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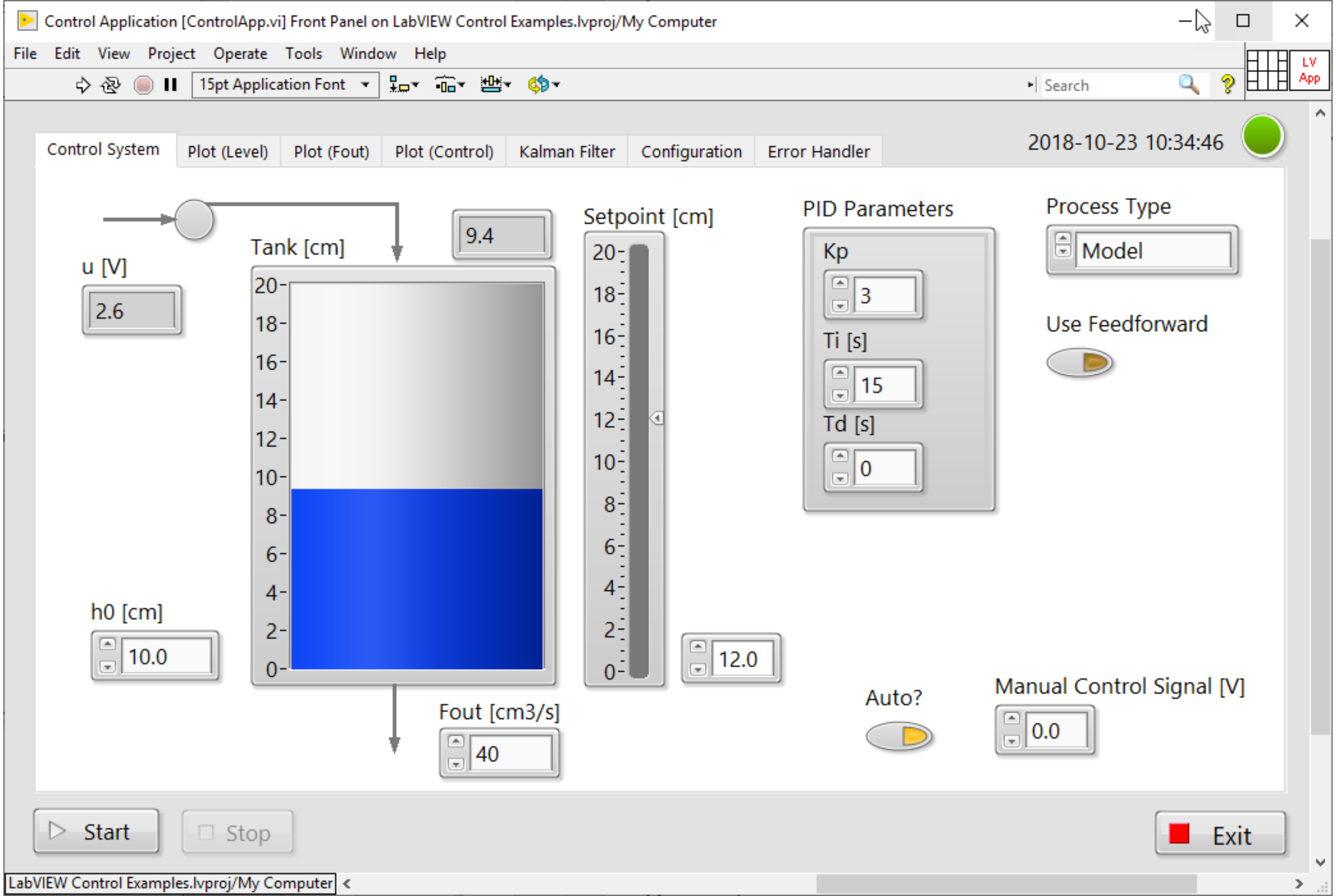
Kalman Filter Application

Hans-Petter Halvorsen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Edit
View
Project
Operate
Tools
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Help
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LV App
Control System
Plot (Level)
Plot (Fout)
Plot (Control)
Kalman Filter
Configuration
Error Handler
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Fout [cm3/s]
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Auto?
Manual Control Signal [V]
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Start
Stop
Exit
LabVIEW Control Examples.lvproj/My Computer

