https://doi.org/10.2352/EI.2025.37.11.HVEI-212

User preference towards HDR10 playback strategies by video player applications.

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Abstract

Modern HDR video playback strategies often involve adjustments by industry stakeholders, such as applying different Electro-Optical Transfer Functions (EOTFs), modifying peak luminance, or altering color characteristics, to enhance visual appeal. These modifications, however, can deviate from the original artistic intent. Understanding observer preferences for such alterations is crucial, especially for smartphone playback under diverse ambient lighting.

This study aims to pilot an assessment of user preferences for different HDR playback strategies on smartphones, focusing on EOTF, luminance, and color reproduction. The challenge lies in balancing these factors to enhance visual comfort and overall experience without compromising visual quality.

A psychophysical experiment employed three HDR10-capable Android video players on identical smartphones within controlled ambient settings (dark, indoor, outdoor). Observers evaluated video playback based on seven criteria, such as overall quality, brightness, skin-tones, contrast etc. . To ensure unbiased results, three-level randomization of video, application, and question order was implemented. Additionally, objective colorimetric data were acquired using an imaging colorimeter.

Preliminary findings from eight observers revealed no significant differences in player ratings in reference conditions. However, differences emerged under low and bright lighting for brightness and contrast preferences, with one player outperforming others in overall quality and color rendering.

Introduction

HDR video playback strategies can differ . Certain decisions are taken by stakeholders in the playback industry to alter the original artistic intent and apply different EOTFs, peak luminance or change the color characteristics of the original HDR video under different ambient illumination conditions. This is done mostly in order to make it more appealing to the final user, often compromising on the original intent. In order to study the effect of using different EOTFs, overall luminance or different color reproduction strategies, a psychophysical experiment was conducted to find which strategy users preferred the most on smartphones. This was done by incorporating three Android HDR video player applications that used very different playback strategies (see **Figure 7**- **Figure 9**) (on three same smartphone models) for HDR10 [1] videos, so that overall user preference could be studied via a strictly controlled psychovisual experiment. The experiment was conducted under three ambient lighting situations. External illumination condition is an important factor that influences human perception. These smartphones had an auto-brightness setting that changes the brightness of the phone depending on the ambient illumination detected by the ambient light sensor of the phone, thereby affecting the its perception [2], [3]. Only the "auto brightness" feature was turned on and not the "adaptive color" feature in the phones. This study 0069s important because it will provide the correct direction to HDR playback research teams in finding the most preferred EOTF, most comfortable brightness as well as most pleasing colors to alter their playback strategies. This will result into better overall user experience.

Methodology

The objective of this study was to conduct a pilot experiment to study user preference towards HDR video playback strategies. Strategies could differ in the way they conserve or alter the original mastering intent of the HDR video. The choice of Electro-Optical Transfer Functions EOTFs can lead to difference in perception of contrast, shadows , highlights or skin-tones. Luminance is another important aspect. As smartphones need to adapt their luminance with respect to ambient illumination, HDR video playback on smartphones involve the choice the optimum luminance for a corresponding ambient illuminant condition. The final user experience towards different luminance settings is often not the same. There is often a risk of too high luminance in a very dark environment, or too low luminance for a very bright environment. Color reproduction is also not experienced the same depending on strategies adopted, especially for memory colors. All these aspects were evaluated by using three different HDR player applications capable of playing HDR10 encoding on exactly three same smartphones under three different ambient illumination environments.

