
GBT: TWO-STAGE TRANSFORMER FRAMEWORK FOR NON-STATIONARY TIME SERIES FORECASTING

1 REQUIREMENTS

- Python 3.8
- matplotlib == 3.1.1
- numpy == 1.19.4
- pandas == 0.25.1
- scikit_learn == 0.21.3
- torch == 1.11.0
- einops==0.4.1
- scipy==1.9.0

Dependencies can be installed using the following command: **pip install -r requirements.txt**

2 DATASETS

- {ETT, ECL, Traffic, Exchange, weather, ILI} were acquired at: <https://drive.google.com/drive/folders/1ohGYWWohJl0lb2gsGTEq3Wii2egnEPR?usp=sharing>.
- WTH dataset was acquired at: <https://www.ncdc.noaa.gov/orders/qclcd/>.

3 USAGE

Commands for training and testing the GBT on Dataset ETT, ECL, WTH, Traffic, Exchange and Weather respectively in the file named as '**<GBT_data>.sh**'.

Here we provide command descriptions for training and testing the GBT combined with different models separately:

- GBT-Vanilla:
python -u main.py --root_path <root_path> --model <model> --data <data> --features <features> --seq_len <seq_len> --label_len <label_len> --pred_len <pred_len> --s_layers <s_layers> --d_layers <d_layers> --attn <attn> --des <des> --itr <itr> --learning_rate <learning_rate> --dropout <dropout> --fd_model <fd_model> --d_model <d_model> --format <format> --use_RevIN <use_RevIN> --instance <instance> --criterion <criterion> --test_inverse
- GBT+FEDformer:
python -u main.py --root_path <root_path> --model <model> --data <data> --features <features> --seq_len <seq_len> --label_len <label_len> --pred_len <pred_len> --hidden_size <hidden_size> --num_levels <num_levels> --num_stacks <num_stacks> --num_groups <num_groups> --concat_len <concat_len> --INN <INN> --dilation <dilation> --positionalEncoding <positionalEncoding> --single_step_output_One <single_step_output_One> --des <des> --itr <itr> --learning_rate <learning_rate> --dropout <dropout> --d_model <d_model> --instance <instance> --criterion <criterion> --test_inverse

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- GBT+ETSformer:

```
python -u main.py --root_path <root_path> --model <model> --data <data>
--features <features> --seq_len <seq_len> --label_len <label_len> --pred_len
<pred_len> --s_layers <s_layers> --d_layers <d_layers> --attn <attn>
--version <version> --L <L> --moving_avg <moving_avg> --des <des>
--itr <itr> --learning_rate <learning_rate> --dropout <dropout> --d_model
<d_model> --instance <instance> --criterion <criterion> --test_inverse
```
 - GBT+SCINet:

```
python -u main.py --root_path <root_path> --model <model> --data
<data> --features <features> --seq_len <seq_len> --label_len <label_len>
--pred_len <pred_len> --s_layers <s_layers> --d_layers <d_layers> --attn
<attn> --sigma <sigma> --K <K> --des <des> --itr <itr> --learning_rate
<learning_rate> --dropout <dropout> --d_model <d_model> --instance
<instance> --criterion <criterion> --test_inverse
```
 - GBT+N-BEATS:

```
python -u main.py --root_path <root_path> --model <model>
--data <data> --features <features> --seq_len <seq_len> --label_len
<label_len> --pred_len <pred_len> --trend_blocks <trend_blocks>
--trend_layers <trend_layers> --trend_layer_size <trend_layer_size>
--degree_polynomial <degree_polynomial> --seasonality_blocks
<seasonality_blocks> --seasonality_layers <seasonality_layers>
--seasonality_layer_size <seasonality_layer_size> --des <des> --itr <itr>
--learning_rate <learning_rate> --dropout <dropout> --num_of_harmonics
<num_of_harmonics> --d_model <d_model> --instance <instance> --criterion
<criterion> --test_inverse
```
 - GBT+N-HiTS:

```
python -u main.py --root_path <root_path> --model <model> --data
<data> --features <features> --seq_len <seq_len> --label_len <label_len>
--pred_len <pred_len> --n_s_hidden <n_s_hidden> --n_x <n_x> --stack_num
<stack_num> --n_blocks <n_blocks> --n_layers <n_layers> --n_hidden
<n_hidden> --n_pool_kernel_size <n_pool_kernel_size> --n_freq_downsample
<n_freq_downsample> --dropout_prob_theta <dropout_prob_theta>
--batch_normalization <batch_normalization> --share_weights <share_weights>
--des <des> --itr <itr> --learning_rate <learning_rate> --dropout
<dropout> --d_model <d_model> --instance <instance> --criterion
<criterion> --test_inverse
```

Detailed descriptions of arguments are shown in ‘main.py’.

