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ACOUSTIC MATERIALS DATABASE PROCESSING IN THE CAD SYSTEM BY THE HOPCROFT-CARP ALGORITHM FOR COMPARISON OF BIPARTITE GRAPHS

І.С. Сінько, І.І. Сидоренко, А.В. Павлишко, М.С. Ішаєва. **Обробка бази даних акустичних матеріалів у системі САПР за алгоритмом Хопкрофта-Карпа для зіставлення дводольних графів.** Розвиток промисловості потребує наявності великого різноманіття промислових приміщень з особливими вимогами до їх акустичних характеристик. Як наслідок, внутрішнє оздоблення промислових приміщень потребує використання акустичних оздоблювальних матеріалів, які в кінцевому підсумку визначають акустику всього виробничого комплексу. Однак, на етапі проектування промислових приміщень, особливо при використанні спеціалізованого програмного забезпечення, виникає ряд труднощів з обгрунтованим вибором для цього акустичних оздоблювальних матеріалів. Враховуючи на те, що існуючі на тепер програми дозволяють лише приблизно розрахувати акустику приміщень і жодна з них не дає відповідь на питання, чи задовольняє отримана модель приміщення вимогам законодавства і замовника існує потреба в розробці нового програмного забезпечення, яке вирішує цю проблему. При розробці нового програмного забезпечення такого типу завжди виникає проблема зберігання та ефективної обробки довідкової інформації, що організована у вигляді бази даних. В роботі запропоновано моделювання потрібної бази даних у вигляді математичного апарату, якій уявляє собою граф. Вирішенні поставленої задачі проведено на моделюванні бази даних акустичних матеріалів дводольними графами. Виходячи з цього, обробка інформації такої бази, з метою пошуку потрібної інформації у найменший час, проведена з використанням одного з алгоритмів для зіставлення дводольних графів. У якості алгоритму використано алгоритм Хопкрофта-Карпа. На основі прикладу установлено, що прийнятий алгоритм не завжди дає вірне рішення, оскільки усуває у прийнятій графовій моделі бази даних ребра із загальними кінцевими точками і створює інцендентні ребра. Виходячи з отриманих результатів дослідження запропоновано і реалізовано у системі AUTOCAD на мові AUTOLISP базу даних акустичних матеріалі, що відповідає графовій моделі у вигляді орієнтованого графового дерева, обробка якого алгоритмами обходу графів DFS и BFS дає вірне рішення з найменшими витратами часу.
Ключові слова: акустичні матеріали, дводольний граф, алгоритм Хопкрофта-Карпа, орієнтоване графове дерево, алгоритми обходу графів DFS и BFS

I. Sinko, I. Sydorenko, A. Pavlychko, M. Ishaeva. **Acoustic materials database processing in the CAD system by the Hopcroft-Carp algorithm for comparison of bipartite graphs**. The development of industry has revealed the need for a wide variety of production facilities with special requirements for their acoustic characteristics. As a result, the interior decoration of any production room requires the use of acoustic finishing materials, which ultimately determine the acoustics of the entire production complex. However, at the stage of designing industrial premises, especially when using specialized software, a number of difficulties arise with the justified choice of acoustic finishing materials for this. Taking into account the fact that currently existing programs allow only approximately calculate the acoustics of rooms and not one of them gives an unequivocal answer to the question, the obtained model of the room meets the requirements of the legislation and the customer, therefore there is a need to develop new software that solves this problem. When developing new software of this type, the problem of storing and efficiently processing reference information organized in the form of a database always arises. The paper proposes modeling the desired database in the form of a mathematical apparatus, which is a graph. The solution of this problem was carried out on modeling a database of acoustic materials with bipartite graphs. Based on this, information processing of such a database, in order to find the necessary information in the least time, was carried out using one of the algorithms for comparing bipartite graphs. The Hopcroft-Karp algorithm is used as an algorithm. Based on an example, it was found that the adopted algorithm does not always give the right solution, since it eliminates edges with common end points in the graph model of the database model and creates random edges. Based on the results of the study, a database of acoustic materials in the AUTOCAD system in the AUTOLISP language is proposed and implemented, which corresponds to a graphical model in the form of a tree of oriented graphs, the processing of which allows you to use DFS and BFS scanning algorithms and get the right solution with the least amount of time.
Keywords: acoustic materials, bipartite graph, Hopcroft-Carp algorithm, oriented graph tree, DFS and BFS graph traversal algorithms

