"quantitative Visual Presence" ("qVP")

A stereo-image-data format concept placed in the public domain on October 21, 2009
- Ref.: www.setterholm.com "Directory.pdf" (page 1 of 6)
and the " /Geodesy" subdirectory content.

Author: Jeffrey M. Setterholm
Systems Engineer
Lakeville, Minnesota, USA
(952) 461-3445
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This is version 1.2; after download, rename:
"quantitativeVisualPresence12.pdf"

Executive Summary:

This technical data demonstrates that a single (4x4) homogeneous transform matrix can map a stereo image pair (a viewed volume of 3-D space) to GPS 3-D (X,Y,Z) coordinates, and that the inverse of the matrix performs the reverse operation.

I have defined **and placed in the public domain** a first-cut at the format of the supporting images+data package.

For more than a decade, I have asserted that data should be transferred at "nodes": i.e. points where the inherent complexity of the data is minimized. QVP's are an example of a data "node".

Further information…

The qVP format may be applied to stereo-images of various scales and in disciplines far removed from geodesy (e.g. microscopy & medical imaging), and also to computer-generated scenes. Furthermore, in the generation of 3-D (stereo) movies, the insertion of volumetric animation material in stereo-real scenes may be simplified by the use of qVP transforms.

Auto-correlation is simplified in well-formed stereo pairs because corresponding points lie in the same horizontal row of both images, narrowing the search. By handing off a specific 3-D location of interest, inter-correlation between qVP's viewing the same volume can have very narrow correlation windows.

Creating accurate qVP's may involve real work, but utilizing qVP's is likely to become a breeze because the viewing/utilization tools can be generic. Such viewers can use auto-correlation to aid the perception of the (considerable number of) people who do not have stereo vision.

For highly accurate oblique geodetic images, particularly at long range, the coefficients of a compact atmospheric refraction correction algorithm will probably need to be added. Refraction can distort the view of a volumetric target in non-Euclidean ways that homogeneous transforms presently seem unlikely to fully correct.

Background:

"Visual Presence" suggests actually being at a location & seeing what's there. For the majority of people, "seeing" includes perception based on two-eyed/binocular/stereo/ three-dimensional (3-D) vision. To clarify: one eye offers a "perspective" view, while two in-focus, synchronized eyes and a properly-functioning visual cortex provide the human mind with a "stereo" view that has (qualitative) depth information as well. "Perspective" is not "stereo", but stereovision is achieved using two mentally-unified perspective views of the same scene.

In my experience, utilization of stereovision varies from person-to-person, somewhat like a bell-shaped curve. Over the years, about 2/3rds of my (~300) subjects were eventually pleased to see stereo images, whereas about 1/3rd of my subjects remained uninterested – a typical comment being: "I could already see the image using just one eye". About 5% of the subjects immediately fused the stereo images and were ecstatic upon seeing them.

"quantitative" implies measurement. Unaided human perception is overwhelmingly qualitative: e.g. "A" is longer than "B", but the length of either "A" or "B" is in question. A rare exception to this is that a small fraction of humanity has "perfect pitch" – the ability to name the exact note associated with an audio tone. Being quantitative in 3-D has two directionalities: one is being able to measure what you see, the other is being able to accurately insert known measurements into your existing stereo view.

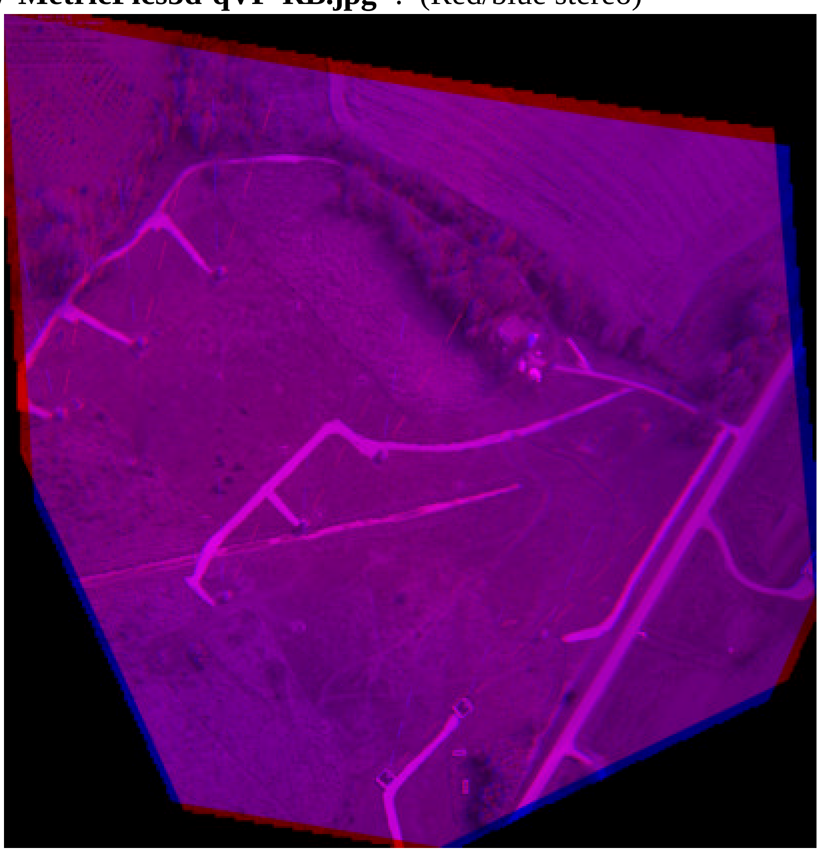
Hence, being able to "see", "measure what you see", and "see what has been measured" is **"quantitative Visual Presence"**. The stereo-image-data format described herein supports doing all three, in an elegant and direct way.

