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Dimension sets detection in technical drawings*

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Abstract

This paper is primarily devoted to an algorithm for detecting dimension sets in engineering drawings that are drawn to ISO drafting standards. Our approach joins those starting with detection of dimension text while most methods are started with the detection of arrowheads. First, we detect among the segments and arcs resulting from the vectorization process those that fulfill some location constraints. A number of segments and arcs are chosen to be candidate parts of dimension lines according to the position and the geometry of their presumed witness lines. We establish the link between the candidates and the detected primitives which are in correspondence with text blocks. Complete dimension lines are found using tracking and fusion processes. Arrowheads are then located thanks to the position of witness and dimension lines. Experimental results are presented.

1 Introduction

A very important research topic in Computer-Aided Design (CAD) is the recognition and understanding of engineering drawings. Primitives such as straight line, arc, circle, etc., are used in engineering drawings to describe the shape and structure of an object. Dimension is an essential part of an engineering drawing that provides the exact size of the object and other important technical information. Therefore, recognizing dimension sets in an engineering drawing is a prerequisite for the recognition and understanding of engineering drawings.

Wesley [17], Lysak [12] and Haralick [9] have given some approaches for the 3D rebuilding of an object starting from a 2D set of sights. Their approaches were already based on the assumption that the separation of dimension elements from an object of a document is already operational.

In the field, one particularly notices the work of D. Dori and A. Pnueli [7] on a web grammar for dimension sets. A morphological and functional classification of dimension sets is presented there. Dimension sets are represented there in the form of web grammars described by undirected graphs whose nodes are labeled. These grammars describe the relationships between the graphic sub-elements of various types of dimensional entities. Later, the need for a basic classification of the lines (including dimension lines) was clearly felt in [6]. In addition, a more formal structure was used to represent a potential dimension set in an image. This structure contains some recording of completude, standard, regularity, symmetry and the type of dimension set, and aims to match between the grammar and the geometry of the drawing.

Tang *et al.* [14] proposed a system, similar to the one of Dori, based on a web grammar as well. They proposed parallel detection of arrow using a matching process with several models. Matching arrows have been also adopted for an interpretation of dimension sets strongly inspired by the work of D. Dori on the dimension sets in conformity with ANSI standard. Indeed S. Collin [3, 4, 1] has taken the same approach again and applied it on dimension sets in conformity with ISO standard. However, one notes her choice for a plex-grammar suitable for the definition given to dimension sets as being a whole of under-form connected by one or more particular points. In addition she described a model of arrows for the technical drawings. The angle between two lines of the model is evaluated and used to find small pairs of segments having a similar angle in the whole image. The confirmation of the assumption of membership of these segments to arrows is made thanks to *a priori* knowledge on the vicinity.

Lai and Kasturi [10] presented a method operating on technical drawings which respect ANSI standard. After the analysis of components and the application of the Hough transform to find the alignment of characters and thus to reconstitute the string, the result is then filtered according to some rules to reduce the detection error rate. Exploiting the fact that the thickness of an arrow varies in an increasing or decreasing way according to the direction one moves, Lai and Kasturi were able to calculate the parameters of their model. Starting from each detected arrow, the

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[*] This work was partly carried out in the ISA group, INRIA-LORIA, Nancy, France, where the first author was a Master student with Prof. K. Tombre.

other elements of the dimension set are found by procedures of follow-up of the primitives on the image containing only graphics.

These approaches generally require good quality images, especially, for an efficient detection of arrows. Indeed, the detection of arrows is difficult when the drawings are not of excellent quality. Moreover some algorithms consider only a few types of arrows for detection, whereas in practice there are far more types of arrows.

It has been noticed that less complex systems leads to better results or at least the same ones. To circumvent the problem of detection of the arrows, Lin and Ting presented in [11] a new approach for the dimension sets detection in a technical drawing. It is about starting with the detection of text blocks and the corresponding lines according to distance criteria, then extending these lines to check the membership of a dimension set and/or supplementing it. The position of the arrows is extrapolated according to the type of dimension set defined by D. Dori [6] and Tang *et al.* [13]. One seeks the other components of the dimension set while basing oneself on a position criteria which they must fulfill for each type of dimension set. As presented, Lin and Ting algorithm is suitable for simple cases and good quality drawings that result in high quality vectorization which leads to a local view of the concerned drawing.

