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Watershed Segmentation Region-Based Criteria Applied to Thermographic Imagery Within the Water-Space

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Abstract
This case study researches a non-invasive forensic approach in order to identify anomalies related to the production and presence of antagonistic components operating in the maritime sector. In accordance with the internal and external consistency that regulates the port development plans, the cyber threat has recently obtained its own acknowledgment within the Port Facility Security Plans (PFSPs), as sealed in principle by the EU Directive 2005/65, becoming key to the Operators of Essential Services (OES). The study is focused on the spectral emissivity of non-contact, active, and Non-Destructive Techniques (NDT), ground and aerial, to be implemented in conjunction with histogram equalizations, transform waveforms, and segmentation image analysis following object detection by template matching. The hyper-parameterization overcomes the environmental limits that easily occur in likely electronic warfare scenarios. According to an emerging bibliography on the subject of modern strategic-military conception for Port Security Authorities (PSAs), a cyber-physical system (CPS) is strictly addressed to the emissivity of the physical theory of semi-conductors in the matter of smart-grid. Due to Electronic Data interchange (EDi), which mostly consists of volatile and unidentifiable stress agents in the digital environment, the malicious drivers are often under-recognized, i.e. non-IP based networking, that requires an urgent response in order to prevent alteration of the Internet of Things (IoT) supply-chain devices, by downgrading their performances or taking possession of their maneuverability. To entrust controllability, unmanned solutions can deliver immediate enforcement with the addition of infrared cameras, to detect electronic agents that cast suspicion and predict breaches across the latest Building Information Model (BIM) levels, all at a safe distance. In defense of water-space, harbor infrastructure pitfalls have demonstrated the upcoming necessity of adopting simultaneous strategies, jointly with private stakeholders and the Departments of Transport (DfT), that corresponds to the critical domain and require adaptation of usage according to international codes of behavior of safety. Sea-surface domain has been gradually analyzed and addressed as a physical area of interest due to its unique phenomena. The research proposes: (1) a set of multi-scalar parametric evaluations, (2) an in-depth theory dissertation, (3) a versatile open-source strategy, and (4) a risk-management implementation concerning maritime cyber security. Due to the limits of research, the author has included a list of references that are susceptible to adaptation to the engaged novel open-source solutions, within the cited optimizations for the Green Build System of the Build Information Model (BIM) techniques. Moreover, because of Unmanned and Infrared systems cost, the work-study implements a licensed aerial dataset for research and a thermal ground camera possessed by the author. Port Authorities are critical non-flying zones whose maneuverability is not granted unless specific designations. The licensed dataset reconciles this missing opportunity, by including specific urban issues and infrastructures.
Keywords: Maritime Cyber Security; Port Authority; Water Space; Digital Forensics; Incident Response; Electronic Warfare.

1. Introduction

As highlighted by the UNCTAD 2021 [1], the Investment Policy Framework for Sustainable Development (IPFSD) developed in 2015 has drawn a link between a set of Core Principles for Investment Policymaking (CPIP), balancing new design criteria for investment planning, threats, and policies.
The Covid19-sars agent outbreak has defined challenging key-guidance of the UNCTAD 2015 framework by which the weakness of a new model of digital economic diplomacy has urged dedicated strategies with budget allocations in the matter of Sustainable Development Goals (SDG) that are locally commuted into multi-stakeholder entities.
To accelerate this informatic transaction towards national bodies capable of stable intermediary roles across international platforms, an SDG financing space was defined in defense of targeted specific coordination of research groups that met the challenge favored by start-ups and Universities, adhering to international standards and consensus-strengthening of foreign investors through scalable ventures such as microfinance backed up with aftercare services.

[1] UNCTAD/DIAE/PCB/2021/1 «Investing in the Sustainable Development Goals: the Role of Diplomats». eISBN: 978-92-1-604005-5

This multipurpose of globalized virtual trade and manufacturing supply chain has confirmed the main strategic role to the Port Authorities. Due to their presence in worrisome landscapes, their economic model [2] [3] has been gradually modeled following the Community advocacies [4] which demanded their own water space and landcover usage in favor of local citizenships [5] that are issued by numerous researchers belonging to the urban studies, these hybrid scenarios surfaced as a well distinguishable paradigm threatened by volatile antagonists that are difficult to be detected. In terms of urban heat islands [6]. the industrial waterfront controllability is often undermined by the dark occlusions scattered by operative infrastructures [7] [8] such as fences, a stack of containers, cranes, bridges, mobile platforms, and canals.

The study surveys the benefits achieved from digital functional imaging applied to hyperspectral thermography in support of surveillance of undeveloped and transborder zonings [9], called into question to penetrate informatic attacks towards the cyber-physical fences [10]of maritime infrastructures.

