SENSOR FUSION

Signal and Systems Matlab Toolbox

Sensor Fusion

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Background

Goals

1. Reproducible examples in theory and exercise books
2. Possibility to vary parameters in the examples
3. Possibility to extrapolate to similar use cases

It is really not a general purpose toolbox that covers all problems that can occur in sensor fusion.
However, many applications can be recast into the standard framework covered by the toolbox.

Model framework

- Sensor fusion as pattern recognition: rewrite problem into standard form

$$
\begin{aligned}
x(t+1) &= f(t, x(t), u(t), v(t); \theta), & v(t) &\in p_v(v) \\
y(t) &= h(t, x(t), u(t), e(t); \theta), & e(t) &\in p_e(e).
\end{aligned}
$$

- Toolbox use is also pattern recognition, with restriction to additive noises

$$
\begin{aligned}
x(t+1) &= f(t, x(t), u(t); \theta) + v(t), & v(t) &\in p_v(v) \\
y(t) &= h(t, x(t), u(t); \theta) + e(t), & e(t) &\in p_e(e).
\end{aligned}
$$

- Model specified by
  - the functions f, h,
  - the dimensions of the signals in alphabetical order (and order of appearance) $n = [n_x, n_u, n_y, n_\theta]$,
  - and the noise distributions p_v, p_e which are default Gaussian.

Main ideas

- The use of classes to define objects
  - `sensor` for sensor models and sensor networks $y(t) = h(t, x(t), u(t); \theta) + e(t)$
  - `nl`, `lss` for motion models with or without sensor $x(t+1) = f(t, x(t), u(t); \theta) + v(t)$
  - `pdfclass` for distributions such as p_v, p_e
  - `sig` for signal objects $\big(y(t), x(t), u(t)\big)$
- Try to reuse a few standard methods, *e.g.* `disp`, `simulate`, `ls/wls/ml`, `plot/xplot/xplot2`
- Plenty of standard models pre-defined in *e.g.* `exsensor`, `exnl`, `exmotion`

Installation

- Download the zip-file from `https://www.control.isy.liu.se/student/tsrt14/`
- Unzip the file structure and save it to a convenient folder
- Place Matlab in the same folder and run `initSigSys` to set the path to all subfolders

Sensor models

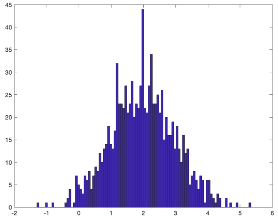
General form: $y(t) = h(x, u, \theta) + e$

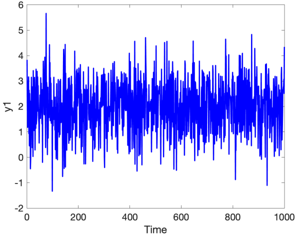
Dimensions: `n=[nx,nu,ny,nth]`

Used for simulation, calibration of θ, estimation of x or x, θ, and to create state space models

Simulation creates a SIG object

```
s=sensormod('x(1)^2+x(2)^2',[2 0 1 0]).      % Simplest
s=sensormod('x(1,:).^2+x(2,:).^2',[2 0 1 0])% Preferred
s.x0=[1;1];                  % Set x
data=simulate(s,1:3)         % Simulate y(1:3)
data.y                       % Display y(t)
s.pe=1                       % Set pe to N(0,1)
data=simulate(s,1:3)         % Simulate with noise
data.y
data=simulate(s,1:1000);     % Generate 1000 y
hist(data.y,100)             % Histogram
plot(data)                   % Plot y(t)
```

