Heterogeneous Computing Approach for High Performance Video Resampling and Resizing

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exceeding media challenges

Heterogeneous Computing Approach for High Performance Video Resampling and Resizing

Proposed Solution

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Context and Goals

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Context and Goals

What does this project want to achieve?

Context

- Increasing popularity of high resolutions of video
- Videos of high resolution are made of an high number of pixels per frame

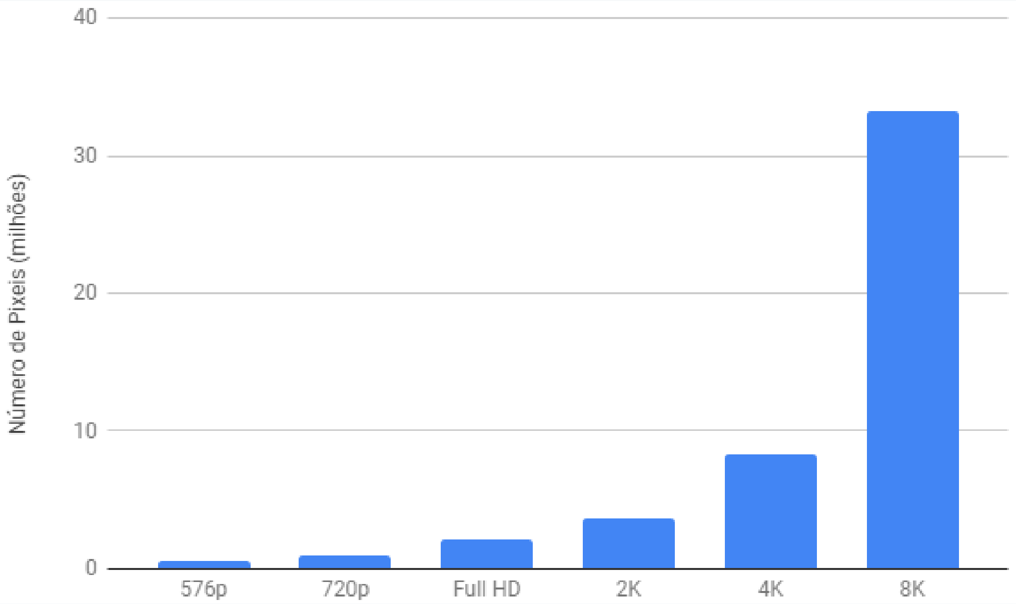

Fig 1: Millions of pixels per frame by video resolution

Problem

- Video production processes operate over each pixel of each frame
- The computational resources needed are proportional to the number of pixels
- Video production solutions must follow the ever stricter customer demands
- Systems should be restructured considering processing scalability

Problem

- Video production processes operate over each pixel of each frame
- The computational resources needed are proportional to the number of pixels
- Video production solutions must follow the ever stricter customer demands
- Systems should be restructured considering processing scalability
- Heterogeneous computing approach uses different types of processing units
  - Different CPU models, in the same machine or in machines of the same network
  - CPU and FPGA, high performance integrated circuit for arithmetic operations
  - CPU and GPU, processing unit destined to render graphic components

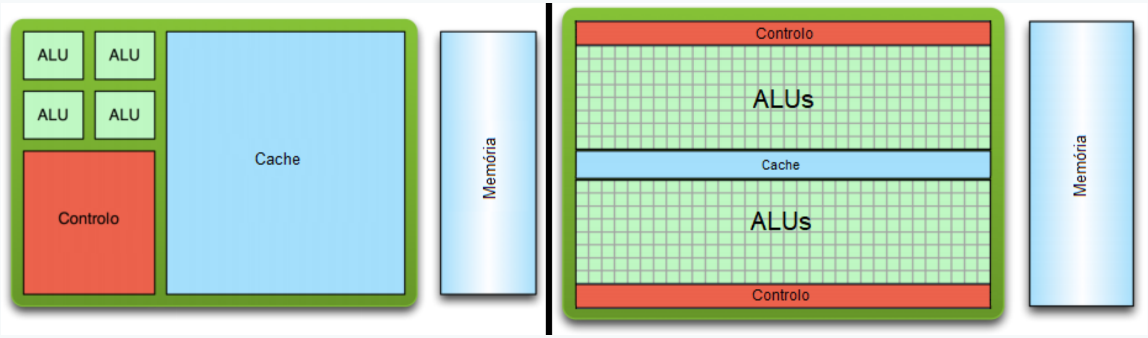

Fig 2: CPU vs GPU architecture

Goals

- Take advantage of the existent hardware in *mxfSpeedRail* products
- Implement an own heterogeneous solution for video resampling and resizing
  - Using a graphics processing unit to speed up the process
- Decrease the execution time of the process in comparison to *FFmpeg*
- Develop a scalable solution to real time video resampling and resizing
  - Of high resolution uncompressed video

