MATLAB DETECTION OF SHADOWS IN IMAGE OF PROFILOMETRY

L.Boleček, V.Říčný

Department of Radio Electronics, Brno University of Technology

Abstract

This paper deals with shadows detection and removal of its influence in profilometry. The proposed algorithm was developed in MATLAB. Elimination of shadows has a crucial effect to the function of unwrapping phase. Unwrapping of phase (one part of the profilometry procedure) can fail when no shadow detection is used. Among other basic operations, morphological operations are used in this algorithm. Finally, the obtained results are evaluated and discussed. The aim of consequent research is to improve the quality of depth map by using profilometry.

1 Principle of fringe pattern profilometry using phase shifting

In general, under the term profilometry belong all methods dealing with searching profile. We can divide profilometry into contact and non-contact. Currently, non-contact profilometry is mostly used. Fringe pattern profilometry belongs to coherent optical methods. The fundamental idea is projection of a fringe pattern onto the scanned object. Additional information is given by projection. Subsequently, using the obtained images, change of phase is evaluated. Changing the phase provides information about the depth distribution of a scene. A detailed description of this method can be found in many articles and books (e.g. [1], [2], [3]). A schematic plan of the measuring workplace is shown in Fig. 1.

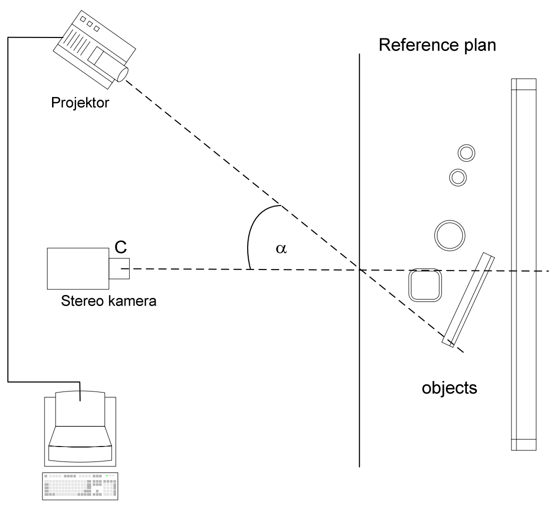


Figure 1: Profilometry: Schematic plan of the workplace for the depth map measuring.

We can obtain information about phase using various approaches (phase-shift, Fourier transform and spatial phase detection). We employ phase shift profilometry in our project. This method works with eight pictures. Four of them are pictures of the object (example in Fig. 2) and other pictures are of the reference plane (example in Fig. 2). During measuring phase of pattern is changed. Flowchart of method phase shifting is given in Fig. 2. Main equation of this approach is given by relation (1) [14] as

$$\phi(x,y)=\phi_m(x,y)-\phi_r(x,y)=\arctan\left(\frac{(I_1-I_3)\cdot(R_2-R_4)-(R_1-R_3)\cdot(I_2-I_4)}{(I_1-I_3)\cdot(R_1-R_3)+(I_2-I_4)\cdot(R_2-R_4)}\right), \tag{1}$$

where I_1, I_2, I_3, I_4 are pictures of the object and R_1, R_2, R_3, R_4 are pictures of the reference plane. This computation is executed in block “Calculation of wrapped phase”. Output from this step is phase in range -π to π, in which wraps occur (rapid phase shifting 2π). Unwrapping is a procedure whose aim is to take away 2π wraps (phase discontinuities) and obtain a continuous phase map. Let's notice that Unwrapping is the most difficult step of the whole method. We adopt the method Unwrapping via Graph Cuts [4]. Unfortunately, the algorithm fails in shadow regions. Whereas that the algorithm has a problem to cope with too frequent false wraps arising in a shadow. Therefore we must detect shadows and eliminate their influence.

