Burning Too

An Ultra HD Multi-projector Media Façade System

Don Ritter
School of Creative Media
City University of Hong Kong
Hong Kong

***Abstract*—This paper discusses *Burning Too,* a large media façade presented by the author on the Run Run Shaw Creative Media Centre in Hong Kong during the opening of the 22nd International Symposium on Electronic Art (ISEA2016). The author configured a hardware system and wrote software for an Ultra HD (4K) video projection of fire onto the building, using four video projectors and a single computer that provided real-time video mapping, edge blending, video playback, interactive audio, and color adjustment functionality. The symbolism of fire is discussed along with the system configuration for a multi-projector media façade using Ultra HD video.**

Keywords—fire symbolism; 4K media façade; GPU functionality; video mapping; edge blending; real-time video

I. Introduction

Burning Too was a 55 x 26 m media façade consisting of video projections and the sounds of fire presented on the Run Run Shaw Creative Media Centre during the opening of ISEA2016. Reference [1] provides a link to an online video of *Burning Too,* and a photograph is shown in Fig. 1.

For much of its history, humanity has been highly dependent on fire for warmth, safety, and food preparation, but actual fire for most people today is an aesthetic experience that only provides them with feelings of warmth or romanticism. Although large and uncontrolled fires are potentially dangerous, *Burning Too* presented its audience with an experience of fire imagery designed to captivate through its large scale, gentle motion, changing colorization, and interactive sound. The *Burning Too* media façade was intended to be a metaphorical depiction of humanity's longstanding relationship with fire.

A technical goal of the project was to configure a unified hardware and software system that could accommodate the following tasks: (1) editing audio and 4K video (approximately 4000 horizontal and 2000 vertical pixels); (2) software programming for a 4K video media façade; and (3) presenting a 4K multi-projector media façade without additional hardware for video mapping, video splitting, edge blending, or color adjustment.

The ability to project and process 4K video imagery using a single computer and four video projectors was made technically possible by the following system components: (1) a sufficiently fast computer with five High-Definition Multimedia Interface (HDMI) outputs; (2) software functionality based on a graphics processing unit (GPU) [2] rather than a computer's central processing unit (CPU); and (3) two high-speed solid-state drives (SSDs) for playing media files. This combination of technical features permitted the seemingly instantaneous processing of a 4K video file at a speed reminiscent of processing an analog video signal.

The remainder of the paper describes the symbolism of fire, the architecture of the building used for the media façade, and the computer hardware, software, and system configuration used to present the *Burning Too* media façade.

II. Fire Symbolism

Fire has contributed to humanity's ability to survive and evolve over history by enabling our food to be cooked, keeping us warm, and furnishing the energy for weaponry and heat-based propulsion. Humans have been fascinated by fire from antiquity to the present, but it was more than a practical tool for our ancestors. Early humans worshipped fire in the form of nearly 100 gods or goddesses, of which most were believed to have supernatural powers [3]. Some ancient gods and goddesses of fire include the following [3], [4], [5].

- Ancient Greek mythology: *Hephaestus*, god of fire; and *Hestia*, goddess of the hearth and fire.
- Aztec mythology: *Xiuhtecuhtli,* god of fire, day, heat, and volcanoes; and *Chantico*, goddess of fire in the family hearth and volcanoes.
- Chinese mythology: *Zhurong,* god of fire.
- Hinduism: *Agni*, god of fire.
- Japanese mythology: *Kamado-gami,* god of fire, the hearth, and the kitchen.
- Korean shamanism: *Jowangsin,* goddess of fire and hearth.
- Mesopotamian mythology: *Gerra,* Babylonian and Akkadian god of fire.
- Mongolian shamanism: *Odqan,* red god of fire who rides a brown goat.
- Roman mythology: *Vulcan*, god of fire, volcano fire, metalworking, and the forge.

Fig. 1. *Burning Too* media façade on the Run Run Shaw Creative Media Centre, Hong Kong.

