УДК 004.93

PYDIC: A FREE AND OPEN SOURCE CODE VERIFICATION FOR STRAIN FIELD MEASUREMENTS

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PYDIC: БЕСПЛАТНЫЙ И ОТКРЫТЫЙ ИСХОДНЫЙ КОД ВЕРИФИКАЦИЯ ДЛЯ ИЗМЕРЕНИЯ ПОЛЯ НАПРЯЖЕНИЙ

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Аннотация. *Современные персональные компьютеры с высокопроизводительными процессорами позволяют применять передовые технологии в области испытаний и инспектирования в гражданском строительстве и машиностроении. Цифровая корреляция изображений (DIC) в настоящее время является одним из наиболее экономичных и удобных в использовании оптических и бесконтактных методов измерения поля напряжении. Pydic - это бесплатный Python-код с открытым исходным кодом для локального 2D DIC, разработанный Дэмиеном АНДРЕ, SPCTS/ENSIL-ENSCI, Лимож, Франция. Pydic основан на OpenCV, это хорошо известная библиотека компьютерного зрения и машинного обучения с открытым исходным кодом. В этой работе код Pydic был проверен для измерений поля напряжении с использованием набора крапчатых изображений, предоставленных SEM DIC вызов. Тот же набор изображений был использован для расчета поля напряжений с помощью программного обеспечения GOM. Оценка точности была произведена путем сравнения результатов кода Pydic и программного обеспечения GOM. Кроме того, при сравнении были приняты во внимание результаты, опубликованные в отчете 'DIC challenge report'. Результаты показывают приемлемое совпадение при визуальном сравнении. Были выделены слабые стороны кода Pydic и обсуждена будущая работа по улучшению кода.*

Introduction. Large structures such as a concrete structure and steel structure are operating under different types of loading. During the operation time of the huge structures under the influence of loads, the structure components are deformed according to the case of loading and some factors related to the structural component itself. Monitoring the deformation of the structural component in different cases of loading is very necessary to predict cracks which needs to apply the required maintenance to this component and to avoid sudden failure of the whole structure. Testing techniques can provide information about the real time strain and deformation of the structural component under the load, however the traditional testing techniques such as extensometer and strain gage are limited. The solution came with the optical inspection techniques such as digital image correlation (DIC). Digital Image Correlation (DIC) is a non-interferometry technique and it is also called the white light speckle technique [1]. Digital Image Correlation is based on comparison between two images for the tested specimen surface before and after deformation. DIC is a non-contact method and this makes it a sufficient testing method to overcome the limitation of the traditional technique. DIC technology can provide a real time displacement field and strain field measurements for the region of interest ROI.

Digital image correlation method mainly consists of the following two parts: obtaining the speckled images of the tested surface before and after the deformation and the image processing using software codes. The image processing using codes is the main topic of this article. Codes for commercial purposes are validated during many experiments, while the open source codes are also usable for a specific task but need to be validated for other tasks. An open source code Pydic was validated comparing to other commercial code GOM correlate.

Pydic code is an open source code written in the Python language. Pydic based on some Python packages such as Numpy, Scipy, Matplotlib, and OpenCV. Pydic could be used to correlate a set of images to obtain the displacement field and strain field using local digital image correlation. Pydic can visualize the strain field results due to Matplotlib package. Pydic is stored in gitlab (https://gitlab.com/damien.andre/pydic/). This work is considered as only a trail to focus on some weaknesses in the open source codes such as Pydic and is aimed to improve this code in the future work.

Methodology. The validation of Pydic code (open source code) was done by comparing the strain field results obtained by Pydic with GOM correlate (commercial code) results. The set of images for the tensile test was obtained from the DIC challenge board. The DIC challenge was created and developed by the society of experimental mechanics (SEM) through cooperation with the international DIC society (iDICs) [2]. Moreover, the DIC challenge has published a result using different code (2D-DIC challenge- MATLAB analysis code). This result is also considered in the validation of Pydic code alongside with the results obtained from the GOM correlate code. The methodology describes image processing stage using the two codes and adjusting the user defined variables such as the subset size (window size), step size, strain type and interpolation type. No calibration was made for the reference image since it was not necessary for 2D-DIC. The strain calculation method was the subset shape function which means that the virtual strain gauge size is equal to the chosen subset size in each case. The user-defined parameters such as subset size, step size and the strain type were chosen according to the recommendations of the practice guide of Digital Image Correlation [3].

