Workshop Program

Preliminary as of May 20 2025

Monday , June 2, 2025		
9:00 - 10:00	Registration	
10:00 - 12:00	**Welcome and Introduction**	**K. Braesicke**
	Workshop organisation	K. Braesicke
	Welcome	K. Schulz
	Introduction	all
12:00 - 13:00	**Lunch**	
13:00 - 15:00	**Session**	**K. Braesicke**
	Exploring the infrared emission of alumina particles in rocket engine plume: influence of particle size and radiation model	T. G. Decker
	Development of a Hardware-in-the-Loop Simulation and Test Infrastructure for an Electro-Optical System Integrated into a Bank-to-Turn Air Vehicle Using Proportional Navigation	S. Benli
	SBIR SANTA BARBARA INFRARED, INC. a HEICO company	Santa Barbara Infrared
	Development and Characterization of Vanadium Oxide Films for Passive Cooling Coatings	M. Kodur
15:00 - 15:30	**Coffee Session**	
15:30 - 17:00	**Session**	**D. A. Vaitekunas**
	Local validation of simulated Cn2 profiles with measurements data at Meppen, Germany.	C. Bellisario
	Evolution of SE-Workbench-EO to model vegetation for EO/IR sensor simulation	A. le Goff
	Simple CUBI-surface temperature model extended – is it better?	A. D. van Rheenen

Tuesday, June 3, 2025

9:00 - 10:30	**Session**	**F. Godillon**
	Experiments with a cold plate – temperature measurements and LWIR recordings	A. D. van Rheenen
	Thermal Imaging Developments for Improved Infrared Target and Signature Assessment	S. Boubanga
	Measurement and Modeling of Wet Naval Surface Paints (2.0)	D. Vaitekunas / M. Kodur
10:30 - 11:00	**Coffee Session**	
11:00- 12:30	**Session**	**A. D. van Rheenen**
	SURFACE OPTICS CORP. BRINGING SOLUTIONS TO LIGHT	Surface Optics
	Dynamic scene simulation for maritime scenarios with object and background modelling using Infinite Studio scene generation software.	M. Pszczel
	Modeling High Energy Laser Beam Reflection at Sea Surfaces for Laser Safety Assessments	F. Schwenger
12:30 - 13:30	**Lunch**	
13:30 - 15:00	**Session**	
	Updated Soft-Kill Analysis using ShipIR/NTCS (v4.4x)	D. Vaitekunas
	Davis Advanced Stealth Technology	Davis Engineering
15:00 - 15:30	**Coffee Session**	
15:30 - 17:00	**Discussion Round**	**K. Braesicke**
		all
19:00 - 22:00	**Evening get-together**	

Wednesday, June 4, 2025

9:00 - 10:30	**Session**	**S. Kessler**
	Measuring image information to improve synthetic data realism	J. Latger
	Synthetic images versus real images for feeding AI datasets	J. Latger
		ThermoAnalytics
10:30 - 11:00	**Coffee Session**	
11:00 - 12:30	**Session**	**C. Bellisario**
	Deep Learning for Automatic Detection and Recognition of Humans using Synthetic EO/IR Imagery	T. Golubev
	Deep Learning for Automatic Detection and Identification of Ground Vehicles using Synthetic Overhead Persistent Infrared Imagery	T. Golubev
		Oktal- SE
12:30 - 13:30	**Lunch**	
13:30 - 15:00	**Session**	**A. le Goff**
	Visible spectral rendering colour augmentation by creating a k-dimensional tree-search colour palette from a physically valid material base	J. Latger
	Impact of truncating image information at sensor output on the Deep Learning algorithms performances	J. Latger
15:00 - 15:30	**Coffee Session**	
15:30 - 17:00	**Session**	
	Organisation of Courses on Thursday Morning	**K. Braesicke**
	Discussion Round	**C. Bellisario**
		all

Thursday, June 5, 2025

Thursday, June 5, 2025

9:00 - 12:00	**Room**	**Course**
	Coulomb	
	Watt	
	Ohm	

[Program and Abstracts](#)

Exploring the infrared emission of alumina particles in rocket engine plume: influence of particle size and radiation model

Thomas Geoffrey Decker[a], Valérie Rialland[a], Adrien Langenais[b]

[a]DOTA, ONERA, Université Paris Saclay, 91120, Palaiseau, France
[b]DMPE, ONERA, Université Paris Saclay, 91120, Palaiseau, France

The thermal signature of a rocket engine is primarily driven by the substantial infrared emission from both gaseous species and solid or liquid residues making up the plume downstream of the nozzle exit. The contribution of gaseous species is well documented in the literature. Conversely, the contribution of residues, in particular alumina particles, is still not fully understood. A first challenge lies in characterizing the alumina particle size within the plume. This parameter is influenced by several factors, including aluminum agglomeration on the burning surface of solid propellants, possible droplet fragmentation during flow acceleration through the nozzle, cooling rate and resultant shape of the solid phase, which can be hollow, thereby complicating radiation scattering calculations. Another reason is the choice of an appropriate radiation model for alumina particles, which may consider alumina solidification, crystalline form, size and shape.

