

DEVELOPMENT OF VOLUME MODEL OF IRREGULAR SHAPED OBJECTS FOR NUMERICAL SIMULATIONS USING SHAPE-FROM-SILHOUETTE METHOD

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Abstract: *This paper deals with development of the volume model of irregular specimens using optical projections. A sequence of 360 projections of the specimen was acquired and processed using a custom set of procedures developed in MatLab environment. The projections were segmented, filtered and smoothed. A semiautomatic procedure was used to calibrate scale of the projections and to remove eccentricity of axis of rotation of the specimen. The volume model was obtained using inverse Radon transform. Additional procedures were developed to obtain cross-section characteristics required for evaluation of corresponding micromechanical test. For verification of the developed procedure volume models of known shaped objects were estimated and compared.*

Key words: *micromechanical testing, optical methods, shape from silhouette, volume model development*

1. Introduction

For evaluation or numerical simulations of micromechanical tests of complex materials an accurate description of the shape of the specimen is required. For many materials (e.g. biological materials [1] or metal foam cell walls) may be challenging or even impossible to prepare specimens of regular shape due to the materials properties as well as small dimensions of the specimens. The paper deals with development of volume model with irregular shape.

Although there are well established methods to reconstruct irregular shaped

volumes, especially methods based on rays outside the range of visible light, these methods require highly specialised laboratory equipment (e.g. X-ray sources, detectors and shielded boxes) [2]. Methods for photometric stereo measurements [3] despite its high precision are not suitable for the purpose as the methods may describe only a sector with a limited angle.

For the reconstruction of the shape a shape-from-silhouette method presented by Pintavirooj [4] was employed. The volume model is obtained by inverse Radon transform of projections of the object placed on a turntable.

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2. Materials and methods

Prior the inverse Radon transform was used to obtain three-dimensional data, several procedures were to be carried out to achieve a proper set of input data for the volume reconstruction.

2.1. Image acquisition

Sequences of projections were acquired by the experimental setup depicted in Fig. 1. Image data were captured by a high resolution CCD camera (VDS 1300F, Vosskuehler, GmbH, Germany) controlled by an open source software Coriander [5]. The camera was attached to an optical microscope (Navitar Imaging Inc., USA) providing up to 24x magnification. Precise control of the angle of rotation of the scanned specimen was performed by a stepper motor (X57, Microcon, s.r.o., Czech Republic) controlled by a driver (Gecko Drive, United Kingdom) governed by an open source software LinuxCNC [6].

Illumination arrangement was chosen according to nature of surface of the scanned specimen. For opaque specimens backlight illumination arrangement might be used, for transparent material the reflection-light illumination was more suitable.

2.2. Projections pre-processing

For the reconstruction an unchanged position of axis of rotation in the projection is required. The way to achieve this was to ensure position of the axis in the middle of each projection. For this purpose the same point in two projections with angular offset 180° was identified and from the coordinates of these points in both projections the eccentricity was estimated. To remove the eccentricity all projections were trimmed.

The projections were acquired in form of

grayscale images (resolution 1280×1024 , colour depth 8bit). As input of the inverse Radon transform binarised images were required. For each projection an optimal threshold value was estimated using built-in procedure of MatLab Image Processing Toolbox to avoid the influence of illumination changes during the acquisition.

On the binarised projections distance transform [7] was performed to achieve better results of the inverse Radon transform. Principles of the distance transform are depicted in Fig. 1. Projection of isolated human trabecular in different steps of the pre-processing procedure is depicted in Fig. 2.

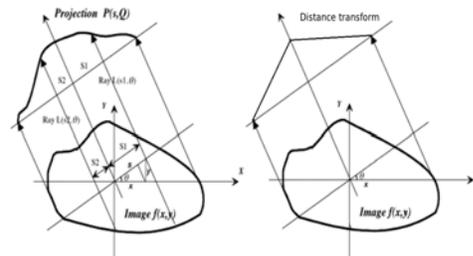


Fig. 1. Distance transform [7]

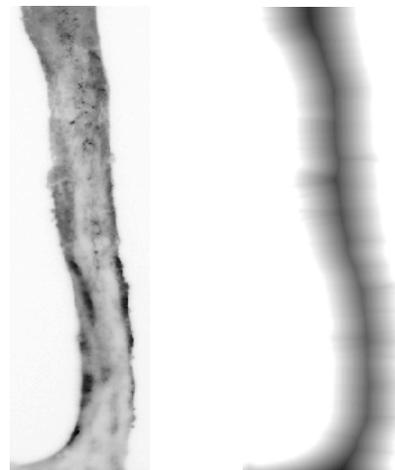


Fig. 2. Pre-processing of the projection (human trabecula). Projection (left), distance transform of the projection (right)

2.3. Reconstruction of slices

For reconstruction of specimen's shape inverse Radon transform was used. This method is well established for computed tomography frequently employed in medical imaging [8]. All projections were divided into rows and each set of rows with certain vertical coordinate was considered as sinogram and used as input of the inverse Radon transform

2.4. Additional procedures

To utilise obtained volume model in numerical simulation of a micromechanical test several additional characteristics were estimated: scale of the projections and geometrical arrangement of the micromechanical test. For tensile type of test the cross-section area corresponding to the break-point was required, for three-point bending arrangement distance between supports, eccentricity of loading tip and moment of inertia of cross-section in the loading point were estimated.

3. Results

3.1. Reconstruction of a known shaped object

For optimisation of the developed procedure the volume model of metric screw (in industrial standards marked as M3) was used. The reconstructed shape of the screw is depicted in Fig. 3.

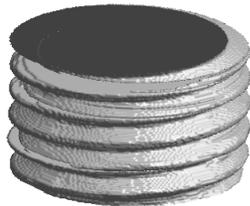


Fig. 3. Reconstructed volume model of M3 screw

Comparison of obtained screw

characteristics with values reported in industrial standards is listed in Tab. I.

Comparison of M3 screw characteristics
 Table 1.

	Measured	Reported
Outer diameter [mm]	3.047	3.000
Inner diameter [mm]	2.408	2.387
Mean diameter [mm]	2.713	2.675

3.2. Reconstruction of human trabecula

As a representative of irregular shaped specimen an isolated human trabecula (used for both tensile and three-point bending tests) was used. Trabecula is a beam formed element which highly porous trabecular bone consists from. Dimensions of the trabecula are less than 2mm (typically 1mm) in length and less than 0.2mm (typically 0.15mm) in thickness. The brittle nature of the trabeculae does not allow machining them to prepare prismatic samples. Volume model of isolated human trabecula is depicted in Fig. 4.



Fig. 4. Reconstructed volume model of human trabecula

4. Conclusions

An image processing tool for development of volume model of irregular shaped specimens was presented. To determinate precision of the presented method reconstruction of a metric screw was performed. Occurred relative deviation in measured lengths was lower than 0.02. In conjunction with additional procedures covering scale calibration and measurement of geometrical arrangement of the test it provides a detailed description of a micromechanical test and it may be employed in numerical simulations of the tests.

Acknowledgements

The research has been supported by Grant Agency of the Czech Technical University in Prague (grant No. SGS12/205/OHK2/3T/16), research plan of the Ministry of Education, Youth and Sports MSM6840770043, Czech Science Foundation (grant No. P105/10/2305) and by RVO: 68378297.

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