The Simplification Method of Engineering Task Sequences used for Engineering Knowledge Portals

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The paper deals with the approach that can be used to increase the efficiency of the engineering task composition and their performance improvement. The simplification method of engineering task sequences is proposed. This method allows forming the minimized set of engineering task elements used for business process design and its execution. The specific algebraic system for designing the sequence of engineering tasks based on the simplification method of engineering task sequences that realized classification and minimization of computation sequence is described. The algebraic system involves formal context-independent structures for the representation of the engineering task elements. The example of using the approach for real engineering tasks is presented. The quantitative evaluation of the efficiency increase in the engineering tasks of the "Strength of materials" subject domain is given.

Key words: engineering tasks, classification and computation simplification, algebraic system, operations, web services.

У статті представлена підхід до проектування бізнес-процесів виконання інженерних завдань на порталах знань, який може бути використаний для підвищення ефективності їх виконання. Запропоновано метод спрощення інженерних розрахунків, який дозволяє сформувати мінімальну послідовність елементів інженерних розрахунків. Описується специфічна алгебраїчна система інженерних розрахункових завдань, яка становить базис для методу спрощення інженерних розрахункових завдань, у якому реалізовано класифікацію та мінімізацію послідовності обчислень. Алгебраїчна система вводить формальні контекстно-незалежні структури для представлення елементів інженерних розрахункових завдань. Наведено приклад використання підходу для реальних інженерних завдань, надано кількісну оцінку підвищення ефективності для інженерних розрахунків предметної області "Міцність матеріалів".

Ключові слова: інженерні розрахунки, класифікація та спрощення обчислень, алгебраїчна система, операції, веб-сервіси.

В статье представлен поход к проектированию бизнес-процессов исполнения инженерных задач на порталах знаний, который может быть использован для повышения эффективности выполнения таких задач. Предлагается метод упрощения инженерных расчетов, который позволяет сформировать минимальную последовательность элементов инженерных задач. Описана специфическая алгебраическая система инженерных расчетных задач, которая составляет базис для метода упрощения инженерных расчетных задач, в котором реализована классификация и минимизация последовательности вычислений. Алгебраическая система вводит формальные контекстно-независимые структуры для представления элементов инженерных расчетных задач. Приведен пример использования подхода для реальных инженерных расчетов, дана количественная оценка повышения эффективности для инженерных расчетов предметной области «Прочность материалов».

Ключевые слова: инженерные расчеты, классификация и упрощение вычислений, алгебраическая система, операции, веб-сервисы.

1. Introduction

Nowadays, different types of web services are widely used for different purposes. Usually such services aimed at carrying on some problem-oriented tasks at the end-user request. To execute such user's request we need to realize the process of web services selection, composition, optimization, etc. Sequence of such user's tasks (which is named the engineering business process) should be executed in optimal way in order to increase the whole business process efficiency. The execution of such user's tasks sequence named engineering business process should be held in most optimal way aiming to increase the whole business process efficiency.

Web services are usually used for executing different processes, such as:
- − general user's tasks,
- − calculation and computational tasks of different subject domain,
- − engineering business processes.

This research deals with performance, execution and realization of the engineering tasks − sequence of specific user tasks that represents complex computational task from various engineering subject domains.

The efficiency of performing engineering tasks depends on their execution time. Execution time depends on several factors: the web service composition time (web services are to be composed in dynamic to form the specific sequence which correlates to the complex engineering task (the task is realized as engineering business process)), the number of web services included in the sequence for the task - engineering business process; the time for such sequence execution. The web service composition time depends on the used composition method and the complexity of the certain engineering tasks structure, while the sequence execution time for the certain engineering task can be optimized by minimizing the number of such engineering task elements (web services, stages).

The paper describes a novel method of engineering tasks simplification based on the algebraic system used for the design of the sequence of the engineering tasks. The method of engineering tasks simplification realizes classification and minimization of computation sequence. The algebraic system allows us to form the minimized set of web services used for the engineering business process execution.

The paper structure:

Section 2 gives analyses of related works and introduces basic notions. Section 3 describes the algebraic system for engineering business process representation. In section 4 the method of engineering tasks simplification is given. Section 5 presents the application of proposed method for real engineering business processes design in terms of "Strength of materials" subject domain. Section 6 depicts the conclusions and the plans for our future work.

