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ON ADAPTIVE MODEL REFERENCED PARAMETER TRACKING TECHNIQUE.AN ADAPTIVE SERVO SYSTEM

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ABSTRACT

The principle of parameter tracking technique in model referenced adaptive control systems first introduced by Donalson and Leondes 1963, stressed that the reference model must be exactly of the same order like the total transfer of the non adaptive portion. This method has been modified by AZAB (Military Technical Academy VAAZ; Brno, 1974) to be generally applicable for less- order models. This leads to an important practical simplification, that it does not require the knowledge of the exact order of the non adaptive portion.

In this paper, the modified parameter tracking (MPT) technique is employed to realize adaptivity for a real nonstationary servo system. The introduced results were obtained by coupling the non adaptive real servo system to the computer EAI-50 (Laboratoire d'automatique, Ecole Superieure d'Electricite, antenne de Rennes, France, 1981) which proved satisfactory adaptive behavior of the realized adaptive system.

1- INTRODUCTION

The most important problems contained in adaptive techniques are those associated with the identification. As an example, to measure the exact variation of air plane parameters and characteristics or to locate the exact pole - zero configuration continuously during flight, it is practically very complicated problem.

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The parameter tracking technique introduced by Donalson and Leondes avoids the identifications problem, but stressed that the order of the reference model must be the same like that of the non adaptive portion, in other words, we should identify the exact order of the system which may cause many practical difficulties.

The parameter tracking technique has been modified by AZAB (1974) to be generally applicable to control physical systems according to less order reference models, hence it does not necessitate the knowledge of the exact order of the non adaptive portion.

In this paper, the modified parameter tracking technique is practically employed to realize an adaptive servo system. After introducing the general adaptation scheme (section 2.1), we deal with the basic assumptions related with the rates of variation of system parameters (section 2.2). Further considerations for using less - order reference models are discussed in section 2.3. In section 2.4 we deal with used generalized quadratic error function. The adaptation laws are derived in general form in (section 2.5).

The introduced results demonstrated in (section 3) have been obtained by coupling the non adaptive servo system to the computer EAI-80 in the laboratory of control; high school of electricity, Rennes, France, aiming at showing the applicabilityof the MPT technique to realize real physical adaptive systems. Further, this work shows that the MPT technique secures un acceptable comprimse between simple realization and high adaptation speed.

2- PRINCIPLE OF ADAPTATION

2.1: General Adaptation Scheme

The principle of adaptation will be explained on a general linear time variant case, represented in figure 1.

The transfer function of individual blocks are assumed to have the following forms :

$$A(p) = \sum_{i=o}^{\gamma} a_{in}\, p^{i} \Big/ \sum_{i=o}^{\delta} a_{id}\, p^{i}, \qquad \delta \geqslant \gamma \qquad (1)$$

$$F(p) = \sum_{i=o}^{\psi} f_{in}p^i / \sum_{i=o}^{\theta} f_{id}p^i \quad , \quad \theta \geqslant \psi \tag{2}$$

$$K(p) = \sum_{i=o}^{\omega} k_{in}p^i / \sum_{i=o}^{\varrho} k_{id}p^i \quad , \quad \varrho \geqslant \omega \tag{3}$$

$$G(p) = \sum_{i=o}^{\varphi} g_{in}p^i / \sum_{i=o}^{\eta} g_{id}p^i \quad , \quad \eta \geqslant \varphi \tag{4}$$

$$H(p) = \sum_{i=o}^{\xi} h_{in}p^i / \sum_{i=o}^{\mu} h_{id}p^i \quad , \quad \mu \geqslant \xi \tag{5}$$

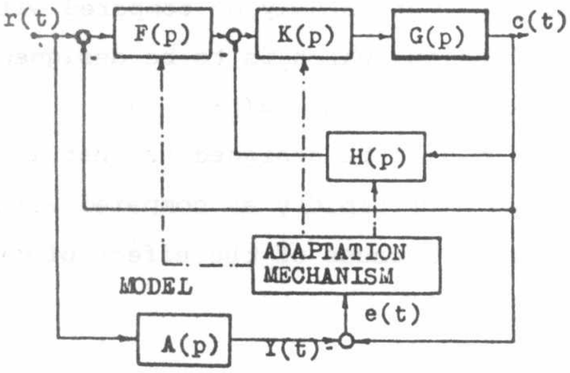

Fig.1. Principle of adaptation.

2.2. Assumptions:

It is assumed that the form of G(p) is known, but its coefficients vary in some unknown and unpredictable manner with time.

The transfer function of the nonadaptive portion is:

$$B(p) = \frac{F(p)\ G_1(p)}{1 + F(p)\ G_1(p)}$$

$$= \sum_{i=o}^{\sigma} \alpha_{in} p^i / \sum_{i=o}^{\gamma} \alpha_{id} p^i \quad , \quad \gamma > \sigma \qquad (6)$$

where
$$G_1(p) = \frac{K(p) \; G(p)}{1 + K(p) \; G(p) \; H(p)} \qquad (7)$$

The operation of multiplying transfer functions is mathematically rigorous only if the coefficients in each transfer function are constant. Otherwise p cannot be treated as the complex variable of the Laplace transform.

These coefficients are not constants, since it is assumed that the coefficients in G(p) vary with time. Further, the objective of the adjusting mechanism design is to vary the coefficients in F(p), K(p) and H(p) to compensate for changes in G(p).

Justification for writing B(p) is based on the following assumptions:

1- The coefficients in G(p) vary slowly as compared with the basic time constants of the physical process and the reference model.

2- The coefficients in G(p) vary slowly as compared with the rate at which the adjusting mechanism, which is to be designed, adjusts the chosen parameters in F(p), K(p), and H(p).

3- The adjusting mechanism will be designed so that it adjusts the parameters in F(p), K(p) and H(p) rapidly as compared with the rate at which f(e) is caused to change because of the effect of disturbances and inputs.

This being true, the operator p is almost eligible to be treated as the complex variable in the Laplace transformation.

This is a justification and not a proof. Its validity can be arbitrarily strong by making the rate of change of the parameters in G(p) arbitrarily slow.

The α_{ij} are function of f_{ij} , k_{ij} , g_{ij} and h_{ij}, what the relationships are will depend on the particular system being considered.
The generalized equations to be derived will yield rates at which α_{ij} must be adjusted to affect the adaptation.

2.3. Further Assumptions for Less Order Models

Further considerations for using a less order reference model, are:

1- The desired output could be obtained by the variation of the coefficients α_{ij}

2- The order of the reference model δ is chosen arbitrarily according to the required behaviour of the system to be less or equal to the order of the nonadaptive part.

3- The number of parameters to be adjusted by the adjusting mechanism can not be greater than the number of coefficients that appear in the characteristic equation of the reference model $(\delta + 1)$.

4- The order of the time derivative of the generalized error function is chosen equal to the order of the characteristic equation of the reference model.

2.4. Used Generalized Quadratic Error Function

The generalized quadratic function of the error $e = c - y$, will be chosen in the following form:

$$f(e) = \frac{1}{2}\left[\sum_{i=o}^{\delta} q_i \frac{d^i e}{dt^i}\right]^2 \qquad (8)$$

2.5. Adaptation Laws by MPT

The rates at which α_{ij} are to be adjusted are :

$$\dot{\alpha}_{id} = K_{id} \frac{\partial f(e)}{\partial a_{id}} \qquad ; \; i=0,\ldots,\delta$$

$$= -K_{id}\left[\sum_{j=o}^{\delta} q_j \frac{d^j e}{dt^j}\right]\left[\sum_{j=o}^{\delta} q_j \frac{d^j u_{id}}{dt^j}\right] \qquad (9)$$

and

$$\dot{\alpha}_{in} = K_{in} \frac{\partial f(e)}{\partial a_{in}} \qquad ; \; i=o,\ldots,\delta$$

$$= -K_{in}\left[\sum_{j=o}^{\delta} q_j \frac{d^j e}{dt^j}\right]\left[\sum_{j=o}^{\delta} q_j \frac{d^j u_{in}}{dt^j}\right] \qquad (10)$$

where :

$$u_{id} = \frac{\partial y}{\partial a_{id}} \qquad ; \qquad i=o,\ldots,\delta \qquad (11)$$

$$u_{in} = \frac{\partial y}{\partial a_{in}} \quad ; \quad i=o,\ldots,\gamma \qquad (12)$$

The error and its derivatives are assumed to be available from the output of the physical process and the referenced model.

