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AN ANALYSIS OF MODELS IDENTIFICATION METHODS FOR HIGH SPEED CRAFTS

J. Aranda[1], R. Muñoz[2], S. Dormido Canto[3], J.M. Díaz[4] and S. Dormido Bencomo[5]

Abstract

Two different approaches of the system identification method have been proposed in order to estimate models for heave, pitch and roll dynamics of a high speed craft. Both of them resolve the identification subject as an optimization problem to fit the best model. The first approach uses genetic algorithms and nonlinear least squares with constraints methods applied in the frequency domain. The second one suggests a new parameterization which facilitates obtaining high quality starting values and avoids non-quadratic functions in the cost function. At last it is shown an example in which the two approximations are applied and compared.
Keywords: system identification, optimization problem, genetic algorithms, nonlinear least squares.

INTRODUCTION

The response of a ship advancing in a seaway is a complicated phenomenon involving the interactions between the vessel dynamics and several distinct hydrodynamic forces. All ship responses are non linear to some extent, but in many cases when nonlinearities are small a linear theory will yield good predictions.

[1] Profesor de la Universidad Nacional de Educación a Distancia (jaranda@dia.uned.es).C/ Juan del Rosal 16. 28040 Madrid. Spain
[2] Profesor Ayudante de la Universidad Nacional de Educación a Distancia (rmunoz@dia.uned.es).
[3] Profesor de la Universidadd Nacional de Educación a Distancia (sebas@dia.uned.es).
[4] Profesor Colaborador de la Universidad Nacional de Educación a Distancia (josema@dia.uned.es).
[5] Catedrático de la Universidad Nacional de Educación a Distancia. (sdormido@dia.uned.es).

The study is focused on a ship advancing at constant mean forward speed with arbitrary heading in a train of regular sinusoidal waves. Experimental and theoretical investigations have shown that a linear analysis of ship motions give excellent results over a wide variety of sea conditions.

The past decade has seen a growing interest on high speed crafts for both cargo and passenger transportation. Different designs have been considered, and a significant attention has been focused on fast mono-hull displacement ships. One of the objectives in the design is passenger comfort and vehicle safety. Vertical accelerations associated with roll, pitch and heave motions are the main cause of motion sickness. For that reason, a first goal is to damp these three movements.

Therefore, it is necessary to build a mathematical model of the dynamical system that permits the designing of a controller which achieves the reduction of the heave, pitch and roll motions, and consequently the reduction of the motion sickness index.

Thus, as an initial study, previous researches of the work group have studied the longitudinal and transversal dynamics separately. Firstly, it has been studied heaving and pitching motion for the case of head seas, (μ=180deg) (Aranda et al., 2004a), modeled actuators and designed different controllers, (Aranda et al., 2002a, 2002b), in order to achieve heave and pitch damping and with successful results. And secondly, it has been analyzed the rolling response for the case of lateral waves (μ=90deg) (Aranda et al., 2003) and in the same way, it has been carried out the actuators modeling and controller designing (Aranda et al., 2004b).

In the present work the study has been extended to an analysis of heave, pitch and roll dynamics with different incidence angles between 180 degrees and 90 degrees.

There are many publications related to the ships modelling (Fossen, 2002; Lewis, 1989). In this work modeling is obtained from system identification method (Söderström et al, 1989; Pintelon and Schoukens, 2004), which is based on the observed input output data.

This research presents two approaches for identifying continuous transfer functions of the vertical and transversal dynamics of a high speed craft. In the first one the problem is set out as a nonlinear optimization problem with nonlinear constraints (Aranda et al., 2004). There, the proposed solution is described with a hybrid optimization method (genetic algorithm + nonlinear optimization algorithm with constraints from the Matlab toolbox). In the second one a discussion on the first method is made (Pintelon and Shoukens, 2004) and some questions are raised, in order to obtain models more efficiently. There, these new improvements and their application are depicted.

Thus, this paper is organized as follows. Firstly it is presented the basic steps in systems identification, where the criterion of fitness is developed. Secondly, it is presented the discussion on identification and the new solution of the problem. Finally, an example is shown in order to compare the two approaches.

SYSTEM IDENTIFICATION

The system identification problem is to estimate a model of a system based on observed input-output data. This procedure involves three basic steps: the input-output data, a set of candidate models (the model structure), and a criterion to select a particular model in the set, based on the information in the data (the identification method).

