fluendo

VVC/H.266 Alpha Channel in GStreamer

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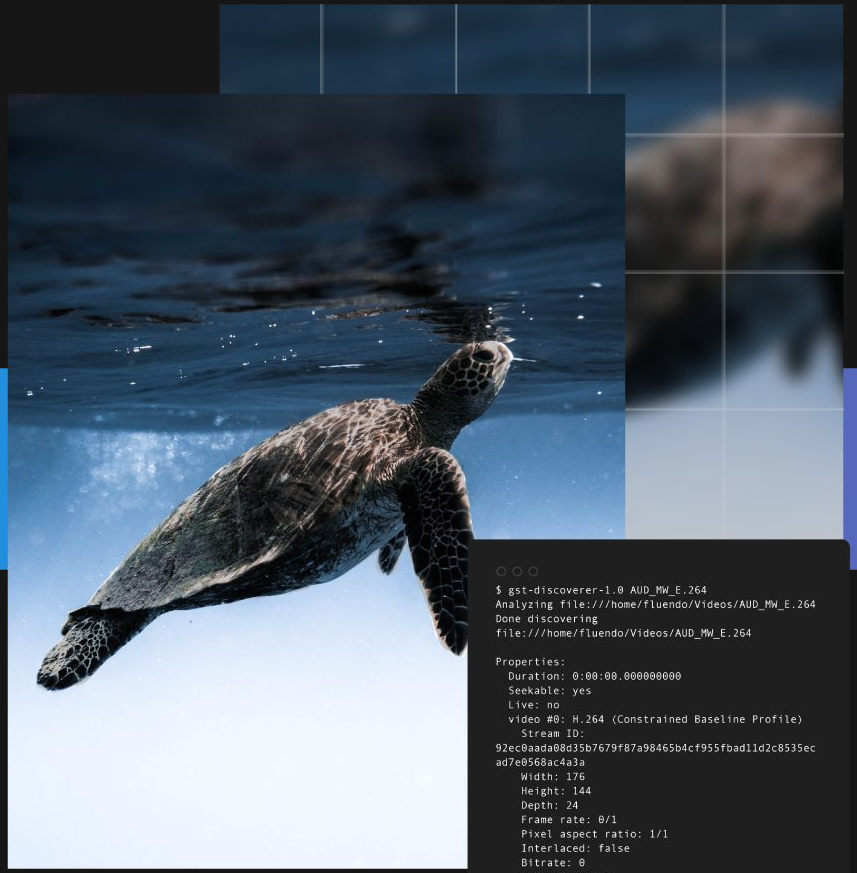
Diego Nieto

GStreamer Conference 2025

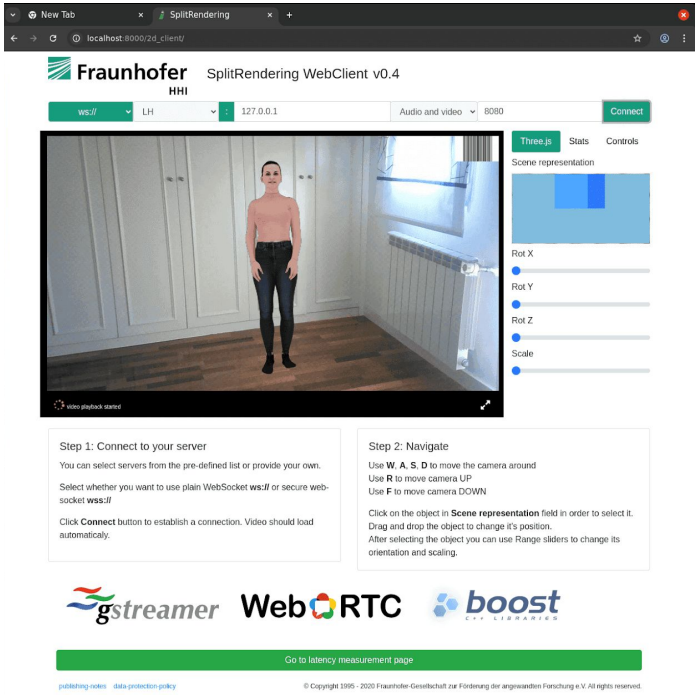


About Me

- Andoni Morales Alastruey @ylatuya
- Working for Fluendo for ~ 14 years
- GStreamer contributor since 2009
- Cerbero author
- Fluster co-author
- LongoMatch Founder

Context & Motivation: The STREAM Project

- **SPIRIT** – Scalable Platform for Real-time Immersive Telepresence:
  - Europe's first multisite and interconnected framework for telepresence applications.
  - Provides a toolkit for telepresence:
    - Capture volumetric data
    - Generate videos with 3D avatars
    - Low-latency video streaming
    - Client rendering in VR environment for an immersive experience
- **STREAM** – Scalable Telepresence with Real-time EnhAnced Multimedia:
  - SPIRIT Open Call 1
  - **Reduce bandwidth** preserving quality for 4k resolution
  - **GStreamer** + **Gst.WASM**
  - **H.266/VVC** + **Alpha Channel** support

