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PROCEEDINGS

STRATEGIC ISSUES

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THE DAFNE PROJECT: HUMAN AND MACHINE INVOLVEMENT

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Abstract – The DAFNE challenge originated with the aim of involving autistic subjects in the post-seismic re-composition of destroyed frescoes, trying to develop their social involvement while favoring their inclusion in productive activities, enhancing their peculiarities and abilities, and promoting their potential. Our goal became to produce also a software tool that applies the most advanced computer techniques, such as Machine Learning and Deep Learning. As different tracks are proposed, this initiative can bring to different applications. It widened then in a research of up-to-date artificial intelligence solutions suitable to the restoration of collapsed buildings, promoting their re-use, enhancing cultural heritage conservation.

INTRODUCTION

We focus on the digital anastylosis of frescoes. The reconstruction of an artwork destroyed by natural events, such as earthquakes, or wars, is a very complex task. Several attempts to restore collected fragments, based on traditional methods, have been done in the last 60 years, but without great success. Since 1998 [1] many efforts have been devoted to the restoration of the inestimable frescoes by Andrea Mantegna – located in the Ovetari Chapel of the Eremitani Church, in Padua (Italy), and destroyed in a bombing during the Second World War – by using mathematical methods and computer techniques based on comparison with an old gray level image of the fresco prior to the damage. Unfortunately, with this technique only a partial reconstruction of the fresco was possible: from the 78.561 pieces, mostly with an area of 5-6 cm^2, less than 8% of the artwork was covered.

A variety of different approaches have been proposed in the last decade. A first broad taxonomy of these techniques [2] is based on the main matching factors: color information [3], geometric outline characteristics [4] or both together (shape as well as sample colors along the border of the pieces) [5, 6, 7].

A number of proposed methods has been explicitly based on the optimization of specific remapping problems. An important one has been defined ‘colorization’; as an example, in the quoted case of the Ovetari Chapel, the simple 8% of coverage of the frescoes was certainly instrumental to a high fidelity to the fresco re-colorization, which is a crucial issue in art restoration [8, 9]. A second example refers to image ‘completion’, focusing on the cases of occlusion areas that produce regions to be completed [10, 11]. A peculiar case is the one of non overlapping images, in which images are extrapolated to cover the gap between them through alignment and inpainting [12]. A related problem is image ‘melting’, in cases of transition regions in which chromatic and structural properties change gradually so that a patch transform allow the implementation of image interpolation and morphing by combining inconsistent images [13, 14].

It is worth to mention another approach, based on the analysis of fracture patterns in order to model the cracking process so that it will be possible to predict the patterns and help future computer assisted anastylosis [15].

In the very last years, two very promising innovative solutions have been proposed, both computation intensive, but now supported by the high performances of the new technology. The first one exploiting a genetic algorithm approach [16] and a second one, becoming more and more popular, exploiting machine learning and deep learning [17]. In this connection, we are proposing this challenge and we foreseen too far, may mature in the next couple of years, a 'blind' anastylosis in which no data on frescoes content and semantics are known [18]!

THE DIGITAL ANASTYLOSIS OF FRESCOES CHALLENGE (DAFNE)

The challenge's goal is to collect the best solutions to virtually recomposing destroyed frescoes, starting from the digitalization of their broken collected elements. This is not meant to replace the restorer's or archaeologist's skills and knowledge, but to be an additional tool in the restoration task. In this context, it can be interpreted as a very challenging 'puzzle' and finding the global position and rotation for each piece, so that all fragments jointly reconstruct the original surface, is the final objective. Critical issues are due to: i) the number of randomly mixed fragments is usually huge; ii) fragments are mostly corrupted, and with general irregular shapes; iii) mismatch of the boundaries of the collected eroded pieces; iv) some pieces have gone irretrievably lost; v) due to extreme fragmentation, presence of spurious/distractors elements, as pieces from different frescoes could be involved in the building collapse.

The challenge entitles participants to use, at their discretion, a number of different cases of destroyed well-known frescoes that have been simulated in order to populate a dataset containing fragmented pieces, useful for the development and testing phases of the challenge. Five different parameters have been used for the generation of elements, in order to respond to the critical issues previously listed: A, the number of fragments; B, the type of random distribution; C, the percentage of missing parts; D, the percentage of spurious fragments; and E, the ratio between the fragment area after the erosion and the original area in the fresco plane tessellation.

Participants are invited to develop solutions that re-assemble a given set of pieces, discarding spurious ones, and are required to submit the reconstructed image generated by their application − showing the fragments properly placed − which will be evaluated in accordance with quality requirements and metrics.