2. Related Works and Basic Notions

The efficiency of web service composition has been examined in various researches. In [1-2] different types of web services composition approaches are described. Some approaches present the composition of web-services based on the phases of service discovery and the stage of service selection [3,4]. Other researches propose to use semantic for web services composition [5-7], or extended SOA architecture [8,9]. The paper [10] presents the approach to composing web-services

for user tasks represented on knowledge portals. Thus, the efficiency of engineering tasks performance (their execution time) depends not only on the time needed for web-services composition. The engineering task execution time can be minimized by optimizing the sequence of web-services that is formed after their composition. Unfortunately, researches described above do not deal with this thesis. To perform such minimization it is urgent to use the some formal system that will set some specific formal structures for engineering tasks (or web-services) description. Therefore, it will be possible to develop some formal simplification method based on minimization of the number of the engineering task sequence elements for the complex system. There are two types of formal systems that can be used for such purposes: mathematical logic and algebraic system [11, 12, 13].

Let us describe basic notions of the research:

Engineering knowledge portals – knowledge portals containing information, knowledge and services in engineering subject domain (engineering Web-services).

User's tasks – the specific tasks that are executed by the request of the end user.

Engineering tasks – user's calculation tasks, the implementation of those tasks are regulated by the standards of engineering subject domain.

Sequence of engineering tasks – an ordered set of specific engineering calculations aimed at solving a complex problem (for example: designing the structure parameters; determining values of reliability, structural strength, etc.);

Web services – the specific program module that executes certain stage of engineering task (or engineering task in total).

Engineering business processes - an ordered set of specific engineering Web services aimed at getting the solution of the complex engineering problem;

Meta descriptions – a specific set of descriptions that describes engineering tasks characteristics and features

This paper deals with engineering tasks that are represented on engineering knowledge portal. The described research operates with a formal system and a method of simplification used for such engineering tasks.

3. Algebraic System for Designing the Sequence of Engineering Tasks

Algebraic system for designing the sequence of engineering tasks allows obtaining the sequence of engineering tasks as ordered set of its parameters and elements by introducing specific formal structures for their description. As the result, this formal description will be used for composing the engineering task elements into an ordered set of specific engineering calculations or engineering business processes (presented as a complex web service) fast and correctly.

Algebraic system for designing the sequence of engineering tasks – is universal algebra (algebra) [12] and is characterized by a set of objects (engineering tasks - *ET*), a set of operations (*O*) and an empty set of relations $A_{ET} = \langle ET, O \rangle$.

Let us introduce the description of algebraic system elements for designing the sequence of engineering tasks.

<u>Objects</u> – are basic elements of the algebraic system, all operations are conducted on them. For the algebraic system the objects are represented by the set of engineering tasks

<u>Data</u> – is the set of elements that are given at the system input and output [14]. For

the algebraic system, the following data could be included: constants, variables, results of operations, etc. At the physical level, the data are represented by the values of various parameters and the subject domain characteristics, formulas, boundaries of values as well as partial services and computational procedures that represent user calculation tasks.

Operations. Operations of the algebraic system for designing the sequence of engineering tasks are divided into several groups according to their characteristics. Let us define those groups of operations:

Simple operations include

1. Elementary operations (operations of elementary algebra according to the definition):
+ - summation,
* - multiplication,

2. Set operations (operation on sets given in the set theory):
⊆ - set inclusion,
⊂ - proper set inclusion,
⊄ - negation of inclusion,
∈ - affiliation,
∉ - non affiliation.

3. Logical operations (logical operations of algebra of relations):
^{d} – supplement,
$^{-1}$ – inversion,
∨ – disjunction,
∧ - conjunction,
\ - difference
~ - equivalence,
∘ - composition
Complex operations are:
Opc - the operation of parallel connection,
Osc - the operation of serial connection,
Oc – the operation of logical composition,
Oi – the operation of inversion,
Om – the matching operation.

The group of simple operations includes standard operations [15-17] and the possibility of their usage for manipulating the elements of algebraic system of engineering tasks has been demonstrated and proved in the research. The group of complex operations is the group that includes novel operations used for the combination of the stages and the elements of engineering tasks in integral complex engineering task on the end user demand.

The properties of all operations have been detected as well. The research had shown that:

for simple operation - the properties are set and proved by an appropriate formal theory (elementary algebra, set theory, theory of relations, etc.),

for complex operations: all operations have the associativity property; all operations except logical composition operation have the following properties - commutativity, neutrality, universality and borders idempotence. The operation of logical composition has the property of distributivity.

A more detailed description of the proposed algebraic system is given in the research [18]. In this paper only main operations are listed and the properties of operations are mentioned as they are used as the base for minimizing a number of engineering tasks.