Consequently, anti-drone countermeasures deploy tailored radio frequencies by implementing these reflections and interference to un-stabilize antagonist drones and neutralize the payload of jammer devices [11].

The purpose of this permeability can rely on a temporary breach of information so that sacrificing a drone might be a convenient choice in a moment by which the consumer electronic market ensures mass devices. Due to their dual purpose, military and civil, Port Authorities forwarded levels of readiness in terms of interoperability by granting access to heavy vehicles, equipment, perishable goods, and personnel. Internal and external Port analysis consistencies are now cyber-dependent through cyber security assessments (CSA) [12].

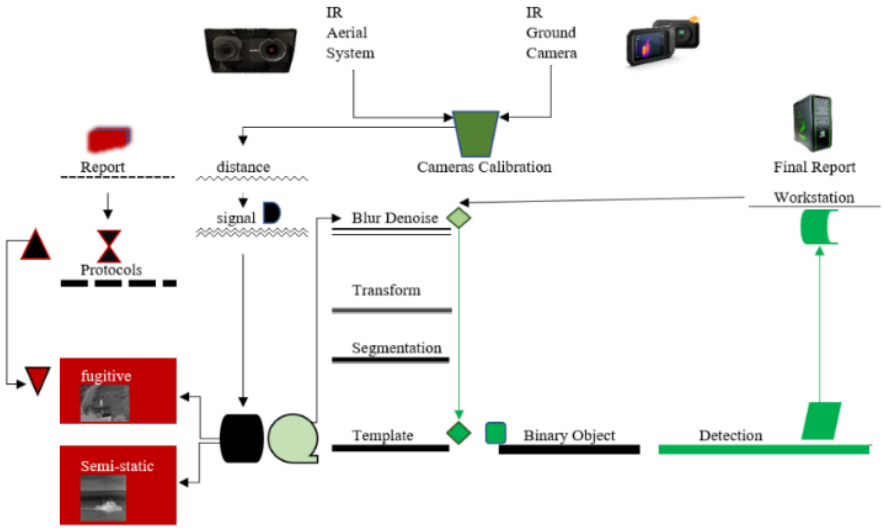

Figure 1. Structure of the Study (Developed by Authors).

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2. Emissivity Discussion Within the Water-Space

As initially stated, the scope of the research is merely investigated for surveillance purposes with an analog *modus operandi* that adheres to search and rescue (SaR) operations [13]. As consequence, infrared applications [14] [15] are carried out in severe and unpredictable environmental conditions [16].

The atmosphere itself is in fact not entirely transparent to IR and behaves like a body being characterized by relative humidity, in the matter of aerosol, temperature, view, and air mass. This synergy of factors occurs whereby attenuation might perform otherwise within specific atmospheric frames (SW – short wave, 3 – 5 μm; LW – longwave, 8-14 μm). Thermal cameras are commercialized referring to these bands, and their manufacturers have developed atmospheric corrections to overcome these difficulties of assessment. Thermography is classified under two categories: passive and active thermography. Surveillance thermal cameras in the majority operate according to the first class [17]. To summarize, the three radiation power modalities are:

Table 1: Radiations.

Radiation from the object	Reflected radiation	Atmosphere radiation
$\varepsilon \cdot \tau \cdot W_{obj}$	$(1 - \varepsilon)\, \tau \cdot W_{refl}$	$(1 - \tau)\, \tau \cdot \mathrm{W}_{\mathrm{atm}}$
ε = emittence of the body	$(1 - \varepsilon)$ = reflectance of the body	$(1 - \tau)$ = emittance of the atmosphere
τ = transmittance of the atmhere	T_{refl} = ambience emission	$\mathrm{T}_{\mathrm{atm}}$ = temperature of the atmosphere
T_{obj} = body temperature		

The spectrum is restricted to optically opaque materials with metals and organic material that are easy to be detected because they present a full opacity; in industrial scenarios, this aspect is well known even though there are semi-translucent materials to infrared heat, i.e. sapphire glass [18]. The imagery of fossil energy is commonly associated with the landscape of harbors so that the impact of private and public petroleum stakeholders [19] has been modeled over the last 150 years, a shaped citizen concept that strengthens corporate brand [20].

The waterspace, in conjunction with the petroleumscape, is indeed a complex scenario [21] [22] to detect antagonists so that special budgets are deployed in order to install a special weather station [23] on the docks.