Methods developed for DAFNE can be tested on cases for which ground truth fragments alignments are available for verification. ANASTYLOSIS DB1 collects for each fresco image more sets of digital fragments, mixed with spurious elements (distractors), that participants have to re-assemble. Two phases will be considered: 1) a development phase, during which registered participants will be provided access to DB1, with fragments and solution (an image file with each fragment provided in the right position and a corresponding table with location and rotation for each fragment); 2) a successive testing phase, during which registered participants will be provided with a dataset DB2 of fragments from the image of five frescoes – with distractors from other frescoes – and the original image of the corresponding fresco, but no ground truth solution will be provided.

FRAGMENT GENERATION: THE CRACKING PROCESS

Studies have been done on the topic of "natural" fragmentation, to model a method for generating surface crack patterns, and different solutions have been proposed. For example, the Berkeley Surface Cracking Toolkit [19] model a hierarchical fracture process that appears in materials such as mud, ceramic glaze, and glass, that the user can control using a set of simple parameters for the characteristics and appearance of the cracks; others [16] run their experiments with data from Princeton Synthetic Fresco, a plaster wall painting created and fractured by Greek archaeologists for the purpose of testing reconstruction algorithms. Some authors [2] used data from artifact/fresco broken based on a fragmentation of dry mud; other [20] evaluated their approach using scanned frescoes from archaeological excavations (but with a dataset limited to 1200 fragments), as well as a modern-day "synthetic" fresco data set, created and then broken into pieces to have fragments similar to the ones found at archaeological sites. In addition, other authors [20] present a system for acquiring images, geometry, normals, and associated metadata, for small objects such as fragments of wall paintings.

Starting from examples of real fragments of destroyed frescoes we based our simulated fragments generation on some generic considerations: the fragments must be in different sizes, they do not have sharp edges, they may be convex or concave, we have to discard the too small fragments (so a threshold has to be fixed in order to eliminate the fragments that result too small after the fragmentation), size and shape of the fragments have not to be dependent from their position inside the image.

An application tool has been developed to generate some examples of plausible fragmentation, to populate the challenge dataset. Figure 1 shows the fragmentation obtained with two different types of distribution: concentrated and uniform. Figure 2 and Figure 3 show two examples of plane tessellations and corresponding ground truth cases.

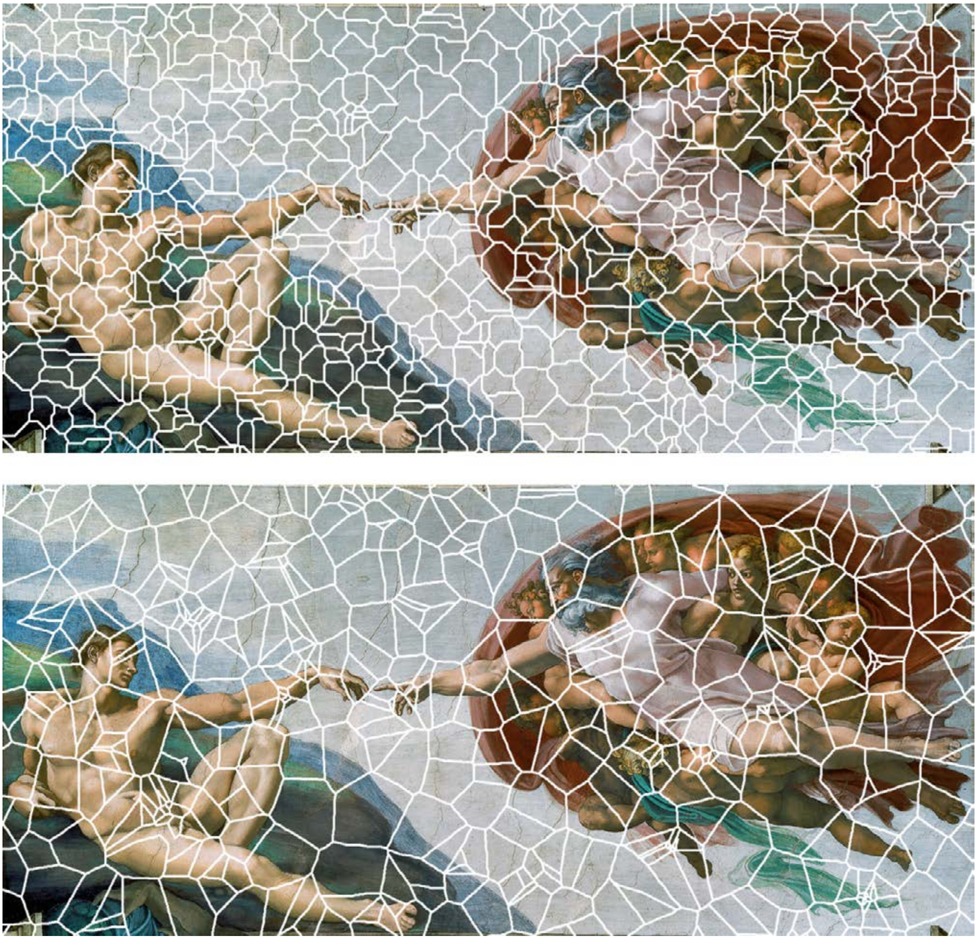

Figure 1. Above: Plane tessellation with a uniform distribution adopting the Manhattan distance (detail of the fresco "The Last Judgment" by Michelangelo Buonarroti, Sistine Chapel, Vatican City, 1536–1541). Below: Plane tessellation with a concentrated distribution adopting the Euclidean distance.