Experiments were conducted by S&C Thermofluids Ltd. on a propulsion bench at the Kemble Engine Test Laboratory. Gases were generated from heated compressed air undergoing a secondary combustion by fuel injection. Calibrated alumina particles were added to the hot gases to reproduce an aluminized plume. The mixture was expelled through a single convergent nozzle. Multiple tests were carried out, differing solely by the size of the introduced particles while maintaining a constant alumina mass flow rate.

To characterize the particle infrared emission, Onera performed CFD simulations of the plume coupled with a radiative transfer code. A parametric study focused on alumina particle size was conducted, exploring diameters ranging from 0.4 to 47 µm. The comparison reveals that increasing the diameter has little impact on plume radiation within the 0.4 and 15 µm range. However, a diameter increase between 15 and 47 µm, corresponding to the alumina oxide cap enlargement, results in a significant enhancement of plume IR radiation. Comparisons were made across multiple models of alumina absorption and refractive indexes, especially in the Short-Wave Infrared Range (SWIR), where particle radiation becomes predominant over gas.

Development of a Hardware-in-the-Loop Simulation and Test Infrastructure for an Electro-Optical System Integrated into a Bank-to-Turn Air Vehicle Using Proportional Navigation

Serkan Benli * [1,2], Coşku Kasnakoğlu † [1], Emrah Onat ‡ [1]

[1] Department of Electrical and Electronics Engineering, TOBB University of Economics and Technology, Ankara, Türkiye
[2] Microelectronics and Electro-Optics Systems, Aselsan A.Ş., Ankara, Türkiye

Abstract

Guided aerial platforms are rapidly gaining popularity and taking on increasingly critical missions. To evaluate their performance under realistic and repeatable laboratory conditions, establishing and developing Hardware-in-the-Loop (HIL) test infrastructures has become a vital necessity. This study focuses on the modeling and simulation of a guided aerial platform using proportional navigation and performing bank-to-turn maneuvers, along with its electro-optical system, within a HIL simulation infrastructure. As part of the study, a six-degree-of-freedom aerodynamic model of the air platform is developed. Aerodynamic models play a central role in flight dynamics simulations of aerial platforms, as these forces and moments are applied to the body throughout the flight. An autopilot system is designed for flight control, and a proportional navigation guidance algorithm is implemented for target engagement. Additionally, the platform's electro-optical capabilities are utilized to ensure target detection and tracking. Realistic target and background scenarios in the infrared band are generated using a synthetic scene generator software; this synthetic scene is projected via an infrared scene projector, thus emulating the targets and background that would be perceived by the electro-optical system. Thanks to the tests conducted in the developed HIL laboratory, the system is evaluated under simulation conditions close to real-world scenarios in terms of guidance accuracy, control effectiveness, and electro-optical system performance. These evaluations provide significant information on the operational feasibility and efficiency of the integrated system, contributing to the advancement of next-generation aerial platforms.

Keywords

Proportional Navigation Guidance, Autopilot, Bank-to-Turn, Electro-optical System, Hardware-in-the-Loop, Synthetic Scene Generator, IR Scene Projector

*mscserkanbenli@gmail.com
†kasnakoglu@gmail.com
‡eonat87@yahoo.com

Title: Development and Characterization of Vanadium Oxide Films for Passive Cooling Coatings

Authors: Moses Kodur, Martin Szczesniak, Sam Dummer, and Joseph Gleave

Abstract:
Passive cooling technologies are critical for spacecraft thermal management, particularly in reducing reliance on active cooling systems. Vanadium oxide (VO_2) films have gained interest due to their thermochromic properties, allowing them to modulate emissivity in response to temperature changes. This study presents the development and characterization of VO_2-based coatings optimized for passive radiative cooling applications. We explore deposition techniques, phase transition behavior, and spectral performance across relevant thermal regimes. Characterization was conducted using the SOC-100 reflectometer to assess emissivity and reflectance properties in the mid-wave and long-wave infrared bands. Results demonstrate the tunability of VO_2 films and their potential for dynamic thermal control in space environments. This work provides insights into the material optimization and testing methodologies necessary for integrating thermochromic coatings into next-generation spacecraft thermal management systems.

ITBM&S, 2-5 June 2025, Ettlingen

Abstract submissions due: **11 April 2025**

Title: Local validation of simulated Cn^2 profiles with measurements data at Meppen, Germany.