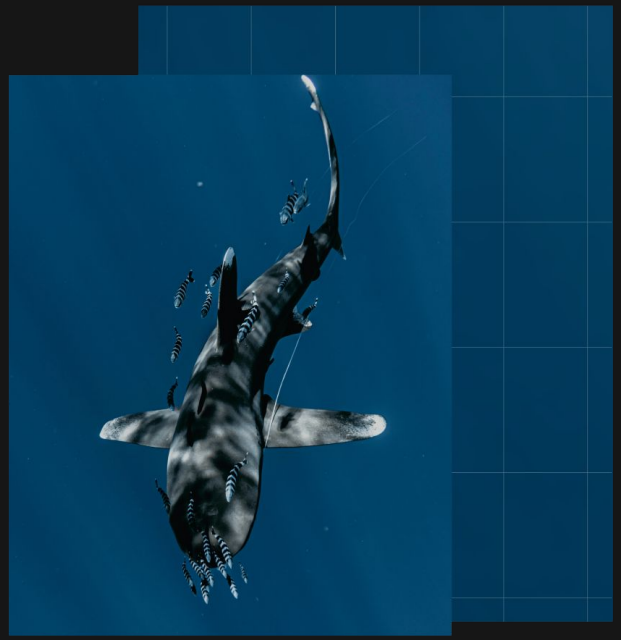


Alpha Channel Fundamentals

What is an Alpha Channel?

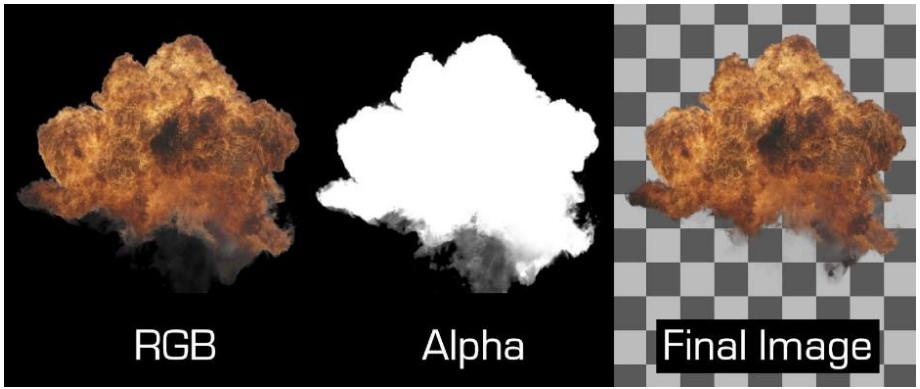
VP8/VP9

VVC / H.266



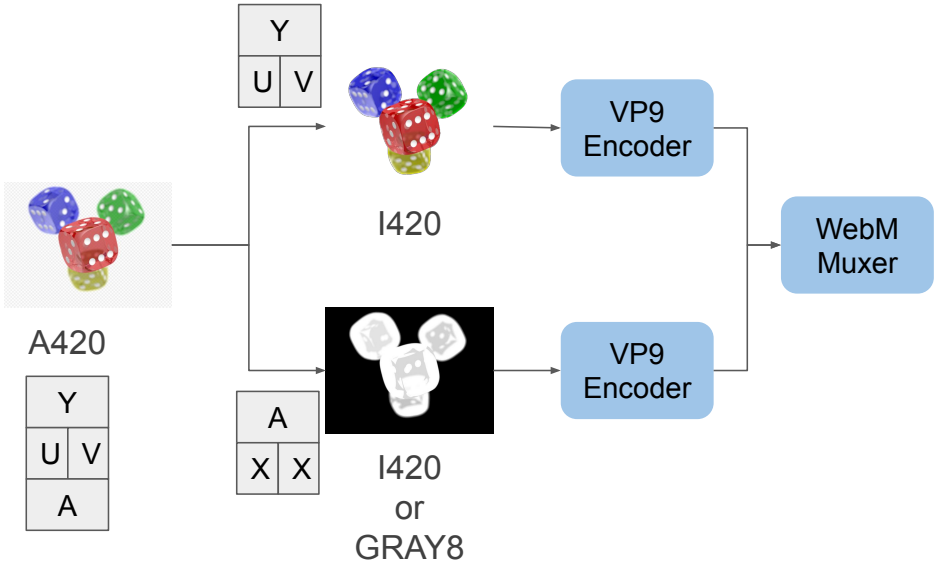
What is the Alpha Channel

- An extra grayscale channel that contains information about pixel transparency.
- Used to create an **alpha mask** to overlay videos without visible borders or backgrounds.
- RGB + A:
  a. 32 bits per pixel, 8R + 8G + 8B + 8A
  b. format: RGBA, ARGB, ...
- YUV + A:
  a. Alpha channel is usually not subsampled
  b. format: AYUV, A420, A422, A444, ...



Alpha Channel in VP8/VP9 with WebM

- Not defined in the codec specification.
- The A420 input stream is split in 2 streams:
  - Main: I420 with alpha stripped
  - Alpha: GREY 8 or I420 (A -> Y channel, U and V are ignored
- Streams are encoded independently
- The main track and the alpha track are muxed with WebM
- Supported in Firefox, Opera and Chrome

