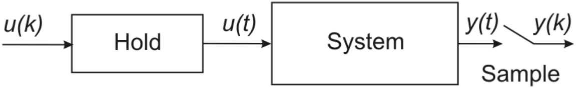
Workflow example

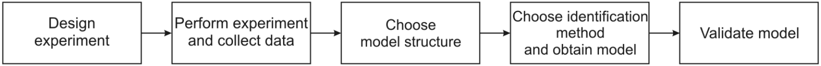
System identification often works in discrete time, as we will work in this example.

Usual procedure for identification in discrete-time:



Here, we consider a flexible robot arm, u = torque, y = arm acceleration. The data is obtained from the Daisy database (`http://homes.esat.kuleuven.be/~smc/daisy/`).

Workflow 1: Experiment design

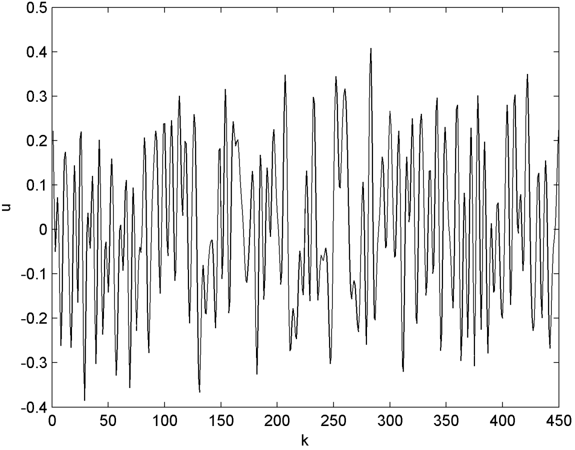


A main part of experiment design consists of selecting the input signal (duration, shape). This signal should be sufficiently rich to bring out the interesting behavior in the system.

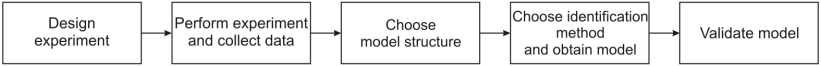
There are usually constraints: the system cannot be placed in dangerous conditions, cannot deviate too much from the operating point, etc.

Workflow 1: Experiment design: Example

Input signal:

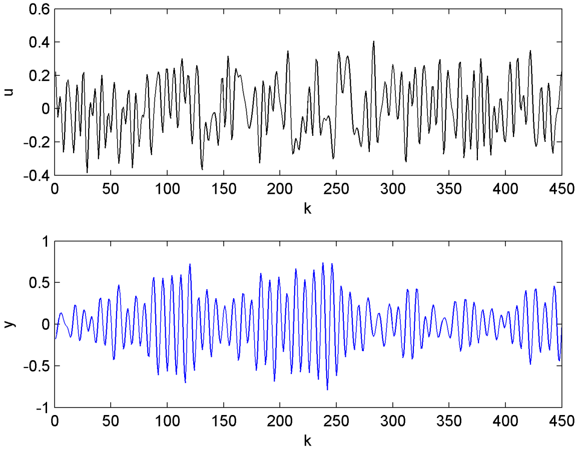


Workflow 2: Experiment



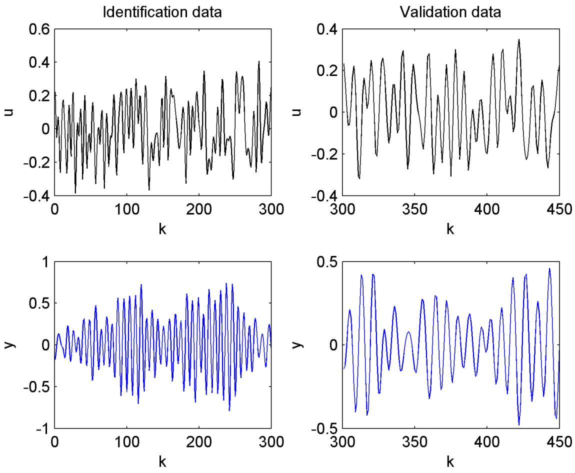
The experiment is performed and the output data is recorded.

