System Identification for Using Initial Conditions as Active Parameters

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Abstract

System identification is a method for using measured data to create or improve a mathematical model of the object being tested. From the measured data however noise is noticed at the beginning of the response. One solution to avoid this noise problem is to skip the noisy data and then uses the initial conditions as active parameters, to be found by using the system identification process. In the first part of this paper describes the development of the equations for setting up the initial conditions as active parameters, and then the simulated data as well as response data from actual shear buildings were used to prove the accuracy of both the algorithm and the computer program , which include the initial conditions as Active Parameters, are precise.

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1. Introduction

System Identification is a method for using measured data to create or improve a mathematical model of object being tested. It has been described as the process of selecting the form of the mathematical model and then using measured test data, systematically adjusting the parameters in this method until, based on a predefined criterion, the best possible correlation is achieved between the predicted and measured response. (Matzen and McNiven p.190) [1]

Several approaches to system identification have been developed and are described in literature. (see for example Hart and Yao [2] and Natke [3]) Many models and approaches have been used, for example linear, nonlinear, time domain, frequency domain, modal parameters and physical parameters. A computer program USID4 has been developed at North Carolina State University by Dr. V. C. Matzen to find the elements of the mass, damping and stiffness matrices of linear structures using a modified Gauss-Newton minimizing algorithm [4] which based on the time domain method. In reference [4] a pull-back-and-quick-release test is used to generate the measured data. In this type of testing, however, all of the parameters are not independent and only a subset of them can be determined uniquely.

By using a torch or a pair of scissors to cut the string to release the structure, the response accelerations were recorded with the Rapid System Digital storage Oscilloscope. The program USID4 then uses the measured accelerations to find the element of [M], [C], and [K]. From the measured acceleration, it is noticed that there is noise (high frequency response superimposed on the expected response.) at the beginning of the response. One solution to this noise problem is to skip the noisy data, establish a new origin for the time scale, and then use initial conditions as parameters to be found by the system identification process. The primary objective of this study is to use the initial conditions as active parameters.

In order to accomplish the objective of this study, several steps were followed. The first was the development of the equations to include the initial conditions as active parameters. Then the computer program USID4 was modified to include these equations. After the program was modified , this program was tested by using simulated data as well as response data from actual shear buildings. In each case, both single degree of freedom and multi-degree of freedom structures were considered.

Part 2 of this paper provides the basic equations of system identification and the algorithms for the initial conditions as active parameters. Part 3 uses simulated data to demonstrate the usefulness and accuracy of the algorithm and the computer program, including the initial conditions as active parameters. Part 4 gives the conclusions and recommendations.

2. System Identification

The system identification process has been divided by Berkey [7] into the following three steps:

(1) Determination of the form of the model (i.e., selection of the model differential equations) and isolation of the unknown parameters.
(2) Selection of a criterion function by means of which the goodness of fit of the model responses to the actual system responses can be evaluated, when both model and system are forced by the same inputs.
(3) Selection of an algorithm or strategy for adjustment of the parameters in such a way that the differences between model and system responses, as measured by the criterion of (2) above, are minimized.

In this part we will discuss the algorithm of system identification. Section 2.3.1 presents the algorithm which uses the initial condition as active parameters.

2.1. Form of the Mathematical Model

A good choice for the model is one that not only is able to produce a good correlation with the measured data, but also contains terms that are directly relative to known physical properties. The mathematical model used for the shear building is assumed to be linear, elastic, and viscously damped.(figure 1) The resulting discrete initial value problem takes the form:

$$[M]\{\ddot{X}\} + [C]\{\dot{X}\} + [K]\{X\} = \{P(t)\} \qquad (1)$$
$$\{\dot{X}\} = \{\dot{X}_0\}, \{X\} = \{X_0\}$$

Where [M], [C], [K] are the mass, damping and stiffness matrices of the. structure; $\{\ddot{X}\}$, $\{\dot{X}\}$, and {X} are the acceleration, velocity, and displacement vectors; and $\{\dot{X}o\}$ and {Xo} are the initial conditions. On the right hand side of the equation is the load vector. The parameters to be obtained in the system identification process are any combination of the elements of the three coefficient matrices and these are placed in a one-dimensional array which is called Active Parameter vector (denoted AP). The algorithm was originally developed to use only zero initial conditions. However, if we include the initial velocity and displacement vectors in the Active Parameter vector, we can start from any time. This will prove to be an easy way to avoid the initial noisy experimental data.

