Fuzzy Prediction of Timeseries

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Abstract

This paper presents an approach to time series extrapolation based on fuzzy control. The standard exponential averaging scheme is inflexible in that it gives a fixed weight to past history, thus ignoring transient phases in system dynamics. We present a modification to the scheme where the control parameter of the averaging scheme is dynamically adjusted by a simple fuzzy logic controller. The design of the controller is described, and the scheme is evaluated by simulation on test workloads and by application to the real-world problem of flow control in communication networks. We also study the sensitivity of our system to its descriptive parameters.

1 Statement of the Problem

A frequently occurring problem in many areas of the physical sciences is that of extrapolating a time series into the future, given that the observed values can be corrupted by noise. Consider a scalar variable θ that assumes the sequence of values $\theta_1, \theta_2, ..., \theta_k, \theta_{k+1}$ and can be represented as

$$\theta_{k+1} = \theta_k + \omega_k$$

where ω_k is a random variable from some unknown distribution, called the *system perturbation*.

Suppose that an observer sees a sequence of values $\{\tilde{\theta}_k\}$ and wishes to use the sequence seen so far to estimate the next value of θ. In many cases, the observed sequence is corrupted by some noise (introduced by the measurement process), so that the observed value $\tilde{\theta}_k$ is not the actual value θ_k. We represent this by

$$\tilde{\theta}_k = \theta_k + \mu_k$$

where μ_k is another random variable from an unknown distribution, referred to as the *observation noise*.

Since the perturbation and noise variables can be stochastic, the exact value of θ_k cannot be determined. What we require, instead, is that $\hat{\theta}_k$, the predictor of θ_k, be optimal in some sense.

2 Classical approach

The standard solution to this problem is to use a Kalman predictor or one of its many variants [1] [3]. This is optimal in the sense that the expected squared error in $\hat{\theta}_k$ is zero. However, the system perturbation and observation noise variables must be from a zero mean, gaussian, white noise distribution and the observer must supply the variances of the system perturbation and the observation noise (though if the noise is colored, the Kalman predictor is still the optimal *linear* predictor of θ_k).

The robustness of the method has made it very popular in the control literature, but it requires the system and observation noise variances to be known in advance. One cannot obtain these values simply by looking at past observations, since the sequence $\{\tilde{\theta}_k\}$ is the result of both the system perturbation and the observation noise. A simple analysis shows that in such a case, the variance of each component cannot be extracted.

In this paper we consider a new approach to prediction based on fuzzy control. The approach is simple, yet it affords much generality, and we believe that it can be applied to a number of practical problems.

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