A qVP: (Two examples of viewing formats)

/Geodesy/KfanMN/"**MetricPics3d-qVP.jpg**": (crossed-eye stereo)

Right eye's view Left eye's view

/Geodesy/KfanMN/"**MetricPics3d-qVP-RB.jpg**": (Red/blue stereo)



.jpg Comment:

In both cases, the .jpg image file has **quantitative** information embedded as a comment in the image file header. For the crossed-eye view above, the header is:

```
/Geodesy/KfanMN/"MetricPics3d-qVP.txt":
qVP - `MetricPics3D`: [title] Copyright 2009 Jeffrey M. Setterholm
 -0.134540924716E+03  0.134452423525E+03 -0.465529357587E-01  0.40246177330E+06
 -0.226820802553E+04  0.226817503098E+04  0.636285537710E-01  0.67762117918E+07
  0.222964292824E+04 -0.222967577483E+04  0.615161061614E-01 -0.66618904135E+07
  0.499879638906E-03 -0.499879638906E-03  0.000000000000E+00 -0.14933996389E+01
         EcefXyz  = ^    hEcefQpix(4,4)  * QvpPixels
 -0.879408340438E+01  0.318241681559E+01 -0.994671180338E+01  0.56441256423E+08
 -0.883015410280E+01 -0.990027170286E+00 -0.565828400670E+01  0.18369118354E+08
 -0.455961021815E+01  0.174309374485E+02 -0.522413726007E+01  0.10116735070E+09
  0.120737994243E-04  0.139662534980E-02 -0.143544814308E-02  0.12743063635E+05
         QvpPixels= ^inv(hEcefQpix(4,4)) * EcefXyz
  0.602845109622E-02  0.697335389036E+00 -0.716719619499E+00  0.63626148834E+07
 -0.885011906701E+00 -0.329945555659E+00 -0.328465911928E+00 -0.27015259162E+06
 -0.465529357587E+00  0.636285537710E+00  0.615161061614E+00  0.18015741097E+05
  0.000000000000E+00  0.000000000000E+00  0.000000000000E+00  0.10000000000E+01
         SocUvw   = ^    hSocEcef(4,4)   * EcefXyz
Internal qVP geometry (+X:in,+Y:right,+Z:down):
                9976                5156                     -pixels in image
  0.498800000000E+03  0.515600000000E+03  0.100000000000E+00 -extent/PixSize
 -0.499300251951E+03 -0.217690396582E+03  0.472887553876E+03 -left  eye loc.
 -0.499300251951E+03 -0.176422405521E+02  0.472887553876E+03 -right eye loc.
  0.000000000000E+00  0.000000000000E+00 -Shift L-eye subimage (pixels)
  0.000000000000E+00  0.000000000000E+00 -Shift R-eye subimage (pixels)
 (`Shift`:provides minor adjustment by editing these values in the .jpg file.)
                      2009.10.01.1310.13    -qVP creation date & time
P0102025  2       971 2006.10.06.1919:23.50 -left  eye: Run,Camera,Frame,Date
P0102025  1      1106 2006.10.06.1920:42.86 -right eye: Run,Camera,Frame,Date
Source images - Geospan Corp. P0102025 ~2006.10.06.1920gmt

          All distances are in meters.
          Pixel:(0.,0.) is the image upper-left corner
          ECEF: native-GPS WGS-84 Earth-Centered,Earth-Fixed coords.
```