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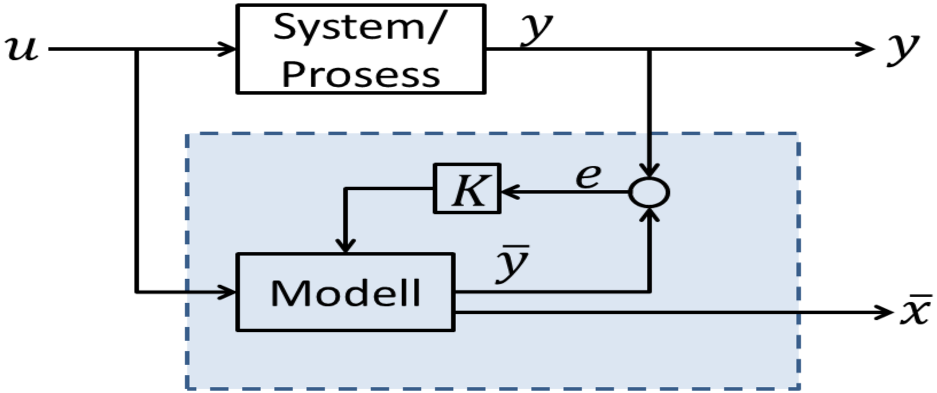
Kalman Filter

Hans-Petter Halvorsen

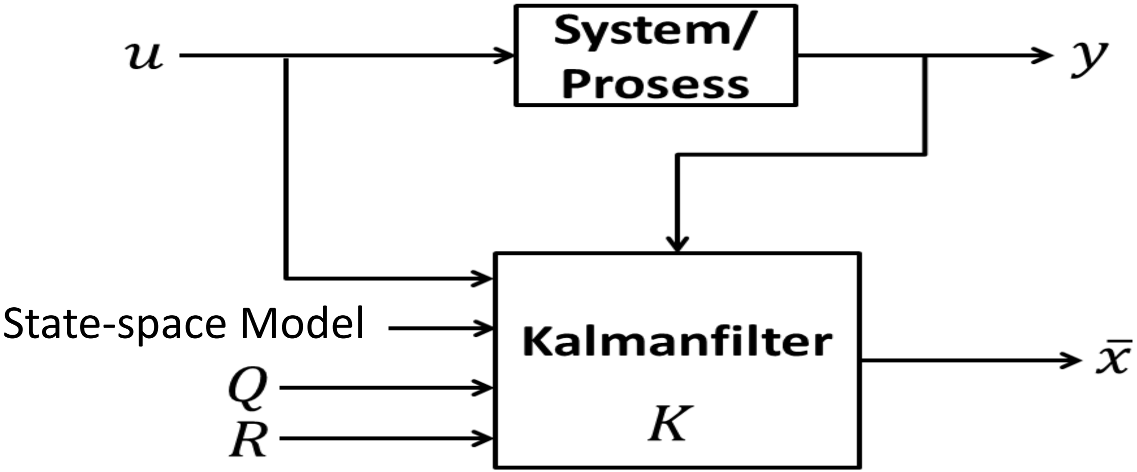
Kalman Filter

- The Kalman Filter is a commonly used method to estimate the values of state variables of a dynamic system that is excited by stochastic (random) disturbances and stochastic (random) measurement noise.
- We will estimate the process variable(s) using a Kalman Filter.
- We will use one of the built-in Kalman Filter algorithms in LabVIEW, but in addition we will create our own Kalman Filter algorithms from scratch.

Kalman Filter



Kalman Filter



Kalman Filter Algorithm

Pre Step: Find the steady state Kalman Gain K

K is time-varying, but you normally implement the steady state version of Kalman Gain K. Use the "CD Kalman Gain.vi" in LabVIEW or one of the functions kalman, kalman_d or lqe in MathScript.

Init Step: Set the initial Apriori (Predicted) state estimate

$$\bar{x}_0 = x_0$$

Step 1: Find Measurement model update

$$\bar{y}_k = g(\bar{x}_k, u_k)$$

For Linear State-space model:

$$\bar{y}_k = C\bar{x}_k + Du_k$$

Step 2: Find the Estimator Error

$$e_k = y_k - \bar{y}_k$$

Step 3: Find the Aposteriori (Corrected) state estimate

$$\hat{x}_k = \bar{x}_k + Ke_k$$

Where K is the Kalman Filter Gain. Use the steady state Kalman Gain or calculate the time-varying Kalman Gain.

