IAPR Workshop on CV - Special Hardware and Industrial Applications OCT.12-14, 1988, Tokyo

AUTOMATED CONVERSION OF MECHANICAL ENGINEERING DRAWINGS TO CAD MODELS: TOO MANY PROBLEMS?

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ABSTRACT

The state of the art of today's drawing conversion systems is described. It reveals a considerable amount of interactive assistance especially on complex pattern recognition and interpretation tasks. The difficulties and the major problems are picked up and reasons and solution approaches are stated.

INTRODUCTION

In spite of today's powerful CAD systems still approximately 80% of mechanical design is made with coventional methods. One reason for this slow spread of CAD methods is, that economical ways to convert engineering drawings to CAD models are still missing. Their applications could be the CAD model archive generation of standard parts, the use of graphical data, e. g. plans, maps, diagrams as input for CAD and CAE-methods and the bridge between drawings and computer assisted manufacturing.
The state of the art represented by the systems and components today available on the market is mainly only automated in the very early processing steps; the creation of data equivalent to a model designed on the CAD systems needs many tedious interactive steps, thus evaluating the productiveness becomes a complex question not yet clearly answered. The difficulties of drawing conversion originate mainly from the following three independent sources: image degradations, depending on age or copy generation of the drawing, complexity of the pattern recognition problems, from simple graphics to dimensioned descriptions of 3D models, and nonconformity with drawing standards, which makes flexible knowledge based methods necessary.
The competitive conversion method in mechanical engineering is generally not the manual digitization of the drawing on a tablet but the redesign on the CAD-system itself. This has certain advantages, because the CAD system is specialized to the application and generates so-called macro procedures automatically, which are represented by a symbol in the drawing consisting of many graphical elements or even groups of such symbols. Typical examples are drill hole types. In the competition of drawing conversion versus CAD systems this means either complex recognition tasks or interactive editing on the target CAD systems, which counts naturally negative in productiveness. Even new information, which is not yet contained in the drawing, e. g. concerning manufacturing, can be easily added by the CAD system.

STATE OF THE ART

Usual drawing conversion processes are shown step by step schematically in Fig. 1.
Automatic interpretation with interactive corrrection:
Along the diagonal from top left to bottom right the typical automated conversion concept is represented.
Halfcircle arrows mean interactive corrections. Alternative process steps, wich shall partly overcome the weaknesses of the automatic steps, mainly by editing, are in the right top area. Dashed lines stand for processes which are not yet realized in systems on the market. The general principle for all these process paths is "automatic interpretation with interactive correction". There is hardly processing of the *grey scale image* due to the huge amount of data: An E-size drawing sampled at about 500 dpi (a carefully chosen sampling rate for pattern recognition on engineering drawings) with 8 bit grey scale ends up with 400 Mbytes, which come down to a few Mbytes by binarization and data compression. Altough line drawings are supposed to be binary, due to the ink flow, eventual copy processes, paper degradation and the scanning process grey scales are captured.
The regeneration of the *binary image* is still sometimes very simple and crudely, i.e. using one

threshold chosen by the operator. But more careful operations which consider background and contrast fluctuations, are now available also. In any case binarization is an estimation which means information losses, e. g. the line width, important for the engineering drawing interpretation, becomes threshold dependent. There are several so-called raster systems, which stay in the binary or raster mode. They are used as digital archiving and drawing modification systems. They offer the entrance to the CAD world only by delivering the raster image as backdrop on the screen for overlay techniques with graphical or CAD elements. The *vector image* can be handled in a usual CAD system, but the number of short vectors often exceeds the capacity of the CAD system. Just for input of non-interpreted graphics like technical illustrations it is useful, if distortions by the usual vectorizing processes can be tolerated.

The *graphical elements* list is suited much better, since e. g. characters and curves like circles, are suitably described by code or parameters. Today the complete graphical elements list can be achieved either by considerably interactive assistance or pattern recognition in the raster image.The *2D model* is the gateway to the CAD world e. g. for mechanical engineering drawings. In this case the most important step, the interpretation of the dimensioning and the according rectification of the geometry, is still missing in most of the systems which can be classified into the strategy "automatic interpretation with interactive correction".

