IMPACT OF SKELETONIZATION METHODS ON ACCURACY OF DIGITAL HOLOGRAMS EVALUATION

Elena Pivarčiová, Pavol Koleda

Department of Informatics and Automation Technology, Technical University in Zvolen

Abstract: *The method of holographic interferometry has been applied to make the temperature fields over the heated-up wooden test specimens visible. We verified impact of skeletonization methods on accuracy of digital holograms evaluation. Individual thinning algorithms have individual approach to thinning and therefore resultant skeletons of digital holograms are different.*

Keywords: *Holographic Interferometry, Interferograms, Thinning Algorithm.*

JEL Classification: *C02, C61, C63, C69, C88, C93.*

1. Introduction

Holographic interferometry (HI) is an experimental method which makes physical fields visible. One of them is also the temperature field and its subsequent qualitative and quantitative analysis. In the presented article we used HI method to make temperature fields over the test specimens visible.

Impact of various thinning methods on interference fringes positions determination and consequence monitoring of accuracy of digital holograms evaluation were verified by number of algorithms.

2. Basic informations

2.1 Holographic interferometry

Holographic interferometry is an optical method that makes it possible to visualise transparent objects, helps explain the physical essence of the investigated events, enables to specify and expand the possibilities of visualisation of physical fields while the investigated area is not disturbed by sensors or sensing heads by which, for example the local temperatures or concentrations are detected.

The methods of holographic interferometry are utilised to study object deformations, vibrations, or small displacements. They are also applied in the field of fluid mechanics, heat transmission, mass transfer, environmental technology and mainly as visualisation methods of investigation of inhomogenities within transparent objects and for three-dimensional recording of the elements in fluids (Černecký et al. 2006).

We now have applications of interference methods in technical and research practice that are possible only after a thorough consideration of the measurement method by the use of a holographic interferometer with digital recording. Applications of interference methods are nowadays largely dependent on the process of computer analysis of interferograms that enables to make precise, fast and effective analysis without subjective errors.

2.2 Digital holograms

In the case of the experiments utilizing holographic interferometry either with transparent (phase) objects or with solid (diffusively reflecting) bodies the first thing to be done is the record of the holographic interferogram. If necessary the image is modified by various techniques and, finally it is qualitatively and quantitatively analysed. Nowadays, in all the phases computers with particular hardware and software (Csongrády, 1996) are successfully used to supply the slow and routine activities by automatic calculation, which considerably simplifies the processes and analyses of the experiments.

At present, during the experiments in the field of holographic interferometry the digital recordings of images are used. Digital recordings allow immediate processing and analysis of images in computer, which markedly makes the research more efficient by holographic-interference methods. Two-dimensional digital record of the object can be obtained if we display three-dimensional objects by means of lenses, for example to the plane of the CCD camera sensor, or we can create it by optical and mechanical resolution of the image, or by digitalisation of analogue image signals through digitising computer cards, or by digitalisation of photographic records by means of a scanner we can transform two-dimensional photographic patterns into two-dimensional digital recordings that are later stored in the form of computer (image) files.

2.3 Thinning algorithm

By the term thinning algorithm we understand points or original image layers removing until all the lines in the image are of width of one scanning point (pixel). Result of thinning algorithm is line file, called skeleton.

Input into thinning algorithm is binary image with brightness values 0 or 1. Objects are represented by points with brightness values of 1. Points with brightness value of 0 belongs to environment.

Concerning fact that most of thinning algorithms essentially depend on in-image-incident noise, the resultant skeleton is not hundred-per-percent straight one, there various vibrations can emerge in it, even some of the algorithms could cause lines interruption. Such malfunctions spoil required skeleton and could be restriction in further image evaluation. To eliminate these incidents in obtained skeleton we apply practices leading to removing of these accidents of continuity, vibrations and spurs.

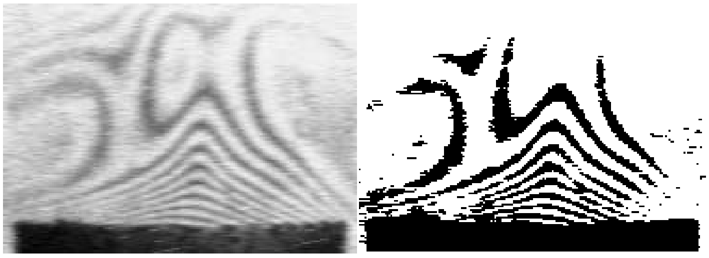
3. Interpretation of interferograms

The interpretation of interferograms obtained from interferometric measurements is a slow, laborious and time-consuming process, therefore, it is advantageous to use computing technology and replace the whole process by automatic computing. This process also increases the precision of computing and partially eliminates subjective influences in the process of analysis.

