New SEDRIS requirements in the frame of multi-physics sensor simulation

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J. LATGER, CEO
OKTAL-SE
Topics:

- An Overview of OKTAL-SE
- Current uses of SEDRIS in SE-WORKBENCH
- OKTAL-SE first implementations and modeling of infrared and other sensor data
- State of the art and the required data for expressing new multi-domain physics-based sensor information
- Ideas for existing or new SEDRIS capabilities in this context
An Overview of OKTAL-SE

- Before 1989: Thalès Training Simulation in Paris
- 1989: OKTAL => Railwail simulators / Automotive simulators
- 2001: OKTAL-SE Defence and Research simulation
- 2005-2007: French MoD projects involving SEDRIS
- 2011: GNSS (Ergospace – GUIDE innovation platform)
An Overview of OKTAL-SE

2011-2012-2013 percentage of SE-WORKBENCH sales (COTS + maintenance + formation)

Worldwide business
10 sales agents in 10 countries

40% Europe

55% Asia

More than 300 licenses around the World

5% America

FR GE UK SW FI TU

Singa, Sth KR Taiwan China Japan India Malay.
An Overview of OKTAL-SE

Targeted applications for the major markets segments:

- Aeronautics: 20%
- Defense: 55%
- Health: 10%
- Automotive: 5%
- Security: 10%

19 years partnership with French DGA
An Overview of OKTAL-SE

Strategic alliances for software results validation

- FGAN - FHR
- SE - RAY - EM

180° ± 20°

RCS amplitude (dB/m²)

- B2 camera
- B1 camera
- Radiometer
- IR tracker

Fraunhofer - Germany

ONERA - France

DGA - France
An Overview of OKTAL-SE
The SE-WORKBENCH interface to third-parties
An Overview of OKTAL-SE

Long term partnerships with customers

- French DGA: 19 years of collaboration
- MBDA Fr and UK: 15 years of collaboration
- ONERA: 13 years of collaboration
- SAGEM: 10 years
- Korean ADD: 9 years
- Swedish FOI: 8 years
- German FGAN: 7 years
- Singapore DSTA: 6 years
- ...

All under multi-years maintenance contracts
An Overview of OKTAL-SE

An overview of data preparation and fusion stages in providing sensor simulations

- 1. Planimetry
- 3. Photography
- 2. 3D terrain
- 4. Altimetry

+ 2D data
+ Sensor
+ Scenario
+ Objects
+ Sensor signal simulation
+ 3D Synthetic Environment
+ Material
+ Atmospheric Properties

19 August 2014
An Overview of OKTAL-SE

The SE-WORKBENCH™: A single kernel for multi-sensor environment modeling

- 3D Object Modeling
- Materials Physical Properties
- Thermal Modeling
- Atmospheric Modeling
- 3D terrain Modeling
- 3D Synthetic Environment

Dual real-time and non real-time solutions

SE-WORKBENCH-EO

SE-WORKBENCH-RF
Current uses of SEDRIS in SE-WORKBENCH: SE-AGETIM

SE-AGETIM = Integrated software tools enabling rapid and realistic 3D synthetic environment generation for multi sensors simulation application (OTW, EO, RF)

- Feature data
- Photos
- Elevation data

GIS facilities, Data Fusion

EO + RF data modeling

3D profiling & EO + RF enhancement using templates

Road Template

External
Common EO + RF

Multi-layer material

painting
plaster
brick
rough coat
painting

Source database fusion

Source database fusion

3D meshed mock-up with EO & RF attributes

Synthetic Environment
Current uses of SEDRIS in SE-WORKBENCH: SE-AGETIM

SE-AGETIM uses SEDRIS for:

- Importing source data from DFAD and GeoTiff databases
- Importing planimetry and altimetry from SEDRIS databases
- Creating SEDRIS databases from altimetry grids
Current uses of SEDRIS in SE-WORKBENCH: SE-FAST-IG

SE-FAST-IG = OKTAL-SE real time image generator for rendering synthetic environments in the visible and EO domain

Used one specific SEDRIS component: the SRM.

Provides a robust and complete description of the spatial coordinates system as defined by SEDRIS: abstract coordinates system and spatial referential.

Also provides functionalities for spatial transformations (coordinates, directions and orientations conversions)
Current uses of SEDRIS in SE-WORKBENCH: SE-FAST-IG

SE-FAST-IG use the communication standard **CIGI** (Common Image Generator Interface).

