

Simulation of Active EO Imaging System based on SE-Workbench and OSMoS software tools

Nicolas DOUCHIN^a, André JOLY^a, Thierry MEYNARD^b, Ali YATSOU^b
^a Oktal Synthetic Environment, France, ^b ATE, France

ABSTRACT

Active EO imaging systems are more and more considered as an outstanding solution for detection/recognition or guidance purposes in severe atmospheric conditions such as heavy fogs or in the presence of smoke due to flares in smoke-producing devices. In particular, flash laser systems that have range gating capabilities enable the elimination of photons that are backscattered by the particles in the atmosphere and hence improve the systems detection performances. Range gated systems also offer recognition/identification capabilities based on the target shape identification. Thus it is of great interest to be able to assess the performances of such systems in different operational conditions and simulation is a good means to do this.

The SE-Workbench workshop, also called CHORALE (French acceptance for “simulated Optronic Acoustic Radar battlefield”) is used by the French DGA to perform multi-sensors simulations. CHORALE enables the user to create virtual and realistic multi spectral 3D scenes, and then generates the physical signal received by a sensor, typically an IR sensor.

Taking advantage of developments made in the frame of Radar simulation, CHORALE is currently enhanced with new functionalities in order to tackle the “active” problem, involving new generation infrared sensors such as laser.

OSMoS is a development software workshop with a suite of modules that allow designers and customers to rapidly develop and deploy mathematically accurate, physics-based, sensor and scene simulation applications. OSMoS gives the user valuable information that can substantially increase the performance and decrease costs of complete optronic systems.

OSMoS is a powerful workshop built on the principle of system decomposition and intended for non-computer specialists. The user builds a virtual active or passive system (optics, detector, and electronics, processing functions) by choosing the appropriate functions available in the OSMoS library (more than 200 functions). Existing models can also be directly used with minor skills.

In the active domain, all the physical phenomena are taken into account: laser-sensor coupling, propagation, attenuation, Modulation Transfer Function (MTF), scattering etc. Validated sight laser detection models are available.

OSMoS also offers an innovative stochastic tool providing false alarm and detection performances by propagating probability density functions through the model.

OSMoS has been validated by the French DGA. It has been developed and constantly upgraded with new models and functions by the Optronic division of ATE for more than 10 years.

The aim of this paper is to demonstrate that combining the SE-Workbench and OSMoS software tools is an adequate solution for the simulation of an active EO imaging system since it allows one to take into account all the main features, which are the attenuation and scattering due to the atmospheric propagation, the effects due to the atmospheric turbulence on both the laser illumination beam and the sensor imaging process and the speckle effects due to the phase coherence of the laser source. The distribution of these features between both software tools is discussed in the paper.

2 different approaches for combining the SE-Workbench and OSMoS are also illustrated in the paper: in the first, data communication between both software tools is achieved through data files, in the second the use of both tools is considered through APIs which allows one to simulate more complex cases such as closed-loop scenarios.

Keywords: Active imagery, simulation, range-gating, optronic sensor modeling, multi spectral scene modeling, atmospheric attenuation, scattering, scintillation, turbulence, speckle, Ray tracing, Open GL, BRDF, MTF, LASER, Radar simulation

1. INTRODUCTION

Active imaging brings much more information than passive imaging, thanks to the presence of a scene laser illuminator; which makes it possible to reach functions not available with passive systems, such as:

- Night vision (in the visible and near infrared domains),
- Vision through obstructing clouds, with the “range-gating” function (explained here below),
- Detection of particular targets, such as optical targets,
- Technical functions using active domain specific skills: telemetry (calculus of the laser pulse propagation time), profilometry (target shape with the range-gating function), speed and vibration calculation (using the signal phase).

The needs in the active domain require more and more simulation tools in order to justify and consolidate the developments in this strategic domain. The association of SE-Workbench and OSMoS is a complete answer to these needs as it couples two competitive tools covering the main physical phenomena involved in active imagery and the whole simulation process, from the scene generation to the sensor output image.

These two tools have nowadays all the necessary functions to model the main phenomena involved. Future developments will bring more and more precision and capability to model the systems of the future, by taking into account all the elements that are to be considered:

- the laser source, with a complete modelling of the laser wave: spatial and temporal modelling, phase, polarization, modulation, ...
- the atmosphere: extinction, radiance, laser beam back-scattering, refraction, turbulence and induced effects on the laser beam, on the scene, on the atmosphere and on the image quality (scintillations, beam spreading, beam wandering, deviations, modification of the coherence, image blurring, image dancing, ...)
- the speckle, generated by interfering wavelets that make up the wavefront,
- the targets and management of their specific behaviour in the scene,
- the background and its interaction with the laser beam,
- Integration of all these elements in the sensor models, and simulation of the associated technical functions: acquisition, detection, localization, telemetry, targets tracking, speed and vibration,...

2. SE-WORKBENCH AND OSMOS

2.1 SE-WORKBENCH

2.1.1 Some generalities

The first development was in 1994 and has been strongly boosted by the French SCALP missile program and the qualification of the IR tracking system. At the beginning, the SE-WORKBENCH was focused on the IR domain, but in 2001, an electromagnetic version of the workshop was initiated, with the help of ONERA French research center, mainly focused on millimeter waves and wide scenes, typically for SAR applications.

The control of the SE-WORKBENCH validity domain is based on both a theoretical validation approach (development of physical models, general modeling and simulation knowledge, elementary tests and validity assessment) and a validation process based on comparisons with experiments (SCALP/EG missile [FR], Storm Shadow missile [UK], AASM missile [FR]).

Its multi sensor capability is one of the key features of the SE-WORKBENCH.

A unified IR+EM approach of physical material management enables to combine different sensors of different domains on the same scene. To perform it, the SE-WORKBENCH includes a multi domain material format and an associated API.

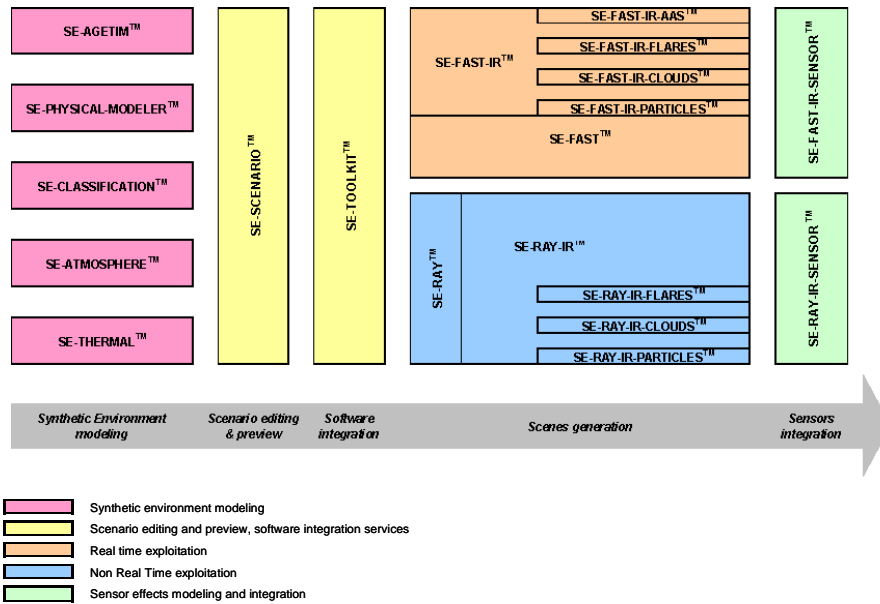
The current version of the SE-Workbench addresses the passive IR systems (see the description of the SE-WORKBENCH-IR hereafter) and the active RADAR systems (see the description of the SE-WORKBENCH-EM hereafter).

