Second in a series of technical white papers from In-Three

Stereoscopic geometry of 3D presentations

By Matt DeJohn, Will Drees, David Seigle, and Jim Susinno

In-Three™

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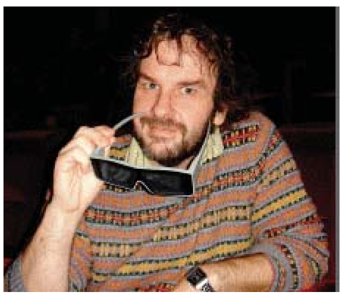
There exists a widespread misconception that viewing 3D may result in eye strain or eye-fatigue if it is watched for any significant length of time. This is somewhat understandable since a fair amount of previously photographed 3D content has been affected by left and right image disparities that, small as they might be, may cause eye strain and visual fatigue.This is not the case with In-Three™ Dimensionalized® content. One of the main advantages of Dimensionalized 3D content, which people recognize quickly, is that there is no eye fatigue.



"I'm here to lend my support along with the other filmmakers in saying that I think this is one of the most exciting developments in cinema to come along for a long long time. The fact that we can now make three-dimensional films that don't have eyestrain, they're bright, they're sharp, they're clear, there's no muddiness, there's no double imaging. The technology now exists to do perfect 3D."

— Peter Jackson, Director of the Lord of the Rings trilogy & King Kong

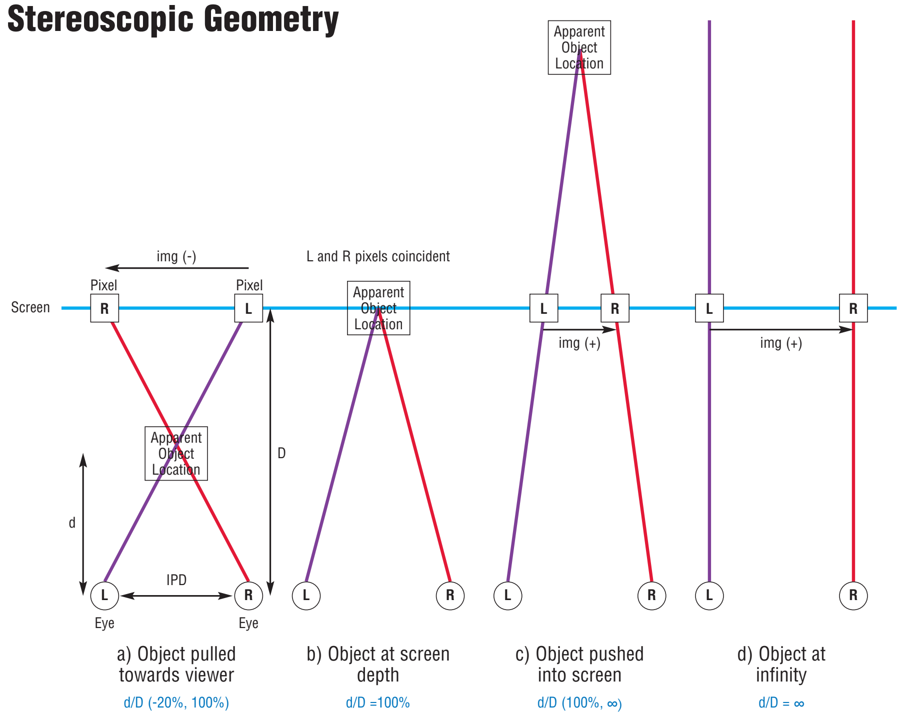
All In-Three Dimensionalized images are geometrically and mathematically mapped in software so as to ensure that there are no disparities between the left and right eye views. The elimination of such disparities was a major design goal in the development of Dimensionalization®.

With the Dimensionalization process, one eye's view remains the original image. For the other eye, objects from the original image are altered to achieve the perception of relative depth. In effect, Dimensionalization creates a virtual second camera. However, each shot can be dimensionally choreographed for a nuanced 3D effect that, for example, dual cameras can not achieve. Because of this the scene will not only appear right but feel right.

