High Frame Rate (HFR) WHITE PAPER

An exploration into the creation of variable frame rate (VFR) stereoscopic 3D narrative productions. Developed by Emily Carr's S3D Centre with the generous support of TELUS Technology Strategy.

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This white paper reveals reports on the aesthetic experiments conducted by the S3D team at Emilly Carr with a focus on **High Frame Rate (HFR)** and **Variable High Frame Rate (VFR)** to provide a basis in for discussing best practices in Stereoscopic 3D production with High Frame Rate technology.

Emily Carr's Stereographic 3D Centre is a national centre of excellece dedicated to advancing the art of stereoscopic 3D through research, education and training.

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S3D = Stereoscopic 3D
A technique for creating or enhancing the illusion of depth in an image, by meansofstereopsisforbinocularvision.

HFR = High Frame Rates
Traditionally, cinema productions are filmed at 24 frames per second, or for broadcast at 29.97 (30) frames per second. There are numerous advantages to filming in HFR, especially in 3D.

VFR = Variable Frame Rates
This is the use of multiple frame rates within the same container/ sequence. Does the utilization of HFR as a 'tool' in this regard change the immersive experience for the viewer? We suspect that the question of whether or not to utilize HFR in a stereoscopic 3D film within a narrative context depends largely on the creative intent of the film itself.

SFR = Standard Frame Rate
24fps in North America, 25fps in Europe.

1.0 Introduction

With the emergent market of Stereoscopic 3D (S3D) television and S3D digital cinema projection, content creators are faced with the challenge of learning how to develop high quality S3D material. Issues surrounding the prominence of distracting motion artifacts have arisen, along with the constant push to make S3D content more immersive and closer to reality than ever before. High frame rates (HFR), which is the capture and projection of a frame rate greater than the current 80 year old standard has been suggested as a means to achieve higher quality S3D. 24 fps has become widely known as the 'cinematic aesthetic' however, certain motion artifacts such as blur and strobing are noticeable due to a shutter speed too slow to capture temporal information. Motion artifacts are of concern in stereoscopic 3D productions because they have been shown to increase viewer discomfort and lead to a distracting experience, the opposite of what most S3D productions are trying to accomplish. Motion artifacts are greatly reduced at higher frame rates resulting in a more comfortable viewing experience with more temporal information. We have identified a conflict between maintaining 'aesthetic', and reducing these problematic motion artifacts.

1.1 Abstract

The S3D Centre is researching the effect of Variable HFR S3D on the aesthetics and immersion in the context of a single narrative. Advances in digital projectors, software, and cameras have made it possible to consider combining frame rates in a production. With technology used to capture and display a complete narrative at multiple frame rates (both standard and higher), what would be the creative benefits and drawbacks of doing so? Would the use of HFR as a 'tool' in this way alter the degree of immersion for the viewer? We created the variable HFR S3D short film "Soul Mate 3D" as a means to explore these questions and see what the results are for both 3DTV and Cinema. We discovered the greatest question of whether to use HFR in a stereoscopic 3D film within a narrative context depends largely on the content and creative intent of the film itself.

High Frame Rate Benefits for the Entertainment Industry

Sterescopic 3D HFR creates new possibilities in content creation, which is of interest to those who make content or purchase/distribute content. Individuals and companies wanting to create content in HFR will need specialized equipment, and this will result in a new market opportunities. Theatres committed to projecting HFR productions will attract audiences not simply because of novelty, but because HFR is the highest quality digital projection available. There are distinct benefits to consumers providing feedback on how they wish to view content, and researchers improving the variety of viewing methods available.

HFR Benefits for Academia

HFR creates a multi-faceted dialogue for researchers. Sub topics include: Human perception of higher frame rates; HFR influence on viewer comfort, immersion, narrative understanding, and situational awareness in virtual reality. In the engineering field, of interest would be the research and development of hardware needed to acquire and display content. In computer science, new algorithms could be developed to process and analyze variable frame rate content. HFR also provides a new area of investigation in film theory and production.