2.2. Criterion Function

A realistic mathematical model must be able to produce a response that matches the structure's response when both the model and the structure are subjected to the same excitation. The error function indicates how well the match is made. There are many error functions available, but the one used here is the integral squared error function. Errors in accelerations, velocities and displacements are all possibilities for inclusion in the error function. In laboratory tests, however, the only response quantity that can be easily measured is acceleration, hence errors in accelerations are the only ones used. The function is divided by the duration of the signal, and the acceleration error at each degree of freedom is weighted by a factor W to form a weighted , mean square error function. The final error

function for a single degree of freedom (SDOF) system takes the form:

$$J(AP) = \frac{1}{td}\int_0^{td} W[\ddot{X}_m(t) - \ddot{X}_c(AP,t)]^2 dt \qquad (2)$$

and for an NDOF system, it takes the form:

$$J(AP) = \frac{1}{td}\int_0^{td} \langle e(AP,t)\rangle \begin{bmatrix} W_1 & 0 & \cdots & 0 \\ 0 & W_2 & \cdots & 0 \\ \vdots & & \ddots & \\ 0 & 0 & \cdots & W_n \end{bmatrix} \{e(AP,t)\} dt \qquad (3)$$

$$\langle e(AP,t)\rangle = [\ddot{X}_{mj}(t) - \ddot{X}_{cj}(AP,t)]$$

Where: n is the number of degrees of freedom.
Xmj(t) is the measured acceleration at the jth DOF
Xcj(AP,t) is the computed acceleration at the jth DOF using the current set of parameters.
Wj is the weighting factor for the jth DOF.

2.3.1. Parameter Adjustment Algorithm

The Gauss-Newton method is selected to systematically adjust the parameters in the mathematical model until the error function is minimized. This method is derived by expanding the error function in Taylor series about the previous set of parameters AP.

Error function

$$J(AP) = \frac{1}{td}\int_0^{td} \langle e(AP,t)\rangle [W]\{e(AP,t)\} dt \qquad (4)$$

Taylor series for a function of one variable:

$$f(x) = f(x_0) + f'(x_0)(x - x_0) + \frac{1}{2!}f''(x_0)(x - x_0)^2 + \frac{1}{3!}f'''(x_0)(x - x_0)^3 + \cdots$$

Use the Taylor series to expand the error function.

$$J(AP) = J(AP_i^0) + \langle AP_i - AP_i^0\rangle \{\frac{\partial J(AP^0)}{\partial AP_i}\} + \frac{1}{2}\langle AP_i - AP_i^0\rangle [H(AP^0)]\{AP_i - AP_i^0\}$$

+ HighOrderTerm (5)

Where: $\{\frac{\partial J(AP^0)}{\partial AP_i}\}$ is the Column gradient vector.

$$[H(AP^0)] = \begin{bmatrix} \frac{\partial^2 J(AP^0)}{\partial AP_1^2} & \frac{\partial^2 J(AP^0)}{\partial AP_1 \partial AP_2} & \frac{\partial^2 J(AP^0)}{\partial AP_1 \partial AP_3} & \cdots \\ & \frac{\partial^2 J(AP^0)}{\partial AP_2^2} & \frac{\partial^2 J(AP^0)}{\partial AP_2 \partial AP_3} & \cdots \\ & & \ddots & \vdots \\ & & & \frac{\partial^2 J(AP^0)}{\partial AP_n^2} \end{bmatrix}$$

is the Hessian matrix.

Ap_i is the ith Active Parameter.

The first three terms in the Taylor series are retained. and the higher order terms are ignored.

