Chimshir Valentin

DSc (Eng.), Associate Professor, Director of the Institute, *orcid.org/0000-0003-3621-2702*
Danube Institute of the National University "Odessa Maritime Academy", Izmail, Odessa Oblast

TEMPORAL PROCESSES ALIGNMENT METHOD FOR COMPLICATED SYSTEMS

Abstract. The presented work researches a possibility to compose temporal processes to reduce complicated system operation expenditures. It is established, that temporal processes are classified into three categories in view of their influence on a system's functional state. They are single (1), repeating (2) and cyclic (3). It is also established, that presence of large number of temporal processes within a system requires an individual approach to their control. Temporal processes alignment method is developed consisting of six fundamental provisions: 1) with none additional restrictions the attraction point falls within the time interval of either of temporal processes; 2) temporal processes' shifting does not involve additional expenditures if it does not generate extra temporal process within the time interval under review; 3) with increased system's stoppage costs the attraction points tend to areas of the system's forced stoppage and increase noticeably their attracting features; 4) attraction area is determined by an area where all the not repeating temporal processes are located; 5) in the course of alignment of temporal processes involving reduction of the number of system's stoppages there is always a limit expenditures value justifying such an alignment; 6) alignment of temporal processes running within relative attraction zone may be implemented providing meeting the conditions. These provisions construe a basis to take a decision about possibility and feasibility of their alignment. It is identified, that one of essential parameters of the processes' alignment is a choice of a proper time for their alignment. An algorithm is offered based on the developed method enabling to implement temporal processes alignment procedure depending on data processing systems' resources to reduce substantially chance of error in adopting a decision in complicated systems' management.

Keywords: Temporal Processes, Complicated System, Lifecycle, Costs, Optimization, Recovery, Forecast, Time Span

Introduction

Development of newer technologies in data processing enables to invent newer methods of objectives' optimization in complicated systems' lifecycle. Optimum temporal processes alignment in complicated systems construes one of such objectives.

A complicated system includes multiple temporal processes throughout its lifecycle and may take two opposite states in relation to them being standard state and out of standard state. The known state encompasses total number of states, in which a system fulfils its functions, as intended. The out of standard state, on the contrary, features such a state in which the system is unable to function properly, totally or partially, as it may be intended.

This research encompasses a review of temporal processes purposed to return a system from out of standard state into its standard state.

As a rule, when complicated systems are explored, a problem rises consisting in an uncertainty of a number of its states. Uncertainty term describes a system's state relatively to ideal conditions of its functioning. Research carried on by Ye. A. Kuzmin [1] systematizes uncertainty aspects referring to complicated systems in which a key part is played by data component.

Therefore uncertainty measure plays a key part in a system's states simulation results.

The objective of research consists in saving costs for complicated systems' functioning restoration applying temporal processes alignment technique.

Research tasks are, as follows:

1. to classify temporal processes referring to their influence upon a system's functional state and restoration expenditures of the latter.

2. to identify parameters affecting temporal processes' alignment.

3. to develop method for temporal processes' alignment.

4. to develop an algorithm for temporal processes' alignment.

Publications review

Temporal processes reviewed by a number of authors are represented with a sequence of events planned at a certain level of a system's management and described by a number of parameters, such as structuredness, duration, velocity. Insufficiently controlled

temporal processes may generate newer processes, which may demand a separate management in future.

Depending on emergence in a system's lifecycle, the temporal processes may be classified into three categories: single, repeating and cyclic.

Single processes are normally performed once within a system's lifecycle. They are well-structured, may have various duration, and, as practice shows, run at a medium velocity.

Repeating temporal processes don't feature a rigid regularity. They depend of environment in which the system operates. They run at a high velocity.

Cyclic temporal processes feature a cyclic nature of running, are rather well-structured, their velocity varies from low to medium.

Great quantity of temporal processes running within a system may demand an individual approach to their management [2]. Processes alignment represents one of such approaches. Alignment approach is very complicated and requires taking into consideration multiple quantities of parameters. Choice of time for alignment is one of essential parameters.