In general terms, an identification experiment is performed by exciting the system and observing its input and output over a time interval. These signals are recorded. Then it is tried to fit a parametric model of the process to the recorded input and output sequences. The procedure is illustrated in Figure 1 (Söderström and Stoica, 1989).

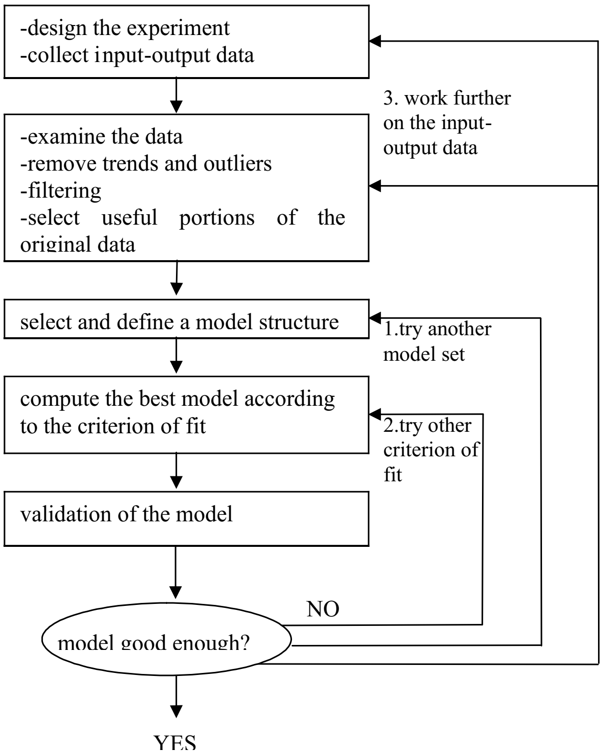

Figure 1. Identification procedure

Diverse experiments in CEHIPAR (El Pardo Model Basin, Spain) are made with a scaled down replica (1:25) of the TF120 ferry. Also there is a second self-propelled replica which is scaled (1:40).

In order to analyze the dynamic of the fast ferry, tests with diverse types of waves, ship speeds and different angles of incidence have been made. Also CEHIPAR has a program simulation PRECAL, which reproduces specified conditions and uses a geometrical model of the craft to predict its dynamic behavior. PRECAL solves the physical equations of the dynamic of a ship by using the Band Theory (Fossen, 2002). The program gives amplitude and phase data at different frequencies.

The experimental input- output data are generated by the program simulation PRECAL. Simulations are tried with regular waves, with the following characteristics,

— natural frequency between the rank [0.393,1.147] rad/s

— angles of incidence 90º, 105º, 120º, 135º, 150º, 165º, 180º

— ship speed 20, 30 and 40 knots.

Tests consist of excitation of the ship system by the sea wave (the input is the wave height (m)). For each type of wave, that is, wave frequency and angle of incidence, the ship responses are measured. In this case, the study is focused on heave, pitch and roll modes. Thus, the given outputs are the following (BAZAN, 1995): amplitude and phase of total the force of excitation heave, amplitude and phase of the total moments of excitation pitch and roll, amplitude and phase of the motion response heave, and amplitude and phase of the motion responses pitch and roll.

The block diagram of the system to identify is depicted in figure 2.

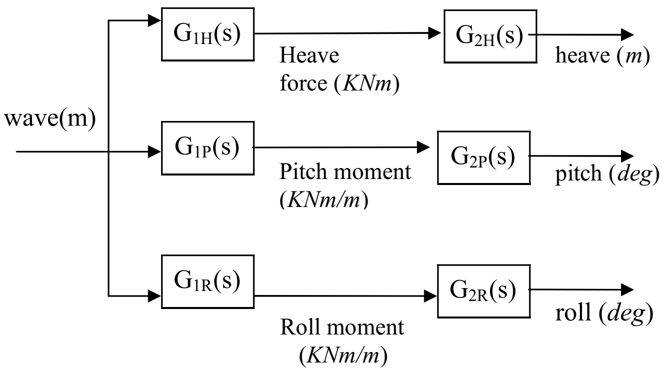

Figure 2. Block diagram of the system

Thus, the transfer functions to be modelled are the following

$G_{1H}(s)$: from wave height (m) to heave force (kN)

$G_{2H}(s)$: from heave force (kN) to heave motion (m)

$G_{1P}(s)$: from wave height (m) to pitch moment (kNm)

