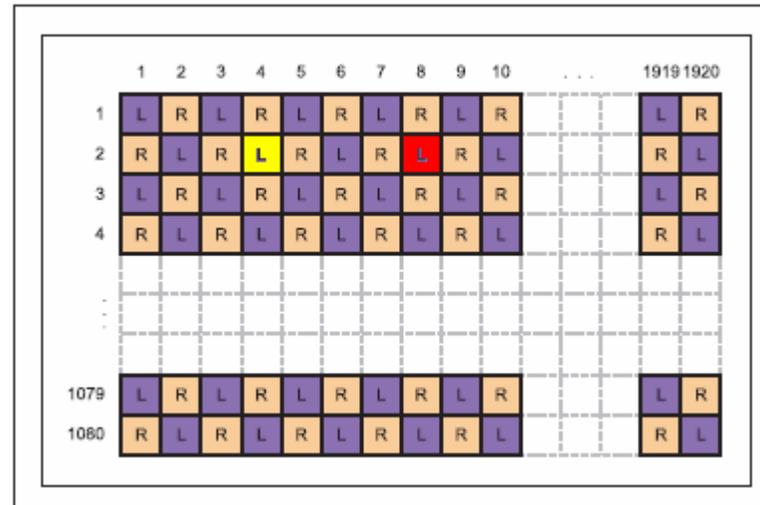


## DLP, Checkerboard, and 3D

Referring to the images (*figures a., b., and c.*) from this article: <http://www.informationdisplay.org/issues/2009/07/art5/art5.pdf>

*Figure a.* is a representation of the left and right sub-frame pixels in a DLP (checkerboard) 2D input. The pixel grid consists of 1920 columns by 1080 rows, with the pixels marked L and R for the appropriate “checkerboard” sub-frame. Pixel 2-4 (2<sup>nd</sup> row, 4<sup>th</sup> column) is colored yellow and pixel 2-8 (2<sup>nd</sup> row, 8<sup>th</sup> column) is colored red to delineate them further for discussion purposes. They are both part of the L sub-frame.



*Figure a. orthogonal checkerboard interleave*

HP’s “Wobulation” or TI’s “SmoothPicture” is the process of shifting the light from the DLP mirrors from the locations shown as purple squares (L), to the locations shown as orange squares (R) in *figure a.* This happens very fast, and the combined sub-frames form one complete video frame.

Now, while the mirror count is approximately halved for DLP displays, the *diamond shapes* (very important) that the mirrors form have twice the area of a normal pixel, with the points of the diamond shapes overlapping one quarter of each of the four surrounding pixels. See *figure b.* below (left sub-frame).

Also, even though there are only half the mirrors in the display, they still form 1920 columns and 1080 rows. (Because of the diamond shapes, they are actually not arranged in a 960 x 1080 square pixel array, but as 960 x 540 *interlocked pairs\**), which is also apparent in *figures b* and *c.*

