HAVC User Guide

Ver 2.0.0 – December 2025

(based on HAVC 5.6.5 and Hybrid 2025.12.21.1)

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1.0 Introduction

This guide has been written to describe the Vapoursynth filter Hybrid Automatic Video Colorizer available on GitHub under MIT License.

The filter (*HAVC* in short)[1] was developed to provide a simple way to coloring black and white movies. Due to the technical limitations lots of videos filmed in the last century are in black and white, making them less visually appealing, but most of these videos have historical values and colorizing them could help to restore their appeal especially to younger audiences. In order to add coloring capability to Vapoursynth, the filter is able to combine the results provided by *DeOldify* and *DDColor* , and in alternative to DDcolor can use the models provided in the project Colorization[2]. These models are some of the best models available for coloring pictures, and by combining them, the filter HAVC is able to obtain final colorized images, that often are better than the images obtained from the individual models.

Unfortunately, directly applying existing image colorization methods does not generate satisfactory colorized videos, as minor perturbations in consecutive input video frames, may lead to substantial differences in colorized video results. To overcome this problem, additional specialized filters have been developed for HAVC, that help improve the final quality of the videos.

In addition, to further improve the temporal stability of the colors, has been added the ability to provide the frames colored with HAVC directly as reference images to ColorMNet , Deep Exemplar based Video Colorization model (*DeepEx* in short) and DeepRemaster. *DeepEx*, *DeepRemaster* and *ColorMNet* are exemplar-based video colorization models, which allow to colorize a movie starting from an external-colored reference image. They allow to colorize a Video in sequence based on the colorization history, enforcing its coherency by using a temporal consistency loss. ColorMNet is more recent and advanced respect to DeepExemplar[3] (DeepEx) and it is suggested to use it as default exemplar-based model. DeepRemaster has the interesting feature to be able to store the reference images, so that is able to manage situations where the reference images not are synchronized with the movie to colorize. Conversely ColorMNet is not storing the full reference frame image (like DeepRemaster) but it stores only the key points (e.g., representative pixels in each frame). This imply that the colored frames could have some colors that are very different from the reference image. DeepRemaster has not this problem since it stores the full reference image. Unfortunately, the number of reference images that DeepRemaster is able to use depends on GPU memory and power, because the time required for inference increase with the number of reference images provided. Instead ColorMNet has some interpolation capability while DeepRemaster is very basic and is unable to properly colorize a frame if is missing a reference image very similar and it need a lot of reference images to be able to properly colorize a movie (the time resolution of DeepRemaster is 15 frames). So, the choice of which exemplar-based video colorization model to use depends on the source to colorize and the number of reference images available.

Starting with HAVC version 5.5.0, a new post-processing filter called B&W Tune was introduced, which can automatically correct most color allocation errors, this filter was further improved in HAVC version 5.6.0 with the inclusion of Retinex and LUTs filters (see chapter: External filters used by HAVC to improve final color quality).

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[1] The first coloring filters added in Hybrid were *DDColor* and *DeOldify*. Subsequently, the DeOldify filter was extended adding the possibility to use *DDColor* to improve the color quality and the filter was renamed **DDeoldify**, then the filter was extended to use more coloring methods, including ColorMNet and the Deep Exemplar based Video Colorization, hence the name of the filter was changed in **HAVC**, because is using a mixture of models (currently are implemented 4 picture-based and 3 exemplar-based models).

[2] The project *Colorization* includes 2 models: *Real-Time User-Guided Image Colorization with Learned Deep Priors* (Zhang, 2017) and *Colorful Image Colorization* (Zhang, 2016). The Zhang (Siggraph, 2017) model is a fairly famous model also adopted by some commercial software. These 2 models have been added as alternative models to *DDcolor* (named: **siggraph17, eccv16**) in short Zhang's models. These models have the same problem of temporal stability of colors observed in DDcolor and thus share the same tweaks developed for DDcolor and in some cases could provide a valid alternative. In this guide the models: *DDColor*, *Siggraph17*, *Eccv16*, will sometimes be referred to as models of the ***DDColor family***.

[3] In the chapter on HAVC Frame Interpolation it will be shown that the model Deep-Exemplar can be used to improving the HAVC coloring speed.

While forcing color stability helps with accuracy, it unfortunately produces a side effect of washed-out colors with a slight pink cast (similar to skin tone). The new post-processing filter can automatically correct this problem and restore image colors to a more natural color. With the version 5.6.0, HAVC has evolved beyond basic colorization, it now delivers vivid, natural colors while ensuring consistent color stability throughout films (see picture below for a comparison).

This guide contains some useful tips, but as everyone knows, the best way to learn is to personally experiment with the functions and parameters present in HAVC[4]. Unfortunately, was not possible to provide a *one size fits-all solution* for coloring the movies. The HAVC parameters suggested in this guide were defined to address the most common situation, but for obtaining the best results, the filter parameters need to be adjusted depending on the specific type of video to be colored.

The guide is organized as follows: the first chapter is dedicated to the description of Hybrid installation (the installation of Hybrid is a mandatory requirement for this guide), then there is a chapter describing the HAVC filter and the main parameters of the filter and their use (the sub-chapters 3.4, 3.5, 3.6, 3.7 are quite technical and could be skipped on first reading). Next there is the, much more interesting, chapter describing how to use Hybrid to colorize movies (the sub-chapter 4.1 is quite technical and could be skipped on first reading). Then there is a chapter on External filters used by HAVC to improve final color quality which were included with the version 5.6.0 of HAVC. Finally, there is a chapter with the reference to the HAVC internal functions. This chapter is useful for the most advanced users, who want to better understand the scripts generated by Hybrid or want to modify them.

[4] There is a thread on Selur forum that can be used to post questions on HAVC filter: DeOldify Vapoursynth filter

1.1 Pictures-based coloring models overview

As stated previously the pictures-base color models included in HAVC are: **ECCV16**, **SIGGRAPH17**, **DeOldify**, and **DDColor**. In the following sections will be summarized the main characteristic of these models.

1. ECCV16 *(Zhang et al., ECCV 2016 — "Colorful Image Colorization")*

- **Architecture**:
  Encoder-only CNN (no skip connections), 313-bin color classification → regression.
- **Input/Output**:
  L* (grayscale) → ab (LAB) → RGB.
- **Resolution**: Trained on **256×256**.

✅ **Strengths**

- Pioneering work — first to show **semantic colorization** from L alone.
- Conservative, **stable colors** (good for archival use).
- Small model → fast inference.

❌ **Limitations**

- **Muted, desaturated** output.
- **Blurry details** (no decoder/skip connections).
- **Flickers badly in video** (frame-by-frame, no temporal awareness).
- Struggles with **rare objects** (relies on 313-bin prior from ImageNet).

📌 **Best for**: Baseline experiments, conservative restoration.

2. SIGGRAPH17 *(Zhang et al., SIGGRAPH 2017 — "Real-Time User-Guided Image Colorization")*

- **Architecture**:
  U-Net style (encoder-decoder **with skip connections**), hybrid loss (classification + regression + perceptual).
- **Input/Output**:
  L* → ab → RGB.
- **Resolution**: Trained on **256×256**.

✅ **Strengths**

- **Sharper details** (thanks to skip connections).
- **More vibrant, natural colors** than ECCV16.
- Better handling of **textures and edges**.
- Still relatively fast.

❌ **Limitations**

- Can **oversaturate** (e.g., skin, skies).
- Still **frame-by-frame** → flickers in video.
- No user guidance in base model (though optional hints exist).

📌 **Best for**: High-quality still image colorization; upgrade over ECCV16.

3. [DeOldify (Video Model)] *(Antic, 2018–2019 — "DeOldify: A Deep Learning based Colorization Framework")*

- **Architecture**: Modified ResNet + **NoGAN training**, temporal smoothing (Video model only).
- **Input/Output**:
  Grayscale (RGB) → RGB (direct).
- **Resolution**: **512×512** (Video model).

✅ **Strengths**

- **Temporal stability** (Video model uses frame blending).
- **Good skin tones and natural palettes**.
- Handles **old film, faces, and common scenes** very well.
- Mature, production-ready (used in real restoration projects).

❌ **Limitations**

- Can be **over-smoothed** (loses fine texture).
- Colors sometimes **muted or inaccurate** for rare objects.
- **Slower** than ECCV/SIGGRAPH.
- Artistic model is **less stable** (HAVC version is blended at 50% with Video to add more stability).

📌 **Best for**: **Video colorization**, archival film restoration.

4. [DDColor] *(He et al., CVPR 2023 — "Towards Photo-Realistic Image Colorization via Dual Decoders")*

- **Architecture**:
  Dual decoders: Semantic (global) + Detail (local), Swin Transformer backbone.
- **Input/Output**:
  Grayscale → **direct RGB** (no LAB conversion).
- **Resolution**: Trained on **512×512**.

✅ **Strengths**

- **State-of-the-art realism**: natural gradients, accurate skin, rich textures.
- **Explicit semantic understanding** (trained with segmentation cues).
- **Best detail recovery** (fabric, foliage, hair).
- Handles **uncommon scenes** better (food, art, etc.).
- No 313-bin prior → more flexible color space.

❌ **Limitations**

- **Heavier/slower** (Swin Transformer).
- **Frame-by-frame** → flickers in video (unless stabilized).
- Requires **512×512 input** for best results.

- Less mature ecosystem (fewer prebuilt tools vs. DeOldify).

📌 **Best for**: **Photo-realistic still images**, high-end restoration.

Quick Comparison Table

MODEL	BEST FOR	TEMPORAL STABLE ?	DETAIL	COLOR REALISM	SPEED	INPUT RES
ECCV16	Baseline	❌	❌ Low	❌ Low	✅ Fast	256×256
SIGGRAPH17	Still images	❌	⚠️ Medium	⚠️ Medium	✅ Fast	256×256
DeOldify (Video)	Video	✅	⚠️ Medium	✅ Medium-High	⚠️ Medium	512×512
DDColor	Photo-realism	❌	✅ High	✅ Highest	⚠️ Medium	512×512

As shown in the table above the input resolution for the models ECCV16 and SIGGRAPH17 is only 256x256, for these models the RenderFactor=16 (used by the **Preset** *veryfast*) is appropriate. The models DeOldify (Video) and DDColor can support input resolution till 512x512, for these models the RenderFactor=32 (used by the **Preset** *veryslow*) is the most appropriate. Fortunately the coloring process is not high-frequency: unlike super resolution, resolutions greater than 512px do not provide additional significant color information.

DDColor(Artistic) should be preferred to DDColor(ModelScope) because was trained with an extended dataset containing many high-quality artistic images. But there are situations where DDColor(Artistic) perform very badly, in these cases is better to use DDColor(ModelScope) . In the image below there is a comparison of DDColor family models:

As it is possible to see in the image above, DDColor(Artistic) was unable to provide a colored image, only the bottom of the images was slightly colored by this model, conversely DDColor(ModelScope) was able to provide a well colored image.

DeOldify is less affected by this problem as shown in the image below:

As it is possible to see in the image above, both DeOldify(Video) and DeOldify(Artistic) were able to provide well colored images, only DeOldify(Stable) provided an image with dull colors, but in any case better than DDColor(Artistic).

As shown in Comparison of Models, the combination of models that provides the best CIEDE2000 scores are:

1. DeOldify(Video) + DDColor(Artistic) -> score(D+D) = 8.3
2. DeOldify(Stable) + DDColor(Artistic) -> score(DS+DD) = 8.0
3. DeOldify(Artistic) + DDColor(ModelScope) -> score(DA+DDs) = 8.0

But given that DeOldify(Stable) has a better score of DeOldify(Artistic) probably could be considered the following combinations:

4. DeOldify(Stable) + DDColor(ModelScope)
5. DeOldify(Video) + DDColor(ModelScope)

The CIEDE2000 it is a metric developed by the *International Commission on Illumination* (**CIE**) that is able to measure the color distance, between 2 images, taking into account the human color perception, so low values are better and a score = 0 is obtained only in the case the 2 images are exactly the same. In the comparison the combination 1 is the preferred despite the fact that that has not the best score. The reason for this preference is that the test was performed taking into consideration single pictures, for coloring videos DeOldify(Video) is preferred because is able to produce stable colored frames across the time. Also DDColor(Artistic) should be preferred but as shown in the previous example there are situations where DDColor(ModelScope) perform much better.

With the initial versions of HAVC the combination #3 and #4 provided colored frames with a lot of color instability. But starting with the version 5.6 of HAVC the coloring pipeline has improved significantly and now with HAVC is possible to use also the combination #4 DeOldify(Stable) + DDColor(ModelScope) with an acceptable level of color noise. But probably the better combination is the #5 DeOldify(Video) + DDColor(ModelScope).

- The models DeOldify(Artistic) and DeOldify(Stable) implemented in HAVC are automatically blended at 50% with DeOldify(Video) to keep the colors more stable in the video coloring pipelines.

1.2 Reference-based coloring models overview

As stated previously the reference-based color models included in HAVC are: **ColorMNet**, **Deep Exemplar based Video Colorization** and **DeepRemaster**. In the following sections will be summarized the main characteristic of these models.

1. ColorMNet

- **Purpose**: Video colorization with temporal consistency.
- **Key Idea**: ColorMNet (Color Memory Network) addresses the challenge of maintaining consistent colors across video frames. It uses a memory-augmented neural network to store and retrieve color information from previous frames, ensuring smooth and coherent color propagation over time.
- **Features**:
    - Uses a memory module to retain color context.
    - Designed to avoid flickering and color inconsistencies common in frame-by-frame colorization.
    - Often builds upon or integrates with other colorization backbones (e.g., based on CNNs or transformers).
- **Publication**: Introduced in a 2023 paper (e.g., *ColorMNet: Memory-Augmented Network for Video Colorization*).

2. Deep Exemplar-based Video Colorization

- **Purpose**: User-guided or reference-based video colorization.
- **Key Idea**: This method allows users to provide a colored reference image (an "exemplar") that guides the colorization of grayscale video frames. The network transfers colors from the exemplar to the target frames while preserving semantic correspondence.
- **Features**:
    - Leverages deep features (e.g., from VGG) to match regions between exemplar and target.
    - Ensures temporal coherence across frames.
    - More flexible than automatic colorization because it respects user-provided color cues.
- **Publication**: Originally proposed by *Luan et al.* in **SIGGRAPH 2017** ("Deep Photo Style Transfer" inspired some ideas, but this is a distinct video-focused method).

3. DeepRemaster

- **Purpose**: Video restoration and colorization of old films.

- **Key Idea**: DeepRemaster combines temporal information and user hints (e.g., sparse color strokes, colored reference frames) to restore and colorize degraded or black-and-white archival footage. It uses a recurrent neural network (often with attention mechanisms) to propagate information across frames.
- **Features**:
    - Handles both restoration (e.g., removing noise, scratches) and colorization.
    - Supports user-guided color hints for better artistic control.
    - Uses optical flow or attention to align features across frames.
    - It relies on **user-provided reference frames** (i.e., color images or video clips) that are **semantically similar** to the target grayscale footage.
- **Publication**: Introduced by **Y. Zhang et al.** in **2019** (*DeepRemaster: Temporal Source-Reference Attention Networks for Video Enhancement*).

Quick Comparison Table

METHOD	GUIDANCE TYPE	TEMPORAL CONSISTENCY	YEAR	KEY INNOVATION
ColorMNet	Automatic/ Exemplar	✅ Yes (memory-based)	2023	Memory module for color propagation
Deep Exemplar-based	Exemplar/reference	✅ Yes	2017	Semantic matching with reference image
DeepRemaster	Exemplar/reference	✅ Yes (attention/RNN)	2019	Joint restoration + colorization

2.0 Installation

To use the HAVC filter is necessary a GPU supporting CUDA, a NVIDIA RTX3060 is the minimum requirement to use this filter satisfactorily. The filter is distributed with the torch package provided with the **Hybrid Windows Addons**. To use it on Desktop (Windows) it is necessary install Hybrid and the related Addons. **Hybrid** is a Qt-based frontend for a lot video filters (including this filter) which can convert most input formats to common audio & video formats and containers. Hybrid represents one of the most comprehensive solutions for implementing A.I. video filters and offers the most user-friendly approach to image colorization using the HAVC filter via VapourSynth. Therefore, this guide focuses on detailed installation and usage instructions for using HAVC within the Hybrid environment[5].

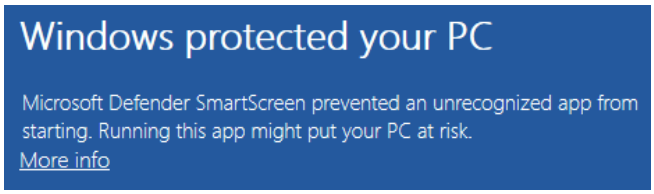
The main advantages of using Hybrid are:

- The availability of a complete working torch package with all the necessary decencies already installed (something that for some users could be a nightmare to complete successfully);
- Hybrid is able to automatically generate all Python/Vapoursynth code to allow all filters available in Hybrid to work properly (is not necessary a knowledge of Python/Vapoursynth to be able to use Hybrid);
- Easy access to all the HAVC functions with all parameters properly filled (HAVC as almost 50 parameters, and it can be very difficult to use it without a good knowledge of the filter or without Hybrid).

To install Hybrid is necessary to download it from https://www.selur.de/downloads, opening the link will be displayed the following page:

It is necessary to download and install the installer (see point 1).

If is displayed the blue window of Microsoft Defender SmartScreen it is possible to install anyway by following the instructions provided in the previous link or by clicking on More Info and clicking on **Run anyway**.



➢ **Remark:** *For using HAVC in Hybrid It is required to install Hybrid in a writable path*, like "C:\Hybrid" or "D:\Programs\Hybrid".

The primary reason for this requirement is that certain coloring models need to download neural networks dynamically, either on demand or when updates become available, which may differ from the versions bundled with Hybrid. To enable this functionality, Hybrid must have write access to its installation directory. However, for security reasons, Selur has disabled running Hybrid with administrator privileges. As a result, Hybrid cannot be installed in protected system directories like "C:\Program Files" or any other location that requires elevated permissions to write files. This requirement is necessary only if Hybrid is used for coloring models with HAVC, the other filters bundled with Hybrid don't have the need to update the neural networks, so Hybrid can be installed also in "C:\Program Files" . But since

[5] For manual installation see the GitHub page: https://github.com/dan64/vs-deoldify

this is the Guide for the filter HAVC I don't consider this an option. Once installed, in the installation folder, create a new subfolder called **`Settings`**, then create the file **`misc.ini`** with the following lines:

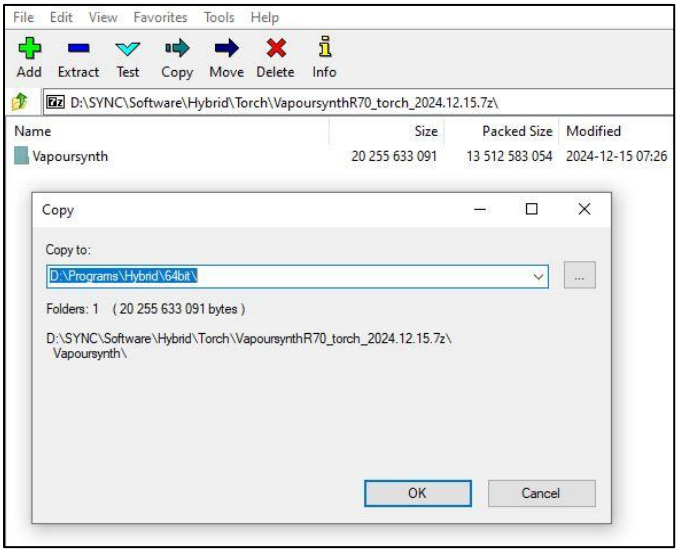
```
[General]

settingPath=.\\Settings

niceness=0
```

In this way Hybrid will run in <u>portable</u> mode[6]. After having installed Hybrid, it is necessary to click on the link GoogleDrive (see point 2), it will be displayed the following page:

The most important file to download is the archive containing the torch packages which are necessary to use HAVC. In this case the file is named: `VapoursynthR70_torch_2024.12.27.7z`.



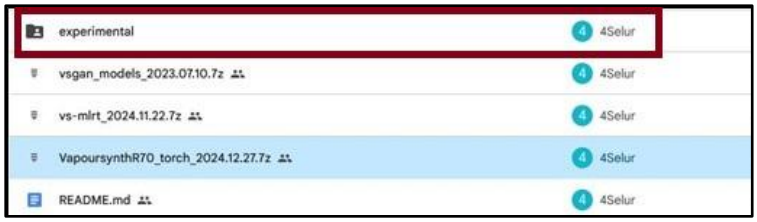
By opening it with 7-zip will be displayed the following window.

It is necessary to extract the folder `Vapoursynth` on the related location in the installation folder. In this case it is assumed the Hybrid has been installed in "D:\Programs\Hybrid", in the case Hybrid was installed in a different folder it is necessary to change the destination path (highlighted in blue in the picture on the left) accordingly.

2.1 Installation of Development Version

Sometime to get the most updated version of HAVC filter is necessary to install the Development version of Hybrid.

In this case all the files to be downloaded are available in the folder **experimental** on <u>GoogleDrive</u>, as shown in the following picture:



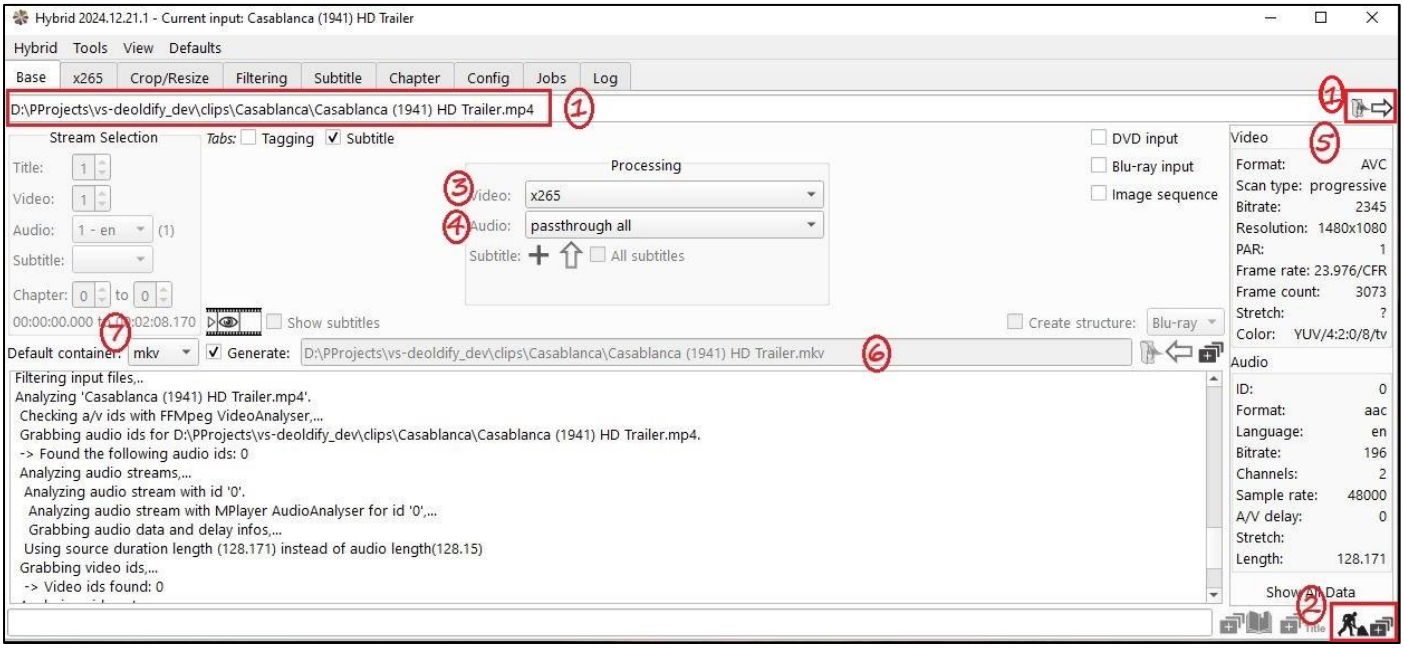
[6] For more useful settings see the page: https://forum.selur.net/thread-10.html

Once inside the folder **experimental**, should be visible the following files:

It is necessary first to download and run the installer (see point 1) and then to download and extract the torch addon archive (see point 2) as described previously.

3.0 Using the Filter

Once Hybrid is installed it is possible to use it to coloring B&W movies. The clip to be colored can be added in input to Hybrid by using drag-and-drop. In the following picture is displayed the Hybrid main GUI window.

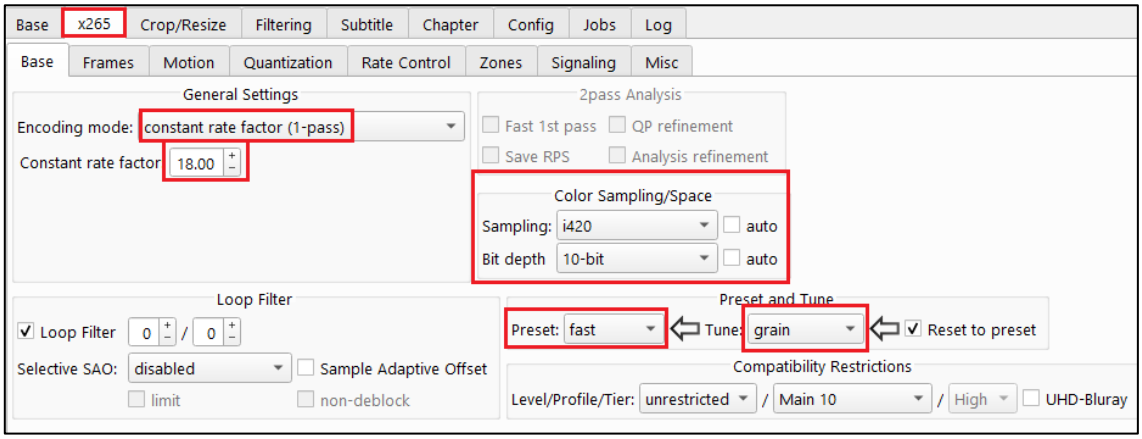


GUI Explanation[7]:

1) Input field, the clip can be inserted with drag-and-drop or by selecting the big arrow on the right of the text box
2) Encoding button, by pressing it Hybrid will start to encode the clip
3) Video encoder, in this case has been selected **x265** (the encoder options are available in the tab “x265”)
4) Audio encoder, in this case has been selected “passthrough all”, all the audio tracks will be included in the container untouched.
5) Media information page
6) Name to be used for the new encoded clip (in this case is auto generated).
7) The container used to store the encoded clip, in this case “mkv”.

3.1 Suggested settings for x265 encoding

In the following picture are shown the suggested settings for encoding with h265 at 10-bits (tab “x265”)

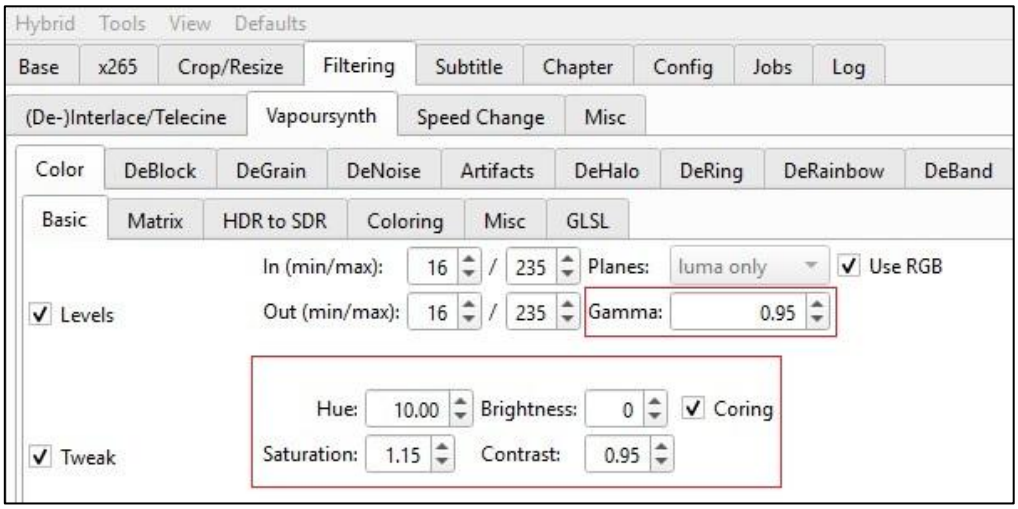


[7] In the following post (a little outdated) is available a small guide to Hybrid: https://forum.selur. net/thread-282.html

With these settings the movie will be encoded at 10 bits, this will increase the color accuracy. When is selected **fast** and **grain** (in this order) it is necessary to click on the big arrows on the right to apply them (in the same order). The constant factor (CF) of 18.00 should be good enough. To get more quality the CF can be decreased till 15.00 (lower values will increase only the size with very little quality improvement).

3.2 Simple Hybrid filters for adjusting colors

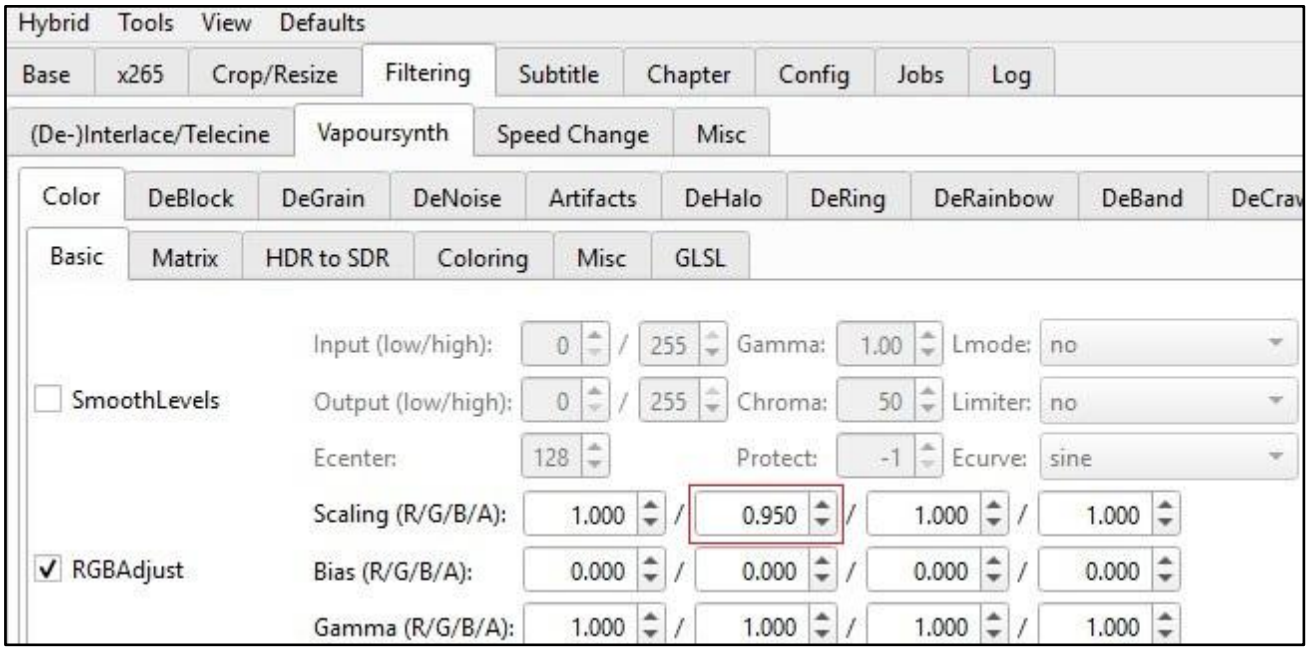
In the chapter Coloring using Hybrid will be suggested some settings that will allow to improve further the color temporal stability and, in the chapter, Best settings for color temporal stability will be provided what could be the optimal settings to get movies with colors very stable. Unfortunately, the color stability has a cost, not only in term of computational speed but also and above all, in terms of variety of colors. With the increase of color stability will decrease the variety and saturation of the colors, this situation improved with the version 5.6.0 of HAVC, but in any case quite often will be necessary to apply some color adjusments. Some useful filters, which will be possible to add as *post-process* to improve the saturation of the colors, can be found in the panel: **Filtering->Vapoursynth->Color->Basic** as shown in the picture below (with some suggested settings):



In the case the colors are too cold, it is possible to increase the **Hue** to mitigate the effect, vice versa if they are too reddish it is possible to decrease the **Hue**. Depending on the clip, suggested values for **Hue** are in the range: -20:+20.

If the colors appear slightly desaturated or washed out, it is possible increase the saturation by assigning a value to parameter **Saturation** above 1.0. Suggested values for **Saturation** are in the range: 0.8:1.20.

However, if the colors tend towards green and is not possible to mitigate the effect with the hue, it possible to adjust the RGB colors directly using the filter **RGBAdjust** as shown in the image below.



In this case the *Green* was decreased by 5%, by applying a scale factor of 0.95. The scaling factors to be used with this filter should not change significantly from 1.0, suggested range value for them is: 0.90:1.10.

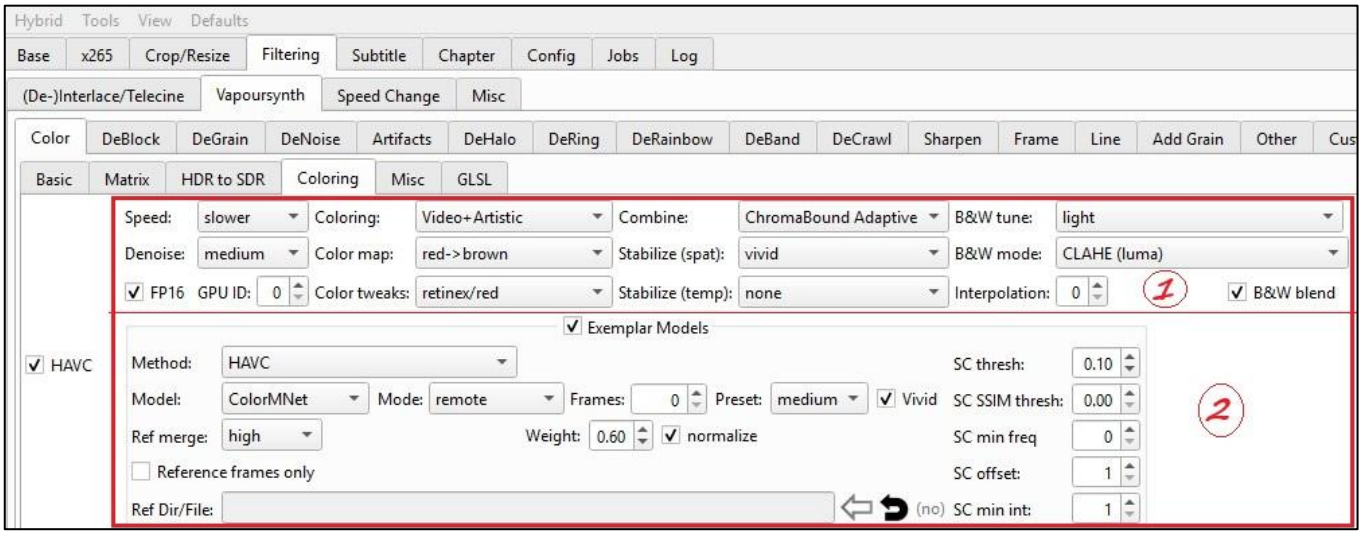
Starting with the version 5.5.0 of HAVC has been introduced some pre/post-process color adjustment filters as described in the chapter B&W Tune and the Color Adjust post-process filter.

3.3 HAVC configuration page

In Hybrid there are a lot of filters, the coloring filters are available at: **Filtering->Vapoursynth->Color->Coloring**.

The HAVC filter is available under the checkbox **HAVC**. The filter was developed having in mind to use it mainly to colorize movies. Both DeOldify and DDcolor are good models for coloring pictures, but when are used for coloring movies they are introducing artifacts that usually are not noticeable in the images but are well observable in the colored movie. Especially in dark scenes both DeOldify and DDcolor are not able to understand what it is the dark area and what color to give it, they often decide to color these dark areas with blue, then in the next frame this area could become red and then in the next frame return to blue, introducing a *flashing psychedelic effect* when all the frames are put in a movie. To try to solve this problem has been developed *pre-* and *post-* process filters.

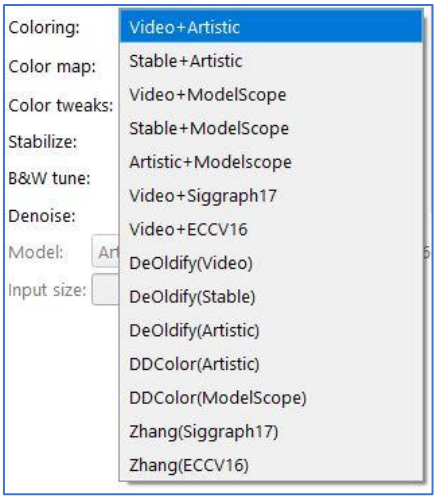
The HAVC filter panel can be divided in 2 group-box (see red rectangles on the picture below):



1) The **Presets group-box**, that allows to set all the filter parameters of the custom section (which are more than 35). It represents, the easiest way to use the filter to get good results. The parameters in this group box are used as input for the internal filter function HAVC_main.

