# Youla (continuous)

About the program:

The program shows the operation of the Youla controller. The process and controller parameters can be set. This version is for simulating continuous systems.
The program shows the output of the controlled process and the controller output on the figures on the right side.

About the simulation:

The simulation happens according to the following block diagram.
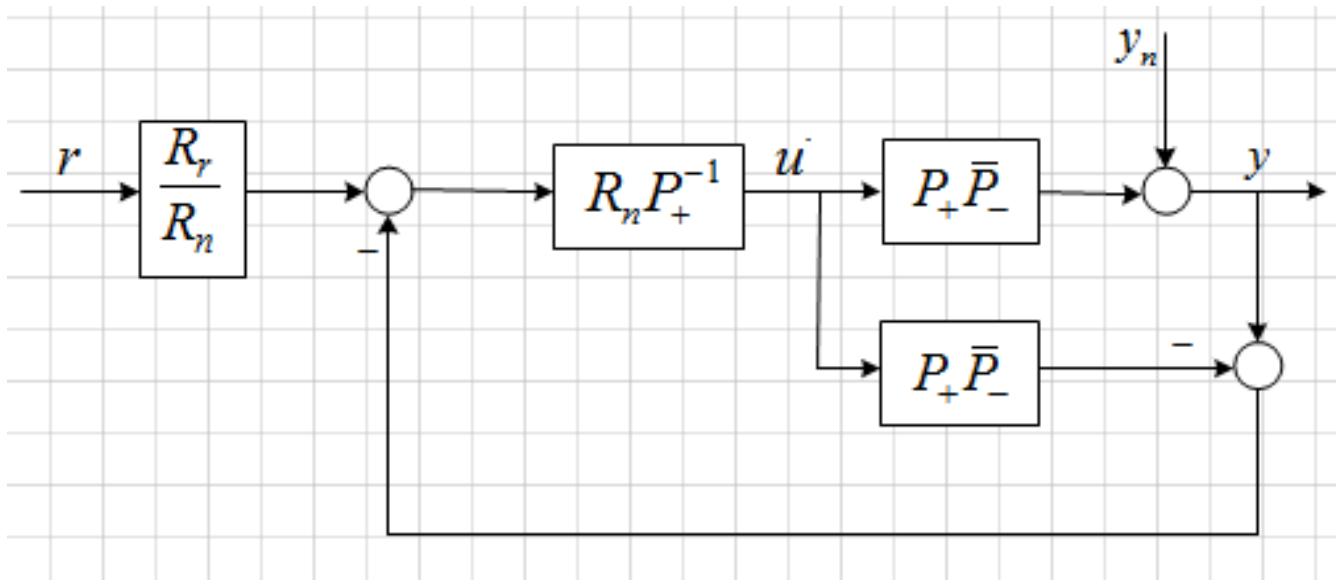
Legend:

r - input signal (reference signal)
u - output signal of the controller (actuating signal)
y - output signal
yn - output disturbance
Rr/Rn   - input signal filter
RnP_+^{-1} - the controller (Q – Youla parameter)
P+P- (upper) - the actual process (P+ denotes the invertible part of the transfer function of the process, P- denotes its non invertible part. The upper line means that dead time is also present, which is also non invertible.)
P+P- (down) - the simulated process (model of the process, which can differ a bit from the real process, so the effect of plant/model mismatch can also be analysed.)
The simulation allows an internal noise signal to be added to "u" and stochastic noise to be added to "y".

How to use the program:

The process to be controlled can be specified in the "Process:" section on the left. To validate the new process, click the "Set Parameters" button and click on "Draw" to draw it.
The polynomials of the numerator and of the denominator have to be given by listing their coefficients, starting from the highest grade component. These have to be divided by either a colon, or a space. Giving these as a product of polynomials is possible. In that case, the polynomials must be enclosed in brackets, and in each polynomial, the coefficient of the highest grade component of the polynomial must come first.
For example: "1,4,4" or „(1,2)(1,2)" input represents the »s² + 4s +4« system.

The controller parameters are individually adjustable under "Controller:" label.
The input syntax form is the same as in the case of the process.

The disturbance and reference signal filters [Rn, Rr] also have to be given. The invertible part [P+] and non-invertible part [P-]) of the process have to be defined. The invertible part of the simulated process [P+m] can be given separately, which can be a bit different from that of the real process. So the effect of plant/model mismatch can be also investigated.

With the sliders below that, you can set dead time, the target value (reference signal), the graph length (simulation time) and the simulation interval. The minimum / maximum values of the last two are interdependent, so it is not possible to use values - using the sliders - to increase the simulation complexity to a level, where the real-time operation of the program would be lost.
Dead time: dead time of the real process
Dead time(m): deadtime of the simulated process (model)
Target: the reference signal
Graph length: length of the output graphs
Timestep: simulation interval. Reducing the time interval makes the simulation more precise, but it also increases the demand for computing!

We can put external and random noise to the output and inside noise to the control signal. Their initial value, length and strength can also be specified (length of random noise is infinite). The slider values range from 0 to 1, where 0 is the beginning of the graph, and 1 is the end of the graph, regardless of its length. For strength 1 it is the same as the target value.
For example: with graphlength 40 and starting value 0.5 the noise will start at 20.

You can specify exact input values when you press the "Use TextFields as Input" button. In this case, instead of the sliders, use the textboxes next to them to give accurate values.
WARNING: Contrary to sliders, the input value on the textbox is not limited! A too big graphlength or a too small timestep can make the program nonresponsive.

Examples

Example 1.

The transfer function of a continuous process with three time constants and dead time is given as

$$P(s) = \frac{1}{(1+2s)(1+4s)(1+6s)} e^{-10s}$$

The non invertible part of the process is the dead time. The inverse of the invertible part of the process, given by transfer function

$$P_+(s) = \frac{1}{(1+2s)(1+4s)(1+6s)}$$

is non realisable. The YOULA parameter,

$$Q = R_n P_+^{-1}$$

would be realisable, if the transfer function of the disturbance filter would be of third degree.

Be the transfer functions of the disturbance filter and that of the reference filter $R_n = \dfrac{1}{(1+s)^3}$ and $R_r = \dfrac{1}{(1+2s)^3}$, respectively. For the realisability of the prefilter the degree of R_n has to be equal or higher than the degree of R_r. The Youla parameter is

$$Q = R_n P_+^{-1} = \frac{(1+2s)(1+4s)(1+6s)}{(1+s)^3}$$

and the prefilter

$$\frac{R_r}{R_n} = \frac{(1+s)^3}{(1+2s)^3}$$

The figure below shows the behaviour of the Youla parameterized control system. Unit step reference signal is applied, then at time point 125 sec a step output disturbance occurs of amplitude 0.5.