2 Shadows detection and elimination

Some specific properties arise from the use of profilometry. As we have more pictures with different content available, we can propose specific algorithms. We consider the original picture of scene (further called *Object*), additionally we have the picture with the projected pattern (further called *Object_pattern*) and picture with pattern projected to background (further called *Pattern*). Another important fact is that we have depth map created by the stereo method (further called *Depth_stereo*). We would like to improve this map by using profilometry. A similar approach was published by Scharstein and Szeliski [5].

Detection of shadow is often solved in video. In this case we have several consecutive pictures. Therefore, the shadow detection methods for video are based on finding differences between consecutive images or comparing an average picture with the actual image. Most methods are based on thresholding techniques. We can find many interesting approaches in literature (e.g. [6], [7], [8], [9], [10], [11], [12] and [13]). We propose two new methods for shadow detection.

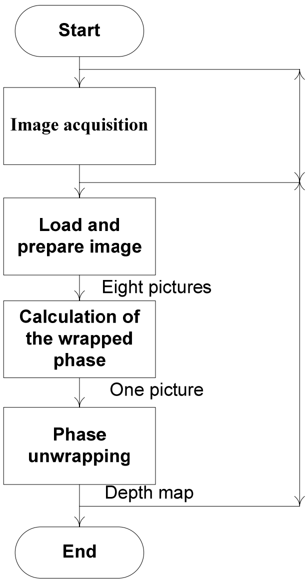


Figure 2: Flowchart of the Fringe pattern profilometry.

Flowchart of the first method is given in Fig. 3. First we calculate the difference between images *Object* and *Object_Pattern*. The idea of this is that in shadows the difference will be minimal and will arise in areas with constant intensity. In rest of the picture a visible fringe pattern remains. The result is shown in Fig.6. Obviously, if we would like to detect shadows we have to do other operations. It is impossible to use a simple threshold at this moment, because there are disturbing artifacts in the image. Artifacts would be evaluated incorrectly as shadow regions. Two different problems arise.

First of them arises in pixels where both pictures (*Object* and *Object_Pattern*) have high brightness. This means that the difference is low as in shadow areas. Therefore, we use the following pseudocode

If (*Pattern* > *Threshold_Projection*)

Shadow = 0;

Else

Shadow = 1;

End

, which says if intensity in *Pattern* image is higher than a given threshold then pixel do not belong to shadow area. The condition agrees with the fact that a shadow area has low brightness.

The second problem arises in areas where objects with dark color appear, which are represented by low brightness in the picture. In our tested picture such object is a brown box. We are going to solve this issue solve using the image *Depth_stereo*. In the depth map, objects have high brightness, because they are located in foreground. Therefore we can use the following pseudocode

If (*Depth_stereo* > *Threshold_Depth*)

Shadow = 0;

Else

Shadow = 1;

End

The result after applying these two conditions is given in Fig. 6 (middle and right). Now we can employ simple thresholding to detect shadows. Eventually in the last step, we can employ some morphological operations to eliminate small artifacts which are mostly no real shadow and improve shapes of correct shadows regions.

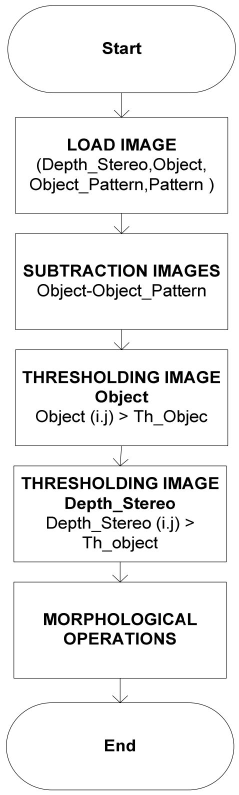


Figure 3: Flowchart of the proposed algorithm for shadows detection based on subtraction of images and tresholding.

