

**APPLICATION OF PARALLEL PROCESSING
FOR TECHNOLOGICAL PIPELINES TRACING
USING WAVE ALGORITHM**

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Abstract: The use of traditional (serial) tracing algorithms for the problems of real production design is hampered by high requirements of these algorithms. Speed up can be achieved by modifying the algorithms for parallel computing. For the wave algorithm for tracing stages of mounting space analysis and wave propagation are good for parallelization. The use of parallel algorithms can achieve significant productivity gains.

Topological synthesis is particularly important and one of the most difficult stages in the design of technological systems [1]. At this stage, the problem of developing enlarged structure of the designed object is solved, including the problem of the choosing space-planning decisions, the problem of locating equipment and routing intra-shop pipelines. These tasks are the most laborious in terms of computation. This particularly applies to the task of tracing process piping. This problem is one of the most time consuming tasks of industries design. Its automation will reduce development time instrumentation of the process flow sheet, as well as to reduce the costs of practical implementation by optimizing the structure of the technological connections.

Automated tracing solution requires large computational resources. Thus, the time of solving the problem increases significantly with increasing number of traced connections and growth of the mounting space. These requirements cause the complexity of traditional tracing algorithms to solve real-world design problems of industrial production. Therefore modification of the algorithms for parallel computing application is topical.

A mathematical model for the trace includes the following limitations: the fragments of pipes in the shop space are orthogonal; the pipelines are lying in the selected areas; it's necessary to ensure the gaps between the tracks, the distance between the fragments of tracks and technical units, the distance between the tracks and building structures [2].

As optimality criterion for the problem uses criterion of the form

$$I = \sum_{j=1}^L (S_{1j}\varphi_j + S_{2j}K_j), \quad (1)$$

where j – the number of pipe; L – number of communications; S_{1j} – the cost per length unit of the j^{th} pipeline; f_j – length of the j^{th} pipeline; S_{2j} – the cost of the technical implementation of a bending of the pipeline, K_j is the number of turns of the j^{th} pipeline.

Formulation of the tracing problem sets as follows: to find a spatial arrangement of piping considering the described restrictions in which the criterion (1) reached a minimum.

Let us consider the possibility of using parallel computing to solve the problem. To do this, select parts of the algorithm, which can be calculated independently of each other with following union of the results and gaining correct result.

First of all solution of the problem can be divided into three serial stages (Fig. 1):

- 1) choosing lines sequence;
- 2) analyzing mounting space;
- 3) tracing each route by chosen method.

In the first stage the set of processors are divided into groups, which amount is not higher than epy number of pipelines and that of processors in each group is not smaller than the latter. The set of projected lines in its turn is divided into subsets, whose number is a multiple to amount of processors groups. Previously all the tracks are ranged according to the diameter of the pipeline, the properties of transported products, and the cost of their production. Thus, each processor receives a certain number of processing routes (Fig. 2). After completing the trace, pipelines of different subsets are checked for intersection with each other. This problem belongs to a class of sorting problems. Parallel implementation of sorting algorithms is described in [3].

