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Integrated Evaluation Technology of Landing Signal Officer for Carrier-Based Aircraft

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Abstract

To get over a difficulty of relying on experience of traditional Landing Signal Officer evaluation technology, this paper designs a universal integrated evaluation of LSO for carrier-based aircraft. After analyzing "evaluation" difficulty, there are four LSO grade technology should be proposed: effect capability integration of multiple flight states attributes; effect capability integration at multiple reference positions; effect capability quantification and evaluation on the final approach. The model simulation results of flight states attribute evaluation at one reference position, reference positions evaluation of one flight states attribute, flight states attribute evaluation on the final approach and reference position evaluation on the final approach indicate the better performance of the new evaluation method in comparison with the traditional way with more accuracy and practicability.

***Keywords**: Evaluation; Effect capability; Flight states attributes; Reference positions*

1. Introduction

To realize landing effect comparison of multiple pilots or multiple flight voyages for one pilot, Landing Signal Officer (LSO) needs to evaluate flight states [1-6]. There are two traditional techniques: static group decision making and dynamic decision making for evaluating multiple voyage, however, the traditional ones are insignificant for the single-pass.

For landing once, LSO should evaluate landing effect for pilot of carrier-based aircraft. Difference from "Decision" technology for multiple voyage, we call it "Evaluation" technology for one voyage.

The rest of this paper is structured as follows: next section we first analyze the difficulty of evaluation technology. Section 3 designs the LSO grade technology, including effect capability integration of multiple flight states attributes; effect capability integration at multiple reference positions; effect capability quantification and evaluation on final approach. The integrated evaluation technology of LSO for carrier-based aircraft will be discussed in Section 4.

2. Analysis of "Evaluation" Technology Difficulty

There are four difficulty points for "evaluation" technology [5-12]:

1) Multi-attribute character is belonged to landing effect analysis. Evaluation results are not only restricted by some one flight state, but also by all influencing factors.
2) Integrity character is belonged to landing effect analysis. Evaluation results are not only restricted by some one reference position, but also by all glideslope process.

3) Quantity character is belonged to landing effect analysis. As for one flight voyage, it's so rough to quantitative grades. We should calculate to evaluate flight effect quantify.
4) There is no comparability in landing effect analysis, as single of evaluation object, without other flight voyages.

Above all, LSO evaluation technology is constituted by "Effect capability integration at multiple reference positions", "Effect capability integration of multiple flight states attributes", "Effect capability quantification" and "Effect capability evaluation for the whole glideslope process", as shown in Figure 1.