HFR Benefits for the Audience

Reception from audience members on early HFR content has been mixed which is unsurprising. The introduction of a new standard often needs a period of acclimation. At first, curiosity about what HFR looks like will drive audience numbers. If indeed HFR creates a more comfortable viewing experience, audience members previously turned off from watching S3D may choose to give it another go. HFR will not only be limited to cinema. It may penetrate the TV market first due to a very receptive audience for sports and nature programs for which HFR provides a real, true to life aesthetic.

Synopsis of "Soul Mates 3D"

A return to the theatre ensures that an elderly husband and wife couple is able to escape once more into their youth- and their youth means nothing without the devotion and love they have formed over their long lives. Elderly dancer Helen Derobe has always been a person of few words, preferring to show rather than tell. Her husband is everything to her and she finds herself becoming more dependent on him. Lately she is unable to use words to describe what her husband means to her, so she reminds him once more- through dance, which had initially brought them close together.

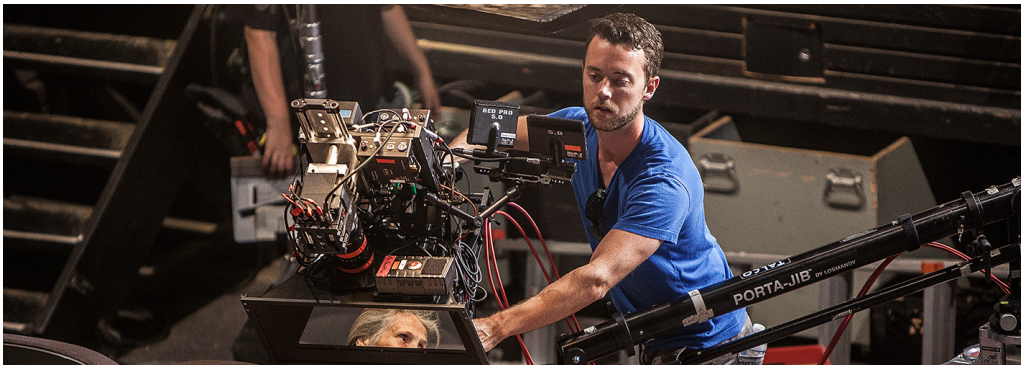
2.0 The History of Human Vision and Frame Rates

In human vision, it is the frame rates higher than 12 frames per second that allows the 'seams' between sequential images to disappear, and we may then perceive motion. The argument of what fluid motion looks like is debatable, with Thomas Edison claiming that 46 fps was the minimum frame rate, "anything less will strain the eye."[1] 24 fps was settled upon by studio executives who wanted to balance the expense of film with motion that was just barely smooth enough for our vision to tolerate, and this is how the 24fps 80 year-old standard was born.

In the 1970's through to the 1980's, Douglas Trumbull (a prominent visual effects specialist) created Showscan, a technology that would be able to project higher frame rates on film. This system increased temporal resolution in the same way that 70mm offered double the spatial resolution of 35mm film. His experiments proved critical, with a much greater sensation of reality and smoother motion experienced by viewers. Notably, Trumbull was able to specifically measure the emotional and physical responses of viewers watching high frame rate content with some very clear results.

"Higher frame rates give a strong sense immersion and realism, made possible by the tremendous reduction of blurring. Showscan was based on photographing 65mm film at 60 fps and then projecting it using 70mm prints at the same rate. We had done laboratory tests to see the impact of high-frame rates images on viewers. Viewers were shown identical films shot and projected at 24, 36, 48, 60, 66 and 72 fps, and all of them were monitored with electromyogram, electroencephalogram, galvanic skin response and electrocardiogram. The results were conclusive that the 60 fps profoundly increased the viewers' visual stimulation."[2]

The only reason Showscan did not become a commercial success was due to the cost involved with the physical nature of film stock. Now that Showscan has gone Digital, the opportunities far exceed the risks in terms of expense. HFR and S3D once combined together is considered to be among the most profound mediums, being not unlike what virtual reality could eventually become. In standard frames rates, motion blur and strobing become even greater of an issue than 2D. In 2D theses motion artifacts are distracting, but with S3D (where depth must be interpreted by the brain), un-fused and blurry images create painful problems. These motion artifacts in S3D can cause headaches and will cause the audience to disengage with the film emotionally. This is because the audience is still subconsciously aware of flicker and blurring at frame rates below 60fps. temporal information. We have identified a conflict between maintaining 'aesthetic', and reducing these problematic motion artifacts.