2.1.2 SE-WORKBENCH-IR

General presentation

The SE-WORKBENCH-IR is made of different components, as described hereafter, corresponding to the successive steps of a IR sensor simulation that are the modeling, the scenario edition, the rendering without the sensor effects and finally the sensor transfer function simulation.

Furthermore, the user can do software integration in order to control the generated scenario execution from a remote or custom application. This can be achieved with the help of the SE-TOOLKIT consisting of a set of libraries and application programming interfaces (API) to help the complex application design and integration.



SE-WORKBENCH-IR components

The PHOTON MAPS METHOD

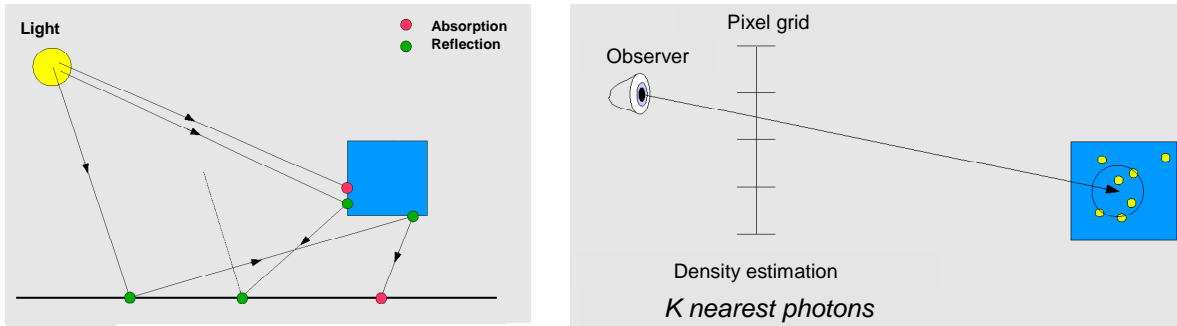
The Photon Maps is a rendering method, available in the SE-WORKBENCH-IR, used to improve surface rendering and soft shadowing effect.

A lot of work has been done on realistic rendering. For the majority of existing techniques, it is difficult to handle scenes with a huge number of extended light sources. In the case of infrared rendering, the ray tracing pass cannot be handled because it is prohibitive to sample efficiently all the sources (all the surfaces) of the scene. Thus we chose to compute the whole illumination using density estimation. But it appeared that we needed a huge number of particles to handle direct illumination correctly and this number cannot be stored in nowadays computer memory. Our research to solve infrared simulation problems leads us to a multi-pass density estimation method that allows us to render 3D scenes containing a lot of light sources without increasing the memory consumption. Our infrared approach can handle all surfaces and participating media as light sources. The memory consumption of the method is independent of the scene complexity and of the number of particles used to render the final image.

The method used in the SE-WORKBENCH-IR to implement the Photon Maps method is a two-pass algorithm (see figure below).

Firstly, the light is propagated through the participating surface using standard ray tracing techniques. A virtual particle, called photon by analogy with the corpuscular theory of the light, is used to store energy at the interaction points of the light with the surface.

The second pass consists of reconstructing the radiance seen by the observer by throwing a ray from the eye to the participating surface.



General principles of Photon Maps applied to surfaces: the two-pass algorithm

The Photon Maps method is available only in the IR workbench in both surface and volume versions.

The PM method has first been introduced in the SE-WORKBENCH-IR for the resolution of the Radiative Transfer Equation when obscurants or clouds are set in the scene: the aim is to be able to reproduce the diffusion effects due to the scattering volume.

More recently the PM approach was also used as a solution to handle scenes with a huge number of extended light sources. Thus it is one of the methods that can be considered for rendering a scene by taking into account the multiple bounce reflections between the polygons of the 3D database.



Without PM (ray-tracing)



Using PM

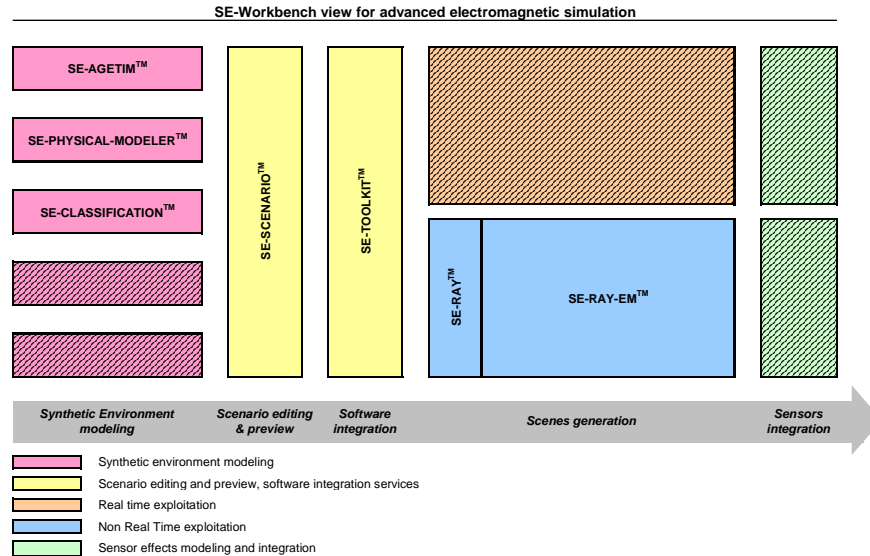
2.1.3 SE-WORKBENCH-EM

General presentation

As illustrated on the figure below, the SE-WORKBENCH-EM shares common components with the Optronic simulation chain: the only difference lies in the rendering part of the simulation chain as the EM formulations are different from the IR ones. But it is very important to notice that the ray tracing kernel is exactly the same for both spectral domains.

The fact that the geometrical modeling is exactly the same for both the EM and IR domains is a key point in our multi spectral approach.

The synthetic environment modeling part is the same in EM and in IR, although the materials characteristics are different from one spectral domain to the other. But the way to assign physical attributes to the materials that are present in a 3D scene are identical in both spectral domains, especially the classification of the visible textures that relies on the same approach in EM and in IR.



SE-WORKBENCH-EM components

Specificities of the EM domain

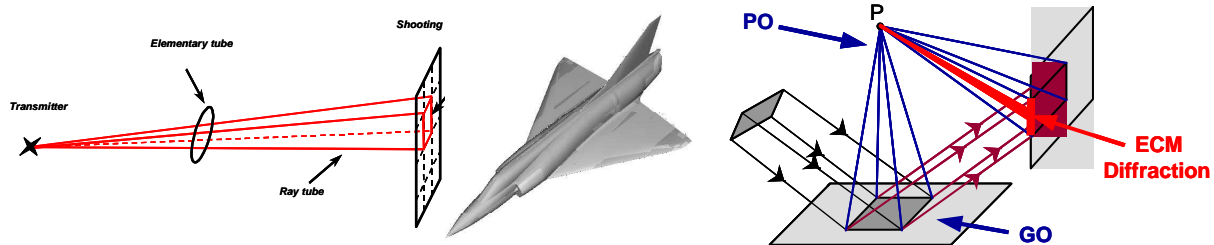
The SE-RAY-EM/FERMAT kernel input is a meshed database made of triangles in order to accelerate the intersections computation.

