# “Intelligent” Adaptive Inverse Control

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At present, the control of a dynamic system (the “plant”) is generally done by means of feedback. This paper proposes an alternative approach that uses adaptive filtering to achieve feedforward control for both linear and nonlinear plants. Precision is attained because of the feedback incorporated in the adaptive filtering.

The control of plant dynamic response is treated separately, without compromise, from the optimal control of plant disturbance. All of the required operations are based on adaptive filtering techniques. Following the proposed methodology, knowledge of adaptive signal processing allows one to go deeply into the field of adaptive control.

In order for adaptive inverse control to work, the plant must be stable. If the plant is not stable, then conventional feedback methods should be used to stabilize it. Generally, the form of this feedback is not critical and would not need to be optimized. If the plant is stable to begin with, no feedback would be required.

If the plant is linear, a linear control system would generally be used. Adaptive inverse control places an adaptive filter whose transfer function converges to the inverse or reciprocal of that of the plant in cascade with it. A simplified schematic representation of the control scheme is shown in Fig. 1. If the controller is indeed an inverse of the plant, the cascade of the controller and the plant will form the identity function. Any deviation from this is considered to be controller error, and is used by an adaptive algorithm to update the controller's transfer function.

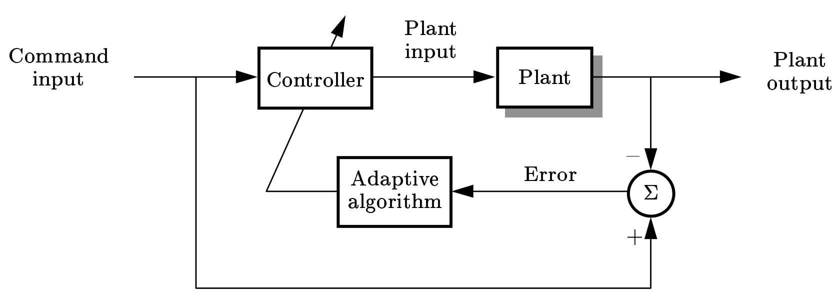


Figure 1: Basic concept of adaptive inverse control.

If the plant is minimum-phase, an inverse is easily obtained. If the plant is nonminimum-phase, a delayed inverse can be obtained. The delay in the inverse results in a delay in overall system response, but this is inevitable with a nonminimum-phase plant. The basic idea can be extended to implement “model-reference control,” by adapting the cascaded filter to cause the overall system response to match a pre-selected model response.

Disturbance in a linear plant, whether minimum-phase or nonminimum-phase, can be optimally controlled by a special circuit that obtains the disturbance at the plant output, filters it, and feeds it back into the plant input.

The circuit works in such a way that the feedback does not alter the plant dynamic response. This sub-system is illustrated in Fig. 2. A model of the plant predicts the plant output and the difference between the model output and the plant output is the estimate of noise and disturbance at the plant output. The estimated disturbance is filtered and combined with the command input in order to cancel the disturbance. Figure 3 shows the square of the output error for a simulated plant. The disturbance canceler was turned on at the 5,000th sample time. Dramatic improvement can be seen.

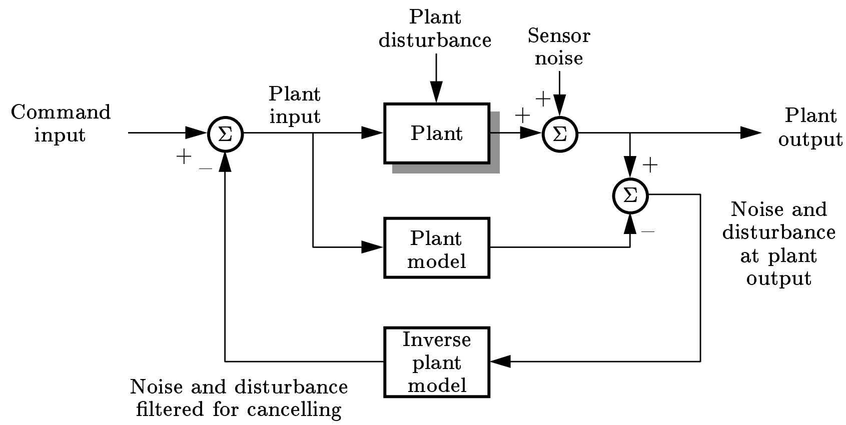


Figure 2: Canceling plant noise and disturbance.

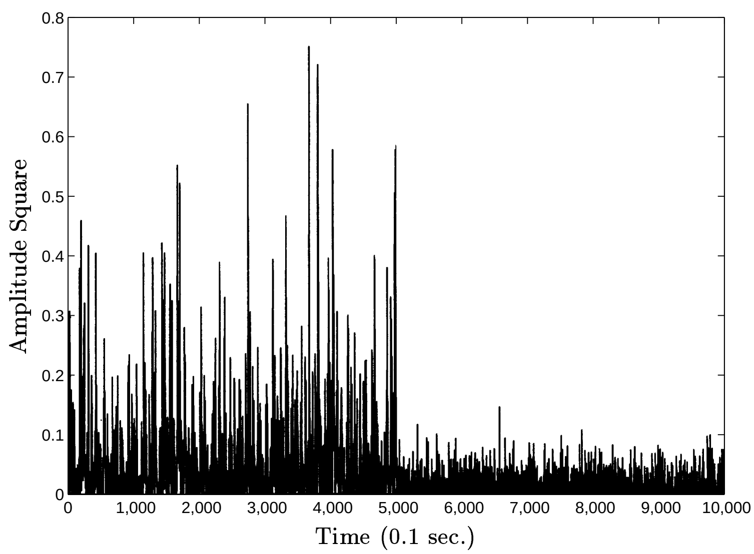


Figure 3: Square of the residual error. Disturbance cancelling began at the 5,000th sample time.

So disturbance control and control of dynamic response can be accomplished separately. The same ideas work for MIMO systems as well as SISO systems.

Control of nonlinear plants is an important subject that raises significant issues. Since a nonlinear plant does not have a transfer function, how could it have an inverse? By using a cascade of a nonlinear adaptive filter with the nonlinear plant, the filter can learn to drive the plant as if it were the plant's inverse. This works surprisingly well for a range of training and operating signals. Control of a dynamic response and plant disturbance can be done. Examples and demonstrations will be presented.

These structures, coupled with simple learning algorithms, show great promise for the control of complicated and highly nonlinear systems. Future work needs to be done to characterize system responses and to establish the optimality of disturbance control. This is very much an open area for research.