Understanding the zSpace 3D system for better spatial design & aesthetics

Philip Captain 3D McNally

Contents

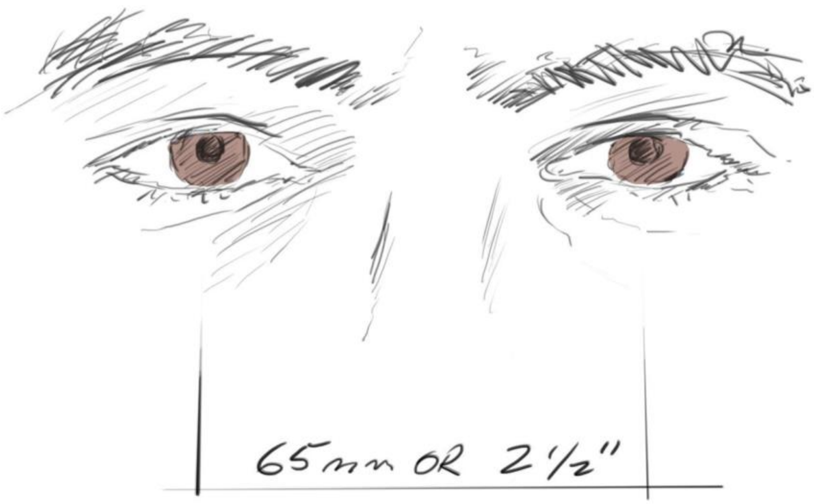
Introduction

The zSpace system is an immersive, interactive hardware and software platform that allows developers and users to interact with computer-generated objects in a three dimensional holographic-like environment.

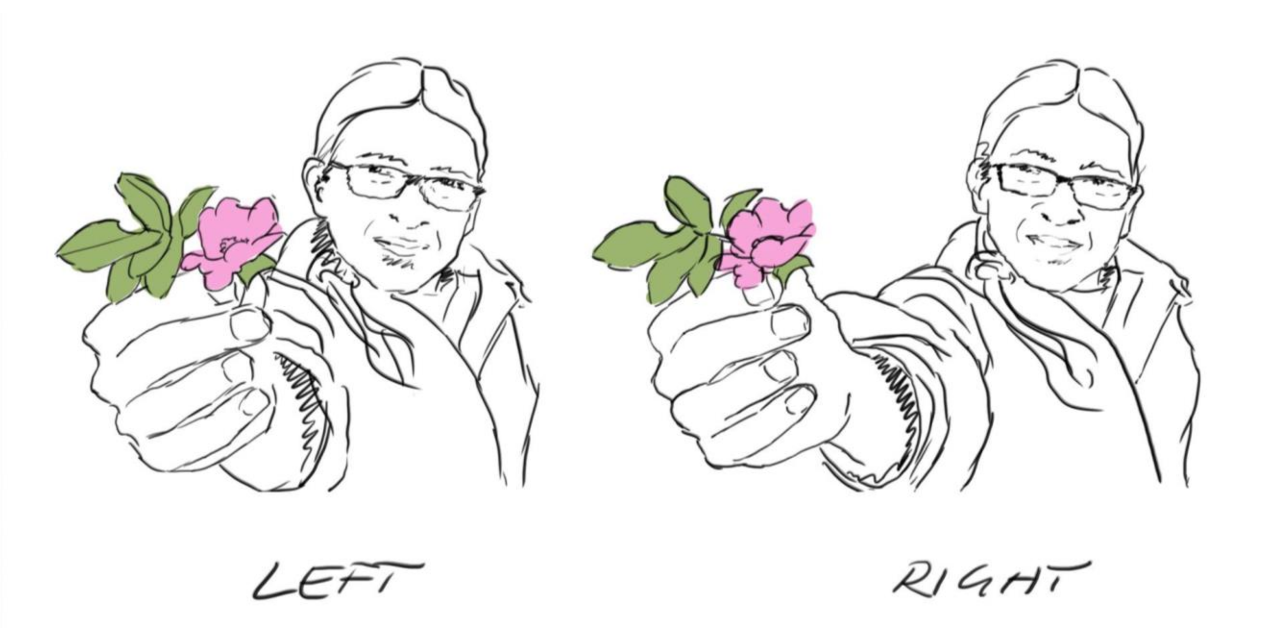
Seeing objects and scenes in 3D is the most natural and efficient way to understand the complex spatial relationships of the world around us. zSpace presents computer-generated imagery in the same dimensional way that we see the world. This creates visual excitement and an instant understanding of complex structures that would otherwise be unfathomable if viewed on a traditional 2D screen.

Human Vision Basics

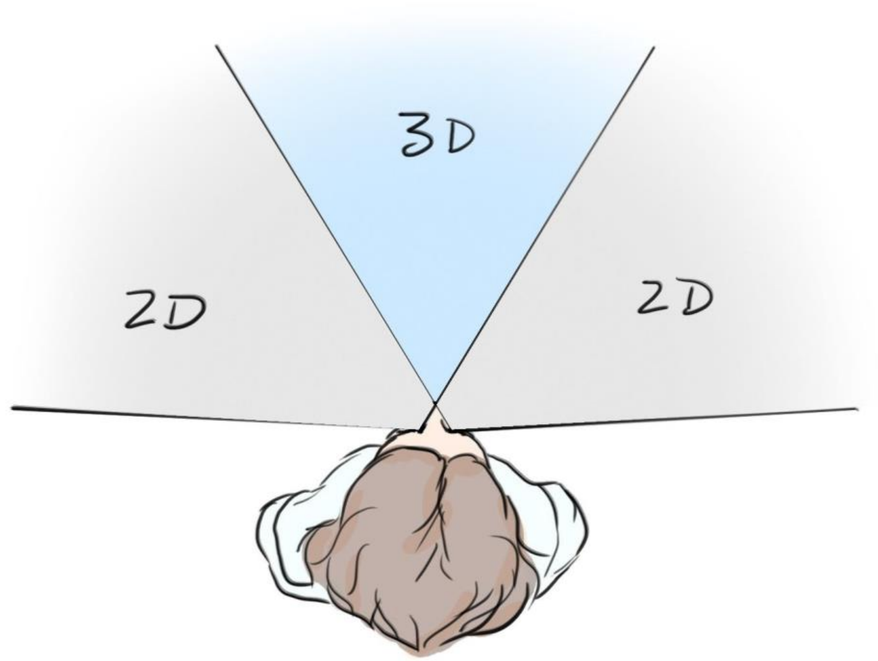
People have two eyes that point forward and we share this design with all hunting animals that need to judge distances with a high level of accuracy. Our two eyes are separated by an *interpupillary distance* of about 65mm or 2 1/2 inches.



This separation allows our two eyes to see slightly different perspectives of the world. Our brain compares these left and right eye differences in order to understand the spatial complexities of the view in front of us.



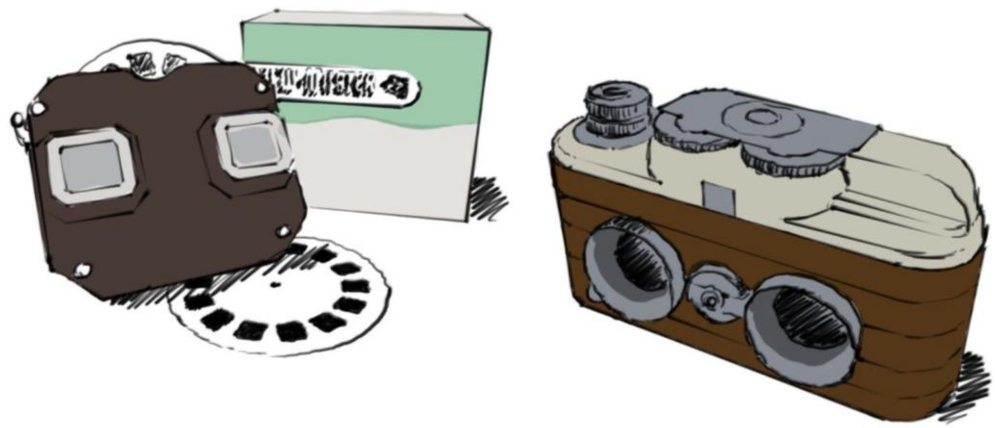
Although we can see far to the left and right, only the center of our vision system can see in 3D. The far left and right areas are mono as our nose partially blocks the view.