The so called “voxelisation” algorithm is implemented in order to be less sensitive to the amount of polygons in the 3D scene. This optimization is compulsory in SAR case, because of the size of the scene we have to deal with and because of the accuracy of representation we need in order to be physically realistic.

The second step concerns all the basic mechanisms enabling to cast rays in the 3D space from the radar. These mechanisms are very sophisticated and self adapted to the local scene complexity. This adaptation is generally called “antialiasing”. To perform this antialiasing, adaptatively and lazily (only if necessary), the general physical model has to be taken into consideration for each interaction.

This is a key point of the technical approach and the only way to spare rays and so be able to analyze a whole radar scene. This approach is radically different from classical asymptotic methods where a first computation of all the possible geometrical paths within the scene is made and then a physical model is applied.

In the frame of SE-RAY-EM/FERMAT, a geometrical Shooting and Bouncing Rays (SBR) technique has been optimized in order to calculate the intersections between rays from the transmitter towards the database and back to a receiving point. EM models of propagation, reflection, diffraction and an operating strategy (thanks to SBR) that enables a unified calculation for the near or far EM scattered fields from the scenes. These models are the formulations of Geometrical Optics (GO), Physical Optics (PO) and Equivalent Current Method (ECM). Again, these models, judiciously coupled with the SBR technique make the computation time slightly independent on the complexity of the treated virtual scene.



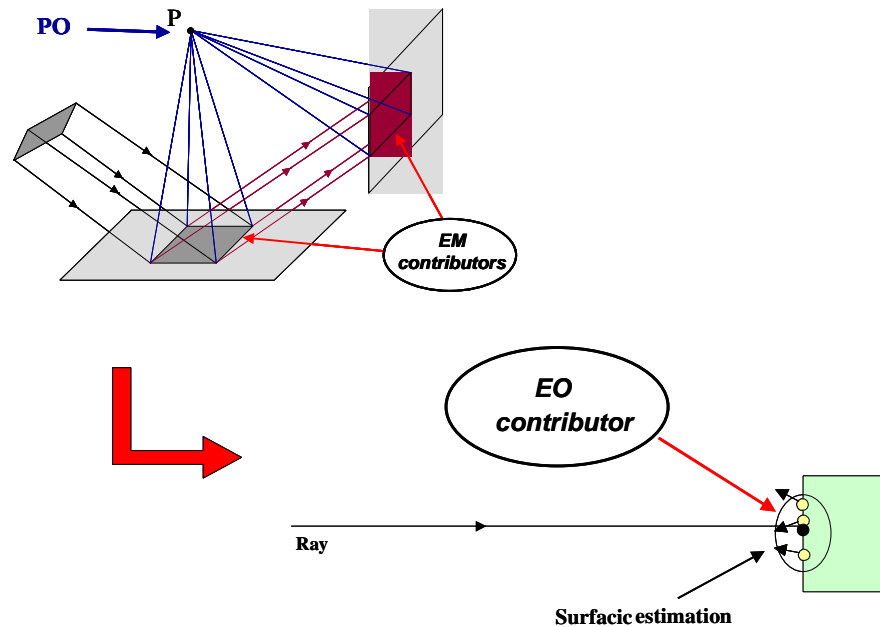
Coupling of SBR technique and EM asymptotic methods

The SE-WORKBENCH-EM takes the following features into account:

- Polarization of EM waves: in SE-RAY-EM, any polarization case can be taken into account as a combination of both basic linear polarizations (H and V)
- Amplitude & phase: the EM formulations are totally coherent as in the ray tracing approach that computes the actual path lengths even in the case of multiple bounce reflections
- Dielectric & “clutter” materials: dielectric materials are characterized by their complex permittivity, their conductivity (and their permeability if necessary), while “clutter” materials correspond to the natural ground materials and are characterized by a backscattering coefficient
- Surface roughness: the height of the surface is locally modified using a texture that is supposed to be representative of the surface roughness
- Multiple bounced specular reflection, scattering & edge diffraction, including the polarization effects (cross polarization generation and depolarization) induced by these interactions
- Divergence factor due to surface curvature: the curvature of a surface is derived from the normal variations at the vertices of the surface using an interpolation scheme such as the Gouraud algorithm
- Doppler effects: the Doppler spectrum is derived from the phase variations with the simulated time
- Range gating: the contributors are summed in each range gate taking into account an auto correlation function that can be defined by the user
- Wave form: the wave form simulation is achieved through the range gate definition along with the auto correlation function of the radar sensor or through multiple frequencies simulation
- Antenna diagram: both the transmitting and the receiving antenna diagrams can be introduced in the simulation scenario
- Monostatic as well as bistatic scenarios can be computed.

In previous papers [1] [2], it has been demonstrated how a new version of the SE-WORKBENCH, called SE-WORKBENCH-AD and dedicated to the EO active domain, can take benefit of both the IR and EM existing workbenches, which is of great importance because it will allow us to guarantee the coherency between the various sensor applications of the SE-WORKBENCH.

As a complement, the two figures hereafter illustrate how to define the concept of EO contributor from the concept of EM contributor that already exists in the EM domain.



In SE-WORKBENCH-EM, for each contributor it is possible to get all the data that are relevant for building a dedicated post-processing such as distance and/or Doppler filtering. For that purpose a specific API has been developed which gives access to each EM contributor and all its associated data.

One can imagine to derive an EO contributor specific API on the same scheme.

2.2 OSMoS

2.2.1 General presentation

OSMoS is the result of more than 10 years software developments, done with the support of the French DGA in order to offer an accurate modeling tool for any Optronic sensor. Every evolution was validated by specialists, who use OSMoS as a reference tool to model and characterize Optronic systems.

Destined for users keen to represent every physical phenomenon involved, the workshop offers rapid model building capabilities without necessitating specific I.T. developments. It integrates several basic modules allowing for the description of detectors and their processing chain. It also supplies characterization tools capable of testing models that have been built and comparing the simulated performances with experimental results.

Once the model has been validated in a MATLAB environment, a C code can be generated automatically from the graphic model which in turn enables the integration of the captor in a complete simulation chain (the carrier's environment, behavior ...).

From passive sensors, OSMoS naturally evolved towards the modeling of active systems. Many new functions, described here under, were developed, in order to take into account all the new elements involved.

