



FPS of Game: Horizon Zero Dawn Multivariate Time Series Analysis

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Outline

- Data Source
- Time Series Plot & CCF => 一階差分
- Model
 - VAR(8) with 5 variables
 - VAR(9) with 3 variables
 - VARMA(6, 1) with 3 variables
- Model Comparison
- Conclusion

Data Source

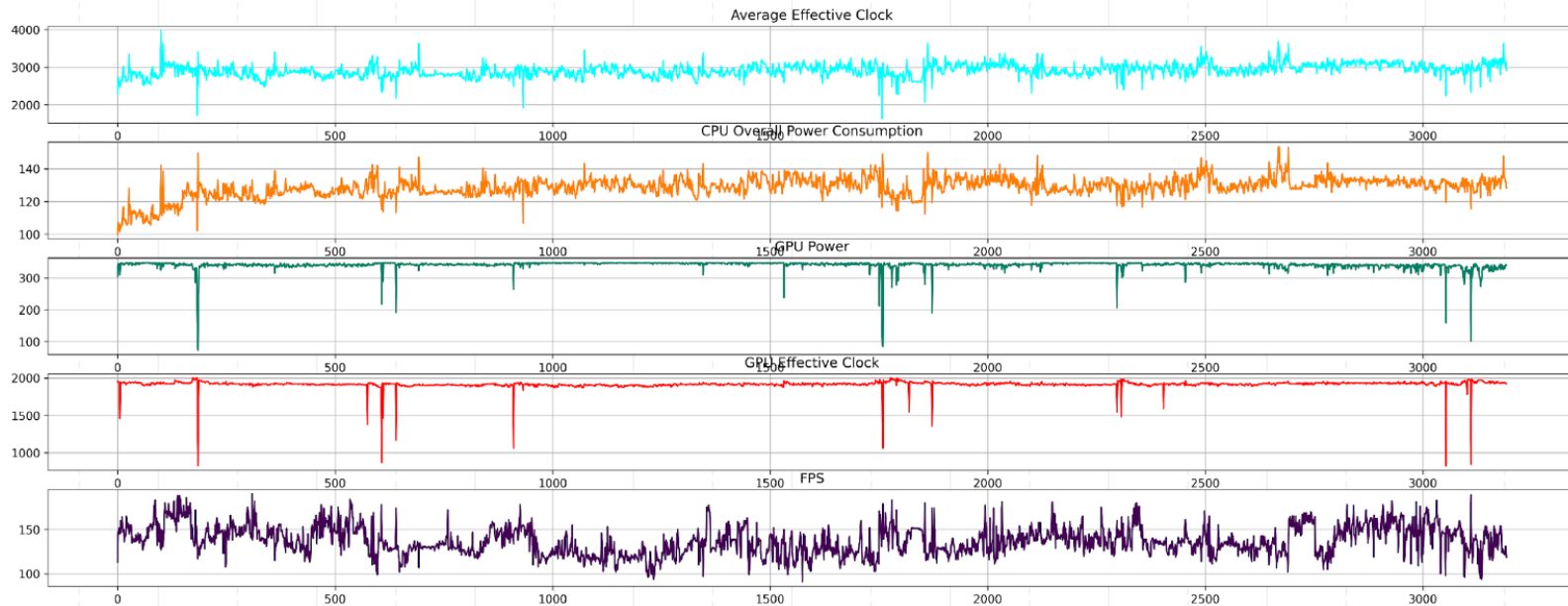
- 監測軟體：HWinfo 
- 來源：遊玩《地平線：期待黎明》時紀錄2K畫質下，特效全開的CPU、GPU時脈和功耗及幀率。
- 時間：每2秒一次，有3193期。
- 訓練資料有2893筆，測試資料有300筆。(約10%)

系統規格

OS	Windows 10 Pro (2009)
CPU型號	11th Gen Intel(R) Core(TM) i7-11700 @ 2.50GHz
GPU型號	NVIDIA GeForce RTX 3080 Ti
GPU驅動程式	512.15 (30.0.15.1215)
RAM大小	32768 MB
VRAM大小	12108 MB

Average Effective Clock(MHz)	CPU Overall Power Consumption(W)	GPU Power(W)	GPU Effective Clock(MHz)	FPS
2295.4	99.895	305.353	1950.3	113
2598.2	104.135	341.418	1941.3	146
2741.5	107.012	345.209	1948.2	147
2660.6	105.918	342.61	1937.2	150
2598.3	103.853	345.456	1936.8	152
2464.6	101.549	309.994	1457.6	145
2593.0	104.649	344.323	1944.0	147
2622.2	105.539	347.015	1937.2	160
2623.1	104.788	346.303	1930.5	155
⋮	⋮	⋮	⋮	⋮

Time Series Plot



ADF Test

p-value: 5.1584×10^{-9}

p-value: 7.5337×10^{-7}

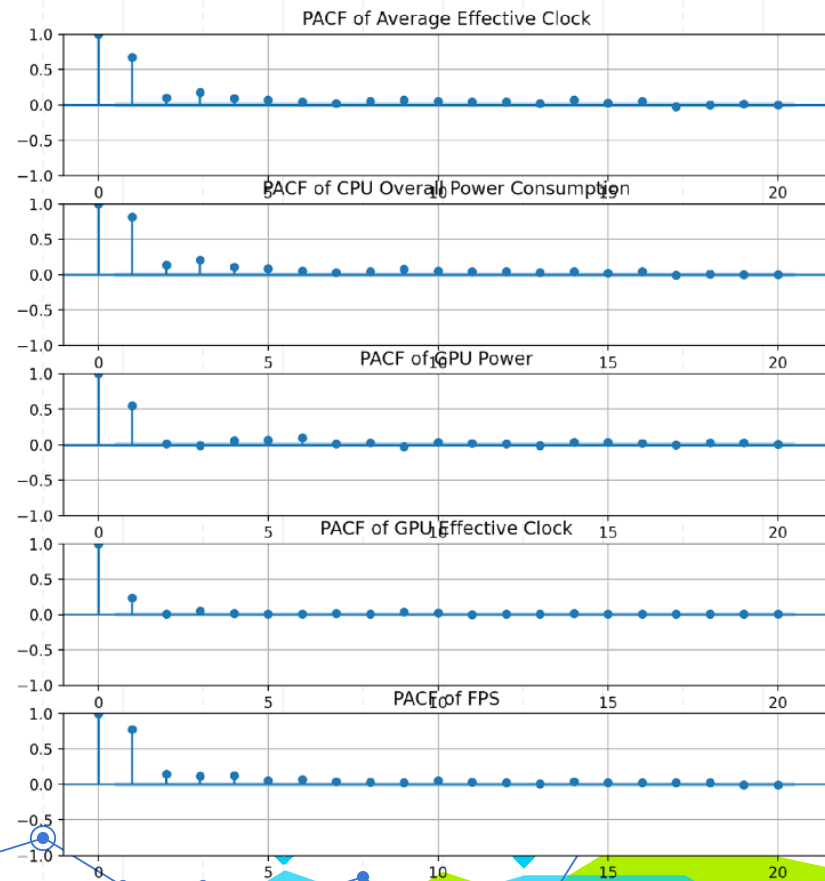
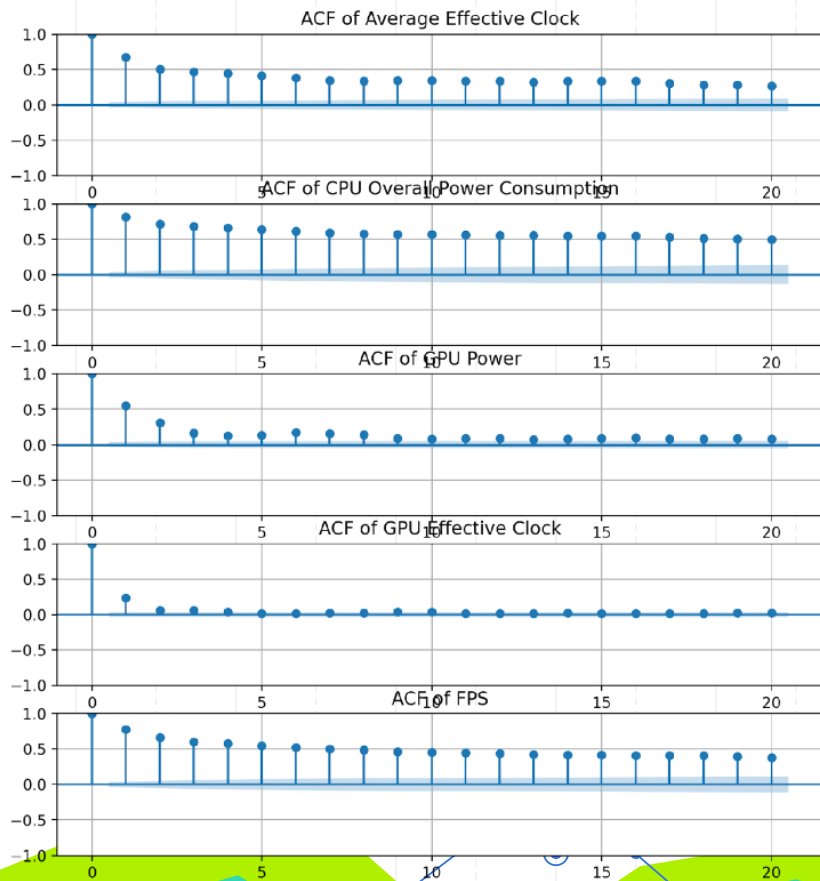
p-value: 6.8367×10^{-13}

