ABSTRACT

3D film allows filmmakers to create visual imagery that is no longer bound to the single plane of the screen. Often occupying the z-space, 3D imagery provides a suture beyond the narrative, by placing the audience within the frame. Although surround sound has been described as being 3D, and new immersive sound technologies are marketing themselves as being 3D, is the contemporary cinema soundtrack homogenous with the 3D imagery? As the image and the sound occupy two individual volumes within the cinematic z-space, the relationship between image and sound is fracturing, highlighting a dislocation. The relationship between the imagery and the soundtrack is being challenged with the added dimension of the visuals. This paper investigates the spatial relationship of 3D film sound and vision within contemporary 3D cinema.

INTRODUCTION

Stereoscopic 3D filmmaking allows filmmakers to rethink the use of the cinematic frame. The increased depth of the 3D image has added to the complexities of framing the accompanying soundtrack. With 2D having height and width defined by X-Y coordinates, 3D additionally has both...
positive and negative z-depth. If an image is framed with negative parallax, the image is perceived to be between the screen and the viewer and inside the negative z-space, whereas if the image is framed with positive parallax, the image is perceived as being beyond the screen in positive z-space. Maintaining a cohesive bond between the sound and image within this z-space is one of the greatest challenges facing 3D film as these 3D volumes do not perfectly overlap. Mendiburu (2009, p.155) states: ‘The multichannel sound occupies the theatre room, with left, centre, right, and LFE sources right behind the screen, and one or two layers of stereophonic sources along the room length. The stereoscopic image occupies a volume designed by the comfort zone, a truncated triangle that extends a long way beyond the screen.’

Adding complication to the issue, each respective volumetric space is relative to each possible seating position within the cinema. For example, the perceived spatial volume occupied by the sound and vision from seat A1 differs from the perceived spatial volume from seat Z40. When a cinema is incorrectly calibrated or the speaker closest to any viewer dominates, especially the surround speakers, additional challenges arise. Each cinema is designed differently, with different dimensions, different noise floors and different acoustic treatment and design. As materials change, and dimensions change, so too do the acoustic properties of the cinema, making it difficult for re-recording mixers to create a single mix that is acoustically transparent across all cinemas, and/or all seating positions.

Lacking confidence due to acoustic and speaker inequalities between cinemas, the re-recording mixer rarely mixes the film for the most spatially accurate outcome, instead opting for a safe mix. These issues are common occurrences, supporting the argument of why mixers tend not to ‘push’ too much sound into the surround speakers. Although not as much an issue for 2D, this lack of confidence in cinema playback spatialisation stifles creativity and more importantly, places limitations on the narrative of 3D films.

Designers of digital technologies are endeavouring to promote self-calibrating cinemas, though this requires costly upgrades. As immersive sound technologies, including Dolby Atmos and Auro 3D, show increased installations into premium cinemas, the concept of creating a ‘spatially confident’ soundtrack is beginning to gain traction. However, despite immersive sound providing a newfound growth in confidence in the panning of soundtrack elements, a dislocation between the image and soundtrack remains evident through competing cinema spaces. Due to a deficiency in language, the inability to articulate the use of space for sound also thwarts overcoming some of the technical and creative limitations.

**FILM DEPTH AND SPACE**

Surround sound provides an additional dimension to 2D films by allowing sound to emanate not only from the image plane, but also from the side and rear of the audience, and now with immersive sound, also
from above; sound emanates from around the perimeter of the auditorium. There is much debate as to what constitutes 3D sound and this paper will not enter this debate. Altman (1992: 24) describes sound recordings as having their own unique “spatial signatures,” carried in the audible signs of each hearing’s particularities. He explains that even though these signatures may not necessarily match the visual data, they still have spatial information. This spatial information is encoded, and the sound designer may choose to exploit this information or they may chose to ignore it through digital audio manipulation. By placing sound through the various cinema speakers, the sound designer can introduce many new aural situations that complement 2D imagery and provide sonic immersion. Lon Bender believes that it is ‘an amazing experience putting sound to picture and have them leap off the screen at you and create a whole three-dimensional world, even when the movie is not 3D’ (Wilkinson 2014.). Sergi (2001: 124) takes this notion further, stating that ‘once inside the auditorium, we are confronted with a situation where we’re placed “inside” the filmic space, not simply in front of one. The invitation to explore these new surroundings is emphasised by the way sound designers have approached the concept of audience space and the reproductive environment.’