2.2 Creating a VFR or HFR film

On August 17–18th, staff from the S3D Centre directed the first variable rate HFR shoot of its kind with talented independent crew and cast members in Vancouver BC. **"Soul Mate 3D"** is a dual short film and applied research project that takes full advantage of HFR capabilities. Shot on the RED Epics on a motorized Kernercam stereoscopic 3D rig in both standard and high frames rates, we used the most recent advances in technology to investigate a question we have been studying for the past year: **If technology were capable of capturing and displaying a complete narrative that incorporates variable standard and high frame rates, what are the creative benefits/drawbacks of doing so? Does the utilization of HFR as a 'tool' in this regard change the immersive experience for the viewer?** We suspect that the question of whether or not to utilize HFR in a stereoscopic 3D film within a narrative context depends largely on the creative intent of the film itself. This short film was a means to explore these research questions.

Initial research conducted in advance of this production consisted of a complete analysis of cameras, stereoscopic rigs, post production and display solutions that were capable of supporting HFR. A camera capable of shooting HFR must be used, and one that provides quick switching between recording frame rates and camera timebase. A noticeable delay on camera will discourage the experimentation of HFR on set. The RED Epics were chosen for their ability to shoot HFR at unprecedented resolution, and the ease of a RED workflow. We used our Kernercam S3D rig with Epic mounts, which proved of critical importance due to its motorization of IA (inter axial), convergence, and focus. We were unable to find a display capable of HFR playback to bring on set, so we monitored on a consumer LG monitor in standard frame rates. It is integral to match the in camera timebase to the recording frame rate. This is an important but easily confused step for HFR projects. A non-matching timebase and frame rate will result in a VariSpeed product, not an HFR product. This is of upmost importance to double check, as the genlock device on a camera configuration could cause a slip in sync (resulting in temporal offset) or reset of timebase.

Cameras capable of HFR in genlocked S3D (at time of writing):

A return to the theatre ensures that an elderly husband and wife couple is able to escape once more into their youth– and their youth means nothing without the devotion and love they have formed over their long lives. Elderly dancer Helen Derobe has always been a person of few words, preferring to show rather than tell. Her husband is everything to her and she finds herself becoming more dependent on him. Lately she is unable to use words to describe what her husband means to her, so she reminds him once more– through dance, which had initially brought them close together.

2.3 Creating a VFR or HFR film: Conception

At a panel on HFR at NAB Show 2012, we observed Fraunhofer and Park Road Post demonstrate stand-alone clips at different frame rates. The clips had been created using a variety of interpolation and filming methods. An observation S3D Centre researchers made at the presentation was that it became difficult to appreciate the effects of HFR when clips were presented outside of a narrative context. If HFR were utilized to enhance and tell a better story, then it would make sense see it within a story. Yet there seemed to be unexpected push back from attendees at CinemaCon 2012 [3] only a week later, when Peter Jackson and company presented 10 minutes of clips from "The Hobbit: An Unexpected Journey". Once more, clips were presented outside of their intended narrative context in a montage format and viewers had some very legitimate concerns over the footage. Comments ranged from 'the shot with the actors talking was too realistic, it took me out of the immersive 3D experience and I was reminded I was watching a film', to 'the landscape and action shots were stunning and incredibly immersive." Douglas Trumbull has stated that HFR could benefit from being used as a selective tool,[4] and it can be agreed that some clips may be appropriate in S3D HFR and others not. Now that digital projectors exist, the firmware and software modifications needed to achieve this can be accomplished in time.

