Some Architect's Perspective Algorithms and Utilities

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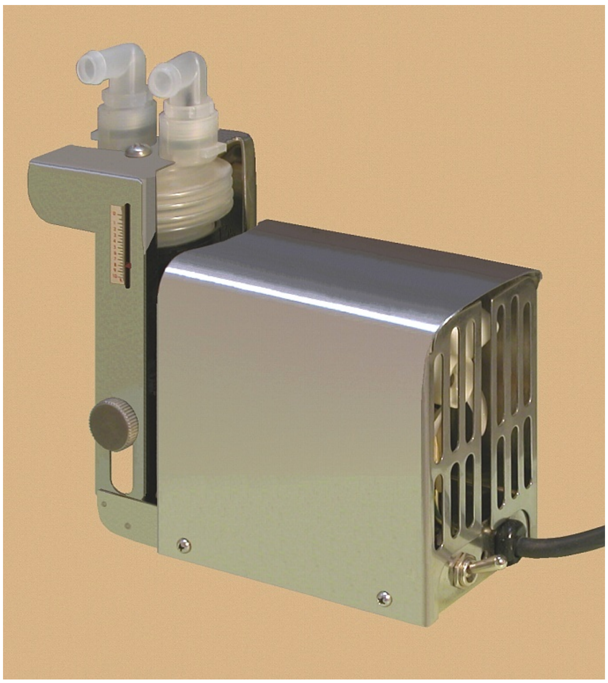
Classic studio view cameras had a number of adjustments on them that allowed image corrections. One of these was a centered **vertical tilt** on the film plane back. Used properly, this tilt could make the sides of buildings (and telephone poles in particular) perfectly vertical. Such an intentional distortion is often called an **Arcihtect's Perspective**.

Today, the same effect can look quite good on **eBay** product photos...



Note how the vertical edges in the image are in fact vertical. I've long had a set of perspective correction utilities available for your use.

Such as **KEYCOR01.PSL** which we reviewed in the **Image Keystone Correction** of **GuruGram #55**. Or our earlier **SWINGT01.PSL** which we reviewed in the **Digital Camera Swings and Tilts** back in **GuruGram #15**.

Sadly, these utilities had a flaw in that they would introduce **curvature distortion** for higher tilt values. This was caused by attempting to work one pixel line at a time when rewriting the **bitmaps**.

With our latest **AOSUTIL1.PSL** utilities first described in our **Bitmap to PS Array Conversions** of **GuruGram #84** and enhanced upon here, it is now possible to do true image remapping in both **X** and **Y** directions at the same time. While greatly reducing any distortions for higher amounts of correction.

A new **ARCHPER1.PSL** utility set is now available that does these improved Architect's Perspective corrections for you. It takes an existing .BMP image , makes suitable tilt and keystone modifications, and then resaves as a new and corrected .BMP image. You use this utility by reading it as an ordinary ASCII textfile, modifying some data values in a textfile or editor, and then sending it to **Acrobat Distiller**.

By **Using Acrobat Distiller as a PostScript Computer**.

While the utility is written in **PostScript** and optionally uses my **Gonzo Utilities**, no knowledge of PostScript programming is required for routine use.

One Gotcha:

> **Acrobat Distiller versions newer than 8.1 default to preventing diskfile access.**
>
> **The workaround from Windows is to run "Acrodist -F" from the command line**
>
> **Solutions for other systems are found here.**

If you think of your image as similar to that on a view camera's ground glass, the tilt correction geometry you will need turns out to be remarkably similar to…

The Starwars Nonlinear Transform

An intro tutorial on nonlinear graphics transforms appears as **NONLINGR.PDF**. In general, a linear transform lets you move, magnify, rotate, or even anamorphically stretch an image.

Anything fancier (such as converting a trapezoid to a rectangle) will demand more exotic nonlinear techniques. As will Architect's Perspective.

One of the more common tutorial examples was this **Starwars Transform**…

Select a tilt angle θ with 0° = flat and 90° = vertical.

Predefine a tilt factor geometric constant k…

$$k = \text{fullheight} * \tan\theta$$

The nonlinear transform is then…

$$x' = xk/(k + y)$$
$$y' = yk/(k + y)$$

The tilt factor **k** is the distance to the vanishing point Both nonlinear transforms follow by way of similar triangles.

We'll need two modifications of the Starwars transform for Architect's Perspective. These involve moving into a **centered space** that the nonlinear transforms will work around.

First, we will add a **ycen** that vertically centers our tilting action. In deference to its view camera heritage and to prevent any "top vs bottom" numeric problems, **we will usually keep ycen at one half the total image height**.

A second **xcen** mod will also be added. **xcen will be the axis of zero horizontal correction**. It is used to apportion (or balance) how much fix is to be applied to the right and left subject edges. In general, **xcen** will **not** be in the middle. And could even be far left or far right if both subject edges lean the same way.

