Master thesis : Development of a simulation model for end-to-end performances in optical systems: EMIOS End-to-end Modeling Interface for Optical Systems

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Development of a simulation model for end-to-end performances in optical systems

Many optical systems are designed and manufactured at *AMOS* and each design must meet several specifications required by the customer. These specifications apply not only on the nominal design but also to the as-built instrument operating in real world conditions. These conditions imply perturbations to the opto-mechanical device impacting the overall performances of the instrument. For example, an instrument manufactured on Earth and working in a satellite is submitted to a gravity release which can induce deformations. Furthermore, the transition from the manufacturing temperature to the working temperature might be followed by a thermal expansion or contraction of the elements composing the whole instrument (mirrors, lenses and other structures).

To quantify the effects of a perturbation on the nominal performances of the system (performances when the design is not submitted to any perturbation), a Finite Element Analysis (FEA) is performed in the software *SAMCEF*. The output of these calculations are then used as input within the optical model of the instrument within the *Zemax* Software (*Zemax* is an optical software that is used to simulate the performances of optical systems). During each analysis, a series of deformations mimicking a chosen operating configuration are applied, modifying the nominal shape of the optical surfaces or their relative positions. Note that a series of scenari are considered since all deformations do not necessarily act at the same time. When the errors are included, it is then possible to compute with this software several performances of the instrument and check if the specifications are still met. However, the amplitude of the deformations is not always perfectly known and thus several simulations with the same deformations but with different coefficients applied to them might be performed.

To perform these simulations, the procedure followed at *AMOS*, the company where the master's thesis and the internship were done, lacks of automatic treatment and is subject to human errors. Furthermore, the procedure required a lot of time. The aim of the thesis is to correct this absence of automatic treatment by the design and the development of an end-to-end simulator. The simulator shall presents the following characteristics:

- User-friendliness: the software should be as user-friendly as possible and it should be interfaced in *Matlab* since it is widely used, easy to use and well known at *AMOS*. However, some functions can be written in other languages, but the user should not have to interact with them;
- Flexibility: among all the sources of degradation that have been computed during the FEA, the user can select which ones to include in the simulation;
- Customization: the user can create as many perturbed optical models as he wants with the same sources of degradation but with different amplitudes. These amplitudes can be either set by the user if they are fully known and/or evolve in time, or follow a certain distribution (uniform, Gaussian, etc.) whose characteristics are set by the user. This is done in order to perform the Monte-Carlo analysis and get a statistical distribution of the performances;
- Automating: The frame of reference on which the deformations of the instruments are computed during the FEA is not the same as the ones used in the optical software *Zemax*. This should be taken into account and the transformation between the different frames of reference should be automated in order to avoid human errors.

The developed *Matlab* interface *EMIOS* (End-to-end Modeling Interface for Optical Systems) is composed of 5 different blocks with different roles. A scheme of this interface is shown in Figure 1:

EMIOS

PART 0

Ⓐ: First Initialization
Ⓑ: Load Cases

PART 1

Load Mirror Parameters

PART 2

Conversion from Mechanical to Optical Frames of Reference

PART 3

Ⓐ: Generation of of Statistical Coefficients
Ⓑ: Standardization of the Size of the Deformation Maps
Ⓒ: Create Perturbed Optical Models

PART 4

Ⓐ: Optical Performances
Ⓑ: Scene Simulation

1. Creation of Input Scene Cube
2. Simulation of the Input Scene

END

Figure 1: General overview of the interface of *EMIOS*

This interface was used to simulate the effects of certain deformations on a telescope and an imaging spectrometer developed by *AMOS*. For example, deformations due to gravity and forces applied at different points on the mirrors of the telescope completely modify the image produced of an input scene. The initial image, which represents the stars observed in the sky, produced by the nominal instrument is shown in Figure 2 and the image produced by the deformed instrument is shown in Figure 3.

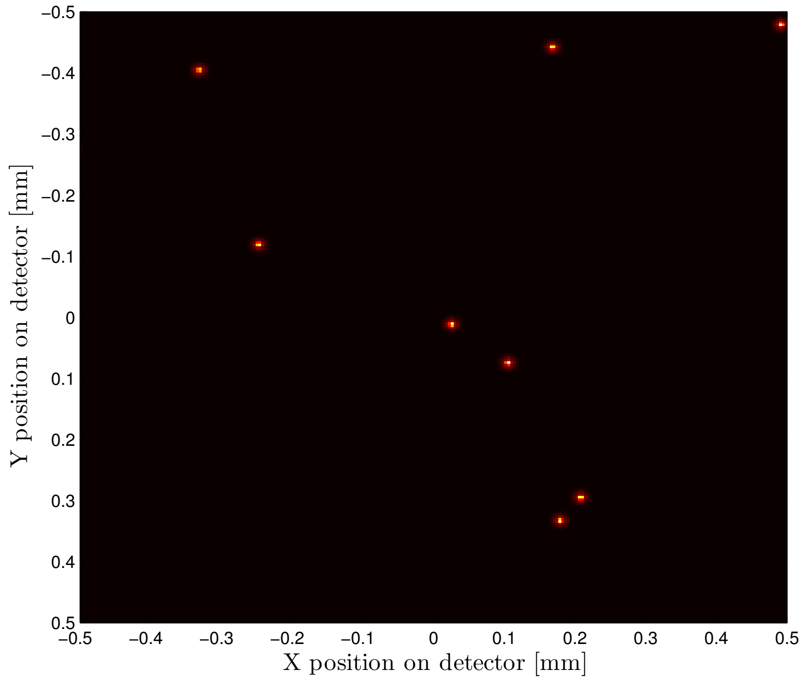

Figure 2: Input scene deformed by the nominal instrument

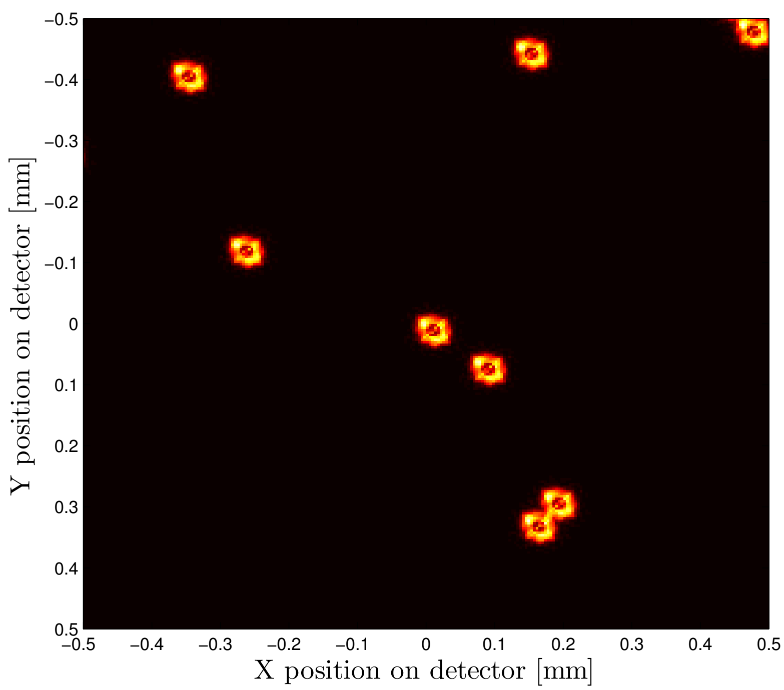

Figure 3: Input scene deformed by the off-nominal instrument