Conference Paper

Methods of Correlation Digital Photonics in the Diagnosis of Complex Medical Conditions

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Abstract

In this paper we analyze the possibility of using special methods and equipment for coherent photonics during working with multiparameter information. Reverse paraphase coding and operational analysis of multiparameter data allow the implementation of various correlation algorithms for photonic medical diagnostic systems - search of precedent, compliance diagnosis, deterministic diagnostics, Bayes and metric algorithms. The results of experimental studies of medical diagnostics and prediction of complex situations are presented. Such analysis is carried out with the help of vector-matrix multiplication by the methods of laser photonics. It is significant that with the extension of the range of probability algorithms, it is possible to preserve the main advantages of the holographic method: multidimensionality, high speed, efficiency and reliability. Photonics methods in diagnostics have particular importance in connection with the development of the first sample of a photonic processor.

Keywords: laser photonics, correlation, coherence, optical computing, photonic processor

1. Introduction

Coherent laser radiation is effectively used in various types of medical diagnostics - optical coherence tomography, blood examination, studying the condition of the skin and teeth, etc. [1-3]. Photonics methods are suitable for diagnosis in the general case. They do not impose any restrictions on the statistical function of the state of the system and allow analyzing information presented in a universal multiparameter form. This is very important and useful for rapid analysis and recognition of images in medicine and other complex situations. In recent years there has been a shift from simple image recognition and processing devices to the development of complex systems for analyzing multiparameter information. In general, such analysis can be carried out by means of vector-matrix multiplication [4, 5]. The possibility of realizing this process by the methods of laser photonics, shown in [5, 6], makes it possible to extend the range of probability algorithms while preserving the known advantages of the holographic method, such as multidimensionality, efficiency, high information capacity, visibility and flexibility in presenting the result.

2. Algorithms of holographic memory

Laser holography provides unique opportunities for parallel processing of two-dimensional data sets, simple implementation of the correlation algorithm, providing fast processing of information and a record high memory density. In medicine, the diagnosis and prognosis of a patient's condition is determined by the combination of a large number of different parameters. In this regard, it is necessary to take into account a large number of different combinations of parameters and the possibility of comparing this multiparameter picture with past experience. Ideally, the first step is to determine the informative weight of each characteristic.

However, the search for the most informative signs is an insoluble problem not only in the general case, but also for most specific situations. In addition, often the informative weight of a particular symptom depends on the final diagnosis. A real approach requires increasing the number of parameters, which increases redundant information and creates two kinds of difficulties. First, the number of analyzes can not be infinitely large, especially if the number of patients is large and an operational diagnosis is needed. Secondly, with increasing excess information, the required power of the processing system exponentially grows with the number of parameters. In view of these circumstances, the merits of the holographic method become fundamentally necessary.

In the general case, statistical processing of multiparameter information can lead to multidimensional distributions. In the simplest case, we must decide whether the situation corresponds to a certain set of symbols belonging to or outside the class.The simplest algorithm for diagnosing is the use of precedent. This is the only algorithm in which the amount of information processed is almost equal to the capacity of data storage. The number of possible states of the system is qm, where q is the number of possible values of a certain parameter, m is the number of parameters. Such algorithm does not require preliminary processing of the original data, but imposes the most stringent requirements on memory capacity. Diagnostic procedures based on metric or probabilistic methods are more acceptable. The most reliable probabilistic algorithms based on the Bayes theorem, according to which the information contained in the symbol Si (or in the symbol system - S), provided that the disease Bj takes place, is equal to the information contained in the diagnosis of Bj, provided that the symbol Si (or system of symbols - S) takes place.

The most attractive algorithm is algorithm for correspondence determining [7, 8]. This is the most general case of classification, which imposes no restrictions on the characteristic independence of the parameters. At the same time, this algorithm does not need to measure the intensity in the correlation plane and gives information about the exact resultant estimate and its probability. This algorithm does not limit the form of the original statistical distribution and makes it possible to take into account the form of a specific statistical distribution in determining the probability of the resulting diagnosis. This algorithm combines the advantages of deterministic and probabilistic methods, but requires the most serious mathematical processing of the initial statistical information.

A comparative evaluation of the possibilities of photonics algorithms is given in the table. It contains a list of tested algorithms in descending order of the necessary amount of information corresponding to a constant number of processed data.

