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PID-CONTROLLER SYNTHESIS SOFTWARE FOR THE STABILIZATION SYSTEM OF THE INERTIAL CONTROL OBJECT

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Abstract**—***Reviewed software creation method for the selection an optimum regulator for the stabilization system of the inertial control object. PID-controller synthesis software implemented by Python and it`s libraries: SciPy, NumPy and Control Systems Library. Schematic decisions of regulators and correction devices for stabilization systems may be different: P, PI, PD, PID. The first three options can be generally obtained by applying restrictions on the PID-model. The exact adjustment of the PID-controller parameters significantly reduces system fluctuations. The full use of the PID-controller advantages is only provided with the correct calculation of these parameters, taking into account the unique characteristics of the controlled objects. At the same time, it is important to have a mechanism (program) for coefficients controlling that would provide a convenient interface between the program and the user.*

Index Terms—Inertial object; stabilization system; step response; PID-controller; correction appliance; Python; Control Systems Library.

I. INTRODUCTION

Stabilization and control systems take an important place in the automated control systems of inertial objects. Their goal is to achieve a sustainable value of a control magnitude or its change for a given control law.

While simultaneous action of control signal, permanent or variable perturbation influences and obstacles on the system, there is a need to solve the problem of minimizing its error.

In order to provide optimal quality indicators, a correction of control systems is widely used for changing of the system dynamic properties. For this purpose, correction devices are entered into the system, which represent dynamic links of various physical nature with specially selected transfer functions.

Currently, in the world market, for integrated control systems are offered universal control microprocessors, which require special setting.

Schematic decisions of regulators and correction devices for stabilization systems may be different: P, PI, PD, PID. The first three options can be generally obtained by applying restrictions on the PID-model.

PID-controller measures the deviation of the regulated by the system coordinate from the given value and issues a control signal, which is the sum of the three components – proportional, integral and differential.

II. PROBLEM STATEMENT

The exact adjustment of the PID-controller parameters significantly reduces system fluctuations However, the full use of the PID-controller advantages is only provided with the correct calculation of these parameters, taking into account the unique characteristics of the controlled objects.

A large number of publications are devoted to modeling of the PID-controller . In particular, the vast majority of research is related to the design of PID-controller models in MATLAB and Simulink. But, as the practice shows, this is not enough.

While designing systems with a PID-controller , it is necessary to investigate the effect of its coefficients on the transition process (or the coefficients choice according to the desired type of transitive function), which requires multiple launch of the model with modified coefficients and constant editing of the model properties.

At the same time, it is important to have a mechanism for coefficients controlling that would provide a convenient interface between the program and the user.

Thus, there is a need to create the universal and up-to-date application, using a high-level program-ming language for researching stabilization and control systems, which will provide a quick and convenient choice of optimal PID-controller coefficients.

III. PROBLEM SOLUTION

At this development level of the Python programming language, it is possible to use it effectively for modeling and optimization of automatic control circuits containing dynamic and statical elements.

In particular, all above difficulties can be overcome by using several Python libraries: SciPy, NumPy and Control Systems Library. Moreover, it is possible to apply elements of the MATLAB environment by connecting the Python Control Systems Library. The python-control package is a set of python classes and functions that implement common operations for the analysis and design of feedback control systems.

Let's solve the problem of the selection an optimal regulator for the nonlinear stabilization system of the inertial control object, for example a ship.

Mathematical model of the stabilization system of the ship course is represented as a block diagram (Fig. 1).

