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# Neural solution to the target intercept problems in a gun fire control system

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**Abstract**

Time delay neural networks trained with the backpropagation algorithm are derived for the gun fire control system to correct the miss distance between a target and the projectiles from the gun. Its performance is compared to optimum linear filter based on minimum mean square error [R.E. Kalman, A new approach to linear filtering and prediction problems, J. Basic Eng. 82D (1960) 35–44.]. The structure of the proposed neural controller is described and performance results are shown.


*Keywords:* Closed-loop fire control; Kalman filter; Time delay neural network

## 1. Introduction

The principle of adjusting input controls on the basis of output performance is well known [2,11,16,10]. Although it is a deceptively simple concept, new applications continue to occur, due not only to improvements in our understanding and modeling of physical systems, but also to the numerous analytical techniques developed in recent years. Many contributions have come in the area of stochastic optimal estimation and control. The problem to be addressed in this paper involves the on-line derivation of gunfire control adjustments to minimize the miss distance between a target and the projectiles from the gun. The feedback signal would be derived from direct measurements of system performance, and would be used to adjust or modify the fire control orders. The basic idea is to determine aim corrections that improve overall system performance by continuously measuring firing results and by taking advantage of prior knowledge of the gun process parameters.

The gun system is comprised of the target tracking radar, the gun fire control system, and the gun itself. By adding a miss distance measuring capability—which is practical—the feedback control concept that is to be considered is shown in Fig. 1. The modified system incorporates prediction of gun error and includes this prediction in the gun orders from the fire control system. It is noted that the radar, fire control, and gun constitute an open loop fire control system; the new components provide closed loop gun fire control of gun error, but the total system remains an open loop control system with respect to the basic gun fire control operation. Recent developments in electronic spotting have demonstrated accuracy and precision in measuring performance, but the utility of such measurement in predicting performance depends on the inherent correction in the gun process itself.

The problem to be overcome involves the on-line derivation of gunfire control adjustment to minimize the miss distance between a target and the projectiles. It is well known that such problems exist, but little has been done to overcome them, primarily since they are a fairly complex stochastic process and the nonlinear process [1,3].

This paper suggests the use of time delay neural network for computing the corrected gun order with gun process. The neural network not only uses all possible past data but also does not effect the nonlinear properties of gun error processes [5,14,18].

This paper is organized as follows. The gun process model is described in Section 2. In Sections 3 and 4, basic CLFC system design concept considered in this paper and neural methods are summarized. The results are shown in

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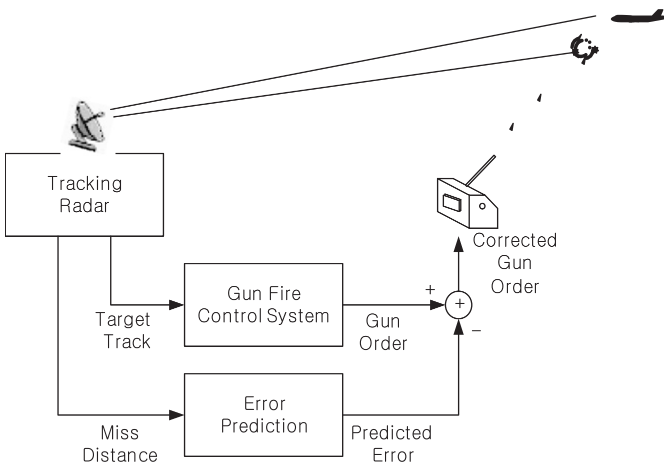


Fig. 1. The closed loop gun fire control system using the measured miss distance.

Section 5. Finally, the discussion and the conclusion are given in Section 6.

## 2. Gun process

The gun system performance is miss distance in range, elevation and azimuth at warhead detonation. A mathematical model of gun system performance is a vector valued discrete random process for which the components of the vector represent the different components of performance, and the successive discrete values of time correspond to the successive projectiles in a firing sequence. It will be assumed that the several components or channels of performance are independent; for instance, a miss in azimuth is assumed independent of a miss in elevation or range. It will therefore suffice to analyze a typical performance component. This assumption of independent channels is certainly consistent with an attempt to require minimal definition of the parameters of the process, but also seems to be a reasonable assumption based on empirical data.

A typical channel can then be described by a scalar random process, denoted $\{X_n; n = 1, 2, \ldots\}$, where the time dependence is suppressed in favor of the integer index, $n$, and $n$ identifies the projectiles in the order they are launched. $X_i$ is therefore one of the components of performance of the $i$th projectile and of course is a random variable.

The second significant assumption is that the gun process $\{X_n; n = 1, 2, \ldots\}$ can be represented as the sum of two processes: an aiming process that will be denoted $\alpha_n$; and a ballistic process that will be denoted $\beta_n$. Each will of course be a discrete random process, giving

$$X_n = \alpha_n + \beta_n. \tag{1}$$

It should be noted that the assumption of an ideal fire control system is key to the mathematical form for the gun process given equation (1). Specifically, the representation of the stochastic process as perturbation from a known, nonstochastic function of time amounts to one of the following assumptions. First, a bias error does exist (which could be a function of time) but is measurable during the engagement and can be corrected for; or second, there is no bias error. The $\alpha$-process will in general be a correlated process and could represent such systematic and time dependent effects as gun temperature and wear, air density and wind variability, and all such phenomena that ideal representation and ideal processing by a perfect fire control system could nullify. The $\beta$-process has no correlated component and represents performance variability among the individual projectiles due, for instance, to variability in aerodynamic characteristics. However, for present purposes it is not necessary to exactly define these processes in physical terms. What will be required is a precise specification of the statistical characteristics of these processes.

### 2.1. Ballistic error $\beta$-process

The $\beta$-process represents noise-like components of error that are statistically orthogonal. That is, denoting the expected value operating by $E\{.\}$, the mean value is specified by

$$E\{\beta_i\} = 0; \quad i = 1, 2, \ldots \tag{2}$$

and orthogonality by

$$E\{\beta_i\beta_j\} = \begin{cases} \sigma_\beta^2; & i = j, \\ 0; & i \neq j. \end{cases} \tag{3}$$

Note that the variance is independent of $i$ (that is, time) and that no assumption is made regarding either the density or distribution functions for the $\beta$-process.

### 2.2. Aiming error $\alpha$-process

The $\alpha$-process embodies all factors that contribute to statistical correlation in the gun process. Its statistical specification must also reflect the acute problems of empirically describing the gun process, and so will be assumed to be first-order Markov, one of the mildest assumptions beyond orthogonality. The $\alpha$-process can be modeled as a linear combinations of the previous variate and a new random variable, $\theta$, that is orthogonal to all preceding variants, as follows:

$$\alpha_n = C_n\alpha_n - 1 + K_n\theta_n, \tag{4}$$

where $C_n$ and $K_n$ are scalars that could depend on $n$, and $\theta_n$ is the $n$th random variable in the sequence $\{\theta_n; n = 1, 2, \ldots\}$, specified by

$$\begin{cases} E\{\theta_n\} = 0, \quad n = 1, 2, \ldots, \\ E\{\theta_n\theta_m\} = \begin{cases} \sigma_\theta^2; & n = m, \\ 0; & n \neq m. \end{cases} \end{cases} \tag{5}$$

It must also be noted that the random variables $\theta_i$ and $\theta_j$ are orthogonal for all values of $i$ and $j$. Further simplifying