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Programming model and implementation mechanism for ternary optical computer

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ABSTRACT

In order to make use of the advantages of optical computing and promote the application and popularization of Ternary Optical Computer (TOC), this paper proposes a new computing-data model, presents the corresponding computing-data file in detail, and gives the implementation method of programming application with the model files. It tries to set up a bridge between users and TOC. Experimental results show that the model presented in this paper is correct and the implementation method is feasible. The model can better simplify TOC's application process, and allow users to apply TOC to carry out various computational applications without needing to understand any details of optical implementation.

1. Introduction

In recent years, the hardware of traditional computers is limited by Moore's Law. So researchers are increasingly concerned about the study of new types of computers, such as DNA computer, quantum computer, and optical computer and so on [1–4]. Because of the characteristics of light, such as the high information capability, high parallelism and so on, optical computing has become a common focus.

Compared with electronic computing, optical computing has advantages: low power consumption, numerous data bits, easy expansion, etc. [5–8]. Using the advantages of optical computing, the architecture and theory of Ternary Optical Computer (TOC) were proposed [3,4]. In TOC, information is expressed with two mutually orthogonal polarized light states (such as vertical polarization and horizontal polarization of light) and no-light state [4]. The processor has many data bits and these data bits can be bitwise reconstructed and grouped, and computational function of each data bit can be reconfigured at runtime. This makes TOC own more advantages over traditional computer systems in solving problems that require more resources and computations.

Through many years research, many meaningful achievements on TOC have obtained. Such as Decrease-radix Design Principle [9], data bits management theory [8], decoder [10,11], MSD adder [12–16], vector matrix multiplication [17,18], three-valued programmable cellular automata [19], MSD iterative division algorithm and implementation [20], FFT algorithm implementation and DFT algorithm implementation [21,22], and performance analysis of a TOC [23], design and implementation of positive and negative discriminator of MSD data for Ternary Optical Processor (TOP) [24] and so on.

However, even much progress has been obtained in TOC, the interaction between TOC and user is still relatively weak. This means user must understand the details about the working mechanism and hardware implementation when using TOC. It seriously restricts TOC's application and promotion. In order to solve this problem and make full use of TOC's advantages, a new computing-data model is proposed. Meanwhile the corresponding computing-data file for this model as well as the implementation method for using the model file is designed which successfully establish a bridge between users and TOC. This study lays an important foundation for the application of TOC. The Computing-data file is also called as San Zhi Guang (SZG) file.

2. Related works

Many scholars have conducted extensive studies on optical computation from different perspectives. To eliminate the secondary cache and increase the processor space, literature [25] designs the all-optical memory by using the high-bandwidth optical characteristics. Literature [26] presents a new type of optical chip which is more efficient, faster, and less power consumption compared with traditional chips when performing computing tasks. Literatures [27,28] mention that the optical technology is a three-dimensional reconstruction of the soft

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tissue surface geometry in the minimally invasive surgery (MIS). Optical interconnection technology is used in the literature [29], to meet the need of extended bandwidth of high performance computing systems. Obviously, optical computing not only has good application prospect in high-performance computing and other computing fields, but also is promising in medicine and communications fields.

Literatures [4,30–32] attempt to construct various optical computer systems. In 1984 A A. Sawchuk et al. designed a set of specific optical devices and array devices to implement binary combinations and sequential logic with optical signals as information carriers [33]. In 1986 bimodal optical computer was developed in the United States [34]. In 1988 the possibility of optical calculations to process data was studied [35]. In 2000 the architecture and theory of TOC was proposed [3,4]. In 2009 L. Schares and X J. Zhang developed a complete optical interconnect blade server cluster [36]. Recently, In Russia, non-contact optical scanning technology was invented [37]. In Japan, optical computer mouse was developed [38], and in Turkey and France, a dynamic energy efficient optical line terminal design for optical access network was designed [39]. In Canada, light quantum gates were designed [40], and in Germany, the technology of creating feasible reflectance data for synthetic optical flow datasets was explored [41].

Literatures [42–45] propose implement methods of reconfigurable processor to confirm TOC's advantages: giant data-bits parallel computing and reconfigurable processor. For instance, literature [46] proposes a double-rotator-structure TOP, in which massive data-bit parallel computing and reconfigurable processors are implemented. In TOC research, these studies are independent modules.

From the above description, we can see that many efforts have poured on the study of optical computers from different perspectives. The paper mainly elaborates programming model and implementation mechanism for TOC.