2) The **Exemplar-based Models** group-box. Using this section is possible to change all the filter parameters related to the exemplar-based color models: ColorMNet, DeepRemaster and DeepEx. These parameters are used as input to the internal filter function HAVC_deepex.

The **Coloring** field in the group-box 1 (see picture on the right), allows to select the pictures-based color models: DeOldify, DDColor and Zhang (siggraph17, eccv16) and their combination. The DeOldify has 3 networks where the Video network is the most stable. DeOldify is the only model with a network trained for coloring videos and using it with the other color models will improve the color stability and quality as shown in the section Comparison of Models on GitHub.



The meaning of remaining group-box filters is the following:

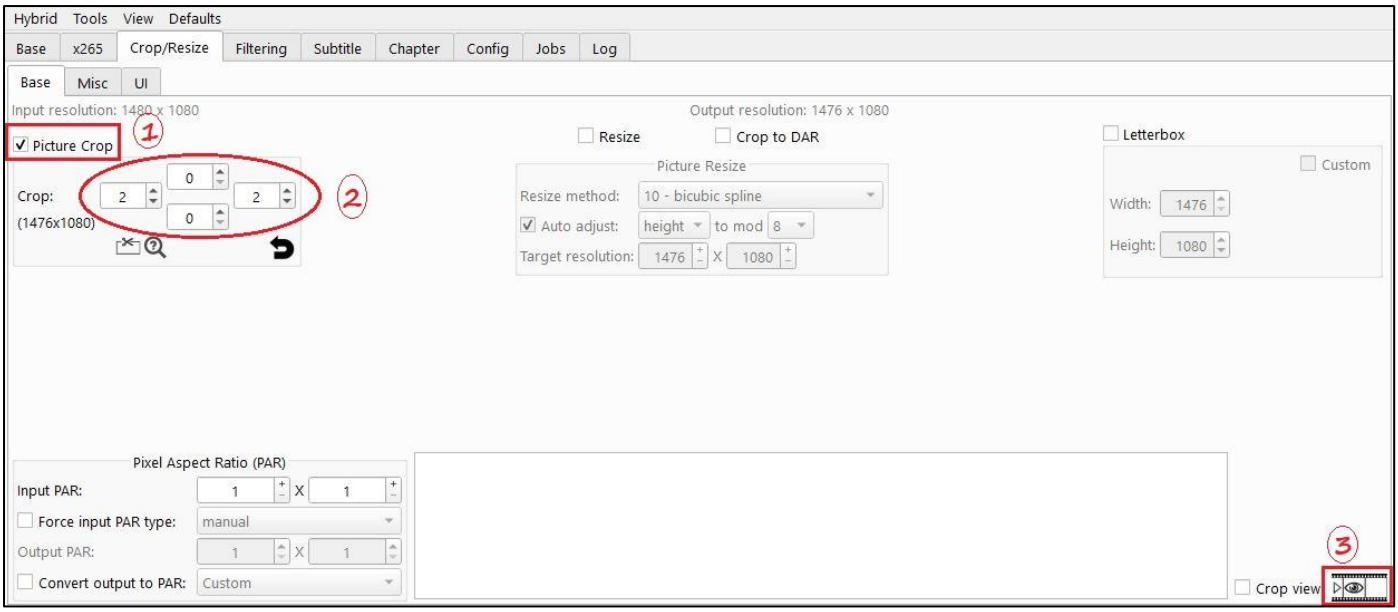
- **Color map**: this field allows to select the Color Mapping presets;
- **Color tweaks**: the fields *ColorFix* and *Denoise* (aka ColorTune) are the Tweaks parameters developed for the pictures-based models. It is possible to disable all the tweaks by setting the field *Denoise* to **none.**

The parameter *Denoise* has effect also on the strength of **Color map**. In the case *Denoise is not set* to **none**, but *ColorFix* is set to **none**, instead of tweaks will be applied the HAVC RGB denoise filter.

- **Stabilize**: it allows to define the weight to assign to the DeOldify Video stabilization network when used in combination with DDColor and the Alternative color models (suggested presets are: Stable and MoreStable).
- **Combine**: it allows to define the method adopted by HAVC to merge the frames colored by 2 models.

The most colorful movies can be obtained using the single pictures-based color models. But the resulting video will be almost unwatchable and this is the main reason behind the development of HAVC. It is possible to improve the color stability using the filters and settings made available in HAVC.

It is recommended to always remove all the black bars (if any) before applying the coloring filters. It is possible to remove the black bar in Hybrid, using the dedicated page **Crop/Resize** (see picture below). It is necessary to enable the **Picture Crop (1)** and then insert the appropriate number of pixels in the **Crop box (2)**. It is possible to preview the crop by clicking on the **Preview Crop button (3)**.



3.3.1 HAVC Speed presets

In HAVC configuration page, the **Speed** preset will allow to select the most appropriate parameters to get the best balance between quality and speed. This table display the full mapping of Speed to RenderFactor:

Model	placebo	veryslow	slower	slow	medium	fast	faster	veryfast
DeOldify (RF)	32	32	32	28	24	22	20	16
DDColor (RF)	32	32	32	28	24	22	20	16

The RenderFactor of 32 will use a frame size of 512x512, this represent also the maximum size used by DeOldify and DDColor to train their models, while the Zhang's models were trained using smaller frame of size 256x256 (see the chapter on Coloring models overview). As it is possible to see the render factor for the presets **veryslow** and **placebo** are the same of preset **slower**. The reason for this setting is that there is no reason in using a RF above 32, because the frame size of 512x512 represent the maximum size used by DeOldify and DDColor. Given that is not possible to increase the size used by the color models, it is possible to slice the input clip in smaller tiles to match better the frame resolution of 512x512. This approach is implemented in the preset **placebo**. More precisely in the preset **placebo**, the input clip is sliced in 4 tiles (2x2 grid) encoded separately using an approach similar to the one described in the Example 9, in this case the encoding speed will a quarter of preset **slower**. Given the high computational requirements of the presets **placebo** it is suggested of using them only on very powerful GPUs (RTX5090 or above) and on HD clips. But it is possible to increase the encoding speed using the parameter FrameInterp so that this approach can be used also on less powerful GPUs (RTX4060 or above).

Example of frame colored with preset **slower**, in the red square has been selected the faces less colored

Same frame colored with preset veryslow, now the faces in the red square are better colored

The high resolution coloring introduced with **veryslow** and **placebo** requires a GPUs very powerful to color a full movie. It is more practical to limit its usage only on the portion of the movie that really need this kind of high resolution coloring. Of course this approach makes sense only if the original clip to color is in high resolution (720p or above).

Suppose that a HD movie has been already colored with HAVC, but some portion of it has not been well colored due to the presence of shots with the faces of many people. Suppose that the frames that need to be colored in high resolution are in the range [3961:4665] and [12421:12776]. In this case it is possible to use the approach described in the Example 8/Example 9 to recolor only these portions of the movie, by writing the following script.

```
# Imports
import vapoursynth as vs
# getting Vapoursynth core
import sys
import os
core = vs.core
# Import scripts folder
scriptPath = 'D:/Programs/Hybrid/64bit/vsscripts'
sys.path.insert(0, os.path.abspath(scriptPath))
# Import scripts
import vsdeoldify as havc
clip = havc.HAVC_read_video(source="havc_colored_clip.mkv")
# ---------------------------------------------------------
# splitting clips to recolor with High Resolution
clip0 = clip[:3961] # ok
clip1 = clip[3961:4665] # to recolor in hd
clip2 = clip[4665:12421] # ok
clip3 = clip[12421:12776] # to recolor hd
clip4 = clip[12776:] # ok
# ---------------------------------------------------------------------
clips1 = havc.HAVC_clip_slice(clip1, 4, 32, 32)
for i in range(4):
    clips1.tiles[i] = havc.HAVC_main(clip=clips1.tiles[i], Preset="slower", ColorModel="Video+Artistic",
CombMethod="ChromaBound Adaptive", VideoTune="vivid", ColorTemp="none", ColorFix="magenta/violet",
FrameInterp=0, ColorMap="red->brown", ColorTune="strong", BlackWhiteTune="strong", BlackWhiteMode=4,
BlackWhiteBlend=True, EnableDeepEx=False)
clip1 = havc.HAVC_clip_reconstruct(clips1, 0.5, True)
# ---------------------------------------------------------------------
clips3 = havc.HAVC_clip_slice(clip3, 2, 32, 32)
for i in range(2):
    clips3.tiles[i] = havc.HAVC_main(clip=clips3.tiles[i], Preset="slower", ColorModel="Video+Artistic",
CombMethod="ChromaBound Adaptive", VideoTune="vivid", ColorTemp="none", ColorFix="magenta/violet",
FrameInterp=0, ColorMap="red->brown", ColorTune="strong", BlackWhiteTune="strong", BlackWhiteMode=4,
BlackWhiteBlend=True, EnableDeepEx=False)
clip3 = havc.HAVC_clip_reconstruct(clips3, 0.5, True)
# ---------------------------------------------------------------------
clip = clip0 + clip1 + clip2 + clip3 + clip4
# adjusting output color to YUV420P10 for x265Model
clip = core.resize.Bicubic(clip=clip, format=vs.YUV420P10, matrix_s="709", range_in_s="full",
range_s="limited", dither_type="error_diffusion")
# ---------------------------------------------------------------------
# output
clip.set_output()
```

In this example to color the first portion, the clip was split in 4 tiles, while to color the second portion the clip was split in 2 tiles. The slicing of the clip in 2 or 4 tiles does not provide the same result. Sometimes the best result is obtained with 2 tiles other times with 4. Overall, using 2 tiles offers the best compromise between color accuracy and speed.

Using the above script, the coloring will be much faster that using the preset **placebo**, moreover by explicitly coloring the split tiles, Vapoursynth will be able to better allocate the multithreads coloring tasks. The big advantage of this approach is that the high resolution coloring is limited only to 1059 frames. Supposing an encoding speed of about 1.5fps, the hd re-color of these frames will require only 12min.

- In the preset **placebo** and **veryslow** the settings *Stabilize (temp)* and *Interpolation* are mutually exclusive. If one is enabled, the other is ignored; precedence is given to the parameter *Interpolation*. The Deep-Exemplar settings are ignored only *Stabilize (temp)* and *Interpolation* can be used.

3.4 HAVC *pre*- and *post*- process filters

The main filters introduced are[8]:

3.4.1 Pre-process Filters

DDColor Tweaks: This filter is available only for DDColor and has been added because has been observed that the DDcolor's *inference* is quite poor on dark/bright scenes depending on the luma value. This filter will force the luma of input image to don't be below the threshold defined by the parameter *luma_min*. Moreover, this filter allows to apply a **dynamic gamma correction**. The gamma adjustment will be applied when the average luma is below the parameter *gamma_luma_min*. The adjustment applied to gamma is defined by the following expression:

gamma_new = MAX[gamma*(luma/*gamma_luma_min*)^*gamma_alpha*, *gamma_min*]

A *gamma* value > 2.0 improves the DDColor stability on bright scenes, while a *gamma* < 1 improves the DDColor stability on dark scenes (see related parameters). Using the dynamic gamma correction is possible to apply a high tweak gamma (parameter [2] in the tweak parameter list) and then thanks to the dynamic gamma correction decreasing it with the luma, so that on dark scenes the gamma will < 1. At the following link there is a comparison between using a gamma = 1 and gamma = 2: https://imgsli.com/MjUyNjY0. For this sample a DDcolor Tweak like this: ddtweak_p=[0.0, 1.0, 2.8, True, 0.3, 0.6, 0.7, 0.5] is appropriate. It is also possible to specify the Chroma Adjustment to be applied to the frames colored with DDcolor (and Alternative models) by adding a string parameter. An example of full tweak is the following:

ddtweak_p=[0.0, 1.0, 2.5, True, 0.3, 0.6, 0.7, 0.5, "300:360|0.5,0.1"]

In this example the last string parameter represent the Chroma Adjustment that will be explained in the next chapter.

In the images below is shown an example of the effect of tweaks on DDColor colored frames.

[8] These filters are automatically applied by Hybrid if is selected a rendering speed above *faster*.

3.4.2 Post-process filters

Chroma Smoothing: This filter allows to reduce the *vibrancy* of colors assigned by DeOldify/DDcolor by using the parameters *de-saturation* and *de-vibrancy*, the effect on *vibrancy* will be visible only if the option **chroma resize** is enabled (default), otherwise this parameter has effect on the *luminosity*. The area impacted by the filter is defined by the thresholds dark/white. All the pixels with luma below the dark threshold will be impacted by the filter, while the pixels above the white threshold will be left untouched. All the pixels in the middle will be gradually impacted depending on the luma value (see related parameters).

Chroma Stabilization: This filter will try to stabilize the frames' colors. As explained previously since the frames are colored individually, the colors can change significantly from one frame to the next, introducing a disturbing psychedelic flashing effect. This filter tries to reduce this by averaging the chroma component of the frames. The average is performed using a number of frames specified in the *Frames* parameter. Are implemented 2 averaging methods:

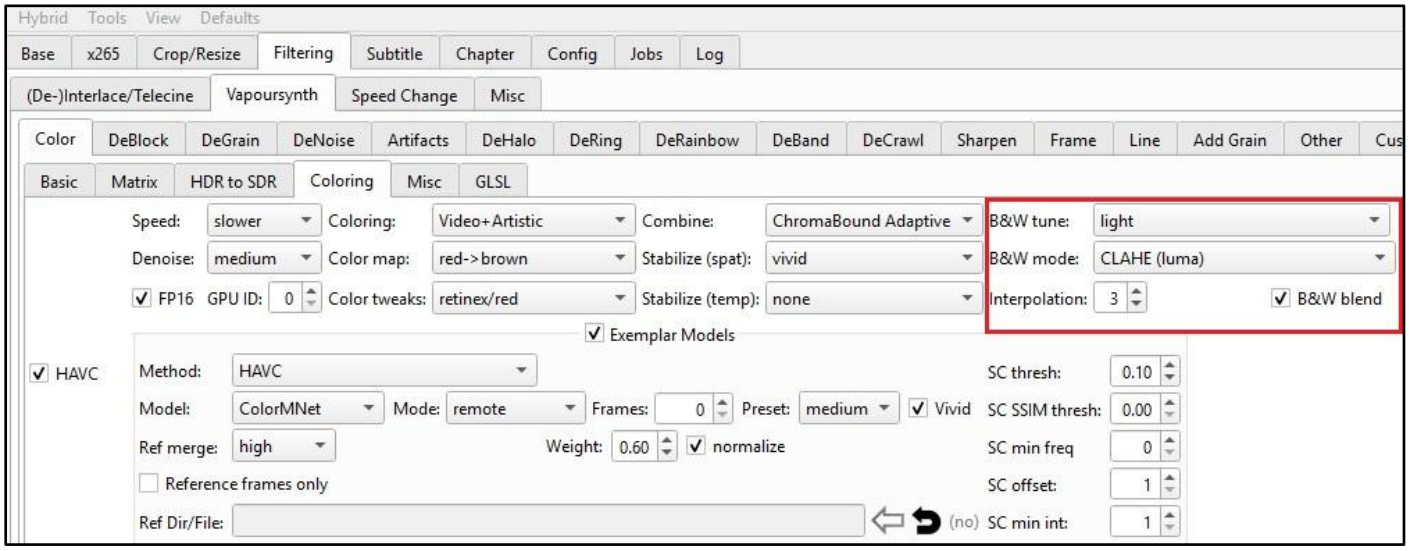
1. *Arithmetic average*: the current frame is averaged using equal weights on the past and future frames
2. *Weighted average*: the current frame is averaged using a weighed mean of the past and future frames, where the weight decreases with the time (far frames have lower weight respect to the nearest frames).

As explained previously the stabilization is performed by averaging the past/future frames. Since the non-matched areas of past/future frames are *gray* because is missing in the past/future the *color information*, the filter will apply a *color restore* procedure that fills the gray areas with the pixels of current frames (eventually de-saturated with the parameter "sat"). The image restored in this way is blended with the non-restored image using the parameter "weight". The gray areas are selected by the threshold parameter "tht". All the pixels in the HSV color space with "S" < "tht" will be considered gray. If is detected a scene change (controlled by the parameter "tht_scen"), the *color restore* is not applied (see related parameters).

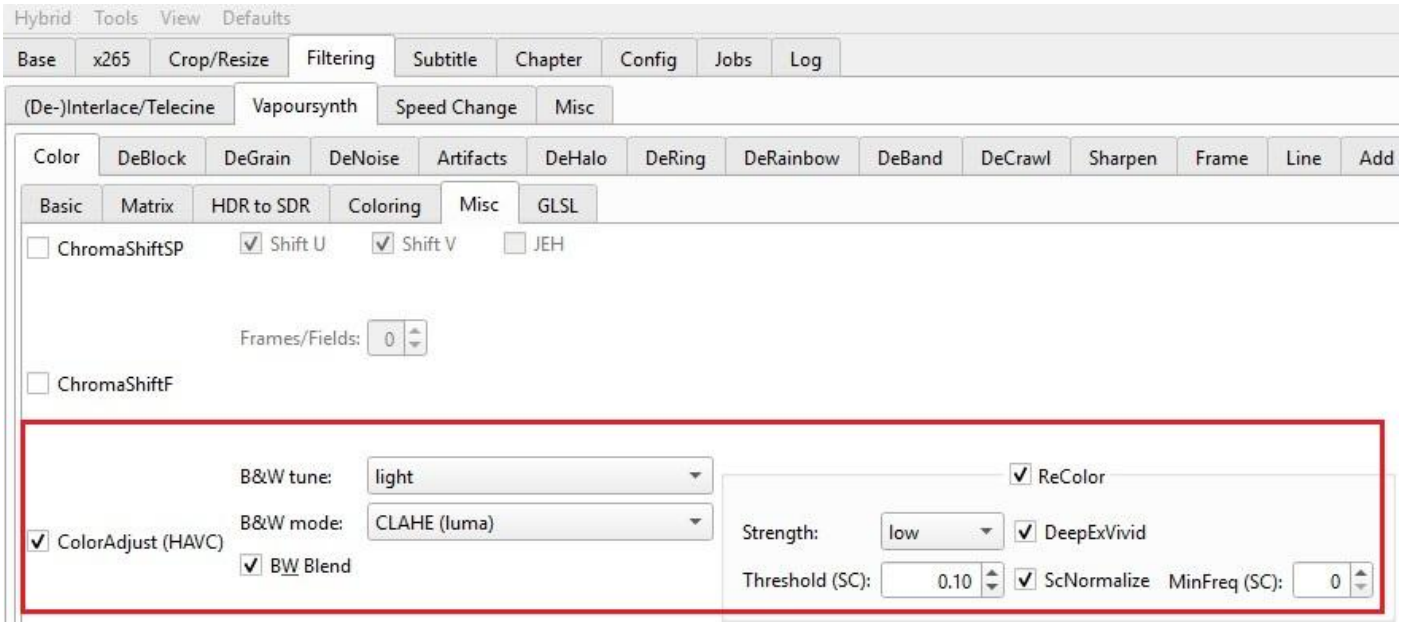
Darkeness: this post process filter will force the dark areas of a frame, identified by the region of pixels having a luma below the *dark_threshold*, to have a dark color, the dark color is obtained by de-saturating the pixels by an amount specified by the parameter *dark_amount* (see related parameters).

3.4.3 B&W Tune and the Color Adjust post-process filter

As previously mentioned, enforcing color stability can result in a side effect: colors appear washed out and slightly tinted pink (reminiscent of skin tones). To address this issue, HAVC version 5.5.0 introduced a new post-processing filter called ***B&W Tune***. In most scenarios, this filter automatically corrects the majority of color allocation errors. This filter is available in the HAVC coloring page (see red box):



And is also available as a separate filter in **Color->Misc** page, as shown in the image below (in this page there is a subset of the options available in the main HAVC filter page)



The reason to add this filter also under **Color->Misc** page, is to allow the possibility to adjust films already colored with HAVC (or other A.I. colorizers) without restart all the coloring process, which is time consuming. The filter parameters available in are:

- **B&W Tune**: This filter allows to define the strength of the filter, the available values are:
  - **None**: the filter is not applied
  - **Light**: the colors are a little cold but still warm (suggested value)
  - **Medium**: the colors are cold
  - **Strong**: the colors are colder

an example of filter effect is shown in the images below

- **B&W Mode**: This filter allows to define the method used to perform contrast/luminosity adjustments, available values are:
  - 0 : CLAHE (luma) (default)
  - 1 : Simple (RGB)
  - 2 : CLAHE (RGB)
  - 3 : CLAHE (luma) + Simple (RGB)
  - 4 : ScaleAbs – LUT
  - 5 : Multi-Scale Retinex (HAVC)

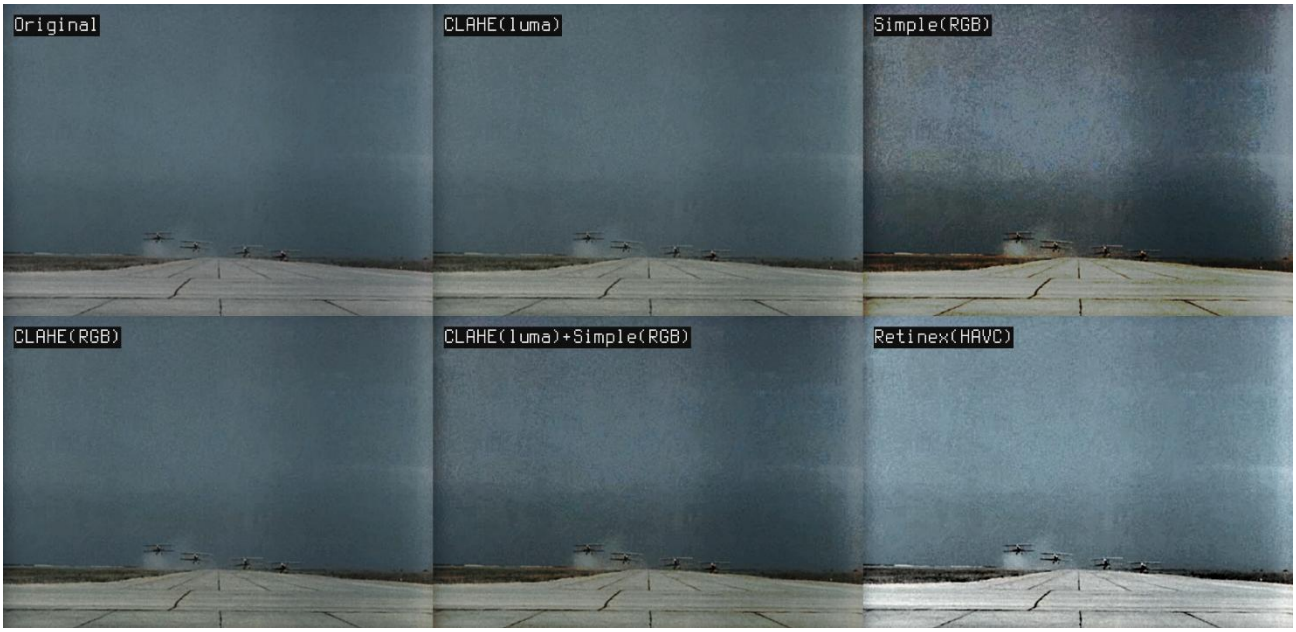
an example of filter effect is shown in the image below

- **B&W Blend**: As shown in the image above the method:1 provides very bright images, unfortunately on dark scenes this can produce visible artifacts, due to the fact that the true colors on dark images are not available. This effect can be mitigated by enabling the check box **B&W Blend** so that frames adjusted with **B&W Tune** will be blended with the original frames, as shown in the image below:

The blending will be activated only on dark images, while on bright images the blending will not be applied.

On bright images the differences on the method applied will be less visible as shown in the image below

But there are cases where the difference will be visible



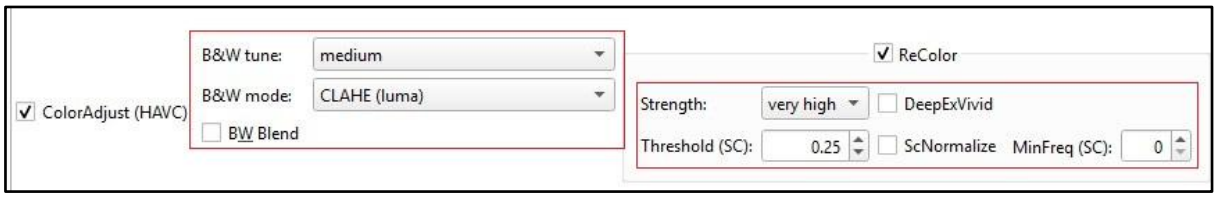
If in the colorized clip there are images like the one above it is safer to use the **method:0**, which is using *adaptive histogram equalization*, this method divide the input image into an 8x8 grid and then apply an equalization to each cell in the grid, resulting in a higher quality output image.

If **ReColor** is enabled the input clip will be recolored using **ColorMNet**, this approach is useful if the clip was colored with a model which produce instable colors (i.e. all the current colors models with only exception of HAVC when is properly configured). In this case the parameters that can be configured are:

- **Strength**: Color temporal stabilization strength, using high level the colors will be more stable but will be also more washed. Allowed values are: 0 = VeryLow (default), 1 = Low, 2 = Med, 3 = High, 4 = VeryHigh
- **ScThreshold**: Scene change threshold used to generate the reference frames to be used by ColorMNet. It is a percentage of the luma change between the previous and the current frame. range [0-1], default 0.10. If =0 are not generate reference frames. default = 0.10

- **ScNormalize**: If true the frames are normalized before using *misc.SCDetect()*, the normalization will increase the sensitivity to smooth scene changes, range [True, False], default: True
- **DeepExVivid**: if enabled (True) the ColorMNet memory is reset at every reference frame update range [True, False], default: True
- **ScMinFreq**: if > 0 will be generated at least a reference frame every "ScMinFreq" frames. range [0-1500], default: 0.

In case the colored clip to be restored has a high frequency of frames with incorrect colors, it is better to reduce the number of frames to be provided as a reference to ColorMNet to a minimum, by increasing the **ScThreshold** parameter to values within the range: 0.15:0.25 as shown in the picture below:



Given that in this case the reference frames used by ColorMNet will be low, it is possible to *uncheck* the option **DeepExVivid** to keep the ColorMNet memory and **ScNormalize** to lower further the number of reference frames.

➢ **Remark**: It is not possible to get the best color adjustment automatically, in most case it will be necessary to fine-tune the colors by applying the color adjustment filters available in Hybrid which are described in the chapter: Simple Hybrid filters for adjusting colors.

3.5 Chroma Adjustment

Unfortunately, when are applied to movies the color models are subject to assign unstable colors to the frames especially on the red/violet chroma range. This problem is more visible on DDColor than on DeOldify. To mitigate this issue was necessary to implement some kind of chroma adjustment. This adjustment allows to de-saturate all the colors included in a given color range. The color range must be specified in the HSV color space. This color space is useful because all the chroma is represented by only the parameter "Hue". In this color space the colors are specified in degree (from 0 to 360), as shown in the HAVC Hue Wheel. It is possible to apply this adjustment on all filters described previously. Depending on the filter the adjustment can be enabled using the following syntax:

Croma Range

chroma_range = "hue_start:hue_end" or "hue_wheel_name"

for example, this assignment:

chroma_range = "290:330,rose"

specify the range of hue colors: 290-360, because "rose" is hue wheel name that correspond to the range:330-360.

It is possible to specify more ranges by using the comma "," separator.

In HAVC are defined the following hue wheel names:

Name	Chroma Range
red	“0:30”
orange	“30:60”
yellow	“60:90”
yellow-green	“90:120”
green	“120:150”
blue-green	“150:180”
cyan	“180:210”
blue	“210:240”
blue-violet	“240:270”
violet	“270:300”
red-violet	“300:330”
rose	“330:360”

While the **color tweaks** are defined

Name	Chroma Range
magenta	“270:300”
magenta/violet	“250:360”
violet	“300:330”
violet/red	“300:360”
blue/magenta	“220:280”
yellow	“60:90”
yellow/orange	“30:90”
yellow/green	“60:120”

Chroma Adjustment

When the de-saturation information is not already available in the filter's parameters, it necessary to use the following syntax:

chroma_adjustment = "chroma_range|sat,weight"

in this case it is necessary to specify also the de-saturation parameter "sat" and the blending parameter "weight".

for example, with this assignment:

chroma_adjustment = "300:340|0.4,0.2"

the hue colors in the range 300-340 will be de-saturated by the amount 0.4 and the final frame will be blended (with weight 0.8=1-0.2) with the frame obtained by applying a de-saturation of 0.4 an all the pixels. (if weight=0, no blending is applied). The weight can also be negative, as shown in the example below:

chroma_adjustment = "300:340|0.4,-0.2"

In this case the hue colors in the range 300-340 will be de-saturated by the amount 0.4 as in the previous example, but the final frame will be blended (with weight 0.8) with the original (non de-saturated) frame (i.e. will be avoid the merge with the de-saturated frame in all pixels).

To simplify the usage of this filter has been added the Preset *ColorFix* which allows to fix a given range of chroma combination. The strength of the filter (i.e. de-saturation) is controlled by the Preset *ColorTune*.

3.6 Color Mapping

Using an approach similar to *Chroma Adjustment* has been introduced the possibility to remap a given range of colors in another chroma range. This remapping is controlled by the Preset *ColorMap*. For example, the preset "blue->brown" allows to remap all the chroma combinations of *blue* in the color *brown*. It is not expected that this filter can be applied on a full movie, but it could be useful to remap the color on some portion of a movie.

To use the color mapping feature is necessary to use the following syntax:

colormap = "chroma_range|hue_shifit,weight"

The color mapping is similar to the chroma adjustment, the difference instead to apply a desaturation to the given color range is applied a chroma hue shift.

For example, with this setting:

colormap ="30:90|+250,0.8"

the color range “30:90” (corresponding to yellow) will be shifted by +250 degrees, the original will be retained at 80%, because has been specified the weight=0.8 (the weight given to the adjusted frame is 0.2=1-0.8).

In the chapter HAVC Color Mapping/Chroma Adjustment are provided useful tips on how to use both the *Chroma Adjustment* and *Color Mapping* features provided by this filter.

In HAVC are defined the following color mapping names:

Name	**Color Mapping**
blue->brown	180:280|+140,0.8
blue->red	180:280|+100,0.8
blue->green	180:280|+220,0.8
green->brown	80:180|+260,0.8
green->red	80:180|+220,0.8
green->blue	80:180|+140,0.8
redrose->brown	300:360,0:20|+40,0.8
redrose->blue	300:360,0:20|+260,0.8
red->brown	320:360,0:15|+50,0.8
yellow->rose	30:90|+300,0.8

3.7 Merging the models

As explained previously, this filter is able to combine the results provided by DeOldify and DDColor, to perform this combination has been implemented 6 methods:

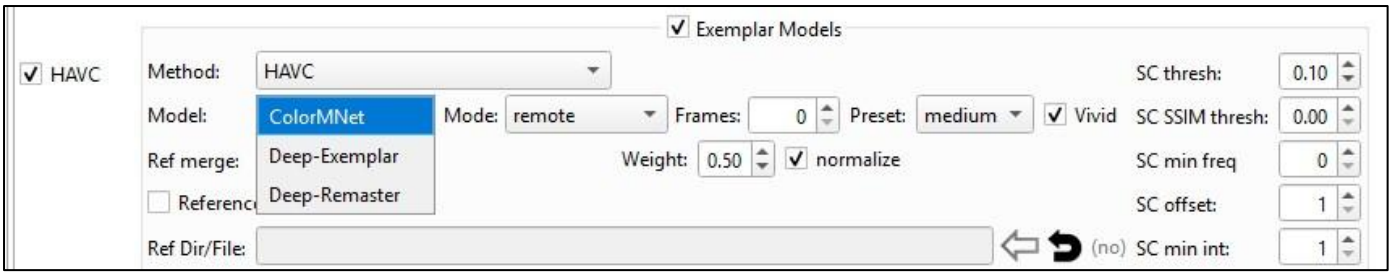
0. *DeOldify* only coloring model (no merge).
1. *DDColor* only color model (no merge).
2. *Simple Merge*: the frames are combined using a *weighted merge*, where the parameter *merge_weight* represent the weight assigned to the frames provided by the DDcolor model, using the following weighted sum: f_out = f_deoldify*(1- *merge_weight*) + *merge_weight* *f_ddcolor (see related parameter).
3. *Constrained Chroma Merge*: given that the colors provided by DeOldify *Video* model are more conservative and stable than the colors obtained with DDcolor. The frames are combined by assigning a limit to the amount of difference in chroma values between DeOldify and DDcolor. This limit is defined by the parameter *threshold*. The limit is applied to the frame converted to "YUV". For example, when threshold=0.1, the chroma values "U","V" of DDcolor frame will be constrained to have an absolute percentage difference respect to "U","V" provided by DeOldify not higher than 10%. If *merge_weight* is < 1.0, the chroma limited DDColor frames will be merged again with the frames of DeOldify using the *Simple Merge* (see related parameter).
4. *Luma Masked Merge*: the behavior is similar to the method *Adaptive Luma Merge*. With this method the frames are combined using a *masked merge*. The pixels of DDcolor's frame with luma < *luma_limit* will be filled with the (de-saturated) pixels of DeOldify, while the pixels above the *white_limit* threshold will be left untouched. All the pixels in the middle will be gradually replaced depending on the luma value. If the parameter *merge_weight* is < 1.0, the resulting masked frames will be merged again with the non-de-saturated frames of DeOldify using the *Simple Merge* (see related parameter).
5. *Adaptive Luma Merge*: given that the DDcolor performance is quite bad on dark scenes, with this method the images are combined by decreasing the weight assigned to DDcolor frames when the luma is below the *luma_threshold*. For example, with: *luma_threshold* = 0.6 and *alpha* = 1, the weight assigned to DDcolor frames will start to decrease linearly when the luma < 60% till *min_weight*. For *alpha*=2, the weight begins to decrease quadratically, because the formula applied is: ddcolor_weight = MAX[weight * (luma/*luma_threshold*)^*alpha*, *min_weight*] (see related parameter).
6. *Chroma Retention Merge*: Given that the colors provided by deoldify() are more conservative and stable than the colors obtained with ddcolor(). This function try to restore the colors of gray pixels provide by deoldify() by using the colors provided by ddcolor(). The gray pixels are identified by the parameter "*tht*". Once are identified the gray pixels are substituted with the desaturated colors in deoldify(), the level of desaturation is identified by the parameter "*sat*". It is performed a "gradient" substitution, i.e. the gray pixels are gradually substituted depending on the level of gray gradient. The steepness of gradient curve is controlled by the parameter "*alpha*". Optionally is possible to resize the frame before the filter application to speed up the filter by setting True the parameter "*chroma_resize*".
7. *ChromaBound Adaptive*: Adaptive version of Constrained-Chroma. In this version the chroma tolerance is adaptive, i.e., it is applied an approach that will allow more color variation in textured/complex regions and less in smooth areas. The texture strength is computed via Laplacian and chroma tolerance is controlled by the following parameters:
    - base_tol: int = 20, *Base chroma tolerance (smooth areas)*
    - max_extra: int = 24, *Extra tolerance for textured areas*

- **Remark**: The merging methods 2-7 are leveraging on the fact that usually the DeOldify *Video* model provides frames which are more stable, this feature is exploited to stabilize also DDColor. The methods 3, 4 and 7 are similar to *Simple Merge*, but before the merge with *DeOldify* the *DDColor* frame is limited in the chroma changes (method 3, 7) or limited based on the luma (method 4). The method 5 is a *Simple Merge* where the weight decreases with luma and the method 7 is an hybrid model that combines the approach of methods 4 and 5.

3.8 Exemplar-based Models

As stated previously to stabilize further the colorized videos it is possible to use the frames colored by HAVC as reference frames (exemplar) as input to the supported exemplar-based models: ColorMNet, Deep Exemplar based Video Colorization and DeepRemaster.

In Hybrid the *Exemplar Models* have their own panel, as shown in the following picture:



For the ColorMNet models there are 2 implementations defined, by the field **Mode**:

- 'remote' (has not memory frames limitation but it uses a remote process for the inference)
- 'local' (the inference is performed inside the VapourSynth local thread but has memory limitation)

The field **Preset** control the render method and speed, allowed values are:

- 'Fast' (faster but colors are more washed out)
- 'Medium' (colors are a little washed out)
- 'Slow' (slower but colors are a little more vivid)

The field **SC thresh** define the sensitivity for the scene detection (suggested value **0.10**), while the field **SC min freq** allows to specify the minimum number of reference frames that have to be generated.

The flag **Vivid** has 2 different meanings depending on the *Exemplar Model* used:

- **ColorMNet** (the frames memory is reset at every reference frame update)
- **DeepEx** (given that the colors generated by the inference are a little washed-out, the saturation of colored frames will be increased by about 25%).
- **DeepRemaster** (given that the colors generated by the inference are a little washed-out, the saturation of colored frames will be increased by about 15% and the Hue by 8).

