Trajectory Initialization in Adaptive Nonlinear Control *

I. Kanellakopoulos
Electrical Engineering Dept.
University of California, Los Angeles
405 Hilgard Ave.
Los Angeles, CA 90024-1594, USA
(+1-310) 206-5278, (+1-310) 206-8495 (fax)
e-mail: ioannis@ee.ucla.edu

M. Krstić
P. V. Kokotović
Electrical & Computer Engineering Dept.
University of California, Santa Barbara
Santa Barbara, CA 93106, USA
(+1-805) 893-4691, (+1-805) 893-3262 (fax)
e-mail: miroslav@tesla.ece.ucsb.edu

Submitted to *1993 IEEE Mediterranean Symposium on New Directions in Control Theory and Applications*

Keywords: Adaptive control, nonlinear systems, tracking, initialization, transient performance.

Abstract

Transient performance is a critical issue that has only recently started receiving some attention in the adaptive control literature. In this paper, we focus on a very simple means of improving transient performance and reducing control effort: *initialization of the reference trajectory.* Using available information about the initial state of the plant, it is always possible to design a reference trajectory which minimizes the initial values of the error variables in the adaptive system. In the case of model reference control, this is achieved by adjusting the initial conditions of the reference model. If, on the other hand, the reference trajectory is given as a precomputed function of time, then it can be initialized through the addition of exponentially decaying terms which define the *reference transients.*

While it is not clear that traditional adaptive schemes, which only guarantee convergence of the tracking error to zero, benefit from trajectory initialization, such an intialization offers

*This work was supported in part by the National Science Foundation under Grant ECS-91-96178, in part by the Air Force Office of Scientific Research under Grant AFOSR 92-J-0004, and in part by a UCLA Faculty Development Award.

ve controllers introduced in our recent
al stability and tracking for linear and
eters. Furthermore, they guarantee con-
manifold, on which only the parameter
g convergence property is owed to the
struction of a full Lyapunov function

n for initialization. It is comprised of
reference trajectory, so that its value at
een the actual trajectory of the system
e essentially *places the initial point of
point of the system trajectory, thereby*
n turn results in a significant reduction
directly related to the inital value of

utput-feedback designs, and show that
transient performance bounds) can be
system. Specifically, in the full-state-
initial parameter estimation error. In
rence output can be chosen to match
l conditions of the reference trajectory
apunov value to the sum of the initial
t any additional knowledge about the
he initialization procedure to further

consider a third-order example with
y φ is multiplied by an unknown pa-

(1)

rdinates

(2)

$\dot{y}_r, \ddot{y}_r)$

; from the *stabilizing functions* α_1 and α_2. At
, at Step 2, we design α_2 as a control law for x_3.
s designed at Step 3. The actual update law $\gamma\tau_3$
; Step 3, while the intermediate update laws τ_1
g functions. The results of the design procedure

(3)

(4)

$$\frac{\partial \alpha_1}{\partial \hat{a}}\gamma\tau_2 + \frac{\partial \alpha_1}{\partial y_r}\dot{y}_r + \ddot{y}_r \tag{5}$$

(6)

$$\frac{\partial \alpha_2}{\partial z_2}\left(-z_1 - c_2 z_2 + z_3 + \frac{\partial \alpha_1}{\partial \hat{a}}\gamma\frac{\partial \alpha_2}{\partial z_1}\varphi z_3\right)$$

$$\dot{y}_r + \frac{\partial \alpha_2}{\partial \dot{y}_r}\ddot{y}_r + y_r^{(3)} \tag{7}$$

(8)

$$+ z_3^2) + \frac{1}{2\gamma}\tilde{a}^2\,, \tag{9}$$

sed-loop system is

$$_2 z_2^2 - c_3 z_3^2 \leq 0\,. \tag{10}$$

rge to the manifold $M = \{z_1 = 0, z_2 = 0, z_3 = 0\}$,
nzero is the parameter error $\tilde{a}$.
this case. From the definition (1) of the error
we see that by choosing

(11)

$$= x_3(0) + \frac{\partial \varphi}{\partial x_1}(y_r(0))\hat{a}(0)\dot{y}_r(0)\,,$$

$$0) = \tfrac{1}{2\gamma}\tilde{a}^2(0).$$

References

[1] I. Kanellakopoulos, P. V. Kokotović, and A. S. Morse, "Systematic design of adaptive controllers for feedback linearizable systems," *IEEE Transactions on Automatic Control*, vol. 36, pp. 1241–1253, 1991.

[2] I. Kanellakopoulos, P. V. Kokotović, and A. S. Morse, "Adaptive output-feedback control of a class of nonlinear systems," *Proceedings of the 30th IEEE Conference on Decision and Control*, Brighton, UK, December 1991, pp. 1082–1087.

[3] M. Krstić, I. Kanellakopoulos, and P. V. Kokotović, "Adaptive nonlinear control without overparametrization," *Systems & Control Letters*, vol. 19, pp. 177–185, 1992.

[4] M. Krstić, I. Kanellakopoulos and P. V. Kokotović, "A new generation of adaptive controllers for linear systems," *Proceedings of the 31st IEEE Conference on Decision and Control*, Tucson, AZ, December 1992, pp. 3644–3651.