Figure 2. Above: Plane tessellation with parameters: A=750; B=random distribution generated adopting the Manhattan distance; C=7.5%; D=7.5%; E=0.10. Below: Ground Truth, with original image in background and overlapping fragments (image of the fresco “The Plague of Milan” by Cesare Nebbia, Collegio Borromeo, Pavia – 1604).

Figure 3. Above: Above: Plane tessellation with parameters: A=253; B=random distribution concentrated distribution adopting the Euclidean distance (annular measures ρ_1=3px, ρ_2=10px, τ=0.5); C=7.5%; D=7.5%; E=0.10. Below: Ground Truth, with original gray image in background and overlapping color fragments (detail of the fresco "The Last Judgment" by Michelangelo Buonarroti, Sistine Chapel, Vatican City,1536–1541).

A graphical interface (Fig. 4) has been designed for handling the fragments to be reassembled. This has been studied and will soon be tested by people belonging to the autism spectrum. This tool allows them to move and rotate each single piece in the position that they suppose it is right. Automatically a table identifying each moved fragment with its final location and rotation will be listed for restorers' usage during the physical phase of artwork reassembling.

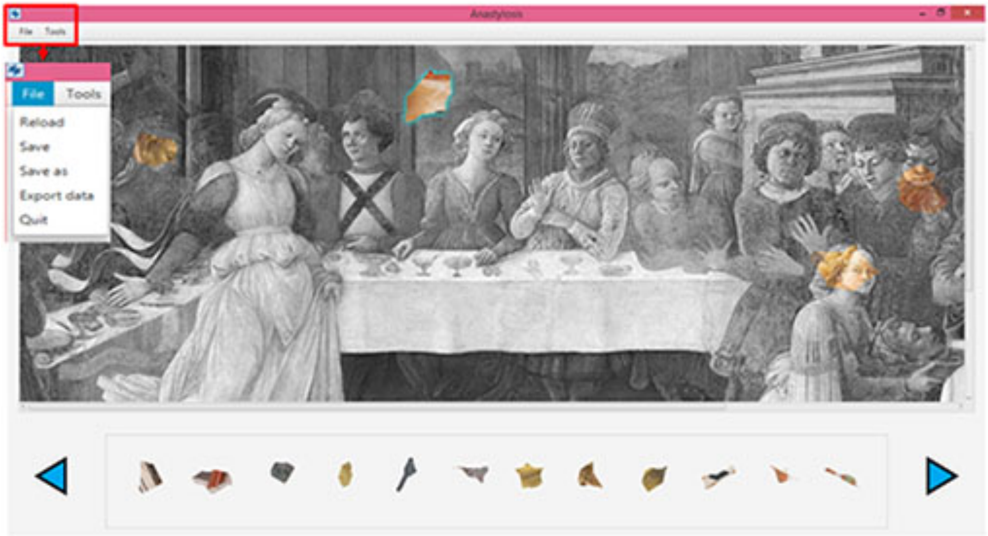

Figure 4. The multi-platform application which provides a set of tools to reconstruct images from pieces, like a puzzle. The interface has been designed to let the user move and rotate the fragments, store them on the provided panel and save the progress, in order to retrieve their position for further usage. The lower part of the screen shows a list of fragments to be reassembled, while the majority of the display is occupied by the image that has to be reconstructed (in figure, a detail of the fresco "Herod's Banquet" by Fra Filippo Lippi, located in Prato Cathedral, Italy). Both mouse and keyboard bindings are provided in order to assure a comfortable usage and allow fast and accurate operations. The fragment with blue borders is the active one.

CONCLUSIONS

This initiative can foster different strategies. The topic is of interest for the Pattern Recognition community and advanced computer techniques such as Machine Learning and Deep Learning can be applied to improve methods and applications.

Restoration of damaged frescoes is a crucial task in cultural heritage preservation and these kind of solutions can result in a precious additional tool for restorers. Furthermore, the involvement of autistic subjects in the post-seismic recomposition of destroyed frescoes, can be both an inclusion opportunity as well as an enhancement of their peculiarities and abilities.

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References

[1] M. Fornasier, D. Toniolo, “Fast, robust and efficient 2D pattern recognition for re-assembling fragmented images”, *Pattern Recognition*, 38, pp. 2074-2087, Elsevier, 2005.