The second proposed method for shadow detection is based on converting the image from RGB to L*a*b. This procedure uses depth map obtained by the stereo method as well as the previous. The flowchart is shown in Fig. 4. Compared to the previous method this method employs only two images. First of them is the depth map (further called *Depth_stereo*) and the second one is the original picture of the scene (further called *Object*). At the begging we perform smoothing on *Depth_stereo*. For this purpose, we apply filtration by lowpass filter in spatial domain. Simultaneously, we convert *Object* from RGB to L*a*b. Then we work only with the 'a' component (Fig. 7.), which is suitable for estimating the shadow by tresholding. Consequently, both images are tresholded. All the pixels in image *Object* which exceed the treshold *Th_object* are marked as suspect of belonging to foreground (set equal to 1). All other pixels are set equal to 0. Similarly, all the pixels in the image *Depth_stereo* which fall within a certain range (defined by *Th_min* and *Th_max*) are marked as suspect of belonging to a shadow (set equal to 1) . All other pixels are set equal to 0. Results are shown in Fig. 7. As the next step, information from both images is combined. Basic assumption says that a pixel cannot be included in foreground and shadow simultaneously. We combine this hypothesis with the fact that we have a set of points supposedly belonging to shadows (gain using color space L*a*b). This idea is expressed by the following pseudocode

```
If (S_S = = & S_O ~ = 1)
        Shadow = 1;
Else
        Shadow = 0;
End
```

In the final phase, small disturbing artifacts are removed by morphological operations and the MATLAB function *bwreaopen*.

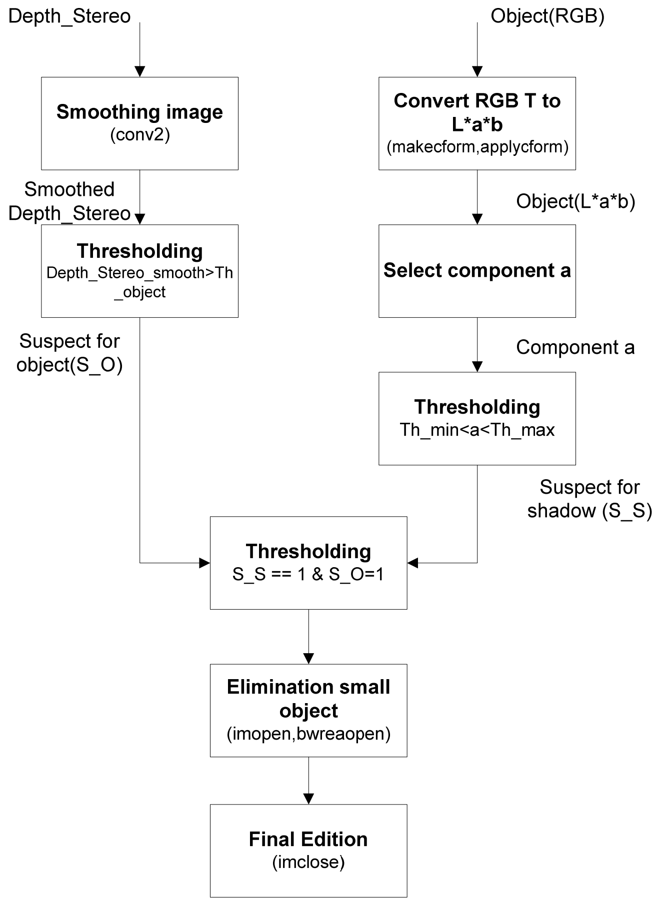


Figure 4: Flowchart of the proposed algorithm for shadow detection based on converting to L*a*b and thresholding.

3 Results and conclusions

The proposed algorithms were implemented in MATLAB, in order to verify their function. We created appropriate functions and a user interface. The GUI performs shadow detection and subsequent creation of depth map using profilometry. Users have the possibility to set up certain properties of morphological operations. The GUI is shown in Fig. 5.

The executed experiment proved usability of both proposed algorithms for shadow detection. The obtained results and intermediate results are shown in Fig. 6-8. Using the proposed procedures, we can detect shadows in images and then eliminate their influence. Consequently, the algorithm for unwrapping phase works well and we gain quality depth maps of objects which should ensure improvement of depth map obtained using stereo algorithm.