Although fire is not a living creature from a contemporary perspective, the visible chemical reaction known as fire shares many characteristics with living creatures. Fire is animated, it gives off heat and sound, it can move from one location to another, and it can kill us like a dangerous animal or a human enemy.

Many ancient societies used mythology to explain how humans discovered the use of fire—such as the ancient Greek myth of Prometheus, who was considered the creator of human beings [4], [5]. After creating mortals, Prometheus tricked the supreme Olympian Zeus into selecting an unsavory offering from humans, causing Zeus to retaliate by hiding fire from humanity. Prometheus, who was also considered the guardian of humanity, stole fire back from Zeus and returned it to the humans. Angered by the theft, Zeus had Prometheus chained to a mountain, where an eagle pecked out his liver every day for 1,000 years—fortunately, it grew back every evening. In addition to being the protector and creator of humans, the ancient Greeks considered Prometheus to be the founder of all the arts and sciences.

Fire has been used symbolically over time to signify various concepts, many of which are conveyed in the Prometheus myth, such as physical strength and power, spiritual power, birth and rebirth, creation and destruction, enlightenment and transformation, divinity and hell, inspiration, intellect, emotions, and wisdom [6].

III. ARCHITECTURE OF THE CMC

The Run Run Shaw Creative Media Centre (CMC) is a crystalline shaped building designed by the noted architect Daniel Libeskind [7]. The CMC is owned by City University of Hong Kong, and has operated as an academic building since it opened in 2011. The School of Creative Media, host of ISEA2016, is housed in the CMC.

The CMC has many surfaces capable of receiving a video projection, but the 55 x 26 m main façade was selected because it is the largest continuous surface on the building. The main façade also faces a student residence building 21 m away, which has a balcony situated 13 m above ground level. This balcony was at an ideal height for holding the video projectors, as the main façade is 26 m high.

The unique architecture of the CMC complicated the video projections, because the building's main façade is angled forward 62 degrees and it has no edges perpendicular to the ground. Although the 11 m wide balcony used to hold the projectors was at an appropriate height, its orientation differed from that of the façade by 12 degrees and its horizontal center was 10 m to the left of the façade's horizontal center. As a result, the distance between the far right side of the façade and the projectors was 37 m, while the left side was only 29 m away.

IV. Media Façade System

A. Video Projection

In this article, the following terminology is used to describe high-definition (HD) video and video projection.

- *2K video:* a digital video resolution that has approximately 2000 horizontal pixels and 1000 vertical pixels, such as *Full HD video,* which has a resolution of 1920 x 1080.
- *4K video:* a digital video resolution that has approximately 4000 pixels horizontally and 2000 pixels vertically, such as *Ultra HD video,* which has a resolution of 3840 x 2160.
- *ANSI lumens:* a standardized unit of measurement for specifying the brightness of a video projector's imagery.
- *Edge blending:* adjusting the brightness and regions of overlapping video projections to create the impression of a single cohesive video projection. Effective edge blending requires that overlapping areas contain the same video imagery.
- *HDMI:* an inexpensive audio/video interface for transferring real-time video or audio data between hardware devices, such as from a computer to a video projector.
- *Keystone effect:* the stretched distortion of a video projection caused by a projection surface not being perpendicular to the direction of a projector's beam, resulting in a trapezoidal projection within which imagery is distorted. A *horizontal keystone effect* is produced when the right and left sides of a projection surface are at different distances from the projector. A *vertical keystone effect* is produced when the top and bottom of a projection surface are at different distances from the projector.
- *Lens throw ratio:* specification of a projector lens that indicates the distance between the lens and the projection surface relative to the width of the projected image. For example, a lens with a lens throw of 0.8 will produce a 1 m wide projection at a distance of 0.8 m.
- *Projection mapping* or *video mapping:* adjusting the outer shape of a video projection to coincide with a desired shape on the projection surface.
- *Projection masking:* preventing specific areas of video imagery from being projected onto the projection surface.
- *Projection scaling:* adjusting the overall horizontal or vertical size of a projection.
- *Projection surface:* the physical surface that receives a video-projected image.