4. The Simplification Method of Engineering Task Sequences

The simplification method of engineering task sequences sequence allows to form the minimized set of engineering task elements used for the complex engineering task execution.

According to the algebraic system for designing the sequence of engineering tasks each engineering task can be presented as:

$$ET_k = \langle M_k, A_k \rangle,$$

where

M_k – the set of metha description of k-th engineering task,

A_k – logical formula of k-th engineering task.

Logical formula of engineering task - $F(ET)$ is a formula that includes elements of engineering tasks - $El(ET)$ (the stages of solving engineering tasks, the data of the algebraic system for the sequence of engineering task design, etc.) connected by operations – O of algebraic system for the sequence of engineering task design.

To increase the efficiency of an engineering task execution it is necessary to reduce the number of elements in the engineering task logical formula (Fig. 1). For this reason the simplification method of engineering task sequence is proposed. The simplification method of engineering task sequence is specific mathematical method used to represent the logical formula of engineering task in a minimal form.
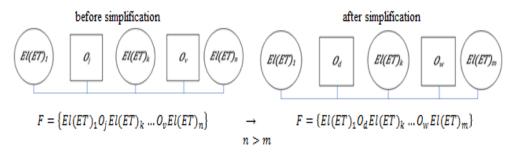

Fig. 1. Engineering task logical formula during the process of simplification

The simplification method of engineering task sequence is based on simplification criteria, the properties of operations and simplification rules.

The criteria - F is the number of elements in the engineering task logical formula. The aim of optimization process is to minimize the criteria:

$$F = \{El(ET)_1 O_j El(ET)_k \dots O_v El(ET)_n\},$$
$$n \rightarrow min$$

The properties of algebraic system operations allow us to held an equivalent conversion of engineering tasks formulas. Simplification rules are introduced based on operation properties. Simplification regulations set the rules of the formula transformations while proposed criterion allows us to give the preference to one transformation over the other.

Some additional rules are involved in the method allowing us to choose the one formula from a set of invariants which is optimal for an engineering task representation. The additional definitions, the rules and the theorems have been described for this purpose.

Thus, the proposed method of engineering task simplification allows us to reduce their execution time by minimizing the number of elements in the algebraic formula.

5. The Execution Efficiency Estimation of Engineering Business Processes

For the estimation of the proposed method applicability the test group of complex engineering calculations has been chosen. This group presents engineering calculations from the "Strength of materials" subject domain [19, 20]:
1. The strength calculation for the power components of magnetic systems.
2. The strength calculation for equipment and pipelines of nuclear power systems.
3. ITER Structural Design Criteria for magnetic components.
4. Magnet DDD 1.1–1.3. Magnet System Design Criteria.
5. The strength calculation for the elements of equipment and pipelines of ship nuclear steam generating systems with water reactors.

All elements of the complex engineering calculations have been represented by using algebraic system for sequence of engineering tasks design. Let us describe how to increase the engineering task execution efficiency (from the test group) by using the proposed method.

The engineering task execution time depends on the process of its formation and the composition of all elements that take part in its execution. During such processes the method of engineering task simplification is used.

As simplification criteria, the number of elements in the engineering task logical formula has been used. The criteria must be minimized which corresponds to the decrease of the number of requests to the storage of services used for engineering task (each element of engineering task) execution.

As the example, one engineering task from the test group is presented in Table 1. It is shown that before the simplification, the formula consists of 157 elements and after the usage of the proposed method, the number of formula elements are 131.

Table 1. The number of elements of engineering calculation formula

The title of the complex engineering calculation	The number of elements of engineering calculation formula	
	Before simplification	After simplification
The strength calculation for the elements of equipment and pipelines of ship nuclear steam generating systems with water reactors	157	131

Thus, the usage of the proposed method allows us to reduce the number of elements in engineering task formula (for the engineering tasks from the test group) by 1.2 times, that leads to the decrease in the number of requests to the storage of services used for engineering tasks by 1.2 times, which in turn leads to the minimization of the engineering task execution time by 17%.

6. Conclusions

The paper describes the simplification method of engineering task sequences based on the specific algebraic system for designing the sequence of engineering tasks aimed at forming the minimized set of web services used for complex engineering calculations execution.

The method allows us to increase the efficiency of various computational tasks execution represented on knowledge portals in different engineering subject domains.

Our future works will deal with the implementation of the suggested method for user tasks of various subject domains which will allow us to demonstrate the method efficiency and applicability for various real world scenarios.

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