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Test DCP for Stereoscopic Subtitles Compliance with SMPTE Specifications

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Abstract: Stereoscopic subtitles play a critical role in enhancing the accessibility and viewing experience in 3D cinema. However, the accurate rendering and playback of stereoscopic subtitles in compliance with the latest SMPTE (Society of Motion Picture and Television Engineers) specifications remain a technical challenge. This paper presents the development of a Digital Cinema Package (DCP) designed specifically to test cinema playback systems for compliance with the latest SMPTE standards for stereoscopic subtitles. The proposed test DCP provides a systematic framework for evaluating and verifying the capabilities of cinema projection systems, ensuring that stereoscopic subtitles are displayed with optimal visual quality and spatial accuracy.
Keywords: digital cinema, subtitles, stereoscopic, SMPTE, compliance

1. INTRODUCTION

With the widespread adoption of stereoscopic 3D in cinema, subtitles have become an integral component of the cinematic experience for audiences across different languages and accessibility needs. SMPTE has established specifications to standardize the presentation of stereoscopic subtitles to ensure consistent and high-quality playback[1]. However, variations in cinema playback systems [2] and software implementations can lead to issues such as depth inconsistencies or even playback errors.

This paper aims to address these challenges by developing a test DCP that enables exhibitors, engineers, and quality assurance teams to validate their systems' compliance with SMPTE specifications[3]. By providing a comprehensive set of test patterns and scenarios, the test DCP serves as a diagnostic tool for identifying and resolving stereoscopic subtitle rendering issues.

2. BACKGROUND

SMPTE standards such as SMPTE ST 429-2[3] and ST 428-7[1] define the requirements for the encoding, transmission, and presentation of subtitles in digital cinema, including those for stereoscopic content. Key considerations for stereoscopic subtitles include:

- Depth placement: Subtitles should be positioned at an appropriate depth within the 3D space to avoid viewer discomfort or confusion. Creation tools and authoring constraints have been outlined in detail in previous research[4].
- Synchronization: Accurate timing of subtitle display with video is essential. Since there is no substantial difference between monoscopic and stereoscopic timing, this topic will not be part of this research.
- Implementation of Optional Elements: Assessment of actual capabilities of the playback system. These optional elements can actually make a big difference in the workload of stereoscopic subtitles. Their assessment is therefore in the principal focus of this research.

Despite the specifications of SMPTE and the Digital Cinema Initiative (DCI), real-world implementation can vary, necessitating a practical means of verification. Even if hardware remains unchanged over years, software updates can change the capabilities of the playback system. As equipment maintenance usually involves feed, cinema owners can decide to update their equipments with different schedules.

As subtitles are often specially created for the presentation at international film festivals, it is important to understand the true features of the projection system in use. Knowing which features are implemented in the projection system can save resources an energy in the process of subtitle creation.

3. TEST DCP DESIGN

The test DCP developed in this study includes the following components:

Test Pattern

The proposed test DCP contains two principal compliance tests: First, depth alignment grids to evaluate subtitle positioning within the 3D space. Second, motion scenarios to examine subtitle synchronization with on-screen action. This section explains the setup of the assessment in the test DCP.

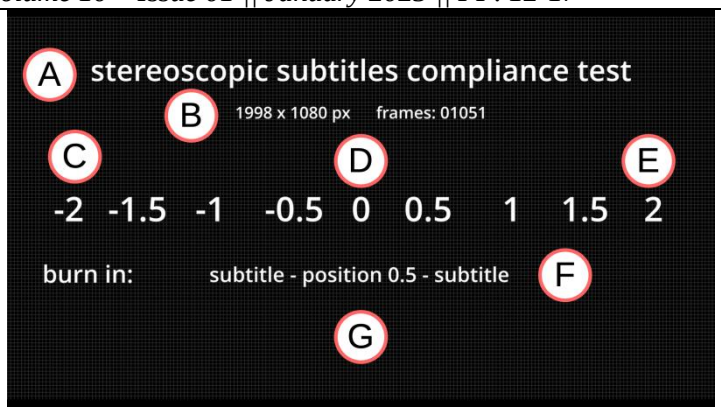

Figure 1. Test pattern

Fig. 1 displays the test pattern design. The individual elements are described as follows:

A displays the title of the test pattern. Line B contains the image dimensions of the primary picture. The numbers below show the exact positions in depth for the percentage values related to the width of the primary picture. Negative values pop out of the screen towards the audience. Positive values appear behind the screen far from the audience. The number zero indicates the zero parallax which is displayed exactly on the screen plane. C shows the foremost advanced text on the test pattern. E shows the most far text position on the test pattern. D in the center displays exactly the screen plane.

Line F shows subtitles as they are burned in in the principal image. There stereoscopic position is fixed during the mastering. G shows the placeholder for the dynamic subtitles as they are included in the DCP and rendered by the playback system at the time of the projection.

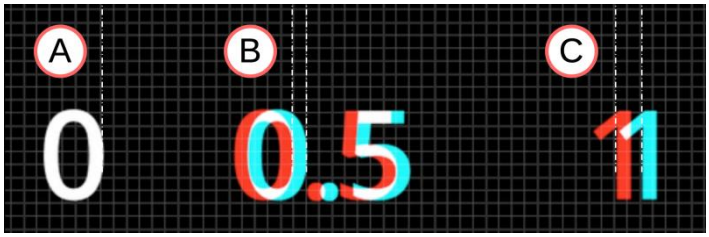

Figure 2. Test pattern Detail

The back of the test pattern is filled with a thin grid. Each square of the grid corresponds to 10 pixels in the principal image. The detail in Fig. 2 shows a magnification of the area with the numbers from zero to one. The numbers show at the same time the amount of parallax as well as their position in space. The term parallax stands for the horizontal difference of a specific point between the left and the right image. Negative values make the point seem nearer to the audience, positive values make the point perceived behind the screen. The numbers are decimal values and correspond to the values that are used in the subtitle file of the DCP to position the subtitle in space in front of the movie. The detail is rendered as an anaglyph image in order to visualize the parallax between the right and the left image. The number zero shown in A does not show any red or cyan border. This indicates zero pixel of parallax and displays the number exactly on the screen plane. The number 0.5 shown in B shows a parallax one grid square. It therefore has a parallax of 10 pixels which corresponds to 0.5% in relation to the width of the principal picture of 1998 pixels. C shows the parallax of 1%. Left and right numbers show a difference of two squares on the grid. The parallax is therefore 20 pixels. The correspondence for the other numbers on the grid and the actual numbers for the convergence settings in DaVinci Resolve are shown in Table 1.

Table 1. parallax and convergence values

percent	pixels	convergence	position
-2,00	-40	20	in front
-1,50	-30	15	in front
-1,00	-20	10	in front

-0,50	-10	5	in front
0,00	0	0	screen plane
0,50	10	-5	behind
1,00	20	-10	behind
1,50	30	-15	behind
2,00	40	-20	behind

The percent values are in relation to the image flat image format of the digital cinema specification and correspond to an image resolution of 1998 x 1080 pixels. Other container formats of the principle image such as full 2024 x 1080 or scope with 2048 x 858 pixels will result in different parallax values with the same percentage values. This is because the Zposition is defined as the percentage of the width of the main picture.

For the purpose of this test, the most comment image container format is selected. While the specifications allows parallax values ranging from -100% to +100%, much smaller values are usually applied in regular stereoscopic projections. The value range from negative parallax of 2% in the front to positive parallax of 2% in the back represent a common range for stereoscopic movies. This parallax is within a range that avoids visual discomfort [5], [6].