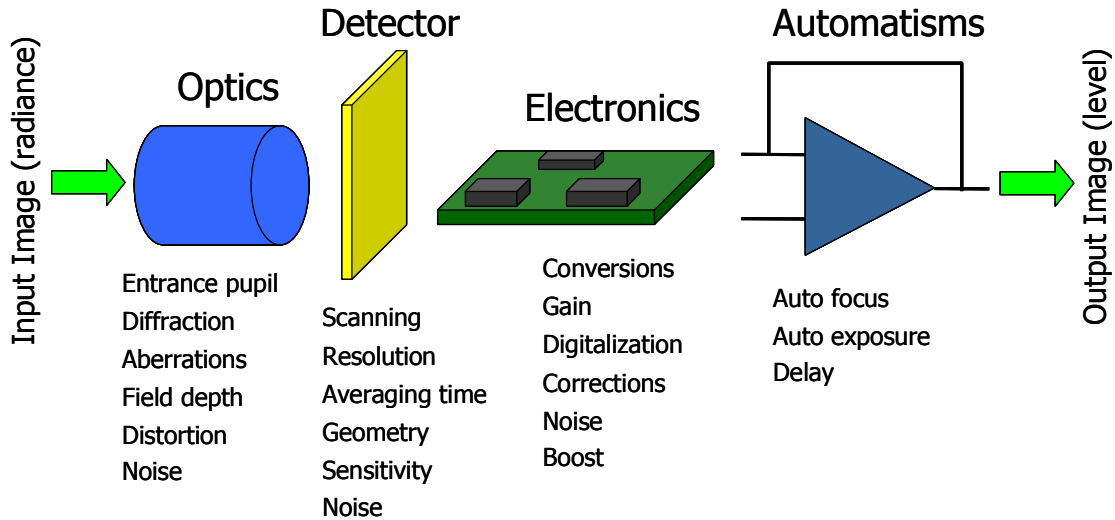
OSMoS is made of two main modes of simulation: "imagery mode" and "stochastic mode":

The image simulation modifies the radiance image of the scene in order to provide an electronic image in the same way that a real sensor would.

The stochastic simulation computes the background and target probability density function (Pdf) at each stage. In order to change the signal-to-noise ratio, the simulator commands the variation of the models control parameter using a user-defined range. It is also able to build the detection chart: detection probability versus signal-to-noise ratio and false-alarm probability.

2.2.2 Modeling principles

The modeling of an Optronic chain is based on its decomposition into different independent functional sub-categories. For example, a camera can be decomposed into: optics, a detector, electronics and automatism.



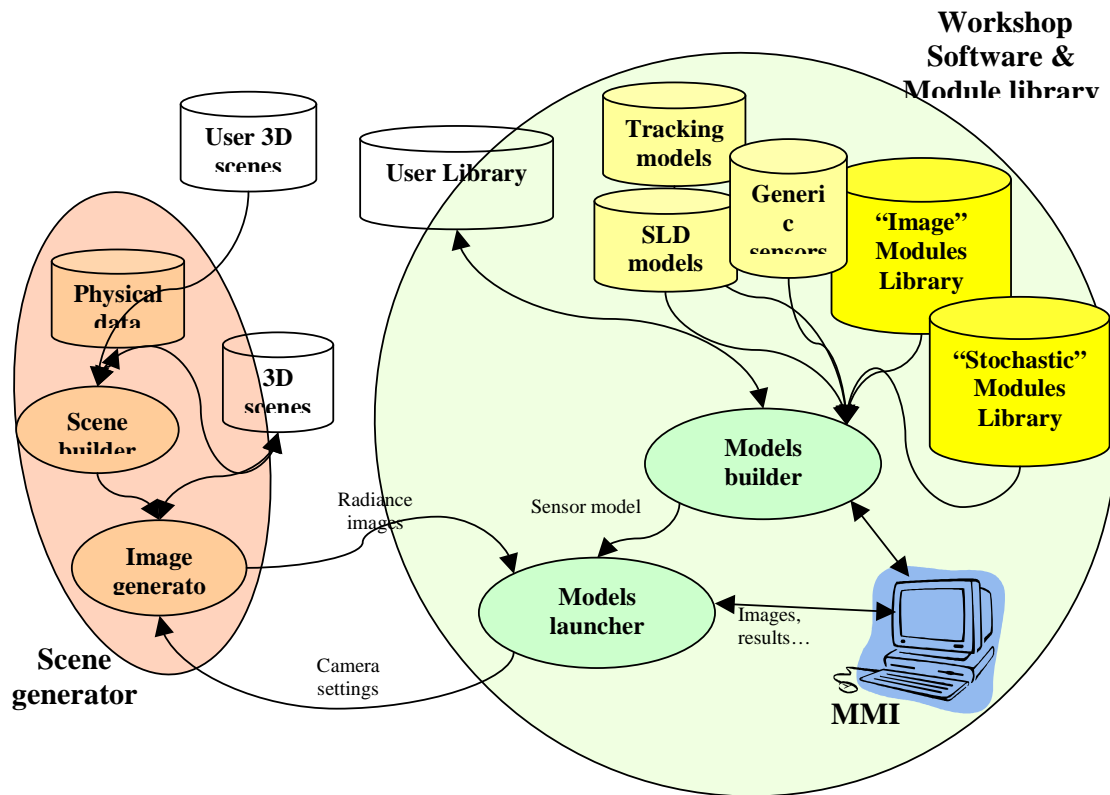
The OSMoS « model » of this type of camera will thus be created by assembling 4 «functional blocks», each associated with a sub-category. Each « functional block » is decomposed into elementary functions. For example, the optical block can be decomposed into an entrance pupil, field depth, distortion and noise. This decomposition continues to the finest level of modeling: the elementary « procedure » which contains the modeling of a physical phenomenon.

The user defines the decomposition into basic functions so as to accurately describe the instrument. Procedures and functional blocks in the OSMoS library can be chosen and tuned, assisted by the MMI (Man-Machine Interface). The building of functional blocks made of basic procedures enables capitalizing the experience: e.g. a block of optics designed for one type of camera can be used in another camera model simply by changing the settings.

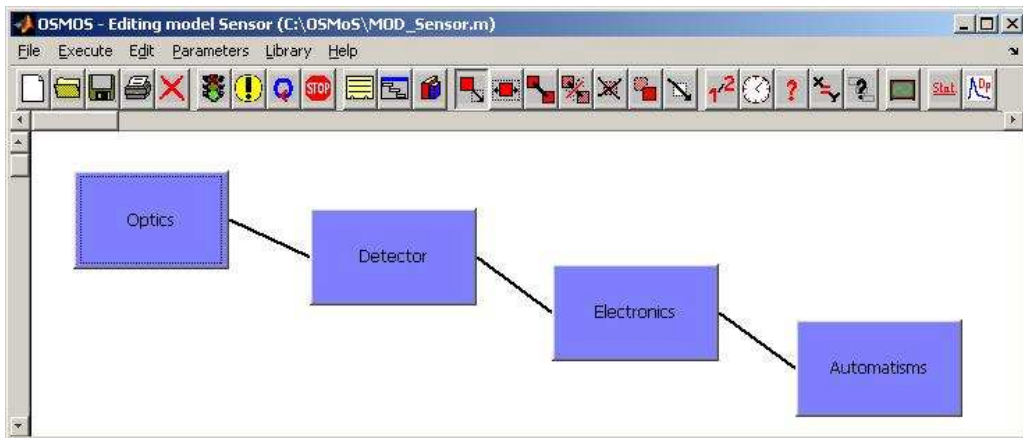
2.2.3 Software architecture

OSMoS is divided into 2 main parts:

- A **software workshop** built on libraries of functions and models with user friendly graphical tools enabling any non-software specialist to build and modify the sensor models, execute the simulation and observe the final and intermediate results using the MMI (Man Machine Interface);
- A **modules library** which includes more than 200 basic functions, which makes it possible to model any Optronic system. These functions are graphically assembled to provide a complete sensor model;



The figure below shows the graphic interface used for building, setting, validating, and running the models (the example is a simplistic camera model):



The toolbar is made up of buttons which control the main operations on the current diagram.

To create a model, the user selects a module (procedure or functional block) in the library. An associated graphical object is automatically created in the workspace.

