Research on Automatic Dimensioning of the Engineering Drawing Based on CBR

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Abstract. In this paper, we describe a novel automatic dimensioning method. The method redefines the characteristics of graphics output primitive and determines the position and type of dimension in new drawings by comparing them with similar engineering drawings which with dimension. Firstly, redefining graphics output primitive so that each graphics output primitive has its own unique attributes, creating dimension templates and each template consists of three parts: the dimension object, the dimension type, and the dimension placement point. Secondly, finding the case that is most similar with the topological structure, geometric structure, and expression function of the new drawing from the case library. At the end, by making a match with the case select from case library to determine the dimension object, dimension type, dimension value, and dimension placement point in the new drawing. Our early experiments show that the presented theory has a good usability.

1. Introduction
With the continuous development of science and technology, big data and intelligent learning technologies play an increasingly important role in various academic fields. The automatic dimensioning technology also has different solutions under the influence of related technologies. Case-based reasoning (CBR) [1] is the process of solving new problems based on the solutions of similar past problems, it belongs to artificial intelligence. Case-based reasoning has been formalized for purposes of computer reasoning as a four-step process: retrieve, reuse, revise and retain. CBR technology has been applied in the field of machinery, such as the intelligent design of mechanical products [2]. Yu Yan and Liu Guoping [3] proposed composite-knowledge reasoning for automatic dimensioning. In this paper we introduce the expression of knowledge in the case library, the design of similarity matching algorithms, and the entire process of automating dimensioning.

2. Dimension knowledge representation
Each case in the case library can be viewed as consisting of graphs and dimension, and each dimension can be regarded as consisting of dimension object, dimension type, dimension placement points and dimension value [4,5] as shown in figure 1. There are main eight types of dimension, which are linear dimension, aligned dimension, diameter dimension, radius dimension, cylindrical diameter dimension, angular dimension, arc dimension, and ordinate dimension. According to the composition method of dimension as shown in figure1, we treat every dimension as a dimension template, as long...
as we have identified the relevant factors, we can add the corresponding dimension. These types of dimension templates are shown in figure 2.

**Figure 1.** Composition method of dimension

Figure 1 shows the composition method of the dimension. As long as the dimension object, dimension type, dimension placement points, and dimension value are determined, we can uniquely identify a dimension.
When we add dimensions to a new drawing, we need to determine each dimension object and the dimension placement points, then we can get the dimension type through dimension object and get dimension value through dimension placement points, some dimension types need to be determined by comparison with a matching case, such as cylinder diameter. We define the placement point of the
dimension as a feature point and redefine the graphics output primitive to give more attributes to the feature point, and then derive the dimension type based on the feature point attribute.

2.1. Definition of feature points
We define the dimension placement points in dimension template as feature points, then we use a 64-bit binary number to represent each feature point’s characteristics. The 64-bit binary number is divided into 5 parts:

For the first part (the 1st to 8th bits), the value of each bit in the binary indicates whether there is a point has straight line connection with itself in each azimuth of the point. If there is a point in the i-th direction has straight line connection with the point 0, the i-th bit value in the binary is 1, else the i-th bit value in the binary is 0, as shown in figure 3.

![Figure 3. Positional relationship between a point and other points](image)

For the second part (the 9th to 24th bits), the value of each bit indicates the positional relationship between point and arc as shown in Figure 4. If the feature point is at the i-th position, the i-th position of the binary number is 1, else the i-th position of the binary number is 0.

![Figure 4. Positional relationship between points and arcs](image)

For the second part (the 9th to 24th bits), the value of each bit indicates the positional relationship between point and arc as shown in Figure 4. If the feature point is at the i-th position, the i-th position of the binary number is 1, else the i-th position of the binary number is 0.
For the third part (the 25th to 32nd bits), if the feature point is a circle center, the value of each bit in
the binary indicates whether there is a center point of a circle in each azimuth of the feature point. As
shown in figure 5, if there is a center in the i-th direction, the i-th bit value in the binary is 1, else the i-
th bit value in the binary is 0, as shown in figure 5.

For the fourth part (the 33rd to 40th bits), the value of each bit in the binary indicates the type of
dimension, and the types of dimension as shown in figure 2.
For the last part (the 41th to 64th bits), this part bits value is reserved for new attributes defined in
future.

2.2. Definition of feature array
We define that every feature point has a feature array and the length of the array is 64. The value of
the i-th position of the array is the attribute value of the feature point corresponding to the i-th bit of
the 64-bit binary number of the attribute value of this feature point (1 ≤ 31).