Authors:

- Christophe Bellisario [(1)]
- Detlev Sprung [(2)]
- Luc Labarre [(1)]
- Yann Lai-Tim [(1)]
- Florian Quatresooz [(1)]

Affiliations:

(1) ONERA/DOTA, Chemin de la Hunière, 91123, Palaiseau, France
(2) Fraunhofer IOSB (Fraunhofer Institute of Optronics, System Technologies, and Image Exploitation), 76275 Ettlingen, Gutleuthausstr. 1, Germany

Abstract:

The expected performance of laser systems and optical links within the atmosphere is hindered by local turbulences. The refractive index structure parameter Cn^2 describes the strength of the turbulence and requires to be estimated at best to depict the performance of the optical systems. With the aim of comparing simulation and data, we use in this study vertical profiling of Cn^2 at the measurements site Meppen, located in North-Western Germany. We present here the instruments and the observations available. Simulations of Cn^2 vertical profiles are carried out at ONERA with radiative transfer model MATISSE up to 30 km. Additional micrometeorological simulations performed by Fraunhofer IOSB complete the model section. We describe the theory and methodology used for the simulations. Comparisons are performed on selected cases and results are discussed. On the one hand, they show that MATISSE simulations have a good match when the downwelling short-wave flux is used. On the other hand, some limitations are highlighted in stable layers cases. Additional calculations using ERA5 and WRF display the climatic tendencies in regards to the selected measurements and expected trends. Both models capture the daily behaviour of Cn^2 at ground level.

PAPER TITLE
Evolution of SE-Workbench-EO to model vegetation for EO/IR sensor simulation

AUTHOR
Alain LE GOFF, DGA Information superiority, France

ABSTRACT TEXT
To provide technical expertise of EO/IR defense systems to equip the French Armed Forces, DGA IS (DGA Information Superiority) relies on simulation, mainly using SE-Workbench-EO software to model complex and dynamic environments, and physically render the observed battlefield with its military targets. In recent years, DGA IS has identified short- and medium-term needs for optronic scene modeling to meet the requirements of upcoming weapons programs, and has had SE-Workbench-EO developed in a number of areas, including 3D and thermal modeling of vegetation. To this end, ONERA was commissioned to carry out a bibliographical study of the thermal behavior of the vegetation in order to specify the physical model to be implemented and the database of material properties to be built up. This article presents and illustrates the design, development, validation and feedback of this new vegetation modeling.

Simple CUBI-surface temperature model extended – is it better?

Arthur D van Rheenen[1]

Norwegian Defence Research Establishment, P. O. Box 25, N-2027 Kjeller, Norway

ABSTRACT – During the 2023 ITM&S workshop we presented a simple model for the surface temperatures of a CUBI and introduced an operational perspective by looking at the true/false prediction rates of such a model as a function of sensor performance and atmospheric transmission. The model describes the temperature difference between facet and air temperature (contrast) as a linear function of the solar irradiance as measured by a pyrgeometer. The sensor performance and the atmospheric transmission were lumped into a single parameter, a required minimum contrast.

There are obvious shortcomings to this simple model:

- The model is not physics based
- Night-time temperature contrasts will be poorly modeled
- During times when a facet does NOT receive direct sunlight, the model performs poorly

However, the model does have merits:

- It is very simple and requires only pyranometer data, air temperature, and time of day
- It takes practically no time to calculate parameter values
- At its best the false prediction rates could be below 10 % over a range of sensor performances. More typically they are lower than 20 %.

In our presentation we explore the advantages and disadvantages of extending the model by introducing extra terms, in particular the long-wave infrared contributions from the sky and the ground, as measured by pyrgeometers.

Compared to the simple model, the extended model produces smaller Root-Mean-Square Errors, tends to track night-time contrasts better, and does a better job predicting facet contrasts when the facet is NOT directly irradiated by sunlight.

From a practical (operational) point of view, when a contrast is larger than the sensor-required minimum value, it does not matter what its exact value is. If time permits, we will investigate the merits of limiting the modeling to contrast value below a maximum value, to emphasize low-contrast situations. The latter are more critical and deserve more attention.

[1] arthur-d.vanrheenen@ffi.no

Experiments with a cold plate – temperature measurements and LWIR recordings

Arthur D van Rheenen[1] and Jon Austad

Norwegian Defence Research Establishment, P. O. Box 25, N-2027 Kjeller, Norway

ABSTRACT – In cold climates, such as the northern Atlantic Ocean, ice can form on ships, and this may affect the infrared (IR) signature of a ship. As a precursor to realistic IR signature acquisition measurements we experimented, in the laboratory, with small aluminum plates that are used for cooling electronic parts. The plates have a recessed track, which is fitted with copper tubing. Heated or cooled fluid may be pumped through the tubing, heating or cooling the plate. In this work we use a mixture of water and glycol as the coolant. A commercial chiller can cool the fluid bath to below -10 ^{o}C. We monitor both the bath temperature and the plate temperature with pt-100 sensors as we cycle the bath temperature from room temperature to -8 ^{o}C and back up to room temperature. A long-wave IR camera is trained on the plate during the temperature cycle, collecting frames every 10 – 15 seconds.

We spray half of the plate with water, keeping the other half dry, and cycle the temperature through cooling, ice formation, and melting. In our presentation we show results of these experiments, where we used three different plates: (i) untreated (shiny) aluminum, (ii) plate painted white (glossy), and (iii) plate painted black (flat). We discuss these results and comment on differences and similarities.