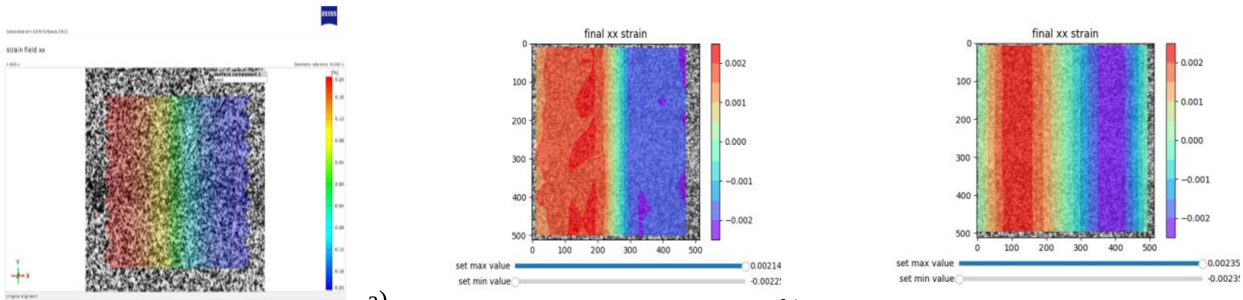
For Pydic code the subset size was set at 70*70 pixels for the interpolation cubic type and the step size 35*35 pixels. The correlation by Pydic code was repeated using subset size 70*70 pixels and the step size 35*35 with the interpolation of spline type. By running the Pydic code, the correlation algorithm follows the movement of each subset in the image series. The displacement field results in x direction were saved automatically to the image folder. The strain field was calculated due to Numpy package also the strain field E_{xx} was visualized and saved from Matplotlib interface.

The GOM Correlate software 2022 was used to compute the strain field results using the same user defined parameters as Pydic code

Results. The strain fields E_{xx} were computed using both the Pydic open source code and the GOM correlate software with nearly the same user-defined parameters except the used interpolation type. The results of the both codes show a good agreement by the visual comparison. Also the results of the strain field E_{xx} published on the DIC challenge report [2] show a good agreement with the results computed by the both codes.

The computed strain field E_{xx} by GOM software shows the most accurate and reliable results due to the advanced interpolation Bi-cubic. While increasing, the subset size results in the so-called edges problem.

The interpolation of cubic type is available with Pydic code, which gives the best refinement for the results after deformation and distortion happened to the image pixels. Some areas with dark purple on the right side of the image and dark red on the left side show the difference between the Pydic code results and GOM software results.



a) b) c)

Fig. 1. The strain field E_{xx} results computed for sample 11b from SEM DIC challenge obtained from the DIC technique [2]. *(a) GOM software results using Bi-cubic interpolation (b) Pydic code results using Cubic interpolation (c) Pydic code results using Spline interpolation*

Conclusion. It could be explained that the dark purple and the dark red areas are the missing values in correlation and the difference between interpolation methods resulting into different values. The Cubic interpolation finds the missing values depending on the neighboring values from one direction while the Bi-cubic interpolation finds the missing values depending on the neighboring values in both directions which means more smoothing for the results.

The last results computed with Pydic code using spline interpolation show the deviation between the Pydic code and the other commercial codes. The deviation results from the nature of Spline interpolation which is not the best choice for this kind of task. This example proves the significant effect of the interpolation on the DIC results.

Future work. The open source code (Pydic) shows acceptable results for this task. However, some improvements are required to be made, which is considered as a future work. Integration of more advanced and optimized interpolation will help to improve the results for similar tasks. Automatic calculation for the optimum subset size and step size depending on the DIC pattern size and density is also a target for the future work.

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