The field **Method** allows to specify the type of reference frames (RF) provided in input to the *Exemplar-based Models*, allowed values are:

- 0 = HAVC same as video (default)
- 1 = HAVC + RF same as video
- 2 = HAVC + RF different from video
- 3 = external RF same as video
- 4 = external RF different from video
- 5 = external ClipRef same as video
- 6 = external ClipRef different from video

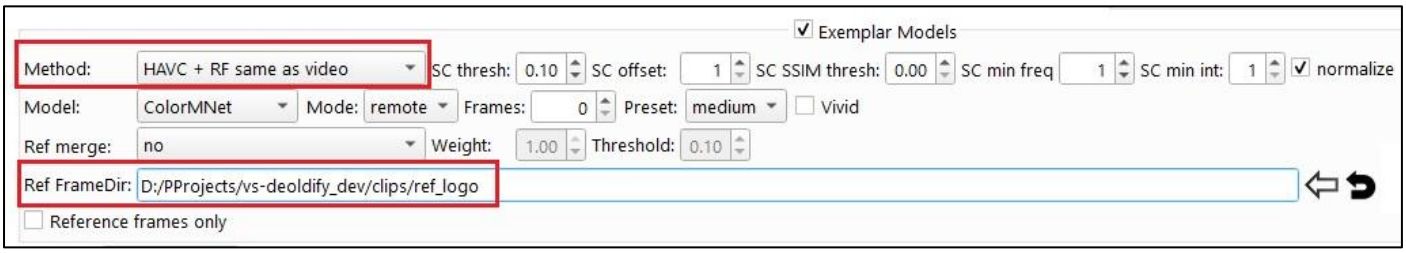
Where "*same as video*" implies that the reference frame provided (from file or video clip) is the same as the frame to be colored with the only exception of the colors. The model **DeepRemaster**, since it needs to access to the future frames, can be used only with methods: 3, 4, 5, 6.

It is possible to specify the directory containing the external reference frames by using the field **Ref FrameDir**. The frames must be named using the following format[9]: *ref_nnnnnn.[png | jpg]*, where the frame's number must have 6 digit. With the methods 5 and 6 it is possible to select as source of reference frames the path to a video clip. This feature is useful in the case a colored movie is already available but is necessary to improve the stabilization of colors using the exemplar-based models.

Finally, the flag **Reference frames only** can be used to export the reference frames generated with the method **HAVC** and defined by the parameters **SC thresh**, **SC min freq** fields. The fields methods: HAVC *+ RF same as video* and *HAVC + RF different from video*, can be used to correct the colors applied by the HAVC filter.

Supposing, for example that the movie to be colored starts with the logo of film producer. In this case it could be possible that the frames colored by the color model will apply different colors to the logo. To correct this problem, it is possible to create a folder that contains the logo reference frames as shown in the picture below:

supposing to have named the folder *ref_logo* it is possible to use it to properly colorize the logo frames using the following settings



In this case has been selected the **Method** *HAVC + RF same as video* because the reference frames were almost equal (with the only exception of the colors) to the B&W frames to colorize. To use this method is necessary to provide in the field **Ref FrameDir** the path of the directory containing the reference frames to be used by the exemplar-based model.

When is selected the Method **HAVC different from video**, it is possible to selected in **Ref FrameDir** a colored video (instead of a directory), that will be used to extract the reference frames to be used for the color inference by ColorMNet[remote all-ref]. This method cannot be used with **Ref merge** because frames different from video cannot be safely merged.

[9] In the chapter *Software for processing batch of pictures* is suggested a windows software for file renaming.

3.8.1 The new features problem

Unfortunately all the Deep-Exemplar methods have the problem that are unable to properly colorize the new "features" (new elements not available in the reference frame) so that often these new elements are colored with implausible colors (see for an example: New "features" are not properly colored)[10]. To try to fix this problem has been introduced the possibility to merge the frames propagated by DeepEx with the frames colored with DDColor and/or DeOldify. The merge is controlled by the field **Ref merge**, allowed values are:

- 0 = no merge
- 1 = reference frames are merged with very-low weight
- 2 = reference frames are merged with low weight
- 3 = reference frames are merged with medium weight
- 4 = reference frames are merged with high weight
- 5 = reference frames are merged with very-high weight

When the field **Ref merge** is set to a value greater than 0, the field **SC min freq** is set =1, to allows the merge for every frame. This parameter has been added to fix the problem reported in the post New "features" are not properly colored. For example, in the picture on the left below there is the frame #20 obtained by merging the propagated frame with the frame colored using DDColor and/or DeOldify. In the middle there is the propagate frame with no merge (the new features added in the frame were the hands). The reference image used for coloring the frame provided in input to the model DeepEx is displayed in the picture on the right:



Using ColorMNet the colored frame (with no merge) is a little better[11] as shown in the following picture:


0020.png


0021.png


0022.png

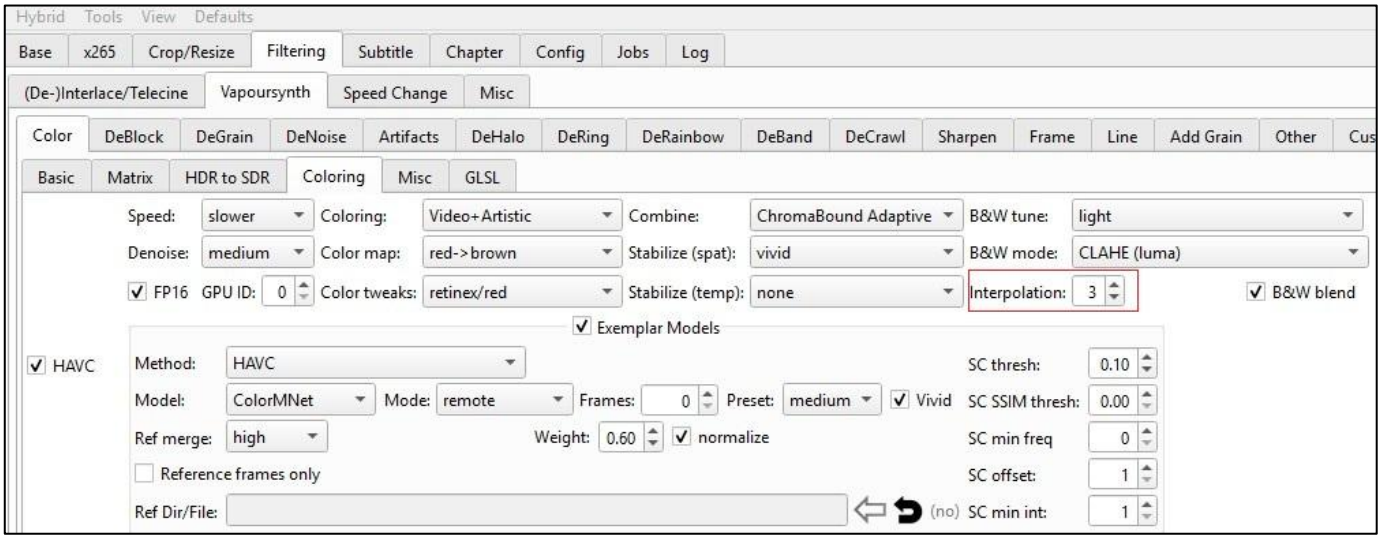
The code used to generate the merged frame #20 was:

```
clip = HAVC_main(clip,Preset='Medium',ColorFix='Violet/Red',ColorTune='Light',
EnableDeepEx=True, DeepExMethod=1, DeepExPreset='Medium', DeepExRefMerge=2,
DeepExModel=1, ScFrameDir="D:/Tests/Green/ref_color")
```

[10] The problem was mitigated with the release of ColorMNet.
[11] It is interesting to observe that ColorMNet was able to colorize 1 hand because was a little visible on the reference image.

3.8.2 HAVC Frame Interpolation: *using Exemplar-based models to speed-up the encoding*

The model Deep-Exemplar (*DeepEx*) and ColorMNet are able to propagate the colors of the reference frames received as input. This capability can be used to speed-up the HAVC coloring process. To enable this feature is just enough to set the filter interpolation to a value above 0, as shown in the image below:



In the example above the value of parameter **Interpolation** was set equal to 3. In this way the coloring filter will be called *only* every 3 frames, thus providing a theoretical speed-up of about 3x on the coloring process. The actual speed improvement is much less because it is necessary to introduce the overhead of Exemplar-based model used to propagate the colors, so that the total encoding speed will increase only of about 30%. The speed increase depends on selected **Speed** parameter as shown in the table below[12]:

Speed	frame/sec (interpolation=0)	frame/sec (interpolation=3)	Speed-up (%)
Placebo	6.1	9.1	49.2%
VerySlow	7.1	10.3	45.1%
Slower	7.6	10.1	32.9%
Medium	10.1	11.4	12.9%
Fast	10.2	11.5	12.7%
Faster	13.8	16.1	16.7%
VeryFast	16.1	16.4	1.9%

Using an **Interpolation** above 4, will increase further the speed, but *DeepEx* could have some problems in propagating correctly the colors because of new features problem described previously. To mitigate this problem when parameter **Interpolation** is set above 4, will be used the ColorMNet model to propagate the colors. Since ColorMNet has a long term memory and is able to propagate for long sequence of frames, the number of frames interpolated with ColorMNet is double, for example when **Interpolation**=10, the actual number of frames interpolated by ColorMNet will 10*2=20.

This increase in speed can be used, to use the HAVC slow presets *Placebo, VerySlow, Slower,* so that the colors generated by HAVC will be more accurate respect to faster presets like Medium (**Speed=***medium*).

- If is available a powerful GPU with at least 16GB of RAM, it is also possible to follow the method suggested in the chapter on Improving encoding speed for high-powered GPUs instead of using the **Interpolation** parameter described in this chapter.

[12] The speed was measured using a RTX 5070ti.

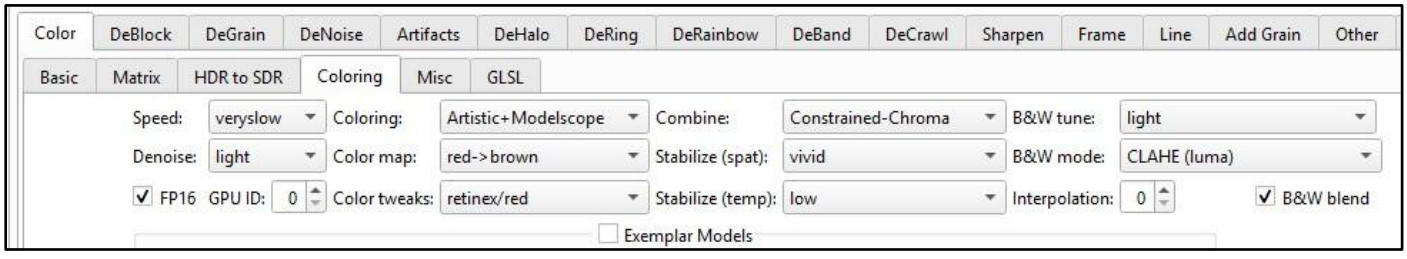
3.9 Problems in coloring old videos

The colorization process is strongly dependent on the luminance. The reason for such strong dependency is that the model during the training sees only the L channel (lightness) as input. In DeOldify and DDColor is implemented some kind of semantic understanding, but they don't have access to the original colors, edges, textures and they must infer color mainly from luminance. While this approach functions reasonably well on modern, clean inputs, it encounters significant obstacles when applied to footage from the 1930s and 1940s. In this era, the "L channel" is rarely a pristine representation of the visual scene; rather, it is often corrupted by the technical limitations of early cinematography. Because the model treats all variations in brightness as meaningful data, it inevitably misinterprets historical artifacts as physical features, leading to specific types of colorization failure.

- **Temporal Instability and Color Strobing**: The primary luminance defect in films of this period was flicker, caused by the unstable burning of Carbon Arc lamps used on set and in projectors. To a neural network, a sudden change in global brightness is not interpreted as a "flicker," but as a change in the lighting environment. The Consequence: When the luminance pulses upward, the model may infer a shift toward intense sunlight (warmer tones). When it drops, the model may infer shadows (cooler tones). This results in chromatic "strobing," where the colors of a static object oscillate rapidly between warm and cool across sequential frames.
- **High Contrast and Texture Loss**: Due to the low sensitivity ("slow speed") of chemical film stocks in the 30s and 40s, cinematographers utilized "hard lighting" to ensure exposure. This resulted in images with high contrast, characterized by crushed blacks and clipped whites. The Consequence: Deep learning models rely heavily on texture gradients found in the mid-tones to identify objects (e.g., distinguishing the texture of a wool suit from a silk dress). When luminance values are clipped at 0 (pure black) or 255 (pure white), this texture information is obliterated. Without these cues, the model cannot identify the object boundaries, leading to "color bleeding" or the rendering of flat, muddy hues in shadow areas.
- **Film Grain as False Texture**: Chemical film grain introduces high-frequency random noise into the luminance channel. A human viewer ignores grain, but a computer vision model sees it as high-contrast edge data. The Consequence: The model frequently mistakes luminance grain for physical surface texture, such as gravel, sand, or rough fabric. This causes the model to assign complex, variegated color patterns to objects that should be smooth, such as faces, sky, or walls, creating a blotchy or "dirty" appearance.
- **Optical Vignetting**: Early optics frequently suffered from vignetting, where the center of the image is bright, but the luminance falls off significantly toward the corners. The Consequence: Because the model assumes Color is a function of Luminance, it interprets the dark corners not as a lens defect, but as a change in the object's reflectivity. This can cause a uniform background, such as a blue sky, to artificially transition into grey, purple, or brown at the edges of the frame.

Conclusion

Ultimately, the failure cases in coloring vintage video are a signal-to-noise problem. In HAVC the presets *VerySlow* has been implemented to try to mitigate the luminance problems of movies filmed in 30s and 40s, and in the next chapter will be suggested to use the following settings.



But if the clip is very old and the damage/noise on luminance is very high, the best option is to keep it in B&W, or to try to coloring it with *Denoise* set to **strong** instead of **light** as shown in the image above.

4.0 Coloring using Hybrid

As stated previously the simplest way to colorize images with the HAVC filter is to use Hybrid. HAVC can be considered the *Swiss Army knife* for coloring videos. It offers a wide range of options, but choosing the best one isn't easy, as they depend on both the GPU's power and the type of film being colored. To simplify the usage has been introduced standard Presets that automatically apply all the filter's settings. But these presets don't cover all the available options.

4.0.1 Best settings based on GPU power

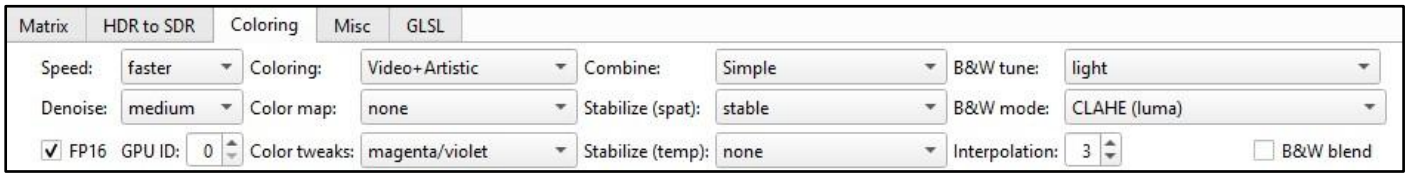
In this section will be suggested some configurations that are able to provide a satisfactory colorization and could be useful for most users.

Best settings for low powered GPU

The configuration parameters are the following:

- **Speed:** faster
- **Color map:** none
- **Color tweaks:** magenta/violet
- **Denoise:** medium
- **Stabilize (spat):** Stable (or MoreStable)
- **Stabilize (temp)**: none
- **Combine**: Simple
- **Interpolation:** 3
- **B&W tune**: Light
- **B&W mode**: CLAHE (luma)
- **B&W blend** : unchecked

then disable the *Exemplar Models* by unchecking the box, as shown in the following picture



Best settings for medium powered GPU

The configuration parameters are the following:

- **Speed:** slow
- **Color map:** red->brown
- **Color tweaks:** retinex/red
- **Denoise:** medium
- **Stabilize (spat):** Balanced (or Vivid)
- **Stabilize (temp)**: none

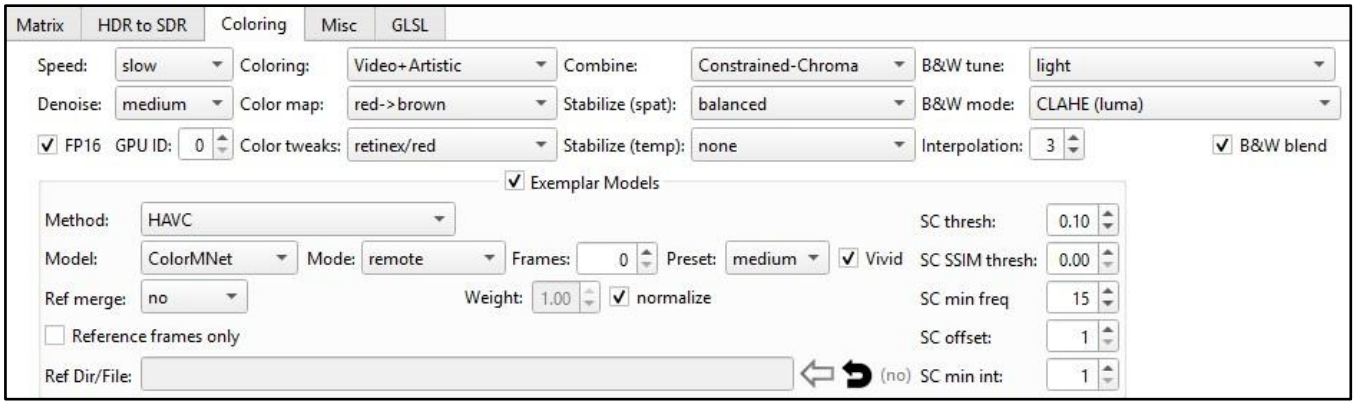
- **Combine**: Constrained-Chroma
- **Interpolation:** 3
- **B&W tune**: Light
- **B&W mode**: CLAHE (luma)
- **B&W blend** : checked

then enable the *Exemplar Models* by checking the box and set the following parameters:

Method: HAVC

- **SC thresh:** 0.10
- **SC SSIM thresh:** 0.0
- **SC min freq:** 15 (5 if is used the *local* mode)
- **normalize:** checked
- **Mode:** remote
- **Frames:** 0
- **Preset:** medium (*slow* will increase the color accuracy but the speed will decrease of 40%)
- **Vivid:** checked

In the following picture are shown the suggested parameters:



In ColorMNet using the flag **Vivid** the internal memory will be reset at every new reference frame; this will allow to assign the maximum weight to the last reference frame during the inference and the color propagation will depend only from the last reference added. By unchecking **Vivid** the last reference frame will be added to the internal memory and the inference will depend from all the reference frames provided in input, this will produce sometime unwanted blend effect where the propagate colors can be different from the last reference image.

Best settings for high powered GPU

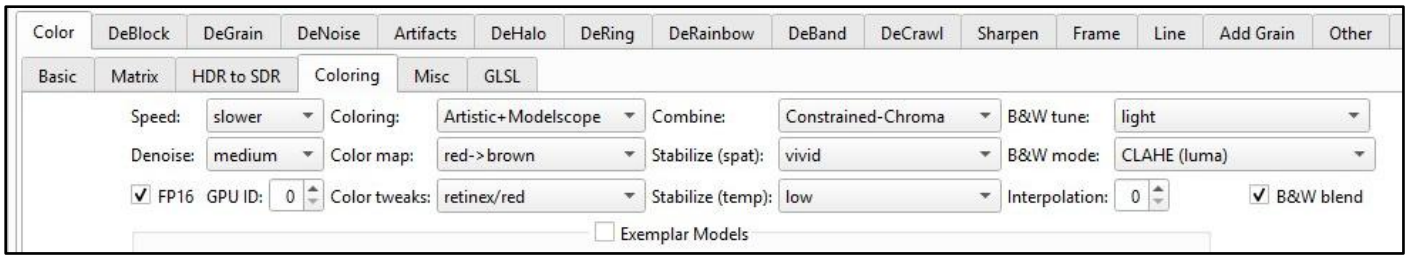
The configuration parameters are the following:

- **Speed:** veryslow (or slower)
- **Coloring:** Artistic+Modelscope (or Video+Modelscope)
- **Color map:** red->brown

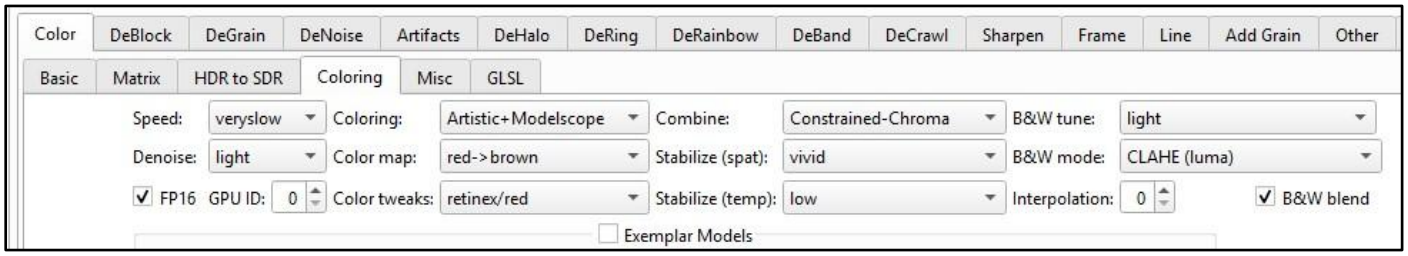
- **Color tweaks:** retinex/red
- **Denoise:** medium (or light)
- **Stabilize (spat):** Vivid (or MoreVivid)
- **Stabilize (temp)**: medium (or low)
- **Combine**: Constrained-Chroma
- **Interpolation:** 0
- **B&W tune**: Light
- **B&W mode**: CLAHE (luma)
- **B&W blend** : checked

then disable the *Exemplar Models* by unchecking the related box.

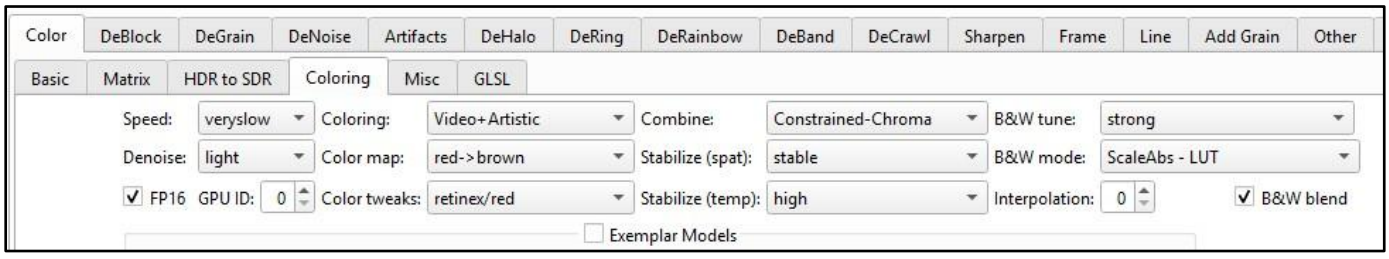
In the following picture are shown the settings for more recent movies *filmed in the 50s and 60s* :



For older movies like the films *shot in the 30s and 40s*, it is possible to use the following settings:



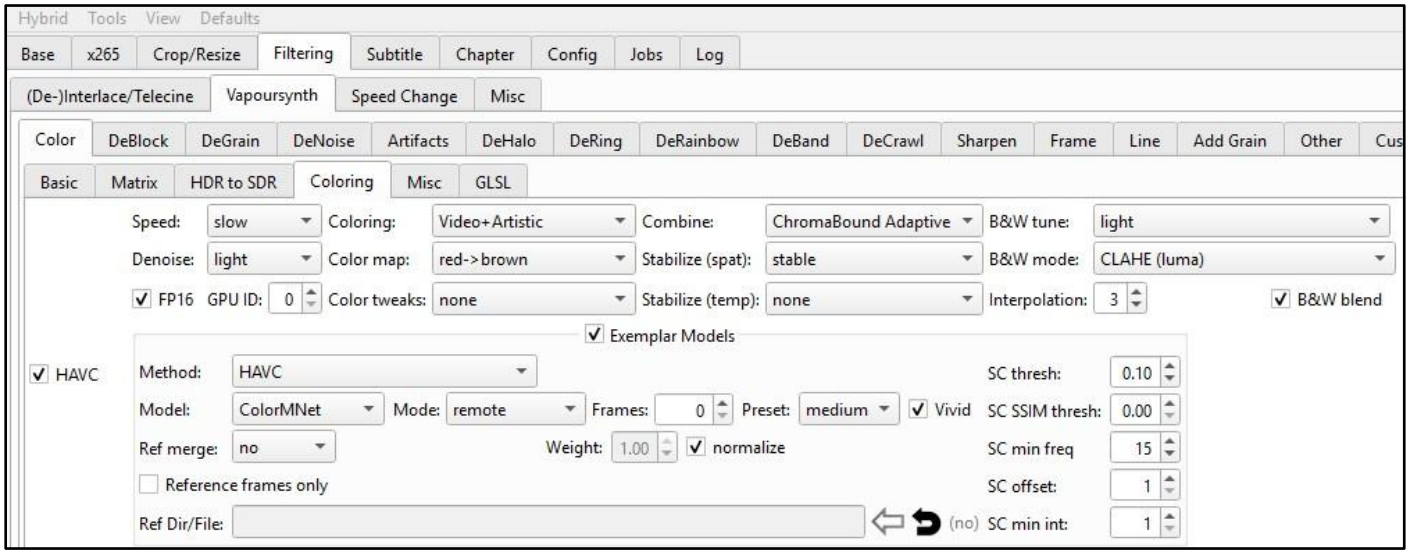
As explained in the chapter on Problems in coloring old videos, the colorization process is strongly dependent on the luminance and unfortunately the movies filmed in the 30s and 40s were affected by luminance problems. The presets *VerySlow* has been implemented to try to mitigate the luminance problems of movies filmed in 30s and 40s. But don't expect miracles if the movie is very damaged, there are no effective filters that can remove the noise on the luminance, in these case it is better to keep the movie in B&W. Alternatively, if the luminance component is very damaged it is possible to try to set the settings shown in the picture below:



It is very important to set the *B&W Mode* parameter to **ScaleAbs-LUT** and *B&W Tune* to **strong** as explained in the section: HAVC Filter + Color tweaks.

Apply HAVC RGB denoise

Another interesting configuration is to disable the *Color tweaks* and to substitute them with the HAVC RGB denoise filter. This filter has the same scope of reducing the color hallucinations as *Color tweaks* but is some case is more effective. To enable it is necessary to set *Color tweaks* to **none** and *Denoise* to **light** as shown in the picture below:

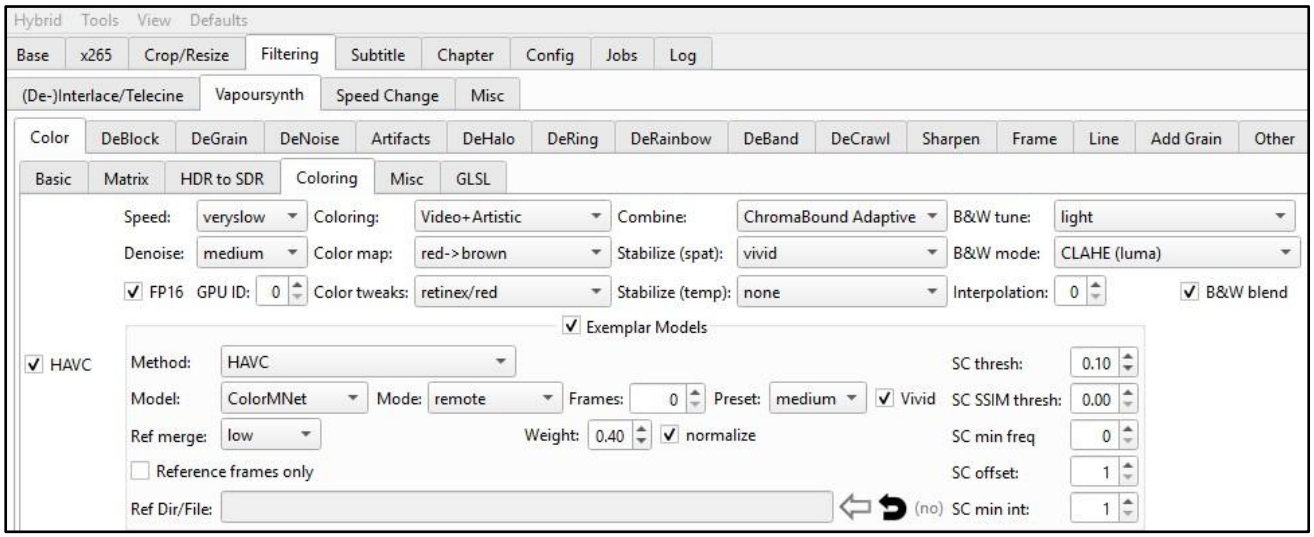


Video Encoding: Once all the filter parameters are set it is possible start the encoding process by pressing the Encoding button 2 as described in the section GUI Explanation.

- **Remark**: Should the encoded video exhibit color desaturation or insufficient rosiness in skin tones, refer to the settings outlined in the chapter for correction: Simple Hybrid filters for adjusting colors.

4.0.2 Best settings for colors temporal stability

Willing to obtain the best results, but at cost of speed it is possible to improve further the color stability using the settings shown in the following picture:



Respect to the previous configuration has been changed the following parameters (highlighted in red box):

- **Speed:** veryslow
- **Ref merge**: low
- **Weight**: 0.40 (automatically filled)
- **Threshold**: 0.10
- **Vivid:** checked
- **Normalize:** checked
- **B&W tune**: light (or medium)

As explained in The new features problem in this way the frames propagated by exemplar-based models will be merged with the frames colored with DDColor and/or DeOldify. In practice will be merged 3 frames. This will improve further the temporal color stability while maintaining the color accuracy, and thus avoiding the color degradation (observed in the frames propagated using the exemplar-based models) when new features are introduced. The strategy adopted by HAVC in this case is the following:

1) all the clip frames are colored using DDColor and/or DeOldify (because the parameter SC min freq = 1)
2) using the threshold specified (in this case 0.10) a subset of colored frames is sampled by the scene change detection algorithm and these frames are used as reference images for the selected exemplar-based model (in this case ColorMNet).
3) the frames obtained at step 1 are merged with the weight specified (in this case 0.50) with the frames propagated by the selected exemplar-based model.

This approach will allow to maintain the temporal color consistency provided by the exemplar-based models[13] and at the same time to keep the color quality provided by DDColor and/or DeOldify. Willing to improve the color temporal consistency it is possible to increase the **SC thresh** from 0.10 to 0.15, uncheck the option **normalize** and **Vivid**, in this way the reference images will be fewer and ColorMNet will be forced to generate more stable colors.

The only methods that can be used with **Ref merge** are **HAVC** and **HAVC + RF same as video**, in this case it is just enough providing a valid path in the field **Ref FrameDir** containing the reference images.

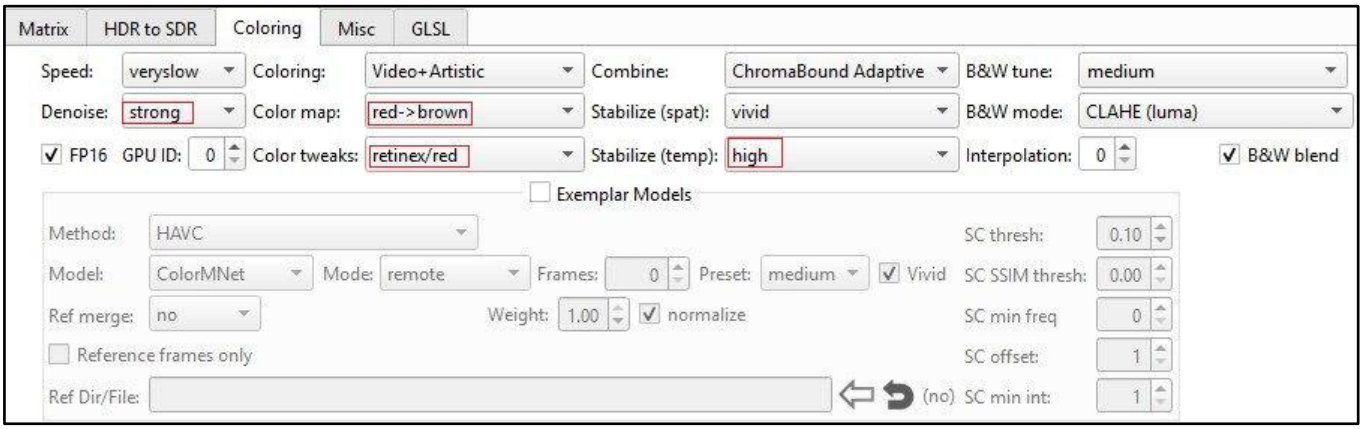
[13] In ColorMNet the effect is reinforced by setting the parameter **Vivid** unchecked.

Unfortunately, this quality improvement has a cost, and using this approach the encoding speed will decrease about of 50% respect to the approach suggested previously. The only way to increase the speed is to upgrade the GPU (Nvidia RTX4070 or above).

- With the HAVC version 5.6.0 has been instructed the option **Stabilize (temp)**, which uses under the hood the model ColorMNet, hen set to *high*, provides a stabilization similar to the one described in this section.

4.0.3 Best settings to remove colors shifting towards red

Unfortunately, all the pictures-based color models: DeOldify, DDColor and Zhang (siggraph17, eccv16), suffer from the problem that they tend to shift the colors towards red. By changing some of the settings described in the previous chapter it is possible to mitigate the problem. The suggested settings are shown in the following picture:

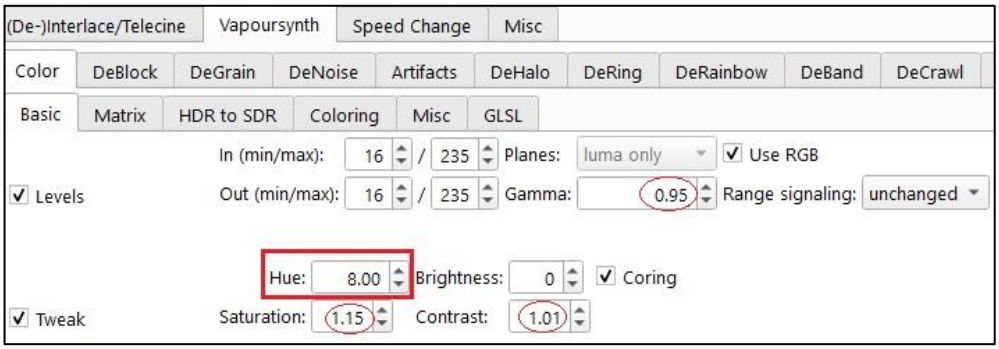


Respect to the previous configuration has been changed the following parameters (highlighted in red box):

- **Denoise**: strong
- **Stabilize (temp)**: high
- **B&W tune**: medium

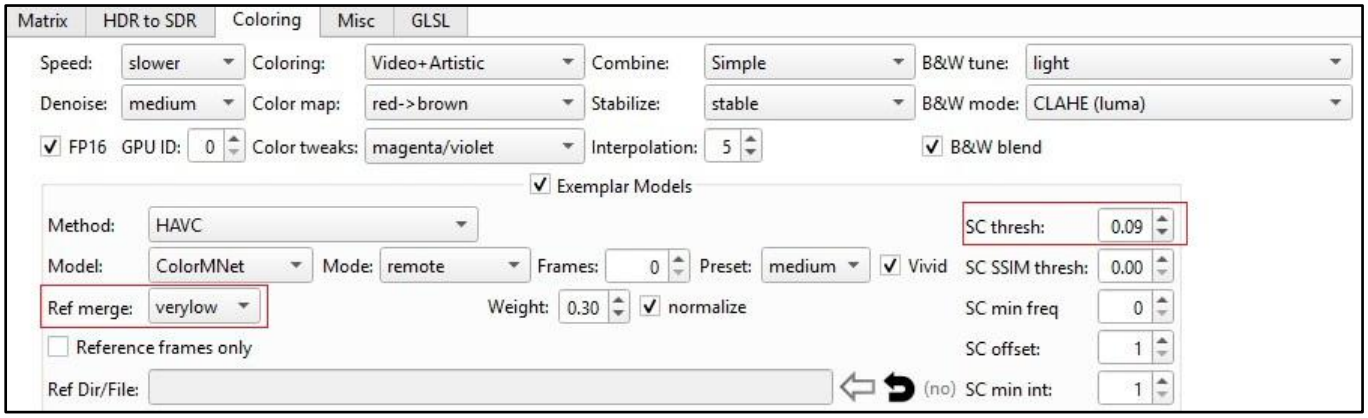
The option B&W Tune is the one most important option to fix the problem of colors that tend to shift towards red. But also the option **Denoise** = *strong* when used in combination with **Color tweaks** = *retinex/red* can contribute significantly to solve the problem. As explained previously the Color Mapping allows to change a range of colors in another range, by shifting the Hue color component (in HSV color space). Using the preset *red->brown* the pixels in the frames having the specified range will be shifted toward the brown color. Using the **Denoise** equal to *strong* the *violet/red* components will be strongly desaturated and this will contribute to mitigate the red-shift problem. To enforce the effect can be selected the **Stabilize (spat)** preset *morestable*, this will lower the weight of color models DDColor and Zhang (siggraph17, eccv16) which are strongly affected by this problem. Finally, can been selected the preset **Stabilize (temp)** equal to *very high*, so that the frames colorized by ColorMNet (used under the hood by **Stabilize temp.)** will have more weight. The exemplar-based model ColorMNet is almost not affected by the problem of shifting the colors towards red, and so by given to it more weight will contribute to mitigate further the problem.

