

ADAPTIVE ESCALATOR STRUCTURE  
FOR LINEAR PREDICTION

*zw*

by

DAE HEE YOUN

B.S., YONSEI UNIVERSITY, 1977

---

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Electrical Engineering

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1979

Approved by:

*Hasin Ahmed*  
Major Professor

Spre. Coll.

LD

2668

.R4

1979

V67

C.2

I would like to dedicate this work  
to my parents and my wife.

## TABLE OF CONTENTS

| Chapter   | Page |
|---|------|
| 1. INTRODUCTION . . . . .                               | 1    |
| 2. DIAGONALIZATION OF SYMMETRIC MATRICES . . . . .      | 8    |
| 3. DIAGONALIZATION OF AUTOCOVARIANCE MATRICES . . . . . | 12   |
| 4. ESCALATOR STRUCTURE DERIVATION . . . . .             | 14   |
| 5. ADAPTIVE ESCALATOR STRUCTURES . . . . .              | 19   |
| 6. EXPERIMENTAL RESULTS . . . . .                       | 21   |
| 7. CONCLUSIONS . . . . .                                | 25   |
| APPENDIX A . . . . .                                    | 26   |
| APPENDIX B . . . . .                                    | 29   |
| REFERENCES . . . . .                                    | 33   |
| ACKNOWLEDGEMENT . . . . .                               | 35   |

## LIST OF FIGURES

| Figure  | Page |
|---|------|
| 1-1. Predictor configuration . . . . .  | 2    |
| 1-2. Tapped delay predictor . . . . .   | 2    |
| 1-3. Lattice predictor for the delay parameter $\Delta=1$ . . . . .                             | 4    |
| 1-4. Prediction considerations via an escalator structure<br>for $\Delta=1$ and $N=3$ . . . . . | 6    |
| 2-1. Pertaining to computation of $W$ , $W_1$ and $D$ . . . . .                                 | 11   |
| 3-1. A ULT transform interpretation . . . . .   | 12   |
| 4-1. ULT transform implementation in factored form . . . . .                                    | 14   |
| 4-2. Signal flowgraph to implement the ULT transform<br>in factorized form . . . . .            | 16   |
| 4-3. Escalator predictor for $N=3$ and $\Delta=1$ . . . . .                                     | 18   |
| 5-1. Adaptive escalator predictor (AEP) . . . . .   | 20   |
| 6-1. Power density spectrum of input data . . . . .   | 22   |
| 6-2. Input and outputs of ALP and AEP . . . . .   | 23   |
| 6-3. Learning curve . . . . .   | 24   |

## CHAPTER 1

### INTRODUCTION

The adaptive linear predictor configuration shown in Fig. 1-1 is a scheme which has found a variety of applications, such as line enhancement [1], spectral estimation [2], speech enhancement [3], and intrusion detection [4]. An integral part of the adaptive predictor is a finite impulse response (FIR) filter, whose coefficients (weights) are updated continuously via a variety of algorithms. They can be updated, for example, using information related to the prediction error  $e(k)$  (see Fig. 1-1), using Widrow's least-mean-square (LMS) algorithm [1]. Information pertaining to the input correlation matrix  $\Sigma_{xx}(k)$  can also be used, as is the case with a class of sequential regression (SER) algorithms [5,6], one of which [5] is also referred to as Godard's algorithm [7]. The LMS and SER filters are usually implemented in the form of a tapped delay line model (see Fig. 1-2), where  $g_i(k)$  denotes the  $i$ -th filter coefficient (weight) at time  $k$ ,  $N$  is the number of weights, which also equals the number of past values  $x(k-1)$ ,  $x(k-2)$ , ...,  $x(k-N)$  used to predict  $x(k)$ . This class of filters is optimum in that if the input is stationary,<sup>†</sup> then the predictor weights (or their expected value in the LMS case) converge to the Wiener solution.

Since the SER algorithms utilize information related to the input correlation matrix  $\Sigma_{xx}(k)$  to update the filter weights, their implementations involve matrix operations. In contrast, the LMS algorithm involves

---

<sup>†</sup> i.e., the input correlation matrix is positive definite.