[1] arthur-d.vanrheenen@ffi.no

Thermal Imaging Developments for Improved Infrared Target and Signature Assessment

Authors: J. Carrock, B. Saute, A. Dumont, J. Gagnon, V. Morton, & S. Boubanga-Tombet

Telops, 100-2600 Avenue St.-Jean-Baptiste, Québec (Québec), Canada G2E 6J5

Corresponding Author Email: v.morton@exosens.com

Scientific infrared (IR) imaging systems continue to be developed rapidly with new models and capabilities being offered on a regular basis, thereby unlocking new utility for imaging data dependent research. Recently developed systems are expected to directly increase the number of effective use cases and improve overall data quality for research efforts related to IR target detection and signature analysis [1][2][3]. Particularly, a newly developed high-dynamic range oriented 'HDR M700' system designed by Telops improves snapshot dynamic range to more than 900C for a single exposure and optical path. This represents a feat only achieved previously by multiple optical paths, or by combining multiple data streams in post processing. The new capabilities offered by the HDR M700 will allow researchers to collect and analyze complex target detection and infrared signature datasets which previously were unobtainable or inactionable due to insufficient dynamic range [2]. Solutions for hyperspectral IR imaging have also improved dramatically in recent years with the introduction of the Hyper-Cam Mini Line of hyperspectral imaging systems in both midwave (2.9-5.2µm) and longwave (7.4-11.8µm) formats as well as airborne and sUAS platforms (LWIR) for remote sensing operations [3]. This report will present the capabilities of these new IR imaging systems and provide examples of the powerful new forms of data which they can provide.

Figure 3: The thermal infrared signature (3.0-5.0µm) of a 9mm pistol muzzle flash as captured by the M700 HDR camera. All-new on chip saturation management functionality allows for a snapshot dynamic range of more than 900C to be captured in a single image with a single optical path and exposure time. This provides superior data quality without concerns owed to low signal or saturation.

References

[1] Dupont, F., Zambon, V., Côté, A., Carrock, J., Saute, B., Dumont, A., & Gagnon, J.-P. (2025). Infrared Imaging at Hypersonic Speeds: Assessing Sub-Microsecond Exposure. Publication Pending: Proceedings of SPIE DCS 2025.

[2] Carrock, J. A., Saute, B., Zambon, V., Dumont, A., Gagnon, J. P., Dupont, F., & Morton, V. (2025, March). HDR M700 next generation high dynamic range thermal infrared imaging system. In Photonic Instrumentation Engineering XII (Vol. 13373, p. 133730J). SPIE.

[3] Carrock, J., Dumont, A., Saute, B., Norman, M., Lariviere-Bastien, M., & Chamberland, M. (2024, June). Telops Hyper-Cam Nano next generation LWIR hyperspectral imaging system. In *Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Sensing XXV* (Vol. 13056, p. 130560T). SPIE.

"Measurement and Modeling of Wet Naval Surface Paints (2.0)"

Moses Kodur – Surface Optics Corporation

David Vaitekunas – Davis Engineering

Michael Beecroft, Martin Szczesniak – Surface Optics Corporation

Abstract:

This paper is a follow up study to our previous work presented at ITBM&S 2023 which focused on the measurement, and modeling of optical properties of a wet painted surface. Our previous study attempted to replicate a 2008 commercial (unclassified) dark navy grey paint used on the Canadian Research Vessel (CFAV Quest) for water film cooling experiments. Those results revealed that solar absorptivity (a function of the pigment size distribution) can vary markedly between different types of metallic paints offered by the same supplier. The first part of this new study will compare three different paint types from the original supplier (Interlac 660, Interfine 979, Interthane 990) with the hope of identifying which of these matches the one used in the 2008 CFAV Quest experiments. Low solar absorptive (LSA) paints are often used to lower the air conditioning load of a naval ship and lower its thermal infrared signature. These properties are well studied for pristine conditions but their optical properties in real conditions, wet and at cold temperatures, are less known. The original study presented in-situ measurement of dry, wet, and icy paint samples using one of the paint types (Interlac 660). The same measurements will be conducted for all three paint types and compared. The instruments at Surface Optics Corporation measure the specular/diffuse hemispherical directional reflectance from 250 nm to 25 µm and the bidirectional reflectance from 4-10 µm to reveal distinct optical properties under different conditions. The second part of this new study will focus on a new optical property model of wetted surfaces, incorporating both the dry sample measurements and existing water properties (Hale and Querry, 1973) to derive a fully analytical hybrid surface property model for input to ShipIR. Since the optical properties of water change markedly below 2.5 µm, and the wetted samples can only be measured below this wavelength at zero incidence (with the sample oriented horizontally), we need at least one of the 3 samples to have a moderate (LSA) hemispherical reflectivity in this region to test and validate the new hybrid model. The current and modified (hybrid) versions of the ShipIR wetted surface reflectance model will be compared against the optical properties measured by Surface Optics Corporation.

Dynamic scene simulation for maritime scenarios with object and background modelling using Infinite Studio scene generation software.

