Model-free iterative control of repetitive dynamics for high-speed scanning in atomic force microscopy

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and actuators—not the properties of the system to be controlled (e.g., mechanical resonances). As an application, we show that our new algorithm improves the speed and accuracy achievable by an AFM scanner.

II. DESCRIPTION OF THE ALGORITHM

A. Linear solver

We begin by describing the existing model-free iterative algorithm for calculating repetitive motion.[10,11] For reasons discussed below, we refer to this algorithm as the "linear solver." The linear-solver routine is initialized by using a naive estimate of the transfer function, $_0 =$. (We assume unity dc gain. A nonunity gain can be absorbed into the definition of .) Subsequent inputs are complex amplitudes $(\omega) \ (\geq 1)$, which are calculated as

$$ = {}_{-1}\frac{}{{}_{-1}},$$

B. Secant solver

We now introduce an alternative model-free iterative algorithm that overcomes this defect of the linear solver. We begin by noting that at each iteration , we seek a set of complex Fourier amplitudes , that leads to an output

$$ _{-1} = \left(\frac{_{-1}}{'\,_{-1}}\right) = -\left(\frac{_{-1}}{'\,_{-1}}\right). \qquad (3)$$

The new secant solver thus reduces to the old linear solver if we set $'_{-2} = {}_{-2} = 0$. This works if the output is a linear function of the control signal $'$, with no offset, but fails when $' = 0$ produces a nonzero output .

(4) We have also examined Muller's method, which generalizes the secant method by fitting a parabola through the last three observations and using the root of that curve as the next iterate. (The secant method uses a straight line through the last two observations). In principle, the higher order of Muller's method should enlarge the basin of stability, implying that a lower accuracy is required of the initial guess. We found that the performance in practice was similar. Since the algorithm is more complicated and needs an extra initial guess, we prefer the secant solver.

(5) The method introduced by Tang ..[12] is also based on the estimation of the Fourier coefficients of the system input $'()$. In a first approach, they also give an algorithm that applies separately to each frequency component. Specifically, they use a proportional-derivative feedback scheme on each error coefficient $(\omega$