The concept behind the ‘atmosphere and ambience’ soundscape is to situate the audience within the onscreen environment. If we think about our real world, we know that our eyes see in front of us, yet we hear sound from all around us; in front, the sides, behind and above. Traditional surround formats have done a believable job of allowing sounds to emanate from in front, from each side and from behind the audience – and through a combination of these, sometimes even from above. The ‘ambience and atmosphere’ tracks are less dependant on onscreen action, as their sole purpose is to situate the audience within the onscreen environment and not to draw attention to any particular onscreen element. By not relating directly to the image, these ‘ambience and atmosphere’ tracks contribute to the image by situating the audience within the frame – within an auditory space. Although the atmospheres and ambiences are less dependent on visual cues, the same cannot be said for the other sound elements including dialogue, sound effects and foley.

Through surround sound, new immersive sound formats and 3D imagery, the frame has become unbound, allowing it to extend into the audience. This differs from previous 2D technologies including Cinerama, which had the vision contained to a single plane, regardless of the screen size. Rick Altman (1995: 68) recognises that ‘sound was once hidden behind the image in order to allow more complete identification with that image, now the sound source is flaunted, fostering a separate sonic identification contesting the limited, rational draw of the image and its visible characters.’

The dialogue, sound effects and foley elements are often dependent on the image, and they are now posing spatial relationship conflicts with the 3D imagery within z-space. 2D films do not require accurate sound placement in z-space as the image is on a single plane, unlike 3D films.
Bonding sound with 2D imagery along the x-axis is possible, as the placement of onscreen sound is positioned utilising a combination of the three screen speaker channels. The surround channels primarily support off-screen cues and are not image dependent. The introduction of 3D vision has meant that the surround channels are now not only used for off-screen sound, but more importantly, they are often required to support the visuals in z-space along the z-axis. The added image depth of 3D is posing new challenges for the accompanying supporting sound. Visual cues are coming ‘out of the screen’ in 3D and require sound effects and dialogue to match the spatial positioning without losing cohesion. Although the soundtrack for 3D remains largely unchanged from 2D, the traditional 2D film sound working methodologies have become incompatible in many instances, as it is difficult to pan sounds ‘off the screen’ into z-space to match the imagery and this creates competing cinema spaces.

During an interview at Skywalker Sound, David Acord (2012) spoke about the differences between 2D and 3D that he has experienced. Acord noted that there had been much discussion at Skywalker about the resurgence of 3D and ‘how to handle that whole centre channel issue.’ The issue of dialogue placed only in the centre channel is highlighted in Hugo (2011) when the Station Inspector, played by Sacha Baron Cohen, speaks to camera. In the 3D version, the Station Inspector is framed in negative parallax, but the dialogue does not follow the imagery along the z-axis, instead only coming from the centre speaker, thus breaking the bond between image and sound through conflicting spaces. The 2D version has the image and the sound originating from the same plane, and this is far more effective. As David Sonnenschein (2001: 159) points out, sound induces the sensation of space, volume, and texturing of a film. He further states that distance and dimensionality is coded by our body, and when it is combined with vision, the viewer is ‘immersed in a more complete virtual reality.’

Despite the widespread use of surround sound, there remains a lack of language able to describe the localisation of sounds. Industry has ways to describe the use of the individual speaker channels, volume and frequencies, but there remains a limitation in the language used to articulate the placement of surround sound within the cinematic space. Terms such as ‘pull off the screen,’ ‘bring into the room,’ ‘push the surrounds,’ ‘reduce the mids,’ ‘hit the sub a bit harder,’ and ‘pull out of the centre,’ describe the process of how to achieve the outcome, however these terms are all relative and lack quantification and specificity.

To allow articulation for the limitations between cinema sound creation and the exhibition of surround sound I introduce two terms. I propose that the term positional data be used to identify the location given to a sound during the input stage (editing and mixing), and the term positional rendering be used to identify the location of the sound when played back during exhibition, relative to the cinema space.