Dr Mark Pszczel[1]

[1]Defence Science and Technology Group
Sensors and Effectors Division
Edinburgh, South Australia
PO Box 1500, Edinburgh, SA 5111, AUSTRALIA
mark.pszczel@defence.gov.au

Abstract

Over a number of years the Defence Science & Technology Group (DSTG) has developed, tested and implemented a physics-based scene generation software package, which has been used in a variety of applications from a hardware-in-the-loop architecture to a man-in-the loop scene projection, and more recently a software-in-the-loop experimental tool used in the modelling and simulation of a variety of problems including maritime scenarios. Currently the scene generation software package is maintained and co-developed with a DSTG industry partner.

All scenarios developed within this package have the ability to be rendered in visible, mid-wave or long-wave infrared bands with assigned material properties to all the objects of interest and to the background, and with specified environmental parameters. In a variety of scenarios one has to consider a single object in a blue sea as well as a littoral scene densely populated with land-based and maritime objects of interest. Additionally it is essential to include clouds, rain, and to assign the relevant sea-state to each scenario. The system has an ability to interface with MATLAB-based models (or models developed in other high-level languges) to render a scene on demand and effectively form a closed loop system, enabling a simulation of imaging sensors and assessing their perfomance in scenarios of interest. Ship motion and the associated wake is also included.

Generic examples of various scenes and objects will be presented and discused.

Modeling High Energy Laser Beam Reflection at Sea Surfaces for Laser Safety Assessments

Frédéric Schwenger*, Adrian Azarian, and Stefan Kessler

Fraunhofer-Institute of Optronics, System Technologies and Image Exploitation IOSB, Gutleuthausstrasse 1, D-76275 Ettlingen, Germany

ABSTRACT

When using a high energy laser beam in a maritime environment, a laser safety concept is essential to protect personnel and uninvolved third parties from uncontrolled reflections of laser light from the sea surface. Therefore, understanding the amount and direction of reflected laser energy is crucial, as these factors vary statistically and are significantly influenced by the dynamics of the wavy sea surface. These dynamics are primarily influenced by wind speed, wind direction, and fetch. To calculate the time-dependent spatial intensity distribution of the laser beam reflected from the dynamic sea surface, a numerical computer model was developed. The reflection characteristics are simulated using an analytical statistical bidirectional reflectance distribution function (BRDF) of the sea surface. The model identifies hazard areas where laser intensities exceed a fixed exposure limit. The forward-reflection direction is particularly important for estimating the risk to third parties, while the back-reflection direction towards the laser source is crucial for assessing self-risk. Simulation results are presented for observer positions along a quarter-circular arc of the specular plane of incidence, with fixed radii from the center of the laser spot for both reflection directions. Additionally, an analytical model is presented to determine whether the exposure limit is exceeded without extensive simulations. This is demonstrated for the back-reflection direction, which also includes a scenario involving a high energy laser beam reflecting off a sea surface covered with whitecaps.

Keywords: Computer simulation of sea surfaces, BRDF of the sea surface, high energy laser beam, laser safety, whitecaps

* frederic.schwenger@iosb.fraunhofer.de; phone +49 (0) 7243 992 311; fax +49 (0) 7243 992 299
www.iosb.fraunhofer.de

"Updated Soft-Kill Analysis using ShipIR/NTCS (v4.4x)"

David Vaitekunas – Davis Engineering

Srinivasan Ramaswamy – Davis Engineering

Pavel Aleksandrov – Davis Engineering

Abstract:

A key component in the multi-layered defense of a naval platform is the flare decoy and tactic used to distract or seduce an infrared (IR) homing signal away from the platform. A rigorous method has already been developed to analyze the impact of infrared signature suppression (IRSS) on IR susceptibility of naval platforms using the statistical analysis of change in detection range for a range of climatic conditions in the Ligurian Sea (ITBM&S 2013). These methods were later expanded to include the assessment of soft-kill effectiveness as a function of different tactics and signature levels, using the naval threat countermeasure simulator (NTCS). A ShipIR model of the Kilgore TALOS IR round and a generic (unclassified) DDG, fitted with different levels of infrared suppression (no suppression, exhaust IRSS, exhaust IRSS with Active Hull Cooling, and variable IRSS) were simulated against an advanced mid-wave imaging seeker for a range of climatic conditions in the Ligurian Sea (ITBM&S 2019).

With recent upgrades to the scene rendering architecture of ShipIR/NTCS (v4.2), it has become apparent that the increased precision of 32-bit floating point color (FPC) has a significant impact on the seeker performance and resultant soft-kill analysis results. This paper will review the previous test scenarios and results (versus version) and how the methodology has been updated to conform with the members of the NATO SCI-310 RTG. Further refinements to the seeker have also produced an overall increase in the probability of a hit (Phit), so the test scenarios were further expanded to assess the impact of decoy range, pumping ratio (of the IRSS) and sky condition (clear versus overcast). Finally, a subset of scenarios were selected, operating on both diesel engines and gas turbines, with different levels of signature, against both a mid-wave and long-wave sensor to further illustrate the importance of signature reduction.

