THE DEVELOPMENT OF APPLICATION FOR STRAIN ANALYSIS - THE WAY FROM THE MATLAB SCRIPT TO THE STANDALONE APPLICATION

J. Jahoda[1], J. Valach[2]

A Faculty of Transportation Sciences of CTU Prague

Abstract

This article presents the implementation of non-invasive optical method - Digital Image Correlation. First, is discusses basic principle how the DIC work is covered with a reference to novel improvements like the process of subpixel approximation, global data smoothing and the processing of image sequence. Presented DIC application is then compared to other commercial applications and systems. The application is provided with the GUI, which enable easy to learn and simple usage by trained user. The output of application is the 2D plots of displacement and strain fields. The project have many possibilities for future application and improvement, some of them are mentioned.

1 Motivation

The recent trend in all of domain is algorithmization of a routine work. Ones of this domain is the optical measurement. This way cost of a measurement can be significantly reduced and at the same time its speed and accuracy can be increased. The algorithmization reduce share of human resource and machine systemic reduce variation from a procedure, i.e. assures repeatability of the data processing. One of the advantage optics measurements is that most of them are non-invasive. This means that there is no physical contact between a measurement device and a specimen. This feature reduce cost of set a measurement devices and decrease a measurement error influenced by bond between measurement device and sample.

2 Introduction

Among optical methods for acquisition of full-field values are included methods based on interferometry, where result is a fringe pattern. The requirement for this type of methods is a coherent light source. In order to interpret interferometry measurements, a fringe processing and a phase analysis is necessary. Among the optical methods that are not based on coherent light and interferometry, privileged role play the methods on basic analysis spatial intensity of light as the grid methods which employ the pattern recognition techniques, or the Digital Image Correlation [1].

The Digital Image Correlation is used to find a displacement full-field between two pictures which are showed the same area. The condition for this method is the assumption that a examine sample is a solid object and that all elements (subset) on the surface of sample create unique pattern of reflection light or least in the area of their search. Input to correlation function is matrices of gray-scale intensities of pixels on first and second pictures. The new location of template subset can be found by correlation a template on first picture and a surrounding area on second picture, where a new location is anticipated. The correlation coefficient is one in case the image of subset is identical to template and this place is a new location of subset.

During matching process each subset is searched in the picture of loaded sample. For better performance is often limited area of search only to anticipated surroundings. If the subsets cover the whole surface then constructed full-field displacement field between two pictures can be derived. Based on this principle, the number of subsets corresponds to the number of displacement field vectors.

---

[1] Ing. Jiří Jahoda xjahoda@gmail.com
[2] Ing. Jaroslav Valach, PhD. valach@fd.cvut.cz

The easy applicability and robust performance explain popularity of the method. This statement is proved by many commercial applications like ARAMIS or VIC-3D 2010 [2].
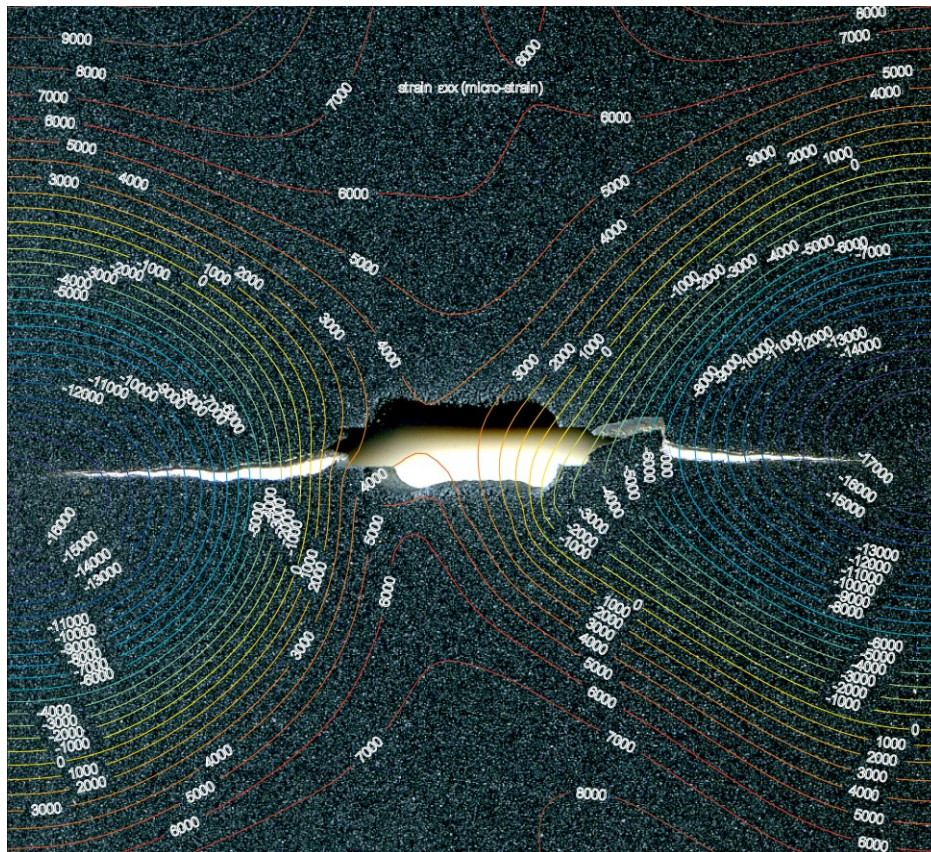

Figure 1: Output from application - Strain exx around opening crack, counter representation

3   Technical improvement

This method looks for the same regions in the image pair. The result of this process is integer representing relative pixel displacement on second picture. For the purpose of finding strain field, which typical values are in order of units percentage displacement, there is needed more accurate result than integer pixels. That's why sub-pixel approximation is used. In this case the approximation is realized by finding the maximum of a parabolic surface representing interpolation of correlation values. On basis of least squares method, the nearest eight values are examined for the maximum. The location where the maximum of parabolic surface is found, the true displacement of subset is assumed; this is usually between pixel values and therefore have non-integral value [3].

The experiments where large deformation between two images occur often fail to find a correct result, because appearance of image subsets on picture loaded sample do not resemble their templates. This happen because deformation is too large therefore their appearance change to unrecognizable. Several techniques exist specialized on reduction of this issue. One of them, which is used this case: Sequential image analysis: the experiment progress isn't recorded only on two pictures - unloaded state and loaded state, but on series of pictures [4,5].

The process of finding new location of subset takes part between adjacent pictures, where deformation is small compare to complete loading process, this step is repeated from first to last pictures, total number of cycles is (n-1). Thanks this technique actual appearance of subset is used for searching and area of search can be reduce because in adjacent pictures have a smaller displacement.

Measurement noise increases with denser field of values. In order to get more reliable values smoothing out values is needed: this removes local maxima or minima where occurrence of error is probable. In this case external Matlab function Gridfit [6] is used. This function not only smooth data, but it interpolates new values in a places where aren't defined if data lie in convex area.
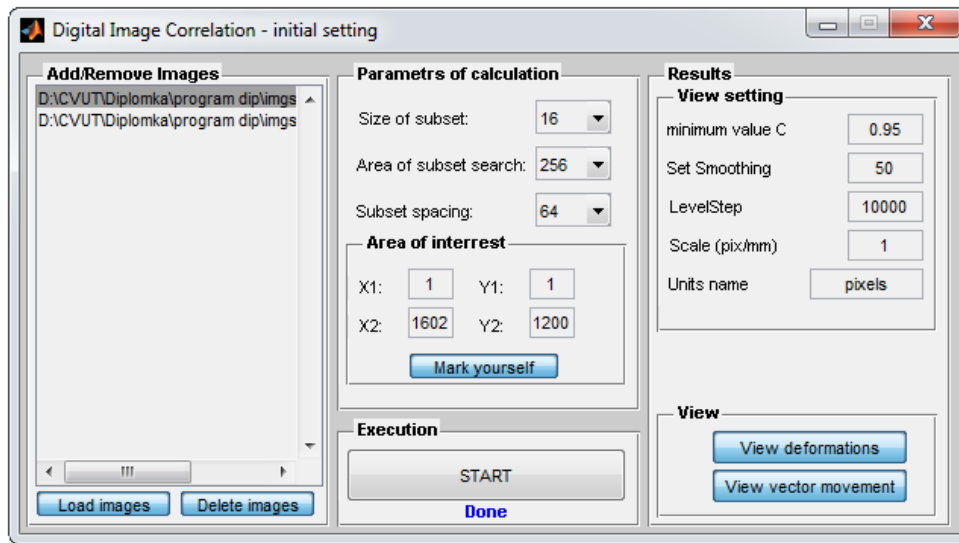
4   Standalone application