We were initially inspired by the idea of HFR after hearing Wim Wenders keynote at the 2011 Toronto International S3D Conference [5]. The accomplished filmmaker expressed his thoughts about his landmark S3D documentary "Pina" being considered a candidate for HFR capture at one point in pre-production. As Wenders explains about his decision to film in S3D: "The two-dimensional cinema screen is simply not capable of capturing Pina Bausch's work, either emotionally or aesthetically. When I watched her dance for the first time twenty-five years ago, I was captivated and deeply moved. I was able to understand human movement, gestures and feelings in a whole new way. And this magic is what I would like to translate to the screen [...] 3D gives us the possibility of taking the audience directly onto the stage, into the middle of the event." With "Pina" already being such a shining example of the art and technical achievement of S3D filmmaking, the thought of it also being filmed in HFR was striking. Would such a graceful, raw example of dance and human emotion of "Pina" become elevated with the use of HFR? Or would the use of HFR, noted for its 'ultra-real' definition, work against the beauty and emotion of the film? It is hard to imagine now what audience reaction may have been, but we did suspect that the use of HFR might have worked both for and against the film if its use was indeed employed.

2.4 Creating a VFR or HFR film: Practical Specifications

Inspired by the beauty of "Pina", we chose to incorporate a dance element into our story. We decided to model the story around the actual capabilities of what we suspected VFR and HFR could demonstrate. The initial shot list that encompassed experiments surrounding VFR/HFR was later discarded as we realized these 'tests' had no meaningful relevance once they were placed into a story narrative. For example, we could not find a legitimate way to test various shutter angles, gigantism, miniaturization, refraction/reflection, and temporal frequency all within the structure of a story. If we were to complete 'tests', they should remain just that- tests that result in comparative analysis of the effects of various VFR/HFR shots which we wanted to avoid doing. So we ended of altering the shot list to contain the priority shots:

1. What do PEOPLE look like in HFR? (CU, MS, WS)
2. What does stationary movement/ fast action look like?
3. How does HFR effect reflection?
4. How does HFR effect depth (foreground/background)
5. How does HFR affect REALISM?

We built the composition, framing, staging and action all within the structure of these five priorities. The final shot list as it appeared on set was used as a tool to guide the shots since the HFR/VFR components were already planned within it. We permitted the DOP and Stereographers to have complete creative control of the lighting and stereography while using the shot list as a guide for framing. The only very relevant stereo 3D tool that was created before production, and is still currently being used for "Soul Mate 3D" is a stereo depth script for post production. Researchers at the S3D Centre based the "Soul Mate 3D" depth script based on Brain Gardner's philosophies towards perception and the art of 3D storytelling.[6]

SOULMATES 3D								JIB SHOT / OTHER	DOLLY SHOT / STATIONARY						
X	SHOT #	I/E D/N	DISTANCE	SUBJECT	ANGLE	LENS	EQUIPMENT	MOVEMENT	COVERAGE	NOTES	SCRIPT TIME	SETUP TIME	PREDIC # OF TAKES	SHOOT TIME	TAKE # (circle best)
				SCENE 1						EXT. LOCATION - EARLY EVENING THEATRE ENTRANCE					
	1.1.	E D		Theatre Ext	ES-WS		Tripod	Tilt down	ES of Metro theatre	Tilt cam movement from Metro lettering to our elderly couple approaching theatre			3	30:00	
	1.2.	E D		Theatre EXT, couple	FS		Tripod	Pan Right	FS couple entering theatre	Follow pan of couple approaching, opening, and entering theatre			3	8.	
	1.3.	I D		Theatre Lobby INT, couple enters	WS		Tripod	Stationary	WS couple having entered theatre, inside lobby	Stationary camera as they enter and approach entrance to theatre			3	8.	
	1.4.	I D		Theatre Lobby INT, wife indicates she will be right back	MCU		Tripod	Stationary	MCU of couple in lobby	Wife whispers to husbands/indicates she will return in a moment			3	6.	
	1.5.	I D		Theatre Lobby INT, husband watches wife depart	WS (same setup as 1.3.)		Tripod	Stationary	WS inside lobby	Husband watches wife depart, walks to door and pauses before opening it			3	8.	
	1.6.	I D		Theatre lobby corner, wife pauses at washroom	MS		Tripod	Stationary	MCU of wife as she approaches washroom	Wife slows at the washroom door to mischeivously pass it by and approach up stairs (what is she up to?)			3	5.	
	1.7.	I D		MS of husband (from behind) opening theatre doors	MS		Dolly Shot	Dolly In	MS of lobby to theatre transition	Husband opens the doors to the theatre, it reveals the theatre			6	5.	
	NOTES:											TOTAL MINUTES FOR	SCENE 1	#REF!	
				SCENE 2						INT. LOCATION - THEATRE LOBBY					
	2.1.	I D		FS Lobby staircase, wife	FS		Tripod	Stationary	MS of wife ascending stairs	Camera positioned at top of staircase shows the wife ascending the stairs			3	5	
	2.2.	I D		WS Theatre	WS		Dolly	Dolly left	WS of husband walking down aisle in theatre	Dolly left following husband as he walks down aisle			6	8	
	2.3.	I D		MCU husband taking seat	MCU		Tripod	Stationary	MCU of husband	Husband takes his seat at the theatre			3	4	
	2.4.	I D		EWS dolly out of theatre from stage	EWS		Dolly	Dolly out	EWS of husband alone in darkened theatre	Reveal of empty theatre from the stage, husband sitting front and centre			3	10	
	2.5.	I D		WS dressing room door	WS		Dolly	Dolly In	WS of dressing room door	Dolly in towards the dressing room door			3	6	
	2.6.	I D		MS wife passes mirror	MS		Tripod	Stationary	MS wife pauses at mirror	The wife pauses at a mirror touchously look at herself, suddenly cange her posture			6	6	

