# **RECOGNOTION OF SYMMETRICAL SHAPES IN SCANNED MECHANICAL DRAWINGS**

## Julian Dimitrov

University of Mining and Geology "St. Ivan Rilski" Sofia 1700, Bulgaria

#### SUMMARY

The scanned mechanical drawings have some defects. Defects connected with the infringement of geometrical form received from scanning are discussed in this paper.

Basic methods for establishing of symmetry relation between vector segments are discussed. Here is offered a decision of automated determination of symmetry and appropriate centerline in mechanical drawings.

Key words: Symmetry detection, deskewing, centerline, symmetry axes, recognition, mechanical drawing

### INTRODUCTION

The qualitative transformation from raster to vector format meets definite difficulties. They follow from ambiguity of possible ways for replacement of raster representation by vector depending on context. The using of heuristics methods is necessary.

There are many program products, which transform from raster to vector format without reading of context. As examples are - GTX RasterCAD and VP HybridCAD . Graphical determined relations between graphical objects are presenting with axes line in mechanical drawings, that are represented as symmetric location and common axis. The symmetric form of some graphical objects is representing. Axis lines uses as basis for reinstatement of regular geometric form of objects in scanned image of GTX RasterCAD and VP HybridCAD.

The scanned image of mechanical drawing contains defects, which can and not exercise influence on the quality of visual perception, but are obstacle to necessary processing. The defects show as small disturbances, expressed in lack of single pixels, or of not large groups of pixels, or in surplus of that. There are distinguishing the follow fundamental types of defects: isolated spots of excess of pixels; isolated white spots of missing pixels; tearing to pixels; false end points in contour of lines; missing end points; disturbances along the length of line. That defects are showing in redundant or in missing pixels and in bending of the form of the objects. Because of that the recognition of the axis line meets some difficulties. If we add to that and the fact that the axes draw up by not clearlydistinguished sequence of lines and points that simultaneously are intersected from another projection elements then the recognition of them becomes impossible without determination of respectively symmetric relation.

## THE PURPOSE

To be systematized the ways for determination of symmetric axis between symmetric elements of raster images.

To be offered a method for detecting of symmetry relation in raster image of mechanical drawing.

## METHODS FOR DETERMINATION AXIS LINE

The papers of Blum (1978), Brooks (1978) and Brady (1984) are initiator workings out for representation the form of rasterdepicted objects in computer as symmetry toward axis. For the purposes of this material is necessary to consider the problem for symmetry axis determination of the multitude M that consists from projection objects at mechanical drawings. Two alternative methods will be formulated – *method of raster elements for recognition of axis line and method for straight lines for recognition of the axis line.* 

## Method of raster elements for recognition of axis line

## - Essence of the method

In this case the multitude M consists from raster elements, that are given with their coordinates  $M=\left\{x_{i}\,,\,y_{i}\right\}$  (Fig. 1). More common variant of this method is considered from Friedberg (1986) for determination the axis lines in axonometric projection of mechanical product. For the purposes of recognition of the objects in orthogonal projection is enough to consider the special case of this method.

Let the multitude  $M = M_1 + M_2$ , where  $M_1$  and  $M_2$  are its two symmetric parts. Let, a chosen point U from axial line is called *point of support*. The centre of gravity M is selected for the point of support U = (a, b), where

$$a = \frac{\sum x_i}{n}$$
,  $b = \frac{\sum y_i}{n}$  and  $n$  is the number of elements of  $M$ .



Figure 1: Symmetrical multitudes of raster elements  $\,M_1^{}\,$  and  $\,M_2^{}$  , point of support and axial line

Let,  $\Lambda = m_{11}x^2 + 2m_{12}x y + m_{22}y^2$  is a quadratic form, where  $m_{11} = \sum (x_i - a)^2$ ,  $m_{12} = \sum (x_i - a)(y_i - b)$  and  $m_{22} = \sum (y_i - b)^2$ . Let, s is the axial line and it conclude angle  $\varphi = (\overrightarrow{Ox}, s)$ with abscissa  $\overrightarrow{Ox}$ .