$G_{2P}(s)$: from pitch moment (kNm) to pitch motion (degrees)
$G_{1R}(s)$: from wave height(m) to roll moment (kNm)
$G_{2R}(s)$: from roll moment (kNm) to roll motion (degrees)
Based on the principle of linear superposition, it yields that

$$G_Z(s) = G_{1Z}(s) \cdot G_{2Z}(s), Z = H, P, R \quad (1)$$

Therefore, the given input output data are used to identify directly the transfer functions $G_Z(s)$ whose input is the wave height, and the outputs are the heave, pitch or roll motions, and similarly the transfer functions $G_{1Z}(s)$, whose input is the wave height, and the outputs are heave force, pitch moment, or roll moment. The identification of the transfer functions $G_{2Z}(s)$ are made indirectly, by using the relation (1).

Once the experiments with the system to model are designed, and the obtained input output data are examined, next step is to select and define a model structure and give a criterion of fit, so that it can be computed the best model that reproduces the dynamic of the ship system more suitably.

The system identification gives the mathematical model in the form of transfer function. Data given by the simulator PRECAL are in the frequency domain. Therefore, it will be carried out a parametric estimation of the transfer functions in the frequency domain.

In this way, consider the general parameterized transfer function (2). The estimation of the model consists of the fitness of the frequency response or Bode diagram of a transfer function with a fixed number of poles and zeros (model structure) to the actual measured data.

$$G(s,\theta) = \frac{B(s,\theta)}{A(s,\theta)} = \frac{b_{m+1}s^m + b_m s^{m-1} + ... + b_1}{s^n + a_n s^{n-1} + ... + a_1} \quad (2)$$

For the identification of the model it is employed a parametric method, characterized by the adjustment of the collected data to an estimated parameter vector θ,

$$\theta = (b_{m+1}, b_m, b_{m-1}, ..., b_1, a_n, a_{n-1}, ...a_1) \quad (3)$$

The parameter vector θ is determined as the vector that minimizes the sum of squared equation errors. Thus, it is defined the cost function J(θ):

$$J(\theta) = \sum_{i=1}^{N} \left| G(j\omega_i) - G(j\omega_i, \theta) \right|^2 \quad (4)$$

in this way, the parameter vector is obtained such

$$\hat{\theta} = \arg\min_{\theta} J(\theta) \tag{5}$$

In order to solve the minimization problem and therefore estimate a transfer function model, it must be considered the following factors

1. A physical insight of the dynamic of the system states that at low frequencies roll and pitch responses amplitudes must tend to zero, while the heave response amplitude must tend to one. That is

$$\begin{aligned} &\text{Heave: } G_{1H}(j\omega), G_{2H}(j\omega) \xrightarrow[\omega \to 0]{} 1 \\ &\text{Pitch: } G_{1P}(j\omega) \xrightarrow[\omega \to 0]{} 0 \\ &\text{Roll } G_{1R}(j\omega) \xrightarrow[\omega \to 0]{} 0 \end{aligned} \tag{6}$$

that it is translated for the parameter vector θ

$$\begin{aligned} &G_{1H}(s) \text{ y } G_{2H}(s) \rightarrow |a_1| = |b_1| \\ &G_{1P}(s) \rightarrow b_1=0 \\ &G_{1R}(s) \rightarrow b_1=0 \end{aligned} \tag{7}$$

2. The system must be stable. It is translated into the poles of the transfer function must belong to the left plane s. Thus, to ensure the stability of the estimated models the transfer functions are reparametrized as

$$G(s,x) = \frac{x_{n+m+1}s^m + x_{n+m}s^{m-1} + \ldots + x_{n+1}}{\prod_{i=1}^{npc}\left(s^2 + 2x_{2i-1}s + x_{2i-1}^2 + x_{2i}^2\right)\prod_{i=1}^{nps}\left(s + x_{npc+i}\right)} \tag{8}$$

with n = nps + npc and

$$\begin{cases} x_{2i-1} < -0.005 \text{ for i} = 1, 2, \ldots, \text{npc} \\ x_{npc+i} < -0.005 \text{ for i} = 1, 2, \ldots, \text{nps} \end{cases} \tag{9}$$

Then, the parameters x are obtained by minimizing

$$\sum_{i=1}^{N}\left|G(j\omega_i) - G(j\omega_i, x)\right|^2 \quad \text{subject to (7) and (9)} \tag{10}$$

It is important to note that the constraint $|a_1| = |b_1|$ is a strongly nonlinear function of x. This nonlinear minimization problem with nonlinear constraints is solved using the nonlinear optimization toolbox of Matlab.