A specific research abstract, “Ship Infrared Detection/Vulnerability” has been well discussed over the years because of its mention in the introduction of physical phenomena occurring to detect anomalies for cargos and other objects

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beyond sea surfaces [24] [25] [26] [27]: solar heating, sunlight at the sea surface (SSS), molar absorptivity, internal heating sources, wind cooling, caused by convective heat transfer, cold sky cooling, determined by apparent sky temperature, sea surface reflection of cold sky/cloud background, sunglint at the sea surface, selective radiation from exhaust gases, sea clutter pattern, spectral response curve of sensor, spatial resolution of sensor, range and aspect angle (azimuth and elevation).
Among these, SSS and cold sky/cloud background are the most critical to handle, by downgrading the emissivity of leaks, gas, and men in the water. The adoption of a simplified atmospheric model by manufacturers [28] [29] [30] has optimized the rapidity of the bundle adjustment even though the air-water at sea-surface domain requires specific physical models that evolved the accuracy against the interferences for the volumetric and through-plane temperature here absorbs and reduce the blur and distance with the target, reinforce the image focus, and pixel resolution.
Aqueous boundary layers of air [24] (J.Kunz and B. Jähne, 2018) account for heat transfer in a matter of minutes and meters. Passive thermography (PT) and active thermography (AT) are both addressable to surveillance- Radiative and evaporative cooling of the water surface. AT relies on the excitation of signals which amplify the spectral firm of water by confirming temperature amplitude and phase shift.

Table 2: Machinery temperatures of exercise and thresholds of emergency.

Class	Operability	Temperature
Severity 0	Regular exercise	Inferior to 210.0 °C
Severity 1	Attention	210.0 °C < temp < 220.0 °C
Severity 2	Risk	> 220.0 °C

The exchange of air masses and gases across the air-water layers is mainly generated by the wind blowing over the sea surface. These layers vary in terms of thickness that weights particularly for the speed of exchange (transfer velocity) and near-surface turbulence. In the air, the heat boundary layers and the mass hold a similar thickness as the viscous boundary layer; such an AT technique uses as a proxy tracer for these masses through a heat flux. The advantage is clearly visible in its response. In water, the mass boundary layer is much thinner (10–350 μm) than the viscous boundary layer, (because in water molecular diffusion for mass (D) is a thousand times slower than for momentum (v), i.e., the Schmidt number $Sc = v/D \approx 1{,}000$.
The transfer velocity k expresses the exchange rates in quantitative terms. It's obtained in form of the ratio between the mass flux density jc and the concentration difference Δc, occurring between air and water.
According to a 2004 statement by loyd's Register, "In the near future, mechanical machinery onboard vessels will also benefit from thermal imaging, especially as a pre-docking strategy to identify and target equipment and systems which need attention as well as to eliminate necessary work". Due to its non-invasive survey method of process monitoring, IR technique has migrated into other scopes. The industry of cargos is commonly associated with the maritime trade and energy-dependent on the logistics of petroleum linked to the versatility of airborne systems, has been recently extended to oil spill detection [31] [32] [33] whose spectrum is detected through IR radiometer or IR/ultraviolet (UV) equipment which benefit of the conjunction with remote sensing hardware like Side Looking

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Airborne Radar (SLAR), Imaging Airborne Laser Fluorosensor (IALFS), Microwave Radiometer (MWR) and photo cameras.

Along with IR applications, Sea-borne systems complete this group and have been designed to rise coating protection against the influences of mechanical forces, anti-reflection, and marine water. Besides, the applicability of the International Convention for the Safety of Life at Sea (SOLAS) special measures to guarantee maritime security and require temporary certifications as life-saving appliances [34] [35] [36] [37] : Electrical installations and general stability, fire protection detection and extinction, personnel arrangements, radiocommunications, and special consideration of strategic assets, i.e. pharmaceuticals and nuclear ships. The adherence to its mandatory protocols started between 17 June 1960 and 26 May 1965 as issued by the International Maritime Organization (IMO). Conditions of endured conditions, provide deterrence for breaches. Cargos are the primary trade vector so specific literature has been developed on their electrical and propulsion systems [38], by enlisting severe criteria of maneuverability [39] [40].

2.1 Cyber Threats and The Harbourscape

According to Directive 2016/1148 (NIS Directive), bodies of ports are identified in the form of "any specified area of land and water, with boundaries defined by the Member State MS in which the port is situated, containing works and equipment designed to facilitate commercial maritime transport operations" [41] that involve operations of the AECO sector [42] [43] [44] [45]. Building Information Model (BIM) [46] has been enhanced until Level 2 by operating in a Common Data Environment (CDE) [6] and included augmented intelligent analysis of real-time data and information gathered to promptly optimize decisions [32]. These Information and Communication Technology (ICT) applications, in the first stage, consented to a file-based coherence of a project who followed an Object model-based exchange (Level 3).