Current Solution

- *FFmpeg* based solution
- Uncompressed video resampling and resizing is a single-thread process

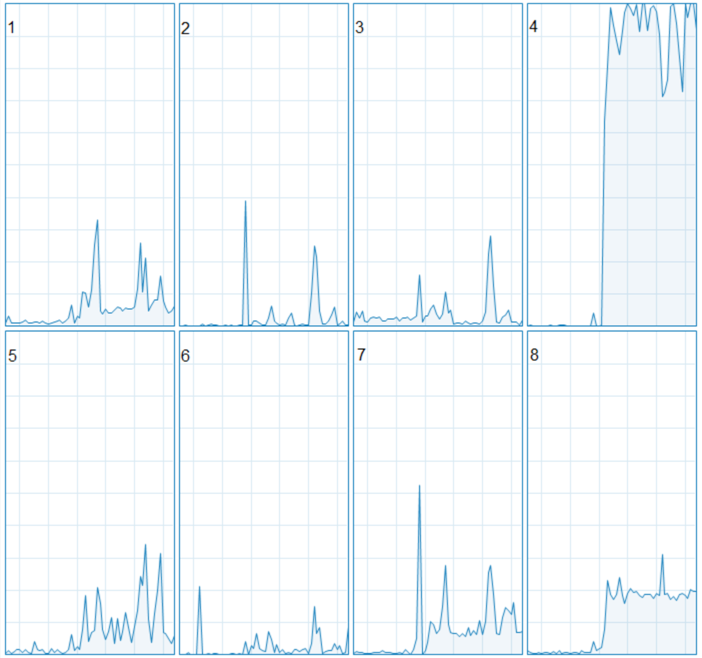

Fig 3: CPU usage of *FFmpeg* video resampling by thread

Current Solution

- Vectorization is used to accelerate the processing speed
- Vectorization allows the implicit parallelization of a block of code
- Using low level code instructions
    - As an example, SSE, AVX and AVX2 intrinsics

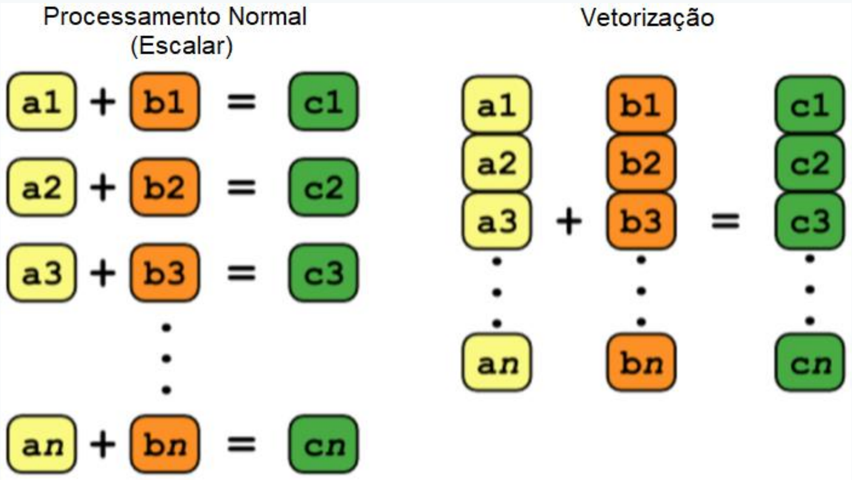

Fig 4: Vectorization of a sum operation

Other Options

- *FFmpeg* already support graphic acceleration of video resampling and resizing
  - BUT only using the Nvidia hardware encoder, NVENC
- The *FFmpeg* implementation is an hardware solution
  - As an example, by a SDI source
- This project solution is purely software

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Video Resampling and Resizing

What is video resampling and resizing?