Starting values are obtained via a genetic algorithm (Michalewicz, 1999) or generated at random. The solution of (10) is used as initial guess for a multistep procedure, also called alternating variables method (Fletcher, 1991).

The multistep procedure is motivated by the fact that direct measurements of the heave force to heave motion, pitch moment to pitch motion, and roll moment to roll motion dynamics are not available. Therefore, transfer functions $G_{1Z}(s)$ and $G_Z(s)$ (with Z = H, P or R) are directly estimated by minimizing (10). The solution given is used to identify the transfer function $G_{2Z}(s)$ (Z = H, P or R) by minimizing

$$\sum_{i=1}^{N} \left| G_Z(j\omega_i) - G_{1Z}(j\omega_i, x_a) G_{2Z}(j\omega_i, x_b) \right|^2 \text{ subject to (7) and (9)} \qquad (11)$$

successively x_a is determined for fixed x_b, and x_b is determined for fixed x_a, with $G_Z(j\omega_i)$ the simulated data and Z = H, P or R.

THE IDENTIFICATION METHOD

In this section some suggestions are made about the method described in the previous section. The fundamental questions are raised about: the excitation signal and plant model, the parametrization of the transfer functions, the choice of the starting values, and the multistep procedure.

Choice of the excitation signal and the plant model

Since the heave, pitch and roll dynamics of a ship are described by nonlinear differential equations (Kenevissi, 2003), it is important the choice of the excitation signal. It is shown that the frequency response of a system depends on the class of excitation signal used.

It is important that the type and power of the waves used for the linear identification experiment (linear approximation of the true nonlinear behaviour) coincides with the type and the power of the waves that the controller or actuators elements should compensate for in real life.

In this particular case the identification and validation are performed with respectively regular (single sines) and irregular (broadband signal) waves. Regular waves do not exist in nature, however they are very useful for the identification method and obtaining a linear model. The frequency rank and height of the sinusoidal signal used belong to the frequency spectral and amplitudes of the irregular waves, which are those that the real system could find.

In system identification the determination of model structure is an important aspect. And overparametrized model structure can lead to unnecessarily complicated computations for finding the parameter estimates and for using the estimated model. And underparametrized models may be very inaccurate. Therefore, it is necessary to employ methods to find an appropriate model structure. In practise identification often is performed for an increasing set of model orders. Then one must know when the model order is appropriate, i.e, when to stop. Needless to say, any real-life data ser cannot be modelled exactly by a linear finite-order model. However, the methods for finding the 'correct' model order are based on the statistical assumption that the data come from a true system within the model class considered.

Concerning the problem of choosing the model structure, the following question is raised: In the comparison between the frequency response or Bode diagram of the modelled transfer functions and the data (Aranda et al., 2004), it is observed that there is a discrepancy in the high frequency range. Thus one can wonder whether these differences are due to the intrinsic nonlinear behaviour of the heave, pitch and roll motions, or to a deliberate simplification of the linear dynamics.

For that reason, it is proposed that one way of guaranteeing that the best (in least square sense) linear approximation has been obtained, and therefore, that all the remaining errors are then due to nonlinear effects, is the utilization of classical model selection criteria such as the Akaike information criterion (AIC), and the whiteness test of the residual applied to the identification data (Ljung, 1999; Söderström et al., 1989).

Therefore, in the new approach of the identification method, these criterions are applied in order to ensure the best model structure and thus the best linearization.

Parameterization issues and starting values

Originally, in order to ensure the system stability, a re-parameterization of the transfer functions is carried out (8). Consequently the constraint (7) results in a cost function (10) that is strongly non-quadratic function of the model parameters. As a consequence of this parameterization, several disadvantages appear (Pintelon and Schoukens, 2004):

— Because of the nonlinear minimization and nonlinear constraints, the generation of starting values is non-trivial, especially for high order systems.

— The selection of the model is more complicated since the number of real nps and complex conjugate npc poles should be estimated. However, parameterization (2) only needs the number of total poles n.

— The classical derivative based nonlinear optimizers (Fletcher, 1991) will degenerate for multiplicities higher than one. On the other hand, parameterization (2) does not impose nor exclude particular pole positions and pole multiplicities.