To minimize J(AP), the gradient with respect to APi is set equal to zero vector:

$$\frac{\partial J(AP)}{\partial AP_i} = 0 + \langle 0 \quad 0 \quad \cdots \quad 0 \quad 1 \quad 0 \quad \cdots \rangle \left(\{\frac{\partial J(AP^0)}{\partial AP_i}\} + [H(AP^0)]\{AP_i - AP_i^0\} \right) \tag{6}$$

Where:

$$H(AP^0) = \frac{\partial^2 J(AP)}{\partial AP_i \partial AP_j}_{AP=AP^0}$$

$$= 2td \int_0^{td} [\langle e(AP,t)\rangle [W] \{\frac{\partial^2 \ddot{X}(AP,t)}{\partial AP_i \partial AP_j}\} + \left\langle \frac{\partial \langle e(AP,t)\rangle}{\partial AP_i} \right\rangle [W] \{\frac{\partial \ddot{X}(AP,t)}{\partial Ap_j}\}] dt \tag{7}$$

In the Gauss-Newton method the first integral term in the Hessian is eliminated. The terms of the remaining symmetric matrix which is called the Approximate Hessian (denoted AH) is given by

$$AH_{ij}(AP) = 2 \int_0^{td} \left\langle \frac{\partial \ddot{X}_c(AP,t)}{\partial AP_i} \right\rangle [W] \{\frac{\partial \ddot{X}_c(AP,t)}{\partial AP_j}\} dt \tag{8}$$

This has been proven in [1]

However, [H(AP)] is not necessarily positive definite, but

[AH(AP^0)] is always a positive definite

Equation (6) can be rearranged to give the following equation:

$$\{AP_i\} = \{AP_i^0\} - a[AH(AP^0)]^{-1}\{\frac{\partial J(AP^0)}{\partial AP_j}\}, \qquad (9)$$

Where a is a positive scaling factor.

This equation is called the Modified Gauss Method.

Equation (9) is widely used in optimization and seems to have the advantage of rapid convergence to the minimum without the need to calculate second partial derivatives.

There are many techniques for solving such problems and the great majority of them fall under the general heading of iteration methods. Luenberger (1973) [8] describes iteration algorithms as follow : An initial parameter vector AP_o is selected and the algorithm generates an improved vector, AP_1 using eq.(9). The process is repeated, and an even better vector AP_2 is found. Continuing the process in this manner, a sequence of ever improving vectors, AP_o, AP_1, AP_2,...,AP_k,..., is found that approaches the solution vector AP*. In real problems, the sequence never actually reaches the solution vector because the process is terminated when a vector "sufficiently" close to the solution vector is found. The final vector is called, somewhat loosely, the minimizing vector; and is designated APmin.

Normally a computer run will terminate when either of the following conditions is met: (1) the slope of the surface at a new point is less than the preselected minimization tolerance or (2) the maximum number of iterations is reached.

2.3.2. Sensitivity Coefficient

To compute the elements of the gradient vector and the Approximate Hessian matrix, it is necessary to evaluate the first partial derivatives of the computed acceleration with respect to each parameter. These first partial derivatives, which are called sensitivity coefficients, are the solutions to partial differential equations. These equations are obtained by partially differentiating Eq.(1) with respect to each parameter.

For example if $AP = M_{13}$,then

$$\left\{\frac{\partial M}{\partial M_{13}}\right\}\{\ddot{X}\} + [M]\left\{\frac{\partial \ddot{X}}{\partial M_{13}}\right\} + [C]\left\{\frac{\partial \dot{X}}{\partial M_{13}}\right\} + [K]\left\{\frac{\partial X}{\partial M_{13}}\right\} = \{0\} \qquad (10)$$

$$[M]\left\{\frac{\partial \ddot{X}}{\partial M_{13}}\right\} + [C]\left\{\frac{\partial \dot{X}}{\partial M_{13}}\right\} + [K]\left\{\frac{\partial X}{\partial M_{13}}\right\} = -\left\{\frac{\partial M}{\partial M_{13}}\right\}\{\ddot{X}\} \qquad (11)$$

Where : $\left\{\frac{\partial \dot{X}}{\partial M_{13}}\right\} = \{0\}, \left\{\frac{\partial X}{\partial M_{13}}\right\} = \{0\}$

