

# MATLAB TOOL FOR IDENTIFICATION OF NONLINEAR SYSTEMS

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## Abstract

**This contribution describes MATLAB tool designed for identification and parameter estimation of nonlinear systems. The tool is based on extended Kalman filter, using fixed model structure and measured input/output data from identified system as inputs for method.**

## 1 Introduction

The problems of parameter and state estimation can be found in many fields of engineering and science. In modeling of real systems, it is not always possible to estimate all necessary system parameters only by knowledge of their physical base. In this case the parameters and states must be estimated by appropriate identification methods. Many general analytical and experimental methods are suitable for identification of linear system, but in the case of nonlinear system we need to choose more sophisticated methods.

The Kalman filter and its modifications [1] are very suitable for methods of signal processing, optimization, system identification and parameter estimation.

The MATLAB itself contains several Kalman filter based functions and also provides the System Identification Toolbox with wide possibilities of system identification.

Some interesting identification toolboxes using Kalman filter are available on the Internet. The EKF/UKF Toolbox has been developed in [2]. The toolbox contains various methods for model identification and parameter estimation, including modifications of Kalman filter (extended KF, unscented KF, Gauss-Hermite KF, and cubature KF). The EKF/UKF Toolbox is built a package of MATLAB functions and also provides good documentation.

The System Identification Tool (SIT) is another MATLAB tool designed for identification of nonlinear systems [3], using extended forms of Kalman filter. It provides the MATLAB application with GUI, where user can import measured data and mathematical model in form of differential equations, and estimate its unknown parameters.

Some interesting MATLAB tools and toolboxes, aimed on identification and nonlinear approximation problems, come also from our Institute [4, 5].

Our MATLAB based tool is built as GUI application containing several MATLAB scripts, functions and Simulink model for identification problem solving. Unlike above mentioned solutions, we provide possibility of using models in the general form of differential equations, without need to transform it in to one of the MATLAB requested forms (e.g. ARX model).

In our approach, we use a continuous-time extended Kalman filter (EKF), which allows the parameters of nonlinear systems to be estimated [6, 7]. The main idea of the extended Kalman filter is to modify the linearized Kalman filter to directly estimate the states of a nonlinear system and also to estimate chosen system parameters by interpreting them as new states.

## 2 Tool Overview

The tool contains a simple GUI for problem definition (Fig. 1). User enters a mathematical model with parameters that need to be identified. The model can consist optionally of 1 -  $n$  differential equations defined in general form as text strings, separated by new lines. Then the user defines the text characters of model, which represents inputs, real states, known constant parameters including their values, and unknown parameters to be estimated. Initial values have to be set for all states and unknown parameters. The additional inputs are the weight matrices  $Q$  and  $R$ , and information, which states have been measured and are included in the input data for identification. The inputs and outputs of identified system are loaded into tool as MATLAB data file, containing matrix with time vector at first column, and measured inputs and outputs in other columns, sorted in the same order as they are listed in problem definition in GUI.

When all necessary input fields are set and identification problem is feasible, user can proceed through identification. The script reads all fields from input GUI and automatically generates the s-function for problem solving.

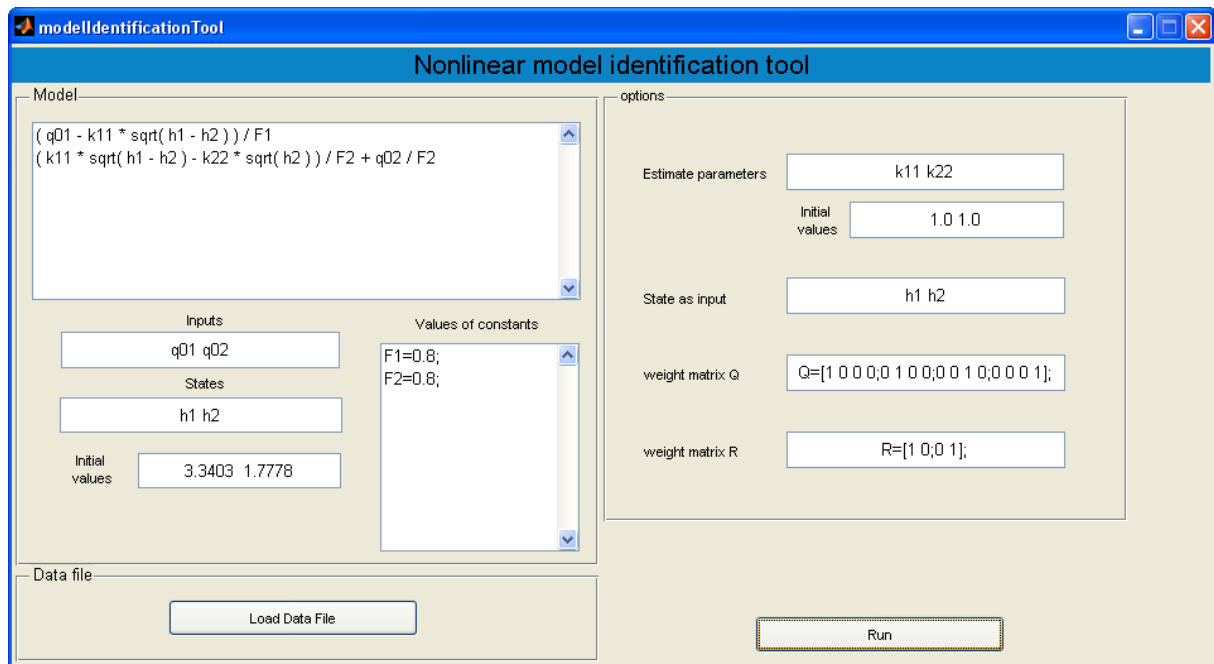


Figure 1: Graphical user interface of model identification tool

## 3 Example

To show how our identification tool works, we choose the system of two liquid storage tanks connected with interaction (Fig. 2), where we can measure the system behavior as input and output data.

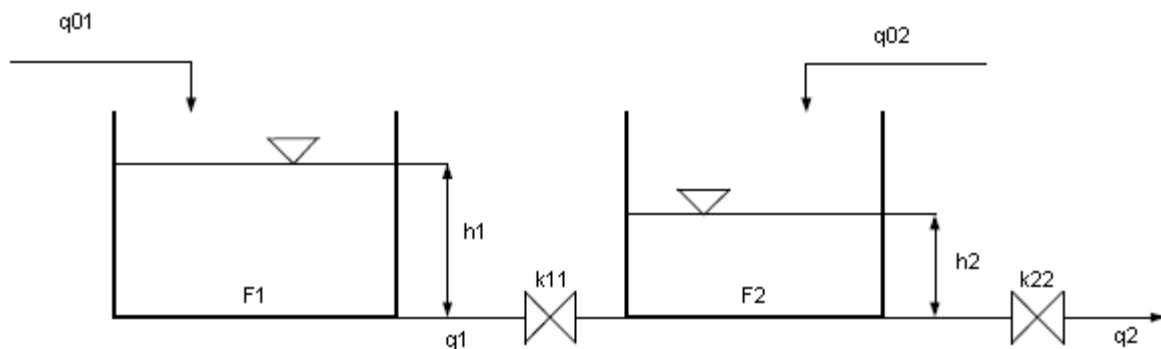


Fig. 2: Scheme of two storage tanks with interaction

The mathematical model of system is in the form of two ordinary nonlinear differential equations

$$\frac{dh_1(t)}{dt} = \frac{q_{01}(t) - k_{11}\sqrt{h_1(t) - h_2(t)}}{F_1} \quad (1)$$

$$\frac{dh_2(t)}{dt} = \frac{k_{11}\sqrt{h_1(t) - h_2(t)} - k_{22}\sqrt{h_2(t)}}{F_2} + \frac{q_{02}(t)}{F_2}, \quad (2)$$

where  $q_{01}$  and  $q_{02}$  are input flows into the tanks,  $h_1$  and  $h_2$  are levels of liquid in tanks,  $F_1$  and  $F_2$  are areas of tanks bases. The  $k_{11}$  and  $k_{22}$  are constant parameters, which represent the flow coefficients of valves.

Consider that input flowrates to tanks and levels of liquid can be measured, and  $F_1$ ,  $F_2$  are known parameters of system. Also consider that valve coefficients  $k_{11}$  and  $k_{22}$  cannot be obtained by physical modeling, so we need to identify them.

User runs the GUI of identification tool by calling main function *modelIdentificationTool* from MATLAB command line. When application window appears, user defines the mathematical model by typing the right sides of differential equations (1)-(2) into model input field (Fig. 4), and loads data file with measured inputs and outputs from plant (Fig. 3).

