ISPRS. REPORT OF THE SCIENTIFIC INITIATIVE

DEVELOPMENT OF AN OPEN SOURCE MULTIVIEW AND MULTIMODAL FEATURE MATCHING TOOL FOR PHOTOGRAMMETRIC APPLICATIONS

PhotoMatch

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REPORT OF THE SCIENTIFIC INITIATIVE

1. INTRODUCTION AND PARTNERSHIPS

The photogrammetric problem of 3D reconstruction from multiple images has received a lot of attention in the last decade, especially focused on its two main pillars: (i) image orientation and self-calibration and (ii) dense matching reconstruction. However, the overall performance of both steps strongly depends on the quality of the initial feature (keypoints) extraction and matching stage. Therefore, determining which feature detectors and descriptors offer the most discriminative power and the best matching performance is of significant interest to a large part of the photogrammetry and computer vision communities. Methods for performing these tasks are usually based on representing an image using some global or local image properties and comparing them using a similarity measure or some machine/deep learning approaches. Nevertheless, most of the existing methods are designed for matching images within the same modality and under similar geometric conditions.
With the aim of providing a contribution in this context, an open source feature extraction and matching platform, called PhotoMatch has been developed. PhotoMatch encloses and combines different state-of-the-art detectors and descriptors, together with different matching strategies. PhotoMatch allows to solve feature extraction and matching step with the following aims: (i) provide a tool that guarantees the best combination of the triplet: detector/descriptor/matcher, in order to maximize precision and reliability; (ii) increase flexibility (working with datasets that combine multiview and multimodal images with important geometric and radiometric variations); (iii) offer an educational tool that allows the user to test and combine different detectors and descriptors, as well as to assess the precision and reliability of the results obtained.
The project has been led and managed by USAL in collaboration with UCLM, UNILEON, FBK, TWENTE and UDINE Universities who supported the image pre-processing, feature extraction and matching, dataset creation and system evaluation. The secret of success has been to find a multidisciplinary and international team with experience in image analysis, photogrammetry and computer vision in order to design and develop this feature matching tool.

2. OBJECTIVES

The **main goal** of the project was to advance with the **development of an open-source feature extraction and matching platform**. The project aims to bring photogrammetry and computer vision even more closer providing an open tool which integrates different feature extraction and matching algorithms for improving the image orientation, self-calibration and dense reconstruction processes. The outcomes will allow non-expert users to have access to a transferable, reliable, functional and practical photogrammetric tool.

Therefore, the contribution of this scientific initiative will consider the following **specific goals**:

- Use oblique, terrestrial and drone imagery datasets for evaluating different feature extraction and matching strategies.
- Develop an open source tool that encloses different state-of-the-art algorithms for tie point extraction, including different detectors and descriptors as well as matching strategies.

- Improve the computational cost exploiting GPU and parallel computing, including CUDA programming capabilities.
- Asses the results from a quantitative point of view using some statistical and robust parameters.
- Release the tool under GitHub in C++ and QT languages so other people have the possibility to upload their own algorithm. Publish the scientific results in a conference and journal paper.

The initiative will provide an open source photogrammetric tool and will enhance the value of ISPRS in the sister scientific communities, widening its visibility and promoting the overall progress of photogrammetric methods.

3. DATASETS

This SI was tested on various datasets (Figures 1, 2, 3), including in-house set of images as well as the ISPRS/EuroSDR's Scientific Initiative "*Benchmark on High Density Image Matching for DSM Computation*".