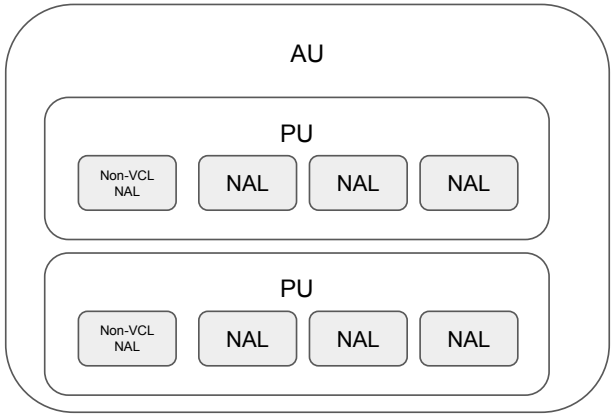


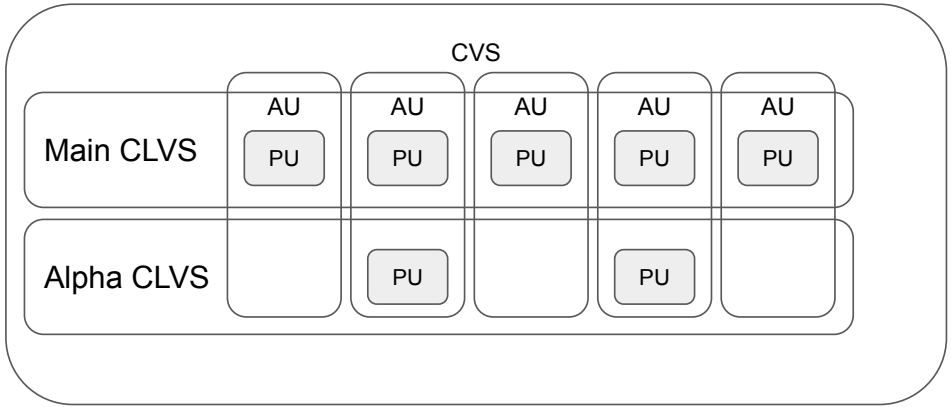
Alpha Channel in VVC/H.266

- Combination of **multi-layer** and **SEI signalling**
- Alpha channel is encoded as an **auxiliary layer**.
- Alpha channel is part of the **bitstream**.
- It's signalled through 2 SEI messages:
  - **Scalability Dimension Info** - SDI (8.19)
  - **Alpha Channel Info** - ACI (8.23)
- Signalling is defined in **ITU H.274**
- The H.274 specification was designed for VVC/H.266, with the goal of being **reusable** by **other codecs** and **applications**.

Definitions

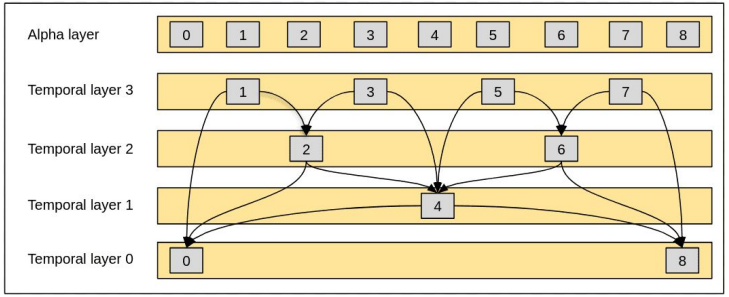
- **video coding layer (VCL) NAL unit:** coded slice NAL units
- **non-VCL NAL unit:** A NAL unit that is not a VCL NAL unit.
- **picture unit (PU)**: A set of NAL units that contain **all VCL NAL and non-VCL NAL** units of a coded picture
- **access unit (AU)**: **A set of PUs** that belong to different layers and contain **coded pictures** associated with the same **output time**.
- **coded layer video sequence** (**CLVS)**: A sequence of **PUs** of the **same layer.**
- **coded picture**: A coded representation of a picture containing all **CTUs of the picture**.
- **coded video sequence** (CVS): A sequence of **AUs**





Alpha Channel Auxiliary Layer

- Multi-layer encoding is commonly used for:
  - **Spatial** scalability: layers increases resolution
  - **Temporal** scalability: layers increase framerate
  - **SNR** scalability: layers increase quality
  - **Multi-view**: one layer per view
- HEVC: multi-layer supported through extensions:
  - **MV-HEVC** (Multiview)
  - **SHVC** (Scalable)
- VVC: multi-layer supported in the spec:
  - **Multilayer Main 10** profile
  - **Multilayer Main 10 4:4:4** profile
- The alpha channel is encoded as an auxiliary layer



Scalability Dimension Info - SDI (8.19)

This SEI message provides **information for the layers** in the current Coded Video Stream (CVS):

- **Multi-view**: the view ID of each layer
- **Alpha** and **Depth**: the auxiliary ID of each layer