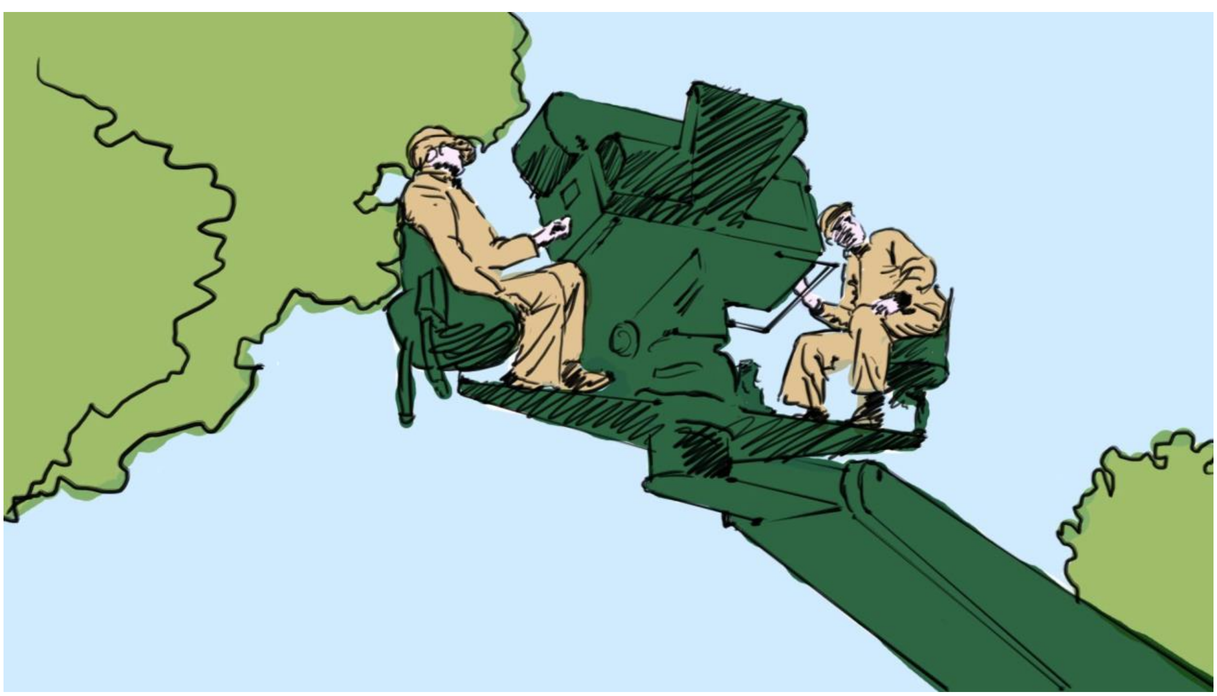
The 3D area of our vision system is a powerful tool for spatial understanding, and 3D zSpace imaging is a powerful way to understand the spatial complexities of computer-generated objects.

A Very Brief History of 3D Imaging

3D imaging has been around since about 1840 through the technique of stereoscopic photography where a twin lensed camera, which represents human eyes, captures the unique, offset left and right eye perspectives of a scene. When viewing the resulting stereoscopic pair of images, each eye receives its own left or right view and the brain recreates the illusion of space from that captured moment. It is as if the viewer had been standing there.



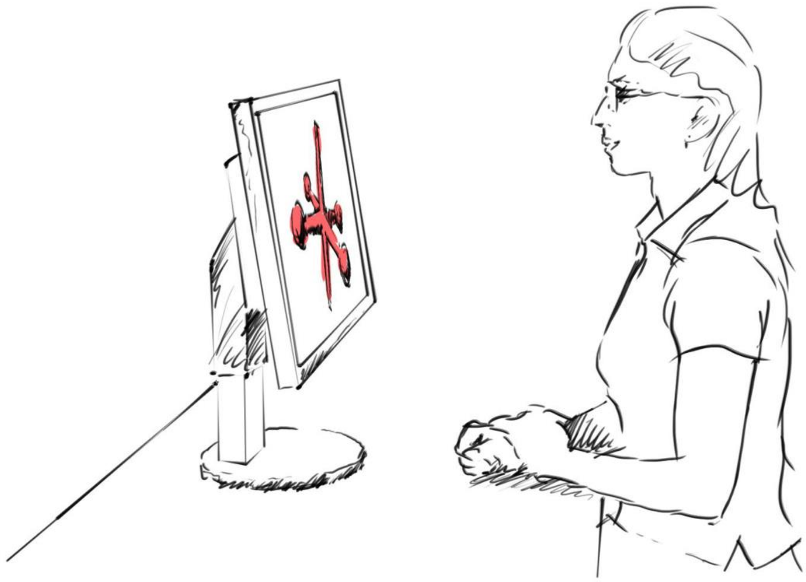
3D movies arrived as early as 1922 with "The Power of Love" and allowed the audience to experience this recreation of space, in motion, for the first time, but again, only from the predetermined viewpoint of the camera that captured scene. The same limitation is seen in 3D movies today.

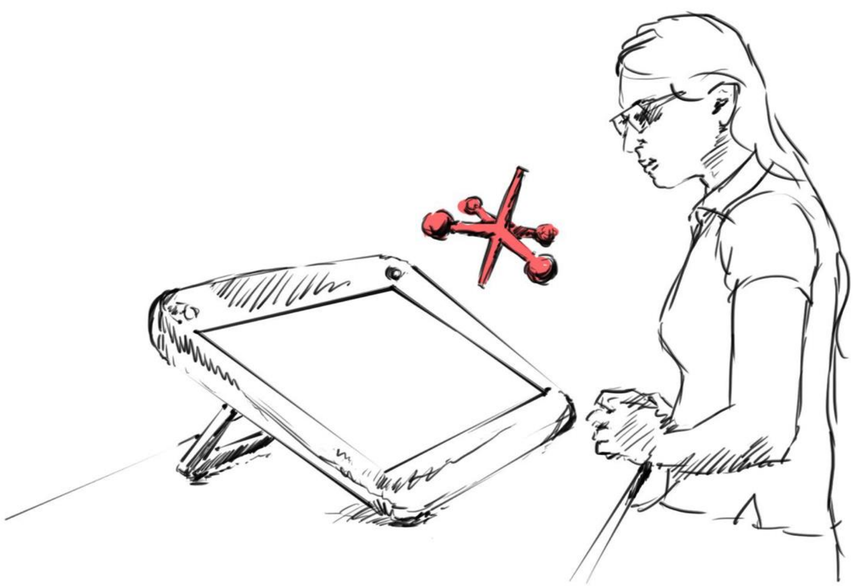


zSpace allows us not only to see 3D in motion but also allows us to look around objects and interact with the digitally-generated scene as if they were there in front of us in real life. This real-time 3D experience is a unique, futuristic, and natural way to view computer-generated imagery and is only possible today with zSpace technology.

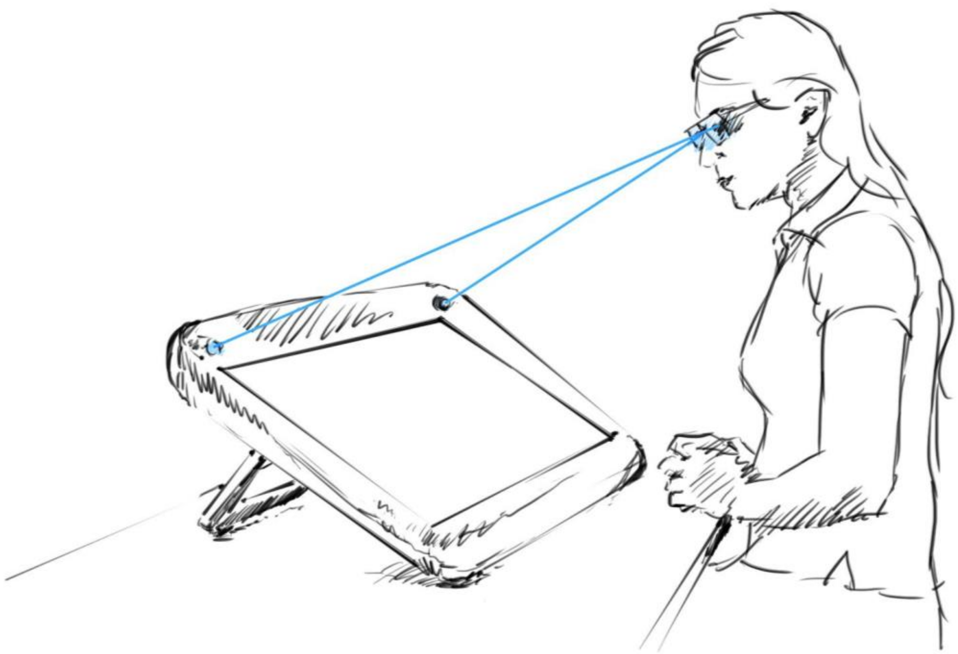
zSpace Vision Basics

The zSpace platform uses computer graphics to generate the unique left and right views needed for stereoscopic vision. This happens in real time and makes it possible for any perspective of a scene to be generated instantaneously. This allows the user to look around the 3D objects by intuitively moving their body or by manual interaction using the zSpace stylus. The result is a sense of amazement at the natural, spatial realism of the recreated computer graphic scene. This spatial realism provides a vastly superior visual experience for understanding the structure of objects and scenes when compared to viewing traditional 2D computer graphics.





zSpace can create spatial realism because it can “see” the position of the viewer’s eyes relative to the screen surface. zSpace does this by following the tracking markers on the 3D glasses worn by the viewer. With this point of view information zSpace accurately generates the correct stereoscopic perspectives on the screen surface to recreate the 3D scene from that specific angle of the viewer’s eyes. Every moment of viewing is a personal, custom made, perspective view. The 3D glasses also perform the traditional 3D role of separating the left and right stereoscopic views to the viewer’s eyes using circular polarization.



