Volumetric Scene Reconstruction For View Synthesis

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Abstract

Our goal is to render new views from a set of captured images. The algorithms that we use require camera pose, so we use the *Chromaglyph* method to automatically estimate pose. *Voxel coloring* [Seitz] is an algorithm for constructing a model of a scene, which can then be rendered for new viewpoints. We have developed several enhancements to voxel coloring, plus a new related geometrical algorithm called Blinking Cubes.

Chromaglyphs for Pose Determination

Chromaglyph wallpaper can be printed with standard large format inkjet printers. Chromaglyphs in the background of a complex scene allow the automatic inference of camera pose*. Given a photograph of such a scene, each fully visible glyph can be detected automatically, even in images with complex occluding geometry. Known 3D world coordinates of the glyph centers are combined with extracted 2D image coordinates to compute a projection matrix, representing camera pose.

* [State et. al. Siggraph '96, Gortler et al Siggraph '96]

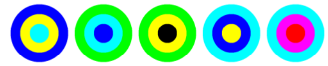
3D Glyph World Coordinates			2D Image Coordinates	
3147.000000	3747.000000	0.000000	965.541199	216.266663
3147.00000	3447.00000	0.000000	917.56024	223.25454
3147.000000	3148.000000	0.000000	867.868347	229.775085
2248.00000	4047.00000	0.000000	1100.67981	283.81698
2248.000000	3747.000000	0.000000	1050.200562	291.482147
3147.00000	750.00000	0.000000	414.86685	293.48352
2248.000000	3447.000000	0.000000	997.374146	300.002686
2847.00000	1349.00000	0.000000	548.88702	304.12851
2248.000000	3148.000000	0.000000	943.674194	308.228577
1948.00000	4047.00000	0.000000	1135.30798	311.32720
2847.000000	1050.000000	0.000000	486.005676	314.286835
1948.000000	3747.000000	0.000000	1082.415649	320.913422
2847.00000	750.00000	0.000000	421.93841	324.01486
1948.000000	3447.000000	0.000000	1028.449951	329.732574
2847.00000	450.00000	0.000000	355.31756	333.78350
2548.000000	1349.000000	0.000000	561.765564	335.440460
1948.00000	3148.00000	0.000000	972.39038	339.21478
...				
151.00000	1050.00000	0.000000	625.81713	751.94268
151.000000	450.000000	0.000000	417.890869	805.131653
151.00000	151.00000	0.000000	306.49780	833.38739

4x4 Projection Matrix

TransMatrix

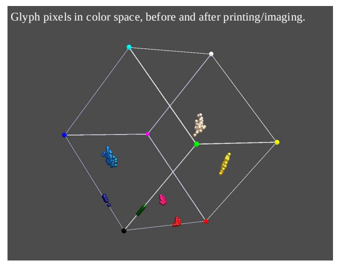
180.524595	1246.514401	462.936277	685243.
-301.898312	-76.475146	1173.041448	2557361.968673
0.718275	0.274692	0.639238	2834.
0.000000	0.000000	0.000000	1.000000

Glyph Color Space



Each glyph is composed of N discs, each with a unique color, chosen from a set of M prototype colors. In the case shown above N=3, M=8. The permutation of disc color uniquely identifies the glyph and is used to lookup the 3d coordinates of the glyph. We must reliably identify these colors under the conditions listed to the right:

- Variations in view direction
- Shading variations due to scene geometry
- Printing nonlinearities and noise
- Imaging nonlinearities and noise

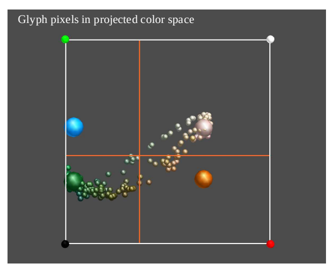


Glyph pixels in color space, before and after printing/imaging.

The image to the left demonstrates the printing and imaging nonlinearities (photoCD based) involved in mapping the corners of the color space into imaged RGB space for a single view. The nonlinearities are extreme and cause us to limit the number of prototype colors to 6. We reject magneta due to its proximity to red and reserve white as a background color.

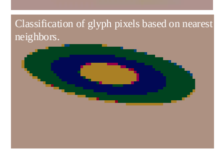
Limitations of Nearest Neighbor Classifiers

Determination of glyph identity requires classifying each pixel as belonging to one of the M=6 prototype colors. A simplistic approach to this is to classify each pixel in the image as being associated with the closest prototype color in color space. This nearest neighbor classification fails at boundaries between regions where pixels see contributions from more than one color. Note the false colors appearing in the classification below. These difficulties are best understood by looking in color space, a 2D projection of which is shown below. Aliased pixels are shown as small spheres between two of the larger spheres, which represent the prototype colors. Note small amounts of noise along the diagonal between prototypes can perturb the pixels and cause them to be misclassified. We choose to classify each pixel as either *pure* or *aliased*, where aliased pixels are some threshold distance away from their closest prototype color. We use only pure colors for determining glyph ID's, as these are never misclassified.



Glyph pixels in projected color space

Raw image of a glyph.

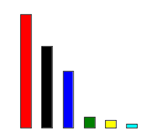


Classification of glyph pixels based on nearest neighbors.

Occluded Glyph Rejection

Our goal is to extract the center position and color identification of as many glyphs in each image as possible. In the presence of occluding objects we must be careful not misestimate glyph centers if a glyph is partially obscured, as this would lead to inaccuracies in the estimation of camera pose. We must also not misidentify occluding geometry as a glyph. We employ a number of heuristics to ensure that the glyph centers are accurately reported. The glyph extraction method extracts connected regions of foreground colors (non-white), classifies each pixel in the foreground region as belonging to one of 6 prototype colors and then checks the distribution of foreground colors.

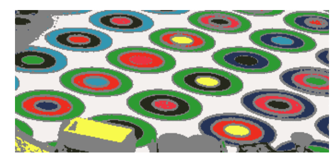
- Only N=3 protoype colors are seen in the region. Disregard any region with more than 5% of its pixels not in the top 3 ranked, classified colors.
- The number of pixels in the top 3 ranked colors corresponds to a distribution expected from a glyph geometry of concentric overlapping discs.
- Disc regions are concentric. The spatial centroid of the top 3 ranked pixel colors should be within a few pixels of each other.
- Pixels in the outer band should have a larger standard deviation of position than those in the inner bands. The rank of the the top N=3 color histogram must match the rank of the top 3 spatial standard deviations.
- A glyph must exceed some minimum size to be usable.
- The glyph ID implied by the top 3 ranked colors must have actually occurred on the particular chromaglyph sheet imaged.



Connected Region Color Histogram

In addition, we can classify each pixel as being either an *pure* or *aliased* pixel. Pure pixels are within some threshold distance in color space to one of the M=6 prototype colors. Aliased pixels are past this threshold distance in color space and presumably are pixels on region boundaries that have contributions from more than one color region. There are further tests we can apply based on this classification.

- Exactly N=3 types of pure pixels are seen in the region.
- Each of the N=3 top ranked buckets must have some minimum number of pixels.



Pure pixels classification