Interactive interpretation eventually with intelligent support:

A quite different strategy is represented by the process steps in the left down area of Fig. 1, shortly described by "interactive interpretation". There the binary image is just used as a reference

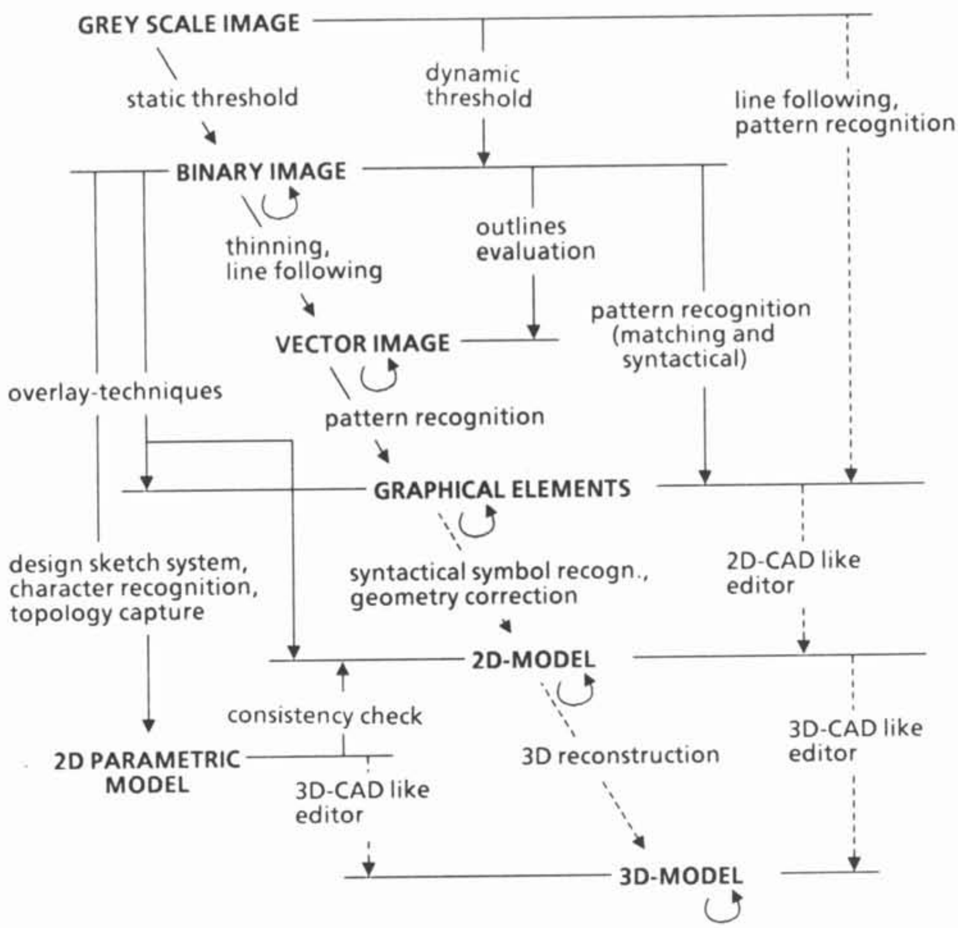

Fig. 1: Schema of drawing conversion processes

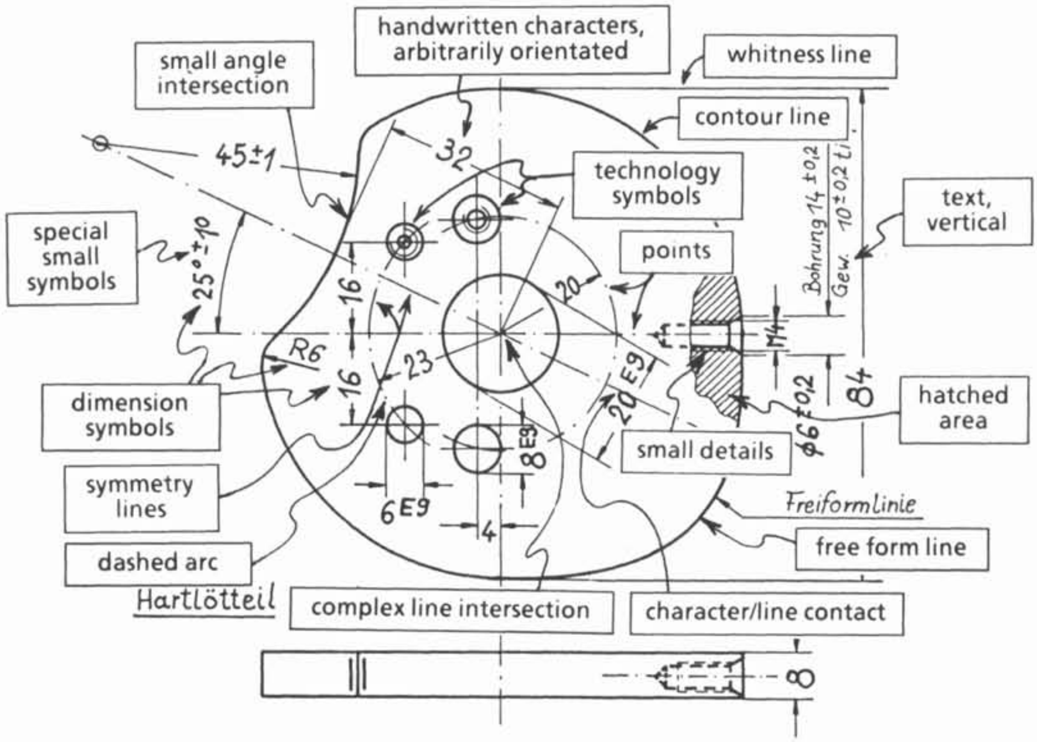

Fig. 2: Example drawing and typical interpretation problems.

on the system's display and a kind of sketching or design system allows the user to redesign the object. Character recognition, automatic geometric constraint capture and e. g. checks for completeness and consistency of the dimensioning are the intelligent part of this conversion methods. It offers also a kind of parametrized model, which is created partly automatically, to be used for design or drawing modifications and variational design.

More detailed information about drawing conversion systems and the 3D reconstruction process step, which cannot be treated here, can be found in the literature, e.g. /CUG,HOF, GU, MEK/. The systems on the market can be classified more or less to one of these strategies. In any case interactive processes take considerable amounts of time. Thus the question about productivity has still no clear answer and can only be answered separately for each application. Application experience is growing but well-founded benchmarkes are still necessary.

PROBLEMS AND SOLUTION APPROACHES

Fig. 2 shows an example drawing and typical interpretation problems. In the following selection of problems there is today no satisfying solution on the market, although solutions are already proposed for limited circumstances and/ or in laboratory conditions.

Information losses or degradations with binarization (e. g. broken or touching lines, line width distortions): adaptive thresholding /KIT/, or better grey scale processing using a priori knowledge about lines, line width or scanner distortions /BUR, NAL, PAV/ will give improvements.