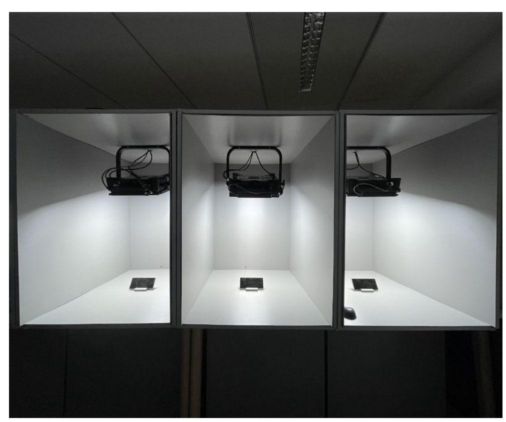

Figure 1*: Setup which was used to conduct the psychophysical experiment.*

A dedicated setup was used to conduct the research (see Figure 1 above). The setup comprised of three viewing booths separated from each other with walls. All surfaces of the booths were made of neutral gray PVC boards. Each booth had an individual Gemini LitePanels 1x1 which used as the ambient lighting for each one of them. The viewing booths were capable of providing an illuminance of 0 to 5000 lux on the plane of the Ambient Light Sensor (ALS) of the smartphones. Three ambient environments were created using this setup, dark (0 lux), indoor (320 lux/100 nits) and outdoor (5000 lux) lighting. The CCT of the illuminance was maintained at D65 for the second and third environment. The luminaires were controlled via DMX and were daisy chained to each other, so that all viewing booths had exactly the same ambient illumination for each of the three lighting scenarios (calibrated with a Sekonic spectrometer).

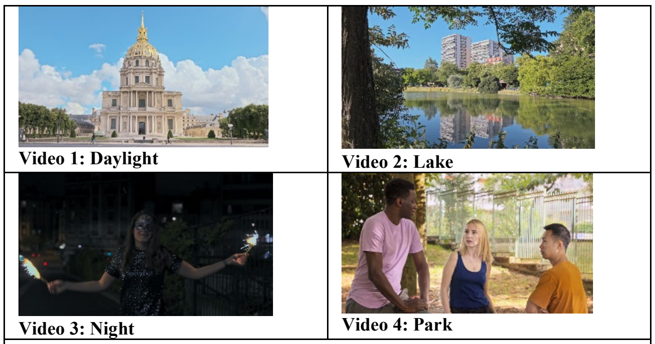

***Figure 2**: HDR10 video pattern dataset used to conduct the experiment.*

For each of the three ambient illumination condition, 4 videos were evaluated and 7 questions were asked to the observers for each of these videos. The 4 videos can be seen in Figure 2 below:

The videos dataset consisted of daylight or nighttime HDR scenes with or without skin-tones, all encoded in HDR10. The seven questions that were asked were:

1. How is the overall video quality?
2. How comfortable is the brightness?
3. How do you like the skin-tones (if any)?
4. How do you like the overall contrast?
5. How do you like the shadow details?
6. How do you like the highlight details?
7. How realistic or natural do the renderings look?

For each of these questions, the observer could give their response on a scale having values between 0 to 10. This was done using a slider based Python Qt GUI which was deployed on a dedicated iPad with which an observer could move from one booth to another providing efficient mobility required for the experiment. For each of the three renderings, the observer could move the slider to score a rendering between 0 and 10 (decimals points were also allowed). This approach is better than a usual Likert scale as it gives a impression of a continuous scale (quasi-magnitude estimation) [4]. To check the repeatability of observers using the method, the first question for the fourth video (Park) was repeated randomly.

A three level randomization (application order, video order and question order) was implemented. In order to avoid order or device bias, for each video, the HDR video application used on the three smartphones was randomized (for a certain video, smartphone A, B and C used application number 2, 3 and 1, while for the next video, the same smartphones could have the application order could be 1, 3 and 2 respectively). As the same three smartphones were used having the same mobile OS version, repeatable application behavior was assumed across phones for the same HDR video player. The videos as well as the question order were also randomized.

In order to quantify the metrological differences between the application in terms of target output EOTF, average frame luminance and color reproduction, the playback of each HDR video application playing a fixed frame version of the 4 videos were captured using the Radiant ProMetric Imaging colorimeter. This objective data will be finally used in another study to correlate the subjective findings of this study using the corresponding questions asked with the metrology of the fixed frames.

