.4%)***	0.497	0.525	0.516	0.523	0.533	0.505	0.582	0.555	2.293
	720	0.497(+3.0%)	***0.497(+1.3%)***	0.533	0.556	0.540	0.548	0.559	0.519	0.597	0.575	2.468

TABLE 5
MSE of Comparison Experiment on End-to-end Baselines During Multivariate Forecasting

Dataset\Baseline		RTNet(E)	RTNet(C)	SCINet	Informer	LogTrans	TCN	LSTMa	LSTNet	Reformer	StemGNN
$ETTh_1$	24	0.340	***0.326***	0.505	0.577	0.686	0.767	0.536	1.293	0.887	0.614
	48	***0.371***	0.372	0.459	0.685	0.766	0.713	0.616	1.456	1.159	0.748
	168	***0.440***	0.451	0.510	0.931	1.002	0.995	1.058	1.997	1.686	0.663
	336	***0.485***	0.505	0.607	1.128	1.362	1.175	1.152	2.655	1.919	0.927
	720	***0.530***	0.539	0.746	1.215	1.397	1.453	1.682	2.143	2.177	—
$ETTh_2$	24	0.269	***0.219***	0.510	0.720	0.828	0.935	1.049	2.742	1.381	1.292
	48	0.481	***0.461***	0.518	1.457	1.806	1.300	1.331	3.564	1.715	1.099
	168	***1.260***	1.038	0.804	3.489	4.070	4.017	3.987	3.242	4.484	2.282
	336	1.499	***1.140***	0.946	2.723	3.875	3.460	3.276	2.544	3.798	3.086
	720	1.580	***1.212***	1.687	3.467	3.913	3.106	3.711	4.625	5.111	—
$ETTm_1$	24	***0.204***	0.210	0.367	0.323	0.419	0.363	0.511	1.968	0.598	0.620
	48	***0.263***	0.271	0.394	0.494	0.507	0.542	1.280	1.999	0.952	0.744
	96	0.299	***0.298***	0.392	0.678	0.768	0.666	1.195	2.762	1.267	0.709
	288	***0.361***	0.363	0.486	1.056	1.462	0.991	1.598	1.257	1.632	0.843
	672	***0.422***	0.432	0.746	1.192	1.669	1.032	2.530	1.917	1.943	—
WTH	24	0.295	***0.294***	0.337	0.335	0.435	0.320	0.476	0.615	0.583	0.396
	48	***0.352***	0.359	0.397	0.395	0.426	0.417	0.763	0.660	0.633	0.459
	168	***0.448***	0.459	0.537	0.608	0.727	0.540	0.948	0.748	1.228	0.572
	336	0.490	***0.486***	0.587	0.702	0.754	0.607	1.497	0.782	1.770	0.583
	720	0.497	***0.497***	0.640	0.831	0.885	0.907	1.314	0.851	2.548	—

TABLE 6
MAE of Comparison Experiment on Feature-based Baselines During Univariate Forecasting

