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Optimization of Approach Trajectory Considering the Constraints Imposed on Flight Procedure Design

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Abstract

Due to recent growth of air traffic demand, inefficiency in flight is becoming a more and more important issue. However present flight trajectory is not completely optimized because of the existence of difficulties in flight procedure design. This paper describes a method to optimize the approach procedure in terms of fuel efficiency. In proposed method, route is parameterized by position of each waypoint and speed above them. Then assuming constant acceleration and point mass model, total fuel consumption is calculated. Optimization is conducted with constraints imposed upon flight procedure design by using genetic algorithm. We applied the method to approach procedure to a real airport and more efficient trajectory is obtained.

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1. Introduction

The steady growth of air traffic demand would cause lack of airspace capacity and bring a lot of problems such as delays, reduction in airline economic efficiency, increase in the emission of greenhouse gases and so on. Therefore efficiency in the usage of airspace has to be enhanced. Thanks to the spread of area navigation (RNAV), flexibility in flight procedure design has been improved and made it possible to design more efficient flight procedure. Despite

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this increase of design flexibility, many rules and constraints are still imposed upon flight procedure and make it difficult. Current design process deals with this by using specific software which detects the violation against the rules and the constraints. However it is not designed according to appropriate indices and there may be rooms for improvement. In order to solve this problem, this paper aims to establish a method for optimal flight procedure design.

Required Navigation Performance Authorization Required approach (RNP AR APCH) is one of the approach procedures based on RNAV and has been introduced to more and more airports in Japan. Although this procedure requires aircrafts to have more precise navigational performance, it enables more flexible and efficient route design. Hence we focus on this approach procedure.

Similar research was conducted by some researchers. Richter expressed RNAV route in a sequence of straight line and arc, then positions of waypoints and radii of arcs were set as optimization parameters which were optimized by solving optimal control problem [1]. Hartjes developed an extention of a tool called NOISHHH which had been developed for noise abatement RNAV trajectory design [2,3]. Both of them showed results that were more realistic and practical. However there are other rules which we have to consider when designing flight procedure. So we add more constraints than these previous studies and aim to create more realistic route.

The rest of the paper is structured as follows: In Section II we discuss how we formulate and solve optimization problem, route parameterization, constraints and objective function are described in this Section. Section III presents an example of optimization by applying proposed method to a real airport. Finally, concluding remarks are made in Section IV.

Nomenclature

C_D	Drag coefficient
C_{D0}	Parasitic drag coefficient
C_{D2}	Induced drag coefficient
C_{f1}, C_{f2}	Fuel flow parameters given in BADA
C_L	Lift coefficient
D	Drag force
g	Gravity acceleration
h_{path}	Altitude of path
$h_{terrain}$	Terrain elevation
L	Lift force
l_i	Length of the i-th segment
m	Aircraft mass
m_{fin}	Final aircraft mass
m_{ini}	Initial aircraft mass
n	Number of waypoints
R	Rate of turn
r	Radius of arc
r_{RF}	Radius of RF leg
T	Thrust
T_{max}	Maximum thrust
T_{min}	Minimum thrust
v_i	Reference speed at the i-th waypoint
$\mathrm{V}_{\mathrm{min}}$	Minimum airspeed restriction
V_{TAS}	True airspeed
V_{TW}	Tail wind component for calculation of turn radius
x	x coordinate of aircraft
$\boldsymbol{x}$	Optimization variables
x_i	x coordinate of the i-th waypoint
y	y coordinate of aircraft