Step 4: Find the Apriori (Predicted) state estimate update

$$\bar{x}_{k+1} = f(\hat{x}_k, u_k)$$

For Linear State-space model:

$$\bar{x}_{k+1} = A\hat{x}_k + Bu_k$$

Step 1-4 goes inside a loop in your program.

Note! Different notation is used in different literature:

Apriori (or Predicted) state estimate: $\bar{x}$ or x_p

Aposteriori (or Corrected) state estimate: $\hat{x}$ or x_c

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Water Tank Process

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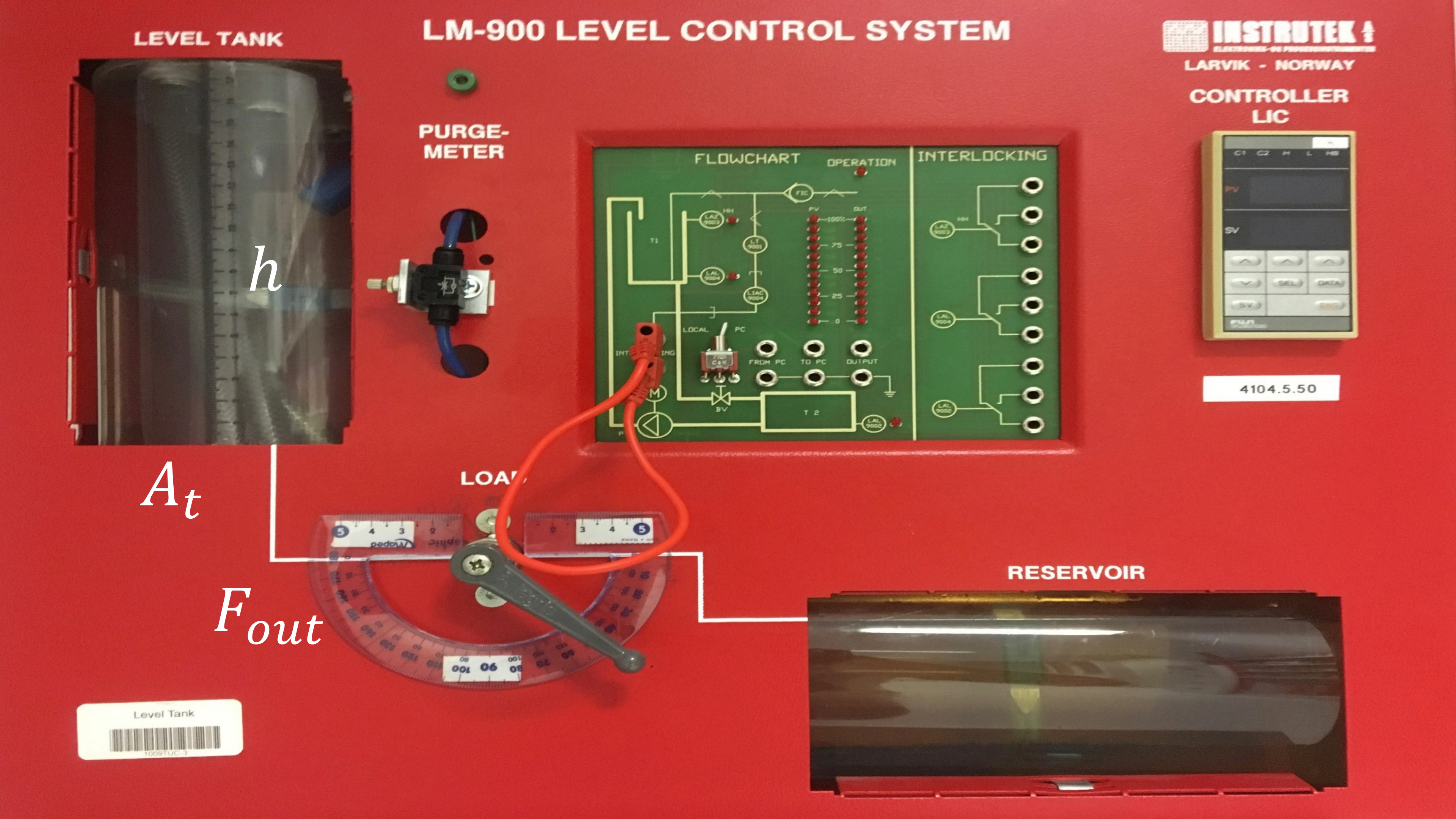
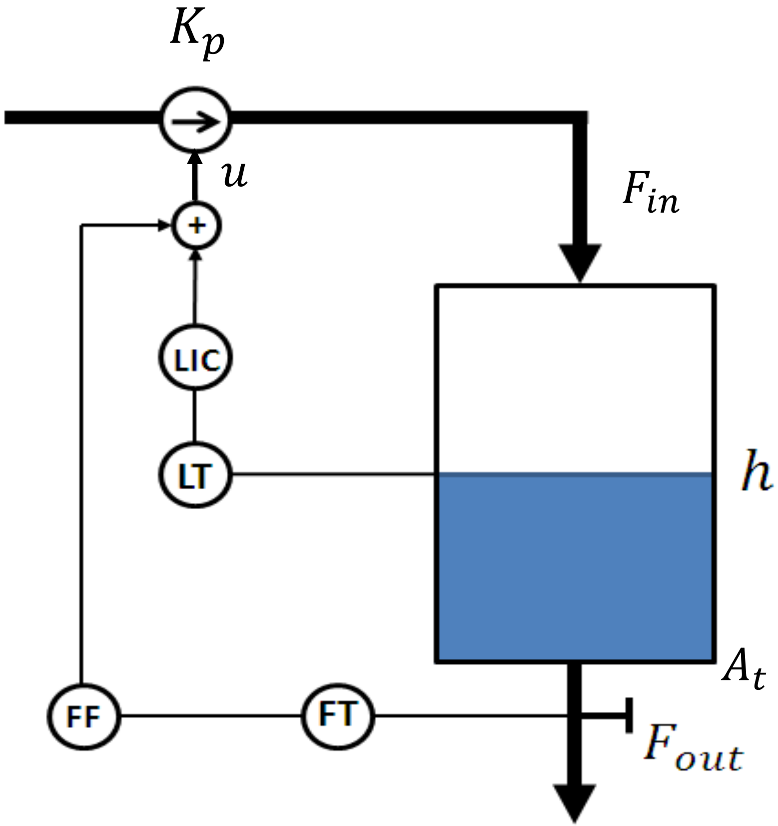