If you observe someone else using zSpace, you will see the complex perspectives being generated in realtime on the zSpace screen. Without the zSpace glasses, you will see both the left and right eye images. Note that observing with the glasses may cause eyestrain because the scene is not drawn for your viewing perspective. You may experience less distortion if you are standing close to the viewer.

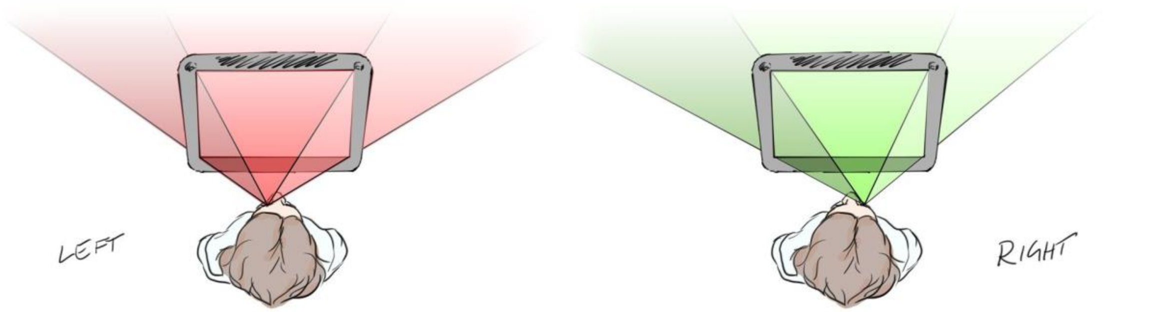
The same tracking technology is used to measure the exact position and orientation of the zSpace 3D stylus. This allows the user to “hold” and manipulate the computer-generated objects in space as if they were real.

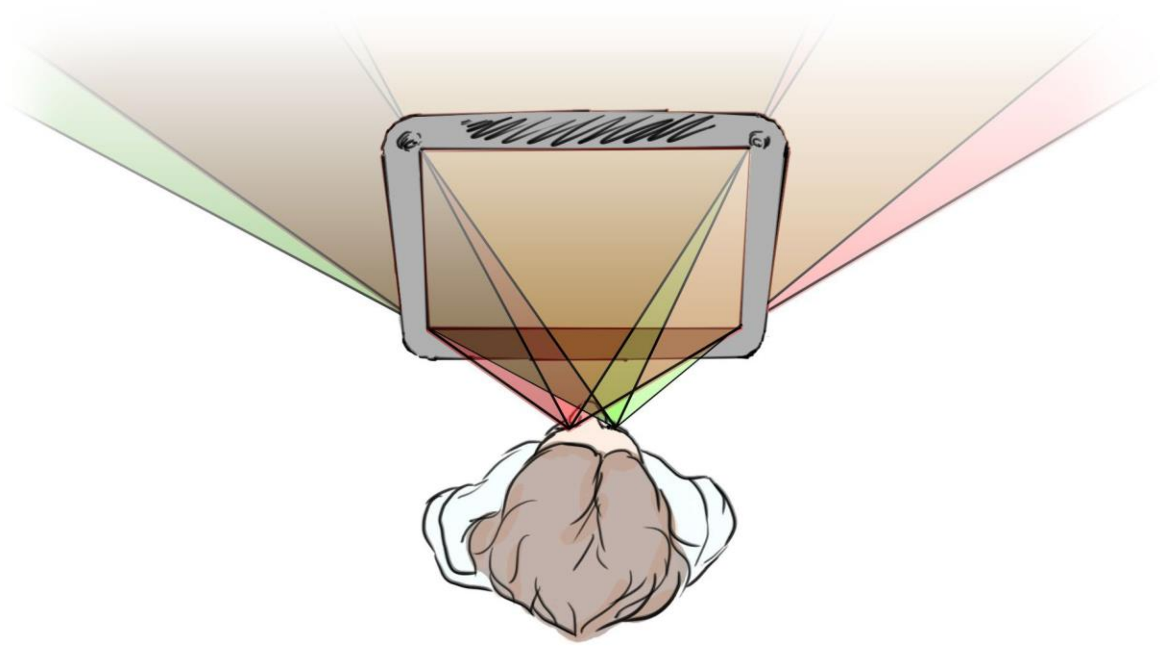
Despite the complexity of generating the unique real time perspectives, the end result is similar to the first stereoscopic photographs: a left and right image, per a moment in time, displayed on the screen surface. The left and right images are displayed alternately at up to 60 frames per second (fps) per eye or 120fps combined. As each left or right image is displayed, the screen alternately polarizes the light so that the left image can only be seen through the left lens of the glasses and the right image can only be seen through the right lens of the glasses. The eyes relay the two unique images to the brain, as they do in real life. The brain puts the images back together, and the viewer magically experiences the illusion of depth as if it were real.

A stereoscopic photograph could be made to match the human viewing condition by choosing lenses with a field of view that matches the human eyes’ field of view, spacing the lenses apart to match the human eyes’ interpupillary distance and viewing the resulting 3D image life size. This is called an *orthographic* stereoscopic image.

zSpace is, at its core, an orthographic stereoscopic experience. Its primary ability is to represent computer-generated objects as if they are sharing the same world space as the viewer watching the 3D scene and the desk supporting the zSpace monitor. Great effort has been made in the development of zSpace to make this illusion as believable as possible. Anything that unknowingly breaks the orthographic stereoscopic experience will break the illusion of three-dimensional reality.

To satisfy the orthographic condition, the screen must display the perspective of an object as if it is seen by a pair of human eyes. In this case, the field of view is not an artistic choice. It is created by the dimensions of the display connecting to the exact position of the human eyes. Two eyes mean two independent fields of view. As the eyes move in space, the fields of view are recalculated to perfectly match the new eye positions.





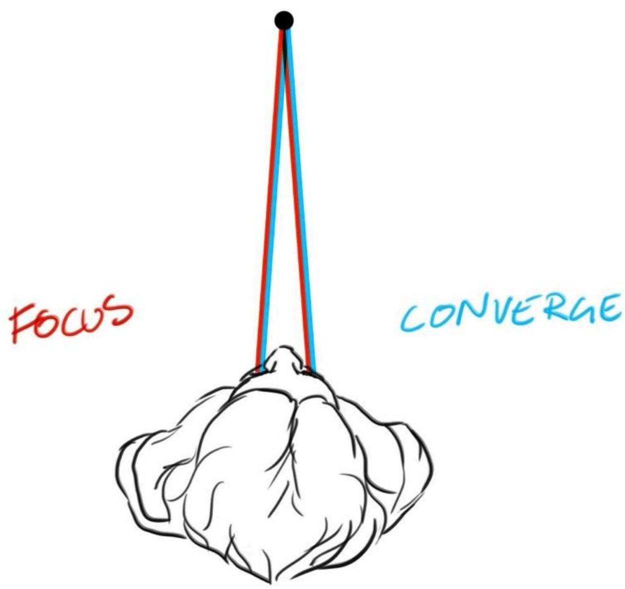
To maintain the orthographic virtual space, the objects being viewed must also match the real world scale. Therefore the perfect object for the zSpace system is an object that can fit within the screen area and maintain real world dimensions, a football or a coffee mug for example. With these conditions satisfied, the orthographic illusion of reality should be complete.

For all of this to work, the tracking of the viewer's eyes, the generation of unique stereoscopic perspectives, the recreation of real world dimensions, and the display timing must be perfectly in sync with each other. That visual combination is what the zSpace system does so well.

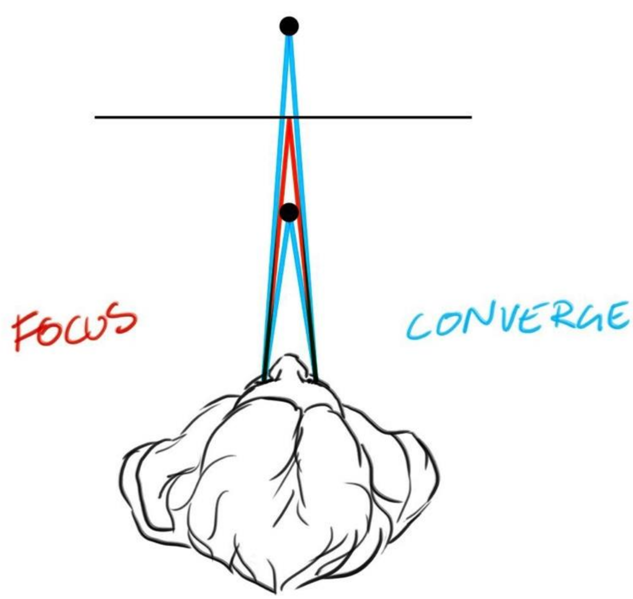
Even so, stereoscopic viewing is still not exactly the same as viewing the real world. As content developers, we must respect the differences to maximize the zSpace experience and to avoid creating eyestrain in the viewer.

Real World vs. zSpace — Focus and Convergence

When we look at an object in the real world, our two eyes converge or look at the object. As they do this, each eye's lens also focuses at the object distance. Converging and focusing become habitually coupled together at a young age.