Once all the different modules are included, according to the simulation requirements, the user simply defines the sequencing of the execution by linking the graphical objects.

The next step is to set the model. Every parameter which has a physical sense is user-definable. For each element of the diagram, the configuration window displays the list of settings, and helps the user to set them by providing the appropriate information. The settings coherence is checked during the saving of the model, according to a criterion defined in the design of each procedure.

For advanced users, it is also possible to create new functions, with the help of a friendly interface which defines the function specifications (name, parameters, values...).

2.2.4 Active domain capabilities

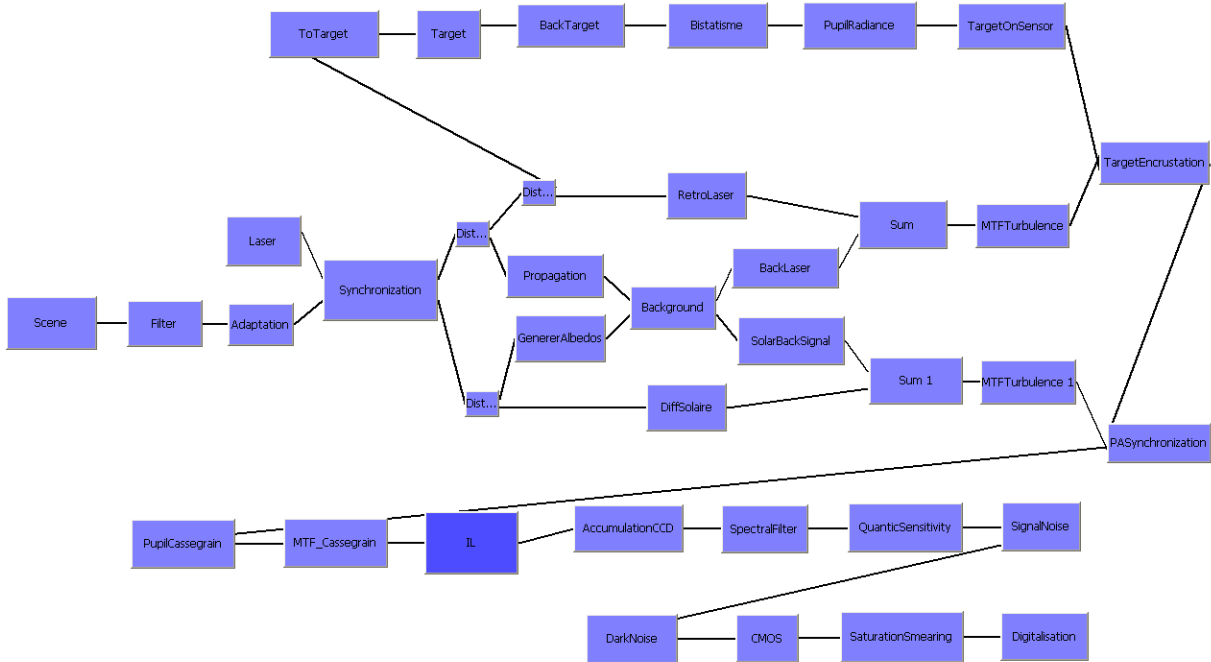
The latest version of OSMoS already integrates active domain skills, based on the modeling of optical targets detection systems.

“Imagery” mode

The main elements developed are the following:

- Laser illuminator: spectral, spatial and temporal management. Phase, modulation and polarization are not taken into account,
- The range-gating effect: some systems use a delay between the beginning of the laser pulse and the beginning of the detector integration; which makes it possible to select a “range” of distance enlightened in the scene, as shown in the preliminary results (part 4 of this paper), and also to “see” through obstructing clouds (the back-scattered photos by the first atmospheric edges are not integrated by the sensor).
- Atmospheric propagation. The main effects considered are:
 - Attenuation, calculated with simplified models or with standard tools (Modtran);
 - Laser propagation, and calculation of the beam spreading;
 - Atmospheric turbulence, which is an essential element in the active imagery domain. This turbulence is based on the Andrews theory, taking into account the beam deviation and spreading, the correlation atmospheric parameters (the Fried radius for example), the beam spatial fluctuations, the global scintillation, and the imagery effects;
 - Background signal, enlightened by solar and laser radiance, using the albedo function. This signal is affected by the speckle noise, bound to the atmospheric parameters and also to the optics pupil diameter;
 - The back-scattering effects: calculated with the adding-doubling method. The contributing depth of the atmosphere depends on the range-gating effect.
- A standard model of optical targets, based on the LES (Laser Equivalent Surface) notion. This LES depends on the optics and detector parameters and on their geometrical configuration. It defines how the laser wave received by the optics is reflected to the detector. There are also optical comparing and calibrating targets, such as spherical caps, and constant back-scattering plans;
- The notion of target encrustation. As the background and the target are defined separately, an encrustation function was developed in order to include finally the target in the scene, managing all the effects, particularly the geometrical considerations. The signal reflected by the target is highly dependent on the detector-target distance, on the optics aperture, and on the gap between the laser and detector axes.
- Sensor specific functions:
 - Light intensification, used in systems using the range-gating function, and very short integration times,
 - 4 elements detector, used in tracking systems: the target position is calculated iteratively according to the signal distribution on the 4 components of the detector;
 - Synchronization functions between the detector and the laser source.

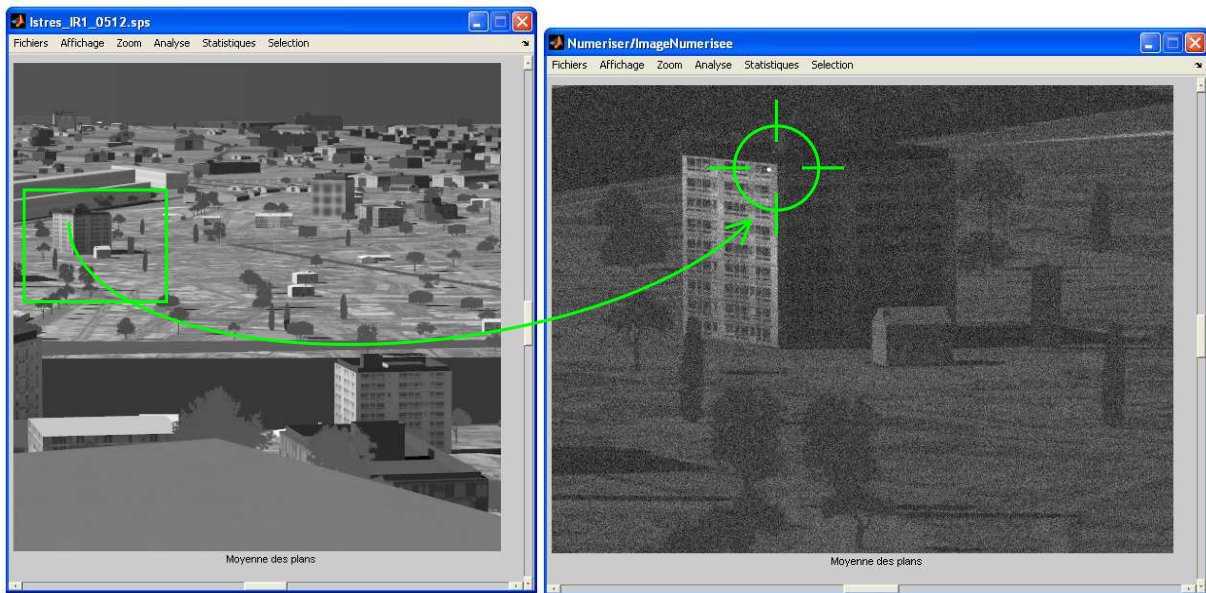
The following figure shows the model of a complete sight laser detection chain: laser illumination, round trip propagation (turbulence, scattering), background reflection, threat reflection, optics, light intensifier, CCD, electronics.