If $AP = C_{13}$ Then

$$[M]\left\{\frac{\partial \ddot{X}}{\partial C_{13}}\right\} + [C]\left\{\frac{\partial \dot{X}}{\partial C_{13}}\right\} + \left\{\frac{\partial C}{\partial C_{13}}\right\}\{\dot{X}\} + [K]\left\{\frac{\partial X}{\partial M_{13}}\right\} = \{0\} \qquad (12)$$

$$[M]\left\{\frac{\partial \ddot{X}}{\partial C_{13}}\right\} + [C]\left\{\frac{\partial \dot{X}}{\partial C_{13}}\right\} + [K]\left\{\frac{\partial X}{\partial M_{13}}\right\} = -\left\{\frac{\partial C}{\partial C_{13}}\right\}\{\dot{X}\} \qquad (13)$$

$$\text{Where}: \left\{\frac{\partial \ddot{X}(0)}{\partial C_{13}}\right\} = \{0\}, \left\{\frac{\partial X(0)}{\partial C_{13}}\right\} = \{0\}$$

If $AP=K_{13}$ Then

$$[M]\left\{\frac{\partial \ddot{X}}{\partial K_{13}}\right\} + [C]\left\{\frac{\partial \dot{X}}{\partial K_{13}}\right\} + [K]\left\{\frac{\partial X}{\partial K_{13}}\right\} + \left\{\frac{\partial K}{\partial K_{13}}\right\}\{X\} = \{0\} \tag{14}$$

$$[M]\left\{\frac{\partial \ddot{X}}{\partial K_{13}}\right\} + [C]\left\{\frac{\partial \dot{X}}{\partial K_{13}}\right\} + [K]\left\{\frac{\partial X}{\partial K_{13}}\right\} = -\left\{\frac{\partial K}{\partial K_{13}}\right\}\{X\} \tag{15}$$

$$\text{Where}: \left\{\frac{\partial \ddot{X}(0)}{\partial K_{13}}\right\} = \{0\}, \left\{\frac{\partial \dot{X}(0)}{\partial K_{13}}\right\} = \{0\}$$

Eqs. (11), (13) and (15) can only be started from the beginning of response because the initial conditions for Eq.(1) are only known at time = 0. As mentioned previously, some experimental data have noise at the beginning and it would be convenient to skip the noisy data and use if they were known initial conditions from a non-zero starting time. However, they are not known. One solution to this dilemma is to make them elements of the AP.

Typical equations for finding sensitivity coefficients for initial displacements and initial velocities are given below:

$AP=\dot{X}_3(t')$ and time start from t'

$$[M]\left\{\frac{\partial \ddot{X}(t)}{\partial \dot{X}_3(t')}\right\} + [C]\left\{\frac{\partial \dot{X}(t)}{\partial \dot{X}_3(t')}\right\} + [K]\left\{\frac{\partial X(t)}{\partial \dot{X}_3(t')}\right\} = \{0\} \tag{16}$$

$$\left\{\frac{\partial \dot{X}(t')}{\partial \dot{X}_3(t')}\right\} = \begin{Bmatrix} 0 \\ 0 \\ 1 \\ 0 \\ \vdots \end{Bmatrix}, \left\{\frac{\partial X(t')}{\partial \dot{X}_3(t')}\right\} = \{0\}$$

Then

$$\left\{\frac{\partial \ddot{X}(t)}{\partial \dot{X}_3(t')}\right\} = [M]^{-1}\left[-[C]\left\{\frac{\partial \dot{X}(t)}{\partial \dot{X}_3(t')}\right\}\right] \tag{17}$$

$AP= X_3(t')$ and time start from t'

$$[M]\left\{\frac{\partial \ddot{X}(t)}{\partial X_3(t')}\right\}+[C]\left\{\frac{\partial \dot{X}(t)}{\partial X_3(t')}\right\}+[K]\left\{\frac{\partial X(t)}{\partial X_3(t')}\right\}=\{0\} \qquad (18)$$

$$\left\{\frac{\partial \dot{X}(t')}{\partial X_3(t')}\right\}=\{0\},\left\{\frac{\partial X(t')}{\partial X_3(t')}\right\}=\begin{Bmatrix}0\\0\\1\\0\\\vdots\end{Bmatrix}$$