p-value: 0.0

p-value: 1.4820×10^{-7}

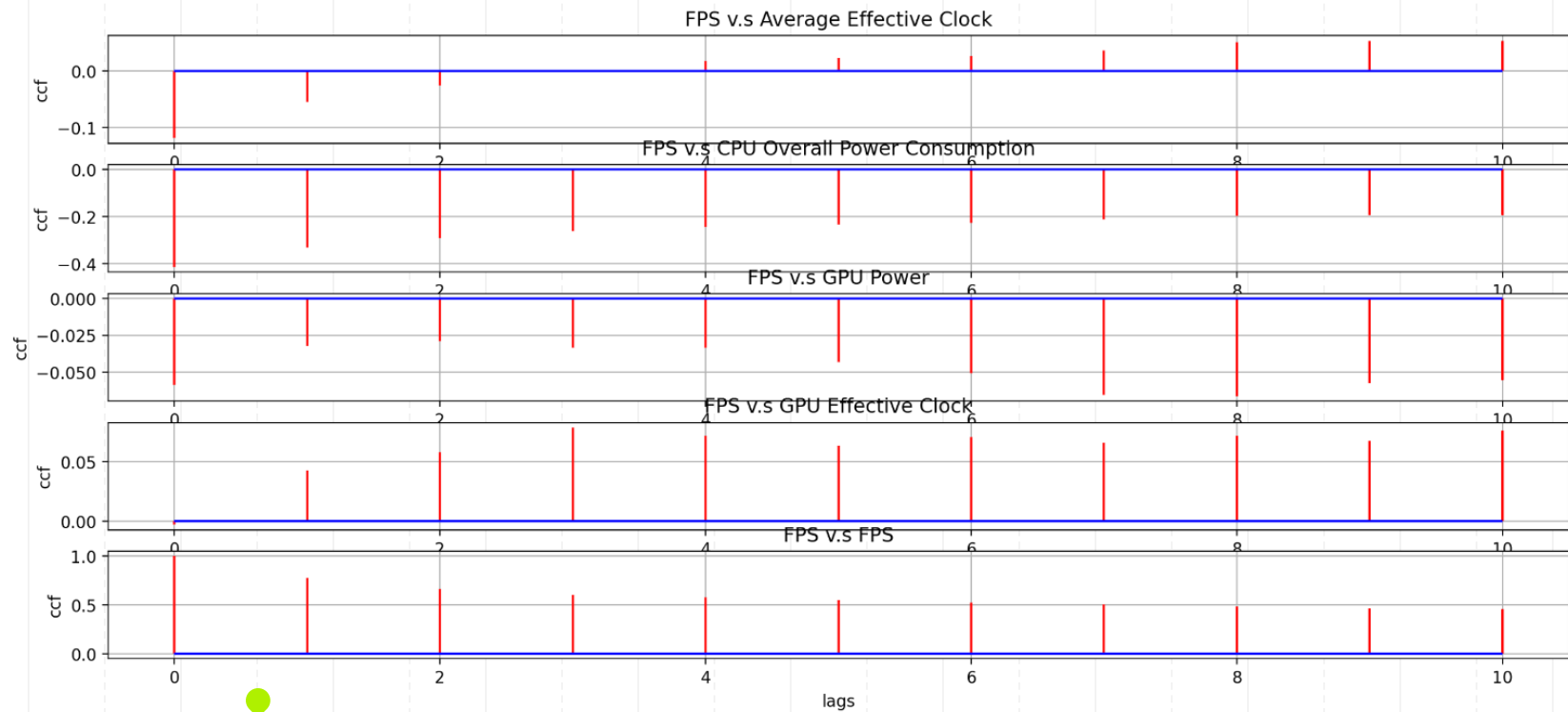


Time Series Plot

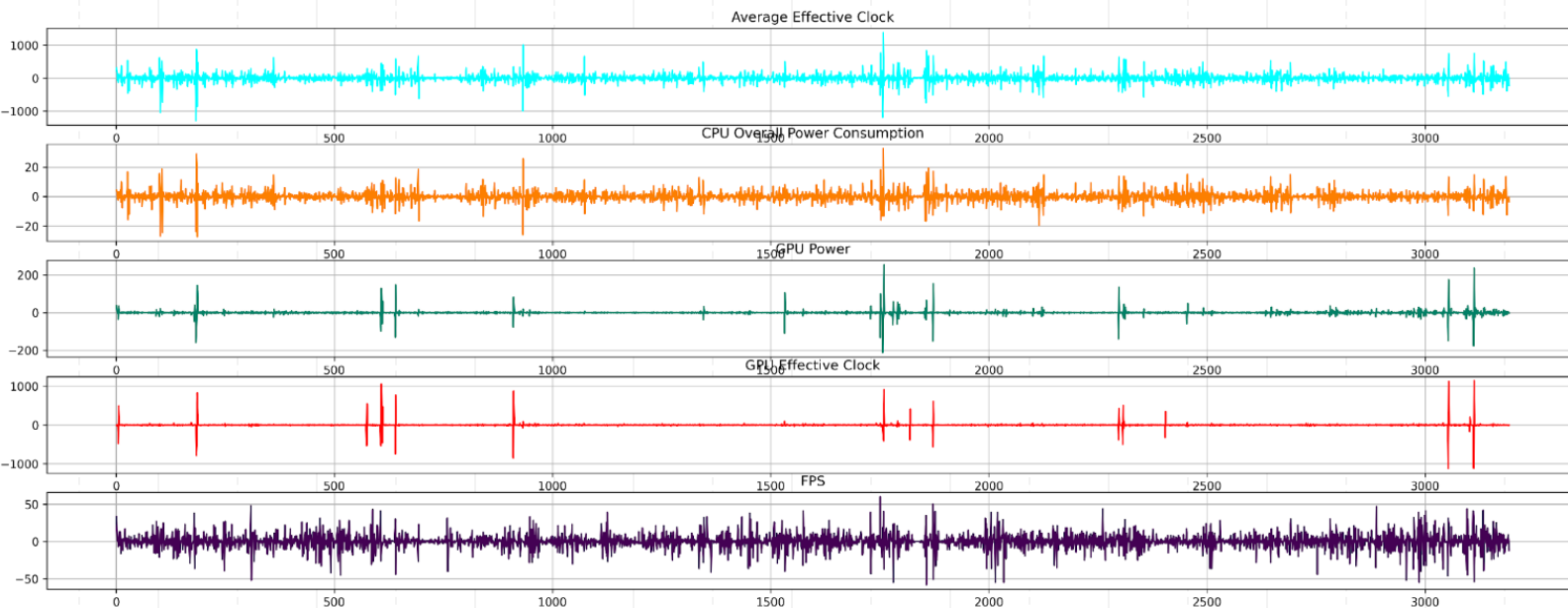


Cross-Correlation Function

Original Data



Time Series Plot



ADF Test