Completely program recognizes image quality and also edges in image and they can define location of interference tape minimum and interference orders distribution, using which they could help to calculate required physical value (i.e. temperature).

One of the most complicated steps in the process of computer interferogram analysis is detection of the interference fringe positions and determination of the interference order. These procedures are followed by refractive index determination itself and calculation of studied parameters.

The digital hologram of the temperature fields the wood test specimen with dimensions of 43 × 40 × 10 mm was used (Fig. 1).



a) b)

Fig. 1: The digital hologram of the temperature fields

a) original image b) image aligned by tresholding with thresh value of 175

Framework algorithms are part of holographic interferograms evaluation program. Target of framework subprogram was to set framework algorithms, that are proper for frameworking of holographic interferograms.

Program of interferograms preprocessing and subsequent implementation of thinning algorithms was built to determination of interference fringe positions. (Fig. 2):

a) Deutsch algorithm (Dobeš, 2008)
b) Deutsch modified algorithm (Dobeš, 2008)
c) Zhang-Suen algorithm (Onat et al 2006)
d) Modified Zhang-Suen algorithm (Kong Rosenfeld, 1996)
e) Guo & Hall algorithm (Zhang et al. 2008)
f) C. J. Hildish algorithm (Yin Narita, 2002)
g) Stover-Iverson algorithm (Stover Iverson, 1986)
h) Sequence algorithm with usage of structural masks (Šmat, 2002)

Framework subprogram was to compare several thinning algorithms and to find framework algorithms, that are proper for frameworking of holographic interferograms.

Software was built in programming language C++, in C++ Builder environment.

For quantitative analysis of holographic images it is necessary to determine the distribution of the refractive index within the object from skeleton, and then calculate the distribution of the measured physical values from it.

From the distribution of refractive index $n(x, y)$ we can determine temperature distribution under constant pressure by state equation (Pavelek et al., 1977):

$$T(x,y) = \frac{T_\infty}{1 - 0{,}805.\dfrac{T_\infty}{l.p_\infty}.\left(s - \dfrac{1}{2}\right)},$$

where $T(x, y)$ – temperature distribution, T_∞ – atmospheric temperature in the reference area, p_∞ – pressure in the given space, s – interference order, λ – light wavelength, l – model length.

Fig. 2 Program for interferograms frameworking

Results comparison of individual thinning algorithms including calculated heights and temperatures above centre of test specimen is in Tab. 1. In table there is gained results transparent comparison upon used framework algorithm shown.

It is possible to see from the images, what the temperature were in various locations above sample body surface.

Values in small tables under the images represents framework-obtained height v above sample surface over sample body center.

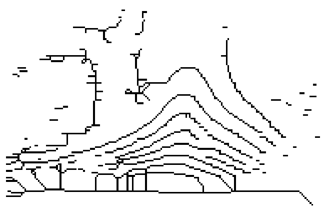
Temperature t was calculated with use of above relation, therefore it is growing in certain jumps. Height changes for single calculated temperatures. We can see that these values differ for single framework algorithms

Obtained values can be applied for another processing, i.e. heat transfer coefficient calculation

Tab. 1: Results comparison of individual thinning algorithms

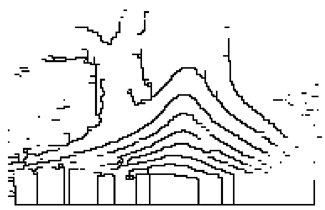
***v* [mm]**	***t* [°C]**
10,10	20,0
7,11	28,4
5,18	47,2
3,49	67,7
2,28	91,5
0,83	118,8