Then

$$\left\{\frac{\partial \ddot{X}(t)}{\partial X_3(t')}\right\}=[M]^{-1}\left[-[K]\left\{\frac{\partial X(t)}{\partial X_3(t')}\right\}\right] \qquad (19)$$

3. Program verification using simulated data

The identification program was tested to ensure that the modified algorithms, using the initial conditions as active parameters and the reduced sensitivity array, were correctly implemented. This was accomplished using simulated data. In these experiments, measured data were numerically simulated by assigning values to all of the parameters. Then, the program is run using initial set parameters different from the assigned set and a non-zero starting time.

Mathematical model was established for a structure with specific mass, damping and stiffness values and then subjected to pull-back-and-quick-release test to simulate the behavior of a structure. The parameters used were similar to those expected from the laboratory models. Simulated responses were generated using the response generating procedure of the USID4 program. The accelerations were then used as an input file, with a varied set of values for the active parameters (mass, damping, stiffness and initial conditions) to the search procedure of USID4.

The numerical experiments used noise-free data and an initial set of parameters which was thought to be typical of the initial estimates that could be made when real test data are employed.

To check the non-zero initial condition modification, four experiments were performed, each starting from a different time. The first try , without skipping any point, started from time equal to zero. The second try, skipping twenty-five points, started from the time of 1.75 seconds. (One time step equal to 0.07 seconds.) The third and forth tries, skipping fifty and seventy-five points individually, started from times equal 3.5 seconds and 5.25 seconds respectively. All results are shown in Table 1 and Table 2. In each case, the program converged in several iterations to a point on the error surface that was approximately stationary, the parameters converged to the assigned values and the correct initial displacements and velocities were obtained. Moreover, the value of the error at this stationary point was very nearly zero.

These simulated data experiments demonstrated that the algorithms and computer

program, derived by authors, are correct.

4. Conclusions and Recommendations

Having completed the simulated data for testing the algorithms, by using the initial conditions as active parameters, with the computer program for the pull-back and quick-release test. It is clear that by using the initial conditions as element of AP present a good idea for skipping the high frequencies points at the beginning of response.

Even through some of the results of this study are quite accurate, the study has uncovered some problems that have an effect on the prediction of response. Many of these problems relate to analytical sources of errors, the most significant of which is the form of the equation of motion. For example, the two story structure was assumed to have two degrees of freedom, and the base and joints were assumed rigid. A non-rigid base and non-rigid joints which to have some degree they could required additional degrees of freedom. Secondly, output of the analysis presents some of random error conditions (1) the calibration and precision of equipment (2) effects of noise sources (3) computational errors (e.g. round off) must also be recognized as potential sources of error. All of those problems will have an effect on the prediction of the actual response and they must be evaluated and controlled for the shear building.

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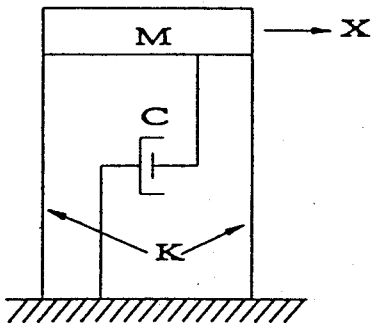
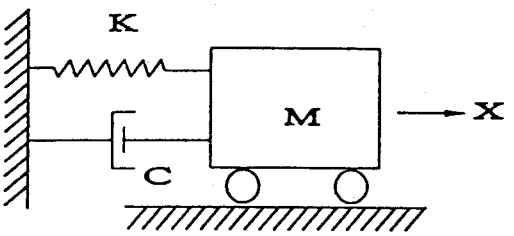
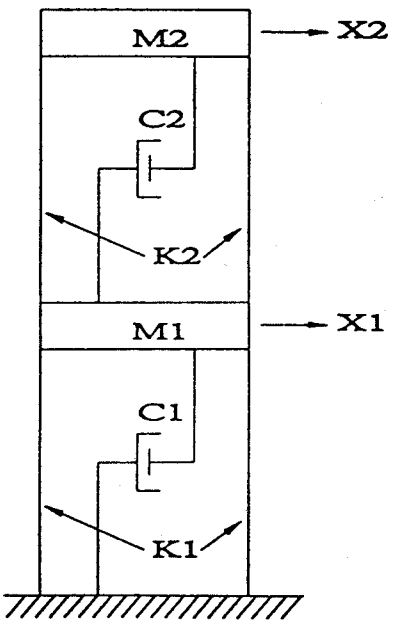


