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Sharpness Mismatch and 6 Other Stereoscopic Artifacts Measured on 10 Chinese S3D Movies

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Abstract

Objective technical quality assessment of stereoscopic movies is crucial for timely detection and correction of potentially problematic scenes in order to decrease the fraction of viewers who might experience visual discomfort. Despite the prior advancements in the field, some recently released movies still contain scenes with significant technical issues. For instance, the movie Mermaid, which grossed over $500 million in box office, contains both artifacts common for natively captured S3D content and artifacts specific to 2D-to-3D conversion. In addition to previously described technical quality metrics this paper introduces our improved approach to measuring sharpness mismatch between stereoscopic views, as well as a detailed analysis of 10 recently released Chinese S3D movies using 7 different quality metrics. The analyzed 10 movies are compared with general stereoscopic movie quality trends evaluated on over hundred S3D movies, produced mostly in Europe and USA.

Introduction

China currently takes up a special place with regards to stereoscopic 3D (S3D) content production. While other countries demonstrate a general drop in interest for stereoscopic movies, Chinese S3D movie market continues to thrive. Significant increase in the number of cinema theaters across the country also contributes to the exponential growth of total box office earnings of S3D productions that is unheard of in other countries. In 2015 the total box office in the mainland China was supposed to be about 44 billion yuan, or 6.8 billion USD, comparing to 3.3 billion USD in 2013 and 1.5 billion USD in 2010. And the majority of the highest-grossing movies are shot and screened in S3D.

Technical quality of Chinese S3D movies is a controversial topic owing to the peculiarities of the production techniques, as well as the fact that the majority of contemporary Chinese S3D movies are converted from 2D. Moreover, it's fairly common for movies screened only in 2D in all the other countries to be converted to S3D specifically for the Chinese market. All of this adds up to the interest in objective quality analysis of Chinese S3D movies.

Quantitative quality analysis of converted S3D content is a fairly challenging problem owing to the multitude of 2D-to-3D conversion techniques which are changing over time and might lead to different types of artifacts. Measurement of issues common for native S3D capture like color or sharpness mismatch also presents some challenges but reasonable estimates can still be computed. Proper measurement of edge-sharpness mismatch [1]—a common artifact specific to 2D-to-3D conversion—is considerably more challenging and no robust techniques of its estimation demonstrating high correlation with perceptual discomfort scores have yet been proposed. It's also often challenging to adequately evaluate cardboard effect in the context of 2D-to-3D conversion—i.e. excessive flatness of specific objects or background in a scene, when taking into account a wide variety of potentially acceptable depth maps and creative choices made in the process. As a result, high objective quality ranks are often achieved by movies with a large fraction of converted scenes, regardless of the actual discomfort perceived by a viewer, as quantitative metrics used throughout this paper are primarily oriented towards issues of native stereoscopic capture. Unfortunately, quantitative evaluation of 2D-to-3D conversion issues is still a very under-researched topic.

Title	Release year	Budget ($M)	Box office ($M)
Flying Swords of Dragon Gate	2011	35	100
Painted Skin: The Resurrection	2012	24	115
Young Detective Dee: Rise of the Sea Dragon	2013	28	98
The Monkey King	2014	100	181
The White Haired Witch of Lunar Kingdom	2014	16	64
Dragon Blade	2015	65	120
Monster Hunt	2015	56	385
Zhongkui: Snow Girl and the Dark Crystal	2015	26	64
The Monkey King: The Legend Begins	2016	68	193
Mermaid	2016	60	553

Table 1: List of analyzed Chinese S3D movies

Nonetheless, technical quality analysis of movies which primarily used 2D-to-3D conversion can help assess their post-production pipelines. After all, it's known that the movies with the best technical quality are often not the ones which were shot with the most expensive cameras (as it's always possible that some errors will be introduced in post-production) and not the ones which employed the most expensive post-production studios (as some improperly shot scenes are nearly impossible to fix). Movies with the best technical quality are the ones that took special care to minimize the number of potential problems in all stages of the process. Carelessness during S3D movie production leads to technical problems that can negatively affect the viewers. And such general carelessness can often be assessed using metrics for common problems such as color and sharpness mismatch or geometric inconsistencies between the stereoscopic views.

(a) Left view

(b) Right view

(c) Left blur magnitude map $\sigma_L(p)$

(d) Right blur magnitude map $\sigma_R(p)$

Figure 1: Example of local sharpness-mismatch analysis results. The brighter the area in (c) is, the sharper the left view is in this area compared to the right one. Similarly, the map in (d) highlights the areas where the right view is sharper than the left one.