Numerical Example (crossed-eye):

```
 Select the midpoint of the stereo pixel field:
 QvpPixels:(iLeft,iRight,jDown,1)=  7482.00  2494.00  2578.00     1.00
         EcefXyz  =      hEcefQpix(4,4)  * QvpPixels
                     ...remember to divide homog. outputs by the 4th component.
 EcefXyz:(X,Y,Z,1)=  -268969.095 -4537528.094  4459645.182 1.000 meters
 WGS-84 LLH:(Lat,Lon,Ht,1.)=   44.64619756713  -93.39232769175   261.955  1.000
                      Elevation - with respect to the Ellipsoid, not the Geoid.
& Reversing... (it works!...)
 EcefXyz:(X,Y,Z,1)=  -268969.095 -4537528.094  4459645.182 1.000 meters
         QvpPixels=  inv(hEcefQpix(4,4)) * EcefXyz
 QvpPixels:(iLeft,iRight,jDown,1)=  7482.00  2494.00  2578.00     1.00
 Note: QvpPixels=(0.,0.,0.,1.) is the image upper-left-corner
Second example: Move the left-eye pixel 9.99 right
 QvpPixels:(iLeft,iRight,jDown,1)=  7491.99  2494.00  2578.00     1.00
         EcefXyz  =      hEcefQpix(4,4)  * QvpPixels
 EcefXyz:(X,Y,Z,1)=  -268969.977 -4537527.995  4459648.731 1.000 meters
 WGS-84 LLH:(Lat,Lon,Ht,1.)=   44.64622058273  -93.39233886581   264.417  1.000
Final example: If the center of the user-defined Gameing Area is:
 WGS-84 LLH:(Lat,Lon,Ht,1.)=   44.64697832300  -93.39199593300   259.248  1.000
 EcefXyz:(X,Y,Z,1)=  -268939.100 -4537466.863  4459705.009 1.000 meters
 QvpPixels:(iLeft,iRight,jDown,1)=  6818.00  1830.00  3196.00     1.00
    Corresponding points are meant to be in the same pixel row.
 Expressing the same point w.r.t. the Stereo-optic-center (Soc)
         SocUvw   =      hSocEcef(4,4)   * EcefXyz
 SocUvw:(U,V,W,1)=      499.300      117.666     -472.888 1.000 meters
!--- Example completed:                                  @ 2009.10.01.1310.53 L
```

Comments can be inserted-in and extracted-from .jpg images in a standard way using "C" software source code that was made public years ago by the Independent JPEG Group; bravo for their excellent work!

The 4x4 matrices (arrays of numbers) in blue, green, and brown above are "homogeneous transforms". Homogeneous transforms are the core mathematics of present-day computer graphics cards which support "OpenGL", a powerful and elegant graphics language developed by Silicon Graphics.

The blue matrix transforms stereo pixels to Global Position System (GPS) X,Y,Z.

The green matrix (which is the inverse of the blue matrix – yes, the inverse is defined!) transforms GPS XYZ to stereo pixels.

The brown matrix transforms GPS XYZ to Uforward,Vright,Wdown coordinates with respect to the stereo-optic center of the qVP.

(The brown matrix can be reverse-engineered from the blue matrix by ray-tracing, but the process is a bit complicated for beginners.)

Note that the brown matrix is a "six-degree-of-freedom" –"6DOF"- (e.g.: x,y,z,roll,pitch,yaw) rigid body transformation, expressed in terms of a translation vector and the direction cosines of the rotation …part of elementary OpenGL.

The multiplying the brown matrix times the blue matrix supports the direct transformation of stereo pixels to coordinates in the observers frame of reference, which is useful for setting up the appropriate viewing frustums in OpenGL. & Since both matrices are invertible, their product is also invertible!

To those of you who have not had a course in Linear Algebra, this first view of homogeneous transforms may be a bit breathtaking; however, I suggest that young students who have a good grasp of Algebra I can segue into Linear Algebra quite gracefully. & Perhaps the students will be delighted by the realization that n-equations in n-unknowns (n>2) is easier to solve (using algorithms & matrices) than solving two-equations in two-unknowns by hand. Simply adding a 4th 1.0 component to a 3-D vector makes it homogeneous, and dividing through by the 4th component of a homogeneous vector de-homogenizes the first three components of the vector …as you'll see in the examples later.

A Robust Testcase:

In order to provide a "proof of concept" of the qVP format, I chose a coordinate-rich volumetric target: the 3x3 antenna array of radio station KFAN, which is located in Credit River township (~ 44.648 N, - 93.393 W), a few miles Northwest of my home. Each antenna has three white and four red sections; I used the six color-change points on each antenna as my targets. (My reverse-engineered 6DOF+DistortionCorrection camera calibrations fit all 54 points in each of the two different oblique views from two separate cameras to about 1.5 pixels RMS.) The next two pages are my first draft summary of KFAN as a camera calibration/qVP target:

`/Geodesy/KfanMN/`"**`KFAN-Geometry-20091002-FirstDraft.txt`**":