In this work we assume that the drawing has been prepared as per the ISO drafting standard. Our algorithm takes into account some well known disadvantages, such as primitive segmentations that result from vectorization, making it more practical for real cases. First, text detection is carried out using the method of Fletcher and Kasturi [8], then we define some rules to identify what we call the *indicating* primitives which are the closest primitives to a text block and supposed to belong to a dimension set.

To find candidates to dimension lines, we check some conditions related to primitives that could be parts of dimension lines. These conditions concern the position of the candidates to dimension lines with respect to other elements that constitute a dimension set. Complete dimension elements are obtained by a fusion process allowed by conditions related to and proximity. The last process in this algorithm is to find arrowheads which is easy once all other dimension elements are found.

2 Preprocessing

Preprocessing is needed for the application of our dimension sets detection algorithm. We applied what is considered to be the most robust [16] algorithms at the moment for text blocks detection, thinning and vectorizing.

2.1 The text blocks detection

The text/graphic separation allows the extraction of a set of rectangles delimiting the areas containing the text in the drawing. We used the method of Fletcher and Kasturi [8] which considers as text the small related components of the image. Starting from the preceding stage, the coherent character strings are reconstituted by the method suggested by Fletcher and Kasturi [8]. This method uses the Hough transform which allows the determination of alignments.

2.2 Vectorization

Thinning is an important preprocessing step for the vectorization process. We have therefore implemented a robust skeletonization method, first proposed by Sanniti di Baja [5], and based on the 3–4 distance transform [2]. This skeletonization method yields very good results [16].

This is followed by the polygonal approximation of Rosin and West [15], based on a previous algorithm proposed by Lowe, and which also allows us to recognize arcs subsequently.

3 Dimension sets detection process

Starting from the vectorized image and block positions, we extract what we call the *indicating* primitives (see figure 1). It is about the segments and arcs that are close enough to a text block such that they could be a starting point for finding the remaining elements that compose a dimension set. In addition, we search what we call *candidates* for dimension lines. Indeed, we suppose that dimension lines are segments or arcs that have close enough *witness* lines. Thus, we can impose some constraints on the checked primitive (segment or arc) to classify it among those that could be dimension lines. This step allows us also to find the witness lines corresponding to each candidate.

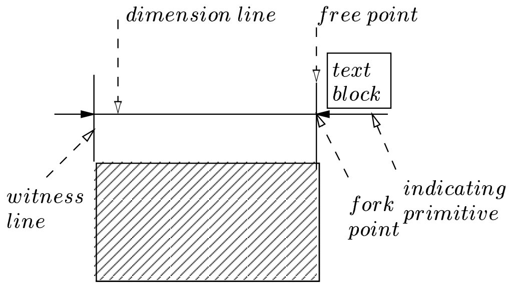


Figure 1: Used concepts.

Among the *candidates* for dimension lines we retain those previously recognized as *indicating* primitives and those directly or indirectly connected to an *indicating* primitive. In fact, we search the following scheme :

$$< Scheme > \rightarrow < ip >< los >< cdl > / < ip >$$

$$< los > \rightarrow < los > / < s > / <>$$

where :

$< ip >$ denotes an *indicating* primitive,
$< cdl >$ a *candidate* for a dimension line,
$< s >$ a segment,
$< los >$ a list of colinear segments.

We call the concerned *candidates* for dimension lines, *atomic* primitives. The term “atomic” is used because the recognized primitive is often a fragment of a complete dimension line. *Atomic* primitives are labeled according to the general form of the scheme they belong to.

Complete dimension lines are found by fusion of *atomic* primitives with other appropriate segments. The resulting dimension line is labeled according to the *atomic* primitive which is originating from.

By keeping trace of *witness* lines at each step and using the label of each *complete* dimension line, we finally locate arrowheads.

In the following, we give more details about each step of the process.

3.1 Indicating primitives

For each rectangle delimiting a text in the graphic, we seek the corresponding primitive (see figure 2). The primitive must have at least one fork point as an extremity. We consider the height of a text as an information on the size of the graphic. Therefore the search field of a primitive, likely to belong to a dimension set, is the vicinity calculated according to the height of the text and given by :

$$0 < d \leq th.h$$

d is the distance separating the barycentre of the rectangle delimiting the text block and the primitive.

h is the height of the text block.

th is a threshold that we define.

