EXPERIMENTAL PARAMETERS IDENTIFICATION OF THE HUMAN-PILOT MODEL BEHAVIOUR

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Abstract:

The paper represents one of the other ways how to optimize alternative mathematical human-pilot model usable in the models of the aircraft flight control in the space. In general, the creation of the equivalent human model is very complicated, because the human characteristics are not constant in the time. The characteristics are changing with immediate human ability. At the simulation of the human behaviour is possible to compile only general, an approximate human model. The contribution shows further possibilities how to explore the human-pilot behaviour during the determining of chosen transfer functions parameters.

Keywords: identification, initial estimation, searched parameters, MATLAB

1 Introduction

Building of an alternative model of human behaviour from the perspective of the automatic control is very extensive and complex task. In the theory of the flight control is more or less at the edge of the theoretical analysis. The possible integration of obtained models of human behaviour to the regulation loop of flight control is usually very rare. This is because of that the human "parameters" and "time constants" are very unstable in time, influenced by the number of factors, that act on human (tiredness, level of training, immediate mood, etc.). Assessing of the human behaviour in the regulation loop at the control of chosen flight mode is possible only with regard to obtaining the regulation results, thus the possible human's ability to realize existing flight mode rightly and in time.

2 Initial Approach to the experimental identification of the transfer function parameters

There are many ways how to create alternative models of human behaviour at general machine control. To determine the transfer function is historically accessed by three ways. In the available literature and in all authors publications, including this paper are human characteristics expressed by linear models, characterized by the transfer functions in the form of PD or PID regulator with the inertia of the first or second order with transport delay. For easier identification individual types of pilot models are called by letters "A" to "C ". Pilot "A" is the most complex model (is formed by the transfer function with the inertia of the second order with transport delay) and pilot „C“ is the simplest model (here is formed by the transfer function with the inertia of the first order with transport delay).

For mention of the form of mathematical pilots models are shown the transfer function in table 1. and in table 2. is then meaning of individual parameters for these functions, based on the previous author's publications [4, 5, 6, 7], or historically from [9, 10]. For the field of driving car are from publication [3].

Tab.1. Transfer functions of pilot models

$F_{(p)} = K \frac{(T_3 p + 1)}{(T_1 p + 1)(T_2 p + 1)} e^{-\tau p}$	„A“
$F_{(p)} = K \frac{(T_3 p + 1)}{(T_2 p + 1)} e^{-\tau p}$	„B“
$F_{(p)} = K \frac{1}{(T_2 p + 1)} e^{-\tau p}$	„C“

Tab.2. The meaning of the parameters of transfer functions

$F_{(p)}$	Transfer function of the pilot model
K	- increasing of force on the steers in relation to their deflection (from 1 to 100)
T1	- integral time constant, i.e. the pilot's ability to realize a variable activities (0,2 to 1s)
T2	- dynamic properties of the pilot power members components (0.1 to 0.2s) (neuromuscular time constant)
T3	- reaction time constant, i.e. reaction ability to rate of change of input signal (5 to 20 s) (prediction time constant)
τ	- transmission delay (0.1 to 0.4s) (time of pilot reaction).

The parameters of the human behaviour model in the process of aircraft flight control are better to specify on the basis of experimental measurement of human response to stimulus. For this purpose the authors are preparing simple measurement workplace, which schematic view is in the Fig. 1. Tested pilot is watching the external stimulus on computer screen - his step change and is trying to attain the same deflection "point“ on the screen by deflection of the throttle. The movement of the throttle is scanned by linear sensor in two perpendicular planes. Waveform of the throttle movement is transferred to the computer and recorded together with the size of the external stimulus. Both of these data together with the time axis are then used in mathematical methods of the experimental identification. Although the obtained model parameters of human's behaviour can not fully characterize the pilot's load in real aircraft flight control in this case, but we can expected at least some approach to the real parameters.