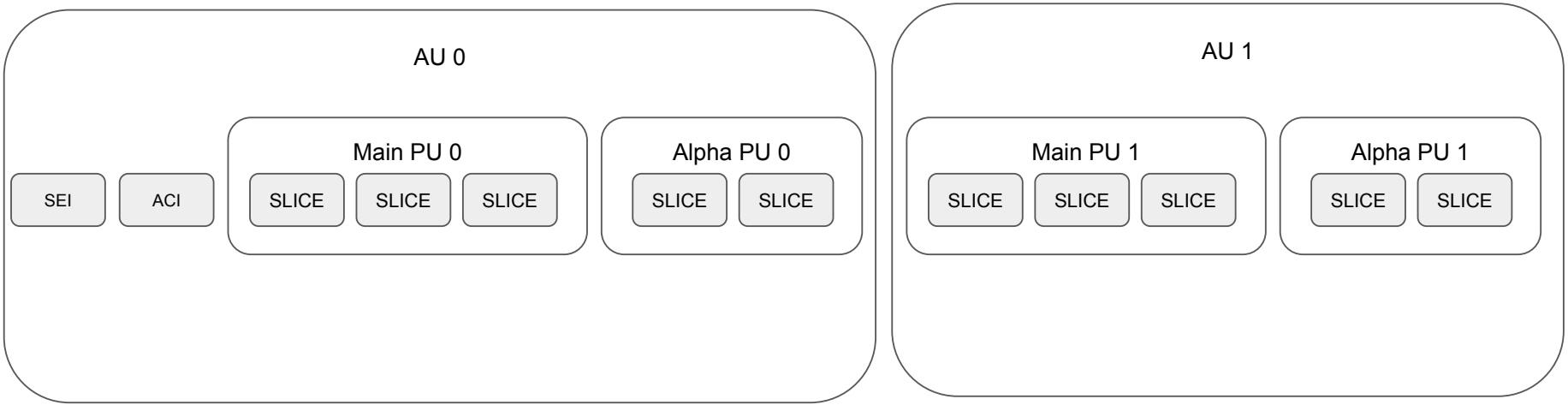
- `sdi_max_layers_minus1`: the maximum number of layers in the CVS
- `sdi_auxiliary_info_flag`: indicates whether auxiliary layers are present in the bitstream or not.
- For each layer:
  - `sdi_layer_id[i]:` ID of the layer
  - `sdi_aux_id`: AUX_ALPHA, AUX_DEPTH
  - `sdi_num_associated_primary_layers_minus1[i]`
  - For each associated primary layer:
    - `sdi_associated_primary_layer_idx`

Alpha Channel Info - ACI (8.23)

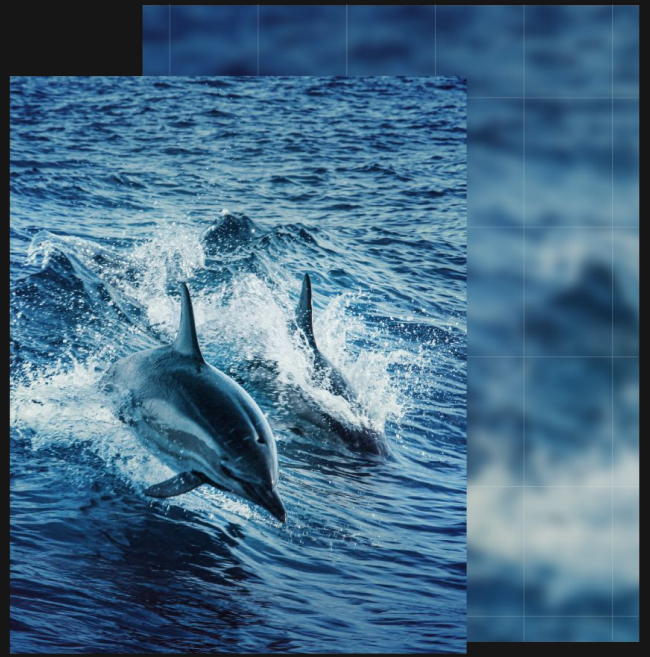
This SEI message provides information about the alpha channel **sample values** and **post-processing**. The alpha channel samples values of a picture **persists** until the next picture or end of CLVS.

- `alpha_channel_cancel_flag:` cancels the persistence of other ACI
- `alpha_channel_bit_depth_minus8`: the bit depth (eg: 8)
- `alpha_transparent_value`: transparent value (eg: 0)
- `alpha_opaque_value`: opaque value (eg: 255)

VVC/H.266 bitstream with alpha channel



Alpha Channel in GStreamer

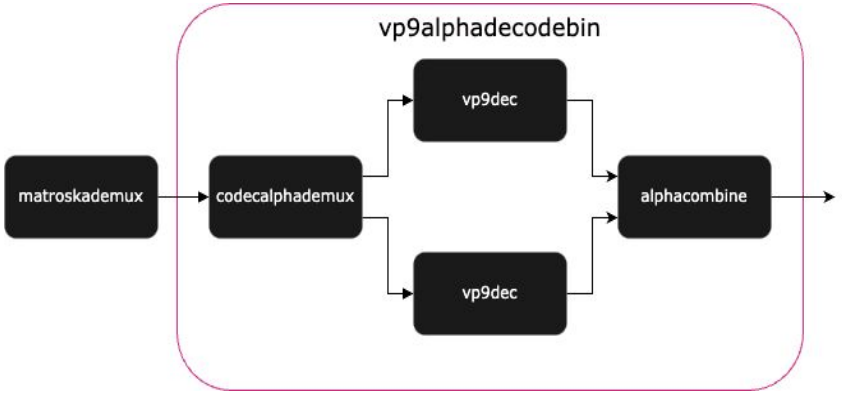


Alpha decoding support in GStreamer

- GStreamer **supports alpha** decoding for VP8/VP9 was introduced in **1.20**
- Streams with an encoded alpha layer are signaled with the ***codec-alpha*** caps.
- Decoders with alpha channel support will set ***codec-alpha=true*** in caps and an output pad with an alpha-capable format (eg: **A420)**
- GstAlphaDecodebin provides a way to support alpha channel decoding with decoders that **don’t support it**.