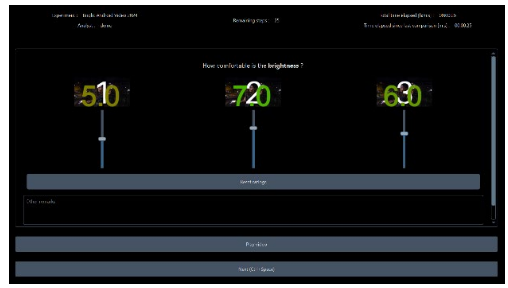

***Figure 3**: GUI deployed on an iPad that was used to conduct the experiment.*

Three types of objective data was finally deduced from the imaging colorimeter acquisitions, namely the EOTF, the average frame luminance and color of certain regions of interests. The EOTF of the frames was deduced using the methodology in a previous work of the authors, see Figure 7 - Figure 9. Eight observers have participated in the pilot experiment. The difference in means of the results were statistically analyzed using ANOVA and Tukey-HSD test. It was found that for the reference conditions, no HDR video player application was found to be statistically significantly different than each other for any of the seven questions considered. The mean overall score was 7, 7.2 and 7.3 for the three HDR players. For the dark scenario, the overall mean scores although not statistically significantly different than each other, were lower than the reference condition at 6.3, 6.3 and 6.5 respectively. However, for the dark scenario, the brightness score (question 2) was found to have a significant difference for player 1 as the score 7.5, 5.4 and 5.5 for the three HDR players respectively. This meant that the overall brightness was perceived better and more comfortably for player 1 as compared to other players in the dark. For the bright scenario, the three players received an overall score of 7.1, 6.2 and 5.3, where player 1 was statistically significantly better than player 3. For the brightness score, player 1 was statistically significantly better than the other two players. For contrast, highlights, shadows and color rendering, player 1 was statistically significantly better than player 3, but not player 2. Colorimetric data has also been acquired (see Figure 4 - Figure 6 below) with the Radiant Imaging colorimeter with which the color of regions of interest have been derived. The motive is to relate the question regarding color rendering (question 3 and 7) with such data to understand the skin-tones or memory color rendering that is the most preferred by users (see example in Figure 10) in a later study.

The novelty of this pilot study is threefold:

1. Preference data on smartphones instead of reference monitors conditions.
2. Preference data across three ambient illumination conditions instead of mastering illumination conditions.
3. Psychophysical data correlation with objective colorimetric data collected in this study.

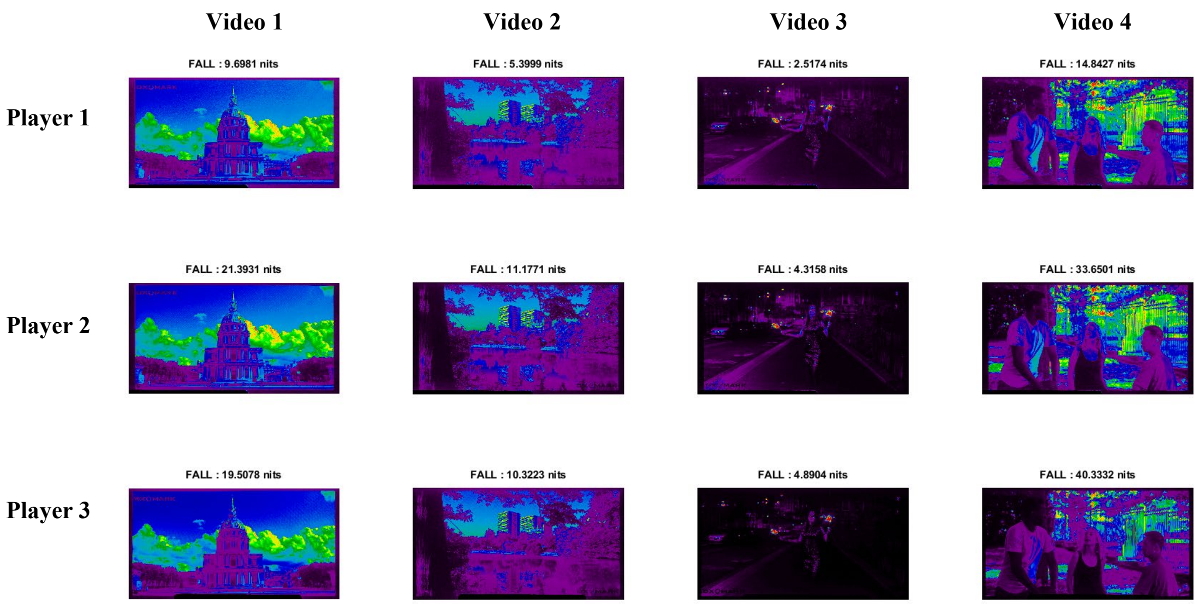

Figure 4: [Reference] 2D imaging colorimeter data showing the luminance map of the fixed frames. Each scene acquisition for each player is complemented with the frame average luminance level (FALL) as the title of the image.