This informatic matter is often targeted by hackers; we might comprehend that BIM is not merely confined to the AECO industry, but extended to daily Contemporary operations and Maintenance (O&M). Smart-grids are continuously visited by security specialists and practitioners who interact with high sensitive proxies, i.e. Bluetooth and 5G, that are interdependently confronted onto URL nodes [6] Research related to this dichotomy [47], has reviewed the cyberthreat-awareness concerning asset information models (AIM) for large infrastructure asset managers complaint within public and private sectors in (ThaiCERT) Thailand Computer Emergency Response Teams from 2011 to 2019. This reporting has underlined the impairment to utilities and core infrastructures with a detailed case record of underestimated informatic deficiencies, i.e. website defacement and cookies data by which scrap data are assemblable. Likelihood has been validated through the years as a comparative pre-assessment of the risk-mitigation

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[48] [49] [50], and well supported by customer questionnaires in a cost-effective manner: Electronic Chart Display and Information System (ECDIS), has been lately officialized within the International Safety Management (ISM) Code safety management system by 1 January 2021. The assignment of the reports to all crew [51], regarding incident handling, influences training, i.e. sea-piracy, and improves the awareness program [52] [53] in favor of sea-air-ground personnel (ENISA).

3 Unmanned Aerial Vehicles (UAV) Systems in Rescue or Surveillance Missions

Intelligence Surveillance Reconnaissance (ISR) has primarily endured its challenges on stationary ground targets to photograph each target with time-saving human resources. The digital environment can be compared with Digital Elevation Model (DEM) and Digital Terrain Elevation Data (DTED) for military purposes [54]. In order to entrust its accuracy, photogrammetric models superimposed with Lidar Detection And Ranging (LIDAR) and Synthetic Aperture Radar (SAR) datasets, have validated accuracy in conditions of critical visibility.

UAV is able to provide a multipurpose payload and according to this scope, in compliance with IR tracking conversion into an electrical signal is performed in the form of raster images in which pixels are commuted into temperature amounts.

Because of sudden intervention, qualitative measurement is preferred rather than quantitative. Sudden movements are a common issue that depends on flight factors, indeed we face an uncontrollable environmental change that compromises automatic object detection [55] [56].

False-positive [57] [58] [59] are moreover promoted by high update temporal information by which one preferred an independent ad-hoc adjustment to confirm the duality of this hybrid approach. For gas detection infrared spectroscopy was developed to identify toxic gases by IR spectroscopy: the vast majority of TICs and CWAs adhere to bands in the MID-IR for their absorption. CWAs (Chemical Warfare Agents) [60] [61] and Toxic Industrial Chemicals (TICs) are a national interest, crossing both military and civilian defenses.

Ideally, the detectors (i.e. surface acoustic wave, flame photometry, Raman spectroscopy, and ionizations) are forced to operate under severe hazards. Due to the finest state of the art of electronic engineering, IR-based detectors are complex to maintain and put into practice for size and weight. Photoacoustic-based IR sensors are in particular affected by many false positives caused by vibrations or do not behave respond to CWA vapors at IDLH levels. Counter-drone defense is another argument that recently emerged and it's addressed to neutralize jamming attacks and smuggling purposes. IoT devices [3] can hence integrate independent anti-drone solutions to facilitate the counter-response of personnel.

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3.1 CLAHE

The Contrast Limited Adaptive Histogram Equalization (CLAHE) is a computer image processing technique used to highlight the contrast in images. It diverges from ordinary histogram equalization in that matter the adaptive method computes several histograms, which are used to redistribute the lightness values of the image.
It is therefore indicated to enhance the local contrast and sharpen the definitions of edges in each region of an image. AHE has a tendency to over-amplify noise in relatively homogeneous regions of an image.

3.2 FAST FOURIER TRANSFORM

A Fast Fourier Transform (FFT) has been performed due to the capability that this algorithm offers to convert digital images from their original domain into the inverse frequency domain. It's based on O(NlogN) algorithm for estimating the signal's duration.

3.3 Segmentation

Watershed image processing is metaphorically related to a geological watershed by which drainage lines are divided. The thresholding method is a simple but effective method to segment an image [62] by which a gray-scale image is commuted into a binary image [63].
The function watershed is able to fill the gaps of ideal catchment basins and watershed lines for any grayscale image. Histogram-based methods are very efficient when compared to other image segmentation methods because they typically require: that the peaks and valleys in the histogram are used to locate the clusters in the image. It requires only one pass through the pixels.