How Dimensionalization Works

The attached figures show the geometries of alternately projected images that act together to create 3D impressions for a viewer. (This discussion is based on a fixed left view and an altered right view. The effects are equivalent if left andright are interchanged in the explanation.) Diagrams a - d show the effects of successive projections of left/right views of a scene. In viewing the diagrams one must assume that the left eye cannot view the right eye's view and the right eye cannot view the left eye's view. (This can be accomplished using different colored filtering lenses; orthogonally polarized left/right lenses; or LCD-based, electronically shuttered glasses.) Thus, the diagrams represent a composite of alternate left/right views that present to the viewer a stereoscopic or 3D image.

Stereoscopic Geometry



Legend

IPD — Interpupilary distance (58-70mm=2.28-2.26)

Img — Image displacement (measured in inches)

D — Distance from viewer to screen

d/D — Apparent depth percentage

The fundamental law of 3D

We at In-Three refer to the formula, d/D= ipd/(ipd – img) to as the fundamental law of 3D. The formula relates an object's apparent depth to the amount of separation between the object's corresponding pixels in a stereo pair. The ratio d/D expresses an object's apparent depth as a percent of the distance from the viewer to the screen.

In properly constructed images the following effects can be seen: When an object is shifted to the left in the right image (diagram a) the right eye will track the object to the left in order to keep the object in its line of sight. This will create the impression that the object are closer to the observer than the screen (d<D).

When objects in both left and right images are unshifted (diagram b) the image appears at screen distance (d=D). When the object is shifted to the right in the right image (diagram c) it will appear behind the screen (d>D).

The maximum distance that an object should be shifted to the right in the right image is equal to the inter-pupil distance of the observer (IPD). With rightward shift of an object constrained to be less than IPD, d/D will never be greater than infinity, and the viewer's eyes will not diverge. For inward movement, a soft limit for apparent depth is about 20% of the distance from the viewer to the screen. This rule of thumb is based on audience judgments made while varying d/D.

$$d/D = \frac{IPD}{IPD-Img}$$

Domain: (-Max, IPD)
Range: (-20%, ∞)

Max ~ = 4 *IPD

The formula above is the In-Three fundamental law of 3D. It relates interpupillary distance to object shift within a right eye image and expresses the results in terms of perceived object depth expressed as a ratio of observed distance to screen distance.

Effects of different screen sizes

If an image has been dimensionalized to look proper on a screen size of X and it is projected on a screen of 2X, then all right image object shifts will be physically doubled. This means that d/D will be increased for objects shifted to appear behind the screen. Also, d/D will decrease for objects shifted to appear nearer to the viewer than the screen.

Thus relative to the screen distance, objects will appear to have greater depth.

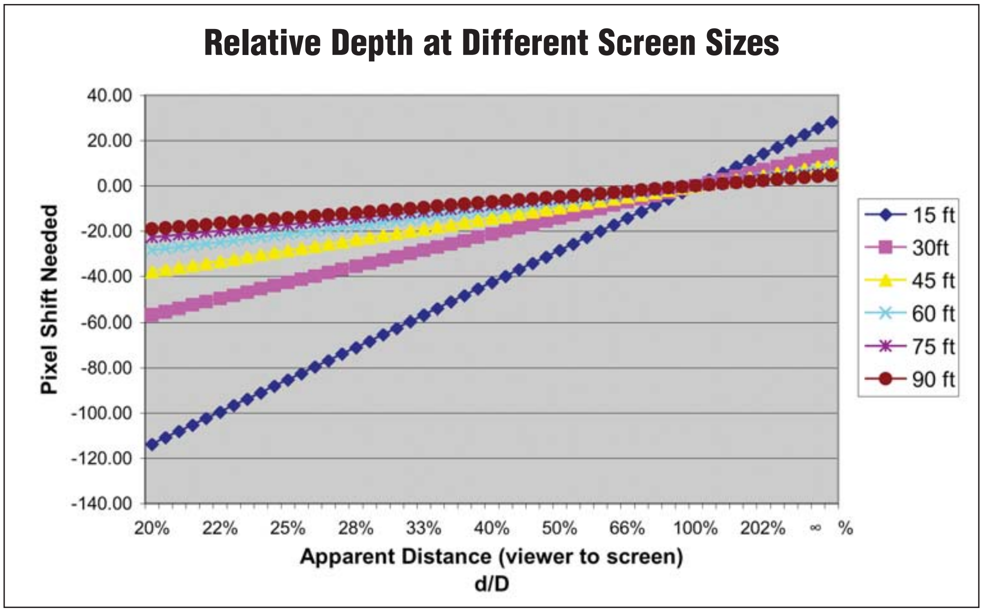
Object shift (in pixels) at various screen sizes to create desired 3D effect