Positional data is the pan location assigned to a sound during the production process. Limitations to positional data can be the result of
the sound team having to work with 2D imagery, or by not having enough
time to pan individual sounds. By not having access to 3D imagery (even if
only used for referencing), the sound crew is unable to identify the position
of objects along the z-axis within z-space. As time spent in the final mix is
expensive, there is seldom time to adjust panning in the final stages of
production. Further compounding the issue, many sound crews are
creating soundtracks for either 5.1 or 7.1 releases and it is not until after
mixing has begun that immersive releases are considered, or the soundtrack
is considered in relation to a 3D stereoscopic release.

Positional rendering refers to the ability of a cinema sound system to
reproduce accurately a sound in order to appear in exactly the same
apparent location as the sounds positional data. Contemporary 3D films
are in either 5.1, 7.1 or immersive sound formats, with the spatial positional
rendering accuracy of the soundtrack confined to the configuration for each
format. For example, the sound in the left surround channel will be
positioned differently between 5.1, 7.1 and the immersive sound formats.
Due to varying speaker placements, there are discrepancies in the spatial
positioning of sounds, contributing to competing cinema spaces.

The utilisation of the cinematic volumetric space is complicated as both
the 3D vision and the surround sound are independently bound to their
own conventions and technical limitations. This highlights not only a void
in the articulation of spatial sound language, but also a void in describing
sound that is dependent on being attached to 3D imagery. Using the visual
xyz coordinate model and applying it to sound enables a more effective and
accurate solution.

3D allows filmmakers opportunities to rethink the use of the frame of
the image as well as the use of depth and space. As 3D film develops, there
are additional considerations and creative opportunities when telling a
story compared to 2D. One of the recent developments has been through
the introduction of the depth script. The use of a depth script allows the
depth of the image to be plotted against the film’s timeline, allowing the
use of z-space to change in relation to the narrative and the on-screen
action. The use of image depth is not unique to 3D film production as it is
also used with 2D films. However, no matter what extent the depth of a
shot is, in 2D the image always sits on a single plane — that is, all depth
cues, including foreground, background and perspective, remain visually
located on a single image plane.

The depth script allows the director to plan for increased immersion,
and therefore the way that scenes are filmed and exhibited. Although a
sonic equivalent does not formally exist, the visual depth script can provide
valuable additional information and cues in creating a more coherent and
immersive soundtrack. This would strengthen the bonding of image and
sound. Randy Thom (1999: 6) suggests that ‘whenever we as an audience
are put into a visual “space” in which we are encouraged to “feel” rather
than “think”, what comes into our ears can inform those feelings and
magnify them.’

It is the soundtrack that provides the additional depth cues to the 2D
imagery. Mixing sound for cinema to evoke apparent depth necessitates
following conventions and working methodologies that allow the sound to provide the illusion of depth. Primarily this includes the use of reverb,
panning frequency filters and volume mapping. David Sonnenschein (2001: 160) indicates that:

Layers of space can be distinguished by their respective sound qualities and the proportion of direct to indirect signals. If characters are close, their voice will have more high frequencies and less reverb from the ground and walls; as they retreat these qualities invert. In this manner, the space and distance can actually be implied by the sound, even if we don’t see the character or source of the sound event.

Although providing additional depth to 2D films, this approach is less effective when applied to 3D films. A thorough understanding of image depth is paramount to effective 3D film production, including an understanding of depth relative to shot composition, depth of field and parallax. Sound is no different and can be compared to its visual counterpart. As stated by Sonnenschein (2001):

With the use of surround channels a tremendous variety of aural movement can accompany images that come and go on the screen. Any such occupation of the real 3D space of the theatre helps break through the 2D film image to create a 3D visual space as well.

Surround sound adds another dimension, however, I argue Sonnenschein’s statement only applies to 2D films. For 3D film, the use of the z-axis and z-space commonly creates dislocation between the sound and image. 2D films have the sound and image on a single plane, with the additional surround speakers adding value and dimensionality. With 3D, as the parallax becomes either negative or positive, the sound becomes detached from the image despite the use of additional surround speakers.

Several complexities obstruct the bond between sound and image. A 3D scene may contain elements that are in negative or positive parallax; or possibly both concurrently. All contemporary surround sound formats are capable of producing a homogenous relationship between image and sound across either a 2D image or a 3D image situated with neutral parallax. Through the use of the three screen channels (Left, Centre and Right), this is effective. As an image comes into z-space, for the sound to maintain its bond, it relies on the use of the surround speaker channels. Capable of producing sounds in z-space, current sound formats are unable to position a particular sound accurately; instead the surrounds flood the space with sound, placing it in its own space. Further limitations become noticeable when an image is in positive parallax. As the image goes beyond the screen plane, the sound emanates from the 2D plane in front of the image, and not within the same space. The only method of
addressing this is to use the 2D sound mixing methodologies, but these are not ideal.