Introduction

The development of industry has revealed the need for a wide variety of production facilities with special requirements for their acoustic characteristics. As a result, the interior decoration of any pro-

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duction room requires the use of acoustic finishing materials, which ultimately determine the acoustics of the entire production complex. In many existing production facilities, sound is absorbed by an acoustic ceiling or vertical buffles, in the frequency range 250…4000 Hz, as well as additional acoustic screens, which helps to reduce reflected noise, for example, from a concrete floor. However, at the design stage of production facilities, especially with the use of specialized software, a number of difficulties arise with the justified choice of acoustic finishing materials for it. So, the existing and actively used programs ULYSSES, Spectra Series, EASE allow only approximately calculate the acoustics of rooms and none of them gives an answer to the question whether the obtained model of the room meets the requirements of the legislation and the customer [1 – 3]. In this regard, a need arose to improve existing or develop new computer-aided design programs for industrial buildings with some acoustic features [2, 4].

Analysis of publications

At present, when developing a new program "Designing premises with the required acoustic characteristics", as a result of the analysis of the design stages, the necessity of designing and creating a specialized database of acoustic materials has become clear [5 – 7]. It is known that databases of this type should be presented in the form of a totality of information on certain acoustic materials, systematized so that the required information can be found and processed with the least loss of time [1, 3, 5].

However, given the saturation of databases with a large amount of information, the latter in some cases seems quite complicated. Therefore, the creation of a database in the form of some mathematical apparatus that allows optimizing the processing of information stored in the database is an important scientific and applied task.

Unsolved problem area is the lack of CAD systems that allow designing buildings, rooms with special acoustic properties and having all the necessary tools, including a database of acoustic materials involved in the calculation of single-layer and multi-layer building structures.

Purpose of the article consists in creating a specialized database of acoustic materials, built on the basis of some scientifically sound mathematical apparatus, the use of which can reduce the time of designing premises with specified acoustic properties.

Tasks that must be completed to achieve the goal of the article:

– perform an analysis of the properties of acoustic materials;

– create a datalogical model of a database of acoustic materials;

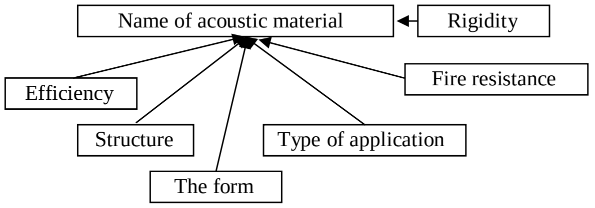
– to develop a model for processing a database of acoustic materials;

– development of an original approach for designing a specialized database.

Acoustic materials database design methodology

When designing a database of acoustic materials, an important role is played by the choice of the method of processing of it; therefore, a preliminary classification of acoustic materials was carried out on the basis of the principle of the functional purpose of these materials, which made it possible to systematize their information, component for the convenience of extracting information in the design of industrial premises and multi-purpose buildings [2, 4]. The developed database is an integral part of the program "Design of industrial premises with the required acoustic characteristics" [5].

The datalogical model of the developed database of acoustic materials differs little from similar databases with unsorted elements for information objects with their individual properties specifically expressed (Fig. 1).



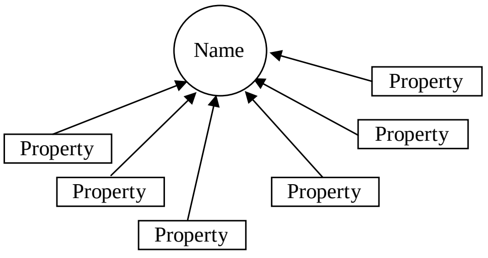


Fig. 1. Model of a database of acoustic materials: datalogical (a) in the form of a directed graph (b)

Moreover, it can be represented both by a datalogical model (Fig. 1, *a*), and in the form of an oriented graph (Fig. 1, *b*).

