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THE NEW TREND IN PARALLEL SPACE-TIME COMPUTER ARCHITECTURE

Raimundas JASINEVITCHIUS

Computer Engineering Departament,
Kaunas University of Technology,
3028 Kaunas, V. Juro St. 50–204, Lithuania

Abstract. This paper presents the new approach to the analysis and synthesis of a parallel-processing architecture. The novelty of the procedure lies in the generalized space-time system of co-ordinates and the space-time transformation of sets in the system. The parallel space-time computing structures (PASTICS) are introduced, main principles are presented and the functional structure of processing unit is analyzed. Computing in the PASTICS is considered as a minimization of a certain potential function which can be derived from the state-transition and output functions, corresponding to the problem to be solved. The problem of synchronization of different processing units must be solved similarly as it is done in the data-flow control computers. Two important cases of application of the PASTICS are mentioned.

Key words: parallel processing, space-time structure.

1. Introduction. Impressive technological advances in microelectronics and computer engineering fields in recent years have a strong impact upon the high performance computing. So now we gave an opportunity and a possibility to develop the computer architecture satisfying the problem to be solved in the most proper way.

The main approach, which is under the consideration in this article, deals with a computing as a process and as an environment where the process is performed. On the other hand this computing process and the environment as well as an input and output data simulate the behavior of real objects, systems of phenomenon.

High effectiveness of such computer simulation can be achieved if and only if the high adequacy between the reality and the computer architecture together with the computing processes in it is obtained.

The whole real world (and so all real problems are) exists in space and time co-ordinates (see, for example Reichenbach (1956)). This is the reason why we emphasize the importance and necessity to analyze and to synthesize an architecture of the next-generation computers in generalized space-time co-ordinates according to the certain problem or a class of problems to be solved (Jasinevitchius, 1988). The computer architecture developed on this concept we call parallel space-time computer structure – PASTICS for short, which is similar to the French word pastiche, and naturally we are very proud of that.

2. Main principles. The approach most often used in the construction of the PASTICS involves the top-down elaboration of the functional description of a given problem and the iterative covering of each description by the corresponding processing unit (PU). Each functional description must be presented in the canonical form with the name of result on the left side of the expression and the names of arguments subjects to the certain operations on its right side. So the data (names of result or arguments) correspond to the arcs and the operations to the nodes of a certain processing graph (PG). This PG is considered as a result of programming in functional, graphical or block-diagram language (Torrero, 1985; Korn, 1978).

The properties of all PU covering the nodes of the PG can be derived from the original mathematical representation of a problem system. Usually a system Σ is specified by five sets $(X, Z, Y, T \times \mathsf{P})$ and two functions (Φ, Ψ) as $\Sigma = \{X, Z, Y, T \times \mathsf{P}, \Phi, \Psi\}$, where:

X is the input set,

Y is the output set,

Z is the state set,

T is the time set, a subset of eral numbers,

P is the set of space co-ordinates,

$\Phi : T \times \mathsf{P} \times T \times \mathsf{P} \times X \times Z \to Z$ is the state-transition function,

$\Psi : T \times \mathsf{P} \times Z \to Y$ is the output-function (Arbib (1974)).

The novelty of the synthesis of the PASTICS according to the PG and PU descriptions lies in the generalized space-time system of co-ordinates $T \times \mathsf{P}$ and the space-time transformations of the sets and operations in the functions mentioned above. The synthesis is based on six main principles:

1) the function dominates the structure of the PU and of the whole PASTICS;
2) the duality exists between hardware and software implementation of each PU;
3) the uniformity of signals circulating in the PG exists at the very early stages of the synthesis;
4) the optimal level of parallelism exists for each PASTICS;
5) the optimal degree of universality of the PU exists (or the optimal degree of deversity of the PU);
6) the special potential function (a certain sort of Liapunov's function) exists for each PASTICS if the stable computing process elements of Z and Y sets in it.