Generally, following considerations are taken into account when choosing time for processes alignment [3]: firstly, these processes are scheduled, i.e. the process should be started after a certain delay independently of a system's state in a preceding period of time; secondly, in case of change in a system's condition affecting its performance or failure to perform certain functions yet being still operable, i.e. capable to function; and, thirdly, when the system is in inoperable state, i.e. when sudden failure of the system's functions occurred, preventing the system's operation.

Formalization of the problem in question supposes, in general, description of all the essential factors affecting the achievement of desirable system's state and their interaction, taking into account restricting conditions and process alignment quality criterion [4].

Thus, the purpose of the optimization problem of both theoretical and practical nature consists in choosing «the best» (permissible or optimum) configuration of multiple alternatives to achieve a certain solution [5].

Neither of enlisted reasons reflects economic aspect as an optimum choice of time to run a temporal process. Placing temporal processes in a certain sequence in time rather substantial cost-saving effect may be achieved in running the system [6].

A great variety of problems is associated with complicated system's operation with each of them solved separately does not always provide an optimum solution in total. For example, methodology developed by Donald V. Steward [7], are efficient at the processes planning stage but actually unacceptable at further stages of complicated systems' lifecycle.

Work [8] illustrated another side of the process in question. Time forecasting of temporal processes' start plays an important part in the matter of their efficient alignment. This work represents an efficient technique of temporal processes' forecasting.

Social effect is another aspect capable to emerge within complicated systems' lifecycle. This effect may indirectly influence a time of staring of either of temporal processes. Work [9] represents a technique enabling to evaluate social effect quantitatively and to forecast its effect on temporal processes within a system.

Method of choosing a technical system described in work [10] represents a great scientific interest. It is a technical system as a complicated system that affects time forecast of temporal processes location.

Certain particular cases require paying attention to complicated system behavior. If the system features a nonlinear behavior and includes casual processes a unique methodology described in [12] may appear to be applicable, to the author's opinion.

Scientific work [13] deals with analysis and development of a special class of complicated management systems. In the case in question it may be helpful in complicated systems' identification and fuzzy simulation.

The research showed that problem of optimum technical object repair works placement in time remains still unsolved.

Work [11] offers a solution technique for this type of problems known as "magnets method". In view of high degree of theoretical component its practical component improvement may be recommended.

Temporal processes composition method

The problem, as below is offered to be reviewed. Supposing, there is a certain complicated system. It consists of components. Each of them is represented by a group of parameters. One of fundamental system's characteristics is a necessity for it to perform a number of functions, which, in its turn, leads to alterations in functional state of the system in general depending on changes in state of each of its components. Actually, each of the system's functions is assigned with a system's component. In this view, the system's component restoration implicitly means system's functional state restoration. The functional state means a measure of the system's capability to perform its intended functions.

Normal system's functioning requires each its element functional state to exceed permissible minimum. Once a system's component state dropped to restricting limit, depending on component's type, appropriate measures should be taken, which involve certain expenditures, and, on the other side, determine the possibility of further system's performance. Since it is supposed, that system's performance is required and determined by a certain efficiency index (relative income value for a certain time unit), whereas, change in limiting system's component state towards greater side (this

process may be called restoration) requires putting the system out of operation, involving decrease of the index, it may be supposed, that there exists a way to arrange temporal processes of the system's functions restoration where the restoration expenditures will be minimal with maximum efficiency of the system's functioning.

Referring to the above a problem may be stated and optimized applying temporal processes alignment techniques.

Suppose, there is a system, which is described with parameters, as outlined below, T – Functioning period being under review; n – System's components number; t_i – ith component service time (i = 1, 2,…, n); nr – System stoppages total number within the T interval; q_i – ith component value (i = 1, 2,…, n); q_{ri} – ith element's restoration cost (i = 1, 2,…, n); relative losses from the system's stoppage due to either of components running to restricting state, or due to other causes; relative income from system's operation per a certain time unit.

Placing certain restrictions to improve apparency and accessibility of essential provisions will not affect forthcoming summarization. Suppose, that system components' number, individual component's service time until achieving a restricting state, total number of the system's stoppages, cost of a particular component and costs of its restoration are constant values for entire service time. So, the system consisting of three components may take a following view (Fig. 1).