The figure shows the setting of the parameters. The upper picture gives the course of the output signal, while the lower picture shows the control signal.
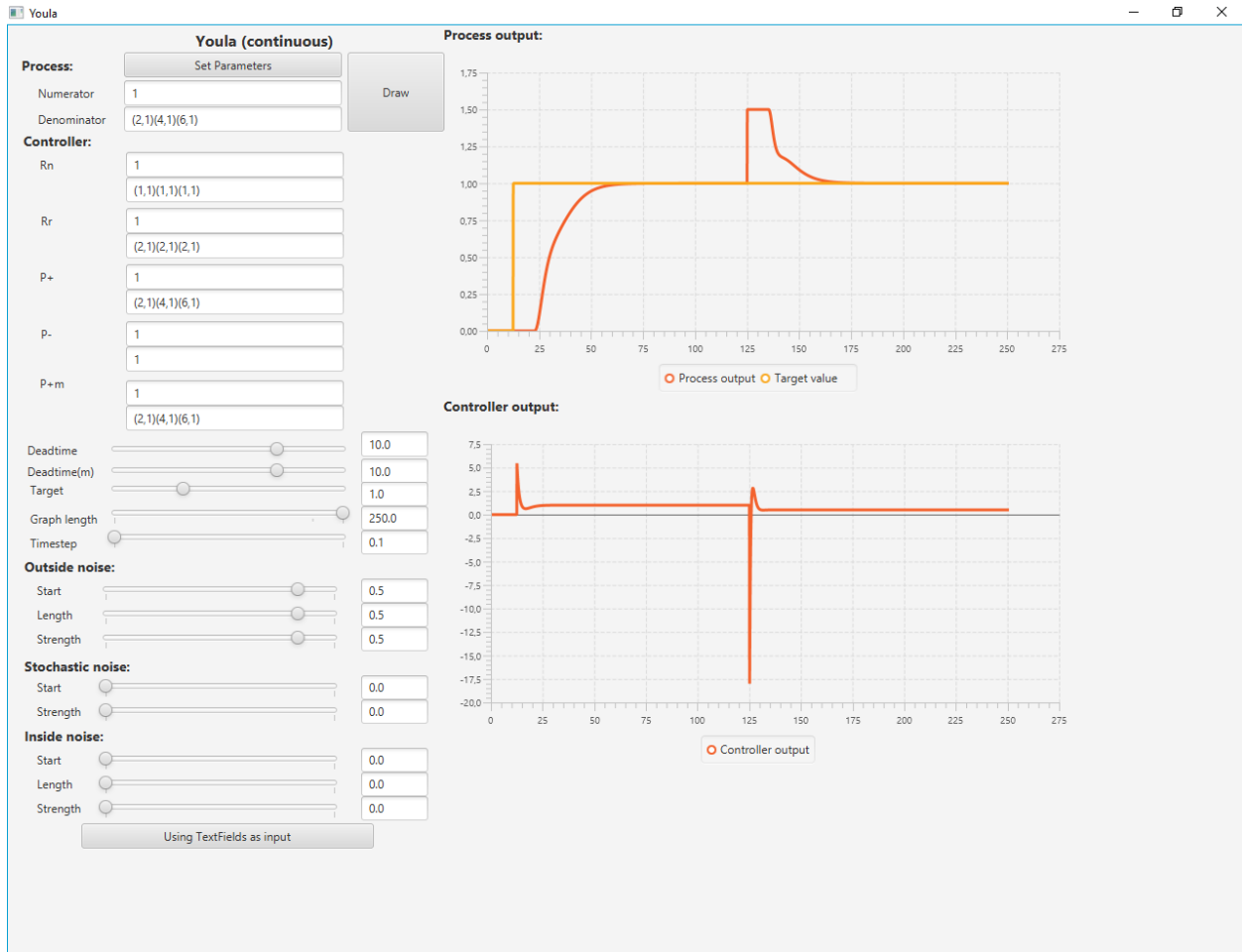
Example 2.

The transfer function of the non-minimumphase system is

$$P(s) = \frac{1-s}{(1+2s)(1+3s)}$$

The invertible part of the process is

$$P_+(s) = \frac{1}{(1+2s)(1+3s)}$$

while the non invertible part is given as

$$P_-(s) = 1-s$$
.

The controller (the Youla parameter)

$$Q = R_n P_+^{-1}$$

will be realizable, if the second order filters are chosen. Let us choose

$$R_n(s) = \frac{1}{(1+s)^2}$$

$$R_r(s) = \frac{1}{(1+1.5s)^2}$$

So

$$F(s) = \frac{R_r(s)}{R_n(s)} = \frac{(1+s)^2}{(1+1.5s)^2}$$

$$Q = R_n P_+^{-1} = \frac{(1+2s)(1+3s)}{(1+s)^2}$$

.

The figure below shows how to give the process and the controller. The output and the control signals are shown, when the reference signal is a step, and a step disturbance of amplitude 0.5 acts at the two third of the simulation time.