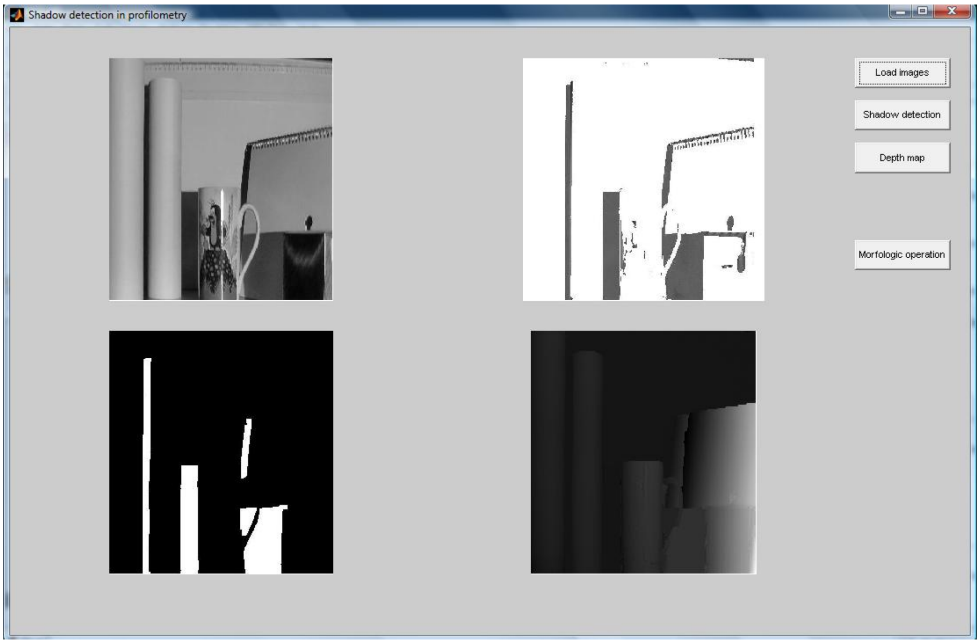
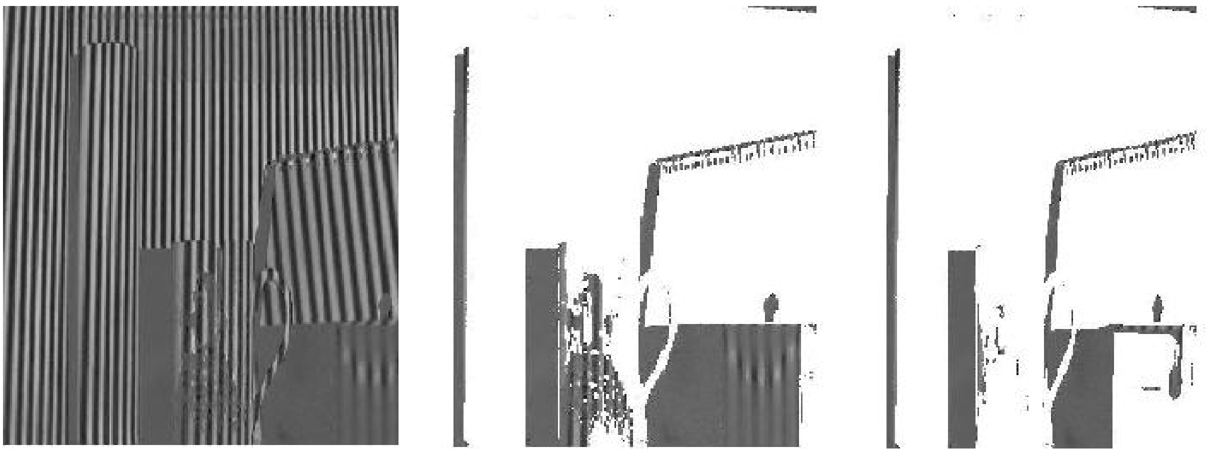


Figure 5: User interface of program for shadow detection: Program allows detect shadow using proposed algorithm and subsequent calculation of depth map.



