A HELICOPTER MODEL ORIENTED TO PRE-FLIGHT THEORETIC TRAINING

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ABSTRACT

The basic idea of the proposed model is to increase simulation cost-effectiveness. Two ways are proposed by the paper: (1)to replace the expensive information derived from flight tests by a theoretic model which describes as accurately as possible the helicopter flight and (2)to extend model applicability to helicopter pilots' pre-flight training and/or for students' education in universities. A concrete application based on helicopter model developed by SIMULTEC Romania is presented in order to illustrate this concept. Finally the training efficiency of this modelling concept is appreciated in direct relationship with the cost of training equipment. In this context, a quantitative criterion of training cost-effectiveness is established based on opinions of an experienced flight instructor and economical/financial aspects.

REASONS FOR A NEW APPROACH

Development of a new simulator respects a Paretto's distribution of costs; that is, the 20% of simulator components represents usually more than 60% of simulator cost (see fig.1).

In this context, it is quite obvious that, if a significant cost decreasing is aimed, only actions directed to simulation model data base cost minimization would be really efficient. So, a modelling procedure, providing a low cost model, would be very attractive.

Additionally, development of new applications in the field of theoretic training could be another feature for improving of simulation model efficiency. This is quite possible due to theoretical development of the model which is fully accessible for modifications both in input data and model parameters. Moreover, the model includes several options to compensate the simplificatory hypotesis we have made during model development. These options can be used for instructional/formation process in universities.

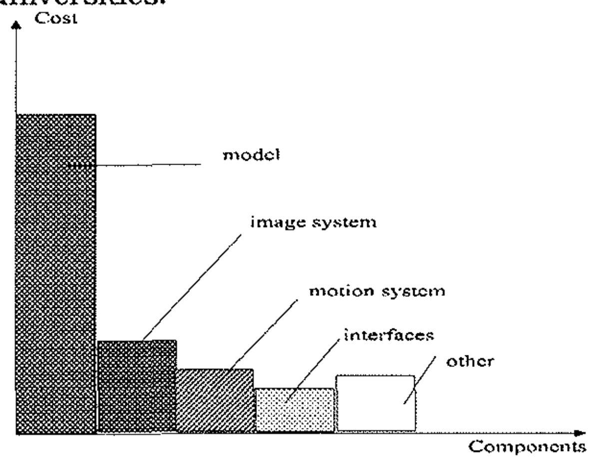

Fig.1. Paretto's distribution for a generic new simulator

BASIC TOPICS OF THE APPROACH

As stated before, two ways are treated in order to improve model cost-effectiveness. The development of a theoretic model able to replace the model based on flight test data is presented in [Iacob, 1994a] and [Iacob, 1994b]. In the present paper only the main steps of this procedure are reminded (see fig. 2), because the paper is intended to present a supplementary application of previously participated in development and acceptance tests of this new feature of the simulation model). Anyway, we are confident that, mainly, this method will be very well *received enhancing the* knowledge level of the intended end users.

In fact it would be rather difficult to quantify the efficiency of a such pre-flight theoretic training. Anyway, pre-flight training is quite necessary, because it points out difficulties and limits in solving dangerous flight situations. This is very important because, sometimes, on simulator training gives the feeling of confidence in solving all special cases and sometimes the pilot "is looking for risk". This "conscience" of risk is enhanced by the theoretic pre-flight training and this could be partially quantified in probability p_i to damage the real helicopter during on helicopter training for learning of 'i" maneuver.