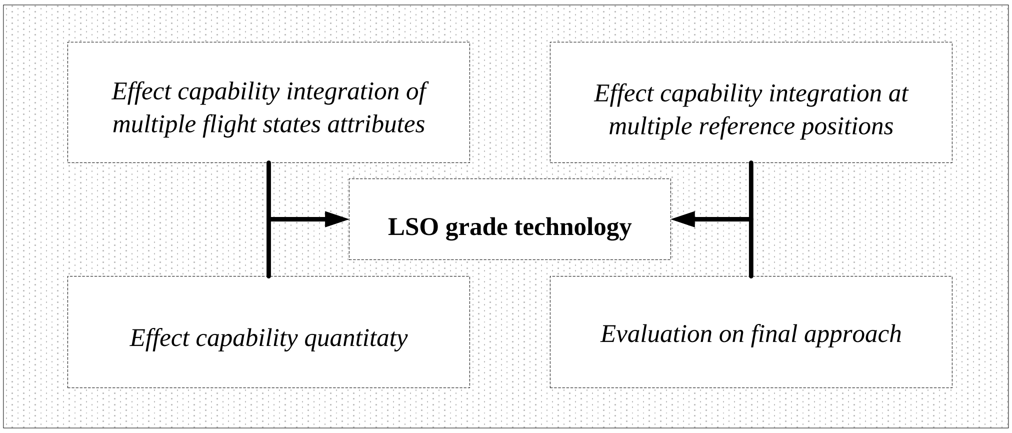


Figure 1. LSO Grade Technology

3. LSO Grade Technology

3.1. Effect Capability Integration of Multiple Flight States Attributes

Let $\boldsymbol{X} = \{x_i \mid i \in M\}$ be a discrete set of glideslope reference positions, and let $\boldsymbol{U} = \{u_j \mid j \in N\}$ be a finite set of flight states attributes. Suppose that $\boldsymbol{\omega} = [\omega_1, \omega_2, \dots, \omega_n]^{\mathrm{T}}$ is the weight vector of flight states, and LSO provide the attribute value $r_{ij} \in \boldsymbol{S}$ of the alternative $u_j \in \boldsymbol{U}$ with the respect to the reference positions $x_i \in \boldsymbol{X}$.

The effect capability integration at multiple reference positions $x_i \in \boldsymbol{X}$ should be realized using TFLWA operator [13-18].

$$r_i = \mathrm{TFLWA}_{\boldsymbol{\omega}}(r_{i1}, r_{i2}, \dots r_{in}) = \sum_{j=1}^{n} r_{ij}\omega_j = r_{i1}\omega_1 + r_{i2}\omega_2 + \dots + r_{in}\omega_n, \quad i \in M \qquad (1)$$

3.2. Effect Capability Integration at Multiple Reference Positions

Let $\boldsymbol{X} = \{x_i \mid i \in M\}$ be a discrete set of glideslope reference positions, and let $\boldsymbol{U} = \{u_j \mid j \in N\}$ be a finite set of flight states attributes. Suppose that $\boldsymbol{\omega}' = [\omega_1', \omega_2', \dots, \omega_m']^{\mathrm{T}}$ is the weight vector of reference positions, and LSO provide the attribute value $r_{ij} \in \boldsymbol{S}$ of the alternative $u_j \in \boldsymbol{U}$ with the respect to the reference positions $x_i \in \boldsymbol{X}$.

The effect capability integration of flight states attributes $u_j \in \boldsymbol{U}$ should be realized using TFLWA operator.

$$c_j = \mathrm{TFLWA}_{\omega'}(r_{1j}, r_{2j}, \ldots r_{mj}) = \sum_{i=1}^{m} r_{ij}\omega'_i = r_{1j}\omega'_1 + r_{2j}\omega'_2 + \ldots + r_{mj}\omega'_m, \quad j \in N \tag{2}$$

3.3. Effect Capability Quantification

Definition 1. Suppose someone flight voyage is virtual perfect landing, where all flight states are in ideal states, with the landing effect triangle fuzzy linguistic description of attribute $u_j \in \boldsymbol{U}$ at reference position $x_i \in \boldsymbol{X}$ is:

$$r_{ij0} = s_{\max} = [s^L_{\max}, s^M_{\max}, s^U_{\max}] = [0.8, 0.9, 1], \quad i \in M, \quad j \in N \tag{3}$$

With the character of TFLWA operator, multi-attribute decision making at reference positions $x_i \in \boldsymbol{X}$ and multi-positions decision making of attribute $u_j \in \boldsymbol{U}$ respectively are:

$$r_{i0} = \mathrm{TFLWA}_{\omega}(r_{i10}, r_{i20}, \ldots r_{in0}) = [0.8, 0.9, 1], \quad i \in M \tag{4}$$

$$c_{j0} = \mathrm{TFLWA}_{\omega'}(r_{1j0}, r_{2j0}, \ldots r_{mj0}) = [0.8, 0.9, 1], \quad j \in N \tag{5}$$

Definition 2. Virtual perfect landing effect grade of attribute $u_j \in \boldsymbol{U}$ at reference position $x_i \in \boldsymbol{X}$ is:

$$p_{ij0} = 100, \quad i \in M, \quad j \in N \tag{6}$$

Calculating actual landing points at reference position $x_i \in \boldsymbol{X}$ as (7) in virtual perfect landing. Quantify:

$$p_i = \frac{r^L_i + r^M_i + r^U_i}{r^L_{i0} + r^M_{i0} + r^U_{i0}} \times p_{i0} = \frac{r^M_i}{r^M_{i0}} \times 100, \quad i \in M \tag{7}$$