- For a horizontal segment, see figure 4(b), (resp: vertical segment, figure 4(a)), the text must be *at the top* (resp : *on the left*) of the segment, that is, $x_{p1} < x_0 < x_{p2}$ (respectivly : $y_{p1} < y_0 < y_{p2}$).
- For a diagonal segment, see figure 4(c), the text must always be *higher* than the segment, that is, $x_{p1} < x_0 < x_{p2}$ and $y_{p1} < y_0 < y_{p2}$
- For an arc of a circle, we make the same tests compared to the cord of the arc.

Notice that, in figure 3, most the *indicating* primitives are found.

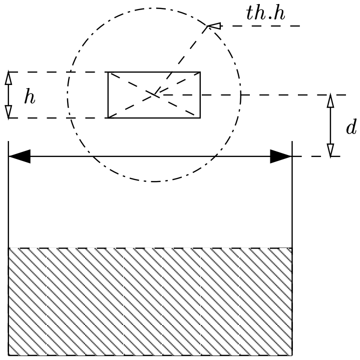
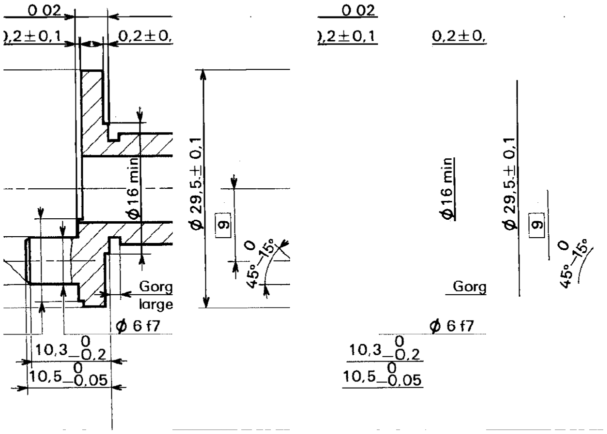


Figure 2: Example of search.



(a) Original image of a technical drawing.

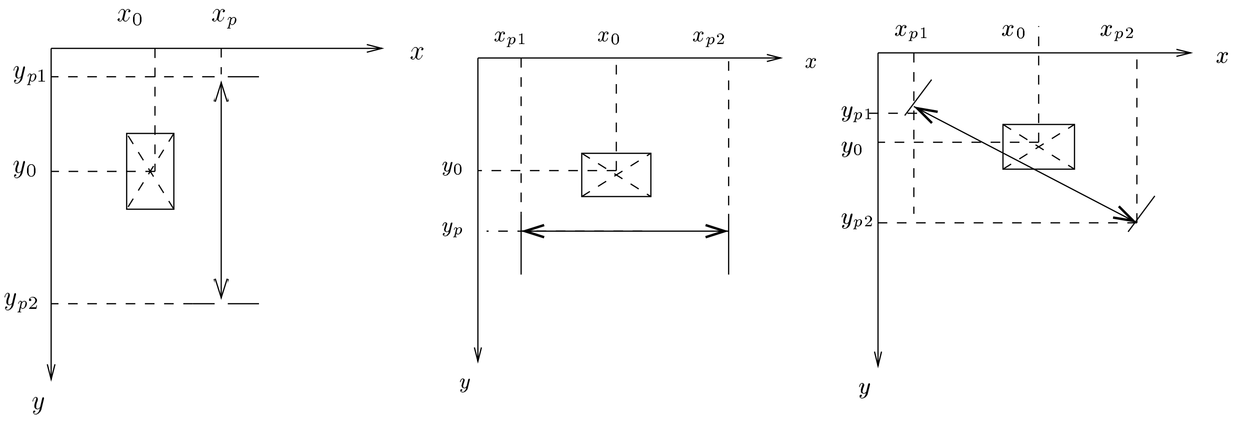
(b) The corresponding indicating primitives.

Figure 3: Detection of the indicating primitives.