This figure shows that every contribution is visible through the model. For example, it is possible to visualize the active or the passive contribution separately. Finally, all these elements are combined in order to obtain the global result.

This is a powerful tool for designers because it allows precise analysis of each physical phenomenon, and its influence on the global result.

The figure below shows the input and output images of the sight laser detection simulation that is dedicated to sniper detection (near infrared):

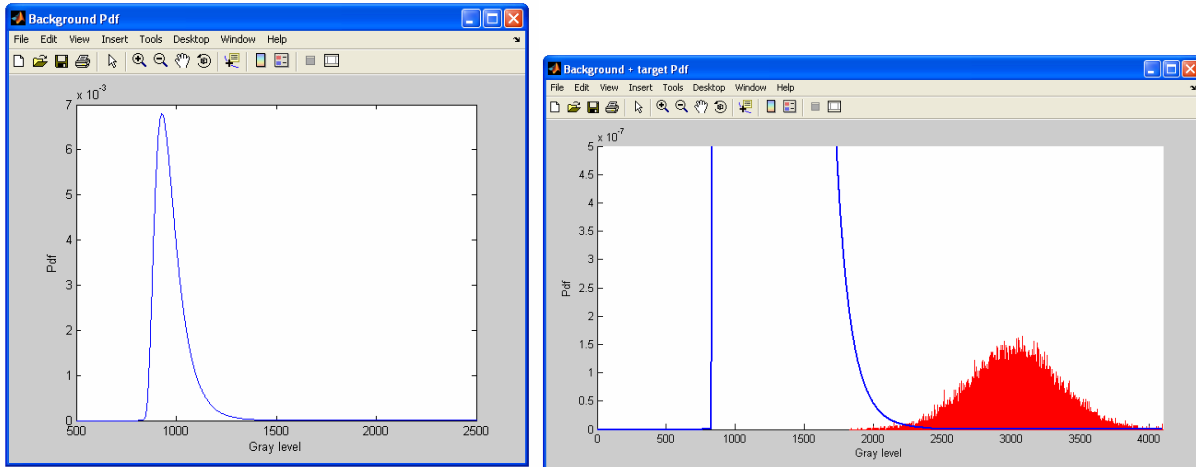


The right image is the output result, with all the effects clearly visible, and the sight laser target surrounded in green.

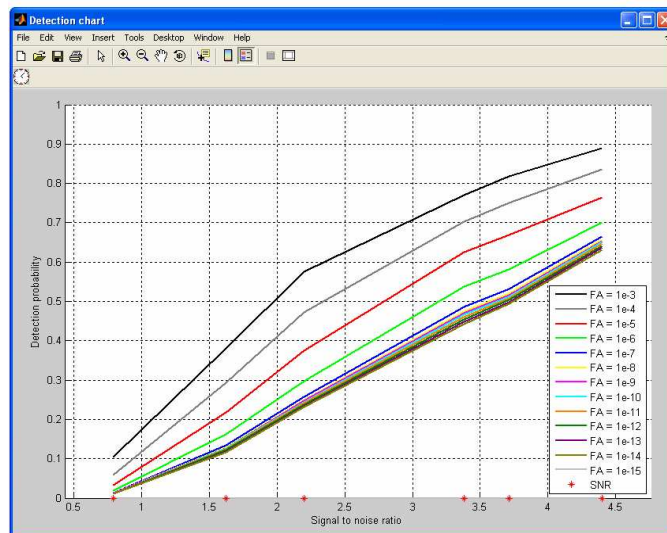
Stochastic skills

All the “imagery” functions are also available in the “stochastic module”; every imaging function has its stochastic equivalent. So, in the same way that the images are transferred from a block to another, the probability density functions (Pdf) are also transmitted through the model. For example, if a sum of two images is computed in the “imagery” module, a sum of two random variables is also calculated in the stochastic module. In other words, the simulator computes the background and target Pdf at each step of the model.

The figures hereunder shows the output background Pdf (synthetic background with log-normal gray-level distribution) on the left, and background (blue) and target (red) Pdf on the same figure on the right :



OSMoS finally draws the detection charts of the modeled scene and detector: detection probability versus signal-to-noise ratio and false alarm probability (there is a plotted curve for each false alarm probability (FA) value).

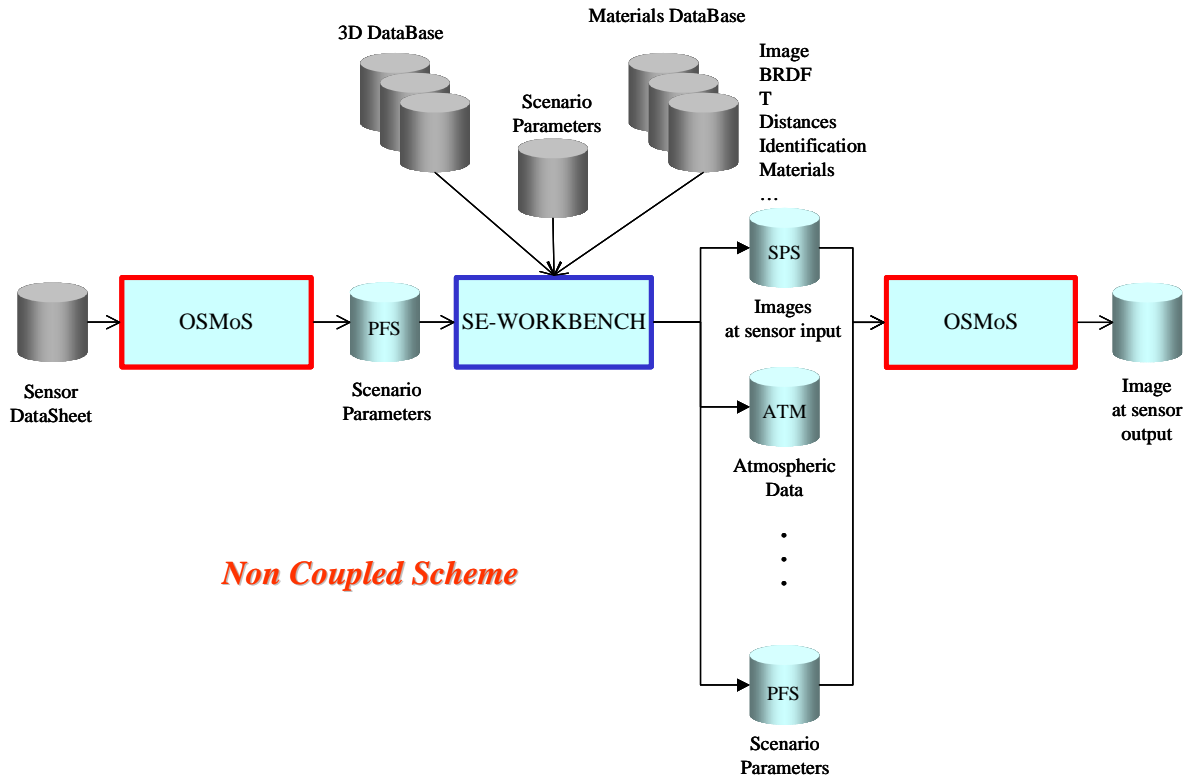


This kind of result is very informative and useful for detection systems because it makes it possible to:

- Study the influence of each parameter on the system performances. For example, this tool can determine the extreme values of the distance between the sensor and the target for which the detection is possible;
- Make reverse engineering;
- Define a complete system design for a specific kind of mission.