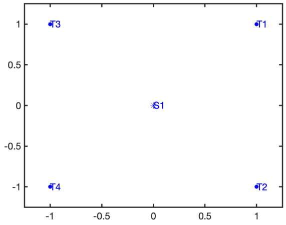


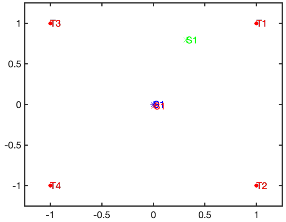


Sensor networks: calibration

Sensor networks is a special case of SENSORMOD.
The parameters θ used to represent sensor positions.
Many example networks in `exsensor(type,M,N)`:
TOA, TDOA, DOA, RSS, etc.
M targets and N sensors.

```
s=exsensor('toa',1,4);              % Standard TOA network
s.x0=[1 1 1 -1 -1 1 -1 -1];         % Set the 4 target pos
s.th=[0 0]; s.pe=0.001*eye(4);      % Sensor pos and dist
y=simulate(s,1);                    % Simulate one meas
s0=s; s0.th=s.th+0.5*randn(2,1);    % Perturb sensor pos
shat=calibrate(s0,y);               % Estimate sensor pos
plot(s,s0,shat)                     % Compare all three
```

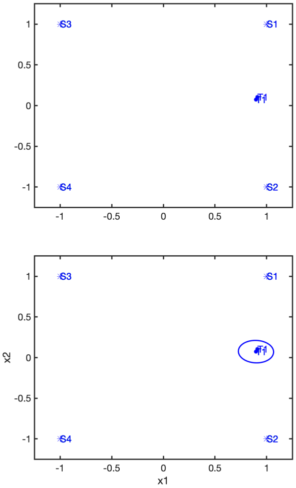




Sensor networks: estimation

Estimate x using `wls`, `ls`, `ml`.
Two outputs: SIG and SENSORMOD (incl. P_x, P_θ) objects.
The method `estimate` estimates any mix of x and θ

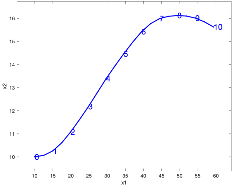
```
s=exsensor('toa',4,1)          % TOA now with 4 sensors
s.th=[1 1 1 -1 -1 1 -1 -1];    % Sensor positions
s.pe=0.01*eye(4);              % Sensor noise N(0,0.01)
y=simulate(s,1)                % Simulate one data point
[xhat,shat]=wls(s,y);          % Estimate target with WLS
                               % Output both SIG and SENSOR
plot(s,shat)                   % Plot both networks
hold on
xplot2(xhat,'conf',90)         % SIG provides covariance
```

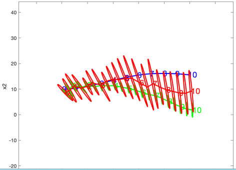


State space models

LSS denotes the class of linear models where the method `kalman` can be applied
NL is the more general class of nonlinear models
Many examples of motion and sensor models in `exnl`, `exsensor`
Motion models and sensor models can be mixed
Filters can be applied to simulated data e.g. `ekf`, `ukf`, `pf`, `crlb`

```
randn('state',2), rand('state',3)
fx=exmotion('ctcv2d')    % Motion model without sensor
hx=exsensor('radar',1)   % Radar sensor
ss=addsensor(fx,hx)      % Add sensor to motion model
yx=simulate(ss,10);      % Simulate 10 seconds
xplot2(yx)               % Plot state trajectory X,Y
xhat1=ekf(ss,yx);        % Apply EKF
ss.pv=2*ss.pv;           % Dithering noise since fx nonlin
ss.pe=2*ss.pe;           % Also hx nonlinear
xhat2=ekf(ss,yx);        % Second try
xplot2(yx,xhat1,xhat2,'conf',90)
axis('equal')            % Compare filters
```





Summary

- Sensor fusion has a very complex scope
- Strict model syntax

$$\begin{aligned} x(t+1) &= f(t, x(t), u(t); \theta) + v(t), & v(t) &\in p_v(v) \\ y(t) &= h(t, x(t), u(t); \theta) + e(t), & e(t) &\in p_e(e). \end{aligned}$$

- Start with working examples from `help`, book, exercises or manual to save time debugging syntax
- The goal with the toolbox is to get problem intuition
- Write your own code is also an important part of the learning process