Core value identification mechanism

Core value definition is only associated with stable conditions of sociotechnical systems. In this view, it is supposed that system's initial and final conditions are identical at the moment of the system's condition fixation. However, processes, which transfer the system from one condition into another, and, consequently, intermediate conditions may be other than stable.

Suppose, a core value of sociotechnical system is represented by a condition function. Increment of such function in any process occurring in the system in enclosed environment is equal to a sum of effects produced upon the system by means of resources causing transition from an initial condition to a final condition.

Possibility to apply such a condition function bases on a provision, that effect produced upon a system in enclosed environment depends only on initial and final conditions of the system and does not depend on a manner, in which the transition occurs. In other words, once it is possible to imagine a system's condition after wrapping its parameters number to two (K_1 and K_2), the transition from conditions S_1, S_2,.., S_{n-1}, to the S_n condition, if ever possible, will be uniquely determinable (Fig. 1).

System's state graph represented in Fig. 1 is built in coordinates with Q-axis representing the system's value

and t-axis – service time. The curve illustrates changes in the system's value depending on temporal processes aimed to restore the system's functionality. Each restoration is accompanied with expenditures, from the one side, and with increase of the system's value, from another side.
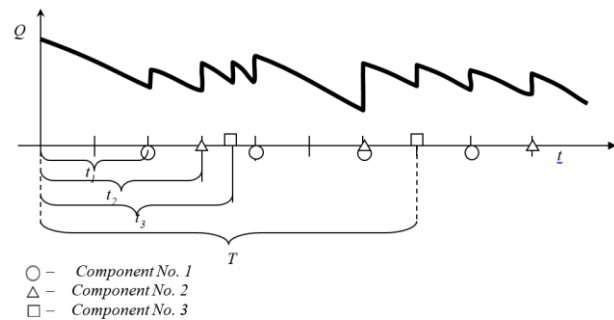

○ – Component No. 1
△ – Component No. 2
□ – Component No. 3

Figure 1 – Lifecycle scheme for a system's three components

Suppose, that the system's performance is subject to following rules and restrictions,

1) Placement of essential components starts from zero-point (0);

2) Distance between adjacent elements within the same i^{th} group may be less or equal to t_i, but greater than 0;

3) Time characteristic is determined by discreet behavior, which means one action performed per time unit;

4) Duration of restoration process for an individual component is expressed in time units, whatever might be conditions of its performance.

Optimization consists in minimizing costs of the system's functions restoration and improvement of efficiency index as a result of temporal processes composition.

Factor affecting the demand for finding a solution is represented with relative cost of the system's stoppage to relative effect of the system's performance per time unit. For convenience it is called *optimum solution demand factor*:

$$k_r = \frac{\bar{z}}{\bar{d}}, \qquad (1)$$

with z – relative costs of the system's stoppage; d – System's relative efficiency.

Obviously, if relative system's stoppage costs tend to zero with constant relative efficiency temporal processes don't require alignment and search for optimum solution is unnecessary. Opposite judgment makes sense as well – the more are relative expenditures the higher is the demand for applying optimization.

Two cases determining the direction of solution search are reviewed below.

1. Temporal processes lie in close proximity to each other and their alignment does not involve further necessity in additional costs to restore system's functionality. These temporal processes are aligned towards those located closer in time. Such an alignment zone may be called *absolute attraction zone*.

2. Temporal processes lie in close proximity to each other. However, their alignment requires additional costs. Their alignment will depend on a number of factors and conditions which should be reviewed more thoroughly. Such an alignment area may be called *relative attraction zone*.

Identification of conditions where temporal processes running within relative attraction zone are aligned is the key to solve the problem applying temporal processes alignment technique.

Essential provisions of temporal processes alignment technique for complicated systems

1. With none additional restrictions the *attraction point* falls within the time interval of either of temporal processes.

