Comparative Study of Overlay and Offset Algorithms in 3-By- 3 Video Wall using Objective Metrics

Paul, N. B.
Department of Computer Engineering,
Kaduna Polytechnic, Kaduna.
paulnaanman@kadunapolytechnic.edu.ng

Omizegba, E.E.
Department of Electrical and Electronics Engineering,
Abubakar Tafawa Balewa University, Bauchi.
eeomizegba@atbu.edu.ng

Okereke, O.U.
Department of Electrical and Electronics Engineering,
Abubakar Tafawa Balewa University, Bauchi.
ouokereke@atbu.edu.ng

Anene, E.C.
Department of Electrical and Electronics Engineering,
Abubakar Tafawa Balewa University, Bauchi.
eanene@atbu.edu.ng

Abstract- **Video wall compared to other large displays, have many unique advantages. However, videos display using video wall are distorted by bezel effects. Evaluation of distortion based on hardware models, limits the study of variable bezel effects. In addition, the use of mean opinion score (MOS), based on subjective assessments, results in uncertainty about the performance of algorithms. Therefore in this paper, a 3 by 3 video wall simulation model for offset and overlay algorithms is developed using open computer vision (Open CV) with python image library (PIL), and CV2 library. While three video quality measurement tools (VQMT); video quality metric (VQM), structural similarity index measure (SSIM) and peak signal to noise ratio (PSNR) mapped to equivalent MOS, are used to evaluate processed video. Results reveal; overlay approach, outperformed the offset approach with up to 12%, 30% and 22% using static video, and up to 10%, 24% and 12% for VQM, SSIM and PSNR respectively with dynamic video. Performance of algorithms, indicate objective assessment are consistent with subjective assessment as in literature and should be upheld for video wall development.**

Keywords—**Video wall; bezel; offset; overlay; objective metrics.**

I. INTRODUCTION

Video wall is simply a collection of multiple display units configured to form a larger screen. It is useful anywhere a large screen is required to lower cost, suit available space or customize layouts and orientation. In addition it offers greater pixel density per unit cost and different information can be displayed on tile concurrently [1, 2, 3, 4, and 5]. To achieve these advantages, liquid crystal displays (LCDs) are used however, LCD based video wall are limited by screen bezel distractions, image stretching, and visual discontinuity (4, 6, 7).

Screen bezels are the outer areas (borders) between monitors which limits the display of image and how close two LCD monitors can be tile together to form a video wall (Fig 1).

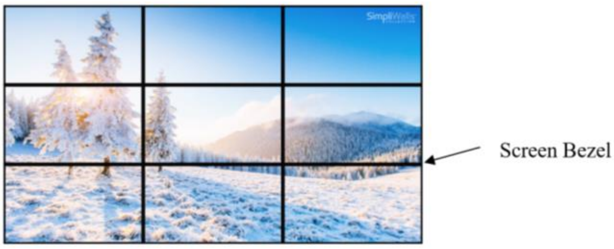


Fig 1: Bezel on LCD Based Video Wall

This paper therefore present a study of video wall image distortion, as a result of bezel variation with bezel compensation algorithms. The study uses simple and easy image semantics for image resizing and cropping to simulate the two common algorithms while objective metrics are used to evaluate.

II. LITERATURE SURVEY

Bezel effects are largely tackled by applying two approaches. First, by physically removing plastic covers and using displays with smaller interior bezels (reducing bezel sizes); which is aesthetically pleasing, but costly and limited by availability of small interior bezel displays. Earlier, efforts such as [8] focused on bezel size reduction by physically removing plastic covers from displays. Back then (in 2009), when typical 24″ desktop LCD monitors bezel size was 15 mm (about 0.6″); bezel-to-bezel size of 30 mm about (1.2″), [9] developed tiled-display using these LCD displays resulting in users distraction.

In [10] further efforts to reduce the image misalignments using smaller bezels showed increased power consumption, higher cost, and limited by availability of small size bezel displays.

Recently in [11] a video wall system developed, with bezel-to-bezel size of 0.2" (5.5 mm) as presented in [10] this improved aesthetics of the display, users distraction but at a high cost.