Assumptions:

Inter-pupulary distance:	2.48 inches
Resolution:	2048x1024

On Screen Image Seperation (inch)	Desired Effect (Apparent Distance from Viewer to Screen)	Pixel Shift Per Screen Size					
		15	30	45	60	75	90
-10	20%	-113.78	-56.89	-37.93	-28.44	-22.76	-18.96
-9.75	20%	-110.93	-55.47	-36.98	-27.73	-22.19	-18.49
-9.5	21%	-108.09	-54.04	-36.03	-27.02	-21.62	-18.01
-9.25	21%	-105.24	-52.62	-35.08	-26.31	-21.05	-17.54
-9	22%	-102.40	-51.20	-34.13	-25.60	-20.48	-17.07
-8.75	22%	-99.56	-49.78	-33.19	-24.89	-19.91	-16.59
-8.5	23%	-96.71	-48.36	-32.24	-24.18	-19.34	-16.12
-8.25	23%	-93.87	-46.93	-31.29	-23.47	-18.77	-15.64
-8	24%	-91.02	-45.51	-30.34	-22.76	-18.20	-15.17
-7.75	24%	-88.18	-44.09	-29.39	-22.04	-17.64	-14.70
-7.5	25%	-85.33	-42.67	-28.44	-21.33	-17.07	-14.22
-7.25	25%	-82.49	-41.24	-27.50	-20.62	-16.50	-13.75
-7	26%	-79.64	-39.82	-26.55	-19.91	-15.93	-13.27
-6.75	27%	-76.80	-38.40	-25.60	-19.20	-15.36	-12.80
-6.5	28%	-73.96	-36.98	-24.65	-18.49	-14.79	-12.33
-6.25	28%	-71.11	-35.56	-23.70	-17.78	-14.22	-11.85
-6	29%	-68.27	-34.13	-22.76	-17.07	-13.65	-11.38
-5.75	30%	-65.42	-32.71	-21.81	-16.36	-13.08	-10.90
-5.5	31%	-62.58	-31.29	-20.86	-15.64	-12.52	-10.43
-5.25	32%	-59.73	-29.87	-19.91	-14.93	-11.95	-9.96
-5	33%	-56.89	-28.44	-18.96	-14.22	-11.38	-9.48
-4.75	34%	-54.04	-27.02	-18.01	-13.51	-10.81	-9.01
-4.5	36%	-51.20	-25.60	-17.07	-12.80	-10.24	-8.53
-4.25	37%	-48.36	-24.18	-16.12	-12.09	-9.67	-8.06
-4	38%	-45.51	-22.76	-15.17	-11.38	-9.10	-7.59
-3.75	40%	-42.67	-21.33	-14.22	-10.67	-8.53	-7.11
-3.5	41%	-39.82	-19.91	-13.27	-9.96	-7.96	-6.64
-3.25	43%	-36.98	-18.49	-12.33	-9.24	-7.40	-6.16
-3	45%	-34.13	-17.07	-11.38	-8.53	-6.83	-5.69
-2.75	47%	-31.29	-15.64	-10.43	-7.82	-6.26	-5.21
-2.5	50%	-28.44	-14.22	-9.48	-7.11	-5.69	-4.74
-2.25	52%	-25.60	-12.80	-8.53	-6.40	-5.12	-4.27
-2	55%	-22.76	-11.38	-7.59	-5.69	-4.55	-3.79
-1.75	59%	-19.91	-9.96	-6.64	-4.98	-3.98	-3.32
-1.5	62%	-17.07	-8.53	-5.69	-4.27	-3.41	-2.84
-1.25	66%	-14.22	-7.11	-4.74	-3.56	-2.84	-2.37
-1	71%	-11.38	-5.69	-3.79	-2.84	-2.28	-1.90
-0.75	77%	-8.53	-4.27	-2.84	-2.13	-1.71	-1.42
-0.5	83%	-5.69	-2.84	-1.90	-1.42	-1.14	-0.95
-0.25	91%	-2.84	-1.42	-0.95	-0.71	-0.57	-0.47
0	100%	0.00	0.00	0.00	0.00	0.00	0.00
0.25	111%	2.84	1.42	0.95	0.71	0.57	0.47
0.5	125%	5.69	2.84	1.90	1.42	1.14	0.95
0.75	143%	8.53	4.27	2.84	2.13	1.71	1.42
1	168%	11.38	5.69	3.79	2.84	2.28	1.90
1.25	202%	14.22	7.11	4.74	3.56	2.84	2.37
1.5	253%	17.07	8.53	5.69	4.27	3.41	2.84
1.75	340%	19.91	9.96	6.64	4.98	3.98	3.32
2	517%	22.76	11.38	7.59	5.69	4.55	3.79
2.25	1078%	25.60	12.80	8.53	6.40	5.12	4.27
2.48	∞ %	28.22	14.11	9.41	7.05	5.64	4.70