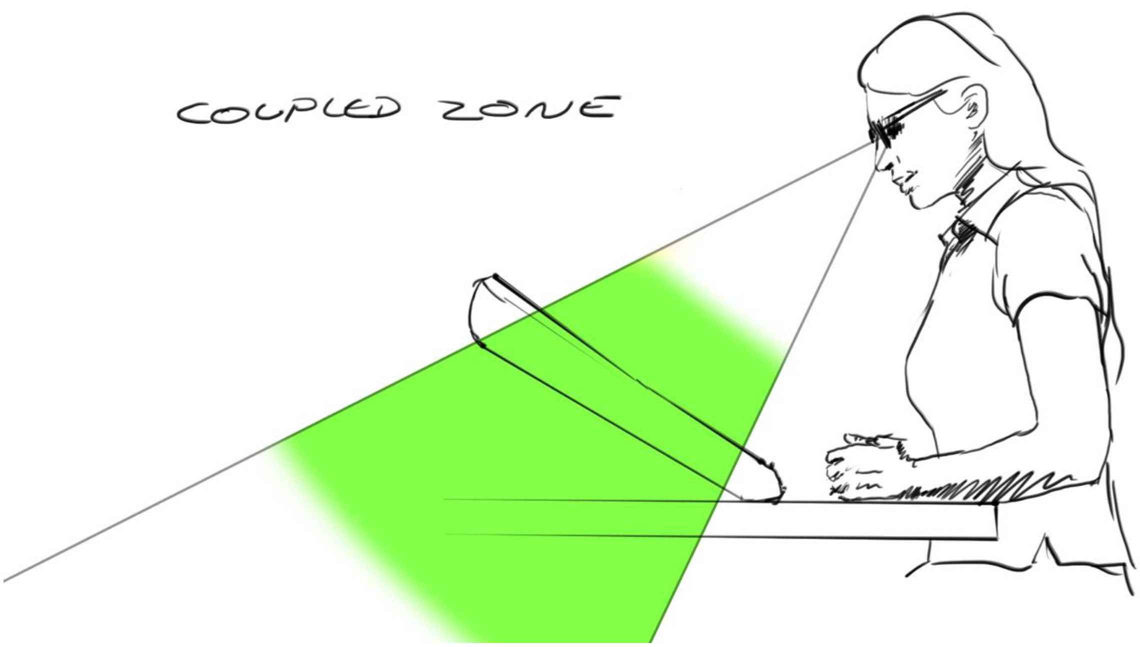
When we look at the zSpace monitor, we must always remain focused on the screen surface in order to keep the image sharp, but we must converge at different depths to see the 3D illusion.



Convergence and focus would, therefore, appear to de-couple when viewing a zSpace 3D image, but this is not the case for normal scenes. *Decoupling* of convergence and focus does not occur if the stereoscopic depth remains within the human eyes' natural depth of field. Depth of field describes the additional distance that remains in sharp focus either side of the actual point of focus.

Shallow depth of field **Deep depth of field**

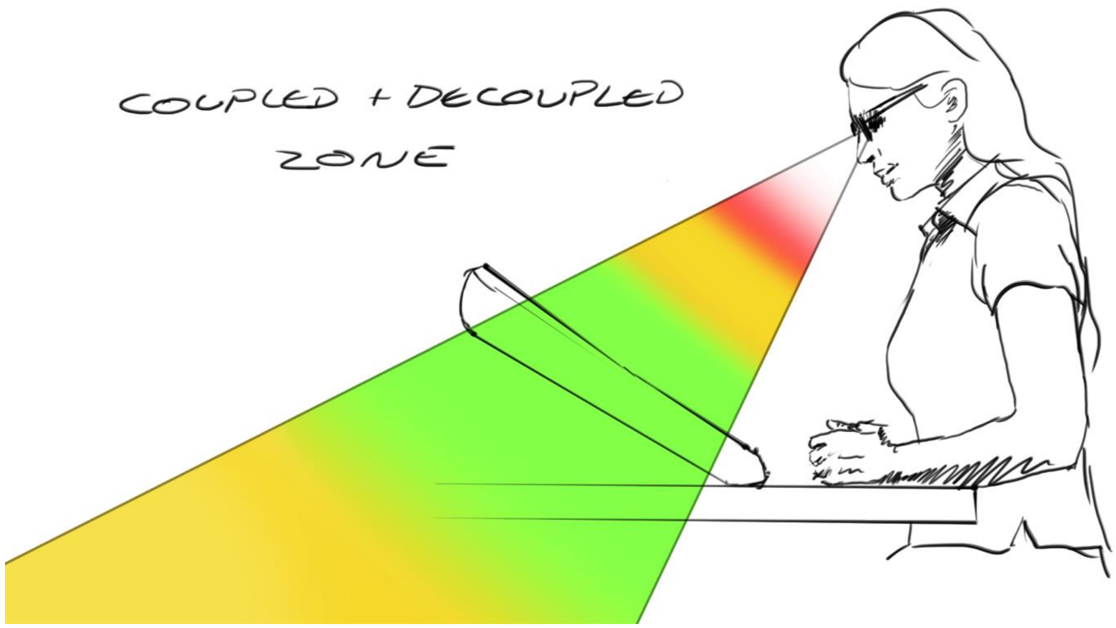
When a viewer looks at the bright zSpace monitor an additional distance, either side of the screen surface will remain sharp thanks to the human eyes' depth of field. Converging within this depth of field range does not require refocusing and remains comfortable for extended periods of time. Convergence and focus remain *coupled*. The *coupled zone* is the zone of comfortable 3D that should be used as the primary compositional space for most 3D scenes or applications on zSpace.



Creating 3D images with points of interest that go beyond the coupled zone is an exciting possibility that should not be avoided.

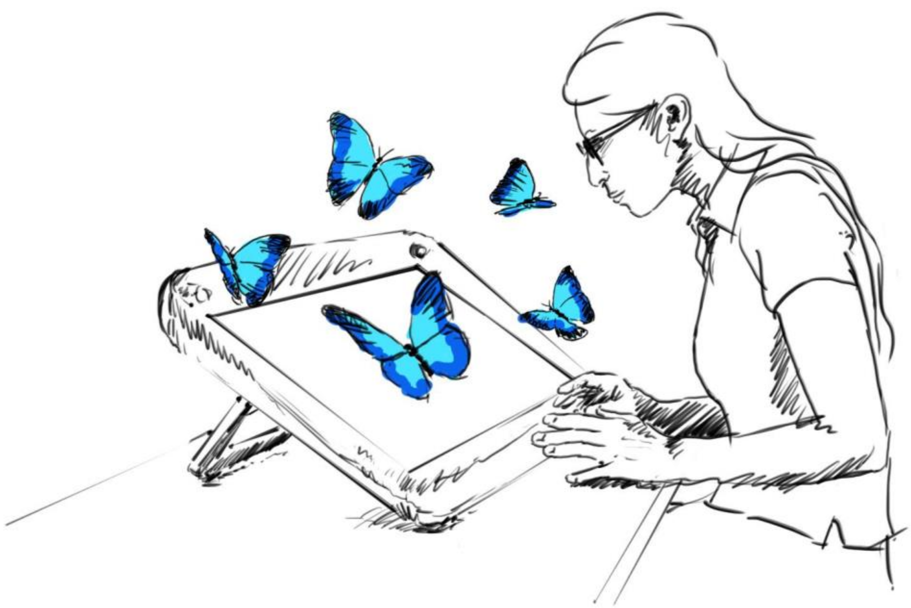
This increased depth will require the viewer's vision system to decouple convergence and focus. This can lead to eyestrain over time, so care must be taken when increased or extreme 3D is used.

The *decoupled zone* is anything beyond the comfortable, coupled zone seen above. As the decoupling increases, the 3D effect increases but so will the eyestrain. At a certain point the 3D illusion will break completely as the viewer will be unable to fuse the two images of the stereoscopic pair. This limit is a little different for each person.



The illustration above shows the depth range is non-linear. Moving objects towards the viewer, in front of the screen, rapidly increases the pixels of separation. Moving objects away from the viewer, behind the screen, increases the pixel count much more slowly. An object separated behind the screen by +250 pixels is effectively at an infinite distance as the lines of sight are parallel.

The decoupled zone can be used for bold 3D effects as long the duration is short or if the decoupled depth only contains peripheral objects that fill the scene but do not require focused attention from the viewer. In this case, the viewer should remain converged within the coupled zone while appreciating the extreme depth in their peripheral vision.



Direct viewing of decoupled objects is much less problematic if the viewer is in control of the depth. zSpace allows the viewer complete control of an object, for example, moving it towards them into an extreme close up position that is far outside the coupled zone. On zSpace this is not an issue as the viewer will choose their own level of acceptable decoupling as they examine an object. If any discomfort is felt, they will naturally reduce the depth by returning the object to the coupled zone.

This extreme 3D effect is impossible to create with a 2D monitor and is one of the most striking aspects of zSpace. The viewer should always be in control when viewing 3D beyond the coupled zone unless the aim is to intentionally create a visual shock. If the viewer does not control the depth of an application, then the coupled zone should be the primary target and extreme 3D can be used sparingly where appropriate.