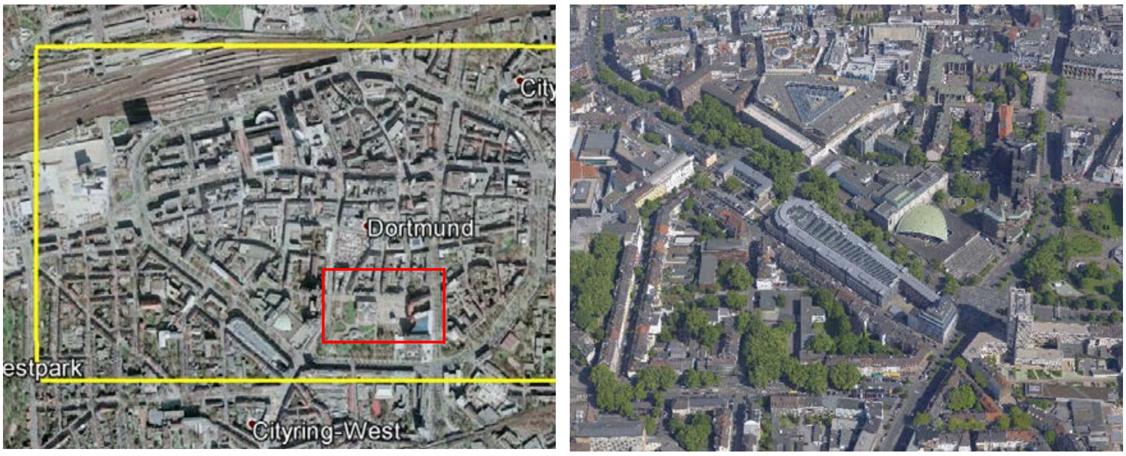

Figure 1: The Dortmund benchmark used for the evaluation of PhotoMatch. The entire area (left) and an oblique image used for testing the tool (right).


Figure 2: The terrestrial image dataset of the Nettuno Temple (Paestum, Italy) used for the evaluation of PhotoMatch. The entire monument (left) and some terrestrial images used for testing the tool (right).

Figure 3: The UAV-based dataset of the WWI Larino Fort (Lardaro, Italy) used for the evaluation of PhotoMatch. The entire area (left) and an oblique UAV image used for testing the tool (right).

4. WORKFLOW FOR DATA PROCESSING

PhotoMatch encloses a photogrammetric pipeline divided in 5 main steps applied sequentially (Figure 4):

1) project/session definition,
2) pre-processing,
3) feature extraction,
4) feature matching and
5) Quality control.

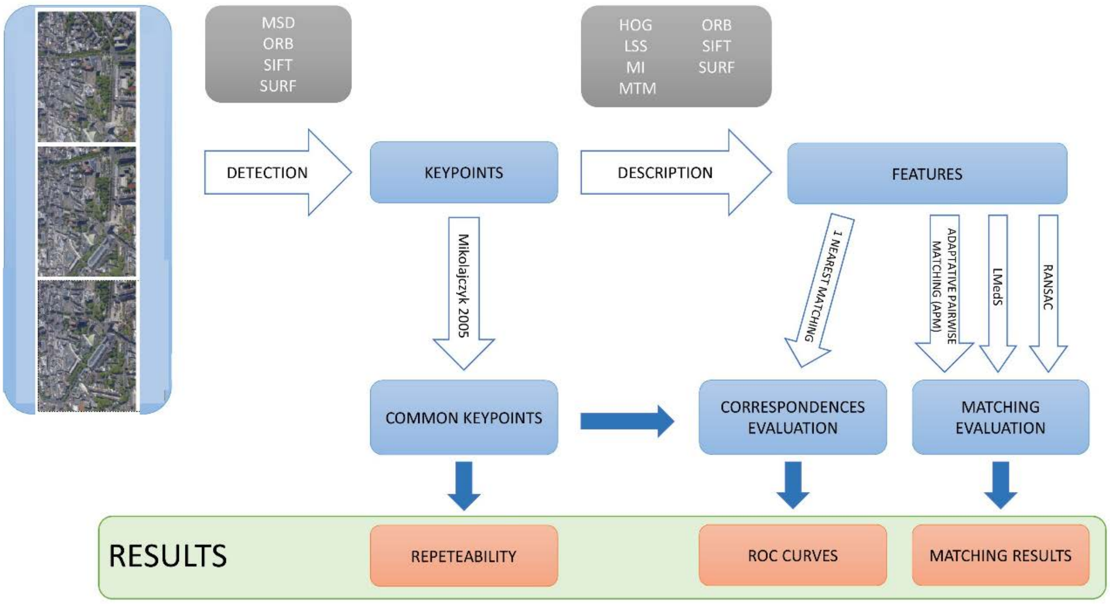

Figure 4. Workflow of the proposed feature extraction and matching methodology.

