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SYSTEM IDENTIFICATION

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Abstract

The basic objective is to construct a Transfer function of the given system. Closed loop system identification and validation are important components in dynamic system modeling. In this report a comprehensive literature survey is compiled on System Identification with a specific focus on closed loop system identification and issues of identification experiment design and model validation. This is followed by simulated experiment on a known Non-Linear system. The identified model structure can be compared with various mathematical models like ARX model, ARMAX model & OE model.

KEYWORDS: Process, disturbances, estimation, model.

I. INTRODUCTION

System identification is basically to obtain a transfer function of a given system. System identification deals with the problem of building mathematical models of dynamical systems based on observed data from the systems. In other words, identification is the modeling based on experiments.

Consider the following system :

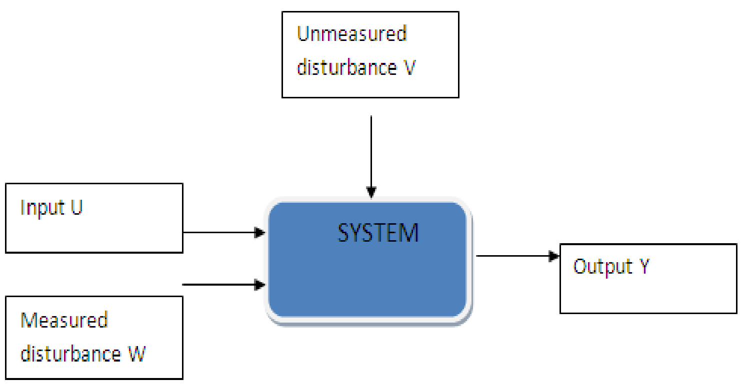

Fig. 1: A simple closed loop system

A system is an object in which variables of different kinds interact and produce observable signals. The observable signals that are of interests to us are usually called outputs. External signals that can be manipulated by observer are called inputs. Other external stimuli are called disturbances and are divided into those that are directly measured and those that are only observed through their influence on their output.

Example: Tank with inlet water flow as a input and the level of water in the tank as output.

II. OPEN LOOP AND CLOSED LOOP IDENTIFICATION:

The identification and validation experiments provided the following findings regarding the effects of different feedback conditions:

- Models obtained from open loop experiments produced the most accurate responses when calculating the linear systems. When approximating the non-linear system, models obtained from closed loop systems were found to produce the most accurate responses.

- Validation sets obtained from open loop experiments were found to be most effective in discriminating between models approximating the linear system while the same may be said of validation sets obtained from closed loop experiments for the non-linear systems.

These findings were mostly attributed to the condition that the open loop experiments produce more informative data than closed loop experiments given no constraints are imposed on system outputs. In the case that system constraints are imposed, closed loop experiments produce the more informative data of the two.

III. NEED FOR CLOSED LOOP IDENTIFICATION:

There are plants that contain an integrator or are unstable in open loop operation. The performance of the closed loop system can be improved using a controller based on the identified model from the closed loop data. This can be theoretically proved when the true system belongs to the model set and for three different control design criteria (Minimum Variance, LQG and model reference control). The measure of the performance is the variance of the error between the output of the optimal closed loop system and that of actual closed loop system. Plant model identified in closed loop system operation is more precise in critical frequency zone for robust control design. This idea led to the well known iterative identification and control scheme. In this scheme the identification is performed with the closed loop data filtered by a filter that depends on objective of control.