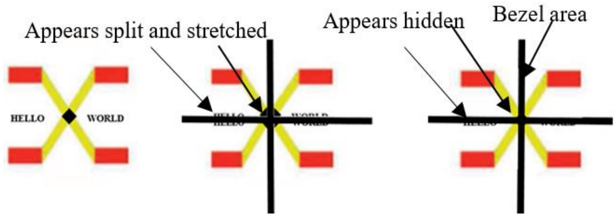
The alternative approach is to use bezel compensation techniques; thereby offering lower cost, increased flexibility, to use available displays (with varying bezel sizes), but with the tradeoff of visually unpleasing image distortion [12].

A. Bezel Compensation Techniques

Bezel compensation techniques to handle image distortions despite the presence of bezels includes;

(a) The offset approach (Fig 2(b)); which simply ignores the bezels and their effect on the continuousness of a scene. With this approach images are split to required forms and scaled to fit the desired displays but, image appear to be stretched; however, it has the advantage that no information gets lost at the monitor borders.

(b) The overlay approach (Fig 2(c)); tries to compensate for the bezel problem by eliminating the images that would fall under the bezel areas. In contrast to the offset approach, this result is an overall continuous image hence, is preferable to the abnormalities that are caused by the offset approach. The disadvantage of this approach is that potentially important information may be "hidden" by the bezels [6].



(a) Original Image (b) Offset (c) Overlay.

Fig 2: Bezel Compensation in LCD Walls

Later studies such as [6, 7, 13] used available LCDs with varying bezels and bezel compensation algorithms to explore aspects of image distortion (user distraction), when bezels are present.

Specifically, using a 3 by 3 video wall with bezel compensation algorithms [6], demonstrated that the overlay approach is better than the offset approach based on mean opinion score (MOS) with static image having 3.25 (54%) against 2.25 (38%), while dynamic video is 4.45 (74%) against 2.25 (38%) for offset approach. In similar manner [12], showed human perception of image displayed on video wall with smaller bezels (1.2 cm or smaller (0.6cm bezel on each side)), introduces less distortion than bigger ones.

In a related study, [13] showed that with bezel size variation 67% of participants prefer thin bezels (0.25 and 0.5 cm) while, 5% of participants prefer large bezels (4 cm), and further reported that 17% of participants prefer overlay, whereas only 5% of participants prefer offset approach. Unexpectedly, effect of bezel size, or differences due to employing bezel compensation are minimal as the overlay approach performed poorly at a bezel of 1 cm instead of 4 cm. Authors concluded that further efforts on these techniques, be investigated as there is no clear conclusion on the comparison of the two algorithms with bezel variation.

B. Video Quality Assessment (VQA)

Video quality assessment (VQA) is a measure of the goodness of a processed video compared to the original or similar processed video, which can be either subjective or objective assessment; the former are assumed to be consistent with actual video quality but dependent on human nature. While latter, are designed based on mathematical algorithms developed to mimic the human judgment and to be consistent. Objective metrics are verifiable and applicable in; monitoring, optimizing algorithms and adjusting video quality, parameter settings and benchmarking of video processing systems [14].

In [15] the performances of objective metrics were compared to subjective metrics using static and dynamic videos. The work used video measurement tool to evaluate objective metric values as well as subjective evaluation. PSNR, SSIM, and VQM metrics evaluations were compared with 5-point MOS obtained from subjective assessments. Differences between the two videos showed an average difference of 38.3 %, 60.1 %, and 28.1 % for the PSNR, SSIM, and VQM metrics, respectively. Similarity between objective metrics and the subjective grades showed correlation of up to 0.9 (90%).

[16] Reported that objective metrics are developed to emulate human perception of videos and produce results that are very similar to those obtained from subjective assessments methods. Authors stated that, developed algorithms have been tested and compared to subjective metrics by Video Quality Experts Group (VQEG).

Similarly, [17] showed that VQA mapping (VQAMap) can be applied to create generic mapping rules to the 5-point MOS scale for PSNR, SSIM and VQM as shown in Table 1.

