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INSTITUTE OF AUTOMATION AND COMPUTER SCIENCE

BRNO UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING

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Topic 7: 2-DOF, Identification systems, Genetic algorithm

Course : Control Theory I (VA1-A 18/19Z)
Teacher : Ing. Roman Parák (Roman.Parak@vutbr.cz), A1/0642
Location : A1/0636

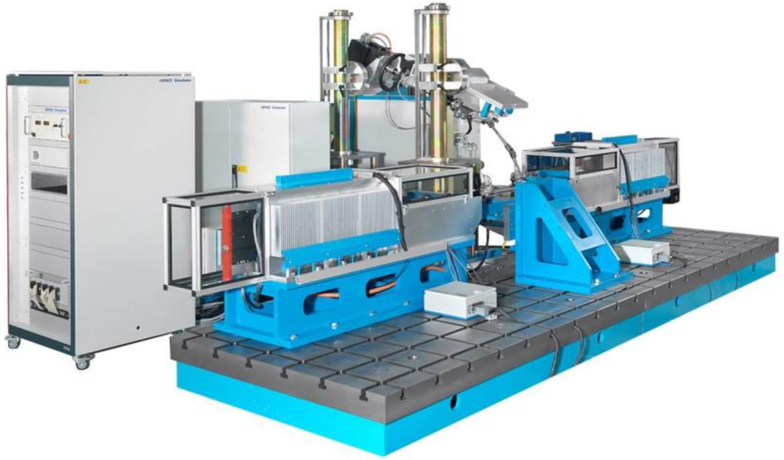
Workshop Humusoft

Topic : Model Based Design and HIL Simulations, dSPACE
Speaker : Jana Sárena, Application Engineer, Humusoft s.r.o
Date : 4.12.2018
Time : 10:00 am
Location : A1/0643
Language : English

MathWorks®

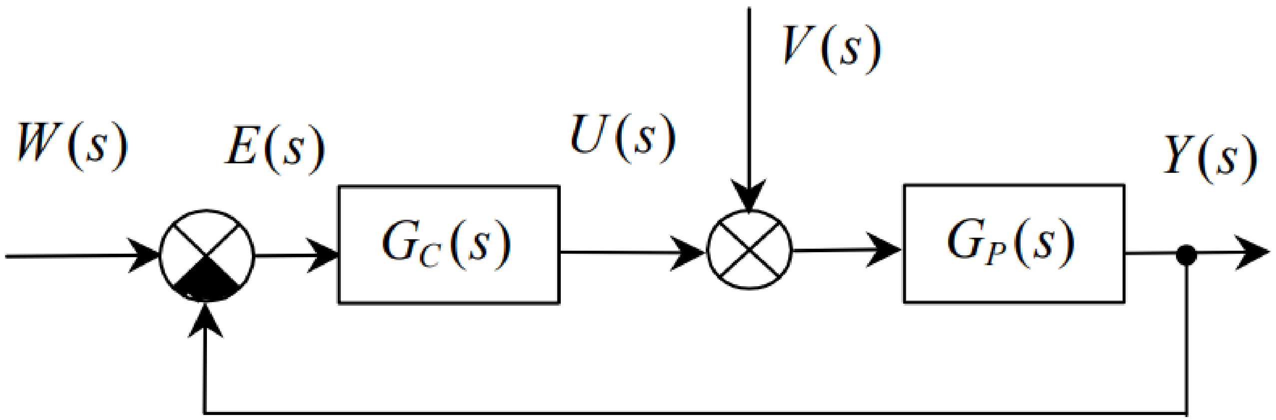
HUMUSOFT®

dSPACE



1-DOF (degrees of freedom)

Control system with standard controller - G_C(the standard controller transfer function) and G_P(the plant transfer function)