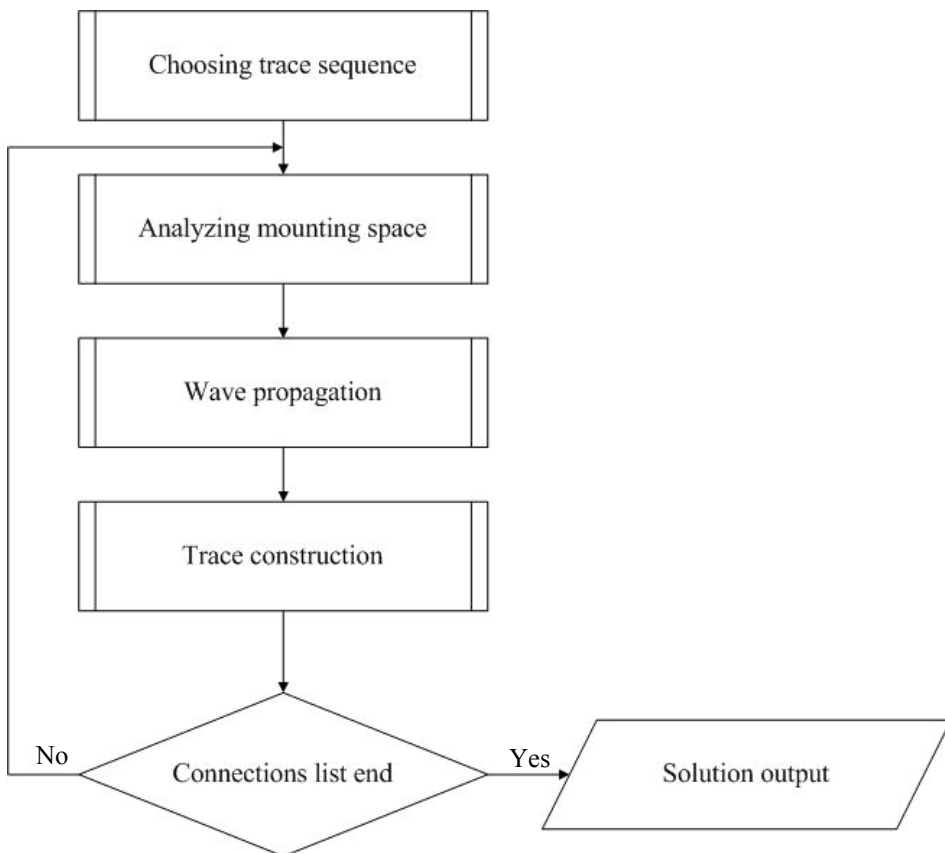


Fig. 1. The classical scheme of the wave tracing algorithm

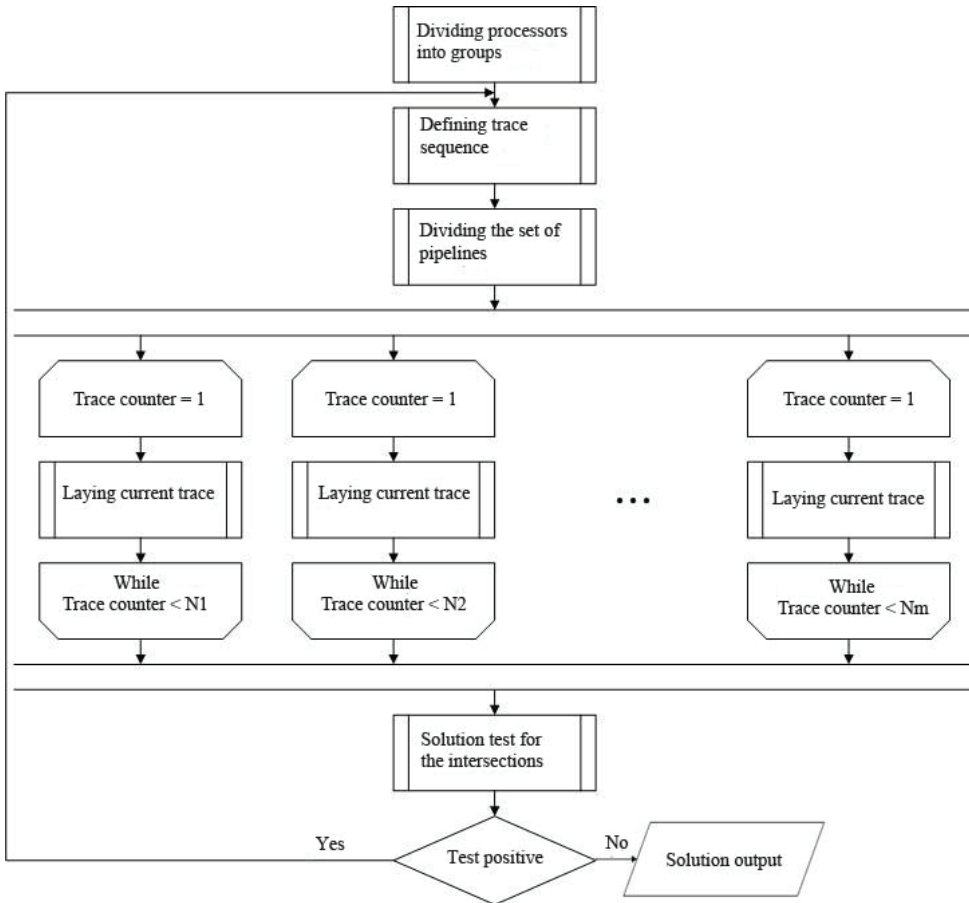


Fig. 2. The parallel scheme of the wave tracing algorithm

In the second stage preparatory steps are carried out: tracing space is divided into set of unit cells $D = \{d_{i,j,k} | i = 1 \dots d_x, j = 1 \dots d_y, k = 1 \dots d_z\}$, where d_x, d_y, d_z – the number of cells in length, width and height respectively. The cell size is chosen multiple of the largest diameter of the pipe, which allows to ensure the greatest number of runs. As a result, tracing region is divided into $K = m \times n \times a$ regions, where $m = d_x, n = d_y, a = d_z$ respectively, information about which is conveniently stored in the matrix $K(m, n, a)$. The appropriate value is assigned to each element $k(m, n, a)$ of the matrix K depending on the properties of the cell $d_{i,j,k}$ (for $i = m, j = n, k = a$) of the set D :

– if the cell $d_{i,j,k}$ contains any object, except for the source nozzle and the receiver nozzle of the route, or contains a zone restricted to the trace (restriction of 5–9 [2]), then $K(m, n, a) = (d_x \times d_y \times d_z) + 2$;

– if the cell $d_{i,j,k}$ does not contain objects, i.e. it is passable for the track, then $K(m, n, a) = (d_x \times d_y \times d_z) + 1$;

– if the cell $d_{i,j,k}$ contains a zone which is temporary forbidden to trace it, then $K(m, n, a) = (d_x \times d_y \times d_z) + 3$. Firstly these cells are considered as no-trace, and if either of the routes which can't be built, then these areas are beginning to be regarded as passable.

Filling each element of the matrix does not depend on the values of other elements. Thus it is possible to select a subset of cells of the matrix and make filling them in some

calculators. For convenience, the matrix $K(m, n, a)$ is divided into an equal subset of rows by band splitting method [3]. Number of rows processed by one processor is $N_r = ma/N_{pr}$, where N_{pr} – the number of available counters. Each computer gets a subset of rows for the processing, which is defined by following expressions: $N_{r-1} = (q-1)N_r$, $N_{r+1} = q \times N_r$, where $q=1, \dots, N_{pr}$ – number of the calculator; N_{r-1} , N_{r+1} – minimum and maximum number of rows in subsets. Then each computer produces described operations with the obtained data.

In the third phase of the piping tracing, depending on the type of connection (single or branched), the following algorithms are used [4]: the double-ray – to implement the connections of single bonds; algorithm for constructing the shortest connecting tree – for branched pipelines; wave algorithm for the construction of the shortest route between the source and receiver with crawl of objects. Solution of the parallelization for the construction of SCT is given in [5]. Algorithm of parallelization for wave method is described below. (Double-ray algorithm is a special case of the wave, and in this work it is not considered.)