p-value: 6.0683×10^{-29}

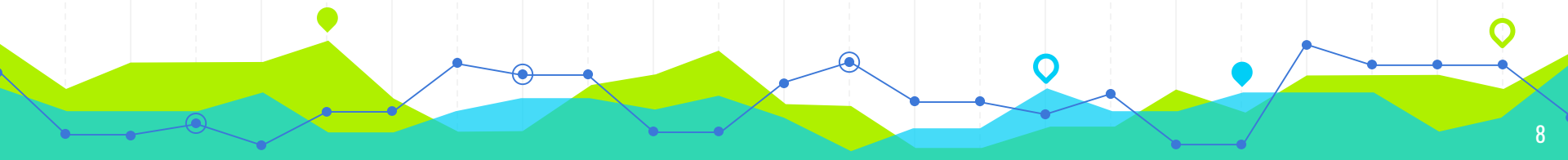
p-value: 1.6066×10^{-28}

p-value: 1.8865×10^{-29}

p-value: 2.0226×10^{-30}

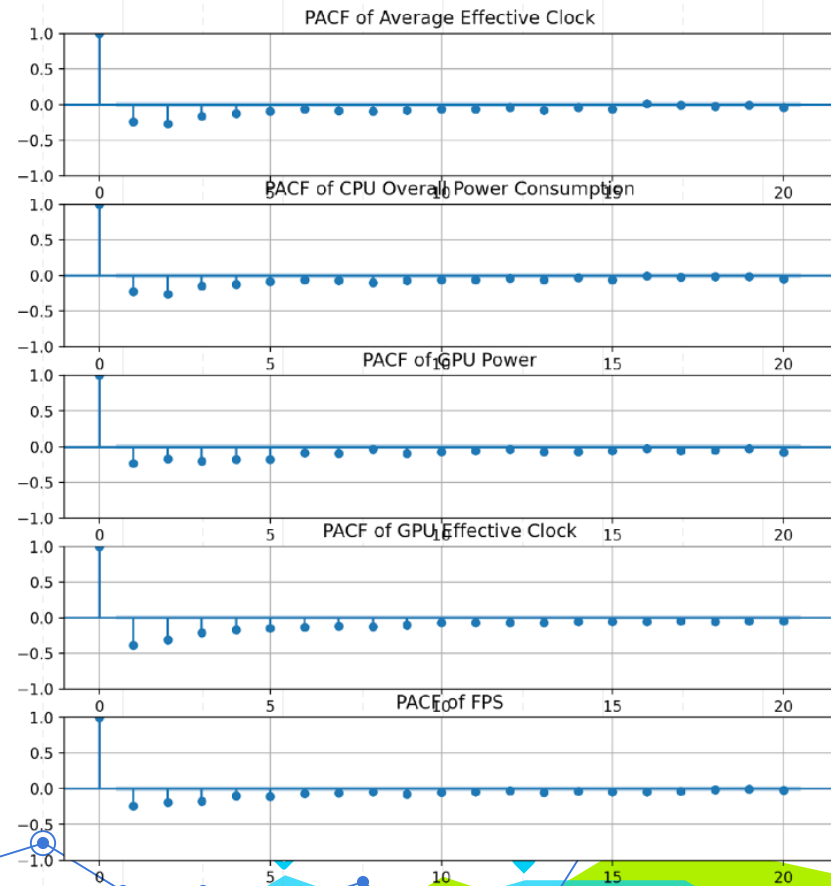
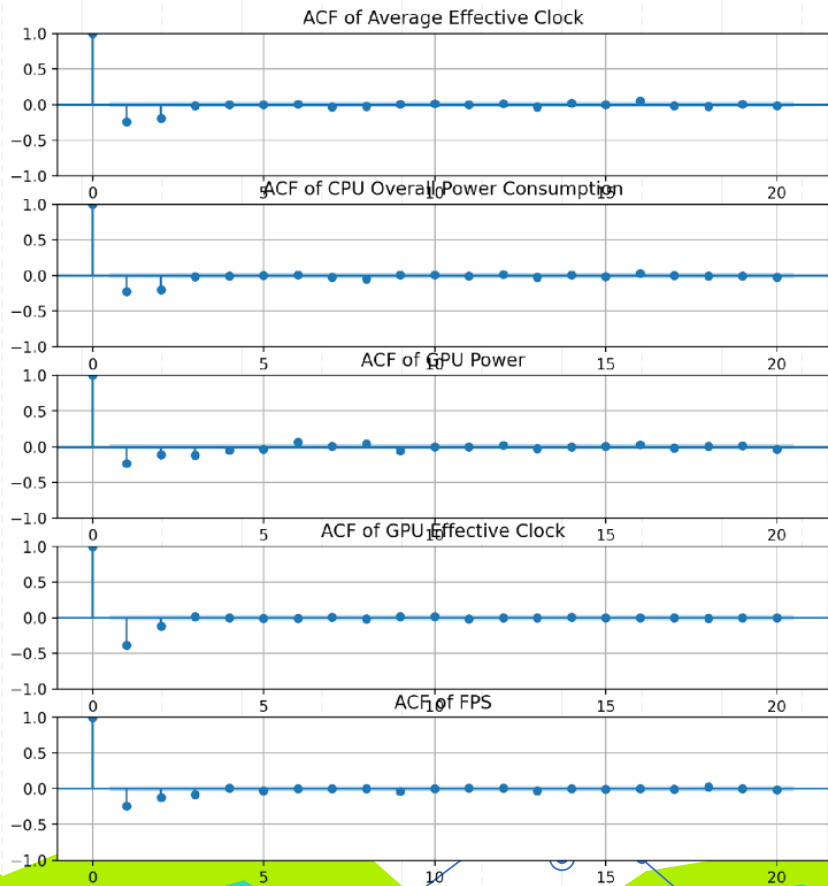
p-value: 0.0

一階差分



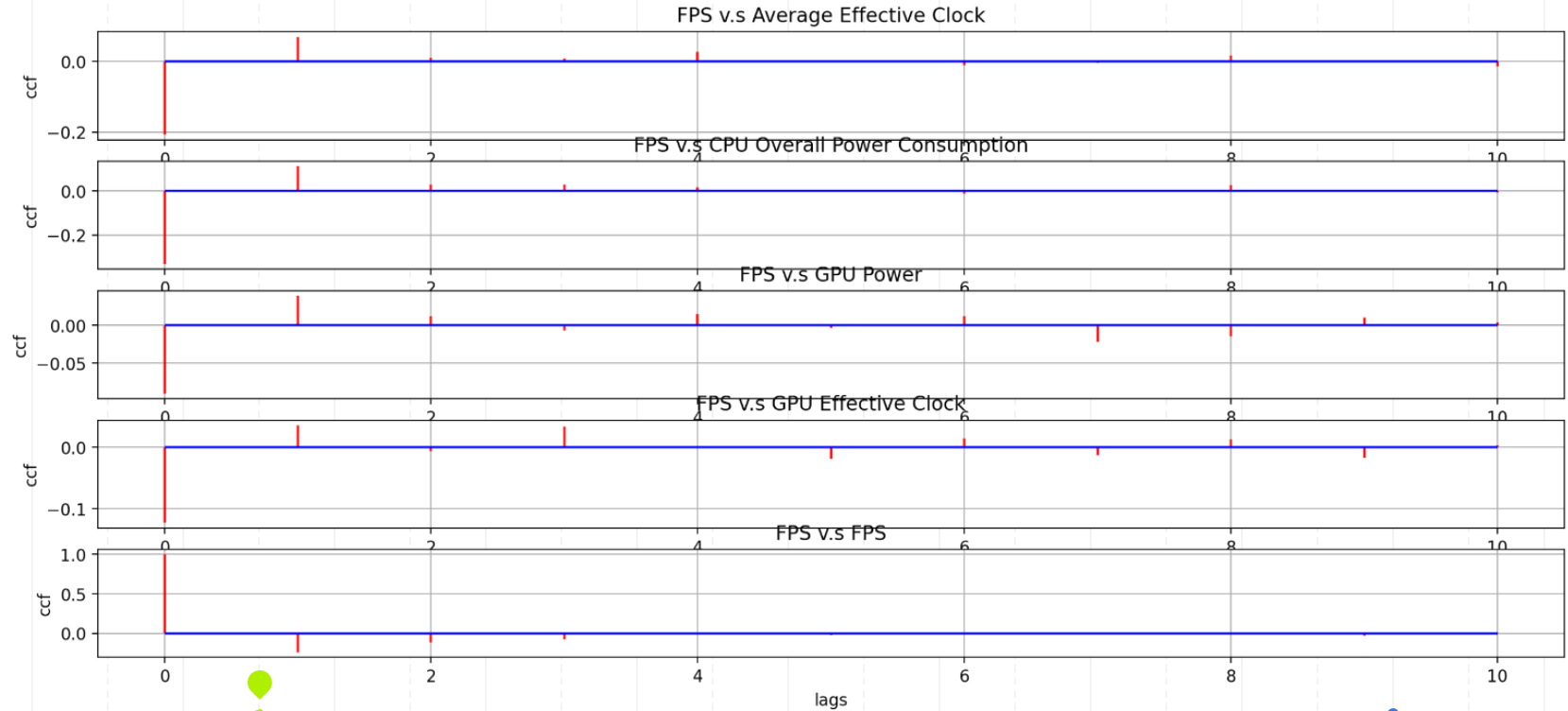
Time Series Plot

一階差分



Cross-Correlation Function

First Order Difference Data

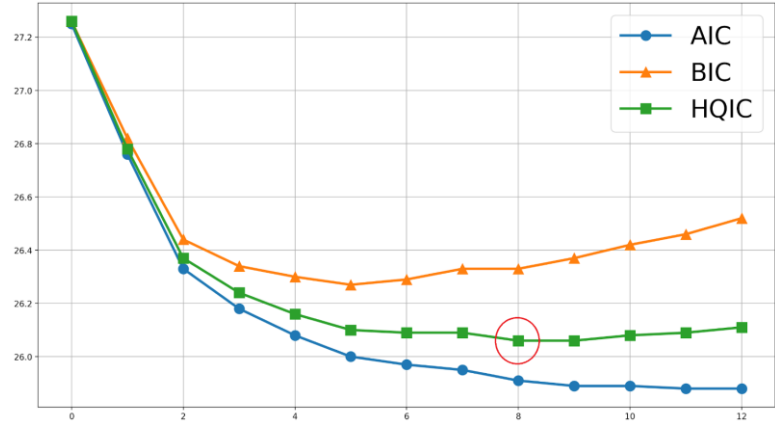


VAR(8) with 5 variables

Summary of Regression Results			
=====			
Model:	VAR		
Method:	OLS		
Date:	Thu, 26, May, 2022		
Time:	21:40:05		

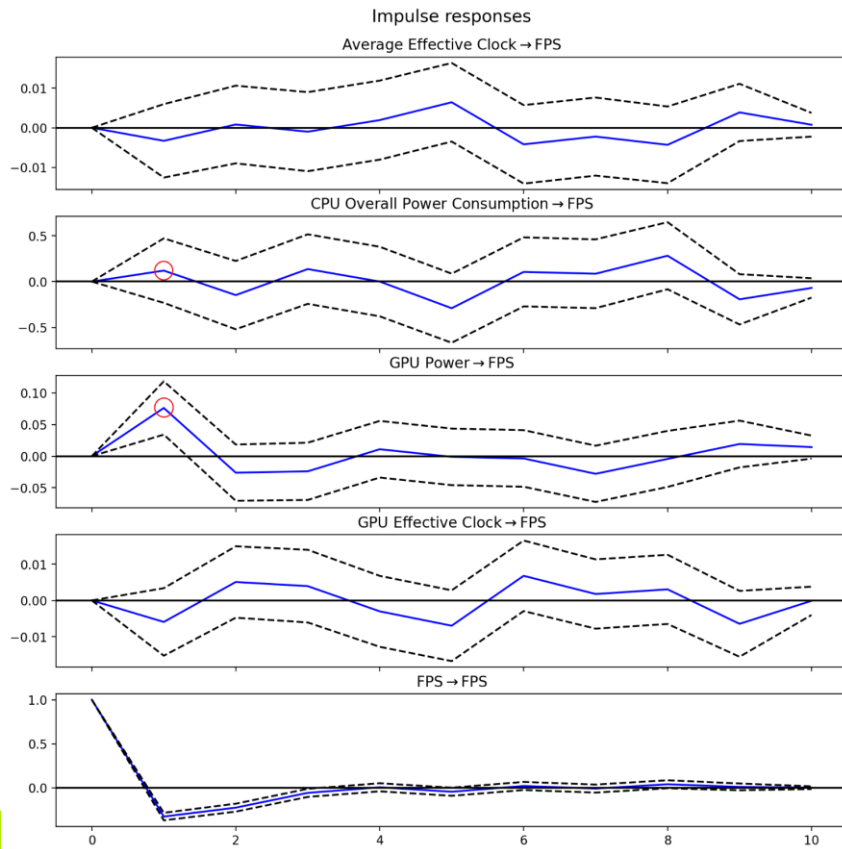
No. of Equations:	5.00000	BIC:	26.3361
Nobs:	2884.00	HQIC:	26.0649
Log likelihood:	-57621.2	FPE:	1.79242e+11
AIC:	25.9120	Det(Omega_mle):	1.67027e+11

