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SYSTOLIC ARRAY FOR ALL-NEXT-NEIGHBOURS PROBLEM

The all-nearest-neighbours (ANN) problem is a fundamental problem in computational geometry. In the letter a new two-dimensional triangular systolic array with mesh-connected cells is proposed for the ANN problem. This array can process a queue of ANN problems at a throughput of one ANN problem per time period, with an efficiency of 100%.

The all-nearest-neighbours (ANN) problem is a fundamental problem in computational geometry. Given a set of \( N \) points with co-ordinates \( r_1, r_2, \ldots, r_N \), a point \( k \) should be found \((k \in \{1, 2, \ldots, N\})\) which is nearest to point \( i \); the computation should be performed for all \( i, i = 1, 2, \ldots, N \).

Fig. 1 shows a systolic array for this problem. The function of one cell is specified in Fig. 2. The small boxes in Fig. 1 denote delay elements which delay signals by one period. (A period is defined as the time required to execute the function given in Fig. 2.)

The components of the tuple \( a_i \) (Fig. 2) have the following meaning: \( r \) is the co-ordinate vector of a point, \( q \) is the distance between two points, and \( i \) is the point number. The components of \( a_0 \), \( a_1 \) and \( b \) have similar meanings. The distance \( d = |r - p| \) between the point with co-ordinate vectors \( r \) and \( p \) and numbers \( i \) and \( j \), respectively, is computed in the cell. It is compared with the distance \( q \) which is input from the cell above, and the lesser of the two values is output to the cell below. The distance \( d \) is also compared with the distance \( s \), which is input from the cell to the left, and the lesser of these two values is output to the cell to the right.

A tuple \( a_i = (r_i, q_{\text{max}}(i), i) \), \( i = 1, 2, \ldots, N \), which is input in a given cell of the first row of the array (Fig. 1) consists of a co-ordinate vector \( r_i \) of point \( i \), a distance value \( q_{\text{max}} \) which is common for all input tuples and which is equal to or greater than all point-to-point distances of the set, and the number \( i \) of the point. The tuple \( a_i \) is moved downwards in the column and, on leaving it, is input to the row below and is moved to the right (Fig. 3). On its way through the array, \( a_i \) meets all
other tuples $a_j$, $j = 1, 2, \ldots, i-1, i+1, \ldots, N$, and the distances $d_{ij} = |r_i - r_j|$ of point $i$ to all other points of the set are computed in the corresponding cells along the path. Parallel to the formation of these distances, the shortest of them is searched in a bubble-sort manner, and is moved along the path and output as $q_i$ in the corresponding output tuple $a_i' = (r_i', q_i, j_i, k_i)$ from the last cell of the path $(N-1)$ periods after the input of $a_i$. The other components of the tuple $a_i'$ are: $r_i' = r_i$ (co-ordinate vector of point $i$), $j_i = i$ (the number of point $i$), and $k_i = k_i$ (number of the nearest neighbour of point $i$).

A second set of tuples (i.e. a second set of $N$ points) can be input in the array immediately after the first and other sets can follow, so that different ANN problems can be processed in a pipeline manner. After an initial phase of $2N - 1$ periods, during which the input values penetrate into the array, the array can processes a queue of ANN problems at a throughput of one ANN problem per time period. All cells of the array are active in this mode, and the array efficiency is 100%.

A linear systolic array for the ANN problem has been given in Reference 2. It makes use of $N$ cells and computes a single ANN problem in $2N - 1$ time periods, and is capable of computing one ANN problem every $N$ periods when processing a queue of ANN problems. The disadvantage of this array is that the underlying algorithm is embedded at the cost of space-time complexity $N^2$ and the array works with an efficiency of 50%, against $N^2/2$ and 100%, respectively, for the array presented here. The cells used are also somewhat more complex.

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NOVEL FABRICATION METHOD OF QUARTER-WAVE-SHIFTED GRATINGS USING ECR-CVD SiNx FILMS

Indexing terms: Lasers and laser applications, Semiconductor lasers

Quarter-wave-shifted gratings were fabricated by novel methods using ECR-CVD SiNx films. SiNx films deposited on photoresist and grooves have a higher etching rate than those deposited on the flat substrate. We made good use of this difference to fabricate the quarter-wave-shifted gratings with a 240 nm period, about 150 nm depth and narrow transient regions.

Distributed-feedback (DFB) laser diodes are promising dynamic-single-mode (DSM) light sources in long-haul, high-bit-rate optical communication systems in the 1.55 µm wavelength region. However, it has been pointed out theoretically that a conventional DFB laser may lase basically in two longitudinal modes, and that the stability of single-mode operation depends strongly on the phases of corrugations at the mirror facets. 3-5 Quarter-wave-shifted DFB lasers are, in principle, expected to lase in a stable single mode irrespective of the phases at the facets. They have been studied extensively, and several fabrication methods of quarter-wave-shifted gratings have been proposed. One of them is a method utilising the simultaneous exposure of positive and negative photoresist, 6,7 while another made use of a spatial phase modulating mask. 8 In these, complex holographic exposure methods or critical exposing conditions were required.

In this letter we propose two novel fabrication methods for quarter-wave-shifted gratings. These only require a conventional holographic exposure step and simple reproducible processes utilising silicon nitride (SiNx) films by electron cyclotron resonance plasma-assisted chemical vapour deposition (ECR-CVD). 9

Fig. 1 shows the process steps of the fabrication method which we call type 1. First, diluted positive photoresist (MP-1400) was spin-coated on to an InP substrate. Then an ordinary holographic exposure with an He-Cd laser beam (325 nm) and development were performed to make a photoresist corrugation with a period of 240 nm. The SiNx film was deposited on it by ECR-CVD at room temperature (Fig. 1a). After spin-coating the photoresist again, striped patterns parallel to the corrugation were formed by conventional photolithography. In this procedure the SiNx film prevented the photoresist corrosion from being dissolved into the developer. Using these striped patterns as a mask, etching of the photoresist from being dissolved into the developer was performed (Fig. 1b). In the region where the SiNx film was taken off, the InP substrate was etched using SiNx film deposition on resist
b Stripe pattern; etch SiNx
c Etch substrate
d Remove resist; etch SiNx with BHF
e Cover grating; etch substrate

1260 ELECTRONICS LETTERS 19th November 1987 Vol. 23 No. 24