# The algorithm applies parallel computing of Schweitzer's method for the main scheme optimizing discrete technology and information processes in strategic planning

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**Abstract.** *A problem of improving the efficiency of solving the problems of strategic planning on the basis of a balanced scorecard in multi-level hierarchical systems of organizational control is considered. A modified algorithm of Schweitzer's method of the main optimization scheme for discrete technology and information processes with parallelization of computations is proposed. Using this algorithm will improve the computational efficiency, and therefore allows using a real dimension large-scale model to solve the problems of strategic planning. Proposed approach and the algorithm can be applied to other types of DTIP.*

## Keywords

Strategic planning, discrete technological and informational processes, Schweitzer's method, parallel processing.

## 1 Introduction

With the advent of modern high-performance computing tools became a crucial question the development of computer technology for their use. In particular, technologies, algorithms and software tools for applied problems solving that require substantial computation. One such problem is the problem of finding the most effective strategy for control of discrete technological and information processes (DTIP). An example of the momentary DTIP is the DTIP strategic planning.

In works [1, 2] the methods of conversion of momentary DTIP to a finite-dimensional stationary discrete service process was studied. The result is a stationary semi-Markov process is a discrete service process for which it is recommended to use the main optimization scheme based on recursive optimization Schweitzer's method (also called Schweitzer's scheme).

The use of recursive optimization Schweitzer's scheme requires a significant amount of computation, especially in large-scale models. One way to increase the efficiency of solving the problem is to improve the computational efficiency, which can be achieved in particular through the parallelization of computations.

In this paper an approach for parallelization of computations and modified algorithm of Schweitzer's method of main optimization scheme of DTIP with parallelization of computations is proposed. As an example a problem of finding the most effective control strategy for strategic planning on the basis of a balanced scorecard in a multi-level hierarchical systems of organizational control is used.

## 2 Related works

Discrete technology and information processes occur in many industries, including the strategic planning phase (SP) in the multi-level hierarchical structures of organizational management. To effectively manage DTIP the automation of control technology (AC) of DTIP was developed [1, 2]. This technology allows us to solve the problem of finding an effective solution for problems with a number of phase transitions up to $10^5$. The feature of the problems of strategic planning is a large dimension of the optimized model. To solve the problem the approximate methods was used, which led to less accurate solutions. So actual is search for methods that will improve the efficiency of solving the problem.

One of the possible ways to increase efficiency, according to the authors, is real dimension models using and the parallelization of computations.

To solve the problems of the strategic planning on the basis of a balanced scorecard (BSC) using automation of control technology of DTIP mathematical model of DTIP of strategic planning was developed [5]. Based on the developed mathematical model of DTIP SP must perform

- the calculation of the parameters of the phase transitions
- a search for the most efficient control strategy.

In work [6] proposed a method for calculating the parameters of the phase transitions DTIP SP with the parallelization of computations. One of the most effective methods to solve problem of searching for the best control strategy are the methods of dynamic programming using recurrent optimization schemes, including Schweitzer's method [3, 4].

The goal of this paper is to describe a modified algorithm for the Schweitzer's method of main optimization schemes of DTIP with the parallelization of computations. Using this algorithm will improve the computational efficiency, and therefore use the large-scale model of the real dimension to solve the problems of strategic planning.

# 3 Schweitzer's method algorithm modified applying parallel computing

## 3.1 The Schweitzer's method

As is known, for stationary Markov and semi-Markov stochastic processes with a finite number of phase states and directives, there are well proven efficient algorithms (schemes) recursive optimization [1, 2]. These schemes are based on the methods of dynamic programming and have a number of advantages over the algorithms, which are based on other methods.

The advantages of recursive optimization algorithms include: the possibility of using for many discrete processes of service rapid convergence and almost linear dependence of the duration of the process of optimization of the number of phase states.

The basis for the main optimization schema of DTIP is Schweitzer's method (also called scheme) [4]. The algorithm of this method has the computational complexity $O(N)$ depending of the number of phase states, while other well-known algorithms (schemes) such as Howard [3], Jewel - $O(N^3)$.

The Schweitzer's scheme has the form:

$$v_i(n+1) = v_i(n) + \omega[F_i(n+1) - g(n+1)], \forall i = \overline{1, N} \quad (1)$$

and

$$F_i(n+1) = \max_{k \in K_i}[q_i^k + \sum_{j=1}^{N} p_{ij}^k v_j(n) - v_i(n)] \quad (2)$$

$$q_i^k = \sum_{j=1}^{N} p_{ij}^k r_{ij}^k \quad (3)$$

$$g(n+1) = F_B(n+1), \ v_B(n) = 0, \forall n, \quad (4)$$

where $g(n+1)$ – average revenue per unit of time, calculated on $n+1$-th iteration cycle;

$\omega > 0$ – relaxation factor (relaxation coefficient);

$i = B$ – basic state;

$q_i^k$ – directly expected revenue for the state $i$ and $k$-th directive;

$p_{ij}^k$ – probability of stepper transition from the state $i$ into state $j$ and $k$-th directive;

$r_{ij}^{k}$ – revenue of stepper transition from the state $i$ into state $j$ and $k$-th directive;

$N$ – the number of phase states;

$K_i$ – set of possible directive in $i$-th state;

$v_i(n)$ – relative weight of $i$-th state on $n$-th step.