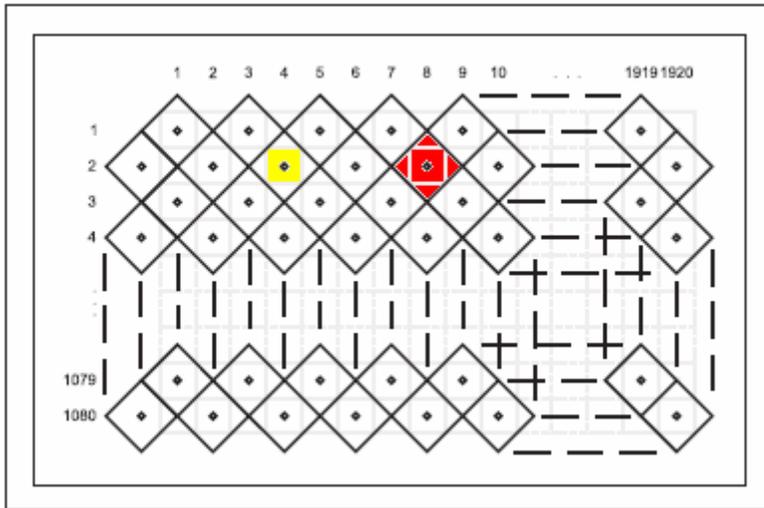


Figure b. left sub-frame

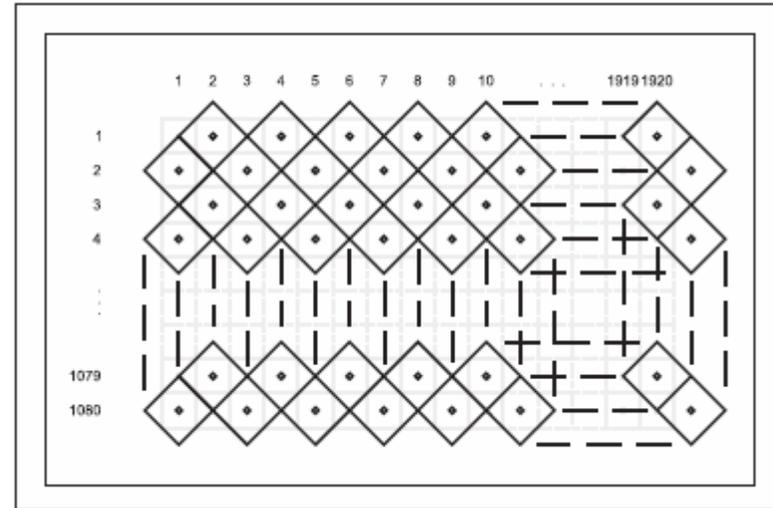


Figure c. right sub-frame

Study figures *b* and *c*. carefully. The lightly drawn gray squares within the diamonds (and with dots in their center) in *figure b* are the standard pixel locations being “painted” by colored light from the mirrors, and correspond to the purple squares in *figure a*. Again, pixel 2-4 is yellow. For clarity, the four corners of the over-sized diamond mirror element are not shaded yellow in the diagram, and the yellow pixel appears as it did in *figure a*. Pixel 2-8 is red, but here the *whole diamond* is shown (properly) as red. Notice how the red color also covers 1/4 of each of the surrounding and unused (as yet) pixels which are the pixels 1-8 above it, 3-8 below it, 2-7 on the left, and 2-9 on the right. Those four surrounding pixels may actually become other colors besides red, and will be painted such during the wobulation to the right sub-frame shown in *figure c*. and the overlap of the diamonds from each sub-frame will form the complete color scheme of all the pixels for the completed frame.

As shown in *figure c.*, the diamond array has shifted (wobulated) to paint the previously unused pixels (orange squares from *figure a*, note that 2-4 and 2-8 no longer have dots). As shown, the diamond mirrors in the array are shifted one half their width (one pixel width) to paint the second sub-frame, which causes additional information overlap (and results in the appearance of standard size pixels). An algorithm calculates the proper color combinations needed to create each “square” pixel (actually a smaller diamond shape) from the combined colored diamonds of both sub-frames. It is also this “wobulation” (pixel overlap) that hides the spaces between the diamond shaped mirrors, which eliminates the “screen door effect” while giving everything a motion picture or film-like appearance. (Thus, the “SmoothPicture” trade name.)

The mirrors are microscopic, and actually move thousands of times per second to blend grayscale and color for one complete frame of video. *Figure d.* (below, left) shows the two sub-frames overlapped, creating mini diamond pixels in the process.