Measuring image information to improve synthetic data realism

[1] Clément Besset, Thomas Gonzalez, Jean Latger

[1] OKTAL Synthetic Environment, 11 avenue du Lac, 31320 Vigoulet-Auzil, France
clement.besset@oktal-se.fr
thomas.gonzalez@oktal-se.fr
jean.latger@oktal-se.fr

Abstract

SE-Workbench-EO, also called CHORALE in France, is a comprehensive set of tools that aims at modelling the 3D environment with a virtual and synthetic approach and at rendering the 3D scene for a given IR/VISIBLE sensor.

Recently, Machine Learning (ML) algorithms have attracted a great deal of interest due to their ability to learn complex behaviors on the basis of their training on a learning dataset. Yet, their performance is directly linked to this critical step and requires careful attention to the data supplied to the models.

Today, thanks to data centers, computer storage capacities and the latest sensors, the available data are numerous. However, this doesn't necessarily make the task of building a learning dataset for a ML algorithm easier. Indeed, real data presents many problems such as labeling uncertainty, completeness, biases, uncontrolled parameters such as atmospheric conditions and, sometimes, the data is too sensitive to be shared.

The solution is to use synthetic data. Synthetic data offers advantages such as parametric control and large-scale production facilities. Although, they present several drawbacks about their dependencies on the physical models used or the diversity of generated data. But the main limit comes from their lack of the realism compared with real data. To overcome this problem, we need to find ways of measuring the difference between real data and its synthetic equivalent in order to diminish them.

In this study, we limit our use case to visible images. Real images, which are ortho-images, were compared with their synthetic equivalents calculated by SE-Workbench-EO tools. Various metrics have been tested in an attempt to quantify the amount and nature of information contained in an image. Taking advantage of the possibility of comparing synthetic and real "twins", metrics were also experimentally tested to quantify the differences between real and synthetic images, at different scales ranging from the structural level of the image to a local pixel-by-pixel comparison. We also add to this the use of color calibration based on Macbeth charts to provide a further physical validation argument for synthetic images.

As a result, some measurements seem to highlight correlations between image realism and the amount of information at the global and local scale of the image. The SE-Workbench-EO technique, such as Material Cover (MC), shows evolving pixelated information, whereas the real image suffers from fixed resolution. We also note a correlation between the Macbeth test on spectral images and their realism score when analyzing the corresponding metric values.

The introduction briefly presents the main features and objectives of SE-Workbench-EO/CHORALE.

In the first part, we specify synthetic image datasets for the advantages of ML algorithms, e.g. automatic labeling. Associated drawbacks and limitations will be discussed.

Next, we focus on the process of generating synthetic images, from real ortho-images. We detail the operation of image cleaning methods (such as cloud removal) and image information enhancement (color enhancement, MC).

The third part is devoted to the metrics used in this study and the information they provide about the data.

Finally, and before concluding, results will be presented to illustrate the simulation capabilities obtained. The next step to be taken in the future will be presented by way of conclusion.

Keywords: Artificial Intelligence, Database development for AI application, Electro Optics, Image comparison, Image entropy, Infrared, Laplace variance, MSE, Material Cover, SE-Workbench-EO, SSIM, Scene simulation, Sensor, Simulation, Spectral rendering, Synthetic images.

Synthetic images versus real images for feeding AI datasets

[(1)] Jean Latger, Clément Besset

[(1)] OKTAL Synthetic Environment, 11 avenue du Lac, 31320 Vigoulet-Auzil, France
jean.latger@oktal-se.fr
clement.besset@oktal-se.fr

Abstract

SE-Workbench-EO, also known as CHORALE in France, is a complete set of tools designed to model 3D environments and render Physics based images caught by a given IR/VISIBLE sensor as close as possible from reality.

Over the past decade, Deep Learning (DL) algorithms have seen their contribution grow exponentially. They have shown exceptional performance in many fields, such as image detection that is OKTAL-SE main target. However, DL algorithms require care during their learning phase in order to work properly on real-life use cases.

SE-Workbench-EO appears as a good candidate for producing huge quantity of synthetic images - with automatic labelling capacities - and makes the creation of datasets dedicated to specific contexts much easier.

Synthetic images can be used to complement or completely replace these datasets. The ultimate challenge with this type of data is to be comparable with real data. In SE-Workbench--EO, the focus is on the physical realism of synthetic images.

In this study, assuming as obvious the basic advantages of synthetic images on real images in terms of diversity, labelling, metadata etc., we want to emphasize the advantage of synthetic image on real image on its sensitive weak point compared to real images which is “realism”. We want to turn into an advantage the apparent drawback of synthetic images against reality.

The introduction briefly outlines the main features SE-Workbench-EO that contributes to realism.

The first part will show a comparison between an aerial ortho-image, that can be consider as reality at first glance, and a simple flat tile of terrain, vertically observed by a SE-Workbench-EO high resolution nadir sensor. Metrix with regard both to colours and to variance will be computed that show no perceptible difference between synthetic and real.

Then special enrichment of the physical classification will be done using the Material Cover new technique that will be briefly presented. Then a new image from the nadir sensor will be computed. The same metrics will be used and we will observe a large improvement of this new image entropy, much better than the real one.

In the third part, we will discuss on the “realism” paradigm of the orthoimages that are actually also a synthetic representation of the real world due to ortho rectification, and atmosphere attenuation in particular.

