ACTIVE OPTICAL SYSTEMS

AN054

DM Alignment and Magnification in Adaptive Optics Systems

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1 Introduction

When building an adaptive optics (AO) system, misalignment or non-ideal magnification (poor prescription) of optics between the deformable mirror (DM) and the wavefront sensor (WFS) both affect the performance of the system. Misalignment in an AO system is often caused by optics being moved or by tilting the DM about a point that is not on the center of the optical surface. Non-ideal magnification is often caused by using commercial off-the-shelf (COTS) optics to build a simple telescope and living with the limited selection of these optics. In this application note, we explore how much each of these affect the system performance.

2 Approach

To study the effect of misalignment or poor prescription, we build an idealized model of an AO system using the AOS Matlab class library. We limited ourselves initially to Gaussian influence functions. To determine the effect of misalignment, we generated an ideal control matrix by inverting the poke matrix generated at the initial position of the actuators with no modes removed (pseudo least squares or SVD inverse) and then multiplied this control matrix by the poke matrix measured for the displaced actuators. In the zero mis-alignment state, we achieve an ideal identity matrix for this matrix multiply with the size being the number of actuators. As an error metric for this study, we examined the average of the diagnonal of this matrix and the RMS of the difference of the result matrix from identity.

To determine the effect of magnification, we analyzed control matrices generated with different sub-aperture spacings. The code for both these studies is in the appendix.

3 Results

3.1 Misalignment

Error! Reference source not found. shows the ideal DM alignment for the first misalignment study in which we used double Fried geometry.

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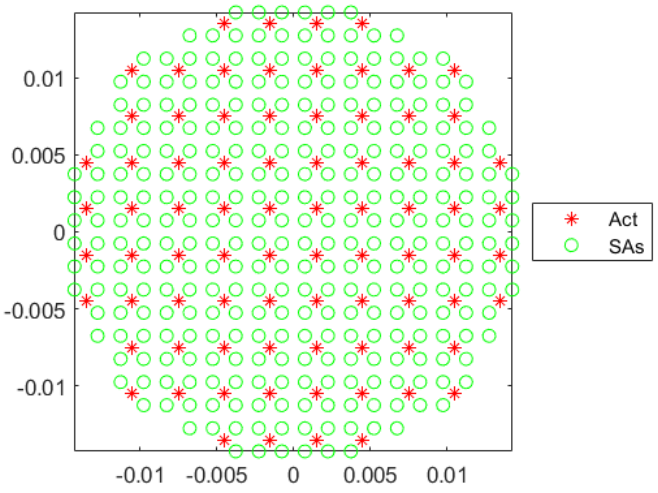

Figure 1: Idealized DM Alignment

Figure 2 shows the average of the diagnonal of the offset poke matrix times the ideal control matrix and the RMS of the difference of the result matrix from identity. If we want to limit our average diagonal to 90%, the maximum offset is around 25% of the actuator spacing. This results in a 5% RMS error in the matrix differences.