4 Results

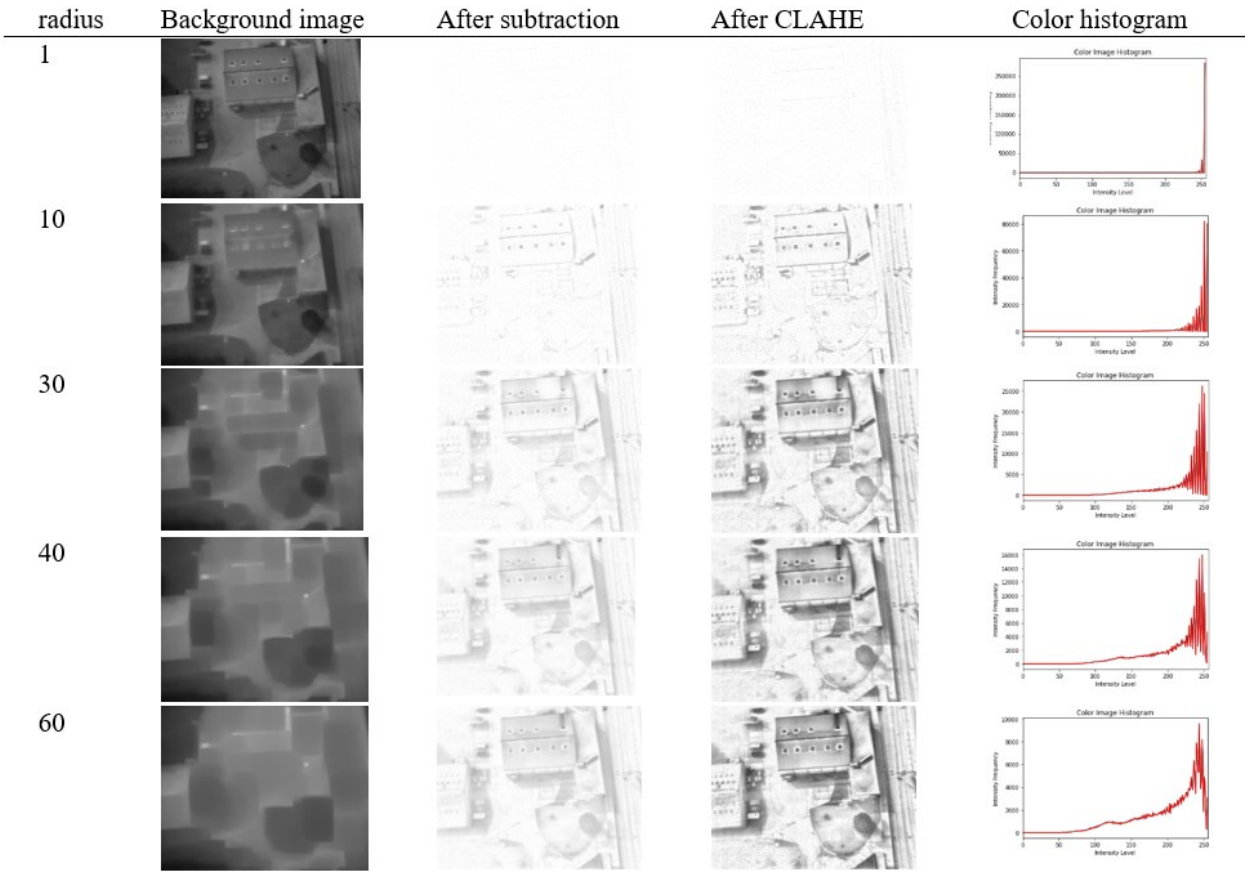

Figure 2. CLAHE hyperparameterization.

[62] Barnett R., Stratulat Alisa, Andrew M., Carl Zeiss Microscopy, Advanced Segmentation for Industrial Materials using Machine Learning, USA 2018
[63] Taguchi et al. Template Matching Processing Device and Template Matching Processing Program. United States Patent 8,971,627 B2 (2015)

This raw-image group [64] [65]has been encountered by the log-normalization function which adjusted the intensity contrast of the image dynamically. In the second instance, a correlation was measured in the splitting of the degree to which was subdivided into two variables agree, to better comprehend the general behavior. The two variables are the corresponding pixel values in two images, template, and source.
CLAHE limits the amplification by clipping the histogram at a predefined value (clip limit) as the threshold value; tile grid size, instead, defines the number of tiles in row and column.
The hyper-parameterization was gradually enhanced to control the visual process. By contrast and efficiency, the scope was directed to ver-amplify noise in relatively similar regions of the frame, in order to expand the available image quality for detection, in accordance with the limitations of available transmission bandwidth.
The radius became stable at 3600 and therefore preferred for a low-computing factor. Additionally, two ROIs were reported: a stack of parking slots, understandable for the recent utilization of hoods, and a roof, by which the heating footprint was gradually confirmed.