As a result of the transformation  $Oxy \rightarrow Us\,\ell$ , that consists from a translation and a rotation with angle  $\varphi$ , the quadratic form transforms in  $\Lambda' = n_{11}s^2 + 2\,n_{12}s\,\ell + n_{22}\,\ell^2$ . Between the coefficients of the linear forms the relation is performed:

$$T\begin{pmatrix} m_{11} & m_{12} \\ m_{12} & m_{22} \end{pmatrix} T' = \begin{pmatrix} n_{11} & n_{12} \\ n_{12} & n_{22} \end{pmatrix}, \text{ where}$$
$$T = \begin{pmatrix} \cos\varphi & \sin\varphi \\ -\sin\varphi & \cos\varphi \end{pmatrix}.$$

From this equation follows:

$$n_{12} = \frac{1}{2} (-m_{11} \sin 2\varphi + 2m_{12} \cos 2\varphi + m_{22} \sin 2\varphi)$$
(1)

Because of the symmetry for every element of  $M_1$  with coordinates  $(s_i,\ell_i),\ell_i>0$ , there is a element of  $M_2$ , such that its coordinates are  $(s_i,-\ell_i)$ .

Then

$$n_{12} = \sum s_i \ell_i = 0$$
 (2)

and from (1) follows

$$2m_{12}\cos 2\varphi = (m_{11} - m_{22})\sin 2\varphi \quad . \tag{3}$$

If  $m_{12} \neq 0$  , then

$$\varphi = \frac{1}{2} \operatorname{arccotg} \frac{\mathbf{m}_{11} - \mathbf{m}_{22}}{2 \,\mathbf{m}_{12}}.$$
 (4)

From the received result can make the following conclusions: - With  $m_{12} \neq 0$  or  $m_{12} = 0$  and  $m_{11} \neq m_{22}$  from equation (4) two values follow for the symmetry angle  $\varphi$  and

$$\varphi + \frac{\pi}{2}$$
 toward  $\overrightarrow{Ox}$ ;

- With  $m_{12} = 0$  and  $m_{11} = m_{22}$  the equation (3) is with innumerable many decisions. In this case, if M is a circle, than they are innumerable many axial lines and if it is a regular polygon – there are determined number of axes of symmetry.

Determination of the symmetry relation

The practical application of attribute (2) is - if **M** is symmetric, then by them can be determined direction of the axis of symmetry. Because of the eventual defects of the image and its raster presenting  $m_{11}$ ,  $m_{12}$  and  $m_{22}$  are considered as accidental variables. As far as the mathematical expectation for  $m_{12}$  is nearly zero, it influences considerably the precision of receiving of  $\varphi$  - i.e. the formula will give more inaccurate results, if  $\varphi$  is nearly zero,  $\frac{\pi}{2}$  or  $\pi$ . This special

feature of the method ought to take into account at program realization, that does not represent the special difficulty.

Obviously, for every multitude M can received two values for  $\varphi$  and if  $m_{12} = 0$  and  $m_{11} = m_{22}$ , then other point of support ought be chosen and then  $m_{11} \neq m_{22}$  and equation (3) will have only two decisions.

After determination of the axis s is verifying for every element of  $M_1$  whether exists a symmetrical element in  $M_2$  and if this elements, for which are no suitable, are no more from determinate with appropriate parameter part of  $M_1$ , then we consider  $M_1$  and  $M_2$  as symmetric.

The application of the method is implemented, as in the parameters of the axial line – point of support and direction, a narrow *area* S from the drawing is defined in which is viewed for the raster image of the axis line with some of the methods for line recognition.

## Method of the lines for the recognition of the axis line - Essence of the method

The representation of the segments in  $(\theta, R)$  space is used, as in this way facilitates the recognition of axis line. This

ANNUAL University of Mining and Geology "St. Ivan Rilski", vol. 44-45 (2002), part III MECHANIZATION, ELECTRIFICATION AND AUTOMATION IN MINES

transformation applies in the method of Hough (Gotchev G., 1998).

Let the multitude M consists from segments. The center of gravity of M is chosen for point of support U and uses rectangular coordinate system Uxy .(fig.2). For determination of angle  $\varphi = \angle(Ux, s)$ , between axis  $\overrightarrow{Ux}$  and axis line s are represented lines, that consist of segments of M in space  $(\theta, R)$ .



Figure 2: Symmetrical multitudes  $M_1$  and  $M_2$ , with them images in  $(\theta, R)$  space

As a result of the transformation, the segments of M represents in the symmetric multitude  $M^{\,\theta}$  from the points of  $(\theta,R)$ , with vertical direction of the axial lines  $s^{\,\theta}$ . The point of support of axis line in  $(\theta,R)$  is determined as point of support of multitude  $M^{\,\theta}$ . After axis building  $s^{\,\theta}$ , its moving toward  $\pi$  is the angle  $\varphi = \angle(Ux,s)$ 

- Determination of the symmetry relation

To be M symmetric multitude,  $M^{\,\theta}$  must be symmetric. In additional must to verify that respective segments in M are symmetric about s

- Application of the method

Because of the specific path is to information's transformation at passing to  $(\theta, R)$  space, this method can be used for determination of the axis line and in the case, when the multitude of segments  $M_1$  is symmetric to submultitude  $\overline{M}_2$  of the multitude of segments  $M_2$  (fig. 3).

