CHAPTER 7
NONLINEAR PREDICTIVE NEURAL CONTROL

7.1 Introduction

Predictive control is now widely used by industry and a large number of implementation algorithms, including generalised predictive control (Clarke et al., 1987), dynamic matrix control (Cutler and Ramaker, 1980), extended prediction self-adaptive control (Keyser and Cauwenberghe, 1985), predictive function control (Richalet et al., 1987), extended horizon adaptive control (Ydstie, 1984) and unified predictive control (Soeterboek et al., 1990), have appeared in the literature. Most predictive control algorithms are based on a linear model of the process. However, industrial processes usually contain complex nonlinearities and a linear model may be acceptable only when the process is operating around an equilibrium point. If the process is highly nonlinear, a nonlinear model will be necessary to describe the behaviour of the process.

Recently, neural networks have been used in some predictive control algorithms that utilise nonlinear process models (Hunt et al., 1992; Willis et al., 1992; Liu and Daley, 2001). Alternative design of nonlinear predictive control algorithms has also been studied (McIntosh et al., 1991; Morningred et al., 1991; Proll and Karim, 1994; Liu et al., 1996a, 1998b). However, in most algorithms for nonlinear predictive control their performance functions are minimised using nonlinear programming techniques to compute the future manipulated variables in on-line optimisation. This can make the realisation of the algorithms very difficult for real-time control.

This chapter considers neural network based affine nonlinear predictors so that the predictive control algorithm is simple and easy to implement. The use of nonlinear programming techniques to solve the on-line optimisation problem is avoided and a neural network based on-line weight learning algorithm is given for the affine nonlinear predictors. It is shown that using this algorithm, both the weights in the neural networks and the estimation error converge and never drift to infinity over time.

The chapter is organised as follows. Section 7.2 gives a brief introduction to linear predictive control. Section 7.3 presents the structure of the affine nonlinear predictors using neural networks. The predictive neural controller is described in Section 7.4. Section 7.5 develops the on-line weight learning algorithm for the neural networks used for the predictors and includes analysis of the properties of the algorithm. The design of nonlinear predictive control using ‘growing’ neural networks is illustrated in Section 7.6. Finally, Section
7.7 gives a simulated example to show the operation of the neural network based predictive control.

### 7.2 Predictive Control

Based on an assumed model of the process and on assumed scenario for the future control signals, predictive control gives a sequence of control signals for discrete systems. Only the first control signal is applied to the process and a new sequence of control signals is calculated when new measurements are obtained. For continuous systems, the predictive control concept is also similar. Clearly, predictive control belongs to the class of model-based controller design concepts, where a model of the process is explicitly used to design the controller.

One of the important features of predictive control is that its controller is relatively easy to tune. This makes predictive control very attractive to a wide class of control engineers and even for people who are not control engineers. Predictive control has other features as follows:

(a) The predictive control concept can be used to control a wide variety of processes without taking special precautions, for example, SISO or MIMO processes, stable or unstable processes, minimum or nonminimum phase processes, and linear or nonlinear processes.

(b) Predictive control can handle process constraints in a systematic way during the design of the controller, which is rather important for industrial process control.

(c) Within the framework of predictive control there are many ways to design predictive controllers, for example, generalised predictive control, dynamic matrix control, and unified predictive control.

(d) Feedforward control action is introduced to predictive control in a natural way to compensate measurable disturbances and to track reference trajectories.

(e) Predictive control can easily deal with pre-scheduled reference trajectories or set points of processes by making use of prediction.

The way predictive controllers operate for single-input single-output systems is illustrated by Figure 7.1. It shows that the control sequences 1 and 2 designed using the past input output data produce different output sequences 1 and 2, respectively. This implies that if the future controller sequence is planned correctly at time $t$ the system output will be very close to or exactly the desired reference trajectory. Predictive controllers are usually used in discrete time. It is also possible to design predictive controllers for use in continuous time. This section gives a brief introduction to predictive control for linear discrete systems.

Let us consider the following single-input single-output discrete-time linear system: