RESEARCH PAPERS
FACULTY OF MATERIALS SCIENCE AND TECHNOLOGY IN TRNAVA
SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA

2014 Volume 22, Number 35

EXPERIMENTAL EVALUATION OF INTEGRAL TRANSFORMATIONS FOR ENGINEERING DRAWINGS VECTORIZATION

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Abstract

The concept of digital manufacturing supposes application of digital technologies in the whole product life cycle. Direct digital manufacturing includes such information technology processes, where products are directly manufactured from 3D CAD model. In digital manufacturing, engineering drawing is replaced by CAD product model. In the contemporary practice, lots of engineering paper-based drawings are still archived. They could be digitalized by scanner and stored to one of the raster graphics format and after that vectorized for interactive editing in the specific software system for technical drawing or for archiving in some of the standard vector graphics file format. The vector format is suitable for 3D model generating, too.The article deals with using of selected integral transformations (Fourier, Hough) in the phase of digitalized raster engineering drawings vectorization.

Key words

paper-based engineering drawing, integral transformations, CAD, vectorization

Introduction

Engineering drawing as an information resource of technical ideas works as a communication tool among the individual elements of technical-economic activities (1). It is a basis for the products manufacturing and represents one of the forms of technical documentation. Engineering drawing has to comply with the predefined requirements, in terms of the form and content. Drawing contains information about the geometrical shape and dimensions of the part, its material, surface treatment, tolerances, etc. Besides, it has to comply with the formal requirements such as size, borders, scale, line type and thickness, font type and size etc. Several types of lines are used for part description and each type of line expresses a specific content. Among others, thickness of the line is also significant. The type and thickness of the line are important features to understand the content. Therefore, we lay emphasis on those features.

Dimensions of the drawing sheets

The size of engineering drawings is defined by the ISO 5457 international standard - Technical Product Documentation - Sizes and Layout of Drawing Sheets. It provides the dimensions and layout of the drawing sheets for engineering drawings in all technical areas. The drawing original should be made on the drawing sheet at the smallest scale still providing readability and clarity of the graphics and text information specified in the drawing.

Title block of the engineering drawing

In each engineering drawing, organizational and identification information is written into a title block arranged according to ISO 7200: Technical Product Documentation - Data Fields in Title Blocks and Document Headers. The title block is placed in the lower right corner of the drawing area. It contains individual drawing data (number, name, origin etc.), which are grouped into rectangular arrays divided into the boxes. The data reading direction in the title block has to be generally consistent with the reading direction of the drawing.

Scale of reproduction

Not all objects can appear in the engineering drawings at the actual size. Most of their images are either in smaller or bigger scales. Recommended scales of reproduction and methods of their writing to all kinds of engineering drawings are defined by the ISO 5455 standard - Engineering Drawings - Scales. Real sizes are defined at the scale of 1:1, enlargement at the scale of X:1 and reduction at the scale of 1:X. In terms of processing, the scale is a coefficient, which all parameters are multiplied by.

Engineering drawing entities

Engineering drawings consist of the numbers of various geometric elements and textual data, e.g.: lines, dimensions, projections, sections, views, annotations etc. General principles for making sections and cross-sections for all kinds of engineering drawings (mechanical, electrical, construction etc.) are established by the STN ISO 128-40, STN ISO 128-44 and STN ISO 128-50 international standards.

Materials and methodology of experiment

At present, we may encounter four major forms of archiving and exchange of production documentation. They are: traditional paper-based drawing, electronic raster and vector drawing and a 3D computer model. Based on the fact that the development of new products is largely based on the modification, adaptation and upgrade of existing products, there is a great effort of accessing the older drawing documentation to modern CAD/CAM systems which work with 3D models and can generate engineering drawing as well as a control program for CNC machine tools. Other reasons are storability, simplified distribution of production information, and, in particular, increased level of re-usability of such documentation. The process of generating a 3D model from a paper-based engineering drawing can be divided into several steps. The first step is scanning the paper-based engineering drawing. The result is a file with drawing's raster format. The next step is pre-processing, where the raster representation of the engineering drawing is adjusted by various methods into a suitable form so that it can be vectorized in the next step. The result of the vectorization is a file with drawing's vector format. Consequently, from the vector representation of the engineering drawing, it is possible to generate a 3D computer model that can be archived in the standard 3D format. The general procedure for re-engineering of such 3D model is shown in Fig. 1.