As you can see from the table on the left, less shifting of objects is required to create the same apparent depth on larger screens than on smaller screens. This phenomenon is detailed in the table, which shows screen sizes from 15 to 90 feet across and apparent distance to the viewer from 20% to approximately infinity. Each cell represents the required distance of an object's shift represented in pixels.



Conversely a 3D film projected onto a smaller screen will have the apparent depth distances shortened and, therefore, appear to have less dramatic impact.

From this one can see that less shifting of objects is required to create the same apparent depth on larger screens than on smaller screens. This phenomenon is detailed in the table [Object shift (in pixels) at various screen sizes to create desired 3D effect] on the previous page, which shows screen sizes from 15 to 90 feet across and apparent distance to the viewer from 20% to approximately infinity. Each cell represents the required distance of an object's shift represented in pixels.

The corresponding graph represents this data graphically for various screen sizes. Note how larger screen sizes require less object shifting to achieve the same result.

Implications

From this discussion we infer the following:

- Creating satisfying 3D movie experiences requires an understanding of the theater projection environments.
- Creating a 3D movie for a small screen and projecting it on a large screen may cause viewer discomfort.
- One can create a 3D movie for a large screen and project it on a smaller screen with a penalty of somewhat reduced relative depth.
- Creating a 3D movie using stereo-cinematography locks a film into fixed relative depth and a certain screen size environment.
- Creating 3D movie using a process and tools like In-Three's provides a director with greater freedom of choice in achieving 3D effect and allows the film to be targeted optimally to different screen size .

Call us today

For a discussion of how we can support your project and a demonstration of our work call Damian Wader at 805-413-7580.

"I don't know if you have seen many great 3-D presentations, but they're just amazing and that can really bring you much more into a film than what you're seeing now. And when digital is in place in theaters, that's going to pretty much be it. The glasses are small lightweight, you don't get headaches anymore, it looks amazing, and you can design effects scenes in depth."

— Dennis Muren, Senior Visual Effects Supervisor, Industrial Light & Magic

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