In such submission of the task is impossible to determination the point of support, at first. The task has decision through search in  $\overline{M}_2$  to detection of symmetry. Using the  $(\theta, \mathbf{R})$ space can decrease the operations significantly. Is a possibly to select and origin of system Uxy in a point that is near to point of support. This can made, for example, as with appropriate weights, calculate the coordinates of point near to the point of support  $M_1 \bigcup \overline{M}_2$ . For the of choice of U, the

projections on a coordinate axis  $U^{\stackrel{\rightarrow}{\theta}}\theta\,$  of points of  $M_1^{\,\theta}$  and

 $\overline{M}_2^\theta$  are symmetrical. By viewing in  $U^{\overrightarrow{\theta}} \theta$ , is receiving the subset  $\overline{M}_2$  and is checking are symmetric to  $M_1$ . The process stops, when finds the multitude  $\overline{M}_2$ .



Figure 3: Representation in  $(\theta, R)$  space were  $M_1$  is symmetrical sub-multitude of  $M_2$ 

## Determination of the axial line at symmetrical arcs of circle - Essence of the method

As a result of recognition of the lines, that represent the projection elements in mechanical drawing, are received vector-described segments and arcs of circles. If in M are arcs of circles with symmetric parts, then they are with equal radiuses. A point of support is the center of the segment, which connected centers of these two arcs. On the fig.4 is illustrated the case, when an arc of circle  $k_1$  is symmetrical to a part of arc of circle  $k_2$ . If the centers of arcs are  $O_1 \neq O_2$ , then the axial line s is the axial line of the segment  $O_1O_2$ .

- Determination of the symmetry relation

The criterion for symmetry of two arcs of circle  $k_1$  and  $k_2$  is the equality of their radiuses. In the case, when two arcs have equal radiuses, with some approximation, then defines the middle point U between the centers of arcs and the symmetric axis s. If the sufficient part of the symmetric image of one arc towards s coincides with another, then the arcs are symmetrical. When the centers of arcs  $O_1$  and  $O_2$  coincide, then two arcs are symmetrical as the axial lines have any direction for s, with that the symmetrical image of one arc covers sufficient part of another arc.

#### DETERMINATION OF THE SYMMETRY RELATION

## Realization on recognition of a fragment of the drawing

Here the surveyed methods are using for determination of symmetry between the multitude  $M_1$  and subset  $\overline{M}_2 \subset M_2$ , in the cases of segments and arcs of circles, for the recognition of the symmetry relation between the vectorized segments of a mechanical drawing.

ANNUAL University of Mining and Geology "St. Ivan Rilski", vol. 44-45 (2002), part III MECHANIZATION, ELECTRIFICATION AND AUTOMATION IN MINES



Figure 4: Determination of the axial line at symmetrical parts from circle

After receiving the vectorzation description of the segments of lines and circles (we here name as a segments), the recognition of the scanned image of the mechanical drawing follows with determination of the symmetry relations between segments and parts of segments. This can be realized full-automatically, as looking for every segment a segment with part that is symmetric to the first. If has such, then in the obtained narrow area S is required the axis line. Independently of defects owing to the raster representation and other difficulties in recognition, the determination of the axis line realizes with representing in  $(\theta, \mathbf{R})$ -space as in Dimitrov (2001).

The presence in area S of a axis line is a necessary condition for the presence of symmetry relation between segments. All segments with one and same axis line are described in one symmetrical multitude - symmetry relation is registered.

The determination of symmetrical sets of segments can be performed with intervention of the operator. He points one or some segments and procedure for searching for symmetrical subset of symmetrical arcs of circles or symmetrical segments. In this aspect the realization has considerable advantages before to abilities that offered VP HybridCAD.

### **Complete decision**

For the processing of real examples of scanned mechanical drawings it is necessary to applied a method for the effective recognition of the objects and symmetrical shapes. For the purpose, here will formulate such a method based on heuristic considerations - the model of the visual perception. The perception is a process of comparison of the images for the object with the ideas for it. The key feature of models is research perception as interaction between processes. The perception is adaptive and at the presence of errors in the object's images, they overcomes if possibly use additional properties for confirmation of the notions. The notion includes different elements about conservatism, that are related with basic principles for depicting on the drawing (BP); Experience from by hand execution and reading (EH) and dynamic variable experience (DVE) - a result of consisted processes of perception of the concrete image (fig.5).