2.5 Creating a VFR or HFR film: Practical Specifications

For **"Soul Mate 3D"**, we decided to shoot every take at 24 frames (standard), and 48 and 60 frames (HFR) rather than interpolate frames in software later. We wanted to know what actual HFR shooting would be like on set and with a direct workflow in post. One concern on location was that switching frame rates between takes would be time consuming, but the only delay was in switching the output on the AJA Gen 10 to keep the cameras in sync. Filming HFR does require additional light, since the shutter remains open over less time as frame rates per second increase. A knowledgeable crew was key in being prepared for the need for additional light requirements.

We spent a considerable amount of time on props and set decoration. In our attempt to test out what HFR looked like, we wanted to experiment with mirrors and surfaces that provided reflection. S3D films typically have issues with reflection, as it can be very distracting in that reflections do not mimic normal perception in real life in floating within the stereo 3D depth. HFR however may reduce some of the motion artifacts that affect perception.

A de-brief after the filming completed led to the research team agreeing that we had stuck very closely to our intent to use variable HFR as a creative tool during the shoot. There were times that once on set, we would look at the shot list and staging yet realize the shot we had in our heads was not entirely realistic, or did not take full advantage of HFR. In looking at the initial footage, the team was overwhelmed at its potential to build a better story and also be used as a scientific plus creative learning tool for 3D stereoscopy. Filming S3D in HFR was very akin to filming a non-HFR production, with the only main difference in that we shot each scene in 24, 48, and 60fps. That may have meant more takes in the long run in order to get coverage.

Filming Specifications

Rig: Kernercam S3D rig with motorized IA, convergence, and focus on Preston controllers.

Cameras: RED Epic filmed at 4096x2160 resolution at 59.94, 48.95 and 23.98fps timebase/recording frame rate with a shutter angle of 180 degrees.

3.0 The choice of frame rates, shutter speeds and shutter angles

The use of 24fps in this production as the SFR was chosen due to our North American location, and audience familiarity with the frame rate aesthetic. 48fps was chosen because it is simple to double the 24 frame rate, and if it is required in double flash for projection, this could be done easily. Because "The Hobbit" was filmed at 48fps, we were curious to see what the aesthetic was like before the blockbuster film was released.

60fps was chosen with television in mind. 60fps performs well on 60Hz, 120Hz and 240Hz TVs without compensation in the motion. 60fps is double the frame rate of regular broadcast television at 30fps, so we considered this might make the frame rate easier for testing in a broadcast environment.

