Guest Editorial: Image and Video Inpainting and Denoising

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Guest Editorial: Image and Video Inpainting and Denoising

Sergio Escalera, Hugo Jair Escalante, Xavier Baró, Isabelle Guyon, Meysam Madadi, Jun Wan, *Senior Member, IEEE*, Stephane Ayache, Yağmur Güçlütürk, and Umut Güçlü

1 Introduction

Dealing with missing and incomplete information is a very relevant problem common for several tasks and scenarios in computer vision and pattern recognition. Together with related tasks like denoising, deblurring, super-resolution, enhancement, etc. inpainting aims at *generating* visual information with models that usually exploit the context of a corrupted visual input. This is a very complex task, because the goal is to produce visual content that is satisfactory and attractive to the human visual system. With the rapid progress of deep learning, impressive solutions for all of these tasks have been developed recently (see e.g., [1]). In order to keep track of all of this progress we edited this special issue focusing on Image and Video Inpainting and Denoising and related tasks.

The scope of the issue comprised all aspects of computer vision and pattern recognition devoted to image and video inpainting, including related tasks like denoising, deblurring, sampling, super-resolutkon enhancement, restoration, hallucination, etc. The special issue was associated to the 2018 Chalearn Looking at People Satellite ECCV Workshop[1] and the 2018 ChaLearn Challenges on Image and Video Inpainting.[2] However, the call for papers was open to the public. A dozen of submissions were received, and every paper was subject to the standard TPAMI review process.

1. http://chalearnlap.cvc.uab.es/workshop/29/description/
2. http://chalearnlap.cvc.uab.es/challenge/26/description/

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In the remainder of this note we briefly summarize the contributions of the articles included in the issue and identify trends and research opportunities on the topic.

2 The Image and Video Inpainting and Denoising Special Issue

This special issue is formed by 3 articles of outstanding quality that together comprise a snapshot of cutting edge techniques on inpainting and denoising of visual information. Table 1 summarizes the main characteristics of the accepted papers.

The contributions focused on different but very related tasks, and the three papers proposed end to end deep learning models with outstanding methodological contributions. On the one hand, He *et al.* dealt with the multimodal face completion problem: synthesizing an RGB image depicting a face from an NIR input [2]. They introduced a cross-spectral model formed by a NIR-RGB GAN synthesizer followed by a pose correction module. Throughout an extensive experimental evaluation they showed their model is robust against pose variations and achieved state of the art performance on face recognition.

The remaining papers that form the special issue dealt with video-related tasks. Kim *et al.* describe two models for addressing the video de-captioning and object removal from videos tasks [6]. An encoder-decoder model taking as input consecutive frames that are aggregated and decoded is proposed. The model is enhanced with recurrent feedback to enforce temporal consistency. With a variant of this model, the authors obtained the best results in the track 2 of the 2018 ChaLearn Challenge on Image and Video Inpainting [7]. Additionally, they show the generality of the proposed model by reporting experiments on generic object removal from videos, where another variant of the model showed outstanding performance.

Szeto *et al.* also worked with video, however, they approached a very novel inpainting task: video frame inpainting, that is, the problem of inferring missing frames in a video [10]. A two stage deep learning model is proposed. First, a bidirectional convolutional LSTM model conditioned on the preceding and following frames makes two intermediate frame predictions. Then an interpolation model aims at blending both predictions by taking into account temporal and hidden activations information to generate a single predicted

TABLE 1
Overview of Articles in the Special Issue on Imagen and Video Inpainting and Denosing

Ref.	Task / Model	Model	Dataset
[2]	NIR-Visible Face Completion, Face Recognition	End-to-end deep neural network combining a texture inpainting model (NIR → Visible) and a pose correction model	CASIA NIR-VIS 2.0 [3], BUAA-VisNir face database [4], Oulu-CASIA NIR-VIS database [5]
[6]	Video inpainting, de-captioning, object removal from video	Recurrent temporal model for frame aggregation based on a encoder-decoder architecture	ChaLearn video De-Captioning [7]. Youtube-VOS [8], DAVIS [9]
[10]	Video frame inpainting	Bidirectional (convolutional LSTM-based encoder-decoder) prediction model and a temporally aware frame interpolation model	KTH Actions [11], UCF-101 [12], HMDB-51 [13]

frame. Impressive results are obtained in human action data sets commonly used for frame prediction and related tasks.

3 Discussion

The special issue is a compilation of cutting-edge research on inpainting and denoising of visual information. Although the topic is very popular among the computer vision and pattern recognition communities, we received a dozen of high quality submissions and after a compelling reviewing procedure three papers were accepted. The three manuscripts deal with very novel tasks, from cross-spectral image synthesis, to video de-captioning and to frame inpainting in videos. Novel deep learning architectures were proposed and every component of the architecture was evaluated, state of the art performance is reported in each of these publications.