These problems can be avoided as follows:
Using parameterization (2), cost function can be written as

$$\sum_{i=1}^{N}\left|G(j\omega_i)-\frac{B(j\omega_i,\theta)}{A(j\omega_i,\theta)}\right|^2 \text{ subjetc to (7) and (9)} \qquad (12)$$

Thus, the nonlinear constraint $|a_1| = |b_1|$ can easily be satisfied by minimizing the cost function two times: first subject to $a_1=b_1$, next subject to $a_1 = -b_1$, and finally selecting the solution with the smallest cost function.

Applying the same trick, high quality starting values for (12) can be obtained via the linear least squares estimate

$$\sum_{i=1}^{N}\left|A(j\omega_i,\theta)G(j\omega_i)-B(j\omega_i,\theta)\right|^2 \qquad \text{subjetc to (7)} \qquad (13)$$

Concerning the stability constraint, two different approaches are possible for imposing it. Either the constraint is imposed during the minimization as proposed in the previous method and in Van Gestel et al. (2001), or first and unconstrained optimal noise removal problem is solved and next a stable approximation is calculated (Mari, 2000). In this case the first scheme is applied.

The Multistep procedure

As it is has been commented in previous sections, the input output data which are obtained from the simulations are the input wave and outputs forces or moments, and the input wave and outputs the movements. These data are used directly for the identification of the transfer functions $G_{1Z}(s)$ and $G_Z(s)$, with Z = H, P or R.

The alternating variables method or multistep procedure proposed to minimize (11) is usually inefficient and is not guaranteed to converge to a stationary point of (11).

Hence, another proposed approach is to minimize simultaneously x_a and x_b. If parameterization (2) is used, this scheme will be easier since high quality starting values are available via (13).

Once questions and how to solve them are set out, next section show the definitive approach for the identification problem.

RESOLUTION TO THE IDENTIFICATION PROBLEM

In this section it is described the procedure developed for the identification of the models, considering all the suggestions raised in previous sections.

Collecting input-output data

For each particular case of force, moment or motion of heave, pitch and roll responses, initially there are a set of N experimental points of amplitude $|G(j\omega_i)|$ and phase *arg*$(G(j\omega_i))$, for each type of wave, characterized by the natural frequency ω_{oi}, with i = 1..N.

It must be considered that the frequency of oscillation of a ship response when a wave with natural frequency ω_o reach the ship with an angle μ, is the frequency of encounter ω_e, which is determined by

$$\omega_e = \omega_0 - \frac{\omega_0^2}{g} U_0 \cos\mu \tag{14}$$

According to this, the starting point are the experimental data, $G(j\omega_{ei})$, i=1…N, that expressed in binomial form are

$$G(j\omega_{ei}) = |G(j\omega_{ei})| \cos(\arg(G(j\omega_{ei}))) + j|G(j\omega_{ei})| sen(\arg(G(j\omega_{ei})) \tag{15}$$

Criterion of fit.

According to what it has been already commented, the identification problem is solved as an optimization problem. The transfer function to be estimated, with m zeros and n poles is :

$$G(s,\theta) = \frac{B(s,\theta)}{A(s,\theta)} = \frac{b_{m+1}s^m + b_m s^{m-1} + ... + b_1}{s^n + a_n s^{n-1} + ... + a_1} \tag{16}$$

where the parameter vector θ is:

$$\theta = (a_1, a_2, ..., a_{n-1}, a_n, b_1, ..., b_{m-1}, b_m, b_{m+1}) \tag{17}$$

In order to facilitate calculations in the resolution of the optimization problem, the parameter vector is redefined in terms of the x variable:

$$x = (x_1, x_2, ..., x_n, x_{n+1}.,,,,,, x_{n+m}) \tag{18}$$

Thus, the transfer function is:

$$G(s,x) = \frac{B(s,x)}{A(s,x)} = \frac{x_{m+1}s^m + x_m s^{m-1} + ... + x_{n+1}}{s^n + x_n s^{n-1} + ... + x_1} \tag{19}$$

and then the cost function J(x) is

$$J(x)=\sum_{i=1}^{N}\left|G(j\omega_i)-G(j\omega_i,x)\right|^2 \qquad (20)$$

The problem of obtaining the value of the parameters x that find the minimum of the multivariable function J(x) is solved with the Matlab optimization toolbox.