Calculating actual landing points of flight states attribute $u_j \in \boldsymbol{U}$ as (8) in virtual perfect landing. Quantify:

$$q_j = \frac{c^L_j + c^M_j + c^U_j}{c^L_{j0} + c^M_{j0} + c^U_{j0}} \times p_{j0} = \frac{c^M_j}{c^M_{j0}} \times 100, \quad j \in N \tag{8}$$

3.4. Evaluation on Final Approach

Quantify points evaluation during landing process:

$$p = \sum_{i=1}^{m} p_i\omega'_i = p_1\omega'_1 + p_2\omega'_2 + \ldots + p_m\omega'_m, \quad i \in M \tag{9}$$

4. Integrated Evaluation Technology of LSO for Carrier-based Aircraft

4.1. Flight States Attribute Evaluation at One Reference Position

After 50 simulation analysis, we could describe the control capability of flight states attribute at one reference position during every flight, such as IC position. Flight states attribute evaluation chart at IC position should be represented in Table 1, and the influence factor of pilots at specified glideslope reference positions should be analyzed from this Table.

Table 1. Flight States Attributes Evaluation Chart at IC Position

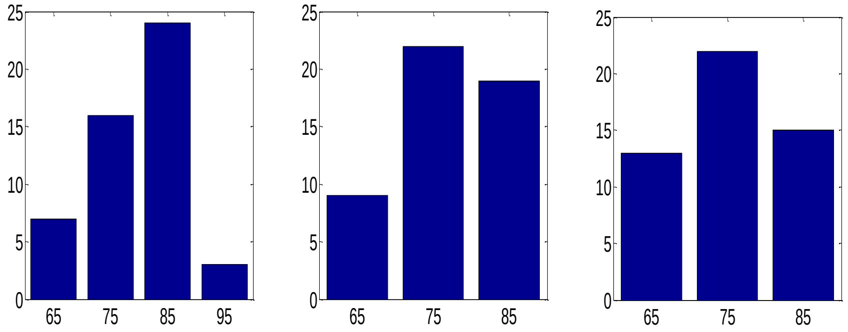
Flight	Operation factor		
	Gldieslope deviation	Velocity	Rate of descend
1	88.89	88.89	77.78
2	77.78	77.78	77.78
3	66.67	88.89	88.89
… …	… …	… …	… …
48	88.89	66.67	66.67
49	100	77.78	88.89

Applying statistics measure, we calculate the flight states attribute points statistics results for 50 flight at IC position for this pilot, as shown in Table 2.

Table 2. Flight States Attributes Analysis Chart at IC Position

	Average	Maximum	Minimum
Gldieslope deviation	85.32	100	66.67
Velocity	83.26	88.89	66.67
Rate of descend	81.37	88.89	66.67

Each flight states attribute point histogram is expressed in Figure2.



(a) Gldieslope Deviation (b) Velocity (c) Rate of Descend

Figure 2. Flight States Attribute Scores Distribution Histogram at IC Position

Combining histograms and statistics data, it is not difficulty to find the pilot has the best control for glideslope deviation at IC position, the average point is up to 83.52, belonging to "B" grade. There are three 100 points during 50 landing flight, indicating perfect control in LSO fuzzy representation. Correspondingly, the control effect of rate of descend is worst, the average point is 81.37.

4.2. Reference Positions Evaluation of One Flight States Attribute

In the same way, we could describe the control capability at reference position of flight states attribute, such as velocity. Reference positions evaluation chart of velocity attribute should be represented in Table 3, and the influence factor of pilots of specified flight states attribute should be analyzed from this Table.