(a) (b) (c)

Figure 6: Intermediate results obtained from the first proposed method: a) The result of image subtraction. b) The picture shows the effect after eliminating fringe. c) The picture gives the result after elimination of the influence of dark objects.

(a) (b) (c)

Figure 7: Intermediate results gained from second proposed method: a) Component ‘a’ from L*a*b. b) Smoothened depth map (from stereo). c) The set of pixels suspicious for be shadow.

(a) (b) (c) (d)

Figure 8: Results: a) Shadows detected by the first method. b) Depth map gained using the first method. c) Depth map detected by the second method. d) Depth map gained using the second method.

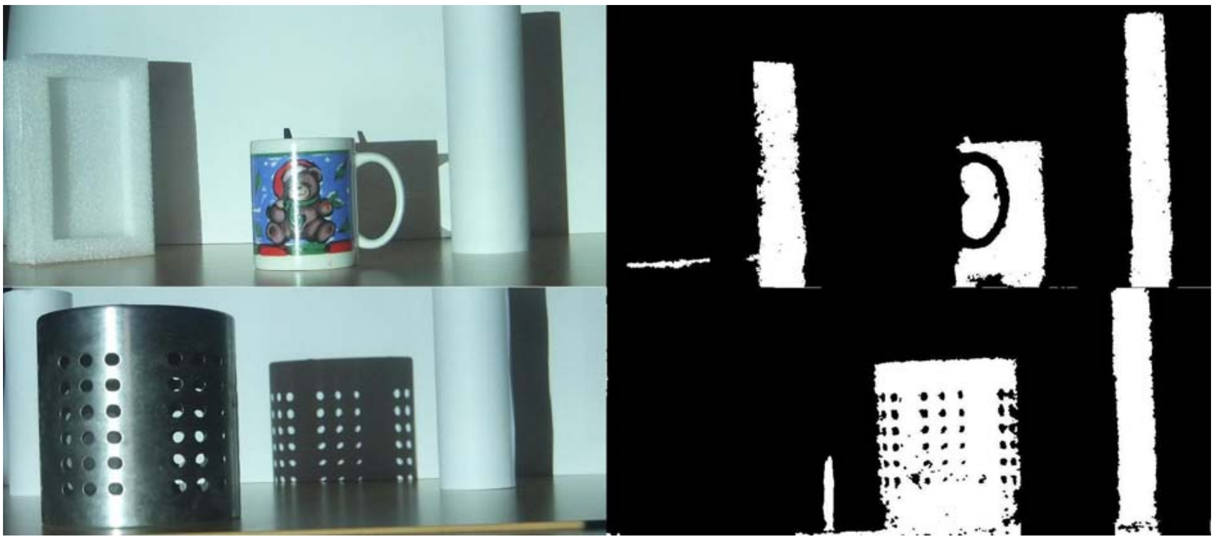


Figure 9:Images and their detected shadows(by second method).

ACKNOWLEDGEMENT

This paper was supported by the grant project of the Czech Science Foundation no. 102/08/H027 - Advanced methods, structures and components of the electronic wireless communication, no. 102/10/1320 - Research and modeling of advanced methods of image quality evaluation(DEIMOS) and by the Research program of Brno University of Technology no. MSM0021630513 - Electronic Communication Systems and New Generation Technology (ELKOM) and the project Signal processing in mobile and wireless communication systems FEKT-S-11-12(MOBYS).

References

[1] HU, Qingying; HARDING, Kevin G. Conversion from phase map to coordinate: Comparison among spatial carrier, Fourier transform, and phase shifting methods map to coordinate : Comparison among spatial carrier, Fourier transform, and phase shifting methods. *Optics and Lasers in Engineering* [online]. 2007, 47, 2, [cit. 2011-10-10]. Available on WWW: <http://www.sciencedirect.com/science/article/pii/S0143816606000480>. ISSN 01438166.

[2] KREIS, Thomas. *Handbook of holographic Interferometry : Optical a digital methods*. Weinheim : WILEY-VCH Verlag GmbH & Co. KGaA, 2005. 535 s. ISBN 3-527-40546-1.