The moment of stabilization is formed through the sensor channel of angular deviation and through the speed sensor of angular deviation of control object:

$$\overline{M_S} = \overline{M_G} + \overline{M_D} \equiv k_G G_m + k_D D_m .$$

After the convolution of contour we obtain an equivalent transfer function of the stabilization system linear part:

$$W(s) = \frac{k_0 k_G G_m}{T_0 T_2^2 s^3 + \left(T_0 T_1 + T_2^2\right) s^2 + \left(T_0 + T_1\right) s + 1 + k_0 k_D D_m} \cdot \frac{1}{s}.$$

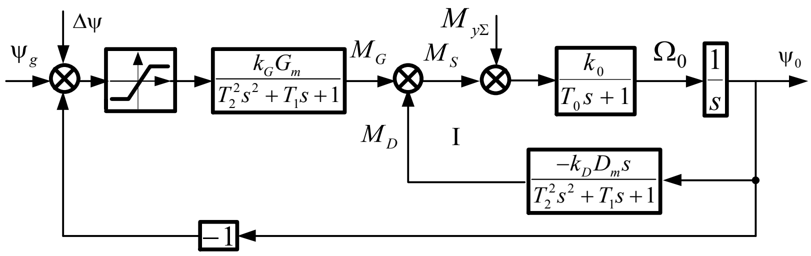

Fig. 1. Nonlinear stabilization and control system of the ship course

Concurrently, the executive drive has a linear characteristic with limitation:

$$z = \begin{Bmatrix} -x_{\max} \; at \; x < -a \\ kx \;\; at \;\; -a \le x \le a \\ x_{\max} \; at \; x > a \end{Bmatrix}.$$

Calculated model of the nonlinear stabilization system of the ship course and equivalent transfer functions of it components allow to begin the direct computer modeling using Python.

Graphical User Interface (GUI) will be implemented using the Tkinter library. For adjusting the PID-controller , GUI will contain:

- interface element for outputting the graph of the investigated system transient process;
- three sliders for setting numerical values of the regulator coefficients *K*1 (*P*-component), *K*2 – (*I*-component) and *K*3 (*D*-component);
- six Entry elements to set the limit values of these coefficients (Max and Min);
- three text Label elements to output current values of coefficients (Current);
- six text items for the corresponding inscriptions.

Let's program this:

```
label_1 = tk.Label (root, text = "P")
label_1.grid(row =8, column =1)
label_2 = tk.Label (root, text = "I")
label_2.grid(row =9, column =1)
label_3 = tk.Label (root, text = "D")
label_3.grid(row =10, column =1)

label_4 = tk.Label (root, text = "Min")
label_4.grid(row =7, column =2)
label_5 = tk.Label (root, text = "Max")
label_5.grid(row =7, column =4)
label_6 = tk.Label (root, text = "Current")
label_6.grid(row =7, column =5)

label_10 = tk.Label (root, text = " ").grid(row =6, column = 3)

min_k1 = tk.Entry (root, width = 5)
min_k1.grid(row =8, column =2)
min_k2 = tk.Entry (root, width = 5)
min_k2.grid(row =9, column =2)
min_k3 = tk.Entry (root, width = 5)
min_k3.grid(row =10, column =2)

k1= tk.Scale (root, from_=0, to=3, orient = tk.HORIZONTAL, resolution = 0.01, length = 210, command = change_scale_P)
k1.grid(row =8, column =3)

k2= tk.Scale (root, from_=0, to=1, orient =tk.HORIZONTAL, resolution = 0.01, length = 210, command = change_scale_I)
```

```
    k2.grid(row =9, column =3)
    k3= tk.Scale (root, from_=0, to=1, orient =tk.HORIZONTAL, resolution = 0.01, length = 210, command = change_scale_D)
    k3.grid(row =10, column =3)

    label_7 = tk.Label (root, text = k1.get())
    label_7.grid(row =8, column =5)
    label_8 = tk.Label (root, text = k2.get())
    label_8.grid(row =9, column =5)
    label_9 = tk.Label (root, text = k3.get())
    label_9.grid(row =10, column =5)

    max_k1 = tk.Entry (root, width = 5)
    max_k1.grid(row = 8, column = 4)
    max_k2 = tk.Entry (root, width = 5)
    max_k2.grid(row = 9, column = 4)
    max_k3 = tk.Entry (root, width = 5)
    max_k3.grid(row = 10, column = 4)
```

The limit values of the regulator's coefficients can be set experimentally. In the work, they are selected based on the performed calculations [3].