Wave tracing algorithm applies to serial. That is, the route is carried out one after another in sequence. However, the most demanding in terms of time-consuming steps are the analysis of mounting space and wave propagation. Similarly, the Huygens principle in physics, every point of the wave front can be regarded as an independent source of elementary oscillations. Thus, to obtain $(N+1)^{\text{th}}$ wave front at each point of N^{th} front can be made in parallel. But we need to monitor conflicts related to the consideration of one cell by different calculators. For parallelization, we use a master-slave paradigm [6]. This Paradigm is widely used in parallelization of various algorithms, such as branch and bound methods [7]. Processor X_0 , called master will manage the even distribution of data on other CPUs X_n , called slaves. Starting from the point of beginning of the wave propagation St , master processor sends to each slave processor one of the cells for processing, the matrix element value of which corresponds to the wave front number that is under consideration at this time. After the slave processor has performed its work with data, it sends a signal to the master processor, which transmits the results, and message that slave was released. In turn, the master processor transmits this slave processor the next cell for processing, the value of the matrix of which equals number of considered or next wave front. After the slave processor has performed its work with data, it sends a signal to the master processor, which transmits the results, and message that slave was released. In turn, the master processor transmits this slave processor the next cell for processing, the value of the matrix of which equals number of considered or next wave front. Each slave processor scans the six neighboring regions of the cell under consideration (each bordered by an edge of the cell under consideration). If some of them are free for tracing and the wave number have not yet given for these cells, the slave processor assigns the elements of the matrix, corresponding to these cells, number of the next wave front $k(m, n, a) = N_{\text{wave}} + 1$. Each slave processor forms a part of the next wave front, which data are transmitted to the master processor, and it passes some of this front for the processing to free slave processors.

After constructing the wave shortest path is determined the same way as in [8] and not considered in this article.

The approach can significantly speed up the tracing problem solution and more fully utilize the resources of modern multi-core and multiprocessor systems. The use of modern high-speed computing for graphics cards that have a large number of calculators, can achieve significant productivity gains of the algorithm. This allows using various options to trace the branched pipeline networks and applying the algorithm for the design of complex real-world chemical production.

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Применение параллельных вычислений для трассировки технологических трубопроводов волновым алгоритмом

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Ключевые слова и фразы: алгоритмы; параллельные вычисления; проектирование производств; трассировка.

Аннотация: Применение традиционных (последовательных) алгоритмов трассировки для задач проектирования реальных производств затрудняется высокими требованиями этих алгоритмов к вычислительным ресурсам. Увеличения быстродействия можно достичь с помощью модификации алгоритмов для использования параллельных вычислений. Для волнового алгоритма трассировки хоро-

шо подлежат распараллеливанию этапы анализа монтажной области и распространения волны. Использование параллельных алгоритмов позволяет достичь значительного прироста производительности.

Anwendung der Parallelrechen für die Trassierung der technologischen Rohrleitungen vom Wellenalgorithmus

Zusammenfassung: Die Anwendung der traditionellen (konsequenten) Algorithmen der Trassierung für die Aufgaben der Projektierung der Realproduktionen wird durch die hohen Anforderungen diesen Algorithmen zu den Rechenressourcen erschwert. Die Vergrößerung der Schnellwirkung kann man mit Hilfe der Modifizierung der Algorithmen für die Benutzung der Parallelrechen erreichen. Für den Wellenalgorithmus der Trassierung sind die Etappe der Analyse des Montageraumes und der Wellenverbreitung für die Abparallelization gut geeignet. Die Benutzung der Parallelalgorithmen erlaubt es, den wesentlichen Zuwachs der Produktivität zu erreichen.

Application des calculs parallèles pour le tracement des tuyauteries technologiques par l'algorithme ondulaire

Résumé: L'application des algorithmes traditionnels (successifs) du tracement pour les problèmes de la conception des industries réelles est compliquée par de hautes exigences de ces algorithmes envers les ressources de calcul. On peut obtenir l'augmentation de la rapidité de l'action à l'aide de la modification des algorithmes pour l'emploi des calculs parallèles. Pour l'algorithme ondulaire du tracement sont bien employées les étapes de l'analyse du domaine de montage et la répartition de l'onde. L'emploi des algorithmes parallèles permet d'élever considérablement la productivité.

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