4 RESULTS

Full results of multivariate/univariate forecasting experiment under $\{ETTh_1, ETTm_2, ECL, WTH, Traffic, Exchange\}$ are shown in Tab.1/2 while full results under weather dataset are shown in Tab.3. The experiment parameters of each dataset are formatted in the ‘.sh’ files in the directory ‘./scripts/’. You can refer to these parameters for experiments, and you can also adjust parameters to obtain better MSE and MAE results or draw better prediction figures.

Table 1: Results of multivariate forecasting

Methods	Metrics	ETTh ₁				ETTh ₂				ECL			
		96	192	336	720	96	192	336	720	96	192	336	720
GBT-Vanilla	MSE	0.398	0.448	0.497	0.538	0.189	0.249	<u>0.324</u>	0.395	0.143	0.175	0.197	<u>0.235</u>
	MAE	0.418	0.442	0.470	0.505	0.276	<u>0.324</u>	<u>0.368</u>	<u>0.419</u>	0.246	0.277	0.298	0.336
FEDformer	MSE	0.419	<u>0.461</u>	0.530	0.686	0.204	0.293	0.342	0.427	0.188	<u>0.198</u>	0.213	0.239
	MAE	0.459	0.483	0.523	0.606	0.288	0.346	0.377	0.424	0.303	0.312	0.321	0.349
Pyraformer	MSE	0.662	0.791	0.902	0.974	0.378	1.192	1.176	6.720	0.418	0.408	0.410	0.407
	MAE	0.611	0.683	0.734	0.780	0.456	0.870	1.033	2.077	0.460	0.454	0.457	0.456
ETSformer	MSE	0.511	0.561	0.599	0.588	<u>0.189</u>	<u>0.253</u>	0.314	0.414	<u>0.187</u>	0.199	<u>0.212</u>	0.233
	MAE	0.487	0.513	0.529	0.541	0.280	0.319	0.357	0.413	0.304	0.315	0.329	0.345
SCINet	MSE	0.531	0.535	0.584	0.685	0.312	0.573	1.870	3.462	0.210	0.234	0.227	0.269
	MAE	0.503	0.513	0.560	0.634	0.415	0.591	1.078	1.753	0.333	0.345	0.340	0.373
TS2Vec	MSE	0.670	0.781	0.911	1.059	0.360	0.534	0.833	1.906	0.336	0.337	0.350	0.375
	MAE	0.588	0.651	0.718	0.794	0.426	0.537	0.694	1.054	0.412	0.415	0.426	0.438
DLinear	MSE	0.436	0.483	0.526	<u>0.556</u>	0.262	0.365	0.474	0.648	0.233	0.233	0.246	0.281
	MAE	0.447	0.475	0.500	<u>0.543</u>	0.364	0.429	0.492	0.577	0.331	0.334	0.347	0.375
N-HiTS	MSE	<u>0.411</u>	0.465	<u>0.523</u>	0.592	0.192	0.284	0.346	0.520	0.198	0.205	0.218	0.254
	MAE	<u>0.419</u>	<u>0.453</u>	<u>0.492</u>	0.556	<u>0.277</u>	0.350	0.376	0.485	<u>0.291</u>	<u>0.301</u>	<u>0.314</u>	<u>0.342</u>

Methods	Metrics	WTH				Traffic				Exchange			
		96	192	336	720	96	192	336	720	96	192	336	720
GBT-Vanilla	MSE	0.434	0.481	0.514	0.523	0.509	0.520	0.535	0.575	0.110	0.179	<u>0.358</u>	0.756
	MAE	0.466	0.506	0.527	0.532	0.282	0.293	0.307	0.317	0.249	<u>0.312</u>	<u>0.446</u>	0.655
FEDformer	MSE	0.531	0.601	0.646	0.631	0.575	0.583	0.596	<u>0.611</u>	0.144	0.264	0.443	1.143
	MAE	0.525	0.564	0.618	0.597	<u>0.358</u>	0.360	<u>0.353</u>	<u>0.375</u>	0.277	0.375	0.482	0.821
Pyraformer	MSE	0.540	0.575	0.593	0.623	0.938	0.939	0.948	-	1.489	1.642	1.744	2.080
	MAE	0.546	0.567	0.578	0.599	0.490	0.488	0.488	-	1.018	1.075	1.107	1.197
ETSformer	MSE	0.538	0.615	0.655	0.719	0.607	0.621	0.622	0.632	0.085	0.182	0.348	1.025
	MAE	0.521	0.566	0.589	0.624	0.392	0.399	0.396	0.396	0.204	0.303	0.428	0.774
SCINet	MSE	0.489	0.526	0.572	0.617	0.581	0.595	-	-	0.221	0.323	0.661	2.691
	MAE	0.495	0.524	0.562	0.586	0.423	0.429	-	-	0.365	0.442	0.564	1.320
TS2Vec	MSE	<u>0.450</u>	<u>0.505</u>	<u>0.532</u>	<u>0.566</u>	0.941	-	-	-	0.184	0.373	0.666	2.941
	MAE	<u>0.472</u>	<u>0.515</u>	<u>0.533</u>	<u>0.557</u>	0.550	-	-	-	0.315	0.452	0.612	1.313
DLinear	MSE	0.514	0.572	0.597	0.646	0.760	0.707	0.715	0.758	0.167	0.269	0.421	<u>0.925</u>
	MAE	0.514	0.553	0.570	0.603	0.475	0.455	0.457	0.474	0.322	0.408	0.509	<u>0.746</u>
N-HiTS	MSE	0.488	0.539	0.565	0.628	<u>0.561</u>	<u>0.543</u>	<u>0.554</u>	0.616	<u>0.099</u>	0.297	0.576	1.288
	MAE	0.496	0.536	0.555	0.596	0.369	<u>0.352</u>	0.357	0.377	<u>0.225</u>	0.390	0.550	0.847