As a rule methodology of work of operators of search and processing of data from such bases is built on a next algorithm: to find the indicated tree of database; transition from one tree to other; to find the copy of segment that meets the condition of search; transition from one segment to other into a tree; transition from one segment to other in order of round of hierarchy; to find and retain for subsequent modification the only copy of segment that meets the condition of search; to find and retain for subsequent modification the next copy of segment with the same terms of search; to find and retain for subsequent modification a next copy for that ancestor; to insert the new copy of segment in the marked position; to renew the current copy of segment; to delete the current copy of segment.

On this basis, a conclusion follows that in basis of treatment of database the cycle of comparison of it is fixed every element with a set value. Such approach is not very rational, especially at plenty of unassed elements, as an amount of comparisons, that will be required for being of the required element, is unknown. It is related to that the sought after element can be the first in an array (that results in only comparison), either is on the last position or an element is absent in general. If, for example, an array consisted of 120 elements, then such is exact amount of operations was required for being of necessary element. If the amount of array cells will increase to 1200, then the amount of operations just will increase to 1200. Thus, in this case dependence turns out linear, at that the amount of operations increases with the increase of amount of elements. Taking into account that access to any array cell occupies constant time, then treatment of such database can delay on long time.

Since a certain hierarchy of the model was used in the development of the database of acoustic materials, in which the integrity of links between ancestors and descendants is automatically maintained, it was initially proposed to consider such a database not as a directed graph, but as a collection of bipartite graphs (bigographs). In a bipartite graph, its set can be divided into two parts in such a way that each edge of the graph connects some vertex from one part (for example, an information object) to some vertex of the other part (individual properties of the information object), that is, there is no edge connecting two vertices from the same part [8 – 10]. Then, information processing in the database of acoustic materials can be carried out using one of the algorithms for comparing bipartite graphs. The Hopcroft-Karp algorithm was adopted as such an algorithm [9, 11, 12].

The essence of the algorithm is as follows – the algorithm takes a bipartite graph as an input and returns the maximum matching power, that is, the largest set of edges. At the same time, the condition that none of the two edges should have a common vertex must be satisfied. The operation of the algorithm can be represented as follows:

$$\begin{gathered}\text{Entrance: Bipartite Count } G\,(U \cup V, E)\\ \text{Output: matching } M \subseteq E\\ M \leftarrow \varnothing\\ \text{cycle}\\ P \leftarrow \{P_1, P_2, \ldots, P_k\}\\ M \leftarrow M \oplus (P_1 \cup P_2 \cup \cdots \cup P_k)\\ \text{until } P \neq \varnothing.\end{gathered} \quad (1)$$

Let consider, as an example, processing the base of acoustic materials according to the adopted algorithm (1). For simplicity of illustration, the following assumption is accepted: the database contains only 4 filters (individual properties of the material) and 8 items of material. Materials are marked with letters from A to H, and filters are selected randomly (Fig. 2, *a*).

Processing the base of acoustic materials according to algorithm (1) carried out according to the founding algorithms for traversing the graphs DFS (Depth First Search) and BFS (Breadth First Search) allowed us to obtain some result. A graphical interpretation of the result shows that the solution according to the Hopcroft-Karp algorithm is not correct (Fig. 2, *b*). A solution that requires edges with common vertices leading to different vertices that define the material and which fall into the same

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subset of filters can be considered true. It is established that in the case under consideration the Hopcroft-Karp algorithm eliminates such edges with common endpoints and creates edges incident to the vertices of both subsets.

