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SERIES EDITORS' FOREWORD

The series *Advances in Industrial Control* aims to report and encourage technology transfer in control engineering. The rapid development of control technology impacts all areas of the control discipline. New theory, new controllers, actuators, sensors, new industrial processes, computing methods, new applications, new philosophies, . . . , new challenges. Much of this development work resides in industrial reports, feasibility study papers and the reports of advanced collaborative projects. The series offers an opportunity for researchers to present an extended exposition of such new work in all aspects of industrial control for wider and rapid dissemination.

Robust control theory has now reached the stage where practical implementation as prototype controllers are appearing. The high performance demands of aerospace flight control are a natural application for H_∞ and structured singular value robust control. Dr. Banda and his colleagues at Wright Patterson Airforce Base, Ohio, U.S.A. had long recognised the aerospace applications potential in the new theory. This volume reports the way in which the robust methodology has to be modified to suit the special features of the system for which controllers are being designed.

Two design case studies are presented for the manual flight control of lateral/directional axes of the VISTA-F-16 test vehicle and an F-18 trust vectoring system. The interplay between theory and the physical features of the systems is self-evident and forms a significant feature of the work presented. Nonlinear system simulations demonstrate the satisfactory performance achieved. Altogether an instructive and invaluable addition to the Advances in Industrial Control Series.

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CONTENTS

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ACRONYMS, ABBREVIATIONS, AND SYMBOLS

Acronyms AND Abbreviations

cg	Center of Gravity
CAP	Control Anticipation Parameter
LQ	Linear Quadratic
V/STOL	Vertical/Short Take-off and Landing
LOES	Low Order Equivalent System
HOS	High Order System
VISTA	Variable Stability In-Flight Simulator Test Aircraft

Symbols

A	System Matrix
B	Control Effectiveness Matrix
B*	Generalized Control Effectiveness Matrix
C	Output Matrix
CS	Control Selector
D	Direct Feed-through Matrix
g	Gravity
h	altitude
I	Identity Matrix
I_x	Inertia About Aircraft X-body axis
I_{xz}	Cross Product of Inertia
I_y	Inertia About Aircraft Y-body axis
j	$\sqrt{-1}$
L	Roll Moment
L_β	Derivative of Roll Moment wrt Sideslip Angle
L_δ	Derivative of Roll Moment wrt Control Deflection
L_p	Derivative of Roll Moment wrt Roll Rate
L_r	Derivative of Roll Moment wrt Yaw Rate
M	Pitch Moment
m	mass
M_α	Derivative of Pitch Moment wrt Angle of Attack
M_δ	Derivative of Pitch Moment wrt Control Deflection
M_q	Derivative of Pitch Moment wrt Pitch Rate
M_u	Derivative of Pitch Moment wrt Forward Velocity
N	Yaw Moment

N_β	Derivative of Yaw Moment wrt Sideslip Angle
N_δ	Derivative of Yaw Moment wrt Control Deflection
N_p	Derivative of Yaw Moment wrt Roll Rate
N_r	Derivative of Yaw Moment wrt Yaw Rate
n_z'	Normal Accel at Instantanious Pitch Center of Rotation
P	Total Roll Rate
p	Perturbational Roll Rate
$\dot{p}_c$	Generalized Roll Acceleration Command
Q	Total Pitch Rate
q	Perturbational Pitch Rate
$\dot{q}_c$	Generalized Pitch Acceleration Command
$\bar{q}$	Dynamic Pressure
R	Total Yaw Rate
r	Perturbational Yaw Rate
$\dot{r}_c$	Generalized Yaw Acceleration Command
Re	Real Part
s	Laplace Operator
T	Control Selector Transformation
T_r	Roll Mode Time Constant
T_s	Spiral Mode Time Constant
U	Total Velocity Along X-body axis
u	Perturbational Velocity Along X-body axis
V	Total Velocity Along Y-body axis
V_T	Total Velocity Along the Flight Path
v	Perturbational Velocity Along Y-body axis
v^d	Desired Eigenvector
W	Total Velocity Along Z-body axis
w	Perturbational Velocity Along Z-body axis
X	Total Force Along X-body axis
x	Perturbational Force Along X-body axis
x	State Vector
X_α	Derivative of Force Along X-body axis wrt Angle of Attack
X_δ	Derivative of Force Along X-axis wrt Control Deflection
X_u	Derivative of Force Along X-body axis wrt Forward Vel
Y	Total Force Along Y-body axis
y	Perturbational Force Along Y-body axis
Y_β	Derivative of Force Along Y-body axis wrt Sideslip Angle
Y_δ	Derivative of Force Along Y-axis wrt Control Deflection
Z	Total Force Along Z-body axis
Z_α	Derivative of Force Along Z-body axis wrt Angle of Attack
Z_δ	Derivative of Force Along Z-axis wrt Control Deflection
Z_q	Derivative of Force Along Z-body axis wrt Pitch Rate
Z_u	Derivative of Force Along Z-body axis wrt Forward Velocity

α	Angle of Attack
β	Angle of Sideslip
δ	Control Deflection
δ^*	Generalized Control Deflection

δ_c^*	Generalized Control Deflection Command
δ_A	Aileron Deflection
δ_{DF}	Differentail Flaperon Deflection
δ_{DT}	Differentail Horizontal Tail Deflection
δ_E	Symmetric Horizontal Tail Deflection
δ_{lat}	Lateral Stick Deflection
δ_p	Pitch Stick Deflection
δ_{ped}	Rudder Pedal Deflection
δ_{PTV}	Pitch Thrust Vectoring Nozzle Deflection
δ_R	Rudder Deflection
δ_{RTV}	Differential Pitch Thrust Vectoring Nozzle Deflection
δ_{YTV}	Yaw Thrust Vectoring Nozzle Deflection
Δ_m	Relative Error
Φ	Total Roll Euler Angle
ϕ	Perturbational Roll Euler Angle
λ^d	Desired Eigenvalue
μ	Structured Singular Value
$\dot{\mu}$	Stability Axis Roll Rate
ν	Desired Dynamics for Dynamic Inversion
Θ	Total Pitch Euler Angle
θ	Perturbational Pitch Euler Angle
ρ	Spectral Radius
$\bar{\sigma}$	Maximum Singular Value
τ_θ	Equivalent Pitch Time Delay
ω	Frequency
ω_p	Phugoid Natural Frequency
ω_{sp}	Short Period Natural Frequency
Ψ	Total Yaw Euler Angle
ψ	Perturbational Yaw Euler Angle
ζ	Damping
ζ_p	Phugoid Damping
ζ_{sp}	Short Period Damping

$\| A \|_p$	p-norm of A
A^T	Transpose of A
A^{-1}	Inverse of A
$A^\#$	Generalized Inverse of A
$\Re$	Set of Real Numbers
C	Set of Complex Numbers

Subscripts/Superscripts

long	Longitudinal
lat/dir	Lateral/Directional
aero	Aerodynamic
tvec	Thrust Vectoring
∞	Infinity