LEVEL TANK
LM-900 LEVEL CONTROL SYSTEM
INSTRUTEK
LARVIK - NORWAY
CONTROLLER
LIC
PURGE-
METER
FLOWCHART
OPERATION
INTERLOCKING
LOCAL
PC
FROM PC
TO PC
OUTPUT
T 2
BV
PV
SV
4104.5.50
h
A_t
F_{out}
RESERVOIR
Level Tank

Level Tank



$$A_t \frac{dh}{dt} = F_{in} - F_{out}$$

or:

$$\dot{h} = \frac{1}{A_t}(K_p u - F_{out})$$

Where:

- F_{in} - flow into the tank , $F_{in} = K_p u$
- F_{out} - flow out of the tank
- A_t is the cross-sectional area of the tank

Level Tank

$$\dot{h} = \frac{1}{A_t}(K_p u - F_{out})$$
$$\dot{F}_{out} = 0$$

Assumption: $F_{out} \approx$ constant

$$\dot{x} = Ax + Bu$$
$$y = Cx + Du$$

$$x_1 = h$$
$$x_2 = F_{out}$$

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \underbrace{\begin{bmatrix} 0 & -\frac{1}{A_t} \\ 0 & 0 \end{bmatrix}}_{A} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \underbrace{\begin{bmatrix} \frac{K_p}{A_t} \\ 0 \end{bmatrix}}_{B} u$$

$$\dot{x}_1 = -\frac{1}{A_t} x_2 + \frac{1}{A_t} K_p u$$
$$\dot{x}_2 = 0$$
$$y = x_1$$

$$y = \underbrace{\begin{bmatrix} 1 & 0 \end{bmatrix}}_{C} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