Related Work

We build on our previous work [3] that involved in-depth analysis of technical quality trends evaluated on 105 Western S3D movies. As noted in [3], the majority of works in stereoscopic quality assessment consider only transmission-related issues with relatively few works focusing on evaluating the problems introduced during production of S3D content. Among the ones that analyze production-related issues we identify studies that aim to predict visual discomfort caused by specific S3D artifacts [4, 5, 6] and technical metrics for various S3D production issues that are not intended for directly predicting perceptual quality [7, 8, 9]. The metrics employed in this work belong to the latter category. In this paper we put an emphasis on measuring sharpness mismatch, so we briefly review the prior work in this area next.

The problem of evaluating sharpness mismatch between stereoscopic views caused by differences in focal distance between cameras was previously considered by Devernay et. al. [10]. They propose to use the SML operator (sum of modified Laplacian) to obtain local noisy estimates of sharpness mismatch and use them to fit a model that relates difference in sharpness between views to disparity values. They classify all possible shapes of the sign of focus difference which introduces another constraint in the model. The final sharpness mismatch estimates produced by their approach are fairly rough however, as they perform quantization into just 5 possible values. Also, their approach heavily relies on the assumptions of live-action S3D capture setting, which can be problematic when assessing sharpness mismatch in final S3D movies where sharpness mismatch can potentially be introduced in post-production or when performing 2D-to-3D conversion.

Liu et al. [9, 11] proposed a different approach which relies on estimating edge-width deviation between the left and right views. They use the Canny edge detector to identify edge pixels which are then segmented into depth planes based on their disparity values. Per-pixel edge width estimation is then applied and differences in edge width between matched pixels are aggregated into one sharpness mismatch probability value per depth plane. This approach was further improved in [12] and a subjective study on sharpness mismatch noticeability was carried out. The authors used a dataset of 35 HD video sequences on which the proposed method was shown to outperform alternative metrics in terms of correlation with perceptual scores. The proposed approach, however, avoids directly measuring the magnitude of sharpness mismatch and produces only the overall sharpness mismatch probability value.

Methodology

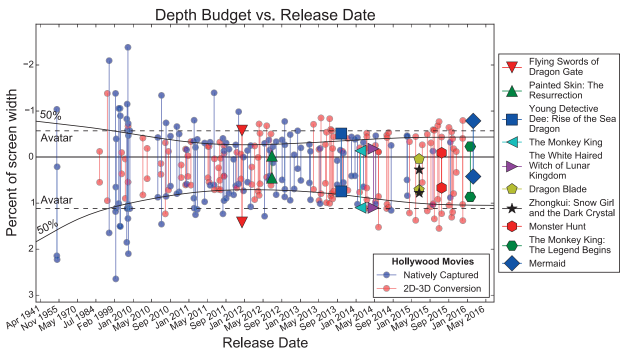
This study employed a number of technical quality metrics to analyze the following parameters of S3D video:

1. Extreme horizontal-disparity values;
2. Color mismatch between views;
3. Geometric inconsistencies, including scale, rotation mismatch and vertical parallax
4. Sharpness mismatch;
5. Specific 2D-to-3D conversion artifacts, including edge-sharpness mismatch and cardboard effect.

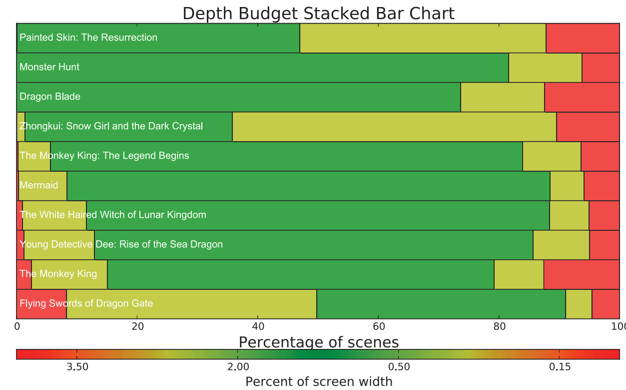
Descriptions of horizontal disparity, color mismatch and vertical parallax metrics can be found in [13]. Our approach to scale and rotation mismatch evaluation is summarized in [3]. 2D-to-3D conversion metrics are described in [1]. Our approach to sharpness mismatch estimation is described next.

