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MODEL REFERENCE ADAPTIVE CONTROL IN THE PRESENCE OF UNMODELED DYNAMICS AND SINUSOIDAL DISTURBANCES

by

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بسم الله الرحمن الرحيم

STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Ph. D. in Electrical Engineering.

The work included in this thesis was carried out by the author, in the Department of Computer and Systems Engineering, Ain Shams University, from January 1991 to August 1993.

No part of this thesis has been submitted for a degree or qualification at any other university or institution.

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I wish to express my heartly gratitude to my parents for their loving attention, continuous encouragement and sincere prayers. First and foremost among those who helped me is my wife. She devoted every time and effort to keep me, not only dedicated for this research but also happy. With all my love, I thank her. My deepest love and thanks to my dear children who suffered a lot, during the long times, I have been taken from them. I only hope that I can make it up for them, in the future.

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TO THE SPIRIT

OF MY MOTHER

Title of thesis:

MODEL REFERENCE ADAPTIVE CONTROL IN THE PRESENCE OF UNMODELED DYNAMICS AND SINUSOIDAL DISTURBANCES

ABSTRACT:

This thesis is concerned with application of Model Reference Adaptive Control(MRAC) technique on real systems. After literature overviewing, it is assured that currently available standard adaptive control algorithms would likely become unstable in the presence of unmodeled plant dynamics and external sinusoidal disturbances. In such nonlinear dynamic control system, there exist two infinite gain operators, which can cause the loop gain to increase without bound; yielding an unstable control system as operation time proceeds.

For such problems to be tackled; we propose a modified MRAC-algorithm, that introduces a new concept of periodic resetting of the adaptation mechanism (PRAM). The optimal adaptation time used in the resetting mechanism, is computed on-line via minimizing an appropriate quadratic criterion.

A convergence test is proposed to detect early, any expected instability; in order to switch on the PRAM-algorithm in the proper time.

For realizing best possible performance , we proposed a new simple procedure to determine on-line the proper vector of gain parameters, in a near-optimal way. The obtained values are used for initializing the PRAM- algorithm .

An illustrative example, chosen from literature, is used to test the validity of the analytical arguments and improvements of the proposed algorithm. The obtained simulation resetuls are quite satisfactory.

The developed technique has been also applied to the longitudinal control problem of a high-speed fighter aircraft, in the presence of unmodeled dynamics and sinusoidal disturbances. Simulation results have proved that the proposed control technique is robust, and capable of solving problems that face the other available techniques.

SYMBOLS AND ABBREVIATIONS

$A(q^{-1})$	denominator polynomial of a discrete transfer function in the backward shift operator q^{-1}.
$B(q^{-1})$	numerator polynomial of a discrete transfer function in the backward shift operator q^{-1}.
$A^{(n)}$	indicates that the polynomial $A(q^{-1})$ has degree n.
$B^{(m)}$	indicates that the polynomial $B(q^{-1})$ has degree m.
n^{*}	indicates relative degree, $n^{*} = n-m$.
s	Laplace transform variable in continuous transfer functions, unless it is stated that $s = \frac{d}{dt}$ (as time-derivative operator).
g_p	plant gain, in plant transfer function.
$y_p(t)$	plant output.
$y(t)$	output of the system.
$u(t)$	control signal, or manipulated input to the controlled
$y_m(t)$	output of the reference model.
$r(t)$	reference command, or reference input (set point).
$e(t)$	output error signal, $e(t)= y(t)-y_m(t)$.
d_p	delay of the plant.
d	delay of the system.
MRAC	Model Reference Adaptive Control.
ROMRAC	Reduced Order Model Reference Adptive Control.
CA1	Continuous Adptive Algorithm No. 1.
DA2	Discrete Adaptive Algorithm No. 2.
$d(t)$	output disturbance.
d_o	amplitude of sinusoidal disturbance.
ω_o	frequency of sinusoidal disturbance, $d(t)= d_o \sin \omega_o t$.

PRTF	Positive Real Transfer Function.
LTI	Linear Time Invariant.
$\underline{\Gamma}$	matrix of adaptation gain coefficients γ_i, or adaptation rate factors.
$\underline{W}$	vector of auxiliary variables, used in the structure of adaptive algorithms (e.g. CA1, DA2).
$\underline{K}$	vector of gain parameters.
$\underline{K}^*$	vector of nominal gain parameters.
τ	indicates time constant .
τ_m	time constant of the reference model.
$\lVert \cdot \rVert$	norm of a function, or a vector.
t	time
T_s	sampling-period of the discrete system.
t_s	settling-time of system's transient response.
T_a	adaptation-time.
$T_{a_{opt}}$	optimal choice for adaptation-time.
$\sum$	summation.
$\oplus$	adder.
$\otimes$	multiplier
CT	Convergence Test.
ΔT	time-interval, every which CT is periodically operated.
V	performance criterion.
SV	Slope of V, or performance gradient (V').
ω_n	natural frequency of a second order system.
ω_d	damped frequency of a second order system.
ξ	damping coefficient of a second order system.
t_{p_1}	time till first overshoot.
Δ_1	first overshoot ratio.

t_{p_2} time till second overshoot.

Δ_2 second overshoot ratio.

PRAM Periodic Resetting of Adaptation Mechanism.

IG's Initial Gains.

IGAA Initial Gains Adjustment Algorithm.

TCYC the cyclic period of resetting the PRAM- algorithm, (TCYC = $T_{a_{opt}}$).

J no. of computatation cycle in the on-line adaptive control.

DF Disturbance-Free.

$\delta_r(K_i)$ absolute relative change of gain parameter K_i.

$\delta_r(V)$ absolute relative change of performance V.

θ the change in pitch angle of aircraft.

θ_r Aircraft reference input of pitch (set point).

sp indicates short-period mode of an aircraft, in the longitudinal vertical plane of motion.

ph indicates phugoid mode of an aircraft, in the longitudinal vertical plane of motion.

α the change in aircraft angle of attack.

δ_e the change in elevator deflection angle.

LIST OF FIGURES AND TABLES