Dynamic Sequences

In addition to the pre-rendered images described above the DCP contains dynamic sequences. The dynamic sequences contain a series of subtitles which are rendered dynamically from the subtitle file included in the DCP. As in monoscopic projection they have a time information their appearance and disappearance on the screen. Additionally the stereoscopic subtitles carry an information which is responsible for the positioning in space. It is principally an optional parameter named Zposition with an indication for the parallax at which the subtitle shall be rendered in the projection. In order to evaluate the capabilities of the playback system two application scenarios are implemented in the test DCP.

- Sample video sequences with pre-rendered stereoscopic subtitles at varying depths and positions.
- Scenarios involving complex subtitle animations to stress-test the playback systems.

The subsequent section describes the testing method and details of the test arrangement.

4. METHODOLOGY

The test DCP is created using industry-standard tools for DCP authoring and subtitle encoding. The software used for authoring of the test pattern is DaVinci Resolve, as the software allows detailed control of all image format parameters as well as fine tuning for stereoscopic settings. The subtitles for the test are created according to the workflow for stereoscopic subtitles described by Hamacher [4]. First, ordinary monoscopic subtitles are created as shown in Fig. 3.

Figure 3. captions containing parallax description

The subtitles are rendered as a movie with transparent background and reimported into the editing software as a stereoscopic video track. The stereoscopic parallax values described in each subtitle are applied to the rendered stereoscopic subtitle according to Table 1. The subtitle is then positioned in area A shown in Fig. 4. The purpose of this procedure is to burn-in the stereoscopic subtitles in the test pattern as a reference. While the subtitles in position A are part of the main picture the subtitles in area B are to be rendered during the projection

of the DCP. The proximity of the two subtitles makes it easy to verify if the subtitle render process of the projection system matches the intended subtitle position during the authoring process.

Evaluation of the projection system compliance with the features of the test pattern can be achieved by simple visual comparison: If the subtitles in area B match all the subtitles shown in area A, the projection system complies with all the features of the subtitle compliance test DCP. If subtitles are omitted, the non matching specifications can be identified. And eventually, if subtitles are rendered, but not positioned as intended, this can indicate, that some features are ignored or not implemented by the projection system.

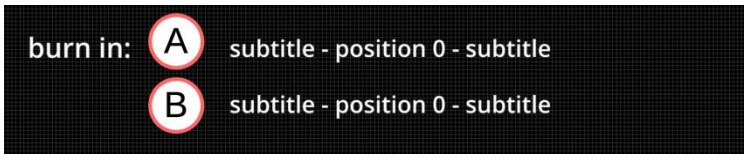

Figure 4. burned-in subtitles (A) and rendered subtitles (B)

Description of the test sequence:

4.1 Static Stereoscopic Subtitles

Subtitles number 1 to number 5 identify the individual parallax positions as indicated on the test pattern. The values correspond to the negative and positive parallax values in table 1. The depth values are expressed in the parameter Zposition of the SMPTE subtitle specification[1]. According to this specification from 2014 the cinema playback system has to render these subtitles in 3D. Systems implementing a standard prior to this specification might not render the stereoscopic digital cinema subtitle as intended. This can be verified by the proposed test DCP. The code in the subtitle file to be evaluated by this part of the test is shown in Fig. 5.

```
<Subtitle SpotNumber="1" TimeIn="00:00:10:00" TimeOut="00:00:15:00">
    <Text Valign="bottom" Vposition="20.00" Zposition="0.0">subtitle - position 0 - subtitle</Text>
</Subtitle>
<Subtitle SpotNumber="2" TimeIn="00:00:15:00" TimeOut="00:00:20:00">
    <Text Valign="bottom" Vposition="20.00" Zposition="-0.5">subtitle - position -0.5 - subtitle</Text>
</Subtitle>
<Subtitle SpotNumber="3" TimeIn="00:00:20:00" TimeOut="00:00:25:00">
    <Text Valign="bottom" Vposition="20.00" Zposition="-1">subtitle - position -1 - subtitle</Text>
</Subtitle>
```