YUV Color Space

- Frequently used in digital video representation
- Additive color model constituted by three different components
    - A luma component and two different chrominance components

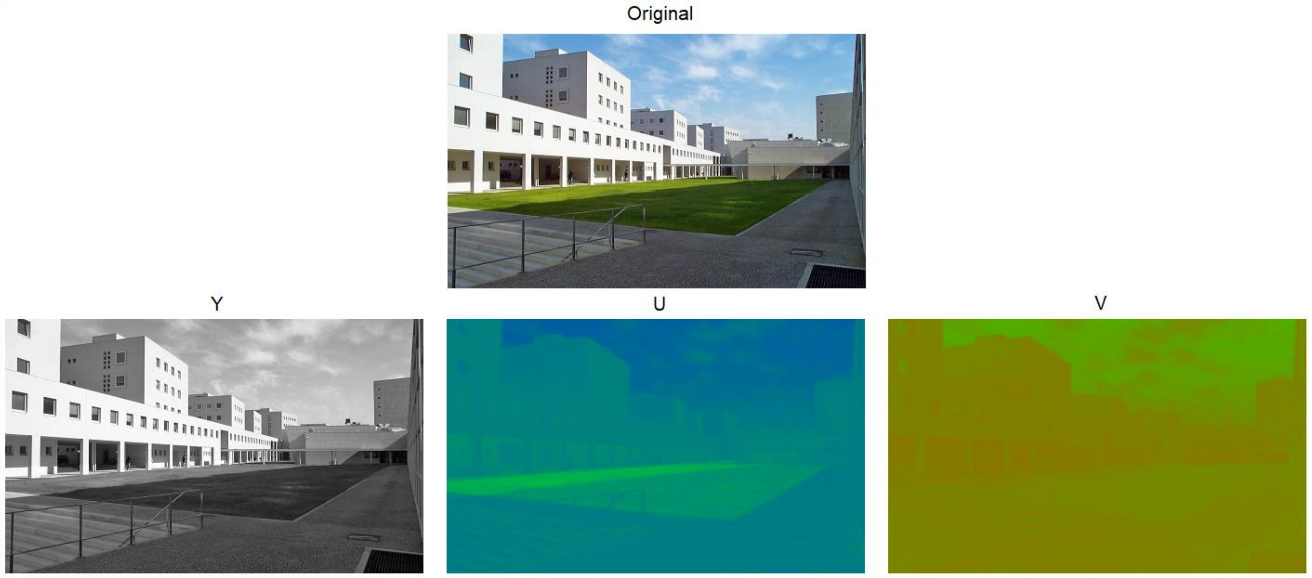

Fig 5: YUV color space components

YUV Color Space – Chrominance Subsampling

- The model takes advantage of the weak visual perception to chrominance changes
- Chrominance subsampling reduces the number of color samples
  - Smaller chrominance components implies a smaller video file size

