Chapter 5
Statistical Characteristics of Optical Signals and Images in Machine Vision Systems

Tatyana A. Strelkova
Kharkiv National University of Radio Electronics, Ukraine

Alexander P. Lytyuga
Kharkiv National University of Radio Electronics, Ukraine

Alexander S. Kalmykov
Kharkiv National University of Radio Electronics, Ukraine

ABSTRACT

The chapter is devoted to the creation of a comprehensive approach to the physical and mathematical description of signals in optoelectronics in machine vision, taking into account the phenomena of interaction of optical radiation with system elements. A new methodology for the study of the statistical properties of input and output signals in optoelectronic systems is proposed, taking into account the availability of grouped statistical properties that do not obey the Poisson statistics. The basis is the joint use of wave and corpuscular description of signals in systems, stochastic flow theories, and elements of statistical detection theory. Information and energetic technology have been developed that integrates the theoretical justification of signal description under various observation conditions and decision-making methods.

INTRODUCTION

The monograph is devoted to the creation of a comprehensive approach to the physical and mathematical description of signals in machine vision optoelectronic, take into account the phenomena of interaction of optical radiation with system elements. A new methodology for the study of the statistical properties of input and output signals in optoelectronic systems is proposed, taking into consideration the availability

DOI: 10.4018/978-1-7998-6522-3.ch005

of grouped statistical properties that do not obey the Poisson statistics. The basis is the joint use some aspects of stochastic flow theory, and elements of statistical detection theory. Information and energetic technology have been developed that integrates the theoretical justification of signal description under various observation conditions and decision-making methods. We have considered the application of the developed stochastic models in applied problems: formation and analysis of signals and images; detection of signals against the interference in various observation conditions, and properties of photosensitive and optical elements.

The problematic issues that arise when registering objects are related to changes in statistical behavior of both signals and interference. The authors propose an approach to the description of the statistical characteristics of the output signals, taking into account the presence of grouped statistical properties of optical radiation. Stochastic models of output signals of optoelectronic systems are based on the analysis of Poisson fluxes with modified dispersion. The analysis of such stochastic processes is based on the process of generating a random variable under the conditions of applicable generalized limit theorems, which use the family of stable distribution laws as limit distributions. When random processes describing the operation of a stochastic system are non-Markovian.

The first section focuses on determining the directions for improving and developing optoelectronic systems. The analysis of methods aimed at increasing the efficiency of optoelectronic systems has been carried out, and the factors constraining the development and improvement of systems have been determined. The constraining factors include physical processes that affect the formation of output signals of systems; statistical instability of signals received by systems and ambiguity of methods of their description (for example, presence of groupings, correlations of photons); uncertain state of the input optical radiation; technical limitations of elements of optoelectronic systems in machine vision. The scientific and technical problem aimed at eliminating contradictions in the existing theoretical methods of receiving and processing signals and experimental data has been posed. Research problems are formulated.

The second section contains the systematization of theoretical methods underlying the description of the input and output signals of optoelectronic systems.

The analysis of theoretical methods for describing input signals with allowance for corpuscular and wave properties has been carried out. The wave theory makes it possible to describe the processes of diffraction and interaction of the field with matter; the corpuscular theory takes into account the absorption processes, since the optical range quantum energy is sufficiently large.

An analysis of the methods for describing the output signals has been made with the consideration of the statistical properties of the signals. The main attention has been paid to statistical models based on the Poisson, Gaussian, log-normal, negatively binomial, Bose-Einstein distributions. Fluctuations in the background and signal components are characterized by distribution laws with finite dispersion, and, according to the theory of errors, are united by a central limit theorem.

The principle of signal formation in Optoelectronics in Machine Vision has been considered as a process having the stochastic character of electromagnetic radiation. Spatial-temporal changes in signals, from the position of the corpuscular theory, take into account the conditions of linearity, invariance, physical feasibility, and stability. The relationship between the input and output streams has been defined as stochastic (at the corpuscular description) dependence.

The third section is aimed at carrying out theoretical and experimental studies of the statistical properties of the output signals of optoelectronic systems with a limited dynamic range. Based on the Poisson and Gaussian statistics, theoretical models of interaction of optical radiation with the optical link of the system on the basis of corpuscular descriptions have been compiled. An approach to the