Designed graphical interface is ready for programming. Let`s add GUI command processing functions:

```
def change_lim():
    k1_to=min_k1.get()
    k1['from_']= k1_to
    k2_to=min_k2.get()
    k2['from_']= k2_to
    k3_to=min_k3.get()
    k3['from_']= k3_to
    k1_to=max_k1.get()
    k1['to']= k1_to
    k2_to=max_k2.get()
    k2['to']= k2_to
    k3_to=max_k3.get()
    k3['to']= k3_to
    return

def change_scale_P(self):
    change_lim()
    label_7['text'] = k1.get()
    global P
    P=float(label_7['text'])
    calculate(P,I,D)

def change_scale_I(self):
    change_lim()
    label_8['text'] = k2.get()
    global I
    I=float(label_8['text'])
    calculate(P,I,D)

def change_scale_D(self):
    change_lim()
    label_9['text'] = k3.get()
    global D
    D=float(label_9['text'])
    calculate(P,I,D)
```

Finally, supplement created program code with a function with main calculations:

```
def calculate (a,b,c):

    w_ob = cn.TransferFunction(30,[0.01,0.2,1,0]) #tf of control object
    w_gain = cn.TransferFunction(0.09,[0.01,1]) #tf of gain

    N=100
    w_con = cn.TransferFunction ([(a/N+c),(a+b/N),b],[1/N,1,0]) #tf of PID controller

    w_m = cn.series(w_gain, w_ob)
    w = cn.series(w_con, w_m) # open-loop system
    sys = cn.feedback(w,1) #closed-loop system

    t=np.arange(0,5,0.001)
    T, yout = cn.step_response(sys, t, 0)
    plt.cla()

    fig = plt.figure(1)
    plt.plot(T, yout,"b")
    plt.title('Step Responsse ')
    plt.ylabel('Amplitude')
    plt.xlabel('Time(sec)')
    plt.grid(True)

    canvasAgg=FigureCanvasTkAgg(fig, master=root)
    canvas=canvasAgg.get_tk_widget().grid(row =0, column =1, columnspan=6, rowspan=5)
```

As a result of running the code above, the dialog opens, as shown in Fig. 2.

The developed interface allows by dialog sliders' engines displacement to determine the coefficients of any type regulator (P, PD, PI or PID) by the view of transient characteristics.

In Figure 2, as an example, the transition function is showed with slider installing in position that corresponds to the optimal coefficients of the PID-controller obtained in previous studies [3].