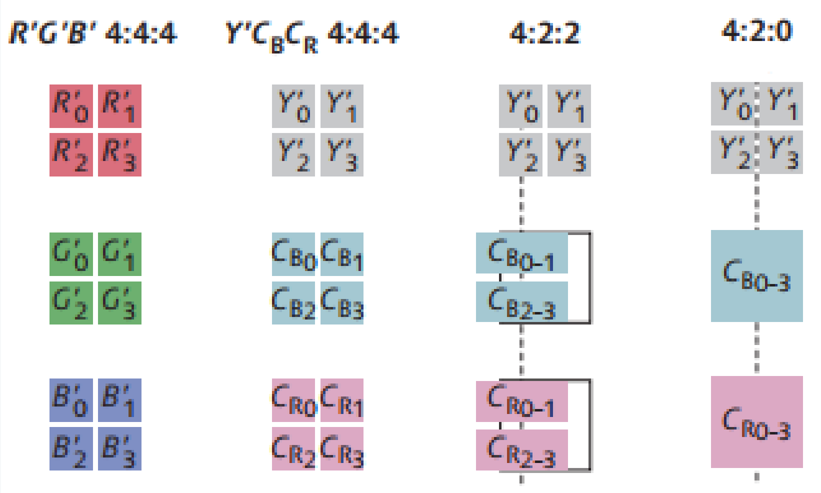

Fig 6: Chrominance subsampling types

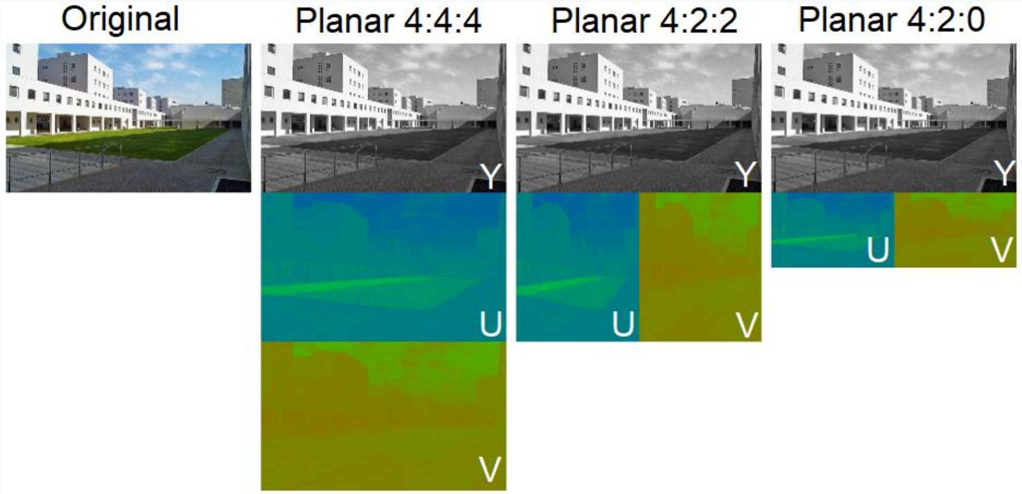

Fig 7: Size of an image's components by type of subsampling

YUV Color Space – Pixel Formats

- This color space pixel formats are divided into different types:

Plano A

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Y0	Y0	Y0	Y0	Y0	Y0	Y0	Y0	Y1	Y1	Y1	Y1	Y1	Y1	Y1	Y1	Y2	Y2	Y2	Y2	Y2	Y2	Y2	Y2	Y3	Y3	Y3	Y3	Y3	Y3	Y3	Y3
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
Y4	Y4	Y4	Y4	Y4	Y4	Y4	Y4	Y5	Y5	Y5	Y5	Y5	Y5	Y5	Y5	Y6	Y6	Y6	Y6	Y6	Y6	Y6	Y6	Y7	Y7	Y7	Y7	Y7	Y7	Y7	Y7

Plano B

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
U0	U0	U0	U0	U0	U0	U0	U0	U2	U2	U2	U2	U2	U2	U2	U2
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
U4	U4	U4	U4	U4	U4	U4	U4	U6	U6	U6	U6	U6	U6	U6	U6

Plano C

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
V0	V0	V0	V0	V0	V0	V0	V0	V2	V2	V2	V2	V2	V2	V2	V2
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
V4	V4	V4	V4	V4	V4	V4	V4	V6	V6	V6	V6	V6	V6	V6	V6

Fig 8: YUV422p planar format

Plano A

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
U0	U0	U0	U0	U0	U0	U0	U0	Y0	Y0	Y0	Y0	Y0	Y0	Y0	Y0	V0	V0	V0	V0	V0	V0	V0	V0	Y1	Y1	Y1	Y1	Y1	Y1	Y1	Y1

Fig 9: UYVY packed format

Plano A

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Y0	Y0	Y0	Y0	Y0	Y0	Y0	Y0	Y1	Y1	Y1	Y1	Y1	Y1	Y1	Y1	Y2	Y2	Y2	Y2	Y2	Y2	Y2	Y2	Y3	Y3	Y3	Y3	Y3	Y3	Y3	Y3
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
Y4	Y4	Y4	Y4	Y4	Y4	Y4	Y4	Y5	Y5	Y5	Y5	Y5	Y5	Y5	Y5	Y6	Y6	Y6	Y6	Y6	Y6	Y6	Y6	Y7	Y7	Y7	Y7	Y7	Y7	Y7	Y7

Plano B

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
U0	U0	U0	U0	U0	U0	U0	U0	V0	V0	V0	V0	V0	V0	V0	V0	U2	U2	U2	U2	U2	U2	U2	U2	V2	V2	V2	V2	V2	V2	V2	V2

