The influence of pre-segmentation on the efficiency of multi-temporal image registration

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Alexander Tashlinskii, Radik Magdeev*, Galina Safina

*radiktkd2@yandex.ru

Introduction

Bridges, crossings, overpasses are of great strategic and economic importance. At the same time, one of the important problems currently facing the organizations maintaining such structures is monitoring the state of integrity of their main elements. To solve this problem, the most promising solution is to use the systems with non-invasive monitoring based on digital image processing. One of the directions to improve the quality of monitoring of steel and reinforced concrete structures in the sense of increasing the probability of detecting various kinds of defects can be the comparison of images of the same section obtained at different times.

Methodology and content of the study

The process of registration of multitemporal images (Photo1 and Photo2) from points (x_1, y_1) and (x_2, y_2) can be explained by the scheme in Fig. 1. If we know the coordinates of the beginning and the end of the studied structure, it is possible to project the multi-temporal images onto the plane corresponding to the observed conditional surface of the bridge, using relatively simple geometric transformations. As a result, the images obtained at different times and from different coordinates can be superimposed one on the other.

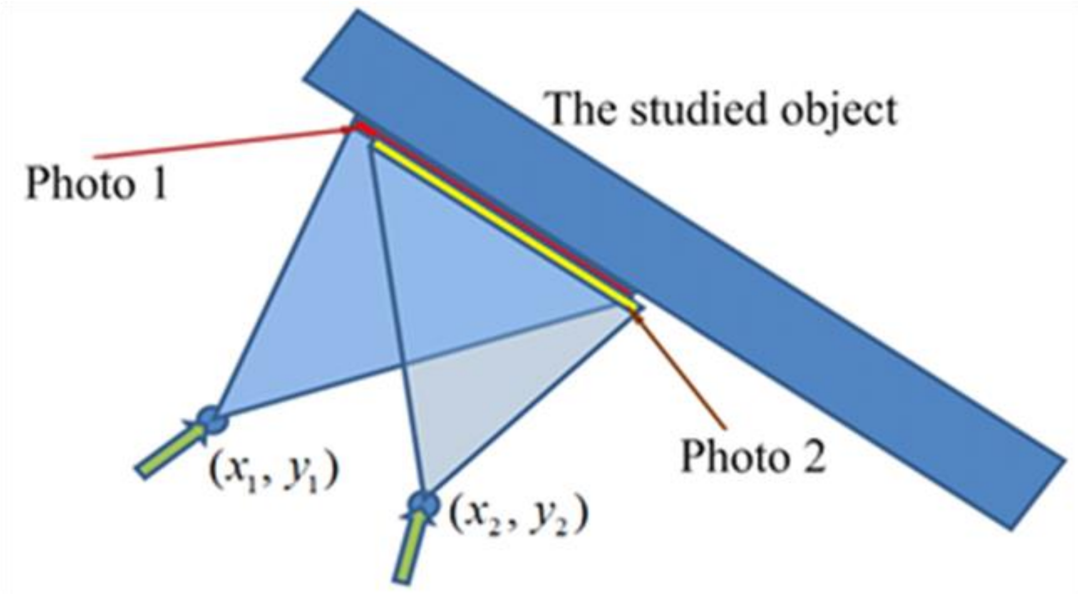

Fig.1. The scheme of preliminary overlay of multi-temporal photos

The georeferenced images of bridge structures, obtained by FRPC OJSC «RPA «Mars» in the course of research work are used (Fig. 2). Visible differences between the images of structural elements are due to the different distances from the conditional plane of the studied object.