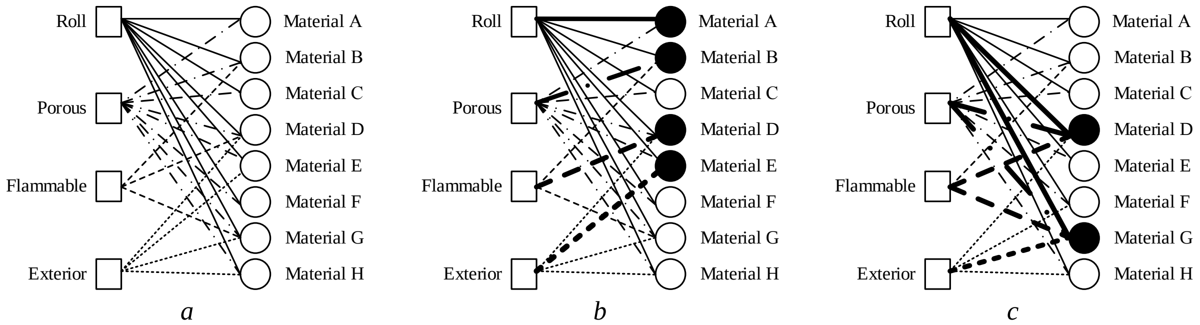


Fig. 2. Processing a database of acoustic materials: a set of bipartite graphs "material – properties" (a); decision algorithm Hopcroft-Karp (b); decision by the criterion "highest degree (valency) of the peak" (c)

In fact, for the correct solution of our example, it is necessary to obtain all coinciding edges that have a common end point – the top of the graph is the defining material. This can be obtained, for example, by determining the degrees (valencies) of the vertices of the graph that determine the materials in the database of acoustic materials and comparing them with some desired value (Fig. 2, *c*). To do this, you can use the formula of the sum of degrees that defines the "Handshake lemma":

$$\sum_{v \subset V} \deg(v) = 2|E|, \tag{2}$$

for a graph with many vertices *V* and many edges *E*.

However, taking into account the obtained research results, it was proposed to create a database of interest to the authors in the form that defines a balanced binary search tree with several primary (external) sort keys with a set of satisfying records. Such a view is defined by an oriented graph tree, the processing of which is also carried out according to algorithms for traversing the DFS and BFS graphs (Fig. 3, *a*).

The base apparatus adopted in the further development in the form of a graph tree allows you to simply get a presentation of the database of acoustic materials according to the hierarchy of individual material properties (Fig. 3, *b*). It was in this form that the model of the acoustic materials database was first implemented, which is implemented in the AUTOCAD system in the AUTOLISP language. The hierarchical database model allows you to perform operations: adding a new record to the database, retrieving a record, changing the data value of a previously extracted record, deleting a record and all records subordinate to it. In the operation of extracting a record, it is possible to specify sampling conditions, which greatly simplifies the work with materials. The developed database is planned to be used in the design of indoor and outdoor rooms with acoustic properties and allows reduce the complexity of calculations, as well as reduce the design time.

Results of the developed original approach and specialized database design methodology

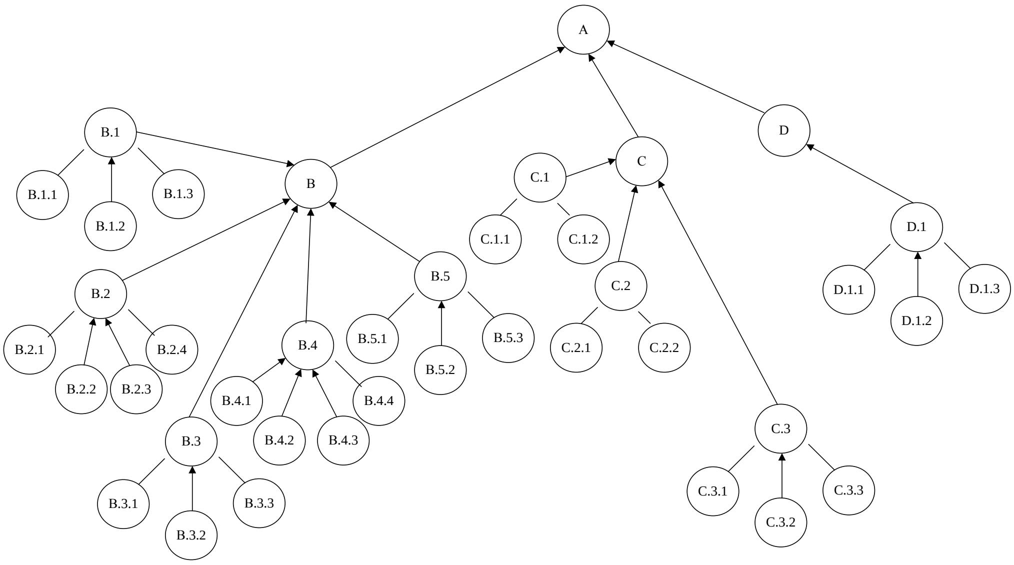
When creating the required database of acoustic materials, an approach was used that consists in the following:

– when designing any object using specialized software, first of all, the client's requests and wishes are analyzed, based on which a possible approach to solving the problem is determined;

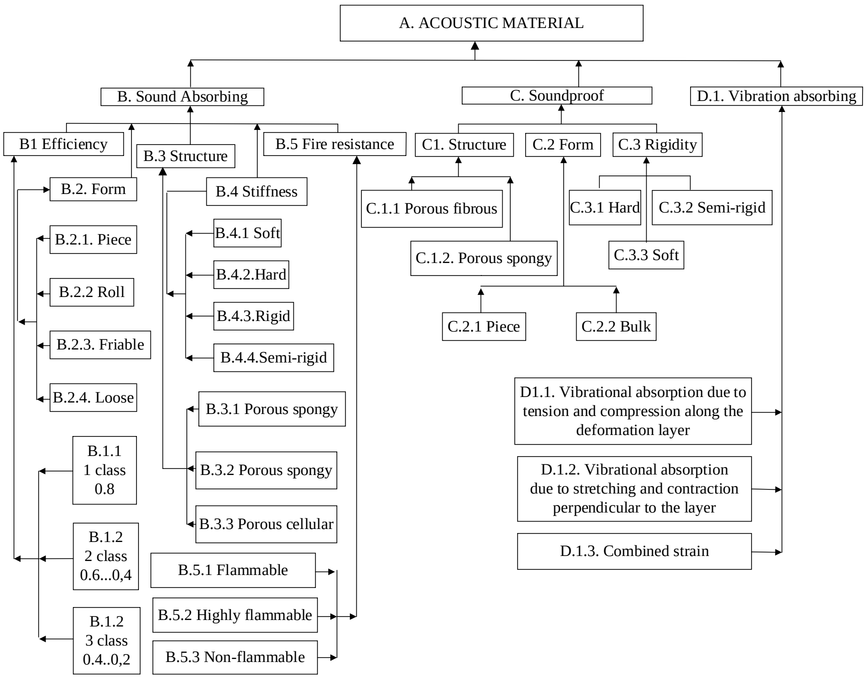
– based on the analysis, a specific model is implemented in a specific software environment;

– the results of each design phase are used as source material for the next stage;

– the database is focused on a specific subject area and is organized on the basis of a certain subset of data.



a



b

Fig. 3. Presentation of a database of acoustic materials: tree of oriented graphs (a); in accordance with the hierarchy of individual material properties (b)

Conclusions

Based on the research, the following is established. The Hopcroft-Karp algorithm when solving problems of bipartite graph matching does not always allow us to achieve the correct result, since it eliminates the edges of the graph with common finite points and creates edges incident to the vertices of both subsets.

DFS and BFS graph traversal algorithms are important tools for solving sampling problems, in the case of constructing a database structure in the form of oriented graphs. It should be noted that the DFS algorithm in some cases has a recursive implementation, which should be eliminated, since additional machine memory is required to be allocated for it. That is why a recursive implementation is

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considered irrational (additional space under the stack and numerous function calls) and even dangerous (stack overflow). In critical programming systems (designing nuclear facilities, spacecraft, etc.), recursion is completely prohibited. When implementing BFS without recursing of the task, it was necessary to use a queue, and the stack was used to implement DFS.

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