Fig 10: NV12 semi-planar format

Resampling and Resizing

- Resampling an image implies the change of its dimensions
  - It is the insertion or remotion of the number of pixels of each of the video's frames
- This process is achieved by different algorithms
  - Each algorithm trades off execution speed by the quality of the operation's results
  - Each pixel's color of a resampled image is obtained by the corresponding original pixels

$$k_{nn}(x) = \begin{cases} 1 & |x| < 0.5 \\ 0 & \textit{senão} \end{cases}$$

Fig 11: Algorithm *Nearest Neighbor*

$$k_{linear}(x) = \begin{cases} 1 - |x| & |x| < 1 \\ 0 & \textit{senão} \end{cases}$$

Fig 12: Algorithm linear

$$k_{spline}(x) = \begin{cases} 1.4 \times |x|^3 - 2.4 \times |x|^2 + 1 & |x| < 1 \\ -0.6 \times |x|^3 + 3 \times |x|^2 - 4.8 \times |x| + 2.4 & 1 \leq |x| < 2 \\ 0 & \textit{senão} \end{cases}$$

Fig 13: Algorithm by *spline*, or cubic

Resampling and Resizing

- The different algorithms differ in terms of execution speed and the quality of the resampled image results

Fig 14: Quality of results of each resampling algorithm

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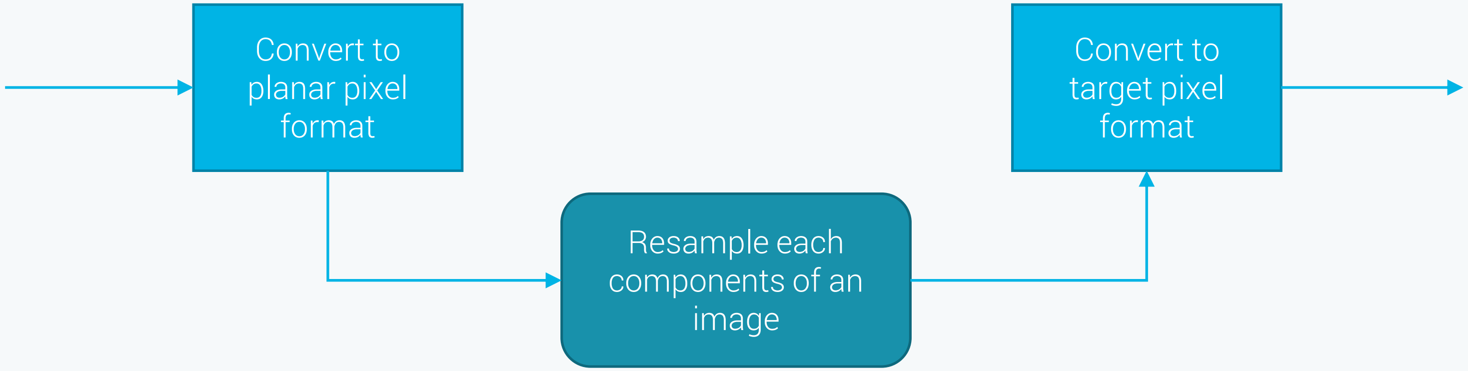
Proposed Solution

How was the solution implemented?

Proposed Solution

- The resampling process is divided into two operations
  - Due to the different combinations of input and output pixel' formats
- The pixel format conversion operation
- The resampling operation



Pixel Format Conversion

- This operation is exclusively executed by the CPU
- The parallelization was achieved by OpenMP