Various calculations and measurements of the CMC building determined that a minimum of four projectors could cover the 55 x 26 m projection surface, with each projector having a brightness of 20,000 ANSI lumens and a lens throw of 0.8.

Projection problems were created by the building's architecture and the balcony's location, because the video projectors could not be positioned where their beams would be perpendicular to the projection surface. The result of this spatial limitation was extreme keystone effects for the projections, especially in the upper right-hand corner of the main façade. These keystone effects also affected the splitting of the 4K video source for the multi-projector configuration, causing the calibration adjustments to be overly sensitive.

The author configured a media façade system that could accommodate the keystone problems through software that enabled quick and accurate calibrations for video splitting, edge blending, keystone removal, video mapping, projection masking, and projection scaling. The calibration controls programmed into the software permitted the slow repositioning of each projection at one-pixel increments. Fig. 2 shows the media façade during the calibration stage.

B. Hardware Configuration.

The hardware for the media façade system included one Apple Mac Pro computer, two SSDs, one audio interface, one audio mixer, two 1000-watt powered speakers and four 20,000 ANSI lumens video projectors, each with a 0.8 lens operating at WUXGA resolution (1920 x 1200 pixels). The same computer was used to program the control software, edit the audio and video source media, and present the media façade. Fig. 3 depicts the hardware configuration used for the media façade.

A standard Apple Mac Pro (2013 model) was used because it has sufficient processing power to accommodate 4K video files and can provide up to six simultaneous HDMI outputs. During the presentation of the media façade, the computer provided four independent HDMI signals for the four video projectors. These four outputs supplied an arrangement of two

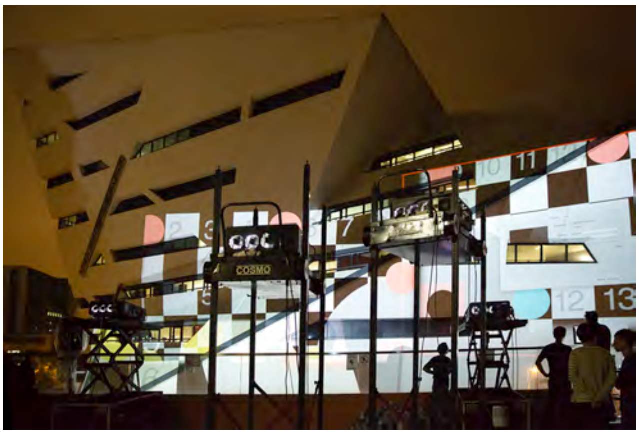

Fig. 2. The four video projectors during the calibration stage.

horizontal by two vertical WUXGA projections, creating an overall projection with a resolution of 3840 x 2400. The perceived resolution was somewhat smaller because each projection overlapped with adjacent projections by approximately 10% for edge blending. A fifth Full HD resolution HDMI output was used for the programming and control monitor.

An important feature of the Mac Pro was its dual GPU video card that enabled high-speed processing of the 4K source video using GPU functionality, accessed through the control software. The GPU functions used by the control software enabled real-time color grading, mapping, scaling, masking, brightness adjustment, gamma adjustment, and video mixing of the 4K source media. Another important feature of the hardware configuration was the two SSDs that enabled high-speed playback of the 4K video files.

C. Media Files

The video files used for playback in the system originated as video recordings of real fire, captured at 4096 x 2160 resolution. The speed of the original footage was reduced to 25% and 50% and resized to an Ultra HD resolution of 3840 x 2160. The speed of the original footage was reduced because the motion of the flames seemed too quick when projected 26 m high. The re-timed footage was rendered using frame blending to generate new video frames between the existing frames.

The Ultra HD video files used for playback in the media façade system used Apple's ProRes 422 HQ codec within an MOV container format. Use of the ProRes codec enabled the efficient processing of the video in real time using the GPU functionality.