Figure 2: GUI of application - all control element are in one window

Collection function connect to one script were run under Matlab environment. The requirement for easy usage by operator and ability work on PC without Matlab lead to change bundle of script to standalone application with graphic interface. The application requires operating system Windows and together with application is needed install Matlab package containing computational engine and basic set of functions. They are necessary for running application. The GUI of application is self intuitive, all control elements are in one window. An operator loads images acquired during experiment to the program. The requirement for images is that they must have same resolution and minimum number of recorded images is two. An operator sets required parameters for calculation as size of subset, area of interest etc. After start, the time of calculation is estimated by program and continuously is updated and displayed to user. The result graph displacement show movement of subsets on background first image, where the rectangles are circumference of subset and the arrow show beginning and end a displacement. The graph of a deformation show the three main components of deformation (exx,eyy,exy) in a contour representation. Some parameters for rendering can be changed as minimal. correlation coefficient, data smoothing, level of detail etc.
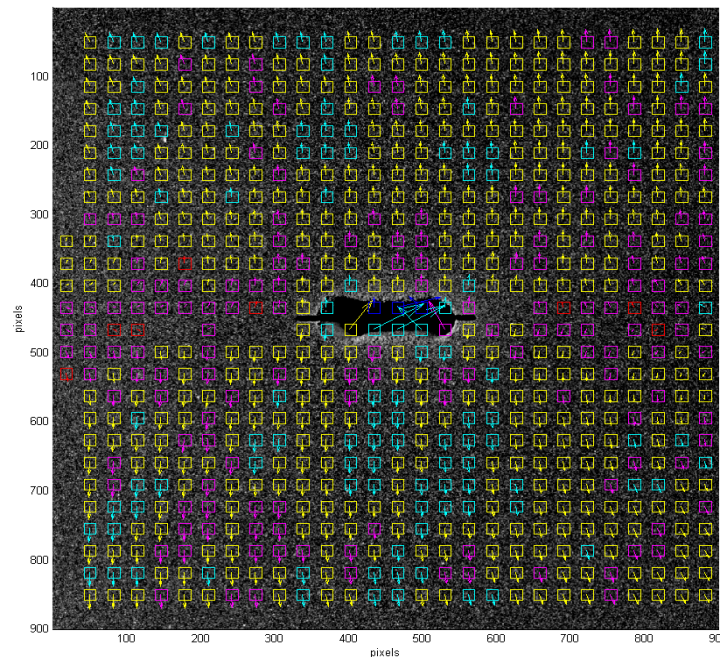

Figure 3: The output from application – The subsets displacement after opening crack, color represent value of correlation coefficient

5   Usage

Reliability of application was provided on experiments: a verification of theoretic distribution of the strain around the opening crack. The determination of the distribution of strain on the iron tape during a pull loading; the verification size and location of the bulge of the beam bridge construction during a vertical loading.

6   Conclusion and Future Work

The next step of the development can be processing data in real-time and display result in augment reality; the extend application to full 3D measurement with a deployment of a second camera.

References

[1] Rastogi, P.K.: (2000) *Introduction. In Trends in Optical Nondestructive Testing and Inspection*, Rastogi PK, Inaudi D (Eds.), Elsevier Science Ltd., UK

[2] Jahoda, J..: *Strain analysis of orthogonal steel bridge element by optical image correlation*, Master thesis 2011. Prague : CTU TS, p. 82 + 1 CDROM

[3] Jahoda, J.; Valach, J.: *Digital image correlation for investigation of the shapes of the steel plate girders´walls in the late stages of fatigue*. In Engineering Mechanics 2009. Praha : ÚTAM, 2009. S. 102-111. ISBN 978-80-86246-35-2.

[4] Jahoda, J.; Valach, J.: *Vliv sekvenciálnosti záznamu na přesnost měření metodou korelace obrazů.* In Technical Computing Prague 2009. Praha : Humusoft, s.r.o, 2009. S. 46-46. ISBN 978-80-7080-733-0.

[5] Jahoda, J. - Valach, J.: *Improvements in processing technique of digital image correlation data for optical measurement of mechanical properties of materials*. In 9th Youth Symposium on Experimental Solid Mechanics [CD-ROM]. Trieste: University Trieste, 2010, p. 158-160. ISBN 978-88-95940-30-4.

[6] D'Errica, *Surface Fitting using gridfit,* http://www.mathworks.com/matlabcentral/fileexchange/8998