GstAlphaDecodebin

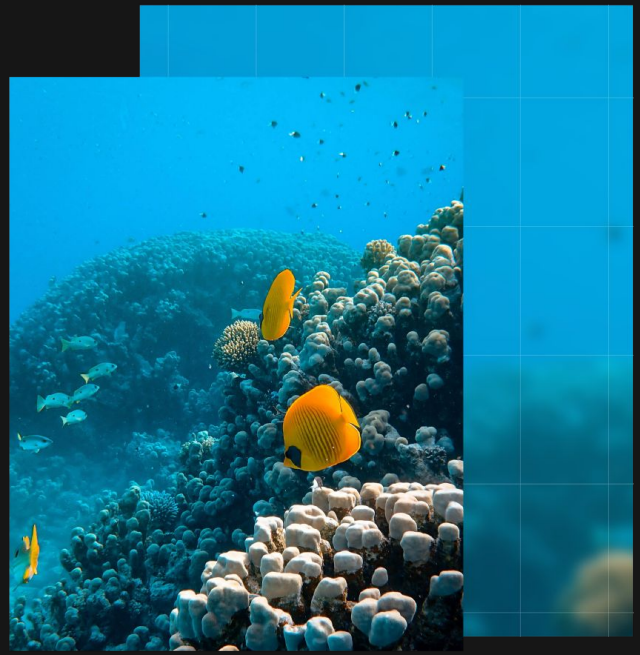
- Requires an input stream where buffers have a `GstVideoCodecAlphaMeta.`
- `codecalphademux`: splits the incoming buffers with the `GstVideoCodecAlphaMeta` into 2 output streams:
  a. Original buffer from the main stream.
  b. Alpha Channel buffers.
- `vp8dec` or `vp9dec`: 2 decoder instances that decode the main video track and the alpha one
- `alphacombine`: combines back the 2 decoded raw buffers into a single.



Encoder & Decoder Implementation

VVenc encoder

GStreamer decoder



Implementation choices

Encoder

- **VVenc:** Open source VVC/H.266 encoder by Fraunhofer.
- Initial support for multi-layer.

Decoder

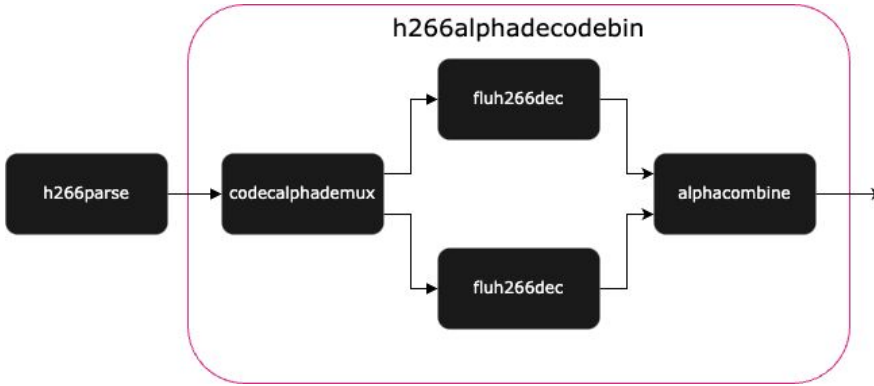
- We analyzed 2 options:
  - Implementing support in **VVdec** (Open source decoder by Fraunhofer)
  - Add support in GstAlphaDecodebin
- We choose GstAlphaDecodebin because it provides the flexibility of being able to switch between different decoder implementations, including hardware decoders.

VVC Encoder with Alpha Support

1. **Multi-layer Support:**
   - Rebase and integrate multi-layer work from the NHK's VVenc fork.
2. **Alpha Layer Encoding:**
   - Reuse existing multi-layer infrastructure; encoding the alpha channel as an independent layer.
   - Add new configurations for alpha layers.
   - *Note/Limitation:* Due to implementation constraints, the 8-bit alpha channel was temporarily encoded as an **I420** (YUV) stream, storing alpha in the Luma channel.
3. **SEI Message Implementation:** Add logic to inject the required **SDI** and **ACI** SEI messages into the bitstream, following ITU H.274.
4. Branch: https://github.com/fluendo/vvenc/tree/alpha-sei

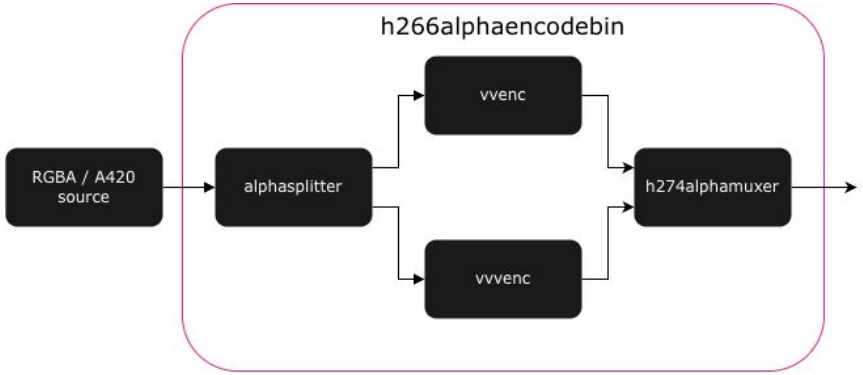
GStreamer Decoder

- `h266parse`:
  1. Add support to parse and process **ACI** and **SDI** SEI messages.
  2. Attach Alpha NALs as `GstVideoCodecAlphaMeta` to the main stream buffer.
- `h266alphadecodebin`: A that:
  1. New element (based on `GstAlphaDecodeBin`)
  2. Splits the stream based on the metadata.
  3. Uses two VVC decoders (main + alpha).
  4. Combines the two decoded raw buffers into a single **AYUV** stream.
- MR: https://gitlab.freedesktop.org/gstreamer/gstreamer/-/merge_requests/8675