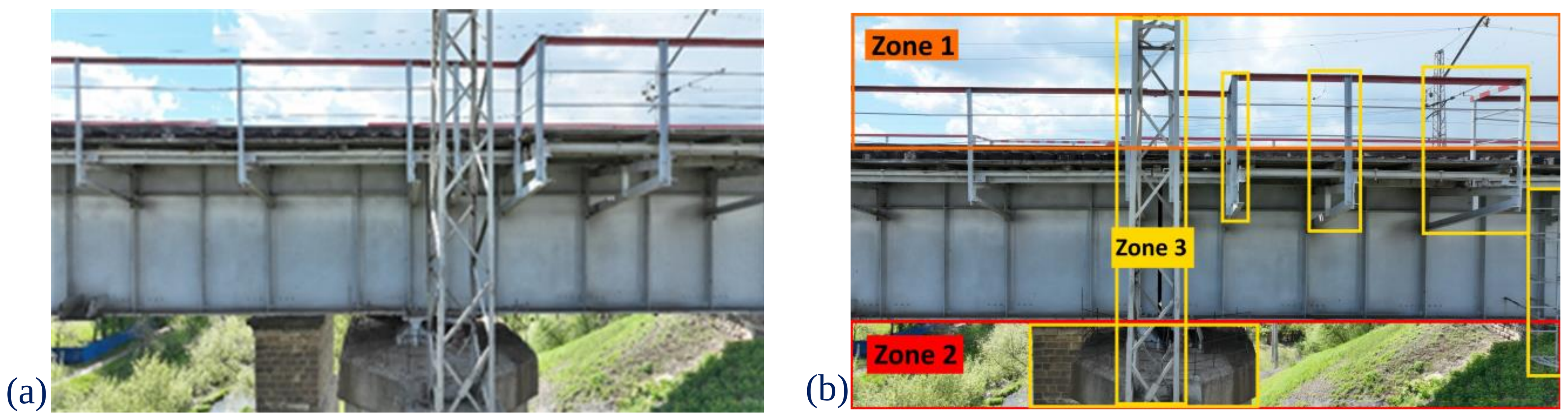

Fig.2. Example of multi-temporal images of the same structure

The next step to combine the images is to select the area of interest, in our case the elements of the bridge structure.

The process of image registration was performed using stochastic gradient procedures (SGP), which ensure subpixel accuracy of registration in complex changing conditions at acceptable computational costs. The advantages of SGP include the absence of the need for preliminary parameter estimation of the studied images and the stability of the generated estimations to impulse interference.

At that, the different models of geometric transformations, including the most general ones, for example, the projective ones, can be used in the SGP procedures. For each specific situation, the choice of similarity measure of images used as a target function of registration quality depends on the class of images, nature of deformations, requirements and conditions of the problem being solved. For the considered problem, due to the high processing speed requirement, the inter-frame correlation is an effective measure, and a similarity model is chosen as a model of spatial deformations, assuming that the influence of projective geometric distortions on images is relatively small.

An important factor for the SGP application for image registration of the object of interest is the preliminary segmentation of the studied object to exclude the influence of the background on which the object is observed. In this paper, the influence of various background components of the image that interfere with the registration of bridge structure images is investigated.

Conducting the research

As part of this study, three «interfering» zones are identified, which reduce the efficiency of combining multi-temporal images using the SGP: the zone № 1 is the sky area (above the bridge structure), the zone № 2 is the ground area (below the bridge structure) and the zone № 3 is the area of structural elements whose depth differs significantly from the conventional plane of the bridge structure (Fig. 2b).

The comparative analysis of registration parameters using multi-temporal images of the same object under different conditions of pre-segmentation is performed. During the study, the main attention is paid to the effective parameter operating range of the parallel shift, because it is the most essential for the multitemporal images. The other parameters change to an insignificant extent, so within the framework of the present study are not taken into account.

For a situation without preliminary segmentation due to a large number of interfering factors, such as changes in clouds and the influence of different distances of the ground cover and structural elements, the operating range of SGA shift estimates is quite limited and is no more than 8 pixels.

For the second case (excluding only the cloudy region), the effective operating range in terms of shift is no more than 22 pixels. The greatest influence is introduced by the factor of different distances of the ground cover elements.

For the third case (exclusion of two interfering zones - cloud cover and ground cover) the effective operating range by the shift parameter is not more than 60 pixels. Segmentation of this type is already sufficient to match the majority of multi-temporal pairs of images of bridge structure, except for such images, where the influence of differently spaced elements of the structure is strong (Fig.2). Studies are conducted on 120 pairs of real multi-temporal images. To increase the volume of experimental base of research, one of the pair images was additionally varied by shift and rotation parameters, due to which the total sample volume was more than 1200 pairs of images.

For the fourth case (exclusion of all interfering zones) the operating range by shift is about 80 pixels. This type of segmentation makes it possible to significantly (up to 10 times) increase the effective operating range of SGP for the problem of bridge structure image registration.

Conclusion

The analysis showed that segmentation of the area of interest is an effective method of increasing the operating range and the quality of alignment when using SGA for registration of multi-temporal images of bridge structures. At the same time, the greatest distortions in parameter estimates and, accordingly, in decreasing their operating range, are introduced by the sky region as the most variable one. It is worth noting that the exclusion of these areas is necessary to obtain correct values of the geometric deformations parameters, and the transformations according to the obtained parameters can also be performed for the original images.

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Ulyanovsk State Technical University, 432027, Severnii Venetz, 32, Ulyanovsk Russia, www.ulstu.ru

Moscow State University of Civil Engineering, 129337, Yaroslavskoye Shosse, 26, Moscow, Russia, www.mgsu.ru