3. SE-WORKBENCH AND OSMoS COOPERATION

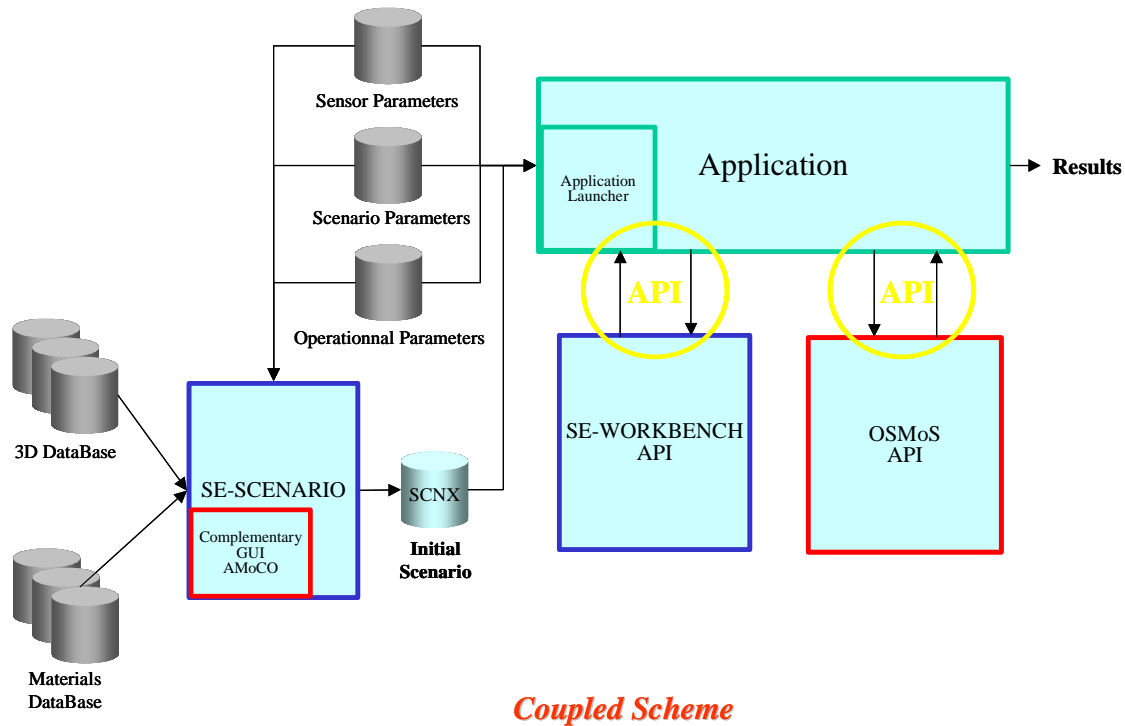
As illustrated on both figures hereafter two different coupling schemes between the SE-WORKBENCH and OSMoS can be imagined.



This non coupled cooperation scheme corresponds to the current situation as used for example by the French DGA at CELAR. In this non coupled scheme the SE-WORKBENCH and OSMoS communicate through files. In its current version, OSMoS only uses SPS images generated by the SE-WORKBENCH as input files.

But, in the future it should be interesting to add to OSMoS input capabilities to some other file formats generated by the SE-WORKBENCH such as ATM file format (atmospheric files). This would allow one to improve OSMoS post-processing of SPS images generated by the SE-WORKBENCH.

It would also be interesting to enrich the SPS file format content with new features in order to improve the communication between the two tools and so to obtain better output results.



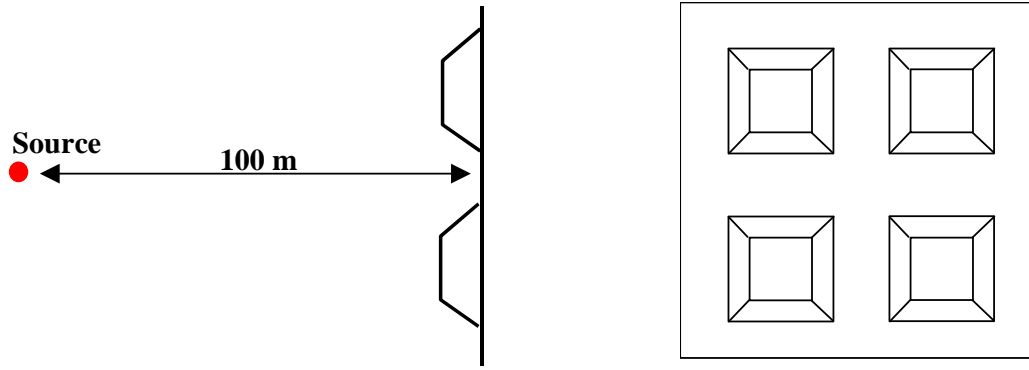
In this coupled scheme the SE-WORKBENCH and OSMoS communicate through an external application using APIs. With this kind of architecture it is possible to simulate closed loop scenarios since the scenario parameters can be changed during the time.

4. PRELIMINARY RESULTS

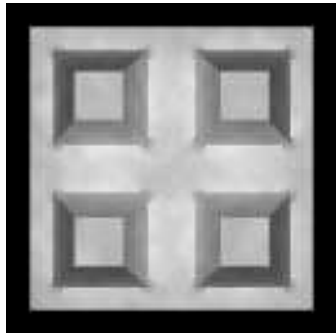
4.1 First trials with adapted Photon Maps

The Photon Maps module that is already available in the SE-WORKBENCH has been adapted in order to take into account the propagation path length in the Photon Maps post-processing and also to reproduce effects due to the phase coherence of the laser source.

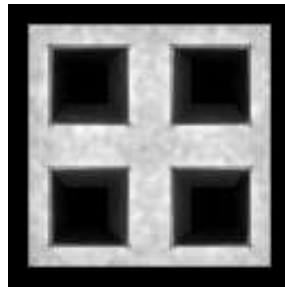
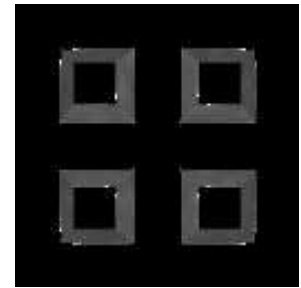
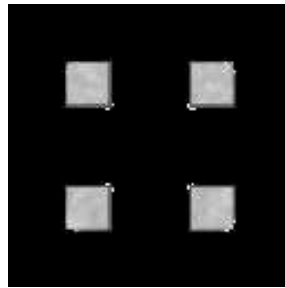
By introducing the propagation path delay into the model it is possible to simulate the range-gating capabilities of the active imaging system as illustrated hereafter.



