Digital Optical Computing at Light Speed Based on Symbolic Substitution

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Symbolic substitution is one of the techniques which can be used to implement the digital optical computing system by utilizing the parallelism of optics. Basically, symbolic substitution is a rule by which the patterns associated with input operands are replaced by new patterns associated with the results of the operation [1]. Some implementations [2] of the digital optical arithmetic processors based on symbolic substitution rely essentially on the conventional ordinary binary number representation. The drawback of these systems is that the processing time for the case of binary addition and subtraction depends on the word size if not on the array size.

The signed-digit number representation proposed by Avizienis in 1961 [3] is one of the weighted number systems and is different from the balanced number system in that the radix r is allowed to be either odd or even, and that the signed-digit number system is based on redundant representation, such that the carry propagation chain is limited to a small portion and highly parallel operation can be performed. It turns out that the modified signed-digit trinary number representation provides better performance and faster computation because of its carry propagation constrained only between adjacent digits due to the redundancy property of the number system.

The modified signed-digit number system requires a set of three different digits $\{\bar{1}, 0, 1\}$ to represent its input operands. Therefore, we need three different symbols which are capable of preventing the crosstalk with minimum signal space. The same symbols presented in [2] can be directly used for this case. Also, increased number of substitution rules have to be involved for the computation, which consequently requires increased optical power.

Nevertheless, all the binary addition and subtraction can be performed in only three stages independent of word size and array size, at the time that light propagates through 3 matched filtering systems. Moreover, the number of substitution rules can be reduced if we use mixed number systems. A smart algorithm will allow binary multiplication based on symbolic substitution. Some results based on this idea will be presented in the near future.

References

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