VAR Order Selection



Results for equation FPS				
	coefficient	std. error	t-stat	prob
const	0.000439	0.173525	0.003	0.998
L1.Average Effective Clock	-0.003303	0.004721	-0.700	0.484
L1.CPU Overall Power Consumption	0.119734	0.179802	0.666	0.505
L1.GPU Power	0.076344	0.021534	3.545	0.000
L1.GPU Effective Clock	-0.005937	0.004757	-1.248	0.212
L1.FPS	-0.326234	0.021782	-14.977	0.000
L2.Average Effective Clock	-0.001742	0.004999	-0.348	0.728
L2.CPU Overall Power Consumption	-0.056732	0.191571	-0.296	0.767
L2.GPU Power	0.026222	0.024127	1.087	0.277
L2.GPU Effective Clock	0.001356	0.005864	0.231	0.817
L2.FPS	-0.331935	0.024568	-13.511	0.000
L3.Average Effective Clock	-0.003592	0.005136	-0.699	0.484
L3.CPU Overall Power Consumption	0.114385	0.196417	0.582	0.560
L3.GPU Power	0.003481	0.026309	0.132	0.895
L3.GPU Effective Clock	0.006055	0.006776	0.894	0.372
L3.FPS	-0.249058	0.025862	-9.630	0.000
L4.Average Effective Clock	-0.000438	0.005214	-0.084	0.933
L4.CPU Overall Power Consumption	0.044869	0.199210	0.225	0.822
L4.GPU Power	0.024465	0.026793	0.913	0.361
L4.GPU Effective Clock	0.002699	0.006980	0.387	0.699
L4.FPS	-0.165569	0.026262	-6.305	0.000
L5.Average Effective Clock	0.005287	0.005214	1.014	0.311
L5.CPU Overall Power Consumption	-0.220135	0.199210	-1.105	0.269
L5.GPU Power	0.019477	0.026874	0.725	0.469
L5.GPU Effective Clock	-0.003951	0.006969	-0.567	0.571
L5.FPS	-0.164654	0.026347	-6.249	0.000
L6.Average Effective Clock	-0.000019	0.005124	-0.004	0.997
L6.CPU Overall Power Consumption	-0.045930	0.196309	-0.234	0.815
L6.GPU Power	0.021823	0.026362	0.828	0.408
L6.GPU Effective Clock	0.001261	0.006688	0.189	0.850
L6.FPS	-0.106064	0.026031	-4.074	0.000
L7.Average Effective Clock	-0.000774	0.004955	-0.156	0.876
L7.CPU Overall Power Consumption	-0.008578	0.190758	-0.045	0.964
L7.GPU Power	-0.018751	0.025001	-0.750	0.453
L7.GPU Effective Clock	0.003824	0.005861	0.652	0.514
L7.FPS	-0.092470	0.024859	-3.720	0.000
L8.Average Effective Clock	-0.005463	0.004619	-1.183	0.237
L8.CPU Overall Power Consumption	0.277783	0.174231	1.594	0.111
L8.GPU Power	-0.022547	0.022560	-0.999	0.318
L8.GPU Effective Clock	0.008412	0.004734	1.777	0.076
L8.FPS	-0.021593	0.022640	-0.954	0.340

Variable Selection



Granger causality F-test. H_0 : ['Average Effective Clock', 'CPU Overall Power Consumption', 'GPU Power', 'GPU Effective Clock'] do not Granger-cause FPS. Conclusion: fail to reject H_0 at 5% significance level.

Test statistic	Critical value	p-value	df
1.310	1.444	0.113	(32, 14215)

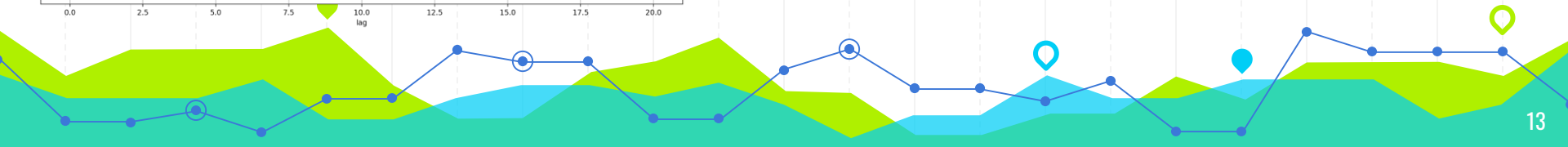
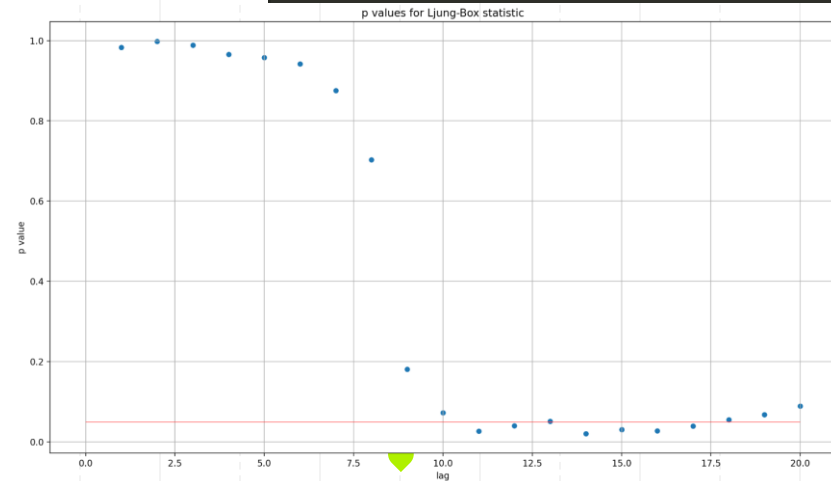
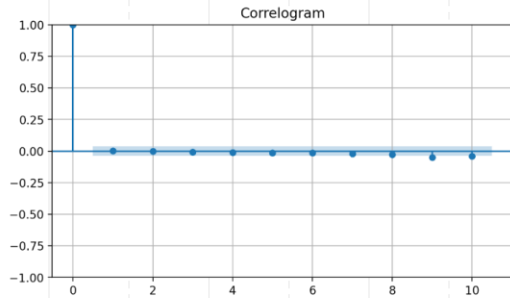
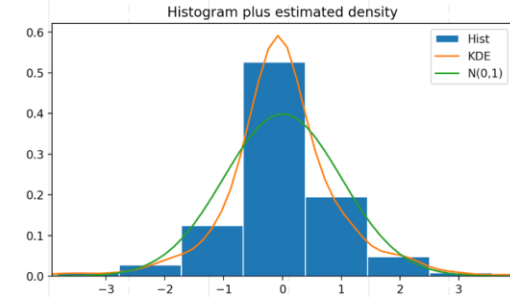
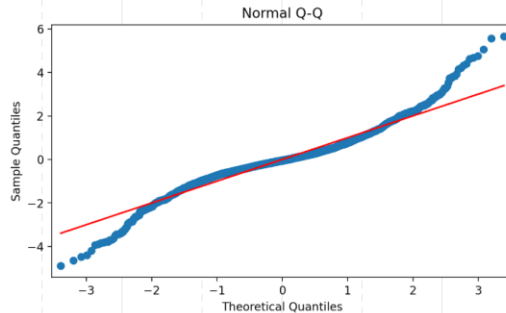
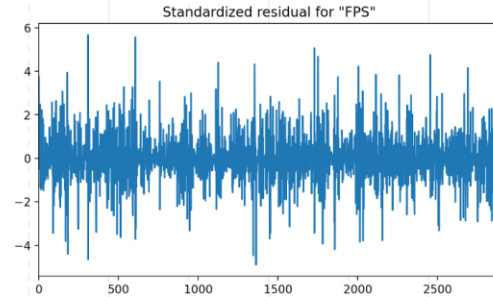
Granger causality F-test. H_0 : ['CPU Overall Power Consumption', 'GPU Power'] do not Granger-cause FPS. Conclusion: reject H_0 at 5% significance level.

Test statistic	Critical value	p-value	df
1.678	1.644	0.043	(16, 14215)

Model Diagnosis of VAR(8) with 5 Variables

Portmanteau-test for residual autocorrelation. H_0 : residual autocorrelation up to lag 10 is zero.
Conclusion: reject H_0 at 5% significance level.