The CIGI piloting frames are **geographic** (latitude/longitude/altitude coordinates, local tangent orientations) while the database visualised use a **local Cartesian frame**

⇒ The SRM API allows precise and efficient conversions
Current uses of SEDRIS in SE-WORKBENCH: SE-FAST-IG
- **OKTAL-SE** first implementations and modeling of infrared and other sensor data: CQCEGC

Software for:

- controlling the quality
- correcting
- exchanging
- managing configurations

for *Environment Database for Simulation* (EDS)
OKTAL-SE first implementations and modeling of infrared and other sensor data: CQCEGC

Mains goals:

• checking conformity of SIF-France EDS with the format specification
• visual control on elements and parts of EDS
• gathering tools for automatic, supervised and interactive correction of EDS
• exchanging EDS in standard formats such as VMAP, DLMS, SIF-France, SEDRIS, Digitised Terrain and Open Flight
• manage configuration of the various versions of EDS
- OKTAL-SE first implementations and modeling of infrared and other sensor data: CQCEGC

**Quality control** → checking the conformity of data with the format and content specifications

**Exchange** → importing and exporting (with some restriction)

**Correction** → modifying the data and metadata

**Configuration management** → EDS versions catalogue (PostGreSQL database)
OKTAL-SE first implementations and modeling of infrared and other sensor data: CQCEGC

Quality control, exchange and correction

**SEDRIS data model**

Able to host data coming from the various formats handled:

- SIF-France v2
- SEDRIS 4.0 (and now 4.1)
- DLMS DFAD
- DLMS DTED
- Open Flight 15.6
- VMAP1
- Digitised Terrain MNT CELAR
- **OKTAL-SE first implementations and modeling of infrared and other sensor data: CQCEGC**

  SEDRIS is used here as a *pivot data container and representation*.

  Every data of a work session is converted to SEDRIS and organised in the data model.

  Corrections are done in the SEDRIS structure and then exported in the input format or another compatible format.
- OKTAL-SE first implementations and modeling of infrared and other sensor data: CQCEGC

Excerpt of the SEDRIS data model: planimetry

- CD Surface Location
- Spatial Index Related Features
- Spatial Index Data
- Union Of Features
- 1..n Culture tile
- CD Surface Location
- 3..n {ordered}
- Source
- Data Quality
- 1..n Data Quality
- Spatial Extent
- Perimeter Data
- Perimeter Related Features
- 0..n Point Feature
- 0..n Linear Feature
- 0..n Areal Feature
- 0..n Point Feature
- other features
- islands
- point light or punctual feature
- point light string
- OKTAL-SE first implementations and modeling of infrared and other sensor data: CQCEGC

CQCEGC GUI
- OKTAL-SE first implementations and modeling of infrared and other sensor data: PROVIDENS

**PROVIDENS** = assistance system for the Interactive PROduction and Validation of Synthetic ENvironment Data

Plugin for the ITCS (Joint Technical Simulation Architecture)

Based on **SEDRIS** as *pivot data container and representation*
OKTAL-SE first implementations and modeling of infrared and other sensor data: PROVIDENS

Environmental data = various and disparate

Usually need to be processed through various steps before being exploitable by simulation applications.
**OKTAL-SE first implementations and modeling of infrared and other sensor data: PROVIDENS**

Most expensive step: transform source databases into generic databases… that are not generic.

So…
Objective of PROVIDENS:

- OKTAL-SE first implementations and modeling of infrared and other sensor data: PROVIDENS
• OKTAL-SE first implementations and modeling of infrared and other sensor data: PROVIDENS

Interoperability ⇒ Facilitate the exchange and reuse of data

**SEDRIS** as a pivot data container and representation for source, generic and target database.

• corrected source data or validated target database → **SEDRIS** → **capitalisation** → retrieval → import → exploited by applications using different native formats

• **SEDRIS** = very comprehensive data representation: only available format/representation able to describe data as various as planimetry or altimetry data, geo-localised photographs, 3D models, atmospheric data, physical properties, etc.
OKTAL-SE first implementations and modeling of infrared and other sensor data: PROVIDENS

