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System Identification-Different Techniques

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Abstract:- Engineering applications require description of the dynamic behavior of the system. Though a no. of applications are known in the field of system identification, three techniques are considered for the identification of linear system. Different techniques are frequency chirp, coherence function and pseudoinverse. In chirp method, wideband excitation such as frequency chirp is used. Frequency response is obtained as the DFT of the output of the system for time-domain input. Inverse method uses SVD function to find pseudoinverse. Coherence function has been used to identify the system using MATLAB function tfestimate. The performances of the methods are demonstrated by means of experimental investigation.

Keywords:- System Identification, SUT, Pseudoinverse, Coherence, Frequency chirp.

I. INTRODUCTION

System identification[1] is a powerful tool in engineering. Its various methods in the frequency and in the time domain have extensively discussed in CISM courses [2]. It deals with the problem of identifying a model describing some physical system by measuring the response of the system. This is done by designing the input signal, which is applied to the system [3], whereas output is taken as impulse response of system. Input signal is used for excitation. In this paper identification has been achieved by basic approaches as variable frequency signal (chirp), coherence function and pseudo inverse.

II. SYSTEM IDENTIFICATION

A suitable system is considered for the application at hand. Then a special input signal is designed such that the system captures the behavior of the system to be modeled. Then an identification experiment is carried out in which Input and output signals are measured. An identification method is selected to estimate the parameters that describe the system from the collected input and output measurements. Finally, the validity of the obtained system is evaluated. An important step in system identification is the determination of the type of system to be used. This decision is based on knowledge of the system under consideration, and on the properties of the system. The methods are presented here below :-

A. Chirp method

Dirac impulse can be used to excite the SUT and output will be impulse response function denoted as h(). The Dirac impulse ('delta function') is not truly a function at all, but a 'unit mass' abstraction [4, p. 5]: The Dirac impulse ('delta function') having infinite amplitude at the point at which its argument is zero, is infinitely narrow and has unity integral over time. In the discrete-time case, we can attempt to approximate this function by an input that changes amplitude entirely within one sampling period, i.e., by a Kronecker delta appropriately scaled in amplitude. In practice, however, this approximation is unlikely ever to be entirely satisfactory. Hence, other wideband input excitations (e.g., band limited white noise, frequency chirp) are sometimes used.

To avoid such difficulties, assuming a causal system, the impulse response function of the SUT can be recovered from the (sampled) output signal {y(n)} for a (sampled) input signal {x(n)} of any general form by the following recursive equation, obtained directly from the convolution-sum:

$$h(n) = \frac{y(n) - \sum_{k=1}^{n-1} h(k)x(n-k)}{x(0)} \qquad (1)$$

However, round-off errors accumulate with larger time indices, making this approach impractical for slowly decaying (i.e., infinite) impulse response functions.

B. Inverse fitering

The transformed-domain approach determines the SUT impulse response function by inverse filtering the output signal by the input signal as $H(z) = Y(z)X^{-1}(z)$. The inversion operation may lead to an unstable inverse filter with no unique Realization. System Identification by inverse filtering requires computation of the (pseudo)inverse of X(z). If the system is assumed casual, then the form of the (p+1)×(s+1) matrix is :

$$X = \begin{bmatrix} x(0) & x(1) & x(2) & . & . & x(s-1) & x(s) \\ 0 & x(0) & x(1) & . & . & x(s-2) & x(s-1) \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & . & x(0) & x(s-p+1) \\ 0 & 0 & 0 & . & . & 0 & x(s-p) \end{bmatrix}$$

where the output sequence has s+1 samples and the impulse response is estimated at p+1 points with p = s.

C. Coherence

For a linear system, the coherence function is given as

$$C_{xy}(\omega_k) = \frac{S_{xy}(\omega_k)}{\sqrt{S_{xx}(\omega_k)S_{yy}(\omega_k)}} \qquad (2)$$

where $S_{xy}(\omega_k)$ is the input-output cross-spectrum (i.e., the power spectrum of the cross-correlation between the input and output functions), and $S_{xx}(\omega_k)$ and $S_{yy}(\omega_k)$ are the power spectra of the autocorrelations of the input and output, respectively. The function $C^2_{xy}(\omega_k)$ can be interpreted as the fraction of the mean square value of y(n) that can be attributed to the component of the input x(n) at frequency ω_k . Usually, pseudorandom noise is used as an input x(n). The two identification methods, direct and inverse, then estimate the system response as

$$H_1(\omega_k) \approx \frac{S_{xy}(\omega_k)}{S_{xx}(\omega_k)} \qquad (3)$$

$$H_2(\omega_k) \approx \frac{S_{yy}(\omega_k)}{S_{xy}(\omega_k)}$$

where $H_1(\omega_k)$ tends to underestimate the true $H(\omega_k)$ and $H_2(\omega_k)$ tends to overestimate it. Generally, $H_1(\omega_k)$ gives a good estimate of the system response near anti-resonances but $H_2(\omega_k)$ gives maximal error near anti-resonances. Conversely, $H_2(\omega_k)$ gives a good estimate of the system response near resonances whereas $H(\omega_k)$ gives maximal error near resonances.