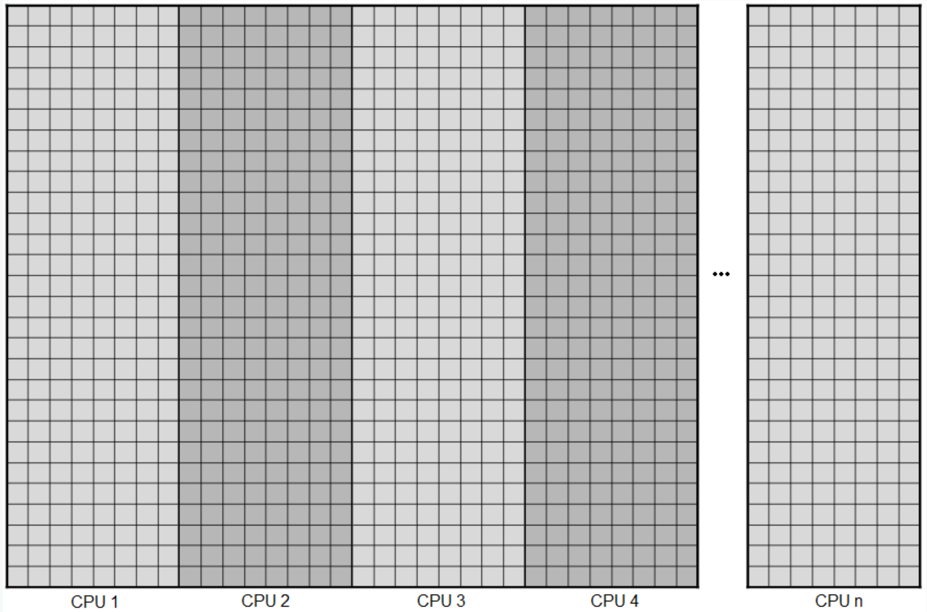


Fig 15: Work division of the conversion operation by different CPU threads

Resampling

- This operation is exclusively executed by the GPU
- Implemented by the Nvidia framework CUDA

Fig 16: Texture memory access

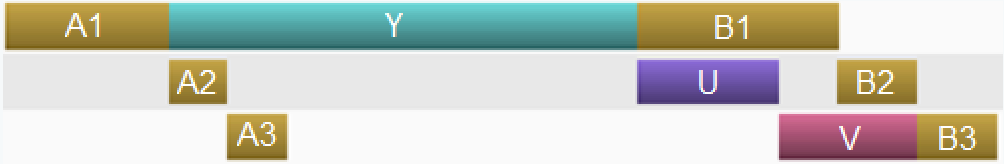


Fig 17: Data transfer parallelization with resample operation

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Results

What are the results achieved by the proposed solution?

Pixel Format Conversion

- Tested with two different CPU models
- Performance gain of 51% in comparison to *FFmpeg*

