A Design Study for a Multivariable Feedback Controller for Aircraft Carrier Landing

دراسة في تصميم نظم التحكم ذات المتغيرات المتعددة لنظام الهبوط على حاملة الطائرات

By

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Abstract

This research studies the design of a multivariable control system for aircraft landing. To improve the safety of aircraft landing, handling quality is improved whilst decreasing the number of critical tasks the pilot has to perform simultaneously with improved responsiveness of the aircraft to the pilot's input commands. By adding another control surface on aircraft's horizontal tail the dynamics of the aircraft motion are improved, and the pilot has the minimum number of inputs to effectively control the aircraft. Simulation of the results demonstrate the effectiveness of the dynamic reaction and steady state system response showing the aircraft response to tailplane or aileron input change. Least effort controller design method provides superior results motivating further application studies.

خلاصة البحث

هذا البحث يدرس تصميم نظام التحكم متعدد المتغيرات لحركة الطائرات في مرحلة الهبوط. في خطوة لتحسين سلامة هبوط الطائرات ، و تحسين جودة التحكم من خلال خفض عدد المهام الحرجة التي يقوم بها الطيار في ان واحد وفي نفس الوقت يحسن من استجابة الطائرة لأوامر إدخال الطيار. ان مهمة اضافة سطح تحكم اخر الى الذيل الأفقي على الطائرة ينطوي على تغيير كبير في هيكل الطائرة. في حين أن ديناميكية حركة الطائرة تتحسن ، فان الطيار لا يزال لديه الحد الأدنى من المدخلات للسيطرة على الطائرة بنحو فعال. ان محاكاة النتائج سوف تثبت فعالية ديناميكية الحركة و الاستجابة النهائية مع المتغيرات المختلفة. المحاكاة سوف تعطي أيضا إرشادات لتحديد عمود التحكم التي سيتم استخدامه من قبل الطيار ؛ إما العمود الذي يسيطر على سطح التحكم الموجود على الجناح أو عمود التحكم المتصل مع سطح الذيل الأفقي. في نهاية المطاف ،سهولة تطبيق تقنية الأقل جهد في التصميم و نتائجها المتميزة تحفز إجراء مزيد من الدراسات باستخدام هذه التقنية على مختلف التطبيقات الأخرى.

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Dedication

To the one who created me from nothing, and bestowed me with countless blessings. To who bestowed me with incredible wife: a wife has been always available helping me to overcome all the hurdles in my life, and patiently standing me at nervous moments. To the one I thank for my sons and daughter: Adam, Edris, and Ilya.

Everything good that is happening to my life is all because of your grace.

My prayer, my living, and my deeds are all for you Allah!

List of Notations and Abbreviations:

$a_{i,j}(s)$	Elements of A(s), $1 \ll i, j \ll m$
$a_{i,j}, b_{i,j}, \dots, \gamma_{i,j}$	Coefficients of $a_{i,j}(s)$
$\boldsymbol{A}$	State Space Matrix
$A(s)$	Numerator of $G(s)$
$b(s)$	Polynomial
$\boldsymbol{B}$	State Space Matrix
$b_0, b_1, \dots, b_{m-1}$	Coefficients of $b(s)$
$\boldsymbol{C}$	State Space Matrix
$\boldsymbol{D}$	State Space Matrix
E	Energy
$e(t)$	Error signal
$d(s), \nabla$	Denominator of $G(s)$
$f, f_1, f_2, \dots, f_m$	Outer Loop feedback gains
F	Outer feedback loop array
$G(s)$	Transfer Function Array (Input/Output)
h	Feedback path gain
$h(s)$	Feedback path Function
$H(s)$	Feedback path compensator
$H^{-1}(s)$	Inverted Closed Loop Transfer Function matrix

h_{ii}^{-1}	Diagonal terms of inverted closed loop transfer function matrix
I_m	Identity Array
J	Performance Index
k	Forward path gain
$k(s)$	Forward path function
$k >< h$	Outer Product of k and h
$< k, h >$	Inner product of k and h
$K(s)$	Forward path controller model (pre-compensator)
$L(s)$	Left (row) factors
M	Mass (kg)
$n, n_1, n_2, \dots, n_{m-1}$	Gain Ratios
P	Pre-compensator array
Q	Coefficient Array
Q^{-1}	Inversion of open loop transfer function matrix
q_{ii}^{-1}	Diagonal terms in inverted open-loop transfer function matrix
q_{ij}^{-1}	Off diagonal terms in inverted open-loop transfer function matrix
$r(s)$	Transformed reference input
$\bar{r}(s)$	Transformed inner loop reference input
$R(s)$	Right (column) factors
$S(s)$	Sensitivity Array

S_s	Steady State Array
$u(s)$	Transformed input
$\boldsymbol{U}$	Input Matrix
$\boldsymbol{Y}$	Output Matrix
$y(s)$	Transformed output
$\Gamma(s)$	Finite time array
$\delta(s)$	Transformed disturbance signal
λ	Eigen Value
INA	Inverse Nyquist Array
L.E.C	Least Effort Control
LQE	Linear Quadratic Estimator
LQG	Linear Quadratic Gaussian
NACA	National Advisory Committee for Aeronautics
PID	Proportional, Integral, and Derivative Controller

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