Finally, we will present next steps planned for this study such as comparison to be made using OpenStreetMap façades pictures, and present a conclusion aiming at changing our minds on synthetic image datasets.

Keywords: CNN, Deep Learning, SWIR, MWIR, LWIR, Monochrome images, RGB, Spectral rendering, Simulation, Synthetic dataset, Infrared, Sensor, SE-WORKBENCH-EO, metrics, Entropy

Deep Learning for Automatic Detection and Recognition of Humans using Synthetic EO/IR Imagery

Mark D. Klein, Zachary J. Edel, Corey D. Packard, Jacob N. Hendrickson, Audrey Levanen, Peter L. Rynes, Timofey Golubev

ThermoAnalytics, Inc.
23440 Airpark Blvd.
Calumet, MI 49913, USA

Machine learning algorithms have demonstrated the capability to analyze image-based scenes and effectively detect and recognize embedded targets. Achieving high performance in these tasks requires robust algorithm training, typically relying on extensive training datasets to support accurate statistical predictions. For electro-optical infrared (EO/IR) remote sensing applications, it is particularly important to have diverse image databases to facilitate adequate machine learning algorithm training. Specifically, human detection and recognition algorithms benefit from training images encompassing variability in clothing, poses, seasons, times of day, sensor viewing angles, background environments, and weather conditions. However, collecting such diverse imagery from real-world sources, particularly within thermal infrared wavebands (e.g., MWIR and LWIR), can be challenging. Synthetic image generation, therefore, presents a viable alternative, provided it follows a careful methodology to ensure robustness in training outcomes. In this study, synthetic EO/IR imagery featuring human subjects with diverse clothing configurations, poses, and environmental conditions are generated using MuSES™ and CoTherm™ software. The performance of the YOLO ("you only look once") deep learning algorithm is evaluated using these synthetic images, and sensitivity to the training data characteristics is discussed.

Deep Learning for Automatic Detection and Identification of Ground Vehicles using Synthetic Overhead Persistent Infrared Imagery

Mark D. Klein, Corey D. Packard, Zachary J. Edel, Eli Datema, Alex J. Klaschus, Jacob N. Hendrickson, Timofey Golubev

ThermoAnalytics, Inc.
23440 Airpark Blvd.
Calumet, MI 49913, USA

Space-based sensor platforms, including existing and planned future satellites, provide surveillance capabilities for observing Earth-based objects and scenes from high altitudes. Overhead Persistent Infrared (OPIR) is an increasingly utilized surveillance technique in which thermal-waveband infrared sensors on orbiting satellites image the Earth's surface. A significant challenge in OPIR is achieving sufficient image resolution to detect, differentiate, and accurately identify ground objects through atmospheric conditions. Recent demonstrations have validated the capability of machine learning algorithms to effectively process imagery, identify targets, and distinguish them from surrounding clutter. Successful algorithm performance relies heavily on robust training, which typically demands extensive datasets to facilitate reliable statistical predictions. Electro-optical infrared (EO/IR) remote sensing, including OPIR, requires diverse and extensive imagery databases to ensure effective learning. Training datasets should incorporate variations in background scenes, vehicle operational states, seasonal conditions, times of day, and weather to provide the necessary variety for algorithm development. Acquiring diverse imagery from real-world sources in thermal infrared bands (such as MWIR and LWIR), poses challenges, especially when adversarial vehicles are of interest. In this work, MuSES™ and CoTherm™ are used to generate synthetic OPIR images depicting several ground vehicles across varying weather conditions, times of day, and background scenes. The performance of the YOLO ("you only look once") deep learning algorithm is evaluated, specifically examining how image resolution affects its detection and recognition capabilities. Considering the anticipated improvement in resolution for future satellite sensors, this research aims to understand the sensitivity of OPIR algorithms to changes in overhead image resolution.

Visible spectral rendering colour augmentation by creating a k-dimensional tree-search colour palette from a physically valid material base

[(1)] Lalaïna Rasonaivo, Thomas Gonzalez, Jean Latger

[(1)] OKTAL Synthetic Environment, 11 avenue du Lac, 31320 Vigoulet-Auzil, France
lalaina.rasoanaivo@oktal-se.fr
thomas.gonzalez@oktal-se.fr
jean.latger@oktal-se.fr

Abstract

SE-Workbench-EO, also called CHORALE in France, is a comprehensive set of tools that aims at modelling the 3D environment with a virtual and synthetic approach and at rendering the 3D scene for a given IR/VISIBLE sensor. The SE-Workbench-EO tools enable users to calculate spectral rendering data in a wide range of fields, such as infrared.

The importance of synthetic data has never been greater, and even more so since their usefulness for Machine Learning applications. For example, Deep Learning algorithms require large datasets for their training, which are intended to be as exhaustive and realistic as possible.

However, synthetic data are not real data. One of the features of synthetic data that differentiates it from real data when generated by SE-Workbench-EO tools is the limitation of colors. If we take the example of visual images, in a standard 8-bit RGB image color diversity exceeds one million possible combinations (over 16 million).