[3] SU, Xianyu; CHEN, Wenjing. Fourier transform profilometry: : a review. *Optics and Lasers in Engineering* [online]. 2001, 35, 5, [cit. 2011-10-10]. Available on WWW: <http://www.sciencedirect.com/science/article/pii/S0143816601000239>. ISSN 01438166.

[4] BIOUCAS-DIAS, J.M; VALADAO, G. Phase Unwrapping via Graph Cuts . IEEE Transactions on Image Processing [online]. 2007, 16, 3, [cit. 2011-9-25]. Available on WWW: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumb er=4099386>. ISSN 1057-7149.

[5] SCHARSTEIN, Daniel; SZELISKI, Richard. High-Accuracy Stereo Maps Using Structured Light. In Computer Vision and Pattern Recognition [online]. [s.l.] : [s.n.], 2003 [cit. 2011-10-10]. Available on WWW: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1211354>. ISBN 0-7695-1900-8 , ISSN 1063-6919.

[6] Li Xu, Feihu Qi, Renjie Jiang, Yunfeng Hao, Guorong Wu,.: “Shadow detection and removal in real images: A survey” Technical report, Shanghai Jiao Tong University, 2006.

[7] HUANG, Chung-Hsien ; WU, Ruei-Cheng . An Online Learning Method for Shadow Detection . In 2010 Fourth Pacific-Rim Symposium on Image and Video Technology [online]. Singapore : Gwangju Institute of Science and Technology, 2010 [cit. 2011-09-25]. Available on WWW: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5673968>. ISBN 978-1-4244-8890-2.

[8] WANG, Yuqi ; TANG, Miao ; ZHU, Guangxi . An Improved Cast Shadow Detection Method with Edge Refinement. In Sixth International Conference on Intelligent Systems Design and Applications [online]. Jinan, Shandong : SHANDONG UNIV, 2006 [cit. 2011-09-25]. Available on WWW: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber= 4021766>. ISBN 0-7695-2528-8.

[9] ZHANG , Liang ; HE, Xiaomei . Fake Shadow Detection Based on SIFT Features Matching. In 2010 WASE International Conference on Information Engineering [online]. Beidaihe, Hebei, China : WASE, Aug. 2010 [cit. 2011-09-25]. Available on WWW: <978-1-4244-7506-3 >. ISBN 978-1-4244-7506-3.

[10] SUN, Bangyu ; LI, Shutao . Moving Cast Shadow Detection of Vehicle Using Combined Color Models. In Pattern Recognition (CCPR), 2010 Chinese Conference on[online]. Chongqing, China: Chongqing University, 2010 [cit. 2011-09-25]. Available on WWW: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber =5659321>. ISBN 978-1-4244-7209-3

[11] GUAN, Ye-Peng . Wavelet multi-scale transform based foreground segmentation and shadow elimination. The Open Signal Processing Journal [online]. 2008, n.1, [cit. 2011-09-25]. Dostupný z WWW: <http://www.benthamscience.com/open/tosigpj/articles/V001/1TOSIGPJ.pdf>. ISSN 1876-8253.

[12] GUO Hai-tao*, Zhang Yan, Lu Jun, Jin Guo-wang Zhengzhou, "Research on the Building Shadow Extraction and Elimination Method" , The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B3b. Beijing 2008

[13] LALONDE, Jean-François ; EFROS, Alexei A. ; NARASIMHAN, Srinivasa G. . Detecting ground shadows in outdoor consumer photographs. In ECCV'10 Proceedings of the 11th European conference on Computer vision [online]. Berlin : Springer-Verlag, 2010 [cit. 2011-09-25]. Available on WWW: <http://www.jflalonde.org/projects/shadows/lalonde_eccv_10.pdf>. ISBN 978-3-642-15551-2.

L.Boleček

Ing. Libor Boleček

Department of Radio Electronics, Brno Univ. of Technology, Purkyňova 118, 612 00 BRNO
E-mail: xbolec01@stud.feec.vutbr.cz