3.2 Candidates for dimension lines

The dimension line is the only primitive of the dimension set that the dimension text is pointing to. In fact, in many cases the dimension line is the reflect of the dimension text. Candidates for dimension lines could be :

- A two fork point segment having a perpendicular segment close to each fork point. These two segments are considered as the *temporary* witness lines of the candidate.
- A two fork point arc of circle having a close segment to each fork point. The two segments must form an angle θ such that $\theta < 90^o$. The angles which form the segments with the cord of the arc must be equal. These two segments are considered as the *temporary* witness lines of the candidate.



(a) Vertical segment.

(b) Horizontal segment.

(c) Diagonal segment.

Figure 4: of text/segment positions.

The *temporary* witness lines cannot be previously recognized as *indicating* primitives.

3.3 Atomic primitives

Atomic primitives are fragments of dimension lines. Finding a fragment of a dimension line allow us to find all the dimension line. An *atomic* primitive could be :

- An indicating primitive which is a candidate to a dimension line. If such a primitive is a segment, it is labeled NLS (Not linked segment), see figure 5. In the case of an arc of a circle, it is labeled NLA (Not linked arc).

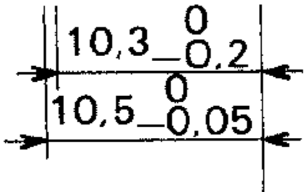


Figure 5: NLS type.

- A primitive p which is candidate for a dimension line having an extremity close to the extremity of a one free point segment recognized as being an indicating primitive i. If the primitive p is a segment, then p is labeled DLS (Direct linked segment). In the case of p being an arc of circle the indicating primitive i must be perpendicular to the the closest *temporary* witness line of the candidate. The primitive p is then labeled DLA (Direct linked arc).

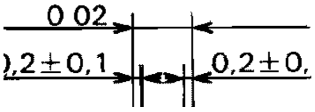


Figure 6: DLS type.

- A primitive p which is candidate for a dimension line and which is not labeled as *Not linked* or *Direct linked* primitive. The primitive p is linked to a one fork point segment, recognized as being an indicating primitive i, by a set S of segments. An element of S must be neither one of the primitives previously labeled nor a two fork point segment already recognized as an indicating primitive or a *temporary* witness line. If the primitive p is a segment, p is labeled ILS (Indirect linked segment). In the case of p being an arc of circle, the closest element of S must be perpendicular to the the closest *temporary* witness line of the candidate. The primitive p is then labeled ILA (Indirect linked arc).

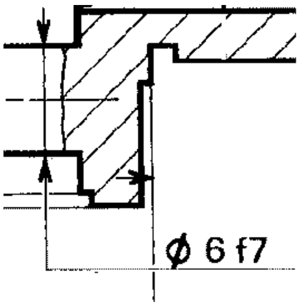


Figure 7: ILS type.

3.4 Complete dimension lines

To get complete dimension lines, *atomic* primitives are fusioned, when possible, with other primitive candidates for dimension lines which are neither *atomic* primitives nor their *indicating* primitives. The fusion (figure 8) is processed with two fork point primitives. If the *atomic* primitive is a segment, the fusion test is done according to the colinearity and proximity of the segments concerned by the fusion. In the case of an arc of circle, colinearity of tangents at the closest extremities of the arcs is tested.

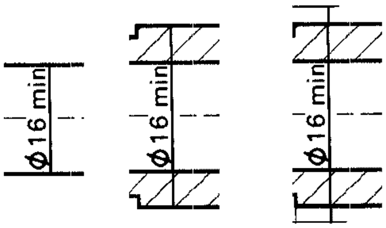


Figure 8: Example of fusion.

In the fusion process primitives must have, theorically, the same thickness.

The remaining one fork point segments recognized as *indicating* primitives are considered dimension lines and are labeled O (Orphan).

3.5 Witness lines

During the fusion of *atomic* primitives, *Temporary* witness lines are updated at each step of the fusion process. Indeed, at each fusion of two primitives we keep trace only of the *temporary* witness lines at the extremities of the resulting primitive.

As the *atomic* primitives fusion process is accomplished, fusion of the resulting *temporary* witness lines with colinear and close segments having the same thickness is processed. Thus, we get final and complete witness lines,

Witness lines and the corresponding dimension lines must have also the same thickness, otherwise, we keep trace of the last *temporary* witness lines in order to use them to delimit the arrowhead position.

