On the Use of a Noncausal FIR Model of the Plant Inverse as a Compensator in Learning and Repetitive Control

R. W. Longman[1] **and B. Panomruttanarug**[2]

Abstract: In feedback control systems, the command given to the system determines a forcing function in a differential equation. The response is a particular solution, and is essentially never equal to the command. Robots in factory operations are given the same commands repeatedly, and hence repeat the same tracking errors many times every day. Iterative learning control (ILC) is a relatively new field which suddenly became very active around 1984, motivated by this problem in robotics. Repetitive control (RC) is a closely related field, that aims to get zero tracking error in following a periodic command, or in following a constant command with periodic disturbances.

The simplest form of ILC and RC can be described as follows. If the error of a robot link at a given time step in the last run (or last period for RC) is 2 degrees too low, then add 2 degrees to the command in the next run. One can prove mathematically that this ILC law converges to zero tracking error for nearly all linear and nearly all nonlinear systems. However, in practice it produces very poor transients, and in the case of repetitive control is nearly always unstable. Hence, in order to make simple learning and repetitive control work in practical applications, one needs to develop some kind of compensator design.

Use of a compensator that is the inverse of the plant transfer function produces an ideal root locus plot, with all roots on the stability boundary going directly into the asymptotically stable region. Unfortunately, the inverse of discrete time transfer functions are almost always unstable, which precludes using this approach. The best solution currently, succeeds in canceling the phase, but not the full system.

This paper develops a noncausal finite impulse response approximation of the plant inverse. By frequency response analysis, it is shown that for typical systems, it is possible to make a very satisfactory inverse model with only a small number of terms. Using a model of feedback controllers of a Robotics Research Corporation robot, it is seen that 20 gains gives very good results, and this number can be reduced very substantially before there is any difficulty with convergence to zero tracking error. Hence, this approach is demonstrated to form a very satisfactory solution to a basic problem in both repetitive control and learning control.

[1] Department of Mechanical Engineering
Columbia University, Mail Code 4703, 500 W. 120th Street, New York, NY 10027, USA
rwl4@columbia.edu

[2] King Mongkut's University of Technology Thonburi, Bangkok, Thailand
Currently, Doctoral Student, Columbia University
bp270@columbia.edu