In the following, the project steps are described in detail. The result of each step will affect the quality of the next one, so achieve good results in each step will be crucial in order to get a good feature matching. Although PhotoMatch requires that the user interacts in each step modifying input parameters, the software offers the possibility to use parameters by default in an automatic way, allowing to perform the whole pipeline in an easy-to-use way, especially for non-expert users.

1. **Project and Session definition**. The user defines a project's name and description. Next, the images of the project are selected and can be examined. PhotoMatch allows to create different sessions per projects, so the different combinations of the triplets detector/descriptor/matcher can be compared and analysed (Figure 5).

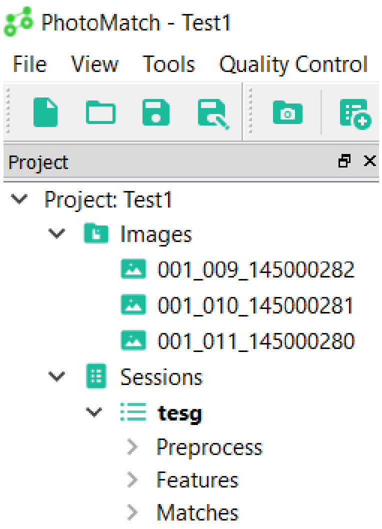

Figure 5. Project and session in PhotoMatch.

2. **Pre-processing**. The image pre-processing is an important step since it can provide a better feature extraction and matching, in particular in those cases where the texture quality is unfavourable. Different pre-processing functions are available in PhotoMatch. Anyway, the user can decide about the pre-processing or not the images (Figure 6).

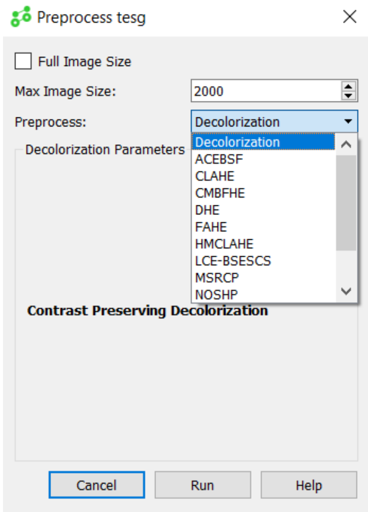

Figure 6. Pre-processing options in PhotoMatch.

3. **Feature extraction**. A keypoint is a point of interest. It defines what is important and distinctive in an image (corners, edges, etc.). Each keypoint is represented by a descriptor: a feature vector containing the essential characteristics of the keypoint. A descriptor should be robust against geometric and radiometric image transformations, although this is not easy to achieve sometimes (e.g. multiview and multimodal dataset). Many algorithms have been developed to cope with these milestones both in the detection and description steps (e.g. SIFT, SURFT, ORB, AKAZE, among others). PhotoMatch includes three algorithms coming from the computer vision community which can be combined and used with different advanced parameters (Figure 7).