If this feature point is an ordinary point, the 0th to 7th values of the feature array are the points' feature
values of the azimuth corresponding to this point. If this feature point is an arc endpoint, the
Corresponding value of one of the 8th to 23th position of the feature array is the attribute value of the
other endpoint of this arc. If this feature point is a center of circle, the 24th to 31th values of the feature
array are circle centers’ feature values of the azimuth corresponding to this center. The last half of the
array position are reserved for new attributes defined in future.

3. Case Reasoning
The knowledge expression of case library is divided into two parts, one is graphic expression and the
other is dimension knowledge expression. For these two expression libraries, each case in one library
corresponds to one case in another library. And the process of reasoning is mainly similar reasoning.

3.1. Graphic similarity
Graphic similarity refers to the degree of similarity between graphs in topological structure, geometric
shape and expressive function. Therefore, we divide the graph similarity into three parts: the similarity
of topological structure, the similarity of geometric shape and the similarity of size constraint.
Similarity results are classified into deterministic similarity and fuzzy similarity. If two graphs similar
in all aspects, we say these two graphs are deterministic similar, otherwise we call them fuzzy
similarity. It is the best result for that a case drawing and the new drawing are deterministic similar. If
every case drawing is not deterministic similar with the new drawing, we need to calculate a similarity.
The specific calculation of similarity is based on reference documentation [5, 6].

3.2. Feature point similarity
Definition similar feature point:

(1) There is a feature point A of a feature in a drawing, we calculate the attribute value num1 of
the feature point A according to the definition of 2.1, and there a feature point B of a feature in another
drawing, we also calculate the attribute value num2 of the feature point B according to the definition
of 2.1. If num1 equals num2, we say that A and B are a pair of similar feature points.

(2) There is a feature point A of a feature in a drawing, according to (1), if we can find two or
more feature points in another drawing which are similar with A, we call these points a B
set Bi \{B_i, B_{i+1}, ..., B_{i+k}\} (1 ≥ 2). According to 2.2, we can get a feature point's feature array, then
we compare the feature array of Bi and the feature array of point A, if the feature array of Bi and the
feature array of feature point A are the same, B_i and A are a pair of similar points (i ≥ 2).

3.3. Feature similarity and reasoning
In a two-dimensional graph, a point usually has only two attributes x coordinate and y coordinate; the
attributes of the line are only the starting point and the ending point; the attributes of the arc are the
center of the circle, the starting point of the arc, and the ending point of the arc; the attributes of the
circle are the center of the circle and the radius of the circle. According to the definition of 2.1 and 2.2, we add some attributes to every point. Then, in addition to the attributes of the x and y coordinates, each point or a center of circle has a 64-bit binary number and an array of features. As shown in figure 2, all feature templates are composed of one or several of points, lines, arcs, or circles. And lines, arcs, and circles are composed of one or several of points and centers. If there are two features that are similar, first their types are similar, and secondly, the points that make up these features are similar one-to-one. When a feature in the new drawing is found which is similar with a feature in the case, then the dimension can be added to the feature of the new drawing according the case' dimension information. The similar relationship is shown in figure 6.

**Figure 6.** Matching relation between target drawing and case drawing

In figure 6, the relationship of the two feature points connected by the dotted line are one-to-one corresponding similar.

4. Results
In order to demonstrate the feasibility of the proposed approach, we implement several experiments and give the automatic dimensioning results of a multipath axes. As shown in Figure 7.

**Figure 7.** The result of experiment
This multipath axes divided into three parts for dimensioning: one main drawing and two sectional drawings. For example, for the first sectional drawing which with a keyway, the first dimension placement point for a linear dimension of length 16 consists of two values: the point 9 and point 16 of Figure.4; and the second dimension placement point for linear dimension of length 16 also consists of two values: the point 3 and point 5 of Figure.3. The first dimension placement point for a linear dimension of length 8 consists of two values: the point 7 of Figure.3 and the point 19 of Figure.4; and the second dimension placement point for linear dimension of length 8 also consists of two values: the point 7 of Figure.3 and the point 18 of Figure.4. In the process of dimension automatic generation, the program first calculates the values of each feature point of the drawing. And then the program searches for the drawing which is the most similar with the first sectional drawing in the case library. According to each set of values of feature points in the case drawing, if the program finds a similar set of feature points in the new drawing, then add the similar dimension to the new drawing.

5. Conclusion
This paper proposes a method of automatic dimensioning based on case-based reasoning, which uses the existing engineering drawings' dimension information to realize automatic dimensioning of new drawings. In this method, we redefine the attributes of feature points, and we divided each kind dimension into four main parts: dimension object, dimension placement points, dimension type and dimension value. Through these operations we give each point more information so that we can use our algorithm to search a similar set of feature points, and according to feature points and the way that a dimension is composed, we can add dimension to a new drawing automatically and correctly.

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