APPLICATION IN A CONCRETE CASE

In case of helicopter flight model developed in SIMULTEC Romania), the previous capabilities were already developed and presented [Iacob 1993a], the whole model being completed having in mind pre-flight theoretic training idea. The previous pre-flight training model is implementable on PC computers (in the cheaper version). Graphic station *application* (actually based *on* Silicon Graphics -SGI) is equally available with supplementary real-time graphic training capabilities. Helicopter structure in case of PC implementation or helicopter body in case of the SGI, with forces and moments acting on it, are presented to the people receiving training. Helicopter body motion is presented for qualitative and intuitive comprehension of the flight dynamic behaviour, but numeric and graphic plotting of state variables are equally available. In fact this model capability was also developed for rapid debugging of the simulation model during its development and implementation phase. Moreover, the model can work in a network including motion, control loading system and simulator interface computers with appropriate capability to *simulate* (graphics included) these systems responses to the model inputs. This feature is intended for a universitary application course which is conceived for specialization of Aeronautical Faculty's students in simulation and simulator development.

Additionally, in order to appreciate the simulation efficiency, the universitary course proposes a formula, so that to give to the student some criteria for developing models intended for flight simulators. Even the formula is not directly related to efficiency of pre-flight training, but only to on-simulator training, we have considered it for presentation, in order to point out all topics involved by our theoretic training programme. This formula *quantify simulation efficiency, that is*, number of flight procedures to be learned and their degree of fidelity in simulation against the training cost. Obviously, a quantitative criterion to appreciate the simulator efficiency would be very useful giving an objective appreciation criteria, even from the starting phase of model development.

EFFICIENCY CRITERION

In order to folllow the efficiency criterion development, the present paper describes the main steps in deduction of final formula (for details see (Iacob 1994a]). So, let be (notations are those used for a helicopter flight simulator):

$\mathbf{c_{so}}$=cost of simulator training hour, including energy cost, simulator maintenance price, estimated number of functioning hours, etc.;

$\mathbf{c_f}$=cost of on-real-object training hour;

$\mathbf{n_i}$=number of minimal hours necessary to practice/learn the "i" maneuver in real operation (stated by national regulations);

$\mathbf{l_i}$=number of on-simulator training hours necessary to learn "i" maneuver;

$\mathbf{m_i}$=number of hours necessary to learn

the "i" maneuver in real flight if "l_i" training hours on simulator has been performed;
p_i=probability of an accident during on-helicopter learning of "i" maneuver ;
h_c=cost of the real helicopter;
k=number of evolutions to be learned;

So, the simulator training hour cost for learning the "i" maneuver could be expressed as:

$$c_{si}=c_{so}+k_i e^{l_i/l_{oi}}/(m_i+m_{oi})$$

where k_i, l_{oi} and m_{oi} are constants appropriately chosen for each "i" maneuver to be learned using the simulator. If we consider that:

$$m_i + l_i = n_i$$

we could consider c_{si} as a function of l_i, the l_{oi} constant representing practically the point of an important changing of c_{si} curve feature, while m_{oi} could be significant for the l_i values which are less than l_{oi}. A curve as presented in fig.3 is obtained. It points out the basic idea of this formula: if simulator performance is so high that the number m_i of on-real-object training hours tends to zero (that is l_i tends to n_i), then the simulator price could be increased considerably, and sometimes without justification (as a function of constants l_{oi} and m_{oi}).