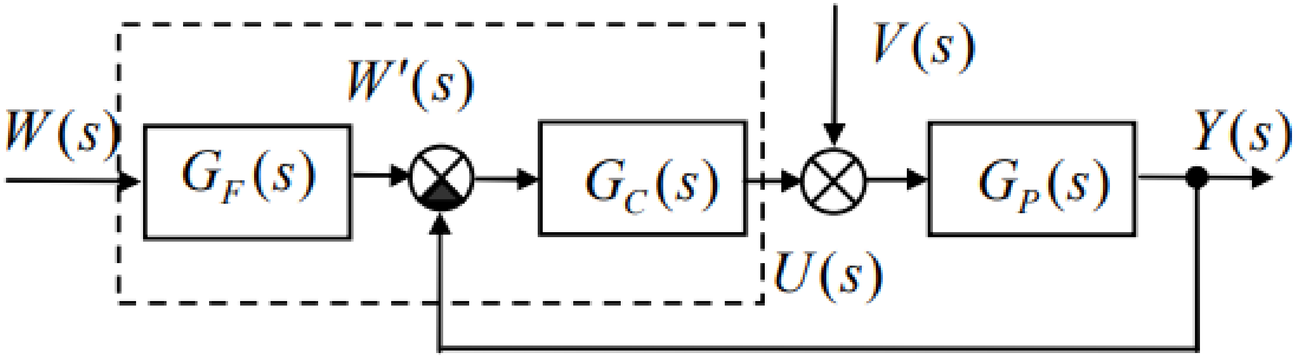
W(s): desired setpoint/ command variable
Y(s): controlled variable
E(s): error value
U(s): manipulated variable
V(s): disturbance variable

G_C(PID):

$$G_C(s) = K_P\left(1 + \frac{1}{T_I s} + T_D s\right)$$

2-DOF (degrees of freedom)

Control system with 2-DOF controller - G_F(the input filter with the transfer function), G_C(the standard controller transfer function) and G_P(the plant transfer function)



W(s): desired setpoint/ command variable
W'(s): filtered desired setpoint/ command variable
Y(s): controlled variable
E(s): error value
U(s): manipulated variable
V(s): disturbance variable

G_F(PID):

$$G_F(s) = \frac{cT_I T_D s^2 + bT_I s + 1}{T_I T_D s^2 + T_I s + 1}$$

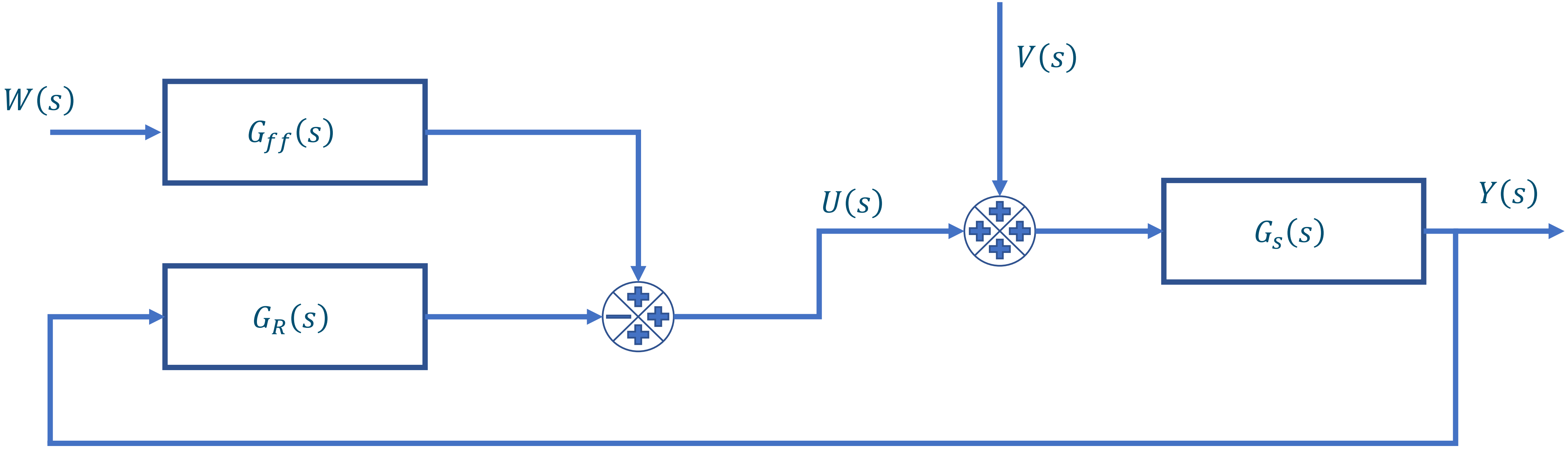
Example: 2-DOF

G_P (the plant transfer function):