3. Computing-data model

The computing-data model is shown in Fig. 1. From Fig. 1, it is easy to find that the model includes two parts: client and TOC. Client answers for providing calculation requirements and original data. TOC is responsible for executing user's calculation. TOC is a photoelectric hybrid computer. It consists of a master computer and a slave computer. The schematic diagram of the structure is as shown of the right part of Fig. 1.

In the model, the relevant contents of my work include the design of SZG file, the creation of SZG file and the implementation of calculations task in TOC. In implementation process, the author should understand the details about each part of TOC.

The master computer is a PC with a windows operating system. The software running on the PC contains two modules: computing-data file receiver/sender (communication server) and the TOC task management software (TMS) [47]. The SZG file receiver/sender side is responsible for communication. It is for receiving various calculation information from the user and sending result information from TOP. User's calculation information is collected into the user's SZG file. SZG file receiver/sender is the cooperation module of the TOC TMS interacting with the user. The master computer is the operating platform of the TOC TMS, and it is the input platform of user where he inputs operation data, operation type, etc. And it generates control information of an optical processor for the control software of the slave computer. The two modules are separated, which guarantee the SZG file receiver/sender side will not be affected when the upgrade of the TOC TMS. The software of master computer and the control software of slave computer are called as TOC monitoring system.

The slave computer, namely, the TOP, which includes the control software, the TOC operator, the reflector and the TOC decoder as presented in Fig. 1. The TOC operator consists of a few simple basic units whose structure is shown in Fig. 2. There are two optical paths in this structure. The input data a enters the main optical path which is a sandwich structure with two polarizers (P1 and P2) and a liquid crystal (LC). The other input signal b enters the control optical path. According to the values of the reconstructed instruction bits k2 and k3, S selects one of the output signals from g1, g2 and g3 and sends the selected signal to Y. Output signal of Y is used to control the optical rotation of LC in the main optical path. When the reconstruction instruction bit k1 is 1, Y makes the S output signal negate, and when k1 is 0, S output signal is unchanged. The difference between SBOUs is that the static rotation of LC is opposite, or polarization direction of two polarizers is different. When the user using TOC operator, users need to understand the function of each part of the basic unit. The operands a and b are processed by optical operator to obtain the result data beam C. According to the user's SZG file, the TOC TMS generates the reconfiguration frame and data frame, which are used to control the TOC operator. The reconfiguration frame is used to reconstruct an appropriate optical processor, and the data frame is used for calculation. The binary results generated after the result light beam C are sent to the decoder. And then all results are included into a SZG result file by the TMS which is returned to user program.

From the above description, it can be seen that the details about TOC's working mechanism and hardware implementation are much complex for common users. This seriously restricts the use of TOC. To solve this issue, a computing-data model is proposed. In the model, user only needs to provide calculation requirements and data. User's computational requirements and original data are submitted with a computing-data file, with which TOC accomplishes the corresponding the application. Therefore, user does not have to understand the contents of the dashed box, the computing-data model greatly reduces the difficulty for users applying TOC, SZG file serves as a bridge between users and TOC.

4. Design of computing-data model file

To easily apply TOC, some parameters about user are needed which includes user's file name, priority, and task scheduling policy of the TMS. Calculation label number is to point out how many kinds of operators in the SZG file. Data type indicates user's calculation data type. If user's calculation is a logic operation, it also needs the corresponding three symbols. To return the result to user, the user IP address must also be included. For each calculation label, needed parameters are calculation rules, data bits, data amount, result data bits, and data start address. In addition, calculation data is also needed. With the TOC's development, the SZG file will also be updated. In order to distinguish between different versions, it also should include the version number.

The characteristics of bitwise allocability and reconfigurability of TOP determine that TOP can calculate the user's data once optical operator be reconstructed. On the basis of operation rules, the assigned processor bits are reconfigured into the different operators. And operation rules are the interface which the SZG file provided for various routines. The number of operation types is the basis for allocating operators types. Data type and data bits are the basis for allocating the number of calculator bits. In order to improve the utilization of the components of TOP, the amount of data is the basis for how many such operators are allocated. From the point of allocating processor bits and reconstructing optical processor, it is necessary to contain various operation rules, data bits, data type and data amount and so on. If user requires accurate result, the number of result data bits should be include. In order to access the original calculation data, the data starting address of each operation should be included.

All of above information except calculation data is structured and fixed information, these information is included in the file header. The user's calculation types are various, the data lengths are different, and the calculation accuracy for each calculation type is also different. Therefore, the calculation data and the result data cannot be structured. These data are stored in file body which only includes calculation data or result data. File body also called as data area. The data b is in front of the