

QUAM_O-Toolbox for MATLAB/SIMULINK™

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1 Theoretical Background

Engineering knowledge and experience usually only grasp the qualitative assessment of system behaviour. The qualitative nature becomes apparent from the fact that not numerically precise signal values but qualitative values like “high”, “increased” or “too much” are referred to [3].

Most of the analysis and control methods begin with an analytical model like:

$$\begin{aligned} \mathbf{x}(k+1) &= \mathbf{g}(\mathbf{x}(k), \mathbf{u}(k), \mathbf{a}), \quad \mathbf{x}(0) = \mathbf{x}_0 & (1) \\ \mathbf{y}(k) &= \mathbf{h}(\mathbf{x}(k), \mathbf{u}(k)) & (2) \end{aligned}$$

where $\mathbf{x}(k)$, $\mathbf{u}(k)$, $\mathbf{y}(k)$ and \mathbf{a} denote the vectors of state, input, output and parameter respectively. However (1) and (2) are almost of no help if either of the initial state, input, or parameter is not numerically but qualitatively known. So it is necessary to deal with a more abstract model. Furthermore, in some applications only the qualitative behaviour of a system is of interest (e.g. in diagnosis the system is in “nominal” or “faulty” condition). Thus qualitative modelling is an alternative way for modelling and analysis.

Instead of using precise values of $\mathbf{x}(k)$, $\mathbf{u}(k)$, $\mathbf{y}(k)$ and \mathbf{a} , the qualitative values $[\mathbf{x}(k)]$, $[\mathbf{u}(k)]$, $[\mathbf{y}(k)]$ and $[\mathbf{a}]$ are used. These qualitative values are obtained from appropriate partitioning of signal spaces by using *quantisers*.

Hence, the quantised system depicted in Figure 1 is the standard structure of the systems to be considered in qualitative modelling. The most important characteristic of the quantised system compared to a classical continuous-variable system is that the input and output signals of the system are not restricted to the real values but the discrete values of the signal spaces introduced by injector and quantiser [2].

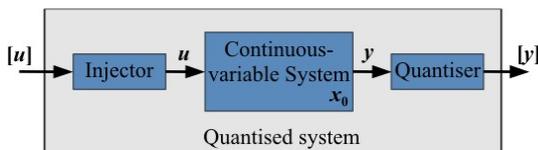


Figure 1: Quantised system

The main idea to deal with quantised systems is to represent their qualitative behaviour by a *stochastic automaton* whose behavioural relation

$$L([\mathbf{x}(k+1)], [\mathbf{y}(k)] \mid [\mathbf{x}(k)], [\mathbf{u}(k)]) \quad (3)$$

describes the probability that the system (1), (2) subject to the qualitative input $[\mathbf{u}(k)]$ moves from the current qualitative state $[\mathbf{x}(k)]$ to the succeeding state $[\mathbf{x}(k+1)]$ and simultaneously produces the qualitative output $[\mathbf{y}(k)]$ [1, 4].

2 Features of the QUAM_O-Toolbox

The Qualitative Modelling (QUAM_O) Toolbox contains functions for creating, analysing and using qualitative models. A successful use of the Toolbox requires the knowledge of MATLAB/SIMULINK™. The main features of the QUAM_O-Toolbox are [5]:

- **Qualitative modelling.** Abstraction of stochastic automata describing quantised systems for given models (1), (2) and given quantisers for all real-valued signals.
- **System analysis.** Simulation and analysis of systems by using merely their qualitative models. This allows the user to visualize the global behaviour of the system.
- **Process supervision and diagnosis.** Reconstruction of the system’s internal qualitative state from quantised measurements of the inputs and outputs. This can be used to solve both observation and diagnostic problems.

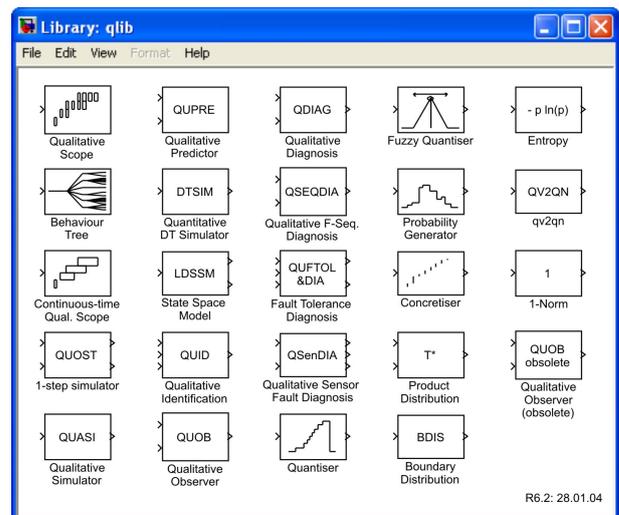


Figure 2: Qualitative Library

Additionally, the QUAM_O-Toolbox contains SIMULINK™ blocks for the real time analysis of systems and the visualization of results. These SIMULINK™ blocks are grouped into

the Qualitative Modelling Library (QLib) and the Process Supervision Library (PSLib). A selection of SIMULINK™ blocks from QLib is depicted in Figure 2.

