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Investigation of knowledge based adaptive course control system for underwater vehicle

SUMMARY

In this paper results of investigation of knowledge-based, adaptive course control system for underwater vehicle are presented.The system is based on tabulation of object parameters, which constitutes a base of knowledge about object. Computer simulation tests of several versions of the system have proved the proposed system to be useful for objects of rapidly changeable state.

INTRODUCTION

Adaptive control systems do not fulfill well their role in the case of small ocean vehicles, whose state may change fast. A solution of the problem, proposed in this paper, is to connect an adaptive system with a system based on tabulation of object parameters. The solution has also an advantage, that identification results being obtained in system operation are not lost. They are collected in a table, which is a representation of object's nonlinear behaviour.

The solution proposed has been checked by computer simulation.

KNOWLEDGE BASED CONTROL SYSTEM

Behaviour of an ocean vehicle is usually described by highly nonlinear differential equations. But when performing synthesis of a control system linear approximations of the equations are usually applied. Coefficients in the linear equations of object behaviour depend on operating and enviromental conditions of the object. They change often in a quite substantial range, which suggests applying a nonlinear control system.

Adaptive control systems in ocean vehicles are effective first of all in the case of not fast changeable parameters of an object. Slow changes allow for adaptation of a control system to object's operating conditions. It mainly concerns such changes in object's enviroment as parameters of sea state, wind, currents, and water depth.

It is quite different in the case of changes of coefficients which arise from change of object's operating conditions. The changes are very rapid when it concerns - in particular small ocean vehicles.

The classical identification-based adaptation fails in this case. An attempt to cope with high nonlinearity of equations describing behaviour of objects of a known structure is tabulation of parameters according to operating conditions.

Control system synthesis is carried out on the basis of parameters retrieved from a table which allows to quickly correct a system setting even in case of fast changing states of an object. The method based on tabulation of parameters is not free however from draw-backs. System settings are not adjusted in this case to changes in environmental conditions of an object and in its loading conditions.

Many of the above mentioned problems are solved applying a method consisting in a combination of the classical adaptive control approach based on parametrical identification with tabulation of parameters. Tabulation of parameters provides for quick readjustment of the control system to the object's state, but identification of parameters in a table allows for adaptation of the system to environment and loading conditions of the object. Identification of parameters in a definite location within a table will be performed if the object is in a range of states corresponding to this location.

The basic variables deciding upon dynamic behaviour of an underwater vehicle are: longitudinal, transverse, and vertical advance velocity components and angular velocity around z axis (Fig.1).

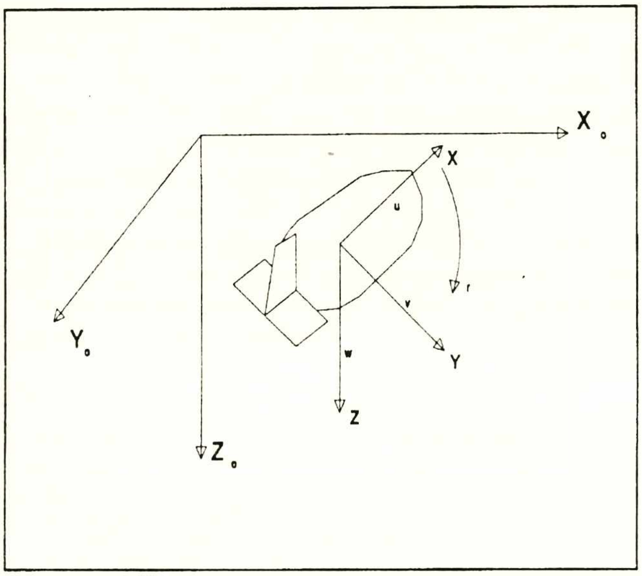

Fig. 1. Motion of an underwater vehicle in the XYZ coordinate system

To ensure taking into account changes of vehicle parameters, respective to all the above specified variables, it is necessary to define a four-dimensional table.