Simplify to



Single degree of freedom (Shear Building)

Mathematical Model



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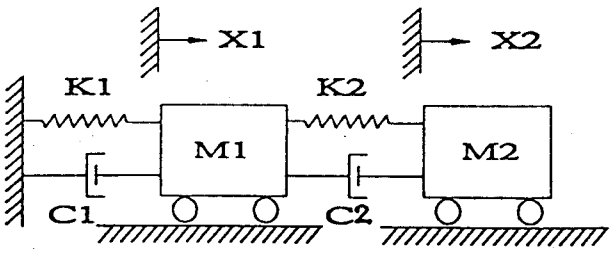

Multiple degree of freedom (Shear Building)

Mathematical Model

Figure 1 : Shear Building

Table 1 : The result of single degree of freedom

M=1	AP_0	Skip points		Iteration Number							Error (%)
				1	2	3	4	5	6	AP min / AP actual	
C= 0. 016 K= 28 Disp.= -0.1 Velo.= 0.2		0	Error	4.28	1.66	3.704*10E-2	5.55*10E-5	4.34*10E-8		6. 04*10E-3 / 0.006	0.67
			Slope	-8.48	-3.33	-7.41*10E-2	-1.11*10E-4	-8.55*10E-8		3.0*10 / 30 -3.0*10E-1 / -0.3	0 0
			Steps	4	3	2	2	1		-3.07*10E-5 / 0	0.0037
C= 0.016 K= 28 Disp.= -0.1 Velo.= 0.2		25	Error	5.18	2.18	7.75*10E-2	4.41*10E-4	4.49*10E-5		6*10E-3 / 0.006	0
			Slope	-1.04*10	-4.35	-1.55*10E-1	-7.93*10E-4	-2.61*10E-7		3.0*10 / 30 -2.71*10E-1 / -0.27	0 0.37
			Steps	3	4	2	2	1		4.46*10E-1 / 0.45	0.89
C= 0.016 K= 28 Disp.= -0.1 Velo.= 0.2		50	Error	6.32	3.34	1.79*10E-1	4.28*10E-3	3.16*10E-5	3.13*10E-5	6.06*10E-3 / 0. 006	1
			Slope	-1.26*10	-6.56	-3.58*10E-1	-8.5*10E-3	-6.75*10E-7	-3.76*10E-10	3.0*10 / 30 -2.01*10E-1 / -0.201	0 0
			Steps	3	5	2	2	2	1	8.07*10-1 / 0.81	0.37
C= 0.016 K= 28 Disp.= -0.1 Velo.= 0.2		75	Error	8.31	4.52	3.59*10E-1	7.44*10E-2	1.2*10E-5	1.16*10E-5	6.06*10E-3 / 0.006	1
			Slope	-1.65*10	-7.28	-7.17*10E-1	-1.49*10E-2	-9.76*10E-7	-1.02*10E-9	0 / 0 -1.0*10E-1 / -0.1	0 0
			Steps	2	3	2	2	2	1	1.03 / 1.03	0

