A System of Graphical Searching for Electrical Circuits and Parts of Instruments

D.R. Kasimov [1], A.V. Kuchuganov [2]

Department of Automated Data Processing and Control Systems,
Kalashnikov Izhevsk State Technical University, Izhevsk, Russia
E-mail: [1] kasden@mail.ru, [2] Aleks_KAV@udm.ru

Received: 09.11.2015

Abstract. We propose a system for content-based retrieval of instrumental graphical documentation on the base of matching graphic patterns of a query image and archival images. Analogous systems are analyzed. Experiments on searching for electrical circuits as well as devices' parts are presented, which show high efficiency of the system.

Keywords: search, recognition, matching, scheme, drawing, part, instrument

INTRODUCTION

When designing new instruments, engineers often rely on existing components and solutions in order to reduce new product development time and to avoid repeated designing.

At an instrument-making enterprise, technical information is usually accumulated in a centralized enterprise archive. In addition, a lot of useful documents can be found at employees' workplaces. A significant proportion of key instrumental documentation is represented in the form of vector and raster schemes, drawings and sketches of devices and their components.

An engineer can manually browse only a small fraction of the total number of available graphic documents, which are estimated in tens or even hundreds of thousands. Automated searching by keywords, text descriptions or ciphers created according to some coding system often has big losses in recall and precision since in such searching a very limited part of a graphic document's content is considered.

A more efficient way of retrieving relevant graphical information is provided by systems of searching by a sample image, which are based on matching graphic objects and evaluating their similarity. In the search process, an image given by a user as a query is compared with all images in a database. Images that are most similar (from the system's point of view) to the query image are placed into results.

We developed the system *GrSearch*, which searches for technical drawings and schemes by a sample image (sketch). The system differs from its analogues by a more advanced search dialog and variety of search types [1].

In this paper we describe the developed system and provide results of its approbation on real instrumental engineering drawings and schemes.

© Kasimov, D.R., Kuchuganov, A.V., 2016

SURVEY OF ANALOGUES

In the experimental system *ShapeLab* of Purdue University [2] two methods of matching parts' drawings are implemented. In the first method images are represented as spherical harmonics; their matching is based on a fast transform. In the second statistical method a drawing is represented as a 2D shape histogram, i.e. as a distribution of distances between pairs of randomly sampled points; the Minkowsky distance is used for measuring similarity between two such histograms.

The commercial system *CADFind* [3] represents a part's drawing by a so-called GT (Group Technology) code, which describes geometry of the part as well as text information related to it (material, process technology, etc.). Comparison of GT codes is performed with help of fuzzy logic.

A system of researchers Wang and Jiang [4] represents drawing images in the form of hierarchical topological graphs and performs their matching on the base of the nested assignment algorithm and the EMD distance (Earth mover's distance).

Existing systems of searching for drawings by a sample image have the following shortcomings:

- methods that are implemented in one systems are operable only on part drawings, and methods that are used in other systems haven't been experimentally verified for applicability for electrical circuits and installation diagrams;
- don't allow to customize queries;
- don't fix elements of similarity and dissimilarity (give only mathematical estimation of similarity of objects).

THE DEVELOPED SYSTEM

In the system *GrSearch* a graph model of description of a drawing image is used, which includes four level of abstraction: graph of singular points and segments; graph of contours; graph of 3D objects; graph of heterogeneous components. Graph nodes describe an image's components, and graph edges represent spatial relations between them in qualitative concepts on the base of linguistic variables [5].

Matching of drawing images is based on applying the beam graph [6]. It allows comparing drawing images of different scales and orientations, performing searching for entries of one graphic object in another one, identify elements of similarity and dissimilarity, considering special requirements that can be attached to particular components of a query image.

An extended model of a search dialog is implemented, which includes several types of searching, the possibility to specify general and specific requirements to search results, visualization of elements of similarity and dissimilarity. It enables a user to implement a flexible search strategy and to refine search needs.

The system also supports searching for scanned raster drawings. Raster images are first vectorized. The feature of our approach to automatic vectorization of drawings is performing ternary segmentation of an image, fuzzy synthesis of a skeleton on the base of two variants, multistep approximation and refinement [7]. As for any other vectorizer, image resolution and the quality of a paper carrier are of great importance. Conducted preliminary experiments have shown that our vectorizer copes with drawings of not very good quality better than commercial analogues (GTX Raster R2V, VPstudio, Scan2CAD, Vextractor).