Table 1: Video Quality MOS Mapping

MOS level	MOS level (0-100)	PSNR	SSIM	VQM
5 Execellent (A)	$80 \leq A \leq 100$	$A \geq 36$	$A \geq 0.93$	$A \leq 6$
4 Good (B)	$60 \leq B < 80$	$29 \leq B < 36$	$0.85 \leq B < 0.93$	$10 \leq B < 6$
3 Fair (C)	$40 \leq C < 60$	$22 \leq C < 29$	$0.76 \leq C < 0.85$	$20 \leq C < 10$
2 Poor (D)	$20 \leq D < 40$	$19 \leq D < 22$	$0.62 \leq D < 0.76$	$30 \leq D < 20$
1 Bad (E)	$0 \leq E < 20$	$E < 19$	$E < 0.62$	$E \geq 30$

Where Correlation coefficient are: PSNR = 0.8; VQM = 0.95. Source: [17].

Research have used subjective methods to investigate bezel effects, however, the use of objective assessment remain unexplored. Unfortunately, these subjective evaluations are inconclusive on the impact of bezel effects. Therefore this paper seek to study bezel variation, using simple and easy image semantics for image resizing and cropping to simulate the two common algorithms.

This paper evaluates performances in comparison with similar bezel-less display using full reference objective metrics; the PSNR for frame drops or frame data corruption, SSIM for structural information change and VQM for video impairments such as blurring, jerkiness, global noise, block distortion, and color distortion. This paper focusses on determining effects of bezel compensation algorithms for smaller bezel (0 mm to 5 mm), with static and dynamic videos using objective metrics to mapping MOS.

III. METHODOLOGY

A. Algorithm development models

To simulate the 3-by-3 video wall, with offset and overlay bezel compensation algorithms were developed using openCV. PIL. While, Python tkinter library base on equations (1-5) obtained from Fig 3 was used to implement graphical user interface;

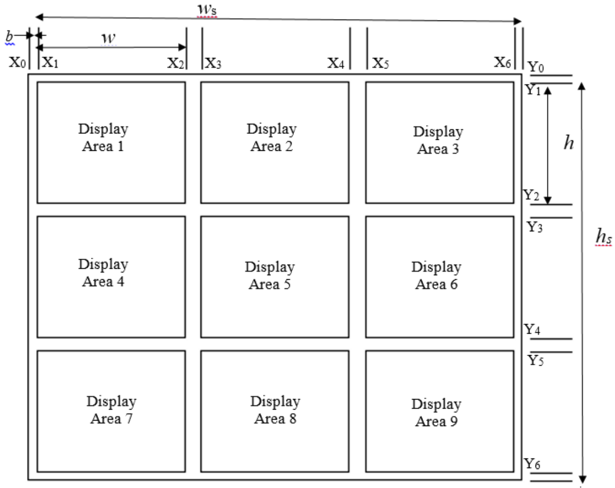


Fig 3: 3 by 3 Video Wall Display Layout

$$f(X_n, Y_n) = \begin{cases} \frac{n}{2}(x) + (n-1)b, & n \ is \ even \\ \left(\frac{n-1}{2}\right)(x) + nb, & n \ is \ odd \end{cases} \quad (1)$$

For: $$w = \frac{W_s}{N} - (2b) \quad (2)$$

$$h = \frac{h_s}{N} - (2b) \quad (3)$$

Where, W_s and h_s stands for Width and height of entire wall, x *is either* w or h for width and height of individual display area, while, N is the number of displays on rows or columns (0, 1, 2, 3, 4, 5…). Also, X_n *and* Y_n represents x and y coordinates for rows and column of display from top left, and n is the number of coordinates point for displays on rows or columns while b is the bezel size.

The wall definition and the individual canvas definition, defined by coordinates and video crop to fit each display based on the model in Fig 1 as expressed in equations 4 and 5:

Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 8 Issue 7, July - 2021

$$T_n = f\,[X_n, Y_n, w, h] \qquad (4)$$

$$Sw = f\,[X_0, Y_0, w_s, h_s] \qquad (5)$$

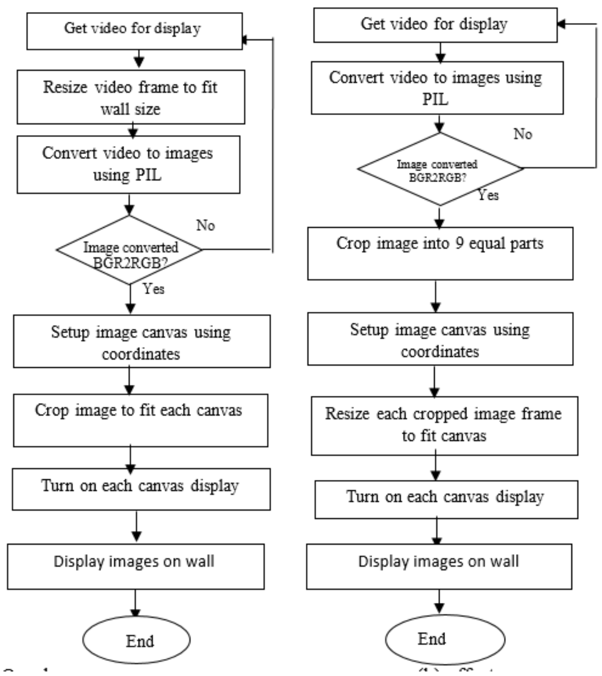
Where, T_n, is the display definition, x_n, y_n represent the x and y coordinate of the display reference crop center while, w and h represents the width and height of the predicted tile display respectively. Sw, is the wall size definition, x_0, y_0 represent the initial x and y coordinate of the wall reference crop center of zero, while w_s and h_s the width and height of the predicted wall size respectively.

a. Overlay model

For overlay method the image is uniformly resized by traditional interpolation to fit the wall size aspect ratio, then split (cropped and remove bezel area) using traditional cropping method into segments to fit each canvas (Fig 4 (a)).

b. Offset model

For simulation, using the offset method, the image is split (cropped) to the required number of segments (canvas) based on aspect ratio using traditional cropping method and then uniformly resized by traditional interpolation to fit each canvas (Fig 4 (b)).



(a) Overlay (b) offset

Fig 4: Bezel Compensation Algorithms

B. Video quality evaluation model

Algorithms developed based on equations above was implemented with, YouTube video of 25fps, 1080p resolution and .mp4 file format [18] downloaded using source site [19]. For comparison purpose, the video was scaled to a resolution of 1215 x 679 (equivalent to size of a typical 55” monitor), with bezels of 0 mm, to 5 mm implanted for simulation.

The 5 mm level was included to reflect current bezels to bezel sizes studied in [10, 11], and typically intended for use in video wall installations. The width of each condition was measured to accurately reflect intended-screen dimensions. In addition, the original (without bezel) and resulting videos (with bezels) were compared and evaluated with the full reference metric by Moscow State University (MSU) VQMT [20] based on the model in Fig 5.

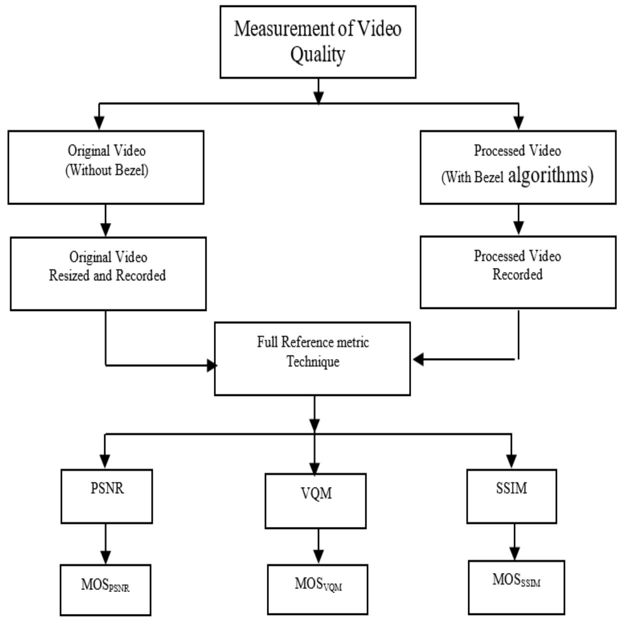


Fig 5: Video Quality Evaluation Model

IV. RESULTS

A. Algorithm simulation

The screenshots of processed scene of video using the two approaches are as shown in Figs 6 and 7. For comparison, all videos were captured using ice cream screen recorder for a set time of 8 minutes each and the same file format. For interpretation of each parameter measured, the referenced values (best quality) of the metrics are PSNR =100, SSIM =1, while VQM = 0 [14].