Unfortunately, by using the preset **Color map** equal to *red->brown* will change also the color of the skin toward the yellow-brown. To fix this *side effect* it is possible to add as coloring post-process, the tweak filter to shift the Hue by a value of 8.0 (or higher). This filter can be found in the panel: **Filtering->Vapoursynth->Color->Basic** as shown in the picture on the right (with some suggested settings highlighted in red). The filters to adjust the colors available in Hybrid are described in the chapter: Simple Hybrid filters for adjusting colors.



At the following links are available some examples of using the proposed settings to reduce the problem of colors shifting towards red: https://imgsli.com/MzM5MjQ1, https://imgsli.com/MzM5MjQ2, https://imgsli.com/MzM5MjQ3.

The approach described previously works well if there are few environments in the movie. In the case in the movie there are a lot of different environments indoor/outdoor, the result obtained could be not satisfactory. In this case it is possible to adopt a different approach by using the settings displayed in the following picture:



Respect to the previous configuration has been changed the following parameter (highlighted in red box):

- **SC thresh**: 0.09
- **B&W tune**: light

The parameter **SC thresh** was lowered to 0.09. For low thresholds below 0.10 the filter will adopt another algorithm that is able to properly handle this low sensitivity levels[14].

For some movies the reference images produced by using a threshold of 0.10 are not enough to allow to ColorMNet to properly propagate the colors. By lowering the thresholds, the generated reference images will increase, allowing ColorMNet to improving the color propagation.

It is not suggested to decrease the threshold too much, because this could generate too many reference frames canceling the stabilizing effect of ColorMNet. This is the reason why it is suggested to start with a threshold of 0.10, because it is the threshold that will produce the maximum stabilization, and to lower it to 0.09 only if there are video

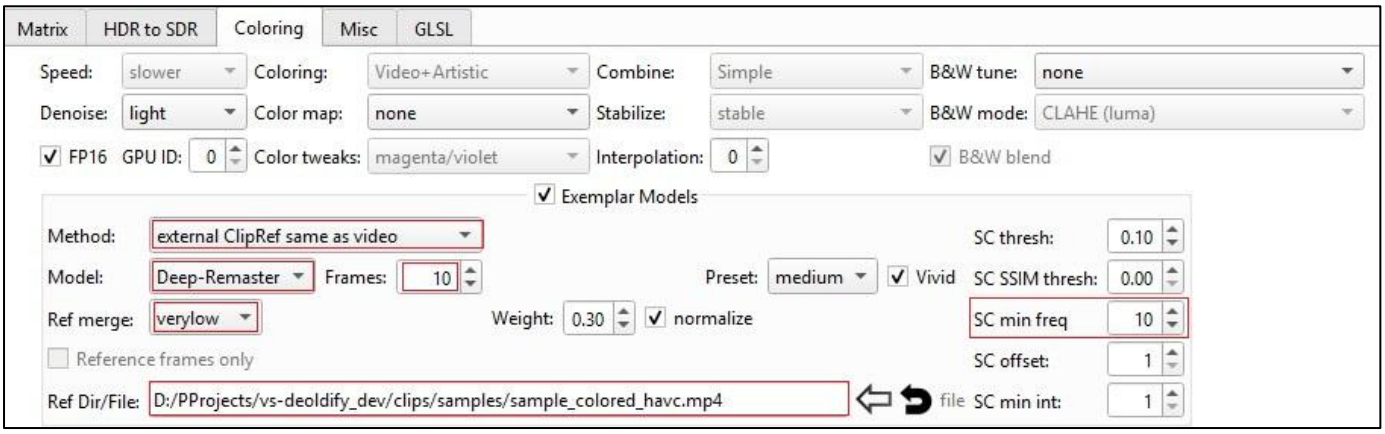
[14] Unfortunately, the function *SCDetect* implemented in Vapoursynth is not working properly with thresholds below 0.10.

sequences not properly colored[15]. Of course, is not guaranteed that by lowering the threshold the problem will be solved, but it's worth giving it a try.

Not knowing in advance if in the movie there are a lot of different environments indoor/outdoor, and not having time to do some test, probably the proposed settings using the threshold of 0.09, is the best option to produce a satisfactory colorized movie.

In the case the movie colored with the settings previously suggested is still not satisfactory because there are still frames with colors that shift towards red. It is possible to adopt a more conservative approach which consists in using the colored movies as source for an exemplar-based model. Among all the exemplar-based models the one that provides the most stable colors is DeepRemaster. Unfortunately, in some cases ColorMNet it is affected by the same DDcolor problem of introducing red artifacts in the frames, and so it is not suggested using it in this combination.

In the following picture are shown the settings with the more conservative approach available in HAVC to remove the problem of frames with colors that shift towards red:



Respect to the previous configuration has been changed the following parameter (highlighted in red box):

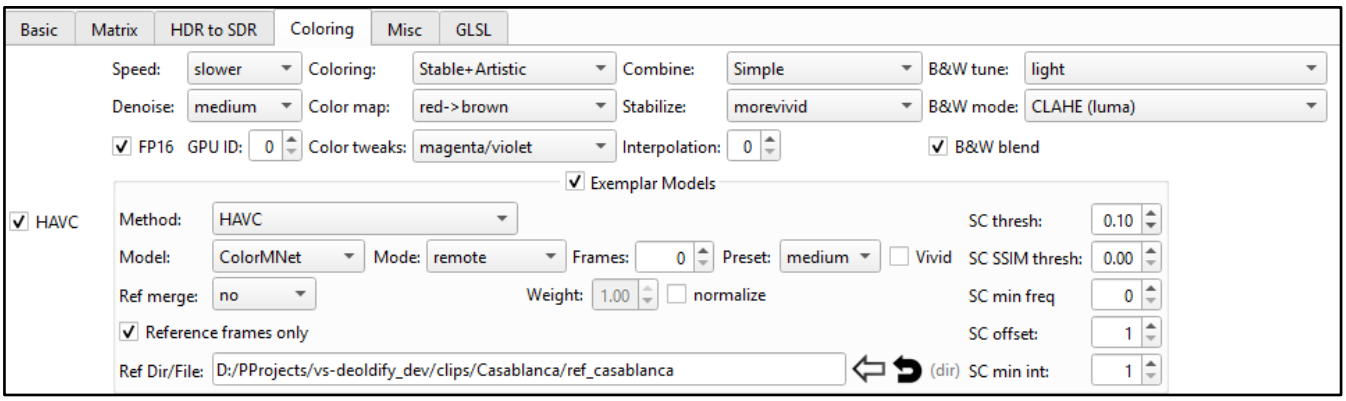
- **Method**: external ClipRef same as video
- **Model**: Deep-Remaster
- **Frames**: 10
- **Ref merge**: verylow (or low)
- **SC min freq**: 10
- **Ref File**: path to the colored movie colored with HAVC with unsatisfactory colored frames

For DeepRemaster a value of frames equal to 10 will allow the model to provide more conservative colors because having more reference frames will allow DeepRemaster to smooth the fast color transitions usually observed when picture-based models are used to colorize movies. A frame number of 4 is the minimum suggested, with a low number of reference frames the color inference will be about 40% faster but probably the estimated colors will be less conservative. An extension of this approach will be described in the chapter on using HAVC to restore colored videos.

➢ **Remark**: It is very difficult obtain the best results using only an automatic colorizer. An approach that is able to provide better result is an hybrid approach that requires both manual and automatic processing. In the chapter *Advanced coloring using adjusted reference frames* will be described how to improve the coloring process by manually selecting the best reference frames to be used for the automatic coloring process. Given the possibility

[15] If the video sequences that are not properly colored are few, it is possible to follow the approach described in the chapter on Advanced coloring using adjusted reference frames, to provide the adjusted reference frames to properly colorize these sequences.

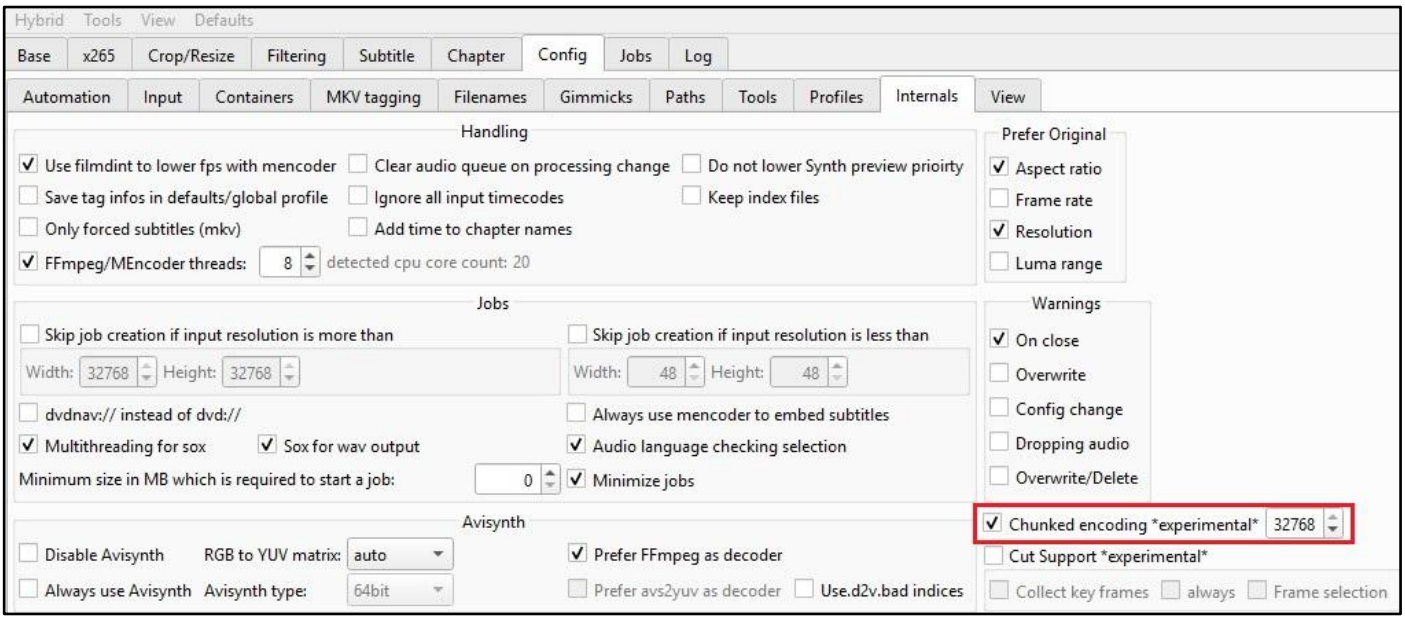
to select the reference frames to be used, it is possible to select the HAVC parameters providing more vivid colors as shown in the following picture:



4.0.4 Improving encoding speed for high-powered GPUs

Having a powerful GPU with at least 16GB, it is possible to speed-up the encoding time by using parallel encoding.

It is possible to enable parallel encoding in Hybrid by enabling the Chunked encoding the option: **Config->Internals-> Chunked encoding:**experimental****, as shown in the picture below

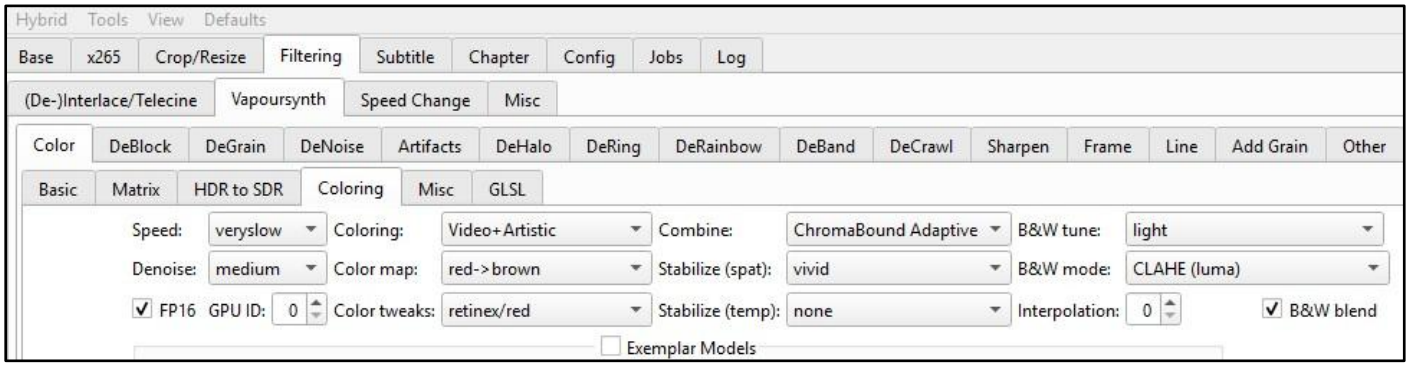


When enabled Hybrid will try to use split the video stream into chunks. Each chunk consists of one scene (which is at least 10 frames long). Encode each chunk separately and then join the chunks before muxing.

The **Min chunk scene size** parameter, allows to set the minimum distance between two scene changes during the chunk building, if the a scene change appears before this minimum it will be added to the next chunk.

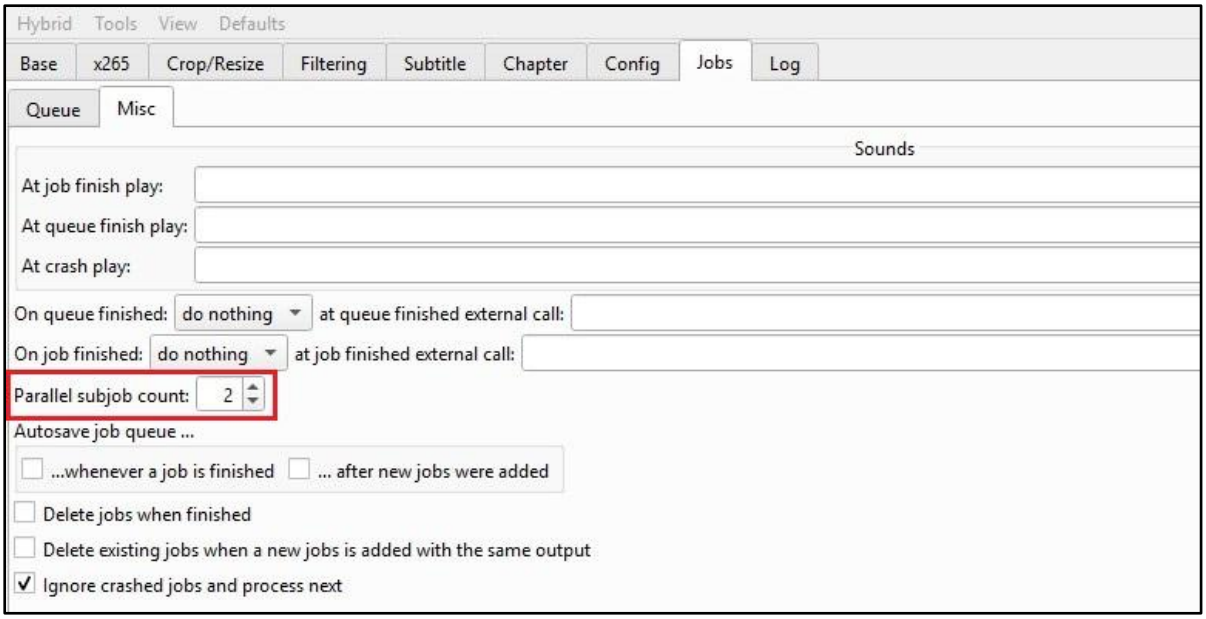
- ***Important** note about chunk encoding*
  - chunking is not possible with two pass encoding
  - it is better to set the **Min chunk scene size** to the max value of 32768 to minimize the number of chunks, with this value will be generated a chunk every 22min.
  - is not possible to use the **Exemplar Models** or **Stabilize (temp)** or **Interpolation** (due to high memory requirements)

The suggested HAVC settings to use for the parallel encoding are shown in the picture below

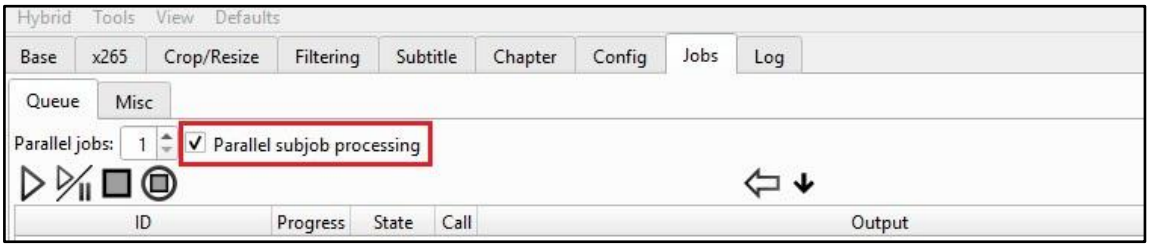


As stated previously, due to the high memory requirements is not possible to use the **Exemplar Models** or **Stabilize (temp)** or **Interpolation**, with a GPU with VRAM less than 24GB. In any case before increment the number of sub-jobs is better to monitor the GPU RAM usage with *Task Manager*.

With this option the clip is split in several chunks, but to be able to encode these chunks in parallel is also necessary to set the number of **Parallel jobs count** to at least 2/3, as shown in the picture below.



Then is necessary to enable the option **Parallel subjob processing** (see picture below), because in Hybrid every chunk encoding is considered a subjob.



Having a GPU with more RAM, for example 24GB, it is possible to increase the number of Parallel subjob to 4 or 5. As stated previously, it is better to monitor the GPU RAM usage with *Task Manager* before decide to increase the number of Parallel subjob above the suggested limit of 2 (*repetita iuvant*).

4.1 HAVC Color Mapping/Chroma Adjustment

In this chapter will be described the usage of parameters colormap and chroma adjustment. As suggested in the previous chapter, the colormap parameter can be used to change a range of colors in another range, and in the previous chapter this feature was used to mitigate the problem of colors shifting towards red. In this chapter will be shown how to use it to change the color of a specific portion of a frame. While this chapter can be useful to understand how to create new color mapping, in the chapter on advanced coloring will be proposed a better way to propagate the color adjustments.

4.1.1 Example of Color Mapping

Let's start with a simple example.

Here a frame obtained by using the HAVC with the following code

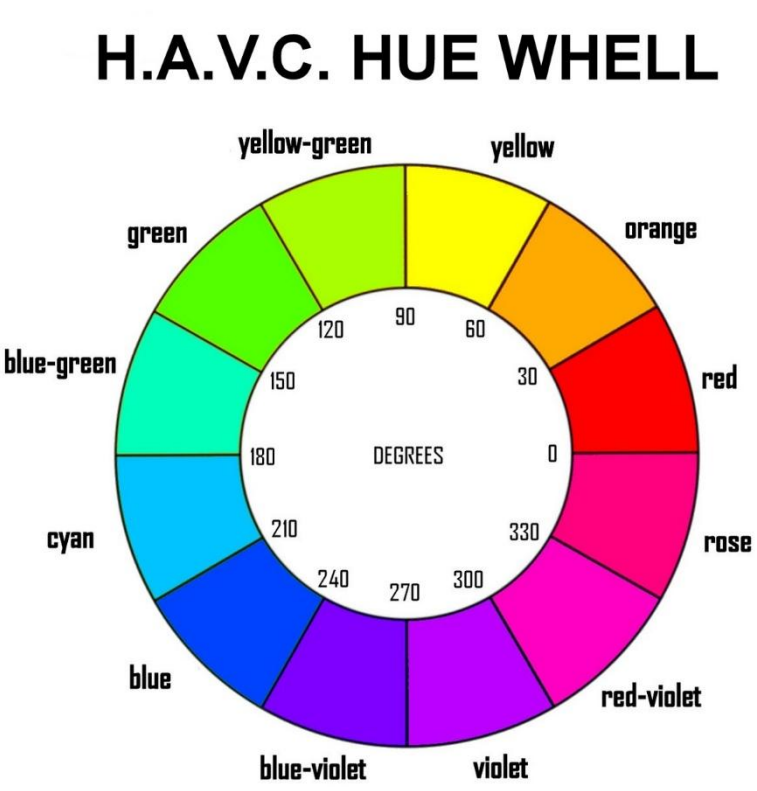
```
clip = HAVC_colorizer(clip=clip, ddtweak=True)
```

The colored frame is quite good, but the woman's hand is almost yellow.

Using the "Color Mapping" feature it is possible to correct this defect.

The "Color Mapping" feature allows to change a given range of colors.

To be able to perform the change in necessary to specify the target range of colors using the HUE defined in HSV color space.



There are a lot of Painting programs that allows to see the HUE of a range of pixels, but the simpler approach is to use the following **HAVC COLOR WHEEL**:

In the HSV color space the colors are specified in degrees from 0 to 360. In this case it is possible to see the yellow range is between 60 and 90. But to be more conservative it is better to include also the orange, so that the chroma range that we want adjust is the following: "30:90".

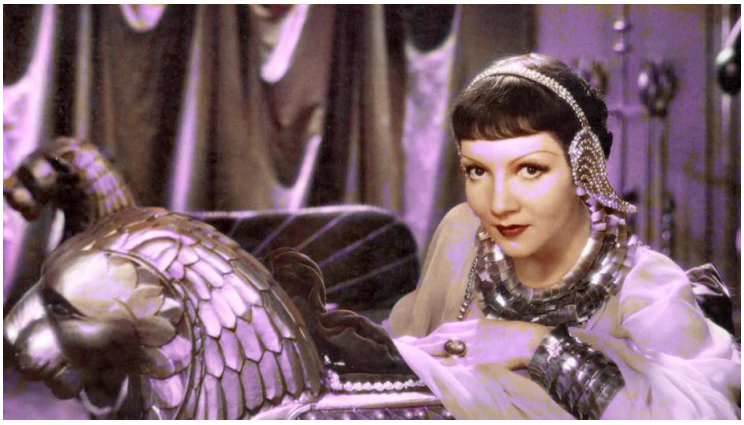
Now that we have selected the range; to change the colors we need to define the HUE SHIFT that need to be added to arrive to our preferred range of colors. We want to arrive in the range that in the HUE WHEEL is called

"red-violet"/"rose". To arrive in this range, we need to add about 250 degrees (250+30=280->"violet", 250+90=340->"rose").

To perform this mapping is necessary to run this code after **HAVC_colorizer**()

```
clip = HAVC_stabilizer(clip=clip, dark=True, colormap="30:90|+250,0.0")
```

In the picture below it is possible to see the result obtained. The result is quite bad, but it is useful to see the range of colors that has been changed.



Now we need to specify the last parameter, the "weight". Using this parameter, it is possible to merge the image obtained using the color mapping with the original image.

In this way it is possible to blend the color differences and obtain a more realistic effect.

Since we want to apply only a little change in color, we can try to retain the 80% of the original image. This can be done by using the following code

```
clip = HAVC_stabilizer(clip=clip, dark=True, colormap="30:90|+250,0.8")
```

Here the new image:

Now the image is more realistic!

It is possible try to increase the HUE SHIFT to include also the RED component, this can be obtained by increasing the shift to 300 degrees.

Let's try the following command

```
clip = HAVC_stabilizer(clip=clip, dark=True, colormap="30:90|+300,0.8")
```

Here the image obtained:

Even this image is quite good.

To simplify the comparison was created the following album: https://imgsli.com/MjYxNjY5

4.1.2 Example of Chroma Adjustment

The "Chroma Adjustment" is similar to the "Color Mapping" the difference is that instead to apply a HUE SHIFT to the selected hue range, the selected colors are de-saturated.

Suppose, for example that in some frames the "Violet/Red" component is too strong. In this case the color is correct but it is necessary to reduce its intensity, to do that is necessary to de-saturate the color.

For example with this command

```
clip = HAVC_colorizer(clip=clip, ddtweak=True, ddtweak_p=[0.0, 1.0, 2.5, True, 0.3, 0.6, 0.7, 0.5, "300:360|0.5,0.1"])
```

the saturation of colors in the range "300:360" (that correspond to "red-violet/rose" of HUE WHEEL) will be reduced by 50% (parameter "|0.5") the final image will be blended at 10% (parameter ",0.1" after the de-saturation parameter "|0.5"). In this case the chroma adjustment will be applied only to the frames colored by DDColor.

Willing to apply the de-saturation on the final-colored frame, it is possible to use the following command

```
clip = HAVC_stabilizer(clip=clip, dark=True, smooth=True, smooth_p=[0.3, 0.7, 0.9, 0.1, "300:360|0.5,0.1"])
```

To apply the adjustments to the frames colored by **HAVC_colorizer()** it is necessary to apply the post-process filter **HAVC_stabilizer()**.

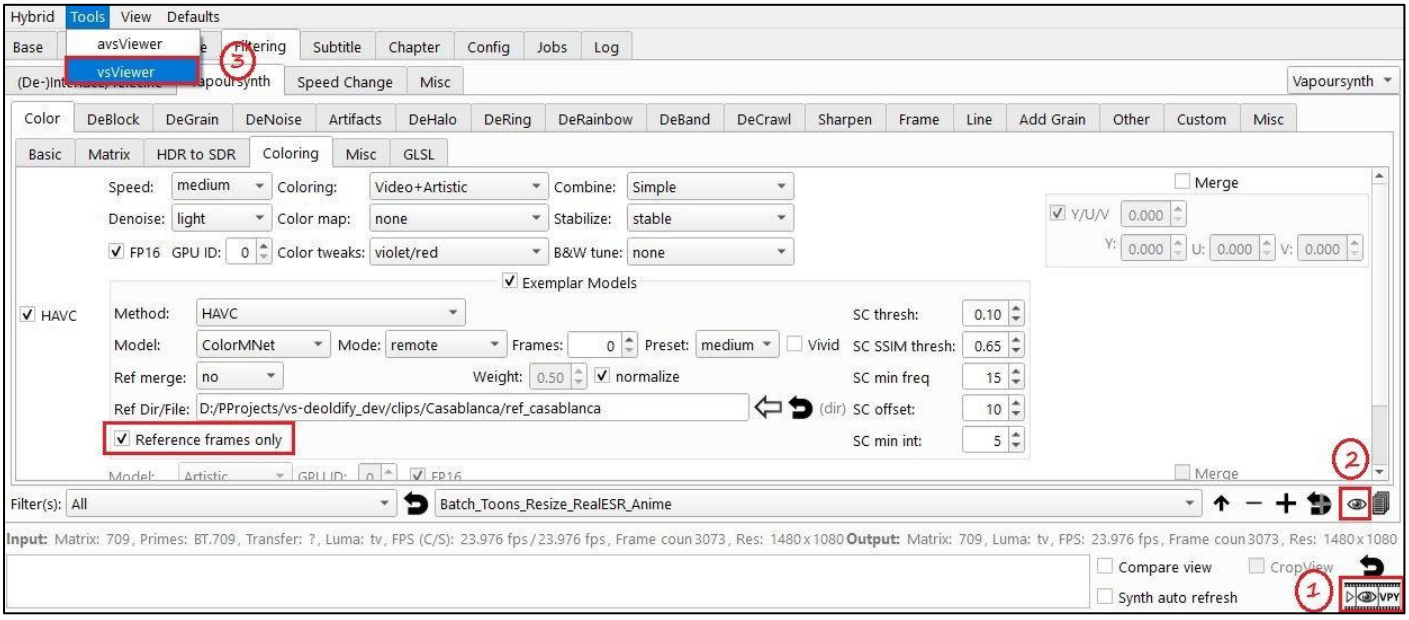
A helpful way to learn how to use these adjustments is to use the Presets.
In Hybrid when is selected a Preset different from "custom" the filter parameters will be disabled, but their values will be updated with the setting defined by the Preset.

The Preset that control the "Color Mapping" is *Color map* while the presets controlling the "Chroma adjustment" are *ColorFix* and *ColorTune*.

4.2 Advanced coloring using adjusted reference frames

In this chapter will be described how to improve the coloring process by manually adjusting the reference frames. In this guide will be used as sample movie to colorize the following clip[16]: https://archive.org/details/casablanca-1941-hd-trailer

Having downloaded the test clip, it is possible to add it in input to Hybrid using drag-and-drop. In order to be able to manually adjust the reference frames, it necessary first to generate and export them in a folder. In the following picture are shown the filter settings necessary to perform the export[17]:



In the GUI there are 2 preview buttons. The **button (1)** will allow to preview the filtered frames, while the **button (2)** will allow to preview the code automatically generated by Hybrid. The check box **Reference frames** only is necessary

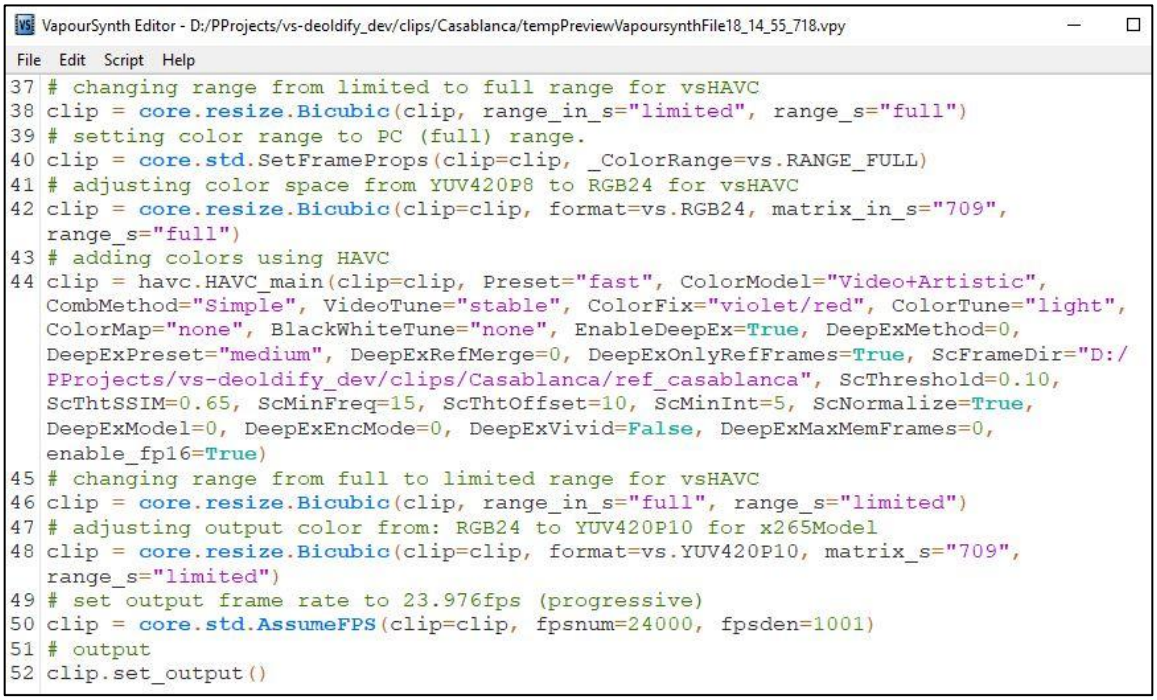
[16] It is suggested to download it using the TORRENT link.

[17] The HAVC settings shown in the picture are provided only as example. To generate the reference frames can be applied any of the settings suggested in the previous chapters. What is important is to check the box **Reference frames only** and provide the directory to output the frames in **Ref Dir/File**.

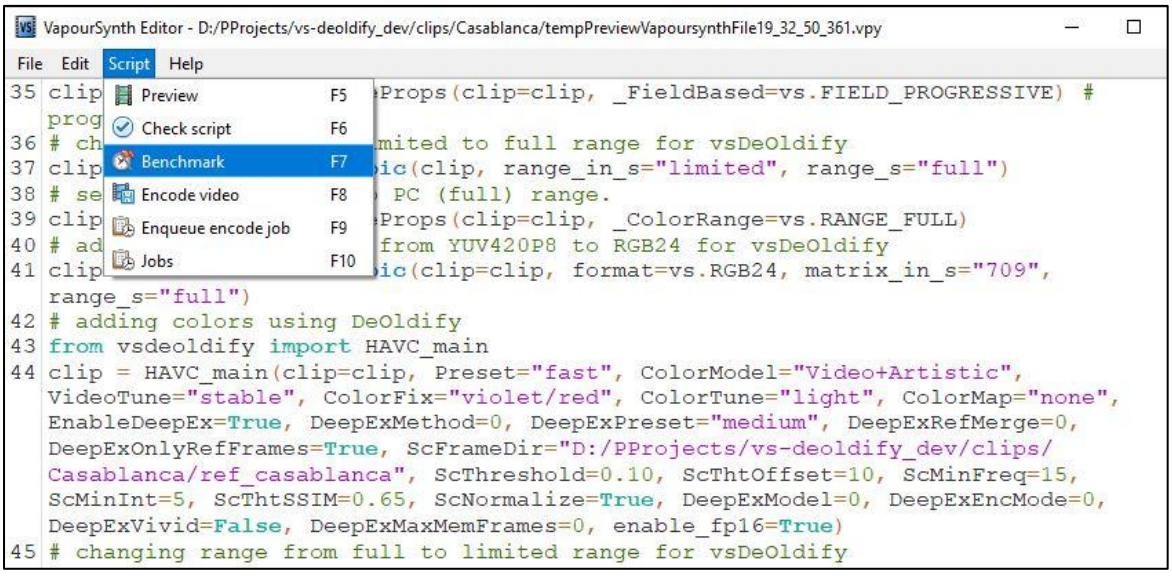
to enable the export of frames that will be used by ColorMNet to propagate the colors. It is interesting to observe that in this case **SC SSIM thresh** has been set to 0.65, this is necessary to filter-out the frames that are similar, since will need to check manually the generated frames, is better to reduce the number of exported frames to the minimum necessary. For the same reason has been set **SC min int** to 5, this setting will guarantee that the minimum distance between 2 consecutive reference images is at least 5 frames. The parameter **SC Offset** has been set to 10 to increase the sensitivity of scene changes detection in the case of blended frames.

Once all the parameters are set it is necessary to press the **Preview button 1** (shown in the previous image) and wait (it could be necessary to wait more than 40sec) till is displayed the preview window (in this case the first frame is black).

Then is necessary open **vsViewer** (see **point 3** in the previous image) that will show the code of preview file (in this case is `tempPreviewVapoursynthFile18_14_55_718.vpy`) as shown in the following picture:

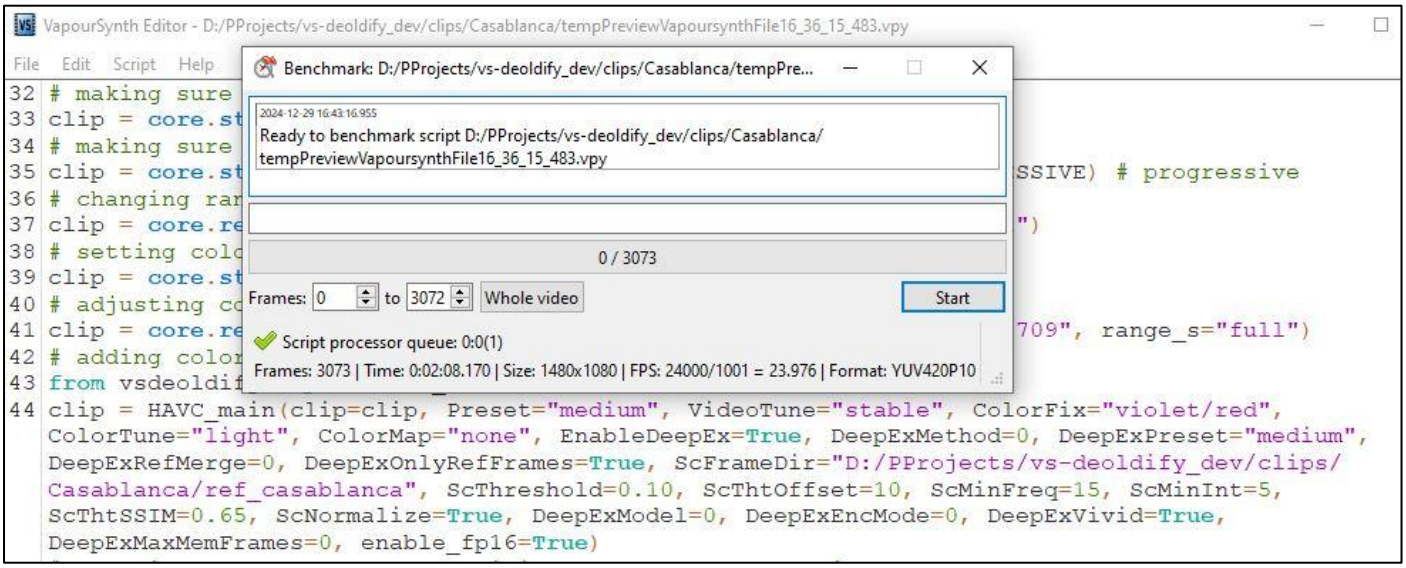


Then is necessary to select **Script-Benchmark** or press **F7**, as shown in the picture below:

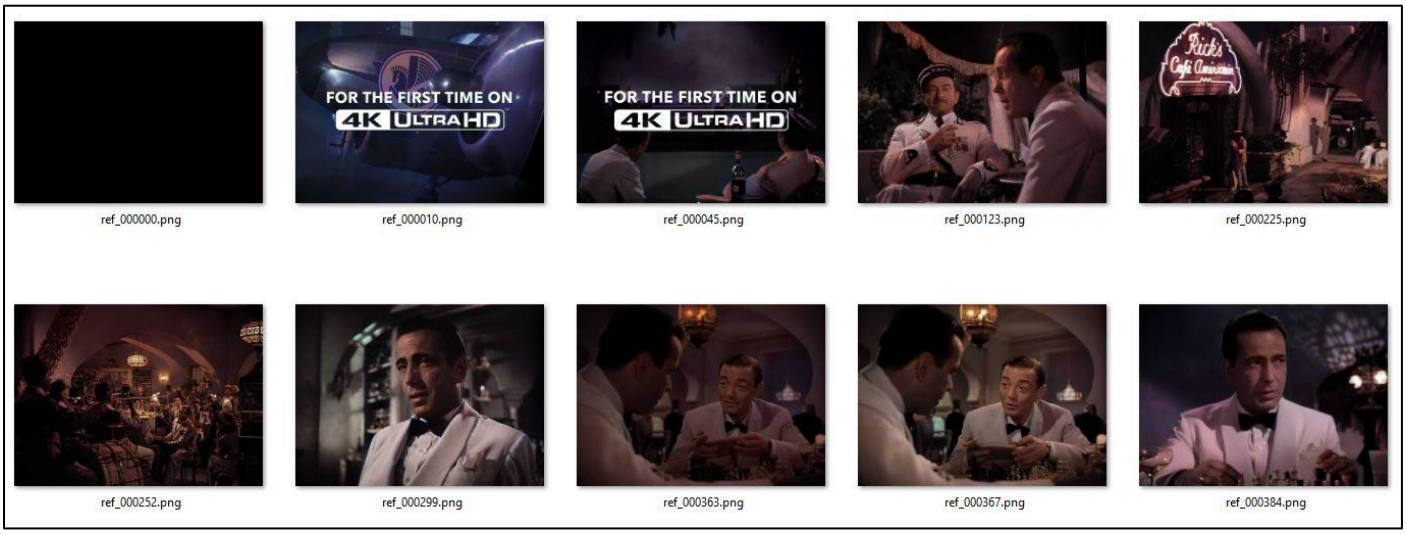


The Benchmark will run the script but will not call the encoding process, to that will not be generated any movie file. This is useful because in this case, what is necessary to generate, are the reference frames and not the clip.