Improved sharpness mismatch metric

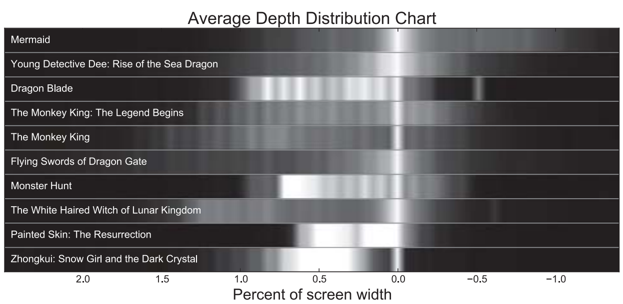
To estimate sharpness mismatch we use an improved version of the metric described in [14] that is more robust in the presence of color mismatch between views and evaluates the magnitude of sharpness mismatch more accurately owing to the explicit computation of blur magnitude according to the used blur model. The algorithm is based on the assumption that the energy of the 2D signal $\mathrm{E}[I] = \sum_{i=1}^{h} \sum_{j=1}^{w} I^2(i, j)$ is monotonically decreasing with



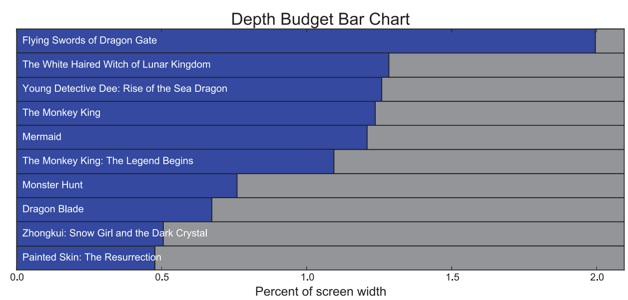
(a) Average depth budget of Chinese movies (denoted by solid markers) in comparison with over 100 Hollywood S3D films (denoted by semitransparent markers)



(b) Stacked bar chart that shows the relative fractions of different types of scenes ranging from very volumetric on the far left to very "flat" on the far right



(c) Histograms illustrating average depth value distributions



(d) Analyzed movies sorted by the average depth budget

Figure 2: Results of depth-budget analysis

the increasing magnitude of blur σ:

$$0 \leq \sigma_0 < \sigma_1 \Rightarrow \mathrm{E}[f_{\sigma_0} * I] > \mathrm{E}[f_{\sigma_1} * I],$$

where f_σ is a point spread function of the used blur model, I is the input image, w and h are its width and height respectively, and "$*$" denotes the convolution operation. We found simple Gaussian blur model to work well enough, i.e. we use $f_\sigma(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$.

In order to evaluate the sharpness mismatch between the left and right views we first compute the disparity map $D(p)$ using a fast local block-matching approach [16]. For every matched pair of left- and right-view pixels $(p, p+D(p))$ we can evaluate local difference in sharpness by considering local image patches W_p^L and W_p^R centered at pixels p and $p+D(p)$ in the left and right views respectively. We use relatively large patches of 65×65 pixels. We then estimate such $\sigma_L(p)$ that the energies of respective left- and right-view patches become equal:

$$\mathrm{E}[f_{\sigma_L(p)} * W_p^L] = \mathrm{E}[W_p^R].$$

When the left view is sharper than the right one, such $\sigma_L(p)$ can always be found by a straightforward binary search. The opposite case is considered when building a similar blur magnitude map for the right view $\sigma_R(p)$ (see Figure 1). In other words, for each pixel p of the left view we compute the standard deviation of the Gaussian blur $\sigma_L(p)$ that we need to apply to the left view to make it as sharp as the right one in the local neighborhood (if the right view is sharper then the left one we set $\sigma_L(p)$ to zero).