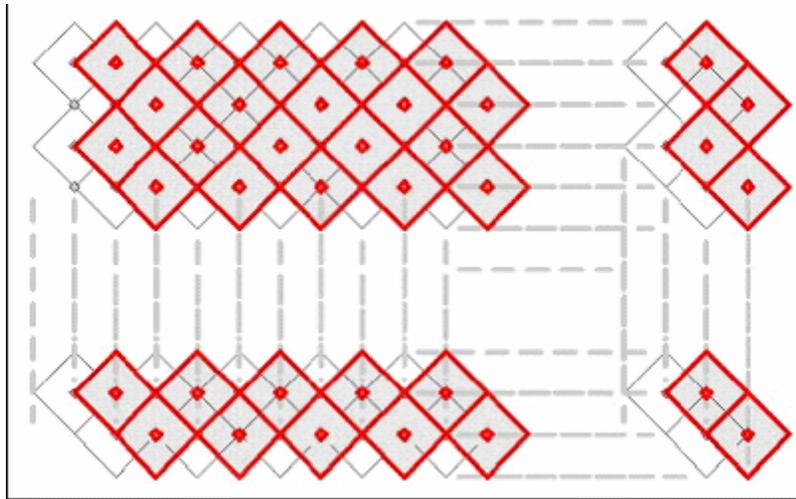


Figure d., overlapped sub-frames

David C. Hutchison, Texas Instruments <http://www.eetimes.com/design/signal-processing-dsp/4013352/The-SmoothPicture-algorithm-An-overview>

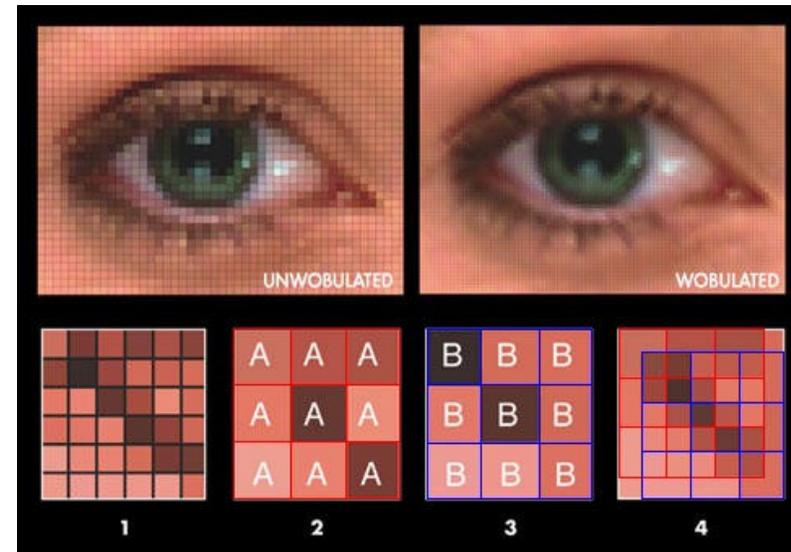


Figure e. wobulation

HP's Wobulation technology takes the original image [1] and breaks it down into two separate sub- images [2 and 3]. Your eye adds the two signals for each pixel shown in 2 and 3, yielding a close facsimile [4] to the original.  
<http://www.popsci.com/00html/article/2005-10/wobulation>

HP wobulation (*figure e.* above, right) is shown done with square mirrors. See the caption in *figure e.* The original signal is shown in #1, a 6 pixel x 6 pixel sample of the picture. Wobulation then overlaps two sub-frames, each with a larger, 3 pixel x 3 pixel image (#2 with nine As, and #3 with nine Bs) blending to create the image (#4), which is the original image without the screen door lines caused by the space between pixels. (#4 actually shows a larger 7 pixel x 7 pixel sample, to show the overlap of sub-frames)

Texas Instrument's SmoothPicture® algorithm is used with diamond shapes as discussed, but is similar. In both, the actual pixel structure will appear correctly when the right sub-frame is overlapped on the left sub-frame, blending everything together. Remember, the mirrors are extremely fast, and paint each pixel thousands of times per second to blend the color properly.

## Checkerboard 3D and DLP

For 3D, each sub-frame is used separately to display each eye's checkerboard view, but the final view does not look like *figure f.*, below (with black “holes” in place of the missing pixels), because the mirrors are not square. The mirrors are diamond shaped, as discussed previously.