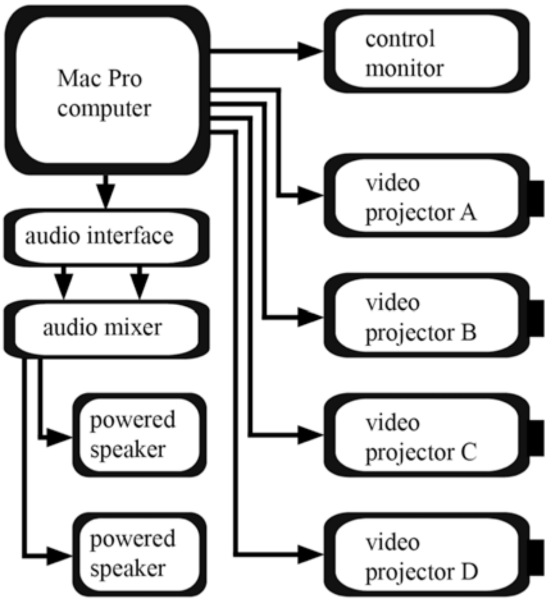

Fig. 3. Diagram of hardware configuration for media façade system.

Two separate uncompressed audio recordings of fire sounds were contained within AIFF audio files. The audio tracks were not placed within the video files, enabling them to be controlled separately from the video tracks.

Additional video files containing black and white checkerboard patterns with colored circles were created to assist with the accurate placement, scaling, and color calibration of the four video projections.

D. Control Software

The functionality of each component within the control software was accomplished in real time at 24 frames per second, coinciding with the frame rate of the Ultra HD source videos. The primary functional components of the software and the flow of data between them are depicted in Fig. 4 and described below.

• *Media library:* contained the video and audio files available for use by the system. All of the media files were stored on an internal SSD or an external SSD to accommodate the high data rate of two Ultra HD video files played simultaneously. The duration of each source video file was 24 minutes, and the files ranged in size from 80 GB to 88 GB, each with a data rate of 440 Mb/s.

• *4K video players 1 and 2:* enabled the selection and simultaneous playback of two Ultra HD source video files.

• *Brightness adjustment:* enabled the selection of a brightness level from 0 to 100% for each source video.

• *Color variation controls:* the outputs of the two video-player components were directed to two color variation components that enabled the color grading of each source video to be adjusted manually or automatically. When adjusted automatically, the color grading of a source video changed within a selectable range of RGB values at a selectable rate of change. The automatic color variation enabled a wide range of color grading to be presented during real-time playback.

• *Brightness calculation:* determined the overall brightness of each video frame in a source video during playback. The calculation was used to control the volume of the audio files.

• *Interactive audio players 1 and 2:* enabled the selection and playback of a specific audio file from the media library. In conjunction with the brightness-calculation component, the volume of the audio file corresponded with the brightness of the master video, creating a sound-image synchronization between the fire imagery and the sounds of fire.

• *Audio level 1 and 2 controls:* enabled the selection of a volume level for each audio file.

• *Source video mixer:* mixed the two source videos at an adjustable level of opacity. The output of the source video mixer was the first stage of the 4K master source video.