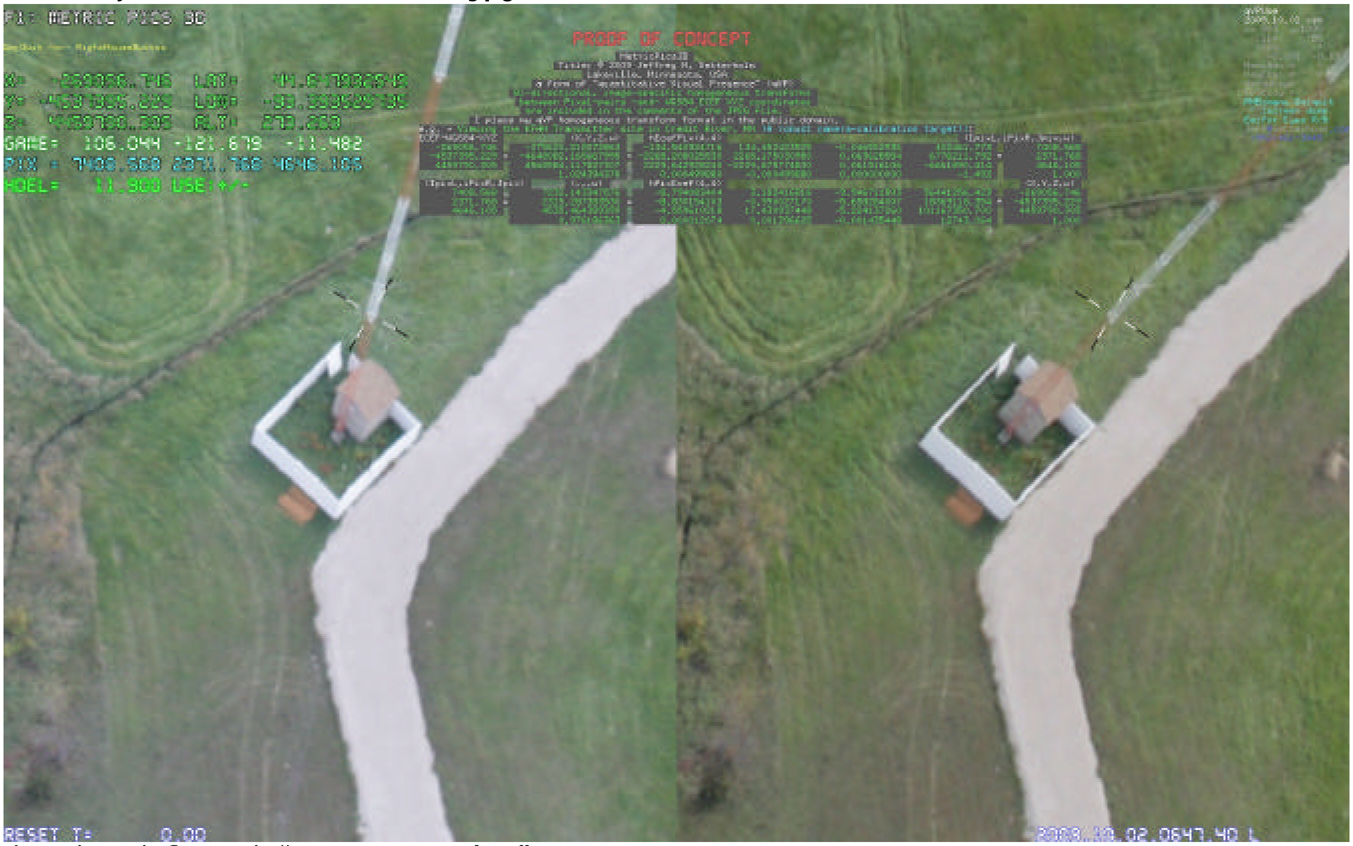
nPoints
72

Id	X	Y	Z	Latitude	Longitude	Elev(m)
01	-269059.954	-4537447.054	4459841.999	44.6479351329	-93.3935314295	346.537
02	-269059.441	-4537438.395	4459833.431	44.6479351347	-93.3935314324	334.345
03	-269058.928	-4537429.737	4459824.863	44.6479351365	-93.3935314354	322.153
04	-269058.414	-4537421.078	4459816.295	44.6479351384	-93.3935314383	309.961
05	-269057.901	-4537412.419	4459807.728	44.6479351402	-93.3935314412	297.769
06	-269057.388	-4537403.760	4459799.160	44.6479351420	-93.3935314442	285.577
07	-269056.875	-4537395.101	4459790.592	44.6479351439	-93.3935314471	273.385
08	-269056.362	-4537386.443	4459782.024	44.6479351457	-93.3935314500	261.193
09	-269081.838	-4537490.453	4459796.828	44.6473638153	-93.3937744192	346.537
10	-269081.325	-4537481.794	4459788.261	44.6473638160	-93.3937744226	334.345
11	-269080.812	-4537473.135	4459779.693	44.6473638168	-93.3937744260	322.153
12	-269080.299	-4537464.476	4459771.125	44.6473638175	-93.3937744294	309.961
13	-269079.786	-4537455.817	4459762.557	44.6473638182	-93.3937744328	297.769
14	-269079.272	-4537447.159	4459753.989	44.6473638190	-93.3937744362	285.577
15	-269078.759	-4537438.500	4459745.422	44.6473638197	-93.3937744396	273.385
16	-269078.246	-4537429.841	4459736.854	44.6473638204	-93.3937744430	261.193
17	-269103.723	-4537533.851	4459751.658	44.6467924971	-93.3940174042	346.537
18	-269103.210	-4537525.192	4459743.090	44.6467924968	-93.3940174080	334.345
19	-269102.697	-4537516.533	4459734.522	44.6467924964	-93.3940174119	322.153
20	-269102.183	-4537507.875	4459725.955	44.6467924960	-93.3940174158	309.961
21	-269101.670	-4537499.216	4459717.387	44.6467924957	-93.3940174196	297.769
22	-269101.157	-4537490.557	4459708.819	44.6467924953	-93.3940174235	285.577
23	-269100.644	-4537481.898	4459700.251	44.6467924950	-93.3940174273	273.385
24	-269100.130	-4537473.239	4459691.684	44.6467924946	-93.3940174312	261.193
25	-268920.889	-4537485.456	4459811.519	44.6475496369	-93.3917529274	346.535
26	-268920.376	-4537476.797	4459802.951	44.6475496379	-93.3917529270	334.343
27	-268919.863	-4537468.138	4459794.384	44.6475496390	-93.3917529265	322.151
28	-268919.350	-4537459.479	4459785.816	44.6475496401	-93.3917529260	309.959
29	-268918.837	-4537450.821	4459777.248	44.6475496412	-93.3917529256	297.767
30	-268918.323	-4537442.162	4459768.680	44.6475496423	-93.3917529251	285.575
31	-268917.810	-4537433.503	4459760.112	44.6475496434	-93.3917529246	273.383
32	-268917.297	-4537424.844	4459751.545	44.6475496445	-93.3917529242	261.191
33	-268942.774	-4537528.854	4459766.349	44.6469783230	-93.3919959330	346.535
34	-268942.261	-4537520.196	4459757.781	44.6469783230	-93.3919959330	334.343
35	-268941.747	-4537511.537	4459749.213	44.6469783230	-93.3919959330	322.151
36	-268941.234	-4537502.878	4459740.645	44.6469783230	-93.3919959330	309.959
37	-268940.721	-4537494.219	4459732.078	44.6469783230	-93.3919959330	297.767