IV. APPROACHES:

1. DIRECT METHOD

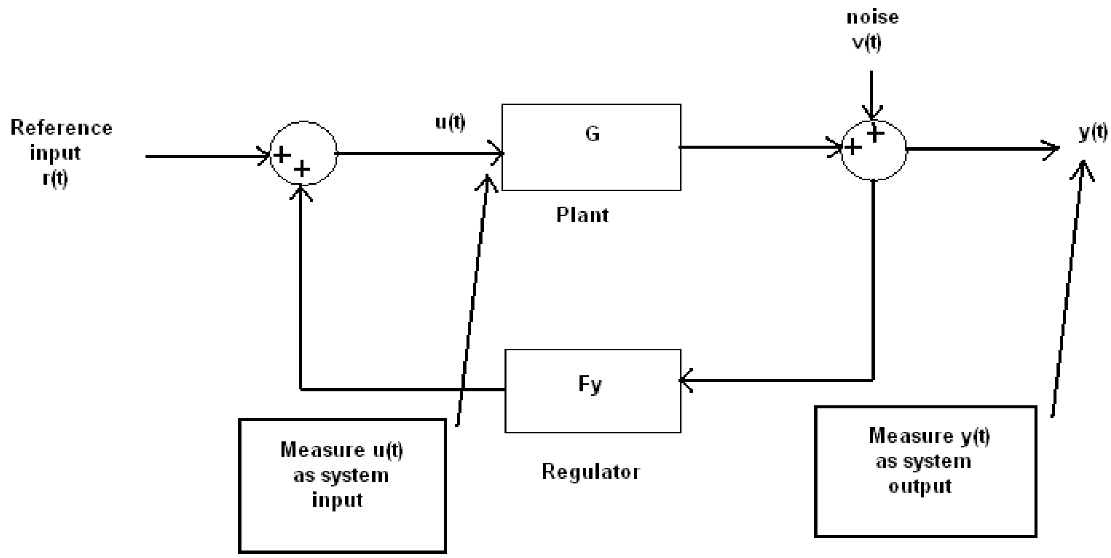

Fig. 2: Direct Identification loop

The direct approach amounts to applying a prediction error method to input- output data, ignoring possible feedback. Any arbitrary feedback mechanism. The direct method coincides with the standard (open loop) prediction error method. It is sometimes claimed that this approach cannot be used if the system is unstable. But it is not correct: Direct method can be applied is the predictor is stable. It works regardless of complexity of regulator, and requires no knowledge about the character of the feedback. No special algorithms and software required.

2. INDIRECT METHOD

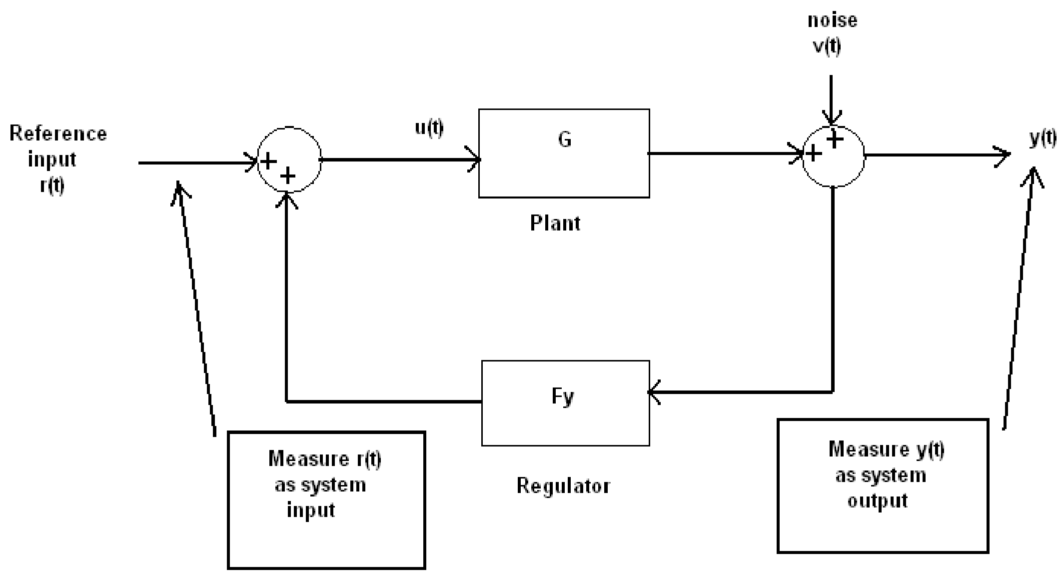

Fig.3: indirect identification loop

This means we can use any method that works in open loop such as spectral analysis, instrumental variables, and subspace methods to find a model of the closed loop system, for instance a subspace method or instrumental variables. A procedure consisting of two steps is outlined:

First the closed loop system is identified.

Then an open loop model is computed

V. ALGORITHM:

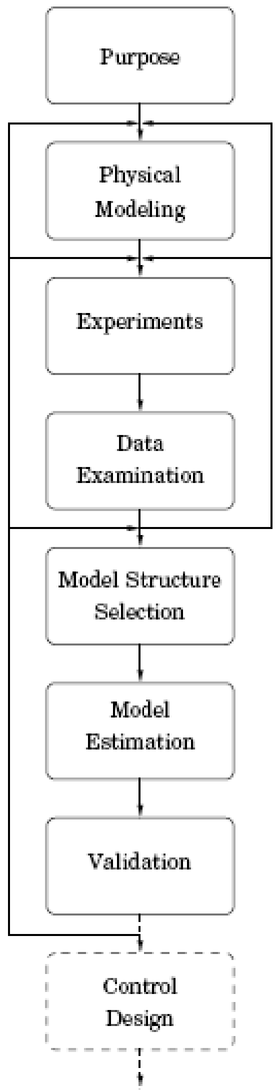

Fig. 4: Algorithm for modeling and system identification

It is important to state the purpose of the model as a first step in the system identification procedure. There are a huge variety of model applications, for example, the model could be used for control, prediction, signal processing, error detection or simulation. The purpose of the model affects the choice of identification methods and the experimental conditions, and it should therefore be clearly stated. It is, for example, important to have an accurate model around the desired crossover frequency, if the model is used for control design.