The K's and q's are constant parameters and would be chosen by the designer so as to secure the stability of the process.

Hence, the only unknown quantities in the equations are u_{id}, u_{in} and their derivatives. These variables could be obtained by taking the partial derivative of equation (1) of the reference model with respect to the particular a_{id} or/and a_{in}, treating the derivative of y with respect to time as a trivial partial derivative and interchanging the order of differentiation. Finally, the partial derivative with respect to time is treated as an ordinary derivative. Doing so, we get

$$\sum_{i=o}^{\delta} a_{id} \frac{d^i u_{jd}}{dt^i} = - \frac{d^j y}{dt^j} \quad , \quad j=o,\ldots,\delta \qquad (13)$$

$$\sum_{i=o}^{\delta} a_{id} \frac{d^i u_{jn}}{dt^i} = \frac{d^j r}{dt^j} \quad , \quad j=o,\ldots,\gamma \qquad (14)$$

3. A REAL ADAPTIVE SERVO SYSTEM USING THE MPT TECHNIQUE

From the application point of view, the MPT gives simple realizability of adaptive loops owing to following concepts :

1) the possibility of using less - order models secures:
   - simple model simulation.
   - simple adaptation mechanism
   - identification of exact order of model is not required.
2) the possibility of realizing the adaptation mechanism without the identification of the non adaptive portion.
3) the adaptation laws do not include multiplication of system's outputs with noise as the signals (u_o , u_1) are generated from the output of model.

The MPT technique has been employed to realize adaptivity for a real non-stationary servo system (figure 2)

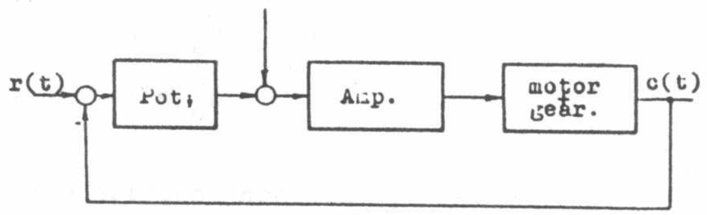

Fig.2. Block diagram of servo system.

Such system has been coupled to the computer EAI-80 in the ESE, Rennes, France to realize the adaptation loops and reference model [5] as seen in figure 3:

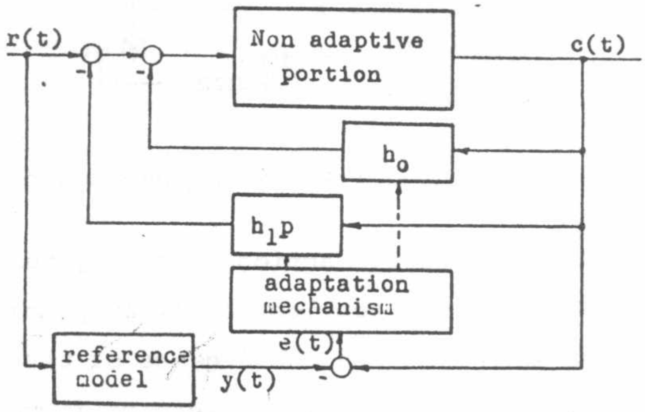

Fig.3. Adaptive servo system

For simplicity, the model is chosen of the first order. Applying the MPT technique for the first order model we use the following adaptation laws:

$$\dot{h}_1 = -k_1(q_o e + q_1\dot{e})(q_o u_1 + q_1\dot{u}_1)$$

$$\dot{h}_o = -k_o(q_o e + q_1\dot{e})(q_o u_o + q_1\dot{u}_o)$$

where $e = c - y$

$T_r\dot{y} + y = r(t)$ model.

$$T_r \dot{u}_1 + u_1 = -\dot{y}$$

$$T_r \dot{u}_o + u_o = -y$$

with the following parameters:

$T_r = 0.032$ (s) , $k_o = 25$

$k_1 = 1000$, $q_o = 1$,

$q_1 = 10$

Figure 4 shows the connection of the non adaptive portion (real servo system) with the model and adaptation mechanism simulated on the computer EAI-80.