Once the Benchmark is selected will be displayed a window like this:



At the end of the Benchmark in the directory defined in the parameter ScFrameDir will be available all the reference frames that will be used by HAVC for coloring the B&W clip. In this case should be available 108 frames out of 3073 frames contained in clip, so about 3.5% of the frames were selected as reference frames for the selected coloring model (in this case ColorMNet). Then is possible to look at the reference frames that will used for coloring the clip as shown is the following picture:

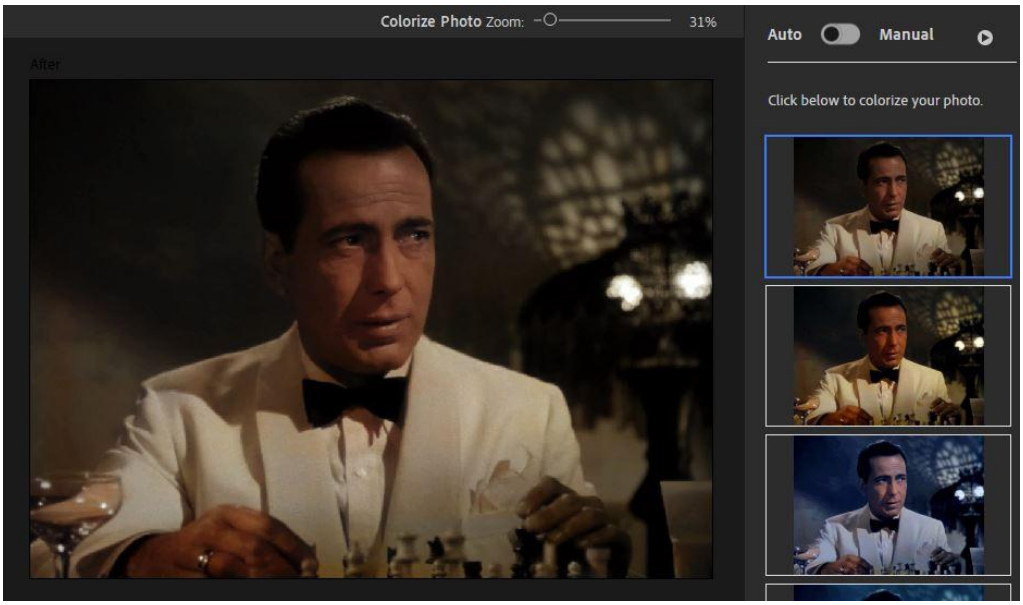


In the sample provided above is possible to see that the frames 363 and 367 are very similar, but 367 has better colors, since in this case we are interested in providing the best *exemplars* to ColorMNet, it is possible to delete the frames 363 and rename the frame 367 in ref_000363.png. When there are similar frames, like in this case, it is better to keep always the frame that appears first, eventually replacing it with a better colored frame.

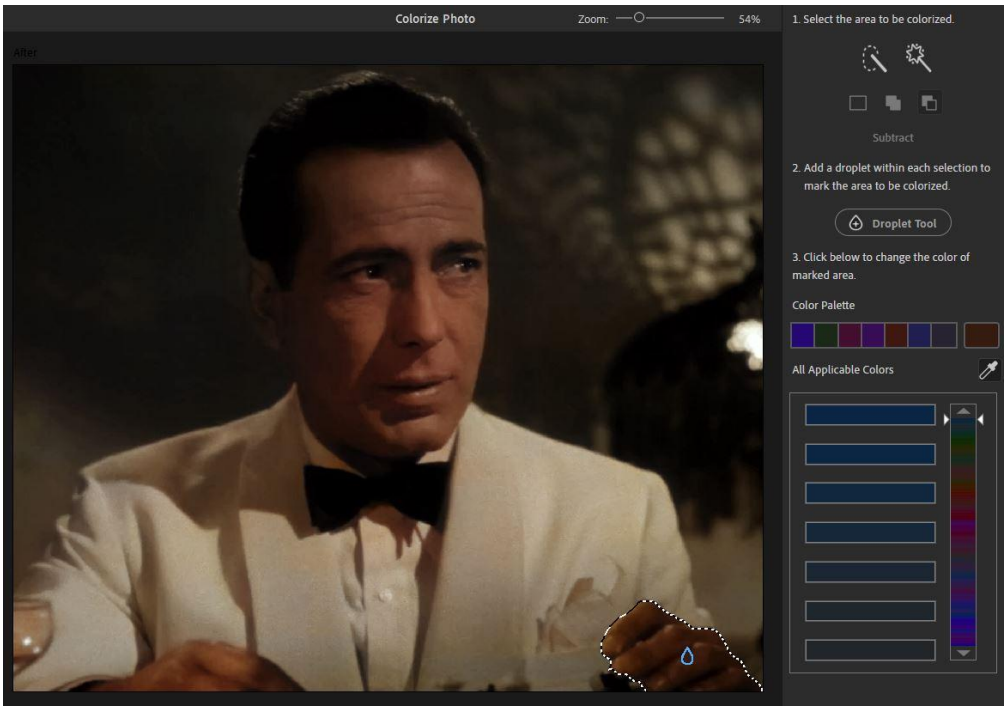
Then is possible to see another common situation, a frame that has wrong or not appropriate colors: in the frame 384, the Humphrey Bogart's jacket is almost pink and not white as it should be. In this case, it is necessary to correct the color. To correct the color, it could be possible to user the Color Mapping procedure described in the previous chapter, but is quite complex because is missing a dedicated GUI to perform this kind of mapping. A simplest way is to use a

dedicated software as suggested chapter Useful companion software. In this case it will be used Photoshop Elements 2024 (see software for coloring pictures).

Using Photoshop Elements, the proposed colored image is quite good, as is possible to see in the following picture:



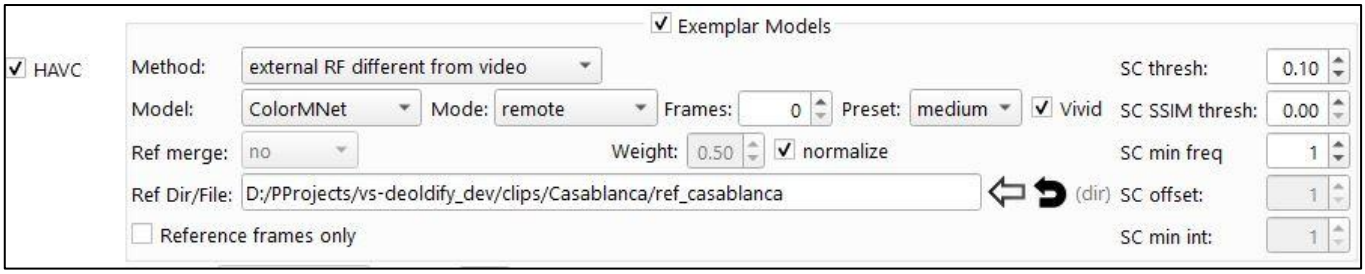
Buth the hand on the right is not colored well and is necessary to adjust the color manually as shown in the picture below:



The situations described previously represent the most common cases that need to be addressed:

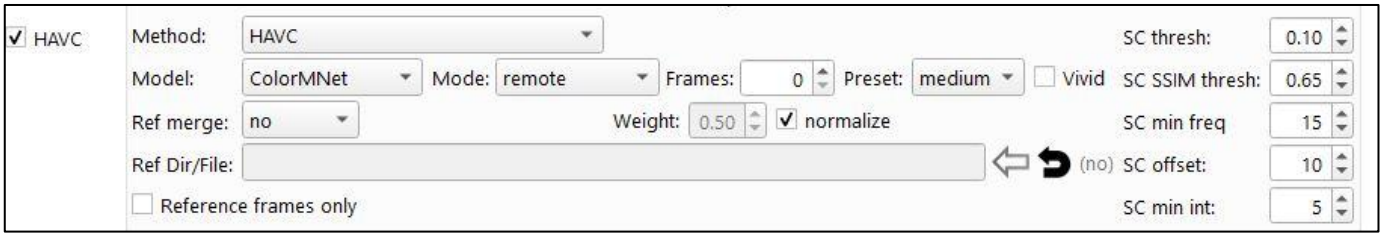
1) similar or duplicated frames: in this case is necessary to selected the best frame (eventually by renaming it) and delete all the remaining frames.
2) frame with wrong colors, in this case it is necessary to adjust the colors.

After having adjusted all the reference frames is possible to finally start to coloring the clip using the settings shown in the following picture:



Having selected the method **external RF different from video**, the clip will be colored using only ColorMNet and the reference frames provided in the folder: “ref_casablanca”.

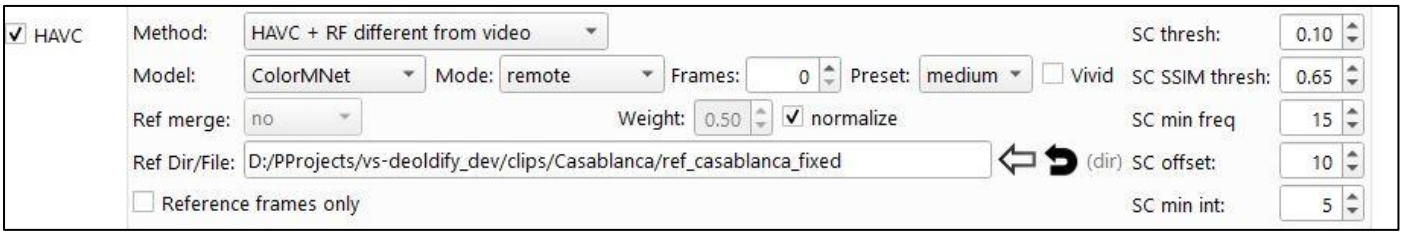
Using the standard method HAVC as shown in the following picture:



the clip will be colored using the previous unadjusted reference frames, so the clip will show the color artifact observed previously, for this reason has been shown how to adjust the reference frames to improve the color quality.

Alternatively, is possible to create a folder that contains only the fixed/adjusted reference frames, as shown in the following picture:

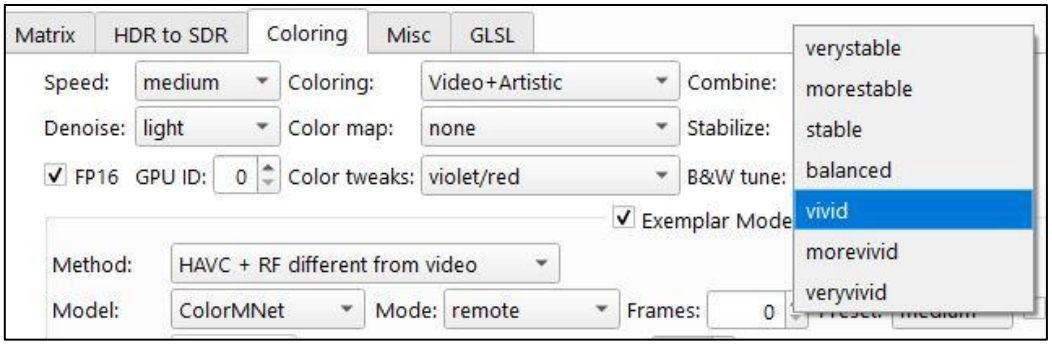
Supposing that the folder is named “ref_casablanca_fixed”, it is possible to color the clip using the following settings:



In this case the filter will use as reference frames the ones colored using HAVC but the frames found in the folder specified by the parameter **Ref FrameDir** will have higher priority and eventually will override the frames generated by HAVC. It is suggested to use **HAVC + RF different from video** even if in this case is appropriate to select **HAVC + RF same as video** since the reference frames were obtained from the same clip that HVC will colorize.

By using **RF same as video** ColorMNet will skip the inference and will provide in output exactly the same colors specified in the reference frame, but the next frame will be colored using the inference and this could lead in some color discontinuity between the reference frame and the next frames. By selecting **RF different from video**, ColorMNet will apply the inference even on the reference images and this will assure more color uniformity between the reference image and the next frames.

The reference frames were obtained using the suggested settings for HAVC (see picture below), with the parameter Stabilize set to **stable**, but it could be also possible to set it equal to **vivid**, in this case will probably necessary to perform more color adjustments.



It is necessary to clarify that by using *AI automatic colorizers* is not possible to get colorful movies with a great variety of colors, because this will increase the instability of colors at a level that the colored movies will be almost unwatchable.

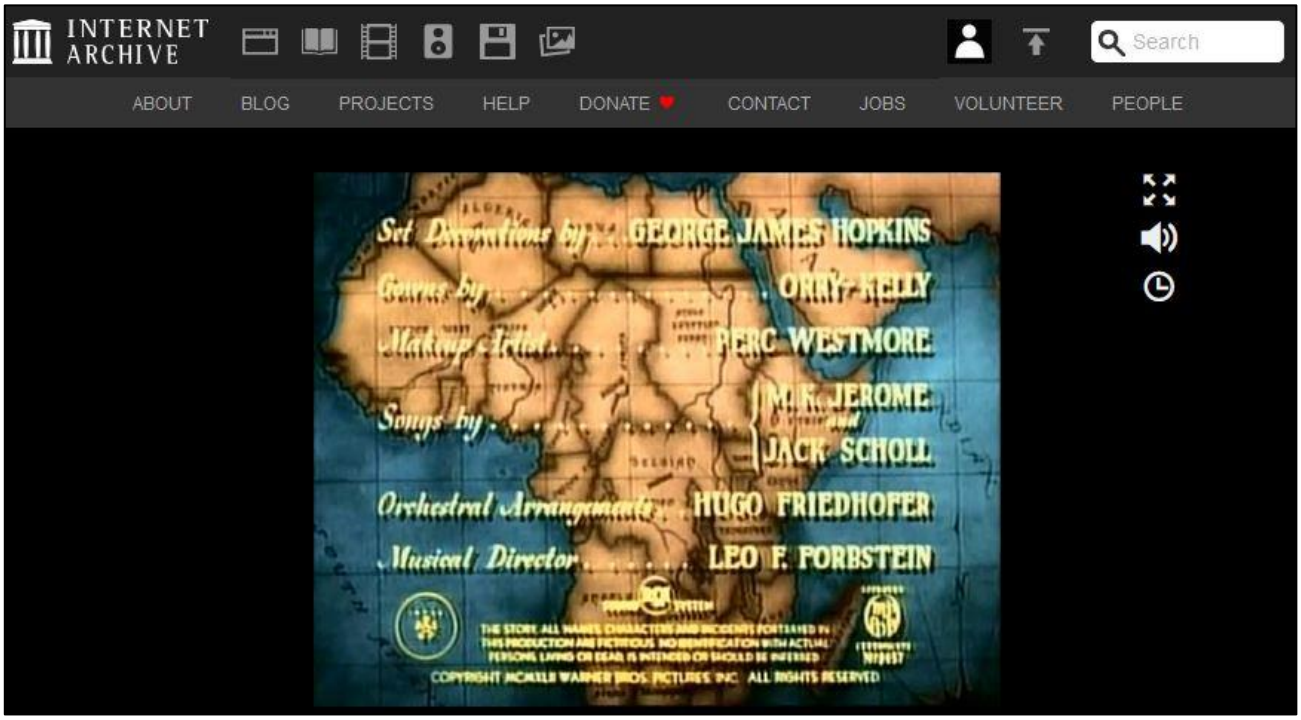
To get colorful movies with a great variety of colors is still necessary a lot of manual work. Using ColorMNet with the method **external RF different from Video** will be possible to obtain colorful movies by providing colored reference images with a great variety of colors.

At the following link there is an example of movie obtained using this approach: The Thing (Colorized, 1951).

Several thousand low-resolution reference images (already available) and hundreds of manually colored images were used to color this clip. But this is a very time-consuming task and *AI automatic colorizers* have been developed precisely to avoid this (boring) manual task.

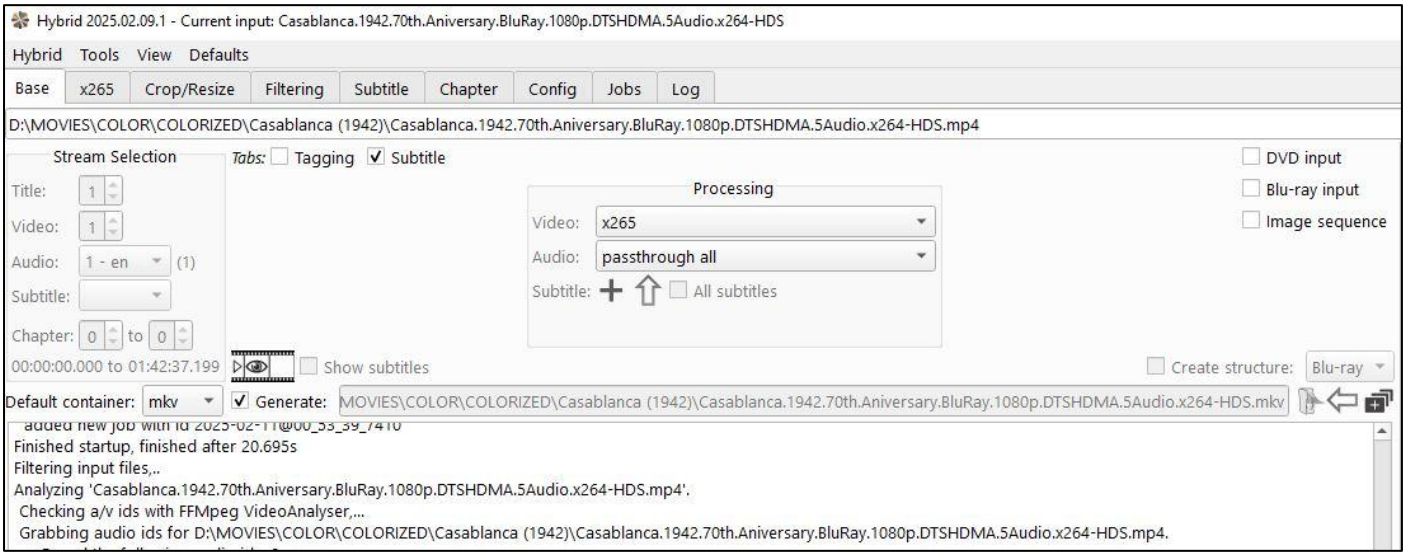
4.3 Using HAVC to restore old colored videos.

Starting from HAVC 5.0 it is possible to use the filter to restore old colored videos. To explain how to use this feature will be used as example the colored video: Casablanca InColor.



This is a low-quality movie, and is almost unwatchable, but with HAVC 5.0 it is possible to restore it to full HD resolution. To do that is necessary the availability of a good HD copy of the movie in B&W. Fortunately in this case is available this HD version of the movie: Casablanca (1942).

Now to restore the colored movie it is necessary to load in the main Hybrid page the HD version as shown below:

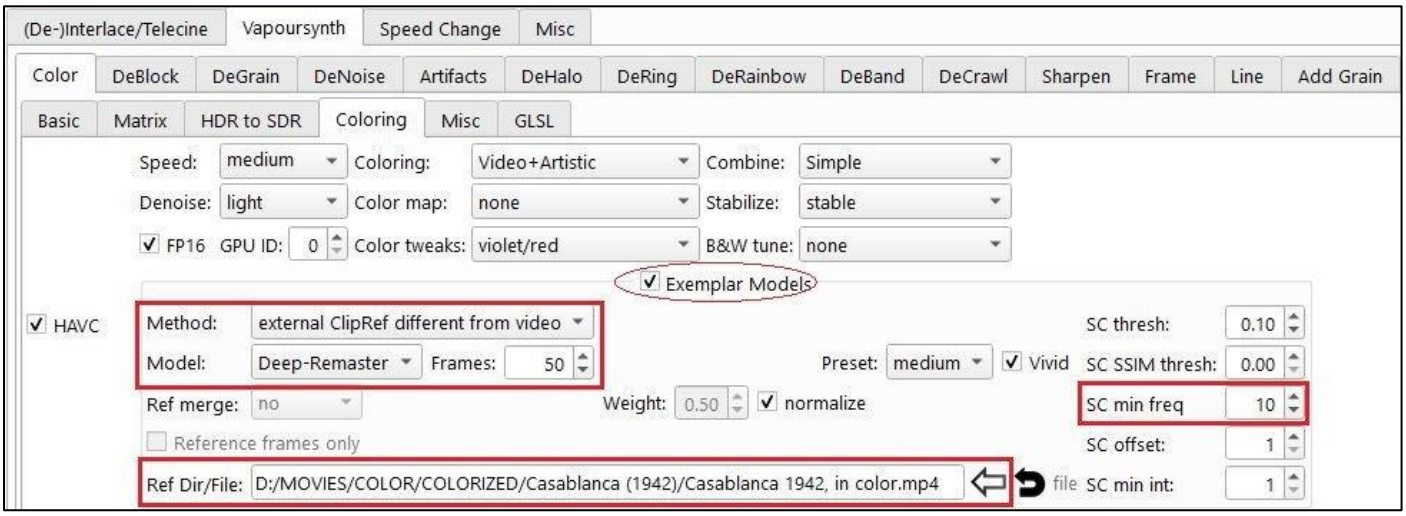


To restore the video, it is necessary to move to the page at: **Filtering->Vapoursynth->Color->Coloring**.

In HAVC 5.0 has been added the possibility to use an external clip as source for the reference images to be used by the exemplar-based models to colorize a B&W movie. In HAVC 5.0 are available 3 models: ColorMNet, DeepEx and DeepRemaster. In the case the B&W movie and the reference-colored movie are perfectly in sync all the 3 models are suitable to be used to propagate the colors of the refence clip in the B&W movie. But in the case, they are not perfectly in sync, as often happens, only DeepRemaster is able to properly propagate the colors. This is possible because in the

HAVC implementation, has been adopted the strategy to provide in input to DeepRemaster 50% of past reference images and 50% of future reference images, respect to the frame to be colored. In this way DeepRemaster is able to manage the situation where the reference frames are either ahead or behind the frame to colorize. DeepRemaster store the full frame in a tensor array and in this way is able to properly apply the colors without compromise. The others models are not able to manage the reference frames in this way.

Since in this case the 2 movies are not in sync, there is a difference of about 200 frames randomly distributed between the 2 movies. It will be used DeepRemaster with the following settings:

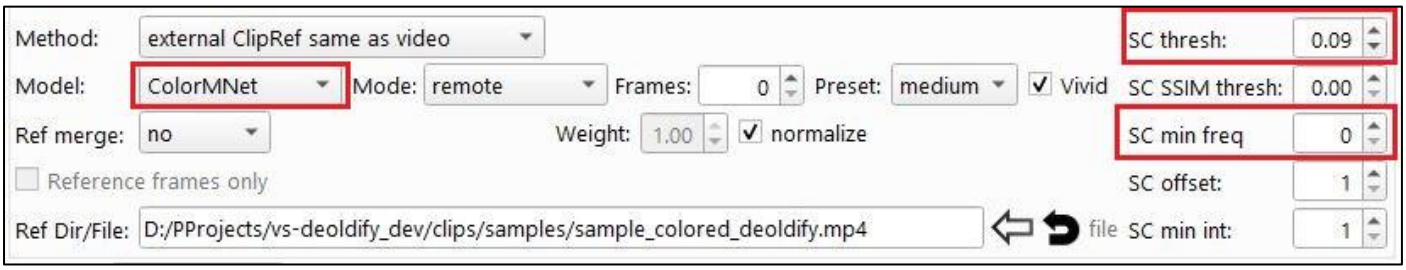


First all is necessary to check the box **Exemplar Models**. Then is necessary to select the model **Deep-Remaster** with Frames equal to 50[18], finally is necessary to select the Method **external ClipRef different from video** and click on the big arrow on the right of the box **Ref Dir/File**. DeepRemaster need a lot of reference frames to properly colorize the movie so it is necessary to set the parameter **SC min freq** to a value between 5 and 15 (in this case was set 10).

Now it is possible to start the encoding and if all goes well after a few hours the colorized HD version should be available[19].

A version of the movie in half-HD colored using this approach is available at: casablanca-remastered-colorized-1942.

The color restoration can be applied also if is available a HD version of a movie colored with another tool (for example DeOldify) in this case could be used the model ColorMNet to provide more stability to the movie colors as shown below:



In this case it is possible to use the movie also as main clip in Hybrid to colorize. In this way the movie will be (automatically) converted in B&W and then (re)colored using ColorMNet. From the colored movie will be taken only the reference images, the remaining frames will be colored by ColorMNet, thus providing more color stability.

[18] The maximum suggested value for the frames to be used with DeepRemaster is 50. If the source is perfectly in sync can be used a lower number of frames 4 or 10. If the difference in frames between the 2 movie is above 200, it is necessary to split the movies in chunks to reduce the difference on the single chunk.

[19] See the [Example1] for a VapourSynth script using this approach.

4.3.1 Fixing DeepRemaster problems

As stated previously DeepRemaster is the only model that is able to restore old colored movies. But depending on the quality of old colored source, DeepRemaster can be affected by the following problems.

1. Flickering

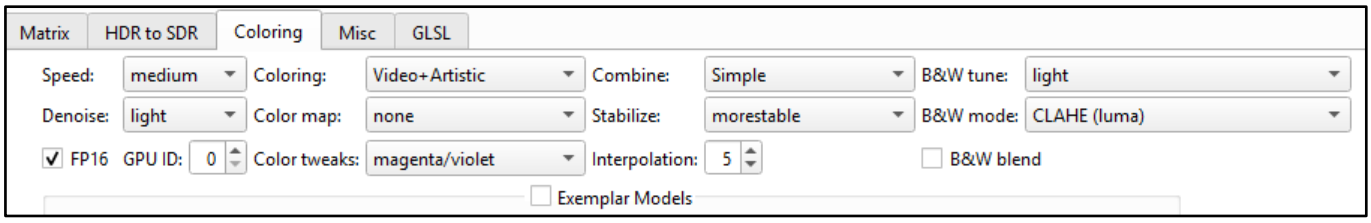
It could happen that if the source is affected by some small flickering effect, DeepRemaster will amplify the effect more than 10 times. In this case is necessary to apply a de-flicker filter. In the Example3 there is a Vapoursynth script which uses in combination 2 of most effective filters to move the flickering: HAVC_stabilizer and ReduceFlicker.

2. Inability to apply colors correctly in dark scenes

If the quality of colors in the source movie is bad, DeepRemaster will not be able to properly colorize the frames in dark scenes. An example of such problem is shown in the picture below.

(colored source frame) (DeepRemaster output) (frame fixed with Example4)

In this case to fix the frame it is necessary to colorize the full movie with HAVC using for example the Coloring model **Video+Artistic** and the Combine method **Simple** as shown in the picture below.



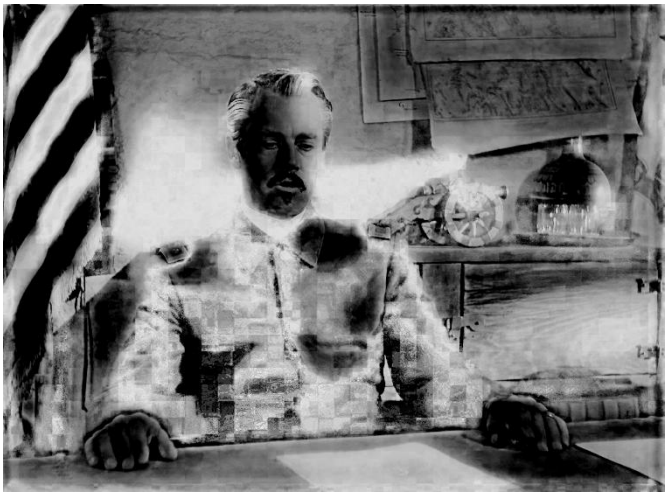
Once the clip colored with HAVC is available it is possible to use it to get the proper colors to apply in the dark scenes. Since in this case the problem is mainly limited to the dark scenes is not suggested to apply a simple merge as shown in the Example2. In this case is better to use the Merging Methods developed in HAVC. In this case the most appropriate merging method to use are Luma Masked Merge the Adaptive Luma. To use these methods is necessary to write a simple Vapoursynth script as shown in the Example4 which uses the function HAVC_merge to combine the 2 clips. In this case was used the Adaptive Luma method, because is able to change the weight adaptively with the Luma, providing more weight to clipa in the dark scenes and more weight to clipb in the bright scenes.

3. Inability to apply colors correctly both in bright and dark scenes

If the quality of colors in the source movie is very bad, DeepRemaster could not be able to properly colorize the frames both in bright and dark scenes. In this case the most frequent artifact is that some portion of the frame is desaturated, almost gray as shown in the pictures below:

Even in this case is necessary to colorize the full movie with HAVC and is not possible to use a simple merge. In effect, to fix this problem is necessary to use a more sophisticated approach which consists in identifying the desaturated regions of the frame and apply a color substitution only on these regions. To do that is necessary to build a mask where the identified regions are white with a gray gradient around the white region to be able to apply a smooth color substitution. To identify the regions is necessary to provide a threshold that defines when a pixel in desaturated. In the HSV color space the saturation has value in the range [0, 255], so a reasonable threshold can be in the range [15, 60]. In the picture below are shown the masks built with a threshold of 60 in the HSV color space.

(Binary Mask) (Gradient Mask)



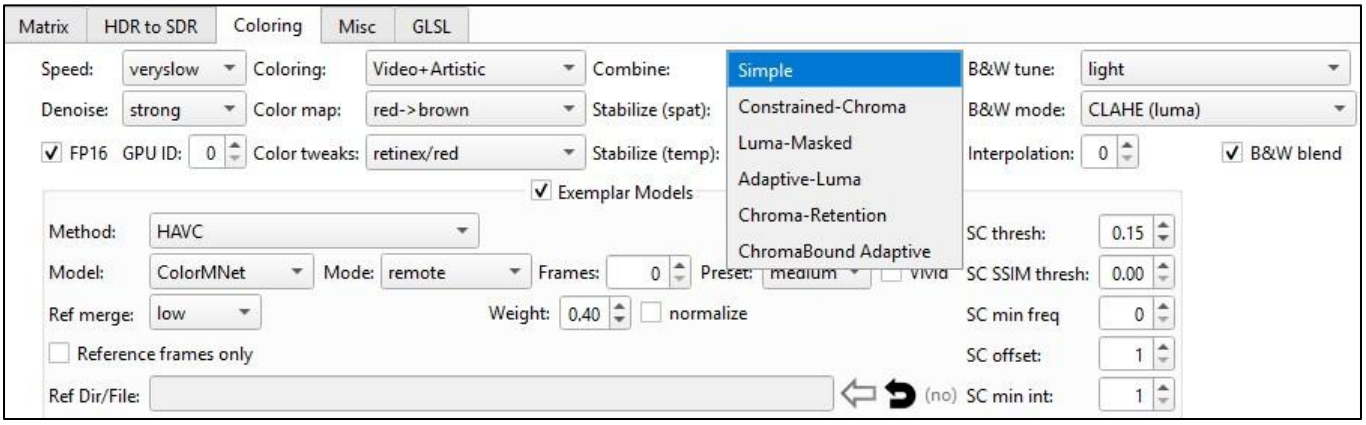
For this type of problem is not possible to use a simple binary mask where the white pixels are substituted by the colored pixels, but the binary mask could be useful to easily visualize the desaturated pixels identified using the assigned threshold. As it is possible to see, in this example, has not been identified only the right side of the face, but also the wall because is almost white and the uniform. As stated previously, to apply a smooth color substitution is necessary to build a gradient mask as shown in the picture above on the right.

To implement this special case of color substitution has been implemented a new HAVC filter function that is available with HAVC version 5.0.4 and is called: HAVC_recover_clip_color. The main parameters of this function are the threshold level tht (previously explained) and the acceleration parameter alpha (values above 2.0 will preserve more pixels, but could introduce some artifacts).

In the Example5 there is the Vapoursynth code using the proposed approach. In the picture below are shown the frames (re)colored using the given example.

4.4 Using HAVC Models merging

With HAVC it is possible to merge 2 frames generated by different models. To perform this merge are available 6 methods, that can be selected with the parameter **Combine**.



The parameter **Combine** allows to select the merging methods used by HAVC to merge the frames colored with DeOldify and DDcolor. The simplest method is **Simple** that merge the frames using the weight defined in the parameter Merge weight.

With the method Constrained Chroma, the frames are combined by assigning a limit to the amount of difference in chroma values between DeOldify and DDcolor. This limit is defined by the parameter *Threshold*, as shown in the picture on the right.

With the method Luma Masked, the frames are combined using a masked merge. The pixels of DDcolor's frame with luma < luma_limit (called *Luma* on the GUI) will be filled with the de-saturated (parameter *Sat* on the GUI) pixels of DeOldify, while the pixels above the white_limit threshold (called *White* on the GUI) will be left untouched. All the pixels in the middle will be gradually replaced depending on the luma value. If the parameter *merge_weight* is < 1.0, the resulting masked frames will be merged again with the non-de-saturated frames of DeOldify using the *Simple Merge*.

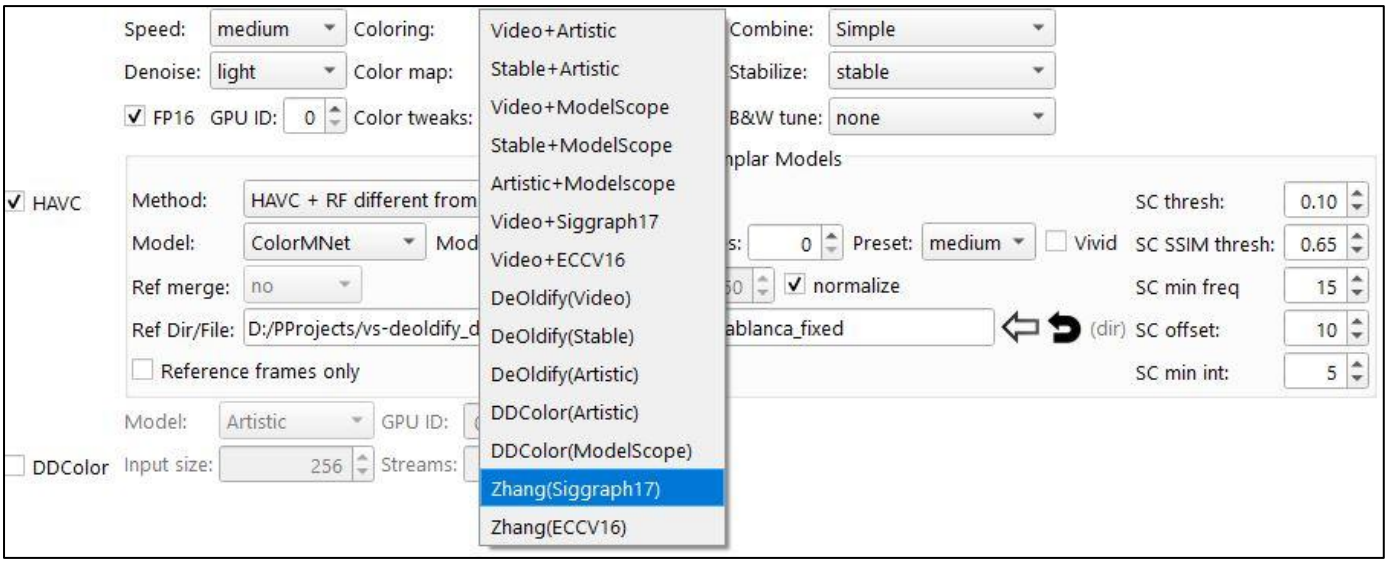
With the method Adaptive Luma, the frames are combined by decreasing the weight assigned to DDcolor frames when the luma is below the *luma_threshold* (called *Thresh* on the GUI). For example, with: *luma_threshold* = 0.6 and *alpha* = 1 (called *Exp* on the GUI), the weight assigned to DDcolor frames will start to decrease linearly when the luma < 60% till *min_weight* (called *Weight* on the GUI). In practice this method is a *Simple Merge* where the weight decreases with luma.