The main problem which arises in that type of control is a low amount of data obtainable for disposal when identifying each of parameters of the table. It is therefore essential to initiate the table with the use of those vehicle parameters, which ensure not necessarily optimal, but correct and safe (stable) operation in its early phase. The parameters would be used until such an amount of data is collected for a given location in the table, which guarantees parameter identification, that is correct and bearing a possibly low error.

An important advantage of the object parameter tabulation is possibility of acquisition of identification results. In a regular identification during operation of an object these results are lost. Tabulation enables to acquireing identified parameters in a table, which describes non-linear behaviour of an object. The table constitutes this way a base of knowledge about an object.

INVESTIGATION RESULTS

General design methods for systems operating on the basis of a table of parameters do not exist. To check whether a system operates correctly, some simulation tests are usually carried out.

A course control system has been tested with a regulator of the PID type, whose settings have been selected on the basis of a table of the identified object's parameters.

The simplest way to describe the behaviour of an underwater vehicle as an object with controlled course is to apply linear equations of state, as follows:

$$\begin{bmatrix}\dot{\Psi}\\ \ddot{\Psi}\end{bmatrix} = \begin{bmatrix}0 & 1\\ 0 & a_4\end{bmatrix} \times \begin{bmatrix}\Psi\\ \dot{\Psi}\end{bmatrix} + \begin{bmatrix}0\\ b_2\end{bmatrix} \times M$$

$$\Psi = \begin{bmatrix}1 & 0\end{bmatrix} \times \begin{bmatrix}\Psi\\ \dot{\Psi}\end{bmatrix}$$

with a relevant transfer function:

$$\frac{\Psi(s)}{M(s)} = \frac{b_2}{s(s-a_4)} = \frac{K}{s(sT+1)}$$

where: M - steering moment of a vehicle;
Ψ - course angle of a vehicle;
s - Laplace operator;
T - time-constant;
K - amplification factor;

Coefficients appearing in the transfer function depend on the object's state. For instance, the relationship for longitudinal velocity **u** is illustrated in Fig. 2.

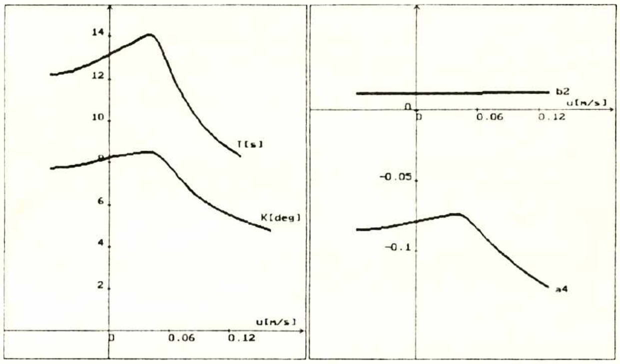

Fig. 2. Variation of coefficients in the linear equations describing behaviour of an underwater vehicle depeding on longitudinal velocity

Coefficient variations due to variation of the velocity **u** are substantial, that is why this feature of an underwater vehicle is used to demonstrate advantages of the control system proposed.

SIMULATION TEST 1

In this test only the dependence was analysed of variation of the coefficients on the variation of the velocity **u**. A full range of values of the longitudinal velocity **u**, obtainable by a vehicle under test, was divided into 6 intervals as follows:

....	0
0	0.05
0.05	0.1
0.1	0.15
0.15	0.2
0.2	....

For each interval, a separate identification was performed just at the moment when the velocity **u** was within it. The coefficient were identified with use of the reccurent least squares method with damping factor and protected against a "run-away" of the values estimated. After identification the coefficients were additionally filtered to eliminate erroneous results, which could destabilize operation of the system.

To each interval the following initial values of the coefficients were assigned:

$$a^0_4 = -0.1327034\,;$$
$$b^0_2 = \;\; 0.0110007\,;$$

which related to velocity u = 0.16 m/s.