- Integration of existing tools in the PROVIDENS platform
- Development and integration of new converters
- Enhancement and integration of existing tools (Focus)
- SEDRIS expertise
- Basis for exchanging terrain modelling tools “work data”
OKTAL-SE first implementations and modeling of infrared and other sensor data: PROVIDENS

PROVIDENS user can:

• retrieve (source or generic) databases in the capitalisation database
• convert them to the native format they need
• request a production plan: best way to perform the data processing needed to produce new (generic or target) databases
• extract and edit their metadata
• capitalise those new databases
- OKTAL-SE first implementations and modeling of infrared and other sensor data: PROVIDENS

Experimentation to validate the process:

- three zones of a same area: large, semi-detailed and detailed.
- various source data
OKTAL-SE first implementations and modeling of infrared and other sensor data: PROVIDENS
- OKTAL-SE first implementations and modeling of infrared and other sensor data: PROVIDENS
- OKTAL-SE first implementations and modeling of infrared and other sensor data: ITCS

After CQCEGC, before PROVIDENS, the most complete attempt to model OKTAL-SE synthetic environment databases in SEDRIS

ITCS = Joint Technical Simulation Architecture: providing support environment for conceiving and realising simulations

OKTAL-SE for ITCS:
- software for exporting EDS in the SDM format (OKTAL-SE format) to SEDRIS and importing SEDRIS EDS in the SDM format
- providing SEDRIS tools
- providing SEDRIS expertise
● OKTAL-SE first implementations and modeling of infrared and other sensor data: ITCS
• modelling of the meshed geometry (easy)

• modelling of the physical properties

• modelling of complex SDM mechanisms:
  − material classification (physical properties of any pixel of a texture) through material images
  − multi-domains materials (materials defined by the association of elementary materials defined on one domain) through data tables
OKTAL-SE first implementations and modeling of infrared and other sensor data: ITCS

Excerpt of the SEDRIS data model: material classification
State of the art and the required data for expressing new multi-domain physics-based sensor information

In the frame of:
- electro-optics
- active electro-optics
- radio-frequency
- GNSS (Global Navigation Satellite System)

what is the needed information to be added to current synthetic environment modeling?

Example:
- roughness description for optics, thermal and radio frequency
- multi-texturing
- sea modeling
- DTH (TThermal Description)
- State of the art and the required data for expressing new multi-domain physics-based sensor information

<table>
<thead>
<tr>
<th>Green concrete wall</th>
<th>Green wood fences</th>
<th>Green metal door</th>
</tr>
</thead>
<tbody>
<tr>
<td>EO green glossy painting properties</td>
<td>EO green glossy painting properties</td>
<td>EO green mat painting properties</td>
</tr>
<tr>
<td>- diffuse reflection</td>
<td>- diffuse reflection</td>
<td>- diffuse reflection</td>
</tr>
<tr>
<td>- specular reflection</td>
<td>- specular reflection</td>
<td>- specular reflection</td>
</tr>
<tr>
<td>RF concrete clutter properties</td>
<td>RF wood clutter properties</td>
<td>RF metal properties</td>
</tr>
<tr>
<td>- layers/thicknesses</td>
<td>- layers/thicknesses</td>
<td>- layers/thicknesses</td>
</tr>
<tr>
<td>- backscattering</td>
<td>- backscattering</td>
<td>- backscattering</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>TH concrete wall physical properties</td>
<td>TH green fence physical properties</td>
<td>TH metal door physical properties</td>
</tr>
<tr>
<td>- layers/thicknesses</td>
<td>- layers/thicknesses</td>
<td>- layers/thicknesses</td>
</tr>
<tr>
<td>- specific heat</td>
<td>- specific heat</td>
<td>- specific heat</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

- Red concrete wall | Red wood fence | Yellow metal door |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EO red mat painting properties</td>
<td>EO red glossy painting properties</td>
<td>EO yellow glossy painting properties</td>
</tr>
<tr>
<td>- diffuse reflection</td>
<td>- diffuse reflection</td>
<td>- diffuse reflection</td>
</tr>
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</tr>
</tbody>
</table>

Examples of “complete” physical materials: a lot of properties are duplicated. “EO” stands for electro-optics, “RF” stands for radio-frequency and TH stands for thermal
State of the art and the required data for expressing new multi-domain physics-based sensor information

Example of material descriptions using the multi-domains library: the properties are shared. “LM” stands for logical material
State of the art and the required data for expressing new multi-domain physics-based sensor information