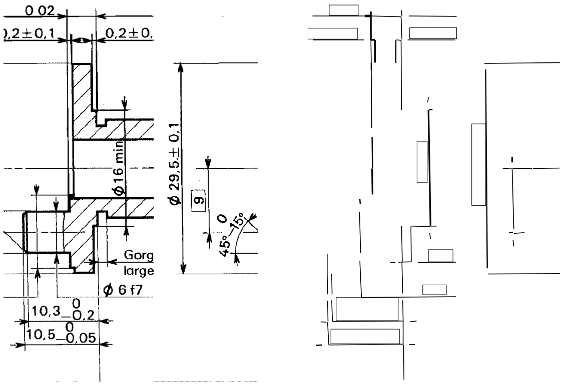
3.6 Positioning Arrowheads

To position the head of arrow :

- If a dimension line labeled NLS or NLA has an arrowhead at each extremity, then the arrowhead is delimited by the witness line.
- If a dimension line labeled DLS or DLA has an arrowhead delimited by it's indicative primitive and the closest witness line, then another arrowhead is delimited by the second witness line and a segment which is close and vertical to it.
- The case of a dimension line labeled ILS or ILA is similar to the case of a dimension line labeled DLS or DLA. Arrowhead is delimited at an extremity by the witness line and the closest segment of the corresponding set S (joining the indicating primitive and the dimension line). An arrowhead is delimited by the second witness line and a segment which is close and vertical to it.
- Orphan dimension lines have one arrowhead pointing to the closest fork point.

4 Experimental results

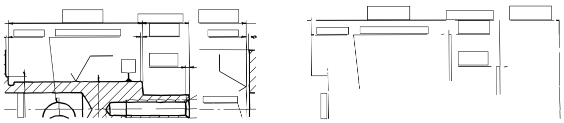
We present in this section some experimental results.



(a) Original drawing.

(b) Extracted dimenion elements.

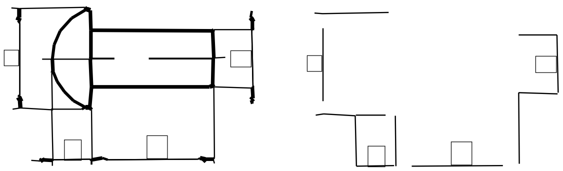
Figure 9: Detection of dimension sets.



(a) Original image after detection of the text and vectorization.

(b) Extracted dimension sets.

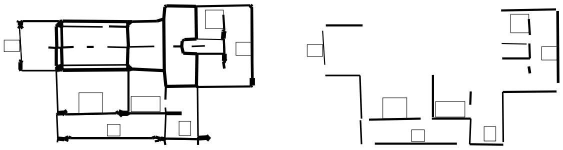
Figure 10: Detection of dimension sets elements.



(a) Original image after detection of the text and vectorization.

(b) Extracted dimension sets..

Figure 11: Detection of dimension sets.



(a) Original image after detection of the text and vectorization.

(b) Extracted dimension sets.

Figure 12: Detection of dimension sets.

- In the drawing of the figure 9, a line of dimension corresponding to the broad dimension is erroneous. It penetrates in fact inside the object whereas its line of fastener is actually outside. This is due to our technique of expansion of the *atomic* lines of dimension,

- in the drawing of the figure 10, a line of erroneous dimension is detected and falsely allotted to a dimension. This directly generates a no for the detection of a dimension set. We allot this error to the lack of rigour in the geometrical definition of a line of dimension. It would be necessary to find more criteria and to be more selective to avoid confusions. However, it might be likely to not detect all of them,

- in the drawings of the figures 11 and 12, which is of a good quality and which contains simple cases, the detection of dimension sets was done without any difficulty.

5 Conclusion

Our results show clearly that in order to detect correctly dimension sets, it is important to give syntaxic definitions to the parts of the graphic that are generally pointed by a dimension set. Therefore, it is important to detect a dimension line in its context. The originality of our algorithm is that the process of detection is not made locally but exploits a global view of the graphic by assuming that the dimension line corresponding to a text could be any candidate to dimension line in the graphic.

To improve the results, it would be very useful to find a complete morphological classification of dimension lines by taking into account the position of primitives in a small neighborhood including those which do not belong to a dimension set. Such a classification will certainly improve the detection rate and avoid detecting false dimension elements.

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