As described previously, the 2D film sound convention of placing dialogue in the centre speaker channel despite the image being in negative parallax is highlighted in Hugo. This is not a unique example – instead this remains the normal dialogue mixing practice for most 3D films. In almost every frame of Hugo the main character dialogue is exclusively reserved for the centre speaker channel. The only dialogue that tends to utilise any other channels is general hubbub and crowd vocalisations. These are generally unintelligible lines of dialogue that help situate the environment. They are placed in the left, right, left surround and/or right surround channels to create the illusion of space. This is also aided by the re-recording mixer applying reverb and filtering to help situate the crowds into a particular space. In Hugo this is the railway station. The obvious solution for this is to pan the dialogue from the centre screen speaker and into the surround speakers. In theory this seems a plausible solution as conventions from 2D filmmaking have had an audience believe that sound coming from the surround speakers is creating 3D sound, or sound with an additional dimension. The execution of this is far from accurate. Due to the acoustic properties of the speakers and the cinematic space, there is crosstalk from the speakers, making sound localisation ineffective. This crosstalk makes the voice appear to be coming concurrently from in front of the audience, and from either side and behind the audience, as shown below.

![Dialogue from centre and surround speakers.](image)

Figure 1. Dialogue from centre and surround speakers.
With sound emanating from the front, sides and rear of the cinema, the localisation of the dialogue is ill-defined, hence the re-recording mixers’ hesitation to change the film sound convention of having the dialogue in the centre speaker. This convention dates back to early cinema sound. Altman (1995) suggests that ‘given Hollywood's establishment during the Thirties of a clear preference for clarity of dialogue over careful matching of sound and image scales, it is hardly surprising that stereo imaging would eventually be reserved primarily for music, with dialogue routed uniquely through the centre speaker.’

Academy Award-winning Re-recording Mixer Andy Nelson also abides by this Hollywood notion of keeping dialogue in the centre channel, even with 3D films. When asked if he mixes dialogue differently for 3D Nelson (2012) states that he doesn’t, ‘because if you even tried to start putting dialogue into the surrounds to pull it off the screen, it would become very much like a voice of god – it wouldn’t really anchor itself on the character, and I don’t personally think that would work.’ Nelson’s notion of not wishing to pull the dialogues off the screen is also shared by Australian Sound Designer/Supervising Sound Editor and Re-Recording Mixer Wayne Pashley. When discussing panning dialogues into z-space, Pashley (2011) states that ‘in a feature film where the story and the dialogue is so important to drive the narrative forward, I think (it) is very dangerous to over push it.’ Gwen Whittle (2012), Supervising Sound editor on *Avatar* (2009) also describes the placement of dialogues in the surrounds as too distracting, taking you away from the screen in front of you. Additionally Whittle suggests that just because the speakers are there, some people abuse this simply because they can, however, they need to be very careful. The art of mixing a film is knowing where to direct the audience’s attention in relation to the story. In many instances, and as history has shown, the direction is always forward towards the screen. *Gravity* (2013) is an example of these rules having been broken deliberately.

With the centre channel reserved for the main dialogue and foley, all other sound elements are placed in any of the remaining channels. This flexibility allows the sound effects and sound design to take advantage of new technological advancements, utilising the creative potential of placing sounds around a room. The simplest of examples is a bird flying from left of screen to right of screen. In this instance the wing flaps and bird tweets pan with the image from the left screen speaker to centre and then through to the right hand speaker, creating the illusion of movement, convincing an audience that the bird is in fact real.

