Comfort Evaluation of Cockpit Based on Dynamic Pilot Posture

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Abstract. Comfortable dynamic pilot posture is the principle for steer design and layout of cockpit design, and is used to study on how to improve the manipulation efficiency. This paper has built a comfort evaluation method considering the consecutive of pilot manipulation based on the static pilot posture, which using the comfort of the dynamic pilot posture to evaluate the comfort of cockpit. The dynamic posture data has be captured by the Measurand@ motion capture system in the cockpit. Then the comfortable evaluation is executed for the pilot postures by fuzzy evaluation method. Form the results, the comfortable evaluation conclusions of cockpit design can be deduced. The better comfortable the pilots have the better design the cockpit is. The result has been validated through the evaluation by JACK software. The conclusion is: the two has the same opinion on the key manipulation equipments, but the new method can analyze the consecutive change of pilot comfort and can discover the interference between pilot and cockpit equipments during the whole manipulation. The evaluation results can instruct the optimization of the cockpit design and improve the control efficiency and flight safety.

Keywords: human-machine interface, comfort evaluation, dynamic pilot posture, cockpit.

1 Introduction

Dynamic pilot posture is a continuous operation process of manipulation system. The comfortable dynamic pilot posture is the basis for flight deck and manipulation equipment design and then improves operation efficiency. The cockpit design and evaluation at present is still limited in the use of static pilot posture [1,2,3,4]. For the equipment evaluation, engineers usually put pilot model that poses a posture as he does the operation, then analysis under this posture if the equipment in the accessible zone, or if the pilot could see the equipment. But the static posture evaluation method can not evaluate the rationality layout of the flight deck and so is the manipulation equipment's position and control run. To evaluate the manipulation system generally and solve the operation efficiency the dynamic evaluation method based on dynamic pilot posture should be built[5]. The dynamic operation process can reflect the cognition performance and motion capability of pilot. Dynamic evaluation method is more sophisticated and general for ergonomic evaluation which evaluates the essence of flight deck ergonomics and ensures the operation efficiency.

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2 Comfortable Evaluation Method of Cockpit Based on Dynamic Pilot Posture

Dynamic pilot posture is a continuous process of manipulation system which can be represented as the joint coordinates changes with motion time. The dynamic pilot posture takes advantage on ergonomics evaluation. This method can evaluate controllability of the whole process, and can also detect the intervention problem, reflect the operation efficiency.

Operation comfort is evaluated by joint angles' comfort. The evaluation method Considers both the overall comfort of action process and each key frames' comfort. Fuzzy evaluation method is used to evaluate the dynamic pilot process which is represented by joint angles changing with time. To evaluate the cockpit comfort, the whole pilot process is divided by frame, which is represented by the present joint angle, the angles' comfort is the posture's comfort at this moment. The normalized result of all frames' comfort is the comfort evaluation result.