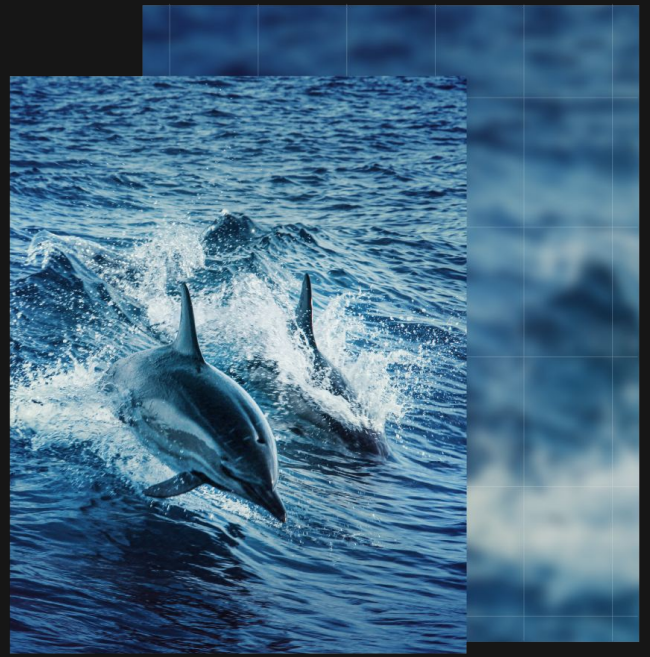


GStreamer VVC/H.266 Alpha Encoder?

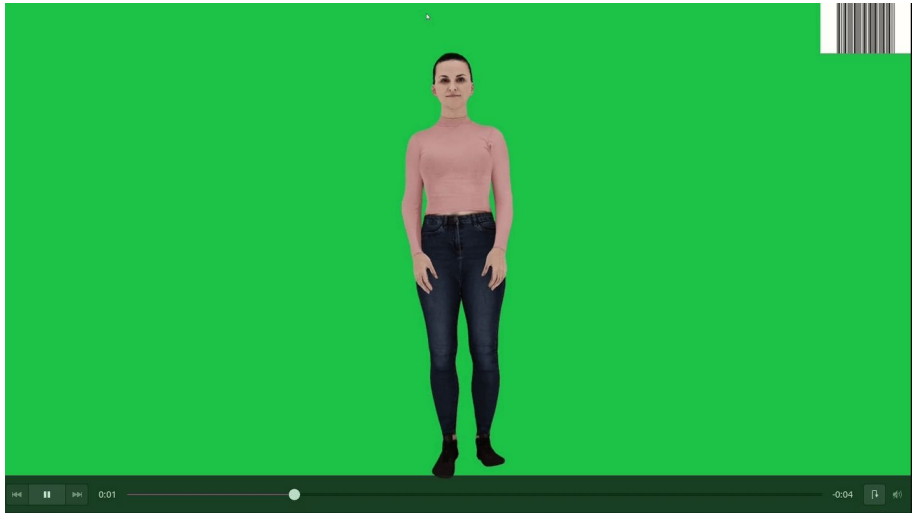
- A similar architecture could be used to support Alpha for encoders.
- It would allow supporting alpha encoder for encoders without multi-layer/alpha support
- Alpha and main are encoded independently
- `h266alphamuxer`:
  1. Combines the 2 bitstreams into a single bitstream, merging CLVS from main and alpha into a single bitstream.
  2. Injects SDI and ACI SEI signalling.



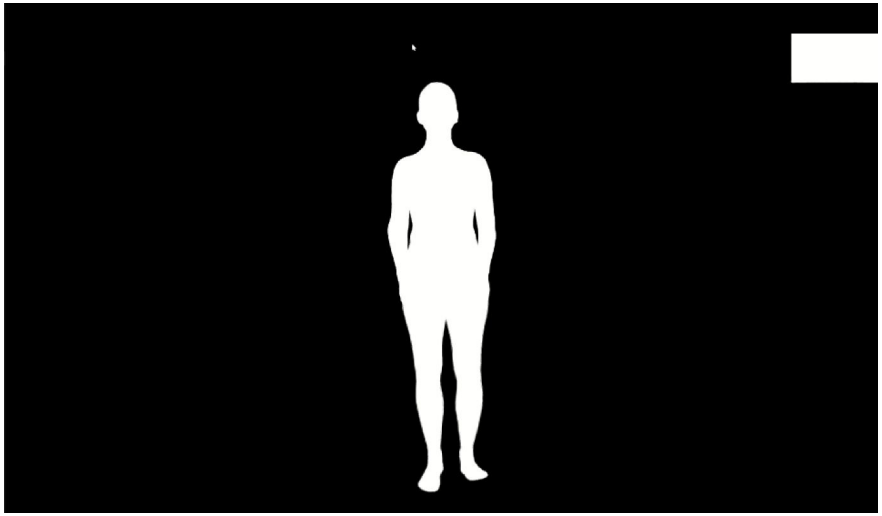
VVC / H266 Alpha Demo



Input Streams



I420 Main



I420 Alpha

VVenc encoding

```
#======== Layers ===============
MaxLayers                     : 2
MaxSublayers                  : 7
AllIndependentLayersFlag      : 1
#======== Alpha ================
SEIAlphaChannel               : 1
SEIScalabityDimension         : 1
#======== OLSs =================
EachLayerIsAnOlsFlag          : 1
NumOutputLayerSets            : 2
NumPTLsInVPS                  : 1
#======== Layer-0 ==============
LayerId0                      : 0
#======== Layer-1 ==============
LayerId1                      : 1
#======== OLS-0 ================
OlsPTLIdx0                    : 0
#======== OLS-1 ================
OlsPTLIdx1                    : 1
```

