Journal of Visual Languages and Computing 28 (2015) 134–146

Contents lists available at ScienceDirect

Journal of Visual Languages and Computing

journal homepage: www.elsevier.com/locate/jvlc

Individual strategies in the tasks of graphical retrieval of technical drawings ☆

Denis R. Kasimov *, Aleksandr V. Kuchuganov, Valeriy N. Kuchuganov

Department of Automated Data Processing and Control Systems, Kalashnikov Izhevsk State Technical University, 426069 Studencheskaya 7, Izhevsk, Udmurt Republic, Russia

ARTICLE INFO

Article history:
Received 11 November 2013
Received in revised form
24 December 2014
Accepted 26 December 2014
Available online 5 January 2015

Keywords:
Technical drawing
Content-based retrieval
Matching graphs
Search strategy

ABSTRACT

A designer's information need can have a lot of finer points not expressible completely by textual attributes or global aggregated image features. The purpose of the study is to develop a cognitive environment for content-based engineering drawing retrieval, allowing a user to concretize queries, to implement strategies that are most effective for the current search task. We propose meaningful customizable graphic search patterns, various comparison modes and visualization of matched elements. The presented experiments show that the approach yields good results in the sense of relevance and is comfortable in terms of controllability. The possibility to customize search patterns can result in improving retrieval precision by 10–15%. In practice, it can significantly increase the degree of automation of the design-reuse process.

1. Introduction

When designing new products it is important to apply accumulated knowledge such as existing components, design solutions and technological processes. It is known that design engineers spend approximately 25% of their time searching for and using design information to complete their work [1]. However, it is difficult to find a required document among thousands of them considering the graphic nature of technical documentation, which includes drawings, 3D models and scanned documents containing both text and graphics.

Currently the drawing retrieval problem is solved mainly on the base of textual–numeric attributes, classification codes and text descriptions created by people. Herewith, in addition to the high cost of manual labor in constructing and maintaining an archive and incompleteness of part geometry description, it is difficult to formulate queries, including because of the influence of subjectivity, when humans describe the same part differently.

These deficiencies are absent in methods that perform drawing retrieval by a user-specified sample image. However, none of existing content-based drawing retrieval systems has a sufficient level of transparency, control and guidance, which, according to [2], are the main goals any search engine has to adhere. The possible reason of this is that in these approaches the representation of a graphic object is weakly connected with its content.

In existing drawing retrieval methods a search dialog is rather primitive, i.e. simply a sample image is specified, and a retrieval system outputs results. Meanwhile, in design activities various kinds of search tasks arise. The most distinctive features of required drawings are different in different situations: a projection view, a projection's fragment, an external contour, standard mechanical features, symmetry of a part, etc. In practice, it is necessary to consider a part's feature (groove, pocket, hole, etc.) as a decisive distinguishing characteristic in some situations and to ignore

Abbreviations: FSLG, fuzzy spatial loaded graph; CSG, Constructive Solid Geometry

☆ This paper has been recommended for acceptance by Shi Kho Chang.

* Corresponding author. Tel.: +7 341 277 6055x3257.
E-mail addresses: kasden@mail.ru (D.R. Kasimov), Aleks_KAV@udm.ru (A.V. Kuchuganov), kuchuganov@istu.ru (V.N. Kuchuganov).

http://dx.doi.org/10.1016/j.jvlc.2014.12.010
1045-926X/

it in other cases, to modify the search prescription without redrawing the sample image, to set exact requirements to similarity of individual components, etc.

Search engines' users can be divided into three classes, depending on how clear they understand their search need [3]: (1) a *browser* has no clear end-goal, performs a series of unrelated searches; (2) a *surfer* does exploratory searches in the beginning, but in the process of working his clarity of what he wants from the system is gradually increased; (3) a *searcher* has a clear intent, performs well related searches leading to an end-result. The same user in different search sessions may relate to different classes, and his search strategies vary considerably. Therefore, a good retrieval system should provide an opportunity for each class of users to build effective strategies, including individual for each person.

The purpose of the study is to develop a retrieval environment allowing a user to concretize queries, to implement various strategies that are most effective for the current search task. It is necessary to expand the existing scenario of the drawing retrieval dialog.