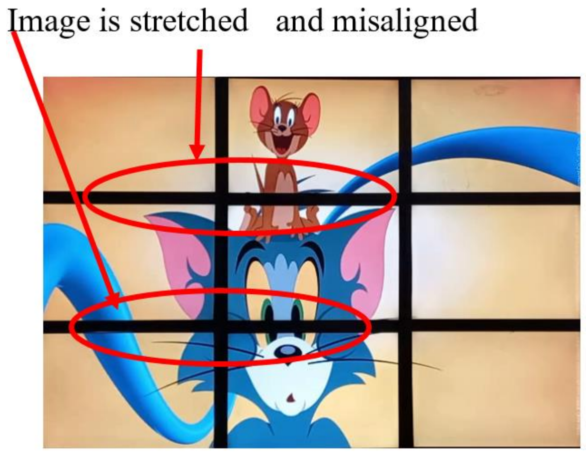
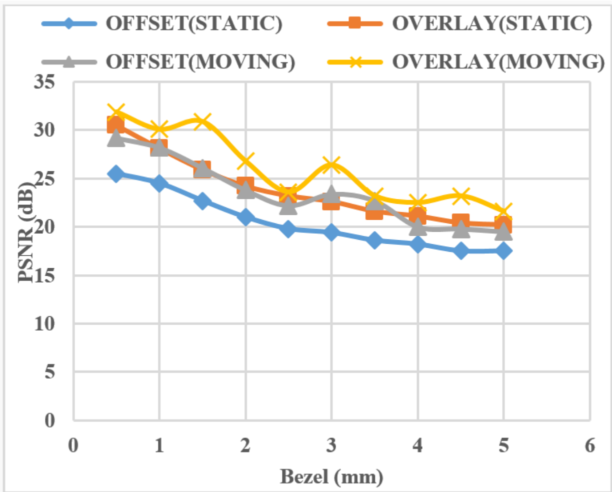


Fig 6: Offset Approach

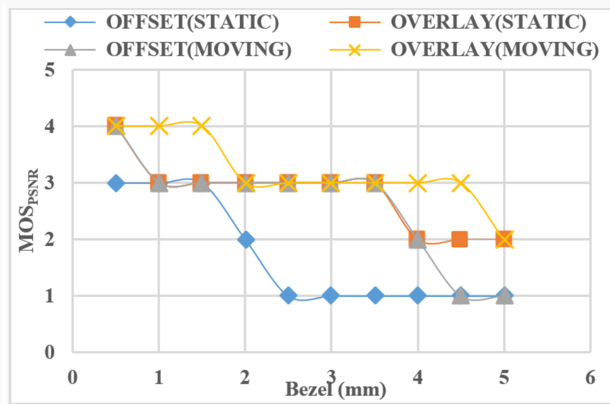
Fig 7: Overlay Approach

B. Algorithm video quality evaluation

The MSU software was used to measure PSNR, VQM, and SSIM values in a video sequence. Average metric values (Avg) for both dynamic (*moving)* and a stationary (*static)* portion of video with varying bezel sizes (0.5 mm to 5 mm) were recorded, mapped using MOS and plot according to metrics as shown in Figs 8, to 11. For the two algorithms, the static video portions are here referred to as “Offset (Static)” or “Overlay (Static)” while, the dynamic potions are referred to as Offset (Moving) or Overlay (Moving) see Figs 8 to 11