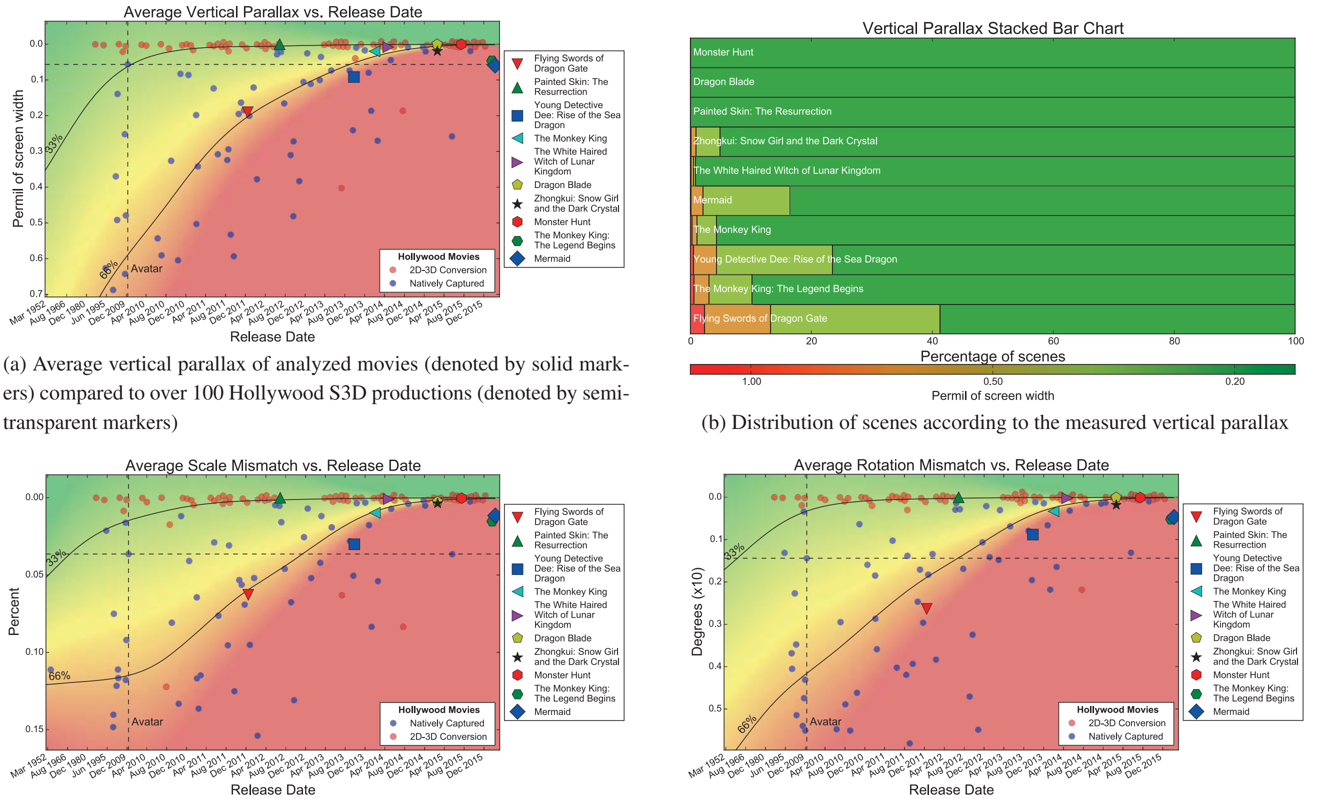
Both the Gaussian blur with different standard deviations σ and computation of the patch energy values are performed in frequency domain, i.e. we use the Fourier transforms of the patches W_p^L and W_p^R instead of the patches themselves. It helps improve the computational efficiency of the algorithm (as convolution is replaced with multiplication in frequency domain) and allows us to ignore the differences in the low-frequency range when computing patch energy values, as they can be caused by irrelevant inconsistencies in luminance between the views.

Stereo-matching errors, as well as presence of half-occlusions in the patches W_p^L, W_p^R can lead to errors in the estimated blur magnitude maps $\sigma_L(p)$ and $\sigma_R(p)$. To minimize the adverse effect of such errors we detect unreliable matches and half-occlusion areas using the LRC criterion [15] and ignore all patches W_p^L, W_p^R that contain such unreliably matched pixels. The final value of sharpness mismatch between the left-view image I_L and right-view image I_R is computed by aggregating all valid local sharpness mismatch estimates:

$$SM(I_L, I_R) = \frac{1}{wh} \sum_{i=1}^{h} \sum_{j=1}^{w} \frac{\sigma_L^2(i,j) + \sigma_R^2(i,j)}{2}.$$

Results

In this section we present the results of our analysis of ten S3D movies which were selected according to film budget and box office results (see Table 1). We focus on identifying the main overall trends and carrying out the technical comparison with typical Hollywood S3D productions. More detailed analysis results



(a) Average vertical parallax of analyzed movies (denoted by solid markers) compared to over 100 Hollywood S3D productions (denoted by semi-transparent markers)

(b) Distribution of scenes according to the measured vertical parallax

(c) Average scale mismatch between the views

(d) Average rotation mismatch between the views

Figure 3: Results of the geometric inconsistency analysis. For each metric lower values indicate better technical quality.

with numerous examples of shots with detected issues will be published as a standalone report [18].

