Biological-psychic state model of the pilot

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Abstract: *The creating of the biological-psychical state model of the pilot is the first aim of my thesis. The creating of this model is connected with the project ACE [Adaptive cockpit environment] and with the project ACS [Adaptive cockpit system], which were solved on the Department of the technical cybernetic and military robotic on the Military Academy in Brno with the cooperation of the University of Delft in the Netherland in years 2001-2005. The aim of the project ACE/ACS was the creating of the intelligent sofistic interface human – machine (pilot – fighter) with adaptable feedback in flight control system of the fighter F-16. The using of the adaptable feedback in the flight control system is a one of the possibility how we can increase the battle effectiveness of the aircraft F-16.*

The important component of the structure ACE is the subsystem SAR [Situation assesment recognizer]. The main task of the subsystem SAR is to identify the environment state, avionic state and pilot's state. For this system identification is used four data inference of easy measured data. Very important component of the structure SAR is the model of the biological and physical state of the pilot too.

With the help of this model it is possible to identify the pilot's biological-psychical state in the flight with high plausibility. When it is identify high psychical and physical load of the pilot then can the adaptable feedback mechanism make the suitable adaptable action to the flight control system.

The biological-psychical state model of the pilot

For the own realization of the biological-psychical state model it is to necessary monitor all relevant influences-external and interior, which work on psychic and physiology of the pilot. The main demand on chosen input model variables is the good express value of such variable about pilot‘s biological and mental state. The next demand is the good measurability of such input variable. Therefore were chosen input variables as gravitation overload, vibrations, heart activity-heartbeat, and respiration activity. Further was chosen the auxiliary variable Ω, which can express contribution to the pilot's stress load in combat flight. Output variables of the model come in to pilot's biostate recognizer.

For the description of the biological psychic pilots state was determined these three variables:

- actual physical load ***P***,
- actual visual load *E*,
- actual stress load *S*,

which can given a good image about mental, physical and visual pilots load in mission and hence can be used in the application of the adaptive flight control.

These variables are considered as the output of the biological-psychic state model. The basic structure of the pilots biological-psychic state model is given on the Fig. 1

