THE GAIA SYSTEM SIMULATOR

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ABSTRACT

The Gaia System Simulator (GASS) is part of the Gaia Simulator. It shares a common structure with the Gaia Instrument and Basic Image Simulator (GIBIS). GASS is designed to simulate the telemetry stream of the Gaia mission according to the GDAAS (Gaia Data Access and Analysis Study) specifications, modelling the astronomical objects and instruments. This telemetry stream provides realistic data for several purposes, such as filling the test data base of GDAAS, test of algorithms (e.g., cross-matching, telemetry compression, ...) and reduction software, or evaluation of the mission performances. GASS is developed in Java.

Key words: Gaia; Simulations.

1. INTRODUCTION

Simulations are essential for many aspects of the Gaia Mission. In this line, the Gaia Simulation Working Group (SWG) was created to coordinate the simulation effort. Apart from simulations used to test specific aspects of the instruments and/or satellite performance, two basic tools have been developed with the purpose of generating a big amount of data (images or telemetry stream) needed to test the global characteristic of the mission, as instrument design, data reduction and analysis or data base design. These two tools are the Gaia System Simulator (GASS) and the Gaia Instrument and Basic Image Simulator (GIBIS) (see Babusiaux 2005). Together, GASS and GIBIS form the Gaia Simulator (see Luri et al. 2005, for more details). The global structure of the Gaia Simulator is showed in Figure 1.

GASS and GIBIS share:

- astronomical and mathematical tools
- satellite and instrument models (scan law, focal plane design, CCD response, ...)
- universe models (Galaxy model, Solar System ephemeris,...)

GASS is specifically designed to produce a realistic approximation to the real data stream that Gaia will generate. This data is mainly used in the development and testing of the data management system and the reduction process, in the context of the Gaia Data Access and Analysis Study (GDAAS) project.

2. GENERAL ISSUES

At its final stage, the complexity of GASS will be very high. Only a modular development can ensure the achievement of this complexity. In this way, GASS is based on an UML (Unified Modelling Language) model made with the aim of breaking down the project into smaller, functionally well-differentiated modules. Each one of these modules corresponds to a Java *package*. As an example, in Figure 2 we show the structure of the package corresponding to the instruments.

The code of GASS is maintained using the CVS (Current Version System) tool, in such a way that many developers can work simultaneously in it. The CVS tool has a file repository where the different versions of the code are stored, allowing a coordinated and controlled code distribution among the developers.

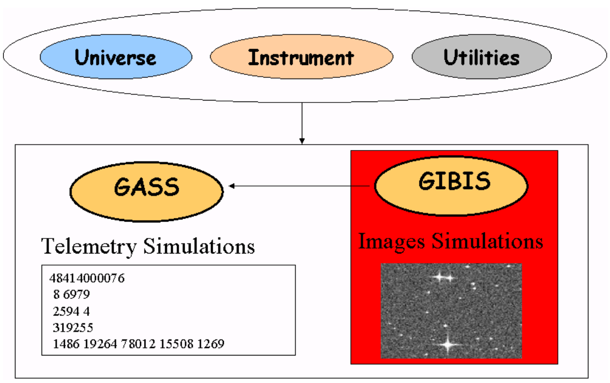

Figure 1. Basic structure of the Gaia Simulator.

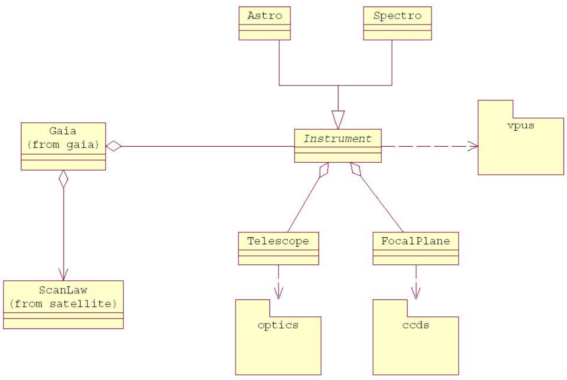

Figure 2. UML diagram for the package Instrument and their relations.

3. THE SIMULATION PROCESS

GASS divides the simulation process into four steps:

3.1. Inputs and initializations

The input parameters can be introduced using the command line or the Graphical Used Interface (Figure 3). In the first case, all the input parameters (described in Table 1) must be set in the *gassConfiguration* file.

Figure 3. Example of the window of the Graphic user Interface.

3.2. Satellite pointing

The simulations are limited to the area of the sky scanned by Gaia during the selected interval of time. To calculate this area, GASS uses the ephemeris of the satellite and the nominal scanning law (the exact solution of Lindegren 2001, or a faster, from the computation point of view, analytic approach of Mignard 2004.) The area is partitioned in a Hierarchical Triangular Mesh (HTM) structure (Figure 4), and the generation of the astronomical objects is performed separately in each HTM triangle.

3.3. Astronomical objects simulation

The *AstroSource* is the basic object that represents an astronomical body (star, minor planet, galaxy, ...). Each *AstroSource* has three basic attributes:

- Astrometry: positions and spatial velocities.
- Photometry: magnitudes and colours for each Gaia band.
- Physical parameters: all the relevant parameters needed to describe the source (temperature, metallicity, ...).