Up until several years ago Chinese 3D was often referred to as "very volumetric" among professionals, even to the point of visual discomfort. The conducted evaluation and comparison with over 100 Western S3D movies, however, failed to support this claim (see Figure 2a). Except for *Flying Swords of Dragon Gate*, the selected movies feature even somewhat smaller depth budgets than Hollywood films of the same category (natively captured or converted). *Dragon Blade* and particularly *Zhongkui: Snow Girl and the Dark Crystal*, released in 2015, show about 1.5 times smaller depth budget than 3D converted Hollywood movies of the same period. Technically, such depth budgets correspond to Hollywood converted movies dated 2010–2011. The last four movies (40% of movies we analyzed and all 3 of evaluated movies released in 2015) are likely to be perceived as overly "flat" when shown in theaters with small screens or on 3DTVs.

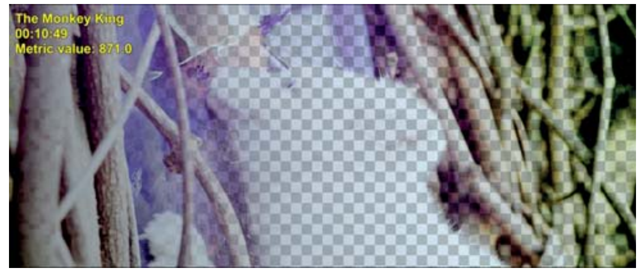
In our previous analysis we have identified a characteristic feature of many converted S3D movies—a striping pattern in the accumulated histogram of horizontal disparity values, which characterizes the quality of the employed stereo generation algorithm and indirectly identifies the percent of converted scenes in a film. These stripes are quite noticeable in 4 of the analyzed movies (Figure 2c). It's also worth noting that the obtained data doesn't reveal any strict standards on object placement in the disparity space, which is in direct contrast with the standards commonly used by European and American films of recent years. It indicates that perceptual quality of Chinese movies can be further improved by standardizing the disparity value distribution across scenes.

Moreover, owing to the imperfections of theater equipment, crosstalk between stereoscopic views can often become noticeable, especially on high-contrast object edges [2]. In the case of linear polarization glasses, high crosstalk can be caused by a simple tilt of the viewer's head. From this standpoint a global shift towards positive disparity space in *Zhongkui: Snow Girl and the Dark Crystal* (which was probably done to improve the visible depth) can lead to a significantly higher level of perceived crosstalk.

As we can see on the depth budget value distribution chart (Figure 2b), in two movies the fraction of "flat" scenes exceeds 50%. However, on average the fraction of flat scenes in Chinese movies is generally comparable to that of Hollywood movies. Potentially problematic scenes with excessive positive parallax which can lead to significant eye divergence were encountered in several movies. The majority of them, however, were in *Flying Swords of Dragon Gate* released in 2011.

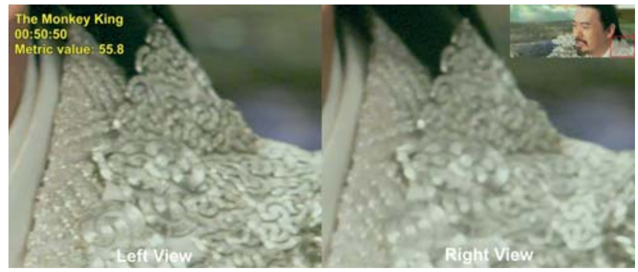
In terms of vertical parallax Chinese movies demonstrate mediocre results when compared to Hollywood productions: 4 evaluated movies are below the 66th percentile (Figure 3a). So, generally, the quality according to this parameter improves more slowly compared to the quality improvement trends identified in Hollywood S3D movies with two high-budget 2016 movies significantly below average. We should also note that these movies contain a lot of converted scenes which should have zero vertical parallax in the absence of post-production errors. In Vatolin et al. (2017) [18] we provide examples of vertical parallax in converted

(a) Example of local color mismatch visualized by shuffling square regions of the two views chequerwise



(b) Example of global color mismatch visualized by shuffling square regions of the two views chequerwise