Other Potential Viewing Distractions

Geometry distortions are a major cause of eyestrain within 3D movies at the cinema. Rotating your head or sitting off to the side can be very uncomfortable due to misalignments of the image compared to your eyes. This is not the case with zSpace. zSpace is an active eye tracking system that creates correct 3D geometry from any viewpoint or rotation, eliminating this potential 3D problem. It is vital the eye tracking is perfect to avoid eyestrain.

Ghosting occurs because glasses-based 3D systems cannot completely separate the left and right image of a stereoscopic pair. This results in each eye receiving some unwanted light from the image meant for the other eye, creating a faint ghost image. Ghosting is most visible in high contrast, highly separated images. A bright moon in the far background over black sky will create ghosting.

If the high contrast object is positioned at the screen surface, ghosting is eliminated, but this may also eliminate the 3D effect. Reducing the overall depth of the scene does little to help ghosting and should be avoided as a solution. Removing the 3D is the last resort.

The best way to avoid ghosting is through careful design and art direction. Reducing the contrast of problematic objects, softening edges, and increasing the surrounding texture will all help to minimize the negative effects of ghosting.

Window violations are most disturbing when a foreground object overlaps the vertical border of the monitor bezel. The border of any stereoscopic image creates a virtual window in space. Objects can appear “behind the window” or out in front, “through the window” towards the viewer. The stereoscopic window of zSpace is formed by the black bezel of the monitor and sits at the screen surface.

Objects behind the bezel or window are almost always comfortable to view. Objects in front of the window can also be comfortable as long as they stay in the center of the screen and avoid hitting the window edges. Once an object closer than the screen hits the window edge, it creates a disturbing visual effect. Our brain struggles to resolve how a foreground object can be cropped by a window that is further away. An image of a person’s head would look like it has been cut in half by the window.

Top and bottom window violations are minor because our eyes are aligned horizontally and only see stereoscopic data from verticals. Left and right edge violations can be very disturbing and should generally be avoided.

Luckily the zSpace system easily allows the user to fix any momentary window violations by simply moving the object away from the edge or by physically shifting their point of view.

Disturbances caused by window violations are dramatically reduced in a moving scene. Objects can comfortably float out in front of the screen, cross the stereo window and disappear without creating a problem. Only when the object stops on the edge, half masked and half visible, does it become a real distraction that could lead to eyestrain.

Point of Attention Jumps

When 3D scenes change rapidly in 3D movies at the cinema, the audience's eyes have to jump from one depth to the next in quick succession. We rarely do this in real life and it becomes exhausting over time. zSpace will typically avoid this problem as the nature of content allows for long viewing durations between depth changes. If rapid changes of objects or scenes are required, it is important to match the depth from one scene to the next so that the viewer's eyes do not have to jump.

zSpace Aesthetics

What Makes Great zSpace 3D

The most obvious rule is to NOT make a 2D experience. Our long tradition of 2D imaging makes it all too easy to slip into creating a 2D visual. You must consciously question this tradition when designing for zSpace.

2D image making has been around since the first caves were painted. The challenge of traditional 2D image making is to somehow represent a three-dimensional world on a two-dimensional plane. Over the centuries many 2D art styles have developed in contrast to the experience of seeing the 3D world in which we live. We have learned to accept and enjoy these alternate versions of the world as artistic expression.

Photography and art today continue to create 2D images in a wide range of styles that are in stark contrast to the human stereoscopic vision system. It is a wonderful form of artistic expression that does not try to match reality.

zSpace uses stereoscopic imaging specifically to try and match reality. It is important to keep this in mind when developing zSpace applications. This is a very different approach from 2D image making, which often represents the world in abstract ways that do not try to recreate reality.

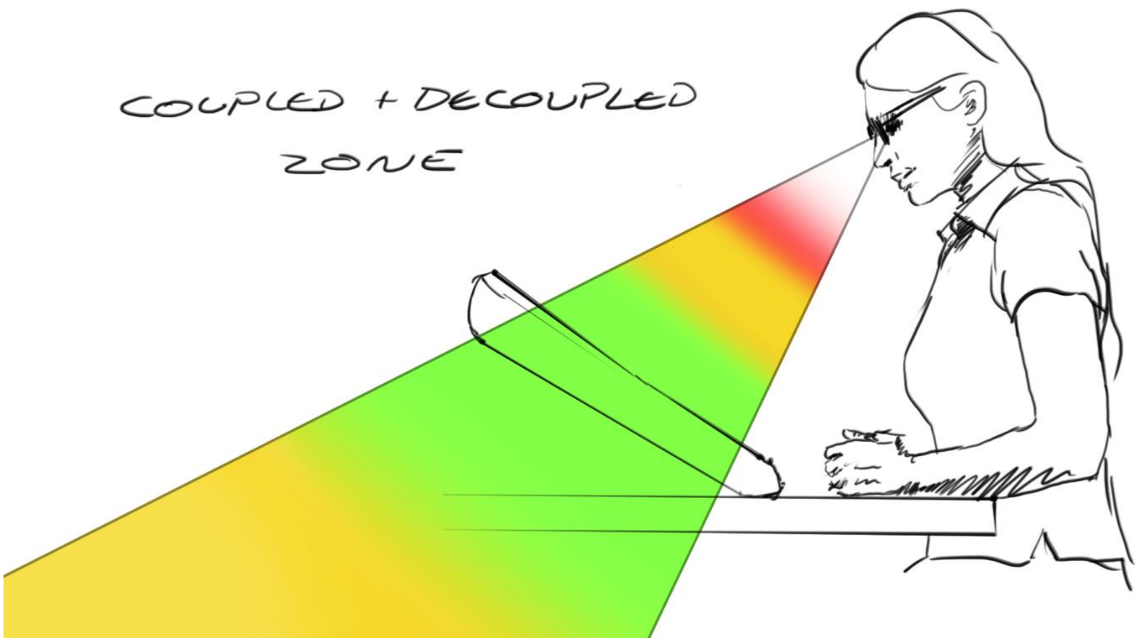
2D art is around us at all times and has become a “normal” way to view the world, but 2D art is really not normal when compared to the 3D world in which we live. When compared to 3D human vision, 2D art is an extremely abnormal and abstract way to view the world.

Compared to 2D image making, styles of 3D image making are still developing. Recent technology like zSpace is making 3D imaging a common part of daily life, and a 3D aesthetic will develop over time. This relative lack of 3D aesthetics makes it an exciting area for design. There is a lot to be discovered.

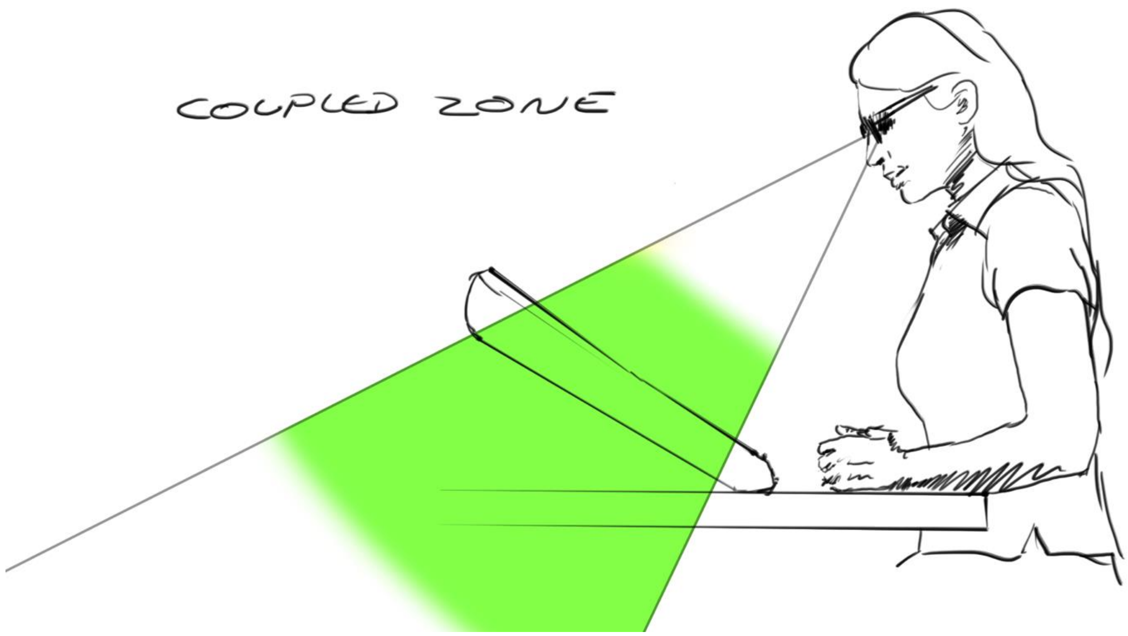
To be successful in zSpace 3D design, always think spatially. You are not creating flat images like a graphic designer. You are creating three-dimensional spaces like a sculptor, architect, or product designer.