Based on the accepted papers and on the received submissions we can outline the following conclusions:

- Visual inpainting and denosing are two very fast moving research fields, with new models and impressive results being reported regularly. This fact makes researchers to focus on fast publication forums.
- Inpainting is a broad reaching methodology having impact into a number of tasks and applications. Three novel tasks were approached in the accepted papers, they surely will motivate further research in the forthcoming years.
- Deep learning with GAN-based learning is a consolidated methodology within inpaiting of visual information. The deep learning architectures that were proposed were sound and designated to solve very specific problems found in the approached tasks. It is difficult to think that automatic solutions (e.g., AutoML [14]) may work reasonably well for this domain.
- As deep learning solutions dominate the field, the creation of large scale and well curated resources will be critical for the next few years in this line of research.

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References

[1] S. Escalera, S. Ayache, J. Wan, M. Madadi, U. Güçlü, and X. Baró, *Inpainting and Denoising Challenges*. Berlin, Germany: Springer, 2019.
[2] R. He, J. Cao, L. Song, Z. Sun, and T. Tan, "Adversarial cross-spectral face completion for NIR-VIS face recognition," *IEEE Trans. Pattern Anal. Mach. Intell.*, to be published, doi: 10.1109/TPAMI.2019.2961900.
[3] S. Z. Li, D. Yi, Z. Lei, and S. Liao, "The CASIA NIR-VIS 2.0 face database," in *Proc. IEEE Conf. Comput. Vis. Pattern Recognit.*, 2013, pp. 348–353. [Online]. Available: https://doi.org/10.1109/CVPRW.2013.59
[4] D. Huang, J. Sun, and Y. Wang, "The BUAA-VisNir face database instructions," Beihang Univ., Beijing, China, Tech. Rep. IRIP- TR-12-FR-001, 2012.
[5] J. Chen, D. Yi, J. Yang, G. Zhao, S. Z. Li, and M. Pietikäinen, "Learning mappings for face synthesis from near infrared to visual light images," in *Proc. IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit.*, 2009, pp. 156–163.
[6] D. Kim, S. Woo, J.-Y. Lee, and I. S. Kweon, "Recurrent temporal aggregation framework for deep video inpainting," *IEEE Trans. Pattern Anal. Mach. Intell.*, to be published, doi: 10.1109/TPAMI.2019.2958083.
[7] S. Escalera *et al.*, "ChaLearn looking at people: Inpainting and denoising challenges," in *Proc. Inpainting Denoising Challenges*, 2019, pp. 23–44.
[8] N. Xu *et al.*, "YouTube-VOS: Sequence-to-sequence video object segmentation," in *Proc. 15th Eur. Conf. Comput. Vis.*, 2018, pp. 603–619. [Online]. Available: https://doi.org/10.1007/978-3-030-01228-1_36
[9] F. Perazzi, J. Pont-Tuset, B. McWilliams, L. V. Gool, M. H. Gross, and A. Sorkine-Hornung, "A benchmark dataset and evaluation methodology for video object segmentation," in *Proc. IEEE Conf. Comput. Vis. Pattern Recognit.*, 2016, pp. 724–732.
[10] R. Szeto, X. Sun, K. Lu, and J. Corso, "A temporally-aware interpolation network for video frame inpainting," *IEEE Trans. Pattern Anal. Mach. Intell.*, to be published, doi: 10.1109/TPAMI.2019.2951667.
[11] C. Schüldt, I. Laptev, and B. Caputo, "Recognizing human actions: A local SVM approach," in *Proc. 17th Int. Conf. Pattern Recognit.*, 2004, pp. 32–36. [Online]. Available: https://doi.org/10.1109/ICPR.2004.1334462
[12] K. Soomro, A. R. Zamir, and M. Shah, "UCF101: A dataset of 101 human actions classes from videos in the wild," *CoRR*, 2012. [Online]. Available: http://arxiv.org/abs/1212.0402
[13] H. Kuehne, H. Jhuang, E. Garrote, T. A. Poggio, and T. Serre, "HMDB: A large video database for human motion recognition," in *Proc. IEEE Int. Conf. Comput. Vis.*, 2011, pp. 2556–2563.
[14] Z. Liu *et al.*, "Autocv challenge design and baseline results," in *Proc. La Conf. sur l'Apprentissage Automatique*, HAL archive, 2019.

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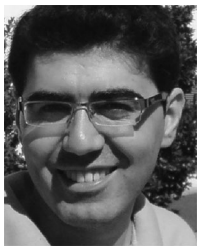

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