Dataset\Baseline		RTNet(E)	RTNet(C)	Contrastive Learning								Feature Engineered
				CoST	TS2Vec	MoCo	TCC	CPC	TNC	Triplet	TST	TSFresh
$ETTh_1$	24	***0.128(+5.7%)***	0.146(+10.4%)	0.152	0.151	0.151	0.175	0.217	0.184	0.289	0.284	0.224
	48	***0.157(+8.2%)***	0.191(+17.0%)	0.186	0.189	0.191	0.209	0.259	0.239	0.306	0.362	0.242
	168	***0.192(+12.5%)***	0.209(+18.6%)	0.236	0.291	0.268	0.284	0.326	0.329	0.336	0.596	0.253
	336	***0.216(+7.4%)***	0.228(+26.8%)	0.258	0.316	0.297	0.320	0.351	0.357	0.333	0.618	0.263
	720	***0.248(+22.1%)***	0.260(+21.1%)	0.306	0.345	0.347	0.343	0.387	0.408	0.368	0.760	0.302
$ETTh_2$	24	0.202(+3.0%)	***0.194(+7.8%)***	0.207	0.230	0.234	0.255	0.251	0.238	0.316	0.281	0.331
	48	***0.233(+6.8%)***	0.237(+0.0%)	0.259	0.274	0.279	0.298	0.301	0.281	0.339	0.321	0.357
	168	***0.294(+4.1%)***	0.304(+4.1%)	0.339	0.355	0.360	0.374	0.392	0.354	0.372	0.404	0.420
	336	***0.332(+5.9%)***	0.336(+0.0%)	0.360	0.364	0.364	0.385	0.388	0.366	0.389	0.413	0.423
	720	***0.352(+7.9%)***	0.366(+14.0%)	0.371	0.371	0.369	0.397	0.389	0.370	0.406	0.420	0.466
$ETTm_1$	24	***0.077(+10.0%)***	0.079(+4.9%)	0.088	0.093	0.091	0.122	0.102	0.103	0.180	0.151	0.128
	48	***0.100(+6.0%)***	0.110(+7.0%)	0.117	0.126	0.122	0.165	0.142	0.142	0.206	0.183	0.159
	96	***0.123(+3.5%)***	0.140(+6.9%)	0.147	0.162	0.153	0.211	0.188	0.178	0.230	0.231	0.178
	288	***0.164(+9.5%)***	0.221(+10.8%)	0.209	0.235	0.219	0.318	0.271	0.244	0.276	0.316	0.245
	672	***0.186(+5.7%)***	0.228(+38.8%)	0.257	0.290	0.268	0.398	0.332	0.290	0.315	0.366	0.274
WTH	24	***0.206(+0.7%)***	0.211(+1.9%)	0.213	0.215	0.216	0.232	0.226	0.221	0.337	0.244	0.330
	48	***0.252(+0.9%)***	0.256(+3.7%)	0.262	0.264	0.264	0.272	0.272	0.264	0.351	0.280	0.361
	168	***0.315(+4.1%)***	0.316(+2.9%)	0.334	0.335	0.326	0.333	0.340	0.328	0.379	0.342	0.415
	336	***0.332(+2.0%)***	0.336(+0.0%)	0.356	0.360	0.350	0.350	0.362	0.347	0.389	0.361	0.429
	720	***0.329(+2.7%)***	0.329(+5.8%)	0.370	0.365	0.357	0.352	0.366	0.353	0.394	0.361	0.499
ECL	24	***0.234(+1.0%)***	0.240(+8.6%)	0.264	0.288	0.280	0.301	0.299	0.278	0.379	0.387	—
	48	***0.243(+0.9%)***	0.243(+13.2%)	0.300	0.321	0.314	0.330	0.339	0.308	0.390	0.416	—
	168	***0.242(+3.0%)***	0.247(+15.7%)	0.375	0.392	0.391	0.402	0.418	0.384	0.459	0.498	—
	336	***0.243(+3.6%)***	0.251(+14.2%)	0.473	0.478	0.482	0.486	0.507	0.466	0.551	0.575	—
	720	***0.242(+3.5%)***	0.257(+12.5%)	0.645	0.651	0.653	0.667	0.679	0.651	0.706	0.729	—

TABLE 7
MAE of Comparison Experiment on End-to-end Baselines During Univariate Forecasting