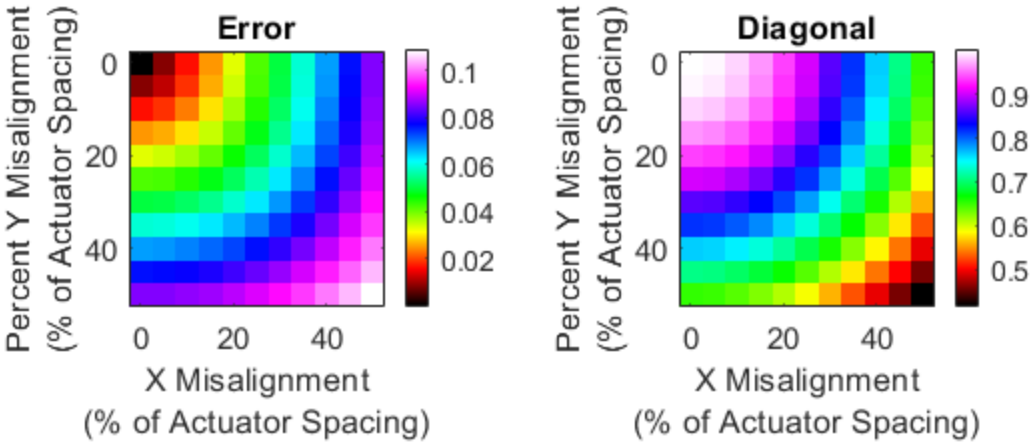

Figure 2: Results of Misalignment Study

3.2 Non-Ideal Magnification

4 Conclusions

In the misalignment study, we identified that a 90% solution is to have the actuators aligned to the original control matrix within 25% of the actuator spacing.

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5 Appendix: Modeling and Simulation Code

5.1 Misalignment Study

```
%
Setup;
ppt = 1;
dbg = 0;

Dap = 30e-3;
dact = 3e-3;
dsub = dact/2;
dxsub = 0;
dysub = 0;
dpix = dsub/8;
focalLength = 50*dsub;
wavelength = 633e-9;
nxy = 512;
dxy = dpix;
Dmesh = nxy * dxy
Dmesh2Dap = Dmesh/Dap

dxvec = (0:0.1:1).*dact/2;
dyvec = (0:0.1:1).*dact/2;
dqvec = 0; %(0:0.2:1).*(pi/4);

% dx = 0; dy = 0; dq = pi/4;
dx = dact/2;  dy = dact/2; dq = pi/4;

if (ppt) TitleSlidePowerPoint('Analysis of the effect of misalignment on AO control matrix
performance'); end;

%% setup baseline ao
a1=AdaptiveOptics();
a1.SetGrid(nxy,dxy);
a1.MakeActGrid(dact,Dap);
a1.MakeSubapertureGrid(dsub, Dap, dxsub, dysub);
a1.SetupSHWFS(dpix,focalLength,wavelength);
a1.MakeIFs();
a1.MakeControlMatrix();

% a1.ShowOverlay();
a2=AdaptiveOptics();
a2.SetGrid(nxy,dxy);
a2.MakeSubapertureGrid(dsub, Dap, dxsub, dysub);
a2.SetupSHWFS(dpix,focalLength,wavelength);

idx = 1;
tic
nf([0.8 0.8]);
fig=gcf;
for dx=dxvec;
    for dy = dyvec;
        for dq = dqvec;
            a2.MakeActGrid(dact,Dap);
            a2.ChangeActGrid(dx,dy,dq);
            a2.MakeIFs();
            a2.MakeControlMatrix();

            test = a2.poke * a1.ctrl;
            error(idx) = RMS(test-eye(size(test,1)));
            diagonal(idx) = mean(diag(test));

            %% draw results
            figure(fig);
            clf;
            subplot(2,2,1);
            imagesc(test); colorbar;
            subplot(2,2,2);
            plot(diag(test));
            subplot(2,2,3);
```


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```
            plot(error); title('RMS Error');
            subplot(2,2,4);
            plot(diagonal); title('Average Diagonal');
            drawnow;

            %% summary
            Nidx = length(dxvec).*length(dyvec).*length(dqvec);
            dt = toc;
            disp(sprintf('Time: %.2f, ix:%i TTC: %.2f minutes',dt,idx,dt*(Nidx/idx-1)/60))
            idx=idx+1;
        end;
    end;
end;
save('singleDMOffsetModel.mat');

%% summary
err2D = reshape(error,length(dxvec),length(dyvec));
diag2D = reshape(diagonal,length(dxvec),length(dyvec));
nf;
subplot(1,2,1); imagesc(dxvec/dact*100,dyvec/dact*100,err2D); title('Error'); colorbar;
xlabel('Percent X Misalignment'); ylabel('Percent X Misalignment');
subplot(1,2,2); imagesc(dxvec/dact*100,dyvec/dact*100,diag2D); title('Diagonal'); colorbar;
xlabel('Percent X Misalignment'); ylabel('Percent X Misalignment');
if (ppt)
    ToPPT('Shift Results');
end;
```


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