Vectorization errors (e.g. too many small vectors not aligned, distorted line junctions): replacement of "dumb" extremely locally operating vectorization algorithms by regionally operating procedures, which use knowledge about line features and widths, about the special treatment of line junctions /DOM/, about connectivity /Ka1/ and noise characteristics /CUG/.

The *small success in graphical element recognition* could be improved by the well-known use of context in character recognition, but also in line width classification (using local differences) and character/ line segmentation. Simple methods for line recognition for any styles have to be developed from first approaches, e.g. /EGE, TUC/.

The *missing fault tolerance* of the recognition algorithms should be established by incorporation of a priori knowledge and context, but also plausibility checks and a principal change in the processing strategy: not just simply static but dynamic sequences are necessary, which would allow to jump back to an earlier process due to unsatisfactory results.

CONCLUSIONS

The state of the art of drawing conversion systems reveals a considerable amount of interactive assistance especially on complex pattern recognition tasks. Current solutions seem to improve only gradually. Proposals for improved methods are available, but why is an *automatic* drawing conversion system still so far away? Too much problems? Two big problems have not yet been clearly addressed: the big size of the images, e. g. 5000^2 to $20{,}000^2$ pixels and the large variety in form, size and orientation of the symbols to be interpretated. A dimensioning symbol, for instance, can be almost as long as the drawing, what makes processing in smaller windows complicated. The earlier solutions therefore have been forced to start with dumb processing like binarization and vectorization, just to come down from the huge pixel numbers. Now fast image processing components and cheaper memory capacity on the one side and experiences and tools from knowlegde based systems research for the application of a priori knowledge and context on the other side should offer a new approach to solve the automation of drawing conversion.

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