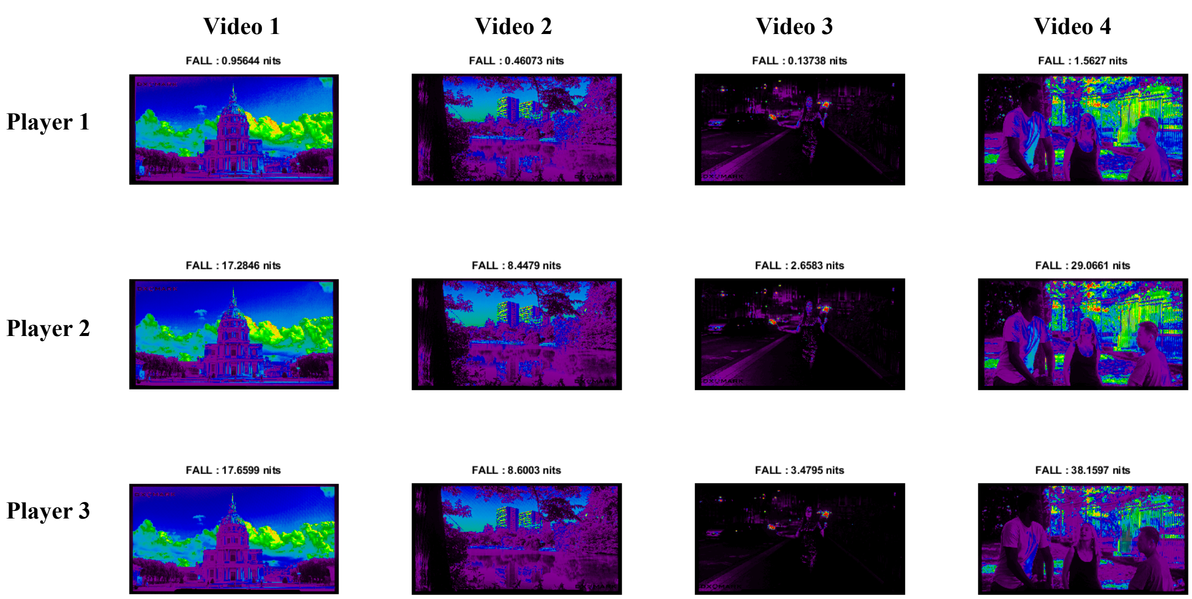

Figure 5: [Dark] 2D imaging colorimeter data showing the luminance map of the fixed frames. Each scene acquisition for each player is complemented with the frame average luminance level (FALL) as the title of the image.

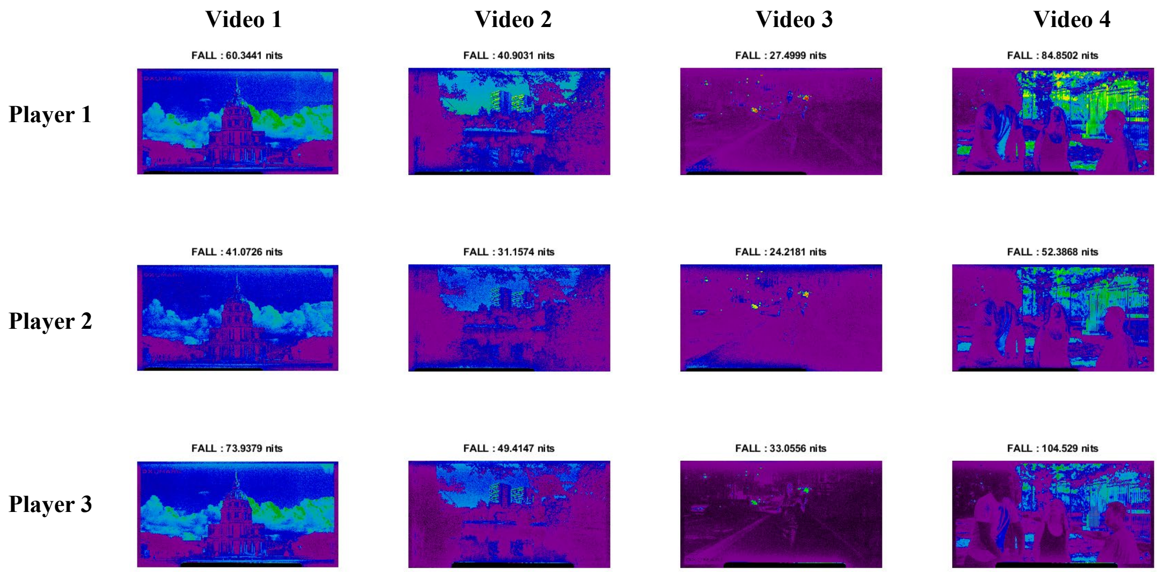

Figure 6: [Bright] 2D imaging colorimeter data showing the luminance map of the fixed frames. Each scene acquisition for each player is complemented with the frame average luminance level (FALL) as the title of the image.

