ID1

Introduction

1.7 CLASSES OF MODELS FOR IDENTIFICATION

Many different classes of models can be considered. The most relevant, from an identification standpoint, are: oriented and non oriented, algebraic and dynamical, causal and non causal, lumped and distributed, constant and time–varying, linear and nonlinear, deterministic and stochastic, single–input single–output (SISO), multi–input single–output (MISO) and multi–input multi–output (MIMO), parametric and non parametric, continuous and discrete.

1.7.1 Oriented and non oriented models

Once the measurable attributes of a system have been defined, it is usual to partition them in two classes: inputs and outputs or also, in econometrics, exogenous and endogenous variables. The inputs can often be seen as the action of the surrounding environment on the system and the outputs as its reaction. It is also possible, following Willems (1986), to describe the outputs as the variables explained by the model and the inputs as those left unexplained by the model. In some cases it can be desirable to avoide any *a priori* orientation of the system and treating all variables in a symmetric way. It is important to note that the orientation can be imposed by the external environment instead than by the system itself.

Example 1.7.1

The measurable attributes of the electrical dipole in Figure 1.7.1 are the voltage and the current at his terminals.

If this dipole is connected to a voltage generator, it will be natural to consider the voltage as input and the current as output while a connection to a current source will reverse the situation. In any other case both orientations are equivalent.

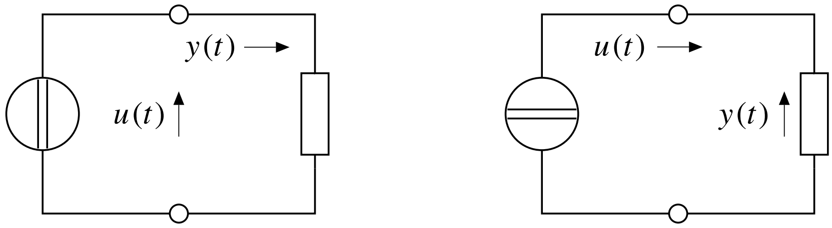

Figure 1.7.1 – Possible orientations of a dipole

1.7.2 Algebraic and dynamical models

Algebraic systems establish an instantaneous link between their variables and are described by sets of algebraic equations. Dynamical systems establish, on the contrary, a link between the values assumed by their attributes at different times and are described by sets of differential or difference equations. Algebraic systems can be treated in a comparatively simple way and describe a very limited slice of the real world; system identification is thus, almost implicitly, considered as dynamic system identification and makes reference to dynamical models. The identification of models for algebraic processes can, however, be more tricky than commonly assumed and present also conditions of non identifiability.

1.7.3 Causal and non causal models

An oriented model is defined as causal when its output at time t is not affected by future input values. While all real systems are causal and can be properly described by models of this kind, it is also possible, from a mathematical standpoint, to introduce non causal models.

1.7.4 Purely dynamic and non purely dynamic models

An oriented dynamic model is defined as purely dynamic when its input at time t does not affect its output at t, i.e. when the system does not establish any instantaneous (algebraic) link between its input and its output. If this condition is not satisfied the model is defined as non purely dynamic. This property interacts with other properties and with the planned use of the model. Thus a non oriented model is necessarily non purely dynamic because a purely dynamic model is intrinsically oriented and would even become non causal for other orientations. A predictive model must, on the contrary, be purely dynamic because (considering discrete systems) the output at time $t+1$ must be predicted at time t on the only basis of measures performed until t.

1.7.5 Lumped and distributed models

Most aspects of reality concern phenomena that don't take place in a single point of the space but affect areas or volumes (e.g. heat transmission, electromagnetic phenomena, energy exchanges, mechanical systems etc.). Such phenomena would require distributed models given, for dynamical systems, by sets of partial differential (or difference) equations, i.e. by distributed models. Lumped models, given by sets of ordinary differential (difference) equations refer to simplified schemes that assume constant values of the system attributes in some, properly defined, space regions.

1.7.6 Constant and time–varying models

Time–varying models, whose parameters are, in general, functions of time, can describe systems whose behavior changes with time. Time–invariant models are described by sets of constant parameters and can describe constant systems. Time–invariant systems, sometimes, look as time–varying because of lack of knowledge on some of their inputs.

1.7.7 Linear and nonlinear models

Linear models describe systems where the superposition principle is valid. Most real systems are nonlinear but can be described accurately by a linear model in the neighborhood of a working condition.

1.7.8 Deterministic and stochastic models

Real systems are always affected by disturbances (noise entering into the system and/or affecting the measures, unknown inputs, quantization errors etc.). These disturbances or their global effect can be described by means of noises acting on the input, state and output of the model which is called, in this case, stochastic. Often the global effect of disturbances is modeled as the output of a filter driven by white noise, and is added to the output of the deterministic part of the model which is thus decomposed into a deterministic and a stochastic part. Depending on the applications it can be sufficient to identify the deterministic part of the model (e.g. diagnosis) or it can be necessary to identify both parts (e.g. prediction).

1.7.9 SISO, MISO and MIMO models

Single–input single–output (SISO), multi–input single–output (MISO) and multi–input multi–output (MIMO) models have self–explanatory names. It can be observed that while SISO models have a limited usefulness (the world is multivariable), a multivariable model can be decomposed into a collection of MISO models. As discussed in the following, an approach of this kind, frequently followed to avoid the more complex tools required by the use of truly multivariable models, has many conceptual and practical limits.

1.7.10 Parametric and non parametric models

Some classes of models are given by sets of equations described by a certain number of parameters (parametric models) while other models are given without assigning any parameter, for instance in a graphical form (e.g. impulse or step responses and frequency response for linear systems).

1.7.11 Continuous and discrete models

Continuous models describe systems whose measurable attributes evolve with continuity in time while discrete models establish quantitative links only between the values assumed by the variables at discrete (sampling) times. While the intrinsic nature of all natural systems and of many technological systems is continuous, the widespread introduction of digital systems emphasizes the use of discrete models that can describe accurately, when the variables are properly sampled, also continuous systems.

1.7.12 Free and non free models

In some cases no action of the environment on the considered system exists or, more likely, can be observed. Systems and models without any input are defined as free; their outputs are called time series.