Dataset\Baseline		RTNet(E)	RTNet(C)	SCINet	Informer	LogTrans	N-BEATS	TCN	DeepAR	ARIMA	LSTMa	LSTNet	Reformer	Prophet
$ETTh_1$	24	***0.128***	0.146	0.253	0.247	0.259	0.238	0.210	0.280	0.190	0.232	0.272	0.319	0.241
	48	***0.157***	0.191	0.245	0.319	0.328	0.367	0.402	0.327	0.242	0.322	0.358	0.395	0.300
	168	***0.192***	0.209	0.257	0.346	0.375	0.391	0.493	0.422	0.456	0.352	0.392	1.089	0.721
	336	***0.216***	0.228	0.309	0.387	0.398	0.388	0.495	0.552	0.537	0.644	0.698	0.978	1.766
	720	***0.248***	0.260	0.405	0.435	0.463	0.490	0.557	0.707	0.684	0.704	0.768	1.226	3.155
$ETTh_2$	24	0.202	***0.194***	0.381	0.240	0.255	0.345	0.251	0.229	0.407	0.275	0.445	0.369	0.345
	48	***0.233***	0.237	0.350	0.314	0.348	0.386	0.302	0.283	0.440	0.318	0.474	0.505	0.428
	168	***0.294***	0.304	0.413	0.389	0.422	0.453	0.366	0.346	0.555	0.470	0.595	0.797	1.018
	336	***0.332***	0.336	0.396	0.417	0.437	0.508	0.391	0.555	0.680	0.548	0.738	1.060	2.487
	720	***0.352***	0.366	0.451	0.431	0.493	0.517	0.367	0.488	0.952	0.613	1.044	1.543	4.592
$ETTm_1$	24	***0.077***	0.079	0.131	0.137	0.202	0.184	0.127	0.205	0.168	0.201	0.206	0.170	0.256
	48	0.100	***0.110***	0.150	0.203	0.220	0.361	0.154	0.332	0.274	0.371	0.306	0.340	0.273
	96	***0.123***	0.140	0.177	0.372	0.386	0.353	0.246	0.450	0.357	0.370	0.399	0.675	0.304
	288	***0.164***	0.221	0.212	0.554	0.572	0.362	0.455	0.739	0.500	0.528	0.558	1.107	0.482
	672	***0.186***	0.228	0.248	0.644	0.702	0.368	0.576	1.256	0.605	0.805	0.697	1.312	1.112
WTH	24	***0.206***	0.211	0.267	0.251	0.279	—	0.306	0.274	0.321	0.222	0.254	0.329	0.403
	48	***0.252***	0.256	0.299	0.318	0.356	—	0.342	0.353	0.375	0.298	0.334	0.381	0.492
	168	***0.315***	0.316	0.364	0.398	0.439	—	0.409	0.451	0.541	0.404	0.448	0.552	1.092
	336	***0.332***	0.336	0.399	0.416	0.484	—	0.540	0.644	0.666	0.476	0.554	0.945	2.406
	720	***0.329***	0.329	0.456	0.466	0.499	—	0.629	0.596	0.853	0.709	0.809	1.352	1.030
ECL	24	***0.234***	0.240	0.492	0.275	0.447	0.330	0.279	0.344	0.726	0.509	0.287	0.840	0.557
	48	***0.243***	0.243	0.509	0.339	0.414	0.392	0.344	0.357	0.797	0.617	0.366	1.515	1.239
	168	***0.242***	0.247	0.369	0.424	0.612	0.538	0.462	0.436	0.834	0.854	0.500	2.088	3.029
	336	***0.243***	0.251	0.385	0.512	0.639	0.669	0.606	0.519	0.883	0.910	0.624	3.913	1.363
	720	***0.242***	0.257	0.427	0.806	0.714	0.881	0.858	0.595	0.908	0.926	0.906	4.913	4.184

TABLE 8
MAE of Comparison Experiment on Feature-based Baselines During Multivariate Forecasting