3. Processing unit. The functional structure of each processing unit is determined by the pair of functions Φ and Ψ

on the certain level of hierarchy and elaboration of the PASTICS to be developed. In general two groups of operations can be found in the PU. The first group contains combinational operations ($*$) and the second one – sequential operations (σ).

The meaning of a sequential operation is tightly connected with the time and space "delay". In the first case the delay is expressed by a number of time intervals (time sampling steps). In the second case it means a number of space sampling steps. So in both cases we deal with the cluster sampling. And we measure the width of the given space cluster and the depth of the time cluster.

If the pair of functions Φ and Ψ shows clearly expressed properties of local relations between the variables involved, this pair can be represented by the pair of difference functions ϕ and ψ respectively. It means that the corresponding processing graph (PG) has strongly emphasized connections between neighboring nodes. In the case when local relations are not dominant the connections in the PG are much more dispersed.

As the PASTICS is a result of the PG mapping into the network of PUs the local, global or combined properties of the functions Φ ans Ψ are reflected in the PASTICS.

An example of the PU model is shown in Fig. 1. Here $x, \xi \in X, y, \tilde{y} \in Y \cup Z, i, K, L, P, R \in \mathsf{P}, n, M, S \in T$ and z^{-1} – means a step time delay element. Fig. 2 shows us an simplified example of a space-time cluster and the interconnections between the two different processing units. The "springs" symbolize the groups of time delay elements.

4. Computing and applications. The stable transient process occurring in the PASTICS synthesized according to the given problem and minimizing the special potential function which can be derived from the state-transition and output functions (Φ and Ψ) we call computing. This paper develops itself in space-time co-ordinates introduced and

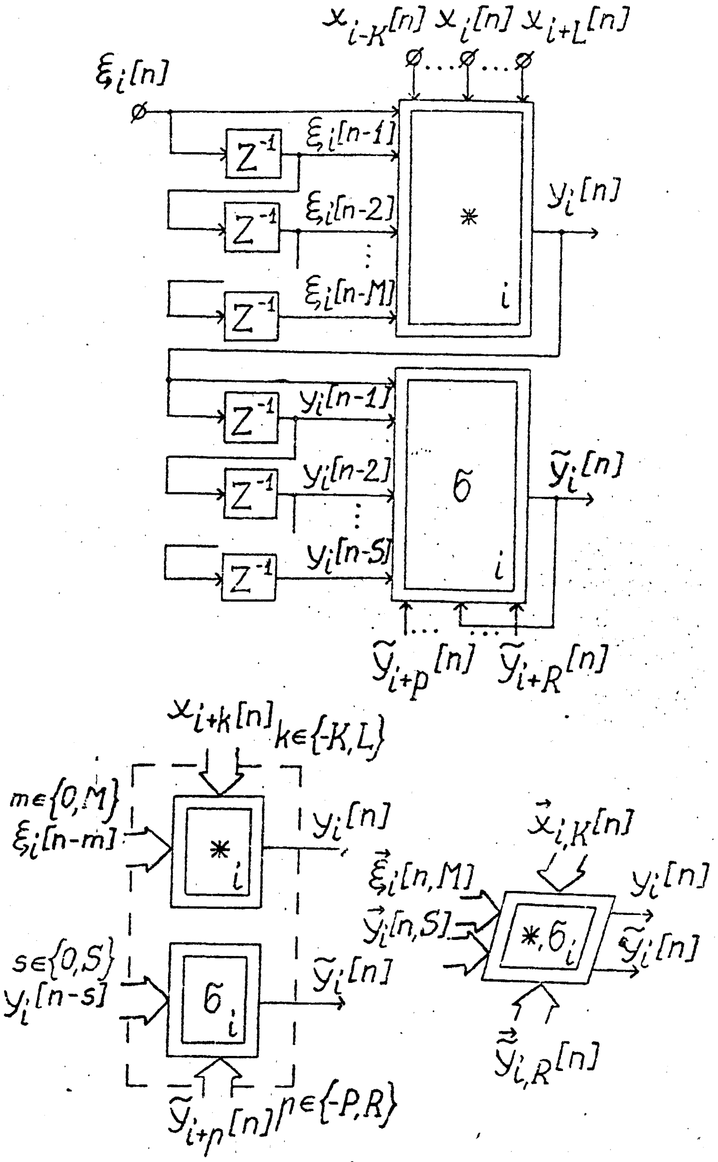

Fig. 1. Model of the Processing Unit (*a*) and its generalizations (*b*).