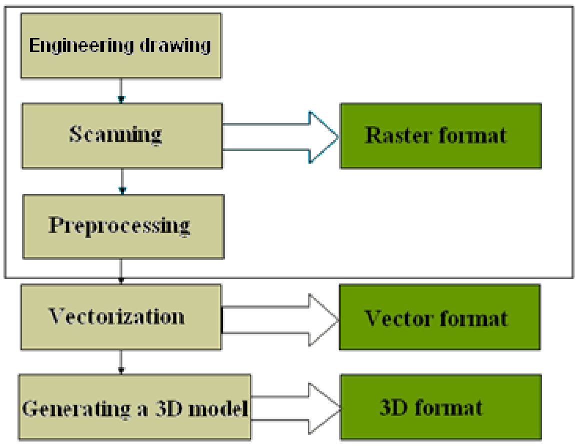

Fig. 1 *The general process of 3D model generation from engineering drawing*

In this paper, we consider the Fourier and Hough transforms. Fourier transform is used to transfer the image to the dual space, which simplifies some operations of the image and is also suitable for understanding the properties of the image and some other phenomena (2). In practice, a sequence of discrete function values is given, and the discrete Fourier transform is used for calculation. In the case of graphic images, it is a sequence of functional values of the individual lines (3).

The Hough transform has been the main means of detecting straight edges for over a quarter of century or so. Since the method was originally invented (Hough, 1962), it has been developed and refined for this purpose. The basic concept involved in locating the lines is point-line duality. A point can be defined either as a pair of coordinates or else in terms of the set of lines passing through it (4).

The Process of Experimental Evaluation

To evaluate the integral transformations, a test application was developed at the Department of Applied Informatics. Application loads a raster image as input. After the application of selected integral transformation, it is possible to view the original image and the vectorized one in order to compare the results. We tested two selected integral transforms (Fourier, Hough) in the experiment. The transforms were used for a specific number of test samples (Fig. 8). The test samples were designed in the graphics vector editor. After that, the samples were printed and scanned to obtain raster representation of image.

Fig. 2 *User interface of the experimental application (5)*

Achieved results with selected samples

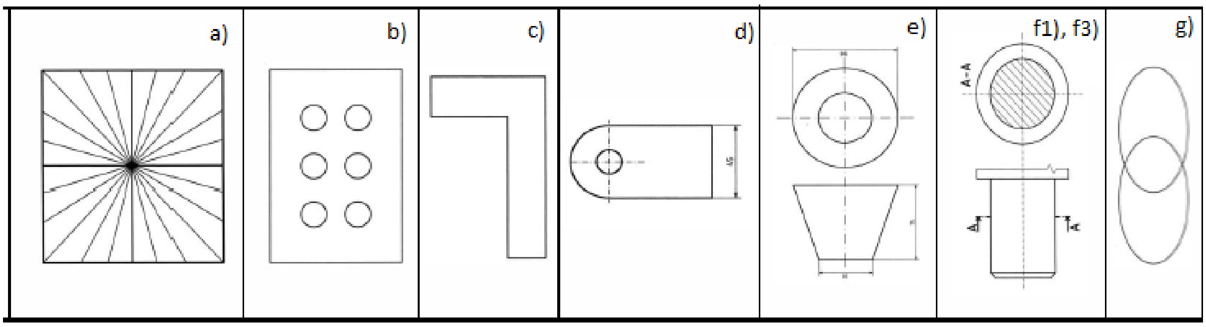

Fig. 3 *Test samples*

Fourier transformation

Test conditions

Sample a)

- resolution of the scanned TIFF image – 600 DPI
- color depth – 1 bit
- Fourier parameters – Min. 180, Max. 1000

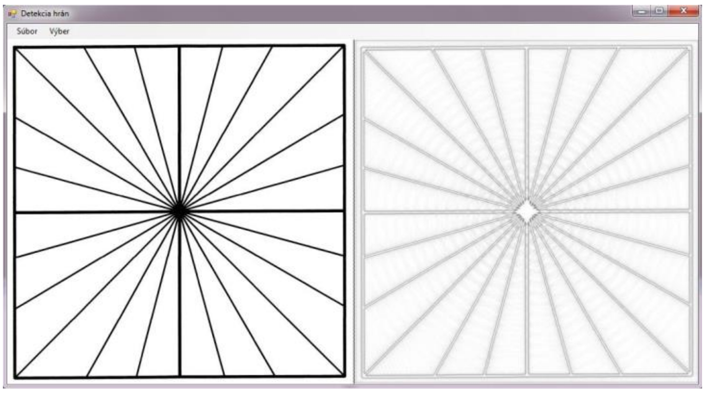

Fig. 4 *Fourier transform with sample a)*

Sample f3)

