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AN050

Comparison of Southwell and Fried Geometry Reconstructors for Shack-Hartmann Wavefront Sensing

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1 Introduction

When we started AOS, we decided to reconstruct wavefronts onto the center of the Shack-Hartmann lenses so that one phase point was created for each lens, which is commonly referred to as the Southwell geometry. The other common reconstruction geometry that is often used for adaptive optics is the Fried geometry in which the reconstructed phase points are at the corners of the lenses. Figure 1 illustrates each of these geometries. In adaptive optics, deformable mirror actuators are placed at the corners of the lenses. In this application note, I take a look at the various reconstructors and illustrate the SVD modes of these reconstuctors in an attempt to divine the better reconstruction method.

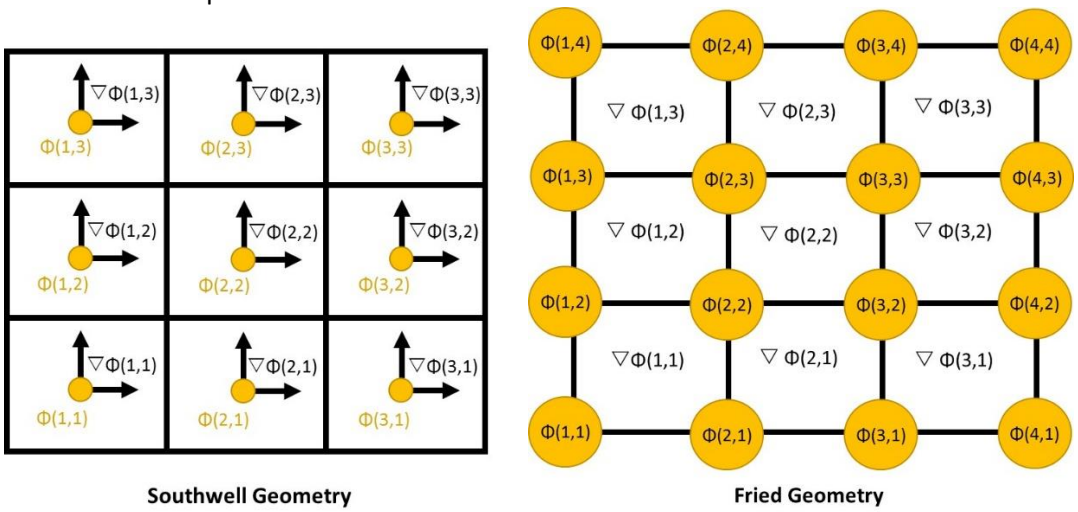

Figure 1: (right) Southwell Geometry; (left) Fried Geometry

2 Analysis & Results

In this note, I used the newest version of the AOS HWFSProcessing.m class to generate the Southwell and Fried geometry reconstructors. I then used the SVD routine in Matlab to generate the modes. I started with a 5x5 area of interest (AOI) geometry, which is shown in Figure 2.

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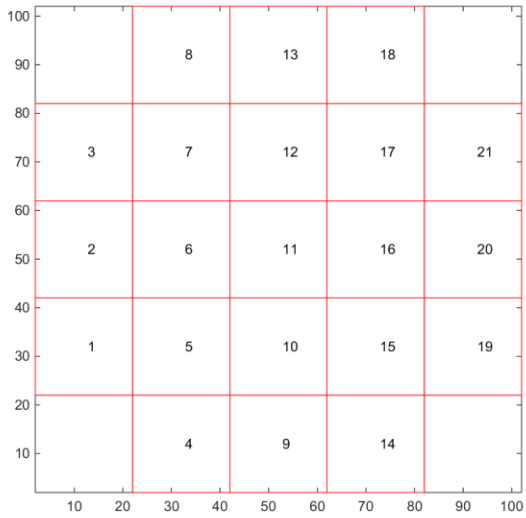

Figure 2: 5x5 WFS Geometry

Figure 3 illustrates the SVD modes of the two geometries. It was clear from this visualization that the Fried modes had significantly more waffle-type content than the Southwell modes. Fearing that this was associated with the odd nature of the number of horizontal lenses, I repeated this analysis for a 6x6 geometry.

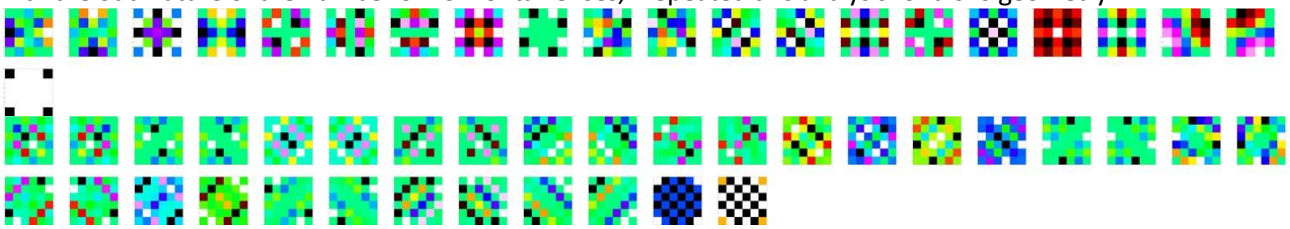

Figure 3: (top) Southwell Modes; (bottom) Fried Modes

Figure 4 shows the 6x6 geometry. Figure 5 shows the SVD modes for each geometry. It was again clear that the SVD modes contained more obvious waffle for the Fried geometry.

