Computer-Mathematical Modeling of Board Oscillations of A Military Marine Vessel Based on The Degenerate Optimal Singular Adaptive M3A1 Computer Observer – Part II

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Abstract. *The paper presents a new approach of discrete adaptive computer observation and modeling of board oscillations of military marine vessels considered to be linear and non-stationary discrete processes so far. The tools of the Theory of optimal singular adaptive computer observation and discrete modeling, which has been developed in the recent 25 years, are applied.*

Keywords. *Discrete systems, degenerate optimal singular adaptive computer observation, identification, discrete modeling, estimation of the initial state vector. board oscillations , military marine vessels, Matlab implementation.*

MATLAB-INTERPRETATION OF THE DEGENERATE OPTIMAL SINGULAR ADAPTIVE M3A1 COMPUTER OBSERVER

Step 1. The one-dimensional arrays and the be-dimensional array of the input-output data are formed by the following Matlab-module:

```
y1 = y(1:n);
y2 = y(n+1; 2*n);
v = u(1:n);
for i = 1:n
    for j = 1:n
        Y12(i, j) = y(i+j-1);
    end
end
```

Step 2. Set up and solution of the respective linear system of algebraic equations:

```
ae = inv(Y12)*(y2-v);
```

Step 3. Assessment of the initial state vector:

```
xe0 = y1;
```

Step 4. The degenerate OSA computer observer is interpreted by the following Matlab-module:

$$b = [zeros(n-1,\ 1);1];$$
$$c = [1;\ \ zeros(n-1,\ 1)];$$
$$g = zeros(n,\ 1);$$
$$I = eye(n\ \text{-}\ 1);$$
$$Ae = [zeros(n-1,\ 1), I;\ \ ae];$$
$$Fe = Ae - g * c';$$
$$xe(:,\ 1) = xe0;$$
$$\text{for}\ \ k = 1 : 2 * n - 1$$
$$xe(:,\ k+1) = Fe * xe(:,\ k) + b * u(k) + g * y(k);$$
$$\text{end}$$

Step 5. The relative error of the degenerate OSA observation is calculated by the following Matlab-module:

$$\text{for}\ \ k = 1 : 2 * n$$
$$ye = c' * xe(:,\ k);$$
$$\text{end}$$
$$\text{for}\ \ k = 1 : 2 * n$$
$$e(k) = norm(y(k) - ye(k))/norm(y(k));$$
$$\text{end}$$

RESULTS OF THE DEGENERATE OPTIMAL SINGULAR ADAPTIVE COMPUTER OBSERVATION AND MODELING .OF THE BOARD OSCILLATIONS OF THE MILITARY MARINE VESSEL

The presented above input-output data were processed further in the mode of three randomly selected samples. The evaluated order of the three discrete sub-models is $\hat{n} = 2$. The degenerate OSA computer observer (at **g**=0) was selected for assessment of the current state vector and of the three discrete sub-models. It is known that all OSA observers calculate the results of the adaptive observation with almost equal accuracy thus the OSA computer observer with the simplest structure for realization was selected.

We shall give the following representative results for the first sample, at k=0,1,2,3:

$$\hat{\mathbf{a}} = \begin{bmatrix} -2.3000 \\ 2.9000 \end{bmatrix},\ \ \hat{\mathbf{x}}(0) = \begin{bmatrix} 0 \\ 2.0000 \end{bmatrix},\ \ \hat{\mathbf{x}}(1) = \begin{bmatrix} 2.0000 \\ 6.0000 \end{bmatrix},$$
$$\hat{\mathbf{x}}(2) = \begin{bmatrix} 6.0000 \\ 13.0000 \end{bmatrix},\ \ \hat{\mathbf{x}}(3) = \begin{bmatrix} 13.0000 \\ 24.1000 \end{bmatrix}.$$

They are obtained with the following relative errors:

$$e(k) = \frac{|y(k) - \hat{y}\ (k)|}{|y\ (k)|} = 0,\ \ k = 0,1,2,3.$$

At that,

$$\mathrm{cond}(\mathbf{Y}_{12}) = 10.9083\,,$$

i.e. the value of the number of condition of the respective Hankel matrix tells that the considered here task for degenerate OSA observation and modeling of the board oscillations of the military marine vessel, modeled by a continuous linear nonstationary mathematical model , is well conditioned in the case of discrete presentation, which leads to a better computer interpretation, e.g. to a minimal computational complexity and to reduction of the operating computer memory to an order of magnitude, compared with the existing method for matrix inversion, solution of linear systems of algebraic equations with a special, dense structure.

The eigenvalues of the state matrix of this sub-model are:

$$\chi_{11} = 1.4500 + 0.4444\mathrm{i},$$
$$\chi_{12} = 1.4500 - 0.4444\mathrm{i}.$$

Interpreted process in this time interval is oscillating with increasing amplitude, i.e. unstable.

