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APPLICATION OF OPTIMIZATION TECHNIQUES TO THE LATERAL CONTROL OF THE E-2A

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SUMMARY*

A hypothetical redesign of the lateral directional stability augmentation system for the Grumman E-2A (Hawkeye) aircraft is described. The major importance of this work is the mathematical formulation and computational solution of a general problem. Due to safety of flight considerations, one of the basic tradeoffs is between structural weight and control authority. The measure of a limited authority controller is defined in terms of reducing unfavorable aircraft reactions without degrading response. In these terms, the best controller can be found as the solution of the optimal regulator problem. The results presented here demonstrate the utility of optimal control theory as a design aid. However, classical theory can only indirectly handle such real world constraints as:

1) Fixed feedback control structure

2) Constant feedback gains for short time intervals

3) Best compromise feedback gains for several flight conditions

In conclusion, the stage is set for dealing directly in the future with the constrained problem.

INTRODUCTION

The objective is to find the most efficient way of determining a practical automatic flight control system which will provide:

1) Rapid and precise response to the pilot's commands

2) Acceptable stability in the Dutch roll, spiral and roll subsidence modes

It is assumed that a desirable trajectory of the aircraft is known for a representative maneuver. The problem can be given an explicit mathematical form, which will open it to an organized attack, by using some measure of the deviation between the actual and desired trajectories as an index of performance. The system can then be optimized against this measure. This amounts to a simultaneous attack on the problems both of stabilization and control, because the input which causes the maneuver should also excite any unstable modes, and the resulting oscillations will lead to greater deviations from the desired trajectory, and a larger value of the performance index. The particular system which is found to be optimal will depend on the choice of the performance index, and optimization is here introduced not with the aim of finding a unique 'best' system, but rather as a means of guiding the calculation. The question is whether a performance index can be found for which the corresponding optimal system satisfies all the criteria embodied in objectives 1 and 2.

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In formulating the problem it is necessary to consider the amount of complexity to be allowed in the configuration of the control system. If, for example, the criterion of merit is taken to be speed of response, then it can be shown that the optimal system is a bang-bang system, which would require on board computation of switching times. In general, one can either try to choose the performance index in such a way that the optimal system is within the desired class of configurations, or one can attach specific constraints on the type of configuration. It is assumed here at the outset that the desired configuration is a linear control system in which the pilot's commands are modified by feedback signals from measurements of the aircraft's motion. It is assumed also that it is desired to use constant feedback gains in the short period, though the gains may be altered with the flight condition. Rather than trying to mechanize a particular optimal system, one may, of course, prefer to use the insight gained from knowledge of optimal systems to design a simpler system.

CONCLUSIONS AND RECOMMENDATIONS

A good method of finding an acceptable system, with performance as good as or better than that obtainable by traditional methods, is to calculate the optimal system for each flight condition, and then to try to simplify it by eliminating some feedbacks and fixing other feedbacks. This method has the advantages that:

1) It is very rapid

2) It is possible to trade different qualities, such as suppression of sideslip and speed of response, by altering the coefficients in the performance index used in the determination of the optimal system

A natural extension is to try to optimize the parameters of the simplified system. This is unfortunately more difficult than the calculation of the free optimal system; the elimination of feedbacks amounts to a constraint on the problem when it is formulated mathematically. Current efforts are concentrating on solving this problem by computerized search. The recently developed accelerated gradient methods give useful approximations to the exact solution, Reference 7.