General Approach to Building the Methods of Filtering Based on the Minimum Duration Principle

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Abstract—A new general approach to building the filtering methods has been created on the basis of minimum duration principle. A class of filtering methods for noisy fixed signals was developed within the framework of this approach. The specified class depends on three freely adjustable parameters and includes the known methods of averaging, median, myriad, and meridian filtering. The efficiency of the proposed approach is achieved by the adjustment of free parameters to their optimal values that depend on the noise scale (dispersion), magnitude of the weight of tails and distribution law waveforms. The general statement and partial statements of the problem of filtering the noisy fixed signal were formulated for a discrete case. The above statements were presented in the form of appropriate optimization problems. Numerical simulation results for the filtering problem of fixed signal distorted by the Gaussian, Laplace, Cauchy noises and mixtures of these noises were also presented.

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INTRODUCTION

Modern trends in the field of development of signal and image processing methods are determined by the practical need of effective filtering of noises with "heavy" tails. The beginning of these trends was initiated by Huber's studies [1, 2], where the idea of robust data processing based on the generalized maximum likelihood method known as M-estimation technique was formulated. The myriad filtering [3, 4] and median filtering [5, 6] methods are among the latest developments. These methods are based on the maximum likelihood principle on assumption that distorted data are independently distributed by the Cauchy law and by the meridian law, respectively.

Despite the common properties, each of these methods represents an individual class of nonlinear filtering techniques with one freely adjustable parameter related to the parameter of distribution law scale. Paper [7] proposes a class of filtering methods that contains the methods of myriad and meridian filtering as particular cases. This class includes two freely adjustable parameters related to the scale parameter and the constant of tail "weight" of the Cauchy generalized distribution law.

This paper presents a new general class of nonlinear filtering methods depending on three freely adjustable parameters. In this class, the first two parameters coincide with the above-specified parameters, while the third parameter is related to the distribution law waveform. Unlike that in [7], the new class is based on the minimum duration principle employing the notion of signal quasi-duration and implemented through the mechanism of cost functions, rather than on the maximum likelihood principle [8].

This study pursues several objectives: firstly, the presentation of a new approach towards building the filtering methods; secondly, the generalization of known methods of filtering; thirdly, the efficiency analysis of methods of the proposed class for the case of noisy fixed signal.

1. PROBLEM STATEMENT

The mathematical statement of tackled problem is based on formalization of "signal duration" notion. Two variants of this notion designated as "rigorous duration" and "quasi-duration" of signal [8] are used in this study.

Rigorous duration D of arbitrary signal s(t) is determined as a measure of the set of its nonzero values. In terms of mathematics quantity D is a functional [8]: