Temporally Consistent Video Colorization with Deep Feature Propagation and Self-regularization Learning

Yihao Liu⋆, Hengyuan Zhao⋆, Kelvin C.K. Chan, Xintao Wang, Chen Change Loy, *Senior Member, IEEE,* Yu Qiao, *Senior Member, IEEE,* Chao Dong

Abstract—Video colorization is a challenging and highly ill-posed problem. Although recent years have witnessed remarkable progress in single image colorization, there is relatively less research effort on video colorization and existing methods always suffer from severe flickering artifacts (temporal inconsistency) or unsatisfying colorization performance. We address this problem from a new perspective, by jointly considering colorization and temporal consistency in a unified framework. Specifically, we propose a novel temporally consistent video colorization framework (TCVC). TCVC effectively propagates frame-level deep features in a bidirectional way to enhance the temporal consistency of colorization. Furthermore, TCVC introduces a self-regularization learning (SRL) scheme to minimize the prediction difference obtained with different time steps. SRL does not require any ground-truth color videos for training and can further improve temporal consistency. Experiments demonstrate that our method can not only obtain visually pleasing colorized video, but also achieve clearly better temporal consistency than state-of-the-art methods. Codes will be available. A Video demo is provided here.

Index Terms—Video colorization, temporal consistency, feature propagation, self-regularization.

1 Introduction

Video colorization aims to generate a fully colored video from its monochrome version. This topic is attractive with wide applications, since there are numerous legacy black-and-white movies produced in the past ages. Colorization can also assist other computer vision tasks such as detection [1], [2], tracking [3], [4] and video action recognition [5].

Colorization is a challenging problem due to its highly ill-posed and ambiguous nature. In recent years, plenty of single image colorization methods are proposed and have achieved remarkable progress [6], [7], [10], [11], [12]. Compared with image colorization, video colorization [8], [13], [14] is more complex, and receives relatively less attention. It requires not only satisfactory **colorization performance** but also good **temporal consistency**, as evaluated in Figure 1. A simple way to realize this task is to treat a video sequence as a series of frames and to process each frame independently using an image-based colorization model. In practice, however, when colorizing consecutive sequences, this naive solution tends to produce results suffering from flickering artifacts (temporal inconsistency). As shown in Figure 2, the results of InsColor [12], a recent state-of-the-art image-based method, are not temporally consistent. Although the colorization effect of each frame is good, the overall results contain unstable flickering, e.g., the colors of the sky and the clothes are inconsistent. This highlights the temporal consistency problem of video colorization.

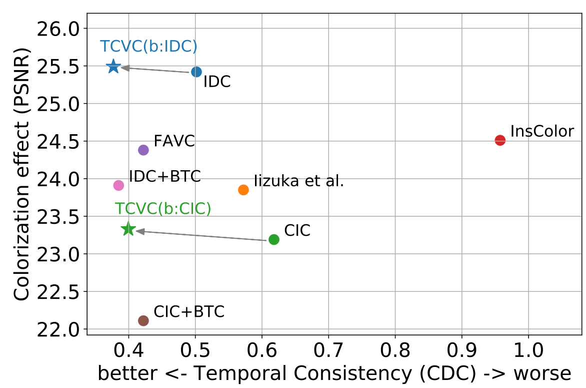

Fig. 1. Compared with existing algorithms (CIC [6], IDC [7], FAVC [8] and BTC [9]), our method achieves both satisfactory colorization performance and good temporal consistency. b denotes the image-based method backbone.

In general, there are currently two ways to realize temporally consistent video colorization. The first one is to redesign a specialized video colorization model with explicitly considering temporal coherence. It demands tedious domain knowledge to devise the algorithm involving delicate exploration of network structures and loss functions [6], [7]. A recent work FAVC [8] first employs deep learning to achieve automatic video colorization by utilizing self-regularization and diversity loss. However, with their focus mainly on consistency, their colorization performance for

Y. Liu, H. Zhao, C. Dong and Y. Qiao are with Shenzhen Institute of Advanced Technology, Chinese Academy of Sciences, Shenzhen, 518055. E-mail: {hy.zhao1, chao.dong, yu.qiao}@siat.ac.cn.
Y. Liu is also with the University of Chinese Academy of Sciences, Beijing, 100049. E-mail: liuyihao14@mails.ucas.ac.cn.
Kelvin C.K. Chan and Chen Change Loy are with Nanyang Technological University. E-mail: chan0899@e.ntu.edu.sg, ccloy@ntu.edu.sg. Xintao Wang is with Applied Research Center (ARC), Tencent PCG. E-mail: xintaowang@tencent.com.
⋆ *Y. Liu and H. Zhao are co-first authors.*