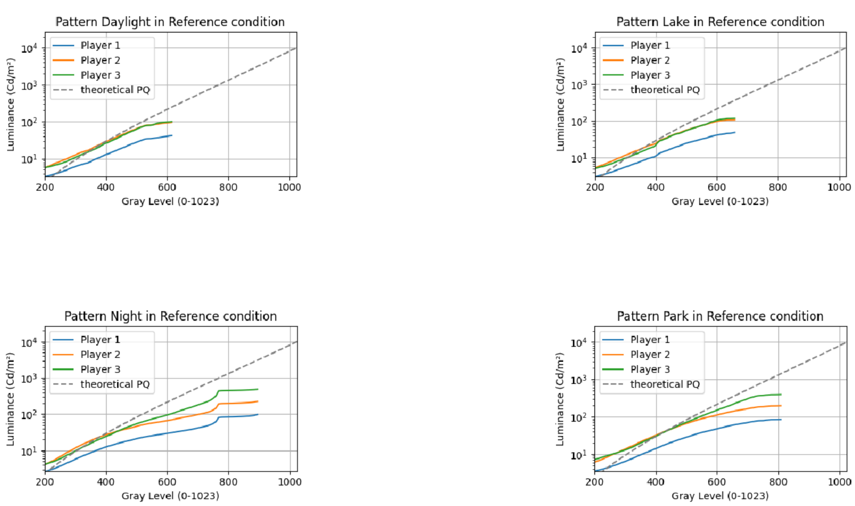

Figure 7: [Reference] Deduced EOTF for the four video patterns under 320 lux reference environment.

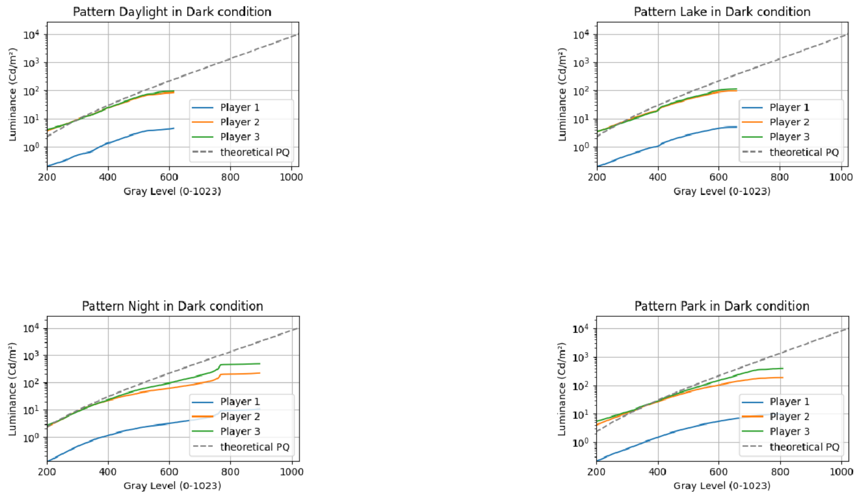

Figure 8: [Dark] Deduced EOTF for the four video patterns under 0 lux dark environment.

