

Signal Analysis of a Three Axis Aircraft Stabilized Platform

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Keywords: Stabilized Platform, noise signal analysis, Multimedia Signal Processing.

Abstract. When an aircraft is on a steady flight, there exists a series of jamming signals, which are detected and recorded by the airborne equipment. By analyzing those signals, the design of a stable platform controller of the aircraft in feed-forward form will be improved. During the analysis of stable flight in time domain, the frequencies of those signals are roughly fetched. Those frequencies are proved to be right through the method in frequency domain. Based on correctness of the precious, the amplitude of those signals are got by the method of Area rule. The phases of those signals will be calculated by the method of correlation. Pairwise compress the composite signal, the simulation match the original signal well.

Introduction

stabilized platform

As is shown in figure 1, a stabilized platform is widely used in the zone of enemy investigation, target location, attack collation, photograph and effect evaluation. The aim of stabilized platform is to isolate external disturbance. Thus the position of the platform can stay the same.



Figure 1: A sample use of stabilized platform

As is showed in picture 2(a), the whole stabilized platform system mainly consists controller, position sensor, three actuating mechanisms and three stories frame structure. The position sensor consists three micromechanical gyroscopes, and three acceleration sensors. Micromechanical gyroscope is used as the feedback element of velocity-loop, and acceleration sensor serves as the feedback element of position loop. Actuating mechanism is realized by DC servo motor. From picture 2(b), the loops of three-axis stabilized platform are azimuth loop, roll loop and pitch loop. The cross point of three axis is immovable. DC servomotors drive the rotors move, and then act on the three loops.

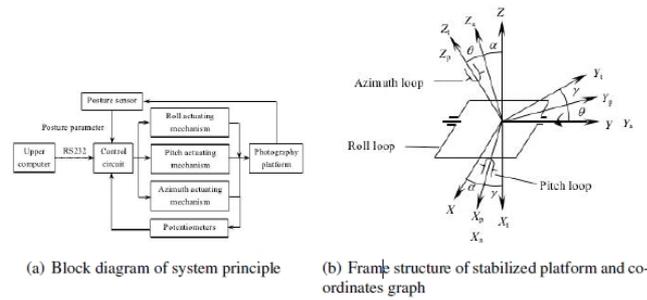


Figure 2: Basic principle of the platform

noise signal

Noise is a factor that influences the stability of the platform, which will impact the development of aerial photograph and robot vision, etc. The analysis of signals will promote the develop of controllers design for the platform. In the work [1], the telemetry signal is usually single channel signal. And when analyzing the time series of the flight test process, it takes the stationary stage signal as the reference noise, and uses it to process the feature stage signal for noise cancellation, which means the method doesn't fit our more complicated situation. In the work [2], basic principle and method of wavelet and wavelet packet analysis are elaborated. On this background, it introduces the general method steps of making a de-noising for signal by using of wavelet packet method. But, the noise signal existing in our stabilized platform is continuous. In the work [3], it searches the optimal frequency shift. But the white noise is continuous. In the work [17], it analyzed multi-source noise components and studies the partial correlation analysis. When the noise signals can't be canceled, the method won't work. In the work [4], it just analyzes the additive white Gaussian noise. In the work [5], the frequencies of the signals have been given. So, it can fit our situation when the signals frequencies are unknown.

In this article, we combine time domain and frequency domain to confirm the element of the signal roughly, use the method of area proportion to confirm the amplitude, and confirm the phase position by means of co-correlation. Without changing the original signal, the composite signal mixed with white noise matches well, which proves the method we use is right.

Data analysis

Through MATLAB, the data recorded during the flight will be analyzed in time domain. By analyzing the figure 3, we cut the data into three phase: launch (0s-620s), stable stage (620s-2652s), landing (2652s-4056s).

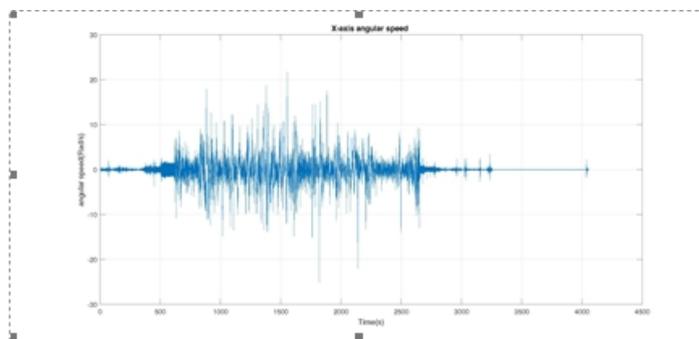


Figure 3: X-axis angular speed

Here, as is showed in figure 4, we dispose the 'stable stage' alone.