During the simulation the steering moment was disturbed with a signal imitating sea wave action. An initial course angle of the vehicle equalled 0^0, but the set one was 15^0. The velocity **u** was altered in time as given in Fig. 3.

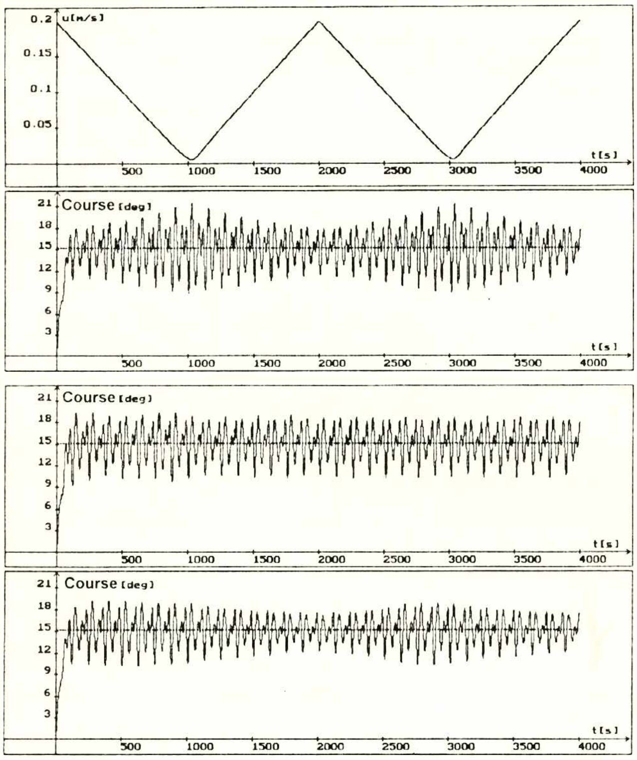

Fig. 3, 3A, 3B, 3C. Results of the simulation test 1.

During the simulation test the following quality ratings were determined:

$$J_1 = \int_0^t |\Psi(t)|dt\,; \quad J_2 = \int_0^t \Psi^2(t)dt\,;$$

$$J_3 = \int_0^t |M(t)|dt\,; \quad J_4 = \int_0^t M^2(t)dt\,;$$

<u>Results of the simulation test 1</u>

In Fig. 3A results are presented of simulation for a system without any adaptive regulator. System settings were calculated on the basis of the coefficients a^0_4 and b^0_2.

A distinct deterioration of system operation was observed for velocity values substantially differing from the nominal one, i.e. , 0.16 m/s.

The quality ratings obtained the following values:

$$J_1 = 154.121;$$
$$J_2 = \;\; 9.504;$$
$$J_3 = 247.459;$$
$$J_4 = \;\; 22.183;$$

In Fig. 3B simulation results are given for a system with an adaptive regulator and tabulation of parameters (in 6 intervals). In this case, a characteristic feature was a "calm down" of oscillation amplitudes about the course set, which happened after an initial period of identification (about 1000 s). The quality rating values were this time as follows:

$$J_1 = 138.910;$$
$$J_2 = \;\; 7.904;$$
$$J_3 = 215.205;$$
$$J_4 = \;\; 16.634;$$

In Fig. 3C simulation results are presented for a system with an adaptive regulator and no tabulation of parameters. Values obtained for the quality ratings were close to those above presented .

In this simulation test the adaptive systems showed a better operation quality than that without adaptation. However, both adaptive systems reached a similar quality. This is caused by a very slow variation of state of the object. In this case tabulation of parameters has not yet proved indispensable.

SIMULATION TEST 2

In the second test presented velocity **u** changes according to Fig.4.