$$G_s(s) = \frac{1}{s^2 + 0{,}5s + 0.1}$$

Bandwidth:

$$\omega_b = 1{,}5 \text{ rad/s}$$



Dead-time process

Dead times appear in many processes in industry and in other fields, including economical and biological systems. They are caused by some of the following phenomena:

(a) The time needed to transport mass, energy or information.

(b) The accumulation of time lags in a great number of low-order systems connected in series.

(c) The required processing time for sensors, such as analysers; controllers that need some time to implement a complicated control algorithm or process.

Dead times introduce an additional lag in the system phase, thereby decreasing the phase and gain margin of the transfer function making the control of these systems more difficult.

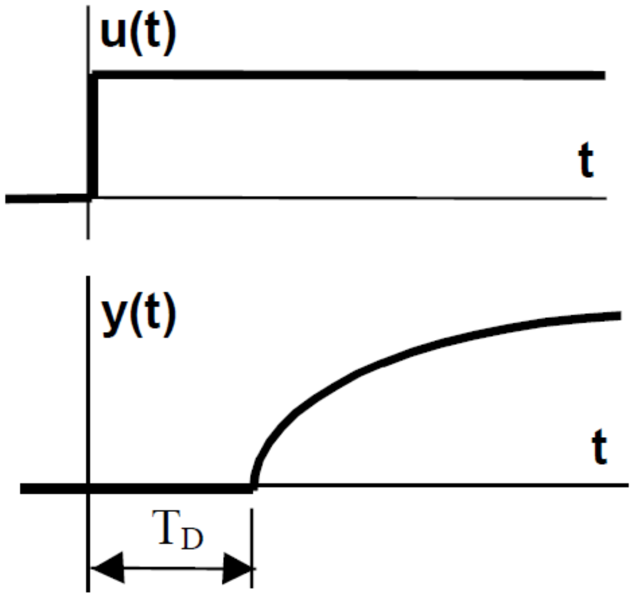
Dead-time process

Differential equation:

$$a_n y^{(n)}(t) + \ldots + a_1 y'(t) + a_0 y(t) = b_m u^{(m)}(t - T_D) + \ldots + b_1 u'(t - T_D) + b_0 u(t - T_D)$$

Laplace transform/Transfer function:

$$G(s) = \frac{b_m s^m + \quad \ldots \quad + b_1 s + b_0}{a_n s^n + \quad \ldots \quad + a_1 s + a_0} e^{-T_D s}$$



T_D: Dead time

Identification system from unit step response

Example:

a) Without dead-time

$$G_s(s) = \frac{2}{10s+1} \rightarrow G_{approx}(s) = \frac{k}{Ts+1}$$

b) With dead-time: A – type

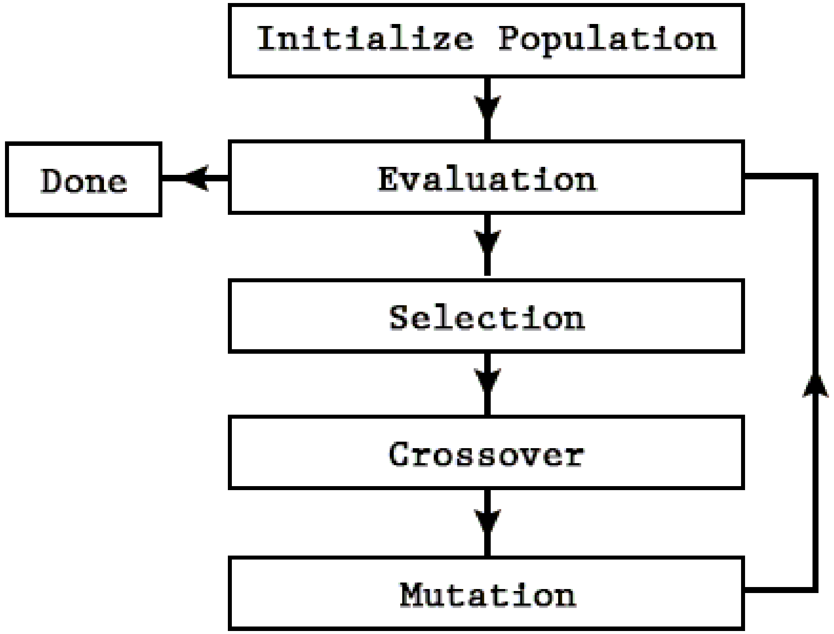
$$G_s(s) = \frac{2}{10s+1} e^{-5s} \rightarrow G_{approx}(s) = \frac{k}{Ts+1} e^{-Tds}$$

c) With dead-time: B – type

$$G_s(s) = \frac{2}{0.1s^2+10s+1} \rightarrow G_{approx}(s) = \frac{k}{Ts+1} e^{-Tds}$$

Genetic algorithm

A genetic algorithm works by maintaining a pool of candidate solutions (named generation). Iteratively, the generation evolved to produce the next generation which has candidate solutions with higher fitness values than the previous generation. This process is repeated for a pre-specified number of generations or until a solution with goal fitness value is found.

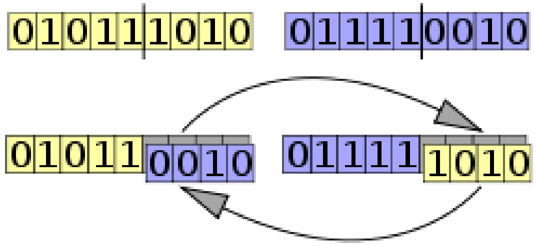


Genetic algorithm

The next generation is created from current generation in a biologically inspired manner that consists of 3 steps:

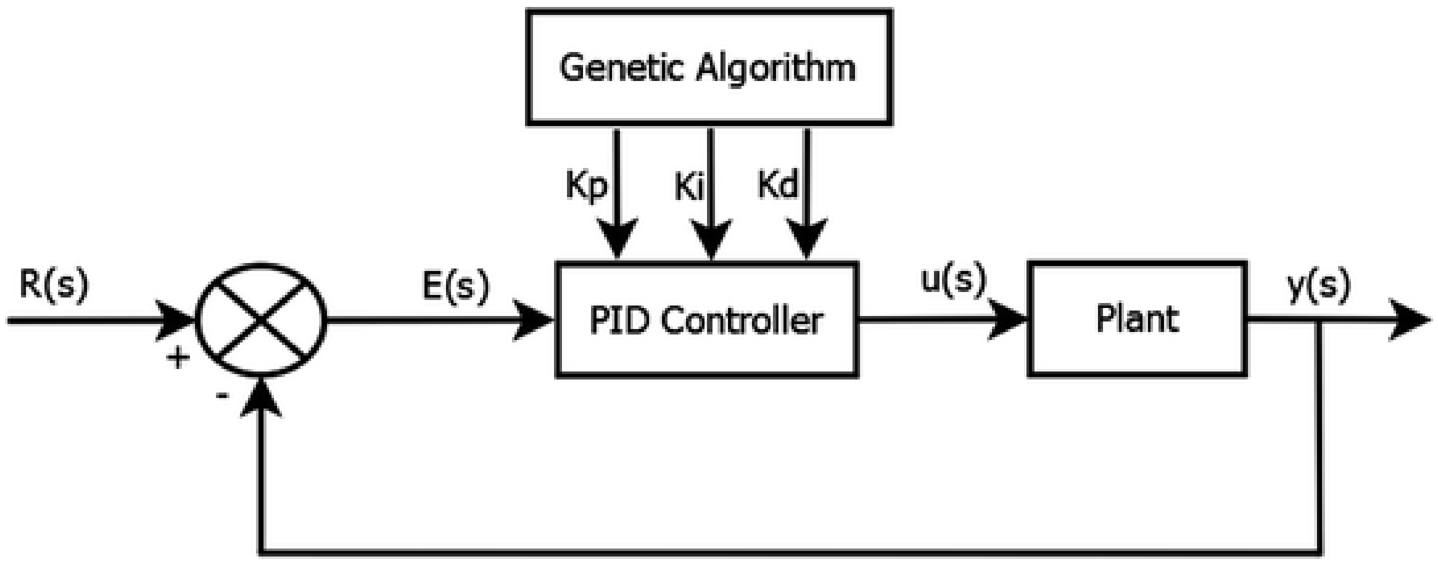
Selection: we evaluate the fitness of members of the current generation, then we select the subset with the best fitness values in order to act as parents for the next generation. In short, survival for the fittest.