38	-268940.208	-4537485.560	4459723.510	44.6469783230	-93.3919959330	285.575
39	-268939.695	-4537476.901	4459714.942	44.6469783230	-93.3919959330	273.383
40	-268939.181	-4537468.243	4459706.374	44.6469783230	-93.3919959330	261.191
41	-268964.658	-4537572.253	4459721.178	44.6464070086	-93.3922389338	346.535
42	-268964.145	-4537563.594	4459712.610	44.6464070075	-93.3922389343	334.343
43	-268963.632	-4537554.935	4459704.043	44.6464070064	-93.3922389347	322.151
44	-268963.119	-4537546.276	4459695.475	44.6464070053	-93.3922389352	309.959
45	-268962.605	-4537537.618	4459686.907	44.6464070042	-93.3922389357	297.767
46	-268962.092	-4537528.959	4459678.339	44.6464070031	-93.3922389361	285.575
47	-268961.579	-4537520.300	4459669.772	44.6464070020	-93.3922389366	273.383
48	-268961.066	-4537511.641	4459661.204	44.6464070009	-93.3922389370	261.191
49	-268781.825	-4537523.858	4459781.039	44.6471641131	-93.3899744489	346.537
50	-268781.312	-4537515.199	4459772.472	44.6471641135	-93.3899744450	334.345
51	-268780.798	-4537506.540	4459763.904	44.6471641138	-93.3899744412	322.153
52	-268780.285	-4537497.881	4459755.336	44.6471641142	-93.3899744373	309.961
53	-268779.772	-4537489.222	4459746.768	44.6471641145	-93.3899744335	297.769
54	-268779.259	-4537480.564	4459738.201	44.6471641149	-93.3899744296	285.577
55	-268778.745	-4537471.905	4459729.633	44.6471641152	-93.3899744258	273.385
56	-268778.232	-4537463.246	4459721.065	44.6471641156	-93.3899744219	261.193
57	-268803.709	-4537567.256	4459735.869	44.6465928030	-93.3902174703	346.537
58	-268803.196	-4537558.597	4459727.301	44.6465928023	-93.3902174669	334.345
59	-268802.683	-4537549.938	4459718.733	44.6465928015	-93.3902174635	322.153
60	-268802.170	-4537541.280	4459710.166	44.6465928008	-93.3902174601	309.961
61	-268801.656	-4537532.621	4459701.598	44.6465928000	-93.3902174568	297.769
62	-268801.143	-4537523.962	4459693.030	44.6465927993	-93.3902174534	285.577
63	-268800.630	-4537515.303	4459684.462	44.6465927986	-93.3902174500	273.385
64	-268800.117	-4537506.644	4459675.895	44.6465927978	-93.3902174466	261.193
65	-268825.594	-4537610.654	4459690.698	44.6460214923	-93.3904604870	346.537
66	-268825.080	-4537601.996	4459682.131	44.6460214905	-93.3904604840	334.345
67	-268824.567	-4537593.337	4459673.563	44.6460214887	-93.3904604811	322.153
68	-268824.054	-4537584.678	4459664.995	44.6460214868	-93.3904604782	309.961
69	-268823.541	-4537576.019	4459656.427	44.6460214850	-93.3904604753	297.769
70	-268823.028	-4537567.360	4459647.860	44.6460214832	-93.3904604723	285.577
71	-268822.514	-4537558.702	4459639.292	44.6460214813	-93.3904604694	273.385
72	-268822.001	-4537550.043	4459630.724	44.6460214795	-93.3904604665	261.193

```
KFAN Transmitter Site: 3x3 antennas, Credit River Township, MN.
Red/white color change points.(WGS-84 ECEF coordinates).
2009.10.02 - First Draft

ID`s (above) and KFAN`s #`s relative locations:
          #2                 #3                #4