Consider this same scenario in 3D with the exception that instead of flying from left to right, the bird now flies from strong positive parallax, through zero and into strong negative parallax. The bond between the visual and the sound panning will no longer be accurate. This is a result of the sound originating from the centre speaker, additionally coming through the left and right speakers depending on the framing, before finishing in the surround speakers. Although we will get some sense of sound in front and then behind us, we are unable to have the bird sound as
though it is flying through the middle of the cinema space. Sonnenschein (2002: 168) suggests ‘when sound works well with the image, the impression is that the sound is already contained in the image itself.’ However if we close our eyes, the apparent position of the soundtrack rendered in space (positional rendering) will be different, and this is different to the space occupied by the visuals. Questioning our understanding of sonic space, Denis Smalley states:

Focusing on space as the key, integrating element requires a reorientation of listening priorities and attentions: in my experience we are not that used to listening out for spatial attributes, for spatial forms, and space-form, partly because there is so much else to listen out for. But perhaps this is also because we are not sure what space really is, in sonic terms, or that we lack a sufficiently comprehensive bundle of concepts to talk about it, or that we think it tangential rather than central. (Smalley 2007: 35)

*Gravity* (2013), a film set in space, provides an example of defining sound space. It is the detail in establishing the environmental vastness that enables the soundtrack to punctuate and accentuate this infinite perception of space portrayed by the visuals. Shot in 3D, *Gravity* has explored not only the visual medium, but also the sonic medium so that both elements work in unison. Smalley suggests that: ‘A listener needs time to progress from an initial listening encounter with the soundscape to a state of engaging actively and fully in scanning and exploring the spectromorphological and spatial properties on offer.’ (Smalley 2007: 37) *Gravity* provides an example of this.

Listening to the sound depth of a film, one must distinguish between the ambience and atmospheric sounds that are creating the locale, and the sounds that are tied to the visual cues. The atmospheric sounds allow the sound designer to portray an infinite amount of depth depending on the story. Although the atmospheric sound is very sparse throughout *Gravity*, it is the use of sonic space through a well-crafted ambience soundtrack that allows the viewer to be further immersed into the visuals. The on-screen action directs the viewer to the movement, and the accompanying sound draws the audience’s active listening attention.

*Gravity* begins with a musical crescendo before abruptly stopping to complete silence, reflecting the science of space. In many ways the film is mixed quite unconventionally, in that the dialogues do in fact pan across screen and beyond, with the characters even panning into the surround speakers. Notably the music is also composed for surround sound with different elements panning throughout the various speakers, at times spinning around the room alongside the camera and dialogues. In an interview for the *Soundworks Collection*, director Alfonso Cuarón makes particular mention of how the panning of the dialogues and the music helps provide a superior immersive experience (Coleman 2013). In combination with the atmospheric soundscape, *Gravity* is successful in providing an aural illusion of infinite space by allowing the music and
dialogue to pan and make use of all speakers. This was a brave move by Cuarón as it goes against convention. Cuarón made a conscious decision to allow the sound and the speakers to work for the narrative of the film, rather than following traditional mixing practices. *Gravity* was released in Dolby Atmos in addition to 5.1.

**IDENTIFYING THE SPACE**

Smalley (2007: 48) uses the terms ‘prospective space,’ ‘panoramic space’ and ‘circumspace’ to describe three identifiable boundaries of the cinematic space as shown in Figure 2. ‘Prospective space is the frontal image, which extends laterally to create a panoramic space within the range of vision; circumspace – space around the listener – extends panoramic space to encompass the listener.’

The diagram above illustrates how stereo sound relates to Smalley’s definition, as the sound emanates from in front of the viewer. With increases in surround sound channels and immersive sound systems, this diagram is no longer applicable. Instead, I propose that the increased spatial definition within contemporary cinema sound systems (that is, 5.1, 7.1 surround, immersive sound) and surround speaker placement provide three spaces ‘around’ the viewer/listener as illustrated in Figure 3.

Current surround sound formats provide adequate directionality and definition in both the prospective and panoramic space, but contemporary
cinema sound is unable to produce sounds exclusively or accurately within the circumspace. A limitation of current technologies and acoustic inconsistencies between cinemas contributes to this.

