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CONTROL SYSTEM SYNTHESIS OF OPTOELECTRONIC HEAD

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Abstract

Designing a control systems have to be made in seven steps:
1) *Establish control goals*
2) *Identify the variables to control*
3) *Write the specifications for the variables*
4) *Establish the system configuration and identify the actuators*
5) *Obtain a model of the process, the actuator, and the sensor*
6) *Describe a controller and select key parameters to be adjusted*
7) *Optimize the parameters and analyse the performance.*

The article will concentrate at the last point. Optimization of the PAD regulator setup was made by analysis of step response. Sometimes, it also is good to study the impulse response. The aim of article is to get the values of PAD regulator by setting the step characteristic parameters like: rise time, settling time, overshot, undershot, settling and final value. The step response after optimization was checked in simulation and at the real object. The final value of the step was calculated from flight parameters of UAV, where the optoelectronic head is mounted. The most important parameters from the UAV are pitch, roll, yaw maximum values and their derivatives. The paper shows both MATLAB Toolboxes – Simulink Identification Toolbox and Simulink Design Optimization Toolbox. The first one was used to find the discrete transfer function of optoelectronic head. The second one was used to calculate the values of PAD regulators for desired performance.

Keywords: *UAV (Unmanned aerial vehicle), rise time, settling time, overshot, undershot, final value, step response, impulse response, step characteristic*

1. Introduction

MATLAB/Simulink is a perfect tool to design the control systems. The aim of the research was the control system synthesis of optoelectronic head. It is possible to calculate values of PAD regulator manually by using known mathematic methods. However, this plant is nonlinear and complicate object, so this methods won`t give good results. The PAD regulator values were calculated by Simulink Design Optimization Toolbox. The discrete transfer function of the optoelectronic head was determined with Simulink Identification Toolbox.

2. Identification of optoelectronic head

Simulink Design Optimization toolbox is counting the gain values by making many simulations and comparing the step response to the demands. Algorithm changes the values of PAD regulator with every simulation until it gets the best match with the desired response. First of all, it is need to design simulation model. The mathematical model can be created by analytical methods (mathematical model of each subsystem of object) or by identification method by matching step response of real object [1]. Simulink Identification Toolbox [2] automatically designates discrete transfer function with data from step characteristic of real object [3].