     #5   01           #1   25           #6   49
          02                26                50
#7   09   03      #8   33   27 ^    #9   57   51
     10   04           34   28 u         58   52
17   11   05      41   35   29 p    65   59   53
18   12   06      42   36   30      66   60   54
19   13   07      43   37   31    h 67   61   55
20   14   08      44   38   32 t    68   62   56
21   15           45   39    r      69   63
22   16           46   40  o        70   64
23                47     N          71
24                48   ~ East->     72

`Top`    points: 01,09,17,25,33,41,49,57,65 -and the-
`bottom` points: 08,16,22,32,40,48,56,64,72
 have the vertical spacing of the color change points

Jeff Setterholm, Lakeville,MN, (952)461-3445, October 2,2009
Helpful contributors: Aaron White of KFAN            - initial overall geometry
                    : Jess Meyer  of ClearChannel     - segment lengths & site access
                    : Brian Udell of Scott Co.,MN GIS - coordination with surveyors
                    : Scott Co.,MN surveyors          - antenna lat/lon's
                    : Scott Co.,MN`s GIS website      - 2' contour information
                    : Geospan Corp., Maple Grove,MN   - Aerial imagery of site
                                                        & permission to proceed.

Per Scott County's surveyors:
!--- Scott County MN survey results:                    KFAN#
  data SurveyLatLon / 44.647934467d0, -93.393528327d0 &  !2 (most Northern antenna)
                     ,44.647363820d0, -93.393774446d0 &  !5
                     ,44.646793172d0, -93.394020561d0 &  !7
                     ,44.647548967d0, -93.391749798d0 &  !3
                     ,44.646978323d0, -93.391995933d0 &  !1
                     ,44.646407679d0, -93.392242063d0 &  !8
                     ,44.647163439d0, -93.389971292d0 &  !4 (most Eastern antenna)
                     ,44.646592799d0, -93.390217442d0 &  !6
                     ,44.646022159d0, -93.390463588d0  / !9
!--- which I compute implies:
  SpacingNorth= 66.353d0     meters
  SpacingEast =147.454d0     meters
  PatternYaw  = 16.890438d0 degrees  (w.r.t. true North)

Per Jess Meyer:
The mechanical segment design lengths are 20 feet exactly.
Each color appears to extend along two segments; hence:
  SpacingDown = 12.192d0     meters

The table's interpoint 3-D geometry reflects a uniform, unskewed, 3-D grid.

To the extent that the antennas themselves are straight and unskewed,
the horizontal registration of the grid should be excellent.

The elevation of the water in the drainage ditch appears to drop about
one meter going from left to right, whereas the flow goes from right to left.
In my visualization tool, the water elevation by antenna #1, is ~ 258.8 meters.

Overall vertical adjustment of the points, to reflect WGS84 ellipsoid height,
needs to be improved. Hence, this is a "First Draft".
```