The translations between our image space and centered space are…

centeredx = imagex - xcen
centeredy = imagey - ycen

imagex = centeredx + xcen
imagey = centeredy + ycen

It is super important to linearly transform between the centered and image spaces, while nonlinearly transforming only about the **0,0** axis of the centered image space. The Architect's Perspective forward nonlinear transforms are…

```
ycnew = ycold*[zzz/(zzz + ycold)]
xcnew = xcold*[zzz/(zzz + ycold)]
```

xcnew simplifies to...

```
xcnew = xcold*(ycnew/ycold)
```

For high processing speeds, **we absolutely must minimize all the individual new pixel-by-pixel calculations**. Fortunately, **ycnew** needs only done once per line, not every pixel.

And our **xcold** requires only a simply scaling at pixel calc time. You can see that **ycnew/ycold** equals **1** at **y=0**. You will definitely want to trap this out to prevent a possible **div0** hassle.

zzz here is now the distance from the center to the vanishing point and will be **ycen** times the tangent of the tilt angle. Our vanishing point will be infinite at 90 degrees and zero when "flat" at 0 degrees.

Normal nonlinear transforms are a "goes to" sort of thing. When pixel remapping, we will instead need **reverse** or "comes from" nonlinear transforms. As detailed in **INVEGRAF.PDF** of **GuruGram #85**.

Here are the Architect's Perspective **reverse** nonlinear transforms...

```
ycold = ycnew*[ zzz /(zzz - ycnew)]
xcold = xcnew*(ycold/ycnew)
```

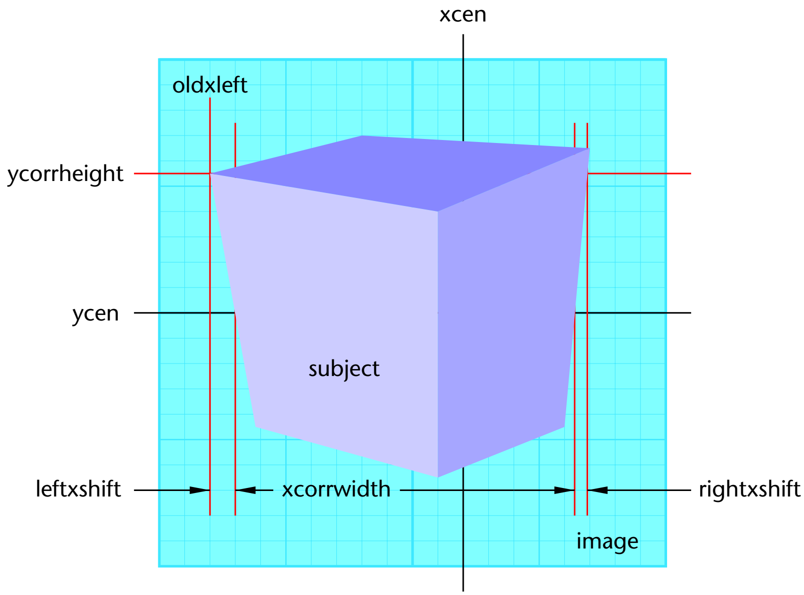
We thus have two variables that control our Architect's Perspective nonlinear transform. The **zzz** (derived from **tiltangle** and **ycen**) decides exactly how much correction to make, and **xcen** decides how to balance that correction between the left and right subject edges. We might use these two values to guess the amount of perspective correction needed for a given image. And then refine our guess with a second or third pass.

But it would seem intuitively better to find a way of...

Improving Data Input

If we know two specific points in an image where an exact amount of correction is required, we can solve the above forward nonlinear transform equations for **zzz** and **xcen**. Letting us get an exact solution on our first attempt.

The geometry might end up looking something like this...



Key points on your image are easily selectable using the rectangle tools and readouts in Paint, **Imageview32**, or similar graphics programs. You first select a **ycorrheight**, which is the point at which your tilt corrections are to be made. And a **xcorrwidth** which will be the new subject width **after** all corrections are made.

Correction values are then measured as **oldxleft**, **leftxshift** and **rightxshift**. Our "missing" values can be treated as dependent variables, noting that **newxleft = oldxleft + leftxshift**. And that **newxright = newxleft + xcorrwidth**. And that our **oldxright = newxright + rightxshift**.

From these values we can now calculate…

> **xcen = xcorrwudth * [leftxshift /(leftxshift - rightxshift)]**
> **+ oldxleft + leftxshift**
>
> **zzz = [oldxleft + xcorrwidth - xcen] * [ycorrheight - ycen]/**
> **leftxshift**

The **xcen** calculation uses plain old similar triangles and **y = mx + b**.

xcen and **zzz** are precalculated and only their results reused. Thus preventing unneeded and time wasting repeated math.