Table 1: Comparative characteristics of holographic memory algorithms.

Algorithm of diagnosing	Probability information Result	Information capacity parameters	Mutual independence Parameters
Search for precedent	-	+	+
Matching diagnosis	+	+	+
Deterministic diagnostics	-	+	±
Diagnosis of Bayesian	+	+	±
Measuring the Hamming distance	+	±	±

In this table, the sign "+" means the possibility of realization, the "-" sign corresponds to the impossibility of realization, the "±" sign means the possibility of implementation, but due to the increase in the information capacity of the input transparency.

3. Implementation of diagnostic algorithms using photonics

In general case, photonics methods are suitable for diagnosing without restrictions on the statistical functions of the system states (the correspondence method), and also for cases when the distribution is represented as a histogram (deterministic method) or the parameters of the system are statistically independent (Bayesian method), or the volume of statistical samples has limited size (metric method). It is important that the system retains all the known advantages of the holographic method. The procedure for diagnosis by photonics includes the following steps:

1. Data preparation and formalization.
2. Encoding and recording of data source - the formation of memory.
3. Operative coding of results of examination of a patient on a dynamic transparency - data entry.
4. Processing the results of the patient's examination and probabilistic comparison with statistical material stored in the archival memory.

The first two stages are preparatory. It is advisable that they be conducted in leading health care institutions and only once, unless it is assumed that memory will be replenished with new data. In the experimental implementation of recording the initial statistical information on a holographic filter and entering data, two cells of a dynamic light modulator are assigned to each parameter. This allows for paraphase coding and normalization of output signals. For modulation, dynamic light scattering is applied by feeding the control potential to the corresponding parts of the input transparency. Individual reference beams are used to record two combined holograms corresponding to a favorable and unfavorable disease prognosis. We have tested the diagnostic system using published data on the diagnosis of liver diseases and distribution, describing stomach diseases. The greatest attention was paid to the direct analysis and prediction of the condition of patients after numerous combined lesions as a result of major catastrophes, when particularly stringent requirements are imposed on the rate of multiparametric analysis. At the first stage, possible states and their results for the patient were determined from a sample of 200 real case histories of the Sklifosovsky institute with 20 parameters each. As a result, a map of medical information was constructed and the matrices of statistical distributions necessary for recording data in holographic memory were compiled. The decision was made taking into account the relative intensity of the correlation signals at the output. Testing on real medical material confirmed the operational efficiency of the multi-parametric photonics system. Comparison with the well-known medical results of the Sklifosovsky Institute showed that the holographic analysis and forecast with such statistical data coincide with the known with an accuracy of more than 80 percent.

4. Summary

In the paper the possibilities of special methods and equipment of coherent photonics are analyzed during working with multiparameter information. Reverse paraphase coding and operational analysis of multiparameter information make possible to implement a number of probabilistic algorithms. The possibility and expediency of realization by photonics methods not only the correlation algorithm, underlying the holographic recognition of images, but also of universal statistical algorithms is substantiated. A comparative analysis of photon systems of medical diagnostics working on a wide class of algorithms is conducted: search for precedent, conformity diagnostics, deterministic diagnostics, probabilistic Bayes algorithm. The results of experimental studies of medical diagnostics and prediction of complex states are presented. Such analysis is carried out with the help of vector-matrix multiplication by the methods of laser photonics. It is significant that with the extension of the range of probability algorithms, it is possible to preserve the main advantages of the holographic method: multidimensionality, efficiency, record high information capacity and speed, visibility and flexibility in presenting the result. The described methods acquire a special urgency in connection with the appearance of the first samples of photonic processors. Methods of coherent photonics can be used not only during working with images, but also when processing information presented in a universal multidimensional form. Our system allows us to realize not only the classical correlation algorithm, but also a number of more sophisticated processing algorithms.Unlike optical methods that work with signals and images in kind, the methods considered allow analyzing information presented in a multiparameter form. Thus, it becomes possible to implement a combined method that combines a record high capacity of holographic memory and the operational implementation of statistical algorithms for processing data using photonics. This universal result acquires an independent significance in connection with the reports [9]. about the development of the first photon processor capable of multiplying the 256-byte vector by a matrix of 256x256 bytes per clock cycle - 8 ns.

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