Figure 5: Figure 4: Determination of the axial line at symmetrical parts from circle

The perception process conditionally divides on procedures and in this way it can be reproduced through programs, in dependence of the elements of the notion (BP, EH or DVE). In every given moment the notion have reference to concrete area of the image. The objects of perceiving are changing dynamically, as that can interpret with moving area on the drawing – a *creeping window*. In every concrete position the creeping window consists perceived objects and only a part of attributes of the system are active (BP, EH and DVE), as only attributes of DVE are dynamic.

This dynamic model is used for recognition, as for every attribute of the system (BP, EH and DVE) is creating a procedure, that works in dependence of the position of the creeping window and the state of DVE. With so defined model receives effective structure of methods for recognition of raster image.

On the stage of recognition of vector segments through this method is solved the question for overcoming of the defect dismemberment of the segments and the places of cutting with another lines. This receives with a constant velocity of moving of the creeping window and these two problems for fusion of different parts of the recognized segment are decided with their faster appearance in comparison with the appearance of the parts of another segments.

Within the boundaries of given position of the creeping window is realizing and recognition of symmetric shapes, as for the multitude  $M_1$  from segments in the creeping window determines appropriate symmetric multitude  $\overline{M}_2 \subset M_2$ .

The model is supplemented with the division of the methods for recognition to methods for separation as the separation of symbol information from projection elements and to methods for recognition – recognition of lines, symbols and marks etc. (Dimitrov, 2001).

## EXAMPLES AND CONCLUSIONS

With the axes lines in mechanical drawings is denoting a particular symmetry between the elements of the drawing:

- A linear symmetry between the parts of objects of the drawing.

- A symmetry with horizontal and vertical axes in simplified cases in depicting of the apertures and cylindrical bodies.

ANNUAL University of Mining and Geology "St. Ivan Rilski", vol. 44-45 (2002), part III MECHANIZATION, ELECTRIFICATION AND AUTOMATION IN MINES

The offered method for definition symmetrical units in a mechanical drawing is implemented with the programmed procedures used immediately of graphics possibility of the display. Before the applying of the method a procedure of separation the projection elements from characters and symbolic set was used. The creeping window is realized with shape of rectangular. At given its position are used simultaneously different stages of the treatment of the image. The operator points on set of projection elements  $\Gamma_{\rm r}$  and after looking for in the set of segments, their symmetrical are determining and the position of axis line is specifying. There is provided a parameter that gives limit of precision of the symmetrical accordance. If the program not recognized the symmetry, then a greater value is giving to the parameter.

After recognition of the axis line, a procedure for determination of all symmetric segments about axis line is implementing. After which, it can correct its position and shape – with this realizes an exact presentation of the symmetric shape.

On the fig 6 are presented two images, that were processed. On processing with VP HybridCAD it turn out that the automatic operation for correcting on the shape and the positioning on the drawing Deskew is performed successfully for the image on the fig.  $6^a$  and can not work for the image  $6^6$ .

The symmetry in image on fig. 6° is discern by offered here method. Here for  $\Gamma_r$  is point segments from contour. The image on fig. 6° is with two axes lines, which are not recognized, directly because of overlapping with hatch lines. From imaging in  $(\boldsymbol{\theta},R)$  space the hatch lines are separating. After that it is received, that the outline is an arc of a circle. In this case the axial lines can be two – horizontal and vertical. At the image is discerned the presence of two lines with this directions.

The offered method reconstructs the exact geometric shape of the symmetric elements of a mechanical drawing. It is realizing with minimum intervention of the operator or fully automatically, if it is performs by tracing in the set of all segments. The method supports and the recognition of axial lines in all cases of their using.



Figure 6: Experimental examples

#### REFERENCES

- Brady J. M., H. Asada, Smoothed local symmetries and their implementation, *Artificial Intell. Lab. Memo*, February, 1984.
- Blum H., R. N. Nagel, Shape description using weighted symmetric axes feature, *Pattern Recognit.* 10, 1978.
- Brooks M. J., Rationalizing edge detectors, Comput. Graphics Image Process, 8, No. 2, 1978.
- Gotchev, G., Computer Vision and Neural Networks, Sofia, 1998.
- Dimitrov J., St. Ivanov, Automated Recognition of Dimensional Lines in Scanned Mechanical Drawing, Third Scientific Conference "Smolian - 2001", 2001.
- Friedberg S., Finding Axes of Skewed Symmetry, *Comput. Graphics Image Process*, 34, 1986.

Recommended for publication by Department of Mathematics, Faculty of Mining Electromechanics