Workflow 2: Experiment: Example

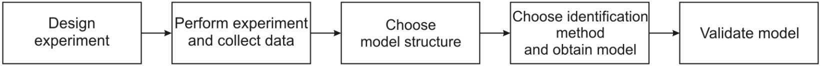


Workflow 2: Experiment: Example (continued)

We split the data into an *identification* set and a *validation* set (see later).



Workflow 3: Structure choice



The structure of the model is chosen: graphical model, or mathematical model.

Any knowledge and intuition about the system should be exploited to choose an appropriate structure: it should be flexible enough to lead to an accurate model, but simple enough to keep the estimation task well-conditioned.

Workflow 3: Structure choice: Example

We choose a so-called 'ARX' model structure, where the output $y(k)$ at the current discrete time step is computed based on to the previous inputs and outputs:

$$\begin{aligned} & y(k) + a_1 y(k-1) + a_2 y(k-2) + a_3 y(k-3) \\ & \quad = b_1 u(k-1) + b_2 u(k-2) + b_3 u(k-3) + b_4 u(k-4) + e(k) \end{aligned}$$

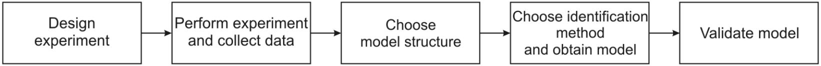
equivalent to

$$\begin{aligned} y(k) = & -a_1 y(k-1) - a_2 y(k-2) - a_3 y(k-3) \\ & + b_1 u(k-1) + b_2 u(k-2) + b_3 u(k-3) + b_4 u(k-4) + e(k) \end{aligned}$$

$e(k)$ is the error made by the model at step k.

Model parameters: a_1, a_2, a_3 and $b_1, \ldots, b_4$.

Workflow 4: Model estimation



A method is chosen and applied to identify the parameters of the structure. Of course, which methods are appropriate depends on the structure chosen.

Workflow 4: Model estimation: Example

Identification consists of finding the parameters $a_1, a_2, a_3, b_1, \ldots, b_4$. We choose a method that minimizes the sum of the squared errors $\sum_{k=1}^{300} e^2(k)$ on the identification data. The actual algorithm will be presented later in the course.

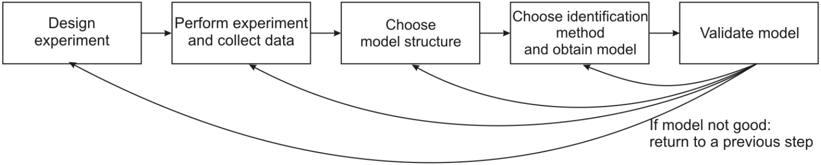
The solution is:

$$a_1 = -2.24, a_2 = 2.17, a_3 = -0.83,$$
$$b_1 = -0.24, b_2 = 0.45, b_3 = -0.41, b_4 = 0.22$$

which replaced in the structure gives the following approximate model:

$$\begin{aligned} y(k) &= 2.24y(k-1) - 2.17y(k-2) + 0.83y(k-3) \\ &\quad - 0.24u(k-1) + 0.45u(k-2) - 0.41u(k-3) + 0.22u(k-4) \end{aligned}$$

Workflow 5: Model validation

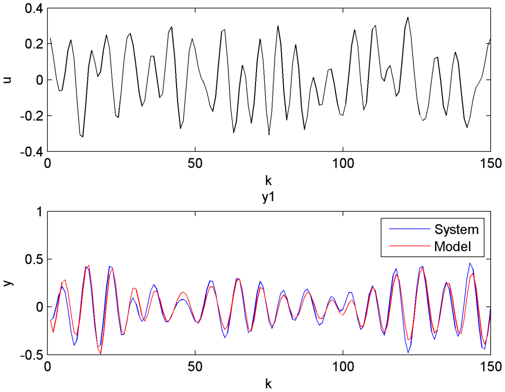


Validation is a crucial step: the model must be good enough *for our purposes*. If validation is unsuccessful, some or all of the previous steps must be repeated.

E.g., the response (outputs) of the obtained model can be compared with the true response of the system, on validation data. This validation dataset should preferably be different from the set used for identification. (Either a different experiment is performed, or the experimental data is split into testing and validation subsets.)

Workflow 4: Model validation: Example

We use the validation data that we kept separate from the start:



Assuming our goal is to simulate the system output (for inputs that are "well represented" by the experimental input chosen), the model is acceptable.