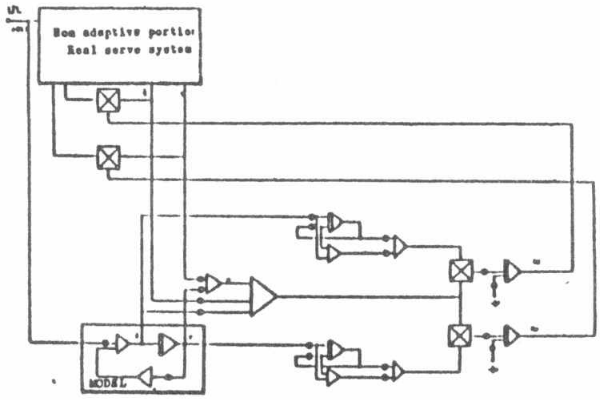

Fig.4. Adaptive System connection

Figure 5. demonstrates adaptive action on the system output c(t) which begins at the instant (A) of application of adaptation to track the model's output y(t). We note also the convergence of the tachometric feed back parameter (h_1) from both directions as seen on figures 5,6.

While in previous graphical results; sequence of square pulses was used as input, we applied also (figure 7) random input to show very rapid and effective adaptation action (less than 0.5 s)

It is of particular importance to indicate the adaptive action by adaptation trajectories showing the parametric convergence of (h_o,h_1) as given on figure 8 for square pulses input and on figure 9 for random input. Both types of inputs secures the same steady state values of parameters h_o,h_1 but the shape of trajectories is somewhat different.

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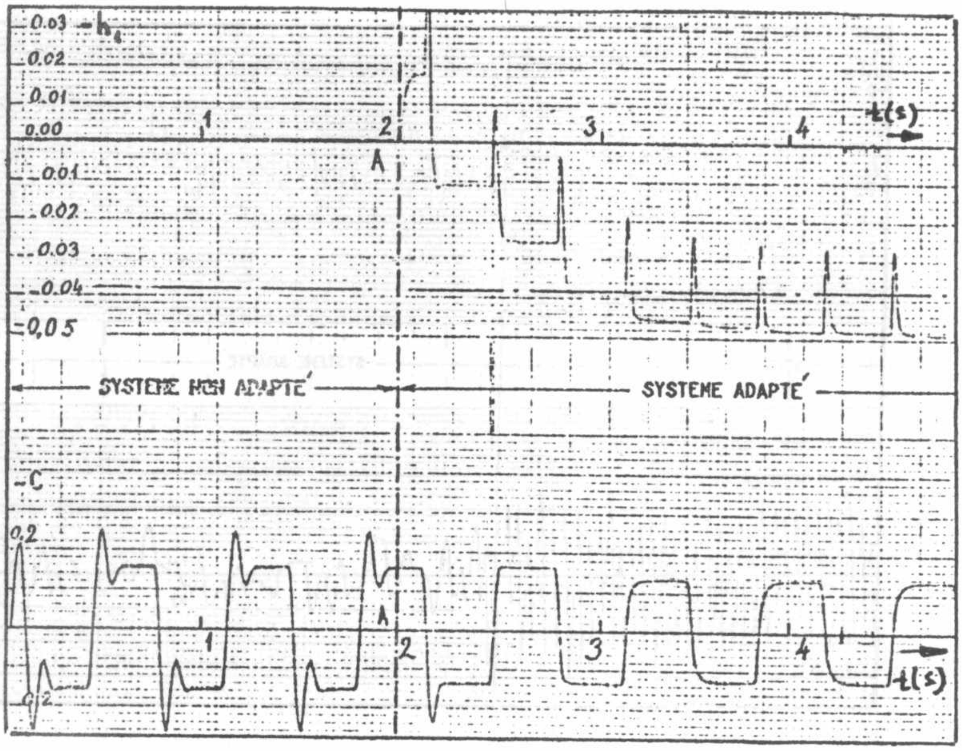

Fig.5. Response of adaptive system.

