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A COMPUTER-AIDED DRAWING CHECK SYSTEM
(PART 2: Dimension Check of A Single Plane Projection Drawing)

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Abstract : CAD drawings contain drawing errors similar to manually-produced drawings. This paper is concerned with a computer-aided drawing check system for the drawing errors. The problem treated in this paper is the checking of dimension errors, deficiency and redundancy of dimension lines in the mechanical drawings made by a CAD system. Graph theory is used for the checking of the deficient and redundant dimensions. The feasibility of this system is confirmed for the checking items.

1. Introduction

Computer-Aided Design (CAD) systems using a minicomputer or a personal computer have rapidly been improved. They lead to substantial improvement in productivity of design drawings. Usually mechanical drawings which represent the results of design are completed through drawing check. The CAD drawings, however, contain drawing errors similar to manually-produced drawings. The checking of CAD drawings is a time consuming work for designers and drawing checkers. Hence it is strongly required to establish the methodology for systematic drawing check.

Drawing informations of CAD drawings are stored in a data-base of a CAD system. If designers or drawing checkers can inspect the drawing informations by using a computer, they can greatly reduce the loads on the checking work of drawing. Therefore we intend to establish the methodology for computer-aided drawing check.

The drawing check is classified into three parts : (1)drawing check of geometrical information, (2)drawing check of functional information and (3)drawing check of manufactural information. Among these drawing check, the geometrical information is elementary and very important, because it determines the size and shape of a design object. We therefore consider the checking method of the geometrical information.

The geometrical information of a drawing consists of (a) projection drawings which describe a shape of a design object and (b) dimensions which specify the size of the object. In this study we propose a checking method of the dimensions, assuming that the projection drawings are correct in the geometry of the design object. This checking method deals with dimension errors, the deficiency of dimension and the redundancy of dimension of mechanical part drawings. The checking method of omissions and mis-writings of dimensioning were already reported in our previous paper.[1]

The dimension check system has been developed for a 16-bit microcomputer by using pascal.

This paper contains 7 sections. In the second section we consider the various meanings of dimensioning and introduce a classification of dimensions. The third section presents limitations of object drawings. In the fourth section, we describe the modeling for dimension check. The dimension check system developed here is described in fifth section. In the next section, a result of dimension check by using this system is discussed. In the final section some concluding remarks are given.

2. Various Meanings of A Dimension

A dimension on a drawing has various meanings. We consider the variety in the meaning of dimensioning and classify the meanings as follows :

1) size dimension and location dimension,
2) local dimension and global dimension, and
3) geometrical dimension and

topological dimension.

The size dimension means the dimension which expresses the size of a design object. The location dimension represents the location of mechanical parts such as the center of a circle or a hole.

The local dimensions involve chamfering dimensions, filleting dimensions and rounding dimensions. If the sizes of these dimensions are varied , the overall shape of the design object is only varied in the local shapes. In this meaning the dimension is called local dimension. On the other hand, the varying of the distance between two surfaces globally affects the overall shape of the object. The dimension is called global dimension.

A dimension which is not directly entered on a drawing can be determined by using other directly entered dimensions. The dimension became over-dimension or redundant dimension, if we enter the dimension on the drawing. This feature of the dimension is topological. On the other hand, the directly entered dimensions such as size dimensions and location dimensions have just the geometrical feature. These features play a very important role on the dimension check.

Following the classification of the meanings of the dimensions described above, the dimension check can be performed to examine two classes, that is local dimensions and global dimensions.(see Fig.1) The local dimensions only involve geometrical dimensions. The topological dimensions, however, involve geometrical dimensions and topological dimensions.

3. Object CAD Drawings

There are various kinds of drawings according to the purpose of using. The drawings dealt with in this paper are limited to the mechanical manufacturing drawings which consist of single plane projection drawings.

Most mechanical parts involve few free-curved surfaces. Hence, we suppose that the projection drawings consist of line segments and circular arcs. The CAD data in a data-base of a CAD system consists of visible outlines, center lines, dimension lines, extension lines, leader lines, dimension figures and symbols.

Under these assumptions, we examine the following items :

1. omissions of the dimension figures or the number of holes
2. compatibility of the described dimensions with the geometrical dimensions
3. deficiency and redundancy of the dimensions

Checking item 1 and 2 is the inspection with respect to the geometrical dimensions, checking item 3 is the inspection with respect to the topological dimensions.

4. Geometrical Model and Topological Model for Drawing Check

First the system extracts line segments, circular arcs, dimension figures and symbols from a data-base of a CAD drawing and changes their data formats. The formatted data are depicted in Fig.2.

The x coordinate means a horizontal coordinate of a drawing plane and the y coordinate means a vertical coordinate. The data in Fig.2 just represent the geometrical model of the object drawing. We call it geometrical model.

If the dimension check system can recognize patterns of the dimension lines, extension lines, etc. according to JIS drawing standard[2], then the system can inspect checking item 1 and 2 of Section 3.

The third checking item has to be inspected with respect to the topological characteristics of dimensions. In this inspection, the geometrical model shown in Fig.2 is not suitable. We propose a graph representation for this purpose.

As previously assumed, visible outlines of a drawing consists of line segments and circular arcs. If we can specify (a) the end points of line segments and (b) the centers, the radius and the end points of circular arcs, the drawing is geometrically specified. Moreover the radius and the end points of circular arc can be checked with respect to geometrical dimension. Therefore we can deal with the end points of line segments and the centers of circle for checking item 3. These

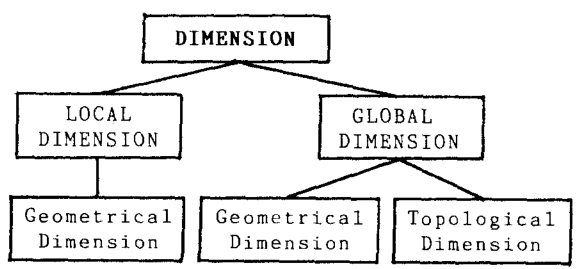

Fig.1 Classification of Dimension

Line_Segment = Record
Line_Type
x_Coordinate_of_Start_Point
y_Coordinate_of_Start_Point
x_Coordinate_of_End_Point
y_Coordinate_of_End_Point

Arc_Segment = Record
Line_Type
x_Coordinate_of_Center
y_Coordinate_of_Center
Radius
Start_Angle
End_Angle

Character_String = Record
Symbol
Value_1
Value_2
x_Coordinate_of_String_Center
y_Coordinate_of_String_Center
Inclination_Angle

Fig.2 Data Records of A Line, An Arc and A Character String

points are named characteristic point.

A dimension line has a function to determine the distance of a pair of characteristic points in the directions of x and y coordinates respectively. Hence the characteristic points are dealt with to project to each coordinate axis of a drawing plane. These projected points are called projection node.

Dimension lines connect a pair of projection nodes. For the checking of the third item it is sufficient to examine the connected relations between the set of projection nodes by the use of the dimension lines parallel to the projection axis.

In this paper we consider that the set of projection nodes are nodes of graph and the set of dimension lines are edges of graph. We can obtain the graph model by the use of the above relations. The graph is called dimension graph.[3,4,5]

Next we will discuss the relationship between the topological structure of the dimension graph and the deficiency and redundancy of dimensions.

If the dimension graph has a tree structure, the dimension lines are necessary and sufficient. Because a projection node can reach to any other node passing some edges and each path is uniquely determined.

If the dimension graph has two more isolated graphs, then there is a deficient dimension line between the two isolated dimension graphs. The number of deficient dimension lines is the number which subtracts one from the number of isolated graphs.

If the dimension graphs involve loops in the connected graphs, then there exists some redundant dimension lines. Because there are more than two paths which connect a pair of projection nodes in the loop. If we remove some edges from the loop, then the graph becomes a perfect tree structure. The removed links are the redundant dimension lines.

In the next section, we will describe the data structure of dimension graphs.

5. Dimension Check Process

The structure of the dimension check software developed here is shown in Fig.3. The process flows from the upper part to the lower part of the figure.

a. Reading CAD Drawing Data and Making Geometrical Model

To make a geometrical model from a CAD data-base we use procedure Data_Transformation1.

b. Dimension Check of Chamfers

Procedure Chamfer_Inspection performs the dimension check of chamfers. The procedure finds out chamfer candidates from the visible outline data. The chamfer candidates are examined if the pattern of the chamfer candidate and one of the reference chamfer patterns based on the JIS specification coincide with each other or not. If they coincide, the size of the candidate chamfer is checked

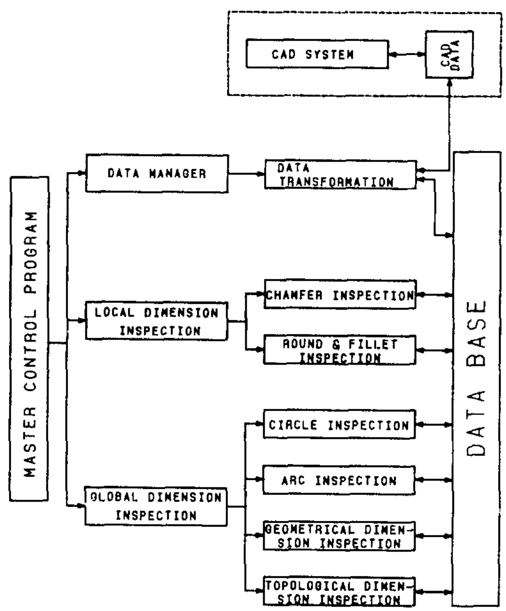

Fig.3 Process of Drawing Check

by using the Character_String data (Fig.2).

c. Dimension Check of Fillets and Rounds

Procedure Round_and_Fillet_Inspection finds out the fillet and round candidates from the data of Arc_Segment. This procedure performs the inspection on each fillet and round similar to the dimension check of chamfers described above. These two processes are regarded as dimension check of geometrical dimension. After these dimension check being completed, the procedure removes the checked chamfers, the checked rounds and the checked fillets from the geometrical model. At the same time the procedure modifies the visible outlines and the extension lines which are connected to the chamfers, the fillets and the rounds.

d. Dimension Check of Circles

Procedure Circle_Inspection performs the inspection of circle size. The procedure saves only the centers of circle(the location dimensions) and removes the circles.

e. Dimension Check of Circular Arcs

Procedure Arc_Inspection performs the inspection of geometrical dimension of circular arcs. The circular arcs are classified into some patterns. These patterns are replaced with some line segments. After that the procedure modifies the dimension lines and the extension lines.

f. Geometrical Dimension Check

Procedure Geometrical_Dimension_Inspection inspects the dimension errors, i.e., the disagreements of geometrical dimensions with filling up dimensions and the omissions of dimensioning.[1]

A modified drawing is obtained through above procedures. The drawing is called primitive drawing.

g. Making Dimension Graph

Procedure Toplogical_Dimension_Inspection (TPDI) makes up dimension graphs. The data structure of the dimension graph is shown in Fig.4. At first, the characteristic points of the primitive drawing mentioned above are projected to the axis of drawing plane. These projection nodes are saved to the point coordinates of the projection_node(PN). (Fig.4) We obtain the list of Projection_Node.

Next one dimension line corresponds to one link of Fig.4. The dimension line connects a pair of characteristic points. Then we can find out Projection_Node PN_1 and PN_2 in the list with corresponding to the two characteristic points respectively. The procedure performs the list of links which contain all dimension lines of the primitive drawing.

The fields of HeightNo, RdnNo and Degree of Projection_Node are determined by the next process. The procedure chooses a PN and sets it to the root of graph. The HeightNo of the PN is set to 1. Using the list of Link, the procedure searches the all PN's connected to the PN. The HeightNo of the connected PN is set to 2. The procedure repeats the operation increasing the HeightNo. When the operation can not continue, the procedure chooses a new PN which is the root of a new graph, and sets HeightNo to last HeightNo + 2. Then the procedure repeats the operation. This operation is repeated until the procedure can not find a new PN.

RdnNo is the number of reference of the PN in the above operation. Degree is the number of the connected Link's.

h. Checking Deficient Dimension Lines

Procedure TPDI inspects the disconnected parts in the series of HeightNo. The number of the disconnected parts coincides with the number of deficient dimension lines. The procedure interactively adds a dimension line between isolated partial graphs.

i. Checking Redundant Dimension Lines

The PN which Degree is 1 corresponds to the leaf of tree of graph theory. Procedure TPDI removes the leaf nodes and the connected links, and decreases 1 from the Degree of the nodes of which connected to these links. The procedure repeats the operation until it can not repeat.

In the theory of graph, the degree of a node in a loop is more than 2. If

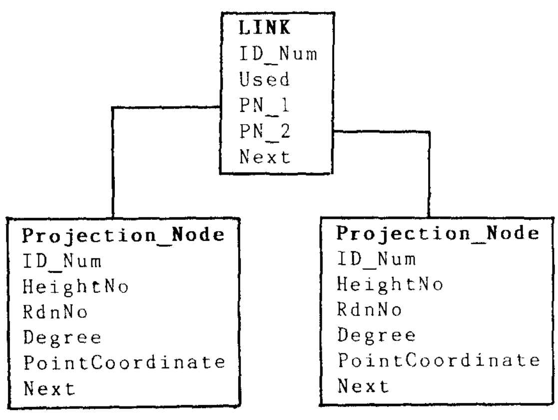

Fig.4 Data Structure of Dimension Graph

a loop exists in the dimension graph, the procedure can find the loop.[3,4] The procedure interactively removes links from the loop, and repeats the operation described above. As the result no node and no link remains, then the removed links are the redundant dimension lines.

This system performs these topological dimension checks with interactive methods between the drawing checker and the computer. The main reason is that the decision of these deficient and redundant dimension lines needs deep knowledges of the design object. If those knowledges are implemented into our systems, the system must impose heavy loads on software.

If the process has finished, then the drawing check is completed.

6. A Result of Dimension Check and Its Discussions

To show the feasibility of the drawing check system developed here, some drawings have been examined. Fig.5 shows an example of object drawings. The drawing consists of line segments, circles, circular arcs, center lines, dimension lines, extension lines and leader lines. The drawing involves two chamfers, four rounds, five circles and four circular arcs. The drawing data were transformed into the checking data by using the drawing check system. The system performed the drawing check with the transformed data. Fig.6 indicates a elemental drawing which consists of visible outlines and center lines.

The first step is the dimension check of chamfers. Fig.7 shows the checking result of the two chamfers. The chamfers in Fig.6 are modified by this system as shown in Fig.7.

The second step is the drawing check of the fillets and rounds in Fig.7. The system can check the errors in round dimension in this step. Fig.7 involves four rounds. Fig.8 indicates the checking result of these rounds. Fig.8 is modified completely, because the system can not find the errors in the rounding dimensions.

The third step is the drawing check of circles. Fig.9 indicates the checking result of the circles. This drawing now involves only five centers of circle.

In the fourth step, the system checks the circular arcs and modifies the parts containing these circular arcs. If drawing errors of circular arcs exist, this system does not modify these parts. Fig.10 only consists of visible lines, center lines and centers of circle. Fig.10 depicts the primitive drawing.

Fig.11 illustrates a drawing for topological dimension check. The characteristic points are projected to the x and y axes. These projected points are the projection nodes. Fig.11 shows the projection nodes as dot points on x and y axes.

Next the system makes the dimension graphs by using the projection nodes and the dimension lines. Fig.12 indicates the dimension graph in x direction. This graph involves one loop which consists of the projection nodes, 3-5-8-1. If the system interactively removes the link 1-8 from the graph, the dimension graph involves no loop. Fig.13 indicates the result of this operation.

The system can check the topological dimensions in Y direction as the same method described above.

7. Concluding Remarks

In this paper, we considered the meanings of dimensioning and made a classification of the dimensions. Following the classification we gave a methodology of the dimension check. For the limited drawings which consist of a single plane projection drawing, we developed a drawing check system. The system automatically finds out the dimension errors, and interactively modifies the deficient and redundant dimensions. By using this system we have confirmed the following inspections.

(1) The drawing check system can automatically inspect the dimension errors of mechanical drawings.
(2) The system can inspect the deficiency and redundancy of the dimensions.
(3) The deficiency and the redundancy of the dimensions can be interactively modified.

The object drawing treated in this paper is a single plane projection drawing. We will extend this system to inspect multiple plane projection drawings.

We would like to express our gratitude to Andor Co., Ltd. for offering the CAD software to the present study.

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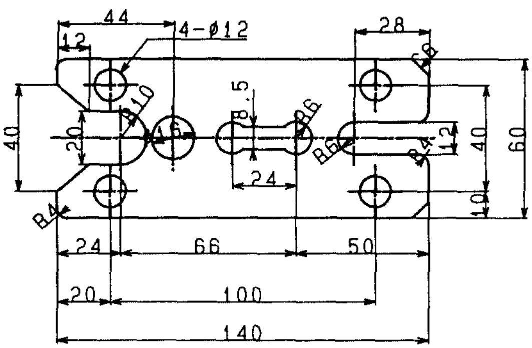

Fig.5 Object Drawing

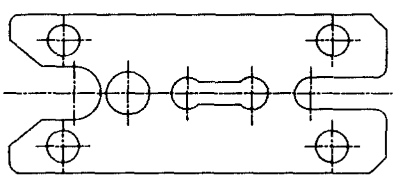

Fig.6 Elemental Drawing of the Object

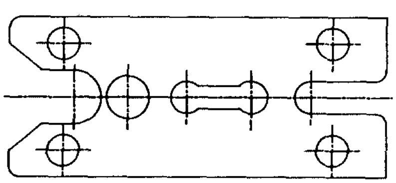

Fig.7 Checking Result of Chamfers

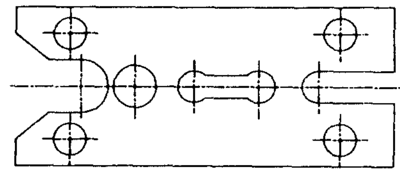

Fig.8 Checking Result of Fillets and Rounds

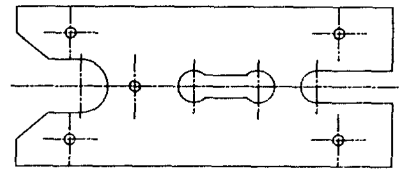

Fig.9 Checking Result of Circles

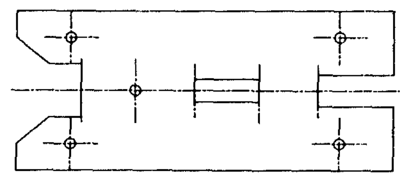

Fig.10 Checking Result of Circular Arcs

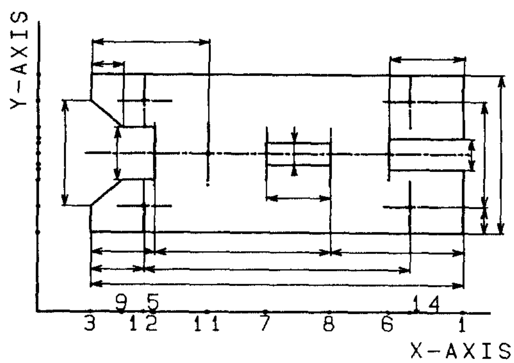

Fig.11 Projection Nodes of Object Drawing

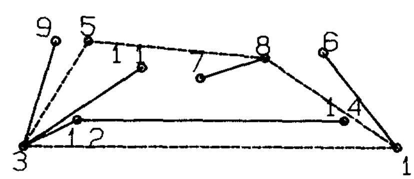

Fig.12 Dimension Graph in x Direction

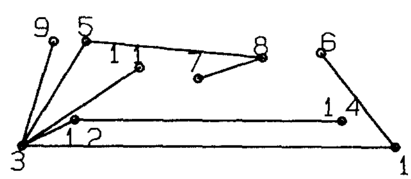

Fig.13 after Modifying Dimension Graph