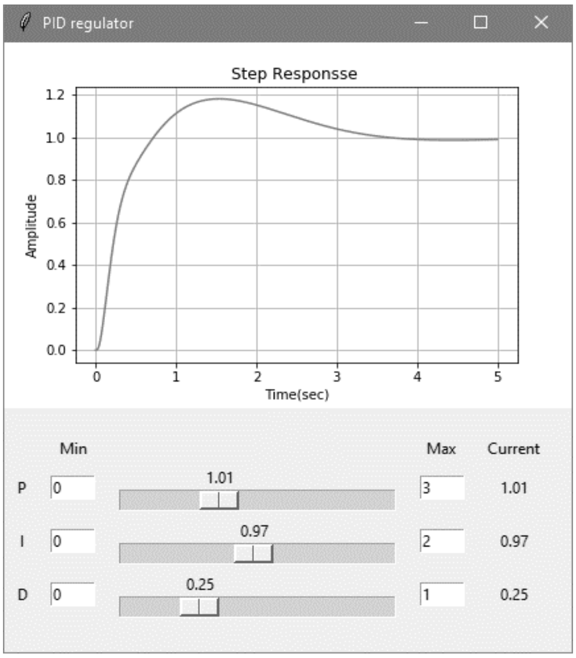

Fig. 2. Dialog interface

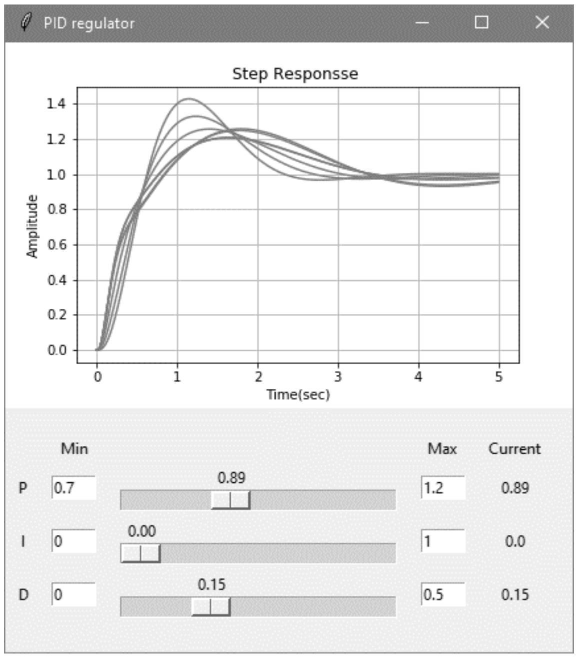

Fig. 3. An example of a characteristics family

By removing the clean command plt.cla() in the program's code, you can get a family of transient characteristics for any set of parameters of the regulator, which can be convenient when choosing the characteristics with the desired quality indicators (Fig. 3).

The designed program allows us to quickly calculate the optimal coefficients for any type of regulator or correction device by removing and combining the necessary channels in them.

IV CONCLUSIONS

Implemented by Python PID-controller synthesis software illustrates the ability of effectively use of this programming language for modeling and optimization automatic control systems.

The above listing of the program can be easily adapted and successfully applied to the any type stabilization system of inertial object.

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О. К. Аблесімов, М. О. Пилипенко, Т. П. Жмурчик. Програмне забезпечення синтезу ПІД-регулятора системи стабілізації інерційного об'єкту
Розглянуто методику створення програмного забезпечення синтезу оптимального регулятора для нелінійної системи стабілізації інерційних об'єктів. Програмне забезпечення синтезу ПІД-регулятора, реалізоване засобами Python та його бібліотеками: SciPy, NumPy та Library Systems Library. Схемні рішення регуляторів і коригувальних пристроїв, можуть бути різними: П, ПІ, ПД, ПІД. Перші три варіанти можуть бути в загальному випадку отримані накладенням обмежень на ПІД-модель. Точне налаштування параметрів ПІД-регулятора суттєво знижує коливання системи. Повноцінне використання переваг ПІД-регулятора забезпечується тільки при правильному розрахунку цих параметрів з урахуванням особливостей характеристик керованих об'єктів. При цьому важлива наявність механізму (програми) управління коефіцієнтами, який би забезпечував зручний інтерфейс між програмою і користувачем.
Ключові слова: інерційний об'єкт; система стабілізації; перехідна функція; ПІД-регулятор, коригувальний пристрій; Python; Control Systems Library.

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А. К. Аблесимов, М. А. Пилипенко, Т. П. Жмурчик. Программное обеспечение синтеза ПИД-регулятора системы стабилизации инерционного объекта
Рассмотрена методика создания программного обеспечения синтеза оптимального регулятора для нелинейной системы стабилизации инерционных объектов. Программное обеспечение синтеза ПИД-регулятора, реализованное средствами Python и его библиотеками: SciPy, NumPy и Control Systems Library. Схемные решения регуляторов и корректирующих устройств, могут быть разными: П, ПИ, ПД, ПИД. Первые три варианта могут быть в общем случае получены наложением ограничений на ПИД-модель. Точная настройка параметров ПИД-регулятора существенно снижает колебания системы. Полноценное использование преимуществ ПИД-регулятора обеспечивается только при правильном расчете этих параметров с учетом особенностей характеристик управляемых объектов. При этом, важно наличие механизма (программы) управления коэффициентами, который бы обеспечивал удобный интерфейс между программой и пользователем.
Ключевые слова: инерционный объект; система стабилизации; переходная функция; ПИД-регулятор, корректирующее устройство; Python; Control Systems Library.

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