A. PHYSICAL MODELLING

It is sometimes possible to derive a model directly from physical laws. This model will most often, however, contain unknown parameters to be estimated. If some parameters are known and some are unknown, it is sometimes (but not always) possible to perform an estimation using the values of the known parameters. We commonly use only the structure of the model derived from the physical model. This structure can be in terms of model order, known pole locations (an integrator or dominating resonance), static nonlinearities etc. If there are no knowledge about the considered system, we use the term *black-box identification*. It is called *grey-box identification*, if some part of the system is known.

B. **EXPERIMENT**

The experiments are done in two steps. In the first step, preliminary experiments such as impulse and step responses are performed to gain primary knowledge about important system characteristics such as stationary gain, time delay and dominating time constants. It should be possible to draw conclusions from these experiments on whether or not the system is linear and time invariant and if there are disturbances acting on the system. The information obtained from the preliminary experiments are then used to deter- mine suitable experimental conditions for the main experiments, which will give the data to be used in the System Identification Toolbox.

C. **DATA EXAMINATION**

Assume that an experiment has been performed and that we have an input sequence and an output sequence represented as column vectors u and y, respectively, in Matlab. It is suitable to split the data into two sets, one for identification and one for validation.

D. **MODEL STRUCTURE SELECTION:**

We discuss model structure selection for parametric models in this section. The model structure determines the set in which the model estimation is performed. For example, a very simple such model set is the set of static gains K mapping the input to the output, that is, the input–output model $y(t) = Ku(t)$.

The complexity of the model structure, of course, affects the accuracy with which the model can approximate the real process. Few dynamical systems can be well approximated by the model y(t) = Ku(t).

Model estimation is treated in next section. Then, both parametric and nonparametric models are considered.

The most general parametric model structure used in
the System Identification Toolbox is given by:

$$A(q)y(t) = \frac{B(q)}{F(q)}u(t-n_k) + \frac{C(q)}{D(q)}e(t) \qquad (1)$$

where y and u is the output and input sequences, respectively, and e is a white noise sequence with zero mean value. The polynomials A, B, C, D, F are defined in terms of the backward shift operator1:

$$\begin{aligned} A(q) &= 1 + a_1 q^{-1} + \ldots + a_{na} q^{-na} \\ B(q) &= b_1 + b_2 q^{-1} + \ldots + b_{nb} q^{-nb+1} \\ C(q) &= 1 + c_1 q^{-1} + \ldots + c_{nc} q^{-nc} \\ D(q) &= 1 + d_1 q^{-1} + \ldots + d_{nd} q^{-nd} \\ F(q) &= 1 + f_1 q^{-1} + \ldots + f_{nf} q^{-nf} \end{aligned}$$

Rarely, we use the general structure (1) but some special forms, where one or more polynomial are set to identity:

- AR model:

$$A(q)y(t) = e(t) \qquad (2)$$

which is a time-series model with no exogenous input (no input u).

- ARX model

$$A(q)y(t) = B(q)u(t-n_k) + e(t) \qquad (3)$$

- ARMAX model

$$A(q)y(t) = B(q)u(t-n_k) + C(q)e(t) \qquad (4)$$

- Output-error (OE) model

$$y(t) = \frac{B(q)}{F(q)}u(t-n_k) + e(t) \qquad (5)$$

E. MODEL ESTIMATION

System identification is the procedure of deriving a model from data and model estimation is the procedure of fitting a model with a specific model structure. We have linear models and parametric models of a specific structure—e.g., physical models, ARMAX models. In addition to parametric linear models, a linear model may consist of a weighting function or a

transfer function in the form of a frequency response. Using the Matlab System Identification Toolbox., we study how transfer function models can be estimated from data. Also when system identification aims towards a specific parametric model, it makes sense to estimate an input-output relationship in the form of a transfer function. Note that a transfer function estimate may also give hints to model complexity and model structure.

F. VALIDATION

The parametric models obtained in previous section can be validated in a variety of ways. Here, we discuss model validity criterion, pole–zero and Bode plots, residual analysis, and simulation and cross validation. In a standard identification session all of these are used to affirm an accurate model.

VI. APPLICATION

1. Process control: most developed ID approaches:

a. All plants and processes are different.
b. Need to do identification, cannot spend too much time on each.
c. Industrial identification tools

2. Aerospace: White box identification, specially designed programs of tests.
3. Automotive: White box, significant effort on model development and calibration.

VII. CONCLUSION:

Without disturbing the performance of the system we find the transfer function and thus deduce the stability of the system.

VIII. FUTURE SCOPE:

The modifications that are possible in system identification include adding an interface between the user and the computer for better interactions. Through this interface it will be possible to remotely operate and compute in a better manner.

IX. ACKNOWLEDGEMENT:

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