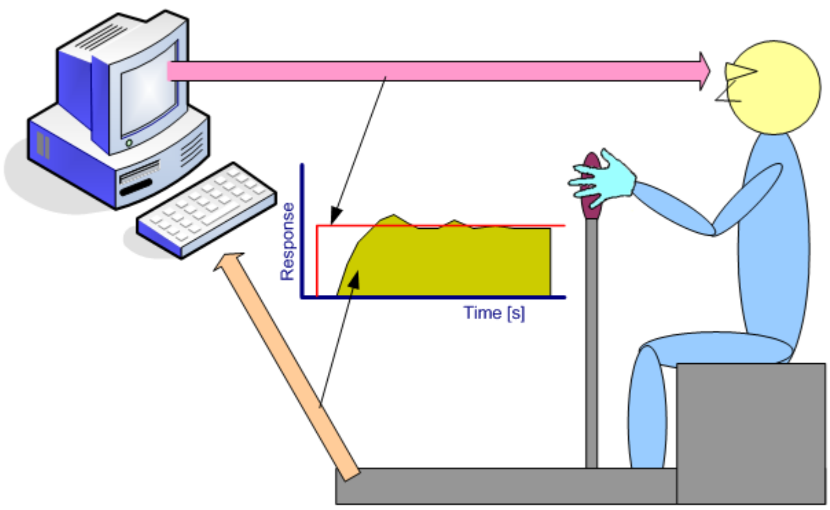

Fig.1. The principle of the human response measuring to the external stimulus

According to the selected type of transfer functions of the pilot model is possible for the time constants determination in human behaviour models to use mathematical methods of the experimental identification of real systems, whose results have been successfully used e. g. in [1, 2]. If input and output signal and the approximate form of the transfer functions are known, is possible to use these methods to specify the parameters of the transfer function. With big advantage is possible to use the simulation program MATLAB®, which already contains some functions for realization of necessary calculations.

Function *fminsearch* is looking for a minimum of scalar function of several variables [8]. With its help the algorithms for parameters identification of the transfer function was assembled for the pilot type „A“ in the form:

$$F_{ei} = \frac{a_1 s + 1}{b_2 s^2 + b_1 s + 1} \ , \tag{1}$$

with criterion condition defined

$$f_{\min} = \sum (y_{id} - y)^2 \ . \tag{2}$$

For the pilot type „B“ is then in equation (1) $b_2 = 0$ and for the pilot type „C“ also $a_1 = 0$. Mentioned algorithm cannot manage calculation of the transport delay. Therefore, the program was completed with a simple subprogram to search the beginning of the pilot response (output value was not zero respectively bigger than the entered low value). After the transport delay evaluation for the identification algorithm the input pulse was moved to the response beginning. The results of the transport delay calculations at all types of pilots practically agree (with an accuracy of calculation step 0.01 s) with input value.

3 Results obtained during the simulation of the human-pilot model behaviour

3.1 Parameters identification of the pilot model type “A”

The pilot type "A" represents the network of the PID regulator with the inertia of second order with transport delay. Identified parameters are mentioned in the Table 3.

Comparison of the parameters identification with the exact values shows, that the parameters identification of the complex transfer function is not quite easy and reached results may not exactly coincide with the input data (in interpretation of coincidence of identified time constant and time constants used in the original model). Nevertheless, the obtained results can be considered as applicable (see Figure 3 - match of the both waveforms) during the further calculations of human behaviour in the system of aircraft flight control.

Transfer function	$\frac{-0.02963s + 1.045}{0.231s^2 + 5.764s + 1}$
Sum of squares	0.010253
Mean-root-square error	0.003200
Number of iterations	246
Transport delay	0.160000 s

Tab. 3. Identified parameters of the pilot type A.

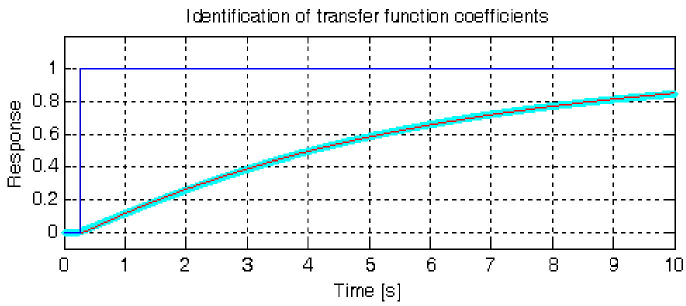

Fig. 3. Waveforms of the identified parameters of the pilot type A.