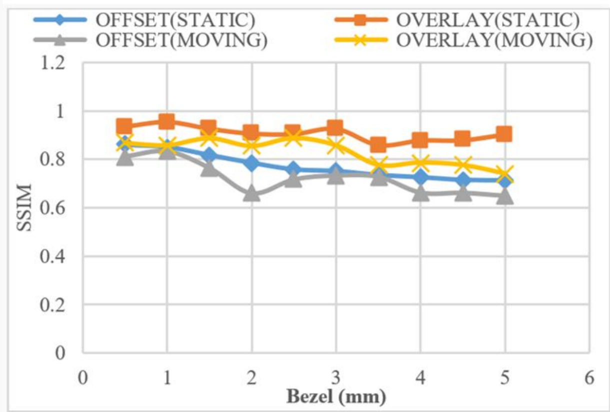


(a) Evaluation with PSNR

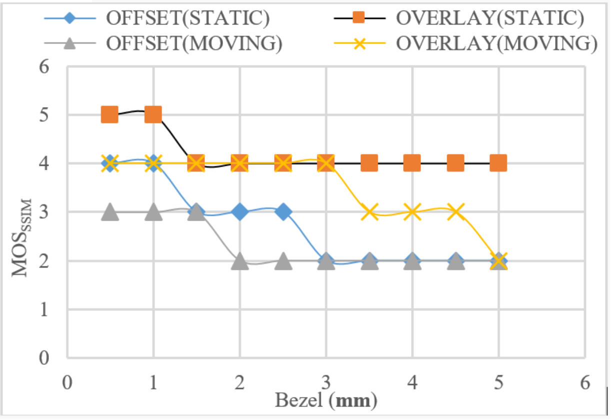


(b) Mean Opinion Scores of PSNR

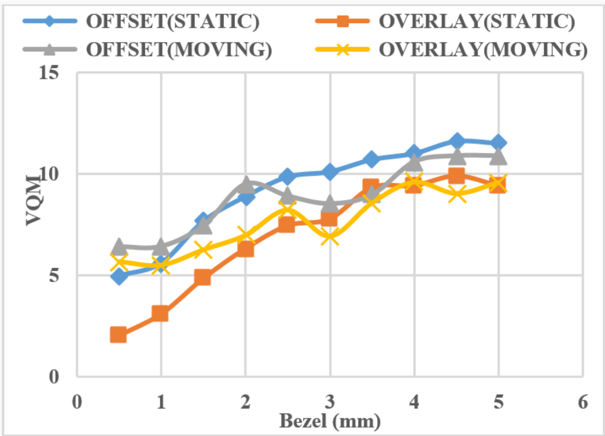
Fig 8: Bezel Effects with PSNR



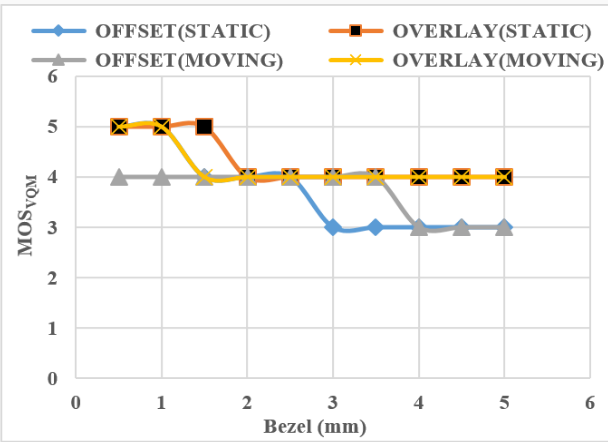
(a) Evaluation with SSIM



(b) Mean Opinion Scores of SSIM
Fig 9: Bezel Effects with SSIM



(a) Evaluation with VQM



(b) Mean Opinion Scores of VQM
Fig 10: Bezel Effects with VQM

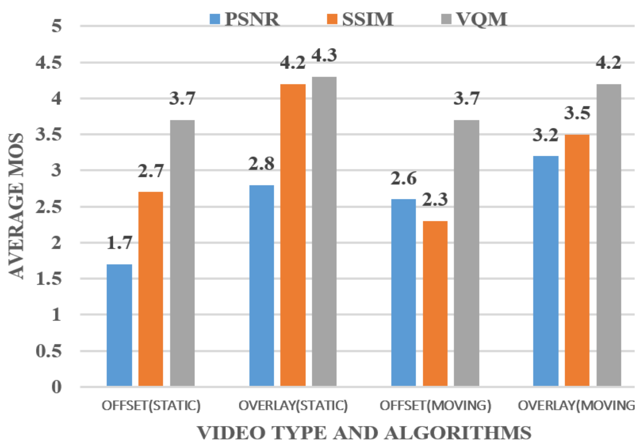


Fig 11: Mean Opinion Scores of Videos.

V. DISCUSSION OF RESULTS

Figs 6 and 7 show how videos are split into nine segments using algorithms, Fig 6 shows the offset approach, this shows that when a video is spitted into nine (9) different non-overlapping segment and displayed on the tiled display, the image will be stretched and or misaligned, while the offset approach in Fig 7 shows that images are aligned and not stretched but information are hidden.