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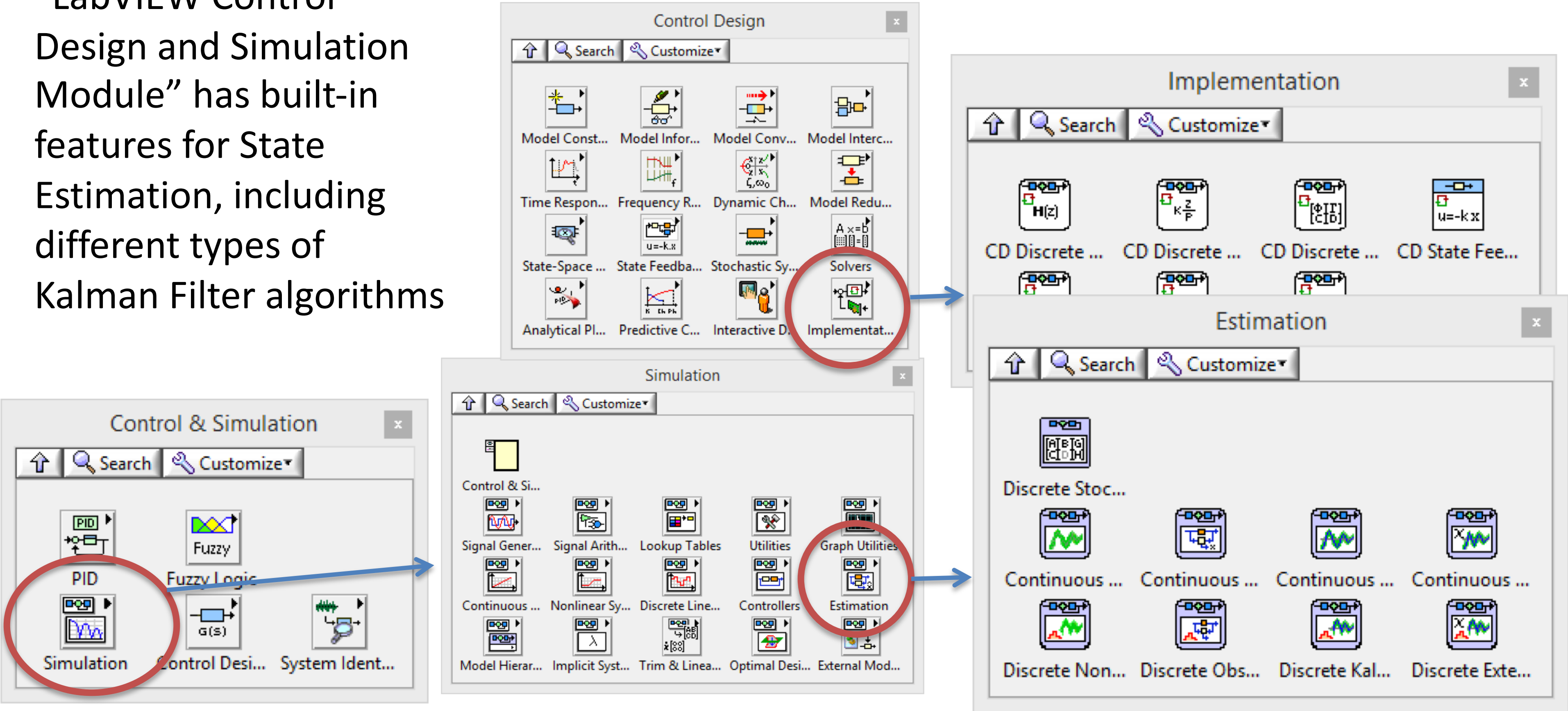
Estimation and Kalman Filters in LabVIEW

Hans-Petter Halvorsen

State Estimation in LabVIEW

“LabVIEW Control Design and Simulation Module” has built-in features for State Estimation, including different types of Kalman Filter algorithms