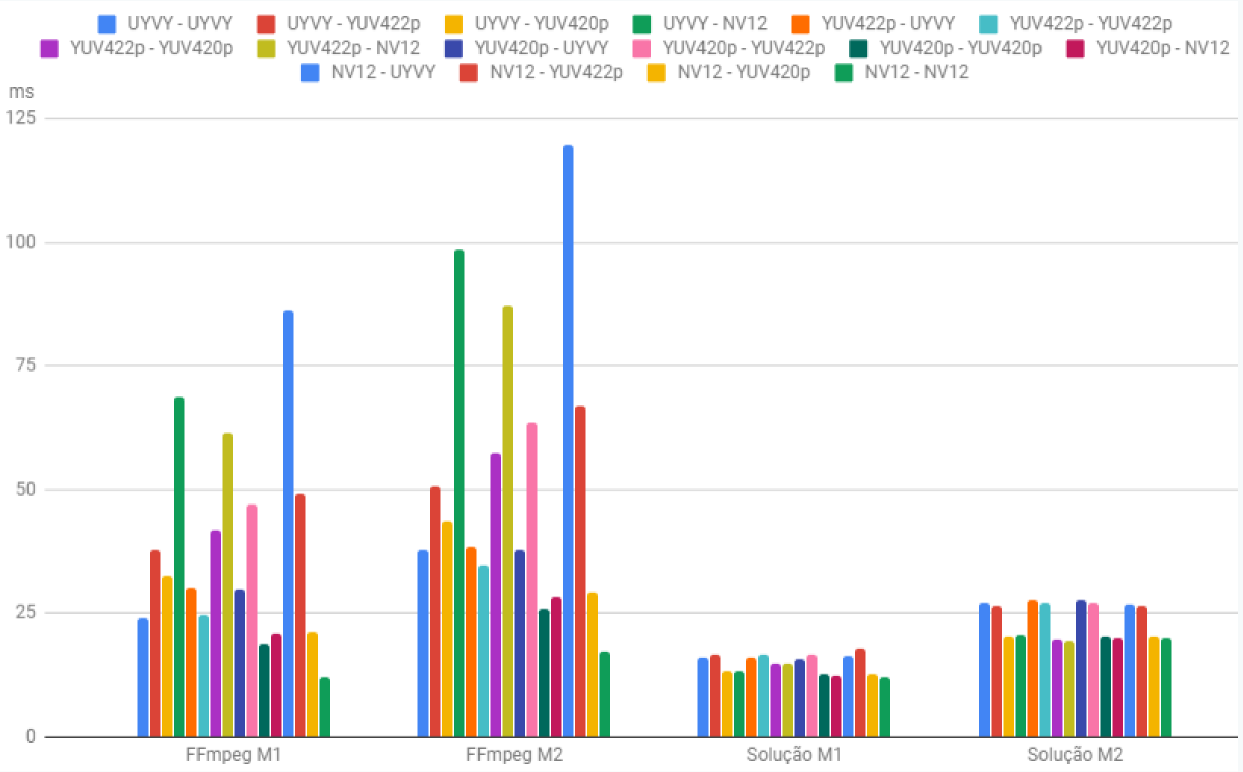

Fig 18: Execution time of the pixel format conversion operation

Resampling

- Tested with two different GPU models (Nvidia Quadro P600 and P2000)
- Performance gain of 58% in comparison to *FFmpeg*