EXPERIMENT ON SEARCHING FOR ELECTRICAL SCHEMES

We have conducted experiments on searching for electrical schemes of various devices. The search system indexed 20 schemes created in the CAD system KOMPAS-3D. Fragments from these schemes as well as sketches made in KOMPAS-3D were used as queries. The search was carried out on the base of graphs of singular points and segments.

Fig. 1 shows an example of search results. At the top of the figure a query fragment and its graph representation are presented. Since the relay and the incandescent lamp may have connections of different length in required schemes, we specified the clarifying requirement “Length = Any” for the corresponding edges of the graph. At the bottom of Fig. 1 the schemes that have been retrieved by the system are presented. All these schemes have the given fragment. The entries have been automatically circled in red by the system.

Search speed depends on the size of a query fragment; in this experiment the search lasted at least 1 s and a maximum of 6 s.

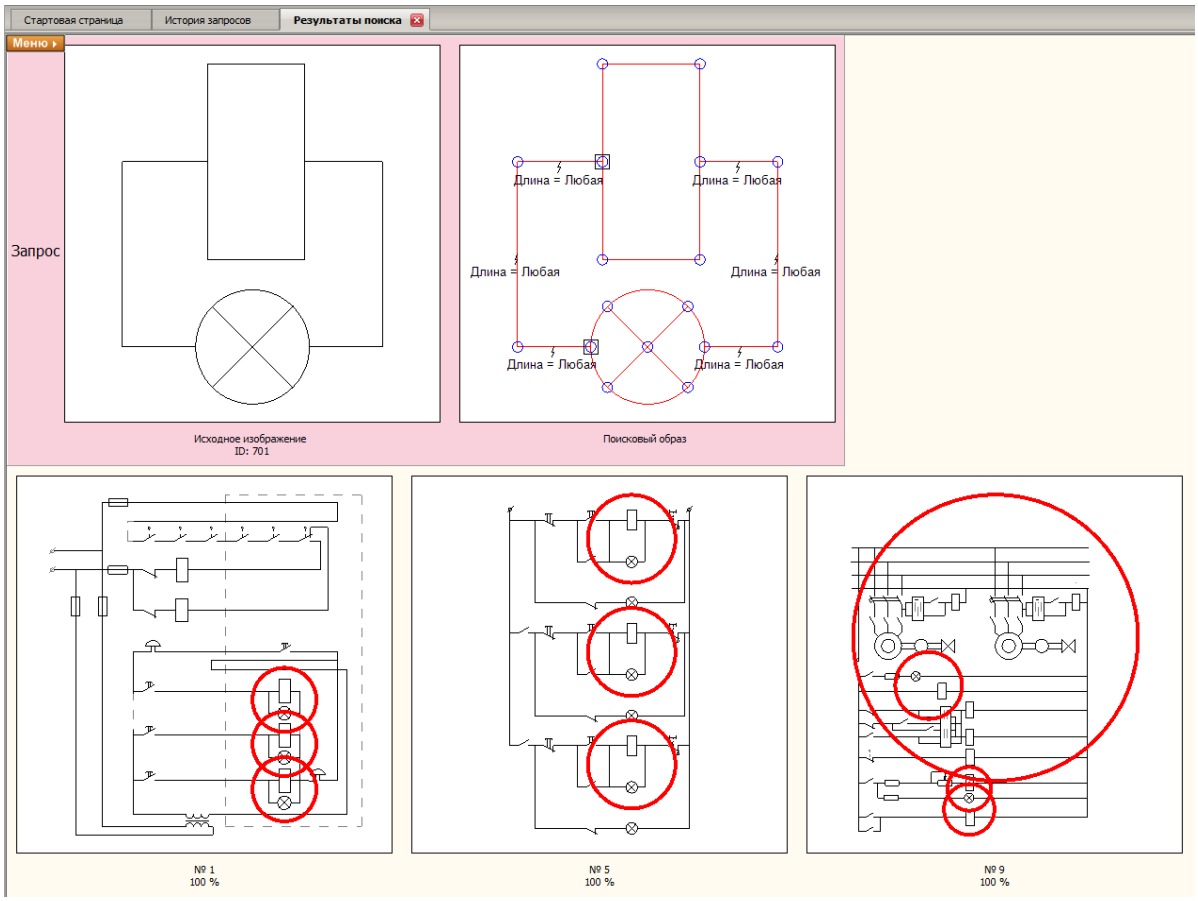

Figure 1. Example of results of searching for electrical circuits containing the given fragment

EXPERIMENT ON SEARCHING FOR PARTS OF INSTRUMENTS

An experiment on searching for instrument drawings has also been conducted. 117 drawings in the DXF format of the Mitutoyo corporation [8], which produces high-precision measuring instruments, have been added to the searchable database. The search was carried out on the base of graphs of contours.