In cases when the commencement time of a temporal process is not essential and with $\overline{d} = const,$ the attraction point shifting relatively to temporal process always involves extra expenditures amounting to the cost of unused resource of restorable system's function (Figs. 2 & 3).
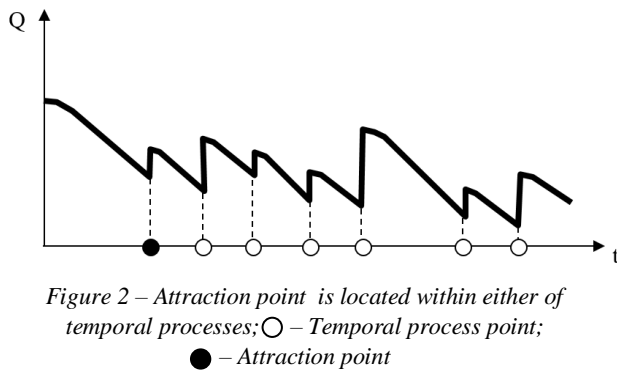

Figure 2 – Attraction point is located within either of temporal processes; ○ *– Temporal process point;* ● *– Attraction point*

2. Temporal processes' shifting does not involve additional expenditures if it does not generate extra temporal process within the time interval under review (Figs. 3 & 7).

3. With increased system's stoppage costs the attraction points tend to areas of the system's forced stoppage and increase noticeably their attracting features.

4. Attraction area is determined by an area where all the not repeating temporal processes are located.

5. In the course of alignment of temporal processes involving reduction of the number of system's stoppages there is always a limit expenditures value justifying such an alignment (Fig. 5).

6. Alignment of temporal processes running within relative attraction zone may be implemented providing only meeting the conditions, as follows,

7. The temporal process is not rigidly located and may be subject to composition;

8. If the composition involves additional costs but does not lead to emergency of extra temporal process with additional expenditures don't, at least, exceed the system's stoppage costs

$$\overline{z} > \sum \overline{q_{н.з.э.}}, \qquad (2)$$

with $\sum \overline{q_{н.з.э.}}$ – value of temporal processes occurred as a result of composition.
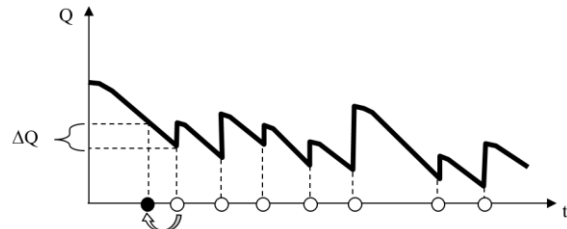

Figure 3 – Attraction point is shifted from either of temporal processes; ○ *– Temporal process point;* ● *– Attraction point*
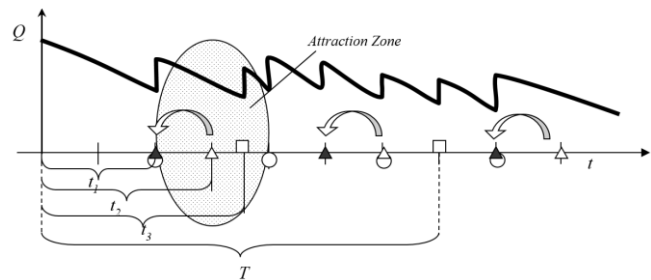

Figure 4 – Scheme of temporal processes alignment caused by restoration of Component 2; ○ *– Component 1;* Δ *– Component 2;* □ *– Component 3*
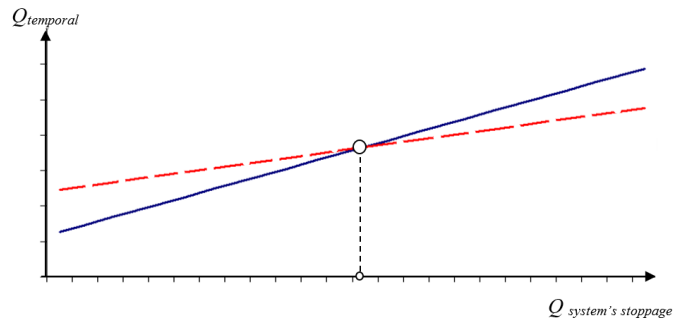

Figure 5 – Relation between costs of temporal process launching and system's stoppage costs: − − − *– minimum temporal processes;* —— *– maximum resources used*

• If the alignment demands additional costs to launch temporal processes causing an additional system's stoppage, but includes one or more adjacent temporal processes, not being a *local attraction point. A local attraction point* is defined as a point keeping within its zone processes, neither of which may be aligned subject to valid restrictions.