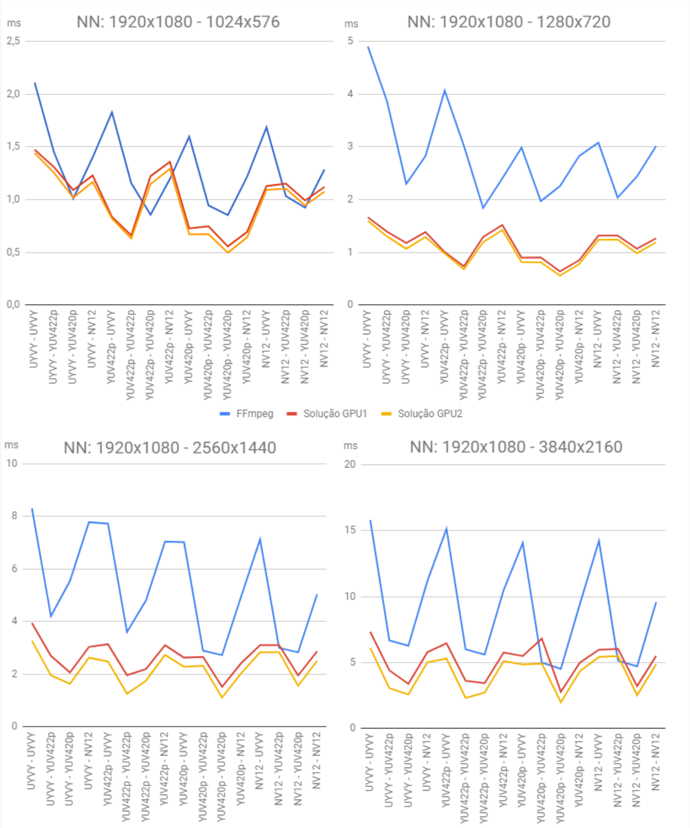

Fig 19: Execution time of the NN algorithm

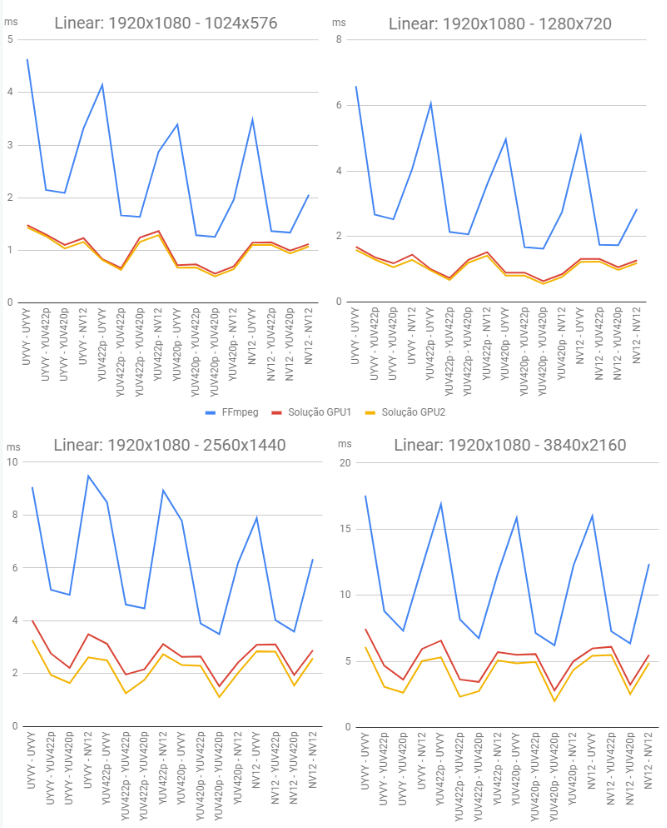

Fig 20: Execution time of the linear algorithm

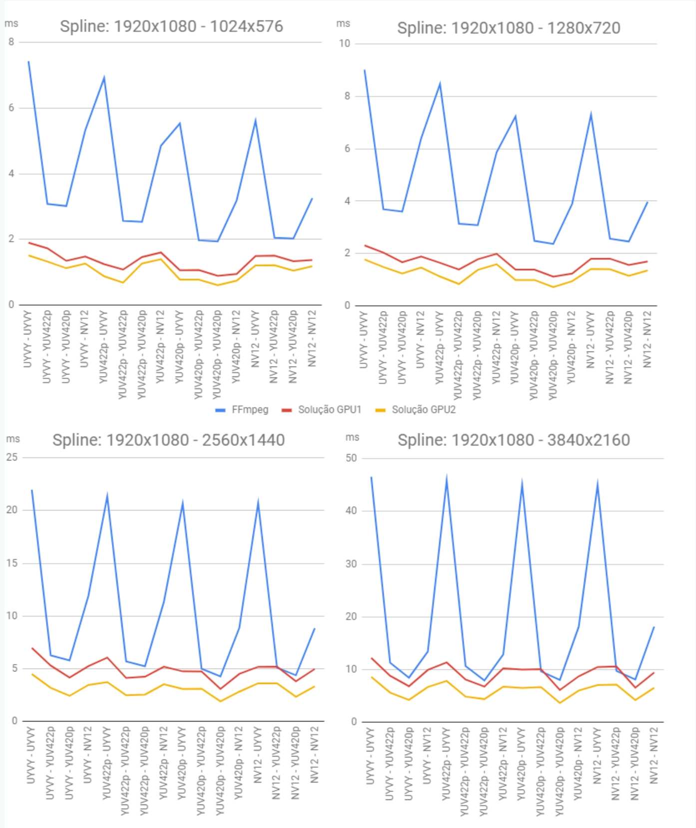

Fig 21: Execution time of the spline algorithm

Video Resampling and Resizing

- Execution time of resampling and resizing a *Full High Definition* video

	Planar				Não Planar			
NN	1024x576	1280x720	2560x1440	3840x2160	1024x576	1280x720	2560x1440	3840x2160
FFmpeg	1,027	2,463	3,701	5,486	1,539	3,262	6,874	12,491
Solução GPU1	-6,08%	-56,86%	-38,75%	-25,86%	-30,48%	-62,13%	-55,93%	-52,73%
Solução GPU2	-11,66%	-60,34%	-51,33%	-41,81%	-33,44%	-64,39%	-62,26%	-58,98%
Linear								
FFmpeg	1,598	2,023	4,282	7,247	3,233	4,488	8,016	14,325
Solução GPU1	-39,44%	-47,54%	-46,45%	-43,10%	-66,81%	-72,20%	-61,37%	-58,48%
Solução GPU2	-42,83%	-51,64%	-57,95%	-55,71%	-68,37%	-74,24%	-67,39%	-64,28%
Spline								
FFmpeg	2,398	2,925	5,206	9,216	5,263	6,520	15,707	30,616
Solução GPU1	-45,69%	-45,51%	-17,06%	-13,61%	-73,63%	-73,22%	-65,93%	-66,44%
Solução GPU2	-58,08%	-60,66%	-48,36%	-44,88%	-78,72%	-79,57%	-77,74%	-77,20%

Fig 22: Performance gain of video resampling and resizing operation in comparison to *FFmpeg*

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Future Work

What can be done to improve the proposed solution?

Future Work

- Implement vectorization in the pixel format conversion operation and compare with the current solution
- Integrate the proposed solution in MOG Technologies' product
- Create a wider support of pixel formats and resampling algorithms
- Scale the proposed solution to a processing distributed system

exceeding media challenges

Any questions?

Thank you!

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