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Frame Rates, Movement and Image Sharpness in Cinematography

By Kommer Kleijn SBC.

Breaking up movement in successive frames as is used in cinematography since 1895 can be seen as one of the first wide spread uses of temporal sampling. As such, it follows the rules of general sampling theorems spite these were written well after cinema was already in commercial use. However, for the reconstruction of sampled motion in the cinema theatre, the projector entirely lacks the mandatory low pass filter. Instead, the bandwidth limits of the human visual system are used. But this filter limits only from 30Hz onwards, not at 24. As a result, traditional cinema using frame rates of 24 or 25 fps has a high risk of judder or strobing.

While a slight judder may be associated with pleasing aesthetics, strong judder or strobing is disturbing and hinders storytelling. Two countermeasures are widely in practice to limit judder, and both work by limiting or removing movement information: (1) limiting movement itself and/or (2) removing image sharpness, both of which the author considers to be contrary to the goals of the cinematographer.

Reducing the quantity of light in projection also helps reduce judder as it further reduces the bandwith capacities of the human visual system. But insuficient projection light again is reducing image quality and thus against the cinematographers wishes.

The quantity of movement in camera is limited per the (in)famous 5/7 seconds rules, but more important is the systematic use of the long per-image exposure time of $1/48^{th}$ of a second. This limits sharpness through motion blur, effectively removing movement information, and it does that in a way conveniently proportional to the quantity of movement at hand.

What seems to be less known is that with the movement information, image resolution is destroyed equally well in the process, as this motion blur is also seriously impeding on the recording of spatial resolution, or sharpness. Indeed, the benefits of modern 4K cameras and projectors can often be enjoyed exclusively on (parts of) images that are fully static, while the goal of cinematographers is storytelling through images that move.

Due to this ‘conflict’ between movement and sharpness, of which only one can be had simultaneously at traditional frame rates, moving cinema images are rarely sharper than 2K, regardless the resolution of the camera sensor. This can be demonstrated by freezing almost any image of an actual movie and measuring resolution. Also, testing cameras on fixed charts may not be as relevant as generally believed, as these tests do not actually relate well to the practical use of the cinematography cameras, where both the subject matter and the cameras usually move.

A general reflection is suggested on how to have the spatial resolution of the cinematographic image (sharpness) progress at all, as long as the frame rates of 24 or 25 fps make high resolution effectively prohibited during any form movement.

For better spatial resolution it is needed that the exposure time per image is significantly shortened. This is a basic rule that can be found in any book about photography. However,

this is not possible in cinema at the traditional low frame rates, because at these low frame rates, sharp images will contain more movement information than the projector, combined with the human low pass filter, can render. This is what then causes unacceptable judder.

Presenting sharp images, also during movement, is only possible through the adoption higher frames rates like 50 fps or 60 fps, combined with short exposure times per image (narrow shutter angles). The author has been able to spot only a single actual feature movie having been shot and presented that way, one that he also worked on.

However, letting go of the traditional 24/25 rates, and creating high image resolution during movement, causes changes in aesthetics and 'feel' of the moving images, and research is needed to evaluate these changes and their consequences for storytelling.

Over the past 15 years, with the author among the initiators, and greatly supported by IMAGO and others, steps have already been taken towards worldwide implementation of higher frame rate presentation capabilities in cinema theatres. Such has recently been achieved in practice, which makes the proposed research also potentially widely applicable.

It should also be noted that other upcoming cinema technologies, like stereoscopic 3D and even greater so High Dynamic Range (HDR), amplify the human sensitivity to judder and strobing, and therefore may form additional incentives for the use of higher frame rates.

About the author / presenter:

Kommer Kleijn SBC is a Cinematographer and Stereographer who is active in perception research, technology development and standardisation. He was the first to shoot images digitally for a large format movie, after he shot the first digitally captured clay animation short. He worked as a 3D cinematographer and stereographer for 20 years in LBE, features, commercials and multi camera live captures. He initiated the first short exposure time on a (3D HFR) feature (1/100th of a second per frame) in 2011/2014. He teached many years in Belgian film schools and also for 3D workshops for professionals internationally. He chaired the IMAGO technical committee for a decade, served as an SBC, UP3D and EDCF board member and chairs SMPTE 21DC Digital Cinema Standardisation Frame Rates groups on behalf of IMAGO since 2006. He is a regular speaker on international image technology and 3D events and was awarded the "Bert Easey Technical Achievement Award" by the BSC for his contributions to implementing the 60 frame rate proposal as an addition to the International Standard for Digital Cinema projection. He received the 2017 Lumière Award - Europe, Best European Stereography and was given the IMAGO International Honorary Member Award in 2019. His interests extend into research on human hearing and he participates in a team lead by John Watkinson FAES that creates new kinds of loudspeakers. His web site is at www.kommer.com.