Shutter speed is the amount of time the shutter is open to expose the sensor / media. Frame rate is the number of frames per second. Shutter angle (in degrees) is the film equivalent to shutter speed and is used by most professional systems. Using this information:

- 360 degree shutter = exposure time to be 100% of frame time
- 270 degree shutter = 75% of frame time
- 180 degree shutter = 50% of frame time
- 90 degree shutter = 25% of frame time

Red Digital Cinema covers shutter angle in a easy to understand method, "By far the most common setting for cinema has been a shutter angle near 180 degrees, which equates to a shutter speed near 1/48 of a second at 24 fps. Any larger, and motion appears more smeared since the end of blur in one frame extends closer to the start of blur in the next frame. Any smaller, and the motion appears more stuttered and disjoint since the blur gap increases, causing frames to become more like discrete images."[7]

For "Soul Mate 3D", it was the DP and Stereographers' choice to keep the shutter angle at 180 degrees for creative purposes and the above reasons concerning judder/blur. 270 degrees was used on "The Hobbit" for what appears to be creative aesthetic reasons, and that particular shutter angle introduces a bit of a cinematic looking blur back into the picture. We had looked at many tests of shutter angles with HFR completed by Fraunhofer and Park Road Post, and it is very clear that each shutter angle also has its own aesthetic. Many HFR enthusiasts claim 270 and even 360 degree shutter angles in HFR content produces a better looking image. More testing will be needed to explore these claims, and this is an area in which the SMPTE HFR work group is very active.[8] Results should be available Summer 2013, and we have an idea after watching "The Hobbit" on what this combination of 270 degree shutter angle/48fps looks like.

Computer Tech Specs

Macbook Pro for on set dailies and offline edit:

17" running 10.7.3. 2.4 GHz Intel Core i7. 8 GB 1333 MHz DDR3. AMD Radeon HD 6770M. GPU Graphics bus, Intel HD Graphics 3000. GPU built in bus.

Footage stored on Pegasus Promise through thunderbolt connectivity.

We have an additional Magma 3-slot chassis that can be used with this configuration, running Red Rockets or other cards.

MacPro tower:

3.2 GHz dual quad core with 18gb ram. Nvidia Quadro FX 4800. Mac Raid Card – Raid 0.
1 x RedRocket. BlackMagic 3D Extreme PCI card for playback.

Cine-Tal Cinemage 2000 monitor for colour grading, and Hyundai Hyundai 46" passive polarized 3D LCD (S465D) for 3D TV playback.

3.1 Technical post production considerations for VFR material

At the 2012 SMPTE Symposium the headline topic was HFR. Since the research team at the S3D Centre has been dealing with many post production considerations over the past months, it comes as no surprise that this is an area of concern echoed relentlessly at the Symposium. Paul Chapman, senior VP of technology at Fotokem led a discussion around challenges that HFR introduces to post. He asserted that support from creative editorial is lacking and is needed and this was a sentiment echoed by additional speakers, including Disney's Howard Lukk. Chapman reported that he conducted an informal survey of dailies vendors, and his findings suggest that all are now testing high frame rates.

"Nico Recagno of SGO Mistika, which is in use at Park Road Post on "The Hobbit" said that managing dailies at HFRs is "horrifically difficult," citing challenges including time code, methods of viewing and QC, and sound sync. Recagno added that the biggest concern that he is hearing from colorists is getting proper calibration during color grading. He and Chapman both urged the community to create HFR standards in some of the discussed areas, including time code."[9]

As members of the SMPTE 21DC high frame rate study group, we at the S3D Centre can echo that these are very new concerns in the digital era. Furthermore, there are simply not many software applications/dailies software and hardware already capable of S3D toolsets, let alone HFR 3D toolsets. SGO Mistika has been reckoned as the ultimate HFR 3D toolset, but with its steep price point we have found it to be out of reach for the majority of filmmakers. Quantel's Pablo Rio has become much more accessible to filmmakers over the past year, and the launch of SynthIA S3D toolset will pave the way for HFR S3D creation. Having used Avid Media Composer and Symphony for S3D in previous projects, we were able to test it on our HFR 3D material in 2012. Avid already has functional S3D toolsets so this made the process of attempting the playback of HFR S3D simplified.