The inability to position sound within the circumspace is increasingly apparent with contemporary 3D films. Taking 2D film as an example, the front speakers suffice in providing an effective panoramic space. There are three discrete front speaker channels in a 5.1 system and these allow for sounds to be screen left, centre, and screen right, with any proportional panning of these speakers allowing a pan across the x-axis. As 2D images are also limited to a single 2D plane, the relationship between the image and sound in 2D films allows for homogeneity across the screen. The surround speakers are not generally used in conjunction with onscreen action and do not relate directly to an image, instead providing added value. For example, a helicopter flying in from behind the audience will use the surround speakers on the helicopter’s approach, but it will then play through the front screen speakers once the helicopter is visually on screen. An exception to this may be in very rare cases of using the first person point of view (POV) shot.
3D differs as the surround speakers can additionally be used to complement on-screen visuals that are in z-space. Although various techniques and methods are often able to create the illusion of sounds bonded to the imagery within z-space, at present there is no single definitive solution. As sound goes between the panoramic space and the prospective space, the spatial definition dissipates due to speaker crosstalk, making it impossible to have defined sound in the circumspace. Although immersive sound formats improve this to some extent by bringing sound closer to the audience through height speakers, they provide a higher level of detail and this only contributes to what becomes a canopy effect.

Creating sound elements that are connected to 3D images in negative parallax is challenging. The solution requires the re-recording mixer to utilise the surround channels to bring the sound ‘off the screen.’ Although the surrounds work well with off-screen cues, using these to bring on-screen imagery off-screen is problematic. As with the issues of bringing the dialogue off the screen, sound effects prove to be similarly challenging. As Mendiburu (2009: 155) asks ‘now that the images have caught up, how do both 3D volumes interact with each other?’

One method of keeping sound effects bonded to the image is through movement. Most sound effects tend to be connected to an action, allowing the sound to pan from speaker to speaker. Additionally with sound effects, the multiple elements that make up the sound can be panned individually. This is in contrast to dialogue that always originates from the character’s lips. An example can be highlighted in *The LEGO Movie* (2014). At the end of the film the giant yellow robot controlled by the protagonist Emmet is running towards camera with chains spinning from both arms. The feet sounds are played through the left and right speakers and the sub woofer, whilst the chain sounds are coming from the front left and right speakers and the surround left and right speakers.

**CONCLUSION**

Little research has been devoted to sound for 3D films, as previous 2D film sound methodologies continue to be used by industry, with sound mixing and sound design practices remaining largely unchanged. Additionally, there is a lack of language to describe the spatial relationship of the soundtrack and the cinematic space. The traditional 2D storytelling capabilities of the soundtrack do not always translate as well when combined with 3D visuals. Despite 3D visuals occupying the cinema z-space, re-recording mixers are hesitant panning dialogue to match the imagery due to cinema inconsistencies, recognising that this may break the suture with the film narrative. Further complicating the creative decisions made by re-recording mixers is the limitation of the cinema multichannel sound systems and acoustics. Gierlich (1992: 220) states the authentic reproduction of sound events is either not possible or only possible up to a point. Re-recording mixers are panning safely, and this limitation of not using the entire cinematic space is creating a dislocation between image and sound within z-space. With limited language, articulating the use of
space by the soundtrack is challenging. This is compounding many of the limitations facing the description and recognition of sound space for film production professionals.

The cinematic experience and conventional cinematic sound systems portray the panoramic space exceptionally well. However, as the number of speaker channels increases, these three discrete spaces become overlapped as the distance between the listener and the speakers varies depending on the seating position and speaker configuration. ‘It is impossible to predict the position of the listener or of the speakers in any given situation and impossible to compensate for multiple listeners.’ (Begault: 2000: 176) This ambiguity of space definition and accuracy contributes to competing cinema spaces between sound and image, especially with 3D films.

3D film expands upon the visual depth of a single 2D plane, and depending on the way the visuals are projected, the circumspace becomes an important sound consideration; one that has been previously overlooked. If the imagery is in positive parallax only, then the sound considerations can remain similar to 2D cinema sound practices, where the sound and image are able to exploit the use of space independent from each other. A positive parallax 3D image will not have any action within the circumspace. However any use of negative parallax will necessitate a considered approach when positioning sounds within the prospective space, and in the circumspace. The use of circumspace is inversely proportional to the amount of negative parallax, that is, as parallax becomes more negative (decreases), the importance of circumspace increases.

The inability to accurately reproduce sounds through positional rendering highlights a shortcoming in the ability of contemporary cinema speaker formats to provide a homogenous audio-visual use of 3D space. In the short term, panning sounds with movement increases the perception of sound spatialisation, increasing the bond with the imagery. Although helping to homogenise the use of the cinema space, this is a patch and not a definitive solution.

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