Table 3. Reference Positions Evaluation Chart of Veltory Attribute

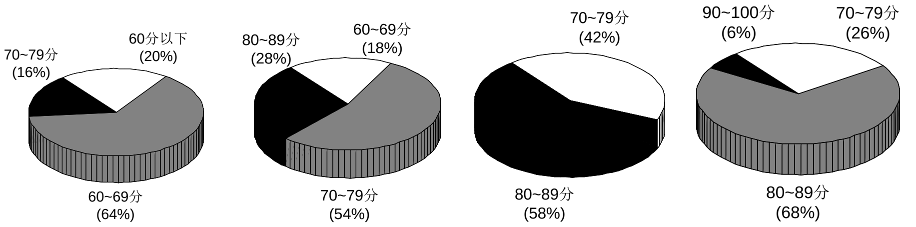
Flight	Reference positions			
	X	IM	IC	AR
1	77.78	77.78	88.89	88.89
2	55.56	66.67	77.78	88.89
3	77.78	77.78	88.89	100
……	……	……	……	……
48	77.78	66.67	77.78	77.78
49	55.56	77.78	88.89	88.89
50	77.78	88.89	88.89	100

Applying statistics measure, we calculate the reference positions points statistics results for 50 flight of velocity for this pilot, as shown in Table 4.

Table 4. Reference Positions Analysis Chart of Velocity Attribute

	Average	Maximum	Minimum
X position	70.68	77.78	55.56
IM position	78.85	88.89	66.67
IC position	82.47	88.89	77.78
AR position	86.15	100	77.78

Each reference position point pie graph is expressed in Figure3.



(a) X Position (b) IM Position (c) IC Position (d) AR Position

Figure 3. Reference Positions Scores Distribution Pie Chart of Veltory Attribute

Combining pie graphs and statistics data, the more control precision with the less of glideslope range. The average point of control precision is up to 86.15 as AR position. There are 74% landing voyage control grades are belonging to "B" grade. Especially, There are three 100 points during 50 landing flight, indicating perfect control in LSO fuzzy representation.

4.3. Flight States Attribute Evaluation on the Final Approach

Flight states attribute integrated evaluation in landing with effect capability integration at multiple reference positions, flight states attribute evaluation chart of some voyages is shown as in Table 5, and the influence factor of pilots at specified glideslope reference positions should be analyzed from this Table.

Table 5. Flight States Attribute Evaluation Chart of Some Voyage

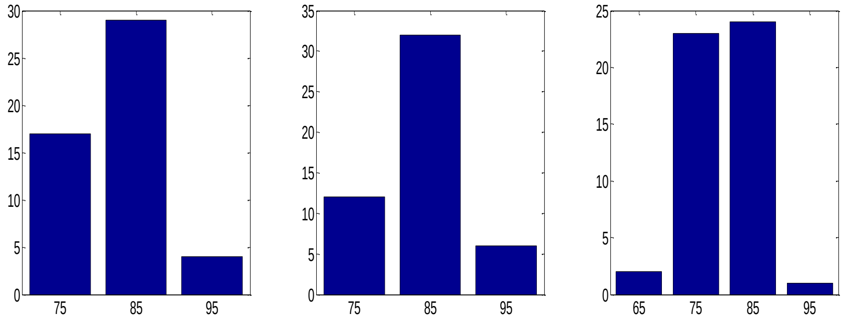
Flight	Operation factor		
	Gldieslope deviation	Velocity	Rate of descend
1	86.24	87.73	78.94
2	72.50	84.76	75.42
3	92.86	96.31	88.16
……	……	……	……
48	90.68	77.07	71.39
49	86.59	86.84	90.84
50	88.29	97.03	79.82

Applying statistics measure, we calculate the flight states attributes points statistics results in landing process for this pilot, as shown in Table 6.

Table 6. Flight States Attribute Analysis Chart of Some Voyage

	Average	Maximum	Minimum
Gldieslope deviation	86.49	94.71	75.67
Velocity	88.93	97.03	75.78
Rate of descend	82.61	92.83	68.42

Each flight states attribute point histogram is expressed in Figure4.



(a) Gldieslope Deviation (b) Velocity (c) Rate of Descend

Figure 4. Flight States Attribute Scores Distribution Histogram on the Final Approach

Combining histograms and statistics data, it is not difficulty to find the pilot has the best control for velocity on the final approach, the average point is up to 88.93, belonging to "B" grade. There are six points greater than 90 during 50 landing flight, indicating perfect control in LSO fuzzy representation. Correspondingly, the control effect of rate of descend is worst, the average point is 82.61.