Fig. 2 provides an example of search results. The query is the image of the working end of a measuring rod. The retrieval contains drawings of linear gauges and digital dial indicators.

Searching for instrument drawings was faster (1–3 s) than searching for electrical schemes since graphs of drawings have a smaller number of nodes and edges.

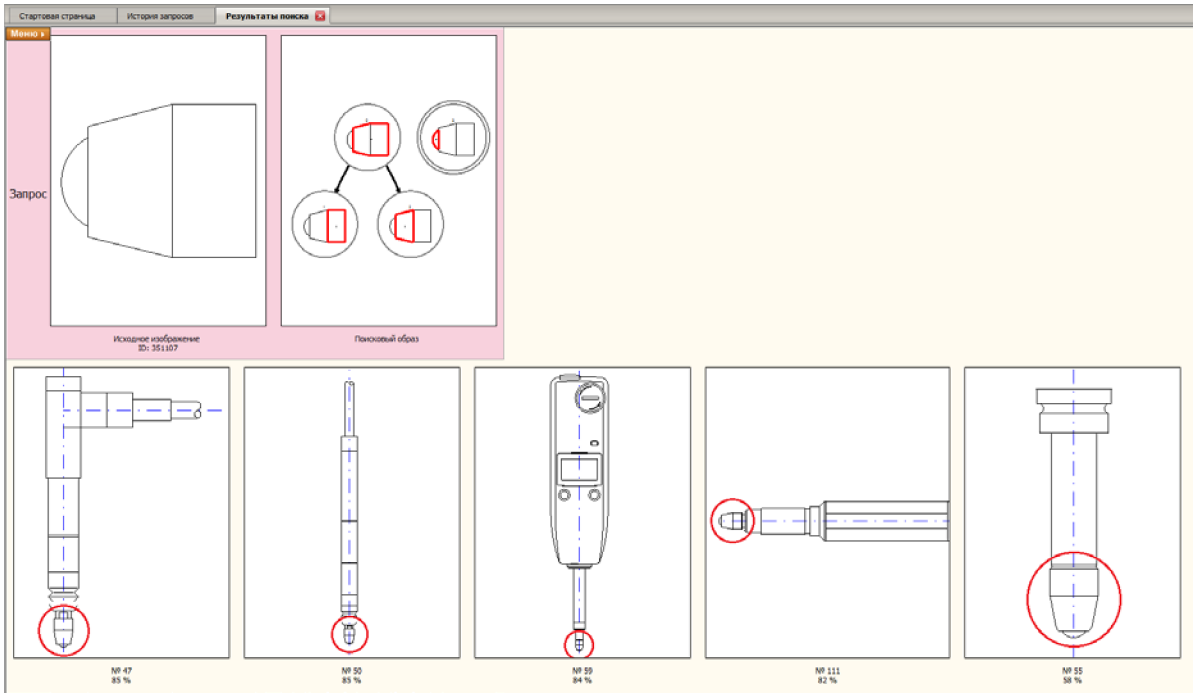

Figure 2. Example of results of searching for measuring instruments having a measuring rod with the given end

EVALUATING THE RETRIEVAL RECALL

A popular way of assessing the search quality is determining the recall parameter. Retrieval recall is the ratio *R/T*, where *R* is the number of retrieved relevant documents, and *T* is the total number of relevant documents in the database [9].

We have assessed the recall of searching for part drawings. Test database contained 2500 CAD drawings. We have performed 10 queries in our system.

Recall charts of searching for analogues that are highly relevant to queries are presented in Fig. 3.

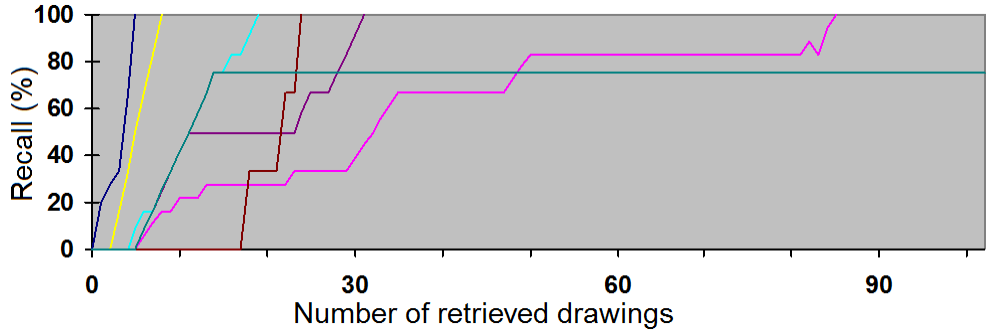

Figure 3. Retrieval recall charts for analogues that are highly relevant to queries

Fig. 4 shows recall charts of searching for analogues that are medium relevant to queries.