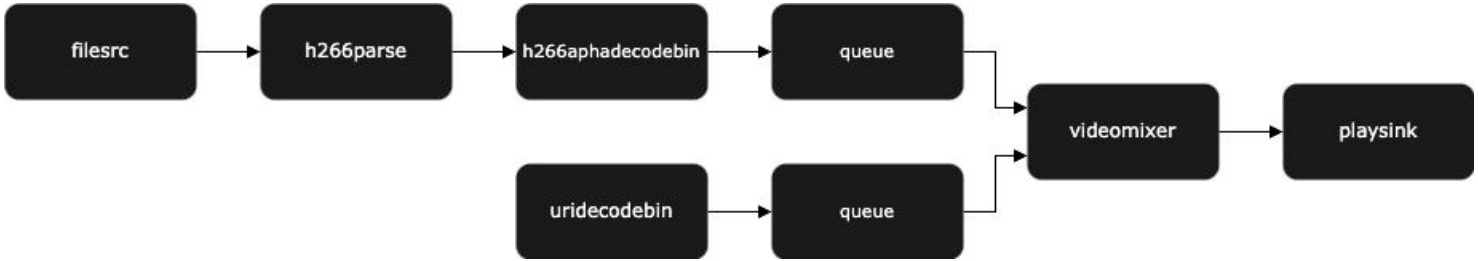
```
./vvencFFapp \

 -c ../../cfg/two_layers_alpha.cfg \

 -c ../../cfg/randomaccess_fast.cfg \

 -l0 -c sequence2K.cfg \

 -l1 -c sequenceAlpha.cfg \

 -l0 -q 22 \

 -l1 -q 22 \

    -l1 --Level=6.1 --VerCollocatedChroma=1 -v 6
```

VVenc encoding

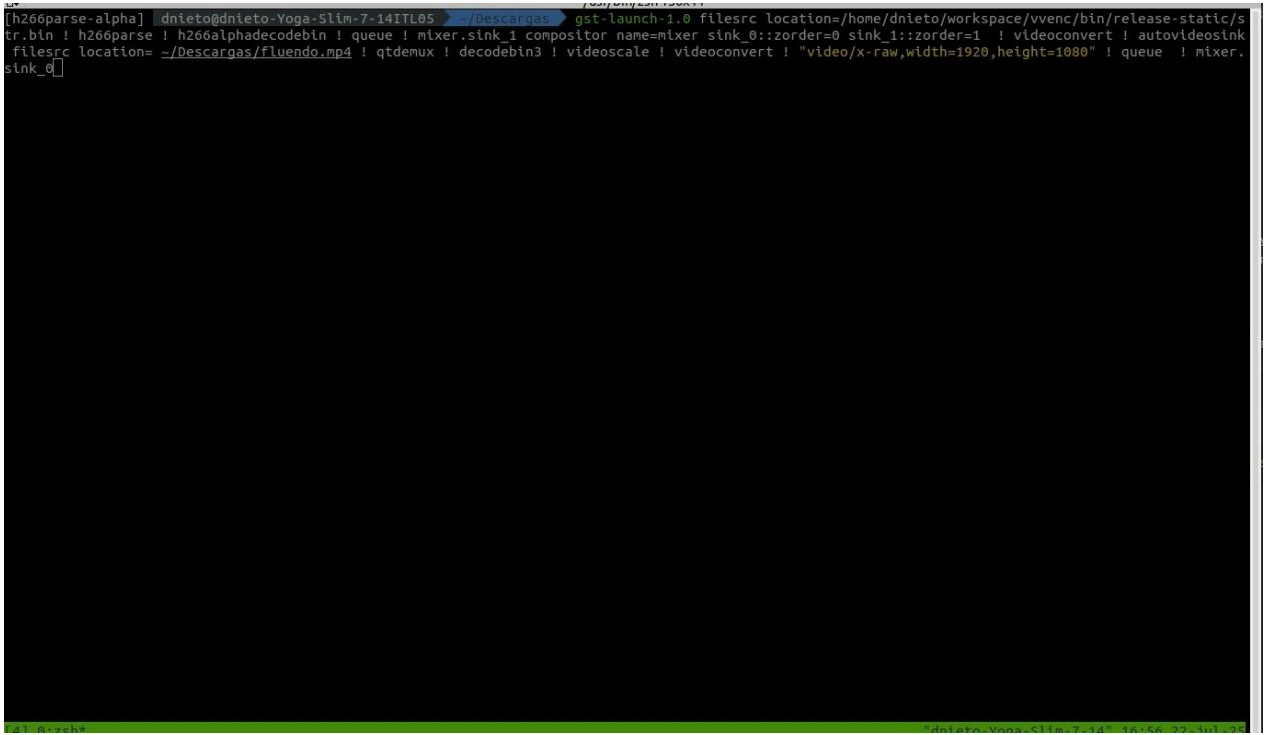
```
LayerId  0

vvenc [info]: SUMMARY ------------------------------------------------------
vvenc [info]:   Total Frames |   Bitrate     Y-PSNR    U-PSNR    V-PSNR    YUV-PSNR   Y-Lossless  U-Lossless  V-Lossless
vvenc [info]:         150    a0     80.5984   62.6694      -nan      -nan   64.0628          0         150         150
vvenc [info]: I Slices-----------------------------------------------------
vvenc [info]:   Total Frames |   Bitrate     Y-PSNR    U-PSNR    V-PSNR    YUV-PSNR   Y-Lossless  U-Lossless  V-Lossless
vvenc [info]:           4    i0    749.8200   70.1888      -nan      -nan   71.9405          0           4           4
vvenc [info]: P Slices-----------------------------------------------------
vvenc [info]:   Total Frames |   Bitrate     Y-PSNR    U-PSNR    V-PSNR    YUV-PSNR
vvenc [info]:           0    p0        -nan      -nan      -nan      -nan      -nan
vvenc [info]: B Slices-----------------------------------------------------
vvenc [info]:   Total Frames |   Bitrate     Y-PSNR    U-PSNR    V-PSNR    YUV-PSNR   Y-Lossless  U-Lossless  V-Lossless
vvenc [info]:         146    b0     62.2636   62.4634      -nan      -nan   63.9643          0         146         146
vvencFFapp [details]: Bytes written to file: 54402 (inf kbps)

LayerId  1

vvenc [info]: SUMMARY ------------------------------------------------------
vvenc [info]:   Total Frames |   Bitrate     Y-PSNR    U-PSNR    V-PSNR    YUV-PSNR   Y-Lossless  U-Lossless  V-Lossless
vvenc [info]:         150    a1     29.3376   71.6481      -nan      -nan   72.7819          0         150         150
vvenc [info]: I Slices-----------------------------------------------------
vvenc [info]:   Total Frames |   Bitrate     Y-PSNR    U-PSNR    V-PSNR    YUV-PSNR   Y-Lossless  U-Lossless  V-Lossless
vvenc [info]:           4    i1    203.7600   82.0603      -nan      -nan   83.8188          0           4           4
vvenc [info]: P Slices-----------------------------------------------------
vvenc [info]:   Total Frames |   Bitrate     Y-PSNR    U-PSNR    V-PSNR    YUV-PSNR
vvenc [info]:           0    p1        -nan      -nan      -nan      -nan      -nan
vvenc [info]: B Slices-----------------------------------------------------
vvenc [info]:   Total Frames |   Bitrate     Y-PSNR    U-PSNR    V-PSNR    YUV-PSNR   Y-Lossless  U-Lossless  V-Lossless
vvenc [info]:         146    b1     24.5589   71.3628      -nan      -nan   72.6736          0         146         146
vvencFFapp [details]: Bytes written to file: 22369 (inf kbps)
```