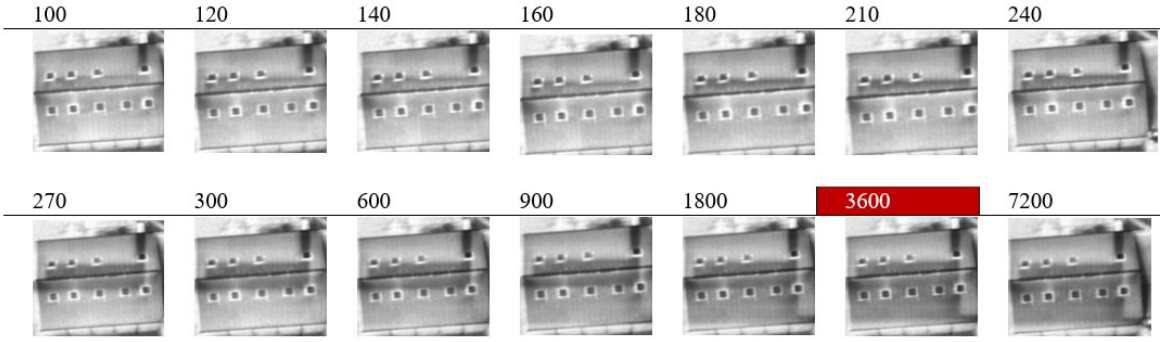

Figure 3. A second insight for the second ROI. Thermal traces of the roof.

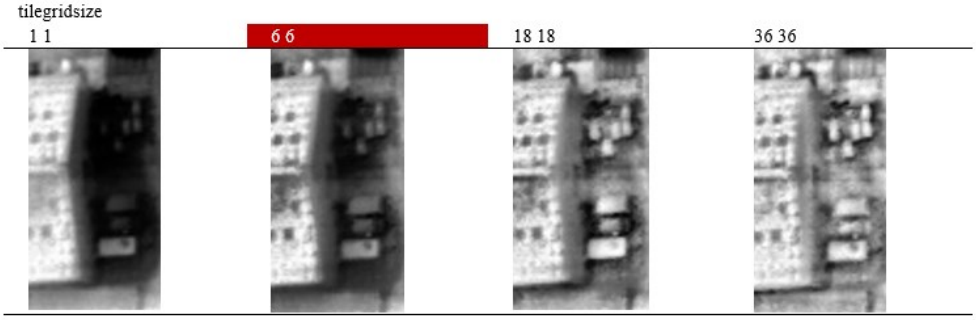

Figure 4. The preferring setting was finally picked up to 6 - 6.

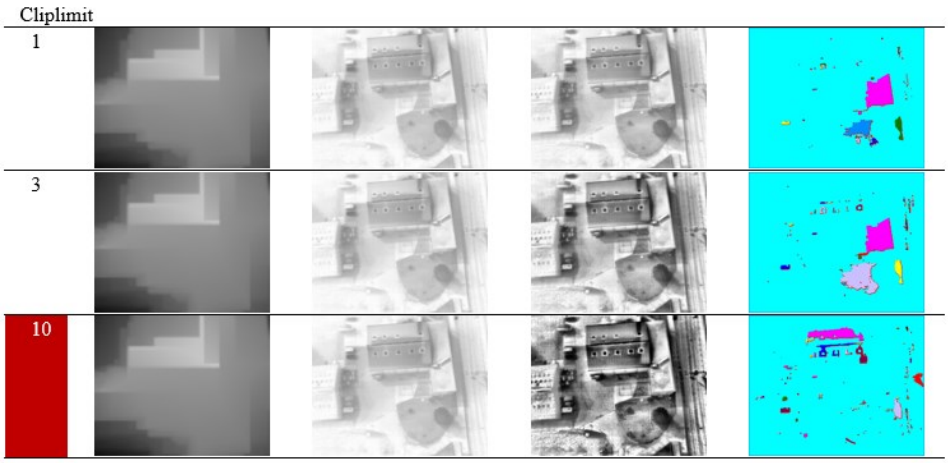

Figure 5. The second parameter was limited to 10 with regard of a first Watershed segmentation preview.

[64] SenseFly® Duet T® Camera Collection; Flir® Duo & Duo R® User Guide (2017)
[65] Flir® C5 User's manual Cx series (2020)