• If the alignment demands additional costs and is associated with generation of additional temporal processes, the alignment may be done provided the following condition is met (3), Fig. 6.

The above provisions indicate that the precision of results obtained by means of applying this technique directly depends on forecast precision for such components, as: the system's relative income $\overline{d(t)}$ within the reviewed period; system's stoppage costs $\overline{z(t)}$; temporal processes implementation costs $\overline{q}$.
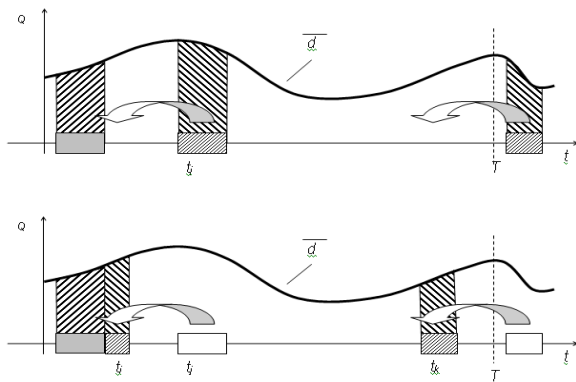
Figure 6 – Temporal processes alignment scheme

$$\overline{\Delta d} = \overline{d(t_j)} - \overline{d(t_i)} - \overline{d(t_k)};$$
$$\overline{\Delta z} = \overline{z(t_i)} + \overline{z(t_k)} - \overline{z(t_j)}; \quad \overline{\Delta d} - \overline{\Delta z} > 0,$$

with $\overline{d(t_i)}$ – system's income within t_i period, in which temporal process will be arranged; $\overline{d(t_к)}$ – system's income within t_k-period of launching newborn temporal process; $\overline{d(t_j)}$ – system's income within t_j, within which temporal process is intended to cease; $\overline{z(t_i)}$, $\overline{z(t_k)}$, $\overline{z(t_j)}$ – temporal process implementation costs within each of the periods.

In view of the above an algorithm may be processed for temporal processes alignment optimization applying minimum implementation costs as a criterion of optimization:

1) The system components should be specified each being in charge of a particular system's function;

2) The first temporal process should be marked from the starting point of reviewed period along the time axis as an attraction point marking the time given as P_1 (P_k in general form);

3) Identify alignment area restricted by an interval, within which temporal processes $P_к$ through $P_к + t$ don't repeat;

4) Forthcoming temporal processes specified at stage 1 are reviewed. Should neither new expenditures occur in the course of temporal processes alignment, it means that they had been located in *absolute attraction zone* and may be aligned without additional clauses. Step 4 may be repeated, otherwise, Step 5 should be applied;

5) If the alignment process involves additional expenditures or generation of new temporal processes, the feasibility of such alignment should be rechecked subject to the sixth provision of proposed technique. Once satisfactory solution is obtained for inequation (3), temporal processes should be transferred to the attraction point and step 4 performed again, otherwise step 6 should be taken;

6) Temporal processes mismatching term (3) become the next attraction point P_{k+1};

7) If there are any temporal processes after newly assigned pole, Step 3, otherwise the algorithm is completed.