GASS has several methods to get astrometry and photometry for a given time. The astrometric model takes into account gravitational light deflection from the Sun and planets, using the model described in Klioner (2003).

3.4. Telemetry generation

The last step in the simulation chain is the generation of the telemetry stream. It needs models of the instruments (field of view geometry, PSF, spectral response, ...) and of the on-board algorithms (detection, transit prediction, ...). For CPU time consumption reasons, GASS uses a model of the on-board algorithms that statistically gets the same results as the detailed implementation.

The telemetry stream is formatted according to Masana et al. (2004) and stored in an ASCII file.

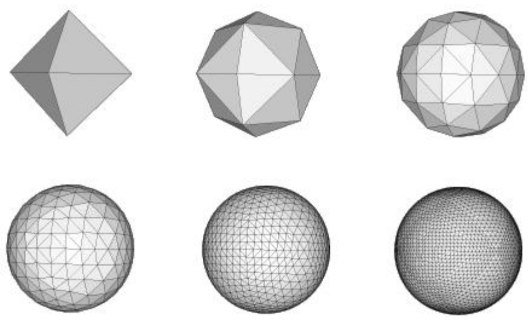

Figure 4. HTM strategy to subdivide the sphere.

Table 1. Relevant input parameters.

Parameter	Description
SimuName	Identifier for the simulation
Instruments	Astro / Spectro
UniverseModel	Galaxy / Solar System / Extragalactic objects
HTMlevel	Parameter related with HTM structure
Limit Magnitude	Limit magnitude of the simulations
SimuInterval	Length of the simulation basic interval
Output Directory	Directory for the output files
Scan Law	Analytic approach or exact solution

3.5. GASS outputs

GASS output consist of several ASCII files:

- Log File: contains the control messages generated during the execution of the simulation.
- Attitude File: contains the quaternion representation of the attitude for each second, together with the time.
- Sources File: the *catalogue* of simulated sources, including identifier, astrometry and photometry). Some kinds of objects, such as binary systems, generate also files containing relevant parameters, as orbital parameters for binary stars, or variability curves for variable stars.
- Telemetry File: file with the telemetry stream.

For test purposes, GASS can generate other files with intermediate data, such as nominal field angles and observed time for each transit.

4. CURRENT STATUS

This section lists the main characteristics of the current implementation of GASS (GASS v2.0).

4.1. Attitude

The satellite's attitude is described by the nominal scan law. The downlinked attitude include a 1 mas random scatter that simulates the attitude measurement absolute error.

4.2. Ephemeris

The Gaia barycentric ephemeris (Mignard 2003), taking into account the orbit of the satellite around L2, are implemented in GASS.

4.3. Galaxy Model

At present, the Barcelona Galaxy Model (Torra 1999) is used to simulate the stellar objects. It includes just main-sequence stars. An implementation of the more realistic Besançon Galaxy Model (Robin 2003) has been completed and will be integrated soon.

A solar type spectrum background, uniform all over the sky (22.5 mag/arcsec^2), is adopted.

4.4. Stellar contents

The stellar content is formed by:

- Well behaved stars: single and non-variable.
- Variable stars: an unique light curve is used for all the variable stars, with different periods and magnitude variability. No actual light curves (i.e., Cepheids, Miras, ...) and distribution period implemented.
- Multiple systems: GASS implements the model provided by Arenou (2003).

4.5. Astrometric model

It includes the light deflection in the Solar System due to the Sun and planets, according to Klioner (2003).

4.6. Photometric Model

Approximate relations giving magnitudes per each band as a function of G magnitude and colour (normally $(V-I)$, obtained from the Galaxy Model) are used to simulate the photometry of each star. The relations were provided by the Photometric Working Group (Jordi 2004).

4.7. Focal plane geometry

We use a simplified model of the variations in the focal plane geometry over time:

- Shifts of the CCDs location with amplitude 0.01μm and period 1 week.
- Rotation of the CCDs with amplitude 0.001μm and period 2 years.
- No tilt (negligible in the final mission).

4.8. PSF/LSF model

According to Lindegren (2003), 5 quasi-monochromatic bands for ASM and AF and one band for BBP and MBP are used to describe the LSFs. Each one of these bands are represented by a set of B-spline coefficients. For the ASM, GASS uses a PSF with the same shape along and across scan. Variations of the LSF over time on a one year time scale are included.

4.9. Chromaticity

GASS implements the effect of the chromaticity of the star in the final position of the star on the focal plane. The chromaticity introduces a shift of the photocentre along scan position according to the colour of the star. See Fabricius (2004) for more details.

5. FUTURE DEVELOPMENTS

Future work can be split into two main lines: first the inclusion of more types of astronomical objects. In this sense the simulation of 10 000 of minor planets will be included in the near future. On the other hand, the Spectro instrument is not yet implemented. As a first step, we will start with the implementation of a simplified model of the MBP.

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