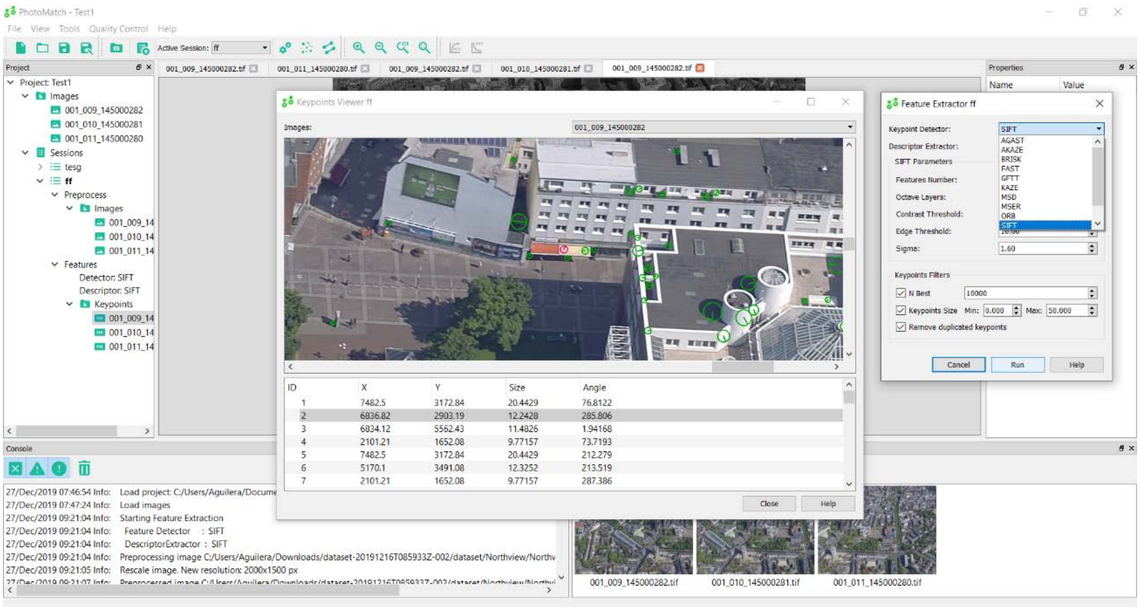

Figure 7. Feature extraction results and the different keypoint detector and descriptors available in PhotoMatch.

4. **Feature matching.** Once keypoints are identified in two or more images, we need to associate or match keypoints among images, so the same keypoint can be found in the other images guarantying accuracy and reliability. PhotoMatch contains different matching strategies (e.g. from brute force, FLANN, robust matched, among others) (Figures 8, 9, 10).

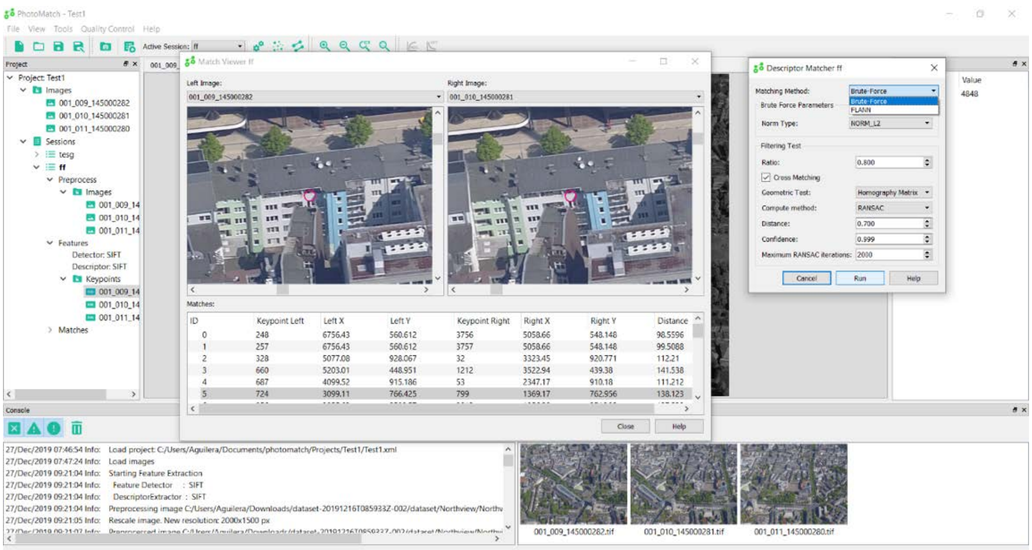

Figure 8. Feature matching results for the oblique aerial dataset of Dortmund.