The paper is organized as follows. In Section 2 related works on content-based technical drawing retrieval are analyzed. In Section 3 we describe our approach for automatically describing and matching drawing images, propose the retrieval environment's elements that are aimed to improve the retrieval flexibility and relevance. In Section 4 the retrieval system's prototype is described, experiments on evaluation of the proposed retrieval environment are provided. In Section 5 we discuss obtained results. Finally, in Section 6 the conclusion is made and directions for further work are listed.

2. Related work

There are many approaches to the content-based technical drawing retrieval. Extensive surveys are even devoted to them [4,5].

In the area of graphical retrieval of drawings and in pattern recognition in general, the approaches prevail in which a global description is given to a graphic object, and comparison of graphic objects consists in applying some algebraic distance measure to their aggregated descriptions. In the experimental system ShapeLab [6] two drawing matching methods are implemented. In the first method, drawings are represented as spherical harmonics; a fast transformation is applied for their comparing. In the second method, a drawing is represented as a 2D shape histogram, a distribution of distances between pairs of randomly selected points; for measuring similarity between two such histograms the Minkowsky distance is used.

In the work [7] an approach for retrieving vector drawings by a sketch drawn by a hand on a tablet device is presented; earlier versions of this approach are considered in [8,9]. The content of drawings is decomposed into topology (spatial arrangement of polygons in a drawing) and geometry (shape of these polygons). Topological information is organized in the form of a graph, in which nodes represent the drawing's polygons, and edges correspond to relationships between them of three types: inclusion; adjacency; and spatial proximity. The topology graph is then converted into multidimensional descriptors on the base of computing its spectrum. To speed up searching, descriptors are indexed on the base of the NB-Tree. The retrieval process is divided into two steps: (1) selecting drawings topologically similar to the query and (2) computing geometry similarity between each candidate drawing and the query sketch.

The method described in [10] is based on the Hough transform, which is applied for generation of a feature vector. Not the whole cumulative matrix is used, which is built when calculating the Hough transform, but only the angular information. Comparison of images is performed by calculating a distance between their feature vectors according to a very simple formula.

The approach proposed in [11] represents drawings as feature vectors of pixel blocks and calculates their similarity by the linear weighted cosine similarity method.

In the method described in [12] an elementary descriptor of a drawing image is a so-called local neighborhood structure (for simplicity, also called as patch), which is obtained by grouping lines/arcs around some reference line. Matching is based on identification of dense regions in a transformation parameter space (object center, scale, rotation) using the mean shift method.

The system CADFind [13] indexes not only geometry of the part in a drawing, but also text information associated with it, including material, manufacturing process. Information extracted from a drawing is represented in the form of a so-called Group Technology (GT) code, a string of textual–numeric symbols. Matching drawings is carried out by fuzzy comparison of corresponding GT codes.

There are also approaches that use a structural description of a drawing's graphic object, but matching drawing images has a mechanical bias; there is no meaningful analysis of components and relations between them. In the paper [14] a method for searching technical drawings on the base of matching attributed graphs describing drawings is proposed. Graph nodes correspond to primitives (lines and curves), and edges describe spatial relations between these primitives. To solve the graph matching problem, the mean field theory is used.

In the paper [15] two alternative methods for searching raster technical drawings in a patent database are considered: by measuring the similarity of graphs and by comparing histograms. Both methods involve transformation of the line set of a drawing into directed graph of 6-nearest (by Euclidean distance between line centers) neighbors, edges of which are loaded by invariant attributes: relative angle and relative position of two lines. These attributes are also used when two-dimensional histograms are created. Matching graphs is carried out with the use of a variant of the Hausdorff distance. Comparison of histograms is performed by measuring the Bhattacharya correlation.

The system that is proposed in [16] represents drawing images in the form of hierarchical topology graphs and performs their matching on the base of nested assignment algorithm and the EMD distance.

The purpose of the work [17] was to carry out matching parts' contours in such a way that the matching result is adequate to engineering interpretation: determining overall structural similarity with tolerance to local bending and stretching. The two-level representation of shapes is