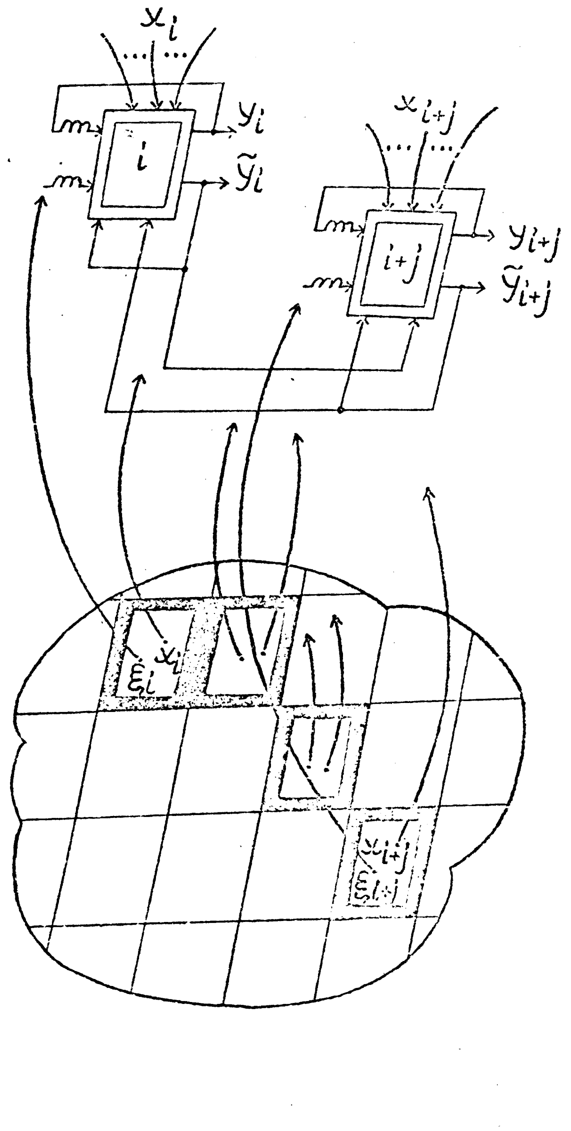

Fig. 2. A simplified example of a cluster and the PU interconnections.

generalized in the second chapter of the article. So we can consider the process of computing in the PASTICS as a space-time signal wave propagation. The problem of synchronization in the PU of the PASTICS mast be solved on the data-flow control concept (see Torrero (1985)). It means that the PASTICS is a parallel-processing architecture in which each processing unit acts on instructions when the data needed become available.

The procedure elaborated were used for the synthesis of the PASTICS when solving two important problems: 1) the synthesis of computing structures to be used for the dynamic two-dimentional pattern recognition; 2) the synthesis of the PASTICS for the flight-flow control in the three-dimentional space.

5. Concluding remarks. The paper presents features of a new approach to the analysis and synthesis of dedicated computing architectures in generalized space-time co-ordinates. We believe it is time for a new chapter to open in the field of the VLSI circuit industry to satisfy the needs of the PASTICS.

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R. Jasinevitchius received his Engineering Degree (MS) in electromechanics (1959) as well as Candidate of Technical Science Degree (Phd) in computer engineering (1968) from the Kaunas Polytechnic Institute. Now he is a professor of System Theory and Computer Engineering at the Kaunas University of Technology. Published 4 monographs and over 100 articles. His research field covers systemology of the new computer architecture.