The method Chroma Retention Merge try to restore the colors of gray pixels provide by deoldify() by using the colors provided by ddcolor(). The gray pixels are identified by the parameter "*tht*". Once are identified the gray pixels are substituted with the desaturated colors in deoldify(), the level of desaturation is identified by the parameter "*sat*". It is performed a "gradient" substitution, i.e. the gray pixels are gradually substituted depending on the level of gray gradient. The steepness of gradient curve is controlled by the parameter "*alpha*". Optionally is possible to resize the frame before the filter application to speed up the filter by setting True the parameter "*chroma_resize*".

The method ChromaBound Adaptive is an adaptive version of Constrained-Chroma. In this version the chroma tolerance is adaptive, i.e., it is applied an approach that will allow more color variation in textured/complex regions and less in smooth areas.

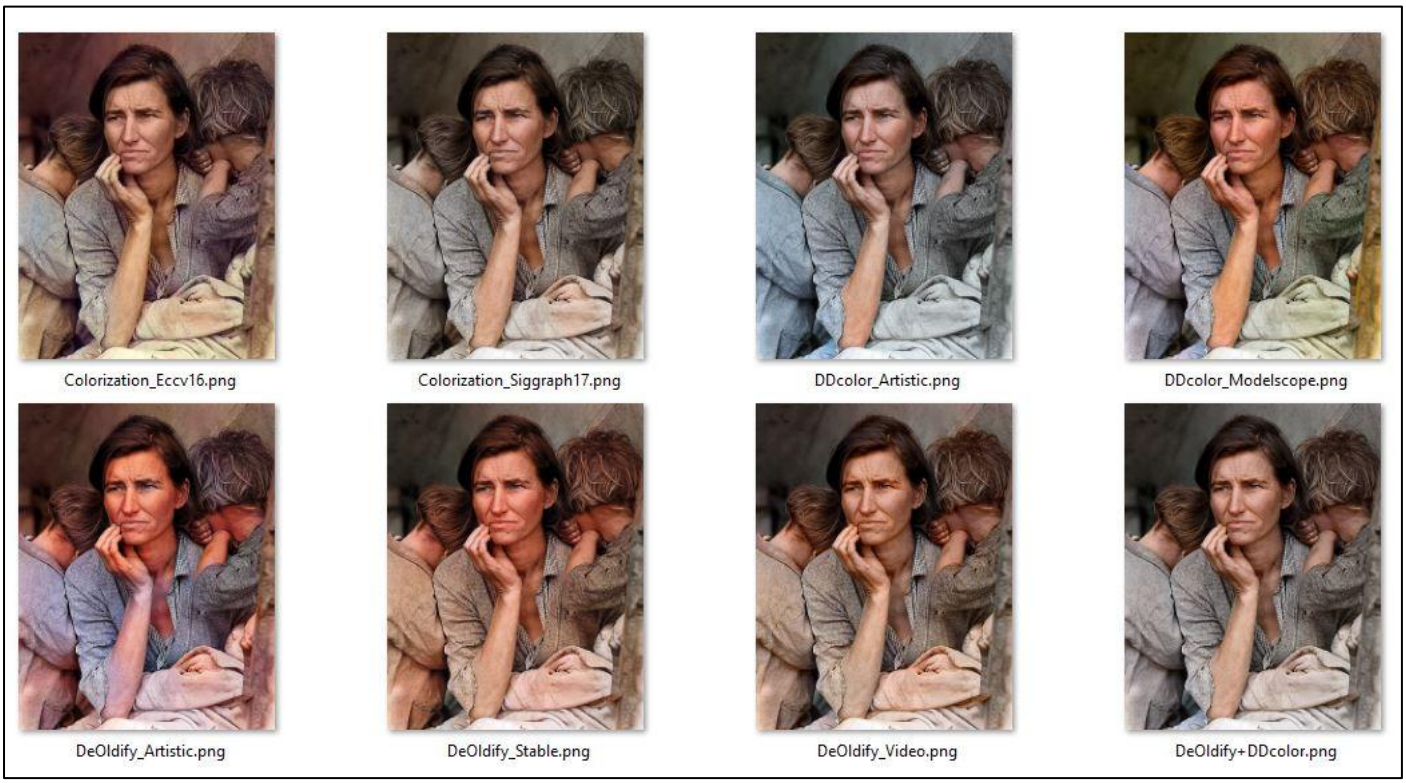
4.4.1 Alternative inference models to DDcolor

In alternative to DDcolor, starting from version 4.6.0 of HAVC is also possible, to use for the color inference the 2 models



provide in the project Colorization: *Real-Time User-Guided Image Colorization with Learned Deep Priors* (named: **siggraph17**) and *Colorful Image Colorization* (named: **eccv16**). These models have the same color instability observed in DDcolor and hence have in common the same settings and tweaks of DDcolor. It is suggested to try them without the Tweaks activated (*Denoise* and *Color tweaks* set to **none**) to see the improvement of this post-process filter on the colored frames.

In the picture below is possible to see a comparison between the 2 alternative models **siggraph17** and **eccv16** with the other models implemented in HAVC:



5.0 External filters used by HAVC to improve final color quality

In some cases, it is possible to improve the final color quality of the movies colorized with HAVC using plugins that are able to change the contrast/luminosity of a movie (like Retinex) or the colors (like the LUT tables).

As explained in the chapter on Problems in coloring old videos, the luminance is the critical variable in colorization, largely because the model sees only the L channel during training. Blind to the original colors and possessing no semantic understanding beyond what is captured in brightness, the model must derive all chromatic information strictly from luminance.. It has no access to the original colors, edges, textures, or semantics beyond what's encoded in brightness. So it must infer color purely from luminance patterns:

- Dark regions → might be shadows, blue sky, black hair, etc.
- Medium gray → could be skin, concrete, foliage.
- Bright regions → could be clouds, snow, white paper, or specular highlights.

But luminance alone is ambiguous. For example:

A dark patch could be:

- Blue jeans (dark due to dye)
- A shadow on white fabric (dark due to lighting)
- Black leather

A medium-bright patch could be:

- Yellow banana
- Light brown wood
- Pale skin

The model resolves this ambiguity using learned statistical priors from ImageNet (e.g., "objects that look like this in L are usually green"). By modifying the input L channel (e.g., by adjusting brightness/contrast), it is possible to change the model's only source of information. In some cases this will have a positive effect, in others, a negative one.

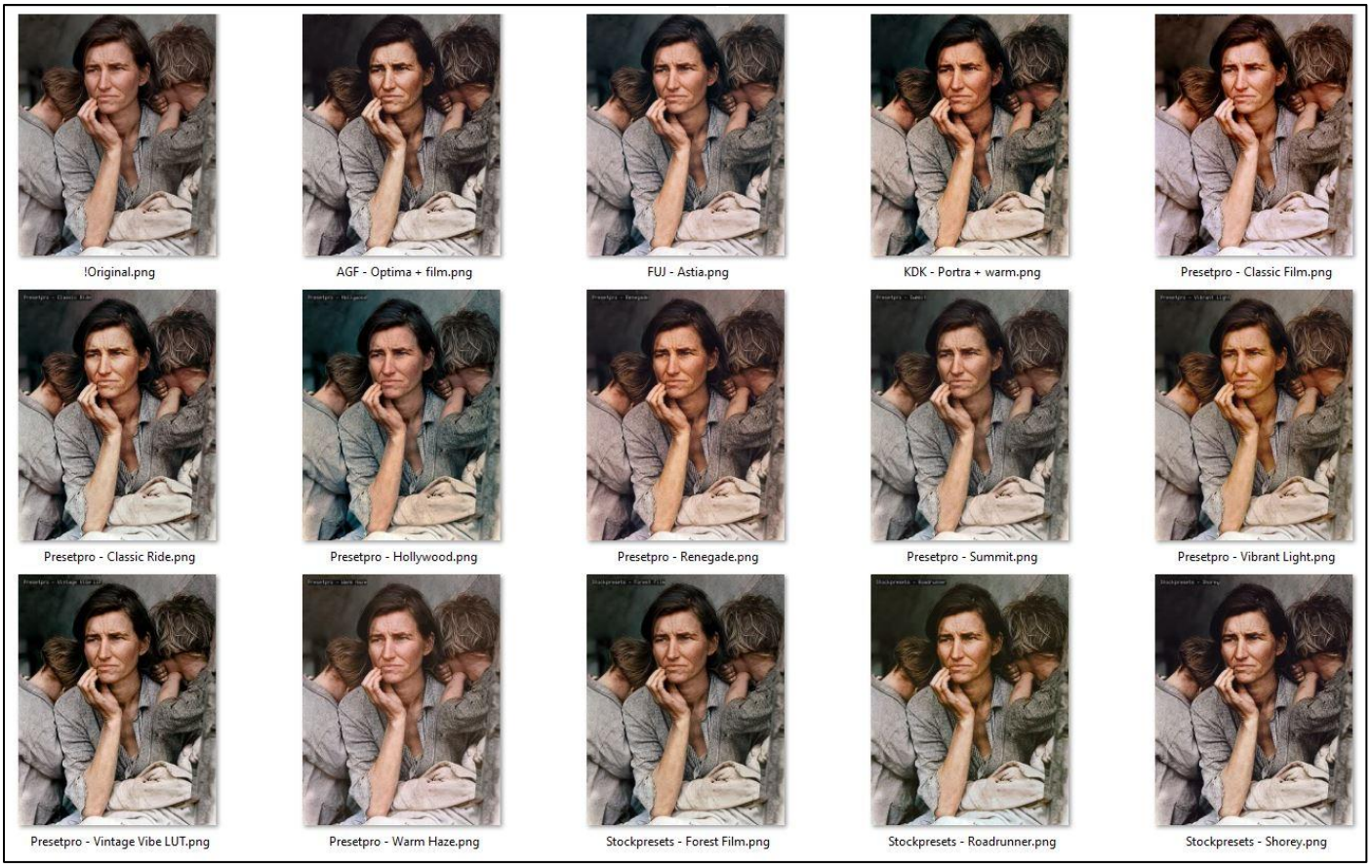
As explained previously, the color stability has a cost in terms of variety of colors. With the increase of color stability will decrease the variety and saturation of the colors. Some useful filters, which will possible to add as post-process to improve the saturation of the colors, can be found in the panel: **Filtering->Vapoursynth->Color->Basic**. In this chapter will be described how HAVC is able to use some advanced filters to improve the final color quality. Unlike the Basic color filters, the advance filters used by HAVC are not suitable to be applied directly on all the movies, for such reason they has been included in the HAVC coloring pipeline in a way that they are adapted to be applied to the movie colored using HAVC without introducing artifacts.

5.1 Using LUT (Lookup Tables) as post-process filter

LUTs (Lookup Tables) are a kind of post-process color filter that can be used to alter the colors of final clip colored with HAVC. They are usually available in .cube format, which is a text-based file format for 3D Look-Up Tables (LUTs). This format is widely supported by professional editing software like DaVinci Resolve and Adobe applications.

The LUTs apply predetermined sets of mathematical formulas to video's existing colors to change those colors and achieve a desired result. They make adjustments to gamma, contrast, saturation, luminance, and hue, essentially taking the original set of colors and changing them into a new set of colors. And they do so completely automatically. Simply put, LUT are powerful tools that can be used to elevate the color correction and color grading of HAVC colored clips.

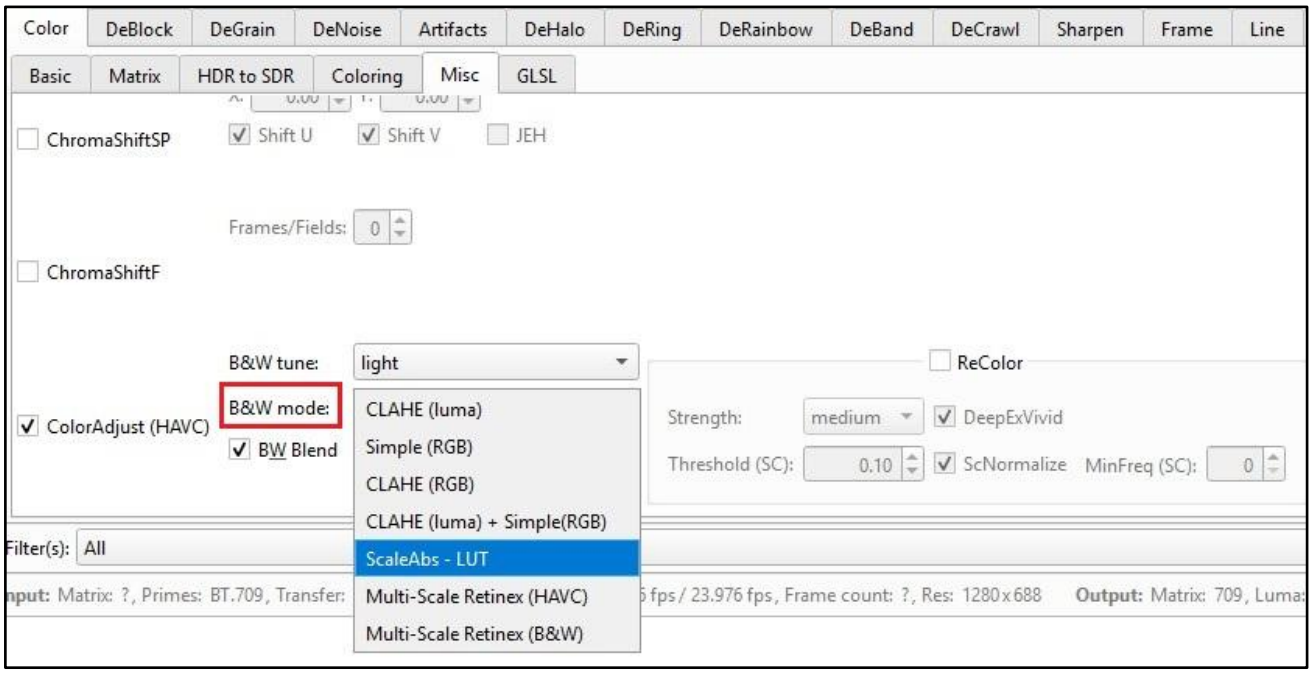
In Hybrid there are already some interesting color LUTs, they can be selected using: **Filtering->Vapoursynth->Color->Matrix**. Some of them are shown in the following picture:



Some of them are able to change the final color of the image in an interesting way. But there are LUTs that if are applied directly to the clip are able to change dramatically the aspect of the clip. Are these the most interesting LUTs because, once they are properly mitigated using weights and colors adjustments, are able to provide the most interesting effects. For such reasons some LUTs has been directly included the HAVC coloring pipeline.

In HAVC there are 2 main parameterizations where LUTs are automatically used.

5.1.1 ColorAdjust (HAVC) Filter



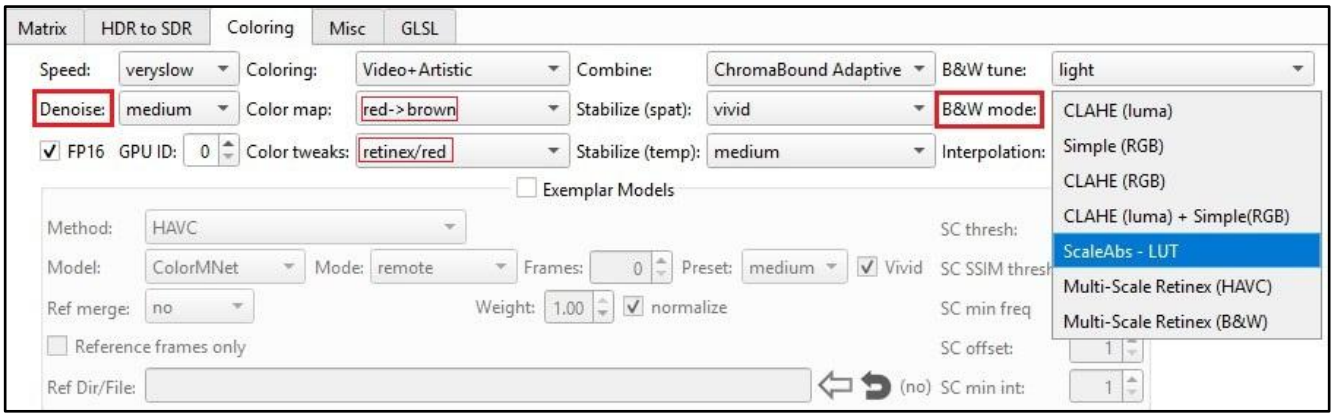
Only for the

ColorAdjust (HAVC) filter, the B&W mode of *ScaleAbs – LUT* and *Multi-Scale Retinex (B&W)* has been redefined because are not applicable in the contest of ColorAdjust filter. When they are selected, will be the following LUTs:

- B&W mode: ***ScaleAbs – LUT***
  - BlackWhiteTune = 'Light' -> LUT_Exploration
  - BlackWhiteTune = 'Medium ' -> LUT_City_Skyline
  - BlackWhiteTune = 'Strong' -> LUT_Amber_Light
- B&W mode: ***Multi-Scale Retinex (B&W)***
  - BlackWhiteTune = 'Light' -> LUT_FUJ_Film
  - BlackWhiteTune = 'Medium ' -> LUT_Flat_Pop
  - BlackWhiteTune = 'Strong' -> LUT_Warm_Haze

In the Example 7, is reported an example to view a comparison of these LUTs filters on the colored input clip.

5.1.2 HAVC Filter + Color tweaks (*retinex/red*)



When is selected as Color tweaks *retinex/red* depending on the *Denoise level* selected, are automatically applied the following (adjusted) LUTs:

1. 'Light' -> LUT_Exploration (*more vibrant colors*)
2. 'Medium' -> LUT_City_Skyline (*more vivid color, the best for HAVC*)
3. 'Strong' and ColorMap != 'Red->Brown') -> LUT_FUJ_Film (*the colors tend towards green*)
4. 'Strong' and ColorMap == 'Red->Brown') -> LUT_Amber_Light (*the colors tend towards brown*)

In this page, if is selected the *B&W mode* ***ScaleAbs – LUT***, will be applied an adjusted version of the following LUTs:

- B&W mode: ***ScaleAbs – LUT***
  - BlackWhiteTune = 'Light' -> LUT_Exploration
  - BlackWhiteTune = 'Medium ' -> LUT_City_Skyline
  - BlackWhiteTune = 'Strong' -> LUT_Amber_Light

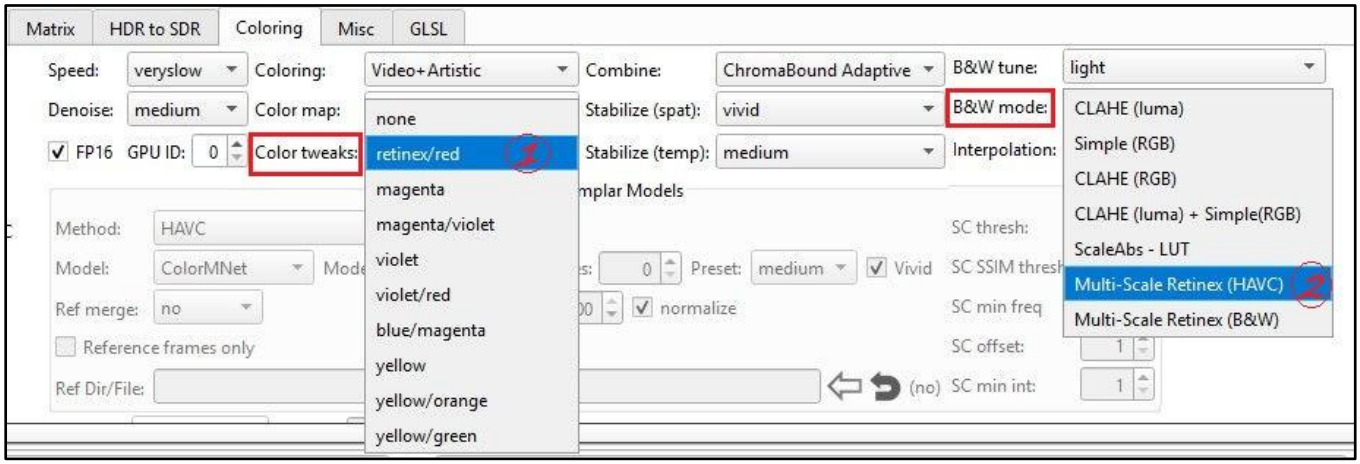
5.2 Using Retinex as pre-process filter

The Retinex filter available in Hybrid is the implementation of the theory of human color vision proposed by Edwin Land to account for color sensations in real scenes. The basic Retinex theory is that the color of an object is determined by the ability of the object to reflect light in long (red), medium (green), and short (blue) light, rather than by the absolute value of the intensity of the reflected light.

The color of the object is not affected by the illumination non-uniformity, and the Retinex filter is based on the consistency of color perception (color constancy), in this way the Retinex filter can balance dynamic range compression, edge enhancement and color constancy, so that it can be used successfully as filter for the color models implemented in HAVC. Unfortunately, the original version released in Hybrid introduces some artifacts (see images below).

For this reason, it was decided to include a patched version of the Retinex filter directly in HAVC that does not introduce any artifacts.

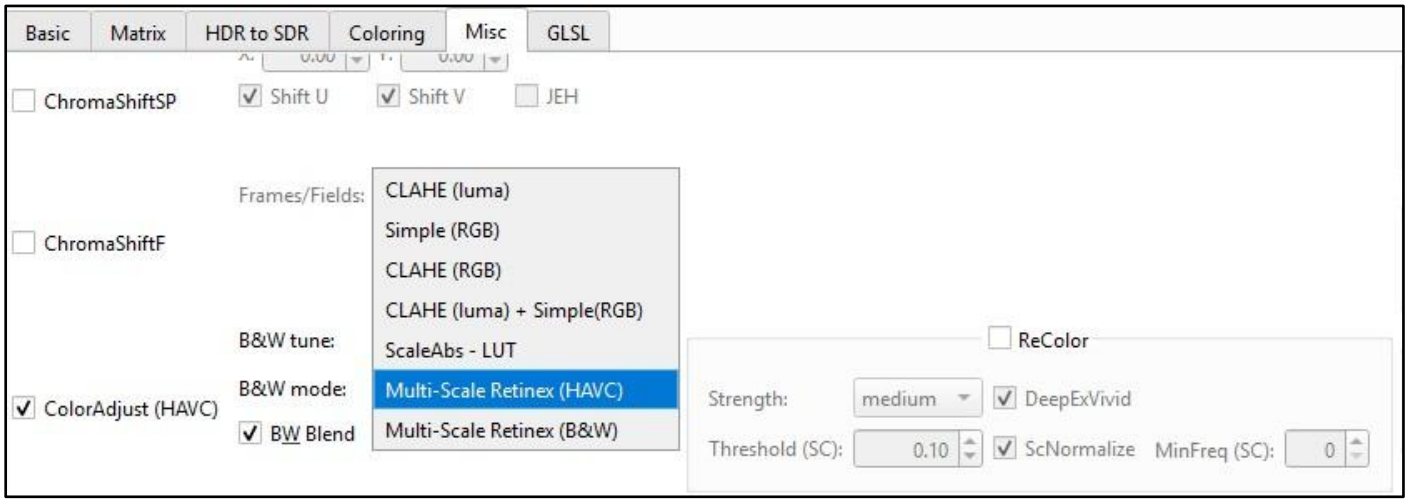
In Hybrid the Retinex filter can be added 3 ways.



1) In HAVC Coloring page by selecting *retinex/red* in ***Color tweaks***. In this way the Retinex filter will be applied only to the DDColor family models and the resulting frames will be merged with DeOldify using the selected Combination method. This is the safest way to use Retinex in the coloring pipeline.

2) Using the ***B&W mode***. In this case there 2 Retinex mode:
    1. Multi-Scale Retinex (HAVC) : the retinex filter will be applied at the end of coloring pipeline on the frames already colored.
    2. Multi-Scale Retinex (B&W) : the retinex filter will be applied at the beginning of the coloring pipeline on the B&W input clip to be colored.

3) Using the filter ***ColorAdjust (HAVC)***. In this case only the ***B&W mode*** Multi-Scale Retinex (HAVC) cab ne used to apply the Retinex as pre/post process filter. The mode Multi-Scale Retinex (B&W) is redefined as explained in the previous chapter: Using LUT (Lookup Tables) as post-process filter.



6.0 HAVC Functions reference

In this chapter will be described the most useful functions available in the filter HAVC.

6.1 HAVC_main

This is the main HAVC function, with the support of Presets, it is a wrapper to the more specialized HAVC and it represents the easier way to use the filter. The header of the function is the following:

HAVC_main(clip: vs.VideoNode, Preset: str = 'medium', FrameInterp: int = 0, ColorModel: str = 'Video+Artistic',

CombMethod: str = 'Simple', VideoTune: str = 'Stable', ColorFix: str = 'Magenta/Violet', ColorTune: str = 'Light',

ColorMap: str = 'None', BlackWhiteTune: str = 'None', BlackWhiteMode: int = 0,

BlackWhiteBlend: bool = True, EnableDeepEx: bool = False, DeepExMethod: int = 0,

DeepExPreset: str = 'Medium', DeepExRefMerge: int = 0, DeepExOnlyRefFrames: bool = False,

ScFrameDir: str = **None**, ScThreshold: float = 0.10, ScThtOffset: int = 1, ScMinFreq: int = 0,

ScMinInt: int = 1, ScThtSSIM: float = 0.0, ScNormalize: bool = False, DeepExModel: int = 0,

DeepExVivid: bool = True, DeepExEncMode: int = 0, DeepExMaxMemFrames=0,

RefRange: tuple[int, int] = (0, 0), enable_fp16: bool = True, debug_level: int = 0) -> vs.VideoNode:

Where:

clip: clip to process, any format is supported.

Preset: Preset to control the encoding speed/quality. Allowed values are: 'Placebo', 'VerySlow', 'Slower', 'Slow', 'Medium' (default), 'Fast', 'Faster', 'VeryFast'.

FrameInterp: This parameter will allow to enable the frame interpolation. This method will use Deep-Exemplar to interpolate the colored frames. If = 0, the interpolation is disabled, if > 0 represent the number of frames used for interpolation. The quality of interpolation will decrease with the number of frames, suggested value is 3. Range [0-10], Default = 0

ColorModel: Preset to control the Color Models to be used for the color inference. Allowed values are: 'Video+Artistic' (default), 'Stable+Artistic', 'Video+ModelScope', 'Stable+ModelScope', 'Video+ECCV16', 'Artistic+Modelscope', 'Video+Siggraph17', 'DeOldify(Video)', 'DeOldify(Stable)', 'DeOldify(Artistic)', 'DDColor(Artistic)', 'DDColor(ModelScope)', 'Zhang(Siggraph17)', 'Zhang(ECCV16)'.

CombMethod: Method used to combine coloring models with (+): Allowed values are: 'Simple' (default), 'Constrained-Chroma', 'Luma-Masked', 'Adaptive-Luma', 'Chroma-Retention', 'ChromaBound Adaptive'.

VideoTune: Preset to control the output video color stability. Allowed values are: 'VeryStable', 'MoreStable', 'Stable' (default), 'Balanced', 'Vivid', 'MoreVivid', 'VeryVivid'.

ColorFix: This parameter allows to reduce color noise on specific chroma ranges. Allowed values are: 'None', 'Retinex/Red', 'Magenta', 'Magenta/Violet' (default), 'Violet', 'Violet/Red', 'Blue/Magenta', 'Yellow', 'Yellow/Orange', 'Yellow/Green'.

ColorMap: This parameter allows to change a given color range to another color. Allowed values are: 'None' (default), 'Blue->Brown', 'Blue->Red', 'Blue->Green', 'Green->Brown', 'Green->Red', 'Green->Blue', 'Red->Brown', 'Red->Blue', 'Yellow->Rose'.

ColorTune: This parameter allows to define the intensity of noise reduction applied by ColorFix. Allowed values are: ‘None’, 'Light' (default), 'Medium', 'Strong'.

If ColorFix = 'Retinex/Red', will be applied the following LUT post-filters, depending on ColorTune value:

- 'Light' -> LUT_Exploration
- 'Medium' -> LUT_City_Skyline
- 'Strong' and ColorMap != 'Red->Brown') -> LUT_FUJ_Film
- 'Strong' and ColorMap == 'Red->Brown') -> LUT_Amber_Light

BlackWhiteTune: This parameter allows to improve contrast and luminosity of colored clip colored with HAVC. Allowed values are: 'None' (default), 'Light', 'Medium', 'Strong'.

BlackWhiteMode: Method used by BlackWhiteTune to perform colors adjustments. Allowed values are:

- 0 : CLAHE (luma) (default)
- 1 : Simple (RGB)
- 2 : CLAHE (RGB)
- 3 : CLAHE (luma) + Simple (RGB)
- 4 : ScaleAbs – LUT
- 5 : Multi-Scale Retinex (HAVC)
- 6 : Multi-Scale Retinex (B&W)

BlackWhiteBlend: If enabled the frames adjusted with BlackWhiteTune will be blended with the original frames.

EnableDeepEx: Enable coloring using Exemplar-based Video Colorization models.

DeepExMethod: Method to use to generate reference frames. Allowed values are:

- 0 = HAVC same as video (default),
- 1 = HAVC + RF same as video,
- 2 = HAVC + RF different from video,
- 3 = external RF same as video,
- 4 = external RF different from video,
- 5 = external ClipRef same as video,
- 6 = external ClipRef different from video.

DeepExPreset: Preset to control the render method and speed. Allowed values are: 'Fast' (colors are more washed out), 'Medium' (colors are a little washed out), 'Slow' (colors are a little more vivid).

DeepExRefMerge: Method used by DeepEx to merge the reference frames with the frames propagated by DeepEx. It is applicable only with DeepEx method: 0, 1, 2. Allowed values are:

- 0 = No RF merge (reference frames can be produced with any frequency),
- 1 = RF-Merge VeryLow (reference frames are merged with weight=0.3),
- 2 = RF-Merge Low (reference frames are merged with weight=0.4),
- 3 = RF-Merge Med. (reference frames are merged with medium weight=0.5),
- 4 = RF-Merge High (reference frames are merged with weight=0.6),
- 5 = RF-Merge VeryHigh (reference frames are merged with weight=0.7).

DeepExOnlyRefFrames: If enabled the filter will output in ScFrameDir the reference frames. Useful to check and eventually correct the frames with wrong colors (can be used only if DeepExMethod = 0).

DeepExModel: Exemplar Model used by DeepEx to propagate color frames. Allowed values are:

- 0: ColorMNet (default),

- 1: Deep-Exemplar,
- 2 : Deep-Remaster.

DeepExVivid: Depending on selected DeepExModel, if enabled (True): (0) ColorMNet: the frames memory is reset at every reference frame update, (1) Deep-Exemplar: the saturation will be increased by about 25%. (2) Deep-Remaster: the saturation will be increased by about 20% and Hue by +10. Range [True, False].

DeepExEncMode: Parameter used by ColorMNet to define the encode mode strategy. Available values are:

- 0: remote encoding. The frames will be colored by a thread outside Vapoursynth.
  - This option doesn't have any GPU memory limitation and will allow to fully use the long-term frame memory. It is the faster encode method (default)
- 1: local encoding. The frames will be colored inside the Vapoursynth environment.
  - In this case the max_memory will be limited by the size of GPU memory (max 15 frames for 24GB GPU). Useful for coloring clips with a lot of smooth transitions, since in this case is better to use a short frame memory or the Deep-Exemplar model, which is faster.
- 2: remote all-ref. Same as "remote encoding" but all the available reference frames
  - will be used for the inference at the beginning of encoding.

DeepExMaxMemFrames: Parameter used by ColorMNet/DeepRemaster models.

For ColorMNet specify the max number of encoded frames to keep in memory. Its value depends on encode mode and must be defined manually following the suggested values.

DeepExEncMode =0: there is no memory limit (it could be all the frames in the clip).

Suggested values are: min=150, max=10000

If = 0 will be filled with the value of 10000 or the clip length if lower.

DeepExEncMode =1: the max memory frames are limited by available GPU memory.

Suggested values are:

- min=1, max=4: for 8GB GPU
- min=1, max=8: for 12GB GPU
- min=1, max=15: for 24GB GPU

If = 0 will be filled with the max value (depending on total GPU RAM available).

For DeepRemaster represent the number to reference frames to keep in memory.

Suggested values are:

min=4, max=50

If = 0 will be filled with the value of 20.

ScFrameDir: if set, define the directory where are stored the reference frames that will be used by Exemplar-based Video Colorization models. With DeepExMethod 5,6 this parameter can be the path to a video clip.

ScThreshold: Scene changes threshold used to generate the reference frames to be used by Exemplar-based Video Colorization. It is a percentage of the luma change between the previous and the current frame. Range [0-1], default 0.10. If =0 the reference frames are not generated.

ScThtOffset: Offset index used for the Scene change detection. The comparison will be performed, between frame[n] and frame[n-offset]. An offset > 1 is useful to detect blended scene change. Range [1, 25]. Default = 1.

ScMinInt: Minimum number of frame interval between scene changes, Range [1, 25]. Default = 1.

ScMinFreq: if > 0 will be generated at least a reference frame every ScMinFreq frames. Range [0-1500], default: 0.

ScThtSSIM: Threshold used by the SSIM (Structural Similarity Index Metric) selection filter. If > 0, will be activated a filter that will improve the scene-change detection, by discarding images that are similar. Suggested values are between 0.35 and 0.75. Range [0-1], default 0.0 (deactivated).

ScNormalize: If true the B&W frames are normalized before scene detection. The normalization will increase the sensitivity to smooth scene changes. Range [True, False], default: True.

RefRange: Parameter used only with DeepExMethod in (5, 6). With this parameter it is possible to provide the frame number of clip start and end. For example RefRange = (100, 500) will return the clip's slice: clip[100:500], if RefRange=(0, 0) will be considered all clip's frames.

enable_fp16: Enable/disable FP16 in DDcolor inference. Range [True, False], default: True.

debug_level: Set the level of HAVC debug messages. Default = 0 (no messages).