Figure 5. static positioning of 3D subtitles using Zposition

4.2 Dynamic Stereoscopic Subtitles

The SMPTE specification from 2014 also describes a procedure for dynamic stereoscopic subtitle positioning[1]. For this the subtitle file uses an array of value-duration pairs loaded in a variable named VariableZ. The purpose of this parameter is to allow a change in depth position during the showtime of one specific subtitle. This can be necessary if the content of the images contains part of an image that suddenly moves to the negative parallax out of the screen. As the subtitles are generally in front of the action, it can be necessary to dynamically move the subtitles in to negative parallax as well. Without this, the subtitles need to anticipate the frontmost position all the time. If the positioning in space is not corrected, visual discomfort and confusion of the viewer can result.

However, this implementation is described as optional in the specification. It is therefore difficult to know which projection system implements the stereoscopic subtitles using VariableZ or not. As the authoring process for a variable parallax positioning of subtitles requires generally more work in the authoring process, it can be useful to evaluate if the additional work will actually be visible in the projection.

The implementation of the dynamic positioning of stereoscopic subtitles can be evaluated in the second part of this test DCP. For this purpose the last series of three subtitles specify different dynamic transitions: The first one move the subtitle over the whole test range from negative 2% to positive 2% parallax. The last two subtitles show transitions with various different durations. The code of the digital cinema subtitle file is shown in Fig. 6.

The specification using VariableZ determines positions and durations for variable subtitles. However, it does not specify how the subtitles moves from one position to another. The test DCP implements a smooth transition and interprets the different positions as dynamic keyframes between which the parallax values are interpolated. This is to make the change in position as much invisible to the viewer as possible. As this is not specified in the specification, the test DCP can also be used to examine how the transition between parallax positions is implemented. This can give recommendations for the future subtitle authoring process.

```
<Subtitle SpotNumber="11" TimeIn="00:01:05:00" TimeOut="00:01:20:00">
    <LoadVariableZ ID="Zvector1">-2.0:120 0.0:120 2.0:120</LoadVariableZ>
    <Text Valign="bottom" Vposition="10.00" Zposition="-2.0" VariableZ="Zvector1">animation -2 to 0 to 2</Text>
</Subtitle>
<Subtitle SpotNumber="12" TimeIn="00:01:24:00" TimeOut="00:01:39:00">
    <LoadVariableZ ID="Zvector2">0.0:120 2.0:120 -2.0:120</LoadVariableZ>
    <Text Valign="bottom" Vposition="10.00" Zposition="0.0" VariableZ="Zvector2">animation 0 to 2 to - 2</Text>
</Subtitle>
<Subtitle SpotNumber="13" TimeIn="00:01:42:13" TimeOut="00:01:57:13">
    <LoadVariableZ ID="Zvector3">2.0:180 0.0:180</LoadVariableZ>
    <Text Valign="bottom" Vposition="10.00" Zposition="2.0" VariableZ="Zvector3">animation 2 to 0</Text>
</Subtitle>
```

Figure 6. Dynamic positioning of 3D subtitles using VariableZ

This sequence of subtitles identifies the potential playback challenges of stereoscopic subtitles for digital cinema. The proposed DCP was then tested on multiple playback systems to evaluate its effectiveness in identifying compliance issues.

5. RESULTS AND DISCUSSION

Initial testing with the proposed DCP revealed that software players such as easyDCP used for quality control in small production companies were able to manage the playback of subtitles using Zposition as intended[7], [8]. This means that this part of the specification was implemented well. The implementation of subtitles using VariableZ throws validation errors during the authoring process on different systems. Fig. 7 shows a part of the playback screen of the software easyDCP. It is clearly visible that the burnt-in subtitles have the same parallax as the rendered subtitles.