Stopping the synthesis of optimal control strategy is, if the relative error of calculation of weights $v()$ and revenue $g()$ on two neighbor cycles will not exceed the specified

The main advantage of this scheme is to optimize the recursive fast convergence and almost linear dependence of the duration of the process of optimization of the number of phase states. In addition, the optimization scheme can be used for a wide range of processes and combines a procedure for finding of weights and improve the strategy. Fig.1. contains a diagram of the Schweitzer's method without parallelization (the single-process algorithm).

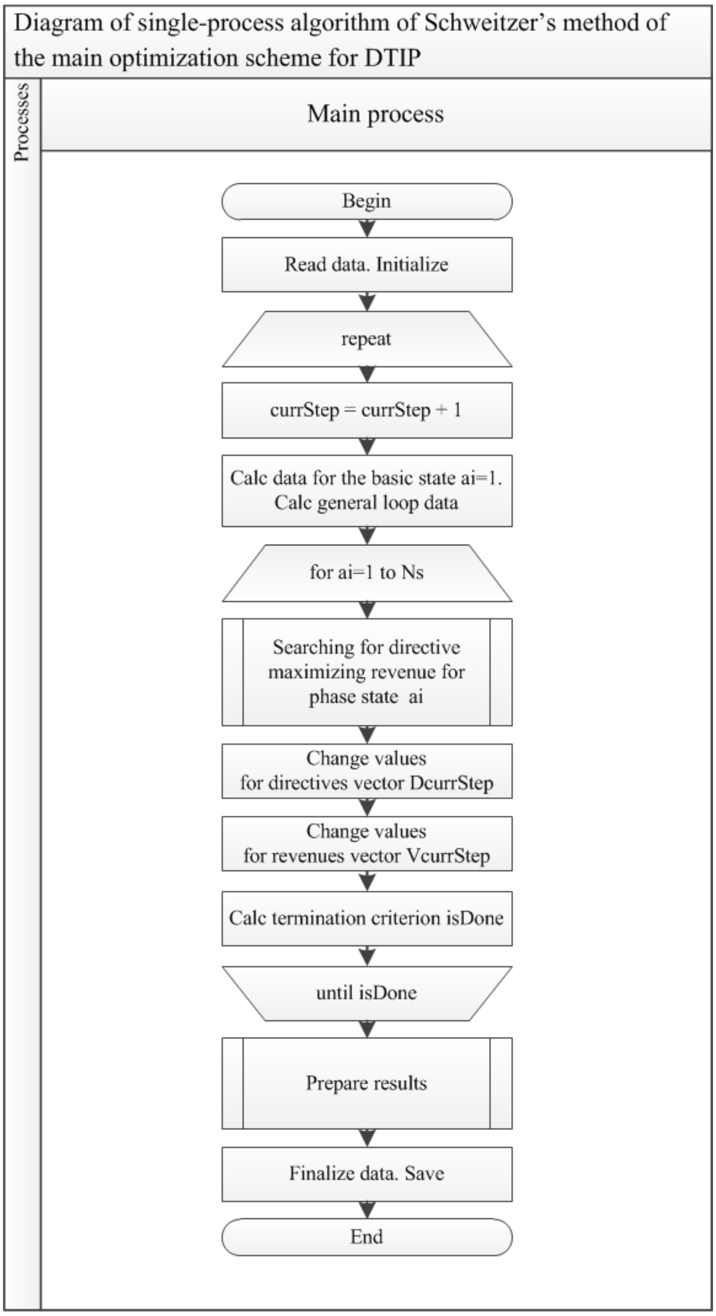


**Fig.1.** Single-process algorithm of Schweitzer's method

### 3.2 Approach for parallelization of the single-process algorithm

It is known that in practice the greatest resource of parallelism in programs focused in cycles. Therefore, the most common approach to parallelization is the parallelization of one way or another iterations in cycles. The prerequisite for this is the lack of information dependencies between iterations in the loop. However, in general, the condition of independence of loop iterations for the Schweitzer's scheme fails.

Single-process algorithm (Fig.1.) Schweitzer's method without parallelization supposes the following actions. At each iteration step is necessary perform the calculation of data for the basic state and the general data for loop. Then, in a loop for each phase state to do the following actions. Find a directive that maximizes revenue from the phase transition to the phase state *ai*. Change directives vector for loop *DcurrStep*. Change revenue vector for loop *VcurrStep*. Perform calculation of the termination criterion *isDone*. If the termination criterion is reached *isDone*, then finish the iterations.