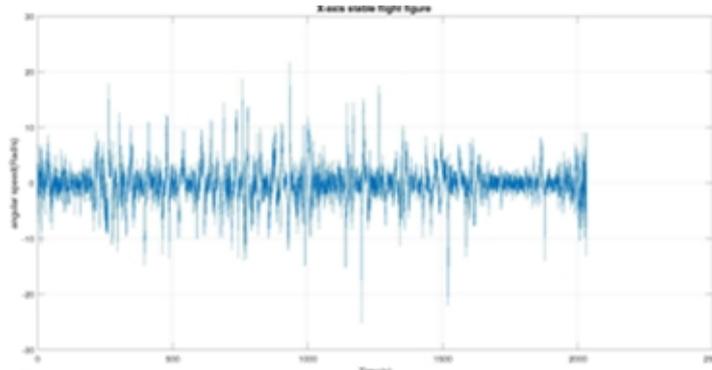


Figure 4: X-axis stable flight figure

signal decomposition

By observing and magnifying the figure above in time domain, we can analyze the signal consists of a series of sinusoidal signals. Based on this, we estimate the frequency of the sinusoidal signals roughly by magnifying the angular rate graphic of the stable stage.

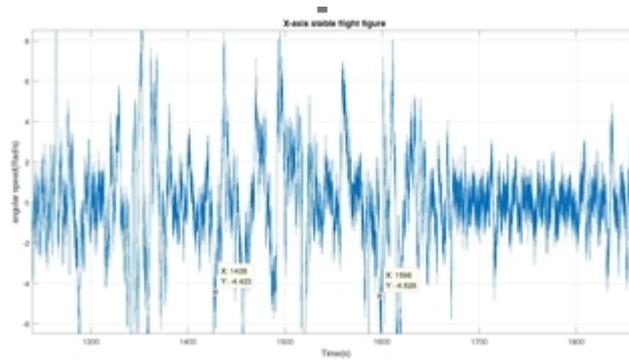


Figure 5: sample of means to get frequency

As showed in figure 5, there exist some sinusoidal signals. During the marked time, we can calculate a kind of sinusoidal signal including 5 periods. So, the frequency is:

$$f = \frac{1}{T} = \frac{1}{\frac{1306 - 1015}{9}} \text{ Hz} = 0.03 \text{ Hz} \quad (1)$$

Through this method, we can get other frequency of the signals 0.62Hz - 18.5Hz.

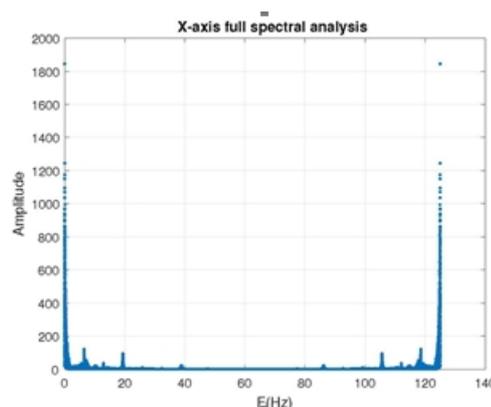


Figure 6: X-axis full spectral analysis

From the picture 6, it shows that there exists a signal of 0.03Hz, which matches the precious result. Also, the signal intensity below 1Hz is powerful. So we consider that there exist some low-frequency sinusoidal signals between 0.03Hz and 1Hz, which have the similar strength and the frequency equals to 0.4Hz.

So, here is the list of the signals:

decrement signals
 0.03Hz
 0.4Hz a series of signals
 6.47Hz
 12.93Hz
 19.4Hz
 38.8Hz
 47.65Hz

amplitude A calculation

Assume that equation 2 is a *sin* signal including frequency of 0.03Hz, whose envelope line with *x*-axis produce an area around 0.03Hz recorded as s_1 ; while equation 3 process Fourier transform in sampling frequency of 125Hz, and the area is marked as s_0 .

$$y_1 = A \sin(2\pi 0.03t + j_2) \tag{2}$$

$$y_2 = A \sin(2\pi 0.03t) \tag{3}$$

then

$$A = \frac{s_1}{s_2} \quad A = 0.2371$$

We can calculate the other frequencies' A by using the same method.