Test statistic	Critical value	p-value	df
262.9	67.50	0.000	50



VAR(9) with 3 variables

Summary of Regression Results

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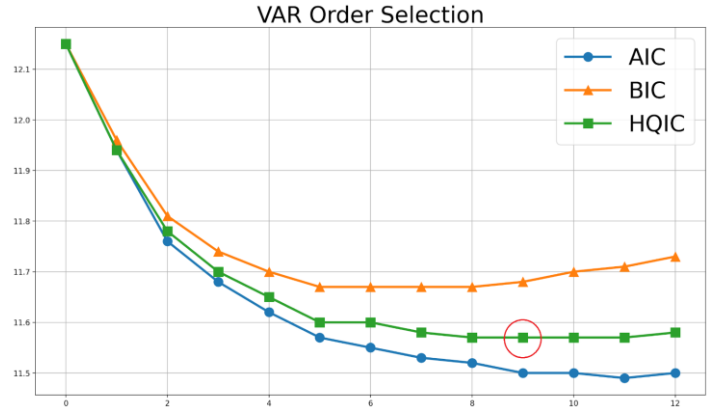
Model:VAR

Method:OLS

Date:Thu, 26, May, 2022

Time:23:53:42

No. of Equations:	3.00000	BIC:	11.6797
Nobs:	2883.00	HQIC:	11.5685
Log likelihood:	-28774.0	FPE:	99291.0
AIC:	11.5058	Det(Omega mle):	96453.3



```
array([[ 1.          ,  0.0899204, -0.38861237],  
       [ 0.0899204,  1.          , -0.11429984],  
       [-0.38861237, -0.11429984,  1.          ]])
```

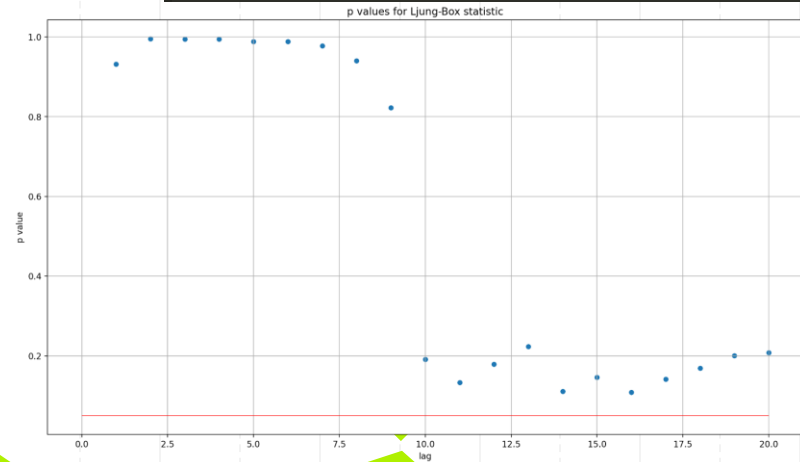
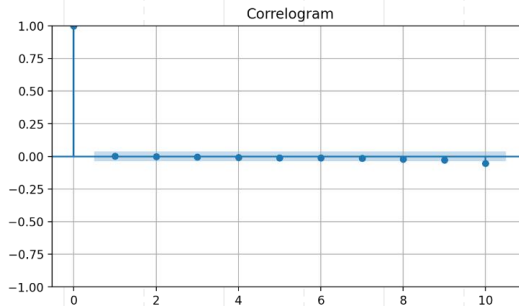
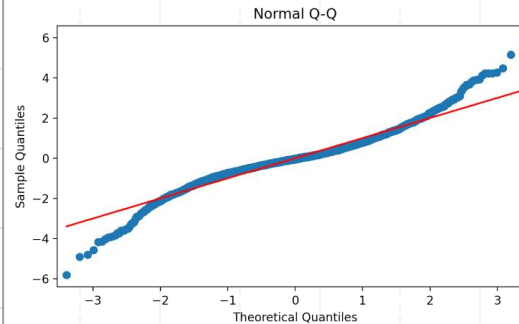
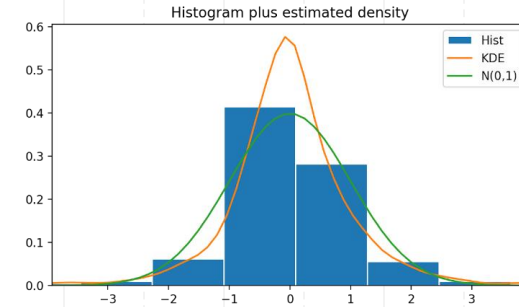
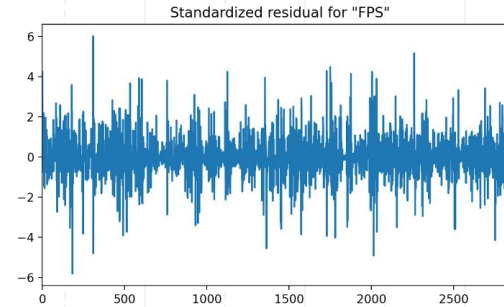
Results for equation FPS				
=====				
	coefficient	std. error	t-stat	prob

const	-0.000059	0.173273	-0.000	1.000
L1.CPU Overall Power Consumption	0.026712	0.060121	0.444	0.657
L1.GPU Power	0.044980	0.014989	3.001	0.003
L1.FPS	-0.331659	0.020370	-16.282	0.000
L2.CPU Overall Power Consumption	-0.090180	0.064923	-1.389	0.165
L2.GPU Power	0.015911	0.016045	0.992	0.321
L2.FPS	-0.339890	0.022388	-15.182	0.000
L3.CPU Overall Power Consumption	0.003891	0.069399	0.056	0.955
L3.GPU Power	0.012410	0.016697	0.743	0.457
L3.FPS	-0.262547	0.023590	-11.130	0.000
L4.CPU Overall Power Consumption	0.044031	0.070683	0.623	0.533
L4.GPU Power	0.035795	0.017300	2.069	0.039
L4.FPS	-0.174830	0.024120	-7.248	0.000
L5.CPU Overall Power Consumption	-0.013810	0.071219	-0.194	0.846
L5.GPU Power	0.019384	0.017491	1.108	0.268
L5.FPS	-0.163461	0.024296	-6.728	0.000
L6.CPU Overall Power Consumption	-0.013920	0.070506	-0.197	0.843
L6.GPU Power	0.022287	0.017320	1.287	0.198
L6.FPS	-0.111963	0.024307	-4.606	0.000
L7.CPU Overall Power Consumption	0.000741	0.069351	0.011	0.991
L7.GPU Power	-0.013434	0.016595	-0.810	0.418
L7.FPS	-0.108320	0.023770	-4.557	0.000
L8.CPU Overall Power Consumption	0.114673	0.064626	1.774	0.076
L8.GPU Power	0.000366	0.015921	0.023	0.982
L8.FPS	-0.045563	0.022657	-2.011	0.044
L9.CPU Overall Power Consumption	0.088168	0.058169	1.516	0.130
L9.GPU Power	0.012324	0.015122	0.815	0.415
L9.FPS	-0.045366	0.020896	-2.171	0.030
=====				

Model Diagnosis of VAR(9) with 3 Variables

Portmanteau-test for residual autocorrelation. H_0 : residual autocorrelation up to lag 10 is zero.
Conclusion: reject H_0 at 5% significance level.