6.2 HAVC_deepex

This is the HAVC function that perform the color inference using the exemplar-based models: ColorMNet, Deep-Exemplar. Some of parameters in input are accepting lists in order to minimize the number of parameters managed by Hybrid. The header of the function is the following:

HAVC_deepex(clip: vs.VideoNode = **None**, clip_ref: vs.VideoNode = **None**, method: int = 0,

render_speed: str = 'medium', render_vivid: bool = True, ref_merge: int = 0, sc_framedir: str = **None**,

ref_norm: bool = False, only_ref_frames: bool = False, dark: bool = False, dark_p: list = (0.2, 0.8),

smooth: bool = False, smooth_p: list = (0.3, 0.7, 0.9, 0.0, "none"), colormap: str = "none",

ref_weight: float = **None**, ref_thresh: float = **None**, ref_freq: int = **None**, ex_model: int = 0,

encode_mode: int = 0, max_memory_frames: int = 0, torch_dir: str = model_dir) -> vs.VideoNode:

Where:

clip: Clip to process, any format is supported

clip_ref: Clip containing the reference frames, it is necessary if method in (0,1,2,5,6).

method: Method to use to generate reference frames (RF). Allowed values are:

- 0 = HAVC same as video (default),
- 1 = HAVC + RF same as video,
- 2 = HAVC + RF different from video,
- 3 = external RF same as video,
- 4 = external RF different from video,
- 5 = external ClipRef same as video,
- 6 = external ClipRef different from video.

render_speed: Preset to control the render method and speed. Allowed values are: 'Fast' (colors are more washed out), 'Medium' (colors are a little washed out), 'Slow' (colors are a little more vivid).

render_vivid Depending on selected ex_model, if enabled (True): (0) ColorMNet: the frames memory is reset at every reference frame update, (1) Deep-Exemplar: the saturation will be increased by about 25%. (2) Deep-Remaster: the saturation will be increased by about 20% and Hue by +10. Range [True, False].

ref_merge Method used by DeepEx to merge the reference frames with the frames propagated by DeepEx.
It is applicable only with DeepEx method: 0, 1, 2. Allowed values are:

- 0 = No RF merge (reference frames can be produced with any frequency),
- 1 = RF-Merge VeryLow (reference frames are merged with weight=0.3),
- 2 = RF-Merge Low (reference frames are merged with weight=0.4),
- 3 = RF-Merge Med. (reference frames are merged with medium weight=0.5),
- 4 = RF-Merge High (reference frames are merged with weight=0.6),
- 5 = RF-Merge VeryHigh (reference frames are merged with weight=0.7).

ref_weight: If (ref_merge > 0), represent the weight used to merge the reference frames. If is not set, is assigned automatically a value depending on ref_merge value.

ref_thresh: Represent the threshold used to create the reference frames. If is not set, is assigned automatically a value of 0.10.

ref_freq: If > 0 will be generated at least a reference frame every "ref_freq" frames. range [0-1500]. If is not set, is assigned automatically a value depending on ref_merge/method values.

ref_norm: If true the B&W frames are normalized before apply the Scene Detection to generate the reference frames. The normalization will increase the sensitivity to smooth scene changes, range [True, False], default: False

sc_framedir: If set, define the directory where are stored the reference frames. If only_ref_frames=True, and method=0 this directory will be written with the reference frames used by the filter. If method!=0 the directory will be read to create the reference frames that will be used by Exemplar-based Video Colorization. The reference frame name must be in the format: **ref_nnnnnn.[jpg | png]**, for example the reference frame 897 must be named: ref_000897.jpg or ref_000897.png. With method 5,6 this parameter can be the path to a video clip.

only_ref_frames: If enabled the filter will output in sc_framedir the reference frames. Useful to check and eventually correct the frames with wrong colors.

dark: Enable/disable darkness filter (only on ref-frames). Range [True, False]

dark_p: List of parameters for darken the clip's dark portions, which sometimes are wrongly colored by the color models, the positional parameters in the list are the following:

- [0]: dark_threshold, luma threshold to select the dark area, range [0.1-0.5] (0.01=1%)
- [1]: dark_amount: amount of desaturation to apply to the dark area, range [0-1]
- [2]: chroma_range (optional), if="none" is disabled, otherwise the filter desaturation will be applied only on the region defined in the chroma range with the requested syntax.

smooth: Enable/disable chroma smoothing (only on ref-frames). Range [True, False]

smooth_p: List of parameters to adjust the saturation and "vibrancy" of the clip, the positional parameters in the list are the following:

- [0]: dark_threshold, luma threshold to select the dark area. Range [0-1] (0.01=1%)
- [1]: white_threshold, if > dark_threshold will be applied a gradient till white_threshold, range [0-1] (0.01=1%)
- [2]: dark_sat, amount of de-saturation to apply to the dark area. Range [0-1]
- [3]: dark_bright, darkness parameter it used to reduce the "V" component in "HSV" color-space. Range [0, 1]
- [4]: chroma_range (optional), if="none" is disabled, otherwise the filter desaturation will be applied only on the region defined in the chroma range with the requested syntax.

colormap: Direct hue/color mapping (only on ref-frames), without luma filtering, using the "chroma adjustment" parameter, if="none" is disabled.

ex_model: Exemplar-based model to use for the color propagation of reference images, available models are: 0 = ColorMNet (default), 1 = Deep-Exemplar, 2 : Deep-Remaster.

encode_mode: Parameter used by ColorMNet to define the encode mode strategy. Available values are:

0: remote encoding. The frames will be colored by a thread outside Vapoursynth.

This option doesn't have any GPU memory limitation and will allow to fully use the long-term frame memory. It is the faster encode method (default)

1: local encoding. The frames will be colored inside the Vapoursynth environment.

In this case the max_memory will be limited by the size of GPU memory (max 15 frames for

24GB GPU). Useful for coloring clips with a lot of smooth transitions, since in this case is better to use a short frame memory or the Deep-Exemplar model, which is faster.

2: remote all-ref. Same as "remote encoding" but all the available reference frames will be used for the inference at the beginning of encoding.

max_memory_frames: Parameter used by ColorMNet/DeepRemaster models.

For ColorMNet specify the max number of encoded frames to keep in memory. Its value depends on encode mode and must be defined manually following the suggested values.

encode_mode =0: there is no memory limit (it could be all the frames in the clip).

Suggested values are: min=150, max=10000

If = 0 will be filled with the value of 10000 or the clip length if lower.

encode_mode =1: the max memory frames are limited by available GPU memory.

Suggested values are:

min=1, max=4: for 8GB GPU

min=1, max=8: for 12GB GPU

min=1, max=15: for 24GB GPU

If = 0 will be filled with the max value (depending on total GPU RAM available).

For DeepRemaster represent the number to reference frames to keep in memory.

Suggested values are:

min=4, max=50

If = 0 will be filled with the value of 20.

torch_dir: torch hub directory location, default is model directory, if set to None will switch to torch cache dir.

6.3 HAVC_colorizer

This is the HAVC function that perform the color inference using the single frame-based models: DeOldify, DDColor and Zhang models. Some of parameters in input are accepting lists in order to minimize the number of parameters managed by Hybrid. The header of the function is the following:

HAVC_colorizer(clip: vs.VideoNode, method: int = 2, mweight: float = 0.4, deoldify_p: list = (0, 24, 1.0, 0.0), ddcolor_p: list = (1, 24, 1.0, 0.0, True), ddtweak : list[bool] = (False, False, False), ddtweak_p: list = (0.0, 1.0, 2.5, True, 0.3, 0.6, 1.5, 0.5, "300:360|0.8,0.1"), cmc_p: list = (0.15, True, 20, 24), lmm_p: list = (0.2, 0.8, 1.0), alm_p: list = (0.8, 1.0, 0.15), cmb_sw: bool = False, sc_threshold: float = 0.0, sc_tht_offset: int = 1, sc_min_freq: int = 0, sc_tht_ssim: float = 0.0, sc_normalize: bool = False, sc_min_int: int = 1, sc_tht_white: float = 0.85, sc_tht_black: float = 0.10, device_index: int = 0, torch_dir: str = model_dir, debug_level: int = 0) -> vs.VideoNode:

Where:

clip: clip to process, any format is supported

method: method used to combine DeOldify with DDColor (default = 2):

- 0: **DeOldify only** (no merge)
- 1: **DDcolor only** (no merge)
- 2: **Simple Merge** (default):
  - the frames are combined using a weighted merge, where the parameter mweight represent the weight assigned to the colors provided by the DDColor frames. With this method is suggested a starting weight < 50% (ex. = 40%).
- 3: **Constrained Chroma Merge**:
  - given that the colors provided by DeOldify are more conservative and stable than the colors obtained with DDcolor. The frames are combined by assigning a limit to the amount of difference in chroma values between DeOldify and DDcolor this limit is defined by the threshold parameter cmc_tresh. The limit is applied to the image converted to "YUV". For example, when cmc_tresh=0.2, the chroma values "U","V" of DDcolor frame will be constrained to have an absolute percentage difference respect to "U","V" provided by DeOldify not higher than 20%. The final limited frame will be merged again with the DeOldify frame. With this method is suggested a starting weight > 50% (ex. = 60%).
- 4: **Luma Masked Merge**:
  - the frames are combined using a masked merge, the pixels of DDcolor with luma < luma_mask_limit will be filled with the pixels of DeOldify. If luma_white_limit > luma_mask_limit the mask will apply a gradient till luma_white_limit. If the parameter mweight > 0 the final masked frame will be merged again, with the DeOldify frame. With this method is suggested a starting weight > 60% (ex. = 70%).
- 5: **Adaptive Luma Merge**:
  - given that the DDcolor performance is quite bad on dark scenes, the images are combined by decreasing the weight assigned to DDcolor when the luma is below a given threshold given by: luma_threshold. The weight is calculated using the formula: merge_weight = MAX(mweight * (luma/luma_threshold)^alpha, min_weight). For example, with: luma_threshold = 0.6 and alpha = 1, the weight assigned to DDColor will start to decrease linearly when the luma < 60% till min_weight. For alpha=2, begins to decrease quadratically (because luma/luma_threshold < 1). With this method is suggested a starting weight > 70% (ex. = 80%).
- 6 : **Chroma Retention Merge**:
  - Given that the colors provided by deoldify() are more conservative and stable than the colors obtained with ddcolor(). This function try to restore the

colors of gray pixels provide by deoldify() by using the colors provided by ddcolor(). The gray pixels are identified by the parameter tht. Once are identified the gray pixels are substituted with the desaturated colors in deoldify(), the level of desaturation is identified by the parameter sat. It is performed a "gradient" substitution, i.e. the gray pixels are gradually substituted depending on the level of gray gradient. The steepness of gradient curve is controlled by the parameter alpha. Optionally is possible to resize the frame before the filter application to speed up the filter by setting True the parameter chroma_resize.

- 7 : **ChromaBound Adaptive**:
  - Adaptive version of Constrained-Chroma. In this version the chroma tolerance is adaptive, i.e., it is applied an approach that will allow more color variation in textured/complex regions and less in smooth areas. The texture strength is computed via Laplacian and chroma tolerance is controlled by the following parameters:
    - [2] base_tol: int = 20, # Base chroma tolerance (smooth areas)
    - [3] max_extra: int = 24, # Extra tolerance for textured areas

The methods 3, 4 and 7 are similar to **Simple Merge**, but before the merge with DeOldify the DDcolor frame is limited in the chroma changes (method 3, 7) or limited based on the luma (method 4).

The method 5 is a **Simple Merge** where the weight decrease with luma.

mweight: weight given to DDcolor clip in all merge methods, range [0-1] (0.01=1%), the final frame is obtained performing the following weighted sum: f_out = f_deoldify*(1-mweight) + mweight*f_ddcolor

deoldify_p: List of parameters for the DeOldify color inference:

[0] DeOldify-model to use (default = 0):

0 = ColorizeVideo_gen

1 = ColorizeStable_gen

2 = ColorizeArtistic_gen

[1] render-factor for the model. Range: 10-44 (default = 24).

[2] saturation parameter to apply to DeOldify color model (default = 1)

[3] hue parameter to apply to DeOldify color model (default = 0)

ddcolor_p: List of parameters for DDcolor inference:

[0] DDColor-model to use (default = 1):

0 = ddcolor_modelscope,

1 = ddcolor_artistic

2 = zhang_siggraph17

3 = zhang_eccv16

[1] render-factor for the model, if=0 will be auto selected (default = 24). Range: [0, 10-64]

[2] saturation parameter to apply to DDcolor model (default = 1)

[3] hue parameter to apply to DDcolor model (default = 0)

[4] FP16: enable/disable FP16 in DDcolor inference

ddtweak: list of flags to enabled/disable tweak parameters for DDcolor. Range [True, False]

ddtweak_p: List of DDcolor tweak parameters:

[0]: bright (default = 0)

[1]: contrast (default = 1), if < 1 DDcolor provides de-saturated frames

[2]: gamma tweak for DDcolor (default = 1)

[3]: luma_constrained_gamma: luma constrained gamma correction enabled (default = False).

Range: [True, False]. When enabled the average luma of a video clip will be forced to don't be below the value defined by the parameter luma_min. The function allows to modify the gamma (g) of the clip if the average luma is below the parameter gamma_luma_min.

A gamma (g) value > 2.0 improves the DDcolor stability on bright scenes, while a gamma (g) < 1 improves the DDcolor stability on dark scenes.

The decrease of the gamma with luma is activated using a gamma_alpha!= 0.

[4]: luma_min: luma (%) min value for tweak activation (default = 0.2), if=0 is not activated, range [0-1]

[5]: gamma_luma_min: luma (%) min value for gamma tweak activation (default = 0.5), if=0 is not Activated. Range [0-1]

[6]: gamma_alpha: the gamma (g) will decrease with the luma using the following expression:

g = MAX(gamma * pow(luma/gamma_luma_min, gamma_alpha), gamma_min),

for a movie with a lot of dark scenes is suggested alpha > 1, if=0 is not activated. Range [>=0]

[7]: gamma_min: minimum value for gamma. Range (default=0.5) [>0.1]

[8]: chroma_adjustment (optional), if="none" is disabled, otherwise will be applied the specified chroma adjustment defined with the requested syntax.

cmc_p: parameters list for methods: **Constrained Chroma Merge** , **ChromaBound Adaptive** (see methods 3, 7 for a full explanation).

- [0] chroma_threshold (%), range [0-1] (0.01=1%), default = 0.15
- [1] red_fix (default = True), # if true red-regions in dark areas are desaturated
- [2] base_tol (default = 20), # Base chroma tolerance (smooth areas)
- [3] max_extra: (default = 24), # Extra tolerance for textured areas

lmm_p: List of parameters for method: **Luma Masked Merge** (see method=4 for a full explanation)

- [0]: luma_mask_limit: luma limit for build the mask used in Luma Masked Merge. Range [0-1] (0.01=1%)
- [1]: luma_white_limit: the mask will apply a gradient till luma_white_limit. Range [0-1] (0.01=1%)

- [2]: luma_mask_sat: if < 1 the DDcolor dark pixels will be substituted with the desaturated DeOldify

Pixels. Range [0-1] (0.01=1%)

alm_p: List of parameters for method: **Adaptive Luma Merge** (see method=5 for a full explanation)

- [0]: luma_threshold: threshold for the gradient merge, range [0-1] (0.01=1%)
- [1]: alpha: exponent parameter used for the weight calculation. Range [>0]
- [2]: min_weight: min merge weight. Range [0-1] (0.01=1%)

crt_p: parameters for method: **Chroma Retention Merge** (see method=6 for a full explanation)

- [0] : sat: this parameter allows to change the saturation of colored clip (default = 0.8)
- [1] : tht: threshold to identify gray pixels, range[0, 255] (default = 30)
- [2] : alpha: parameter used to control the steepness of gradient curve, range [>0] (default = 2.0)
- [3] : chroma_resize: if True, the frames will be resized to improve the filter speed (default = False)

cmb_sw: if true switch the clip order in all the combining methods. Range [True, False]

sc_threshold: Scene changes threshold used to generate the reference frames to be used by Exemplar-based Video Colorization. It is a percentage of the luma change between the previous and the current frame. Range [0-1], default 0.0. If =0 the reference frames are not generated and will be colorized all the frames.

sc_tht_offset: Offset index used for the Scene change detection. The comparison will be performed, between frame[n] and frame[n-offset]. An offset > 1 is useful to detect blended scene change. Range [1, 25]. Default = 1.

sc_tht_ssim: Threshold used by the SSIM (Structural Similarity Index Metric) selection filter. If > 0, will be activated a filter that will improve the scene-change detection, by discarding images that are similar. Suggested values are between 0.35 and 0.85. Range [0-1], default 0.0 (deactivated).

sc_normalize: If true the B&W frames are normalized before scene detection. The normalization will increase the sensitivity to smooth scene changes. Range [True, False], default: True.

sc_min_int: Minimum number of frame interval between scene changes. Range [1, 25]. Default = 1.

sc_min_freq: If > 0 will be generate at least a reference frame every sc_min_freq frames. Range [0-1500], default: 0.

sc_tht_white: Threshold to identify white frames. Range [0-1], default 0.88.

sc_tht_black: Threshold to identify dark frames. Range [0-1], default 0.12.

device_index: device ordinal of the GPU, choices: GPU0...GPU7, CPU=99 (default = 0)

torch_dir: torch hub directory location, default is model directory, if set to None will switch to torch cache dir.

debug_level: Set the level of HAVC debug messages. Default = 0 (no messages).

6.4 HAVC_stabilizer

This is the HAVC function that allows to apply to the input clip the color stabilization filters, which can be applied to stabilize the chroma components in colored clips. Some of parameters in input are accepting lists in order to minimize the number of parameters managed by Hybrid. The header of the function is the following:

HAVC_stabilizer(clip: vs.VideoNode, dark: bool = False, dark_p: list = (0.2, 0.8), smooth: bool = False,

smooth_p: list = (0.3, 0.7, 0.9, 0.0, "none"), stab: bool = False, stab_p: list = (5, 'A', 1, 15, 0.2, 0.8),

colormap: str = "none", render_factor: int = 24) -> vs.VideoNode:

Where:

clip: clip to process, any format is supported.

dark: enable/disable darkness filter. Range [True, False]

dark_p: List of parameters for darken the clip's dark portions, which sometimes are wrongly colored by

the color models:

- [0]: dark_threshold, luma threshold to select the dark area. Range [0.1-0.5] (0.01=1%), default = 0.2
- [1]: dark_amount: amount of desaturation to apply to the dark area. Range [0-1], where a value of 0 will not apply any desaturation, default = 0.8
- [2]: chroma_range (optional), if="none" is disabled, otherwise the filter desaturation will be applied only on the region defined in the chroma range with the requested syntax.

smooth: enable/disable chroma smoothing. Range [True, False]

smooth_p: List of parameters to adjust the saturation and "vibrancy" of the clip.

- [0]: dark_threshold, luma threshold to select the dark area, range [0-1] (0.01=1%)
- [1]: white_threshold, if > dark_threshold will be applied a gradient till white_threshold, range [0-1] (0.01=1%)
- [2]: dark_sat, amount of de-saturation to apply to the dark area. Range [0-1]
- [3]: dark_bright, darkness parameter it used to reduce the "V" component in "HSV" color-space. Range [0, 1]
- [4]: chroma_range (optional), if="none" is disabled, otherwise the filter desaturation will be applied only on the region defined in the chroma range with the requested syntax.

stab: enable/disable chroma stabilizer. Range [True, False]

stab_p: List of parameters for the temporal color stabilizer:

- [0]: nframes, number of frames to be used in the stabilizer. Range [3-15]
- [1]: mode, type of average used by the stabilizer. Range ['A'='arithmetic', 'W'='weighted']
- [2]: sat: saturation applied to the restored gray pixels. Range [0,1]
- [3]: tht, threshold to detect gray pixels. Range [0,255], if=0 is not applied the restore, its value depends on merge method used; suggested values are:
    - method 0: tht = 5
    - method 1: tht = 60 (DDcolor provides very saturated frames)
    - method 2: tht = 15
    - method 3: tht = 20
    - method 4: tht = 5
    - method 5: tht = 10
- [4]: weight, weight to blend the restored image (default=0.2), range [0-1], if=0 is not applied the blending

- [5]: tht_scen, threshold for scene change detection (default = 0.8), if=0 is not activated, range [0.01-0.50]
- [6]: chroma_adjustment (optional), if="none" is disabled, otherwise will be applied the specified chroma adjustment defined with the requested syntax.

colormap: direct hue/color mapping, without luma filtering, using the color mapping syntax, if="none" is disabled.

render_factor: render_factor to apply to the filters, the frame size will be reduced to speed-up the filters, but the final resolution will be the one of the original clip. If = 0 will be auto selected. This approach takes advantage of the fact that human eyes are much less sensitive to imperfections in chrominance compared to luminance. This means that it is possible to speed-up the chroma filters and ultimately get a great high-resolution result. Range: [0, 10-64]

6.5 HAVC_read_video

This is a utility HAVC function used to read a movie to be used as input for the function HAVC_restore_video, The clip provided in output will be already in RGB24 format. The header of the function is the following:

HAVC_read_video(source: str, fpsnum: int = 0, fpsden: int = 1, width: int = 0, height: int = 0,

return_rgb: bool = True) -> vs.VideoNode:

Where:

source: Full path to the video to read

fpsnum: FPS numerator, for using it in HAVC, must be provided the same value of clip to be colored: **clip.fps_num**

fpsden: FPS denominator, for using it in HAVC, must be provided the same value of clip to be colored: **clip.fps_den**

width: If > 0 the clip is resized to width using Spline36

height: If > 0 the clip is resized to height using Spline36

return_rgb: If True the clip will be converted to RGB24 format

Return: clip in RGB24 format if return_rgb is True

6.6 HAVC_restore_video

This is the HAVC function used to colorize a movie using a video clip as source of reference images. Usually, the reference clip to provide in input is obtained by a previous call to the function HAVC_read_video. The header of the function is the following:

HAVC_restore_video(clip: vs.VideoNode = **None**, clip_ref: vs.VideoNode = **None**, method: int = 6,

render_speed: str = 'medium', ex_model: int = 0, ref_merge: int = 0, ref_weight: float = **None**,

ref_thresh: float = **None**, ref_freq: int = **None**, ref_norm: bool = False, max_memory_frames: int = 0,

render_vivid: bool = True, encode_mode: int = 0, torch_dir: str = model_dir) -> vs.VideoNode:

Where:

clip: Clip to process, any format is supported

clip_ref: Clip containing the reference frames, it is necessary if method in (0,1,2,5,6).

method: Method to use to generate reference frames (RF). Allowed values are:

- 0 = HAVC same as video (default),
- 1 = HAVC + RF same as video,
- 2 = HAVC + RF different from video,
- 3 = external RF same as video,
- 4 = external RF different from video,
- 5 = external ClipRef same as video,
- 6 = external ClipRef different from video.

render_speed: Preset to control the render method and speed. Allowed values are: 'Fast' (colors are more washed out), 'Medium' (colors are a little washed out), 'Slow' (colors are a little more vivid).

render_vivid Depending on selected ex_model, if enabled (True): (0) ColorMNet: the frames memory is reset at every reference frame update, (1) Deep-Exemplar: the saturation will be increased by about 25%. (2) Deep-Remaster: the saturation will be increased by about 20% and Hue by +10. Range [True, False].

ref_merge Method used by DeepEx to merge the reference frames with the frames propagated by DeepEx.
It is applicable only with DeepEx method: 0, 1, 2. Allowed values are:

- 0 = No RF merge (reference frames can be produced with any frequency),
- 1 = RF-Merge VeryLow (reference frames are merged with weight=0.3),
- 2 = RF-Merge Low (reference frames are merged with weight=0.4),
- 3 = RF-Merge Med. (reference frames are merged with medium weight=0.5),
- 4 = RF-Merge High (reference frames are merged with weight=0.6),
- 5 = RF-Merge VeryHigh (reference frames are merged with weight=0.7).

ref_weight: If (ref_merge > 0), represent the weight used to merge the reference frames. If is not set, is assigned automatically a value depending on ref_merge value.

ref_thresh: Represent the threshold used to create the reference frames. If is not set, is assigned automatically a value of 0.10.

ref_freq: If > 0 will be generated at least a reference frame every "ref_freq" frames. range [0-1500]. If is not set, is assigned automatically a value depending on ref_merge/method values.

ref_norm: If true the B&W frames are normalized before apply the Scene Detection to generate the reference frames. The normalization will increase the sensitivity to smooth scene changes, range [True, False], default: False

ex_model: Exemplar-based model to use for the color propagation of reference images, available models are: 0 = ColorMNet (default), 1 = Deep-Exemplar, 2 = Deep-Remaster.

encode_mode: Parameter used by ColorMNet to define the encode mode strategy. Available values are:

0: remote encoding. The frames will be colored by a thread outside Vapoursynth.

This option doesn't have any GPU memory limitation and will allow to fully use the long-term frame memory. It is the faster encode method (default)

1: local encoding. The frames will be colored inside the Vapoursynth environment.

In this case the max_memory will be limited by the size of GPU memory (max 15 frames for 24GB GPU). Useful for coloring clips with a lot of smooth transitions, since in this case is better to use a short frame memory or the Deep-Exemplar model, which is faster.

2: remote all-ref. Same as "remote encoding" but all the available reference frames will be used for the inference at the beginning of encoding.

max_memory_frames: Parameter used by ColorMNet/DeepRemaster models.

For ColorMNet specify the max number of encoded frames to keep in memory. Its value depends on encode mode and must be defined manually following the suggested values.

encode_mode =0: there is no memory limit (it could be all the frames in the clip).

Suggested values are: min=150, max=10000

If = 0 will be filled with the value of 10000 or the clip length if lower.

encode_mode =1: the max memory frames are limited by available GPU memory.

Suggested values are:

min=1, max=4: for 8GB GPU

min=1, max=8: for 12GB GPU

min=1, max=15: for 24GB GPU

If = 0 will be filled with the max value (depending on total GPU RAM available).

For DeepRemaster represent the number to reference frames to keep in memory.

Suggested values are:

min=4, max=50

If = 0 will be filled with the value of 20.

torch_dir: torch hub directory location, default is model directory, if set to None will switch to torch cache dir.

6.7 HAVC_SceneDetect

This is the HAVC function to set the scene-change frames in the clip. When is detected a scene change, the frame property '_SceneChangePrev' is set = 1 and '_SceneChangeNext' is set = 0. The header of the function is the following:

HAVC_SceneDetect(clip: vs.VideoNode, sc_threshold: float = 0.10, sc_tht_offset: int = 1,

sc_tht_ssim: float = 0.0, sc_min_int: int = 1, sc_min_freq: int = 0, sc_normalize: bool = False,

sc_tht_white: float = 0.85, sc_tht_black: float = 0.10, sc_debug: bool = False) -> vs.VideoNode:

Where:

clip: clip to process, any format is supported.

sc_threshold: Scene changes threshold used to generate the reference frames.

It is a percentage of the luma change between the previous n-frame (n=sc_the_offset)

and the current frame. range [0-1], default 0.10.

sc_tht_offset: Offset index used for the Scene change detection. The comparison will be performed,

between frame[n] and frame[n-sc_tht_offset]. An sc_tht_offset > 1 is useful to detect blended scene

change. Range [1, 25], default = 1.

sc_normalize: If true the B&W frames are normalized before apply scene detection filter, the normalization will

increase the sensitivity to smooth scene changes.

sc_tht_white: Threshold to identify white frames, range [0-1], default 0.85.

sc_tht_black: Threshold to identify dark frames, range [0-1], default 0.10.

sc_tht_ssim: Threshold used by the SSIM (Structural Similarity Index Metric) selection filter.

If > 0, will be activated a filter that will improve the scene-change detection,

by discarding images that are similar.

Suggested values are between 0.35 and 0.85. Range [0-1], default = 0.0 (deactivated)

sc_min_int: Minimum number of frame interval between scene changes. Range [1, 25], default = 1.

sc_min_freq: If > 0 will be generated at least a reference frame every sc_min_freq frames.

Range [0-1500], default = 0.

sc_debug: If True will enable scene changes debug messages. Range [True, False], default = False

6.8 HAVC_extract_reference_frames

This is an HAVC utility function that perform Scene change detection and the export the reference frames. The header of the function is the following:

HAVC_extract_reference_frames(clip: vs.VideoNode, sc_threshold: float = 0.10, sc_tht_offset: int = 1,

sc_tht_ssim: float = 0.0, sc_min_int: int = 1, sc_min_freq: int = 0, sc_framedir: str = "./",

sc_sequence: bool = False, sc_normalize: bool = False, ref_offset: int = 0,

sc_tht_white: float = 0.85, sc_tht_black: float = 0.10,

ref_ext: str = "jpg", ref_jpg_quality: int = 95,

ref_override: bool = True, sc_debug: bool = False) -> vs.VideoNode:

Where:

clip: clip to process, any format is supported.

sc_threshold: Scene changes threshold used to generate the reference frames.

It is a percentage of the luma change between the previous n-frame (n=sc_the_offset)

and the current frame. range [0-1], default 0.10.

sc_tht_offset: Offset index used for the Scene change detection. The comparison will be performed,

between frame[n] and frame[n-sc_tht_offset]. An sc_tht_offset > 1 is useful to detect blended scene

change. Range [1, 25], default = 1.

sc_normalize: If true the B&W frames are normalized before apply scene detection filter, the normalization will

increase the sensitivity to smooth scene changes.

sc_tht_white: Threshold to identify white frames, range [0-1], default 0.85.

sc_tht_black: Threshold to identify dark frames, range [0-1], default 0.10.

sc_tht_ssim: Threshold used by the SSIM (Structural Similarity Index Metric) selection filter.

If > 0, will be activated a filter that will improve the scene-change detection,

by discarding images that are similar.

Suggested values are between 0.35 and 0.85. Range [0-1], default = 0.0 (deactivated)

sc_min_int: Minimum number of frame interval between scene changes. Range [1, 25], default = 1.

sc_min_freq: If > 0 will be generated at least a reference frame every sc_min_freq frames.

Range [0-1500], default = 0.

sc_framedir: If set, define the directory where are stored the reference frames.

The reference frames are named as: **ref_nnnnnn.[jpg | png]**, for example the reference frame 897

must be named: ref_000897.jpg or ref_000897.png.

sc_sequence: If True, the reference frames will be exported in sequence, using consecutive numbers. Default = False

ref_offset: Offset number that will be added to the number of generated frames, default = 0.

ref_ext: File extension and format of saved frames. Range ["jpg", "png"] , default = "jpg"

ref_jpg_quality: Quality of jpg compression. Range [0, 100], default = 95

ref_override: If True, the reference frames with the same name will be overridden, otherwise will be discarded. Range [True, False], default = True

sc_debug: If True will enable scene changes debug messages. Range [True, False], default = False

6.9 HAVC_export_reference_frames

This is an HAVC utility function that export the reference frames of a clip. The clip must have the frame property '_SceneChangePrev' and '_SceneChangeNext' set. The header of the function is the following:

HAVC_export_reference_frames(clip: vs.VideoNode, sc_framedir: str = "./", ref_offset: int = 0,

ref_ext: str = "jpg", ref_jpg_quality: int = 95, ref_override: bool = True) -> vs.VideoNode:

Where:

clip: clip to process, any format is supported.

sc_framedir: If set, define the directory where are stored the reference frames.

The reference frames are named as: **ref_nnnnnn.[jpg | png]** , for example the reference frame 897 must be named: ref_000897.jpg or ref_000897.png.

ref_offset: Offset number that will be added to the number of generated frames, default = 0.

ref_ext: File extension and format of saved frames. Range ["jpg", "png"] , default = "jpg"

ref_jpg_quality: Quality of jpg compression. Range [0, 100], default = 95

ref_override: If True, the reference frames with the same name will be overridden, otherwise will be discarded. Range [True, False], default = True

6.10 HAVC_bw_tune

Post process filter for improving colors and contrast/luminosity of colored clips with HAVC.

HAVC_bw_tune(clip: vs.VideoNode = None, bw_tune: str = 'light', bw_method: int = 0,

luma_blend: bool = True, range_tv: bool = True, chroma_resize: bool = False) -> vs.VideoNode

Where:

clip: Clip to process, any format is supported.

bw_tune: This parameter allows to improve contrast and luminosity of input clip colored with HAVC.

Allowed values are:

- 'None'
- 'Light', (default)
- 'Medium',
- 'Strong'

bw_method: Method used to perform the histogram equalization. Allowed values are:

- 0 : CLAHE (luma) (default)
- 1 : Simple (RGB)
- 2 : CLAHE (RGB)
- 3 : CLAHE (luma) + Simple (RGB)
- 4 : ScaleAbs – LUT
- 5 : Multi-Scale Retinex (HAVC)
- 6 : Multi-Scale Retinex (B&W)

luma_blend: If enabled the equalized image is blended with the original image, darker is the image and more weight will be assigned to the original image. default = True

range_tv: If True, perform the color adjustments on limited TV range (the filter works better in TV range).

chroma_resize: If True, the clip will be downscaled before applying the filter to speed up the processing.

6.11 HAVC_merge

Utility function with the implementation of HAVC merge methods.

HAVC_merge(clipa: vs.VideoNode= **None**, clipb: vs.VideoNode= **None**, clip_luma: vs.VideoNode = **None**, weight: float = 0.5, method: int = 2, cmc_p: list = (0.15, True, 20, 24), lmm_p: list = (0.15, 0.65, 1.0), alm_p: list = (0.8, 1.0, 0.15), crt_p: list = (0.8, 30, 2, False, 0, 0)) -> vs.VideoNode:

clipa: first clip to merge, any format is supported

clipb: second clip to merge, any format is supported

clip_luma: if specified, clip_luma will be used as source of luma component for the merge. It is an optional parameter, and it is suggested to provide the clip with the best luma resolution between clipa and clipb. It is used only with the methods: 3, 4, 5 and can speed up the filter when it uses these methods.

method: method used to combine DeOldify with DDColor (default = 2):

- 0: **clipa only** (no merge), if clip_luma is not None is luma merged with clip_luma
- 1: **clipb only** (no merge), if clip_luma is not None is luma merged with clip_luma
- 2: **Simple Merge** (default):
  - the frames are combined using a weighted merge, where the parameter mweight represent the weight assigned to the colors provided by the DDColor frames. With this method is suggested a starting weight < 50% (ex. = 40%).
- 3: **Constrained Chroma Merge**:
  - given that the colors provided by DeOldify are more conservative and stable than the colors obtained with DDcolor. The frames are combined by assigning a limit to the amount of difference in chroma values between DeOldify and DDcolor this limit is defined by the threshold parameter cmc_tresh. The limit is applied to the image converted to "YUV". For example, when cmc_tresh=0.2, the chroma values "U","V" of DDcolor frame will be constrained to have an absolute percentage difference respect to "U","V" provided by DeOldify not higher than 20%. The final limited frame will be merged again with the DeOldify frame. With this method is suggested a starting weight > 50% (ex. = 60%).
- 4: **Luma Masked Merge**:
  - the frames are combined using a masked merge, the pixels of DDcolor with luma < luma_mask_limit will be filled with the pixels of DeOldify. If luma_white_limit > luma_mask_limit the mask will apply a gradient till luma_white_limit. If the parameter mweight > 0 the final masked frame will be merged again, with the DeOldify frame. With this method is suggested a starting weight > 60% (ex. = 70%).
- 5: **Adaptive Luma Merge**:
  - given that the DDcolor performance is quite bad on dark scenes, the images are combined by decreasing the weight assigned to DDcolor when the luma is below a given threshold given by: luma_threshold. The weight is calculated using the formula: merge_weight = MAX(mweight * (luma/luma_threshold)^alpha, min_weight). For example, with: luma_threshold = 0.6 and alpha = 1, the weight assigned to DDColor will start to decrease linearly when the luma < 60% till min_weight. For alpha=2, begins to decrease quadratically (because luma/luma_threshold < 1). With this method is suggested a starting weight > 70% (ex. = 80%).
- 6 : **Chroma Retention Merge**:

        - Given that the colors provided by deoldify() are more conservative and stable than the colors obtained with ddcolor(). This function try to restore the colors of gray pixels provide by deoldify() by using the colors provided by ddcolor(). The gray pixels are identified by the parameter tht. Once are identified the gray pixels are substituted with the desaturated colors in deoldify(), the level of desaturation is identified by the parameter sat. It is performed a "gradient" substitution, i.e. the gray pixels are gradually substituted depending on the level of gray gradient. The steepness of gradient curve is controlled by the parameter alpha. Optionally is possible to resize the frame before the filter application to speed up the filter by setting True the parameter chroma_resize.
    - 7 : **ChromaBound Adaptive**:
        - Adaptive version of Constrained-Chroma. In this version the chroma tolerance is adaptive, i.e., it is applied an approach that will allow more color variation in textured/complex regions and less in smooth areas. The texture strength is computed via Laplacian and chroma tolerance is controlled by the following parameters:
            - [2] base_tol: int = 20, # Base chroma tolerance (smooth areas)
            - [3] max_extra: int = 24, # Extra tolerance for textured areas

The methods 3, 4 and 7 are similar to **Simple Merge**, but before the merge with DeOldify the DDcolor frame is limited in the chroma changes (method 3, 7) or limited based on the luma (method 4).

The method 5 is a **Simple Merge** where the weight decrease with luma.

weight: weight given to clipb in all merge methods. If weight = 0 will be returned clipa, if = 1 will be returned clipb. range [0-1] (0.01=1%)

cmc_p: parameters list for methods: **Constrained Chroma Merge** , **ChromaBound Adaptive** (see methods 3, 7 for a full explanation).

- [0] chroma_threshold (%), range [0-1] (0.01=1%), default = 0.15
- [1] red_fix (default = True), # if true red-regions in dark areas are desaturated
- [2] base_tol (default = 20), # Base chroma tolerance (smooth areas)
- [3] max_extra: (default = 24), # Extra tolerance for textured areas

lmm_p: List of parameters for method: **Luma Masked Merge** (see method=4 for a full explanation)

- [0]: luma_mask_limit: luma limit for build the mask used in Luma Masked Merge. Range [0-1] (0.01=1%)
- [1]: luma_white_limit: the mask will apply a gradient till luma_white_limit. Range [0-1] (0.01=1%)
- [2]: luma_mask_sat: if < 1 the DDcolor dark pixels will be substituted with the desaturated DeOldify Pixels. Range [0-1] (0.01=1%)

alm_p: List of parameters for method: **Adaptive Luma Merge** (see method=5 for a full explanation)

- [0]: luma_threshold: threshold for the gradient merge, range [0-1] (0.01=1%)
- [1]: alpha: exponent parameter used for the weight calculation. Range [>0]
- [2]: min_weight: min merge weight. Range [0-1] (0.01=1%)

crt_p: parameters for method: **Chroma Retention Merge** (see method=6 for a full explanation)

- [0] : sat: this parameter allows to change the saturation of colored clip (default = 0.8)
- [1] : tht: threshold to identify gray pixels, range[0, 255] (default = 30)
- [2] : alpha: parameter used to control the steepness of gradient curve, range [>0] (default = 2.0)
- [3] : chroma_resize: if True, the frames will be resized to improve the filter speed (default = False)

6.12 HAVC_recover_clip_color

Utility function to restore the colors of gray pixels in the input clip by using the colors provided in the clip: clip_color. Useful to repair the clips colored with DeepRemaster.