(c) Sharpness mismatch example from a low-budget movie



(d) Sharpness mismatch example from a high-budget movie

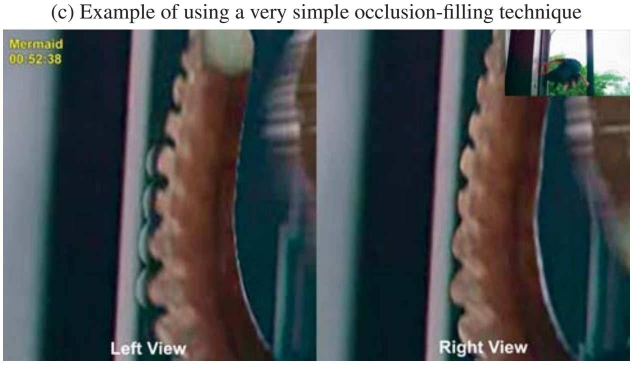
Figure 4: Examples of detected color and sharpness mismatch

(a) Edge-sharpness mismatch example

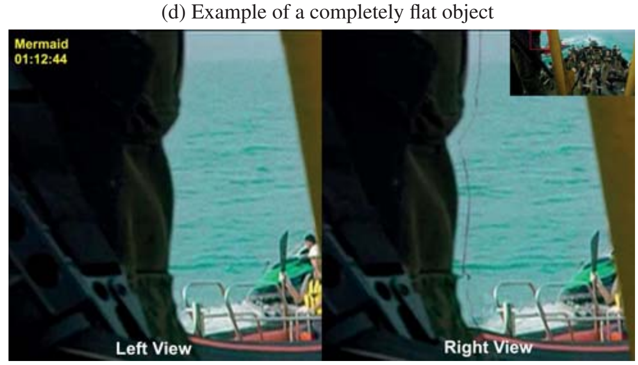
(b) Edge-sharpness mismatch example

(c) Example of using a very simple occlusion-filling technique

(d) Example of a completely flat object

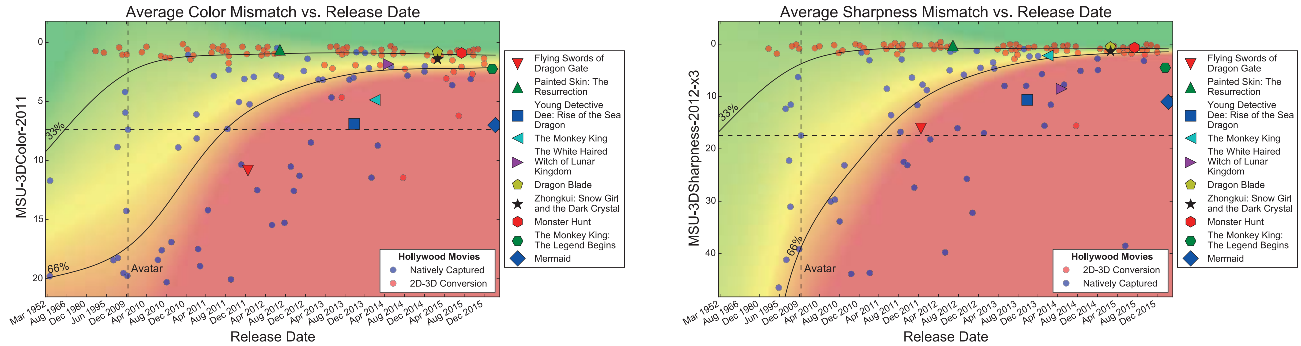


(e) Result of using a depth map with misaligned object edges



(f) Result of using a depth map with misaligned object edges

Figure 5: Examples of detected 2D-to-3D conversion issues



(a) Average color mismatch between views

(b) Average sharpness mismatch between views

Figure 6: Results of color and sharpness mismatch analysis. For each metric lower values indicate better technical quality.

scenes which are clearly caused by mistakes in the 2D-to-3D conversion pipeline. *Mermaid* and *The Monkey King: The Legend Begins* have over 10% of scenes containing vertical parallax (Figure 3b), which indicates that a significant fraction of scenes were shot in S3D and some of them probably weren't fixed in post-production.

The situation with scale and rotation mismatch is fairly similar: relative positions of movies change very little, which also supports the assumption that the natively captured scenes weren't corrected in post-production as well as they could be. Given that using specialized software such correction can be done within approximately 2 weeks by one specialist and that analyzed movies are relatively high-budget, such high amount of geometric inconsistencies is somewhat surprising.