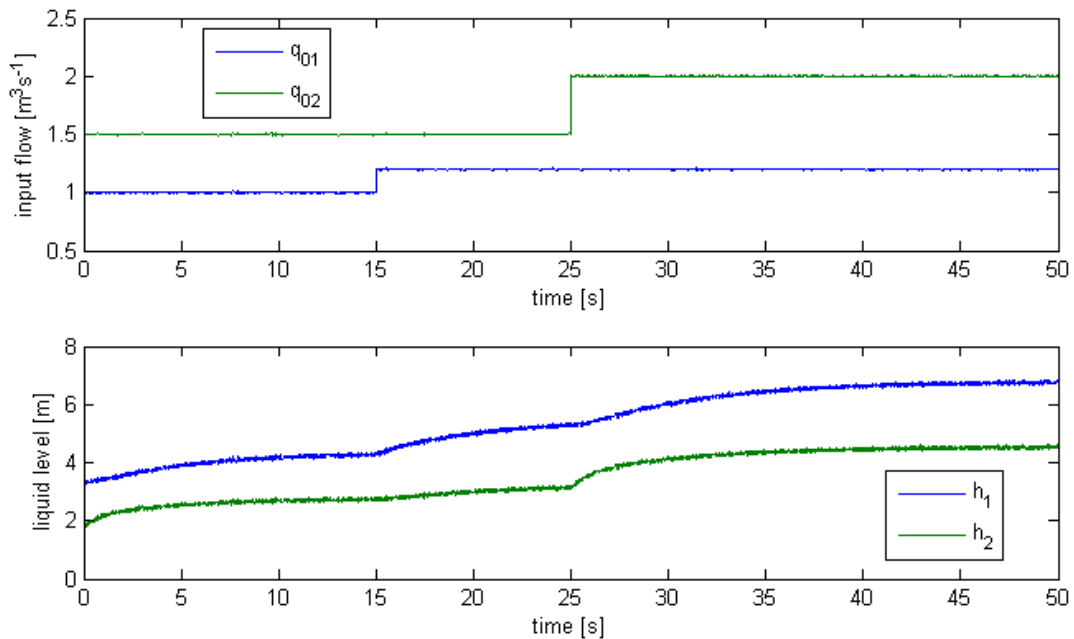


Figure 3: Inputs and outputs measured from identified system

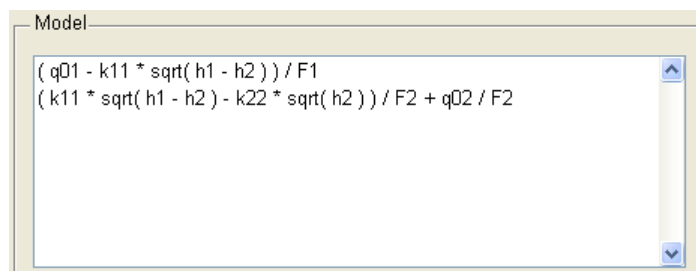


Figure 4: Mathematical model definition

Some general information about model is also required. User defines text characters representing inputs ( $q_{01}$ ,  $q_{02}$ ), states ( $h_1$ ,  $h_2$ ), and values of known parameters of the model (Fig. 5).

Inputs	q01 q02
States	h1 h2
Initial values	3.3403 1.7778
Values of constants	F1=0.8; F2=0.8;

Figure 5: Additional model information

User enters text characters representing unknown parameters of model ( $k_{11}$ ,  $k_{22}$ ) which will be estimated into field *Estimate parameters*, (Fig. 6).

Estimate parameters	k11 k22
Initial values	1.0 1.0

Figure 6: Definition of unknown parameter

Finally, the additional settings for identification method have to be set, by selecting states that appears in measured data from plant and weight matrices for identification method (Fig. 7).

State as input	h1 h2
weight matrix Q	$Q=[1\ 0\ 0\ 0;0\ 1\ 0\ 0;0\ 0\ 1\ 0;0\ 0\ 0\ 1]$
weight matrix R	$R=[1\ 0;0\ 1]$

Figure 7: States representing data inputs and weight matrices for identification method

When all inputs for method are set correctly, user can execute identification procedure by pressing the *run* button. The results are displayed as graph of reconstructed states and estimated parameters of plant (Fig. 8).

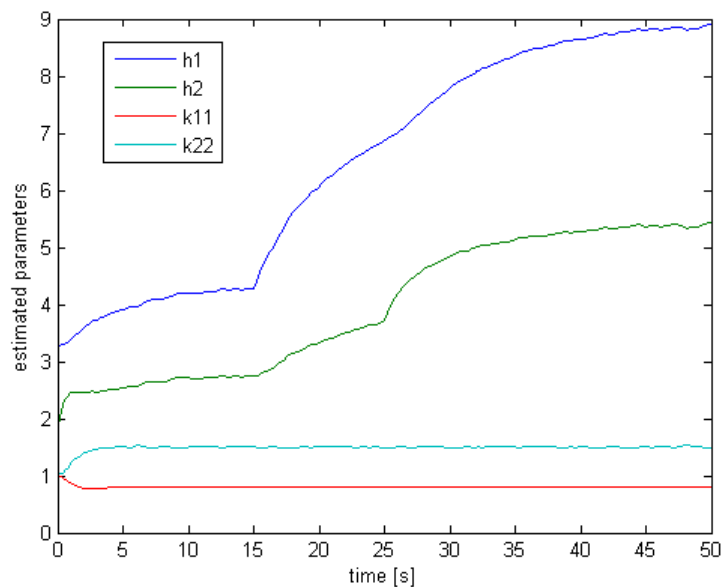


Figure 8: Graphical result with estimated states and parameters of nonlinear system

## 4 Conclusion

In this paper we have presented a MATLAB tool for identification of nonlinear systems by parameter and state estimation using extended Kalman filter. We have developed a MATLAB application composed of several program scripts for problem computation and GUI for better interaction between user and application. The solver of identification problem is generated automatically by scripts, so user can define the problem in general form.

In the future, we plan to extend our tool with new features and develop more sophisticated MATLAB toolbox aimed on identification and parameter estimation of nonlinear systems.

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