3.2 Parameters identification of the pilot model type "B"

The pilot type "B" represents the network of the PID regulator with the inertia of first order with transport delay. Identified parameters are mentioned in the Table 4.

By comparison of the calculated coefficients T_2 and T_3 with input values, is possible to enunciate the complete agreement with identified parameters (see Table 4). Identification of the PID element, which contains only first order inertia, is easier than identification of the second order inertia. The ratio of time constants T3/T2 will be also decisive to achieve acceptable results. If the ratio is smaller than 1, the integration element in the model will be dominant and the waveform of the response will correspond to the Figure 4. If the ratio will be bigger than 1, derivation element will dominate in transfer and in the first moment of stimulus the response contains a significant overshoot.

Transfer function	$\frac{-0.9023s+1}{1.199s+1}$
Sum of squares	0.563021
Mean-root-square error	0.023716
Number of iterations	169
Transport delay	0.300000 *s*

Tab. 4. Identified parameters of the pilot type B.

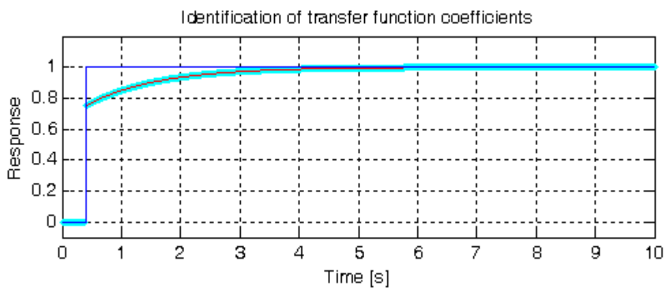

Fig.4. Waveforms of the identified parameters of the pilot type B.

3.3 Parameters identification of the pilot model type "C"

The pilot type "C" represents the network of the PI regulator with the inertia of first order with transport delay. Identified parameters are mentioned in the Table 5.

By the comparison of the calculated coefficient T_2 with the input value, is also possible to enunciate complete agreement of identified parameters. The identification of very simple regulation element with the inertia of first order is much easier. The identification algorithm converges very quickly to the right values - short calculation duration, small number of iterations (see Table 5). Achieved transient process (see fig 5.) is practically identical with the input waveform.

Transfer function	$\frac{0.9994}{1.186s+1}$
Sum of squares	0.002684
Mean-root-square error	0.001638
Number of iterations	101
Transport delay	0.300000 *s*

Tab. 5. Identified parameters of the pilot type C.

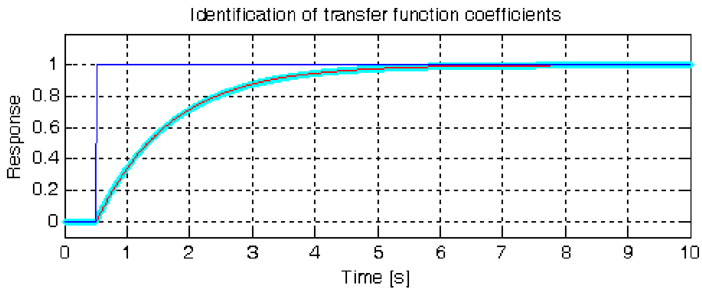

Fig.5. Waveforms of the identified parameters of the pilot type C.

Conclusion

The authors by paper imply, what possibilities are currently available in simulation tools such as MATLAB - SIMULINK. The parameters specifying of human behaviour model with mentioned procedure and method brings farther possibilities in building mechatronic system pilot - aircraft and their subsequent analysis.

The procedures of parameters specifying of human behaviour model described in the paper suppose linear dependence only. Nonlinear dependence e.g. in the form of range limitations will be implemented to the models later.

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