Table 2: Results of univariate forecasting

Methods	Metrics	ETTh ₁				ETTm ₂				ECL			
		96	192	336	720	96	192	336	720	96	192	336	720
GBT-Vanilla	MSE	<i>0.051</i>	<i>0.074</i>	<i>0.080</i>	<i>0.119</i>	<i>0.068</i>	<i>0.091</i>	<i>0.109</i>	<i>0.163</i>	<i>0.254</i>	<i>0.282</i>	<i>0.324</i>	<i>0.359</i>
	MAE	<i>0.173</i>	<i>0.206</i>	<i>0.221</i>	<i>0.276</i>	<i>0.194</i>	<i>0.229</i>	<i>0.257</i>	<i>0.316</i>	<i>0.363</i>	<i>0.386</i>	<i>0.417</i>	<i>0.444</i>
FEDformer	MSE	0.115	0.137	0.142	0.144	<u>0.068</u>	0.106	0.139	0.199	<u>0.258</u>	<u>0.299</u>	0.354	0.435
	MAE	0.266	0.292	0.295	0.302	<u>0.198</u>	0.249	0.290	0.347	<u>0.374</u>	<u>0.398</u>	0.438	0.493
Pyraformer	MSE	0.143	0.159	0.196	0.230	0.461	0.781	1.372	5.780	0.347	0.436	0.493	0.614
	MAE	0.309	0.322	0.372	0.410	0.527	0.683	0.913	1.878	0.432	0.493	0.526	0.605
ETSformer	MSE	<u>0.060</u>	<u>0.081</u>	<u>0.098</u>	<u>0.119</u>	0.080	0.110	0.136	0.185	0.726	0.667	0.770	0.766
	MAE	<u>0.190</u>	<u>0.221</u>	<u>0.248</u>	<u>0.282</u>	0.213	0.252	0.283	0.333	0.656	0.625	0.677	0.674
SCINet	MSE	0.119	0.129	0.160	0.243	0.076	<u>0.102</u>	<u>0.129</u>	<u>0.176</u>	0.312	0.314	<u>0.332</u>	0.364
	MAE	0.269	0.280	0.322	0.414	0.210	<u>0.248</u>	<u>0.280</u>	<u>0.328</u>	0.411	0.416	<u>0.427</u>	0.451
TS2Vec	MSE	0.098	0.153	0.169	0.164	0.088	0.122	0.158	0.200	0.315	0.333	0.347	<i>0.350</i>
	MAE	0.241	0.302	0.326	0.327	0.224	0.271	0.314	0.357	0.419	0.430	0.440	<u>0.447</u>
DLinear	MSE	0.111	0.136	0.166	0.280	0.094	0.130	0.164	0.223	0.411	0.385	0.410	0.447
	MAE	0.258	0.286	0.325	0.453	0.237	0.278	0.316	0.369	0.473	0.455	0.470	0.502
N-HiTS	MSE	0.144	0.172	0.178	0.291	0.071	0.113	0.164	0.226	0.328	0.343	0.395	0.449
	MAE	0.308	0.338	0.342	0.463	0.195	0.251	0.314	0.374	0.405	0.412	0.449	0.489