Viewing the Results: Points #7, #39, & #66 above are measured using the blue homogeneous transform, and reverse-located using the green transform above. See the full-size images to read the descriptive detail.

/Geodesy/KfanMN/ “**KFAN-ID#07.jpg**”:



/Geodesy/KfanMN/ “**KFAN-ID#39.jpg**”:

/Geodesy/KfanMN/ “**KFAN-ID#66.jpg**”:

qVP Generation – more involved:

While the ***use*** of the qVP format is easy to describe, the ***generation*** of qVP’s from arbitrary images involves a great deal of both analytical and image warping skill; in the case of Earth-registered images, skill in Geodesy is also required. However, there are so many bright people involved in computer animation these days; a substantial number of such people will be able to generate qVP’s once the usefulness of quantitative Visual Presence is appreciated.

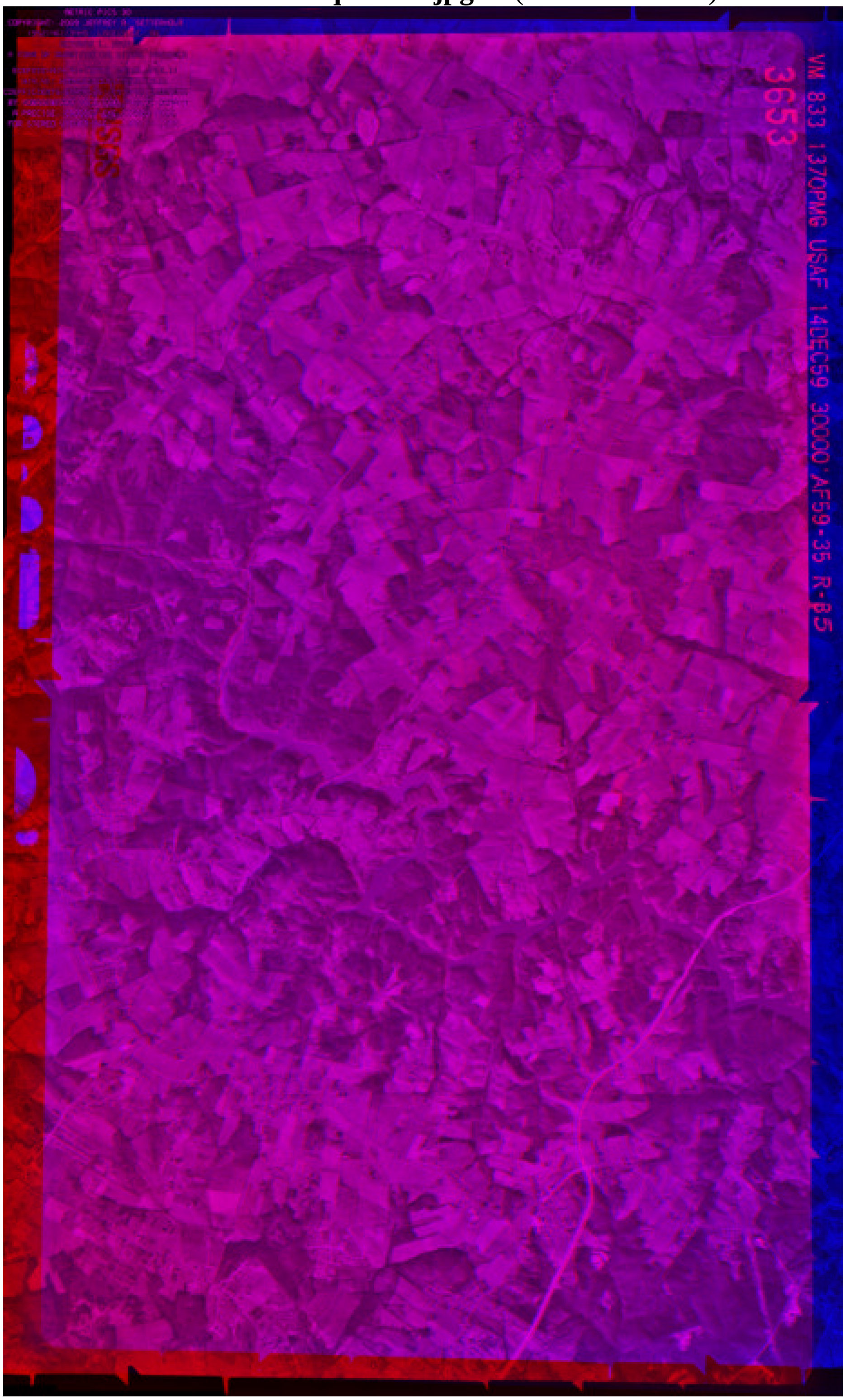
QVP’s – Now in the Public Domain:

At a local Society of Automotive Engineers (SAE) Section meeting in January, 1999, Ted Lachinski and I, both Geospan Corporation employees, publicly disclosed a concept called “Quantitative Stereo Pairs” (QSP’s). My professional opinion is that qVP’s are an obvious extension of QSP’s, re-expressed in terms of homogeneous transforms. Hence, I put the format in the public domain, rather than being blocked from using the format by a patent granted to someone else relatively “unskilled in the art”. At the same time, homogeneous transforms may now move to center stage in many different disciplines where “quantitative Visual Presence” proves to be useful, including in geodesy. **While creating stereo images using stereo cameras has been done for scores of years, use of some other *non-coplanar* image sources is part of the subject of Geospan Corporation’s U.S. Patent #5,633,946, which is still active.**

Downward-looking qVP from legacy USAF aerial photography:

1959 USAF 30,000' – grayscale stereo-photography.

/Geodesy/FultonMD/ "**FultonMD-1959-qVP-RB.jpg**": (Red/Blue stereo)