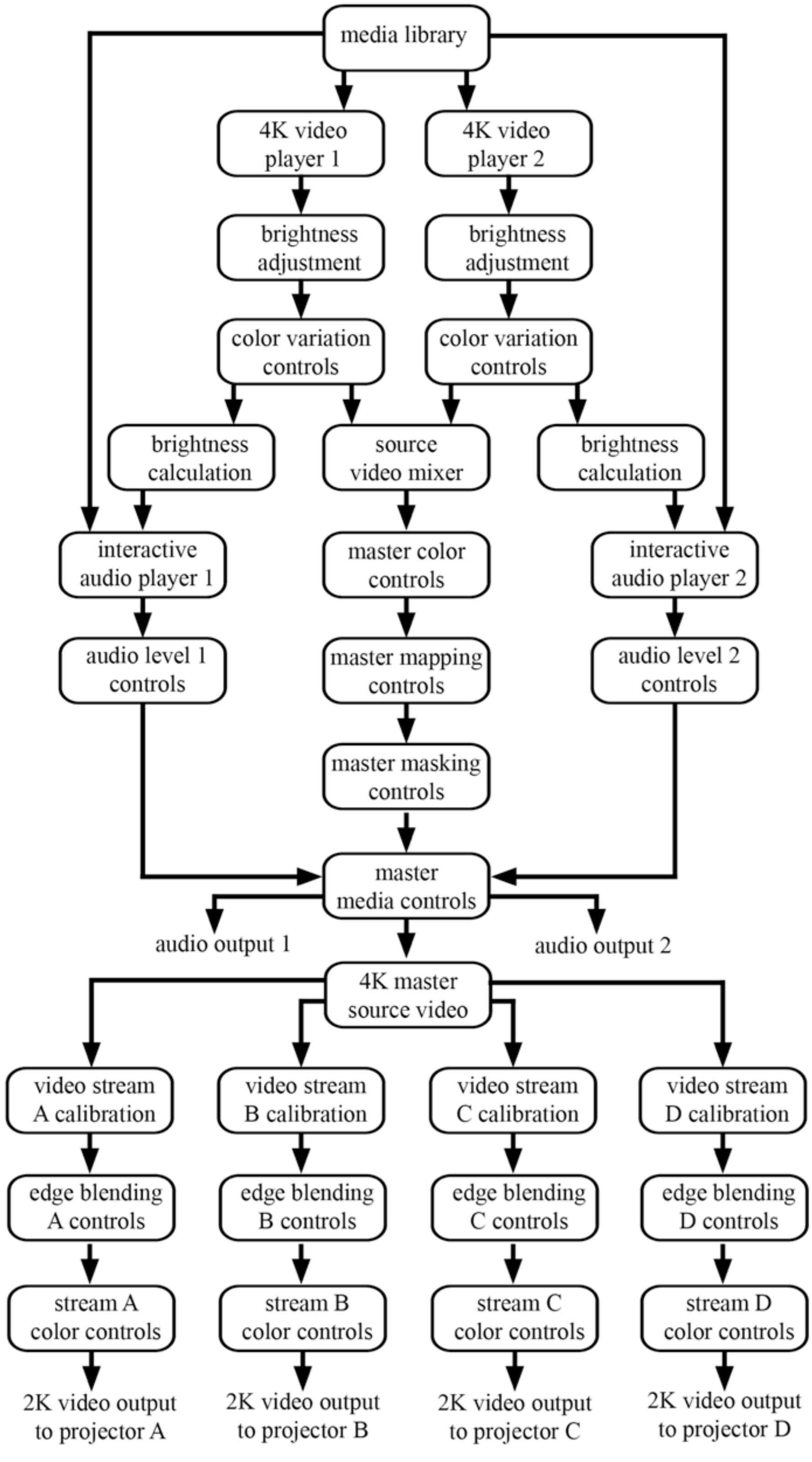

Fig. 4. Diagram of the functional components within the control software.

• *Master color controls:* permitted adjustments of luminance and saturation for the master source video.

• *Master mapping controls:* permitted the accurate video mapping of the master source video onto the projection surface. Any edge point of the projection could be moved individually or collectively in the X, Y, or Z direction, causing a corresponding rescaling of the video imagery.

• *Master masking controls:* permitted the masking of any region of the master source video, thereby limiting which portions of the video imagery were projected onto the projection surface.

• *Master media controls:* provided various controls for the master source video and audio sent to the video projectors and sound system, such as pause, play, maximum brightness, automated fade in, automated fade out, and master audio level.

• *4K master source video:* the master source video containing the source video mix, video mapping, masking, brightness, saturation, and color variation. The master source video was duplicated as four 4K streams, which were sent to the video stream calibration components A, B, C, and D.