Test statistic	Critical value	p-value	df
83.60	16.92	0.000	9



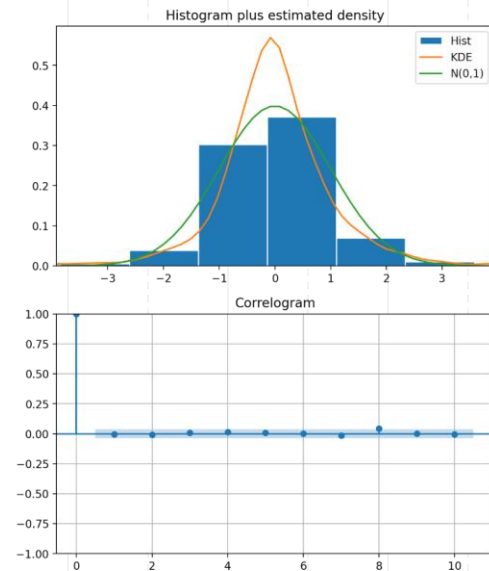
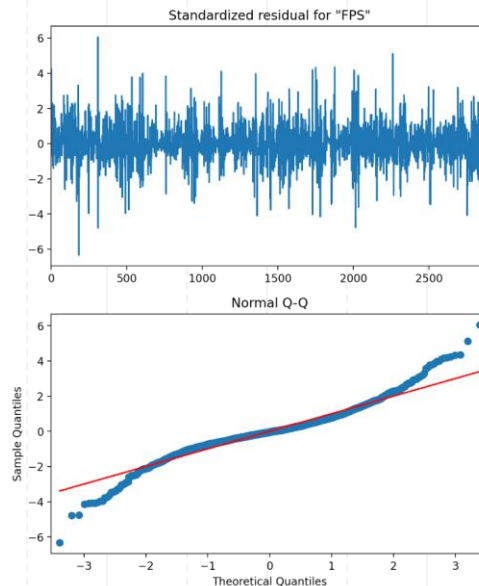
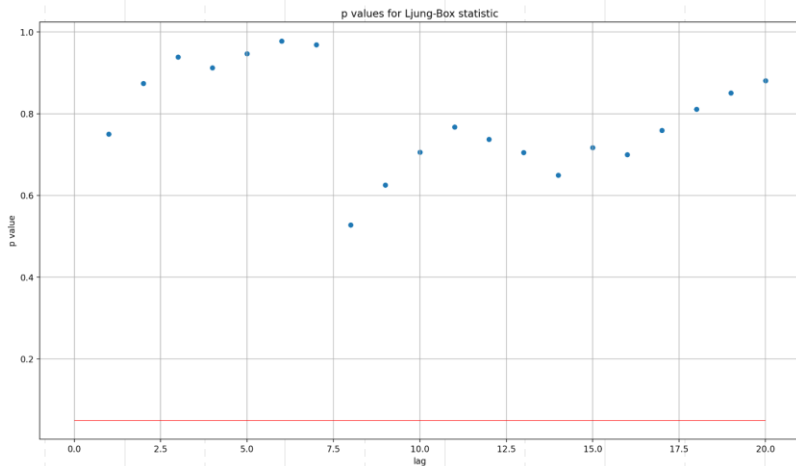
VARMA(6,1) with 3 variables

p-values table of Extended Cross-correlation Matrices:
Column: MA order
Row : AR order

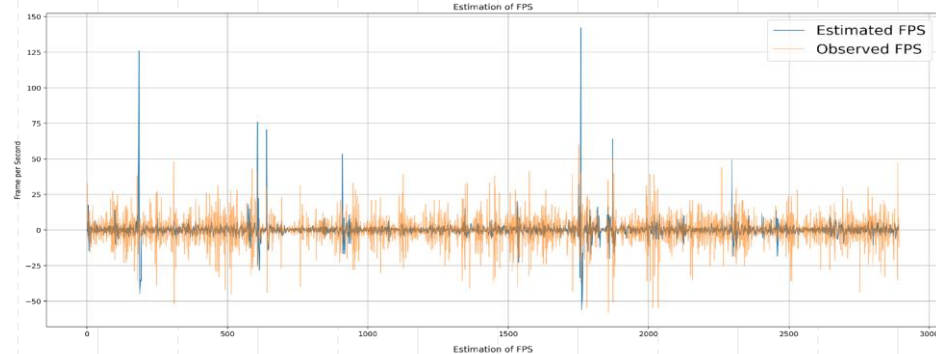
	0	1	2	3	4	5	6	7	8
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007
1	0.0000	0.0000	0.0000	0.0000	0.0033	0.0000	0.0013	0.0000	0.0279
2	0.0000	0.0000	0.0126	0.0015	0.0033	0.0000	0.0475	0.3875	1.0000
3	0.0000	0.0000	0.0067	0.4344	0.0102	0.0456	0.3496	0.9810	0.9998
4	0.0000	0.0000	0.9048	0.2727	0.4395	0.3180	0.0632	0.9217	0.9996
5	0.0000	0.0000	0.7233	0.8814	0.6856	1.0000	0.9024	0.9999	0.9999
6	0.0000	0.0619	0.0603	0.9724	0.9999	0.9991	0.9988	1.0000	1.0000
7	0.0000	0.0000	0.9998	0.9999	1.0000	1.0000	1.0000	1.0000	0.9998
8	0.0002	0.9994	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Results for equation FPS						
	coef	std err	z	P> z	[0.025	0.975]
intercept	0.0058	0.032	0.178	0.859	-0.058	0.069
L1.CPU Overall Power Consumption	0.0505	0.082	0.617	0.537	-0.110	0.211
L1.GPU Power	0.0854	0.016	5.349	0.000	0.054	0.117
L1.FPS	0.5784	0.028	20.412	0.000	0.523	0.634
L2.CPU Overall Power Consumption	-0.0640	0.068	-0.937	0.349	-0.198	0.070
L2.GPU Power	-0.0180	0.020	-0.918	0.359	-0.056	0.020
L2.FPS	-0.0405	0.022	-1.869	0.062	-0.083	0.002
L3.CPU Overall Power Consumption	0.0942	0.072	1.308	0.191	-0.047	0.235
L3.GPU Power	0.0168	0.022	0.775	0.438	-0.026	0.059
L3.FPS	0.0277	0.024	1.166	0.244	-0.019	0.074
L4.CPU Overall Power Consumption	0.0826	0.071	1.162	0.245	-0.057	0.222
L4.GPU Power	0.0209	0.021	0.985	0.324	-0.021	0.063
L4.FPS	0.0421	0.023	1.792	0.073	-0.004	0.088
L5.CPU Overall Power Consumption	4.517e-05	0.074	0.001	1.000	-0.145	0.145
L5.GPU Power	0.0127	0.014	0.914	0.361	-0.015	0.040
L5.FPS	-0.0105	0.024	-0.436	0.663	-0.057	0.037
L6.CPU Overall Power Consumption	0.0923	0.067	1.377	0.168	-0.039	0.224
L6.GPU Power	0.0250	0.015	1.627	0.104	-0.005	0.055
L6.FPS	0.0314	0.021	1.494	0.135	-0.010	0.073
L1.e(CPU Overall Power Consumption)	-0.0187	0.059	-0.316	0.752	-0.135	0.097
L1.e(GPU Power)	-0.0402	0.012	-3.404	0.001	-0.063	-0.017
L1.e(FPS)	-0.9153	0.023	-39.127	0.000	-0.961	-0.869
Error covariance matrix						
	coef	std err	z	P> z	[0.025	0.975]
sqrt.var.CPU Overall Power Consumption	3.0614	0.024	125.111	0.000	3.013	3.109
sqrt.cov.CPU Overall Power Consumption.GPU Power	1.1041	0.167	6.614	0.000	0.777	1.431
sqrt.var.GPU Power	11.3268	0.056	202.250	0.000	11.217	11.437
sqrt.cov.CPU Overall Power Consumption.FPS	-3.4453	0.149	-23.144	0.000	-3.737	-3.154
sqrt.cov.GPU Power.FPS	-0.7529	0.122	-6.147	0.000	-0.993	-0.513
sqrt.var.FPS	8.5170	0.080	106.174	0.000	8.360	8.674

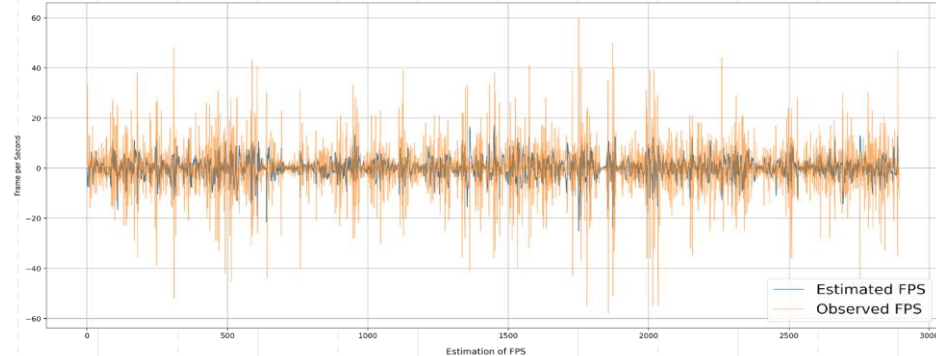
Model Diagnosis of VARMA(6,1) with 3 Variables