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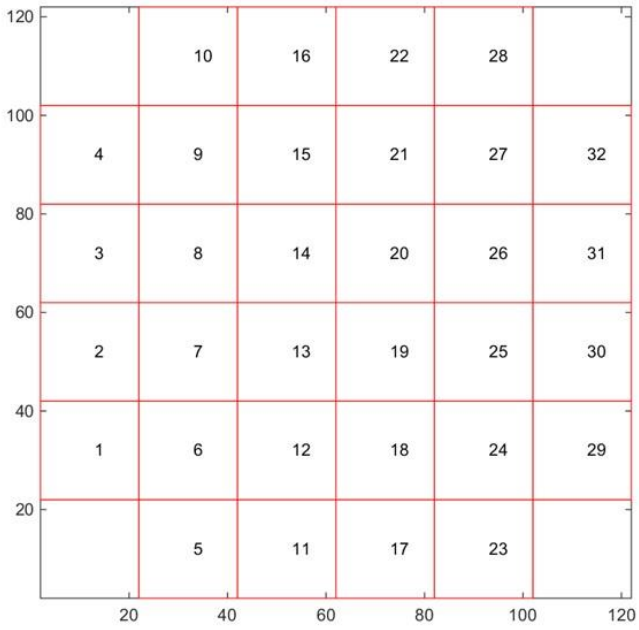

Figure 4: 6x6 AOI Geometry

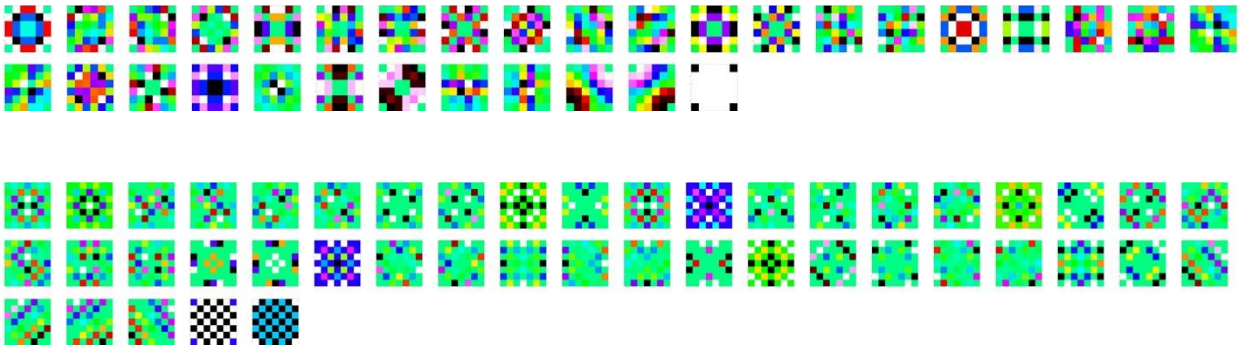

Figure 5: (top) Southwell Geometry Modes; (bottom) Fried Geometry Modes

3 Conclusions

In conclusion, this analysis showed that the Fried geometry modes were more prone to the containing waffle in every mode than the Southwell reconstructor.

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4 Appendix: Matlab Code

```
% script to test Fried and non-Fried geometry
Setup;
ppt=1;

Nx = 6;
Ny = Nx;
dsub = 150e-6;
dpixX = 7.5e-6;
dpixY = 7.5e-6;
wfsSeparation = 6.7e-3;
DapSF = 1.0;

if (ppt) TitleSlidePowerPoint('Analysis of Fried vs. Southwell Geometry');
end;

p = HWFSProcessing();
p.MakeExampleData(Nx,Ny,dsub,dpixX,dpixY,wfsSeparation,DapSF);
p.plotAOIs();
axis image;
if (ppt) ToPPT(); end;

v = [0 0 0 1 0 0 0 0 0 ];
p.MakeZernikeData(v);
[dx,dy,I,phs0]=p.get2DData;
figure;
quiver(dy,dx);
drawnow; pause(1.0);

p.MakePhaseReconstructionMatrix();
p.MakePhaseReconstructionMatrixFried(2);
figure; show(p.MinvFried);

[p2,phs] = p.reconstructPhaseFried(2);
figure;
subplot(1,2,1); show(phs0); title('Input');
subplot(1,2,2); show(phs); title('Output');

%% analyze the base matrices for modal structure

for type=1:2;
    if (type==1)
        M = p.Mbase; % AOS recon - Southwell Geometry
        pix = p.PhaseIndexX;
        piy = p.PhaseIndexY;
    else
        M = p.MbaseFried; % Fried recon
        pix = round(p.FriedPhaseIndexX+0.5);
        piy = round(p.FriedPhaseIndexY+0.5);
    end;
    [U,S,V] = svd(M);
    gains = diag(S);
    nf; semilogy(gains,'b--*');
```


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```
    figure;
    clear mp;
    for i=1:size(U,2);
        mp = zeros(max(pix),max(piy));
        for j=1:length(pix);
            mp(pix(j),piy(j)) = U(j,i);
        end;
        clf;
        SPFill(1,1,1);
        imagesc(mp); axis image; title(sprintf('Index: %i',i));
        drawnow;
        if (ppt)
            ToPPT(gcf,sprintf('Type=%i',type),[10 20 i],i==1);
        end;
    end;
end;
```


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