Color and Sharpness Mismatch

As with geometric inconsistencies, color mismatch is more often seen in natively captured shots. An example of a scene with color mismatch from *Zhongkui: Snow Girl and the Dark Crystal* is provided in Figure 4a . In this case severe color mismatch in the bottom right corner of the frame can easily lead to noticeable visual discomfort. Unfortunately, such problems are numerous even in high-budget movies. For example, Vatolin et al. (2017) [18] presents visualizations for a number of scenes with severe color mismatch from *The Monkey King*. Sometimes, even global difference in luminance is present (Figure 4b), which is quite easy to fix. Overall, the analyzed movies have significant issues with color mismatch compared to Hollywood movies of the same release dates (Figure 6a). Four movies are in the "red" zone (below 66th percentile) and another three are in the "yellow" zone (between 33rd and 66th percentiles).

Our sharpness mismatch measurements have also led to detection of many scenes with noticeable issues. In some scenes severe sharpness mismatch was even present on the main objects of interest (Figure 4c), while some scenes with sharpness mismatch were found in high-budget movies (Figure 4d). On average, overall trends in sharpness mismatch are similar (Figure 6b).

During our measurements we have found many scenes produced by the means of 2D-to-3D conversion that contain artifacts common for native capture. We have previously developed an automated classification approach for determining the scene production method (native capture, 2D-to-3D conversion or CGI). However, the specific features of Chinese movies, including multitude of typical native capturing artifacts in converted scenes, have led to relatively poor performance of the classifier, so we omit the classification results from this paper. Collection of a more representative training set could potentially improve the results.

2D-to-3D Conversion Artifacts

As mentioned earlier, proper measurement of potential discomfort caused by specific 2D-to-3D conversion artifacts can be quite challenging and further research is required in this area. Nonetheless, using our previously proposed qualitative edge-sharpness mismatch metric [1] we have managed to detect numerous potentially problematic artifacts in the analyzed 10 movies. Notable examples of edge-sharpness mismatch are presented in Figures 5a, 5b. Such issues often occur on semi-transparent object edges which typically require additional manual processing to achieve high-quality results. Development of new video matting approaches [17] and introduction of new software tools could help alleviate the problem. A lot of other edge-sharpness mismatch examples detected in the analyzed movies are available in Vatolin et al. (2017) [18].

Issues with filling the half-occlusion areas are also quite common for 2D-to-3D conversion and can cause visual discomfort, as simple occlusion-filling techniques often lead to unsatisfactory results (Figure 5c). Such issues are still numerous due to the lack of robust general-purpose video completion algorithms. However, it's currently a topic of active research (`http://videocompletion.org`), so further improvement of automatic occlusion-filling tools can be expected.

Another major concern when performing 2D-to-3D conversion is the quality of the used depth maps. Absence of fine-scale depth-map variations can lead to unrealistically looking scenes. Many cases of completely flat foreground objects (Figure 5d) were detected using a specialized cardboard-effect metric. Misaligned depth-map edges can also be problematic and lead to characteristic artifacts (Figures 5e, 5f).

Conclusion

In conclusion of conducted study we would like to point out that the presented analysis can be further expanded by using our other previously developed S3D quality metrics. We identify the following possible future work directions:

- Detection of scenes with swapped views. We have previously detected scenes with swapped left and right views in 23 of 105 analyzed S3D movies with one of them having

as many as 15 scenes with swapped views. So it could be interesting to compare it with the Chinese S3D productions;
- Analysis of temporal synchronization between views. One scene containing such artifact was detected when analyzing geometric inconsistencies, so probably more scenes can be detected by using a specialized temporal shift metric;
- Estimation of average depth continuity on shot boundaries in comparison with Hollywood productions;
- Detection of peculiar inconsistencies between 2D and S3D versions of the converted scenes, including background replacement (which is generally harmless), object deformation (which could lead to noticeable distortions) and determining the position of 2D source with regards to generated stereoscopic views. However, such analysis is made problematic by the fact that all 2D versions on evaluated Blu-ray discs turned out to be identical to one of the stereoscopic views. It generally leads to degradation of 2D version quality owing to the introduced 2D-to-3D conversion artifacts.

Also, as yet we have only analyzed 10 Chinese movies, partly because very few S3D movies are released as Blu-ray discs in mainland China. However, based on the collected data we can estimate the Chinese movie market to be behind Hollywood in terms of technical quality by approximately 4 years.

We plan to continue improving the existing quality metrics, as well as develop new ones for detection of specific 2D-to-3D conversion artifacts and we are always open for collaboration in these areas. Improvements in general computer vision algorithms can gradually simplify the correction of all artifacts common for native stereoscopic capture, as well as improve 2D-to-3D conversion quality, which could lead to another wave of interest to S3D on a new level of quality.

Full analysis results will be published in a standalone report which will be available on the main VQMT3D project page: `http://compression.ru/video/vqmt3d/`.