In general, the main optimization scheme of DTIP based on Schweitzer's method suggests that transition can be made from any state with a lower number to any state with a large number (Fig. 2a.)

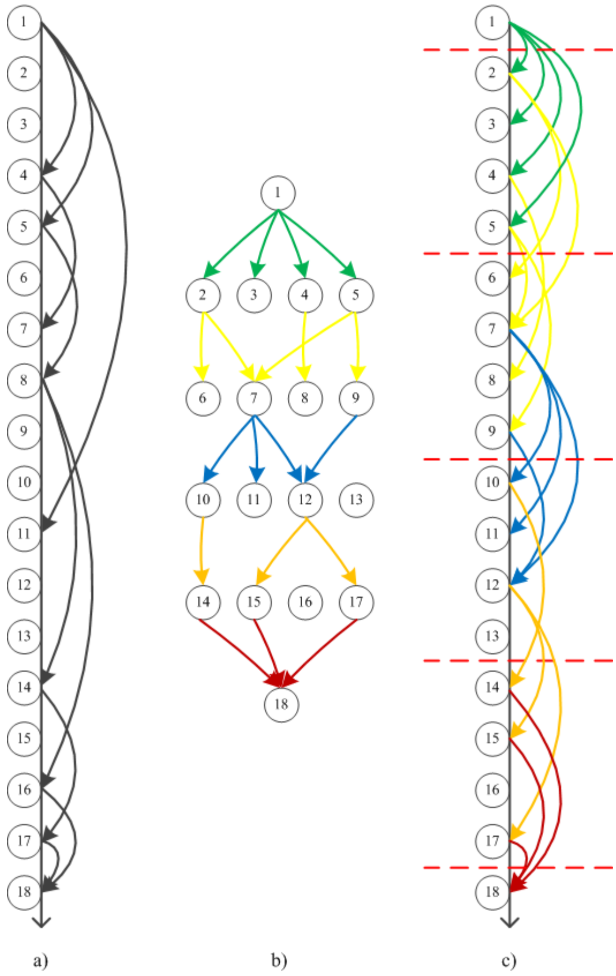

**Fig.2.** Transitions between phase states

However, the logic of mathematical model of calculation of phase transitions parameters of DTIP, particularly DTIP SP [6] can be represented as a graph in Fig. 2b.The top node of the graph is the base state. From the base state transition can be executed only in one of the phase state (corresponding to one resource from 0 to Nc) for fixed request from 1 to M. A subset of states for a fixed requests from 1 to M will be called a level. Then, according to the mathematical model of numerical optimization DTIP SP, for phase states of level 1 transition may be performed only in the phase transition state, which is on the level 2, and so on until the M-level.

Thus, from the point of view of the calculation of the Schweitzer's method algorithm, a subset of the phase states corresponding to a single level can be considered independent. Since the transitions within these subsets are not possible (Fig.3c). Therefore algorithm can be parallelized within a subset of the phase states of one level. In each such subset is Nc +1 state in accordance with the number of of resources.

### 3.3 Multi-process algorithm of Schweitzer's method

In fig.3. the algorithm of Schweitzer's method for DTIP SP with parallelization of computations is presented.


**Fig.3.** Multi-process algorithm of Schweitzer's method

The difference multi-process algorithm of single-process algorithm is as follows. After reading the data of the problem and the initialization, it is necessary to calculate the ranges of resources numbers *procUpNc*, *procDownNc* to be processed by each of the processors. Then perform the initial transfer of data to processors.

At each iteration loop, after calculating the data for the basic state and the general loop data, it is necessary to perform transfer of initial values for the vector of directives *DcurrStep* and the vector of revenues *VcurrStep* to processors. Then each process for each request from *1* to *M* searching for directive maximizing revenue in a range of processor resources numbers from *procUpNc* to *procDownNc*. This defines a local maximum of revenue for each process and the corresponding directive. After that, each process executes a return of the local maximum revenue of the process and the corresponding directive in the main process. The main process performs the determination of the better directive which maximizing revenue among all processes. Then, the main process performs transfer of better directive and the corresponding values of the vectors *DcurrStep* and *VcurrStep* for all processes.

The proposed algorithm will be effective only for a large number of phase transitions. The authors of this paper are performed works for practical verification of the effectiveness of the algorithm. In the nearest future it is planned to complete the development of a software prototype and conduct a series of experiments.

# 4 Conclusion

The algorithm with parallelization of computations of Schweitzer's method of the main optimization scheme for DTIP is proposed. The modified algorithm will improve the computational efficiency, and therefore, allows using a real dimension large-scale model to solve the problems of strategic planning. Proposed approach and the algorithm can be applied to other types of DTIP. In particular, a range of real applications of momentary DTIP described in work [2].

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