- resolution of the scanned TIFF image – 150 and 600 DPI
- color depth – 8 bit
- Fourier parameters – Min. 200, Max. 1000

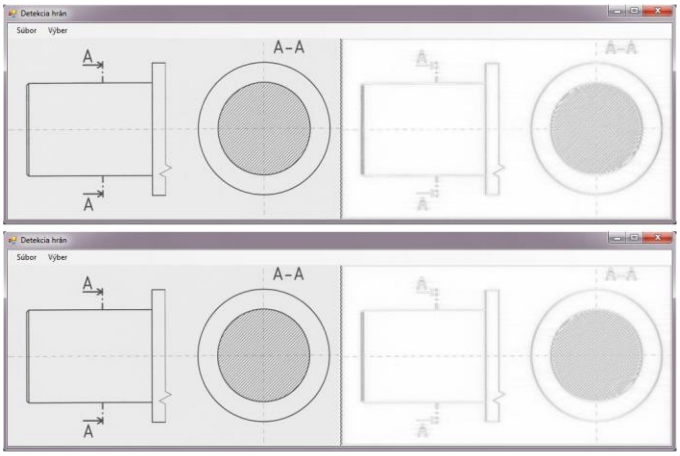

Fig. 5 *Fourier transform with the sample f3, results at resolution 150 and 600 DPI*

Hough transformation

Test conditions

Sample a)

- resolution of a scanned TIFF image – 600 DPI
- color depth – 8 bit
- minimum intensity of line 270, minimum intensity of circle 150

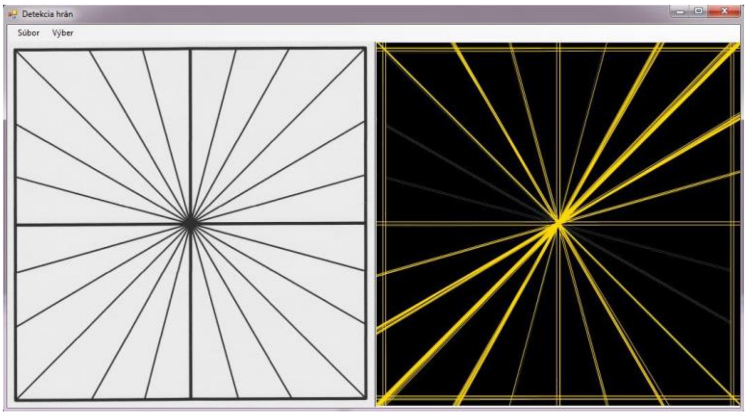

Fig. 6 *Hough transform with sample a*

Sample f1)

- resolution of the scanned TIFF image – 600 DPI
- color depth – 1 bit
- minimum intensity of line 250, minimum intensity of circle 180

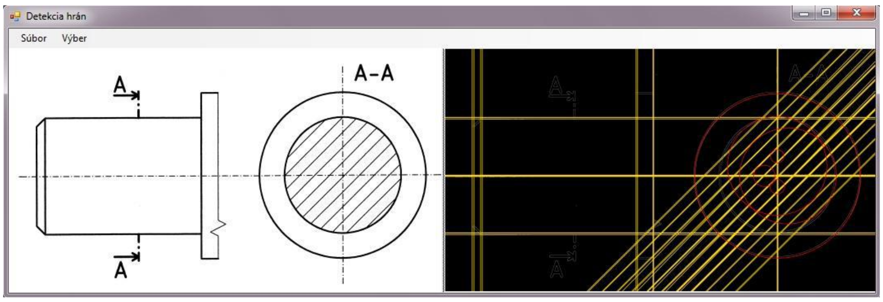

Fig. 7 *Hough transform with sample f1*

Sample d)

- resolution of a scanned TIFF image – 150 and 600 DPI
- color depth – 8 bit
- minimum intensity of line 230, minimum intensity of circle 75