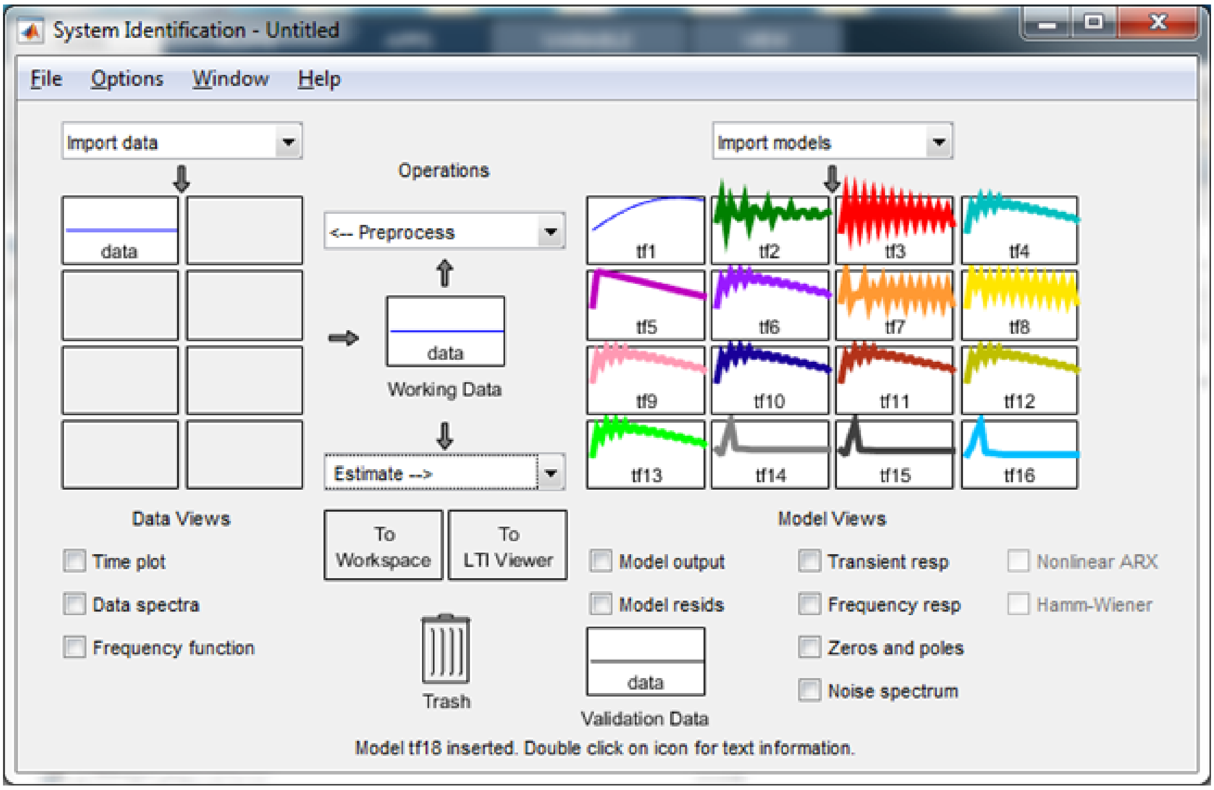

Fig. 1. Window of Simulink Identification Toolbox while estimating transfer function

Figure 1 shows many step responses of new transfer functions, which were calculated, from imported data. The result of this calculation is shown below:

```
tf28 =

  From input "u1" to output "y1":
              0.0003387 z^-1 - 0.0003387 z^-2
  -------------------------------------------------------
  1 - 2.061 z^-1 + 0.2169 z^-2 + 1.752 z^-3 - 0.9083 z^-4

Name: tf28
Sample time: 0.001 seconds
Discrete-time identified transfer function.

Parameterization:
   Number of poles: 4   Number of zeros: 2
   Number of free coefficients: 6
   Use "tfdata", "getpvec", "getcov" for parameters and their uncertainties.

Status:
Estimated using TFEST on time domain data "data".
Fit to estimation data: 93.53% (simulation focus)
FPE: 0.8404, MSE: 0.02138
```

Fig. 2. Discrete Transfer Function as a result of Simulink Identification Toolbox

Figure 2 shows new discrete transfer function with 4 poles and 2 zeros. The fitting of step response to estimation data is about 93%. This result can ensure reliable values of synthesis calculations.

3. Analysis step response of mathematical model

This chapter shows an influence of PAD values at step response of the plant. Fig. 3 shows the model with discrete transfer function of optoelectronic head, source (step) and scope.

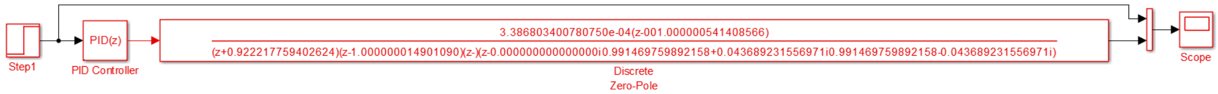

Fig. 3. Plant with PAD regulator

Figure 4 shows that the step response has overshot (5%), undershot (5%), rise time (0.7 s), settling time (1.1 s) and gets desire final value at 20 deg.

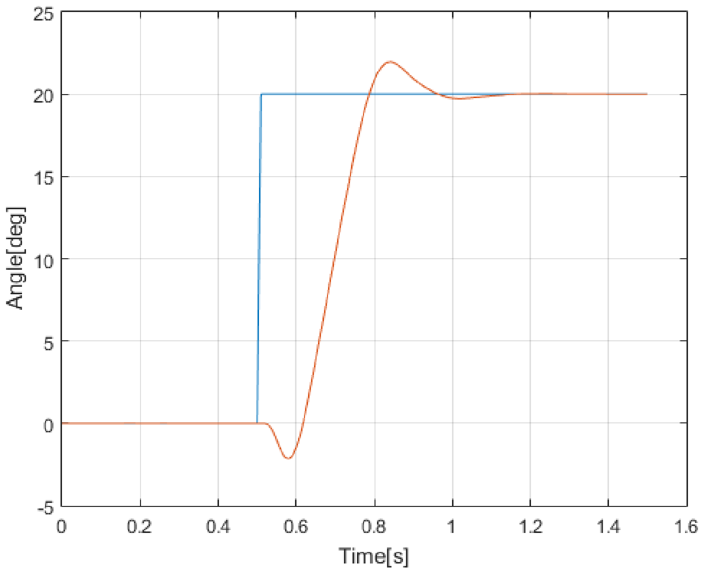

Fig. 4. Step response with large P value

The fact that the step response has over- and undershot does not mean that object works bad, because sometimes it is need to get faster rise times than settling time etc.