• *Video stream calibration A, B, C, D:* enabled the Ultra HD source video to be adjusted to a WUXGA resolution stream for presentation through one of the four video projectors, labeled as projectors A, B, C, and D. This software component allowed a specific region of video within the master source video to be selected according to the XY position, zoom level, Z rotation, width, height, and XY distortion of each corner. The procedure accomplished by this component was related to video mapping, but its function was to arrange the four projections into a single cohesive projection with overlap between adjacent projections.

• *Edge blending controls*: enabled adjustments to the location, angle, size, and blurring of selected edges within a video stream, enabling adjacent projections to visually blend into a single cohesive projection. See Fig. 5 for a close-up photograph of an edge blended projection. Adjacent projections were required to overlap by at least 10% to create a visually effective edge blend.

• *Stream color calibration:* permitted the gamma and RGB brightness levels to be adjusted for video streams A, B, C or D, enabling the four projectors to be color matched. The illusion of a single cohesive projection could not have been created if the four projectors had differed in color balance. This control was required because even video projectors of the same model may require different settings for a matched color balance.

The entire procedure for using the control software to present the media façade is listed below.

1) Place video projectors at required locations with a minimum of 10% overlap between adjacent projections.

Fig. 5. Detail of *Burning Too* media façade on the Run Run Shaw Creative Media Centre, Hong Kong.

2) Configure and connect all hardware components: computer, video projectors, audio interface, and sound system.

3) Use the control software to display the calibration screen through each projector.

4) Adjust the video stream calibration controls for each projection to create a single calibration screen with overlap between adjacent projections.

5) Adjust the edge blending controls for each projection to create a single cohesive calibration screen.

6) Adjust the stream color calibration controls to obtain color matching between the four video projectors.

7) Adjust the master mapping and masking controls.

8) Adjust the source brightness, color variation, video mixer, audio level, source brightness, and source saturation controls.

9) Operate media façade using master media controls.

V. Conclusion

Burning Too was the second media façade presented by the author that used fire imagery with sound. The first, titled *For All The Museums That Forgot To Offer An Exhibition To Me,* was a 100 x 25 m media façade presented in 2015 on the Daegu Culture and Arts Center in South Korea [8]. See Fig. 6. The presentation system for that media façade did not use a single real-time system for video mapping, edge blending, or distributing video signals to multiple projectors. Instead, a video file was mapped onto a corresponding 3D model before being projected onto the building, and the video signal for the four projections was split using video distribution hardware.

Fig. 6. *For All The Museums That Forgot To Offer An Exhibition To Me* media façade on the Daegu Culture and Arts Center, South Korea.

The author recently presented a third media façade of fire with sound at the Ars Electronica Festival 2016 in Linz, Austria. This project, also titled *Burning Too* [9], had many differences from *Burning Too* in Hong Kong. The Ars Electronica presentation used a single Full HD video projector oriented on its side to create a projection 23 m high and 10 m wide. The imagery in Linz also contained fireball explosions, and the sound of these explosions caused a corresponding deformation of the fire in real-time.

The ability to configure a reasonably priced system that can play and process 4K video in real time is relevant for anyone involved in the creation of media façades or interactive video installations, especially media creators involved in non-commercial productions. 4K video systems can present visual imagery at a perceptual quality that is technically similar to 35 mm cinema, and when this high-quality imagery is coupled with real-time processing and interactive control, there is potential for creating new types of media experiences that are more realistic and more aesthetically appealing. The limiting economic factor for large-scale presentations of 4K video is, however, the high cost of appropriate video projectors.

This article has focused primarily on the technical aspects of the *Burning Too* project in Hong Kong, though the author's motivation for creating a media façade of fire imagery evolved from his longtime fascination with fire. Humans have been dependent on fire throughout history for warmth, safety, and food preparation, but these practical applications have often been accompanied by an attraction to fire based on metaphysical or aesthetic reasons. Although many viewers of the *Burning Too* media façade interpreted the project's symbolism as an expression of aggression mixed with beauty, the author's conceptual motivation was only to demonstrate humanity's enduring fascination with fire.

Acknowledgment

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