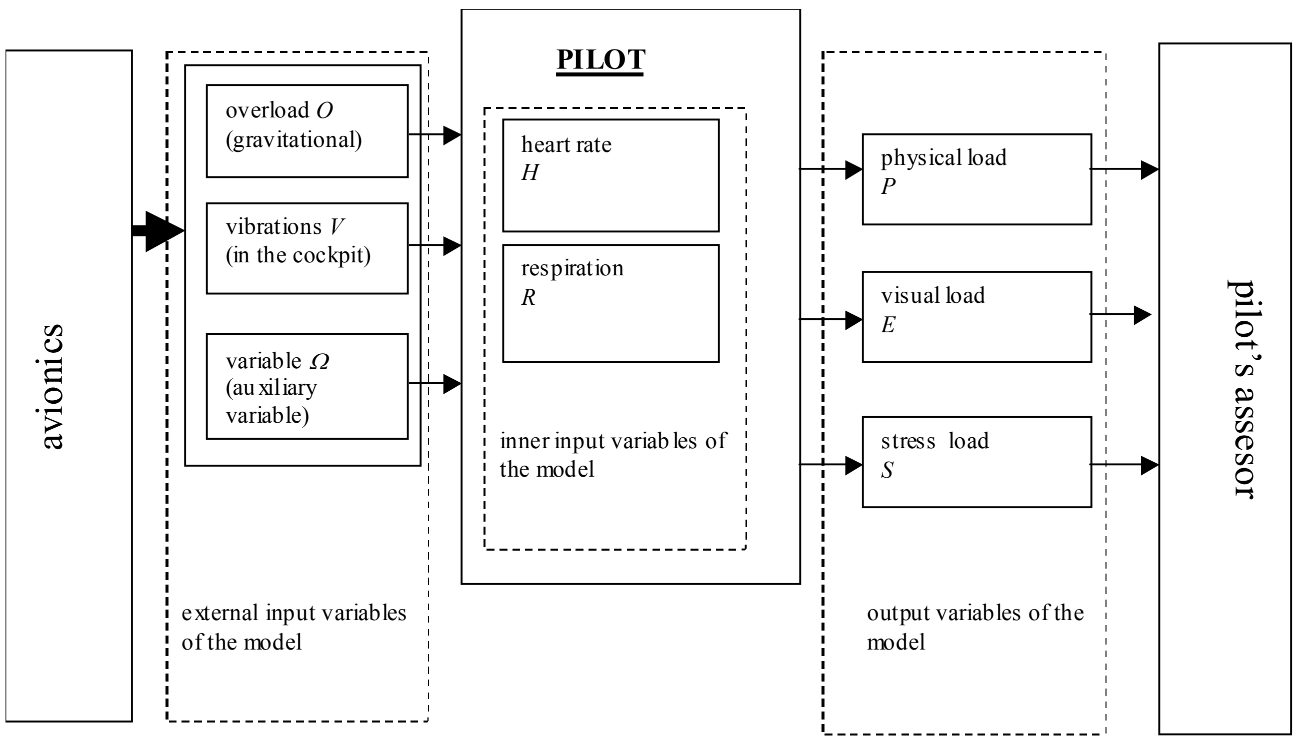

Fig. 1 Basic structure of the pilot biological-psychic state model

The variable actual physical load- variable *P*

One of output variables of this model it is the variable physical load - the variable *P*. This variable gives information about actual pilots physical load during the flight. Physical load of the pilot has the variable character. When the pilot does normal flight and does not extremaly flight manoeuvre has the physical load of the pilot ordinary process. When the pilot does in the flight difficult flight manoeuvre (in the battle against to the enemy aircraft) is the physical load of the pilot very high.

With help of knowledge from the medicinal physiology about the pilot was the variable *P* defined as the function of two variables: the variable *H*-heart rate and the variable *R*- respiration intensity. The mainly reason for the choice of variables *H* and *R* it is their relatively easy measurity no in streng conditions of the laboratory only, but in the battle flight directly.

Calculation of the variable *physical load*:

$$P=f\,(H(t),R(t),\mu_1,\mu_2,t), \qquad (1.1)$$

$$P = H(t)\cdot\mu_1 + R(t)\cdot\mu_2, \qquad (1.2)$$

$$P\in\langle 0,1\rangle,\ H\in\langle 0,1\rangle,\ R\in\langle 0,1\rangle, \qquad (1.3)$$

$$\mu_1+\mu_2=1, \qquad (1.4)$$

where:

$R(t)$ … variable heart rate

$H(t)$ … variable respiration intensity

μ_1 … coefficient expressed the rate of the influence of the variable *H* (set by expert)

μ_2 … coefficient expressed the rate of the influence of the variable *R* (set by expert)

t … time

Quantification of the variable *P*

Necessary variables, which are important for the computation of the variable *P* are showed on the table 1. On this table are showed short descriptions of input variables (*H*, *R*), as factors, ways of indication, type of the variable.

Tab. 1 **Quantification of the variable *P***

The variable physical load *P*	Indication	Type and rate	R_i	Linguistic description	Rate of the influence $\mu_i \langle 0,1 \rangle$
heart rate variable: ***H***	heart rate measuring	number (4) $R_H = \langle 50,150 \rangle$ [tep / min]	$R_4 = \langle 120,150)$	very high, *H*=1	μ_1=0.6
			$R_3 = \langle 100,120)$	high, *H*=0,7	
			$R_2 = \langle 80,100)$	increased, *H*=0,4	
			$R_1 = \langle 50,80)$	normal, *H*=0,2	
respiration variable: ***R***	respiration measuring	number (4) $R_R = \langle 10,30 \rangle$ [breath, brething out/ min]	$R_4 = \langle 25,30 \rangle$	very high, *R*=1	μ_2=0.4
			$R_3 = \langle 20, 25)$	high, *R*=0,7	
			$R_2 = \langle 15,20)$	increased, *R*=0,4	
			$R_1 = \langle 10,15)$	normal, *R*=0,2	

Off-line record of the variable *P* during the flight

The figure 2 represented the time record of variables ***R***, ***H***, ***P***. Records of variables *R* and *H* were measured during the simulated battle flight. This flight was under way 360 sec. During the interval 200-300 sec came on in the duration 100 sec to the simulated air-to-air combat. In this phase came to the increasing of the pilot physical load.