Fig 8(a) shows increase in bezel size results in video quality decreases mainly because more pixels are lost as bezel increases. Similarly, fig 8 (b) show that using equivalent MOS for PSNR (MOS_{PSNR}) dynamic video has MOS_{PSNR} of 4 (rank as good) for bezel between 0.5 mm to 1.5 mm. However, at 5mm bezel both the static and dynamic videos become poor (MOS_{PSNR} of 2) for the overlay approach. While at the smallest bezel of 0.5 mm all form of videos are good (MOS_{PSNR} of 4) except the static video using the offset approach which gives a fair performance (MOS of 3).

Fig 9(a) shows generally as the bezel size increases the video quality decreases because more structural deformation occurs, similarly, Fig 9 (b) shows equivalent MOS for SSIM (MOS_{SSIM}) with bezel range (0 to 5mm). The static video has MOS_{SSIM} of 5 (rank as excellent) for bezel between 0.5 to 1 mm and MOS_{SSIM} of 4 (ranked as good) for bezel of 1.5 to 5 mm. However, at 5 mm bezel the static video using overlay approach remain good (MOS_{SSIM} of 4) while all other videos become poor (MOS_{SSIM} of 2). At the midpoint of 1.5 and 3 mm all videos based on overlay approach become and remain good (MOS_{SSIM} of 4).

Fig 10(a) shows that as the bezel size increases the video quality decreases because video impairments such as blurring, jerkiness, global noise, block distortion, and color distortion increases, similarly, Fig 10(b) shows equivalent MOS for VQM (MOS_{VQM}) with bezel range (0 to 5mm). The overlay approach has MOS_{VQM} of 5 (rank as excellent) for bezel between 0.5 to 1.5 mm and MOS_{VQM} of 4 (ranked as good) for bezel of 1.5 to 5 mm. However, with 5 mm bezel, both the static and dynamic video remained good (MOS_{VQM} of 4) for the overlay approach while both videos for the offset approach becomes fair (MOS_{VQM} of 3). At the midpoint of 2 and 2.5 mm all videos become and remain good (MOS_{VQM} of 4).

Fig 11 shows the evaluation of algorithms based on equivalent average MOS within the bezel range (0 to 5mm). Results show static and dynamic videos processed using overlay approach outperformed the same video using the offset approach. The overlay approach for static video has average MOS of 4.3 (86%), 4.2 (84%), and 2.8 (56%) for VQM, SSIM and PSNR respectively. While the offset approach for static video has average MOS of 3.7 (74%), 2.7 (54%), and 1.7 (34%) for VQM, SSIM and PSNR respectively. Similarly, the overlay approach for dynamic video has average MOS of 4.2 (84%), 3.5 (70%), and 3.2 (64%), while the offset approach for dynamic video has MOS of 3.7 (74%), 2.3 (46%), and 2.6 (52%) for VQM, SSIM and PSNR respectively. Considering the static video, results reveal the overlay approach, outperformed the offset approach with up to 12%, 30% and 22% for VQM, SSIM and PSNR respectively. While considering the dynamic video, results reveal that overlay, outperformed the offset approach with up to 10%, 24% and 12% for VQM, SSIM and PSNR respectively.

VI. CONCLUSIONS

This paper has implemented bezel compensation algorithms and evaluated with three objective metrics. VQM shows differences of up to 10% video impairments such as blurring, jerkiness, global noise, block distortion, and color distortion. SSIM show a differences of up to 30% in structural information change. While the PSNR reflects frame drops or frame data corruption of up to 22%.

The overlay algorithm developed in the work, outperformed the offset algorithm with up to 12%, 30% and 22% with static video, while with dynamic video the differences is up to 10%, 24% and 12% for VQM, SSIM and PSNR respectively. This paper has also shown a new approach using objective video quality metrics to evaluate the performance of bezel compensation algorithms. Based on result, this approach is recommended for video wall development as an alternative to the use of subjective assessment.

REFERENCES

[1] K. Ogawa and R. Mitsuhashi (2011). Development of a Video Wall Display System Using Ultrathin-Bezel LCD Panels, General Papers, *Mitsuhashi Renichi NEC Technical Journal. 6 (3)*: 84-88.

[2] G.G. Ramón and C.V. Rodríguez (2014). *Implementation of a Low Cost Video Wall using R-pi devices*, Master Thesis, Master of Science in Telecommunication Engineering and Management, Universitat Politechnica De Calalunya.

[3] R. Bundulis and G. Arnicans (2014). Concept of Virtual Machine Based High Resolution Display Wall, *Information, Electronic and Electrical Engineering*, pp. 1-6, Nov 2014.