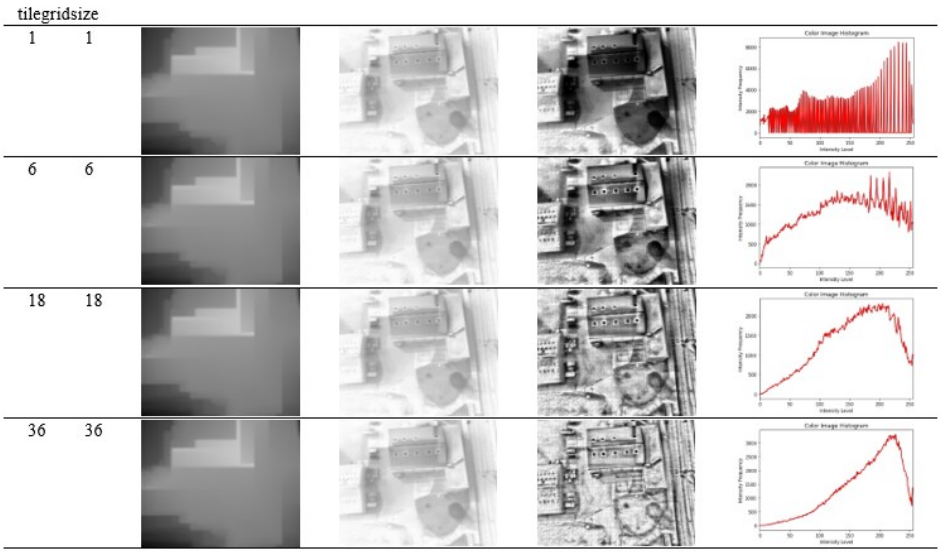

Figure 6. The tilegridsize block-based processing, amplified and finished to apply histogram equalization to each of the occlusions.

5 Watershed segmentation

The results of the watershed over-segmentation of FFT allowed for enhancing even tiny and apparently insignificant infrared differences. Removing minima traces is considered too shallow, due to the impossibility of operating with military measuring devices that better accomplish an ideal environment.

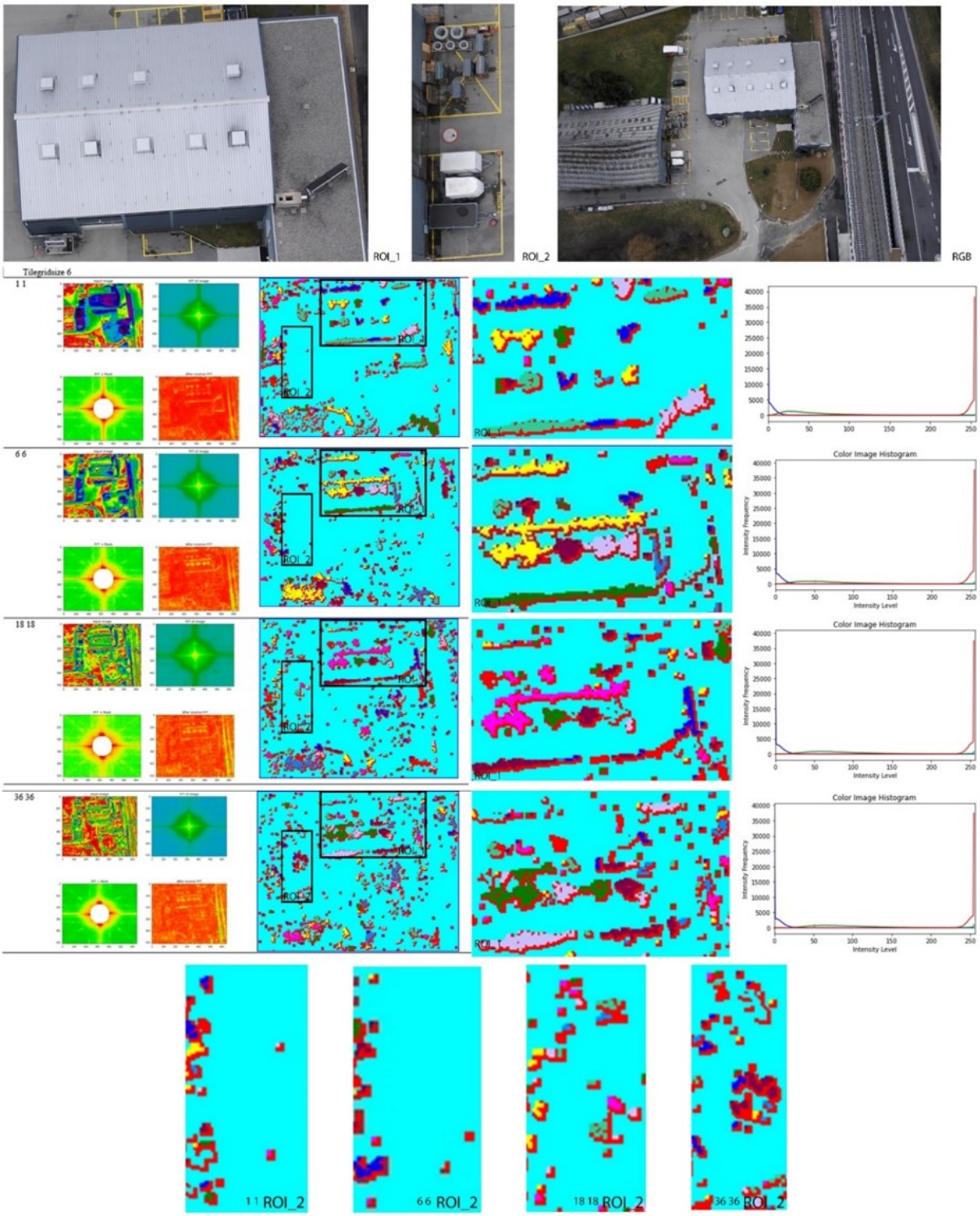

Figure 7. Results of final Watershed segmentation. The RGB histograms vary at the increment of tiles.