Understanding the zSpace Stage

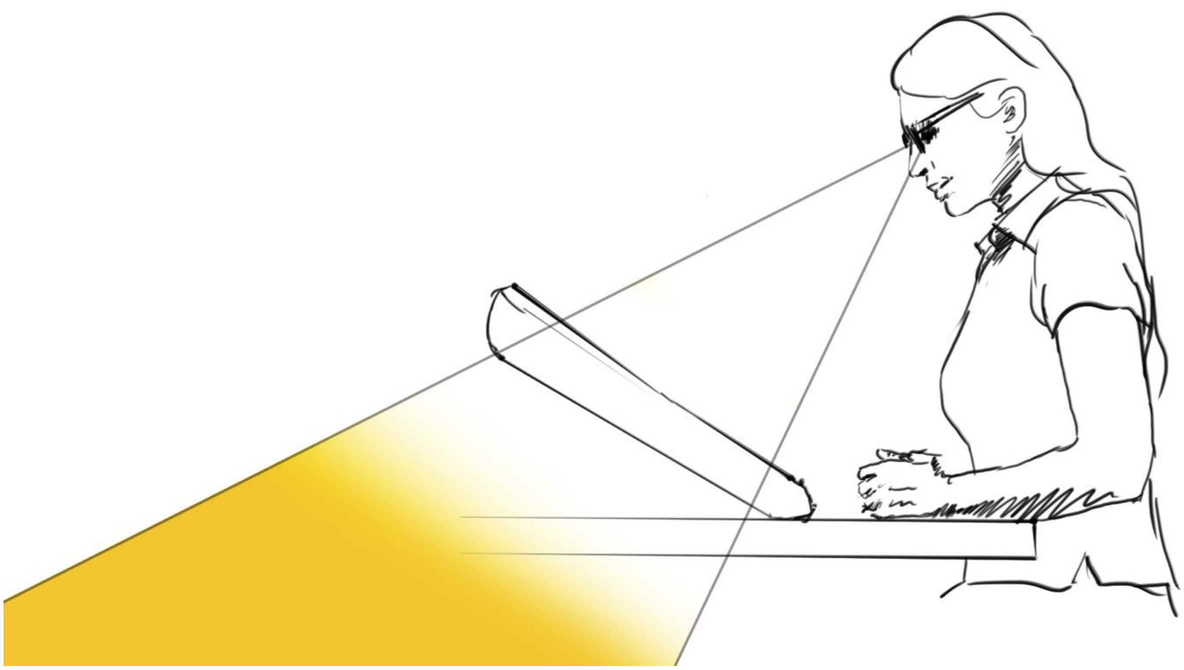
The zSpace compositional space is like a stage made up of the coupled and decoupled zones, in front and behind the screen. Understanding the advantages and disadvantages of each zone will maximize the effect of your application.



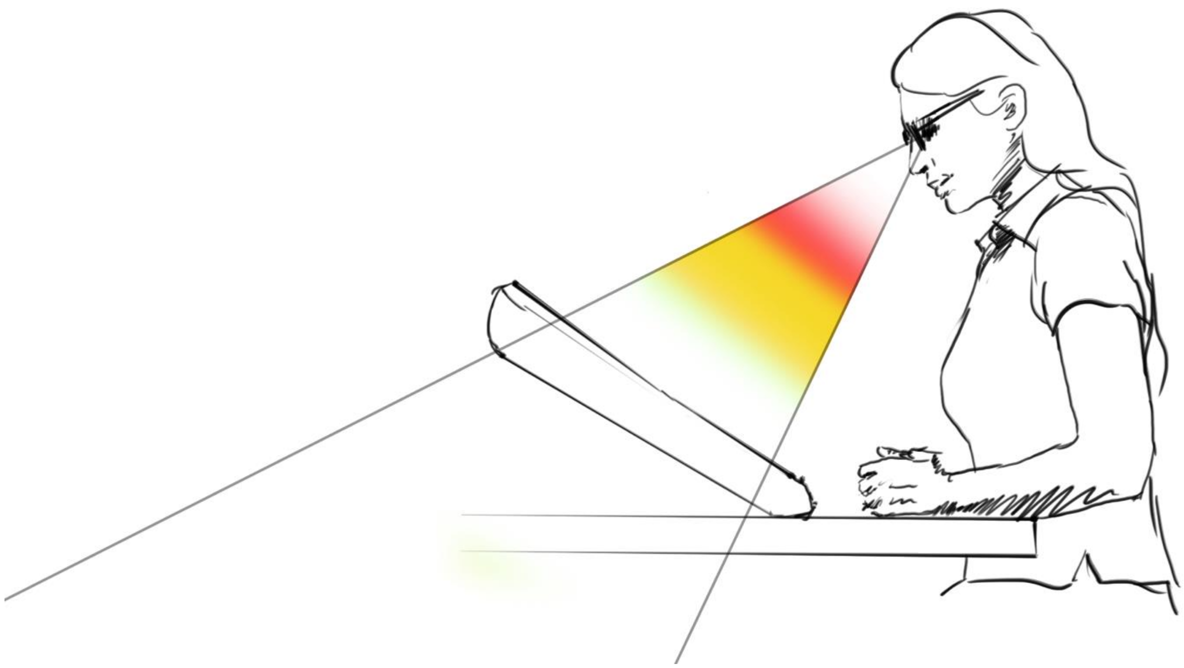
The *coupled zone* is bisected by the screen surface. The closer an object is to the coupled zone, the more comfortable it will be to view for long periods of time. This zone should be used as the primary compositional space. Applications can maximize their 3D impact by using the full depth of the coupled zone and be confident that any scene will remain comfortable for the viewer. Venturing outside of the coupled zone needs to have good reason and be well planned to avoid eyestrain.



The *background decoupled zone* can be used to extend the depth of the scene into the far background. Even if the viewer's attention remains inside the coupled zone, a deep background as peripheral depth can add a sense of vastness to any scene. Deep space or distant mountains can benefit from using the background decoupled zone. High contrast areas should be avoided if they display ghosting, but even very deep backgrounds can be viewed by most people for short periods of time.