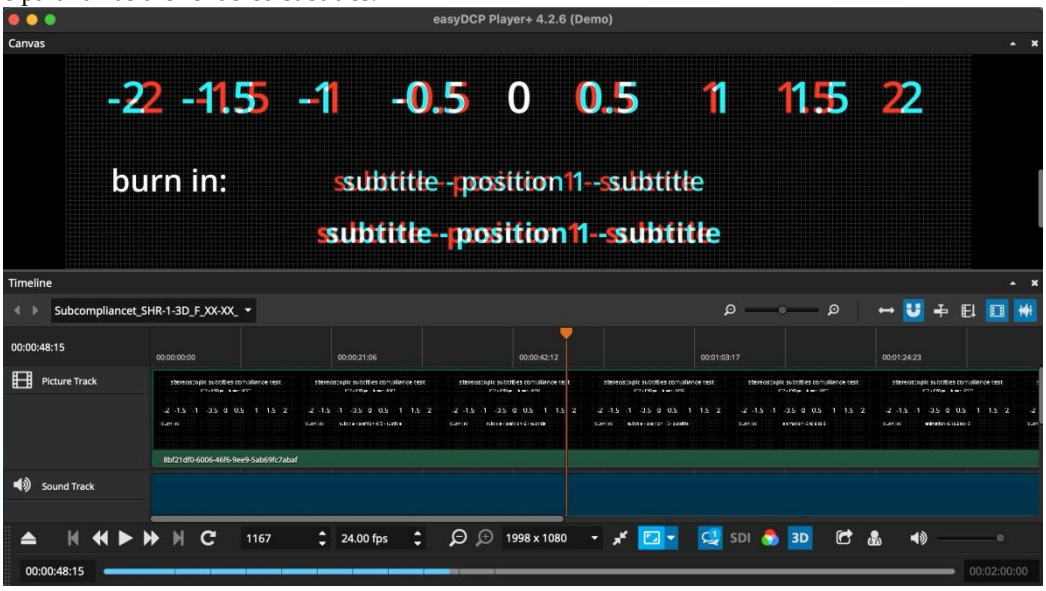

Figure 7. playback of the test DCP

The test DCP is able to reveal inconsistent depth rendering. Additional feedback from cinema operators and engineers indicated that the DCP's test patterns and scenarios provided valuable insights into system performance.

6. CONCLUSION AND FUTURE WORK

The development of a stereoscopic subtitle compliance test DCP represents a significant step toward ensuring consistent and high-quality subtitle playback in 3D cinema. The proposed test DCP is specially designed to determine the capabilities of the stereoscopic subtitle playback system. It represents a valuable tool, to verify the compliance of the playback system with the latest SMPTE stereoscopic subtitle specifications.

Some challenges remain. Fig. 7 shows some different in text size is visible which requires further matching in the subtitle file and the rendered subtitle in the main picture. Future work will focus on expanding the test DCP to include additional scenarios and also evaluate the legibility of stereoscopic subtitles in the compliance verification. It also occurred that the important validation of the subtitle xml by means of an xml schema definition (XSD) file accepts any arbitrary value of text in the parameter of variableZ while it should

contain an array of decimal values and integers to signify parallax and duration, the parallax value always being the same type of decimal value as in variableZ. Fig. 8 shows the definition of variableZ and Zposition.

```
– <xs:attribute name="Zposition" use="optional" default="0">
  – <xs:simpleType>
    + <xs:restriction base="xs:decimal">
    </xs:simpleType>
  </xs:attribute>
– <xs:attribute name="VariableZ" use="optional">
  – <xs:simpleType>
      <xs:restriction base="xs:string"/>
    </xs:simpleType>
  </xs:attribute>
```

Figure 8. xml schema definition for elements variableZ and Zposition

Updating the schema definition could improve the validation process of stereoscopic subtitles for digital cinema. As mentioned in the previous section the transition between different parallax values could be defined more precisely. An additional recommendation for the implementation of subtitle rendering could help standardize projection and authoring process.

7. CONFLICTS OF INTEREST

The authors declare no conflict of interest.

8. ACKNOWLEDGEMENTS

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