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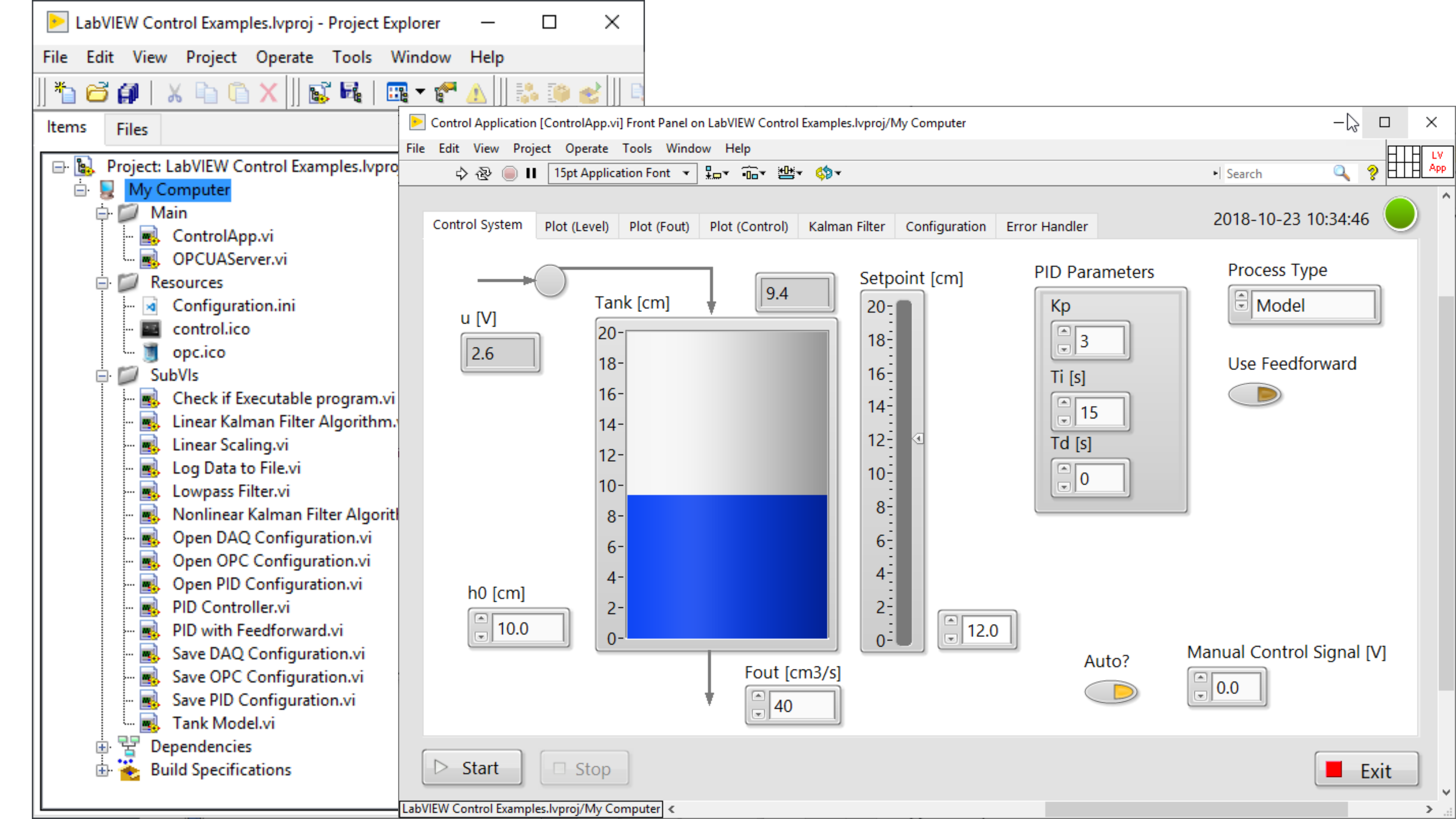
Kalman Filter LabVIEW Application

