Chapter 13
Development of Nonlinear Filtering Algorithms of Digital Half-Tone Images

E. P. Petrov
Vyatka State University, Russia

E. V. Medvedeva
Vyatka State University, Russia

I. S. Trubin
Vyatka State University, Russia

S. M. Smolskiy
Moscow Power Engineering Institute, Russia

ABSTRACT

This chapter is devoted to solving the problem of algorithms and structures investigations for Radio Receiver Devices (RRD) with the aim of the nonlinear filtering of Digital Half-Tone Images (DHTI) representing the discrete-time and discrete-value random Markovian process with a number of states greater than two. At that, it is assumed that each value of the DHTI element is represented by the binary g-bit number, whose bits are transmitted via digital communication links in the presence of Additive White Gaussian Noise (AWGN). The authors present the qualitative analysis of the optimal DHTI filtering algorithm. The noise immunity of the optimal radio receiver device for the DHTI filtering with varying quantization and dimension levels is investigated.

INTRODUCTION

The assumption in synthesis of algorithms and devices for the one-dimension (per line) optimal and quasi-optimal digital half-tone image filtering that the filtering process represents the discrete valued Markovian Process (MP) with several states, has no a practical significance. It however permits better understanding of the synthesis approach of more complicated algorithms and structures of static and dynamic digital half-tone image filtering. That notwithstanding, we shall assume that the sample volume of the discrete multi-level MP is limited (for example, by the image line length) and each sample can be represented by the binary g-bit number, whose bits are transmitted through digital communication links in the presence White Gaussian Noise (WGN). The realization of a line (a column) of the digital half-tone image can be an example of such processes.

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First solutions of the continuous prototype of this type of problems for binary signals were obtained by Stratoniovich, Kulman, Tikhonov, Yarlykov, Sosulin, and others (Kulman, 1961; Stratonovich, 1959, 1960; Tihanov, 1970; Yarlykov, 1980). The filtering equations in (Kulman, 1961; Stratonovich 1959, 1960; Tihanov 1970; Yarlykov 1980) represented in the continuous form are rather complicated in realization and are not suitable for the investigation of the characteristics of pulse signal processing devices. Moreover, the absence of qualitative and quantitative features does not permit the evaluation of its effectiveness. Another interpretation of the sequence of multi-level correlated pulse signals is offered in the literature (Trubin et al, 2004; Petrov, Trubin, & Butorin, 2005; Petrov, Trubin, & Chastikov, 2007; Petrov, Trubin, & Tikhonov, 2003). The discrete signal parameter can be approximated in them via the Markov chain (MC) with several states. Equations of nonlinear filtering for the uniform MC with two equiprobable states obtained in (Petrov, Trubin, Butorin; 2005; Petrov, Trubin, & Chastikov; 2007), and devices for binary correlated signal filtering synthesized on its basis had demonstrated a high efficiency, have the simple structure, are suitable in implementation and research. The significant peculiarity of the filtering devices synthesized in (Petrov & Trubin; 2007; Petrov, Trubin, & Butorin; 2005; Petrov, Trubin, & Chastikov; 2007) is the presence the nonlinear function unit, which contains all *a priori* data about statistics of the filtered process. This creates the favorable conditions for investigation of the filtering efficiency, its stability to variation of *a priori* data and to construction of the adaptive filtering algorithms. The structure of filtering devices in (Petrov, Trubin, & Butorin, 2005; Petrov, Trubin, & Chastikov, 2007) is such that it can serve as a basis for construction of filtering devices of multi-dimension DHTI.

EQUATIONS OF ONE-DIMENSION NONLINEAR FILTERING OF THE DISCRETE-VALUE MARKOVIAN PROCESSES

Now we suppose that a discrete parameter of pulse correlated signals, which are adequate to elements of static and dynamic DHTI, represents the uniform Markovian chain with the finite state number and the finite dimension. It is necessary to obtain the filtering equations of such signals and to synthesize the filtering device structures for DHTI recovering, which are distorted by the additive WGN $n\left(t\right)$ with zero mean value and the variance σ_n^2.

Let us consider the per line (one-dimension) DHTI filtering. Let the discrete parameter μ_k of the pulse signal $s\left(\mu_k, t_k\right)$ of $k-$ th image element of the independent line takes in the each time step $k = 1 \ldots m-1$ (m is the number of elements in the image line) of operation one of several values $M_1, \ldots, M_N$ with probabilities $p_1, \ldots, p_N$, accordingly. We assume that the process μ_k is the uniform Markovian chain with the given matrix of transition probability (MTP) from the state M_i in $k-$ th sample into the value M_j in $\left(k+1\right)-$ th sample of the following type:

$$\Pi = \begin{pmatrix} \pi_{11} & \pi_{12} & \ldots & \pi_{1N} \\ \ldots & & & \\ \pi_{N1} & \pi_{N2} & \ldots & \pi_{NN} \end{pmatrix}. \quad (1)$$

Signals applied to the RRD input increase the knowledge about the process $\mu_1, \mu_2 \ldots \mu_{k+1}$ compared with *a priori* information. Now this knowledge is defined in the $\left(k+1\right)-$ th time step of