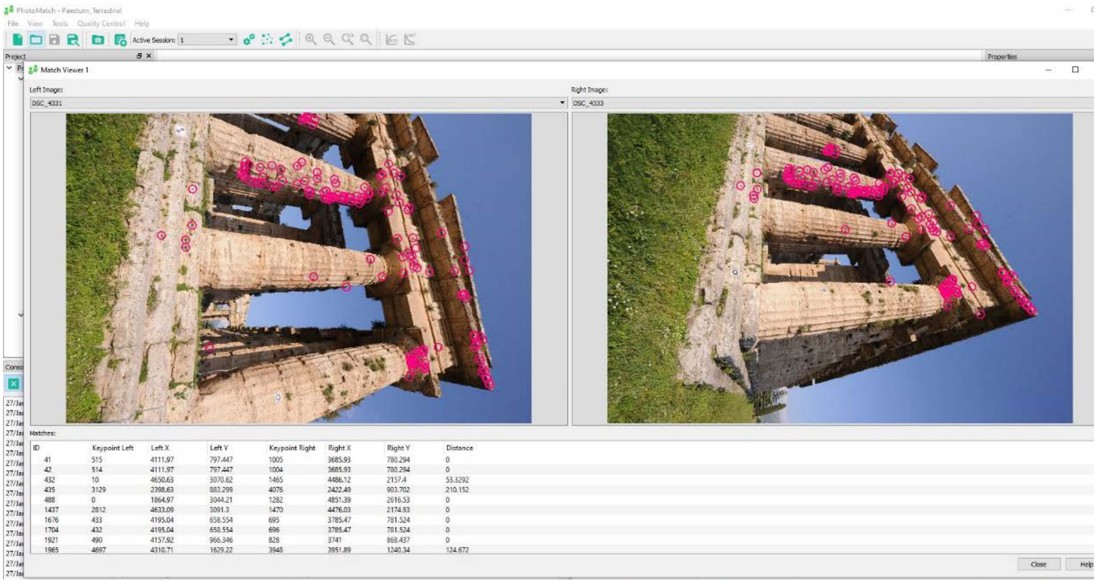

Figure 9. Feature matching results for terrestrial dataset of the Nettuno Temple.

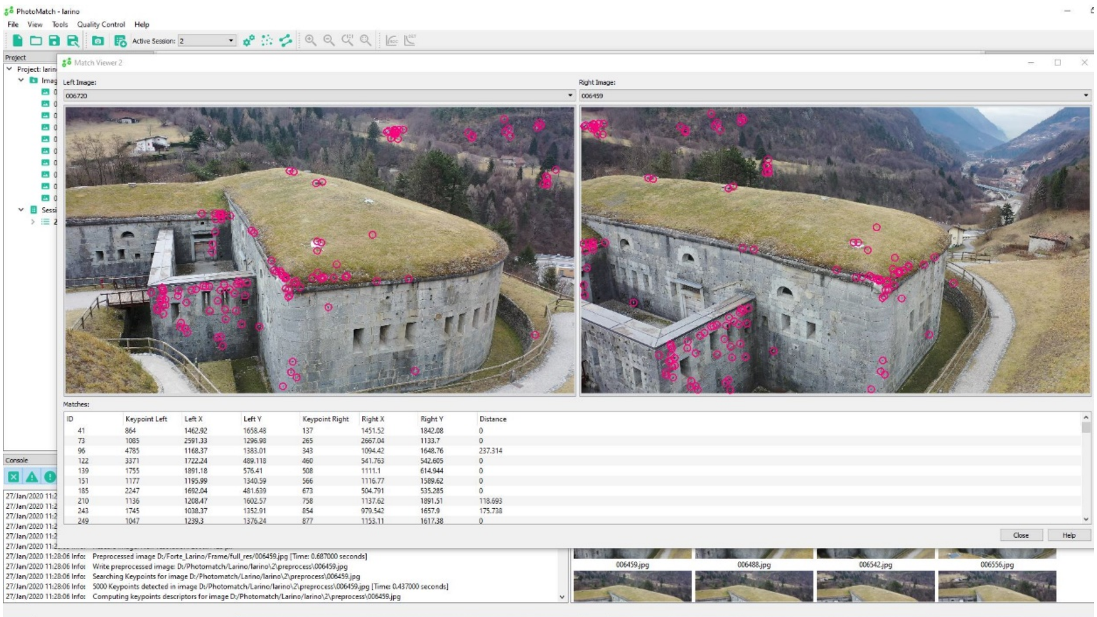

Figure 10. Feature matching results for UAV-based dataset of the Larino Fort.

5. **Quality control.** PhotoMatch includes several options for validating and analysing the matching results. Quality assessment can be checked based on different approaches: (i) defining a ground truth manually or coming from an input file; (ii) through the resulting homography; (iii) analysing different quality control parameters such as repeatability, ROC/DET curves (Receiver Operating Characteristic/Detection Error Tradeoff), which measure the precision and recall of the retrieved correspondences. Last but not least, PhotoMatch allows to deliver the tie points and matchings results in format compatible with most common photogrammetric and SfM software, so the final user can validate the orientation step (Figure 11).

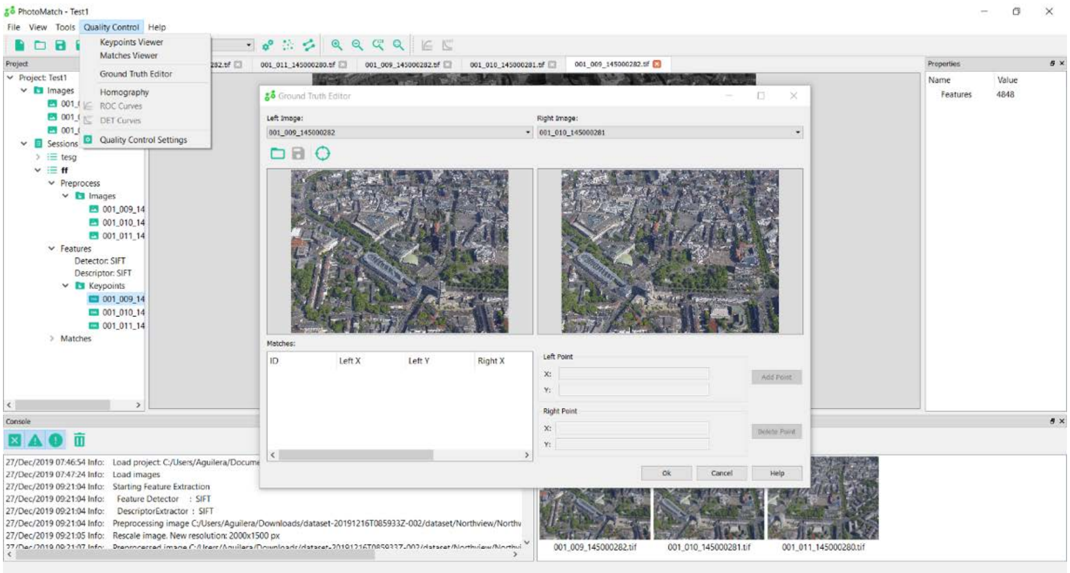

Figure 11. Quality control: different options offered by PhotoMatch.

5. TUTORIAL AND MANUAL

PhotoMatch includes an abstract description of the implemented algorithms on every step, i.e. pre-processing, feature extraction, feature matching and quality control. The tutorial has dual purpose:

- to give the user the necessary information of the functionality of the algorithms and facilitate thus the optimal combination decision based on each project's needs;
- to serve as an educational tool for the non-expert users on the contrary of other black-box solutions.