Figure 5 shows the example when the step response can`t reach the final value. These settings of PID regulator are unacceptable. Every parameters of step characteristic don`t fit with demands.

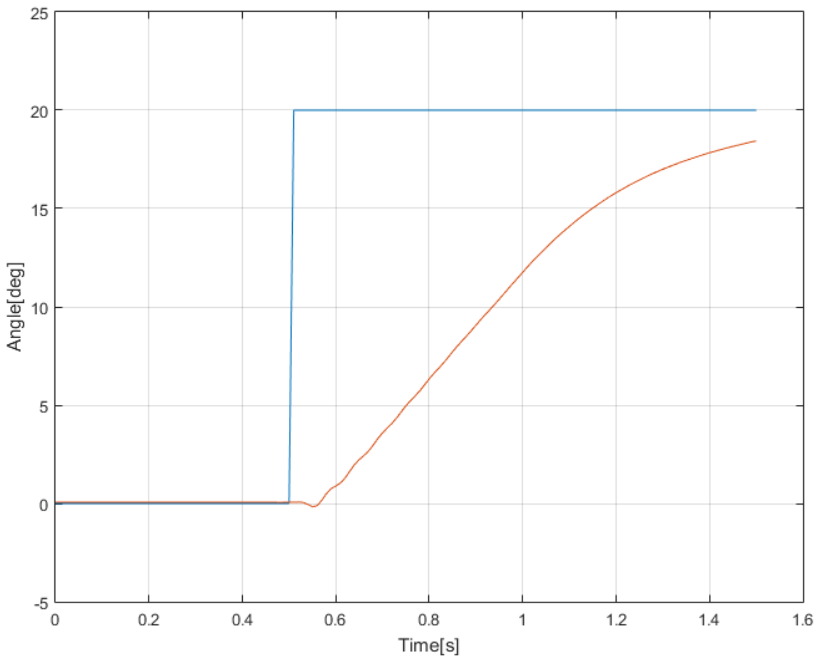

Fig. 5. Step response with small P and I value

Figure 6 from 0.7 s to 1.2 s shows object at limit of stability next the step response shows that optoelectronic head is unstable.

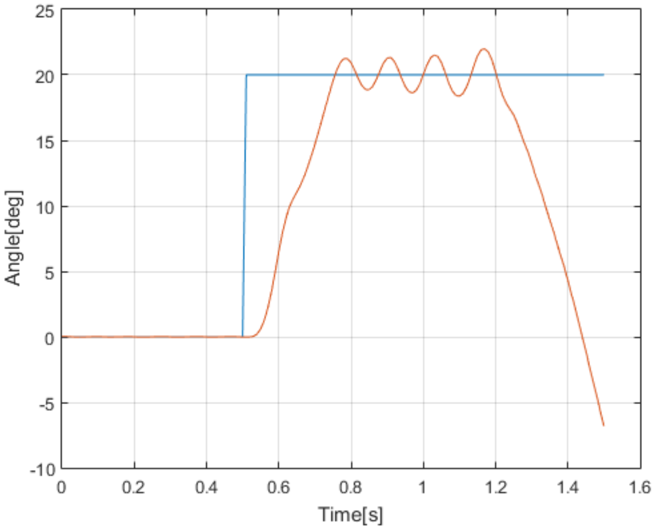

Fig. 6. Step response with large P and D

Small changes of this 3 parameters P, I and D have huge influence at the step response and performance of the object. This is why it is need to make synthesis of PID regulator.

4. Control system synthesis of optoelectronic head

There are many traditional methods, which allow computing values of the regulators gains:
- method of Ziegler – Nichols,
- stability criterion aperiodic,
- the criterion for optimum module,
- parameters step response system,
- integration of quality indicators,
- method of dynamic inversion.

However, this synthesis was made by Simulink Design Optimization. Fig. 7 shows working of the optimization algorithm. Every next response has better parameters.