III. RESULTS AND DISCUSSION

The identification of Chebyshev IIR,10th order with 20db ripple have been examined. Both finite and infinite impulse responses can be identified too. Identification of IIR systems is generally more difficult than FIR systems. Chebyshev filters are more difficult to identify because they have a sharper cutoff than **B**utterworth filters.

A. Chirp method

Identification can be achieved using a wideband excitation such as frequency chirp (swept sinusoid). Frequency response is obtained as the Discrete Fourier Transform of the output of the system for such a time-domain input. For low pass filter responses, this method works well but a chirp signal has poor high frequency content and this affects the identification. Below fig. shows the identification of the chebyshev high pass filter response by using the DFT and a chirp signal.

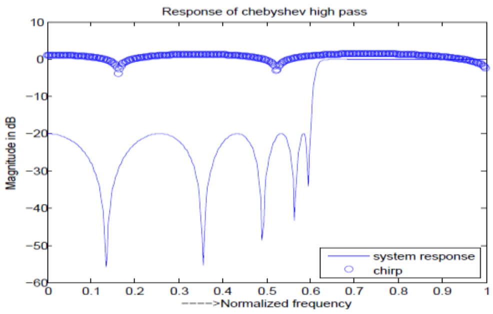

Fig 1 : Frequency response of chebyshev high pass filter identified by the chirp method

B. Inverse method

The pseudoinverse is found by singular value decomposition using MATLAB function svd. The input excitation for the SVD identification was a pseudorandom sequence of length 1000 samples (truncated to 512 points for subsequent FFT processing to find the system function). SVD minimizes the squared error between the output sequence and the convolution of the input with the identified system response. Figure shows the comparison of the wavelet based method with time-domain SVD for our example Chebyshev high-pass filter. The SVD used here reduces its rank based on discarding 1% of the data variance (comparable to the added noise). However, this takes quite a long time to perform (several minutes with a Sun Ultrasparc).

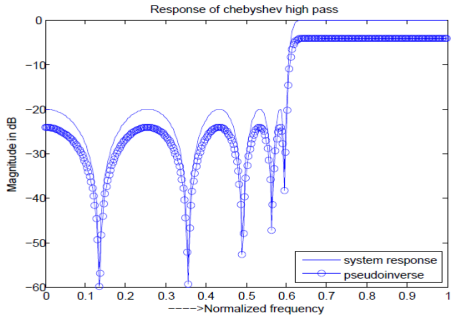

Fig 2 : Frequency response of chebyshev high pass filter identified by the Inverse filtering method

C. Coherence method

Equation(2) has been used to identify the Chebyshev high-pass filter using MATLAB function tfestimate (transfer function estimate) from the signal processing toolbox. The input excitation for the coherence identification was a pseudorandom sequence of 10,000 samples (truncated to 512 points for subsequent FFT processing to find the system function).

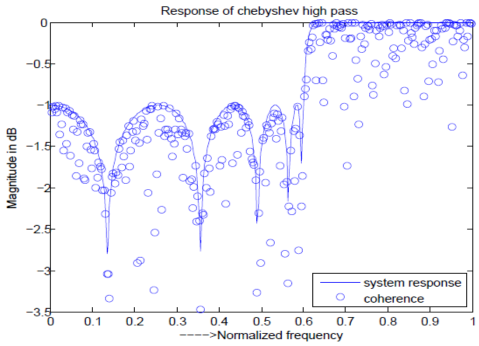

Fig 3 : Frequency response of chebyshev high pass filter identified by the Coherence method

IV. CONCLUSION

Frequency chirp has been used for excitation in chirp method, where as a pseudorandom sequence has been used for input excitation in pseudoinverse and coherence approach. In fig.1 response is away from system response, in fig.2 response due to inverse filtering is near to system response and in fig.3 coherence approach shows random response. Hence, it is clear that inverse filtering is more suitable for system identification. However, it takes quite a long time to perform.

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