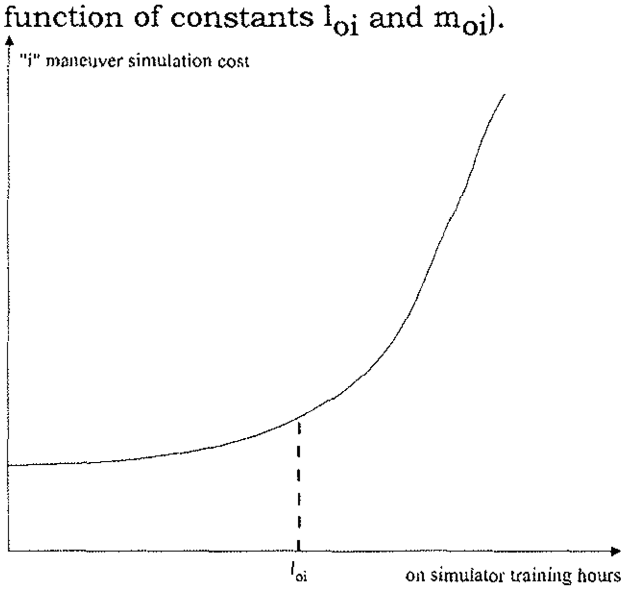

Fig.3 .Cost of simulation versus on-simulator training hours

How reasonable will be the simulator price increasing can be evaluated only if the on-real-helicopter training is also evaluated. The proposed formula takes into consideration the cost c_f of normal functioning (including fuel cost, equipment operational life, etc.), as well as the risk p_i of real object damaging during learning of "i" maneuver. So, the resulting formula for the cost of k maneuvers to be learned during on-real-helicopter training becomes:

$$T_{fk} = \Sigma\, n_i(p_i h_c + c_f)$$

and similarly the cost of the same k maneuvers learned by using l_i on-simulator training hours becomes :

$$T_{sk}=\Sigma m_i(p_i h_c+c_f)+l_i(c_{so}+k_i e^{l_i/l_{oi}}/(m_i+m_{oi}))$$

So, the simulator efficiency criterion for k maneuvers learning could be given by:

$$R_k = T_{fk} - T_{sk} = \max !$$

But this formula is relevant only if it is expressed as a ratio, that is, as a part of the training performed using only the real helicopter. So, a more appropriate formula is:

$$r_k=(T_{fk}-T_{sk})/T_{fk} = 1-T_{sk}/T_{fk}= \max !$$

that is

$$e_k=T_{sk}/T_{fk}= \min !$$

or more detailed:

$$e_k = \sum_i^k \frac{m_i(p_i h_c + c_f) + l_i c_{si}}{n_i(p_i h_c + c_f)} = \min !$$

Supposing that the relation $m_i+l_i=n_i$ is approximately true, the above formula depends only on the number of training hours l_i to be performed on simulator to learn maneuver "i", that is :

$$e_k = \sum_i^k \frac{(n_i - l_i)(p_i h_c + c_f) + l_i c_{si}}{n_i (p_i h_c + c_f)} = \text{min !}$$

From this relation we can obtain further:

$$e_k = \sum_i^k 1 + \frac{-l_i (p_i h_c + c_f) + l_i c_{si}}{n_i (p_i h_c + c_f)} = \text{min !}$$

or eliminating the constants and changing the sign we have:

$$e_k = \sum_i^k \frac{l_i (p_i h_c + c_f - c_{si})}{n_i (p_i h_c + c_f)} = \text{max !}$$

and finally, taking into account formula for c_{si}, we have the most appropriate formula for optimization:

$$e_k = \sum_i^k \frac{l_i}{n_i} \left(1 - \frac{c_{so} + \frac{k_i e^{l_i/l_{oi}}}{n_i + m_{oi} - l_i}}{p_i h_c + c_f}\right) = \text{max !}$$

This formula can be obtained, in order to evaluate from the financial point of view, if simulation accuracy improvement will be efficient for the global cost of training process. According to this formula the basic maneuvers and their required degree of fidelity in simulation could be identified for an efficient simulator minimizing the training global cost. Of course, the absolute cost of the simulator for learning k maneuvers has to be also taken into account (see the T_{sk} formula). A such calculation is now under development in order to evaluate the e_k value for the Romanian made PUMA helicopter simulator which, unfortunately, was developed before a such analysis has been performed. Now, only a post-factum calculation of this merit criterion e_k was carried out.

CONCLUSIONS

The additional pre-flight theoretic training capability provided by the helicopter model developed in SIMULTEC Romania is a new step directed towards model efficiency increasing.

It offers a friendly and expected to be efficient tool both for helicopter pilots and students teaching. It is now under development; the concept efficiency will be evaluated during the next year.

These capabilities are available to be provided based on PC and other more advanced (graphic stations) computers.

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