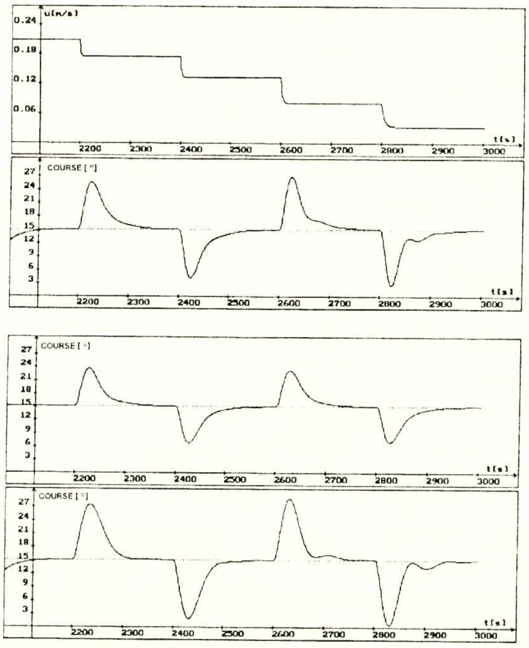

Fig. 4, 4A, 4B, 4C. Results of the simulation test 2

In the time instants when velocity changes, the steering moment is disturbed by the stepwise values: 0.2 N and -0.2 N. For the system with tabulation of parameters it has been assumed that it is already operating for some time and the knowledge base about the object is by now properly filled. The course angle has been assumed as being 15^0.

Results of the simulation test 2

The results of this simulation test are presented as follows:

In Fig. 4A - for the system with a stationary regulator.

In Fig. 4B - for the system with an adaptive regulator and tabulation of parameters.

In Fig. 4C - for the system with an adaptive regulator but without tabulation.

The system with tabulation of parameters operates definitely best of all in the case of rapid changes of state of the object. It offers the smallest deviations from a course set, constant for different values of velocity **u**, and an oscillation-free operation of the system.

CONCLUSIONS

The simulation tests performed have proved the proposed control system to be useful for objects of rapidly changeable state. First of all it concerns small ocean vehicles.

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Conferences

XVIth Ship Technology Scientific Session

Polish naval architects and marine engineers hold every second year a meeting to present their scientific and professional achievements in marine technology. This year XVIth session of the kind was held from 30 May to 1 June in Szczecin, being organized by common efforts of Szczecin Shipyard Co, Merchant Marine Academy in Szczecin, Marine Technology Faculty of The Technical University of Szczecin, and The Polish Association of Naval Architects and Marine Engineers - KORAB.

The Honourable Committee of the session was chaired by dr inż. M. Tałasiewicz, the governor of the Szczecin Province. About 250 participants, representing several tens of various shipbuilding and shipping organizations, took part in the session. As usual a number of guests from abroad - this turn from Denmark, France, Germany, Sweden and Ukraine - were also present.

The entire session was mainly devoted to actual problems of Polish shipbuilding industry, therefore plenary sessions were focussed on:

- ownership transformations in Polish shipyards,
- restructuring of Polish shipbuilding industry,
- Polish state maritime policy,
- cooperation of scientific and industrial organizations,
- Quality Assurance systems in compliance with ISO 9000 standard,
- implementation of Computer Aided Design systems,
- safety at sea.

These topics were reflected in 87 papers (20 of which - presented during the plenary sessions). Full session proceedings have been edited in four volumes.

There were two contributions of special interest: that of prof.J. Doerffer on Polish state maritime policy and of dr inż. M. Tałasiewicz on a role of Szczecin Province in its implementation.

Actual results of restructuring of the Polish shipbuilding industry and its development prospects were highlighted by prof. J. Biliński from the University of Gdańsk. Papers presented by dipl.ing. A. Klimaschewski from Germanischer Lloyd and mgr inż. K. Krukowski from Szczecin Shipyard on elaboration and implementation of QA systems in compliance with ISO 9000 standard focussed attention of representatives of various firms.

Numerous specialist problems such as: ship power plant systems, shipbuilding materials, production engineering processes and management, being of interest to narrower groups of participants, were presented and discussed at topic sessions.

The Session was also accompanied with exhibitions of numerous products and presentation of designs and know- how projects of potential use in shipbuilding.

The Session participants were given an opportunity for visiting shipbuilding departments of Szczecin Shipyard and ships under construction there.