We can optionally find our tilt angle…

```
tiltangle = atan(zzz/ycen)
```

If **xcen** and **zzz** are calculated from actual image data, **tiltangle** will not normally be needed for the nonlinear transforms. **tiltangle** ends up simply an optional visualization aide.

Staying on the Same Page

Certain reverse nonlinear transforms from **xcnew** and **ycnew** may try to reach out-of-range data that is above, below, left, or right of the original **.BMP** bitmap.

Error testing each individual new pixel one-on-one would likely be highly time prohibitive. Instead, **limits should be precalculated**. These precalculations need be done only once per project or once per line at a ridiculously lower total time penalty.

Here is one way to calculate limits to prevent off bitmap access attempts…

```
IF yfract = [ zzz /(zzz + ycen) ] > 1
THEN ymin =  floor {-ycen * yfract } + 1
ELSE ymin = -ycen + 1

IF yfract = [ zzz /(zzz + ycen) ] < 1
THEN ymax = floor { ycen / yfract } + 1
ELSE ymax = ycen - 1

IF xfract = [ zzz/(zzz + ycnew)] < 1
THEN xmin = int [floor {-xcen * xfract}] + 1
ELSE xmin = -xcen

IF xfract = [ zzz/(zzz + ycnew)] < 1
THEN xmax = int [floor {(xwidth - xcen) * xfract}] - 1
ELSE xmax = xwidth - xcen - 1
```

For stronger tilt corrections, some recentering or y axis scaling may be needed. These linear transformations are easiest provided in further post processing.

A Working Utility

You can explore Architect's Perspective corrections using our **ARCHPER1.PSL** utility. What follows here is best understood by having **ARCHPER1.PSL** up in a separate textfile window.

The utility operates by capturing the original bitmap to three **PostScript** arrays of red, green, and blue strings.

As detailed in our **BMP2PSA.PDF** of **GuruGram #84**. A new three arrays of strings are separately created as **redAOS1**, **greenAOS1**, and **blueAOS1**. Reverse nonlinear transformations combined with **bilineal interpolation** then get done on a pixel by pixel basis to do the transformation. Finally, the new arrays of strings are converted into a final new and corrected bitmap.

The utility is in four parts, consisting of the basic array-of-strings manipulation procs, some globally exportable routines that may also be of use elsewhere, the actual Architect's perspective code specifics, and a final example area.

Specifically, our main code loop in **ARCHPER1.PSL** is **fixtilt**. This first captures our input bitmap to red, green, and blue arrays of strings as **redAOS** , **greenAOS**, and **blueAOS**. Data overflow limits are then calculated for later use. Each new pixel is then processed by way of a combination of a nonlinear reverse transform and a bilineal interpolation.

Effectively moving each pixel to its corrected position. Finally, the corrected arrays of strings are rewritten to a new output **.BMP bitmap** .

Going into more detail, the high level pixel processing is handled by **procpixels**. This mid level code sets up a loop within a loop that grabs the output pixel positions one line at a time and then one pixel at a time. Each pixel is then processed by **procrgbpers**.

procrgbpers in turn does the reverse nonlinear transforms and writes the repositioned old data to appropriate new pixels.

In general, the old x and y values needed for the current pixel location will be fractional. One of three **bilineal interpolators** named **doredbilin**, **dogreenbilin**, and **dobluebilin** are called. Each writes its interpolated old pixel result to the appropriate array of strings. Limits are precalculated to prevent out-of-bounds pixel errors.

Speed Issues

On a faster PC, **ARCHPER1.PSL** presently takes around five seconds to correct a **512x512** pixel bitmap. The processing time goes up roughly with the **square** of the resolution. A guideline…

> **Perspective corrections are best done at DOUBLE the final image size.**
>
> **Otherwise, crop as tightly as possible and use the lowest possible resolution.**

Speed has been partially optimized on **ARCHPER1.PSL**. Besides all of the usual **PostScript Speedup Tricks**, we might be able to make further improvements.

Further speedups should also be possible by optimizing the **nonlinear transforms** and the actual **bilineal interpolations**. But might make the code more obtuse and difficult to understand. And finally, being very careful when making correction measurements can eliminate the need for any second pass adjustments.

For More Help

The basic full two dimensional **.BMP bitmap to PS Array of Strings** tutorial appears as **BMP2PSA.PDF** with its actual PS utility at **PIXINTP1.PSL**. A recent addition was **AIRBRUSH.PDF** whose capabilities coincidentally appear in our first image above. Additional .BMP manipulation enhancements and expansions are planned.

News about the latest updates and addons should first appear in **WHTNU08.ASP** or later blog entries.

Similar tutorials and additional support materials are found on our **PostScript** and our **GuruGram** library pages. As always, **Custom Consulting** is available on a cash and carry or contract basis. As are seminars and workshops. For details, you can email **don@tinaja.com**. Or call **(928) 428-4073**.