Returning to the system with lifecycle represented in Fig. 1. The «Temporal processes composition method» produces results, as follows,

1) Component 1 with time t_1 becomes a pole P_1. Component 2 is located in absolute attraction zone and tends to pole P_1. Component 3 is located in relative attraction zone and therefore its alignment is under question. Supposing that all the components meet conditions imposed in the sixth provision, Component 3 may be also aligned to the P_1 pole. The result is represented in Fig. 7);

2) Choosing the second pole Component 1 is taken again with repair time $2t_1$. Components 2 and 3 are located within absolute attraction zone and tend to the P_2 pole;

Choosing the third pole subject to certain chance the choice again stops on Component 1 with term of repair $3t_1$. This pole does not attract components since from P_3 to the end of reviewed period no repairs are scheduled (Figs. 7).
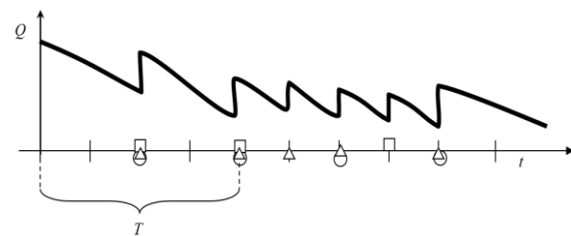

Figure 7 – Temporal processes' alignment technique demonstration

Results review

Thus the research resulted into conclusions, as below:

1. Temporal processes have been classified referring to their influence upon a system's functional state. Three types for processes' classification are proposed, single, repeating and cyclic. They are described as well as their displayed characteristics.

2. Parameters are identified affecting the alignment of temporal processes including *inter alia*, income and expenditures in time, temporal process implementation cost, system's functions restoration costs.

3. Temporal processes alignment method including three essential provisions is developed. These provisions form a basis to make a decision of possibility and feasibility of temporal processes alignment.

4. Temporal processes alignment algorithm is developed enabling to identify possibility and feasibility of temporal processes alignment on a step by step basis.

Conclusions

The research shows that the temporal processes alignment problem is challenging and has no common solution in essence. Such a situation provokes to start a search in optimizing and summarizing a number of separate problems.

The obtained results enable to implement the

temporal process alignment procedure applying the data processing system aids, which may reduce considerably errors in the course of making decision in running complicated systems. Further research may be directed towards the method's modification to encompass greater quantity of solvable optimization problems.

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Чимшир Валентин Іванович
Доктор технічних наук, доцент, директор інституту, *orcid.org/0000-0003-3621-2702*
Дунайський інститут Національного університету "Одеська морська академія", м. Ізмаїл, Одеська область

МЕТОД ОБ'ЄДНАННЯ ТИМЧАСОВИХ ПРОЦЕСІВ У СКЛАДНИХ СИСТЕМАХ

Анотація. Досліджено можливість об'єднання тимчасових процесів з метою зниження витрат на функціонування складної системи. Встановлено, що тимчасові процеси, а отже, відповідно ознаки їх впливу на функціональний стан системи, діляться на три класи: поодинокі, повторювані і циклічні. Розроблено метод об'єднання тимчасових процесів, який включає в себе шість основних положень: 1) за відсутності додаткових обмежень точка тяжіння обов'язково збігається з часом одного з тимчасових процесів; 2) зміщення часових процесів не тягне за собою додаткових витрат, якщо він не тягне за собою появу додаткового тимчасового процесу в межах прогнозованого тимчасового відрізка; 3) при збільшенні витрат на зупинку системи точки тяжіння прагнуть в області вимушеної зупинки системи і помітно збільшують свої притягувальні властивості; 4) область тяжіння обумовлюється областю, в якій перебувають всі неповторювальні тимчасові процеси; 5) при об'єднанні тимчасових процесів, в разі, коли це спричинило за собою зменшення кількості зупинок системи, завжди буде існувати межа витрат, за якої таке поєднання буде виправдано; 6) об'єднання тимчасових процесів, які перебувають в області відносного тяжіння, можна здійснити тільки при дотриманні умов. На основі цих положень приймається рішення про можливість і доцільність об'єднання тимчасових процесів. На основі розробленого методу запропоновано алгоритм, який дає змогу за допомогою інформаційних систем реалізувати процедуру об'єднання тимчасових процесів, з метою суттєвого зниження ймовірності помилки при прийнятті рішень в управлінні складними системами.

Ключові слова: тимчасові процеси; складна система; життєвий цикл; витрати; оптимізація; відновлення; прогноз; часовий відрізок

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