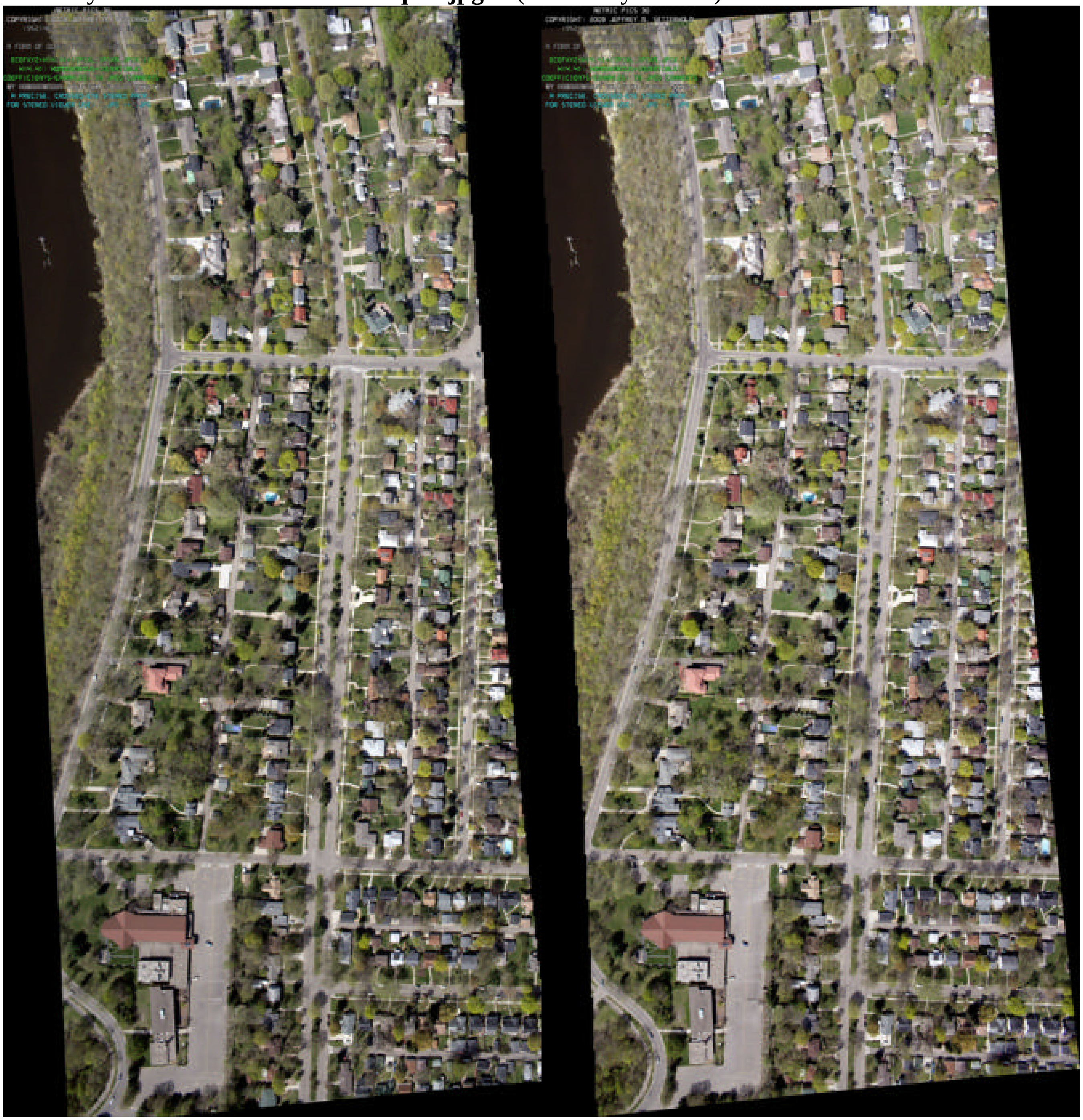


See: /Geodesy/FultonMD/ "**FultonMD-1959-qVP-RB-ReadMe.txt**" for details.

A low-altitude downward-looking qVP:

Geospan Corporation provided the images of St. Paul, Minnesota, just North of the Ford Motor Company plant on the East bank of the Mississippi River.

/Geodesy/StPaulMN/ "**StPaul-Down-qVP.jpg**": (crossed-eye stereo)



No "known ground control points" were used in aligning the underlying set of 10 images.

/Geodesy/StPaulMN/ "**StPaul-Down-SamplePoint.jpg**": Viewer (crossed-eye stereo)

The **file formats** used here are:

Adobe Acrobat's	:	**.Pdf**	- such as this file, for which the readers are free.
WinZip's	:	**.Exe**	- self-extracting file collections which decompress themselves when run into multiple files *of various types*. No reader is required.
	:	**.Zip**	- for those who own a copy of WinZip to accomplish the decompression.
Independent JPEG Group's	:	**.Jpg**	- compressed images (very widely used).
ASCII Text	:	**.Txt**	- can be viewed in any text reader.