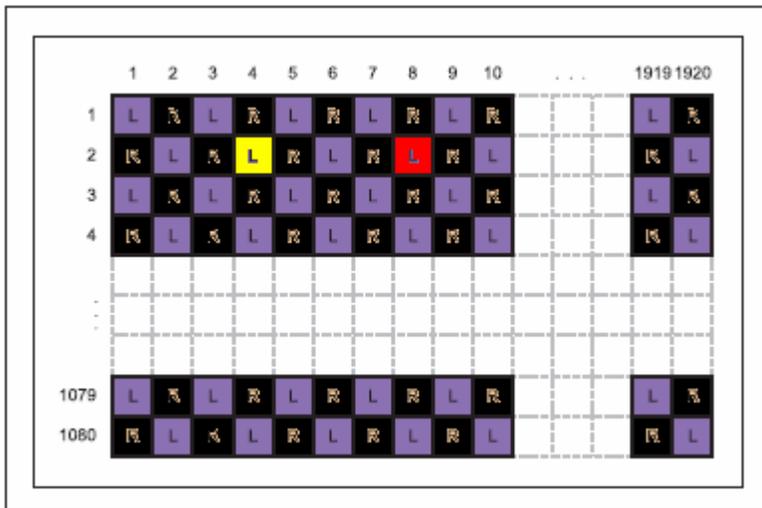


Figure f. left orthogonal sub-frame (3D)

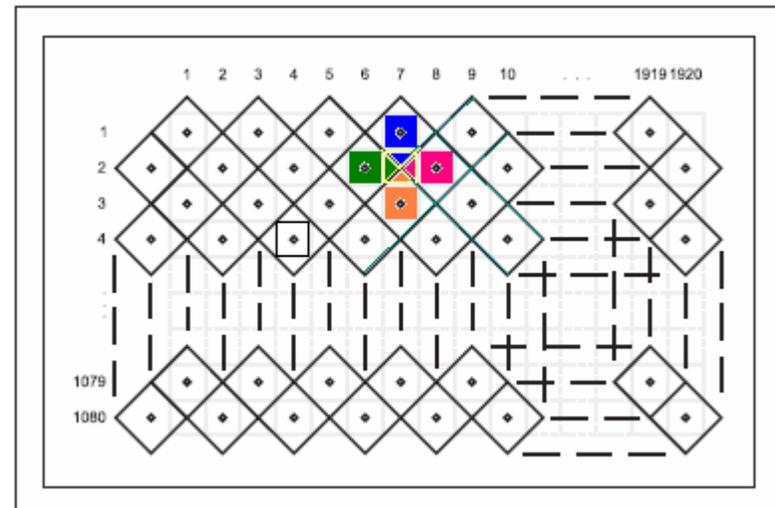


Figure g. left DLP sub-frame (3D)

So what happens to the “holes”? They are covered by the points of the diamonds in the adjacent active pixels and, because there is no second sub-frame (it's now being used for the right eye view) to blend and create them from the source, the pixels appear to be a blend of the colors around them, as shown in *figure g.*, above. Note the different colors of the diamond pixels surrounding the “hole” where pixel 2-7 should be. The color of pixel 2-7 appears as a combination of the other four diamond colors, and is formed by the intersection of their adjacent corners. (The other three corners of each of the adjacent colored diamonds are left blank for clarity). So even with just one sub-frame, the entire 1920 x 1080 grid is still painted during 3D viewing, and because there are no “holes” as such, each eye's 3D frame appears quite complete.

\*From <http://www.eetimes.com/design/signal-processing-dsp/4013352/The-SmoothPicture-algorithm-An-overview?pageNumber=1> “...with 960 distinct column pairs and 540 distinct row pairs (a row pair consists of one black and one white row). This permits display of a 1920x1080 image using ½ the number of pixels”... “SmoothPicture technology combines the diamond grid DMD, with its inherently high mirror switching speed and an optical actuator to create a system which can display a full resolution image onscreen containing all of the original image pixels. With SmoothPicture, the actuator optically displaces the DMD image horizontally, coordinated with the display of two separate sub-frames of data on the DMD”.