REVIEW ON MODELS FOR GENERALIZED PREDICTIVE CONTROLLER

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ABSTRACT

Keeping of vehicles on track under non-linear dynamics conditions is important for unmanned navigation, because it saves fuel and journey time. Keeping this in view, an efficient model is required for controller that incorporates non-linear dynamics. Currently researchers are using models like "A-R","M-A", "ARMA", "ARMA with Exogenous Input", to improve the accuracy of tracking, but still drawback exists because of identical disturbance random sequence and excessive control effort. Hence "ARIMA" model is used which overcomes these disadvantages. This paper discusses design details of "ARIMA" model along with comparisons of other models used for ship tracking.

KEYWORDS

Generalized Predictive Controller, CARIMA, Non-Linear

I. INTRODUCTION

The Unmanned Navigation of (UAV) vehicles or ship requires not only an efficient control but also an efficient model for the navigation and control of rudder movement under the real time condition [3]. There are many innovations going on ship navigation technology to reduce the complexity in navigation, fuel consumption and to increase the flexibility in controlling the ship under critical environmental conditions. The widely used models are models like "A-R", "MA", "ARMA", "ARMA with Exogenous Input", and "ARIMAX" [4]. This paper discusses different models used for ship navigation technology. Section-II discusses different models used for ship navigation. Section-III discusses the most opted CARIMA model for ship navigation.

2. MODELS FOR SHIP NAVIGATION

2.1. A-R Model

A-R Model stands for "Auto-Regressive" Model. It is one of the simplest forms of time series, where the current value of a time variable is assumed to be a function of past values and noise.

$$Y(t) = C + \sum_{i=1}^{P} a_i Y_{t-i} + \xi(t) \qquad (1)$$

The model consists of three parts namely a constant part, an error or noise part, and the autoregressive summation. The actual summation represents the fact that the current value depends only on previous values. The variable "P" represents the order of the model. The higher the order of the system, the more accurate will be the representation. The above equation (1) shows a representation of regression of a time variable with it self at different time instants.

The advantage of "Auto-Regressive" Model is that one can determine current output easily and the disadvantage of "Auto-Regressive" Model is that the **past disturbances** and **process model** are not considered.

2.2. M-A Model

M-A Model stands for "Moving-Average" Model. Here the current value is expressed as a weighted sum of all past and present values of ξ

$$Y(t) = \xi(t) + \sum_{i=1}^{Q} b_i \xi_{t-i} \qquad (2)$$

The model consists of two parts namely a present noise and the summation part includes Parameters of the model, ($b_1 b_2 \ldots \ldots b_Q$) and the error terms are (ξ_{t-1} ξ_{t-2})

The advantage of "Moving-Average" Model is that one can determine current output based on past & present disturbance and the disadvantage of "Moving-Average" Model is that the **past output** & **process behavior** is not considered.

2.3. ARMA Model

ARMA Model stands for "Auto-Regressive Moving-Average" Model. It is a representation of both "Auto-Regressive" and "Moving-Average". The notation ARMA (p, q) refers to a model with p autoregressive terms and q moving average terms.

$$Y(t) = \xi(t) + \sum_{i=1}^{P} a_i\, Y_{t-i} + \sum_{i=1}^{Q} b_i\, \xi_{t-i} \quad (3)$$

The model consists of parts namely sum of present noise and the summation part includes Parameters of the model, (a_1 a_2 ……. a_Q), the past output terms are (Y_{t-1} Y_{t-2}), Parameters of the model, (b_1 b_2…………b_Q), and the error terms are (ξ_{t-1} ξ_{t-2})

The advantage of "Auto-Regressive Moving-Average" Model is that they provide a simpler representation and the disadvantage of "Auto-Regressive Moving-Average" Model is, **process behavior** is not considered.

2.4. ARMAX Model

ARMAX Model stands for "Auto-Regressive Moving-Average with Exogenous Input" Model which is also called as a "CARMA" Model. It is an Extension of an "Auto-Regressive Moving-Average" Model .

$$Ay(t) = B\, u(t-k) + C\xi(t) \quad\quad (4)$$

The model consists of parts namely an input parameter includes, u (t – k) and disturbance parameter as ξ (t) in the form of a straight line equation for deducing output y(t).

The Advantage of "Auto-Regressive Moving-Average with Exogenous Input" is that **forecasting of future** values gives good results by considering the **process behavior**.

The Disadvantage of "Auto-Regressive Moving-Average with Exogenous Input" is

    a.   Noise was assumed to be an identically distributed random sequence.

    b.   It exerts an excessive control effort and can't be applied to Non-Minimum phased system for a "Minimum variance control".

2.5. ARIMAX Model

ARIMAX Model stands for "Auto-Regressive Integrated Moving-Average with Exogenous Input" or also called as a "Controlled Auto-Regressive Integrated Moving Average", Model.