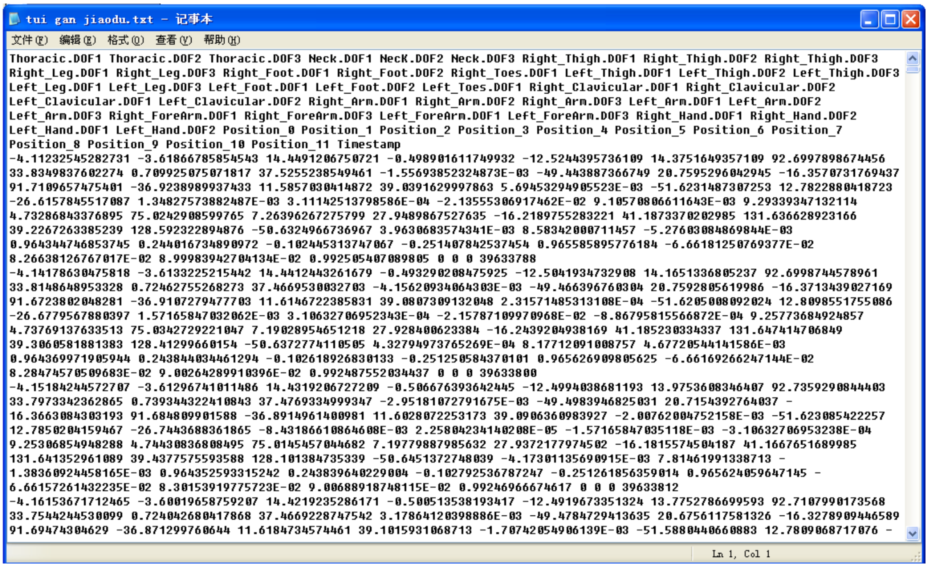
3 Dynamic Manipulation Data Capture

There are three factors that limit the capture system' choose. First is the cockpit environment. The cockpit is full with electromagnetic environment and also has problem of narrow and small room, and unevenness of luminance; second, the capture system shall not influence the pilot's operating; and the final limit factor is capture system itself which is still combined with the cockpit environment. For example, the optic system demands luminance and room, but the electromagnetic system is limited by the electromagnetic environment of cockpit. The fiber optical motion capture system Measurand@ was chosen to complete the job. The Sampling frequency is 83.3HZ, position resolution is 1-3mm, angular resolution is 0.5º, and the system can capture 18 joints and 40 degrees of freedom.

Fig. 1. The scene of pilot dynamic posture capturing

There are 5 pilots completing the experiment on the cockpit simulator. Every pilot do the same action 10 times. The data is recorded by the fiber optical motion capture system.

The original data has been filtered according to the video and data consistency. The data is shown in figure 2. Data is indexed by time including position and angle.



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Right_Leg.DOF1 Right_Leg.DOF3 Right_Foot.DOF1 Right_Foot.DOF2 Right_Toes.DOF1 Left_Thigh.DOF1 Left_Thigh.DOF2 Left_Thigh.DOF3
Left_Leg.DOF1 Left_Leg.DOF3 Left_Foot.DOF1 Left_Foot.DOF2 Left_Toes.DOF1 Right_Clavicular.DOF1 Right_Clavicular.DOF2
Left_Clavicular.DOF1 Left_Clavicular.DOF2 Right_Arm.DOF1 Right_Arm.DOF2 Right_Arm.DOF3 Left_Arm.DOF1 Left_Arm.DOF2
Left_Arm.DOF3 Right_ForeArm.DOF1 Right_ForeArm.DOF3 Left_ForeArm.DOF1 Left_ForeArm.DOF3 Right_Hand.DOF1 Right_Hand.DOF2
Left_Hand.DOF1 Left_Hand.DOF2 Position_0 Position_1 Position_2 Position_3 Position_4 Position_5 Position_6 Position_7
Position_8 Position_9 Position_10 Position_11 Timestamp
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Fig. 2. The captured data sample

4 Comfort Evaluation of Dynamic Pilot Data

The whole pilot process is divided by frame, every frame is a static posture. The normalized result of all frames' comfort is the comfort evaluation result. The fuzzy evaluation method is used to evaluation the comfort.

The evaluation steps are as follows:

1) Define the evaluation factors

The factors influence the final result is defined as factors set. For pilot, the set is simplified as: $U = \{u_1, u_2, \cdots, u_m\} = \{\text{shoulder joint}, \text{elbow joint}, \text{wrist joint}\}$

2) Define the comment set

The comment set is $V = \{v_1, v_2, \cdots, v_n\} = \{\text{comfort}, \text{ordinary}, \text{discomfort}\}$. For the pilot, every comment corresponds range is shown in table 1.

Table 1. Joint angle range

joint	degree of freedom	angle range (°)		
		comfort	ordinary	discomfort
shoulder joint	flexion/extension	-15~75	-60~-15 75~170	other
	abduction / adduction	0~30	-18~0 30~80	other
elbow joint	flexion/extension	16~100	0~16 100~140	other
wrist joint	flexion/extension	-45~25	-70~-45 25~80	other

3)Define membership

Quantified every factor u_i $(i=1,2,\cdots,m)$, and determine the membership R/u_i of u_i to v_i, then the judge matrix is:

$$R=\begin{bmatrix} R/u_1 \\ R/u_2 \\ \cdots \\ R/u_m \end{bmatrix}=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}_{m\times n} \tag{1}$$

4) Define weight vector A

$A=\{a_1,a_2,\cdots a_m\}$. Where, $0<a<1$ and $\sum_{i=1}^{m}a_i=1$.

The A is acquired by the analytic hierarchy process. The final weight vector which has passed the consistency test is shown in table 2.

Table 2. Weight vector A

factors	U1	U2	U3	U4	weight value
U1	1	1/3	14/15	7/9	0.157
U2	3	1	14/5	7/3	0.472
U3	15/14	5/14	1	5/6	0.169
U4	9/7	3/7	6/5	1	0.202

5) Evaluation result

Evaluation result $B=A\times R=(b_1,b_2,\cdots,b_n)$

6) Normalized the result

The final result $\overline{B}=(\overline{b}_1,\overline{b}_2,\cdots,\overline{b}_n)$, where $\overline{b}_i$ is membership of evaluation object to v_i .