Methods	Metrics	WTH				Traffic				Exchange			
		96	192	336	720	96	192	336	720	96	192	336	720
GBT-Vanilla	MSE	<u>0.188</u>	<i>0.221</i>	<i>0.239</i>	<i>0.218</i>	<i>0.133</i>	<i>0.140</i>	<i>0.138</i>	<i>0.174</i>	<i>0.100</i>	<i>0.186</i>	<u>0.408</u>	<u>0.925</u>
	MAE	<u>0.318</u>	<i>0.348</i>	<i>0.372</i>	<i>0.349</i>	<i>0.222</i>	<i>0.228</i>	<i>0.234</i>	<i>0.268</i>	<i>0.249</i>	<i>0.343</i>	0.522	<u>0.743</u>
FEDformer	MSE	0.236	0.289	0.332	0.335	<u>0.189</u>	<u>0.189</u>	<u>0.199</u>	<u>0.216</u>	0.143	0.282	0.469	1.232
	MAE	0.358	0.407	0.431	0.437	<u>0.288</u>	<u>0.289</u>	<u>0.295</u>	<u>0.315</u>	0.294	0.420	0.533	0.856
Pyraformer	MSE	0.213	0.262	0.303	0.398	0.501	0.541	0.557	0.596	0.627	1.010	1.227	1.742
	MAE	0.342	0.383	0.415	0.483	0.512	0.532	0.541	0.561	0.639	0.820	0.915	1.134
ETSformer	MSE	0.243	0.296	0.339	0.432	0.243	0.241	0.240	0.252	<u>0.100</u>	0.226	0.434	0.990
	MAE	0.363	0.400	0.430	0.492	0.355	0.352	0.353	0.362	<u>0.252</u>	<u>0.353</u>	<i>0.500</i>	0.821
SCINet	MSE	0.213	0.255	0.287	0.352	0.217	0.299	0.259	0.278	0.209	0.347	0.575	1.378
	MAE	0.341	0.375	0.399	0.449	0.330	0.397	0.365	0.379	0.366	0.475	0.604	0.939
TS2Vec	MSE	0.199	0.240	<u>0.262</u>	<u>0.281</u>	0.357	0.359	0.368	0.380	0.184	0.373	0.666	2.941
	MAE	0.323	0.361	<u>0.384</u>	<u>0.405</u>	0.431	0.433	0.440	0.447	0.315	0.452	0.612	1.313
DLinear	MSE	0.207	0.257	0.293	0.378	0.361	0.309	0.305	0.351	0.118	<u>0.222</u>	<i>0.400</i>	<i>0.837</i>
	MAE	0.336	0.376	0.402	0.470	0.442	0.395	0.392	0.425	0.277	0.382	<u>0.506</u>	<i>0.722</i>
N-HiTS	MSE	<i>0.183</i>	<u>0.227</u>	0.265	0.359	0.284	0.264	0.269	0.298	0.241	0.870	1.809	2.144
	MAE	<i>0.307</i>	<u>0.352</u>	0.384	0.462	0.369	0.354	0.361	0.384	0.372	0.700	1.061	1.152

Table 3: Forecasting results under weather

Methods	Metrics	weather (Multivariate)				weather (Univariate)			
		96	192	336	720	96	192	336	720
GBT-Vanilla	MSE	0.434	0.481	0.514	0.523	<u>0.188</u>	0.221	0.239	0.218
	MAE	0.466	0.506	0.527	0.532	<u>0.318</u>	0.348	0.372	0.349
FEDformer	MSE	0.531	0.601	0.646	0.631	0.236	0.289	0.332	0.335
	MAE	0.525	0.564	0.618	0.597	0.358	0.407	0.431	0.437
Pyraformer	MSE	0.540	0.575	0.593	0.623	0.213	0.262	0.303	0.398
	MAE	0.546	0.567	0.578	0.599	0.342	0.383	0.415	0.483
ETSformer	MSE	0.538	0.615	0.655	0.719	0.243	0.296	0.339	0.432
	MAE	0.521	0.566	0.589	0.624	0.363	0.400	0.430	0.492
SCINet	MSE	0.489	0.526	0.572	0.617	0.213	0.255	0.287	0.352
	MAE	0.495	0.524	0.562	0.586	0.341	0.375	0.399	0.449
TS2Vec	MSE	<u>0.450</u>	<u>0.505</u>	<u>0.532</u>	<u>0.566</u>	0.199	0.240	0.262	<u>0.281</u>
	MAE	<u>0.472</u>	<u>0.515</u>	<u>0.533</u>	<u>0.557</u>	0.323	0.361	0.384	<u>0.405</u>
DLinear	MSE	0.514	0.572	0.597	0.646	0.207	0.257	0.293	0.378
	MAE	0.514	0.553	0.570	0.603	0.336	0.376	0.402	0.470
N-HiTS	MSE	0.488	0.539	0.565	0.628	0.183	<u>0.227</u>	<u>0.265</u>	0.359
	MAE	0.496	0.536	0.555	0.596	0.307	<u>0.352</u>	<u>0.384</u>	0.462