LOS data reduction process

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0.0.1 Method

The differential evolution(DE) algorithm is used in LOS data reduction. The DE estimator is designed to solve non-linear problem and used widely. Detail information can be founded at the website:\
http://www1.icsi.berkeley.edu/~storn/code.html. Some applications of DE algorithm can be found on this site. The valuable advantage of this method is that the problem to be solved can be parallel coded and the algorithm is robust.

0.0.2 data process

while calling de estimator the parameters variation range and value function $y(t) = f(c0, c1, c2..., t)$ is needed. in los data reduction process the value function ls(data block i):

$$y_i(t) = (c_4 + c_5 t)cos(c_0 + c_1 t + c_2 t^2 + c_3 t^3) \tag{1}$$

where c_{1-4} are the coefficients of phase polynomial which is expanded at data block center. c_4 is the signal amplitude and c_5 is slope of amplitude(when amplitude is stable c_5 is not necessary). so at any time within data block signal phase and frequency can be expressed as

$$\begin{aligned} \phi_i(t) &= c_0 + c_1 t + c_2 t^2 + c_3 t^3 \\ f_i(t) &= c_1 + 2c_2 t + 3c_3 t^2 \end{aligned} \tag{2}$$

at border of data block phase and frequency can be calculated as:

$$\begin{aligned} \phi_i(\text{left}) &= \text{mod}(c_0 - c_1 + c_2 - c_3, 2\pi) \\ \phi_i(\text{right}) &= \text{mod}(c_0 + c_1 + c_2 + c_3, 2\pi) \\ f_i(\text{left}) &= c_1 - 2c_2 + 3c_3 \\ f_i(\text{right}) &= c_1 + 2c_2 + 3c_3 \end{aligned} \tag{3}$$

at beginning(data block 1) parameters variation range can be determined by short time fft technique. after process is running the variation of parameters will be automatic locked by software. in data process the variation of c_0 is set as $0 \sim 2\pi$

0.0.3 Sample of data regression

A sample of data regression is like:

	UTC time	c_0	c_1	c_2	c_3	c_4	c_5	total_phase	RSS	data quality index
	2013-12-28T19:24:38	6.102	146782.529							
block1(center)	2013-12-28T19:24:39	5.670	146566.029	-108.151807	0.066	4728.3	6.7	293132.189	3424636.172	1
	2013-12-28T19:24:40	2.563	146349.922							
	2013-12-28T19:24:40	2.585	146349.721							
block2(center)	2013-12-28T19:24:41	3.319	146133.984	-107.928933	-0.040	4713.0	-18.4	292267.887	3417344.713	1
	2013-12-28T19:24:42	1.824	145918.005							
	2013-12-28T19:24:42	1.831	145918.155							
block3(center)	2013-12-28T19:24:43	4.412	145702.273	-107.838436	0.068	4721.2	-10.5	291404.683	3425031.927	1
	2013-12-28T19:24:44	4.946	145486.801							
	2013-12-28T19:24:44	4.933	145486.642							
...	2013-12-28T19:24:45	3.474	145271.151	-107.703009	0.028	4749.4	-2.9	290542.359	3427429.823	1
	2013-12-28T19:24:46	0.237	145055.830							
	2013-12-28T19:24:46	0.238	145055.809							
...	2013-12-28T19:24:47	1.568	144840.493	-107.600678	0.038	4710.2	2.9	289681.063	3423038.571	1
	2013-12-28T19:24:48	1.325	144625.406							
	2013-12-28T19:24:48	1.316	144625.163							

2013-12-28T19:24:49	5.865	144410.414	-107.439969	-0.044	4725.1	-35.5	288820.741	3419870.188	1
2013-12-28T19:24:50	2.878	144195.403							
2013-12-28T19:24:50	2.893	144195.292							
2013-12-28T19:24:51	4.936	143980.762	-107.331095	-0.044	4726.0	-0.9	287961.436	3424449.594	1
2013-12-28T19:24:52	5.946	143765.968							
2013-12-28T19:24:52	5.962	143766.015							
2013-12-28T19:24:53	5.951	143551.478	-107.244130	0.016	4711.1	-4.7	287102.989	3424489.034	1
2013-12-28T19:24:54	5.081	143337.038							
2013-12-28T19:24:54	5.106	143337.164							
2013-12-28T19:24:55	3.608	143122.853	-107.113158	0.028	4710.5	-5.7	286245.762	3419445.809	1
2013-12-28T19:24:56	1.512	142908.711							
2013-12-28T19:24:56	1.497	142908.715							
2013-12-28T19:24:57	5.237	142694.705	-106.952688	0.035	4709.9	2.9	285389.480	3418848.526	1
2013-12-28T19:24:58	2.417	142480.904							
2013-12-28T19:24:58	2.437	142480.624							
2013-12-28T19:24:59	5.570	142267.018	-106.825240	-0.015	4682.0	6.7	284534.007	3433902.863	1
2013-12-28T19:25:00	2.398	142053.323							
2013-12-28T19:25:00	2.423	142053.323							
2013-12-28T19:25:01	5.553	141839.818	-106.749860	0.002	4723.8	-62.4	283679.639	3425058.105	1
2013-12-28T19:25:02	2.529	141626.323							
2013-12-28T19:25:02	2.587	141626.269							
2013-12-28T19:25:03	6.124	141413.148	-106.594540	-0.023	4695.7	21.3	282826.251	3425182.622	1
2013-12-28T19:25:04	3.818	141199.891							
2013-12-28T19:25:04	3.844	141200.026							
2013-12-28T19:25:05	2.070	140986.908	-106.466701	0.062	4712.0	-4.5	281973.938	3411485.204	1
2013-12-28T19:25:06	0.992	140774.159							

Output file give the information of six coefficients at the center data block time tag and the frequency(rad/s) and phase(Eq.3) at border. Details output at center of data block time tag :

UTC time	c_0	c_1	c_2	c_3	c_4	c_5	total_phase	RSS	data quality index
2013-12-28T19:33:49	1.472	44310.955	-79.659	0.004	4923.0	-9.5	88621.918	3438906.417	1

Total phase is the phase change in data block:

$$\phi_i(total) = \text{UnMod}[\phi_i(\text{left}) - \phi_i(\text{right})] \tag{4}$$

0.0.4 Phase and frequency continuity check at block border

From the data regression sample we can see the phase (Mod) and frequency are continuous with small noise