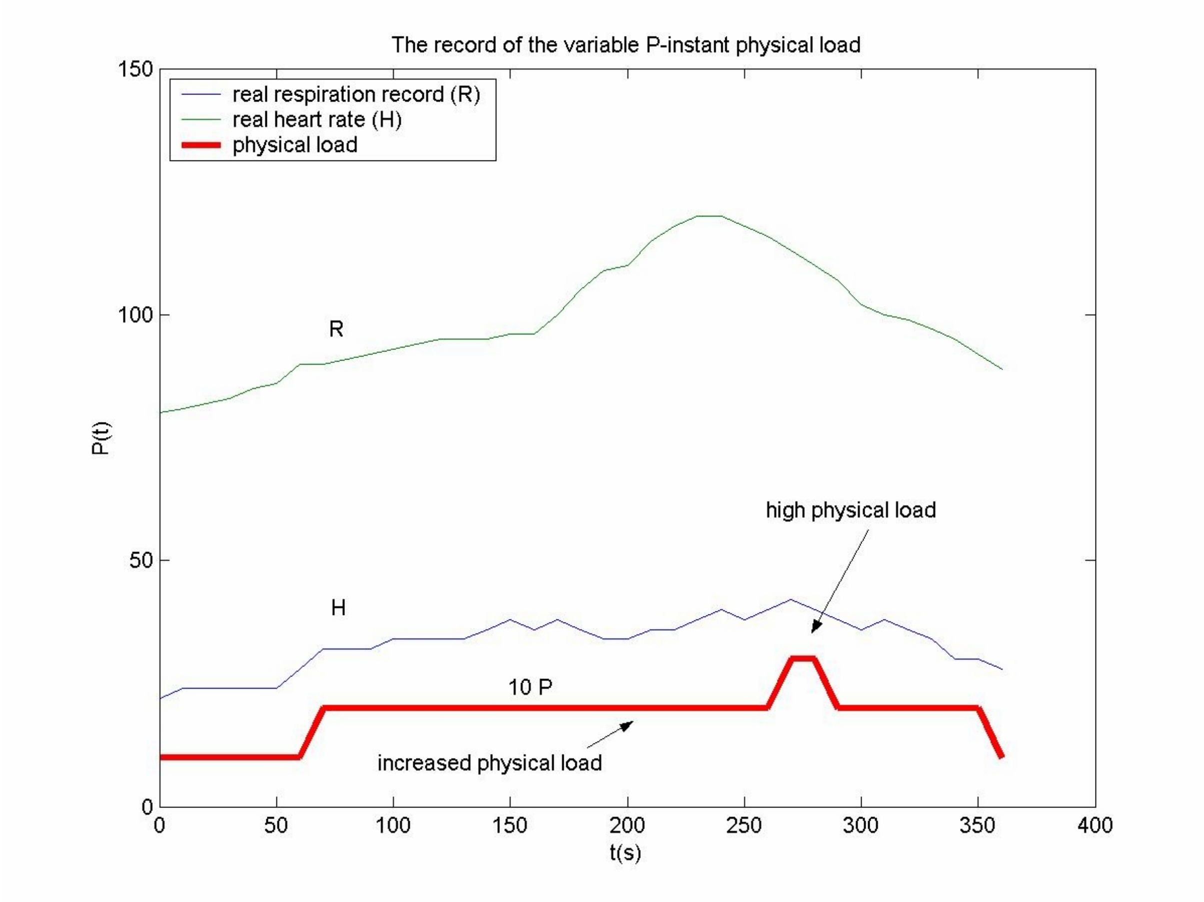

Fig.2 Off-line-record of the variable *P*

The variable instant visual load *E*

The second of output variables of the model is the variable instant visual load-variable *E*. This variable offers information about pilot's instant visual load due to external influence. These external influences work on pilot through the fly by overload and mechanical vibration in aircraft's cockpit. Both of them have a negative influence to the optical sensor's function. In case of normal fly, vibrations of pilot's cockpit participate on visual load. In cases of pilot's difficult manoeuvring (air combat, antimissile manoeuvres, etc.) overloads applied to the pilot participate on visual loads. Positive overload values cause "blackout" – visual