Regardless of your software, real-time playback of S3D material is a serious problem. Unfortunately HFR and VFR footage only exemplified this issue further. This is where the greatest expense may be incurred by an HFR / VFR S3D shoot: the cost of a reasonably new workstation, additional video/PCI cards, and fast storage to get near real time ingestion and playback of footage.

Software Capable of viewing HFR that we used:

- **Dailies:**

  1. **RedCine X** (limited depth grading/ convergence tools, some colour grading tools. Great way to view camera metadata and export new clips. Somewhat confusing to create S3D containers)
  2. **DaVinci Resolve 9** (excellent metadata capabilities, easy to create S3D containers but ONLY from EDLs created within Resolve. Excellent colour and depth grading. Easy to switch between left and right image. You can export literally any deliverable in HFR from DaVinci Resolve.)

- **Editing Solution that we used:**

  1. **Avid Media Composer or Symphony.** Can work directly from RED footage using AMA, or you can create proxies either from a dailies software OR inside Avid directly using the transcode tool. Easy to create S3D containers, easy to adjust sync on clips. Excellent depth grading and colour grading. Can export 720p60 media.

We were very encouraged to discover that **Avid DS** can utilize 23.98, 24, 47.95, 48, 59.94, 60fps timebases and footage among many other frame rates. It also had S3D toolset, and was capable of delivering full HD and 2K video. Unlike MC and Symphony, DS uses a different plugin scheme than AMA, but it has been built to match the experience and settings as closely as possible to AMA.

When planning on editing with proxies (this is likely going to be the only affordable way to view the S3D HFR material in real-time) an editor can one light and encode to HD within dailies program. You can then advance to your editing software (in our case, Avid). Our original clips were 4096x2160 at 59.94, 48.95 and 23.98. A computer can get almost real time playback of this material in S3D within Redcine, rasterized to 1/4 with a RedRocket in chassis connected on the MacBook Pro, and ¼ raster with the MacPro with a RedRocket inside. Similarly, within Avid we were able to view real time playback of AMA 3D HFR material at draft quality.

Depending on the requirements of the final output, these dailies and editing software can be used to export to a variety of deliverables. Avid Symphony exported any QuickTime or video desired, and Avid DS was able to export TIFF 16bit Image Sequences if a conversion for DCP was needed. RedCine was able to create new Red clips (called trims), to nearly any video codec and some image sequence options. DaVinci Resolve had excellent deliverables support of video, image sequences, and DPX.

3.2 Technical post production considerations for VFR material

The observation of very early results impacted the way that decisions were creatively made in post production to finish the short film "Soul Mate 3D". After viewing the HFR proxies in 2D and then S3D alongside standard frame rate material, researchers discovered it to be difficult to go back to watching the material in SFR after being exposed to the HFR versions of the material. While watching the SFR version of the material if felt that visual information was missing. Additionally, imperfect movements whether a shaky moving shot or jerky dance move became even more pronounced in HFR S3D. To counter this, the 23.98fps version of the clip used its blurred frames to 'smooth' the image compared to the HFR versions.

Similarly the dancer in the short film was a very beautiful dancer but sometimes the HFR created a kind of 'animated' look to her dancing. 23.98fps seemed to retain the 'soft, graceful' aesthetic of dance, but it also enhanced blur and judder to the point that it was unwatchable in 23.98fps. Lighting on a human subject appeared more defined in HFR, and when viewers of the material suggested it made a person look video-game like, it can be speculated that this sharper lighting was the reason. We had used fog machines to soften the lighting, so this appears to be a genuine HFR concern.

The HFR handheld shots were shockingly intimate, and could be intercut among different moments to create unique effects. Likewise HFR close ups of faces often broke the tolerable intimacy boundary for the viewer. It can be considered that this observation can be a strength, or major distraction depending on the focus of the story. All researchers observed that the background separated and was more defined in the HFR versions than in 23.98fps within the film. This is an advantage for S3D, but it should be noted that caution with set decoration must be taken. Any flaws in the background become more pronounced in HFR.