a) Deutsch algorithm



***v* [mm]**	***t* [°C]**
11,80	20,0
8,20	28,4
6,51	47,2
4,83	67,7
3,63	91,5
2,19	118,8

b) Deutsch modified algorithm



***v* [mm]**	***t* [°C]**
9,85	20,0
6,97	28,4
5,40	47,2
3,36	67,7
1,92	91,5
0,48	118,8

c) Zhang-Suen algorithm

***v* [mm]**	***t* [°C]**
9,69	20,0
6,79	28,4
5,10	47,2
3,41	67,7
2,20	91,5
0,75	118,8

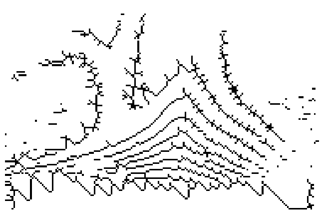
d) Modified Zhang-Suen algorithm

***v* [mm]**	***t* [°C]**
9,42	20,0
6,76	28,4
5,70	47,2
3,38	67,7
2,17	91,5
0,97	118,8

e) Guo & Hall algorithm

***v* [mm]**	***t* [°C]**
9,93	20,0
7,28	28,4
5,34	47,2
3,65	67,7
2,20	91,5
0,75	118,8

f) C. J. Hildish algorithm



***v* [mm]**	***t* [°C]**
9,58	20,0
6,70	28,4
5,20	47,2
3,34	67,7
1,89	91,5
0,45	118,8

g) Stover-Iverson algorithm

***v* [mm]**	***t* [°C]**
8,84	20,0
6,21	28,4
4,54	47,2
2,87	67,7
1,43	91,5

h) Sequence algorithm with usage of structural masks

v – height above centre of test specimen
t – calculated temperature

4. Conclusion

Holographic interferometry is an optical imaging method that enables us to investigate with high sensitivity and precision the displacements and deformations on the surface of real objects, to study vibrations, small displacements of objects, to visualise physical fields. We do not consider only the immediate visualisation, but also the permanent display of the field that is later possible to analyse.

Concerning the fact that interferogram evaluation is very time consuming and laborious, it is possible to evaluate more measurements removing subjective influences using suitable software.

Impact of various thinning methods on interference fringes positions determination and consequence monitoring of accuracy of digital holograms evaluation were verified by number of algorithms.

Individual thinning algorithms have individual approach to thinning and therefore resultant skeletons of digital holograms are different.

Implementation of Guo-Hall and Stover-Iverson algorithms is not useful for interferogram frameworking, because they produce undesirable spurs and the resulting framework is rather complicated (it is an attribute of the above mentioned algorithms, see. Tab. 1 e) g)). By contrast, when using Deutsch, Zhang-Suen and Hilditch algorithm the resulting framework is rather smoothed and formed spurs are easy to remove by further processing of the framework and by curves smoothing. So these algorithms are suitable for interferograms frameworking.

The program can be used in school area by students in expert, semestral, diploma and disertation works processing.

References

[1] CSONGRÁDY, T. Niektoré aspekty automatickej identifikácie tvaru guľatiny. In: *Automatizácia a počítače v riadení procesov* – Zborník referátov, Technická univerzita vo Zvolene, 1996

[2] ČERNECKÝ, J., SILÁČI, J., KONIAR, J. Vizualizácia prúdenia popri zakrivenej ohrievanej stene. In: *Trendy lesníckej, drevárskej a environmentálnej techniky a jej aplikácie vo výrobnom procese*: Zborník referátov z medzinárodno-vedeckej konferencie. Zvolen: Technická univerzita vo Zvolene, 2006. s. 44–49. ISBN 80–228–1650–7

[3] DOBEŠ, M. *Zpracování obrazu a algoritmy v C++*. Praha: BEN – technická literatura, 2008. 144 s. ISBN 978-80-7300-233-6.

[4] KONG, T. Y., ROSENFELD, A. *Topological algorithms for digital image processing. Amsterdam*: Elsevier Science B. V., 1996. 292 s. ISBN 0-444-89754-2

[5] ONAT, A., YILDIZ, F. et al. Script Recognition Using Hidden Markov Model. Proceedings of World Academy of Science, *Engineering and Technology* volume

14 August 2006. ISSN 1307-6884. Available on-line: <http://www.waset.org/pwaset/v14/v14-15.pdf>

[6] PAVELEK, M., RAMÍK, Z., LIŠKA, M. *Použití holografické interferometrie k vizualizaci tepelných mezních vrstev u přirozené konvekce ve vzduchu*. Strojnický časopis, 28, 1977, č. 3, s. 301–311

[7] STOVER, D. L., IVERSON, R. D. A One-Pass Thinning Algorithm and Its Parallel Implementation. *Computer Vision*, Graphics and Image Processing 40, 1986

[8] ŠMAT, M. *Metody digitální holografické interferometrie*. Diplomová práca. Západočeská univerzita v Plzni, 2002

[9] YIN, M., NARITA, S. *Speedup Method for Real-Time Thinning Algorithm*. Available on-line: http://www.aprs.org.au/dicta2002/dicta2002_proceedings/Yin258.pdf>

[10] ZHANG, F., WANG, Y., GAO, Ch. et al. *An Improved paralel thinning algorithm with two subiterations*.

Available on-line: <http://www.springerlink.com/content/u84k0n10 v8433045/fulltext.pdf>

Contact Address

Mgr. Elena Pivarčiová, Ph.D.
Technical University in Zvolen, Faculty of Environmental and Manufacturing Technology, Department of Informatics and Automation Technology
Masarykova 24, 960 53 Zvolen, Slovakia
E-mail: epivarci@vsld.tuzvo.sk
E-mail: pavol.koleda@zoznam.sk
Phone number: +421 455 206 477

Ing. Pavol Koleda
Technical University in Zvolen, Faculty of Environmental and Manufacturing Technology, Department of Informatics and Automation Technology
Masarykova 24, 960 53 Zvolen, Slovakia
E-mail: pavol.koleda@zoznam.sk