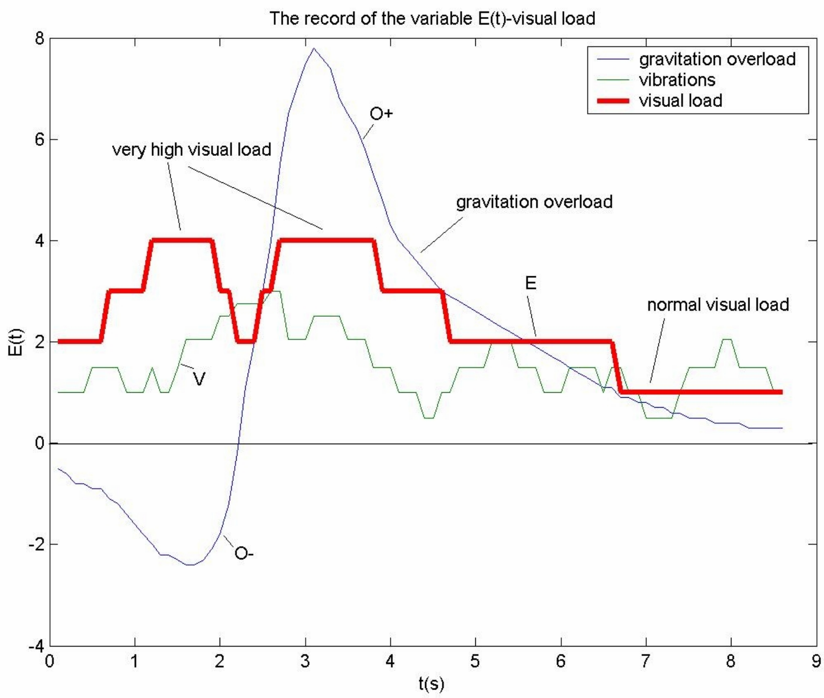

Fig.2 Off-line-record of the variable *E*

field gets grey till black. Negative overload values cause "redout" – visual field gets red, displeasing filling in the eyes, etc.. The overload values work on the pilot's body we can get by accelerometers located in cockpit. Effective vibration value we can get by the similar way with special accelerometers. Computation of the variable *E* and using of rules is analogic like by variable *P*. The record of the variable visual during the flight load is showed on the figure 2.

Instant stress load of the pilot – the variable *S*

There are many critical situations in combat conditions, which pilots must solve till border of pilot's resistance. Pilots reacts by stereotyped reactions, which is marked as the

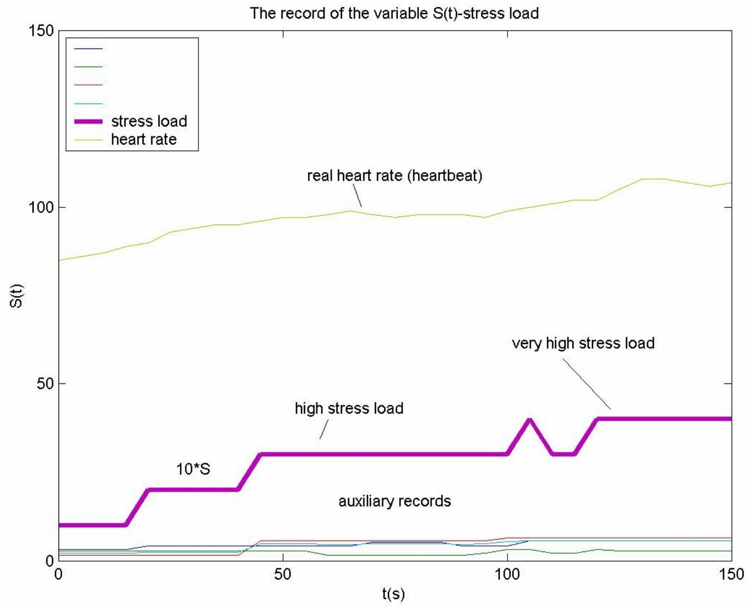

Fig.3 Off-line-record of the variable *E*

stress. There are many factors that influence pilot's stress loading through combat flight. These factors are fear of death, danger as anti-air missiles, enemies aircrafts, stress experience from previous missions, atc.

There is value instantly stress loading to represent pilot's stress. This value providing information about instantly stress, which have negative influence in mostly incidents.

The variable ***S*** [stress load] is depended on negative influence of the overloading through the flight and negative vibration in the cockpit and on physical overloading expressed with the value ***Ω***. The negative influence of the overloading through the flight and the negative influence of vibration is in value ***E*** [visual load]. The physical load is included in the value of the variable ***P*** [physical load].

The size of the value ***Ω*** equals answering the seriousness of flight tasks and the influence of conflict situations. This value have dominant influence to the pilot's stress load. This value is adjusted by expert. Computation of the variable *S* and using of rules is analogic as by variable *P* and variable *E*. For the determination of the visual load of the pilot are used expert rules. The record of the variable stress load during the flight load is showed on the figure 3.

Summary

The description of the biological-psychic pilots state with three variables: ***S***-stress load, ***E***-visual load, ***P***-physical load is done for the using in the adaptive flight control possible. Values of coefficients in relations for the calculations have a variable character, the expert can these values adjust for every pilot especially. Biological-psychologic state of the pilot is determined by experts rules. The biological-psychic state of the pilot with using expert rules could be determined with high plausibility and usability. The knowledge base with expert rules could be with My-SQL database modify very easy and advantageous.

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