Constraints

The constraints of the problem are

i) $|b_1| = |a_1|$ for $G_{1H}(j\omega_e)$, $G_{2H}(j\omega_e)$

This condition is translated for the parameters vector x into:

$$\left|x_{n+1}\right|=\left|x_1\right| \qquad (21a)$$

ii) $|b_1| = 0$ for $G_{1P}(j\omega_e)$

In order to ensure that this constraint is satisfied in the identification of the model wave to pitch moment, it is necessary to impose in the parameter vector x that

$$x_{n+1}=0 \qquad (21b)$$

iii) System stability. This constraint forces the real part of the poles to be negative, that is, to be in the left hand on the s-plane.

Starting values.

High quality starting values, i.e, near to the global optimum, are basic to reach the convergence point. In [1], starting values are obtained via a genetic algorithm or generated at random. The trouble met in the identification of new models with different angles of incidence is that in many occasions, due that starting values were not adequate or distant from the minimum, the procedure of minimization was long and costly. This was intensified when genetic algorithms were used, since it is a method based on the heuristic that did not give good results in many cases. For that reason, it is developed a new method to obtain the starting values x_0. This method consists of a linear least square estimation. From the cost function J(x) expression:

$$J(x)=\sum_{i=1}^{N}\left|G(j\omega_{ei})-G(j\omega_{ei},x)\right|^2=\sum_{i=1}^{N}\left|G(j\omega_{ei})-\frac{B(j\omega_{ei},x)}{A(j\omega_{ei},x)}\right|^2 \qquad (22)$$

it yields:

$$\sum_{i=1}^{N}\left|A(j\omega_{ei},x)G(j\omega_{ei})-B(j\omega_{ei},x)\right|^2 \qquad (23)$$

Therefore, a problem of least squares is set out. For each frequency value ω_{ei}, the denominator $A(j\omega_{ei},x)$ and numerator $B(j\omega_{ei}, x)$ are only function of the vector x, and $G(j\omega_{ei})$ is a complex value. Hence, rewriting the above expression leads to an equation of the type c * x – d = 0, where x is the parameters vector (the starting values) to estimate.

Next, considering all the points i = 1..N, that is, all the frequencies w_{ei}, one matrix C with N files and n+m columns, and one column vector with n+m size are given. Thus it is raised a least squares problem

$$C \cdot x - d = 0 \tag{24}$$

Multistep procedure. Identification of the transfer functions $G_{2Z}(s)$.

In this work, originally it is proposed the multistep procedure, where $G_{2Z}(s,x_b)$ is identified from the previously estimated transfer function $G_{1Z}(s,x_a)$ and the data $G_Z(s)$ (11). As an alternative to this procedure, it is suggested to solve simultaneously both transfer functions and estimate the parameters vector x_a and x_b at the same time.

Another approach for estimating $G_{2Z}(s)$ is to make a previous hypothesis of linearity and determine the points to fit the transfer function from the linear superposition principle. Thus, for each frequency of encounter of wave ω_{ei}, i =1..N:

$$|G_{2Z}(j\omega_{ei})| = \frac{|G_Z(j\omega_{ei})|}{|G_{1Z}(j\omega_{ei})|}; \qquad \arg\left(G_{2Z}(j\omega_{ei})\right) = \arg\left(G_Z(j\omega_{ei})\right) - \arg\left(G_{1Z}(j\omega_{ei})\right) \tag{25}$$

where Z = H, P, R.

AN EXAMPLE

The whole work tries to identify a continuous linear model of heaving, pitching and rolling dynamics. Specifically, models of G_{1H}, G_{2H}, G_{1P}, G_{2P}, G_{1R}, and G_{2R} are identified for incidence waves between 90 and 180 degrees. Each plant models set have the same number of poles and zeros.

In this section it is shown a practical case of application and comparison of the two approaches commented. Specifically, it is presented the identification of the model corresponding to the wave to heave force plant, for the incident angle 135º and ship speed 40 knots.

Thus, for each case, it is presented the transfer function model identified and the Bode diagram in which it is compared with the true data. Besides it is shown the temporal response of the final model identified, for the particular case of irregular waves SSN=5.