3 Application Example

The QUAMO-Toolbox has been applied successfully in many applications concerning manufacturing, process, or chemical engineering. As an example, the qualitative observation task of a two-tank system is shown here.

Problem: The input u of the two-tank system (Figure 3) is the inflow from the pump to Tank 1. Only the level x_2 of Tank 2 is a measurable output y . The problem is to reconstruct the level x_1 of Tank 1 from the measurement and the input. Therefore quantisers are applied that allow to measure the qualitative values $[u], [y]$ of input and output.

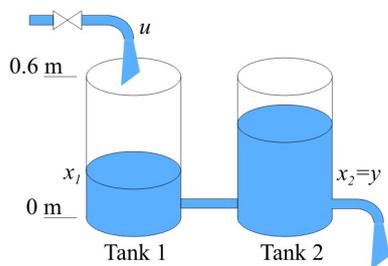


Figure 3: Application example two-tank system

To solve this problem, the two-tank system is modelled by a stochastic automaton, whose behavioural relation is obtained with the QUAMO command

```
>> L=linss2a(area_x,area_u,area_p,
             AbOp,A,B,C,D,px,pu,py);
```

where px , pu and py represent the signal partitions and A , B , C and D the matrices obtained from the linearised two-tank model.

Solution: The qualitative level of Tank 1 is obtained with the QUAMO SIMULINK™ blocks shown in Figure 4. The block QUOB contains an observation algorithm to qualitatively reconstruct the unknown state from the input and output measurement. The result is a probability distribution over the quantised tank levels $[x_1], [x_2]$, which is shown in Figure 5 in grey scale. With ascending time the probabilities show the qualitative state more distinctly (darker grey).

4 Installation

The current version of the QUAMO-Toolbox runs under MATLAB™ Version 6.5. Some demo movies are available at:

<http://www.atp.rub.de>

For additional information please contact:

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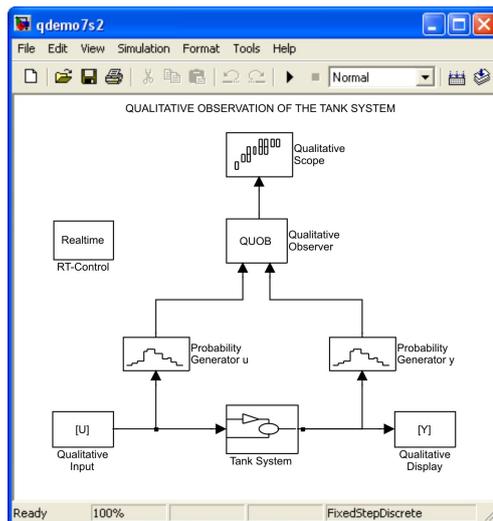


Figure 4: SIMULINK blocks from QLib to solve observation problem

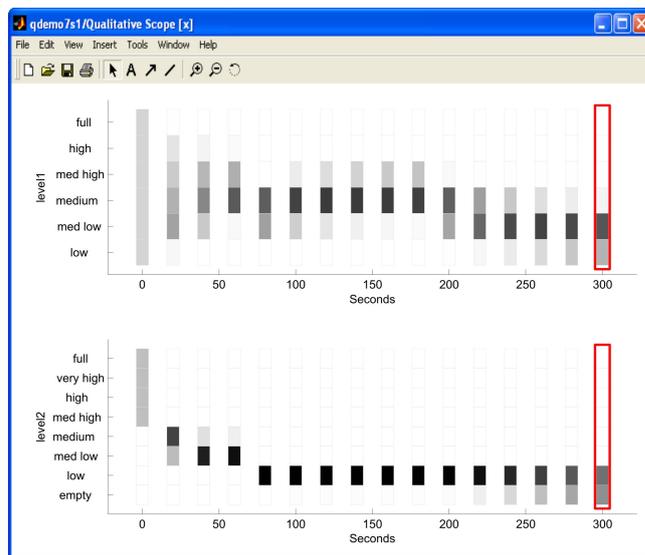


Figure 5: Qualitative observed signals of the tank system

References

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