Table 2 : The result of multi. degree of Freedom

M11=1	AP_0	Skip Points		Iteration Number					APmin	AP actual	Error (%)
				1	2	3	4	5			
M22	1.02	0	Error	1.75*10E-1	5.0*10E-2	2.32*10E-3	1.77*10E-5	1.2*10E-9	1.0	1	0
C11	0.0025								4.92*10E-4	0.0005	1.6
C12=C21	-0.0009		Slope	-3.5*10E-1	-1.0*10E-1	-4.66*10E-3	-3.54*10E-5	-2.315*10E-9	-3.03*10E-4	-0.0003	1
C22	0.0013								8.9*10E-4	0.00086	3.49
K11	5.2								5.0	5	0
K12=K21	-2.01		Steps	3	2	2	2	1	-2.0	-2	0
K22	3.8								4.0	4	0
X1 Displ.	-0.13								-1.3*10E-1	-0.13	0
X2 Displ.	-0.2								-3.33*10E-1	-0.33	0.11
X1 Velo.	0								4.5*10E-6	0	0
X2 Velo.	0								2.239*10E-6	0	0
M22	1.02	25		7.36*10E-1	9.77*10E-2	1.68*10E-2	2.49*10E-4	2.8*10E-7	1.0	1.	0
C11	0.0025								4.91*10E-4	0.005	1.8
C12=C21	-0.0009			-1.47	-1.94*10E-1	-3.36*10E-2	-4.98*10E-4	-2.37*10E-7	-2.80*10E-4	-0.0003	6.67
C22	0.0013								8.65*10E-3	0.0086	0.58
K11	5.2								5.0	5	0
K12=K21	-2.01			3	3	3	2	1	-2.0	-2	0
K22	3.8								3.98	4	0.5
X1 Displ.	-0.13								-7.13*10E-2	-0.07122	0.11
X2 Displ.	-0.2								-2.29*10E-1	-0.22863	0.16
X1 Velo.	0								2.95*10E-1	0.29515	0.05
X2 Velo.	0								-5.67*10E-2	-0.056928	0.40
M22	1.02	50	Error	5.92*10E-1	8.27*10E-2	6.09*10E-3	1.01*10E-4	3.44*10E-8	1.0	1	0
C11	0.0025								4.91*10E-4	0.0005	1.8
C12=C21	-0.0009		Slope	-1.18	-1.62*10E-1	-1.22*10E-2	-2.02*10E-4	-3.91*10E-8	-3.07*10E-4	-0.0003	2.33
C22	0.0013								8.86*10E-3	0.0086	3.02
K11	5.2		Steps	2	3	2	2	1	5.0	5	0
K12=K21	-2.01								-2.0	-2	0
K22	3.8								4.0	4	0
X1 Displ.	-0.13								5.64*10E-2	0.056358	0.07
X2 Displ.	-0.2								9.03*10E-3	0.0090	0.33
X1 Velo.	0								-3.95*10E-1	-0.3953	0.08
X2 Velo.	0								1.35*10E-1	0.13525	0.18
M22	1.02	75	Error	9.28*10E+1	1.81*10E-1	6.09*10E-3	5.89*10E-4	2.67*10E-6	1.97*10E-7	1.0	1	0
C11	0.0025									4.93*10E-4	0.0005	1.4
C12=C21	-0.0009		Slope	-1.86	-3.57*10E-1	-1.21*10E-1	-1.18*10E-3	-4.95*10E-6	-9.24*10E-10	-2.93*10E-4	-0.0003	2.33
C22	0.0013									8.51*10E-3	0.0086	1.05
K11	5.2		Steps	2	3	5	2	2	1	5.0	5	0
K12=K21	-2.01									-2.0	-2	0
K22	3.8									4.0	4	0
X1 Displ.	-0.13									4.15*10E-3	0.0049	1.5
X2 Displ.	-0.2									3.01*10E-1	0.30158	0.19
X1 Velo.	0									5.79*10E-1	0.5799	0.16
X2 Velo.	0									2.17*10E-1	0.21683	0.08

系統識別之使用起始條件為主動變數

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關鍵詞：起始條件、無雜訊、動力分析

摘　要

系統識別是利用量測資料去創造或改良實驗物體之數學模型，但於實驗所得之資料，發現在起始資料中具有高頻率之雜訊，解決的方法是跳過這些雜訊，本文將探討以起始條件為主動變數之數學公式及驗證結果。數學模型之建立以 Berkey 之三步驟為準則，並以誤差平方積分式顯示其接近的程度，本文選擇高斯－牛頓法，系統調整數學模型的變數直到誤差方程式達到最小化，再將以上推導之方程式引入程式中。為了驗證其正確性，以剪力房屋進行單自由度及多自由度之數值模擬，分別進行不同時間開始的實驗，結果程式中誤差函數收斂快速，且主動變數收斂於相當近似的真值。