Acknowledgments

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References

[1] A. Bokov, D. Vatolin, A. Zachesov, A. Belous, and M. Erofeev, Automatic detection of artifacts in converted S3D video, in Stereoscopic Displays and Applications XXV, Proceedings of SPIE-IS&T Electronic Imaging, SPIE Vol. 9011, 901112 (2014).

[2] A. J. Woods, Crosstalk in Stereoscopic Displays: a review in Journal of Electronic Imaging, 21(4), 040902 (2012).

[3] D. Vatolin, A. Bokov, M. Erofeev, and V. Napadovsky, Trends in S3D movies quality as evaluated on 105 movies and 10 quality metrics, in Stereoscopic Displays and Applications XXVII, Proceedings of IS&T Electronic Imaging, no. 5 (2016). DOI: 10.2352/ISSN.2470-1173.2016.5.SDA-439.

[4] D. Khaustova, J. Fournier, E. Wyckens, and O. Le Meur, An objective method for 3D quality prediction using visual annoyance and acceptability level, in Stereoscopic Displays and Applications XXVI, Proceedings of SPIE-IS&T Electronic Imaging, SPIE Vol. 9391, 93910P (2015).

[5] J. Chen, J. Zhou, J. Sun, and A. C. Bovik, Binocular mismatch induced by luminance discrepancies on stereoscopic images, IEEE International Conference on Multimedia and Expo (ICME), pp. 1–6. (2014).

[6] L. Goldmann, J. S. Lee, and T. Ebrahimi, Temporal synchronization in stereoscopic video: Influence on quality of experience and automatic asynchrony detection, IEEE International Conference on Image Processing (ICIP), pp. 3241–3244. (2010).

[7] Q. Dong, T. Zhou, Z. Guo, and J. Xiao, A stereo camera distortion detecting method for 3DTV video quality assessment, Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA), pp. 1–4. (2013).

[8] S. Winkler, Efficient measurement of stereoscopic 3D video content issues, in Stereoscopic Displays and Applications XXV, Proceedings of SPIE-IS&T Electronic Imaging, SPIE Vol. 9011, 90160Q (2014).

[9] M. Liu and K. Muller, Automatic analysis of sharpness mismatch between stereoscopic views for stereo 3D videos, International Conference on 3D Imaging (IC3D), pp. 1–6. (2014).

[10] F. Devernay and S. Pujades, Focus mismatch detection in stereoscopic content, in Stereoscopic Displays and Applications XXIII, Proceedings of SPIE-IS&T Electronic Imaging, SPIE Vol. 8288, 82880E (2012).

[11] M. Liu, I. Mademlis, P. Ndjiki-Nya, J. C. Le Quintrec, N. Nikolaidis, and I. Pitas, Efficient automatic detection of 3D video artifacts, IEEE International Workshop on Multimedia Signal Processing (MMSP), pp. 1–6. (2014).

[12] M. Liu, K. Mller, and A. Raake, Efficient no-reference metric for sharpness mismatch artifact between stereoscopic views, Journal of Visual Communication and Image Representation, pp. 132–141. (2016).

[13] A. Voronov, D. Vatolin, D. Sumin, V. Napadovsky, and A. Borisov, Methodology for stereoscopic motion-picture quality assessment, in Stereoscopic Displays and Applications XXIV, Proceedings of SPIE-IS&T Electronic Imaging, SPIE Vol. 8648, 864810 (2013).

[14] A. Voronov, D. Vatolin, D. Sumin, V. Napadovskiy, and A. Borisov, Towards automatic stereo-video quality assessment and detection of color and sharpness mismatch, International Conference on 3D Imaging (IC3D), pp. 1–6. (2012).

[15] G. Egnal, M. Mintz, and R. P. Wildes, A stereo confidence metric using single view imagery with comparison to five alternative approaches, Image and Vision Computing, 22(12), pp. 943–957. (2004).

[16] K. Simonyan, S. Grishin, D. Vatolin, and D. Popov. Fast video super-resolution via classification, International Conference on Image Processing (ICIP), pp. 349–352. (2008).

[17] M. Erofeev, Y. Gitman, D. Vatolin, A. Fedorov, and J. Wang, Perceptually Motivated Benchmark for Video Matting, British Machine Vision Conference (BMVC), pp. 99.1–99.12. (2015).

[18] D. Vatolin, A. Bokov, D. Koryabkin, V. Napadovsky, VQMT3D project stereo-film-quality analysis report 11, in preparation. (2017).

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