4.4. Reference Position Evaluation on the Final Approach

In the same way, we could describe the reference position evaluation on the final approach with effect capability integration of flight states attribute, reference positions evaluation chart of some voyages should be represented in Table 7, and the influence factor of pilots of specified flight states attributes should be analyzed from this Table.

Table 7. Reference Positions Evaluation Chart of Some Voyage

Flight	Reference positions				Landing Effect
	X	IM	IC	AR	
1	73.24/**(13)**	78.62/**(11)**	86.67/**(5)**	87.54/**(14)**	84.29/**(14)**
2	66.67/**(33)**	64.52/**(36)**	77.78/**(35)**	80.12/**(35)**	78.29/**(35)**
3	80.46/**(4)**	81.75/**(4)**	80.00/**(7)**	89.88/**(4)**	87.77/**(4)**
……	……	……	……	……	……
48	68.86/**(29)**	65.23/**(32)**	75.56/**(37)**	81.96/**(26)**	79.58/**(29)**
49	78.96/**(7)**	72.39/**(14)**	88.89/**(4)**	88.91/**(6)**	87.45/**(7)**
50	75.68/**(12)**	76.53/**(13)**	82.22/**(6)**	85.59/**(15)**	84.20/**(13)**

Applying statistics measure, we calculate the reference positions points statistics results of some voyages for this pilot, as shown in Table 8.

Table 8. Reference Positions Analysis Chart of Some Voyage

	Average	Maximum	Minimum
Landing Effect	82.19	93.43	67.82
X position	76.53	84.67	57.19
IM position	79.28	90.02	63.27
IC position	82.59	91.48	62.98
AR position	84.69	94.92	76.51

Landing efficiency scores distribution pie chart is expressed in Figure5.

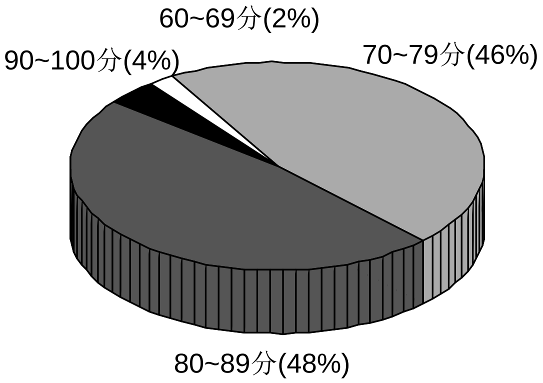
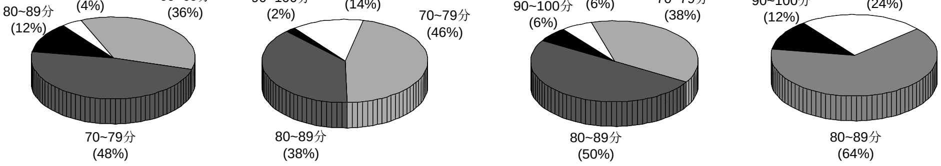


Figure 5. Landing Efficiency Scores Distribution Pie Chart

Reference positions scores distribution pie chart is expressed in Figure 6.



(a) X Position (b) IM Position (c) IC position (d) AR position

Figure 6. Reference Positions Scores Distribution Pie Chart of Veltory Attribute

Combining pie graphs and statistics data, the more control precision with the less of glideslope range. The average point of control precision is up to 84.69 at AR position. There are 76% landing voyage control grades are belonging to "B" grade, especially, 12% landing voyage control grades are belonging to "A" grade.

6. Conclusion

This paper has presented an integrated evaluation manner for landing approach on aircraft carrier. There are four LSO grade technology should be proposed: effect capability integration of multiple flight states attributes; effect capability integration at multiple reference positions; effect capability quantification and evaluation on final approach. From evaluation technology example, including flight states attribute evaluation at one reference position, reference positions evaluation of one flight states attribute, flight states attribute evaluation on the final approach and reference position evaluation on the final approach, the evaluation method we research achieves the better performance with more accuracy and practicability.

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