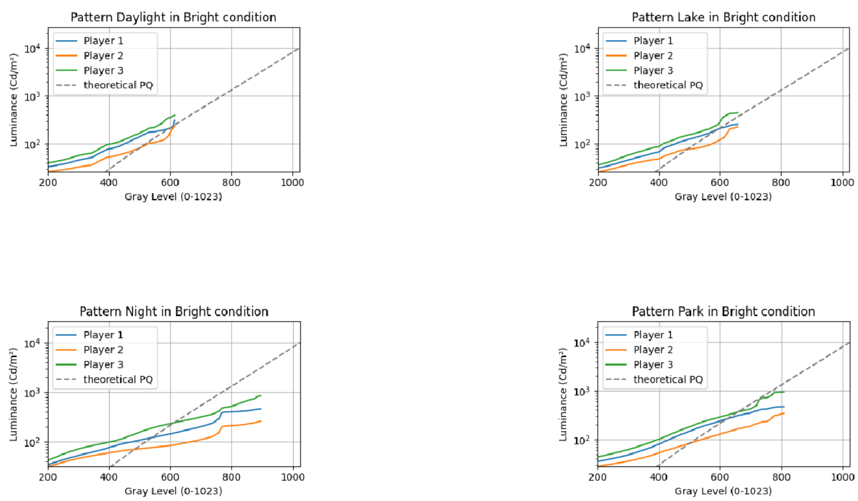

Figure 9: [Bright] Deduced EOTF for the four video patterns under 5000 lux bright environment.

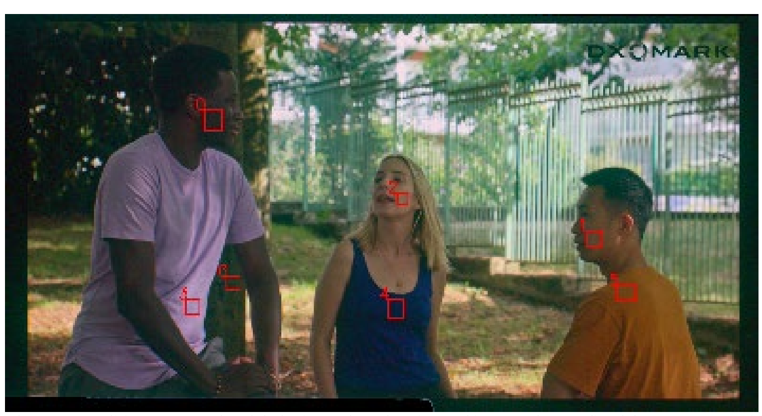

Figure 10: [Reference Conditions] Example of deducing color of regions of interest from a fixed frame HDR10 video. Skin-tone and clothes color are derived from this scene.

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Author Biographies

***Pooshpanjan Roy Biswas** holds a Ph.D in Color Science and specializes in display metrology and psychophysical experimentation. He is a member of CIE TC1-100. Before joining DXOMARK as a color scientist , he worked for Renault and HP Inc. where he had filed for four patents and published multiple papers. His current area of interest lies in HDR video tone mapping, video and image color management, ICC workflows and psychophysical testing of user preference towards imaging algorithms.*

***Thibault Cabana** is a graduate of the Institut d'Optique (2011). After 10 years in the defense and automotive industries, he spent the past 4 years as head of the display quality evaluation department at DXOMARK. His work, mainly focused on smartphones, aims to improve users' display experience and analyze their preferences.*

***Adrien Carmone** graduated in 2011 from Polytech Paris-Saclay with an engineering degree in opto-electronics. He started at Renault working on driving assistance systems. In 2019, he joined DXOMARK as a Camera Image Quality engineer and transitioned to the Display Image Quality team, where he led the design of display testing protocols.*

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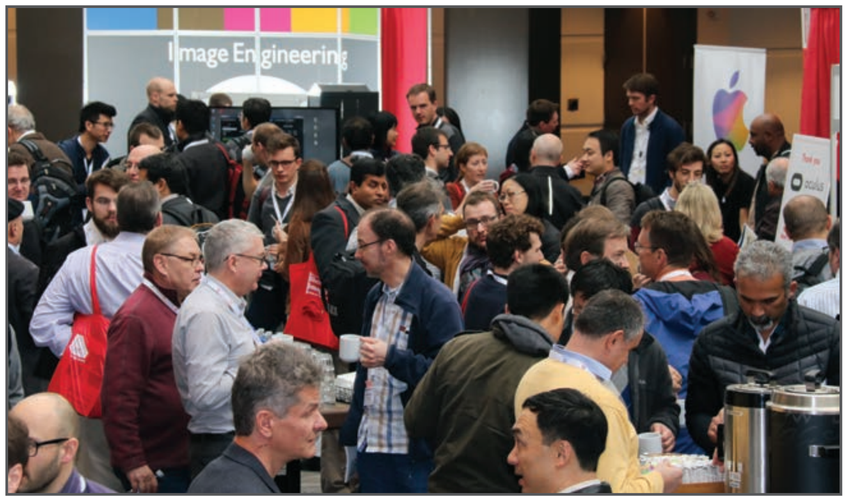

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