Hans-Petter Halvorsen


LabVIEW Control Examples.lvproj - Project Explorer
File Edit View Project Operate Tools Window Help
Items
Files
Project: LabVIEW Control Examples.lvproj
My Computer
Main
ControlApp.vi
OPCUAServer.vi
Resources
Configuration.ini
control.ico
opc.ico
SubVIs
Check if Executable program.vi
Linear Kalman Filter Algorithm.
Linear Scaling.vi
Log Data to File.vi
Lowpass Filter.vi
Nonlinear Kalman Filter Algorit
Open DAQ Configuration.vi
Open OPC Configuration.vi
Open PID Configuration.vi
PID Controller.vi
PID with Feedforward.vi
Save DAQ Configuration.vi
Save OPC Configuration.vi
Save PID Configuration.vi
Tank Model.vi
Dependencies
Build Specifications
Control Application [ControlApp.vi] Front Panel on LabVIEW Control Examples.lvproj/My Computer
File Edit View Project Operate Tools Window Help
15pt Application Font
Search
LV App
Control System
Plot (Level)
Plot (Fout)
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Kalman Filter
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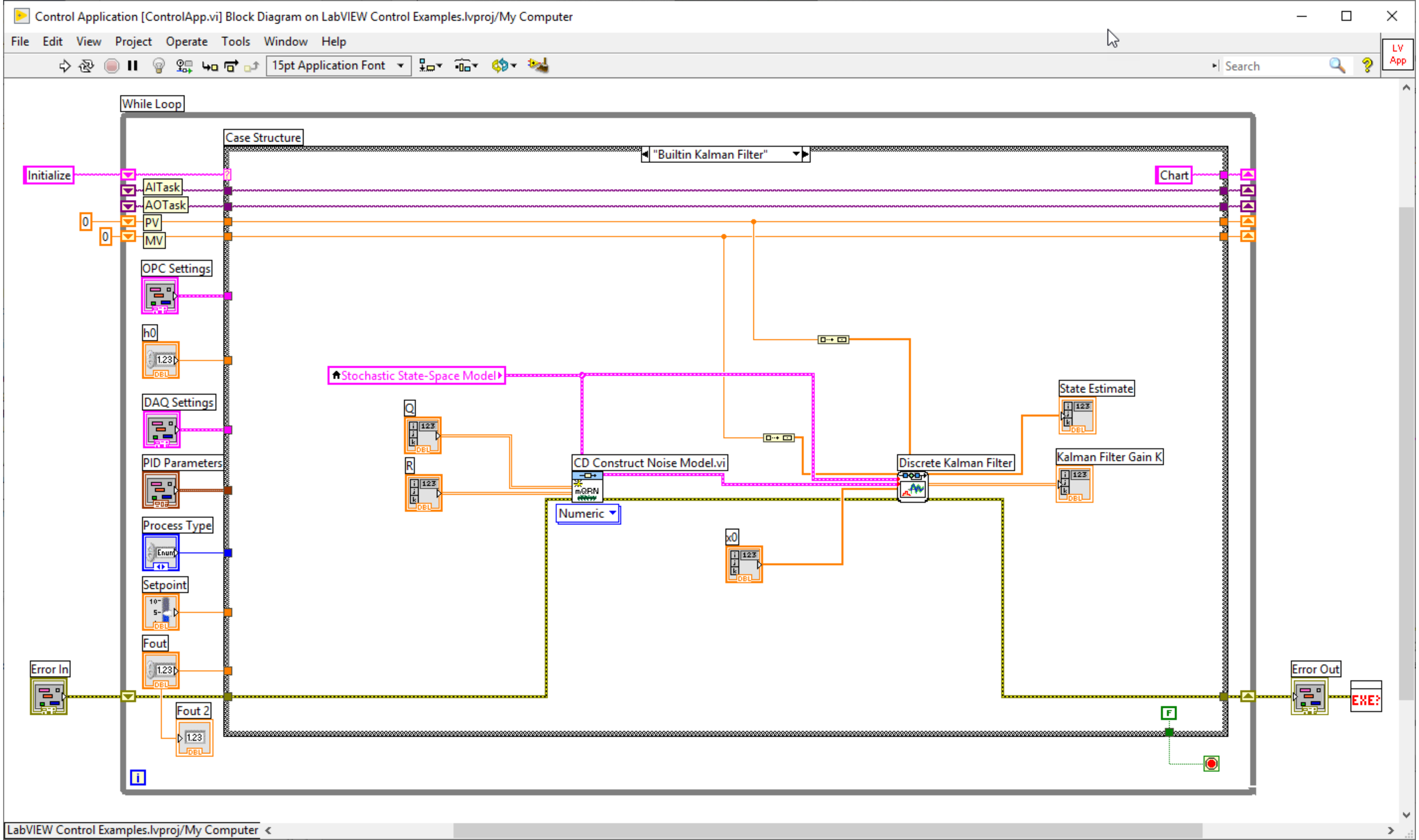
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File Edit View Project Operate Tools Window Help
15pt Application Font
Search
LV App
While Loop
Case Structure
"Builtin Kalman Filter"
Initialize
AITask
AOTask
PV
MV
0
0
OPC Settings
h0
DAQ Settings
PID Parameters
Process Type
Setpoint
Fout
Fout 2
Error In
Chart
Stochastic State-Space Model
Q
R
CD Construct Noise Model.vi
Numeric
x0
Discrete Kalman Filter
State Estimate
Kalman Filter Gain K
Error Out
F
LabVIEW Control Examples.lvproj/My Computer

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