Example of classification with logical materials
State of the art and the required data for expressing new multi-domain physics-based sensor information

Example of classification with logical materials
State of the art and the required data for expressing new multi-domain physics-based sensor information

Example of classification with logical materials

<table>
<thead>
<tr>
<th>Material name</th>
<th>Optronic</th>
<th>Thermal</th>
<th>EM</th>
<th>Roughness</th>
</tr>
</thead>
</table>
State of the art and the required data for expressing new multi-domain physics-based sensor information

multi-domains material library = open format toward the number and the kind of domains it contains

This possibility may be used in future release of the SE-WORKBENCH, but for now, the current domain names and contents are static:

- Optronic
- Thermal
- EM
- Roughness

Roughness problem: three models in our material descriptions… that we were not able to store using the SEDRIS DRM
State of the art and the required data for expressing new multi-domain physics-based sensor information

Statistic model
The statistic model is based on roughness properties that are used by He-Torrance and Li-Torrance BRDF models:
- the RMS roughness height of
- the roughness correlation lengths.
This is quite logical since the BRDF and the roughness are related: the way a material reflects light is directly linked to its roughness.

Considers roughness as a set of hollows and bumps with infinitesimal heights (the order of magnitude is the micron) forming a pattern. The correlation lengths (in X and Y) are the sizes of the roughness pattern. This defines the pattern repetitions number on a surface mapped by this material.

Height map with quadratic height of roughness of 6µm, a correlation length of 1 in X and 2 in Y
State of the art and the required data for expressing new multi-domain physics-based sensor information

**Natural convection**
The natural convection is a mechanism, or type of heat transport, in which the air motion is not generated by any external source (like a pump, fan, wind, etc.) but only by density differences in the air occurring due to temperature gradients.

air surrounding a heat source → becomes less dense and rises → surrounding air cooler air moves to replace it → heated by the heat source...

The link between natural convection is quite easy to understand: that is why radiator is non-planar. The natural convection depends on the surface state: the more there are bumps and hollows, the greater the air exchange surface is. So if a material has a low natural convection, chances are that its surface is quite smooth. If its natural convection is high, chances are that the material is rough.
• State of the art and the required data for expressing new multi-domain physics-based sensor information

Bump multi-texturing
The bump multi-texturing: a way to associate a bump material (that is a material using the height map model) to another material. To do that the user must use a multi-texturing technique of type “Bump”. This is a useful way to create, for example, a roof material with a tile texture and relief created by the bump.

⇒ SEDRIS OK for natural convection but not for statistic model (or at least we were not able to model it)
State of the art and the required data for expressing new multi-domain physics-based sensor information

Sea models: Sinus sea model, Swan sea model

Sinus sea model
This model is defined as a sum of sinusoidal waves. A wave "i" is characterised by:
- a wavelength $\lambda_i$
- an amplitude $A_i$
- an initial phase $\phi_i(0)$
- an orientation $\theta_i$
- a speed $c_i$

The description of all the waves is given in an hypertexture file.
State of the art and the required data for expressing new multi-domain physics-based sensor information
State of the art and the required data for expressing new multi-domain physics-based sensor information

**SWAN sea model**
SWAN (Simulating WAves Nearshore) = third-generation wave model, developed at Delft University of Technology

SWAN computes random, short-crested wind-generated waves in coastal regions and inland waters. SWAN takes into account the “shoaling” and the refraction due to current and depth, wave generation by wind, 3 and 4 wave interaction, white capping, bottom friction and depth-induced breaking, dissipation due to vegetation, wave-induced set-up, transmission through and reflection (specular and diffuse) against obstacles, diffraction.

For the OKTAL-SE SE-SEA product, 2 SWAN output files are used (.spc file and .tab file)

💡 How to store such data in SEDRIS? (the source data and the way to interpret them)
State of the art and the required data for expressing new multi-domain physics-based sensor information

**Influence Thermal Description**
Thermal Description: element describing the thermal law of an object or a material
Influence Thermal Description: thermal law using influence volumes
State of the art and the required data for expressing new multi-domain physics-based sensor information

Influence Thermal Description

 대하여

How to store such data in SEDRIS ?
Ideas for existing or new SEDRIS capabilities in this context

• roughness
• sea model
• influence thermal description
• procedural generated geometry
• …