The help menu follows the format of Read-The-Docs, a technical documentation commonly used for documenting software (Figure 12).

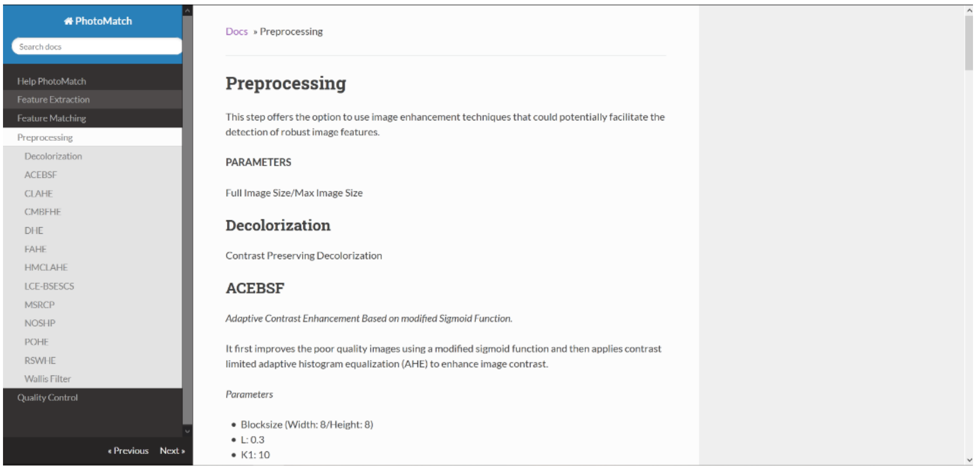

Figure 12. A screenshot of the PhotoMatch tutorial.

6. DISSEMINATION

The Scientific Initiative will be advertised during the different ISPRS/CIPA/EuroSDR events that will take part during 2020. In these events, the involved researchers will get the opportunity to show the project aims through a flyer or showing tool capabilities during technical or demo sessions.

Last but not least, PhotoMatch will be presented at CATCON contest in the 2020 ISPRS International Congress in Nice. In addition, some of the case studies tested with PhotoMatch will be presented as a full paper submitted to an indexed journal.

7. SCIENTIFIC INITIATIVE BUDGET

Grant provided by ISPRS: 10000 CHF (9176 EUR)
Total grant: **9176 EUR**
Expenses - incl. 21% VAT:

- Staff costs - implementation and validation: 15000.00 €
- ISPRS Congress Registration: 440.00 €

Total expenses: **15440.00 EUR**
USAL - as PI and manager of the SI funds – has co-financed the missing funds.

References

Apollonio, F., Ballabeni, A., Gaiani, M., Remondino, F., 2014. Evaluation of feature-based methods for automated network orientation. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 40(5), pp. 47-54.

Balntas, V., E. Riba, D. Ponsa, and K. Mikolajczyk. Learning local feature descriptors with triplets and shallow convolutional neural networks. In BMVC, 2016.

Bay, H., T. Tuytelaars, and L. V. Gool. SURF: Speeded-Up Robust Features. In ECCV, 2006.

Brown, M, G. Hua, and S. Winder. Discriminative Learning of Local Image Descriptors. PAMI, 2011.

Bursuc, A. G. Tolias, and H. J´egou. Kernel local descriptors with implicit rotation matching. In ACM Multimedia, 2015.

Fischler, M.A., Bolles, R.C. Random sample consensus: A paradigm for model fitting with applications to image analysis and automated cartography. Commun. ACM 1981, 24, 381–395

Förstner, W. and Gülch, E., 1987: A fast operator for detection and precise location of distinct points, corners and circular features, Proc. Intercommission Conf. on Fast Processing of Photogrammetric Data, pp. 281-305.