It is natural that the recall level is a bit less for parts that are vaguely similar to queries.

The average recall is 72 %. In our opinion, this value is a good enough since parts that are very different in shape can be considered as relevant in some engineering tasks (see Fig. 5).

The minimum search time was 5 s, and the maximum was 40 s.

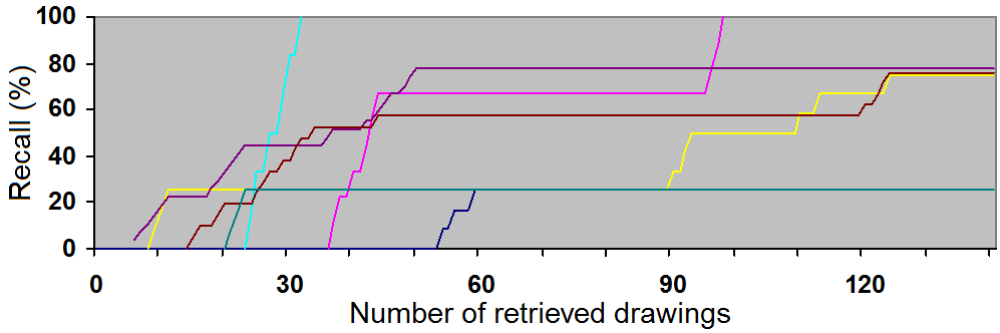

Figure 4. Retrieval recall charts for analogues that are medium relevant to queries

Figure 5. Examples of parts that are relevant to each other but have significant differences in shape

CONCLUSION

Existing ways of searching for drawings don't completely meet designers' needs in terms of relevance, the range of tasks, controllability and transparency.

Our methods and software tools of searching for drawings and electrical schemes by a sample image (sketch) allow a user to effectively retrieve useful information from archives of technical documentation.

The proposed system provides several types of the search, allows a user to clarify a query by means of customizing a search pattern, and visualizes matched elements in search results. A user can implement flexible search strategies.

The effect of applying the system is reducing the time and costs of designing new products.

This work was partially supported by the State assignment of the Ministry of Education and Science of the Russian Federation No. 625 and Russian Foundation for Basic Research No. 15-07-08077A.

REFERENCES

1. D.R. Kasimov, A.V. Kuchuganov, V.N. Kuchuganov, "Individual strategies in the tasks of graphical retrieval of technical drawings," Journal of Visual Languages and Computing, Vol. 28, pp. 134–146, 2015.
2. J. Pu, K. Ramani, "On visual similarity based 2D drawing retrieval," Computer-Aided Design, vol. 38, iss. 3, pp. 249–259, 2006.
3. D. Love, J. Barton, "Aspects of design retrieval performance using automatic GT coding of 2D engineering drawings," IDDME 2004 Proceedings, 2004.
4. P. Wang, S. Jiang, "An engineering drawing retrieval method based on nested assignment algorithm," Journal of Computational Information Systems, vol. 9, iss. 2, pp. 713–720, 2013.
5. L.A. Zadeh, "The concept of a linguistic variable and its application to approximate reasoning," Journal of Information Science, vol. 8, No. 3, pp. 189–281, 1975.
6. A.V. Kuchuganov, D.R. Kasimov, "Multilevel cognitive analysis in graphical retrieval of drawings," Pattern Recognition and Image Analysis, vol. 23, No. 4, pp. 518–523, 2013.

7. A.V. Kuchuganov, D.R. Kasimov, “Soft Computing in the Task of Vectorizing Archive Drawings,” Proceedings of International Conference on Artificial Intelligence and Systems IS&IT'15, vol. 1, pp. 266–271, 2015.
8. Mitutoyo Deutschland CAD-Zeichnungen, URL: http://mitutoyo.de/de_de/downloads/cad-zeichnungen/.
9. C. Manning, R. Prabhakar, H. Schütze. Introduction to Information Retrieval, New York: Cambridge University Press, 2008.