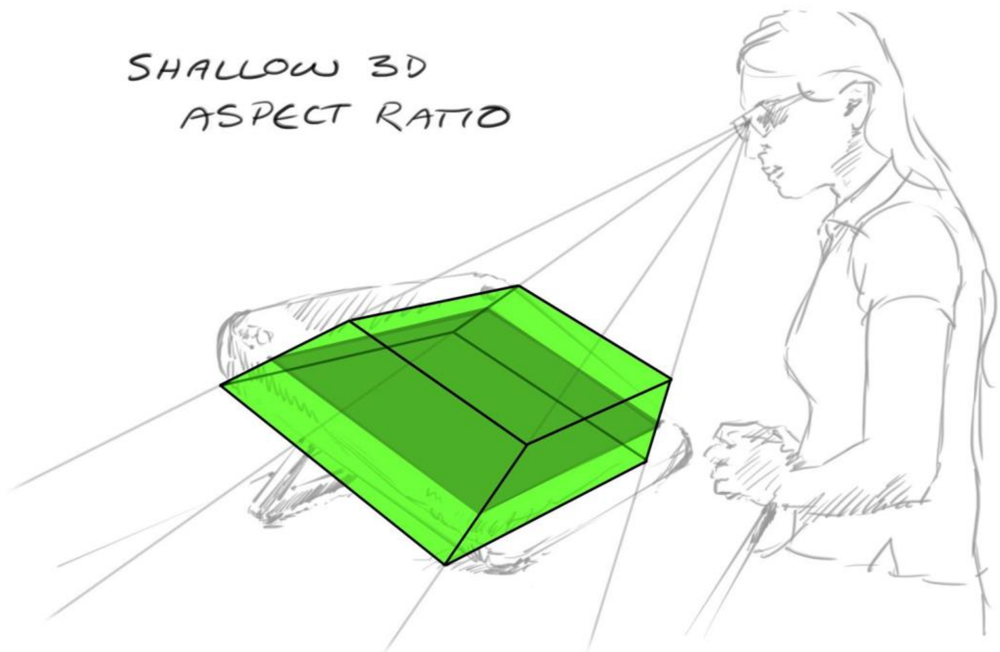


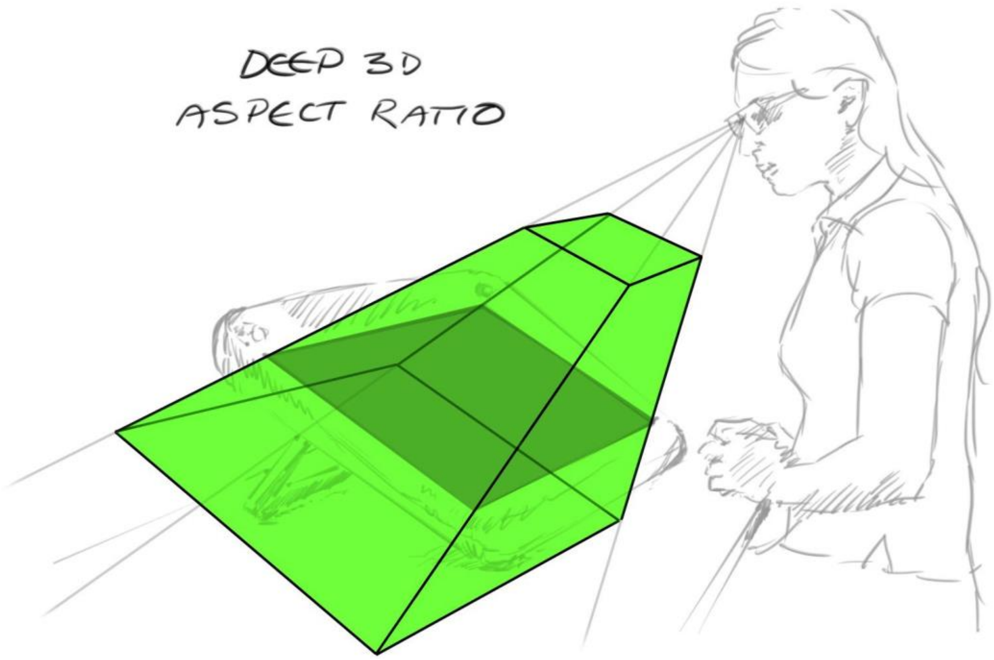
The *foreground decoupled zone* is the most magical of the zSpace zones. It allows objects to float out in space, disassociating themselves from the normal constraints of the screen surface. It is the "WOW" moment of any 3D experience. Many people associate 3D with this "pop out" effect and look forward to this powerful illusion when they view 3D. Applications should design ways to deliver this effect either through shock and surprise or by encouraging users to pull objects towards them, in front of the screen, under their own control. Either way, durations of pop out 3D should be kept relatively short to avoid eyestrain.



The zSpace 3D aspect ratio of your application is another new consideration. The 1920 x 1080 screen dictates the 2D aspect ratio of the stereoscopic window within the 3D stage. However, the 3D stage has an additional Z dimension that can either be shallow or deep, extend behind the window, in front of the window, or both.

The 3D aspect ratio is defined by the relationship of the viewer's eyes to the screen and forms a pyramid shape projecting out from the viewer's eyes through the corners of the screen and beyond. The pyramid can have a shallow or deep aspect ratio.





The 3D pyramid can move left, right, up, down, in, or out as the viewer's head is moved, but no 3D image can exist outside of the pyramid as there is no screen to create the image beyond the 1920 x 1080 dimensions. This ability to move around creates a virtual space vastly larger than the physical screen size suggests.

Applications should encourage head movement to discover objects within the full zSpace stage.

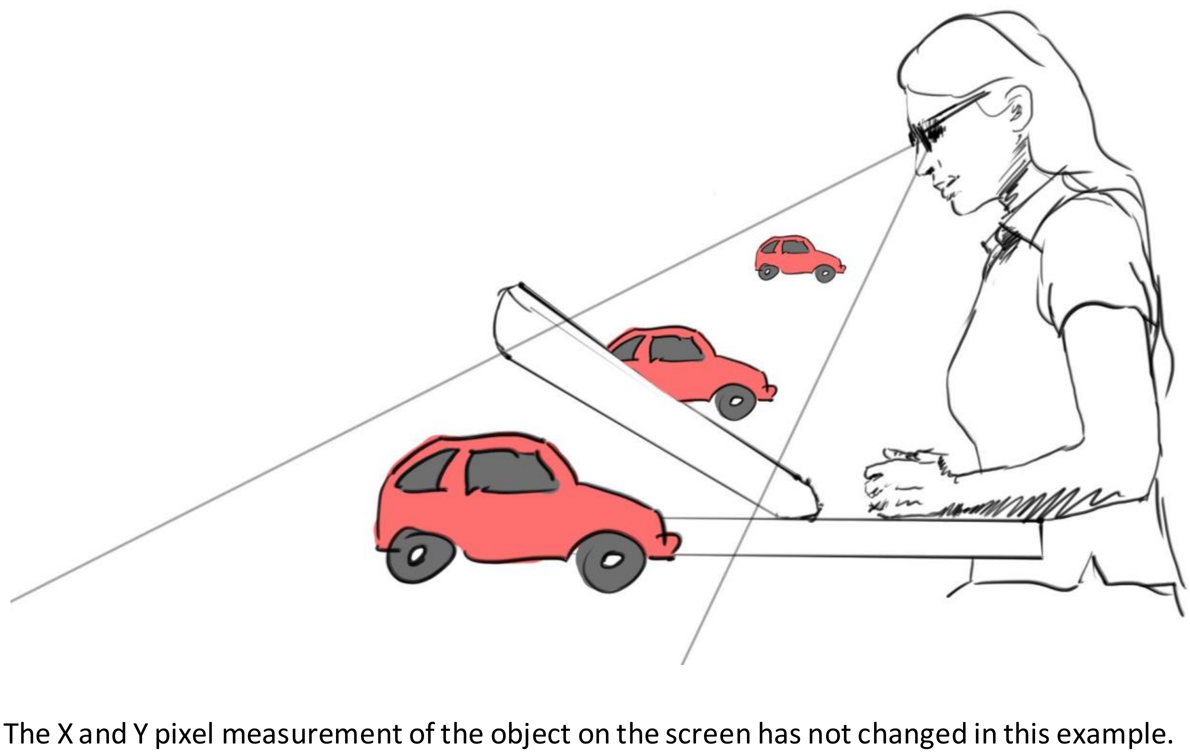
zSpace Object Placement and Scale

The large zSpace stage allows for a wide variety of object placement. An object could be to the left or right of the stage, but it can also pop out to the front of the stage or be deep at the back of the stage. Choosing to stay within the coupled zone still allows for a wide range of spatial composition.

Objects that are closer naturally draw our attention first. Objects that are distant become secondary or peripheral to our attention. zSpace application design can take advantage of this natural effect by placing objects or instructions of immediate importance towards the front of the stage. Front of stage placement can also be used to distract or misdirect the viewer while something surprising happens in the background.

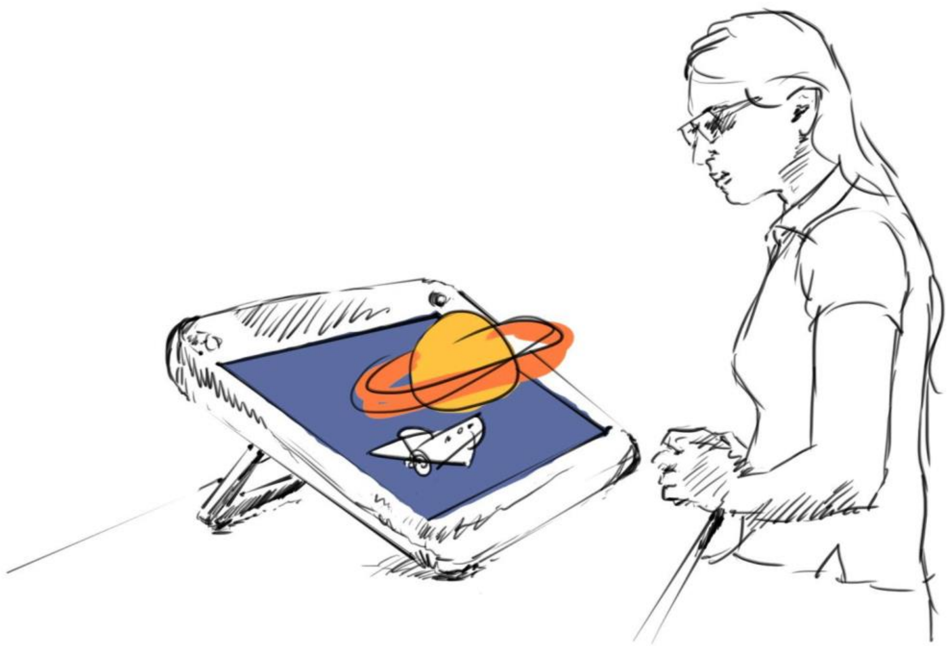
As the placement of an object drops to the back of the stage, it can appear less important and passive to the viewer. It can seem visually out of reach or far away.

The scale of an object is also affected by the placement within the zSpace stage. An object that is at the front of the stage is contained within the "pointy" end of the pyramid. It will appear small and close. The same object at the back of the zSpace stage is now filling the wide base of the pyramid and will appear much larger.

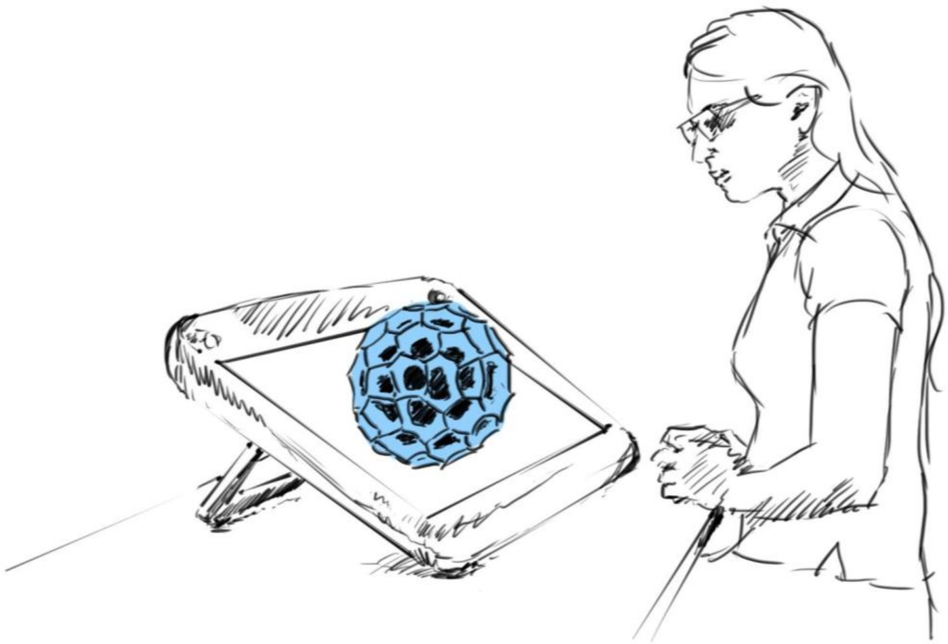


The X and Y pixel measurement of the object on the screen has not changed in this example. Only the depth data creates the scale illusion. Staging objects closer can make them seem smaller and less intimidating. Staging objects further away can make them appear large and powerful.