Wave to Heave Force $G_{1H}(s)$ Model:. First approach

As it has been noted in previous sections, first step is to select a set of candidate model structures. Table 1 shows two of these considered model structures (m,n,nps), and the value of the cost function *J* for speed 40 knots. Here, *m* is the number of zeros, *n* is the total number of poles, and *nps* is the number of simple poles. The parameter vector *q* and transfer function are determined for each model structure. These all models give very similar Bode plots in the frequency range of interest, so this is a proof that these must reflect features of the true system. Structure with minimum *J* is selected as the best model.

model structure (*m,n,nps*)	cost function J
(3,4,2)	0.51
(3,3,1)	0.79

Table 1. Model structures, cost function J and AIC

Finally, structure (3,4,2) is chosen, and the estimated transfer function is

$$G_{1H}(s) = 9333 \frac{76.56s^3 - 22.21s^2 + 322.5s - 14.92}{s^4 + 21.26s^3 + 154.7s^2 + 289s + 14.92} \tag{26}$$

Figure 3 shows the Bode plots of the estimated transfer function and the simulated true data. It can be seen that the model is quite capable of describing the system.

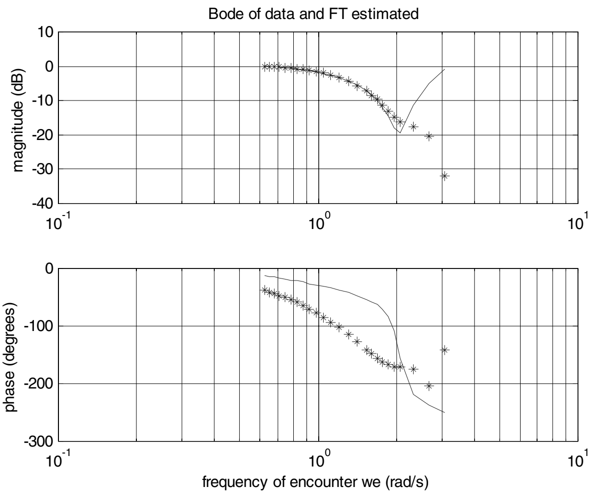

Figure 3.Bode plot of $G_{1H}(s)$ and experimental data

Finally, figure 4 shows the response in the temporal domain of the model identified.

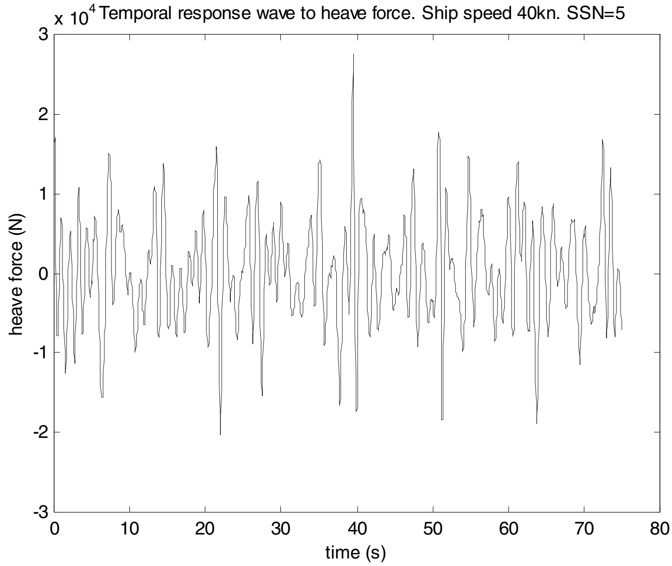

Figure 4.Temporal response $G_{1H}(s)$

Wave to Heave Force $G_{1H}(s)$ Mode: Second approach.

Table 2 shows two of the model structures (*m* is the number of zeros,and *n* the number of poles) that had been tried, and the respective values of AIC and cost function *J*. According to Akaike's theory, those with the lower value AIC is selected. In this case, structure (3,4), with $m = 3$ zeros and $n = 4$ poles gives the best result, so this structure is the chosen one.

model structure (m,n)	AIC	cost function J
(3,4)	-63.31	0.0347
(3,3)	-54.71	0.055

Table 2. Model structures, cost function J and AIC

Once model structure is fixed, the identification procedure is executed and the following transfer function is estimated:

$$G_{1H}(s) = 9333\,\frac{26.02s^3 - 22.13s^2 + 160.9s^1 + 0.9}{s^4 + 125.4s^3 + 149.1s^2 + 181.3s^1 + 0.9} \qquad (27)$$

Figure 5 shows the comparison between the Bode diagram of the transfer function identified and the actual data. It is shown that the model fits the data quiet good. Next, figure 6 shows the temporal response of the final estimated model.