[2] N. Derech, A. Tal, I. Shimshoni, “Solving Archaeological Puzzles”, arXiv:1812.10553v1 [cs.CV] 26 Dec 2018.

[3] E. Tsamoura, I. Pitas, “Automatic color based reassembly of fragmented images and paintings”, *IEEE Trans Image Process*, 19 (3), pp. 680-690, 2010.

[4] W. Kong, B. Kimia, “On Solving 2D and 3D Puzzles Using Curve Matching”, *Proceedings of Computer Vision and Pattern Recognition*, 2, pp. 583–590, 2001.

[5] W. Youguang, X. Li, M. Li, “Color and Contour Based Reconstruction of Fragmented Image”, *8th International Conference on Computer Science & Educatio*n (ICCSE 2013), IEEE Conferences, pp. 999-1003, 2013, ISBN 978-1-4673-4463-0/13, 2013.

[6] S. Mahajan, S. Lonare, K. Bhnandarkar, P. Marathe, S.N. Bhadane, “Reconstruction of Fragmented Images Using Color and Contour”, *International Research Journal of Engineering and Technology (IRJET)*, Vol. 3, Issue 3, pp. 1394-1396, 2016.

[7] K. Zhang, X. Li, “A graph-based optimization algorithm for fragmented image reassembly”, *Graphical Models*, 76, pp. 484-495, 2014.

[8] M. Fornasier, “Faithful Recovery of Vector Valued Functions from Incomplete Data. Recolorization and Art Restoration”, F. Sgallari, A. Murli, N. Paragios (Eds.), *SSVM 2007*, LNCS 4485, Springer-Verlag Berlin Heidelberg, pp. 116-127, 2007.

[9] M. Fornasier, “Nonlinear Projection Recovery in Digital Inpainting for Color Image Restoration”, *J. Math Imaging Vis.*, 24, Springer, pp. 359-373, 2006.

[10] S. Iizuka, E. Simo-Serra, H. Ishikawa, “Globally and Locally Consistent Image Completion”, *ACM Transactions on Graphics*, Vol. 36, No. 4, Article 107, pp. 107:1-107:14, 2017.

[11] J-J. Huang, P.L. Dragotti, “Photo Realistic Image Completion via Dense Correspondence”, *IEEE Transactions on Image Processing*, Vol. 27, No. 11, pp. 5234-5247, 2018.

[12] Y. Poleg, S. Peleg, “Alignment and Mosaicing of Non-Overlapping Images”, ICCP 2012, Seattle, USA, *IEEE Int. Conf. on Computational Photography*, pp. 1-8, 2012.

[13] S. Darabi, E. Shechtman, C. Barnes, D.B. Goldman, P. Sen, “Image Melding: Combining Inconsistent Image using Patch-based Synthesis”, Proceedings of SIGGRAPH 2012, *ACM Transactions on Graphics (TOG)*, Vol. 31, No. 4, Art. 82:1-82:10, July 2012.

[14] T.S. Cho, S. Avidan, and W.T. Freeman, “The patch transform”, *IEEE Pattern Analysis and Machine Intelligence*, 32 (8), pp. 1489-1501, 2010.

[15] H. Shin, C. Doumas, T. Funkhouser, S. Rusinkiewicz, K. Steiglitz, A. Vlachopoulos, T. Weyrich, “Analyzing and Simulating Fracture Patterns of Theran Wall Paintings”, *ACM Journal on Computing and Cultural Heritage*, Vol. 5, No. 3, Article 10: 1-14, October 2012.

[16] E. Sizikova and T. Funkhouser, “Wall Painting Reconstruction Using a Genetic Algorithm”, *Journal on Computing and Cultural Heritage*, 11(1):1-17, December 2017.

[17] C. Le, X. Li, “JigsawNet: Shredded Image Reassembly using Convolutional Neural Network and Loop-based Composition”, arXiv:1809.04137v1 [cs.CV], 11 Sep 2018.

[18] B. Taskesen, A.G. Constantinides, “Interactive Image Reconstruction from its Incomplete, Irregular and Imprecise Fragments”, Vito Cappellini (ed.), *Electronic Imaging & the Visual Arts*, Proceedings of EVA 2018 Florence, Firenze University Press, pp. 26-33, May 2018.

[19] H.N. Iben, J.F. O’Brien, “Generating surface crack patterns”, *Graphical Models*, 71, 6, pp. 198-206, 2009.

[20] B.J. Brown., C. Toler-Franklin, D. Nehab, M. Burns, D. Dobkin, A. Vlachopoulos, C. Doumas, S. Rusinkiewicz, and T. Weyrich,. “A System for High-Volume Acquisition and Matching of Fresco Fragments: Reassembling Theran Wall Paintings”, *ACM Transactions on Graphics (Proc. SIGGRAPH)*, Vol. 27, No. 3 August 2008.

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