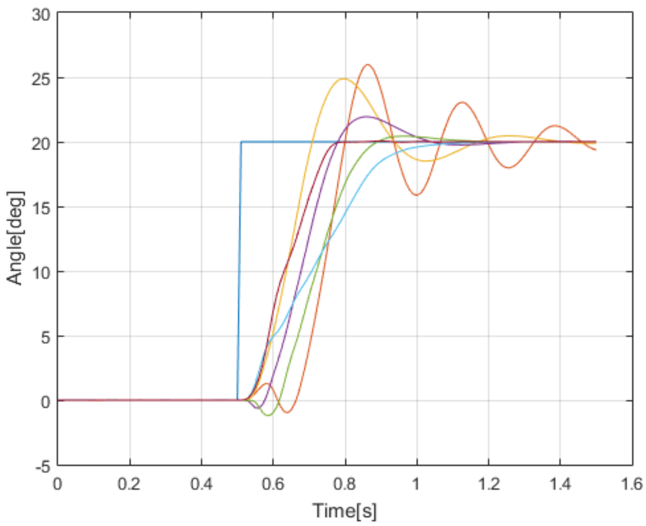

Fig. 7. Step responses for few iteration while optimization

Figure 8 shows smooth response with 0.8 s rise time, without under- and overshot, 1 s settling time and final value at 20 deg. Object with this settings will have quite good performance and smooth behaviour.

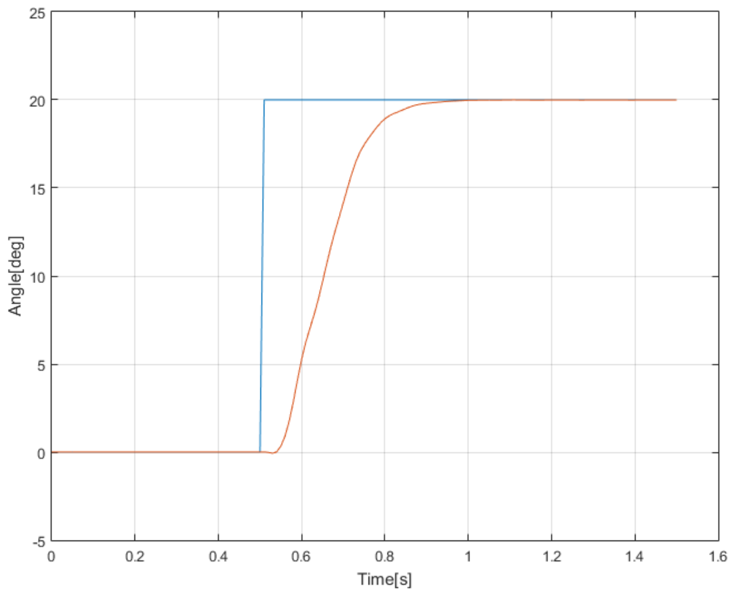

Fig. 8. Smooth step response

Figure 9 has large performance, 0.7 s rise time, 0.9 settling time, final value at 20 deg., but also has an overshot (0.5%).

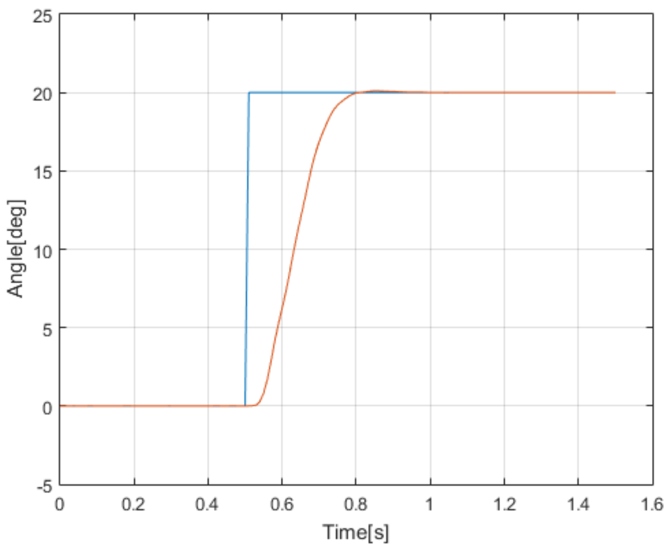

Fig. 9. Aggressive step response

5. Conclusion

Simulink Identification and Design Optimization Toolbox allow calculating control gain values according to demands of step response characteristic in easy and fast way. Synthesis of control system of optoelectronic head has shown that it is easy to manipulate how object behaves. This kind of control designing doesn`t need expensive equipment like industrial robots. Synthesis of PID regulators is the most important task to make product work perfectly. Very good identification and optimization ensure that object is working, as it is demand.

References

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