The final result of pilot operating stick is shown in Table 3.

The comfort evaluation result of joy stick is 78.27 which is not a good score for manipulation system. According to analysis the whole operate process, it suggests that there is not plenty operate room for pilot to finish the action, and all the joints covered here can not extended comfortably, especially wrist joints, during the whole process, the flexion/extension freedom of joint angles are always between 25°and 80°which is the ordinary comfort interval, and the freedom of extension is too big for pilot. For 50 percent pilot the manipulation room of the cockpit is inadequate, according to the analysis and evaluation result above.

Table 3. The final evaluation result

joint angle	com-fort	ordi-nary	discom-fort	evaluation result	final result	norma-lized result
shoulder joint flexion/extension	312	0	0	(1,0,0)	(0.45687,0.54313, 0)	78.27
shoulder joint ab-duction / adduction	158	154	0	(0.51,0.49, 0)		
flexion/extension	108	204	0	(0.35,0.65, 0)		
wrist joint flex-ion/extension	0	312	0	(0,1,0)		

Note: (comfort =(80~100); ordinary = (60~79); discomfort =(0~59))

5 Validation of the Method

The evaluation result by dynamic pilot posture is validated by the result through commercial evaluation software JACK. The researchers have built the same Chinese pilot model in JACK, which has been used to evaluate the comfort of the cockpit. The evaluation result of JACK is shown in figure 3 that represents the comfort of different joints. The joint angles in the box are the joints concerned here. Different color represents different comfort. Yellow means discomfort, green means comfort on the contrary. From figure 3 the wrist is always discomfort, and the discomfort score is about 4.5 which is ordinary discomfort in JACK. The other three joints are all in comfort interval. The result is just the same as the result by the dynamic postures' key frame. The research thinks the correct evaluation process and result means correct final result. So the dynamic posture evaluation method can be thought correct.

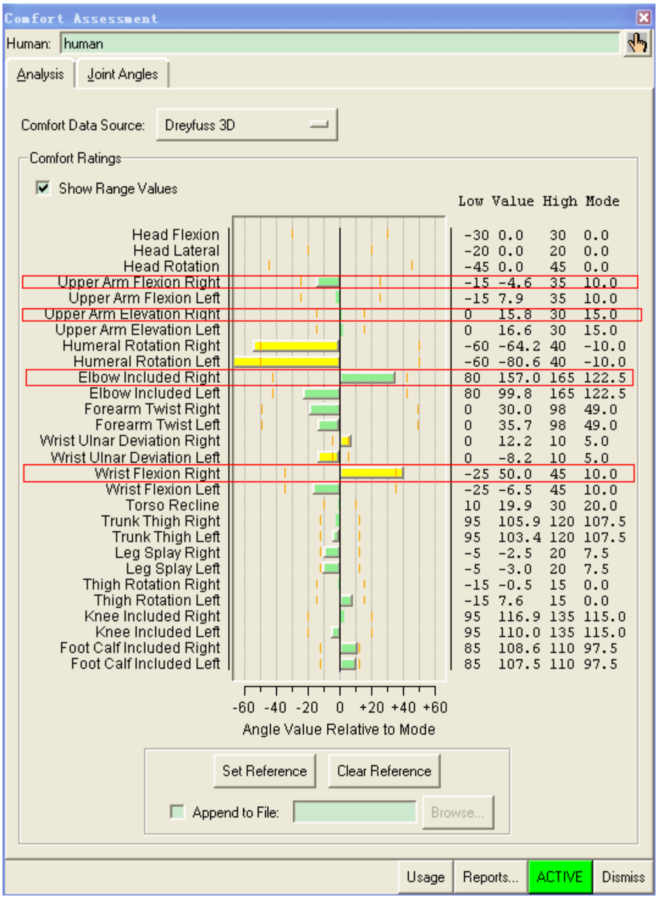

Fig. 3. The result by JACK

6 Conclusion

The whole pilot process is divided by frame, every frame is a static posture. The evaluation is just for the key frame, and the compared result suggests that the dynamic posture evaluation method is effective and correct. The new method can analyze the consecutive change of pilot comfort and can discover the interference between pilot and cockpit equipments during the whole manipulation. The evaluation results can instruct the optimization of the cockpit design and improve the control efficiency and flight safety.

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