Crossover: we merge pairs from the selected parents to generate new offspring child solution. Crossover can happen in different forms, simplest form is the one-point crossover which splits the string representation of each solutions into two parts at the same position, then concatenate the first part of one solution with the second part of the second one to form the offspring solution representation.



Mutation: In biology, mutation happens with low probability where a child can have a feature that was not inherited from the parents. Likewise, in genetic algorithm mutation step perturbs the offspring solution with very small probability (e.g. flipping one bit of the bit string representation of the solution)

Genetic algorithm – PID

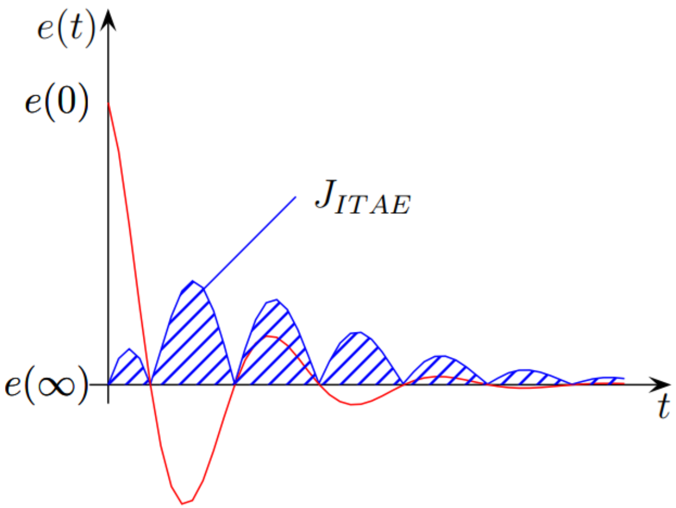


ITAE criterion

Many methods are presented in literature that minimizes a certain error criterion. One of the methods called, Minimum ITAE approximate model for controller tuning rules . Integral of the time weighted absolute error [ITAE] is defined as:

$$J_{ITAE} = \int_0^{\infty} |e(t)| t \, dt$$

The time weighting 't' is used, because the initial error for a step response is always large, and for most set point cases it is reasonable to weigh this error less.



Project

Name : Design and Implementation of the Controller for the selected systems
Deadline : 16.12.2018
Language : English/Czech/Slovak = paper; MATLAB/Simulink, Python, C/C++ = SW
Points : 15p

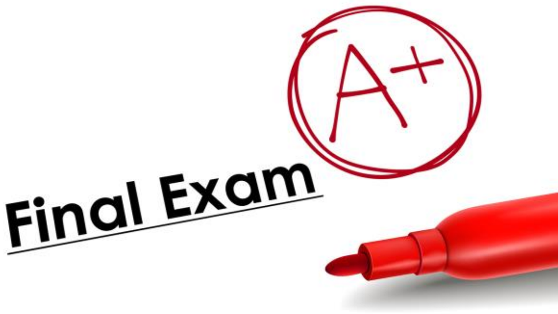
15p (project) + 10p (activity) = 25p (seminar)

+

75p (exam)

=

100p



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