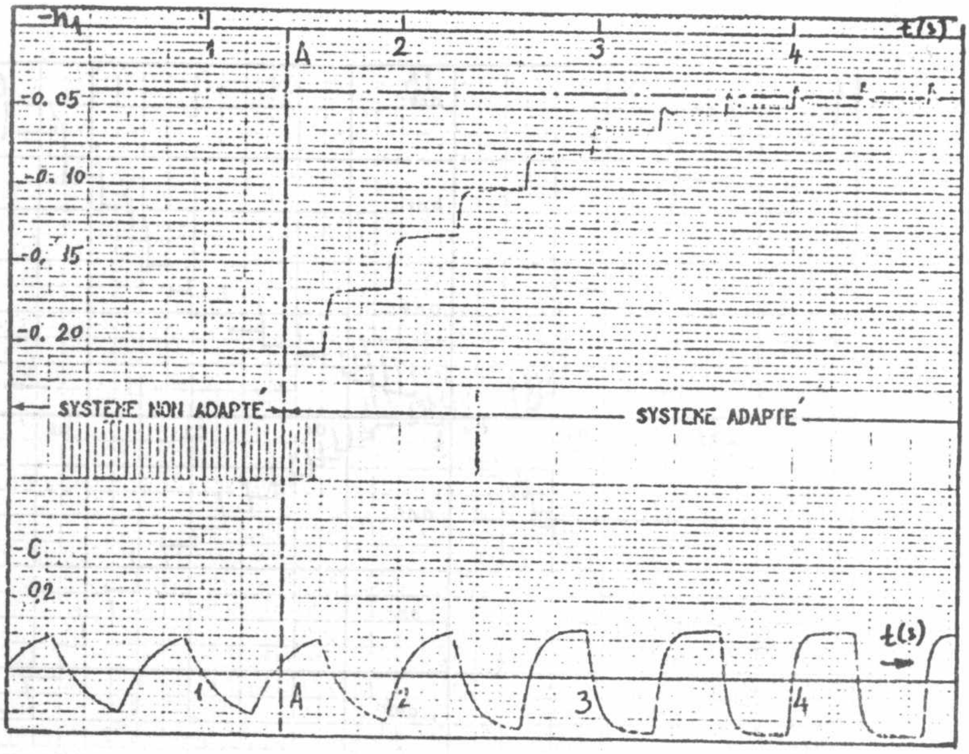

Fig.6. Response of adaptive system.

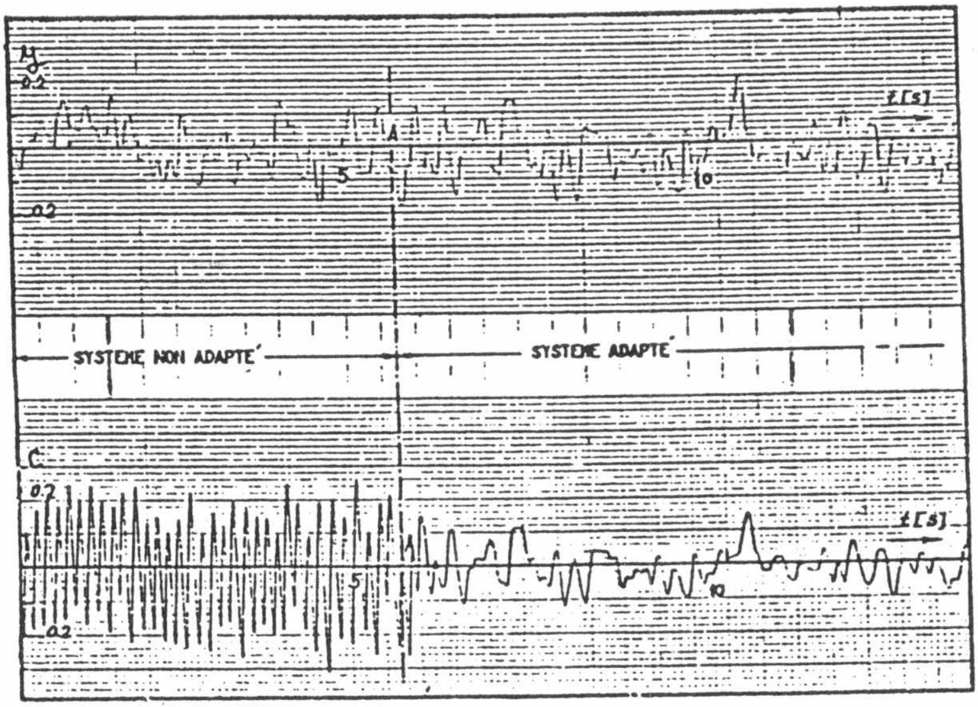

Fig.7. Adaptive system response with random input.

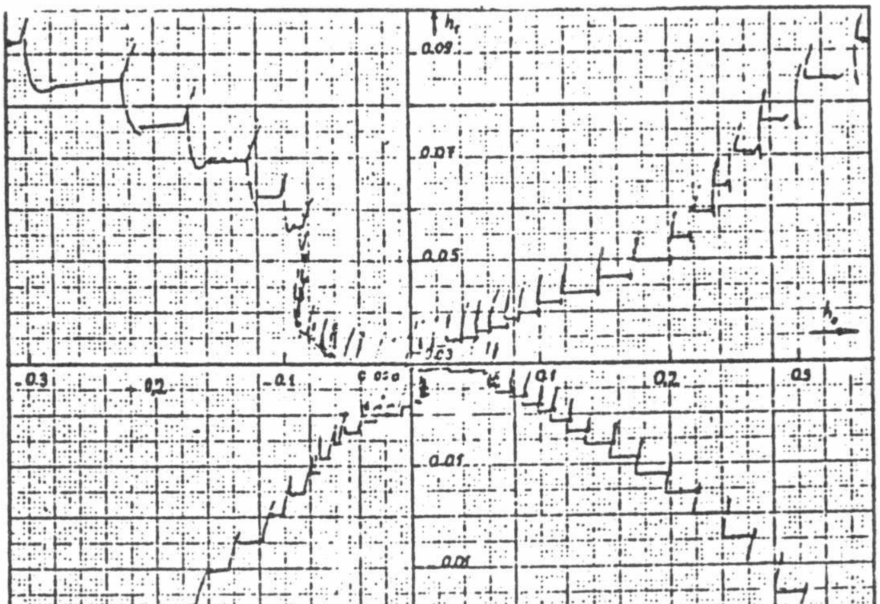

Fig.8. Parameters convergence with square pulse input.

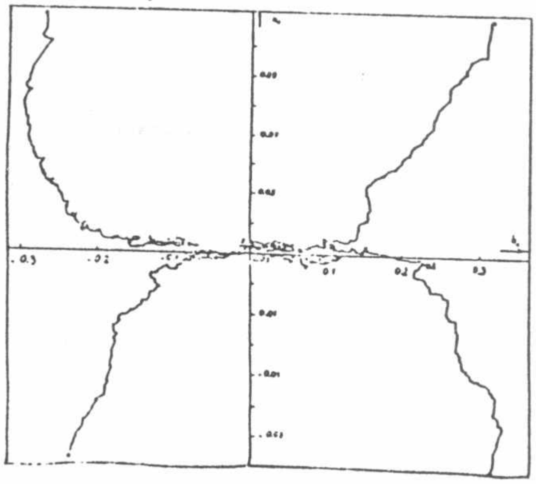

Fig.9. Parameters convergence with random input.

CONCLUSION

From the point of view of application; the MPT secures simple realization of adaptive mechanism with less order model, with no need to identify the non adaptive portion and without multiplication of disturbed system's output and noise signals. The demonstrated results prove the applicability of the MPT on real physical systems. Such results indicate that this technique realizes certain satisfactory compromize between the simplicity of realization and the speed of adaptation.

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