Although it is technically possible to recreate a full scale truck or even a solar system within the zSpace stage, it may not be aesthetically desirable. Viewing a distant planet at real world scale on the zSpace system would be like looking through a small window to a very distant and flat space scene at the back of the zSpace stage. It may be technically correct, but it is likely to be uncomfortable and visually disappointing. Scaling down the solar system and expanding its three-dimensional volume so that it uses more of the zSpace stage will be much more interesting to the viewer, giving them a giant's view of the scene. A sense of miniaturization called hyper-stereo is created and can be adjusted to your aesthetic preference. This miniaturization can be fun.



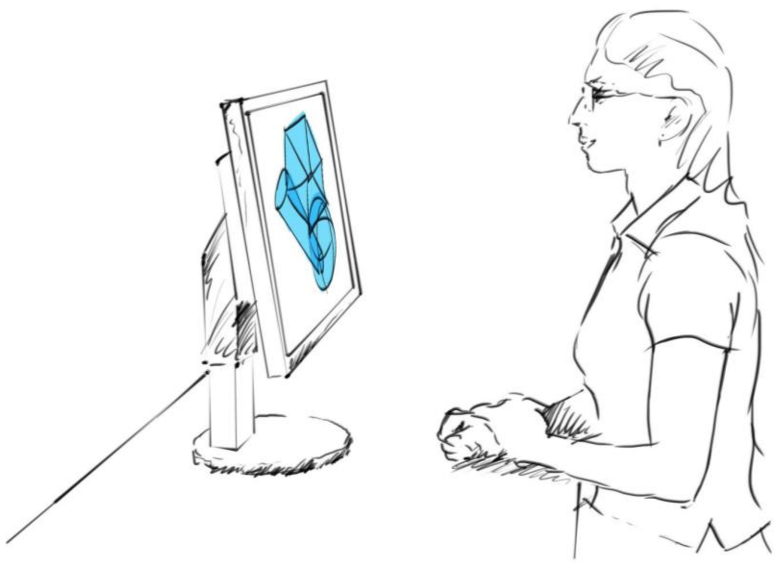
In contrast, a microscopic world would be impossible to see if represented life size. Scaling up the microscopic world to fill the zSpace stage with a hypo-stereo image will provide a sense of wonder and exploration.



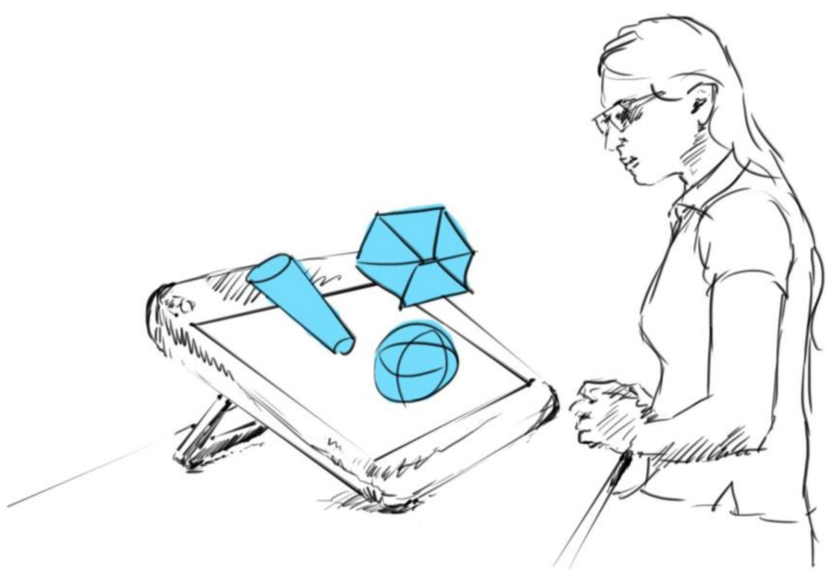
An application that includes both micro and macro worlds may choose to bias the placement of the micro worlds towards the front of the zSpace stage and macro worlds towards the back while keeping both within the comfortable range of the coupled zone or slightly beyond. These placement adjustments will create scale differences between the worlds that will enhance the viewer's experience and understanding of the information.

Visual Complexity and zSpace

Beautiful images in 2D are often simplified, minimal, graphic representations of the complex world we live in. Visual complexity quickly overwhelms traditional 2D imaging techniques to a point where we can no longer understand the message.



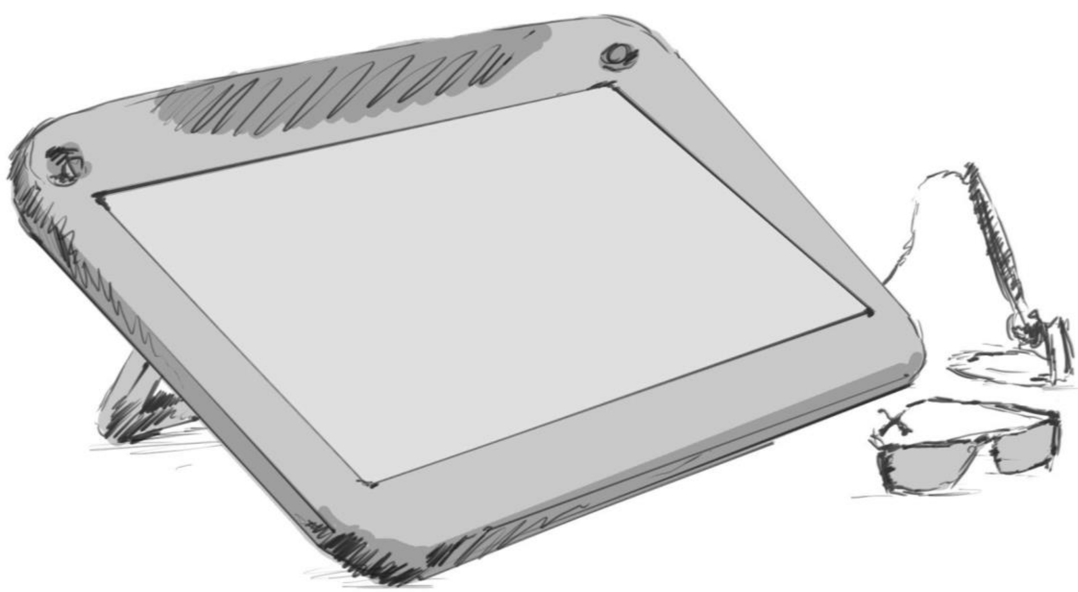
3D on zSpace is the opposite. Spatial complexity often enhances the 3D experience. A tangle of overlapping shapes that creates confusion in 2D becomes instantly understood when viewed in 3D on zSpace.



Increasing visual complexity and density often increases spatial understanding and enjoyment of a 3D scene. This should be explored and encouraged by application designers.

Summary

zSpace can be used to visualize a broad range of experiences from the literal duplication of a coffee mug in virtual reality to exploring an invisible, micro world or the vast reaches of space. The zSpace 3D experience enhances the ability to understand the world being explored and accelerates learning by providing complex spatial information in an instant of viewing. Applications that maximize the zSpace 3D experience for the viewer will be vastly more enjoyable to the user and create an experience unquestionably different from anything seen on a traditional 2D screen.



About the Author

Phil Captain 3D McNally is the co-author of the book “3D Storytelling” and most recently served as Stereoscopic Supervisor on DreamWorks Animation’s Turbo. Prior to Turbo, he worked in the same capacity on all of their 3D releases including The Croods, Madagascar 3, Puss in Boots, How to Train Your Dragon, Shrek, and Monsters vs Aliens.

Hailed as the expert on all things 3D, McNally was introduced to stereoscopic photography in 1990 while studying at the Royal College of Art in London. This hobby soon became his passion and has developed over the years through a range of creative projects—from Viewmaster promotional reels to gallery installations to movies.

In 2001 McNally moved to California to work as an Animator at Industrial Light & Magic after the success of his short animated film Pump-Action. His stereoscopic experience was rewarded when Disney tasked ILM with converting Chicken Little into a 3D release in 2005. McNally also supervised the stereoscopic work on Disney’s Meet the Robinsons and advised on The Nightmare Before Christmas conversion into 3D.

Index