Regarding the unmanned dataset, the ROI_2 36-36 frame benefitted from the hyper-parameterization with the vehicle thermal traces on the environment [66] (depending on sunlight to vehicle heat transfer) and recent utilization

[66] Libra, Martin, Milan Daneček, Jan Lešetický, Vladislav Poulek, Jan Sedláček, e Václav Beránek. «Monitoring of Defects of a Photovoltaic Power Plant Using a Drone». Energies 12, n. 5 (27 febbraio 2019): 795. https://doi.org/10.3390/en12050795.

characteristics [67] (heated or cold engine). This railway infrastructure, [68] [69] [70] [71] [72] [73] [74] [75] is in fact specified in the literature review by which we assist in an upgrade of awareness spectral signatures obtained with the "heat islands" roof emissivity and pieces of machinery, parked in a stack.

Regarding the ground thermal survey, instead, the segmentation has, with the need for extended enhancement, augmented the silhouettes of the ships, in the condition of cast sunlight day and night light. In particular, some qualitative signs have been reported: three persons on board (Fig.8a), the heterogeneity of cliff composition (Fig.9a), and structural deficiencies of the hulf (Fig.10a). In compromised light conditions, it was necessary for a hyper-parameterization of radius and tiles, to better detect the objects cast in the obscurity of the cliff.

The personnel on board was not easily identifiable at distance, except for the face. The emissions were on the contrary clear at the stern/bow rather than the human factor.

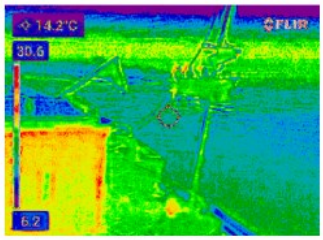

Figure 8a: Small vessel.

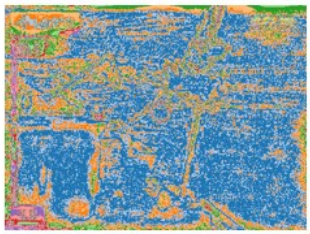

Figure 8b: FFT (ropes and edges).

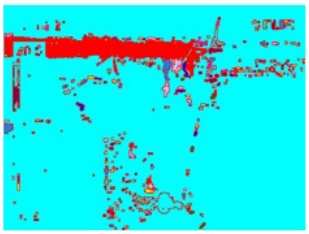

Figure 8c: Watershed (three figures).

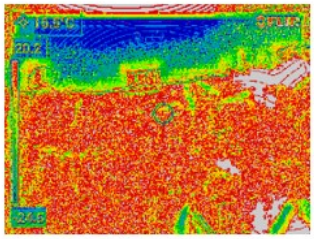

Figure 9a: Castle and rock cliff.

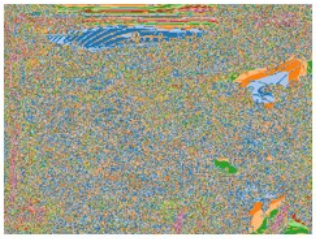

Figure 9b: FTT (rock formations).

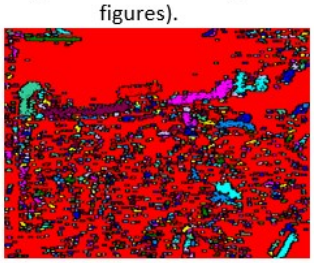

Figure 9c: Watershed (rocks and castle).

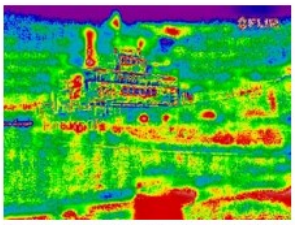

Figure 10a: Ro-Ro refuelling in harbour.

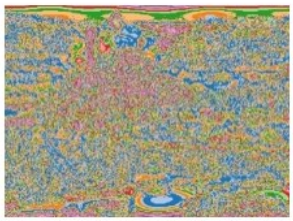

Figure 10b: FFT (berth, hulf, chimnery).

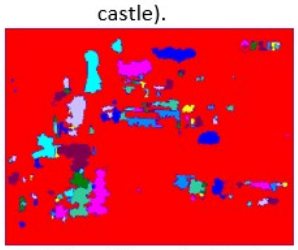

Figure 10c: – Watershed (reflected heat island).

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Conflict of Interests
The authors declare no conflict of interest.

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