Simulated Image Distortion Implemented in MagicDraw and MATLAB

Matthew Dolan, SAGE IV MBSE Intern
NASA Langley Research Center

SysML Concepts

- SysML, or the Systems Modeling Language, is a systems engineering oriented adaptation of UML[1]
- Can be used to describe an entire system within a single cohesive model
- Enables single point of truth requirements management, system architecture, relations, and analyses[1]

Strengths of SysML-Driven Analyses

- SysML is can be implemented through numerous programs, including MagicDraw[1]
- SysML allows systems engineers to analyze their model and run system trades to determine whether or not a given solution will be viable for their model.
- Analyses can be performed in MagicDraw's parametric suite and through integrations with other scriptable analysis tools[5]
  - Common tools include MATLAB, Abaqus, etc.
- Through MagicDraw, these programs may be run using defined values from within the single-point-of-truth system model.

Point Spread Function Modeling

The modeling of the point spread function of an optic is greatly aided by the use of Zernike polynomials.

- Used to mathematically describe the deformation of a wave front on a unit circle.[6]
- By combining several Zernikes an approximation of wavefront error can be created.[2]

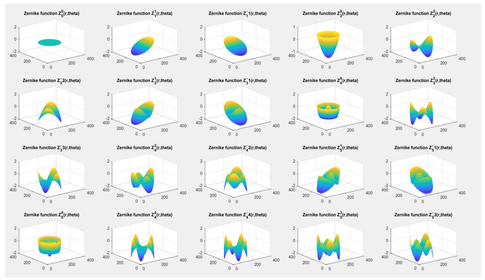

Figure 4: The first 20 Zernike polynomials used in modeling WFE[6]

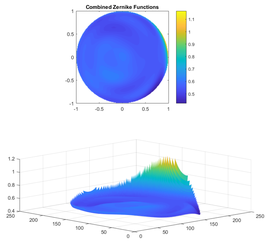

Figure 5: (Right) The combination of the first 37 Zernike polynomials after modification by a series of coefficients. When combined in this manner, this set of Zernikes represent an approximation of the WFE of one of the mirrors used in the SAGE IV optical system

MATLAB Image Distortion Overview

Light interacting with a mirror will not be reflected without some degree of generated wavefront error (WFE).[2] This error is largely due to the surface figure error (SFE) of the mirror, which is best described as deviations of the mirror from its ideal shape.[4] The resulting WFE will distort the image, resulting in a "blurring" effect. This WFE can be modeled by a set of Zernike polynomials, as described below. By convolving the resultant WFE with an initial sample image, the theoretical distortion of an image as light passes through each optical element can be obtained[3], as seen in Figure 1.

- As seen in Figure 2 below, the image will only distort slightly due to each individual mirror.
- When this effect is combined, the distortions can have a noticeable effect on quality
- The distortions modeled here are for proof-of-concept purposes only, and do not reflect actual distortion amounts that will be present on SAGE IV at this time.

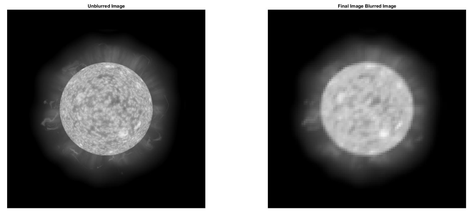

Figure 1: Original vs. Distorted Final Image[7]

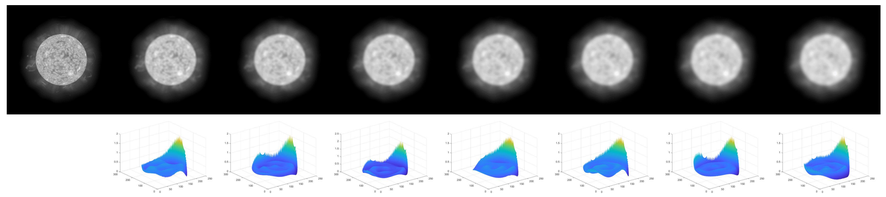

Figure 2: Simulated sequence of blurring as image passes through the optics of SAGE IV's imager. Each successive optic distorts the image as a function of its surface figure error. The point spread function applied to each image is displayed below it. While the error from one optic is relatively small, when combined they create dramatic differences in image quality.