<i>f</i>	<i>A</i>	<i>x</i> (<i>n</i>)
0.03	0.1558	$0.1558 \sin(2\pi \times 0.03t)$
0.4	0.0582	$0.0582 \sin(2\pi \times 0.4t)$
6.47	0.1002	$0.1002 \sin(2\pi \times 6.47t)$
12.93	0.0093	$0.0093 \sin(2\pi \times 12.93t)$
19.4	0.0664	$0.0664 \sin(2\pi \times 19.4t)$
38.8	0.0089	$0.0089 \sin(2\pi \times 38.8t)$
47.65	4.7824×10^{-5}	$4.7824 \times 10^{-5} \sin(2\pi \times 47.65t)$

calculation j

relevance proof of a conclusion

If, two sequence as shown in equation 4, while $h_x(n)$ and $h_y(n)$ are two independent noise signals.

$$\begin{aligned}x(n) &= s_1(n) + h_x(n) = a \cdot e^{j(wn+q_x)} + h_x(n) \\y(n) &= s_2(n) + h_y(n) = b \cdot e^{j(wn+q_y)} + h_y(n)\end{aligned}\quad (4)$$

Introducing reference signal $z(n) = e^{jwn}$ mutually correlates $x(n)$ and $y(n)$ respectively.

$$r_{xz}(n) = E[x(n)z(n)] = E\{[s_1(n) + h_x(n)]z(n)\} = E\{s_1(n)z(n) + h_x(n)z(n)\} = r_{s_1z}(n) + r_{h_xz}(n) \quad (5)$$

In equation 5, $h_x(n)$ is independent of $z(n)$. Thus

$$r_{h_xz}(n) = 0$$

then

$$r_{xz}(m) = r_{s_1z}(m) = E[a \cdot e^{-j(wm+q_x)} e^{jwm}] = a \cdot e^{-jq_x} \quad (6)$$

therefore

$$r_{yz}(m) = r_{s_2z}(m) = E[b \cdot e^{-j(wm+q_y)} e^{jwm}] = b \cdot e^{-jq_y} \quad (7)$$

By combining equations 6 and 7

$$\frac{r_{yz}(m)}{r_{xz}(m)} = \frac{b}{a} e^{j(q_x - q_y)}$$

then,

$$q_x - q_y = \arg \frac{r_{yz}(m)}{r_{xz}(m)} \quad (8)$$

Application in our case

let $f = 0.03\text{Hz}$ for instance, there will be

$$x(n) = 0.1558 \sin(2\pi \times 0.03t) + h(t)$$

$h(t)$ is a noise signal.

$$y(n) = 0.1558 \sin(2\pi \times 0.03t) + d(t)$$

in which, the sampling time of $y(n)$ is 0.008s. The average value of white noise $d(t)$ is 0, the variance of it is 0.000003.

$$z(n) = \sin(2p \times 0.03t)$$

then

$$j = -0.0933$$

We can find the j of other signals through the same method.

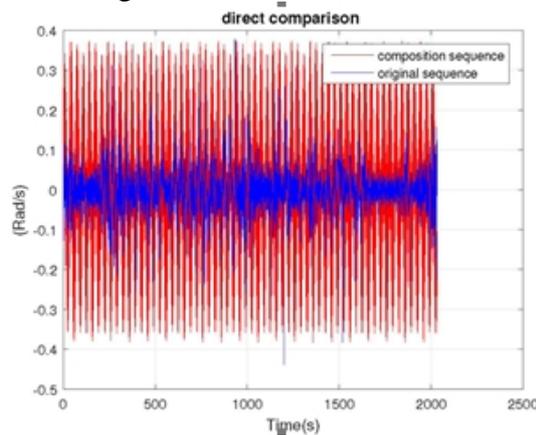
verification

$$\begin{aligned} x_1 &= 0.1558 \sin(2p \times 0.03t - 0.0933) \\ x_2 &= 0.0582 \sin(2p \times 0.4t - 0.0571) \\ x_3 &= 0.1002 \sin(2p \times 6.47t - 0.0933) \\ x_4 &= 0.0093 \sin(2p \times 12.93t - 0.000024051) \\ x_5 &= 0.0664 \sin(2p \times 19.4t - 0.000033886) \\ x_6 &= 0.0089 \sin(2p \times 38.8t - 0.0000082362) \\ x_7 &= 0.0000047824 \sin(2p \times 47.65t + 0.000000047182) \end{aligned} \tag{9}$$

let

$$x = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + u \tag{10}$$

In equation 9, the average of white noise u is 0, the variance of it is 0.000003. The comparison between composite signal and the original one is below:



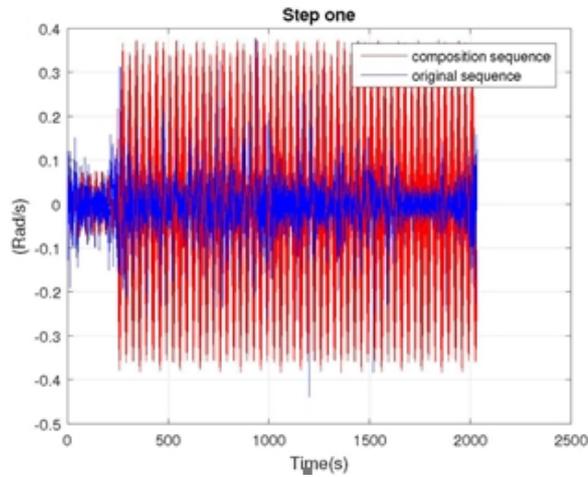
So we consider subsection process of the signal. The coefficient of compressibility is below:

	time sharing stage	duration	coefficienty
one	0 - 250	250s	0.2
two	250 - 1675	1425s	0.4
three	1675 - 1850	175s	0.1
four	1850 - 2032	182s	0.2

Now, the verification will be done step by step.

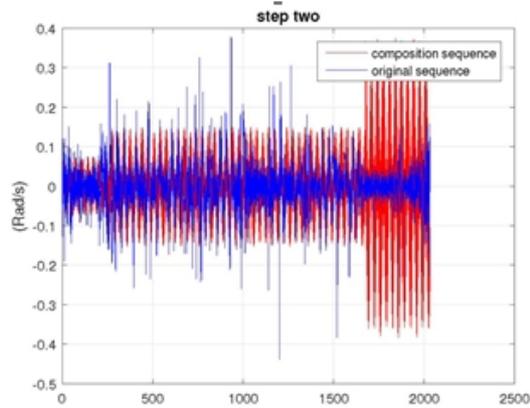
During step one, we multiply stage 0-250s with 0.2, the rest holds on.

$$x_{T_1} = 0.2x_{t_1} + x_{\Delta 1}$$



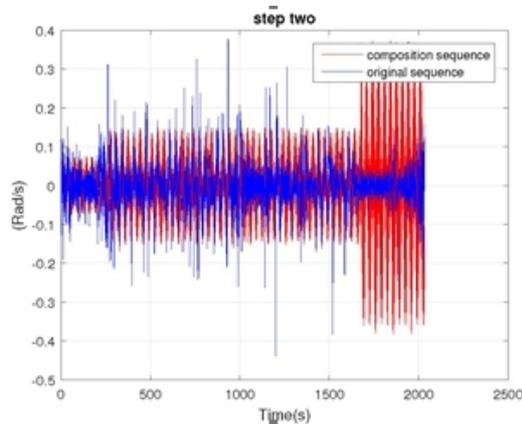
During step two, based on step one, stage 250s-1675s multiplies 0.4. The rest hold on.

$$x_{T_2} = 0.2x_{t_1} + 0.4x_{t_2} + x_{\Delta 2}$$



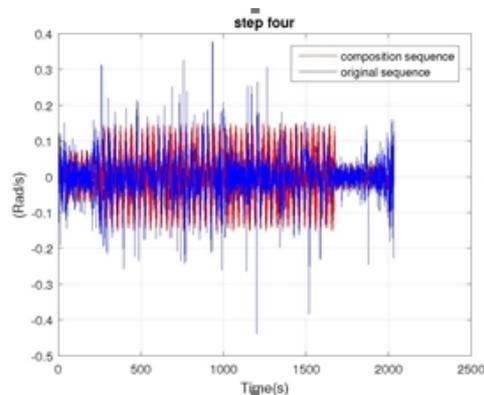
During step three, based on step two, stage 1675s-1850s multiplies 0.1, the rest holds on.

$$x_{T_3} = 0.2x_{t_1} + 0.4x_{t_2} + 0.1x_{t_3} + x_{\Delta 3}$$



During step four, based on step three, stage 1850s-2032s multiplies 0.2, and we finally get:

$$x_T = 0.2x_{t_1} + 0.4x_{t_2} + 0.1x_{t_3} + 0.2x_{t_4}$$



Thus we verify the correction of the method.

Conclusion

In this article, we propose a method that how to analyze a complex noise signal in a useful way. This method is more effective when used in most engineering applications these don't need high accuracy. Our further study will be focused on how to improve the accuracy of the method.

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