The eigenvalues of the degenerate OSA computer observer (at **g**=0), are obviously the same, but the stated OSA observer instability does not impact negatively the exceptionally high accuracy of the described observation and modeling

We shall give the following representative results for the second sample, at k=11, 12, 13, 14:

$$\hat{\mathbf{a}} = \begin{bmatrix} -0.9107 \\ 1.7487 \end{bmatrix},\ \hat{\mathbf{x}}(11) = \begin{bmatrix} -6.0000 \\ 11.0000 \end{bmatrix},\ \hat{\mathbf{x}}(12) = \begin{bmatrix} 11.0000 \\ 25.0000 \end{bmatrix},$$
$$\hat{\mathbf{x}}(13) = \begin{bmatrix} 25.0000 \\ 34.0000 \end{bmatrix},\ \hat{\mathbf{x}}(14) = \begin{bmatrix} 34.0000 \\ 36.9886 \end{bmatrix}.$$

They are obtained with the following relative errors:

$$\mathrm{e}(\mathrm{k}) = \frac{|\mathrm{y}(\mathrm{k}) - \hat{y}(\mathrm{k})|}{|\mathrm{y}(\mathrm{k})|} = 2.0898.10^{-14},\ \ \mathrm{k} = 11,12,13,14.$$

At that,

$$\mathrm{cond}(\mathbf{Y}_{12}) = 2.9986\,,$$

i.e. in the considered time interval the task for degenerate OSA computer observation and modeling is also well.conditioned

The eigenvalues of the state matrix of this sub-model are:

$$\chi_{21} = 0.8744 + 0.3824i,$$
$$\chi_{22} = 0.8744 - 0.3824i,$$

i.e. the interpreted process is oscillating with decreasing amplitude, i.e. stable.

We shall give the following representative results for the third sample at k=22, 23, 24, 25:

$$\hat{\mathbf{a}} = \begin{bmatrix} -1.3004 \\ 1.8176 \end{bmatrix},\ \hat{\mathbf{x}}(22) = \begin{bmatrix} 10.0000 \\ 23.0000 \end{bmatrix},\ \hat{\mathbf{x}}(23) = \begin{bmatrix} 23.0000 \\ 29.0000 \end{bmatrix},$$
$$\hat{\mathbf{x}}(24) = \begin{bmatrix} 29.0000 \\ 23.0000 \end{bmatrix},\ \hat{\mathbf{x}}(25) = \begin{bmatrix} 23.0000 \\ 4.2921 \end{bmatrix}.$$

They are obtained with the following relative errors:

$$\mathrm{e}(\mathrm{k}) = \frac{|\mathrm{y}(\mathrm{k}) - \hat{y}(\mathrm{k})|}{|\mathrm{y}(\mathrm{k})|} = 1.5447.10^{-16},\ \mathrm{k} = 22,23,24,25.$$

At that,

$$\mathrm{cond}(\mathbf{Y}_{12}) = 8.2427\ .$$

The eigenvalues of the state matrix of this third sub-model are:

$$\chi_{31} = 0.9088 + 0.6889i,$$
$$\chi_{32} = 0.9088 - 0.6889i.$$

Obviously the comments regarding the behavior of the oscillated process in this time interval are analogical to the previous discrete structure, approximating the dynamic behavior of the military marine vessel in the respective time sub-interval.

CONCLUSION

A successful attempt at adequate description of board oscillations of a marine military vessel has been made in the present paper for the purposes of their optimal and adaptive reduction which in some cases, e.g. marine military battles, is of crucial importance for the precision of the hits of the fire arms located on the deck of a military marine vessel.

The applied test input influences interpret better the complex weather circumstances which might surround the military marine vessel in the case of a military marine study practice or a battle as compared to the classical case of an influence, constant in amplitude.

The results of the computer processed input-output data on the basis of the proposed approach, M3A1 degenerate observer and Matlab software illustrates the possibility to solve the task for optimal singular adaptive computer observation and discrete modeling of the board oscillations of the military marine vessel with guaranteed accuracy. These computational results illustrate the mathematical and program consistency of the algorithmic synthesis of OSA computer observers.

The computer processing of arbitrary, sequential or sequential with overlapping samples of input-output data for the oscillated process allows to interpret the considered class of linear and non-stationary continuous systems with a limited set of discrete sub-models with constant structure, variable parameters and variable initial and current states..

The respective processing of experimental information of this type can be used for design, modeling and realization of adaptive systems for regulation, stabilization of the board oscillations of the military marine vessel and other objects on the basis of identifiers, optimal computer estimators of initial state, optimal singular adaptive computer observers of current state, regulators and stabilizers..

It can be shown [4÷17], that the assessments received above are optimal in terms of the minimum of the quadratic functional of the type:

$$\|\mathbf{e}(k)\|^2 = \|\mathbf{x}(k) - \hat{\mathbf{x}}(k)\|^2, \quad k = 0,1,2,..., \tag{10}$$

where

$$\mathbf{e}(k) = \mathbf{x}(k) - \hat{\mathbf{x}}(k), \quad k = 0,1,2,..., \tag{11}$$

and the norm is defined as:

$$\|\mathbf{e}(k)\| = \sqrt{<\mathbf{e}(k), \mathbf{e}(k)>}, \quad k = 0,1,2,..., \tag{12}$$

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