In general, stereo 3D shots were enjoyed when held longer in editing, and the entire edited sequence's pacing was slowed to allow the viewer time to absorb and appreciate the depth effects of VFR S3D. It is a commonly shared opinion by post production professionals to slow S3D pacing and with VFR we found the shots need to be held even a fraction longer. HFR seems to provide even more information and there is more to look at with the added frames and background depth. The movie "Life of Pi" in S3D provides an excellent example of this style of editing. The scenes were artfully composed with spectacular scenery, with immense depth noticeable even within the reflections of water. If this film were filmed and projected in HFR the shot length would have become even more important due to the increase of detail and audience observation.

The post production team on "The Hobbit" used Avid Media Composer and SGO Mistika, yet they actually edited the film in 24fps only to online the film in Mistika later, a fact revealed after several conversations. Creative decisions were made in SFR and this was in part due to technical limitation in HFR 3D at the time, but also the editor's familiarity to the SFR pipeline. More toolsets are due out soon that may promote actual creative editing and decision making based on the aesthetics of VFR and HFR, and this whitepaper may serve as an example to the value of observing HFR in post production.

4.0 Early Results & Conclusion

Early results with the variable frame rates of 24, 48 and 60 fps have shown that the emotional impact of static shots far exceeds what was originally expected for the viewers, and dynamic shots still suffer from motion artifacts that are actually caused by the HFR. A comparison of the VFR/HFR and SFR version of "Soul Mate 3D" show that VFR is indeed a valuable flexible tool dependent on the content of the narrative. We recognize that our outlined method in this whitepaper of filming multiple versions of a take to capture various frame rates on set is not practical for many productions, for example live events or documentaries. As such, this method is recommended for testing and evaluative purposes only, with the consideration that a production could be filmed at one choice of frame rate (and from within potentially other frame rates can be extracted to create VFR). Short films are a good candidate for multiple frame rate takes given that there is sufficient planning and understanding of HFR/VFR prior to the commencement of filming.

For researchers at the S3D Centre and other establishments, the combination of S3D with HFR creates a situation as close to reality as we can afford. Early results from the VFR S3D investigations at the S3D Centre have shown better visual memory retention of the S3D VFR version of "Soul Mate 3D" than 2D SFR version, and more emotional commentary from viewers on the subject matter. The findings are not surprising as stereoscopic 3D provides another depth dimension to a dynamic image, and HFR provides up to 5 times the amount of temporal resolution as a standard frame rate. This allows for extra information and detail for the viewer, as well as a new level of intimacy with the pictures' subject matter. Likening it to a 'first person' experience, a combination of spatial resolutions greater than 2K and surround sound, we can attempt to create more emotionally profound content thanks to the availability of digital capture and projection.

The appreciation of the aesthetic appearance of HFR/VFR remains divided between viewers who are not accustomed to the look and the viewers who have began the process of familiarity. It is likely that comparisons between HFR/VFR aesthetics and 'bad daytime TV show' aesthetic will become eliminated with the increase in detail to lighting, costume, action and camera movement on a film. Viewers who have been playing HFR video games on 60Hz or higher television sets have already become acclimatized to the aesthetic appearance of HFR. Conversely, if a SFR aesthetic is desired for certain elements of a film, they can be filmed with relative ease within a HFR workflow. Similarly, if a production films its content at HFR only to decide to re-introduce blur to the frame later, it is possible to do so using light field data (depth mapping) within software.

The S3D Centre has been working with companies that range form image capture to content delivery in formulating workflows for S3D VFR. We have since undertaken the creation of a 'cheat sheet' for use on S3D VFR productions, from pre-production through to post production that should be of use to the creative community.

The Engagement of VFR for viewers

S3D provides a dimension of depth to dynamic video, and HFR provides up to 5 times the amount of temporal resolution as our standard 24 fps rate. The combination provides increased detail for the viewer's enjoyment, as well as a new level of intimacy with the picture's subject matter. Researchers can attempt to create more emotionally profound content closer to reality thanks to the availability of digital capture and projection.

MOTION ANALYSIS

24.95fps 180 degree Shutter Angle 1/8 Raster in Redcine X

47.95fps 180 degree Shutter Angle 1/8 Raster in Redcine X

59.94fps 180 degree Shutter Angle 1/8 Raster in Redcine X

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6.0 Resources

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