[4] C. Papadopoulos, K. Petkov, A. E. Kaufman, and K. Mueller, (2014). The Reality Deck--an Immersive GigGUIxel Display. *IEEE computer graphics and* applications, 35 (1): 33-45.

[5] S.D. Kim and S.E. Lee (2015). Architecture for A Zero Client Based Scalable Large Format Display System, *International Journal of Computer and Information Technology. 04 (03)*

[6] A. Ebert, T. Sebastian, O. Peter-Scott, M. Joerg and H. Hans (2010). Tiled++: An Enhanced Tiled Hi-Res Display Wall, *IEEE Transactions on Visualization and Computer Graphics. 16 (1)*: 120-132

[7] X. Bi, S.-H. Bae, and R. Balakrishnan, (2010). *Effects of interior bezels of tiled-monitor large displays on visual search, tunnel*

steering, and target selection. In Proc. CHI 2010, CHI ’10, ACM (2010), 65–74.

[8] R. Ball, M. Varghese, B. Carstensen, E. D. Cox, C. Fierer, M. Peterson and C. North (2005). *Evaluating the Benefits of Tiled Displays for Navigating Maps*,” Proc. Int’l Assoc. Science and Technology for Development (IASTED) Int’l Conf. Human-Computer Interaction.

[9] T. A. DeFanti, J. Leigh, L Renambot, B. Jeong, A. Verlo, L., Long, … L. Smarr (2009). *The OptIPortal, a scalable visualization, storage, and computing interface device for the OptiPuter. Future Generation Computer Systems, 25(2), 114–123*. doi:10.1016/j.future.2008.06.016

[10] Leyard and Planar (2018). ClarityMatrix G3 LCD Video Wall System, *clarity-matrix-g3-lcd-video-wall-system-brochure_5-18,* Leyard Optoelectronics Co., Ltd. and Planar Systems, Inc.

[11] M. Saleem, H. E. Valle, S. Brown, V.I. Winters, and A. Mahmood (2018). The Hiperwall tiled-display wall system for Big-Data research. *Journal of Big Data*. 5(41) https://doi.org/10.1186/s40537-018-0150-7

[12] A. Bezerianos, and P. Isenberg, (2012). Perception of visual variables on tiled wall-sized displays for information visualization applications. *IEEE Transactions on Visualization and Computer Graphics 18(12) (2012).*

[13] G. Smith, R. J. Teather, J. Lass, and J. Carette, (2015). *Effects of interior bezel size and configuration on gaming performance with large tiled displays*, 2015 IEEE Games Entertainment Media Conference (GEM), Toronto, ON, 2015, pp. 1-8.

[14] S. Karim, H. He, A. R. Junejo; and M. Sattar (2020). Measurement of Objective Video Quality in Social Cloud Based on Reference Metric, *Hindawi Wireless Communications and Mobile Computing Volume 2020.*

[15] M. Vranješ, S. Rimac-Drlje, and D. Žagar (2007). Objective Video Quality Metrics, *ELMAR 2007, Zadar, 2007, pp. 45-49, doi:10.1109/ELMAR.2007.4418797 https://ieeexplore.ieee.org/document/4418797*

[16] M.O. Martínez-Rach, P. Piñol, O. M López, M. P. Malumbres, J. Oliver, and C.T Calafate (2014). On the Performance of Video Quality Assessment Metrics under Different Compression and Packet Loss Scenarios. *Hindawi Publishing Corporation e Scientific World Journal Volume 2014, Article ID 743604, 18 pages http://dx.doi.org/10.1155/2014/743604*

[17] A. Moldovan, I. Ghergulescu and C. H. Muntean, (2016). VQAMap: A Novel Mechanism for Mapping Objective Video Quality Metrics to Subjective MOS Scale," *in IEEE Transactions on Broadcasting, Sept 2016, 62(3):610-627 doi: 10.1109/TBC.2016.2570002.*

[18] YouTube (2017).Tom & Jerry | No Way Out | Boomerang Africa - Sunday Morning Shake Up. https://www.youtube.com/watch?v=bShpwwJR3Tg uploaded 2 July 2017.

[19] Tube offline (2020). https://www.tubeoffline.com/download-youtube-videos.php

[20] MSU Quality Measurement Tool: Download Page (2020).