Dataset\Baseline		RTNet(E)	RTNet(C)	Contrastive Learning								Feature Engineered
				CoST	TS2Vec	MoCo	TCC	CPC	TNC	Triplet	TST	TSFresh
$ETTh_1$	24	0.386(+0.4%)	***0.375(+1.6%)***	0.429	0.531	0.555	0.629	0.600	0.592	0.729	0.633	1.574
	48	***0.402(+1.0%)***	0.403(+2.3%)	0.464	0.555	0.586	0.657	0.629	0.619	0.746	0.671	1.674
	168	***0.442(+2.6%)***	0.446(+2.6%)	0.582	0.639	0.674	0.731	0.714	0.699	0.825	0.768	1.500
	336	***0.463(+4.6%)***	0.474(+2.0%)	0.679	0.728	0.755	0.786	0.779	0.768	0.859	0.797	1.329
	720	***0.509(+3.1%)***	0.515(+1.8%)	0.771	0.799	0.831	0.859	0.835	0.830	0.916	0.798	1.283
$ETTh_2$	24	0.330(+14.3%)	***0.307(+36.1%)***	0.502	0.489	0.495	0.838	0.572	0.595	0.911	0.779	2.311
	48	***0.432(+10.1%)***	0.446(+15.5%)	0.637	0.605	0.595	0.983	0.684	0.716	0.966	0.850	2.746
	168	0.679(+7.1%)	***0.668(+10.4%)***	0.982	1.074	1.034	1.459	1.213	1.213	1.155	1.265	3.779
	336	0.811(+1.6%)	***0.712(+13.5%)***	1.042	1.197	1.186	1.420	1.304	1.349	1.101	1.337	3.006
	720	0.857(+5.2%)	***0.763(+13.6%)***	1.092	1.370	1.292	1.523	1.399	1.394	1.139	1.334	3.335
$ETTm_1$	24	***0.287(+2.1%)***	0.292(+4.9%)	0.329	0.444	0.444	0.478	0.459	0.472	0.592	0.491	0.589
	48	***0.327(+2.9%)***	0.333(+1.8%)	0.386	0.521	0.528	0.559	0.550	0.567	0.624	0.560	0.629
	96	0.352(+2.1%)	***0.350(+1.1%)***	0.419	0.554	0.553	0.583	0.593	0.595	0.623	0.581	0.606
	288	0.391(+3.7%)	***0.389(+0.3%)***	0.486	0.597	0.606	0.633	0.644	0.649	0.662	0.644	0.702
	672	0.429(+3.5%)	***0.426(+3.3%)***	0.574	0.653	0.674	0.689	0.700	0.712	0.720	0.709	0.767
WTH	24	***0.353(+1.1%)***	0.354(+1.3%)	0.360	0.363	0.365	0.392	0.383	0.373	0.533	0.404	0.909
	48	***0.387(+6.1%)***	0.410(+1.9%)	0.411	0.418	0.416	0.439	0.433	0.421	0.543	0.445	0.936
	168	***0.467(+6.1%)***	0.483(+1.0%)	0.491	0.506	0.499	0.510	0.512	0.495	0.565	0.518	0.985
	336	0.509(+0.7%)	***0.503(+0.2%)***	0.517	0.530	0.523	0.532	0.536	0.514	0.572	0.541	0.969
	720	0.515(+1.0%)	***0.511(+0.4%)***	0.542	0.552	0.540	0.549	0.553	0.525	0.582	0.555	0.961

TABLE 9
MAE of Comparison Experiment on End-to-end Baselines During Multivariate Forecasting

Dataset\Baseline		RTNet(E)	RTNet(C)	SCINet	Informer	LogTrans	TCN	LSTMa	LSTNet	Reformer	StemGNN
$ETTh_1$	24	0.386	***0.375***	0.489	0.549	0.604	0.612	0.528	0.901	0.630	0.571
	48	***0.402***	0.403	0.467	0.625	0.757	0.617	0.577	0.960	0.750	0.618
	168	***0.442***	0.446	0.501	0.752	0.846	0.738	0.725	1.214	0.996	0.608
	336	***0.463***	0.474	0.577	0.873	0.952	0.800	0.794	1.369	1.090	0.730
	720	***0.509***	0.515	0.667	0.896	1.291	1.311	1.018	1.380	1.218	—
$ETTh_2$	24	0.330	***0.307***	0.519	0.665	0.750	0.754	0.689	1.457	1.475	0.883
	48	0***0.432***	0.446	0.527	1.001	1.034	0.911	0.805	1.687	1.585	0.847
	168	0.679	***0.668***	0.662	1.515	1.681	1.579	1.560	2.513	1.650	1.228
	336	0.811	***0.712***	0.725	1.340	1.763	1.456	1.375	2.591	1.508	1.351
	720	0.857	***0.763***	0.992	1.472	1.552	1.381	1.520	3.709	1.793	—
$ETTm_1$	24	***0.287***	0.292	0.422	0.369	0.412	0.397	0.517	1.170	0.489	0.570
	48	***0.327***	0.333	0.431	0.503	0.583	0.508	0.819	1.215	0.645	0.628
	96	0.352	***0.350***	0.431	0.614	0.792	0.578	0.785	1.542	0.795	0.624
	288	0.391	***0.389***	0.497	0.786	1.320	0.735	0.952	2.076	0.886	0.683
	672	0.429	***0.426***	0.700	0.926	1.461	0.756	1.259	2.941	1.006	—
WTH	24	***0.353***	0.354	0.382	0.381	0.477	0.355	0.464	0.545	0.497	0.449
	48	***0.387***	0.410	0.433	0.459	0.495	0.455	0.589	0.589	0.556	0.484
	168	***0.467***	0.483	0.535	0.567	0.671	0.525	0.713	0.647	0.763	0.555
	336	0.509	***0.503***	0.575	0.620	0.670	0.555	0.889	0.683	0.997	0.575
	720	0.515	***0.511***	0.606	0.731	0.773	0.825	0.875	0.757	1.407	—