Yet in SE-Workbench-EO, a color is related to material, and only a few materials have spectral measurements (in other words, have their spectral response physically validated). A bijective function linking the color space of the RGB image to the color space proposed by the physically validated materials of the CHORALE model is therefore impossible. Until now, the solution has been to interpolate colors on the basis of a list of materials.
However, this procedure has two major drawbacks. The first is that there is no control over which color is seen during rendering, leading to rendering instability. The second is the inconsistency of the materials that can be created.

To remedy this, another classification procedure is introduced. Based on the creation of a palette matrix from the declination of colors from the existing material, the principle consists in finding the color pair closest to the initial texture on the RGB image. This palette matrix search uses the KD-tree algorithm, which enables a 3-dimensional dichotomy to find the optimal color pair faster. This new approach makes it possible to control the visible spectral rendering of the pixel, to obtain calculated colors closer to the RGB image and to propose a coherent linear combination of colors.

The first part presents the current method and the problems encountered, particularly with regard to visual spectral rendering.

Next, the new approach is presented and we detail the whole process, from a reference 8-bit RGB image to the final visual spectral rendering based on the color augmentation algorithm.

In the third part, we focus in more detail on the computation of the palette matrix of color combinations. We also explain the decision to work directly on the colors of the materials and not on the materials themselves.

Finally, and before concluding, results will be presented to compare the old and new approaches on visual spectral images. We also show improved results in the infrared domain, with a few examples.
The next step to be taken in the future will be presented.

Keywords: Color augmentation, Electro Optics, KD-Tree, Pixel classification, RGB images, Realism, Scene simulation, Spectral rendering, Synthetic data.

Impact of truncating image information at sensor output on the Deep Learning algorithms performances

[(1)] Thomas Gonzalez, Jean Latger

[(1)] OKTAL Synthetic Environment, 11 avenue du Lac, 31320 Vigoulet-Auzil, France
thomas.gonzalez@oktal-se.fr
jean.latger@oktal-se.fr

Abstract

SE-Workbench-EO, also known as CHORALE in France, is a complete set of tools designed to model the 3D environment with a virtual and synthetic approach, and to render the 3D scene for a given IR/VISIBLE sensor. CHORALE helps users evaluate the performance of a sensor in relation to a specific environment.

Over the past decade, Deep Learning (DL) algorithms have seen their contributions grow uninterruptedly. They have shown exceptional performance in many fields, such as image detection. However, DL algorithms are also a technology that requires care during its learning phase in order to work properly on real-life use cases. Datasets for DL applications need to be comprehensive, large and correctly labelled (in this study, we only consider supervised learning).

Ensuring data relevance can be difficult when dealing with real images, due to their heterogeneity and sometimes availability. To avoid this problem, synthetic images can be used to complement or completely replace these data sets. The ultimate challenge with this type of data is to be comparable with real data. In SE-Workbench-EO, the focus is on the physical realism of synthetic images.

The variety and diversity of images is a major challenge. Image accuracy is another challenge. To this end, the images in this study's dataset will be generated using a SE-Workbench-EO technique called Material Cover (MC). By replacing pixel color with material texture, the MC technique enables detailed rendering at higher resolution with lower memory consumption.

In this study, we want to observe the impact of information loss on images when they are converted to RGB format at the output of the sensor pipeline. Indeed, the sensor output signal has undergone several transformations, such as the sensor effect, but also truncation and loss of information when the luminance matrix is mapped to a classical image in *png* or *jpeg* format. We want to measure the impact of this loss of information at several scales, starting from a multi-frequency physical spectral rendering. The idea is to rethink the sensor pipeline (block diagram of the sensor transfer function) using physical based synthetic databases in order to improve the performance of DL algorithms. It is also an opportunity to test DL algorithms such as convolutional neural networks (CNN) on luminance matrices with multi frequency information, and to explore the CNN adaptation ability in the frequency domain.

The introduction briefly outlines the main features and objectives of SE-Workbench-EO/CHORALE. The need for realistic synthetic rendering is then emphasized. The Material Cover technique is explained.

A brief discussion is introduced on the operational requirements for the application of Artificial Intelligence in the Defense field, and more specifically for detection/navigation applications using image processing.

In the third part, we will focus on synthetic image datasets for Machine Learning. The advantages of synthetic imaging will be detailed, such as automatic labelling. The associated disadvantages and limitations will be discussed.

In the fourth part, we will explain spectral rendering theory and how a classical sensor pipeline causes information loss. The SE-Workbench-EO sensor model proposes an alternative to bypass this problem.

The generation of the dataset will be briefly presented, as well as the CNN structure adopted for the experiments.

Finally, and before the conclusion, results will be shown to illustrate the resulting simulation capabilities.
The next step to be taken in the future will be presented.

Keywords: Artificial Intelligence, CNN, Deep Learning, Electro Optics, Frequency domain, Infrared, LWIR, MWIR, Monochrome images, Multi spectral, RGB, SE-Workbench-EO, SWIR, Sensor, Simulation, Spectral rendering, Synthetic dataset.