

Data science methodology for time delay estimation and data preprocessing of the time delay challenge

Table A5. Complete results from Rung 1-lower is better (except column labeled f where higher is better)
Preprocessing: 1) Christiano-Fitzgerald filter, Trend-(CF-Trend); 2) Christiano-Fitzgerald filter, Cycle-(CF-Cycle); 3) Christiano-Fitzgerald filter (CF-Trend/Cycle), combines two components: Trend-(CF-Trend) and Cycle-(CF-Cycle); 4) Differencing; 5) Simple Net Return (SNR); 6) Wavelet Denoising (WD); 7) Raw Data (preprocessing technique was not applied). Time delay estimation methods from COSMOGRAIL: a) D3 Curve Shifting (D3CS); b) Free-Knot Spline Fit (SPL); c) Spline Difference (SDI). Time delay estimation methods employed in this research: I) Dispersion Spectra (DS_1^2); II) Discrete Correlation Function (DCF); III) Locally Normalized Discrete Correlation Function (LNDCF); IV) Interpolated Cross-Correlation Function (ICCF). Selection techniques for Cross-correlation methods: A) Mean (proposed alternative); B) Max, typical selection procedure of estimation.

Methods	Preprocessing	f	χ^2	P	A	MAD	MSE	$RMSE$	$MAPE$	uncertainty	average search length
D3CS		0.655	0.38	0.31	0.12	2.72	26.27	5.13	11.84	6.75	
SDI		0.618	1.66	0.12	0.07	1.51	11.07	3.33	7.55	3.21	
SPL		0.651	0.86	0.08	0.05	1.25	7.56	2.75	4.55	1.82	
DS_1^2	CF-Trend	1.0	3.40	0.39	0.13	2.84	13.65	3.69	13.31	9.21	25.32
DS_1^2	CF-Cycle	1.0	6.82	0.34	0.10	2.45	12.09	3.48	10.05	7.01	17.09
DS_1^2	CF-Trend/Cycle	1.0	1.56	0.37	0.09	2.04	7.26	2.69	8.61	8.11	21.21
DS_1^2	Differencing	1.0	5.39	0.38	0.11	2.49	12.36	3.52	10.62	8.64	17.33
DS_1^2	SNR	1.0	7.30	0.35	0.11	2.54	12.66	3.56	10.83	7.44	17.37
DS_1^2	WD	1.0	6.18	0.29	0.12	2.55	12.05	3.47	12.26	6.64	27.92
DS_1^2	Raw Data	1.0	5.91	0.34	0.11	2.39	10.98	3.31	11.34	7.67	27.60
DCF-Max	Differencing	0.993	1.19	0.28	0.12	2.97	19.53	4.42	12.33	9.21	47.11
DCF-Mean	Differencing	0.993	1.11	0.28	0.09	1.86	7.49	2.74	8.63	9.21	43.37
DCF-Max	Raw Data	0.998	4.22	0.48	0.22	4.79	33.86	5.82	22.13	13.73	49.36
DCF-Mean	Raw Data	0.998	4.02	0.48	0.14	2.68	11.57	3.40	14.25	13.73	44.31
DCF-Max	WD	0.996	1.84	0.49	0.24	5.38	39.20	6.26	24.24	14.29	46.68
DCF-Mean	WD	0.996	1.72	0.49	0.16	2.95	13.16	3.63	15.52	14.29	37.48
DCF-Max	SNR	0.995	2.35	0.47	0.24	5.21	37.89	6.16	23.98	13.86	46.99
DCF-Mean	SNR	0.995	2.23	0.47	0.16	2.88	12.93	3.60	15.77	13.86	36.92
DCF-Max	CF-Trend	0.990	1.69	0.49	0.24	5.43	39.66	6.30	24.97	14.47	47.32
DCF-Mean	CF-Trend	0.990	1.58	0.49	0.15	2.95	13.38	3.66	15.25	14.47	37.97
DCF-Max	CF-Cycle	0.986	1.38	0.46	0.22	5.07	37.08	6.09	22.64	13.65	47.24
DCF-Mean	CF-Cycle	0.986	1.26	0.46	0.13	2.68	11.42	3.38	13.49	13.65	36.09
DCF-Max	CF-Trend/Cycle	0.996	0.81	0.48	0.18	3.85	21.77	4.67	18.60	13.99	47.17
DCF-Mean	CF-Trend/Cycle	0.996	0.74	0.48	0.12	2.18	7.64	2.76	12.42	13.99	36.98
LNDCF-Max	Differencing	0.978	0.73	0.29	0.10	2.70	16.95	4.12	10.39	9.49	48.98
LNDCF-Mean	Differencing	0.978	0.66	0.29	0.07	1.73	6.50	2.55	7.16	9.49	46.13
LNDCF-Max	Raw Data	0.999	1.02	0.37	0.14	3.16	19.08	4.37	14.48	11.16	53.93
LNDCF-Mean	Raw Data	0.999	0.77	0.37	0.09	1.81	6.17	2.48	9.30	11.16	52.71
ICCF-Max	Differencing	0.998	7.83	0.24	0.23	5.43	39.40	6.28	23.39	6.71	62.30
ICCF-Mean	Differencing	0.998	7.64	0.24	0.19	4.25	25.32	5.03	18.98	6.71	41.99
ICCF-Max	Raw Data	0.993	5.87	0.29	0.29	6.94	55.46	7.45	29.14	7.62	74.60
ICCF-Mean	Raw Data	0.993	4.60	0.29	0.18	4.01	20.05	4.48	17.64	7.62	46.60
MIX-DS_1^2 with CF-Trend/Cycle and LNDCF-Mean with Differencing		1.0	0.16	0.34	0.06	1.42	3.72	1.93	6.27	8.81	33.31