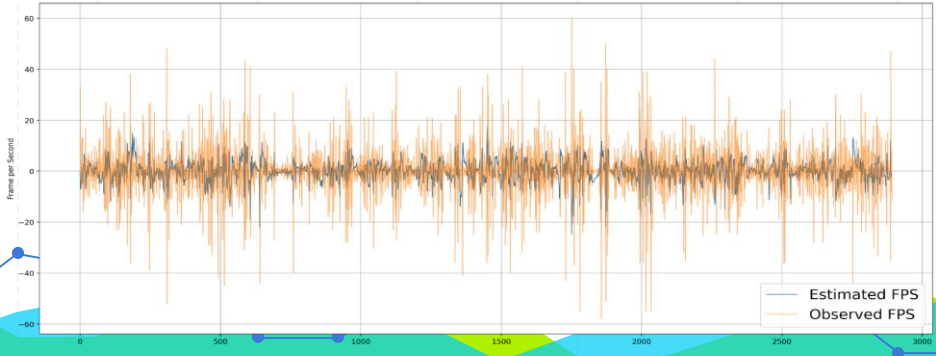
Prediction



VAR(8) with 5 variables

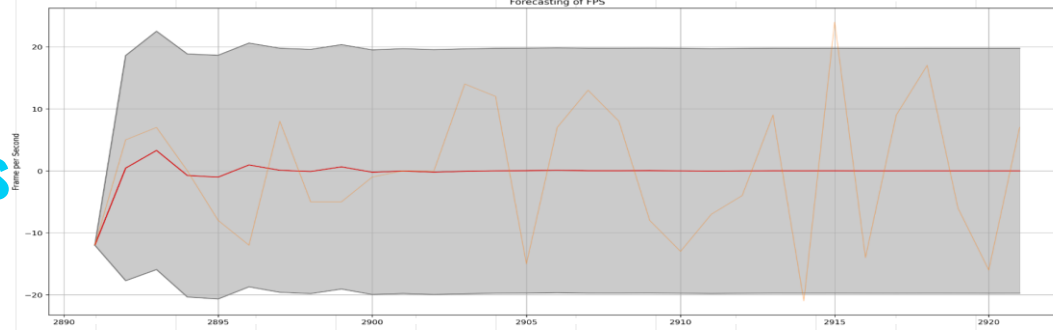


VAR(9) with 3 variables

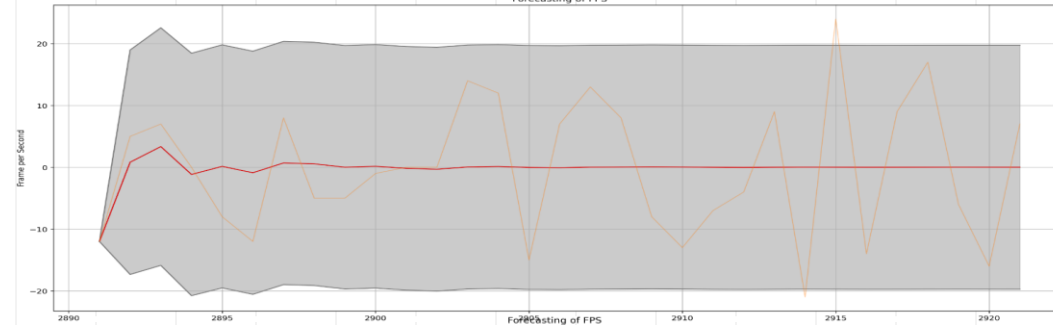


VARMA(6, 1) with 3 variables

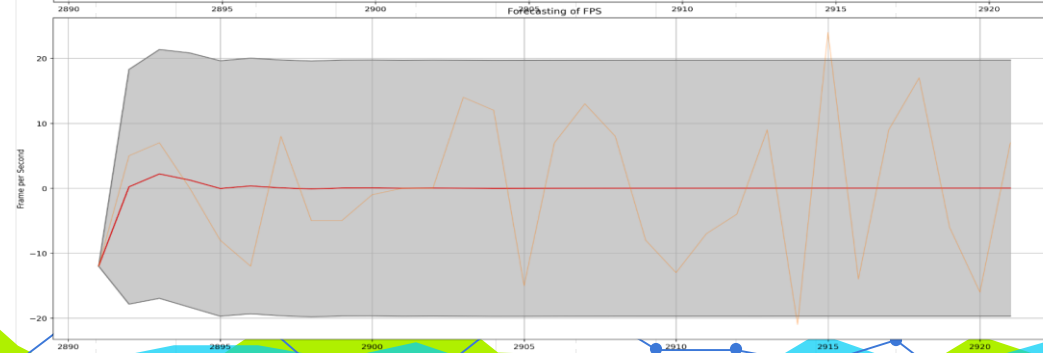
Forecasting 300 samples



VAR(8) with 5
variables



VAR(9) with 3
variables



VARMA(6, 1) with
3 variables

Model Comparison for Forecasting 300 samples

Diebold-Mariano Test with criterion MSE

VARMA(6,1) with 3 variables vs. VAR(8) with 5 variables

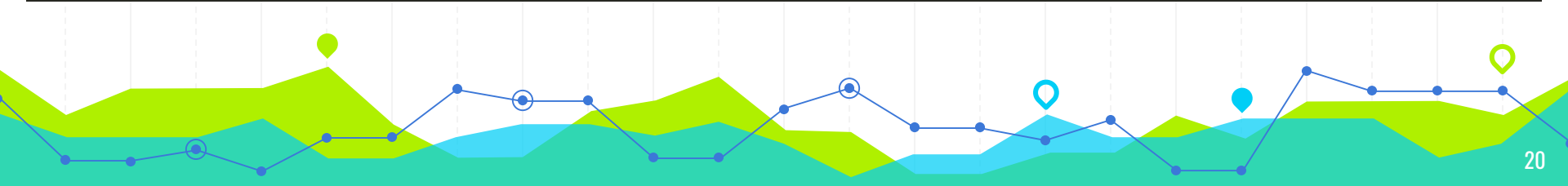
`dm_return(DM=0.7620863469495835, p_value=0.4466091949610975)`

VARMA(6,1) with 3 variables vs. VAR(9) with 3 variables

`dm_return(DM=0.9936717093878844, p_value=0.3211861796172248)`

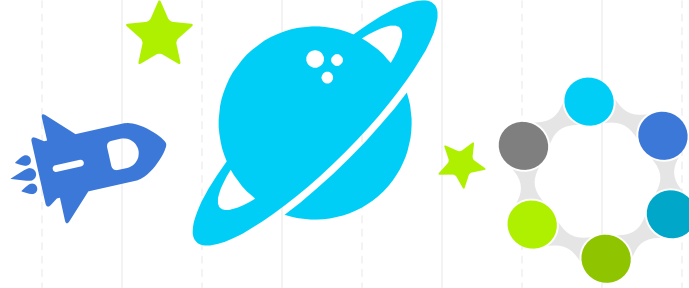
VARMA(6,1) with 3 variables vs. ARMA(1,0,3)

`dm_return(DM=1.390658805497409, p_value=0.16536304987503422)`



Conclusion

- ◎ VARMA(6, 1) with 3 variables : CPU Overall Power Consumption(W)、GPU Power(W)、FPS
 - ◎ CPU 與 FPS 有瞬間負相關，但並沒有顯著動態相關。
 - ◎ GPU 與 FPS 存在動態正相關。
 - ◎ FPS 與 FPS 存在動態負相關。



Thanks