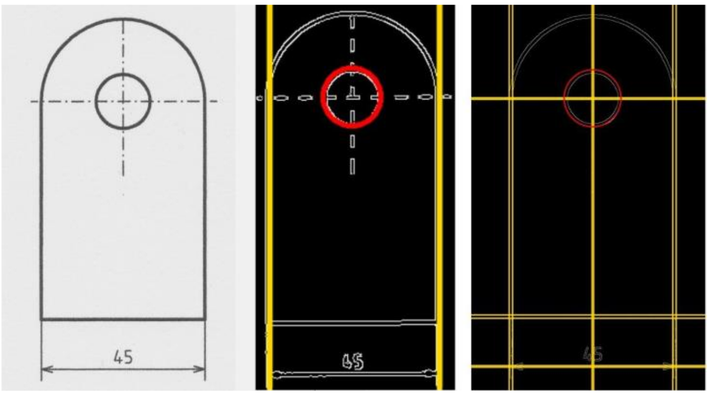

Fig. 8 *Hough transform with sample d, results at resolution 150 and 600 DPI*

Sample b)

- resolution of a scanned TIFF image – 300 DPI
- color depth – 8 bit
- minimum intensity of line 300, minimum intensity of circle 100 → 105

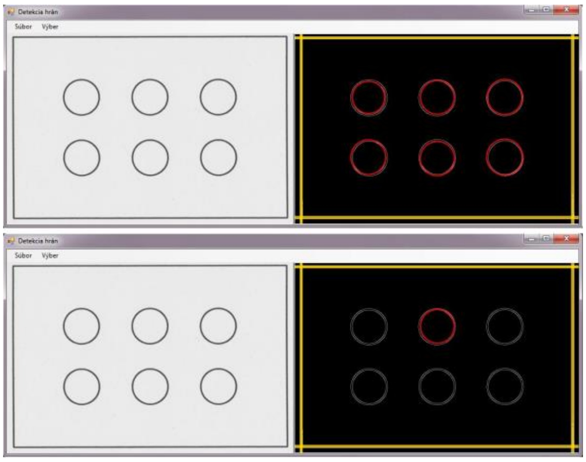

Fig. 9 *Hough transform with sample b, change of the minimum circle intensity value*

Discussion on results

Evaluation of the Fourier transform results

Based on the above-mentioned tests, it can be stated that the Fourier transform algorithm can largely recognize almost all elements of engineering drawing. There were minor problems with the detection of two or more edges close to each other, e.g. the betrayed and shading, where there is a smearing of individual edges in solid lines. The attained results are quite substantially affected by the set value of the minimum and maximum frequencies. After applying the transformation to the image at a lower resolution, we observed only partial differences in the attained results. Fourier transform gives significantly better results when applied to the scanned black-and-white image, and later, when uploaded to the application, it is converted to the desired format in the shades of gray.

Evaluation of Hough transform results

Based on the above-mentioned tests, it can be stated that the results of Hough transform largely depend on the resolution of the input image and the image preprocessing. At the resolution of 150 DPI, the transformation failed to portray where there are edges of the lines. The results were satisfactory until at 600 DPI.

For the purpose of preprocessing of the image, Gaussian filter was used to smooth the noise, and then Canny edge detector was applied to the input image. Hough transform would fail to provide almost any real results without such modified input. Upon detection of the horizontal, vertical and oblique edges of each line, it was found that the transform is unable to identify the start and end points of the lines, except for the lines that pass through to the overall picture. Upon detection of the edges of a rectangular arrangement of the holes in some cases, it was impossible to find inscribed circle or circumscribed circle. Similarly, it was impossible to recognize the edges of other elements of the engineering drawing such as curvature, dimensions, technical writing and elliptical shape.

The Hough transform algorithm is sensitive to parameters setting. The parameters provide a threshold, when line edge or circle edge have to be plotted and when not. At the lower values of individual intensities, Hough transform portrays also nonexistent lines and circles, and, vice versa, at higher values, some of them are not displayed.

Conclusions

The test of the Fourier and Hough transform suitability for raster engineering drawings vectorization with the focus on recognition of the line type and thickness shows that both transformations are suitable for solving the first task - line type recognition. By Fourier transform provides good results in the recognition of geometric shapes and hatched regions, too. Hough transform has greater sensitivity to set parameters. The line thickness recognition in the test did not provide desired results. Thicker lines were recognized as two parallel thin lines. To exactly confirm the obtained results, it is still necessary to extend the testing to various adjustable parameters, mainly to the Hough transform.

Acknowledgement

Európska únia
Európsky fond regionálneho rozvoja

This publication is the result of implementation of the project: "UNIVERSITY SCIENTIFIC PARK: CAMPUS MTF STU - CAMBO" (ITMS: 26220220179) supported by the Research & Development Operational Programme funded by the EFRR.

Operačný program VÝSKUM a VÝVOJ

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Reviewers:

doc. RNDr. PaedDr. Ladislav Huraj, PhD.
hosť. profesor Ing. Augustín Gese, CSc.