Gruen, A. Adaptive least squares correlation: A powerful image matching technique. S. Afr. J. Photogramm. Remote Sens. Cartogr. 1985, 14, 175–187.

Han, X., T. Leung, Y. Jia, R. Sukthankar, and A. C. Berg. MatchNet: Unifying feature and metric learning for patchbased matching. CVPR, 2015.

Hartmann, W., Havlena, M., Schindler, K., 2015. Recent developments in large-scale tie-point matching. ISPRS Journal of Photogrammetry and Remote Sensing, in press.

Hartley, R.; Zisserman, A. Multiple View Geometry in Computer Vision; Cambridge University Press: New York, NY, USA, 2003.

Heinly, J., E. Dunn, and J.-M. Frahm. Comparative Evaluation of Binary Features. In ECCV, 2012.

Ke, Y., and R. Sukthankar. PCA-SIFT: A More Distinctive Representation for Local Image Descriptors. CVPR, 2004.

Kwang, M., E. Trulls, V. Lepetit, and P. Fua. LIFT: Learned Invariant Feature Transform. ECCV, 2016.

Maini, R., Aggarwal, H., 2010. A comprehensive review of image enhancement techniques. Journal of Computing, Vol. 2(3).

Mikolajczyk, K., and C. Schmid. A performance evaluation of local descriptors. PAMI, 2005.

Mikolajczyk, K., T. Tuytelaars, C. Schmid, A. Zisserman, J. Matas, F. Schaffalitzky, T. Kadir, and L. Van Gool. A comparison of affine region detectors. IJCV, 2005.

Moisan, L., Stival, B. A probabilistic criterion to detect rigid point matches between two images and estimate the fundamental matrix. Int. J. Comput. Vis. 2004, 57, 201–218.

Morel, J.-M., Yu, G., 2009. ASIFT: A new framework for fully affine invariant image comparison. SIAM Journal on Imaging Sciences, Vol. 2, 438-469.

Muja, M., Lowe, D.G., 2009. Fast Approximate Nearest Neighbors with automatic algorithm configuration. VISAPP (1) 2, 331-340.

Remondino, F., Spera, M.G., Nocerino, E., Menna, F., Nex, F., 2014. State of the art in high density image matching. The Photogrammetric Record, Vol. 29, pp. 144-166.

Simonyan, K., A. Vedaldi, and A. Zisserman. Learning local feature descriptors using convex optimisation. PAMI, 2014.

Strecha, C., A. Bronstein, M. Bronstein, and P. Fua. LDAHash: Improved Matching with Smaller Descriptors. PAMI, 2012.

Tombari, F., Di Stefano, L., 2014. Interest Points via Maximal Self-Dissimilarities. Proc. ACCV, pp. 586-600.

Tola, E., V. Lepetit, and P. Fua. Daisy: An efficient dense descriptor applied to wide-baseline stereo. PAMI, 2010.

Tolias, G., Y. Avrithis, and H. J´egou. Image search with selective match kernels: aggregation across single and multiple images. IJCV, 2016.

Trzcinski, T. M. Christoudias, and V. Lepetit. Learning Image Descriptors with Boosting. PAMI, 2015.

Vedaldi A., and B. Fulkerson. VLFeat: An open and portable library of computer vision algorithms. http://www.vlfeat.org/, 2008.

Verhoeven, G., Karel, W., Stuhec, S., Doneus, M., Trinks, I., Pfeifer, N., 2015. Mind your grey tones - examining the influence of decolourization methods on interest point extraction and matching for architectural image-based modelling. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 40(5/W4), pp. 307-314.

Wallis, K.F., 1974. Seasonal adjustment and relations between variables. Journal of the American Statistical Association, Vol. 69, pp. 18-31.

Zhang, Z., Deriche, R., Faugeras, O., Luong, Q.-T., 1995. A robust technique for matching two uncalibrated images through the recovery of the unknown epipolar geometry. Artificial intelligence 78 (1), 87–119.