**THIS BOOK  
CONTAINS  
NUMEROUS PAGES  
WITH DIAGRAMS  
THAT ARE CROOKED  
COMPARED TO THE  
REST OF THE  
INFORMATION ON  
THE PAGE.**

**THIS IS AS  
RECEIVED FROM  
CUSTOMER.**

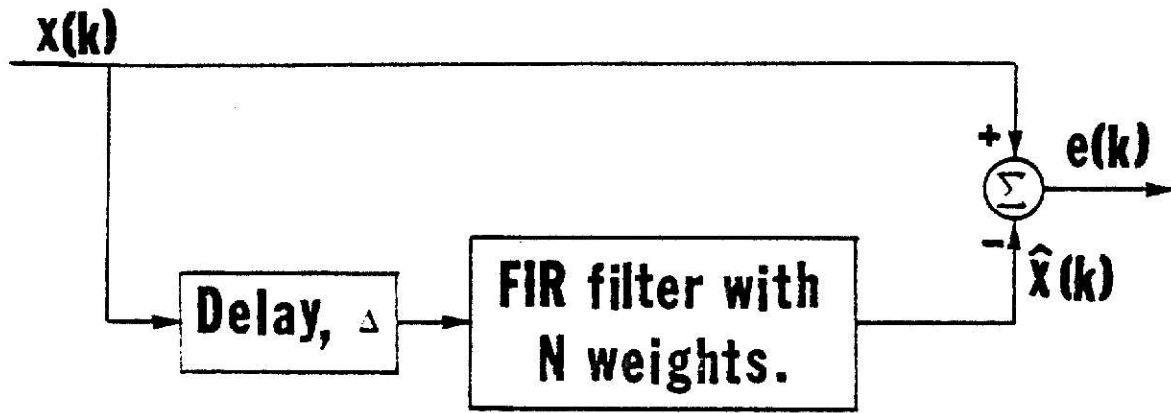


Fig. 1-1. Predictor configuration.

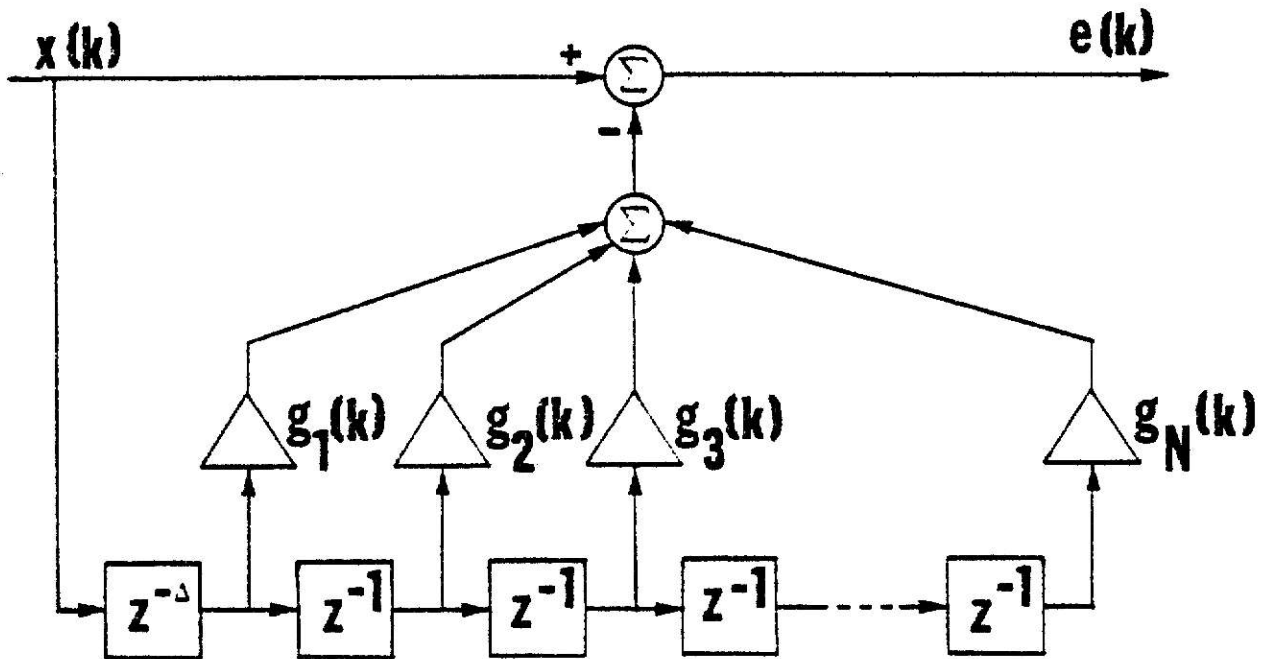


Fig. 1-2. Tapped delay line predictor.