It's an Extension of an "Auto-Regressive Moving-Average with Exogenous Input"

The model consists of a process behavior [as input] and also the disturbance term/noise showing drifting characteristics. In fact, the CARIMA representation is now the standard form used for predictive controller design, because of its following advantages.

Advantages of "ARIMAX" model are as follows

a. Most of the time noise shows drifting characteristics and also offset free response.

b. It also tracks both varying and constant future set points.

c. A CARIMA model is used to obtain good output predictions and optimize a sequence of future control signals to minimize a multistage cost function defined over a prediction horizon. The inclusion of disturbance is necessary to deduce the correct controller structure.

3. DESIGN OF CARIMA MODEL

Design of "CARIMA", Model can be carried with the following steps,

Step 1: Objective Function

Step 2: Process Model

Step 3: Minimization of a control law and development of output.

Objective Function

The objective function must include two parameters namely a future error reducing part and a controller input to drive the output. The error part which involves difference between predetermined output and calculated output will be available in future time.

$$J(N_1 \ N_2 \ N_u) = \sum_{j=N_1}^{N_2} \delta(j) \ [\hat{y}(t+j/t) - w(t+j)]^2 + \sum_{j=1}^{N_u} \lambda(j) \ [\Delta \ u(t+j-1)]^2 \quad (6)$$

The "Objective functions", has the following importance. That is the future output on the considered horizon should follow a determined reference trajectory,so as to drive the output as close as to the set point or desired (reference).

Process Model

Since future values are not available in the present time, hence one has to consider the process model which relates the controlled output "y" to the manipulated input "u", by also considering the disturbance
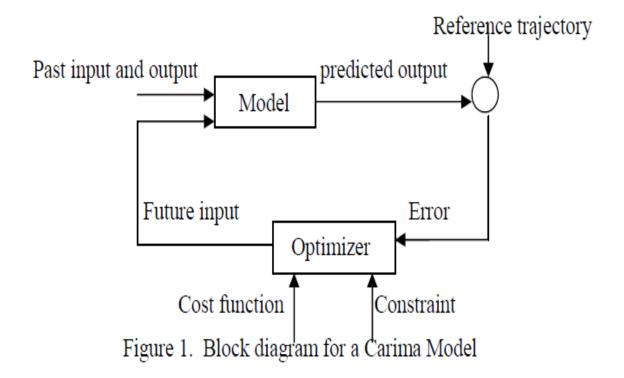
$$Ay(t) = B \ u(t-k) + C \frac{\xi(t)}{\Delta} \quad (7)$$

To deduce the prediction of y in future we have to consider an identity and then by using identity we are able to relate our output to the future prediction in terms of a straight line equation.

Minimization of a control law and development of output.

After implementing the process model, future values are substituted back into objective function. Then by minimizing this objective function with respect to a control increments will yield a value and that helps in driving the output as close as possible or nearer to the reference trajectory.

$$\frac{\partial J}{\partial u(t)} = 0 \qquad (8)$$

Figure 1. Block diagram for a Carima Model

The CARIMA model consisting of a process model, cost function is as shown in the block diagram. The process is as follows,

1. With the help of past inputs and outputs along with future control increments forecasting is done to predict the future control outputs.

2. A process model "CARIMA", is necessary to carry the forecasting.

3. The error that is obtained is fed back, so that future control outputs will be on the controlled horizon.

The Nomenclatures used in this Review paper are as follows

$y(t)$= Plant output

$u(t)$= Plant input

$\hat{y}(t + j/t)$ = Predicted value of output

J = Cost function

e = Vector of future error

N_1= Minimum costing horizon

N_2 = Maximum costing horizon

N_u = Control horizon

w = reference trajectory

$\xi(t)$ = disturbance

$w(t + j)$ = First order approach to known reference

Δ = backward shift operator

$\delta(j)$ = Error weighted co-efficient

A, B, C = Polynomials

Table 1. Comparison of different models

No of Models	ADVANTAGES	DIS-ADVANTAGES
1.A-R	Forecasting of output is based on past outputs	Not considering past disturbances and process model (controlled input)
2.M-A	Forecasting of output is based on past and present disturbances.	Not considering past outputs and process model (controlled input)
3.AR-MA	Forecasting of output is based on past /present disturbances and outputs	Not considering process model (controlled input)
4.ARMAX	Forecasting of output is based on process model, disturbances and outputs.	a. Excessive control effort. b. Noise shows random characteristics.
5.ARIMAX	Forecasting is good and based on ARMAX model but noise shows drifting characteristics.	

4. CONCLUSION

In this paper a detailed discussion of models used for controllers is carried o ut and from the comparison, it can be concluded that CARIMA model is the best suited for predictive controller.

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