HAVC_recover_clip_color(clip: vs.VideoNode = **None**, clip_color: vs.VideoNode = **None**, sat: float = 0.8, tht: int = 30,

strength: float = 1.0, alpha: float = 2.0, mask_weight: float = 1.0, chroma_resize: bool = True,

return_mask: bool = False, binary_mask: bool = False, algo: int = 0) -> vs.VideoNode:

Where:

clip: clip to repair the colors, any format is supported

clip_color: clip with the colors to restore, only RGB24 format is supported

sat: this parameter allows to change the saturation of colored clip (default = 0.8)

tht: threshold to identify gray pixels, range[0, 255] (default = 30)

strength: represent the strength of the filter. Range[0,1] (default = 1.0)

alpha: parameter used to control the steepness of gradient curve, values above the default value,

will preserve more pixels, but could introduce some artifacts, range[1, 10] (default = 2)

mask_weight: represent the weight of masked colored clip when merged with input clip.

Range[0,1] (default = 1.0)

chroma_resize: if True, the frames will be resized to improve the filter speed (default = True)

return_mask: if True, will be returned the mask used to identify the gray pixels (white region),

could be useful to visualize the gradient mask for debugging, (default = false).

binary_mask: if True, will be used a binary mask instead of a gradient mask, could be useful to get

a clear view on the selected desaturated regions for debugging, (default = false).

algo: algorithm to build the mask, allowed values are:

- [0] = Linear decay with steep gradient, (default)
- [1] = Linear decay
- [2] = Exponential decay

6.13 HAVC_ColorAdjust

Utility function for restoring the colors of clip previously colored with HAVC (or any other colorizer) by improving temporal consistency and contrast/luminosity of colored frames.

HAVC_ColorAdjust(clip: vs.VideoNode, BlackWhiteTune: str = 'Light', BlackWhiteMode: int = 0,

BlackWhiteBlend: bool = True, ReColor: bool = True, Strength: int = 0, ScThreshold: float = 0.10,

ScNormalize: bool = True, DeepExVivid: bool = True, ScMinFreq: int = 0,

chroma_resize: bool = False) -> vs.VideoNode:

Where:

clip: clip to repair the colors, any format is supported

BlackWhiteTune: This parameter allows to improve contrast and luminosity of colored clip colored with HAVC.

Allowed values are: 'None' (default), 'Light', 'Medium', 'Strong'.

BlackWhiteMode: Method used by BlackWhiteTune to perform colors adjustments. Allowed values are:

- 0 : CLAHE (luma) (default)
- 1 : Simple (RGB)
- 2 : CLAHE (RGB)
- 3 : CLAHE (luma) + Simple (RGB)
- 4 : ScaleAbs – LUT
  - BlackWhiteTune = 'Light' -> LUT_Exploration
  - BlackWhiteTune = 'Medium ' -> LUT_City_Skyline
  - BlackWhiteTune = 'Strong' -> LUT_Amber_Light
- 5 : Multi-Scale Retinex (HAVC)
- 6 : Multi-Scale Retinex (B&W)
  - BlackWhiteTune = 'Light' -> LUT_FUJ_Film
  - BlackWhiteTune = 'Medium ' -> LUT_Flat_Pop
  - BlackWhiteTune = 'Strong' -> LUT_Warm_Haze

BlackWhiteBlend: If enabled the frames adjusted with BlackWhiteTune will be blended with the original frames.

ReColor: If True the clip will be re-colored with ColorMNet to enforce color temporal stabilization.

To be used if the clip was colored using an AI automatic video colorizer like HAVC. Default = False

Strength: Color temporal stabilization strength, using high level the colors will be more stable but

will be also more washed. Allowed values are:

- 0 = VeryLow (default)
- 1 = Low
- 2 = Med
- 3 = High
- 4 = VeryHigh

ScThreshold: Scene change threshold used to generate the reference frames to be used by ColorMNet. It is a percentage of the luma change between the previous and the current frame. range [0-1], default 0.10. If =0 are not generate reference frames, Default = 0.10

ScNormalize: If true the frames are normalized before using misc.SCDetect(), the normalization will increase the sensitivity to smooth scene changes, range [True, False], default: True

DeepExVivid: if enabled (True) the ColorMNet memory is reset at every reference frame update range [True, False], default: True

ScMinFreq: if > 0 will be generated at least a reference frame every "ScMinFreq" frames. range [0-1500], default: 0.

chroma_resize: If True, the clip will be downscaled before applying the filter to speed up the processing,

default = False

6.14 HAVC_tweak

Pre/post - process filter for adjust: hue, saturation, brightness, contrast and gamma of a video clip.

HAVC_tweak(clip: vs.VideoNode = **None**, hue: float = 0, sat: float = 1, bright: float = 0,

cont: float = 1, gamma: float = 1) -> vs.VideoNode

Where:

clip: Clip to process, any format is supported.

hue: Adjust the color hue of the image. hue>0.0 shifts the image towards red. hue<0.0 shifts the image towards green. Range -180.0 to +180.0, default = 0.0

sat: Adjust the color saturation of the image by controlling gain of the color channels. sat>1.0 increases the saturation. sat<1.0 reduces the saturation. Use sat=0 to convert to GreyScale. Range 0.0 to 10.0, default = 1.0

bright: Change the brightness of the image by applying a constant bias to the luma channel. bright>0.0 increases the brightness. bright<0.0 decreases the brightness. Range -255.0 to 255.0, default = 0.0

cont: Change the contrast of the image by multiplying the luma values by a constant. cont>1.0 increase the contrast (the luma range will be stretched). cont<1.0 decrease the contrast (the luma range will be contracted). Range 0.0 to 10.0, default = 1.0

gamma: Change the gamma of image which controls the degree of non-linearity in the luma correction. Higher gamma brightens the output; lower gamma darkens the output. Range -10.0 to 10.0, default = 1.0.

6.15 HAVC_adjust_rgb

Utility function to change the color and luminance of RGB clip. Gain, bias (offset) and gamma can be set independently on each channel.

HAVC_adjust_rgb(clip: vs.VideoNode = **None**, strength: float = 0.0, factor: list = (1.0, 1.0, 1.0),

bias: list = (0, 0, 0), gamma: list = (1.0, 1.0, 1.0)) -> vs.VideoNode:

Where:

clip: Clip to process, any format is supported.

strength: This parameter allows to control the strength of the RGB normalization, strength=0 is equivalent to no normalization, while with strength=1 will be applied 100% normalization. The RGB normalization is applied before the other RGB adjustments. Range [0, 1], default=0

factor: List of Red, green and blue scaling factor, in the list format: (r, g, b). Range 0.0 to 255.0, default = (1, 1, 1). For example, r=1.3 multiplies the red channel pixel values by 1.3.

bias: List of Red, green and blue bias adjustments, in the list format: (rb, gb, bb). Bias adjustment add a fixed positive or negative value to a channel's pixel values. For example, rb=16 will add 16 to all red pixel values and rb=-32 will subtract 32 from all red pixel values, default = (0, 0, 0).

gamma: List of Red, green and blue gamma adjustments, in the list format: (rg, gg, bg). Gamma adjustment an exponential gain factor. For example, rg=1.2 will brighten the red pixel values and gg=0.8 will darken the green pixel values.

6.16 HAVC_rgb_denoise

Color post process filter for restoring the correct colors for clip previously colored using: DDColor & Zhang's models. The best results are obtained by using it in combination of HAVC_bw_tune.

HAVC_rgb_denoise(clip: vs.VideoNode = **None**, denoise levels: list[float] = (0.3, 0.2),

factor: list = (0.98, 1.02, 1.0)) -> vs.VideoNode:

Where:

clip: Clip to process, any format is supported.

denoise levels: denoise level for colors and contrast:

- [0] color denoise, range[0,1] (default = 0.3)
- [1] contrast denoise, range[0,1] (default = 0.2)

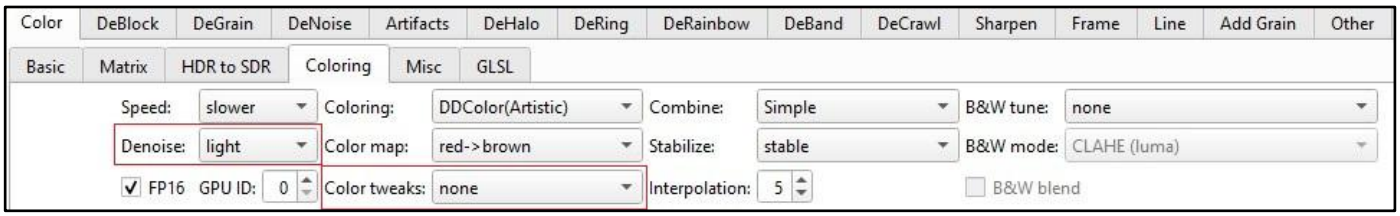
factor: RGB adjustment factors

- [0] RED adjustment factor, range[0,1] (default = 0.98)
- [1] GREEN adjustment factor, range[0,1] (default = 1.02)
- [2] BLUE adjustment factor, range[0,1] (default = 1.0).

This function is able to fix some of the frequent colors hallucinations introduced by the models: DDColor & Zhang's models. In effect, with the only exception of DeOldify, which is stable like a rock, the other models are subject to provide implausible and fast changing colors, which I call colors hallucinations. An example of such hallucinations are shown in the pictures below:

This filter can automatically reduce the amount of color hallucinations as shown in the pictures below:

This filter is automatically selected by HAVC if in the GUI the parameter *Denoise* is not set to **none** and *Color tweaks* is set to **none**, as shown in the picture below:



6.17 HAVC_clip_slice

Utility function to slices the input clip into 2 or 4 overlapping tiles (2x2 grid). This function is useful to color HD films with a resolution significantly higher than 512x512, which represent the maximum resolution used by DeOldify or DDColor. For example a 1920x1080p can be divided in 2 horizontal tiles of size 960x540 or 4 tiles of size 480x270.

See sample scripts Example 8 and Example 9 for an example of usage.

HAVC_clip_slice(clip: vs.VideoNode, slices: int = 2, overlap_x: int = 32, overlap_y: int = 32) -> ClipTiles:

Where:

clip: clip to be sliced in 2 or 4 tiles, any format is supported.

slices: number of slices, allowed values are 2 or 4, default = 2

overlap_x: horizontal overlap pixels size, default = 32

overlap_y: vertical overlap pixels size, default = 32 (used only if slices = 4)

Returns:

class ClipTiles with items:

- clip_orig: original clip
- tiles: [tl, tr, bl, br] — each larger than H/2 x W/2 due to overlap
- original_width: original width
- original_height: original height
- base_tile_w: base tile width (without extra padding)
- base_tile_h: base tile height (without extra padding)
- overlap_x: actual horizontal overlap pixels
- overlap_y: actual vertical overlap pixels

6.18 HAVC_clip_reconstruct

Utility function to reconstructs the original clip from 2 or 4 overlapping tiles, previously sliced using the HAVC function HAVC_clip_slice.

HAVC_clip_reconstruct(clip_tiles: ClipTiles, blend_weight: float = 0.5, chroma_resize: bool = False) -> vs.VideoNode

Where:

clip_tiles: class ClipTiles with items:

- clip_orig: original clip
- tiles: [tl, tr, bl, br] — each larger than H/2 x W/2 due to overlap
- original_width: original width
- original_height: original height
- base_tile_w: base tile width (without extra padding)
- base_tile_h: base tile height (without extra padding)
- overlap_x: actual horizontal overlap pixels
- overlap_y: actual vertical overlap pixels

blend_weight: fixed weight to merge the overlapping region, if == 0 is performed a merge with linear increasing weight from 0 to 1 in the overlapping region for smooth transitions, default = 0.5

chroma_resize: if True will be performed a chroma Resize. The Y plane of reconstructed clip will be replaced by the Y plane of the original clip.

6.19 HAVC_clip_overlay

Puts clip overlay on top of clip base using different blend modes, and with optional x, y positioning, masking and opacity.

HAVC_clip_overlay (base: vs.VideoNode, overlay: vs.VideoNode, x: int = 0, y: int = 0, mask: vs.VideoNode | None = None, opacity: float = 1.0, mode: str = 'normal', planes: (int | Sequence[int]) | None = None, mask_first_plane: bool = True) -> vs.VideoNode

Where:

base: This clip will be the base, determining the size and all other video properties of the result.

overlay: This is the image that will be placed on top of the base clip.

x, y: Define the placement of the overlay image on the base clip, in pixels. Can be positive or negative.

mask: Optional transparency mask. Must be the same size as overlay. Where mask is darker,

overlay will be more transparent.

opacity: Set overlay transparency. The value is from 0.0 to 1.0, where 0.0 is transparent and 1.0 is fully opaque.

This value is multiplied by mask luminance to form the final opacity.

mode: Defines how your overlay should be blended with your base image.

Available blend modes are:

- 'normal',
- 'addition',
- 'average',
- 'difference',
- 'divide',
- 'exclusion',
- 'multiply',
- 'overlay',
- 'subtract'.

planes: Specifies which planes will be processed. Any unprocessed planes will be simply copied.

mask_first_plane: If true, only the mask's first plane will be used for transparency.

6.20 HAVC_auto_levels

Pre-/Post-process filter using Histogram Equalization or Retinex for improving contrast/luminosity of B&W clips to be colored with HAVC.

HAVC_auto_levels (clip: vs.VideoNode, mode: str = 'Light', method: int = 0, luma_blend: bool = False, range_tv: bool = True) -> vs.VideoNode

Where:

clip: clip to process, any format is supported.

mode: This parameter allows to improve contrast and luminosity of input clip. Allowed values are:

- 'Light', (default)
- 'Medium'
- 'Strong'

method: Method used to perform the histogram equalization. Allowed values are:

0. CLAHE (luma) (default)
1. Simple Histogram Equalization on all RGB channels
2. CLAHE on all RGB channels
3. CLAHE (luma) + Simple (RGB)
4. ScaleAbs + LUT
    a. mode = 'Light' -> LUT_Exploration
    b. mode = 'Medium ' -> LUT_City_Skyline
    c. mode = 'Strong' -> LUT_Amber_Light
5. Multi-Scale Retinex on Luma

luma_blend: If enabled the equalized image is blended with the original image, darker is the image and more weight will be assigned to the original image, default = False

range_tv: If True, perform the color adjustments on limited TV range (the filter works better in TV range), default = True

6.21 HAVC_TimeCube

Utility function to apply LUTs effect using TimeCube.

HAVC_TimeCube (clip: vs.VideoNode, strength: float = 1.0, lut_effect: int = 0, factors: list = **None**

) -> vs.VideoNode

Where:

clip: clip to process, any format is supported.

strength: strength of the filter, range [0, 1]. Default = 1

lut_effect: LUT effect to apply, range [0,6], allowed values are:

- DEF_LUT_Forest_Film: int = 0
- DEF_LUT_City_Skyline: int = 1
- DEF_LUT_Exploration: int = 2
- DEF_LUT_FUJ_Film: int = 3
- DEF_LUT_Hollywood: int = 4
- DEF_LUT_Classic_Film: int = 5
- DEF_LUT_Warm_Haze: int = 6
- DEF_LUT_HDR_Color: int = 7
- DEF_LUT_Amber_Light: int = 8
- DEF_LUT_Blue_Mist: int = 9
- DEF_LUT_Vintage_Fox: int = 10
- DEF_LUT_Flat_Pop: int = 11

factors: if is not set to None, is necessary to provide a list with the full adjustment factors,

with the following order:

- factors[0] -> hue (default = 0)
- factors[1] -> sat (default = 1)
- factors[2] -> bright (default = 0)
- factors[3] -> cont (default = 1)
- factors[4] -> gamma (default = 1)

6.22 HAVC_export_list_frames

Utility function to export frames included in a list.

HAVC_export_list_frames (clip: vs.VideoNode, sc_framedir: str = "./", ref_list: list[int] | **None** = **None**, offset: int = 0, ref_ext: str = "jpg", ref_jpg_quality: int = 95, ref_override: bool = True, fast_extract: bool = True) -> vs.VideoNode

Where:

clip: clip to process, any format is supported.

sc_framedir: If set, define the directory where are stored the exported frames.

The frames are named as: ref_nnnnnn.[jpg|png].

ref_list: List of frame numbers to export. default: **None**. If ref_list contains only one frame number, for example ref_list = [25], will be exported a frame every 25 frames

offset: The offset will be added to the frame number. default = 0.

ref_ext: File extension and format of saved frames, range ["jpg", "png"] . default: "jpg"

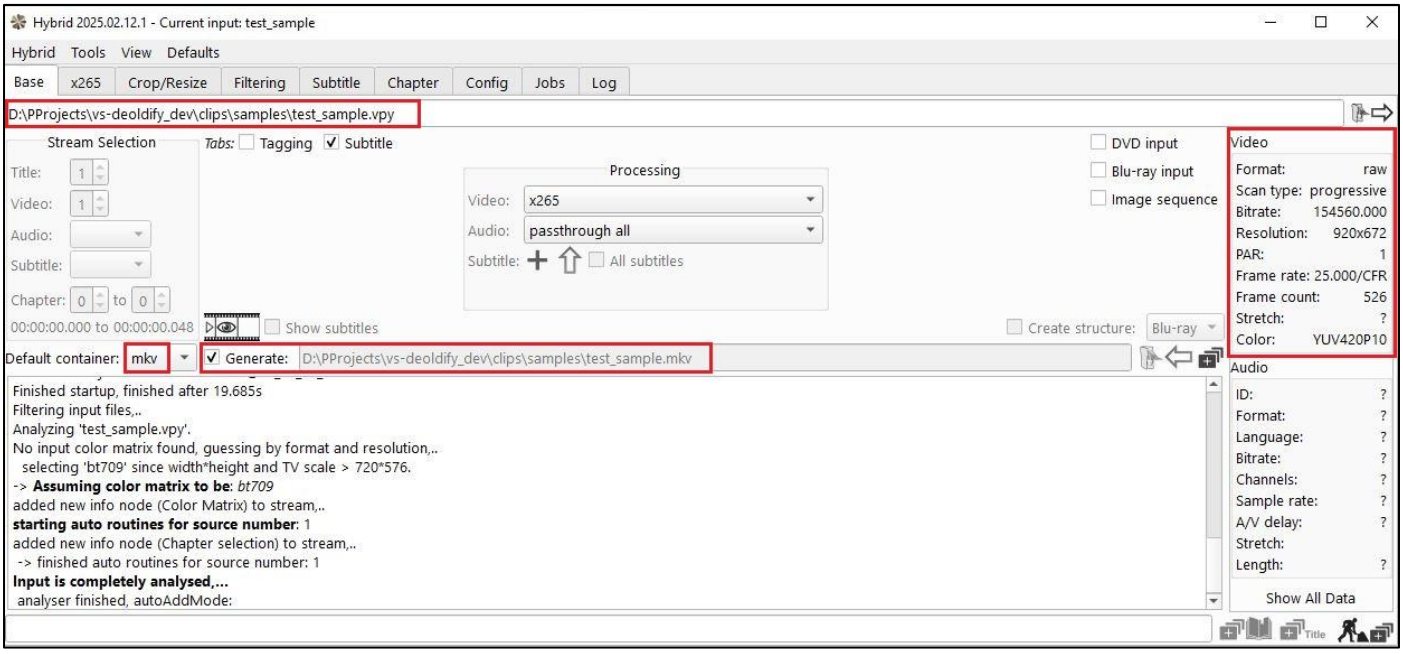
ref_jpg_quality: Quality of "jpg" compression, range[0,100]. default: 95

ref_override: If True, the frames with the same name will be overridden, otherwise will be discarded. default: True

fast_extract: If True, the frames will be extracted directly with get_frame(), otherwise will be performed a full parsing of the clip (necessary if there is a sequential temporal dependency in the script calling this function). default = True

7.0 Sample scripts

In this chapter will be shown some useful Vapoursynth scripts using the HAVC functions. In Hybrid is possible to provide in input, not only movies, but also Vapoursynth scripts as shown in the picture below:



Once the script has been loaded by Hybrid it is possible to encode it directly or to add some filters before start the encoding process.

All the filters that will be added in Hybrid after the loading of Vapoursynth script will be applied on the clip generated by the script in input. The script that will be executed is the following:

In this example were added the filters: **CAS** (to increase the sharpness) and **AddGrain** (to add some grain).

As is possible to see these filters are applied on the script output, which must be a clip.

Example 1: script to restore a colored video using DeepRemaster

```
# Imports
import vapoursynth as vs
# getting Vapoursynth core
import sys
import os
core = vs.core
# Import scripts folder
scriptPath = 'D:/Programs/Hybrid/64bit/vsscripts'
sys.path.insert(0, os.path.abspath(scriptPath))
# Import scripts
import vsdeoldify as havc
clip = havc.HAVC_read_video(source="source_bw_clip.mp4")
clipRef = havc.HAVC_read_video(source="reference_colored_clip.mp4", fpsnum=clip.fps_num, fpsden=clip.fps_den)
# change of hue, saturation, contrast and bright (optional)
clipRef = havc.HAVC_tweak(clipRef, hue=5.00, sat=1.05, cont=0.80, bright=-1.1)
# ------------------------------------------------------------------------------
clip = havc.HAVC_restore_video(clip, clipRef, ex_model = 2, ref_thresh = 0.10, ref_freq = 10,
max_memory_frames = 50, render_vivid = True)
# adjusting output color to YUV420P10 for x265Model
clip = core.resize.Bicubic(clip=clip, format=vs.YUV420P10, matrix_s="709", range_s="limited")
# set output frame rate (progressive)
clip = core.std.AssumeFPS(clip=clip, fpsnum=clip.fps_num, fpsden=clip.fps_den)
# output
clip.set_output()
```

Example 2: Merging of 2 colored clips and restore of the original luma e resolution of B&W clip

```
# Imports
import vapoursynth as vs
# getting Vapoursynth core
import sys
import os
core = vs.core
# Import scripts folder
scriptPath = 'D:/Programs/Hybrid/64bit/vsscripts'
sys.path.insert(0, os.path.abspath(scriptPath))
# Import scripts
import vsdeoldify as havc
# clip_YUV = B&W Clip
clip = havc.HAVC_read_video(source="source_bw_clip.mp4")
# Resize clip
clip = core.resize.Spline36(clip=clip, width=1280, height=784)
# adjusting output color to YUV420P10 for x265Model
clip_YUV = core.resize.Bicubic(clip=clip, format=vs.YUV420P10, matrix_s="709", range_s="limited",
dither_type="error_diffusion")
# clip = CLIP COLORED WITH HAVC
clip = havc.HAVC_read_video(source="colored_havc_clip.mp4", fpsnum=clip_YUV.fps_num, fpsden=clip_YUV.fps_den)
# clip = CLIP COLORED WITH DEEPREMASTER
clip_ref = havc.HAVC_read_video(source="colored_deepremaster_clip.mp4",fpsnum=clip_YUV.fps_num,
fpsden=clip_YUV.fps_den)
clip_ref = havc.HAVC_bw_tune(clip=clip_ref, bw_tune="medium")
# --------------------- START MERGING & RESTORE LUMA -----------------------------------
clip = core.std.Merge(clipa=clip, clipb=clip_ref, weight=0.60)
# adjusting output color YUV420P10 for x265Model
clip = core.resize.Bicubic(clip=clip, format=vs.YUV420P10, matrix_s="709", range_s="limited",
dither_type="error_diffusion")
clip = core.std.ShufflePlanes(clips=[clip_YUV, clip, clip], planes=[0, 1, 2], colorfamily= vs.YUV)
# set output frame rate to (progressive)
clip = core.std.AssumeFPS(clip=clip, fpsnum=clip_YUV.fps_num, fpsden=clip_YUV.fps_den)
# output
clip.set_output()
```

Example 3: Remove the flickering produced by DeepRemaster

```
# Imports
import vapoursynth as vs
# getting Vapoursynth core
import sys
import os
core = vs.core
# Import scripts folder
scriptPath = 'D:/Programs/Hybrid/64bit/vsscripts'
sys.path.insert(0, os.path.abspath(scriptPath))
# Import scripts
import vsdeoldify as havc
clip = havc.HAVC_read_video(source="sample_deepremaster_flicker.mp4")
# -------------------------------------------------------
clip = havc.HAVC_stabilizer(clip, dark=True, stab=True, stab_p = (5, 'A', 1, 0, 0, 0))
# adjusting output color to YUV420P10 for x265Model
clip = core.resize.Bicubic(clip=clip, format=vs.YUV420P10, matrix_s="709", range_s="limited")
# removing flickering using ReduceFlicker
clip = core.rdfl.ReduceFlicker(clip=clip, strength=2, aggressive=0)
# -------------------------------------------------------
# set output frame rate (progressive)
clip = core.std.AssumeFPS(clip=clip, fpsnum=clip.fps_num, fpsden=clip.fps_den)
# output
clip.set_output()
```

Example 4: Merging a DeepRemaster clip with a simple colored clip with HAVC_merge

```
# Imports
import vapoursynth as vs
# getting Vapoursynth core
import sys
import os
core = vs.core
# Import scripts folder
scriptPath = 'D:/Programs/Hybrid/64bit/vsscripts'
sys.path.insert(0, os.path.abspath(scriptPath))
# Import scripts
import validate
import vsdeoldify as havc
clip1 = havc.HAVC_read_video(source="sample_deepremaster.mkv")
# decrease the saturation of deepremaster clip (optional)
clip1 = havc.HAVC_Tweak(clip1, hue=0.00, sat=0.90, cont=1.0, bright=0.0)
clip2 = havc.HAVC_read_video(source="sample_simple_colored.mkv")
# merging the 2 clips using the method: Adaptive Luma Merge
clip = havc.HAVC_merge(clipa=clip2, clipb=clip1, weight=0.80, method=5, alm_p=(0.9, 1.0, 0.65))
# adjusting output color from: RGB24 to YUV420P10 for x265Model
clip = core.resize.Bicubic(clip=clip, format=vs.YUV420P10, matrix_s="709", range_s="limited")
# set output frame rate (progressive)
clip = core.std.AssumeFPS(clip=clip, fpsnum=clip.fps_num, fpsden=clip.fps_den)
# output
clip.set_output()
```

Example 5: Recover DeepRemaster gray colors using a colored clip with HAVC_recover_clip_color

```
# Imports
import vapoursynth as vs
# getting Vapoursynth core
import sys
import os
core = vs.core
# Import scripts folder
scriptPath = 'D:/Programs/Hybrid/64bit/vsscripts'
sys.path.insert(0, os.path.abspath(scriptPath))
# Import scripts
import vsdeoldify as havc
clip1 = havc.HAVC_read_video(source="sample_deepremaster.mkv")
# decrease the saturation of deepremaster clip (optional)
clip1 = havc.HAVC_tweak(clip1, hue=0.00, sat=0.90, cont=1.0, bright=0.0)
clip2 = havc.HAVC_read_video(source="sample_simple_colored.mkv")
# recover the gray colors
clip = havc.HAVC_recover_clip_color(clip1, clip2, tht=60, strength=0.5, alpha=2, return_mask=False)
# adjusting output color from: RGB24 to YUV420P10 for x265Model
clip = core.resize.Bicubic(clip=clip, format=vs.YUV420P10, matrix_s="709", range_s="limited")
# set output frame rate (progressive)
clip = core.std.AssumeFPS(clip=clip, fpsnum=clip.fps_num, fpsden=clip.fps_den)
# output
clip.set_output()
```

Example 6: Direct application of filter B&W tune with some colors final adjustment

```
# Imports
import vapoursynth as vs
# getting Vapoursynth core
import sys
import os
core = vs.core
# Import scripts folder
scriptPath = 'D:/Programs/Hybrid/64bit/vsscripts'
sys.path.insert(0, os.path.abspath(scriptPath))
# Import scripts
import vsdeoldify as havc
clip = havc.HAVC_read_video(source="sample_deepremaster.mkv")
# application of filter B&W tune
clip = havc.HAVC_bw_tune(clip, bw_tune='medium', bw_method=0, luma_blend=True, range_tv=True)
clip = havc.HAVC_adjust_rgb(clip, strength=0.5, gamma=(1.0,0.95,1.0))
clip = havc.HAVC_tweak(clip, hue=0.00, sat=1.15, cont=0.95, bright=0.0, gamma=0.98)
# adjusting output color from: RGB24 to YUV420P10 for x265Model
clip = core.resize.Bicubic(clip=clip, format=vs.YUV420P10, matrix_s="709", range_s="limited")
# set output frame rate (progressive)
clip = core.std.AssumeFPS(clip=clip, fpsnum=clip.fps_num, fpsden=clip.fps_den)
# output
clip.set_output()
```

Example 7: Comparison of LUTs filters used by HAVC_ColorAdjust

```
# Imports
import vapoursynth as vs
# getting Vapoursynth core
import sys
import os
core = vs.core
# Import scripts folder
scriptPath = 'D:/Programs/Hybrid/64bit/vsscripts'
sys.path.insert(0, os.path.abspath(scriptPath))
# Import scripts
import vsdeoldify as havc
clip = havc.HAVC_read_video(source="sample_colored_clip.mkv")
# application of LUT filters
# Comparing HAVC LUTs
# ----------------
clip1 = havc.HAVC_ColorAdjust(clip=clip, BlackWhiteTune="light", BlackWhiteMode=4, BlackWhiteBlend="True",
ReColor=False)
clip1 = core.text.Text(clip=clip1,text="Forest Film", scale=1,alignment=7)
# ----------------
clip2 = havc.HAVC_ColorAdjust(clip=clip, BlackWhiteTune="medium", BlackWhiteMode=4, BlackWhiteBlend="True",
ReColor=False)
clip2 = core.text.Text(clip=clip2,text="City Skyline", scale=1,alignment=7)
# ----------------
clip3 = havc.HAVC_ColorAdjust(clip=clip, BlackWhiteTune="strong", BlackWhiteMode=4, BlackWhiteBlend="True",
ReColor=False)
clip3 = core.text.Text(clip=clip3,text="Exploration",scale=1,alignment=7)
# ----------------
clip4 = havc.HAVC_ColorAdjust(clip=clip, BlackWhiteTune="light", BlackWhiteMode=6, BlackWhiteBlend="True",
ReColor=False)
clip4 = core.text.Text(clip=clip4,text="FUJ Film", scale=1,alignment=7)
# ----------------
clip5 = havc.HAVC_ColorAdjust(clip=clip, BlackWhiteTune="medium", BlackWhiteMode=6, BlackWhiteBlend="True",
ReColor=False)
clip5 = core.text.Text(clip=clip5,text="Amber Light", scale=1,alignment=7)
# ----------------
clip6 = havc.HAVC_ColorAdjust(clip=clip, BlackWhiteTune="strong", BlackWhiteMode=6, BlackWhiteBlend="True",
ReColor=False)
clip6 = core.text.Text(clip=clip6,text="Warm Haze", scale=1,alignment=7)
# ----------------
stack1 = core.std.StackHorizontal([clip1, clip2, clip3])
stack2 = core.std.StackHorizontal([clip4, clip5, clip6])
clip = core.std.StackVertical([stack1, stack2])
# ----------------
# adjusting output color from: RGB24 to YUV420P10 for x265Model
clip = core.resize.Bicubic(clip=clip, format=vs.YUV420P10, matrix_s="709", range_s="limited")
# set output frame rate (progressive)
clip = core.std.AssumeFPS(clip=clip, fpsnum=clip.fps_num, fpsden=clip.fps_den)
# output
clip.set_output()
```

Example 8: Coloring a clip sliced in 2 horizonal tiles

```
# Imports
import vapoursynth as vs
# getting Vapoursynth core
import sys
import os
core = vs.core
# Import scripts folder
scriptPath = 'D:/Programs/Hybrid/64bit/vsscripts'
sys.path.insert(0, os.path.abspath(scriptPath))
# Import scripts
import vsdeoldify as havc
clip = havc.HAVC_read_video(source="sample_colored_clip.mkv")
clips = havc.HAVC_clip_slice(clip, 2, 32, 32)
# ------------------------------------------------------------------------
clips.tiles[0] = havc.HAVC_main(clip=clips.tiles[0], Preset="slower", ColorModel="Video+Artistic",
CombMethod="ChromaBound Adaptive", VideoTune="vivid", ColorTemp="none", ColorFix="retinex/red",
FrameInterp=0, ColorMap="red->brown", ColorTune="medium", BlackWhiteTune="light", BlackWhiteMode=0,
BlackWhiteBlend=True, EnableDeepEx=False)
# ------------------------------------------------------------------------
clips.tiles[1] = havc.HAVC_main(clip=clips.tiles[1], Preset="slower", ColorModel="Video+Artistic",
CombMethod="ChromaBound Adaptive", VideoTune="vivid", ColorTemp="none", ColorFix="retinex/red",
FrameInterp=0, ColorMap="red->brown", ColorTune="medium", BlackWhiteTune="light", BlackWhiteMode=0,
BlackWhiteBlend=True, EnableDeepEx=False)
# ------------------------------------------------------------------------
clip = havc.HAVC_clip_reconstruct(clips, 0, True)
clip = core.resize.Bicubic(clip=clip, format=vs.YUV420P10, matrix_s="709", range_s="limited",
dither_type="error_diffusion")
# ------------------------------------------------------------------------
# output
clip.set_output()
```

Example 9: Coloring a clip sliced in 4 tiles (2x2 grid)

```
# Imports
import vapoursynth as vs
# getting Vapoursynth core
import sys
import os
core = vs.core
# Import scripts folder
scriptPath = 'D:/Programs/Hybrid/64bit/vsscripts'
sys.path.insert(0, os.path.abspath(scriptPath))
# Import scripts
import vsdeoldify as havc
clip = havc.HAVC_read_video(source="sample_colored_clip.mkv")
clips = havc.HAVC_clip_slice(clip, 4, 32, 32)
# ------------------------------------------------------------------------
clips.tiles[0] = havc.HAVC_main(clip=clips.tiles[0], Preset="slower", ColorModel="Video+Artistic",
CombMethod="ChromaBound Adaptive", VideoTune="vivid", ColorTemp="none", ColorFix="retinex/red",
FrameInterp=0, ColorMap="red->brown", ColorTune="medium", BlackWhiteTune="light", BlackWhiteMode=0,
BlackWhiteBlend=True, EnableDeepEx=False)
# ------------------------------------------------------------------------
clips.tiles[1] = havc.HAVC_main(clip=clips.tiles[1], Preset="slower", ColorModel="Video+Artistic",
CombMethod="ChromaBound Adaptive", VideoTune="vivid", ColorTemp="none", ColorFix="retinex/red",
FrameInterp=0, ColorMap="red->brown", ColorTune="medium", BlackWhiteTune="light", BlackWhiteMode=0,
BlackWhiteBlend=True, EnableDeepEx=False)
# ------------------------------------------------------------------------
clips.tiles[2] = havc.HAVC_main(clip=clips.tiles[2], Preset="slower", ColorModel="Video+Artistic",
CombMethod="ChromaBound Adaptive", VideoTune="vivid", ColorTemp="none", ColorFix="retinex/red",
FrameInterp=0, ColorMap="red->brown", ColorTune="medium", BlackWhiteTune="light", BlackWhiteMode=0,
BlackWhiteBlend=True, EnableDeepEx=False)
# ------------------------------------------------------------------------
clips.tiles[3] = havc.HAVC_main(clip=clips.tiles[3], Preset="slower", ColorModel="Video+Artistic",
CombMethod="ChromaBound Adaptive", VideoTune="vivid", ColorTemp="none", ColorFix="retinex/red",
FrameInterp=0, ColorMap="red->brown", ColorTune="medium", BlackWhiteTune="light", BlackWhiteMode=0,
BlackWhiteBlend=True, EnableDeepEx=False)
# ------------------------------------------------------------------------
clip = havc.HAVC_clip_reconstruct(clips, 0.5, True)
clip = core.resize.Bicubic(clip=clip, format=vs.YUV420P10, matrix_s="709", range_s="limited",
dither_type="error_diffusion")
# ------------------------------------------------------------------------
# output
clip.set_output()
```

8.0 Useful companion software

To perform advanced coloring could be useful the following software:

8.0.1 Software for coloring pictures

The project interactive-deep-colorization , whose automatic colorization model is included in HAVC with the name of siggraph17, provides a useful tool that help to interactively colorize pictures. The installation of this software is quite complex, fortunately this software has been added in Photoshop Elements since version 2020, see this link for more details: Automatically colorize your photos.

8.0.2 Software for processing batch of pictures

Sometime it will be necessary to process a significant number of reference frames, for example to change the size and recompress in jpg. There are a lot of software to perform this task. I found that XnView is good tool to perform these tasks and I suggest to use it.

Sometime it will be also, necessary to rename a significant number of reference frames. There are a lot of software to perform this task. I found that Advanced Renamer is a good tool to perform this task and I suggest to use it.

8.2 Useful Web Links

In this chapter are provided some useful links related to the colorization

- The Hybrid forum has a specific thread for the filter HAVC: https://forum.selur.net/thread-3595.html
  - It has also a specific thread for general questions: https://forum.selur.net/forum-3.html
- On GitHub there is a specific project in collecting colorization papers: https://github.com/MarkMoHR/Awesome-Image-Colorization
- The Internet Archive Site is a useful resource to get interesting B&W movie to colorize.
  - huge list of movies: https://archive.org/details/opensource_movies
  - list of contributed AI colored movies[20]: https://archive.org/details/colorized-movies
  - list of contributed movies colored with HAVC: havc-colorized-movies
- For the users that want to understand better the scripts generated by Hybrid, using the Vapoursynth functions, is suggested to read the Vapoursynth documentation: http://www.vapoursynth.com/doc/

[20] Most of them are based on DeOldify with additional contrast and color correction via Avidemux.