Real Time 360º Video Stitching and Streaming

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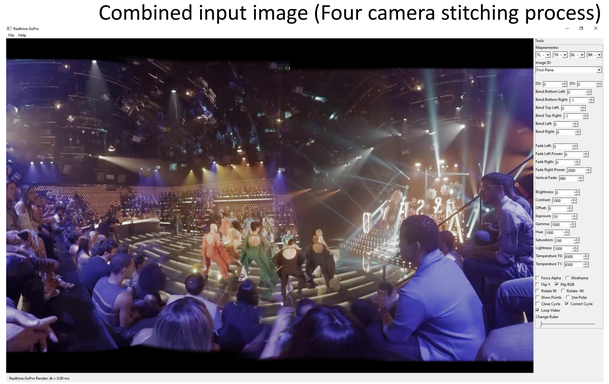
1. Introduction

The image stitching process is a well know algorithm [Brown and Lowe 2007] for non-real time applications. However, the growing of immersive video production for HMDs (Head Mounted Displays) forces the improvement of these techniques to operate in high performance. The most important application is 360º video production for live events, which imposes a drastic processing time reduction, and requires a rigorous set of deterministic processing, encoding and transmission algorithms.

In this paper we propose a processing methodology focused on GPU use, which reduces processing time and create a scalable solution for use in large resolutions such as 4K and 8K per camera.

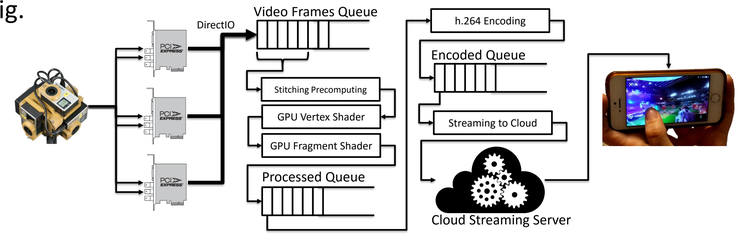
Combined input image (Four camera stitching process)



Processing software showing the output

2. Our Approach

The present work uses 4 or 6 cameras to produce videos with 360º or 180º field of view in real time. In such model, we use three video capture cards (two inputs each) with a Genlock synchronization mechanism. Furthermore, to keep the cameras fixed and provide power and connect the HDMI cables to the capture card, we design and build a camera rig.



To perform the task, the solution has four processing threads (with shared OpenGL contexts). The first one loads each video frame into video card memory, using a circular buffer. After that, using the synchronization, the system can perform the stitching using the last 4 or 6 frames in the buffer. The stitched image is pushed to another circular buffer and prepares to be encoded using the OpenGL texture ID. Finally, the encoder outputs the byte stream to the CPU and the last thread transmits it over the network.

3. Processing Methodology

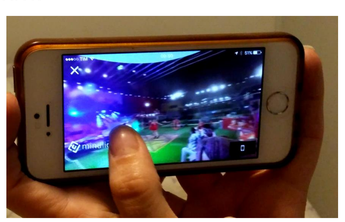
Therefore, the first process makes copies in parallel to GPU, using the PBO (Pixel Object Buffer) interface. After that, the stitching algorithm uses a tessellated plane to map the input images. This planes can be deformed using some pre-defined distortions (radial, linear, manual moving), each one is processed with the vertex shader. The solutionautomatically computes the values using Surf [Bay et al. 2008] and RANSAC [Fischler and Bolles 1981] method (to create the features between the input frames), then it minimizes the input parameters to reduce the distance between features.

At runtime, the user can load a pre-calibrated mesh or use interval to compute new values (processed in a parallel thread), also it can manually change the values to accommodate fine details (figure 1b). Lastly, it is processed by a robust fragment shader, that computes the blending and color correction, also manual changes can be made.

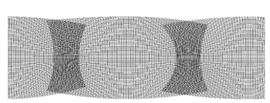
Moreover, the result is sent to NVEnc Library [NVIDIA 2012] that performs H.264 encoding and copies the final byte stream to the CPU, after that, the system transmits it to an HMD. The receiver system is a mobile application with a simple H.264 decoder. When it receives the stream and decodes it, the image is projected onto a sphere (or cylinder), creating the sense of immersion.

4 GoPro Camera Rig

6 GoPro Camera Rig



Streamed and Projected Image



Precomputed Mesh

4. Results

Finally, applying those techniques, the total processing time, after receiving the frame from the video capture card and before transmitting, is about 70 ms, using one video card for processing and 4 video cameras. The frame size is a Full HD image with 8 bits per channel (RGB). The solution proved to be stable and scalable. Also, some improvements can be developed, such as Pinned Memory for DMA between the video capture card and the GPU (called DirectIO). Moreover, it is possible to perform broadcasting using cloud architectures like Wonza (that uses Amazon EC2).

Final Image

5. References

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