Decoding and playback with GStreamer

```
gst-launch-1.0
 filesrc location=aplphastream.vvc !
 h266parse ! h266alphadecodebin ! queue ! mixer.sink_0
 uridecodebin uri=file:///Path/To/fluendo.mp4 !
 queue !  mixer.sink_1
 mixer.sink_1 compositor name=mixer sink_0::zorder=0 sink_1::zorder=1 !
 playsink
```



Decoding and playback with GStreamer



Q&A

i Don’t miss Carlos Bentzen’s talk “VVC/H.266 in GStreamer” at 16pm

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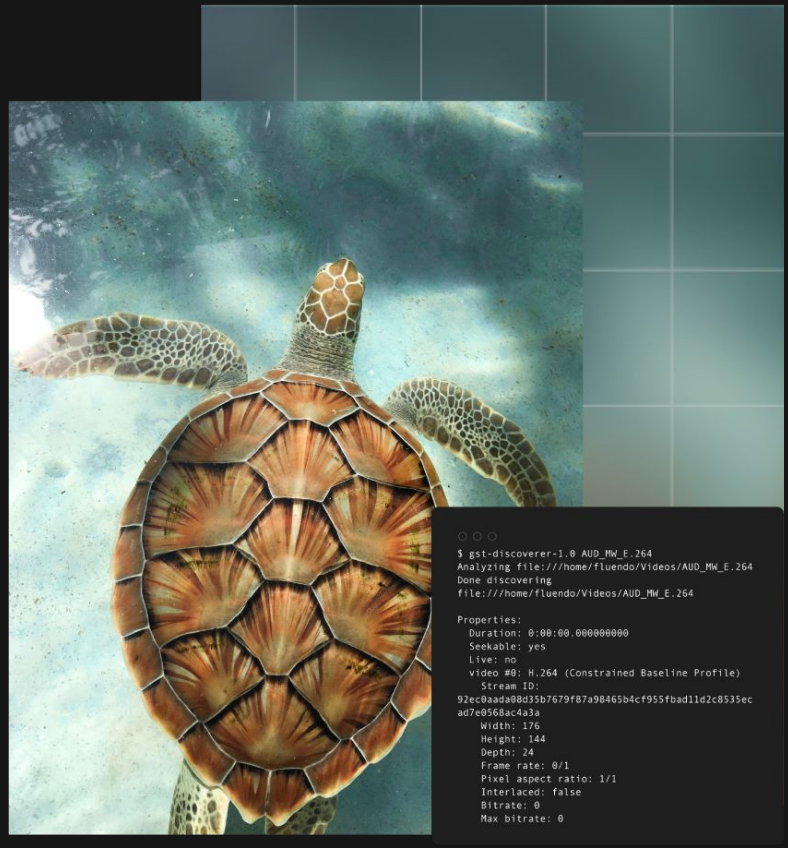
Stop taking risks.
Start finding solutions.

Thank you!



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