MagicDraw Parametrics

MagicDraw contains its own in-program parametric analysis suite using the Cameo Systems Toolkit. An example of its use in the sizing of optics is below.

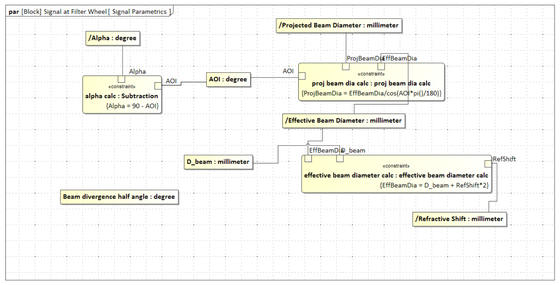

Figure 3: Example of parametric analysis in MagicDraw

Parametric diagrams such as this one allow for constraints to be applied to a system model in order to determine required system parameters.[5]

- In the example above, the constraints applied determine the projected diameter of a beam of light impacting an optical element in the SAGE IV filtering apparatus.[3]
  - This is based upon the sizing of elements in the filter apparatus, defined elsewhere in the model
- The constraints applied in this scenario are calculations driven by MagicDraw's in-house engine.
- However, these constraints can also be formatted to run analyses in other programs.[5]

Implementation in SysML Model

MagicDraw's internal parametric analysis suite, while powerful independently, is only enhanced by the addition of integrations with external analyses. As demonstrated here, an integration with MATLAB allows the aforementioned image blur prediction algorithm to be run from the SysML model directly.[5]

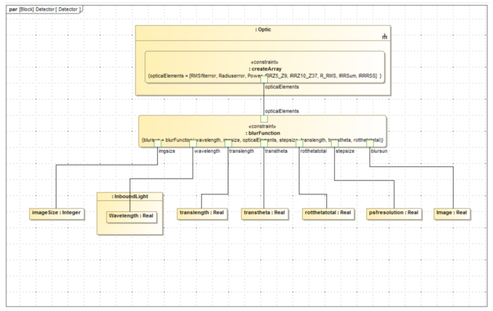

Figure 5: MATLAB function integration with a SysML Model

- The associated MATLAB function will reference the dimensions and values stored in system elements and output its results to an image file depicting a blur approximation.
- Can also be configured to modify elements of the model in order to store results on an instance level[1]
- Allows engineers to run system trades from entirely within the model.

System Requirement Traceability

MagicDraw also enables requirement management and satisfaction within the model. Requirement diagrams can be created separately from system architecture, and then be connected back to system architecture through satisfaction and allocation relationships.[1]

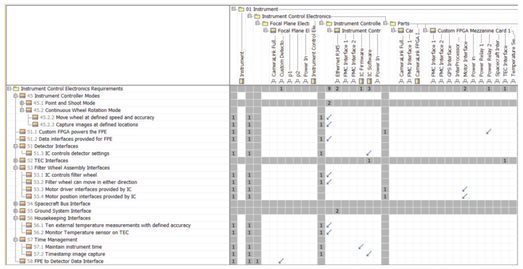

Figure 5: Allocation table for the Instrument Control Electronics on the SAGE IV Ground Demonstration System

In this example, a series of requirements for the Instrument Control Electronics are allocated out to the various components of the Instrument.

- Table format allows for engineers to determine subsystem requirement responsibility
- Additional table formats are available for other relationship types (satisfy, verify, etc.)[1]
- Results are easily accessible and store numerous system requirements in one location for quick reference

Future Exploration

- Integration with MATLAB is only one of the many possible uses of MagicDraw's parametric suite.
- Other analysis programs can be connected, such as Abaqus or Zemax
- In future program updates, the ability to perform Monte-Carlo analyses from within MagicDraw will be added[5]
- Future additions will improve the simulation capabilities of a project while keeping system information in a single point of truth model.

References

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