Scenario definition

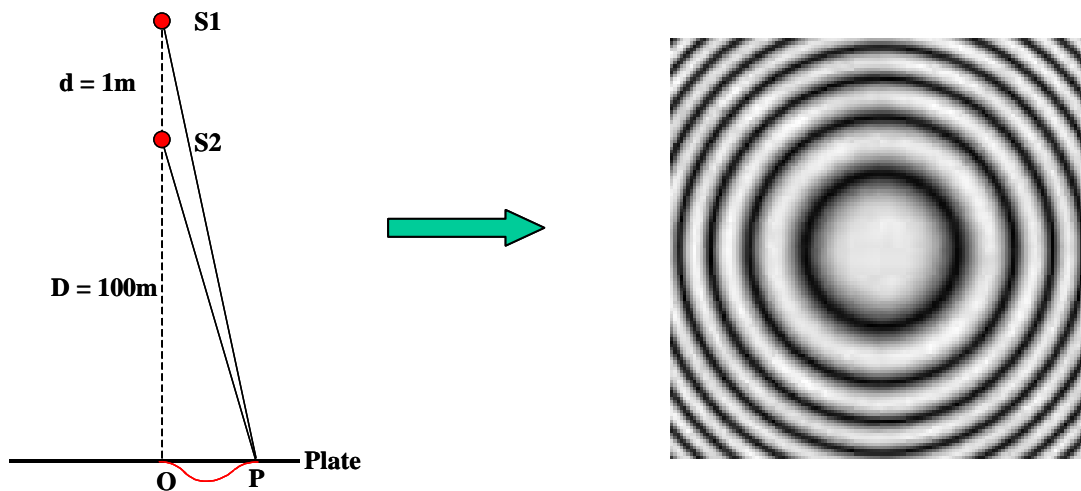


Passive image



Range-gated active images

By introducing the phase in the second pass of the Photon Maps approach it is possible to simulate interference effects as illustrated below.



4.2 Recent joint model

Recent developments lead SE-Workbench and OSMoS to develop joint models in order to simulate active imaging systems, particularly an existing Canadian system. The physical model was previously validated by the French DGA, and gave very realistic results.

The objective of the joint model was:

- To illustrate the contribution of active imagery under low enlightening conditions
- To demonstrate the advantages of active imaging by night, in the near infrared domain
- To apply the range-gating principle through very foggy conditions.

The approach adopted here is the following:

- First step: using the SE-WORKBENCH, production of sensor input images of the synthetic environment composed by the classified terrain, the atmosphere and the classified target
- Second step: OSMoS processing of the files provides by SE-WORKBENCH. These files are composed of two images, the passive one, and the active one. The range gating and the laser illumination are directly integrated into the input active image. All the other effects are managed by OSMoS:
 - The atmospheric attenuation is provided by SE-WORKBENCH but applied and harmonized by OSMoS,
 - Laser propagation effects;
 - Atmospheric turbulence : turbulence maps are calculated and applied to the appropriate values all along the model;
 - Speckle effects are also calculated as maps;
 - The imagery effects are applied by FTM functions;
 - The back-scattering effects are calculated according to the range-gating parameters provided by SE-WORKBENCH;
 - Sensor specific functions and model management parameters: light intensification, sensor specific effects, synchronization between the detector and the laser source.



Passive image

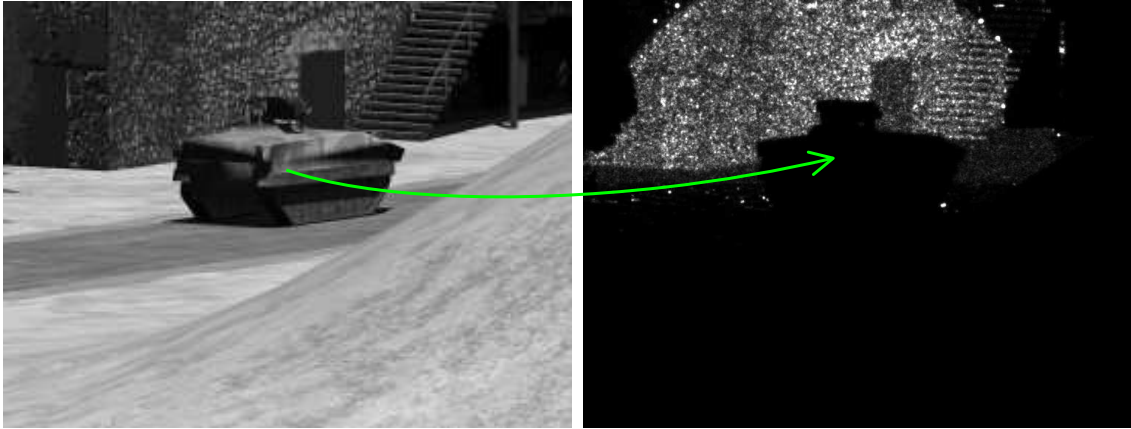


Pure active range-gated image



Active + Passive components

The results obtained demonstrated the very high accuracy of the simulation and validated the contribution of active imagery for functions such as: night vision, target identification by shape comparing, range-gating, as shown in the following figure:



The image on the left is the complete radiance scene (input of the model) and the image on the right is the output result, where the range-gating, the atmospheric and detector noises and the tank shape are clearly visible. For example, in this case, the integration of the sensor signal begins when the laser pulse is enlightening the background behind the tank.

5. CONCLUSION AND PERSPECTIVES

In this paper a solution for a realistic simulation of active EO imaging systems has been described based on the combination of the SE-WORKBENCH for synthetic environment generation and OSMoS for sensor definition and sensor effects simulation.

Two different coupling approaches of both software tools are presented and first results based on the non coupled cooperation scheme are given. These results show the ability to provide very realistic and accurate simulation of specific features of active EO imaging such as speckle effects and range gating. For computing these first purely synthetic EO active images the turbulence and speckle effects are introduced in OSMoS model as perturbations of the sensor input image produced with the SE-WORKBENCH. This kind of approach may have some limitations for example in the case of strong turbulence.

To try to overcome this limitation we plan in the future to introduce the atmospheric turbulence in the SE-WORKBENCH synthetic environment model and so to simulate turbulence effects in the sensor input image rendering phase. Different approaches are under study for taking into account the turbulence during the image rendering in the SE-WORKBENCH: one of them is to consider the turbulence effects as perturbations on both the amplitude and the phase of each EO contributor and thus to compute the turbulence effects in the EO contributor post-processing phase.

This solution is much more than a simple simulation tool. The association of SE-WORKBENCH and OSMoS provides a design and development tool, able to model any existing or futurist active or passive system. The user can access to any influent parameter, and analyze its impact on the system performances, which makes it possible to do reverse engineering or system design for a specific kind of mission, with a control on the whole simulation process, from the scene to the sensor.

The future works to be achieved also consist in validating the coupled cooperation scheme between the SE-WORKBENCH and OSMoS particularly in the case of a closed loop scenario.

REFERENCES

1. Jean Latger, Thierry Cathala, Nicolas Douchin, Alain Le Goff, *Simulation of active and passive infrared images using the SE WORKBENCH*, SPIE Proceedings, Vol. 6543, April 2007
2. Jean Latger, Thierry Cathala, Nicolas Douchin, Alain Le Goff, *Simulation of active and passive infrared images using the SE WORKBENCH*, ITBM&S 2007 Proceedings, June 2007
3. Landry Chopin, Thierry Meynard, 06-0155-A OSMoS *technical description*, October 2006.