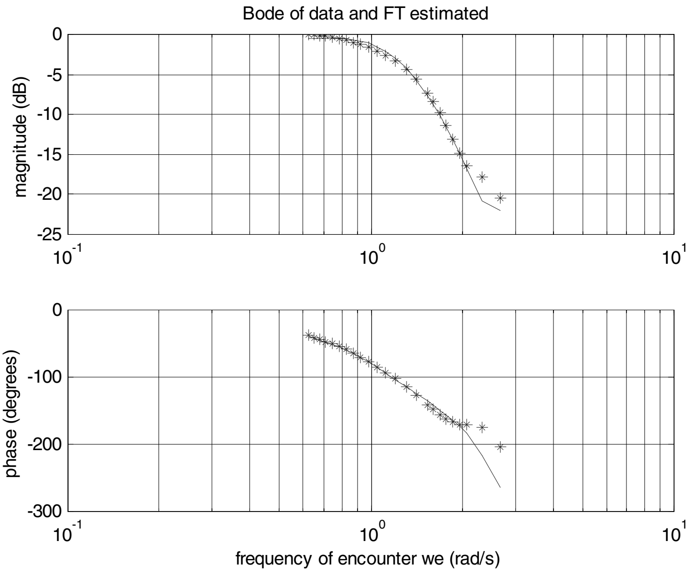

Figure 5. Bode plot of $G_{1H}(s)$ and data

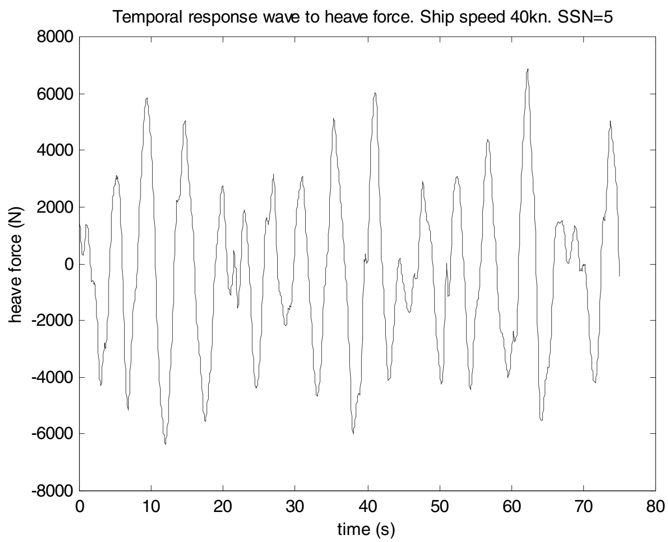

Figure 6. Temporal response $G_{1H}(s)$

Wave to Heave Force $G_{1H}(s)$ Model: Comparison.

Evaluating the results of the two implementations, it is seen in numerical results and graphics that the second approach estimates a transfer function model that fits the data more accurately. In addition, in the Bode diagram of the first $G_{1H}(s)$ it is observed that the amplitudes at high frequencies are too much large, which is translated into a very oscillatory and not proper behaviour in the temporal response.

CONCLUSIONS

In this paper two different approaches of the system identification method has been proposed in order to analyse and identify models for the heave, pitch and roll dynamics of a high speed craft.

The first approach uses genetic algorithms and non linear least squares with constraints methods applied in the frequency domain as a criterion of fit to compute the best model. This method has been employed to model the vertical dynamic (heave and pitch modes) for the particular case of waves from directly ahead. However, when the study is extended to the horizontal dynamic (roll mode) and in addition other angles of incidence, it is not obtained such good models. Furthermore, it is observed that the technique does not guarantee the best linear approximation, and involves a lot of computational load due to non quadratic functions.

For that reason it is suggested another procedure. The second approach changes the type of parameterization, in order to facilitate the model selection and avoid non-quadratic functions in the cost function. Moreover and most important, this new parameterization promotes obtaining high quality starting values via a linear least squares estimate.

The chapter is concluded with an example in which the two approximations are applied. The particular case is the wave to heave force plant, with incidence wave 135º and ship speed 40 knots. For each method, obtained model's properties are examined. Bode plots are computed, graphed and compared with experimental data. It is seen that estimated model describes data information. Models which best agree with the experimental data are selected. Temporal response is also depicted. Finally, it is shown that the second approach obtains more accurate models that the first one.

AKKNOLEDGMENTS

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